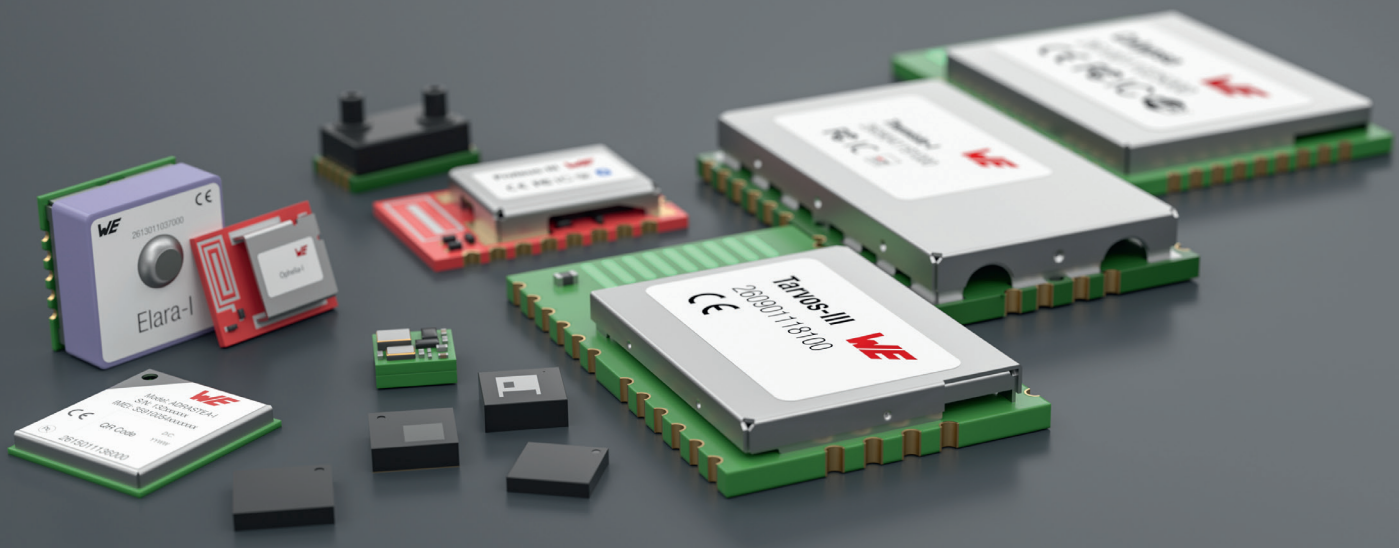

ANR022

Radio module cross migration guide

Tarvos-III/Telesto-III/Thebe-II/Themisto-I to Thyone-I

Version 1.1

July 19, 2023

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

Revision history

Manual version	Notes	Date
1.0	• Initial version	January 2023
1.1	• Updated `Important notes` and meta data	July 2023

Abbreviations

Abbreviation	Name	Description
ACK	Acknowledgement	Radio packet sent back to the transmitter to acknowledge the reception of data.
CE	Conformité Européene	CE conformity indicates that a product has been assessed by the manufacturer and deemed to meet EU requirements. For radio modules this means beside safety, health and EMC also spectrum requirements.
CTS	Clear-to-Send	UART flow control signal line
FCC	Federal Communications Commission	FCC regulates interstate and international communications by radio, television, wire, satellite, and cable in U.S. territories.
IC	Industry Canada	Canadian Authority regulating and approving wireless products certification.
ID	Identity document	An official document used for identification.
IO	Input & Output	
LRM	Long range mode	Special radio profile for large transmission ranges.
PCB	Printed Circuit Board	
RF	Radio frequency	Describes wireless transmission.
RTS	Request-to-Send	UART flow control signal line
RX	Receive	UART data signal line
SRD	Short Range Device	Unlicensed frequency bands.
SWD	Serial Wire Debug	
TELEC	Telecom Engineering Center	TELEC is the main registered certification body for radio equipment conformity certification in Japan.
TX	Transmit	UART data signal line
UART	Universal Asynchronous Receiver Transmitter	Universal Asynchronous Receiver Transmitter allows communicating with the module of a specific interface

Contents

1 Introduction

The radio frequency spectrum is regulated by designated regulatory authorities that define how specific spectrum bands can be used. As each frequency band has its strength, Würth Elektronik eiSos provides for each frequency band proprietary and standardized radio modules, which allow the user to decide the best module for the end application. The most common characteristics to choose radio modules are frequency, energy efficiency, data transmission rate and transmission protocols.

With the evolution of radio chips, new proprietary and standardized radio modules have been developed, that are more energy efficient during data transmission and reception. Furthermore new coding and modulation techniques have been added, that allow higher transmission ranges (long range mode) and/or higher data rates.

Due to the worldwide operation the interest of using the 2.4 GHz frequency band increases. This application note describes an adapter board, that is used to place a 2.4 GHz Thyone-I radio module on the footprint of a Tarvos-III/Telesto-III/Thebe-II/Themisto-I radio module.

Furthermore, the steps for hardware and firmware integration to replace an existing Tarvos-III/Telesto-III/Thebe-II/Themisto-I radio module by a Thyone-I radio module are described.

For reasons of simplicity, in the whole document we use the term **sub-GHz proprietary module** instead of listing the modules Tarvos-III, Telesto-III, Thebe-II and Themisto-I.

Due to changes in hardware platform and firmware when replacing a radio module, the end device's radio certification becomes void. A new radio certification or declaration needs to be acquired by performing actions according to the local statutory requirements at the location of deployment. It is advised to go through the relevant modules to get detailed information on radio certification and declaration.

To evaluate the migration to Thyone-I, Würth Elektronik eiSos GmbH & Co. KG is able to provide adapter boards. Please get in contact with your local sales.

2 Supported radio modules

The supported 2.4 GHz Würth Elektronik eiSos radio modules described in this application note is the proprietary radio module **Thyone-I**

Module	Form factor [mm^2]	Freq. band [MHz]	Antenna	Protocol	Certification
Tarvos-III	27x17	868	50 Ω pad	Proprietary	CE
Telesto-III	27x17	915	50 Ω pad	Proprietary	IC FCC
Thebe-II	27x17	868	50 Ω pad	Proprietary	CE
Themisto-I	27x17	915	50 Ω pad	Proprietary	FCC IC
Thyone-I	12x8	2440	Smart antenna	Proprietary	CE FCC IC TELEC

Table 1: Comparison: Features

Smart antenna connection gives the possibility to either connect the module's internal antenna or to use 50 Ohm connection toward an external antenna.

Module	VDD [V]	I_{TX} [mA]	I_{RX} [mA]	I_{Sleep} [µA]	$Power_{TX}$ [dBm]
Tarvos-III	2.2 to 3.8	26	8	0.2	14
Telesto-III	2.2 to 3.8	26	8	0.2	14
Thebe-II	2.2 to 3.7	500	12	0.9	27
Themisto-I	2.2 to 3.7	400	12	0.9	25
Thyone-I	1.8 to 3.6	18.9	7.7	0.4	6

Table 2: Comparison: Electrical characteristics

Due to the form factor and pin compatibility, an adapter board is necessary to use a 2.4 GHz module in the place of **sub-GHz proprietary module**.

3 Adapter board

3.1 Schematic

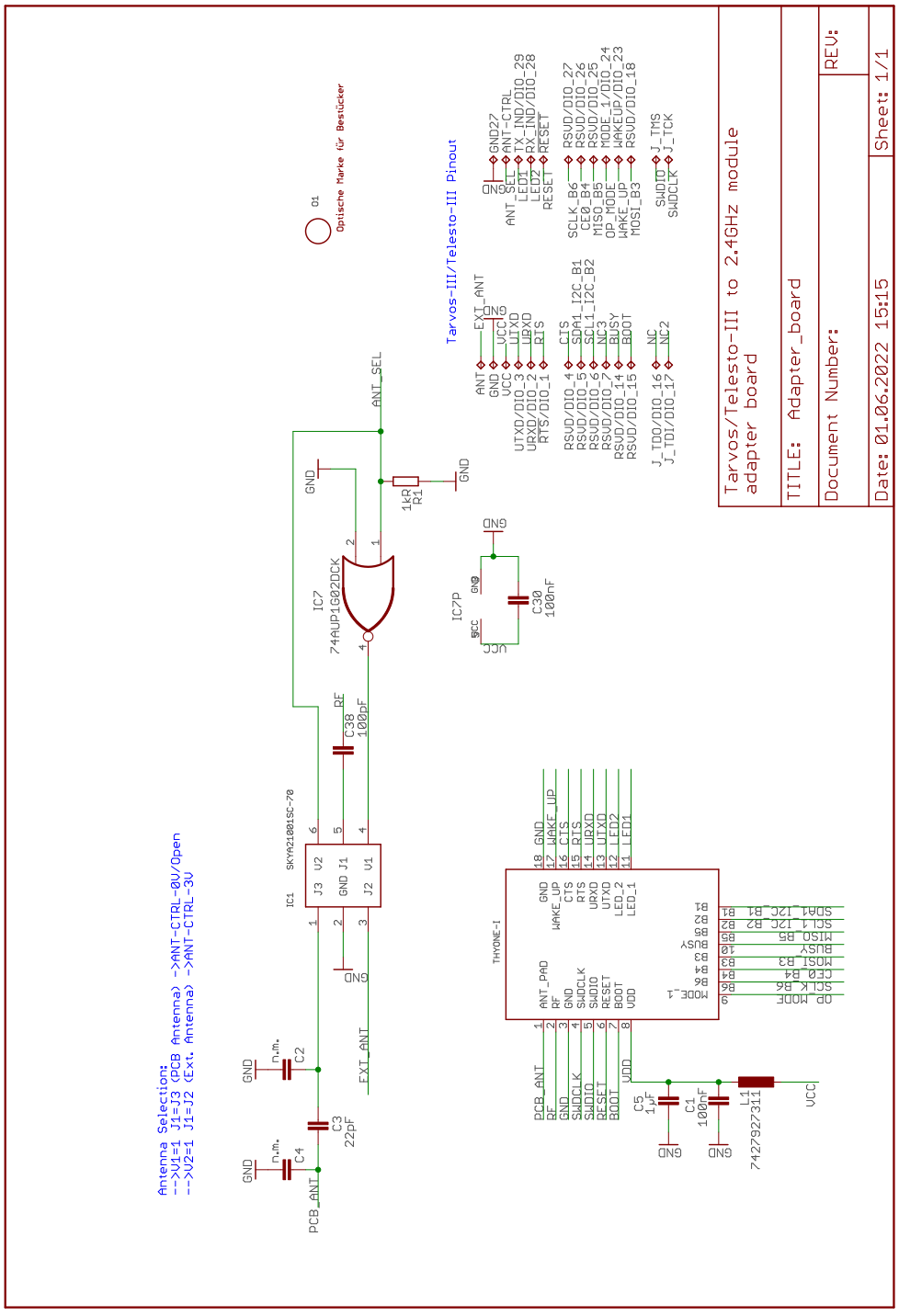

Figure 1: Adapter board schematic

3.2 Board

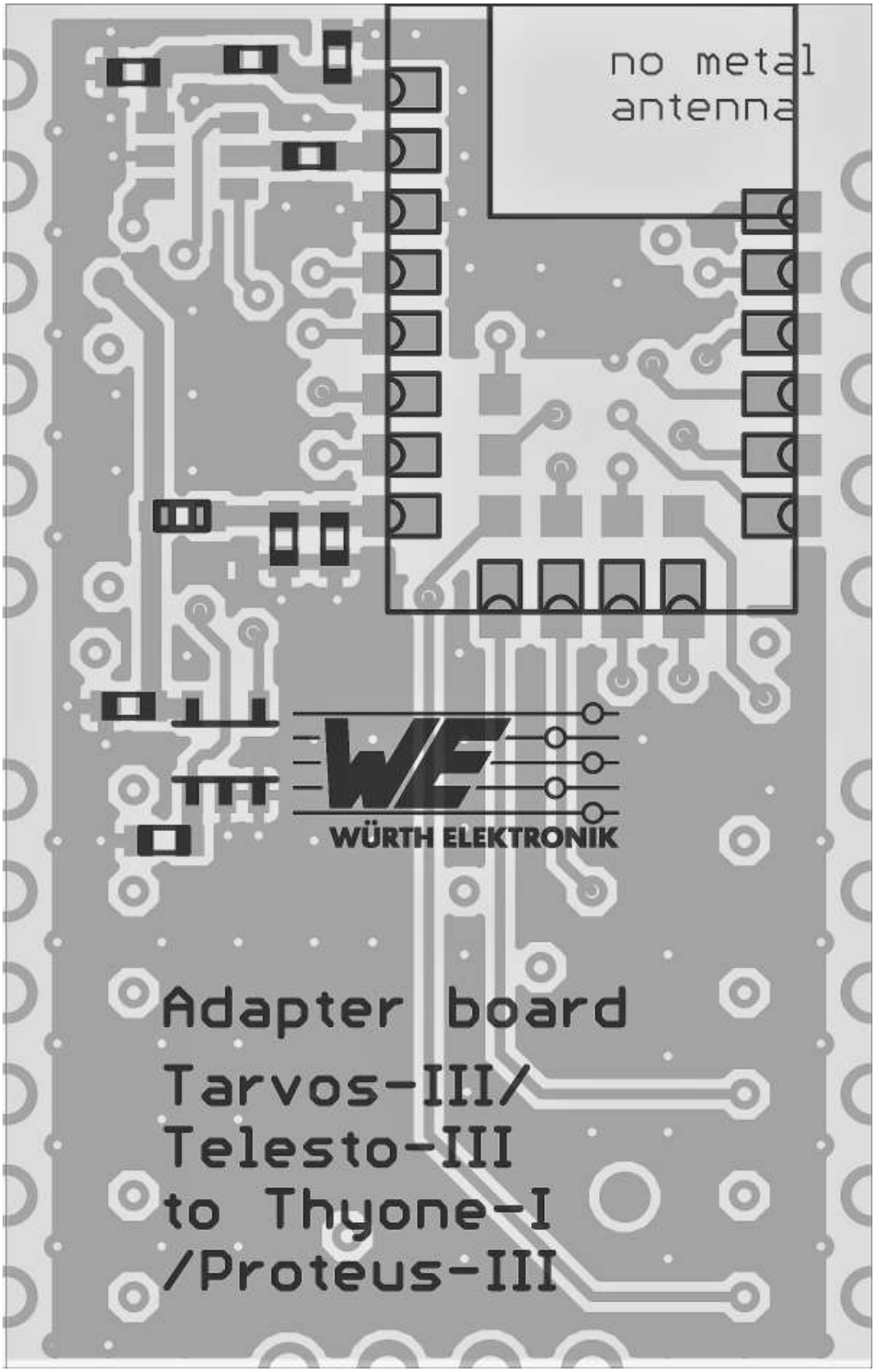

Figure 2: Adapter board layout

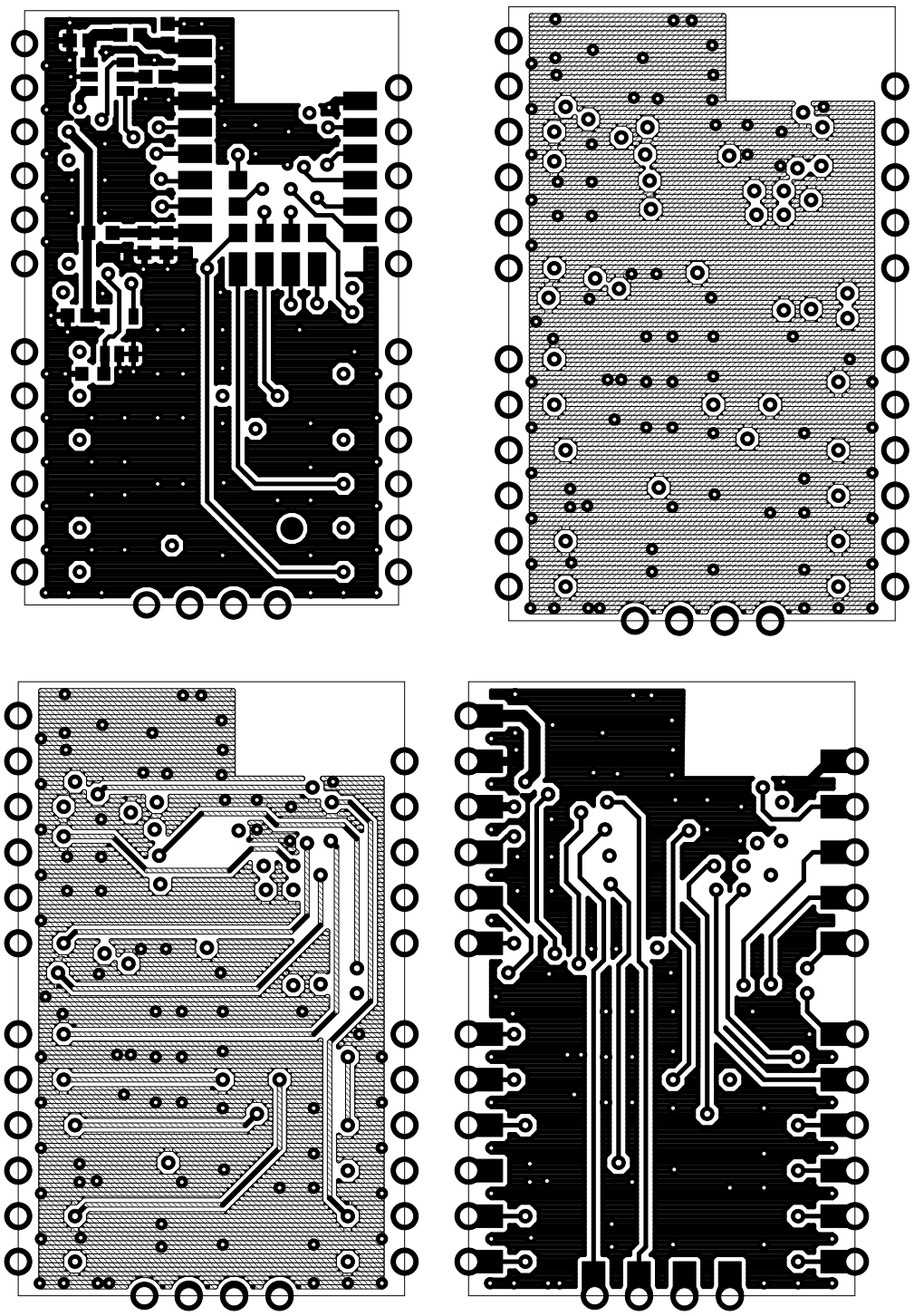

Figure 3: Top, bottom & internal layers

3.3 Assembly

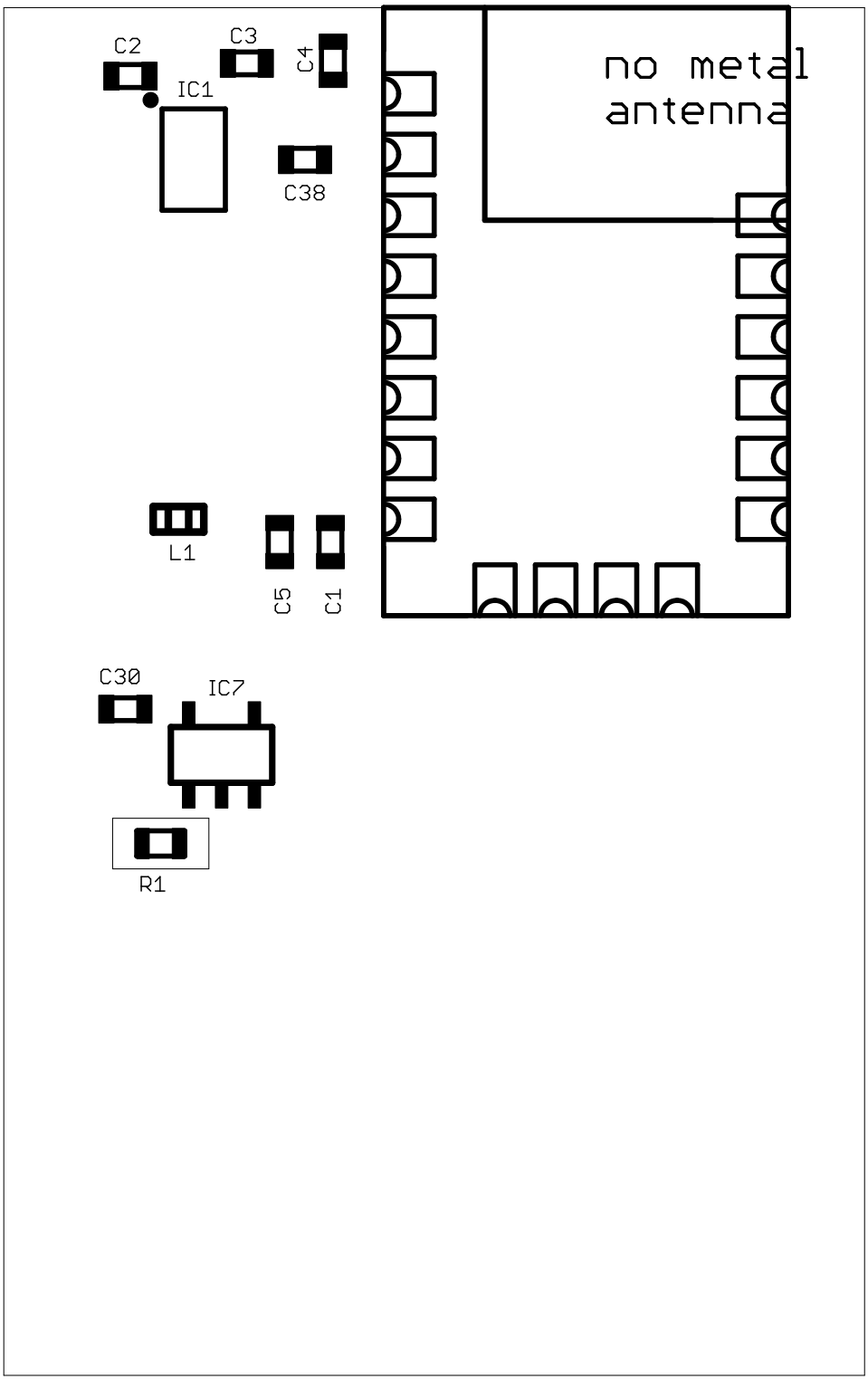

Figure 4: Assembly

3.4 Bill of materials

Part	Value	Package	MANUFACTURER	NR
C1	100nF	C0402_IPC	Würth Elektronik	885012205037
C2	n.m.	C0402_IPC	Würth Elektronik	885012105012
C3	22pF	C0402_IPC	Würth Elektronik	885012005027
C4	n.m.	C0402_IPC		
C5	1µF	C0402_IPC	Würth Elektronik	885012105012
C30	100nF	C0402_IPC	Würth Elektronik	885012205037
C38	100pF	C0402_IPC	Würth Elektronik	885012005031
IC1	RF Switch	6-PIN_SC-70		
IC7	NOR Logic gate	SC70-5		
L1	7427927311	L0402_WE-MK	Würth Elektronik	7427927311
R1	1kR	R0402_IPC		
THYONE-I	2611011021000	SMD	Würth Elektronik	2611011021000

Figure 5: Bill of materials

4 Replacing by the Thyone-I

The Tarvos-III, Telesto-III, Thebe-II and Themisto-I is a family of sub-GHz proprietary radio modules that share the same footprint. This chapter describes how to use the adapter board mentioned in chapter 3 to replace one of the mentioned sub-GHz proprietary modules by a Thyone-I 2.4 GHz module.

The adapter board allows the user to test the possibility of migrating from **sub-GHz proprietary module** to Thyone-I. The user shall modify the adapter board design according to the existing host or application if needed.

4.1 Hardware adaption

4.1.1 Foot print

The adapter board has the same dimensions as the **sub-GHz proprietary module**. Furthermore, it is pin compatible.

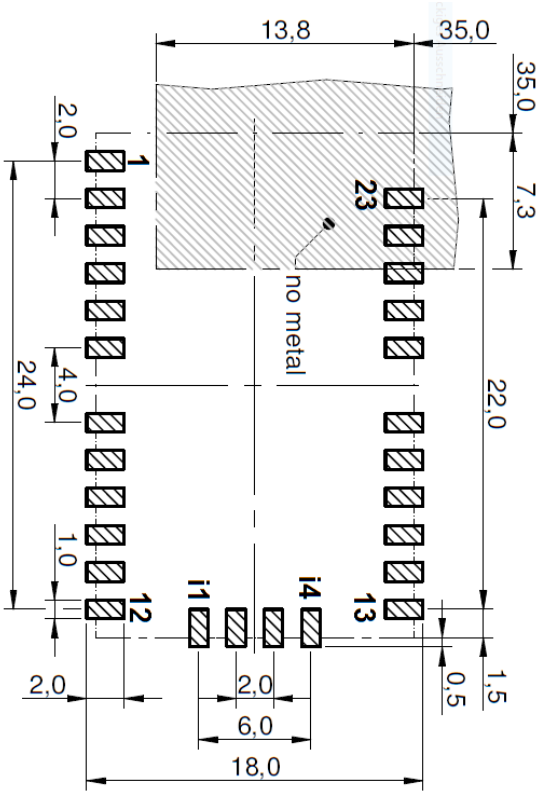

Figure 6: Footprint (Top view)

The internal PCB antenna of Thyone-I module on adapter board can be used only if the no metal area in footprint is implemented on the host PCB.

The Tarvos-III and Telesto-III are available in two hardware variants. The first variant provides the radio signal at the *ANT* pin. In this variants 2609011**1**81000 (Tarvos-III) and 2609011**1**91000 (Telesto-III) an external antenna matched to 50 Ω can be connected at this pin.

The second variants 2609011**0**81000 (Tarvos-III) and 2609011**0**91000 (Telesto-III) offers an integrated PCB antenna. The integrated PCB antenna is strongly miniaturized and therefore supports reduced efficiency and range. Using this variant the *ANT* pin has no function and can be left open. No external antenna has to be connected. The explanation how to use the different connection variant is described in chapter 4.1.3

4.1.2 Pinout

Table 3 lists the pin mapping of the **sub-GHz proprietary module** to the Thyone-I in the adapter board:

Pin No.	Thyone-I	**sub-GHz proprietary module**	Description
1	*ANT & RF*	*ANT*	Antenna pin connection
2	*GND*	*GND*	Ground
3	*VCC*	*VCC*	Supply voltage
4	*UTXD*	*UTXD*	UART TX
5	*URXD*	*URXD*	UART RX
6	*/RTS*	*/RTS*	UART */RTS*
7	*/CTS*	*RESERVED*	UART */CTS*
8	*B1*	*RESERVED*	
9	*B2*	*RESERVED*	
10	Not connected	*RESERVED*	
11	*BUSY*	*RESERVED*	
12	*BOOT*	*BOOT*	The *BOOT* pin is used to enable the bootloader for firmware updates. Boot pin operation is inverted between the modules, please look into the section 4.2.6.
13	*B3*	*RESERVED*	
14	*WAKE_UP*	*WAKE-UP*	Pin function changed. The *WAKE-UP* pin is used to wake-up the module from sleep mode.
15	*MODE_1*	*MODE_1*	The *MODE_1* pin is used on the **sub-GHz proprietary** module and **Thyone-I** module to determine the mode of operation during boot up.
16	*B5*	*RESERVED*	
17	*B4*	*RESERVED*	
18	*B6*	*RESERVED*	
19	*/RESET*	*/RESET*	Reset pin
20	*LED1*	*/TX_IND*	
21	*LED2*	*/RX_IND*	

Pin No.	Thyone-I	**sub-GHz proprietary module**	Description
22	Not connected	*RESERVED* on sub-GHz proprietary module **ANT-CTRL** on Adapter board	ANT-CTRL *Pin 22* of the adapter board controls RF switch to change between antenna
23	*GND*	*GND*	Ground
i1	SWDIO	*TEST*	Debug Interface
i2	SWDCLK	*TEST*	Debug Interface
i3	Not connected	*TEST*	
i4	Not connected	*TEST*	

Table 3: Pin mapping between Thyone-I and **sub-GHz proprietary module**

4.1.3 Antenna

Using the adapter board along with Thyone-I module, the option to switch between internal and external antenna connection is available. The *ANT* pin (No.1, Ext_ANT in the schematic) of the adapter board is used for an external antenna connection matched to 50 Ω.

The *ANT-CTRL* pin (No.22) is used to switch between Thyone-I on-board PCB antenna and the external antenna pin *Ext_ANT* of the adapter board.

The *ANT-CTRL* pin (No.22) has an internal pull-down resistor and selects internal PCB antenna by default. An external pull-up resistor on this pin shall be avoided.

By applying a high logic level to the *ANT-CTRL* pin, the *ANT* Pin of the adapter board can be used for external antenna connection. If *Pin 22* is left open or a low level is applied, the Thyone-I on-board PCB antenna is used.

4.1.4 Trace design

Thyone-I Module itself complies with FCC and IC certification. For evaluation purpose, the adapter board uses an IC to switch between the on-board PCB-antenna of the Thyone-I module and the external RF PAD connection. Due to which the adapter board differs from the trace design and is not approved to be FCC and IC compliant.

To reference the end device to the Würth Elektronik eiSos' FCC ID it is mandatory to use the trace design. Based on the end application and antenna option needed, the user can implement one of the two variants of the trace designs.

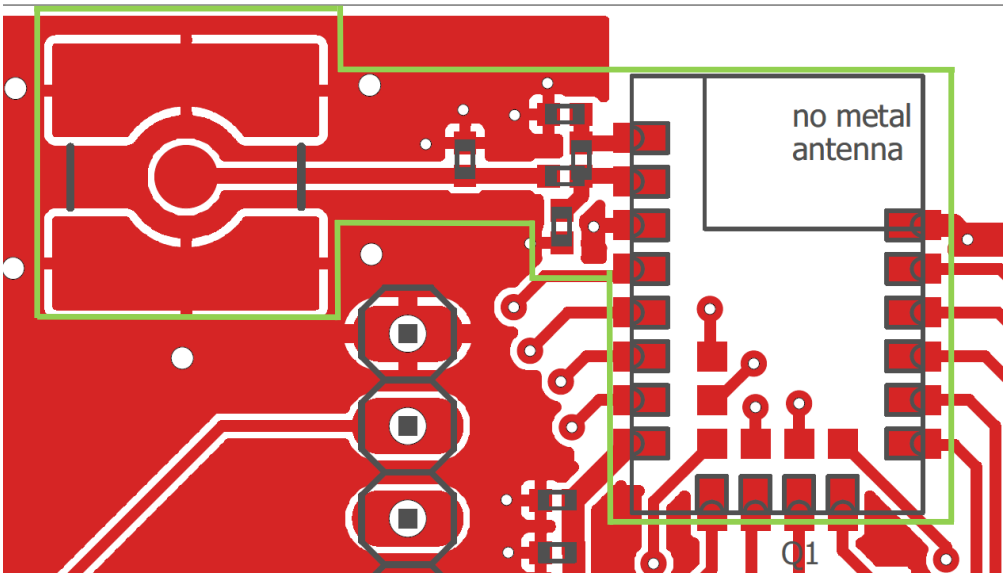

Figure 7: Trace design: Layout

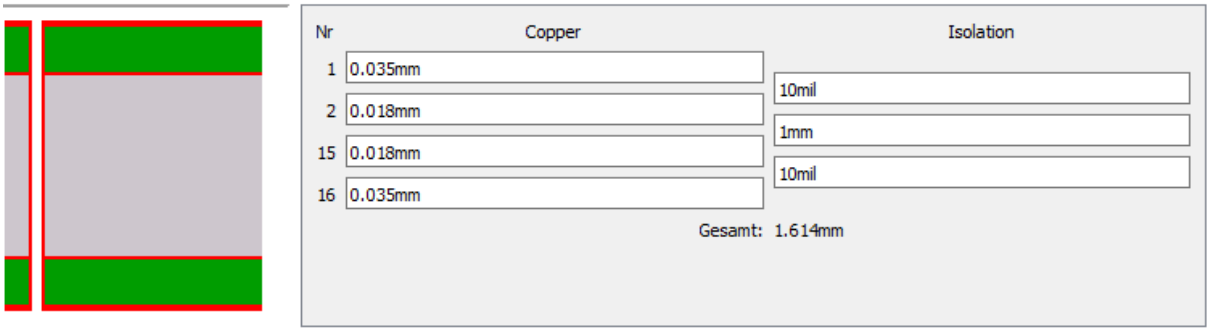

Figure 8: Reference design: Stack-up

- Top layer is used for routing, filled with ground plane except area under the module and antenna free area.
- Second layer is filled with ground plane, 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 too small parts.
- Bottom layer is used for routing and filled with ground.

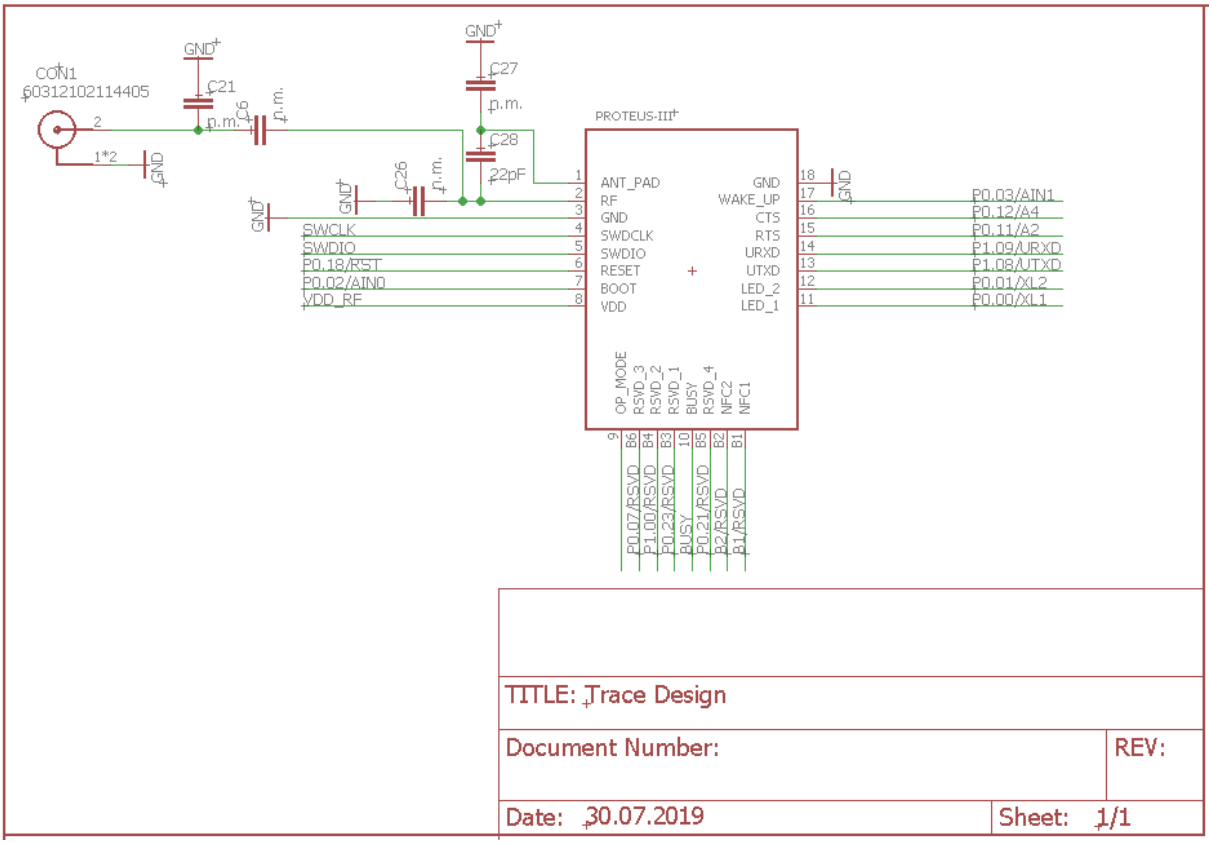

Figure 9: Trace design: Schematic

The RF pin of module can be coupled to the modules on-board PCB antenna or an external antenna.
Two variants of the Thyone-I module are certified:

- For the modules on-board PCB antenna: 22 pF shall be assembled on C28.
  - If additional tuning is needed in the end application, C27 and C26 can be assembled.
  - The exact values of C27 and C26 shall be specified in the end application corresponding to the individual need.

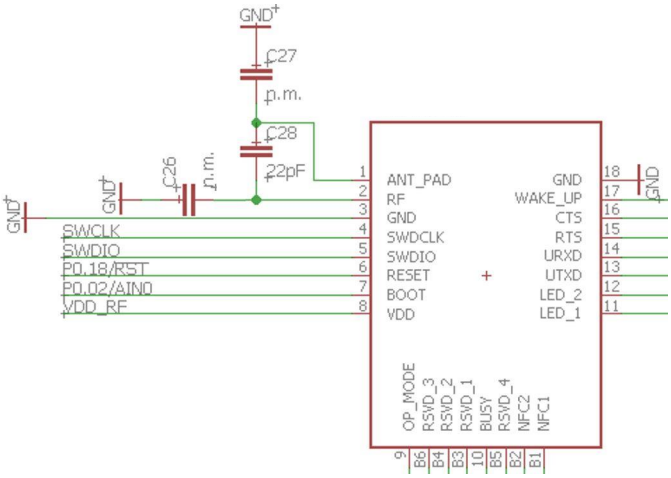

Figure 10: On-board PCB antenna

- For the external antenna: 22 pF shall be assembled on C6.
  - If additional tuning is needed in the end application, C21 and C26 can be assembled.
  - The exact values of C21 and C26 shall be specified in the end application corresponding to the individual need.

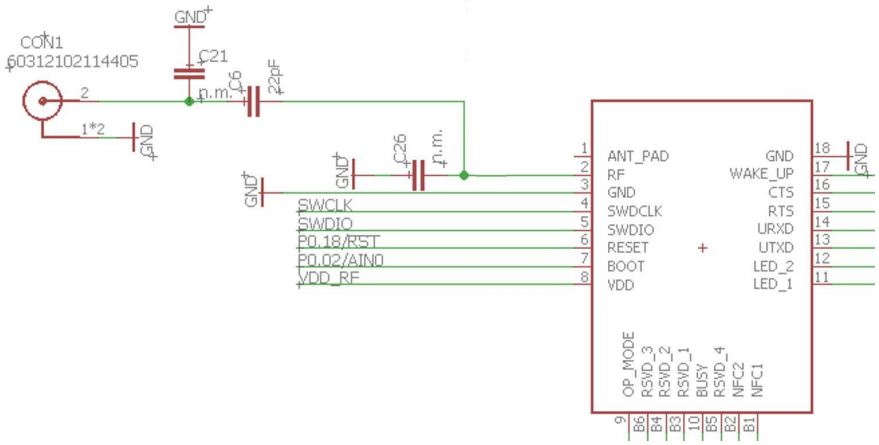

Figure 11: External antenna connection

4.2 Host firmware adaption

4.2.1 Overall behavior

As the **sub-GHz proprietary module** and the Thyone-I are both proprietary radio modules, both are similar w.r.t. their behavior. This means that the same network topologies are supported and the same data transmission can be used.
Due to this, the application's behavior must not be changed when replacing a **sub-GHz proprietary module** by a Thyone-I radio module.

4.2.2 UART interface

Both, the Thyone-I as well as the **sub-GHz proprietary module**, use an UART interface. It is configured as 115200 Baud 8n1 by default.
The **sub-GHz proprietary module** supports all baud rates between 9600 and 921600 Baud, where the Thyone-I supports only distinct baud rates between 1200 and 1000000 Baud. Furthermore, for baud rates higher than 115200 Baud, the flow control must be used at Thyone-I.

For Thyone-I the flow control of the UART is enabled when running a firmware update via the UART interface.

Both, the Thyone-I as well as the **sub-GHz proprietary module**, provide a transparent mode and command mode:

Transparent mode: All bytes sent to the radio module are transmitted via radio. All bytes received via radio are output by the UART without any protocol (header and footer). See chapter 4.2.2.1.

Command mode: Hexadecimal commands of pre-defined structure are used to control the radio module, like triggering a transmission or going into sleep mode. See chapter 4.2.2.2.

On both modules, the operation mode can be chosen in the same way:

- Applying a low signal to the *MODE_1* pin during the reset till the module is booted up, starts the command mode.
- Applying a high signal to the *MODE_1* pin during the reset till the module is booted up, starts the transparent mode.

4.2.2.1 Transparent mode

The transparent modes on both modules have the same function. Only the trigger that starts the radio transmission of data may differ. There are several options such as:

- Transmit radio data after timeout
- Transmit radio data after ETX character has been received via UART

4.2.2.2 Command mode

As described above, in command mode hexadecimal commands are used to control the radio module. Both, the **sub-GHz proprietary module** and the Thyone-I, use a similar command structure, whereas the Thyone-I uses a 2-byte length field and the **sub-GHz proprietary module** uses a 1-byte length field:

Start signal	Command	Length	Payload	CS
0x02	1 Byte	2 Bytes	Length Bytes	1 Byte

Table 4: Command structure of the Thyone-I

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

Table 5: Command structure of the **sub-GHz proprietary module**

Furthermore, the commands themselves differ. See the `CMD_DATA_IND` command for example, that outputs the radio data on the UART:

Start signal	Command	Length	Src Addr	RSSI	Payload	CS
0x02	0x84	2 Bytes	4 Bytes	1 Byte	(Length - 5) Bytes	1 Byte

Table 6: `CMD_DATA_IND` command of the Thyone-I

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

Table 7: `CMD_DATA_IND` command of the **sub-GHz proprietary module**

Besides the length of the Length field as already described, the Command byte itself (`0x81` vs. `0x84`) as well as the location of the remaining fields changed.
As consequence of this all commands must be updated to the new commands.

Please note that the Wireless Connectivity SDK [1, 2] implements all these commands. Thus, only the driver of the **sub-GHz proprietary module** must be replaced by the Thyone-I driver to update the application to the new commands.

4.2.3 Radio interface

4.2.3.1 Network and mesh

Both, the **sub-GHz proprietary module** and Thyone-I, provide several network topologies. Data can be transmitted from point to point (unicast), point to a sub net (multicast) or point to

the whole network (broadcast). Furthermore, both radio modules provide the repeater function, that allows to setup a flooding mesh network, where all messages are distributed throughout the whole network.
In the **sub-GHz proprietary module** a so called "address mode" is configured to define which network structure is used. The Thyone-I always runs a star network, but provides several commands for the radio transmission of broadcast, multicast and unicast messages.

4.2.3.2 Radio settings

The radios of the **sub-GHz proprietary module** and Thyone-I are different, but have the same options. Both contain

- The so called "radio profiles" that allow to define the radio data rate and the resulting transmission range.
- The radio channels that define the frequencies that are used to transmit data via radio.
- The TX power that define the transmission range and current consumption when transmitting.

Thus, the behavior of both radios is the same, except of the used channel and data rate, and the resulting range and current consumption.

4.2.4 Timing

Due to the higher data rate of the Thyone-I radio profiles, the time to transmit radio data is shortened w.r.t. the **sub-GHz proprietary module**. Thus, the accelerated timing behavior must be considered in the application.

4.2.5 Power saving modes

Both radio modules provide at least one sleep mode. It can be enabled by sending the respective command to the radio module. On both modules, the *WAKE-UP* pin is used to leave the sleep mode again and enable the normal operation.

4.2.6 Boot mode

Both radio modules provide a so called "boot mode", that must be entered to enable the firmware update via the UART interface. The boot mode is started by pulling the *BOOT* pin of the radio module to the respective pin level during the reset. To do so, the level of the *BOOT* pin must be

- LOW on the Thyone-I.
- HIGH on the **sub-GHz proprietary module**.

In case, the *BOOT* pin is hardwired to ground on the **sub-GHz proprietary module**, a replacement by the Thyone-I is not possible, as the Thyone-I would always start in boot mode.

If the Boot pin is hardwired on the Host PCB, adapter board design shall be modified by integrating an inverter IC on the BOOT pin of the Thyone-I module.

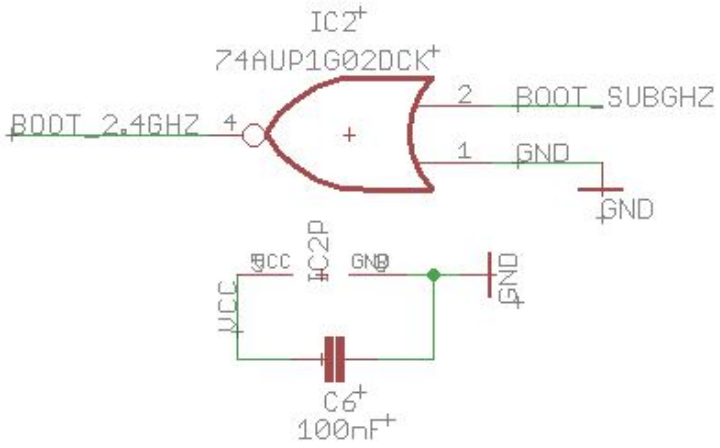

Figure 12: Boot pin modification

5 References

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

[2] Würth Elektronik. Wireless Connectivity SDK for STM32 - Radio module drivers in C-code. https://github.com/WurthElektronik/WirelessConnectivity-SDK_STM32.

6 Important notes

The Application Note and its containing information ("Information") is based on Würth Elektronik eiSos GmbH & Co. KG and its subsidiaries and affiliates ("WE eiSos") knowledge and experience of typical requirements concerning these areas. It serves as general guidance and shall not be construed as a commitment for the suitability for customer applications by WE eiSos. While WE eiSos has used reasonable efforts to ensure the accuracy of the Information, WE eiSos does not guarantee that the Information is error-free, nor makes any other representation, warranty or guarantee that the Information is completely accurate or up-to-date. The Information is subject to change without notice. To the extent permitted by law, the Information shall not be reproduced or copied without WE eiSos' prior written permission. In any case, the Information, in full or in parts, may not be altered, falsified or distorted nor be used for any unauthorized purpose.

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List of Figures

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