Ophelia-I reference manual

2612011022000

Version 1.0

January 27, 2022

Revision history

Manual version	HW version	Notes	Date
1.0	1.0	• Initial release	December 2021

Abbreviations

Abbreviation	Name	Description
BER	Bit Error Rate	
DC	Direct Current	
ESD	Electrostatic Discharge	
EV (Board)	Evaluation (Board)	Ophelia-I populated on motherboard with USB interface for test and evaluation purpose.
FCC	Federal Communications Commission	
GND	Ground	Ground signal level that corresponds to 0 V.
GPIO	General Purpose Input/Output	
IC	Integrated Circuit	
I/O	Input/output	Pinout description
LDO	Low Dropout	Low dropout voltage regulator
Bluetooth LE	Bluetooth Low Energy	
PCB	Printed Circuit Board	
RAM	Random Access Memory	
RF	Radio frequency	Describes wireless transmission.
RSSI	Receive Signal Strength Indicator	The RSSI indicates the strength of the RF signal. Its value is always printed in two's complement notation.
SMA	SubMiniature version A	
SWD	Serial Wire Debug	
UART	Universal Asynchronous Receiver Transmitter	Allows the serial communication with the module.
VDD	Voltage Drain Drain	Supply voltage
VSWR	Voltage Standing Wave Ratio	

Contents

1 Introduction

1.1 Operational description

The Ophelia-I is a radio module for wireless communication between devices such as control systems, remote controls, sensors etc. The module is based on the radio chipset nRF52805 from Nordic Semiconductor and is meant as hardware-only module: no firmware is implemented on the module. It is customer's responsibility to develop the firmware for the module fulfilling the requirements of the specific application.

Since the Ophelia-I does not integrate any firmware, no radio certification is provided for this radio module. Nevertheless, the Ophelia-I is ready for CE/RED, FCC, IC and TELEC. The Ophelia-I hardware platform mounting Bluetooth® LE firmware has been tested within the certification of Proteus-e [3]. Test reports can be requested from BDM or support.

Depending on the firmware developed and flashed on the module, a wide range of applications is possible. For example, the module can be configured to communicate with external sensors, can use security configurations, and can be optimized for low power consumption.

Ultra small dimensions of 7 x 9 mm including a strongly miniaturized PCB antenna make the Ophelia-I ideal for small form factor design. It is possible to connect an external antenna, in case higher radio ranges are required.

For firmware development and all functional topics, please refer to the documentation and resources available for the nRF52805 chipset [1].

For firmware customization topics, please refer to chapter 5 and to the Bluetooth® 5.1 radio module Proteus-e [3].

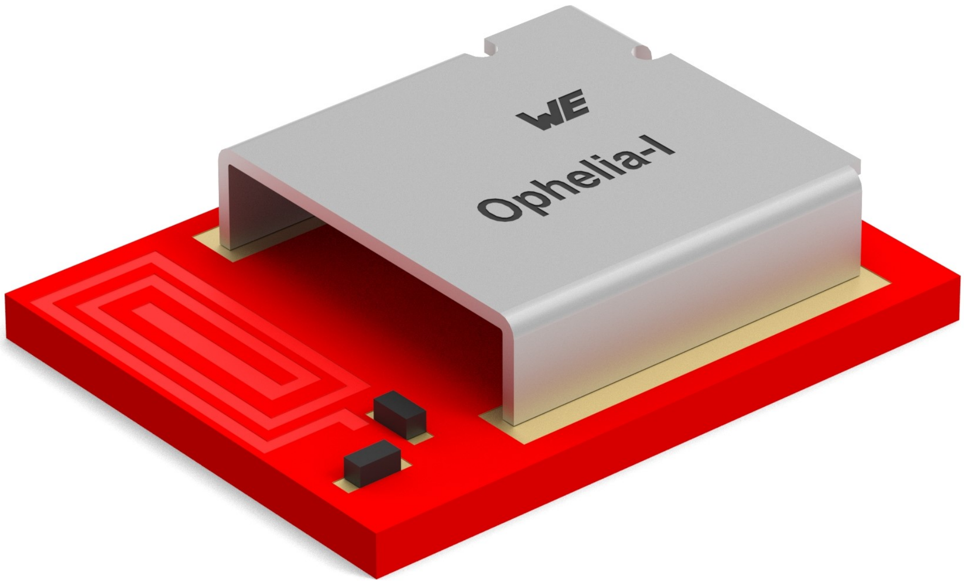

Figure 1: Ophelia-I

1.2 Block diagram

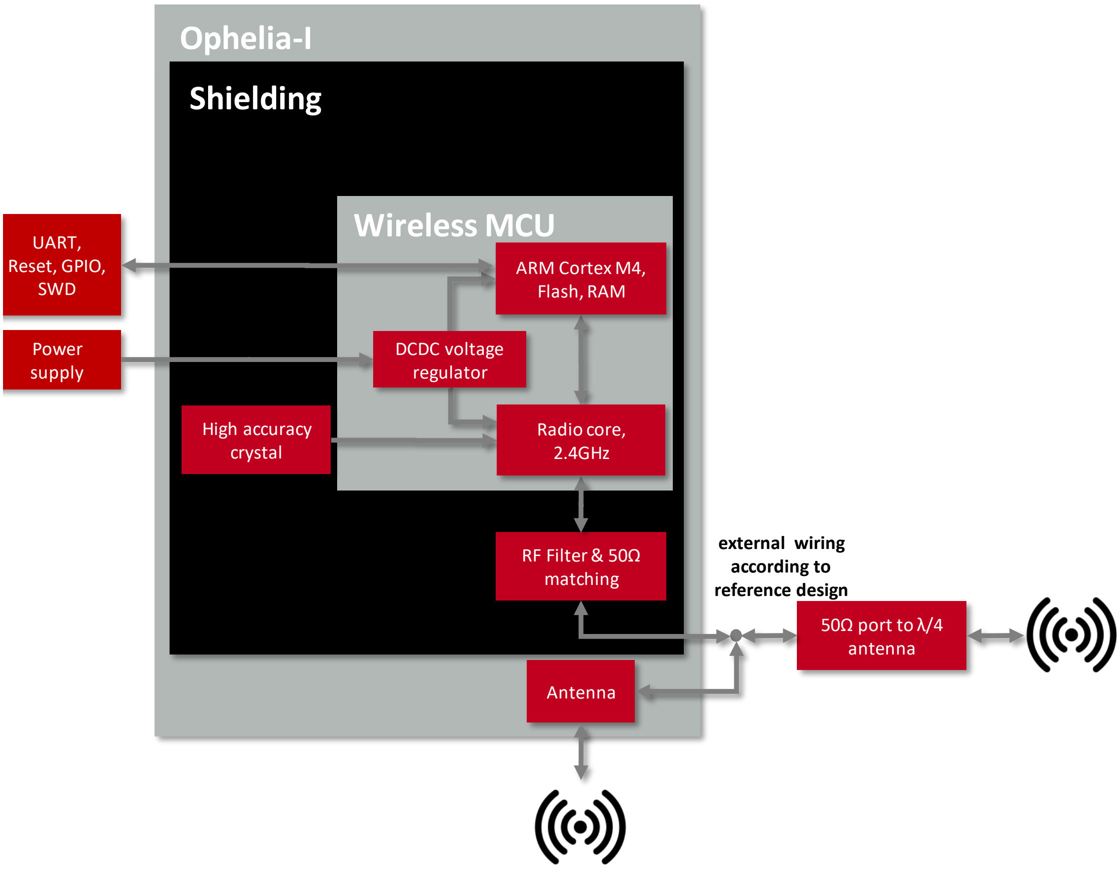

Figure 2: Block diagram of the module

1.3 Ordering information

WE order code	Description
2612011022000	Ophelia-I Module, Tape & Reel
2612019022001	Ophelia-I Evaluation Board

Table 1: Ordering information

2 Electrical specifications

Unless otherwise stated, the values specified are measured on the evaluation board of the Ophelia-I with T=25 °C, VDD=3 V, f=2.44 GHz, internal DC-DC converter in use.

Many electrical specifications depend on the specific firmware flashed on the module. For example specifications with Bluetooth® LE 5.1 firmware, please refer to the Proteus-e user manual [3]. For chipset specifications, please refer to documentation from Nordic [1]

2.1 Recommended operating conditions

Description	Min.	Typ.	Max.	Unit
Ambient temperature	-40	25	85	°C
Supply voltage (VDD)	1.8	3	3.6	V
Supply rise time (0V to $\geq$ 1.7V)			60	ms

Table 2: Recommended operating conditions

The on-chip power-on reset circuitry may not function properly for rise times longer than the specified maximum.

An instable supply voltage may significantly decrease the radio performance and stability.

2.2 Absolute maximum ratings

Parameter	Min.	Max.	Unit
Supply voltage (VDD)	-0.3	+3.9	V
Voltage on any digital pin (VDD<3.6V)	-0.3	VDD+0.3	V
Voltage on any digital pin (VDD$\geq$3.6V)	-0.3	3.9	V
Input RF level		10	dBm
Flash endurance	10 000		Write/erase cycles

Table 3: Absolute maximum ratings

2.3 Power consumption

2.3.1 Static

Parameter	Power	Test conditions	Value	Unit
TX Current consumption	Maximum out put power	Transmitter only, 1Mbps Bluetooth® LE, CPU current not included, from nRF52 data sheet	8	mA
		Full module current consumption (Proteus-e module, Bluetooth® LE firmware)	9.3	mA

Table 4: Current consumption - transmitting

Parameter	Test conditions	Value	Unit
RX Current consumption	Receiver only, 1Mbps Bluetooth® LE, CPU current not included, from nRF52 data sheet	6.1	mA
	Full module current consumption (Proteus-e module, Bluetooth® LE firmware)	6.8	mA

Table 5: Current consumption - receiving

Parameter	Test conditions	Value	Unit
Current consumption	Sleep (system off mode)	0.3	µA

Table 6: Current consumption - low power

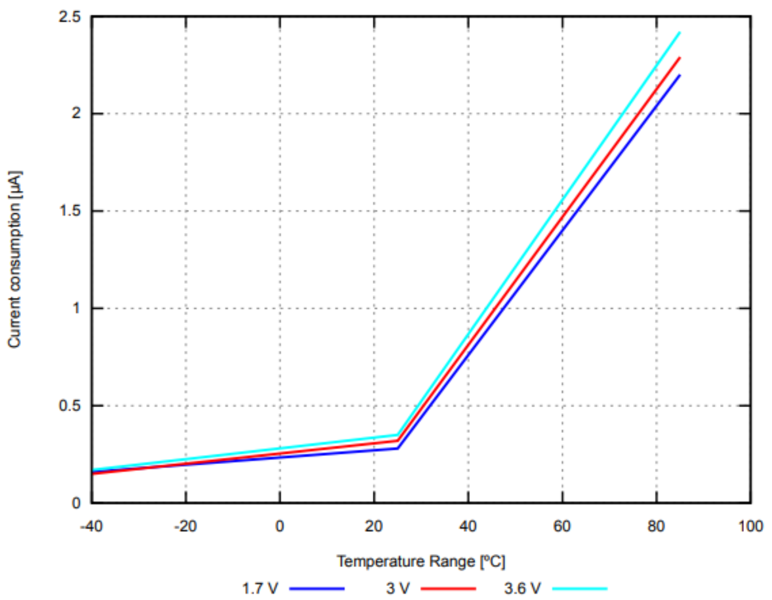

Figure 3: Sleep current (no RAM retention, wake on reset) over operating temperature range

2.4 Radio characteristics

Parameter	Min.	Max.	Unit
Frequency	2360	2500	MHz

Table 7: Frequency range

Parameter	Min.	Max.	Unit
RSSI accuracy valid range (±2dB)	-90	-20	dBm

Table 8: RSSI accuracy

Parameter	Value	Unit
Enable TX or RX delay	140	µs
Enable TX or RX delay (fast mode)	40	µs
Disable TX delay	6	µs
Disable RX delay	0	µs

Table 9: Timing

Parameter	Test conditions	Value	Unit
Output power	Conducted	+4	dBm
	Radiated	-4	dBm
Input sensitivity	Conducted, BER=1E-3, 1Mbps, Bluetooth® LE	-93	dBm
	Conducted, BER=1E-3, 1Mbps, Bluetooth® LE, LDO mode	-97	dBm
	Radiated, BER=1E-3, 1Mbps, Bluetooth® LE	-85	dBm

Table 10: Transmit and receive power

All transmit and receive power levels are measured on the evaluation board. The values already include losses of transitions from module to motherboard to SMA or modules PCB antenna. They are realistic values for the end application.

2.5 Pin characteristics

Specifications from nRF52 data sheet are reported here below.

Description	Min.	Typ.	Max.	Unit
Input high voltage	0.7 ×VDD		VDD	V
Input low voltage	VSS		0.3 ×VDD	V
Current at VSS+0.4 V, output set low, standard drive, VDD ≥1.7V	1	2	4	mA
Current at VSS+0.4 V, output set low, high drive, VDD ≥ 2.7 V	6	10	15	mA
Current at VSS+0.4 V, output set low, high drive, VDD ≥ 1.7 V	3			mA
Current at VDD-0.4 V, output set high, standard drive, VDD ≥1.7V	1	2	4	mA
Current at VDD-0.4 V, output set high, high drive, VDD ≥ 2.7 V	6	9	14	mA
Current at VDD-0.4 V, output set high, high drive, VDD ≥ 1.7 V	3			mA
Internal pull-up resistance	11	13	16	kΩ
Internal pull-down resistance	11	13	16	kΩ

Table 11: Pin characteristics

3 Pinout

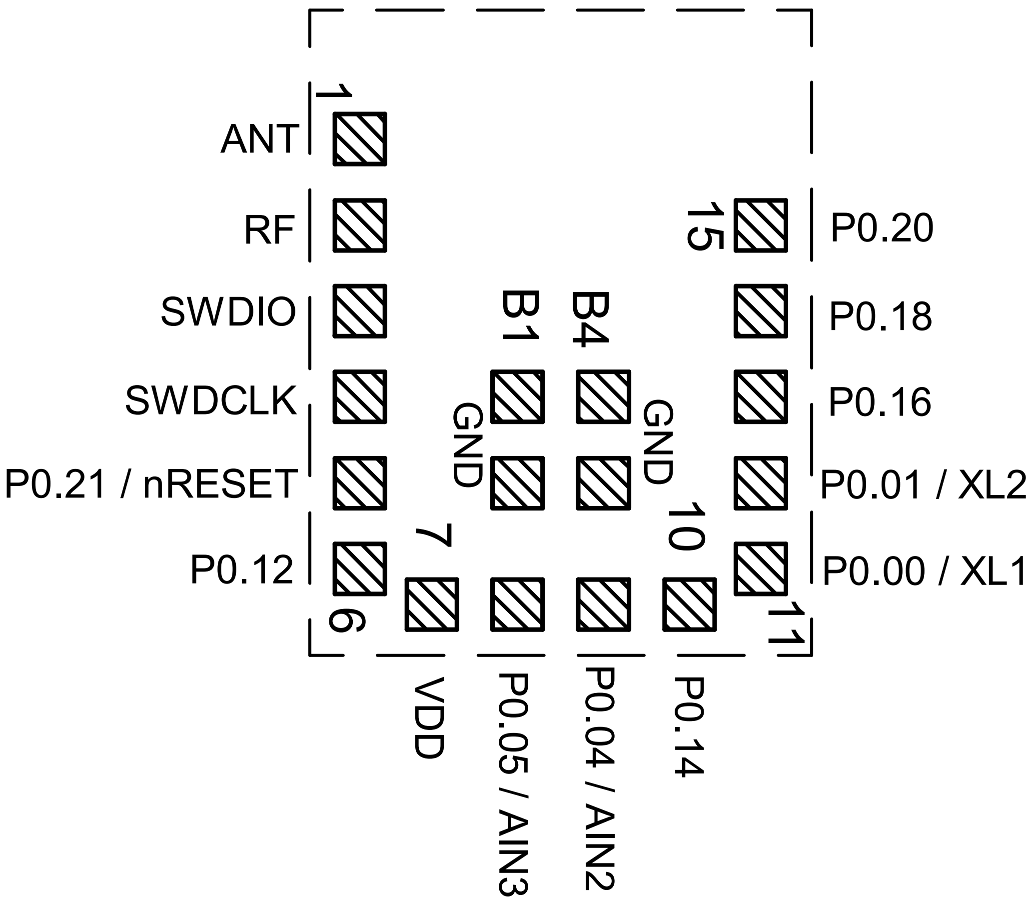

Figure 4: Pinout (top view)

No	Designation	Type	Description
1	*ANT*	I/O	RF connection to PCB antenna. (see chapter 4)
2	*RF*	I/O	50 Ω RF connection through radio front end to transceiver part of chipset. (see chapter 4)
3	*SWDIO*	I/O	Serial wire input/output (SWD Interface).
4	*SWDCLK*	I/O	Serial wire clock (SWD Interface).
5	P0.21 / nRESET	I/O	General purpose I/O. Configurable as pin reset.
6	P0.12	I/O	General purpose I/O.
7	*VDD*	Supply	Supply voltage
8	P0.05 / AIN3	I/O, analog input	General purpose I/O, ADC input.
9	P0.04 / AIN2	I/O, analog input	General purpose I/O, ADC input.
10	P0.14	I/O	General purpose I/O
11	P0.00/XL1	I/O	General purpose I/O, connection for 32.768 kHz crystal
12	P0.01/XL2	I/O	General purpose I/O, connection for 32.768 kHz crystal
13	P0.16	I/O	General purpose I/O
14	P0.18	I/O	General purpose I/O
15	P0.20	I/O	General purpose I/O
B1	*GND*	Supply	Ground
B2	*GND*	Supply	Ground
B3	*GND*	Supply	Ground
B4	*GND*	Supply	Ground

Table 12: Pinout, first part

4 Antenna connection

Ophelia-I's smart antenna configuration allows the user to choose between two antenna options: onboard PCB antenna and external antenna. Detailed description on how to implement different antenna solution is given in chapter 7.3, 7.4, 7.5 and 8.

4.1 On-board PCB antenna

The Ophelia-I has an on-board PCB antenna optimized for strong miniaturization operating in the 2.4 GHz frequency band. To use this integrated antenna, it has to be connected to the radio chip by connecting the pins *RF* and *ANT*.

> **!** The use cases for the integrated antenna are miniaturization of the end application and applications with required radio range of just few meters.

4.2 External antenna

For applications that use an external antenna, the Ophelia-I provides a 50 Ω RF signal on pin *RF* of the module. In this configuration, pin *ANT* of the module has to be left open and pin *RF* has to be connected to the external antenna via 50 Ω feed line.

> **!** An external antenna is normally used to increase the achievable radio range, at the cost of more space needed in the device/application. Also, an external antenna could be needed to fit the specific application environment of the module, for example when a metal housing is used.

5 Custom firmware

5.1 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 an 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.

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

5.2 Contact for firmware requests

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

6 Firmware flashing using the production interface

The Ophelia-I offers a serial wire debug and programming interface (SWD) for module flash access. This interface can be used by customers to erase the entire chip and install their own firmware.

STOP Customers flashing their own firmware are fully responsible for certification, declaration, listing and qualification.

7 Design in guide

7.1 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 for the filter parts 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 particularly 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, when using an external antenna the RF-pin could be accessible and should be protected in this case.

- 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.

> **!** No fixed values for the filter and matching components can be recommended, as they depend on the influencing circumstances of the application (antenna, interferences etc.).

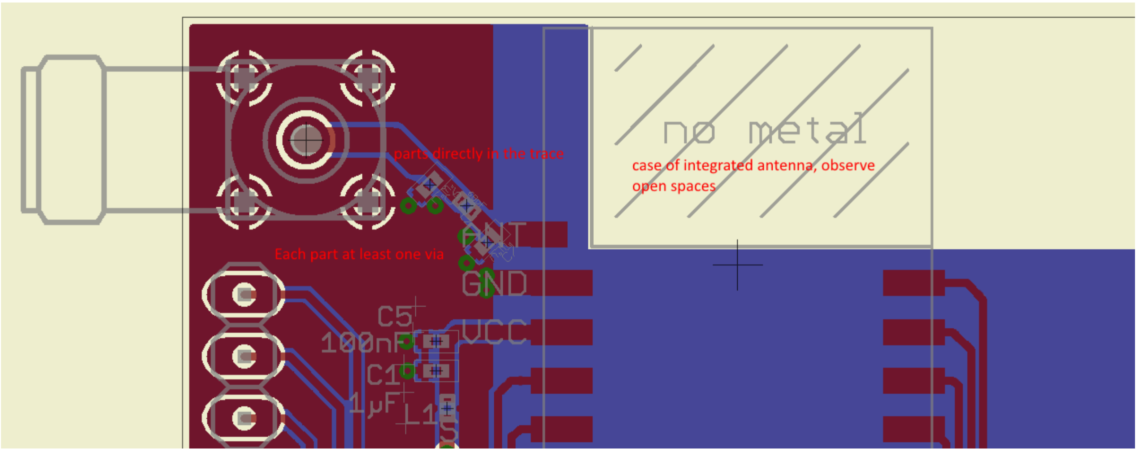

Figure 5: Layout example, layout of the corresponding evaluation board is published in the evaluation board manual

- 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.

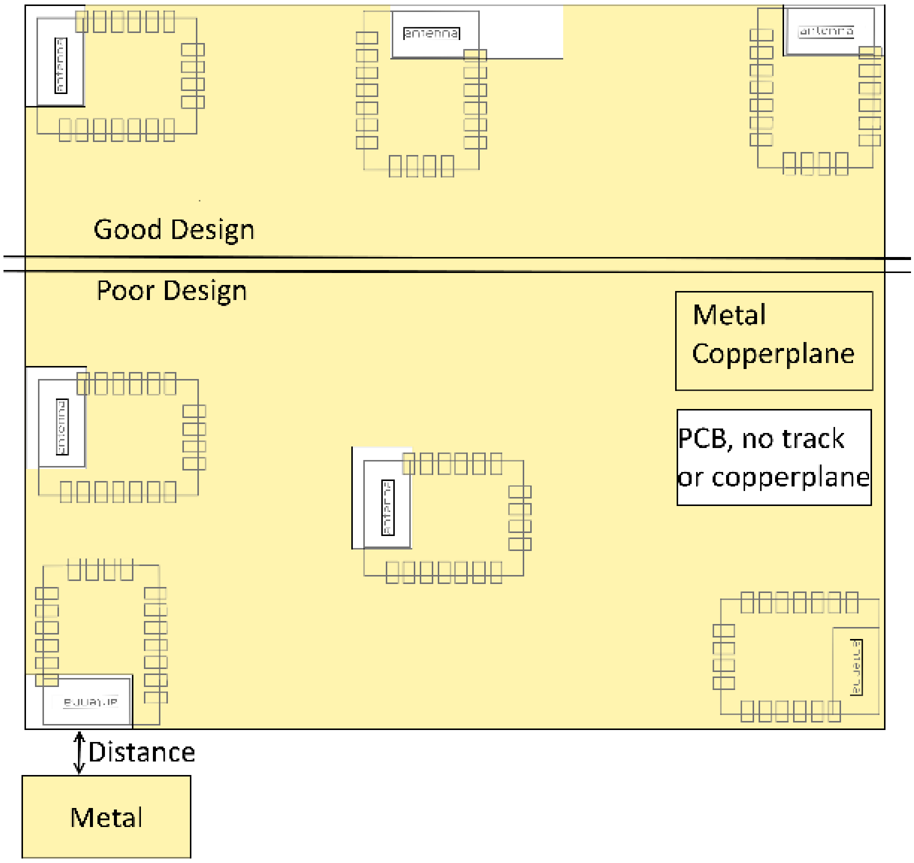

Figure 6: Placement of the module with integrated antenna

7.2 Dimensioning of the micro strip antenna line

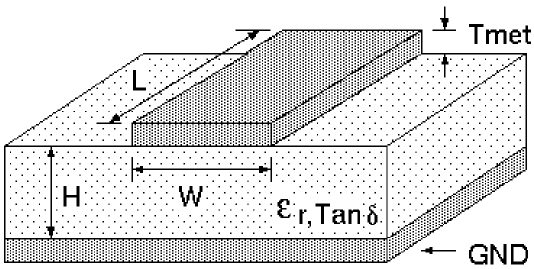

Figure 7: Dimensioning the antenna feed line as micro strip

The antenna track has to be designed as a 50 Ω feed line. The width W for a micro strip can be calculated using the following equation:

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

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

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

7.3 Antenna connection

To provide best options following reference designs are tested:

- A simple short between the pins *RF* and *ANT* pin to be used if size and price is critical and the range is uncritical.
- A 22 pF capacitor connecting *RF* and *ANT* pin to be used if size and price is less critical, but an assembly variant with external antenna is also be used.
- A 22 pF capacitor connecting *RF* pin to an external antenna, for example Himalia [2], described in chapter `7.5.4.1`. This configuration suits best if size and price is less critical, but radio range should be optimized.

The reference designs use the same layer stack.

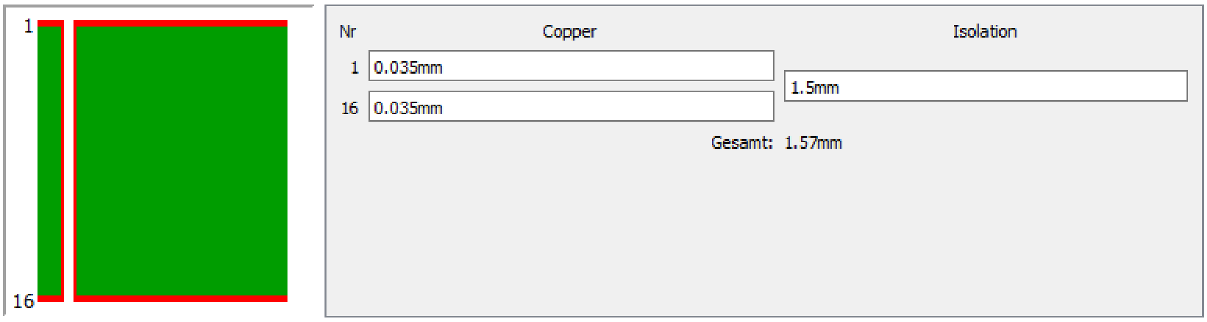

Figure 8: Stack-up

- Top layer is used for routing, filled with ground plane except the area under the module and the antenna free area.
- Bottom layer is the ground plane with as few as possible routing dividing it.

7.3.1 Simple short using internal antenna

The simple short is a 50 Ω coplanar strip connecting *RF* and *ANT* pin. Figures 9 and 10 show this in detail.

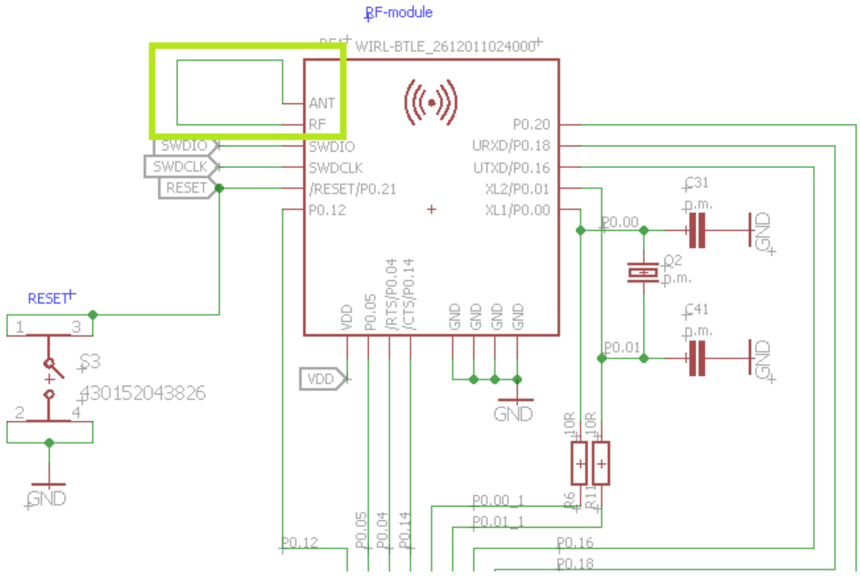

Figure 9: Simple short schematic

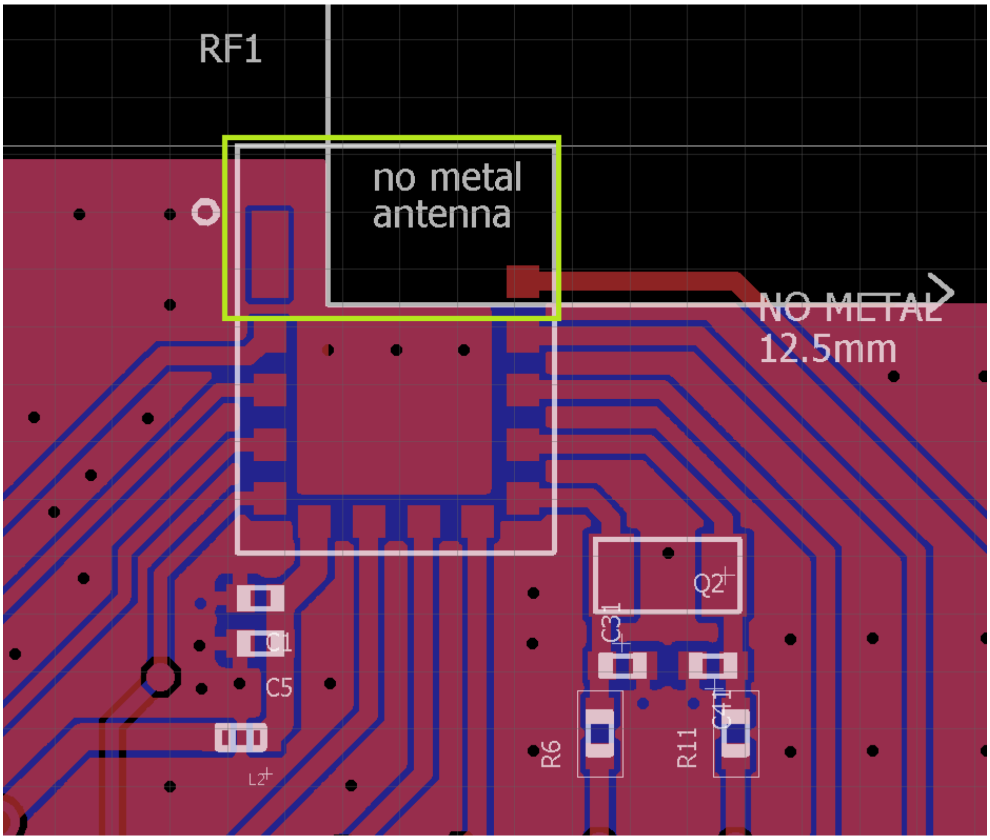

Figure 10: Simple short layout

7.3.2 22 pF coupling capacitor using internal antenna

In this configuration, instead of the simple short, a 22 pF capacitor is used at C9 connecting *RF* and *ANT* pin. C6, C7, C8 and C10 are left unassembled. Figures 11 and 12 show this in detail.

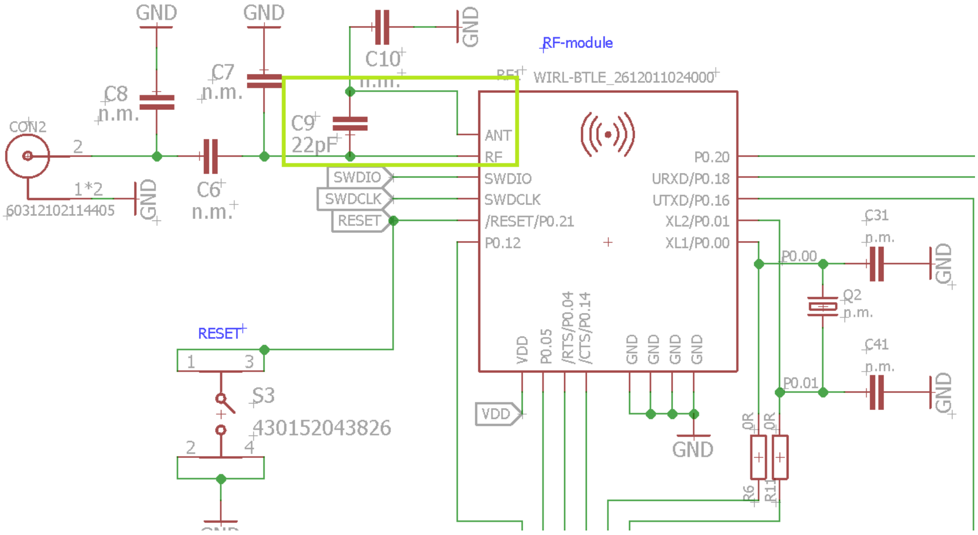

Figure 11: Capacitor internal antenna schematic

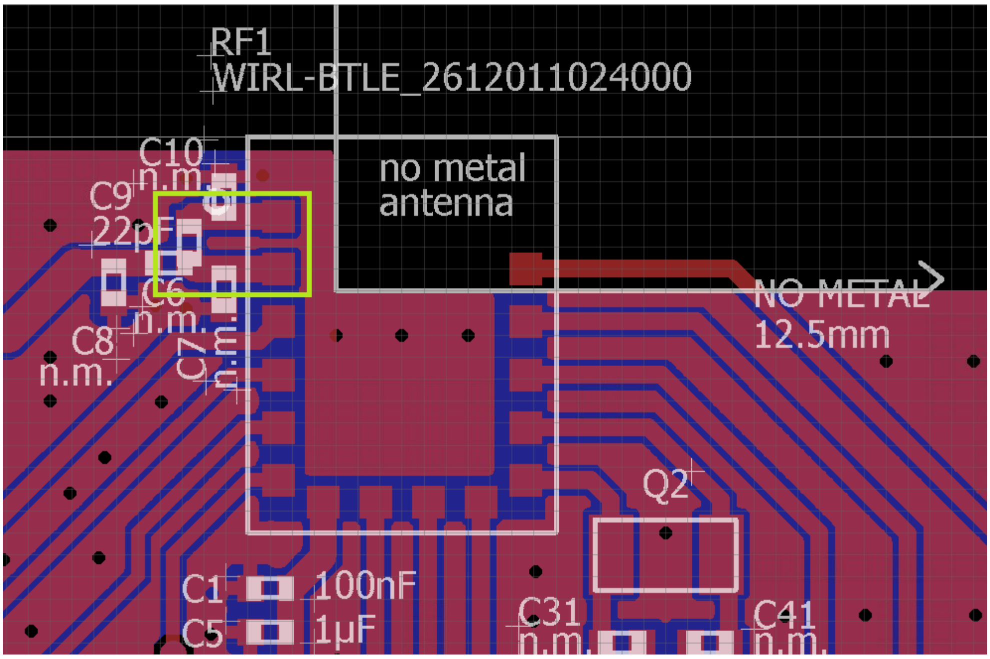

Figure 12: Capacitor internal antenna layout

7.3.3 22 pF coupling capacitor using external antenna

In this configuration, the 22 pF capacitor is used at C6 connecting the *RF* pin to a dipole antenna (Himalia [2], chapter `7.5.4.1`). C7, C8, C9 and C10 are left unassembled. Figures 13 and 14 show this in detail.

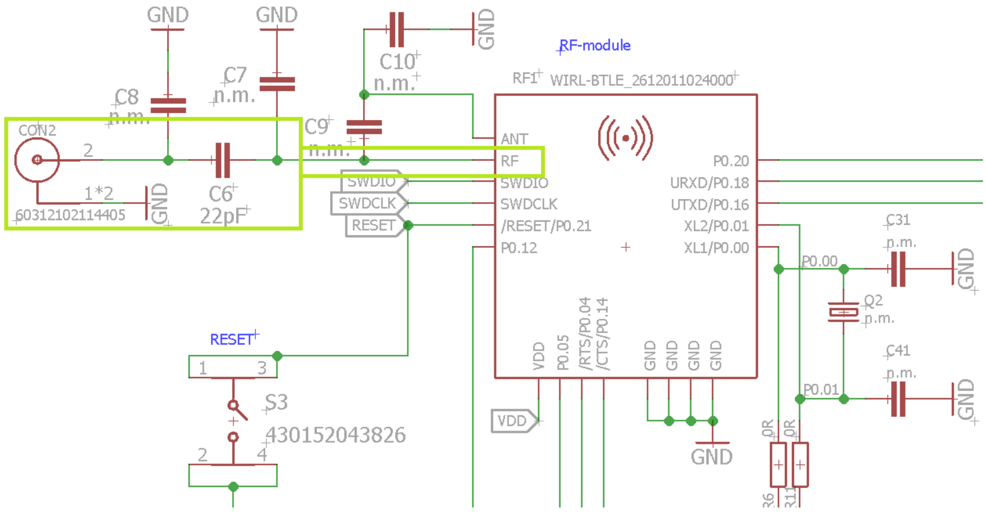

Figure 13: Capacitor external antenna schematic

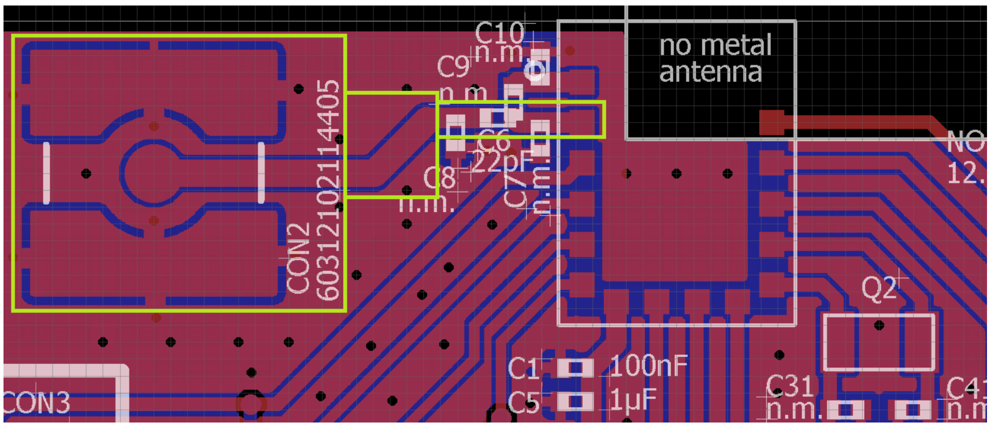

Figure 14: Capacitor external antenna layout

7.4 Antenna fine tuning

Engineers with experience in radio design and the necessary measurement equipment can consider tuning the antenna performance by impedance matching. If implemented as per reference design, smart antenna configuration provides the possibility to tune both internal and external antenna.
Due to the influence of mounting conditions as metallic objects close to the antenna, or the characteristics (size, thickness, stack-up, etc.) of the mother-pcb and ground plane, there might be some detuning of the antenna. The capacitors C7, C9, C10 can be used in combination to tune the internal antenna. The capacitors C6, C7, C8 can be used in combination to tune the external antenna (see Figure 11).

STOP

Simultaneous connection of internal and external antenna should be avoided. i.e. capacitor C6 and C9 shall not be assembled together.

7.5 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 behavior 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.

7.5.1 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 λ/4 radiator has approximately 40 Ω input impedance. Therefore, matching is not required.

7.5.2 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.

7.5.3 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.

7.5.4 Antennas provided by Würth Elektronik eiSos

7.5.4.1 2600130021 - Himalia - 2.4 GHz dipole antenna

Figure 15: 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. [°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.

8 Reference design

Ophelia-I was tested on the corresponding Ophelia-I evaluation board.

Complete layout and schematic information can be found in the manual of the Ophelia-I evaluation board.

> The reference design is the same for the Proteus-e and Ophelia-I radio modules. The module's pins on the schematic are named according to Ophelia-I module. The pin compatibility table between Ophelia-I and Proteus-e is shown in the schematic.

8.1 EV-Board

8.1.1 Schematic

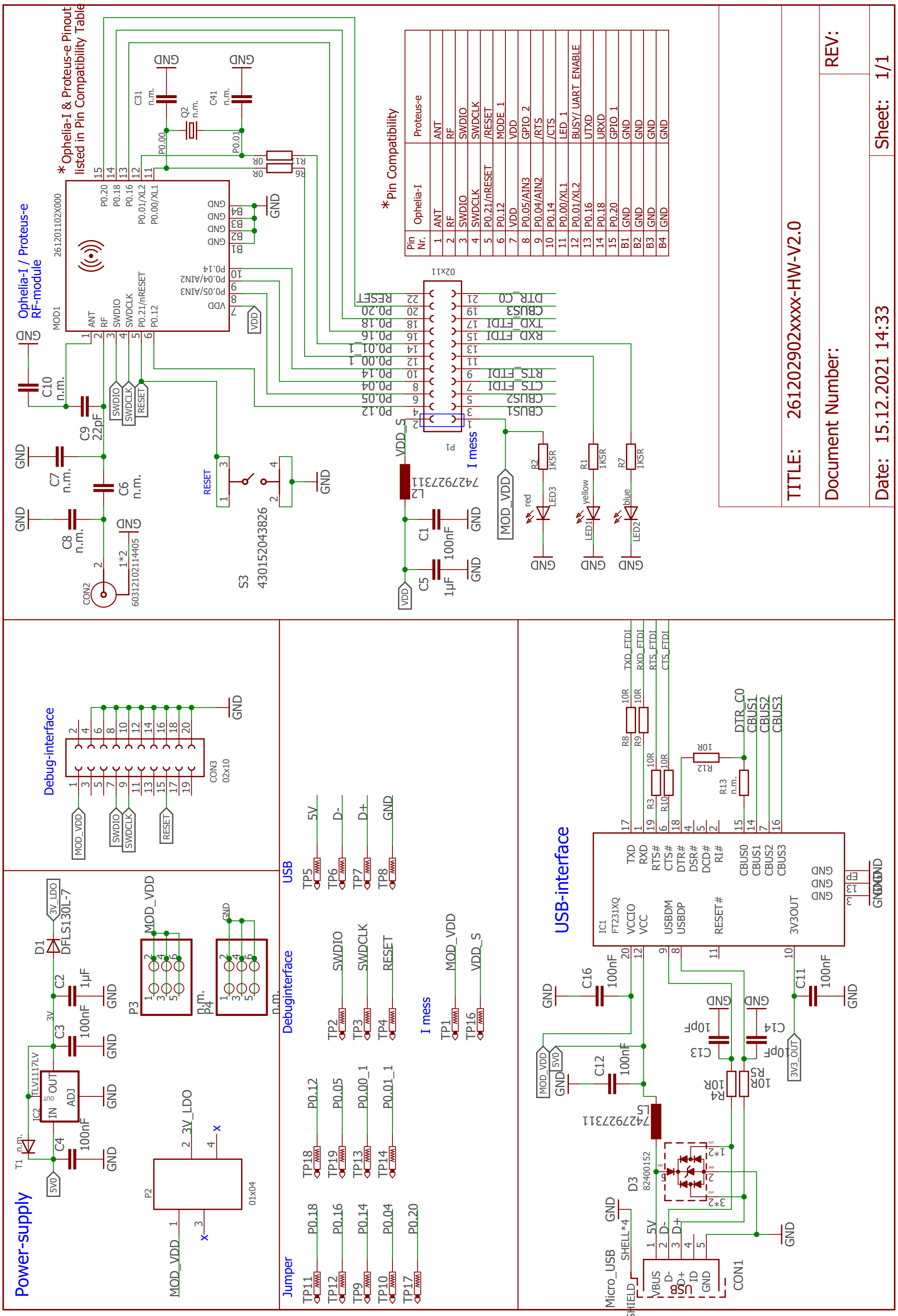

Figure 16: Reference design: Schematic

8.1.2 Layout

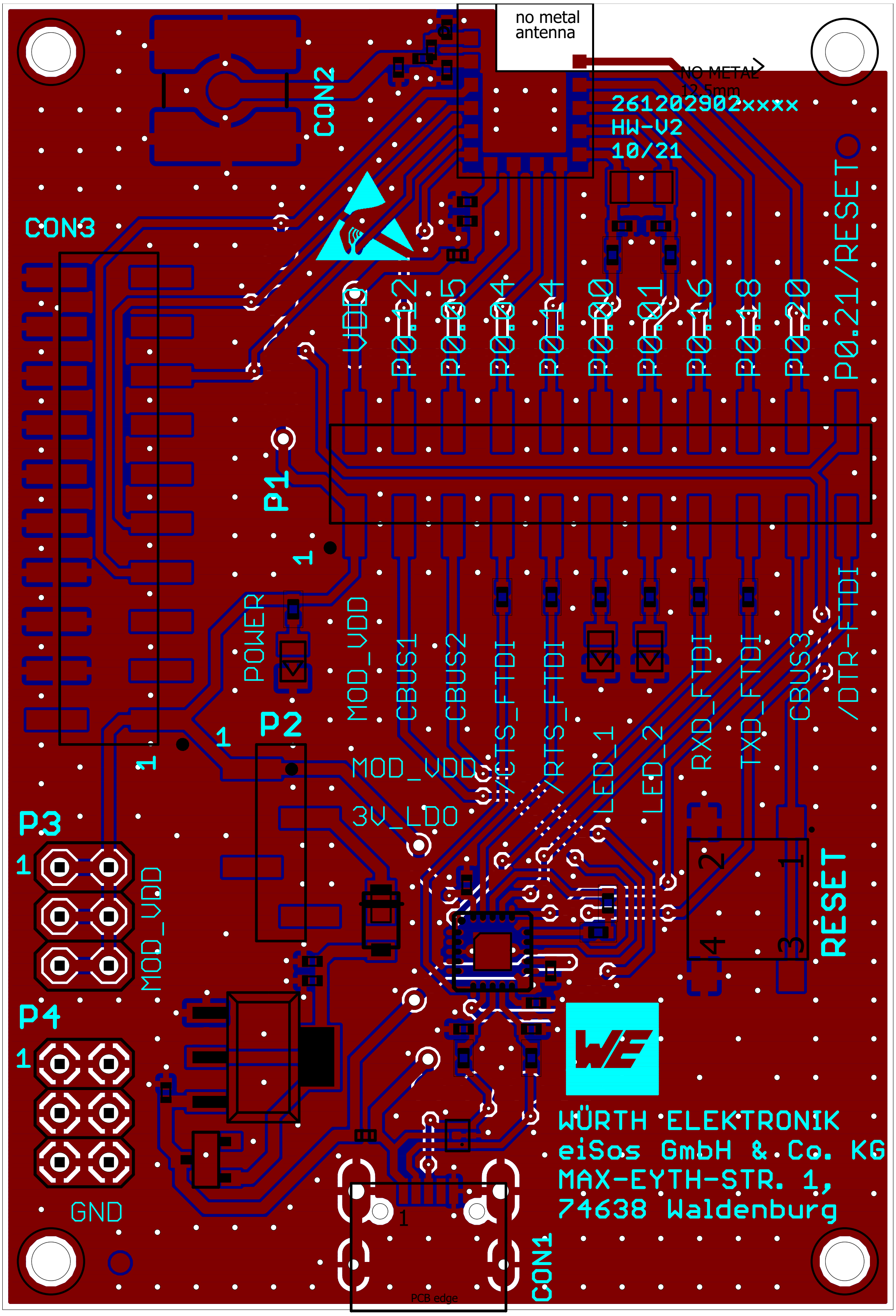

Figure 17: Reference design: Layout

9 Manufacturing information

9.1 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*.

9.2 Soldering

9.2.1 Reflow soldering

Attention must be paid on the thickness of the solder resist between the host PCB top side and the modules bottom side. Only lead-free assembly is recommended according to JEDEC J-STD020.

Profile feature		Value
Preheat temperature Min	$T_{S\ Min}$	150 ℃
Preheat temperature Max	$T_{S\ Max}$	200 ℃
Preheat time from $T_{S\ Min}$ to $T_{S\ Max}$	t_S	60 - 120 seconds
Ramp-up rate (T_L to T_P)		3 ℃ / second max.
Liquidous temperature	T_L	217 ℃
Time t_L maintained above T_L	t_L	60 - 150 seconds
Peak package body temperature	T_P	260 ℃
Time within 5 ℃ of actual peak temperature	t_P	20 - 30 seconds
Ramp-down Rate (T_P to T_L)		6 ℃ / second max.
Time 20 ℃ to T_P		8 minutes max.

Table 13: Classification reflow soldering profile, Note: refer to IPC/JEDEC J-STD-020E

It is recommended to solder this module on the last reflow cycle of the PCB. For solder paste use a LFM-48W or Indium based SAC 305 alloy (Sn 96.5 / Ag 3.0 / Cu 0.5 / Indium 8.9HF / Type 3 / 89%) type 3 or higher.

The reflow profile must be adjusted based on the thermal mass of the entire populated PCB, heat transfer efficiency of the reflow oven and the specific type of solder paste used. Based on the specific process and PCB layout the optimal soldering profile must be adjusted and verified. Other soldering methods (e.g. vapor phase) have not been verified and have to be validated by the customer at their own risk. Rework is not recommended.

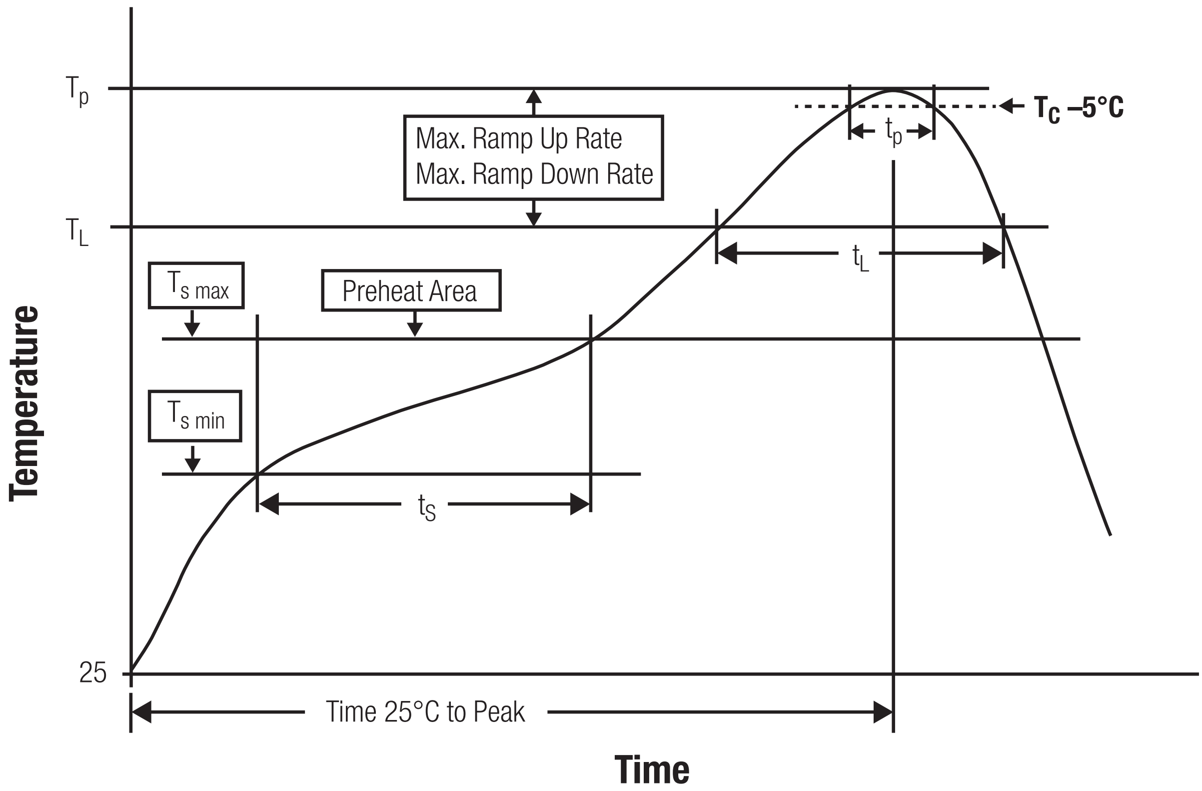

Figure 18: Reflow soldering profile

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

9.2.2 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.

9.2.3 Potting and coating

- If the product is potted in the customer application, the potting material might shrink or expand during and after hardening. Shrinking could lead to an incomplete seal, allowing contaminants into the component. Expansion could damage components. We recommend a manual inspection after potting to avoid these effects.

- Conformal coating or potting results in loss of warranty.
- The RF shield will not protect the part from low-viscosity coatings and potting. An undefined amount of coating and potting will enter inside the shielding.
- Conformal coating and potting will influence the parts of the radio front end and consequently influence the radio performance.
- Potting will influence the temperature behaviour of the device. This might be critical for components with high power.

9.2.4 Other notations

- Do not attempt to improve the grounding by forming metal strips directly to the EMI covers or soldering on ground cables, as it may damage the part and will void the warranty.
- Always solder every pad to the host PCB even if some are unused, to improve the mechanical strength of the module.
- The part is sensitive to ultrasonic waves, as such do not use ultrasonic cleaning, welding or other processing. Any ultrasonic processing will void the warranty.

9.3 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.

9.4 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.

10 Physical specifications

10.1 Dimensions

Dimensions
9 x 7 x 2 mm

Table 14: Dimensions

10.2 Weight

Weight
<1g

Table 15: Weight

10.3 Light sensitivity

Inside the Ophelia-I a light sensitive WLCSP package is used. This package is sensitive to visible and near infrared light. As the chip is not completely shielded on the sides, any mounting without enclosure could lead to malfunction. This should be taken into account when designing an enclosure for the end device.

10.4 Module drawing

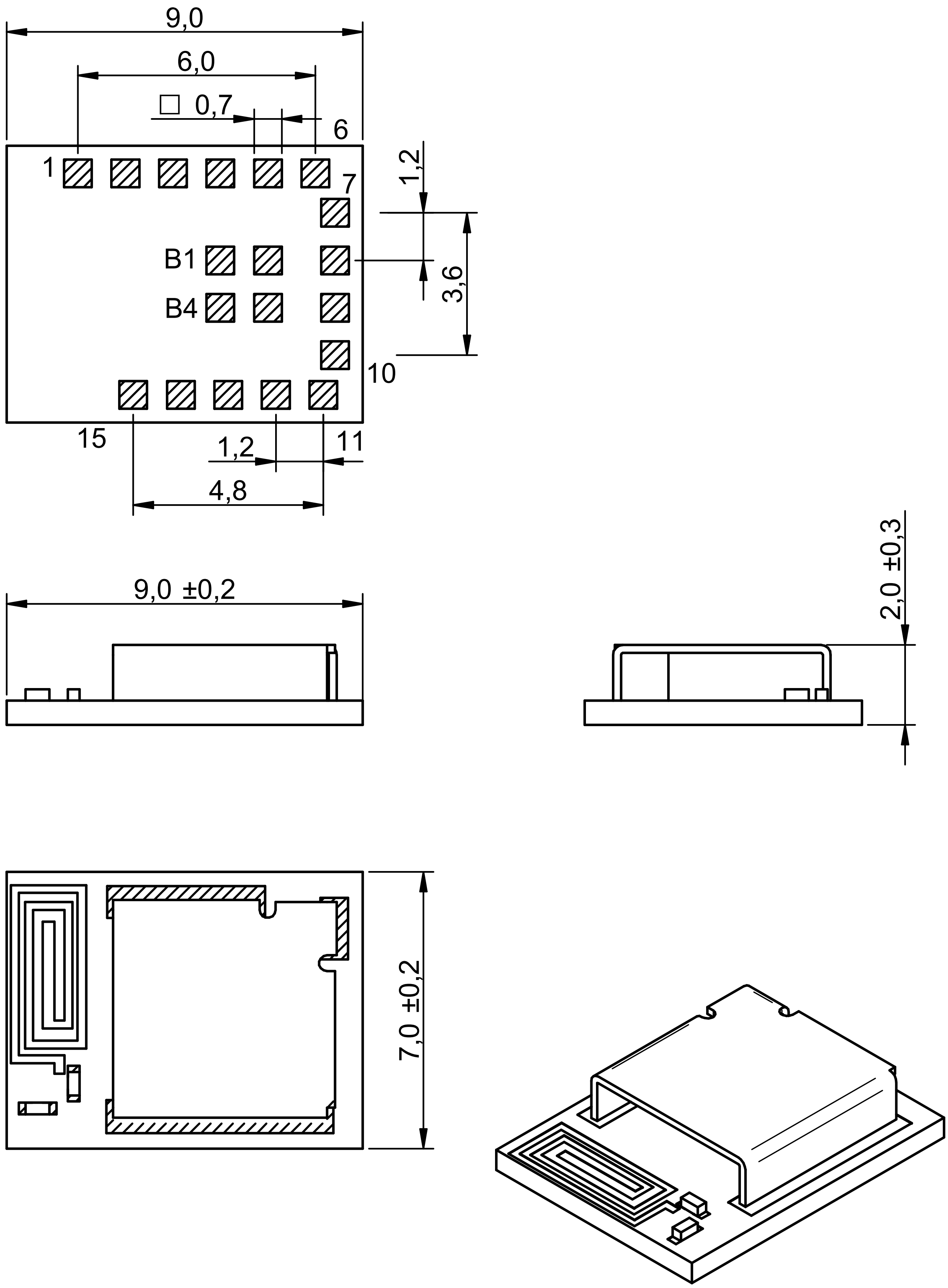

Figure 19: Module dimensions [mm]

10.5 Footprint WE-FP-4+

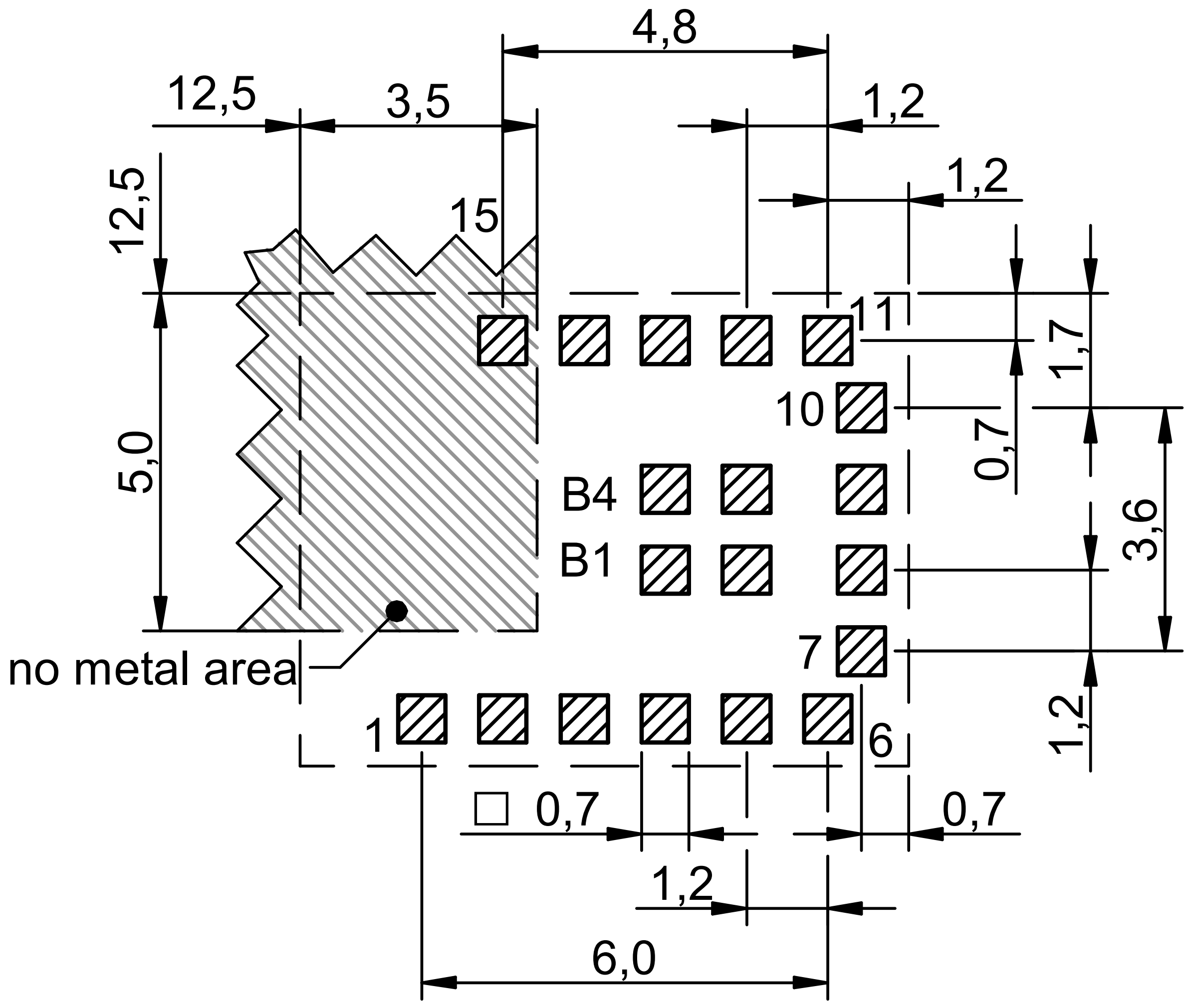

Figure 20: Footprint WE-FP-4+ [mm]

10.6 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 (see figure 20). Even though metal parts would influence the characteristic of the antenna, but the direct influence and matching keep an acceptable level.

11 Marking

11.1 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.

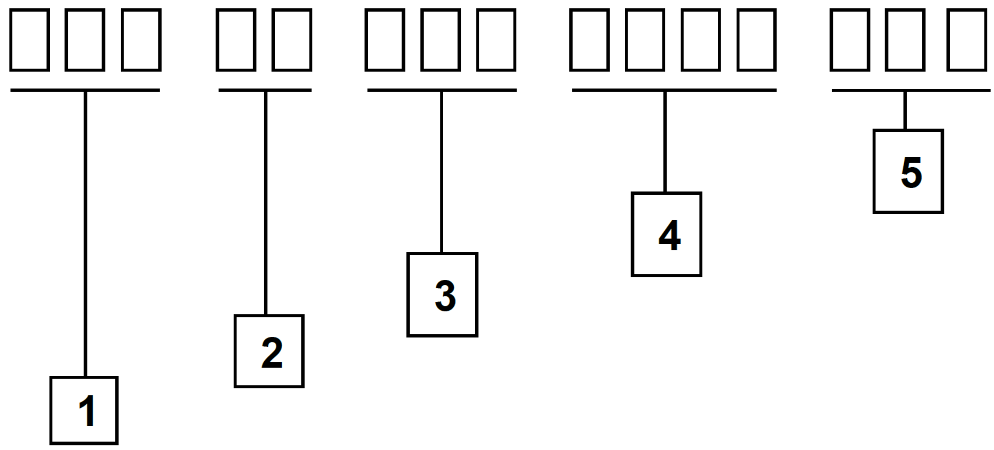

Figure 21: Lot number structure

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	2103 = week 03 in year 2021, 2216 = week 16 in year 2022
5	Firmware version, 3 digits	V3.2 = 302, V5.13 = 513

Table 16: Lot number details

12 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 5 dBm for radio pad.
- The total amount of capacitance of all capacitors is 6.8 µF.
- The total amount of inductance of all inductors is 10.009 µH.
- A DC/DC regulator is included in the chip set and used to obtain low power functionality.

13 References

[1] Nordic Semiconductor. Nordic nRF52805 resources. https://www.nordicsemi.com/products/nrf52805.

[2] Würth Elektronik. Himalia. https://www.we-online.com/catalog/en/WIRL_ACCE_2600130021.

[3] Würth Elektronik. Proteus-e user manual. https://www.we-online.de/katalog/de/manual/2612011024000.

14 Important notes

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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.

14.2 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.

14.3 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.

14.4 Customer support for product specifications

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

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Due to constant product improvement, product specifications may change from time to time. As a standard reporting procedure of the Product Change Notification (PCN) according to the JEDEC-Standard, we inform about major changes. In case of further queries regarding the PCN, the field sales engineer, the internal sales person or the technical support team in charge should be contacted. The basic responsibility of the customer as per section `14.1` and `14.2` remains unaffected. All wireless connectivity module driver software ¨wireless connectivity SDK¨ and it's source codes as well as all PC software tools are not subject to the Product Change Notification information process.

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