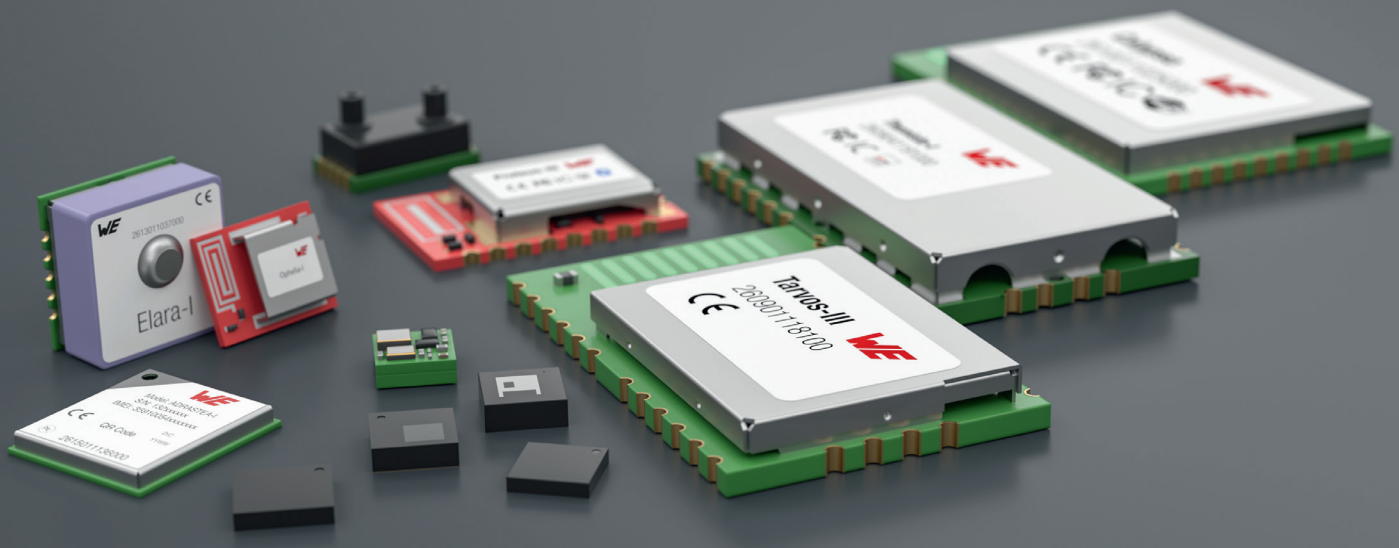

User manual

Ophelia-IV

2621011022000

Version 1.0

November 19, 2025

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

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Overview of helpful application notes

Application note ANR010 - Range estimation

http://www.we-online.com/ANR010
This application note presents the two most used mathematical range estimation models, Friis and two ray ground reflection, and its implementation in the range estimation tool of the RED-EXPERT.

Application note ANR027 - Bluetooth qualification guide

http://www.we-online.com/ANR027
Every product containing Bluetooth® technology needs to be qualified at the Bluetooth® SIG (special interest group). This application note explains the steps to be done to gain a Bluetooth® qualification for the end product using a Würth Elektronik eiSos Bluetooth® LE radio module.

Application note ANR030 - nRF Connect

http://www.we-online.com/ANR030
This application note gives a short overview about the options to create a custom firmware for Würth Elektronik eiSos radio modules by using the hardware platform and the embedded nRF5x system on chip. It presents options on firmware development environments and accessories (like SDKs) for the use within the nRF5 ecosystem. The reader is informed on how to access to a multitude of radio standards (like Bluetooth® LE, Bluetooth® MESH, Bluetooth® LE Audio, Matter, Zigbee, Thread, Wirepas) for custom firmware developments whilst the hardware platform can stay the same.

Application note ANR031 - Certification of custom modules

http://www.we-online.com/ANR031
This application note explains how certifications of a standard product can be used to gain the certification of a customized product. This is done for firmware, which has been adapted by Würth Elektronik eiSos, as well as for firmware written by customer.

1 Revision history

Manual version	HW version	Notes	Date
1.0	2.0	• Initial release	November 2025

2 Abbreviations

Abbreviation	Name	Description
BYOF	Build your own Firmware	Modules that do not come with standard software pre-installed are perfect to develop your own firmware.
DTM	Direct test mode	Mode to test Bluetooth® specific RF settings.
EV (Board)	Evaluation (Board)	Ophelia-IV populated on motherboard with USB interface for test and evaluation purpose.
IEEE	Institute of Electrical and Electronics Engineers	IEEE is a global community for technologists
I/O	Input/output	Pinout description.
MAC		MAC address of the module.
NFC	Near Field Communication	
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.
SDK	Software Development Kit	It is a collection of software development tools (compiler, debugger, software framework etc.) in one installable package.
SPI	Serial Peripheral Interface	Allows the serial communication with the module.
UART	Universal Asynchronous Receiver Transmitter	Allows the serial communication with the module.
[HEX] 0xhh	Hexadecimal	All numbers beginning with 0x are hexadecimal numbers. All other numbers are decimal, unless stated otherwise.

3 Introduction

The Ophelia-IV is a compact radio module designed for wireless communication between devices such as control systems, remote controls, sensors, and more It offers developers the flexibility to create custom firmware using the Nordic nRF Connect SDK [1, 2], supporting protocols like Bluetooth® LE, Matter, Thread, ZigBee, IEEE 802.15.4, NFC-Tag, and 2.4 GHz proprietary solutions.

Even with it's small dimensions of 8 x 12 x 2.3 mm, Ophelia-IV provides a strongly miniaturized integrated PCB antenna. Besides of that, it is possible to connect an external antenna, if high radio ranges are of interest.

The Ophelia-IV comes with a pre-installed DTM-firmware, that can be used for certification and hardware testing of the radio module. Find more information about DTM-firmware in chapter `Direct test mode`.

The DTM-firmware must be removed before flashing any other firmware.

The Ophelia-IV shares the same hardware platform as the Bluetooth® LE enabled Proteus-IV module.

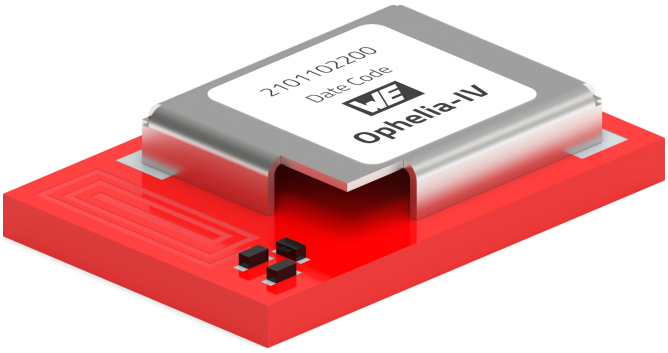

Figure 1: Ophelia-IV

The Ophelia-IV offers the following key features:

nRF54L series microprocessor generation provided by Nordic Semiconductor: The heart of Ophelia-IV is the Bluetooth® LE nRF54L15 chip [3], offering high performance values combined with low power consumption. It is a 128 MHz Arm Cortex-M33 with TrustZone technology, 1524 kB RRAM (non volatile memory), 256 kB RAM and up to 8 dBm output power. The System on chip includes Nordic's 4th generation 2.4 GHz radio.

Flexible application development with nRF Connect SDK: Ophelia-IV is equipped with extra pins suited for custom applications such as integrating actors and sensor connections. With help of these, a tailored "BYOF" firmware can be developed, which is optimized to the customer's needs. The pins can be configured to various functions such as UART, SPI, I^2C, ADC, PWM, NFC and GPIO.

High design flexibility: Ophelia-IV offers a smart antenna selection feature which allows developers to connect either an external antenna or use the integrated PCB antenna. This feature enables the user a high grade of freedom when developing an application.

Multi-protocol support: Developer can create custom firmware for protocols like Bluetooth® LE, Matter, Thread, ZigBee, IEEE 802.15.4, NFC-Tag, and 2.4 GHz proprietary.

Ultra small size: Ultra small size 8 x 12 x 2.3 mm of Ophelia-IV make it suitable for size constraint applications.

Extended operating temperature: Ophelia-IV offers extended industrial operating temperate range (-40 to +105 °C).

3.1 Block diagram

The smart antenna connector can select either intergrated antenna, by feeding the RF signal back to the module or to route the RF signal of the module to a matching and further to an external external antenna. Please checkout the trace design and (mini) Evaluation boards user manuals.

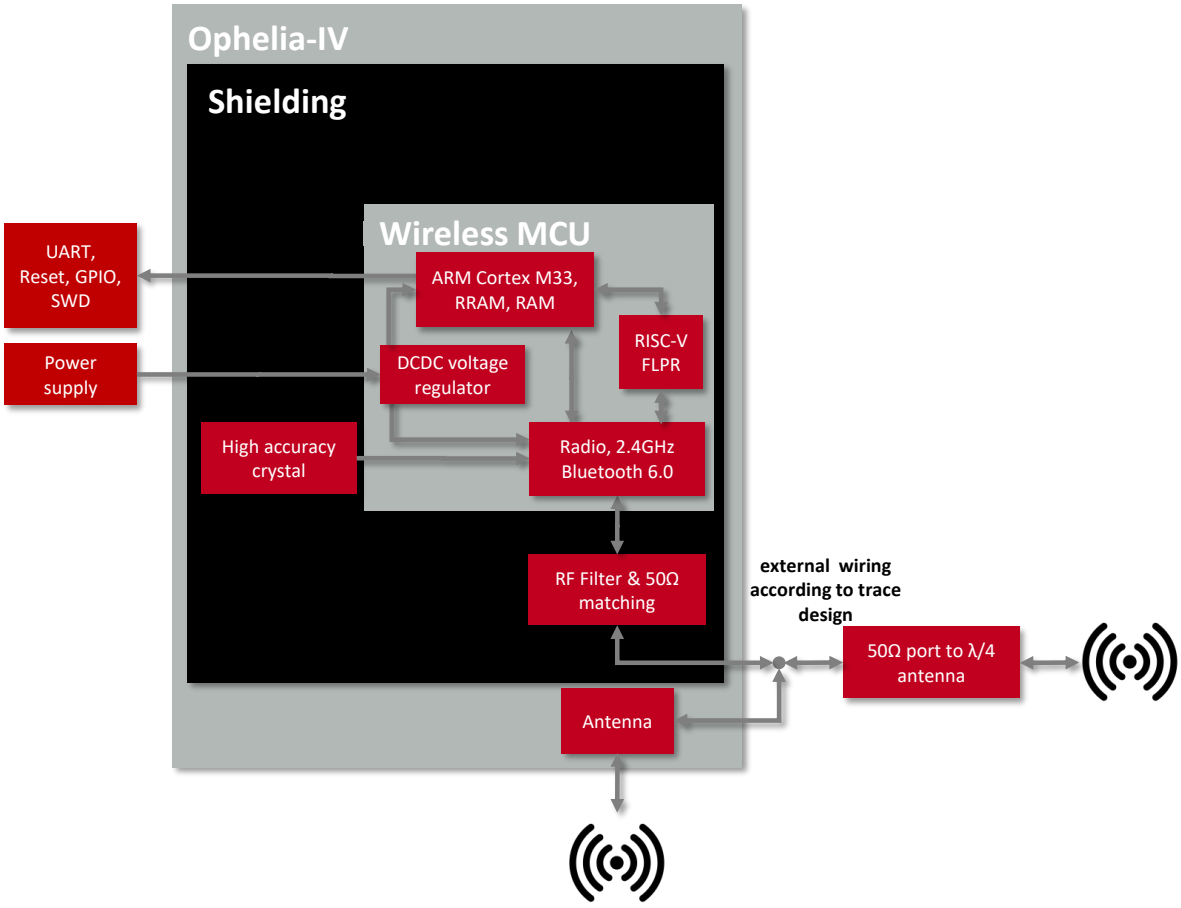

Figure 2: Block diagram of the module

3.2 Ordering information

WE order code	Description
2621011022000	Ophelia-IV radio module, Tape & Reel
2621119022001	Ophelia-IV Family EV-Board

Table 3: Ordering information

4 Electrical specifications

If not otherwise stated, the following values have been measured on an Ophelia-IV EV-Board with T = 25 ℃, VDDS = 3 V, f = 2.44 GHz, internal DC-DC converter in use.

4.1 Operating conditions

Description	Min.	Typ.	Max.	Unit
Temperature	-40	25	105	° C
Supply voltage (VDD) at -40 - 85 ° C	1.7	3	3.6	V
Supply voltage (VDD) at 85 - 105 ° C	1.7	3	3.4	V

Table 4: Operating conditions

4.2 Absolute maximum ratings

Description	Min.	Typ.	Max.	Unit
Supply voltage (VDD)	-0.3		+3.9	V
Voltage on any digital pin, VDD $\leq$ 3.6 V)	-0.3		VDD+0.3	V
Voltage on any digital pin, VDD $>$ 3.6 V)			3.9	V

Table 5: At -40 - 85 ° C

Description	Min.	Typ.	Max.	Unit
Supply voltage (VDD)	-0.3		+3.7	V
Voltage on any digital pin, VDD $\leq$ 3.4 V)	-0.3		VDD+0.3	V
Voltage on any digital pin, VDD $>$ 3.4 V)			3.7	V

Table 6: At 85 - 105 ° C

Description	Min.	Typ.	Max.	Unit
Input RF level			10	dBm
RRAM (non-volatile memory) endurance	10 000			Write/erase cycles

Table 7: General

4.3 Power consumption

4.3.1 Static

Parameter	Power	Test conditions	Value	Unit
TX current consumption	Maximum output power (`RF_TXPower` = 8)	Transmitter only, DC/DC converter enabled, 1 Mbps Bluetooth® LE, CPU current not included, nRF54L15 product specification	9.8	mA
		Full[1] module current consumption DC/DC converter enabled (Bluetooth® LE firmware)	12	mA

Table 8: Current consumption - transmitting, 1Mbit BLE profile

Parameter	Test conditions	Value	Unit
RX current consumption	Receiver only, DC/DC converter enabled, 1 Mbps Bluetooth® LE, CPU current not included, nRF54L15 product specification	3.4	mA
	Full[1] module current consumption DC/DC converter enabled (Bluetooth® LE firmware)	3.6	mA

Table 9: Current consumption - receiving, 1Mbit BLE profile

Parameter	Test conditions	Value	Unit
Current consumption	Sleep (system off mode)	0.6	µA

Table 10: Current consumption - low power

[1] For ease of use, our current measurements include all active components and options of the SoC that are active in an operation state in the stated value (e.g. CPU, radio, UART, timers, flash, RAM...).

4.4 Radio characteristics

Parameter	Min.	Max.	Unit
Frequency	2402	2480	MHz

Table 11: Frequency range

Parameter	Min.	Max.	Unit
RSSI accuracy valid range (± 2 dB)	-90	-30	dBm

Table 12: RSSI accuracy

Parameter	Test conditions	Value	Unit
Output power	Conducted (50 Ω), `RF_TXPower` = 8	7.5	dBm
	Radiated, `RF_TXPower` = 8	2.0	dBm
Input sensitivity	Conducted, BER = 1E-3	-96	dBm
	Radiated, BER = 1E-3	-90	dBm

Table 13: Measured transmit and receive power, 1 Mbit Bluetooth® LE physical layer

All transmit and receive power levels are measured on the EV-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.
Radiated tx power and rx sensitivity was measured using the radio module's integrated PCB antenna.

4.5 Pin characteristics

The following specifications are from the nRF54L15 datasheet.

Description	Min.	Typ.	Max.	Unit
Input high voltage	0.7 ×VCC		VCC	V
Input low voltage	VSS		0.3 ×VCC	V
Current at VSS+0.4 V, output set low, standard drive, VDD ≥1.7V	1	3	4	mA
Current at VSS+0.4 V, output set low, high drive, VDD ≥ 1.7 V	3			mA
Current at VSS+0.4 V, output set low, extra drive, VDD ≥ 1.7 V	16			mA
Current at VDD-0.4 V, output set high, standard drive, VCC ≥1.7V	1	3	4	mA
Current at VDD-0.4 V, output set high, high drive, VDD ≥ 1.7 V	4			mA
Current at VDD-0.4 V, output set high, extra drive, VDD ≥ 1.7 V	14			mA
Internal pull-up resistance	12	14	16	kΩ
Internal pull-down resistance	12	14	18	kΩ
Output pin rise/fall time, high drive mode, 20-80%		4		ns
Output pin rise/fall time, extra drive mode, 20-80%		0.9		ns

Table 14: Pin characteristics

5 Pinout

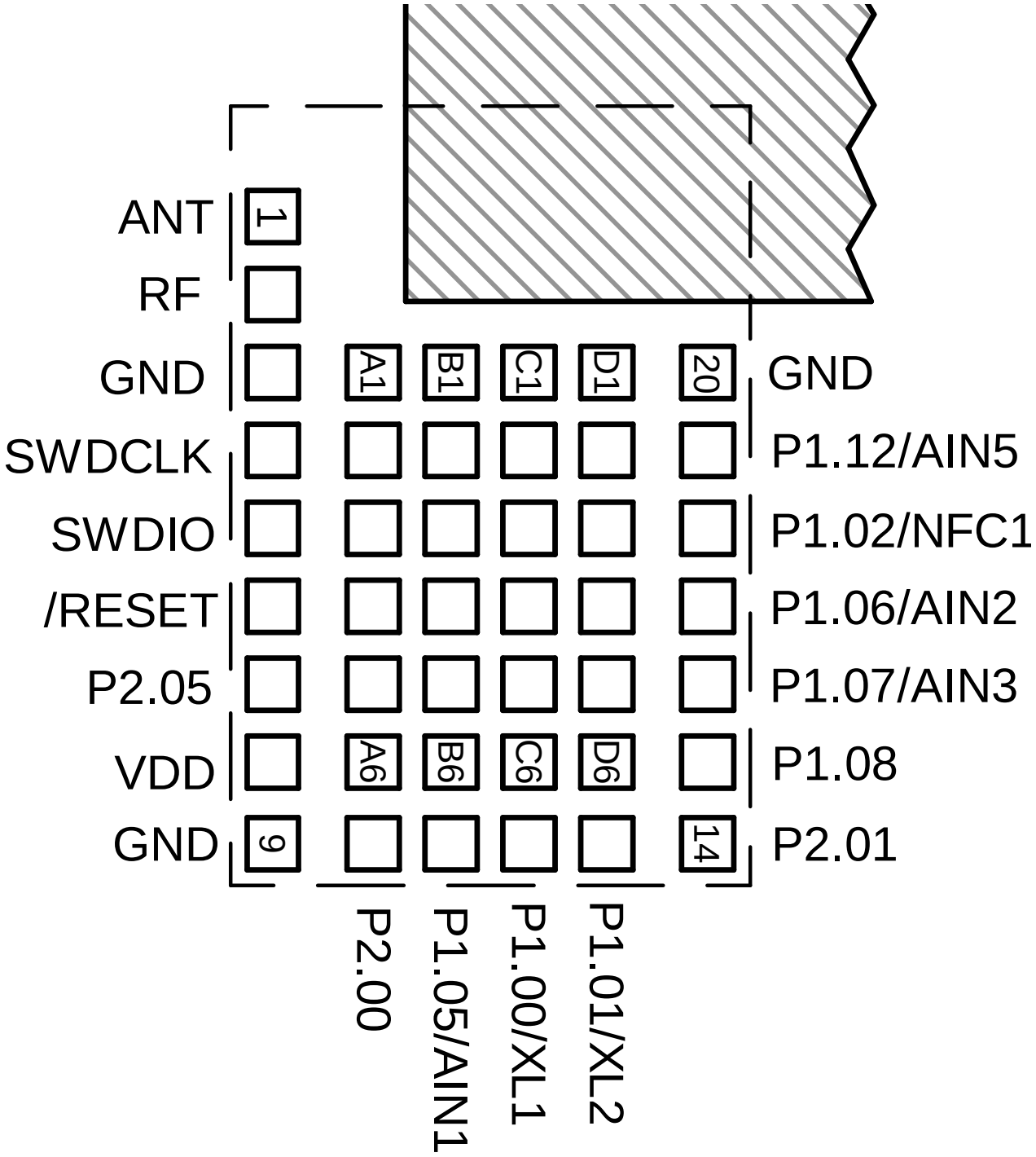

Figure 3: Pinout (top view)

No	µC Pin	I/O	Description
1	*ANT*	I/O	RF connection to PCB antenna. (see section 8)
2	*RF*	I/O	50 Ω RF connection through radio front end to transceiver part of chipset. (see section 8)
3	*GND*	Supply	Ground
4	*SWDCLK*	I/O	Serial wire clock (SWD Interface). Uses internal pull down resistor. Do not connect if not needed.
5	*SWDIO*	I/O	Serial wire input/output (SWD Interface). Uses internal pull up resistor. Do not connect if not needed.
6	*/RESET*	I/O	Reset pin
7	P2.05	I/O	General purpose I/O
8	*VDD*	Supply	Supply voltage
9	*GND*	Supply	Supply voltage
10	P2.00	I/O	General purpose I/O
11	P1.05/AIN1	I/O	General purpose I/O
12	P1.00/XL1	I/O	General purpose I/O
13	P1.01/XL2	I/O	General purpose I/O
14	P2.01	I/O	General purpose I/O
15	P1.08	I/O	General purpose I/O
16	P1.07/AIN3	I/O	General purpose I/O
17	P1.06/AIN2	I/O	General purpose I/O
18	P1.02/NFC1	I/O	General purpose I/O
19	P1.12/AIN5	I/O	General purpose I/O
20	*GND*	Supply	Ground
A1	P0.00	I/O	General purpose I/O
A2	P2.10	I/O	General purpose I/O
A3	P2.09	I/O	General purpose I/O
A4	P2.06	I/O	General purpose I/O
A5	P2.04	I/O	General purpose I/O
A6	P2.02	I/O	General purpose I/O
B1	P0.01	I/O	General purpose I/O
B2	P2.08	I/O	General purpose I/O
B3	*GND*	Supply	Ground
B4	*GND*	Supply	Ground
B5	P2.03	I/O	General purpose I/O
B6	P2.07	I/O	General purpose I/O
C1	*GND*	Supply	Ground

C2	P1.10	I/O	General purpose I/O
C3	*GND*	Supply	Ground
C4	*GND*	Supply	Ground
C5	P1.03/NFC2	I/O	General purpose I/O
C6	P1.04/AIN0	I/O	General purpose I/O
D1	*GND*	Supply	Ground
D2	P1.09	I/O	General purpose I/O
D3	P1.11/AIN4	I/O	General purpose I/O
D4	P1.13/AIN6	I/O	General purpose I/O
D5	P1.14/AIN7	I/O	General purpose I/O
D6	P1.15	I/O	General purpose I/O

Table 15: Pinout

6 Development

The Ophelia-IV is a product without application firmware[1]. For the development of custom firmware, Nordic Semiconductor offers the nRFConnect SDK [1, 2]. It contains the hardware description of the Ophelia-IV, chip related drivers and various examples codes to demonstrate the use of these drivers. Refer to application note *ANR030* for a more detailed description.

Besides the nRFConnect SDK and an Ophelia-IV EV kit, a Segger J-Link Flasher is recommended for debugging and flashing operations. The Ophelia-IV offers a serial wire debug and programming interface (SWD) for module flash access. This interface can be used by customers to install their own firmware.

Make sure the SWD pins are exposed to be able to flash the radio IC in the end device. The first action to install a custom firmware on the Ophelia-IV should be the "unprotect" action which will clear the entire non-volatile memory content of the chipset.

To benefit from the certifications of Würth Elektronik eiSos products and transfer them to the new product, refer to application note *ANR027* [4] (Bluetooth® listing) and application note *ANR031* [5] (radio certification).

After the firmware has been developed, Würth Elektronik eiSos offers the service to flash the firmware at our production site. Please contact your local contact person or *WCS@we-online.com* for quotes regarding these topics.

[1] The Ophelia-IV comes with a pre-installed DTM-firmware, that can be used for certification and hardware testing of the radio module. Please find more information in chapter `Direct test mode`. This firmware must be removed before flashing any other firmware.

7 Direct test mode

The **direct test mode** (2-wire DTM) is an interface for Bluetooth® testing defined by the Bluetooth® standard. It uses a 2 byte UART protocol to run radio transmission and reception tests. These modes are used for product testing in Würth Elektronik eiSos production site, as well as in test houses for radio module certification and Bluetooth® tests.

Please remove the DTM firmware, by using the unprotect operation of the nrfutil flasher tool, before flashing any other firmware.

The DTM firmware uses the UART interface on the pins TX: *P1.04*, RX: *P1.15*, with 115200 Baud 8n1 configuration.

Make sure the UART pins are exposed to be able to control the test modes of the radio IC for certification tests.

The module's UART can be connected to a Bluetooth® tester or the HCI-DTM-Gui PC tool provided by Würth Elektronik eiSos on request (*WCS@we-online.com*).

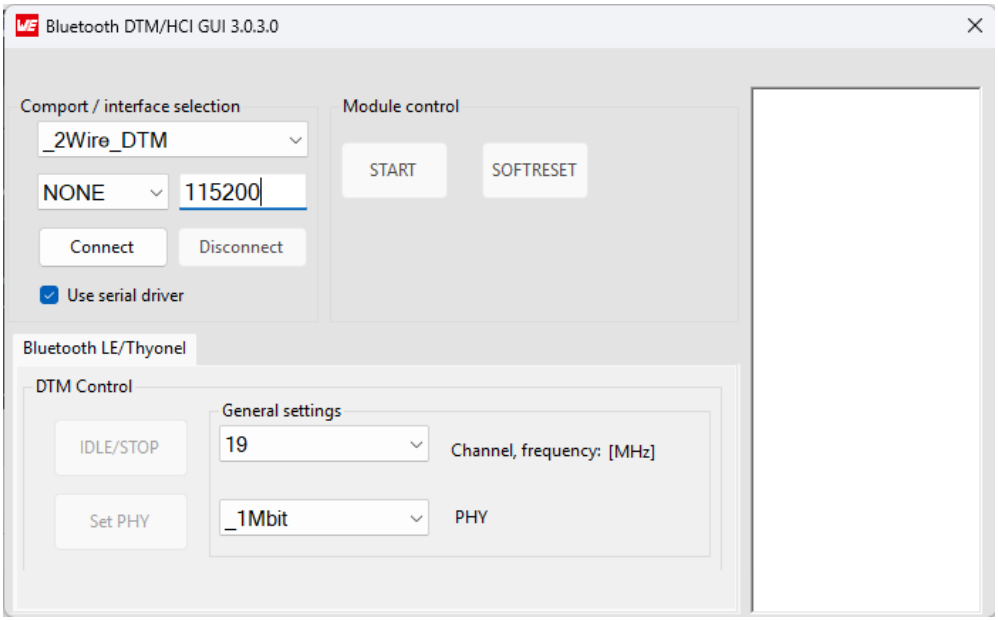

Figure 4: HCI DTM GUI

This tool provides access to the radio test functions via a simple GUI.

8 Antenna connection

Ophelia-IV's smart antenna configuration enables the user to choose between two antenna options:

8.1 On-board PCB antenna

The Ophelia-IV has an on-board PCB antenna optimized for strong miniaturization operating in the 2.4 GHz frequency band. A simple short between the pins *RF* and *ANT* feeds the RF output of the module to the on-board antenna of the Ophelia-IV. In this configuration, the module does not require any additional RF circuitry.

8.2 External antenna

For applications that use an external antenna, the Ophelia-IV provides a 50 Ω RF signal on pin *RF* of the module. In this configuration, pin *ANT* of the module has to be connected to ground and pin *RF* to the external antenna via 50 Ω feed line. Refer to chapter 11 for further information.

The use cases for the integrated antenna are miniaturization and re-use of module certifications for the end-application. In order to be to be able to inherit radio certifications for FCC and IC the trace design must be followed.
The use cases for the external antenna are optimization of radio range spending more space for the antenna and differentiated antenna for example when metal housings are used.

9 Hardware history

Version 2.0 "Release"

- First production release
- nRF54L15, WLCSP

10 Design in guide

10.1 Advice for schematic and layout

For users with less RF experience it is advisable to closely copy the relating EV-Board with respect to schematic and layout, as it is a proven design. The layout should be conducted with particular care, because even small deficiencies could affect the radio performance and its range or even the conformity.

The following general advice should be taken into consideration:

- A clean, stable power supply is strongly recommended. Interference, especially oscillation can severely restrain range and conformity.
- Variations in voltage level should be avoided.
- LDOs, properly designed in, usually deliver a proper regulated voltage.
- Blocking capacitors and a ferrite bead in the power supply line can be included to filter and smoothen the supply voltage when necessary.
- 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.
- The use of an external reset IC should be considered if one of the following points is relevant:
  - The slew rate of the power supply exceeds the electrical specifications.
  - The effect of different current consumptions on the voltage level of batteries or voltage regulators should be considered. The module draws higher currents in certain scenarios like start-up or radio transmit which may lead to a voltage drop on the supply. A restart under such circumstances should be prevented by ensuring that the supply voltage does not drop below the minimum specifications.
  - Voltage levels below the minimum recommended voltage level may lead to malfunction. The reset pin of the module shall be held on LOW logic level whenever the VDD is not stable or below the minimum operating Voltage.
  - Special care must be taken in case of battery powered systems.
- 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.

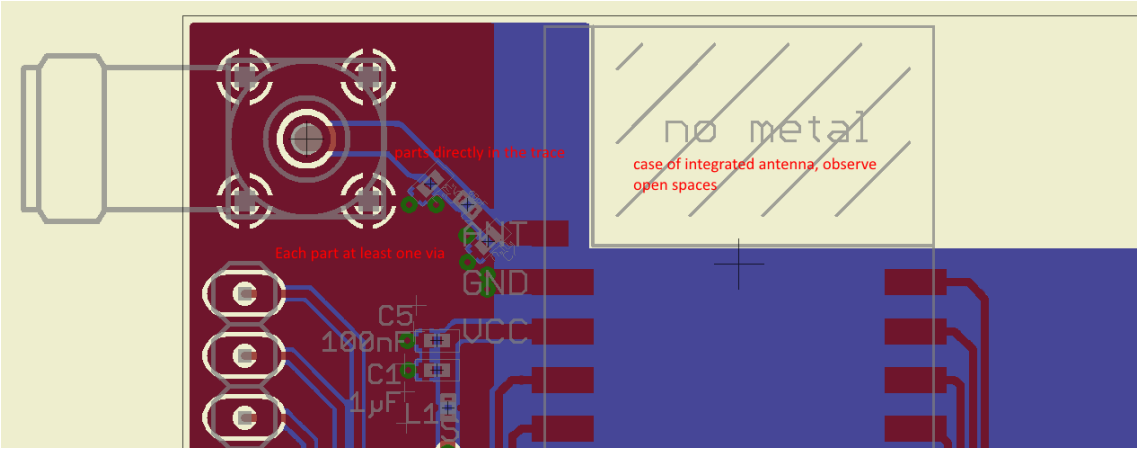

Figure 5: Layout

- In case of integrated antennas it is required to have areas free from ground. This area should be copied from the EV-Board.
- The area with the integrated antenna must overlap with the carrier board and should not protrude, as it is matched to sitting directly on top of a PCB.
- Modules with integrated antennas should be placed with the antenna at the edge of the main board. It should not be placed in the middle of the main board or far away from the edge. This is to avoid tracks beside the antenna.
- Filter and blocking capacitors should be placed directly in the tracks without stubs, to achieve the best effect.
- Antenna matching elements should be placed close to the antenna / connector, blocking capacitors close to the module.
- Ground connections for the module and the capacitors should be kept as short as possible and with at least one separate through hole connection to the ground layer.
- ESD protection elements should be placed as close as possible to the exposed areas.

Fixed values can not be recommended, as these depend on the circumstances of the application (main power source, interferences etc.).

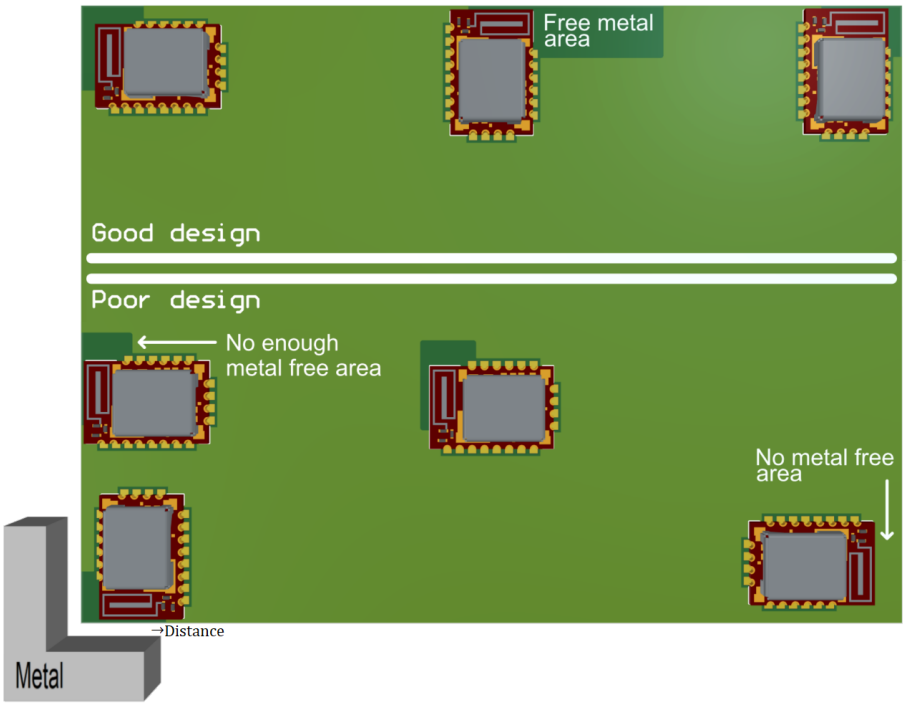

Figure 6: Placement of the module with integrated antenna

10.2 Designing the antenna connection

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

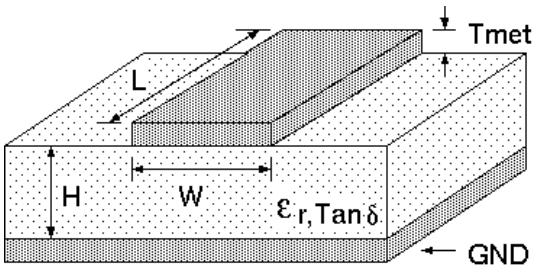

Figure 7: Dimensioning the antenna connection as micro strip

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

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

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.

10.3 Antenna solutions

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

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

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

10.3.1 Wire antenna

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

10.3.2 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.

10.3.3 PCB antenna

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

10.3.4 Antennas provided by Würth Elektronik eiSos

Besides the radio modules Würth Elektronik eiSos provides various antennas tailored for the different frequency bands. The recommended single external antennas are shown in the subsequent chapters.

In case integrated multilayer chip antennas are needed because of space limitations, please refer to *https://www.we-online.com/en/components/products/WE-MCA*.

10.3.4.1 2600130021 - Himalia dipole antenna

Figure 8: Himalia 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 fulfill the requirement of permanently attached antenna or unique coupling, for example by using the certified dipole antenna in a closed housing, so that it is possible to remove it only through professional installation.

11 Reference design

Ophelia-IV was tested and certified on the corresponding Ophelia-IV EV-Board. For the compliance with the EU directive 2014/53/EU Annex I, the EV-Board serves as reference design. This is no discrepancy due to the fact that the EV-Board itself does not fall within the scope of the EU directive 2014/53/EU Annex I as the module is tested on the EV-Board, which is also the recommended use.

Further information concerning the use of the EV-Board can be found in the manual of the Ophelia-IV EV-Board.

11.1 EV-Board

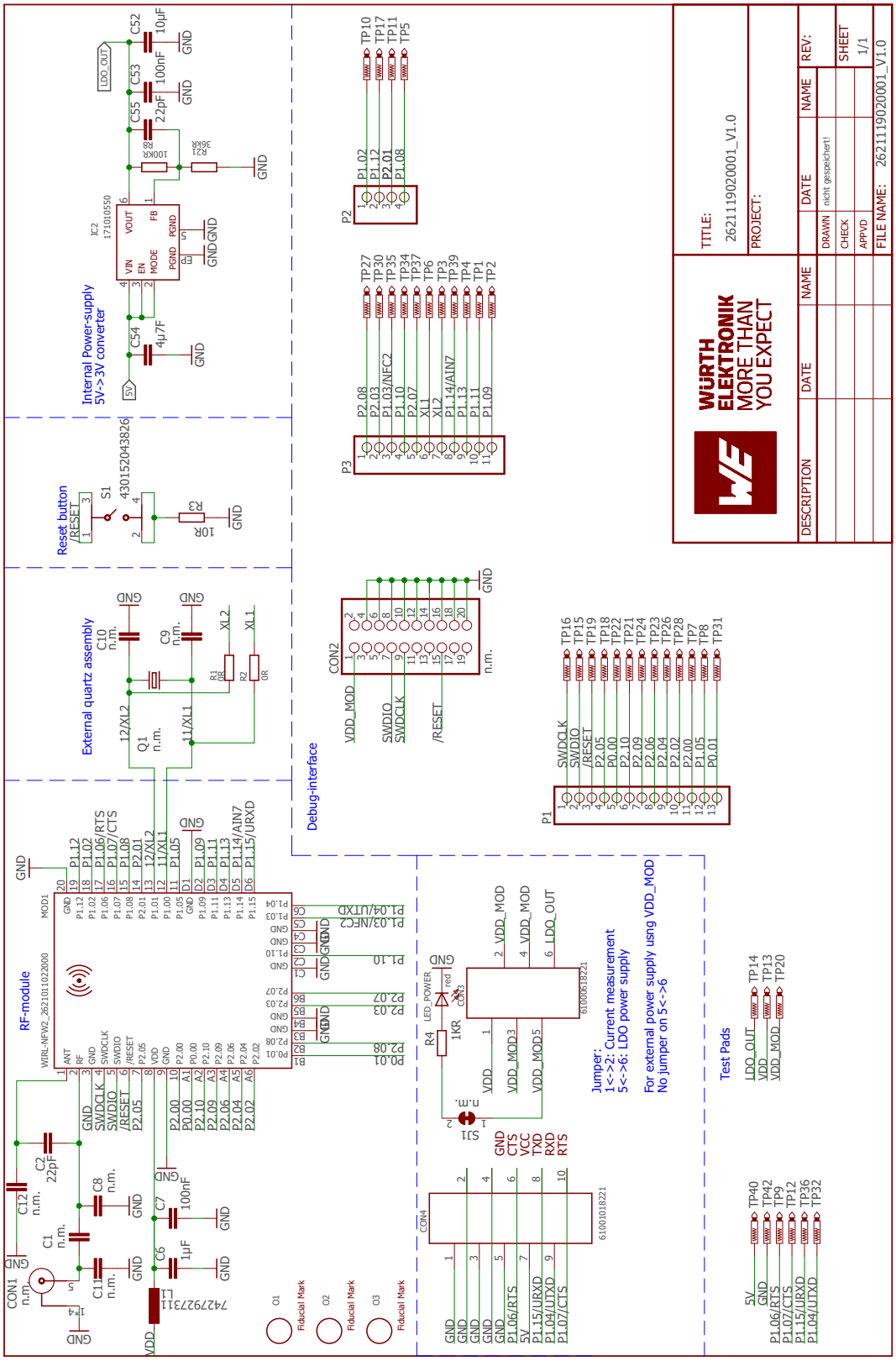

Figure 9: Reference design: schematic page

11.2 Layout

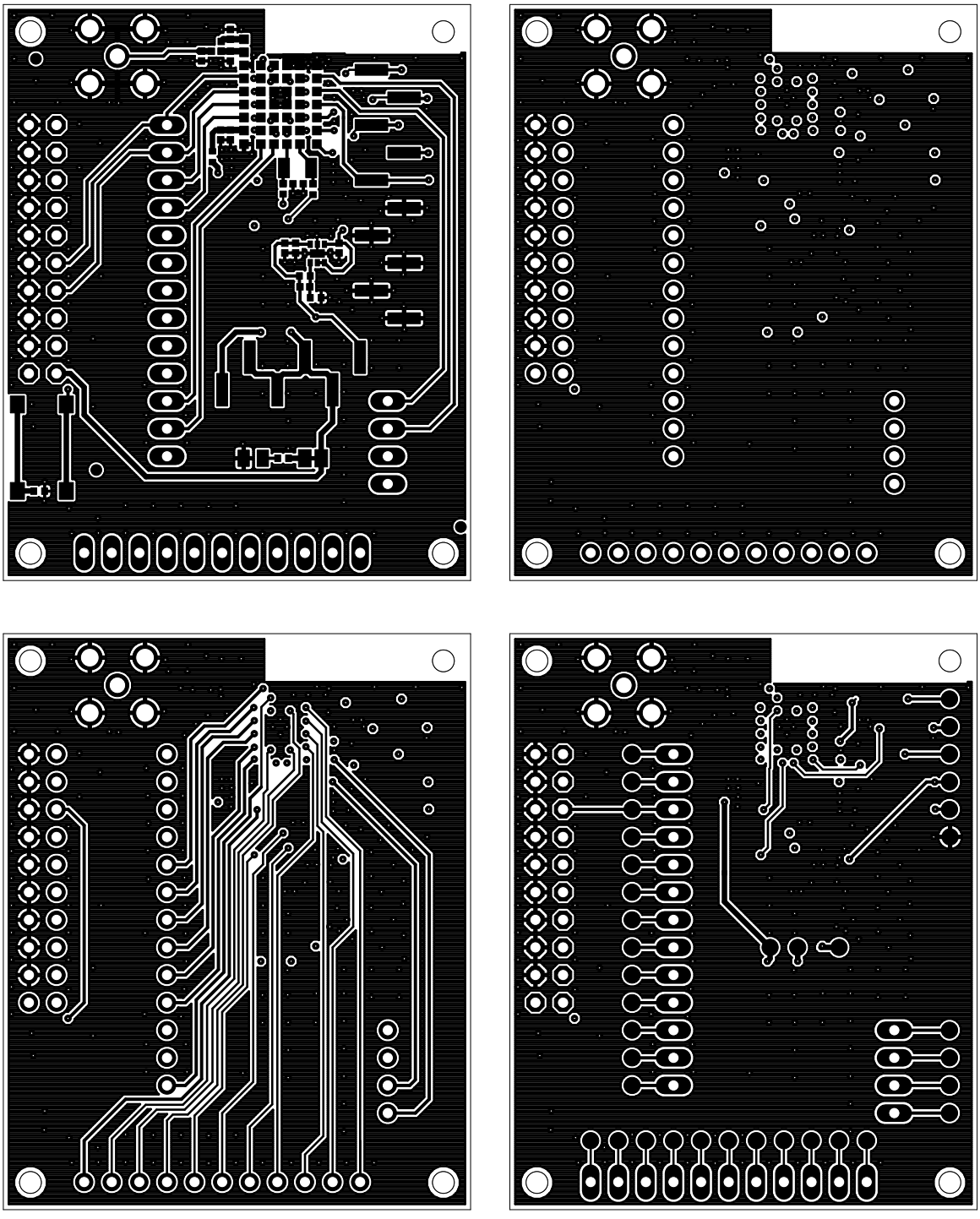

Figure 10: Top layer (top left), second layer (top right), third layer (bottom left), bottom layer (bottom right)

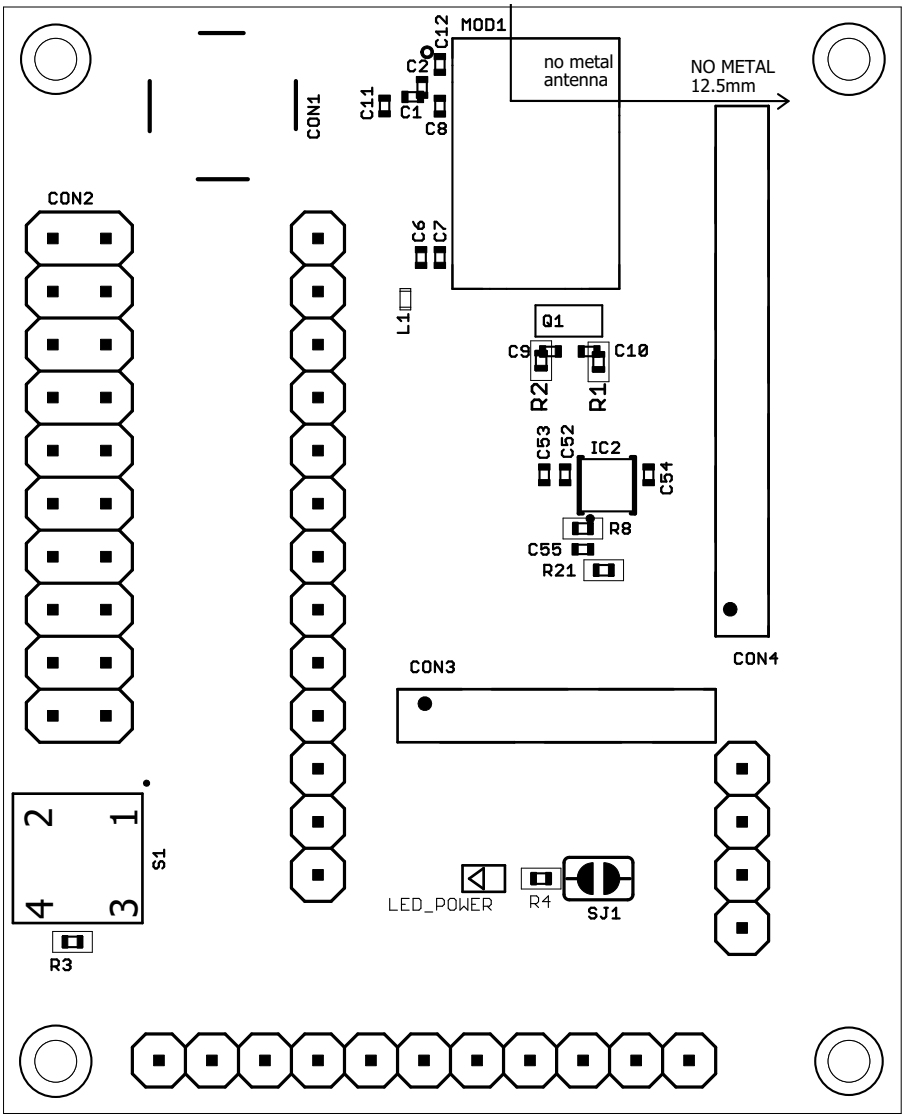

Figure 11: Reference design assembly plan

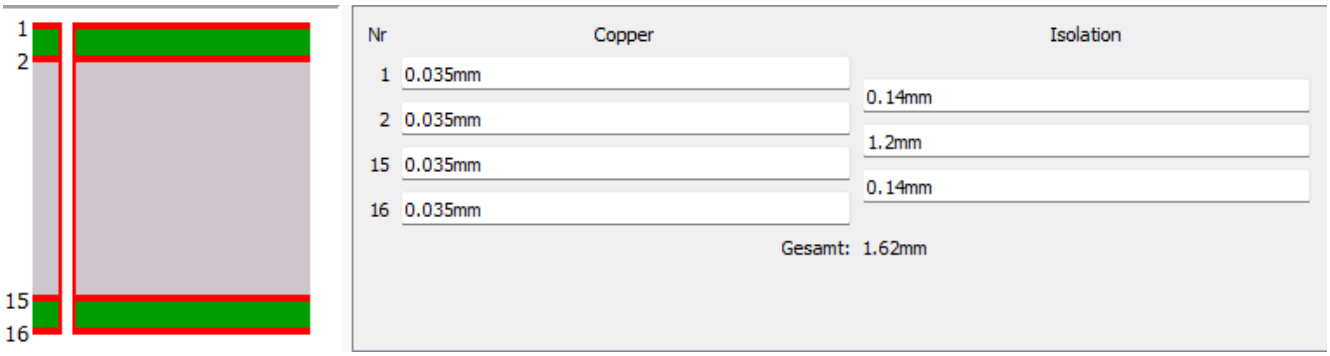

Figure 12: Reference design: Stack-up

- Top layer is used for routing and filled up with ground except underneath the module and the antenna free area.

- Second layer is ground, except the antenna free area.
- Third layer is the supply layer, except antenna free area. Some routing is allowed, not dividing the supply layer in to many or to small parts.
- Bottom layer is used for routing.

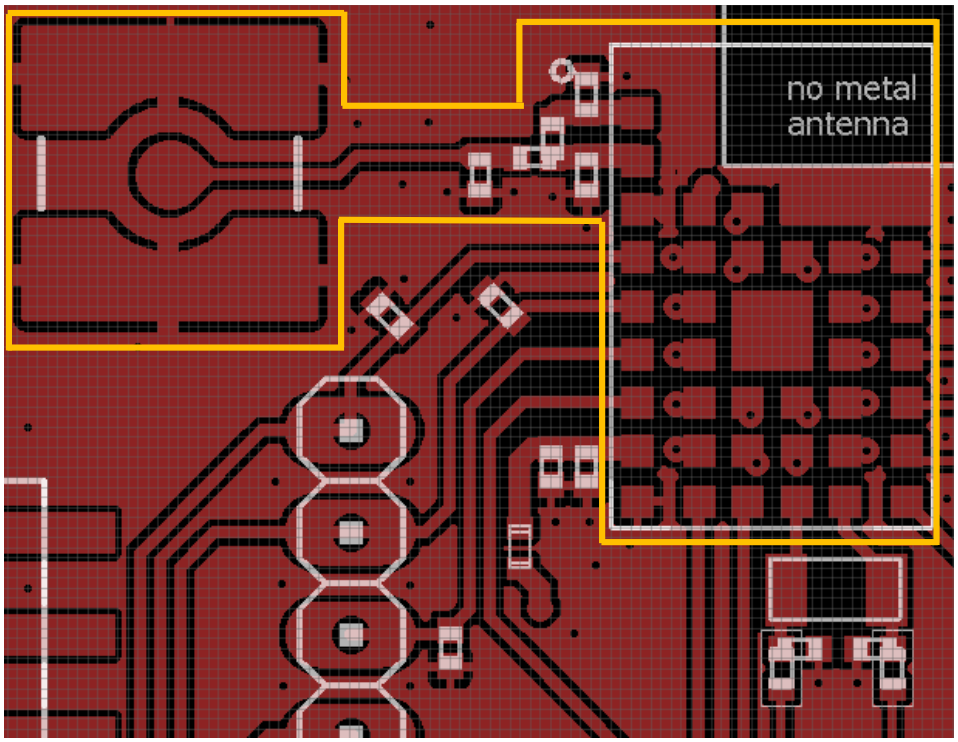

Figure 13: Trace design

12 Manufacturing information

12.1 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*.

12.2 Soldering

12.2.1 Reflow soldering

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

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

Table 16: 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.

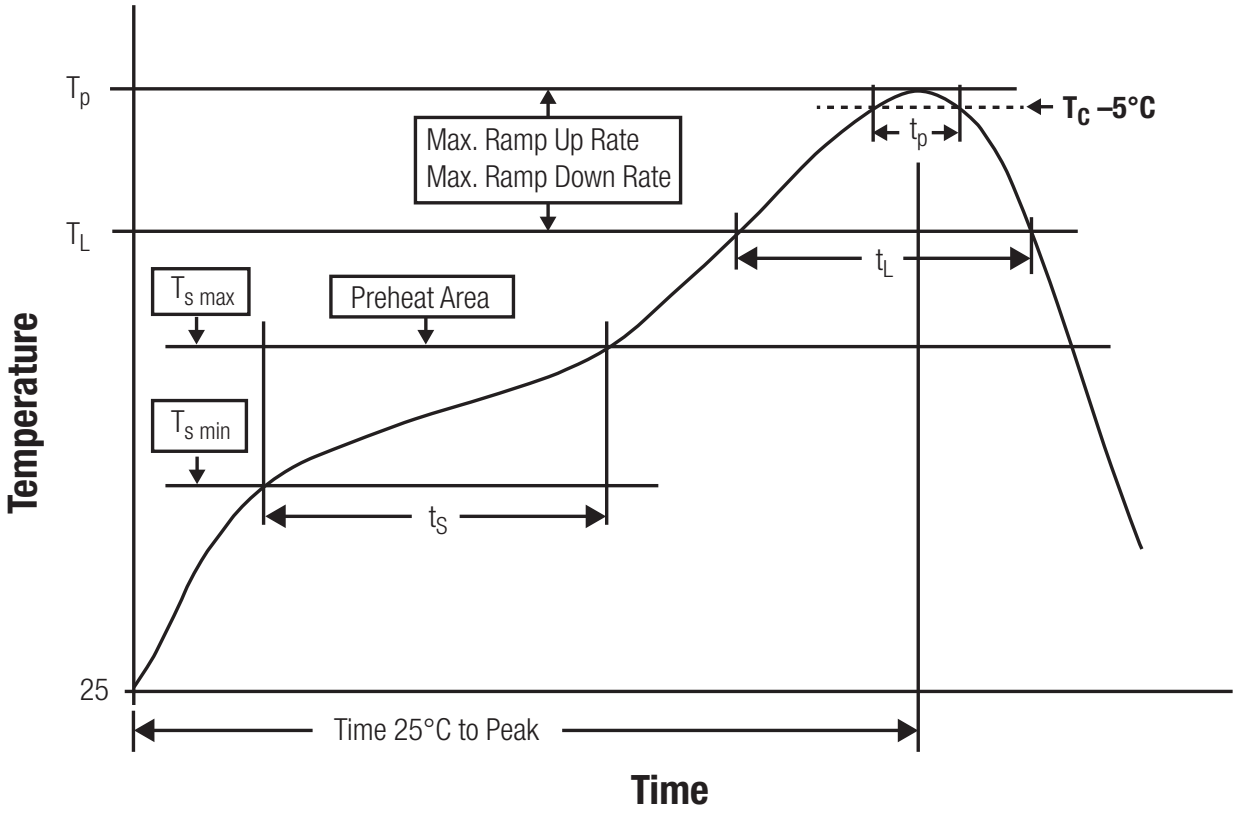

Figure 14: Reflow soldering profile

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

12.2.2 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.

12.2.3 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 behavior of the device. This might be critical for components with high power.

12.2.4 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.

12.3 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 4. 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.

12.4 Safety recommendations

It is your duty to ensure that the product is allowed to be used in the destination country and within the required environment. Usage of the product can be dangerous and must be tested and verified by the end user. Be especially careful of:

- Use in areas with risk of explosion (for example oil refineries, gas stations).
- Use in areas such as airports, aircraft, hospitals, etc., where the product may interfere with other electronic components.

It is the customer's responsibility to ensure compliance with all applicable legal, regulatory and safety-related requirements as well as applicable environmental regulations. Disassembling the product is not allowed. Evidence of tampering will void the warranty.

- Compliance with the instructions in the product manual is recommended for correct product set-up.
- The product must be provided with a consolidated voltage source. The wiring must meet all applicable fire and security prevention standards.
- Handle with care. Avoid touching the pins as there could be ESD damage.

Be careful when working with any external components. When in doubt consult the technical documentation and relevant standards. Always use an antenna with the proper characteristics.

Würth Elektronik eiSos radio modules with high output power of up to 500 mW generate a large amount of heat while transmitting. The manufacturer of the end device must take care of potentially necessary actions for his application.

13 Product testing

13.1 Würth Elektronik eiSos in-house production tests

To achieve a high quality standard, Würth Elektronik eiSos follows a philosophy of supplying fully tested radio modules. At the end of the production process, every unit undergoes an optical inspection. Here the quality of soldering, edge castellation and edge milling is monitored.

If this has been passed, the radio modules are handed over to the automatic test equipment for the electrical characterization. This includes:

- Voltage and current tests to ensure proper electrical performance
- RF characteristics (frequency, spectrum, TX power) measurement and calibration
- Radio communication tests
- Firmware and serial number programming
- Host interface communication tests

The automated testing process is logged for internal quality control. The gained measurement data of each unit is analysed to detect defective parts and investigate the corresponding root cause. Defective radio modules are discarded, in order to guarantee a 100% failure-free delivery to customers.

13.2 EMS production tests

The rigorous in-series production testing ensures that EMS don't need to duplicate firmware tests or measurements. This streamlines the process and eliminates the need for additional testing over analogue and digital interfaces during device production. When it comes to device testing, the ideal focus should be on module assembly quality:

- All module pins are soldered properly on the base PCB
- There are no short circuits
- The mounting process did not damage the module
- The communication between host and radio module is working
- The antenna is connected properly

Simple "Go/No go" tests, like checking the RSSI value, give already a hint if the power supply and antenna have been connected properly.

In addition to such standard testing procedures, radio module integrators have the flexibility to perform additional dedicated tests to thoroughly evaluate the device. Specific tests they can consider are:

- Measure module current consumption in a specified operating state. Deviations from expected results (compared to a "Golden Device") can signal potential issues.

- Perform functional tests, including communication checks with the host controller and verification of interfaces.
- Assess fundamental RF characteristics (modulation accuracy, power levels, spectrum). Verify that the device meets expected performance standards.

14 Physical specifications

14.1 Dimensions

Dimensions
12 x 8 x 2.3 mm

Table 17: Dimensions

14.2 Weight

Weight
< 1 g

Table 18: Weight

14.3 Module drawing

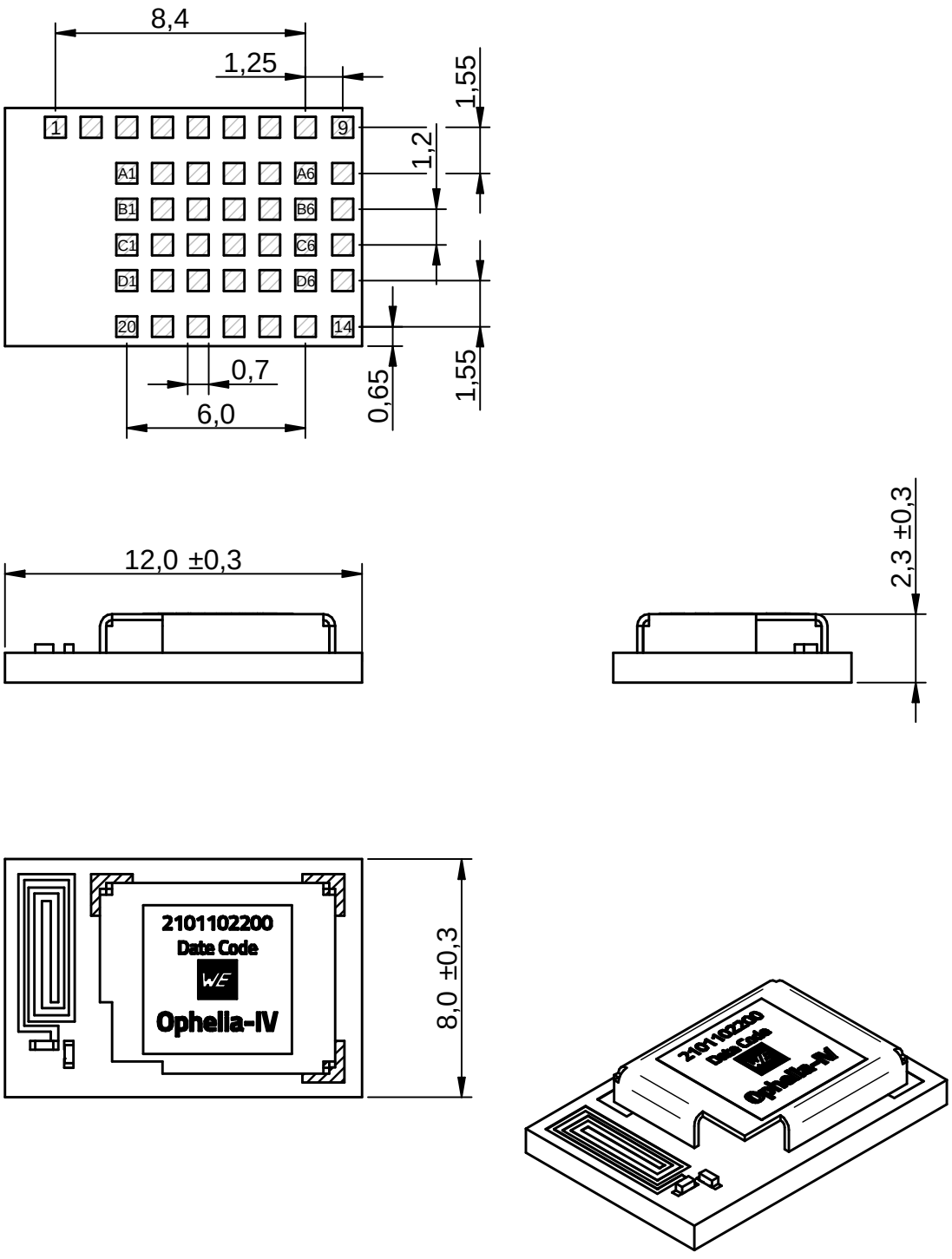

Figure 15: Module dimensions [mm]

14.4 Footprint

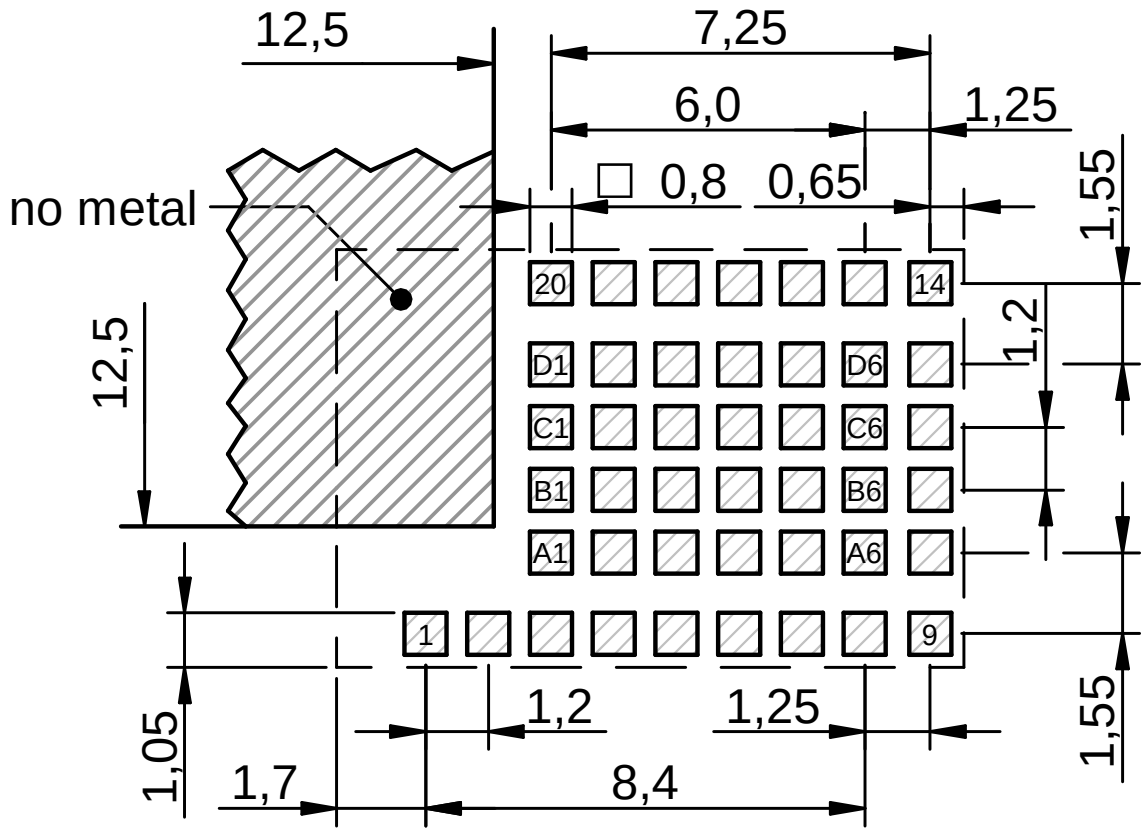

Figure 16: Footprint [mm]

14.5 Antenna free area

To avoid influence and mismatching of the antenna the recommended free area around the antenna should be maintained. As rule of thumb a minimum distance of metal parts to the antenna of λ/10 should be kept (see figure 16). Even though metal parts would influence the characteristic of the antenna, but the direct influence and matching keep an acceptable level.

15 Marking

15.1 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.

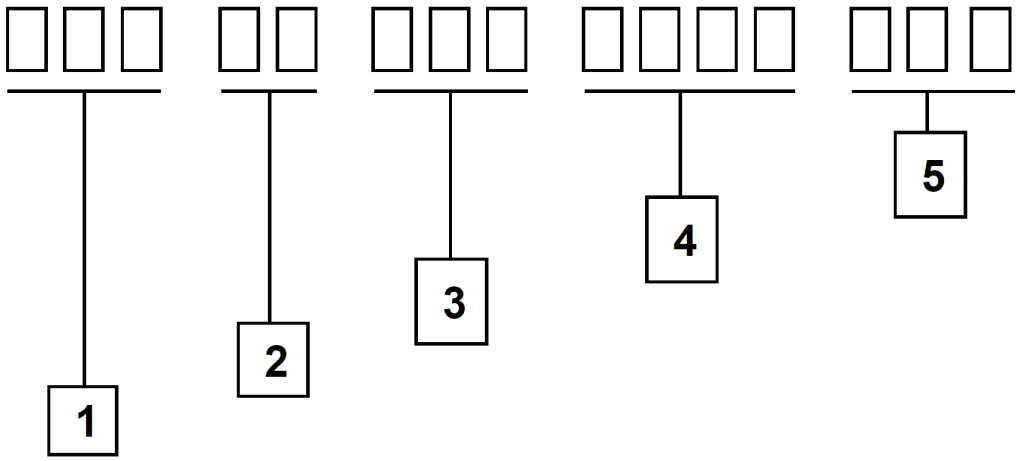

Figure 17: Lot number structure

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	2103 = week 03 in year 2021, 2216 = week 16 in year 2022
5	eiSos internal, 3 digits	000

Table 19: Lot number details

16 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 7.5 dBm for external antenna and 2 dBm for internal antenna.
- The total amount of capacitance of all capacitors is 14.62 µF.
- The total amount of inductance of all inductors is 4.71 µH.
- A DC/DC regulator is included in the chip set and used to obtain low power functionality.

17 References

[1] Nordic Semiconductor. nRF Connect SDK. https://www.nordicsemi.com/Products/Development-software/nRF-Connect-SDK.

[2] Würth Elektronik. Application note 30 - nRFConnect. https://www.we-online.com/ANR030.

[3] Nordic Semiconductor. Nordic nRF54L15 resources. https://www.nordicsemi.com/products/nrf54l15.

[4] Würth Elektronik. Application note 27 - Bluetooth listing guide. http://www.we-online.com/ANR027.

[5] Würth Elektronik. Application note 31 - Certification of custom modules. https://www.we-online.com/ANR031.

18 Important notes

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

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

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

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

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

Product improvements
Due to constant product improvement, product specifications may change from time to time. As a standard reporting procedure of the Product Change Notification (PCN) according to the JEDEC-Standard, we inform about major changes. In case of further queries regarding the PCN, the Business Development Engineer (BDM), the internal sales person or the technical support team in charge should be contacted. The basic responsibility of the customer as per section 18 and 18 remains unaffected.
All software like ¨wireless connectivity SDK¨, ¨Sensor SDK¨ or other source codes as well as all PC software tools are not subject to the Product Change Notification information process.

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

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

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

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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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