EnOcean

TCM 410J – Transceiver Gateway Module

Observe precautions! Electrostatic sensitive devices!

Patent protected:
WO98/36395, DE 100 25 561, DE 101 50 128,
WO 2004/051591, DE 103 01 678 A1, DE 10309334,
WO 04/109236, WO 05/096482, WO 02/095707,
US 6,747,573, US 7,019,241

REVISION HISTORY

The following major modifications and improvements have been made to the first version of this document:

No	Major Changes
1.00	Initial version
1.10	Added certification information and PCB Design
1.2	Changed power support information
1.3	Updated Energy consumption. Added example circuits for reset and prog_en pins. Extended PIN description. Added IOVDD and PINs circuits when using dee psleep.
2.0	Module revision update, added enhanced security mode,
	MSL4 -> MSL 3 and type approval updated.
2.1	Corrected Smart Ack Mailbox count and added description for repeating after POR
2.2	Update of ARIB regulations.

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Important!

TABLE OF CONTENT

1. MODULE VARIANTS AND RELATED DOCUMENTS

This document describes operation of TCM 410J module with the frequency 928.35 MHz. Subject of description is the:

- build in software Dolphin V4 Decoding Gateway – short: DolphinV4 GWC S.
- used hardware TCM 410J

In the Document we refer to the Hardware and Software characteristic by the module name TCM 410J.

In addition we recommend following our application notes, in particular

- AN101: Power Supply Layout – Layout considerations for Line-Power
- AN102: Antenna Basics – Basic Antenna Design Considerations for EnOcean based Products

The specification of the serial protocol ESP3 can be found here:
http://www.enocean.com/esp

2. GENERAL DESCRIPTION

2.1 Basic functionality

TCM 410J is a SMD mountable radio transmitter module enabling the realization of gateways for EnOcean 928.35 MHz radio systems. It provides a bi-directional radio interface and a bi-directional serial interface. Radio messages are sent transparently through the serial interface in both directions from and to an externally connected host processor or host PC. On demand the outgoing radio communication can be encrypted & incoming radio communication can be decrypted by the TCM 410J module. In addition control commands can be sent from the host, e.g. to configure the repeater functionality or to manage Smart Ack functions. TCM 410J can act as postmaster for up to 15 bi-directional sensors using Smart Ack technology.

Features
- Smart Ack controller functionality
- Transparent radio channel
- Programmable repeater functionality (1 Level)
- ESP3 support (EnOcean Serial Protocol V3)
- Enhanced security communication
- API programmable!

Security features:

- Decodes secured telegrams

- Encodes telegrams into secured telegrams

- Handling and storing Rolling Codes and Security Keys

    - For outgoing communication

    - For ingoing communication

- I2C Implementation to communicate with external EEPROM

- Attack detection

- Configurable security parameters (RLC Window, etc.)

2.2 Technical data

Features overview

Antenna	External whip or 50Ω antenna mountable
Frequency	928.35 MHz (FSK)
Radio Standard	Enocean Radio Protocol 2 (FSK)
Data rate/Modulation type	125 kbps FSK
Receiver Sensitivity (at 25°C)	typ. −95 dBm
Conducted Output Power	typ. 0dBm
Power Supply	2.6…5V
Serial Interface	UART - EnOcean Serial Protocol 3
Current Consumption	Receive mode (incl. CPU current): 27 mA Transmit mode (incl. CPU current): 22 mA
Dimensions of PCB	22x19x3.1 mm
Operating temperature	-25 to +85°C
Radio Regulations	*ARIB STD-T108*

2.3 Physical dimensions
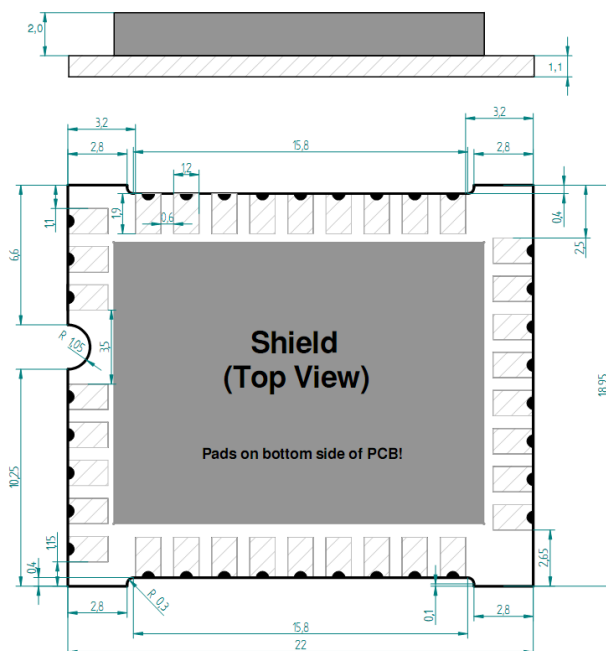
Unless otherwise specified dimensions are in mm.

Tolerances:

PCB outline dimensions ±0.2 mm

All other tolerances ±0.1 mm

TCM 410J (pads on bottom side of PCB!)

PCB Dimension	22 x 19 x 3.1 mm
Weight	1.9 g

2.4   Environmental conditions

Operating temperature	-25 °C … +85 °C
Storage temperature	-40 °C … +85 °C
Storage temperature in tape & reel package	-20 °C … +50 °C
Humidity	0% … 93% r.H., non-condensing

2.5   Ordering information

Type	Ordering Code	Frequency
TCM 410J	**S3063-K410**	**928.35 MHz**

2.6   References

1.   EnOcean Radio Standard Specifications -
        https://www.enocean-alliance.org/what-is-enocean/specifications/
2.   EnOcean Serial Protocol v3.0 -
        https://www.enocean.com/esp
3.   EnOcean Tools -
        https://www.enocean.com/en/knowledge-base/

3. FUNCTIONAL DESCRIPTION

3.1 Pin out
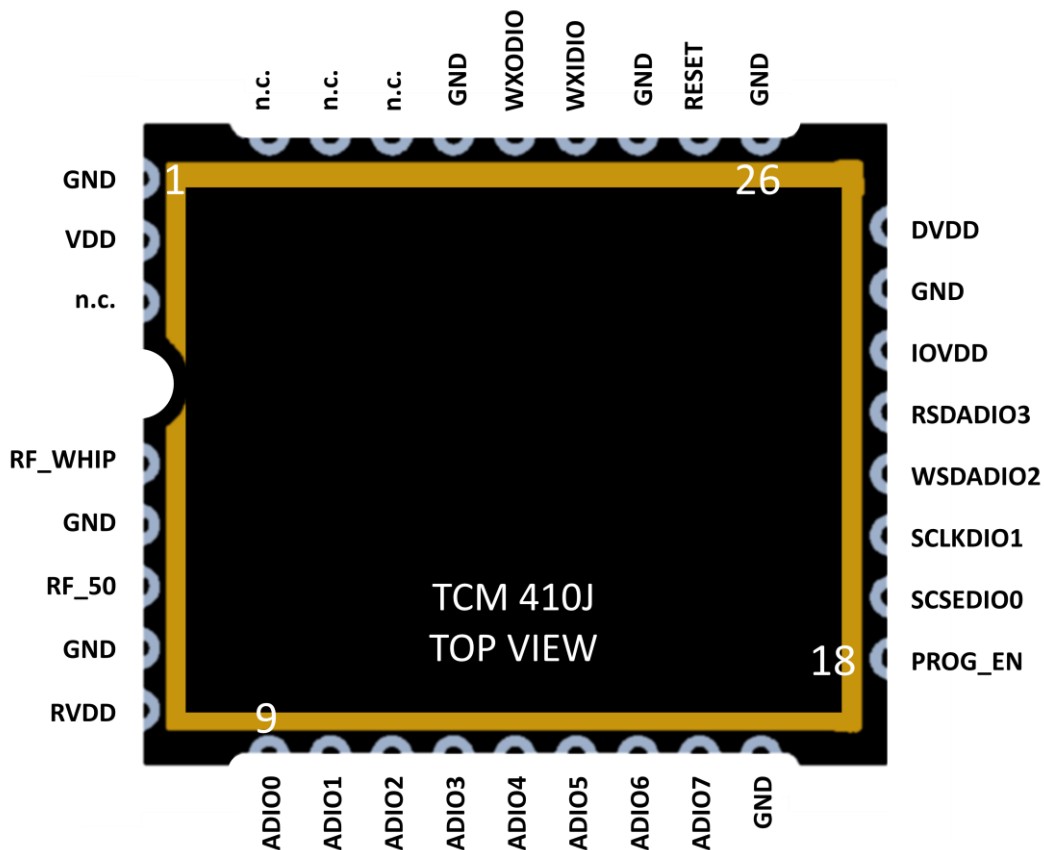
The figure above shows the pin out of the TCM 410J hardware. The pins are named according to the naming of the Dolphin chip to simplify usage of the DOLPHIN API 2.
The table in section 0 shows the translation of hardware pins to a naming that fits the functionality of the built-in firmware..

3.2　　　Pin description and operational characteristics

HW Symbol	Pin #	Function	Characteristics
GND	1, 5, 7, 17, 24, 26, 28, 31	Ground connection	Must be connected to GND; see 5.4
VDD	2	Supply voltage	2.6 V … 5 V
RVDD	8	RF supply voltage regulator output	Leave open
DVDD	25	Digital supply voltage regulator output	1.8 V Output current: max. 5 mA
IOVDD	23	GPIO supply voltage	Must be connected to desired interface supply voltage (see 3.4) See also 3.2.1.
RESET	27	Reset input Programming I/F	Active high reset. External 10 kΩ pull-down parallel to 10nF capacitor recommended. See 3.5.
PROG_EN	18	Digital input, Programming I/F	HIGH (at start up): programming mode active LOW: operating mode External 10 kΩ pull-down parallel to 10nF capacitor recommended. See 3.5.
ADIO0	9	Not used by standard FW.	Configured as Digital In with Pull Up
ADIO1	10	Not used by standard FW.	Configured as Digital In with Pull Up
ADIO2	11	Not used by standard FW.	Configured as Digital In with Pull Up
ADIO3	12	Not used by standard FW.	Configured as Digital In with Pull Up
ADIO4	13	Not used by standard FW.	Configured as Digital In with Pull Up
ADIO5	14	Not used by standard FW.	Configured as Digital In with Pull Up
ADIO6	15	UART input – RX	See 3.7
ADIO7	16	UART output - TX Programming I/F	See 3.7
SCSEDIO0	19	Interface for external EEPROM with I2C interface Programming I/F	Digital I/O for I2C Data communication.
SCLKDIO1	20	Interface for external EEPROM with I2C interface. Programming I/F	Digital Output, Clock pin for I2C Communication
WSDADIO2	21	Not used by standard FW. Programming I/F	Configured as Digital In with Pull Up
RSDADIO3	22	Not used by standard FW. Programming I/F	Configured as Digital In with Pull Up
WXIDIO	29	Not used by standard FW.	Configured as Digital In with Pull Up
WXODIO	30	Not used by standard FW.	Configured as Digital In with Pull Up
RF_WHIP	4	RF output	Output for whip antenna
RF_50	6	RF output	50 Ohm output for external antenna

n.c.	3, 32,33, 34	Not connected	Do not connect!

3.2.1 GPIO supply voltage - IOVDD

For digital communication with other circuitry (peripherals) the digital I/O configured pins of the mixed signal sensor interface (ADIO0 to ADIO7) and the pins of the serial interface (SCSEDIO0, SCLKDIO1, WSDADIO2, RSDADIO3) may be operated from supply voltages different from DVDD. Therefore an interface voltage supply pin IOVDD is available which must be connected either to DVDD or to an external supply within the tolerated voltage range of IOVDD.

⚠️ If DVDD=0 V (e.g. in any sleep mode or if VDD<VOFF) and IOVDD is supplied, there may be unpredictable and varying current from IOVDD caused by internal floating nodes. It must be taken care that the current into IOVDD does not exceed 10 mA while DVDD=0 V.
If DVDD=0 V and IOVDD is not supplied, do not apply voltage to any above mentioned pin. This may lead to unpredictable malfunction of the device.

⚠️ For I/O pins configured as analogue pins the IOVDD voltage level is not relevant! However it is important to connect IOVDD to a supply voltage as specified in 3.4.
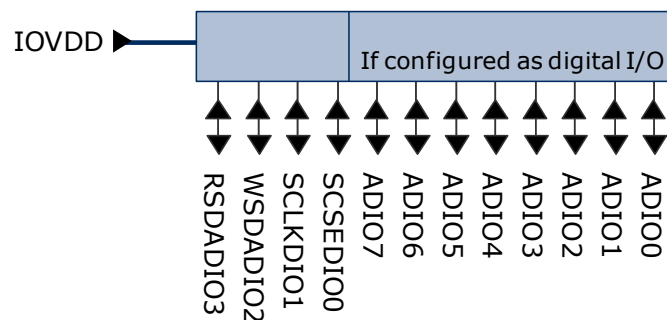
3.2.2 Handling IOVDD and PINs with sleep mode

TCM 410J is aimed for line powered applications to communicate over UART. But sometimes it is desirable to put the device into sleep mode. As stated in chapter 3.2.1. it is not recommended to supply IOVDD or connect voltage to IOs if DVDD = 0 V (e.g. in any sleep mode or if VDD<VOFF).
If the module is put into deep sleep mode (i.e. with the serial command CO_WR_SLEEP, see chapter 3.7) it is important to respect above statement and cut IOVDD supply and do not apply voltage on IOs. The IOs concern mostly the UART interface

The following example applies to cut the IOVDD from supply and IO by the DVDD as controlling signal.
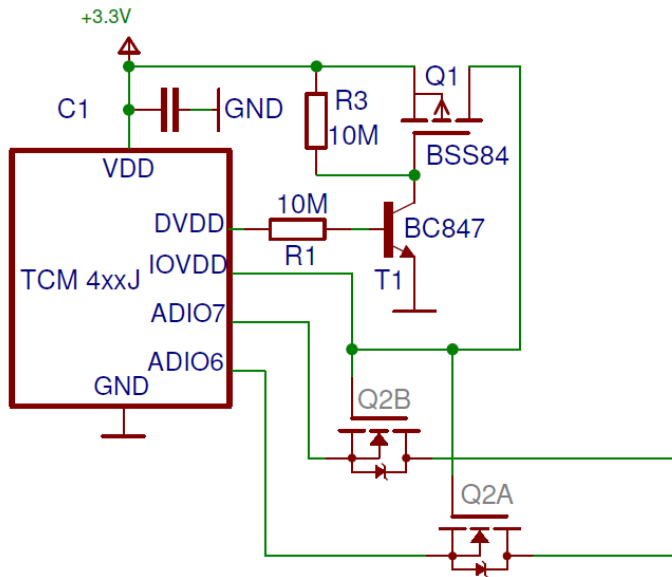
3.3 Absolute maximum ratings (non operating)

Symbol	Parameter	Min	Max	Units
VDD	Supply voltage at VDD	-0.5	5.5	V
IOVDD	GPIO supply voltage	-0.5	3.6	V
GND	Ground connection	0	0	V
VINA	Voltage at every analog input pin	-0.5	2	V
VIND1	Voltage at RESET, and every digital input pin except WXIDIO/WXODIO	-0.5	3.6	V
VIND2	Voltage at WXIDIO / WXODIO input pin	-0.5	2	V

3.4 Maximum ratings (operating)

Symbol	Parameter	Min	Max	Units
VDD	Supply voltage at VDD	2.6	5	V
IOVDD	GPIO supply voltage (see also 3.2.1)	1.7	3.6	V
GND	Ground connection	0	0	V
VINA	Voltage at every analog input pin	0	2.0	V
VIND1	Voltage at RESET, and every digital input pin except WXIDIO / WXODIO	0	3.6	V
VIND2	Voltage at WXIDIO / WXODIO input pin	0	2.0	V
VDDR	Max. ripple at VDD		50	mVpp

3.5 Suggested RESET and PROG_EN circuitry

In order to ensure reliable operation it is recommended to connect both the RESET and the PROG_EN with a 10 kΩ resistor in parallel with a 10 nF capacitor to ground. This avoids spurious signal detection in very noisy environments and in situations where an external programming header is provided.

The suggested circuit is shown below.
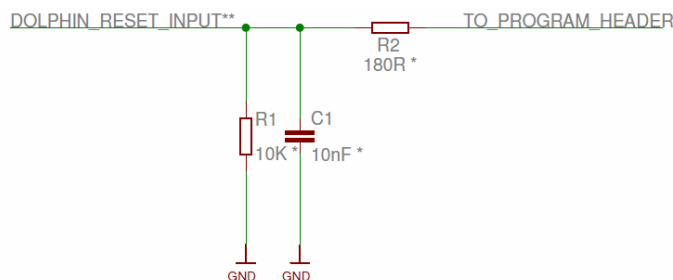
3.6 System environment

In the figure below, TCM 410J is shown in a typical system environment.

TCM 410J – Transceiver Gateway Module

**Uni or bidirectional
Actuator
e.g. TCM 410J**

Radio   Gateway

**Unidirectional
Sensor or
Switch e.g.
PTM 210J, STM4xyJ**

external
µC

TCM410J

Smar

**Ack
Remote management**

Transparent radio

Smart Ack Sensor

**STM400J
With API
SmartAck**

Backbone   or PC

Radio Gateway

Back -
bone

or PC

TCM410J

ext .
µC
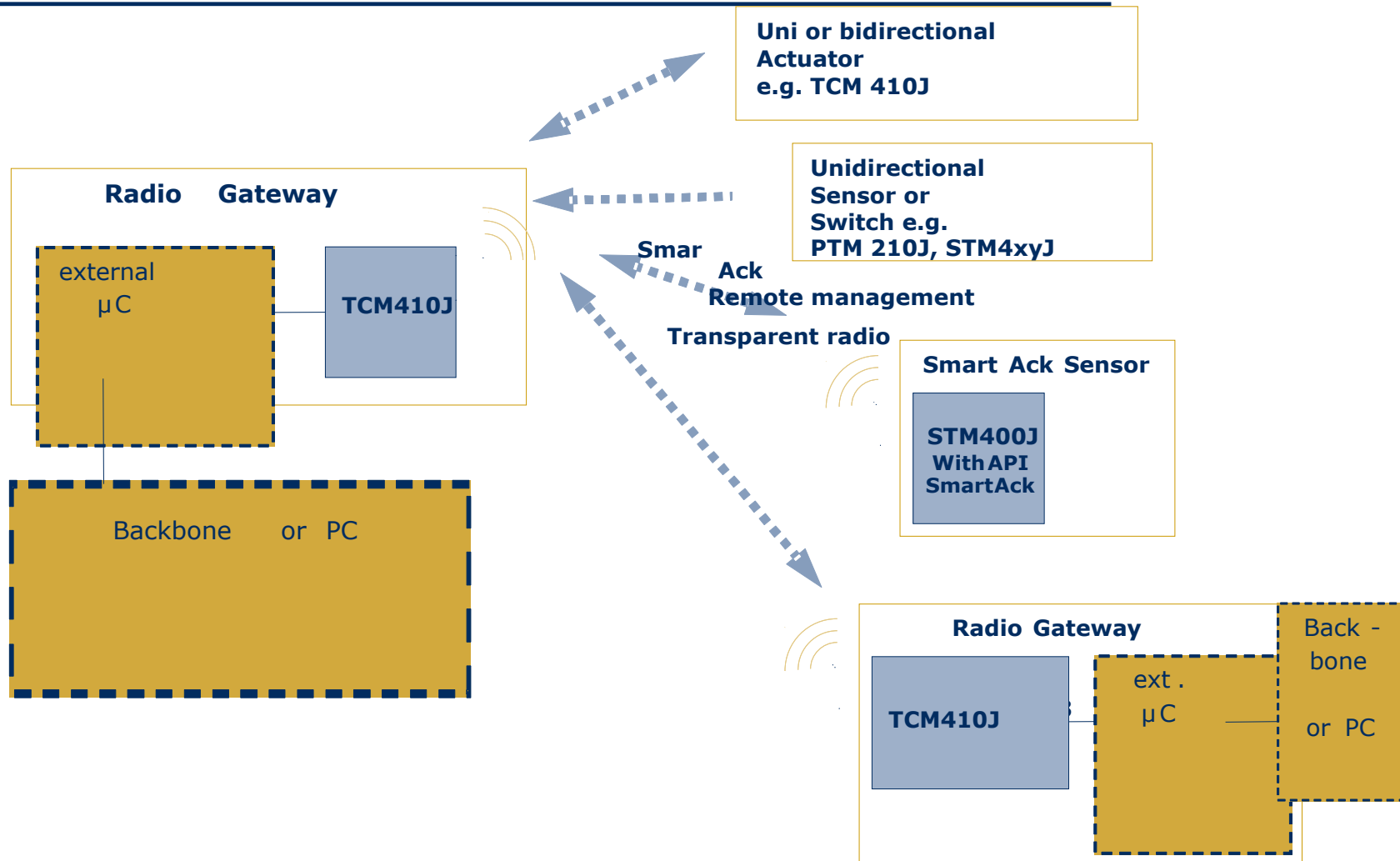
3.7 Serial Interface

TCM 410J provides a bi-directional serial interface which conforms to the EnOcean ESP3 specification. For details regarding ESP3 please refer to the ESP3 specification[1]. The data rate on the serial interface is 56.8 kbit/s which is usually interoperable with systems running at 57.6 kbit/s.

Direction	Nominal serial data rate	Tolerance
TX (sent by module)	56888 bit/s (=57600 bit/s - 1.23%)	< 50 ppm
RX (received by module)	56888 bit/s	< 5%

The following ESP3 commands are supported:

- Type 1 Radio command for transparent mode (compatible mode)
- Type 10 Radio command for transparent mode (native mode)
- Type 2 Responses
- Type 4 Event
    - SA_CONFIRM_LEARN to confirm/discard learn in/out
    - CO_READY to indicate wake up from deep sleep initiated by CO_WR_SLEEP
- Type 5 Common commands
    - CO_WR_SLEEP to enter energy saving mode (deep sleep mode)
    - CO_WR_RESET to reset the device
    - CO_RD_VERSION to read SW/HW versions, chip ID etc.
    - CO_WR_BIST to perform flash BIST operation
    - CO_WR_IDBASE to write ID range base number
    - CO_RD_IDBASE to read ID range base number
    - CO_WR_REPEATER to configure repeater functionality
    - CO_RD_REPEATER to read repeater state
    - CO_WR_FILTER_ADD to add filter to filter list (up to 10 filters are supported)
    - CO_WR_FILTER_DEL to delete filter from filter list
    - CO_WR_FILTER_DEL_ALL to delete all filter
    - CO_WR_FILTER_ENABLE to enable/disable supplied filters
    - CO_RD_FILTER to read supplied filters
    - CO_WR_WAIT_MATURITY to wait maturity time before returning radio telegrams
    - CO_WR_MODE - Sets the gateway transceiver mode, either packet type 01 or packet type 10
- Type 6 Smart Acknowledge commands
    - SA_WR_LEARNMODE to set/reset Smart Acknowledge learn mode
    - SA_RD_LEARNMODE to get learn mode
    - SA_WR_LEARNCONFIRM to add or delete a mailbox of a client
    - SA_WR_RESET to send a reset command to a client
    - SA_RD_LEARNEDCLIENTS to get learned mailboxes/clients
    - SA_WR_POSTMASTER to activate/deactivate post master functionality
- Type 7 Remote Management messages up to 256 Bytes

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[1] http://www.enocean.com/en/enocean_modules/tcm-310/

All configuration values set via ESP3 commands are held in RAM and will therefore be lost after RESET or after a deep sleep phase. Only Smart Ack mailboxes are stored in FLASH and are available also after RESET or a deep sleep phase.

After sending a CO_WR_RESET command, the following CO_READY event indicates wake up reason 06 meaning "A memory request from the CPU core does not correspond to any valid memory location." This is caused by the real reset cause used when CO_WR_RESET will be performed. It is not a SW/HW malfunction.

Additionally these security tasks related commands are supported:
- Type 5 Common commands
    CO_WR_LEARNMODE
    CO_RD_LEARNMODE
    CO_WR_SECUREDEVICE_ADD
    CO_WR_SECUREDEVICE_DEL
    CO_RD_SECUREDEVICE_COUNT
    CO_RD_SECUREDEVICE_BY_INDEX
    CO_RD_SECUREDEVICE_BY_ID
    CO_WR_SECUREDEVICE_SENDTEACHIN
    CO_WR_SECUREDEVICE_ADD_PSK
    CO_WR_TEMPORARY_RLC_WINDOW
- Type 4 Event
    CO_EVENT_SECUREDEVICES

This commands are NOT relevant to this Firmware and they are also not supported:
- Type 5 Common commands
    CO_RD_SECURITY
    CO_WR_SECURITY

Due to storage limitations these commands are not longer supported:

- Type 5 Common commands
        CO_WR_MODE – Compatible mode
- Type 1 Radio command for transparent mode (compatible mode)

3.8   Built-in Repeater

TCM 410J provides the option to activate a one level repeater for EnOcean radio telegrams. 1 Level Repeater, If a received telegram is a valid and original (not yet repeated), the telegram is repeated after a random delay.

The repeated telegram is marked as "repeated" by an increased repeater counter.

Configuration of the repeater is done via serial interface commands.

For detailed recommendations regarding the usage of repeaters please refer to our application note EnOcean Wireless Systems - Installation Notes (PDF), 09/2010.

3.8.1 Persistent repeater settings after POR

The TCM 410J supports a configuration to either save the Repeater settings in volatile memory (standard functionality) or non-volatile memory (extended functionality). The repeater settings are configured via the ESP3 command CO_WR_REPEATER. To enable the extended functionality and configure the repeater to keep configuration also after a POR please use the optional data field of the ESP 3 command.

The complete CO_WR_REPEATER command is defined as following:

Group	Offset	Size	Field	Value hex	Description
-	0	1	Sync. Byte	0x55	
Header	1	2	Data Length	0x0003	3 bytes
	3	1	Optional Length	0x00	0 byte
	4	1	Packet Type	0x05	COMMON_COMMAND = 5
-	5	1	CRC8H	0xnn	
Data	6	1	COMMAND Code	0x09	CO_WR_REPEATER = 09
	7	1	REP_ENABLE	0x00…0x02	Repeater OFF = 0, ON all = 1, ON filtered = 2
	8	1	REP_LEVEL	0x00…0x02	When Repeater OFF must be 0, when ON then 1 for Level-1 , 2 for Level-2
Optional Data	9	1	Store configuration in non-volatile memory	0x00 – 0x01	0x00 (or no optional data) = DO NOT store configuration in non-volatile 0x01 = DO store configuration in non-volatile
-	10	1	CRC8D	0xnn	

3.9 Smart Acknowledge

TCM 410J provides a post master function with 10 mailboxes for sensors using Smart Ack technology. For more information on smart acknowledge please refer to 1.

⚠ When teaching-in a device using Smart Acknowledge please take care to switch off all TCM 4xyJ devices which are not continuously powered. Otherwise these TCM 4xyJ modules could be declared postmaster. As soon as the power supply is switched off, a postmaster would be missing and Smart Acknowledge would not work any longer!

3.10 Remote Management

TCM 410J provides a transparent radio channel also for remote management messages with a message length of up to 256 bytes. This enables an external micro controller connected to TCM 410J to handle remote management request from external devices or to control other devices via remote management. For more information on remote management please refer to 1.

### 3.11 Serial communication with TYPE 01 or TYPE 10

TCM 410J operates as transparent gateway so the received radio telegrams are forwarded on as serial packets to external controller with type 01 or type 10. The mode can be switched by the serial command CO_WR_MODE.
- Usage of Type 01 is for compatibility reasons (compatibility mode)
- Usage of Type 10 is native for the Radio Protocol of TCM 410J.

The scenario is depicted on the figure below.
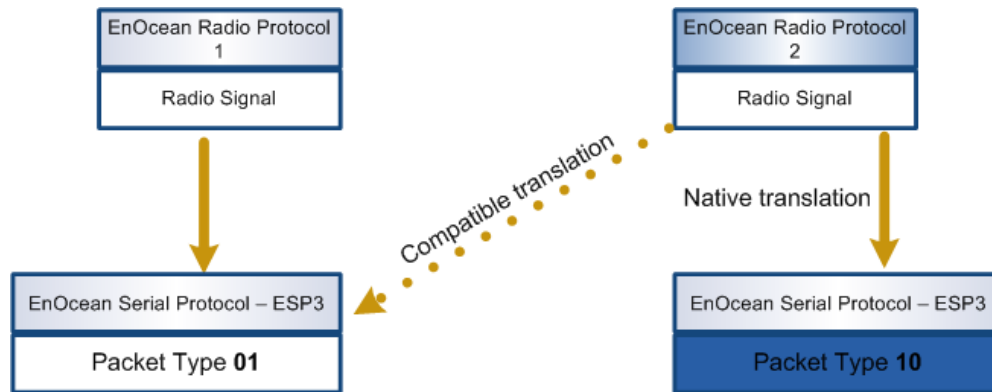
For transmission requests from external controller to the TCM 410J both types can be used at any time of the operation.

3.12   Module configuration

Configuration parameters will be stored in a non-volatile memory on the TCM 410J module. The parameters will be changeable with the Dolphin Suite configuration. The following parameters will be adjustable:

- default mode selection – if serial message are forwarded with serial type 01 or serial type 10
- sniffer mode selection – puts module into sniffer mode, which is suiting for network observation and evaluation
- baud rate selection

4.   SECURITY DETAILS

Following Security Level Formats are supported:

- Content Encryption:
  - No data encryption
  - VAES 128
  - AES – CBC

- Rolling code usage:
  - No RLC usage
  - 2 byte RLC
  - 3 byte RLC

- CMAC usage:
  - No CMAC usage
  - 3 byte CMAC
  - 4 byte CMAC

- Teach-in protection:
  - Plain teach-in

o Teach in protected by PSK (pre-shared key)

Supported Security Tasks:
- Decoding / Encoding

- Validation CMAC

- Handling RLC

For details on Security Tasks and Security Level Format please see reference 1.

4.1 Operational modes

The Decoding Gateway has two operational modes:
- Teach in mode (inbound / outbound)

- Gateway operational mode

For inbound and outbound communication the Dolphin V4 Decoding Gateway is maintaining entries of security profiles records. A security profile is the combined information of KEY, RLC and SLF. Inbound and outbound profiles are stored separately. By using commands
- CO_WR_SECUREDEVICE_ADD
- CO_WR_SECUREDEVICE_DEL
- CO_RD_SECUREDEVICE_BY_INDEX
- CO_RD_NUMSECUREDEVICES
- CO_RD_SECUREDEVICE_BY_ID

The Direction (inbound / outbound) must be specified. When using command CO_RD_SECUREDEVICE_BY_INDEX then please notice than for inbound and outbound have separated indexes. Both start at 0.
The entries in the inbound table are unique referenced by:
- Index in the storage
- Sender ID of the device which is taught in

The entries in the outbound table are unique referenced by:
- Index in the storage

- One of possible Base Ids of Dolphin V4 Decoding Gateway – communication is broadcast, Sender ID = Specified Base ID

  or

- The Chip ID of Dolphin V4 Decoding Gateway – communication is broadcast, Sender ID = Chip ID

  or

- The Chip ID of the opposite device, in which the Dolphin V4 Gateway is taught in – communication is unicast, Sender ID = Chip ID of Dolphin V4 Decoding Gateway, Destination ID = Chip ID of the opposite device

Please consider to select the correct ID based on your use case when adding devices to the outbound table with the serial command CO_WR_SECUREDEVICE_ADD.

4.1.1 Inbound communication – Teach-in & Data

In Figure 1 the processing of incoming radio telegrams is shown. Also the teach-in mode and resynchronisation feature is shown. Please find more details in the text below.
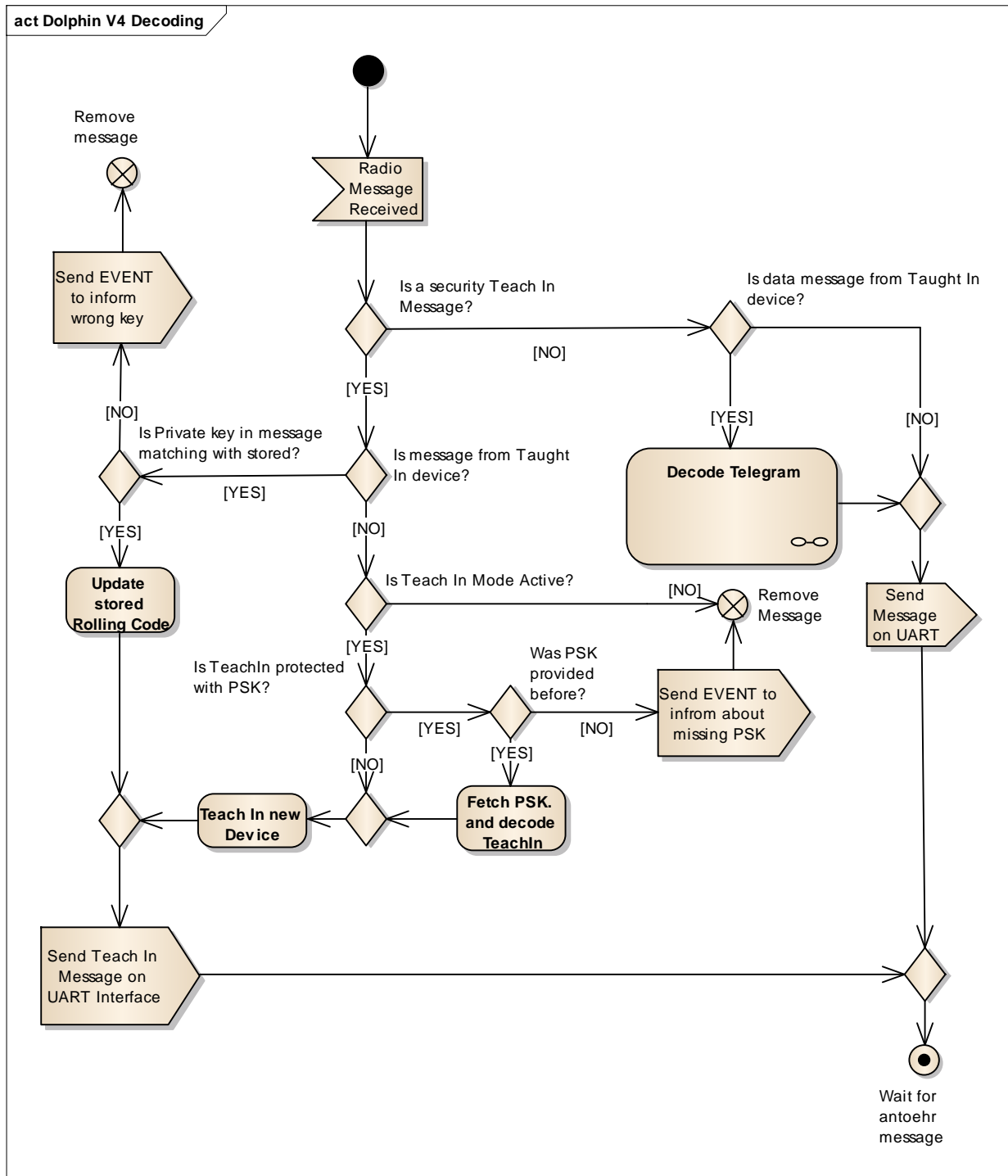
Figure 1 Operational functions - decoding

For the Dolphin V4 Decoding Gateway to decode data telegrams from the transmitting device the security information included in a teach-in message must be received. For this purpose also the Dolphin V4 Decoding Gateway must be put into LRN Mode with the correct

UART Command (CO_WR_LEARNMODE, CO_RD_LEARNMODE). If not in LRN mode, the teach-in request is ignored. See reference 2 for details on serial command.
If the teach-in process is realized with PSK (pre-shared key) then it must be available at teach-in time. The Dolphin V4 Decoding Gateway can be initialized with a PSK with an UART command (CO_WR_SECUREDEVICE_ADD_PSK). See reference 2 for details on the serial command.

After a successful teach-in process the whole teach-in message is passed as one serial packet type 10 on the serial interface.

Once the security information of a transmitting device is know the Dolphin V4 Decoding Gateway can decode all incoming data communication and forward it to the serial interface as packet type 10. All other telegrams received (with additional secure features or not) are also forwarded to the serial interface. During operation mode the Dolphin V4 Decoding gateway behaves as the Gateway Controller.

4.1.1.1 Resynchronisation of Taught In Secure Devices

During operating mode (not teach-in mode) teach in requests from unknown devices are ignored. If a taught in device sends a teach-in request, the RLC code information is updated. This is aimed for the case where the receiver and sender's RLC becomes desynchronized. The DolphinV4 Decoding Gateway also checks if the private key is matching. If not, it may be a potential attack and the Decoding Gateway sends a CO_EVENT_SECUREDEVICES for your information. See reference 2 for details on serial command.
If the resynchronization request is protected by the PSK then it must be present at the Dolphin V4 Gateway.

4.1.1.2 Decoding Telegrams in detail

In Figure 2 the decoding process is shown in detail. Please notice these two important features:

■ Temporary RLC window extension

For special purpose (e.g. power-up after long term power drop) the rolling code can be extended for one telegram to enable user-friendly RLC resynchronization. The Dolphin V4 Decoding Gateway will apply this temporary window for every taught-in device but only one time for every devices next incoming telegram. To set or unset the Temporary RLC window a serial command is specified (CO_WR_TEMPORARY_RLC_WINDOW). See reference 2 for details on serial command.

■ Security RLC window – amount of failed CMAC validation attempts

This value defines the count of the wrong CMAC validation attempts, before the Dolphin V4 Decoding Gateway module sends the event serial command (CO_EVENT_SECUREDEVICES). This event can signalize that a devices RLC is not synchronized any more.

act Decode Telegram

Decoding
requested

●

Is one time rolling window activated?

[NO]

[YES]

**Try to validate
CMAC within
normal RLC
window.**

**Try to validate CMAC
within one-time RLC
window.**

**Reset one-time
RLC - it wound get
used next time.**

Decoding succesfull?

[NO]

[YES]

**Increase security
window counter.**

**Prepare
message for
serial
interface.**

Has security window count
reached maximum?

[NO]

[YES]

Send event, that
security window
reached.

**Reset
security
window
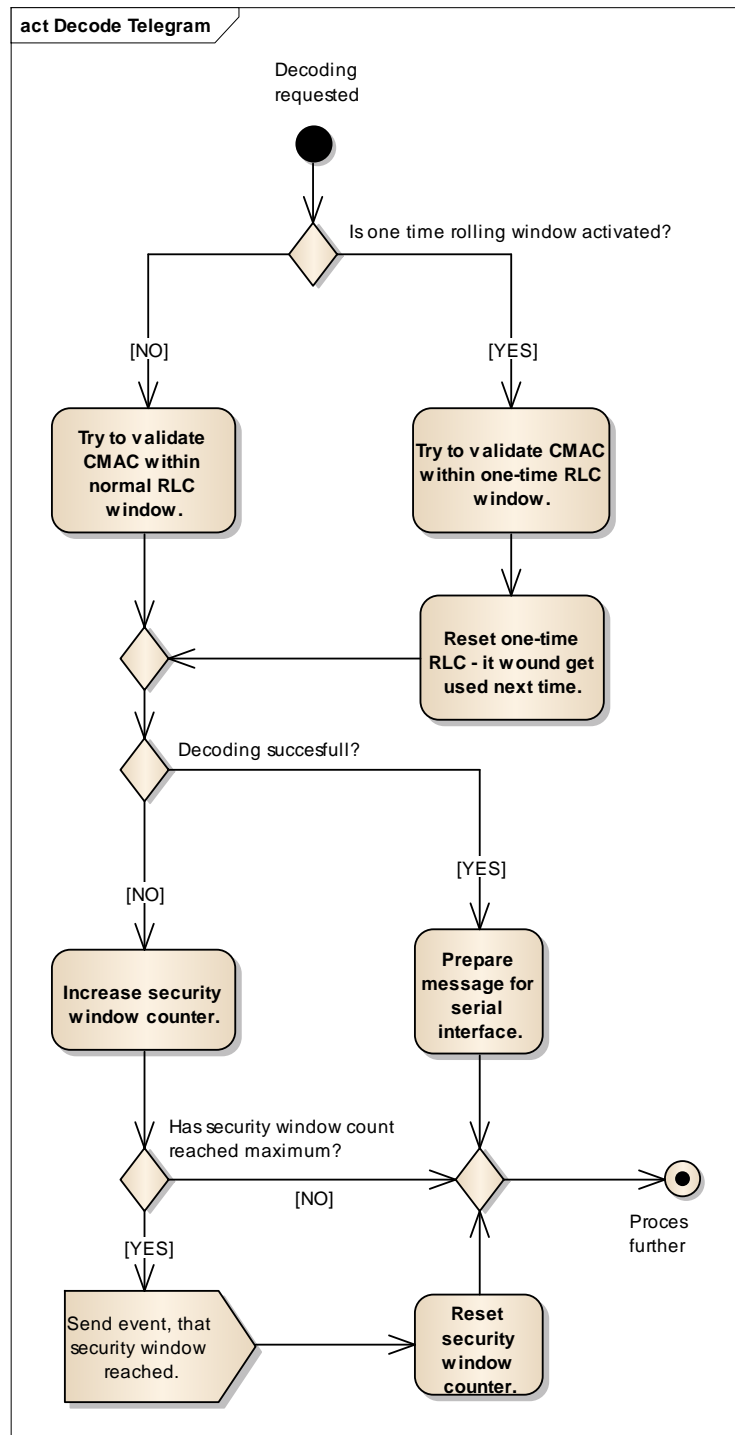counter.**

◉

Proces
further

Figure 2 Decode telegram activities

4.1.1.3   Filtering

Data communication filtering is complete independent from inbound and outbound security profiles lists. To filter incoming communication with the filter functionality on the Dolphin V4 Decoding Gateway the common filter interface can be used, see also 2. To enable filter-

ing of inbound security profiles they have to be added to the list by the external Controller by a serial command (e.g. CO_WR_FILTER_ADD) as any other device. See reference 2 for details on serial command for filtering function.
It is not mandatory to use the filter interface. The Dolphin V4 Decoding Gateway has 60 filters available. The filters information is not stored in non-volatile memory. After module restart the filters have to be set again.

4.1.2   Outbound communication – Teach-in & Data

4.1.2.1   Teach In

Before the Dolphin V4 Decoding Gateway can encrypt outgoing communication the SLF format, KEY and RLC of the outgoing communication must be specified. The Dolphin V4 Decoding Gateway can have several outgoing communication profiles.
To add a secure device the command serial command CO_WR_SECUREDEVICE_ADD is specified. See reference 2 for details on serial command.
To complete the security teach-in process the Dolphin V4 Decoding Gateway has to send a security teach-in telegram to the other communication partner and so inform him about the used security profile. To trigger the transmission of the teach-in telegram the serial command CO_WR_SECUREDEVICE_SENDTEACHIN is specified. See reference 2 for details on serial command. In CO_WR_SECUREDEVICE_SENDTEACHIN command an ID reference must be specified. Prior teach-in the entry with this ID must be added into the outbound table. Please chapter 4.1 for details on ID reference.
If you would like to use PSK protection of the send teach-in request, then please specify it respectively in the Optional Field – TeachInInfo of the command CO_WR_SECUREDEVICE_SENDTEACHIN. The PSK for all outgoing protection is same and only readable and changeable trough Dolphin Suite 3.
If bidirectional teach-in should be performed please specify this also in the TeachInInfo field. Please find more details on the TeachInInfo also in the Security specification reference 1

4.1.2.2   Data communication

In data communication it is sufficient to specify the correct reference ID in the Destination ID field or Source ID field and the Dolphin V4 Decoding Gateway will automatically encrypt the data communication. Please find details on outbound data communication in Figure 3.
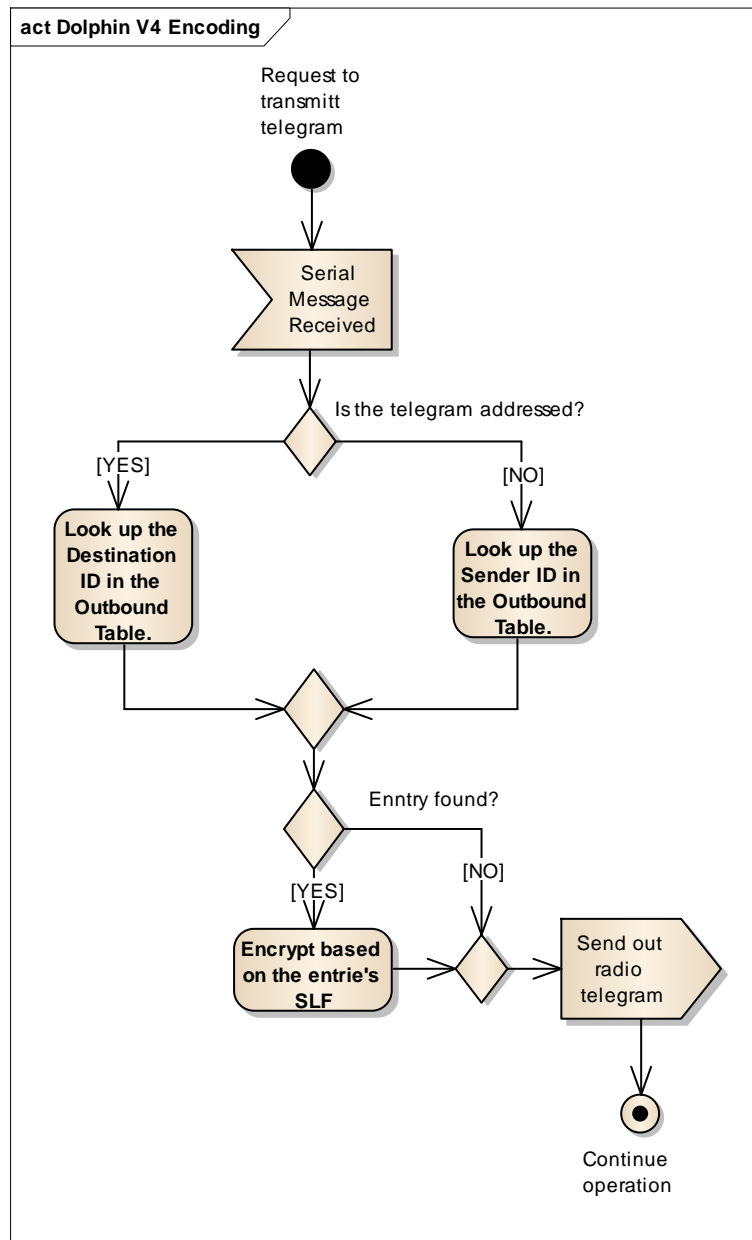
Figure 3 Encoding activities

4.2   Storage for Rolling Codes and Keys

For security functionality the Gateway needs to store the following for each learned in device:

- Security AES 128 key – 16 bytes
- Rolling Code information – 2 or 3 bytes

The key is stored in the internal Dolphin V4 Chip and the RLC in an external EEPROM memory.

Following maximum supported security profiles are possible:
- 30 outbound security profiles – devices
- 30 inbound security profiles - devices

The security Key of a device is constant. The RLC will change with every telegram transmission. Therefore the receiver needs to store it periodically during whole operational time. For the case of power off the RLC needs to be store also in the non-volatile memory.
We define two storage frequency parameters – how often to store a RLC:
- Outbound communication storage frequency – default every transmission
- Inbound communication storage frequency – default every 30th transmission

Both parameters can be adjusted trough Dolphin Suite 3.
We used external memory for storage of rolling codes, because it ensures higher safety through separating the rolling code storage place from program memory storage place and enables a higher storage frequency.

4.2.1   Possible external memories

Decoding Gateway is used with external memory, we can refer to this possible EEPROM:
- 24AA08 Microchip – 8 kilobit.

As the Dolphin V4 Decoding Controller was developed using this module compatibility is guaranteed. Based on the characteristics of the EEPROM module they can be connected directly to the EnOcean Module. See example below:
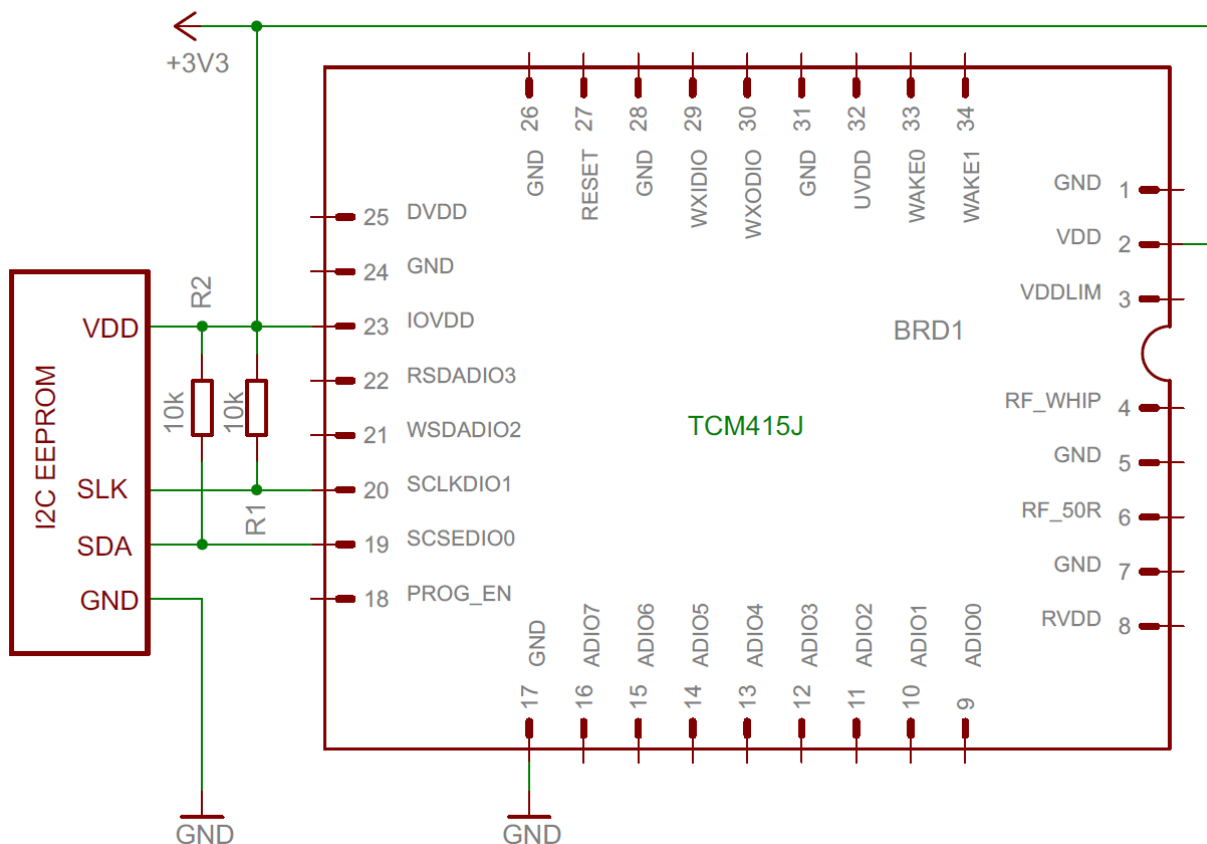

Figure 4 EEPROM Connection

> ⚠ Please check second source memory modules for compatibility before use. Chang-es in the Dolphin V4 Decoding Gateway I2C interface may be required.

4.2.2 Voltage drops

During critical tasks, in particular erasing a page, it must be ensured that enough power is available. A power drop during this operation can cause unexpected behavior. Therefore we recommend attaching an external capacitor to overcome a sudden power drop.

■ In case of EEPROM usage as Rolling Code Storage a small capacitor is needed – erase time takes 5 ms @ 0.1 mA.

The storing of the KEY in the Dolphin V4 Chip memory is a one-time event executed only at teach-in time. Due to low probability of failure at this time no additional measures were taken.

4.3 Configurations

The security configurable values are stored in CFG Area. You can change them with Dolphin Suite. The following parameters are available:

■ Security RC storage cycle outbound – Address in CFG: 0x23 Default value: 1

  This value defines how many telegrams of one security profile will be send prior to up-dating the rolling code in persistent memory.

■ Security RC storage cycle inbound – Address in CFG: 0x22 (Length: 1 byte), Default value: 30

  This value defines how many telegrams of one security profile will be send prior to up-dating the rolling code in persistent memory.

■ Wrong CMAC count – Security RLC window – Address in CFG: 0x20 (Length: 1 byte), Default value: 100

  This value defines the count of the wrong CMAC validation attempts, before the Decod-ing Gateway module sends the event serial command (CO_EVENT_SECUREDEVICES).

■ RLC window – Address in CFG: 0x1C (Length: 4 bytes), Default value: 128

  This value defines how big the Rolling Code window can be. The Rolling code window de-fines the amount of tries where the device tries to validate the RLC from a message.

■ PSK – Pre-shared key - Address in CFG: 0x1C (Length: 16 bytes), Default value: N/A – set in production

  The PSK which can used for outbound security teach-in.

Please see configuration window from Dolphin Suite as reference:

Security		
Brute Force Limit	100	Count of receiving wrong CMAC to send an CO_EVENT_SECUREDEVICES
Rolling-Code Window	128	Rolling code window size
Rolling-Code In Save	30	Save rolling code to EEPROM after every Nth inbound telegram
Rolling-Code Out Save	1	Save rolling code to EEPROM after every Nth outbound telegram

Security Keys

Define Pre-Shared

Pre-shared Key   A5 73 D5 B1 B5 33 4E D1 EA 52 5C 97 CD 34 D5 AA   16   -   +

5.   APPLICATIONS INFORMATION

5.1   Transmission range

The main factors that influence the system transmission range are type and location of the antennas of the receiver and the transmitter, type of terrain and degree of obstruction of the link path, sources of interference affecting the receiver, and "dead" spots caused by signal reflections from nearby conductive objects. Since the expected transmission range strongly depends on this system conditions, range tests should categorically be performed before notification of a particular range that will be attainable by a certain application.

The following figures for expected transmission range are considered by using a PTM, a STM or a TCM radio transmitter device and the TCM radio receiver device with preinstalled whip antenna and may be used as a rough guide only:

- Line-of-sight connections: Typically 30 m range in corridors, up to 100 m in halls
- Plasterboard walls / dry wood: Typically 30 m range, through max. 5 walls
- Ferro concrete walls / ceilings: Typically 10 m range, through max. 1 ceiling
- Fire-safety walls, elevator shafts, staircases and supply areas should be considered as screening.

The angle at which the transmitted signal hits the wall is very important. The effective wall thickness – and with it the signal attenuation – varies according to this angle. Signals should be transmitted as directly as possible through the wall. Wall niches should be avoided. Other factors restricting transmission range:

- Devices mounted on metal surfaces (shielding and detuning of antenna may cause heavy loss of transmission range)
- Hollow lightweight walls filled with insulating wool on metal foil
- Suspended ceilings with panels of metal or carbon fibre
- Lead glass or glass with metal coating, steel furniture

The distance between EnOcean receivers and other transmitting devices such as computers, audio and video equipment that also emit high-frequency signals should be at least 0.5 m

A summarized application note to determine the transmission range within buildings is available as download from www.enocean.com.

5.2 Antenna options

5.2.1 Overview

Several antenna types have been investigated by EnOcean. Please refer to our application notes AN102, and AN105 which give an overview on our recommendations.

5.2.2 Whip antenna
928.35 MHz
Antenna: 64 mm wire, connect to RF_WHIP

Minimum GND plane: 50 mm x 50 mm
Minimum distance space: 10 mm

Positioning and choice of receiver and transmitter antennas are the most important factors in determining system transmission range.

For good receiver performance, great care must be taken about the space immediately around the antenna since this has a strong influence on screening and detuning the antenna. The antenna should be drawn out as far as possible and must never be cut off. Mainly the far end of the wire should be mounted as far away as possible (at least 15 mm) from all metal parts, ground planes, PCB strip lines and fast logic components (e.g. microprocessors).
Do not roll up or twist the whip antenna!

Radio frequency hash from the motherboard desensitizes the receiver. Therefore:
- PCB strip lines on the user board should be designed as short as possible
- A PCB ground plane layer with sufficient ground vias is strongly recommended
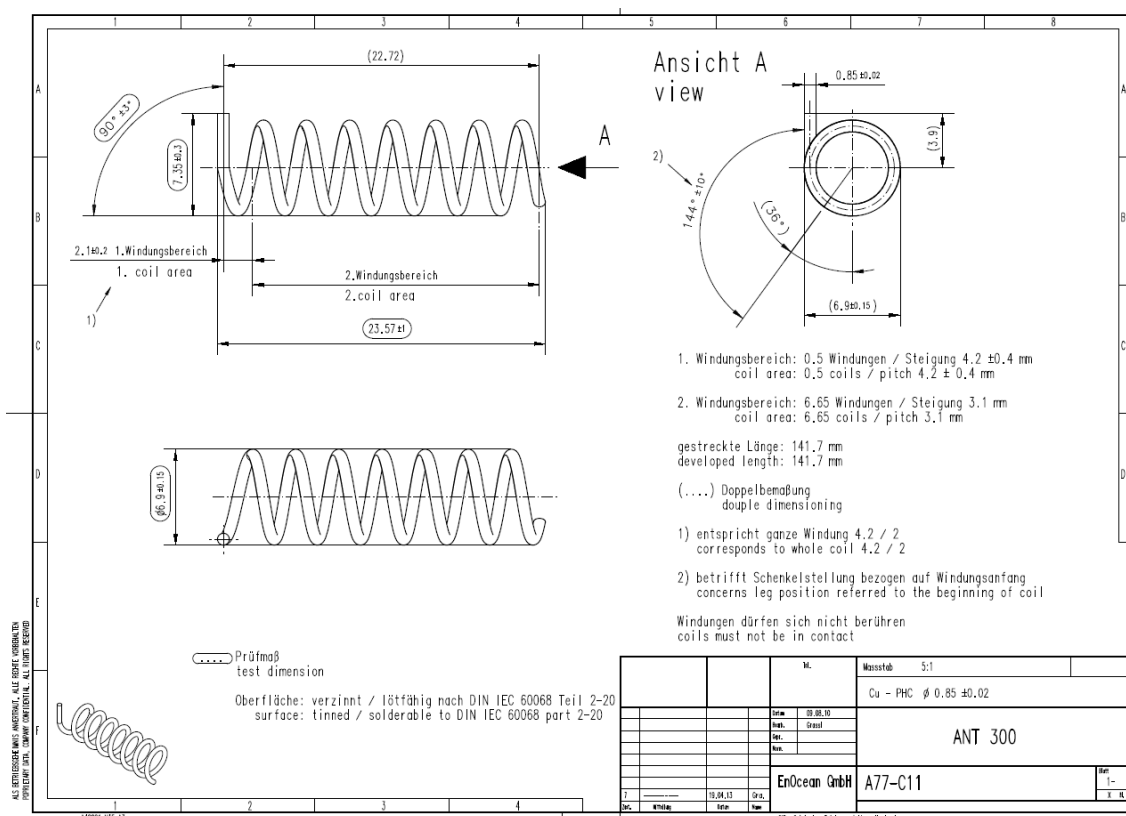
5.2.3 Helical antenna

928.35 MHz
according to drawing below, connect to RF_WHIP
Minimum GND plane: 35 mm x 30 mm
Minimum distance space: 10 mm

5.2.4 Top loaded PCB spiral antenna

The design of the antenna made on a 1mm thick, two layer FR4 PCB. The dimensions are given in figure below. The hatched areas are double sided in layout. The large area to the left is a ground area. Components can be placed here as long as the area is not split by this nor has long cuts in it which can act as radiators its self.
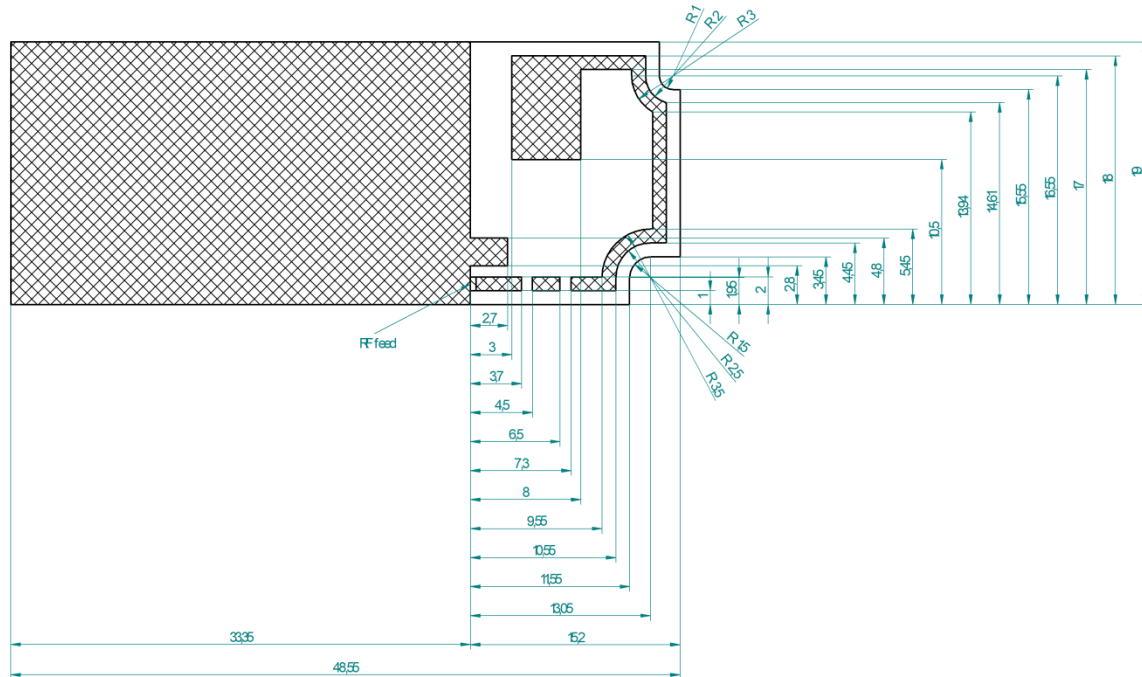
Dimensions of the PCB antenna.

Parameter of PCB	VALUE
PCB material	FR4, 2 layer
Thickness (total)	1,27mm
Shape	Rectangular with millings
Dimension	19*48,55 mm

Layer	Thickness in µm	Exact description
Solder Mask		Solder resist
Top Layer	35	Cu, >35um after electroplating
Core	1200	
Bottom Layer	35	Cu, >35um after electroplating
Solder Mask		Solder resist
Total	1270	

The PCB antenna uses three discrete matching components. The position of these components can be seen in figure below.
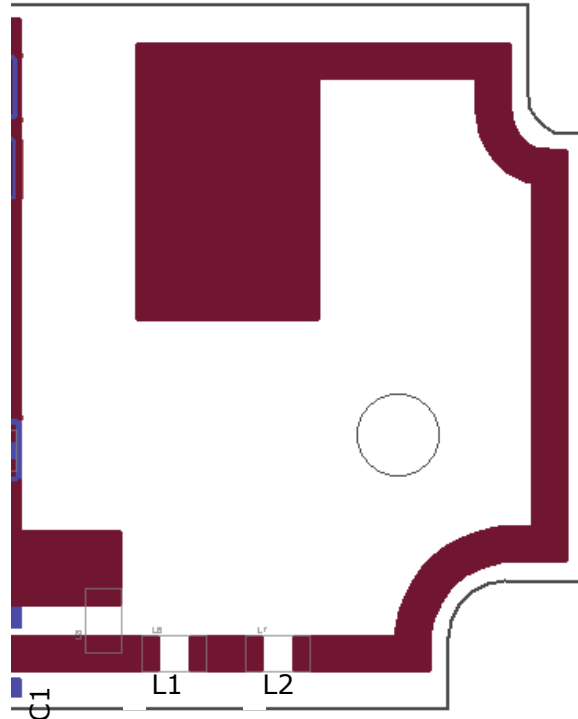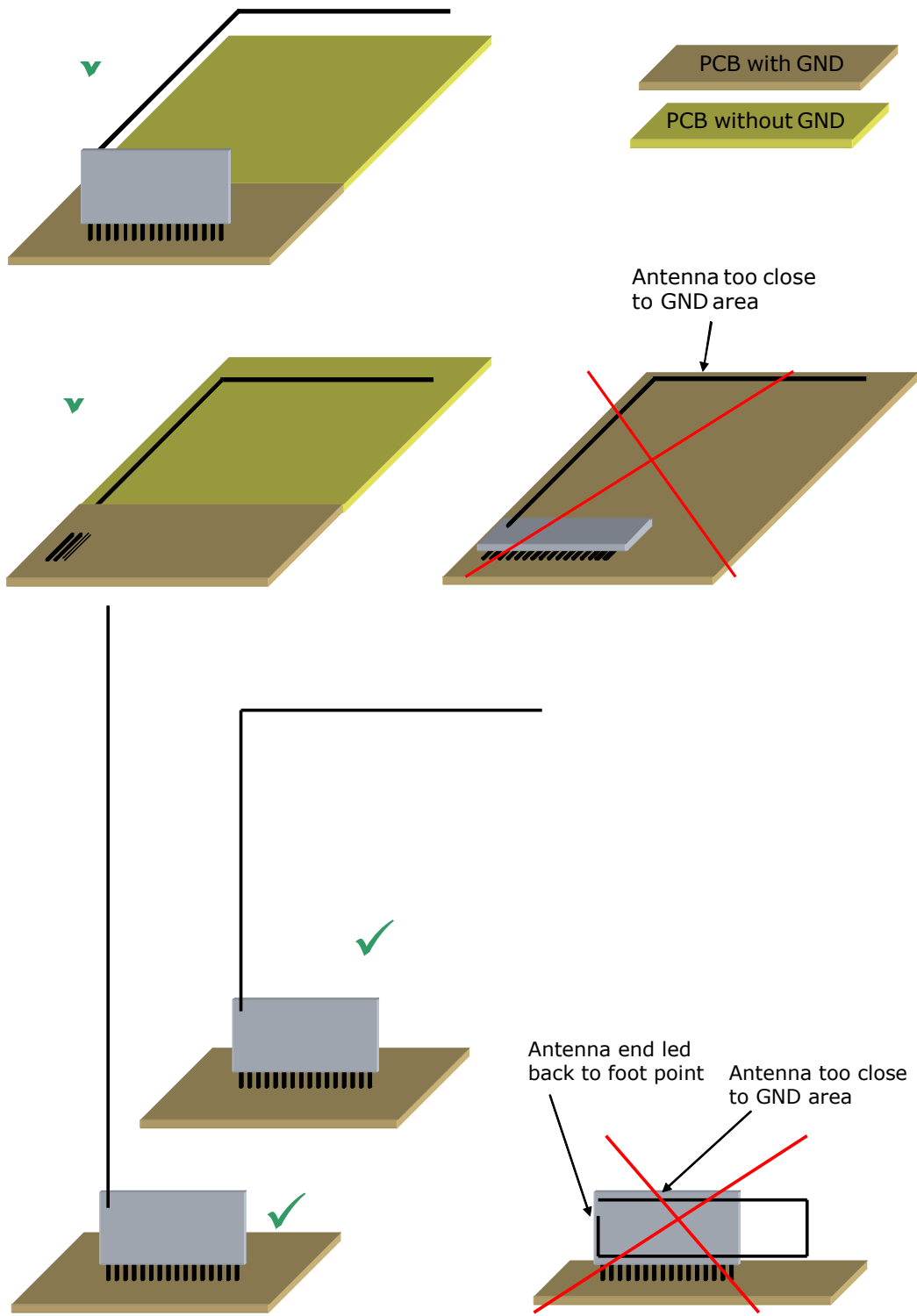
Position of matching components

The antenna was matched to 50Ω input impedance at the feed point. A compromise for a good matching when plugged into a laptop and when plugged to the end of a USB cable was chosen. Several environments in the proximity of the antenna where also evaluated for this compromise. The following table shows the values of the proposed components.

Component	Value
C1	3.3pF
L1	12nH
L2	12nH

0603 components where used for the antenna matching. For the capacitor general purpose C0G capacitors with 5% tolerance are sufficient. The inductors should be wire wound inductors from the Würth WE-KI series or the Murata LQW series.

5.3 Recommendations for laying a whip antenna

PCB with GND

PCB without GND

Antenna too close
to GND area

Antenna end led
back to foot point

Antenna too close
to GND area

5.4   Power supply requirements

In order to provide a good radio performance, great attention must be paid to the power supply and a correct layout and shielding. It is recommended to place a 22 µF ceramic capacitor between VDD and GND close to the module (material: X5R, X7R, min 6.3 V to avoid derating effects).
In addition, an HF SMD EMI Suppression Ferrite Bead such as the Würth WE-CBF HF SMD EMI Suppression Ferrite Bead (Würth order number 742863160) shall be inserted in the power supply line.

For best performance it is recommended to keep the ripple on the power supply rail below 10 mVpp (see 3.4).

⚠ All GND pins must be connected to GND. Be careful not to create loops! The ground must be realized ideally on both sides of the PCB board with many Vias. At least there must be a short star connection. Otherwise RF performance can be reduced!

5.5   Layout recommendations

⚠ The length of lines connected to I/Os should not exceed 5 cm.

⚠ It is recommended to have a complete GND layer in the application PCB, at least in the area below the module and directly connected components (e.g. mid-layer of your application PCB).

Due to unisolated test points there are live signals accessible on the bottom side of the module.

Please follow the following advices to prevent interference with your application circuit:

- ■ We suggest avoiding any copper structure in the area directly underneath the module (top-layer layout of your application PCB). If this is not possible in your design, please provide coating on top of your PCB to prevent short circuits to the module. All bare metal surfaces including vias have to be covered (e.g. adequate layout of solder resist).

- ■ It is mandatory that the area marked by the circle in the figure below is kept clear of any conductive structures in the top layer and 0.3 mm below. Otherwise RF performance will be degraded!

Furthermore, any distortive signals (e.g. bus signals or power lines) should not be routed underneath the module. If such signals are present in your design, we suggest separating them by using a ground plane between module and these signal lines.

5.5.1 Recommended foot pattern

Top layer

Solder resist top layer

GND restricted 0...0,3mm below
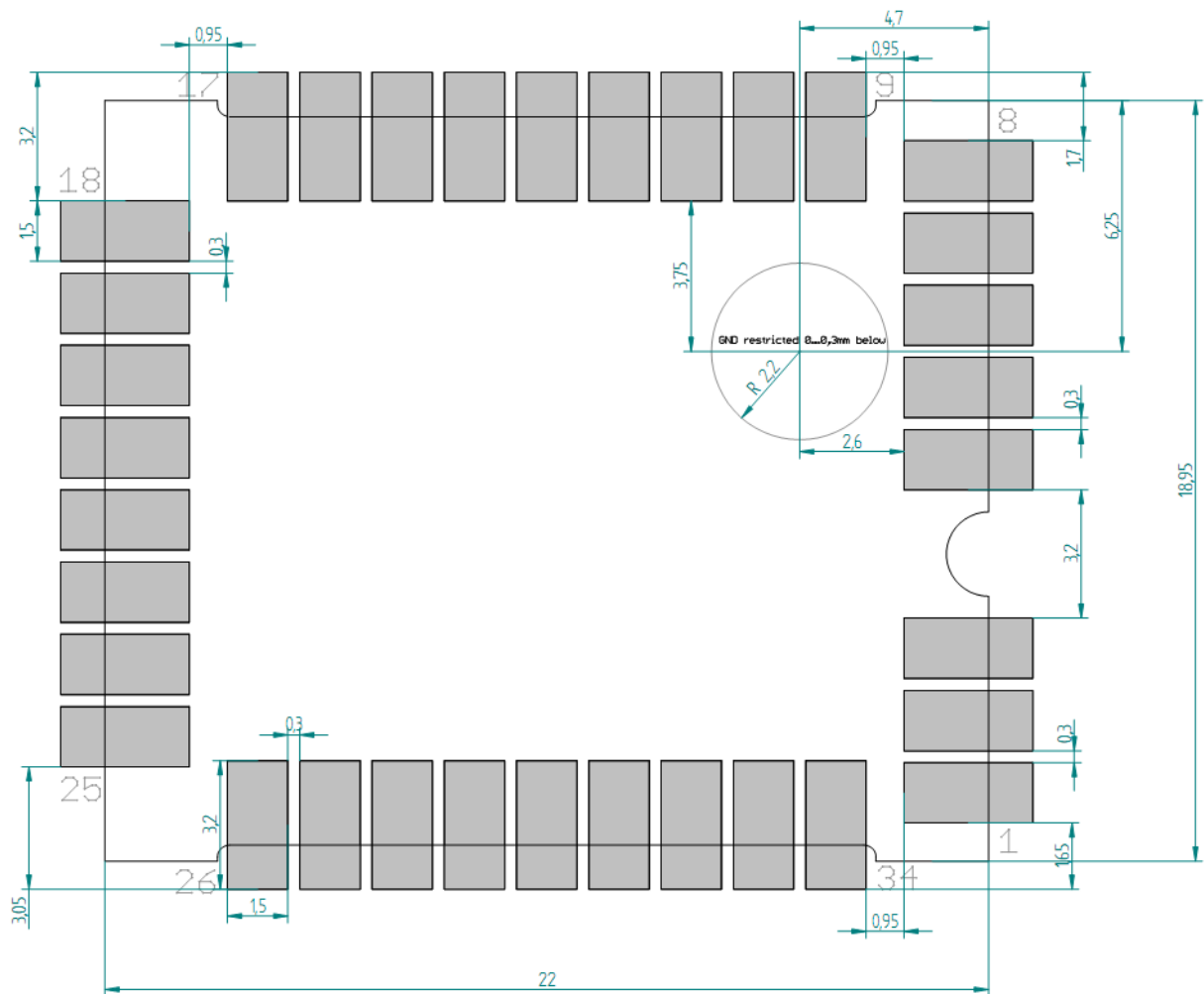
Solder paste top layer
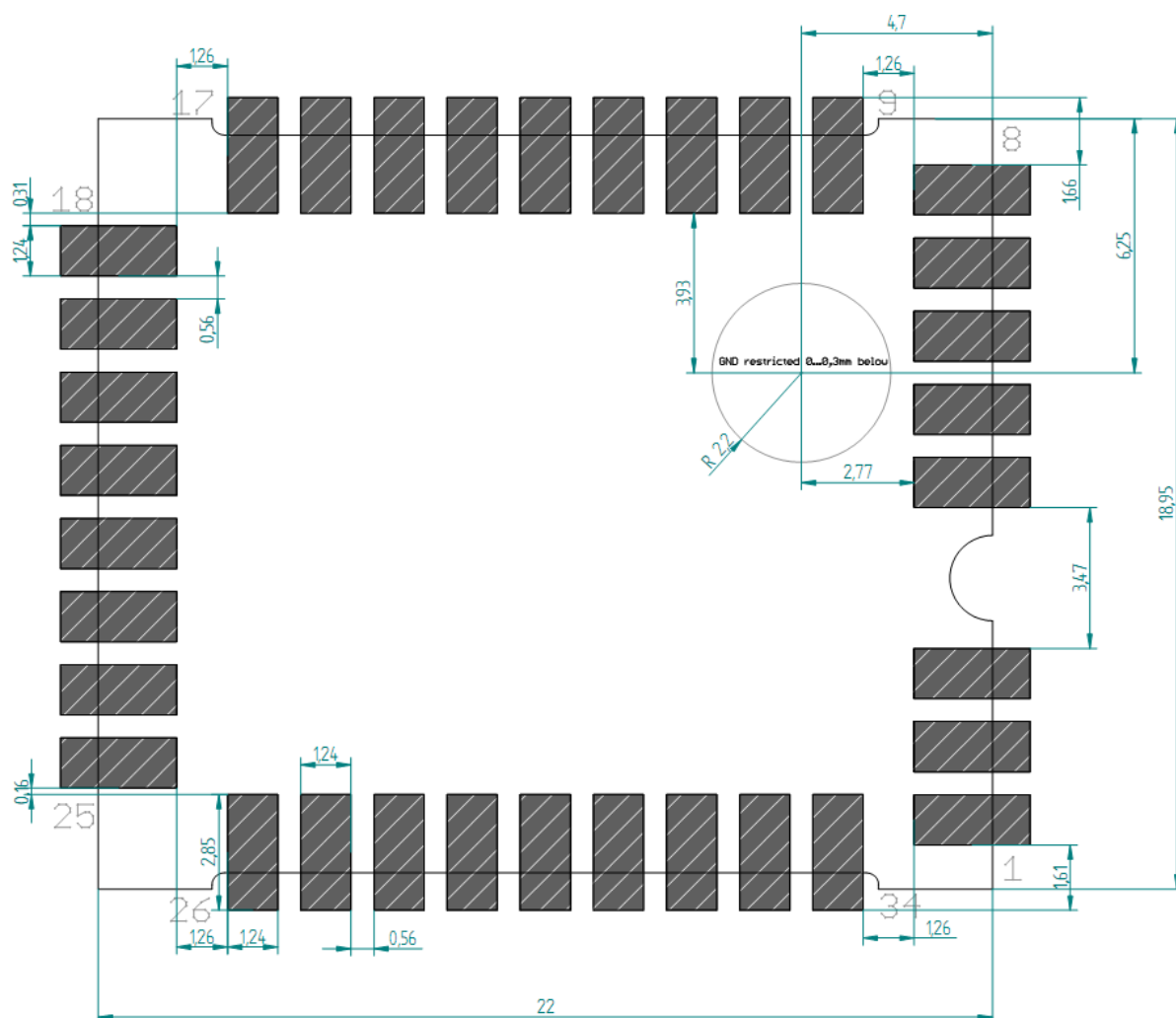
The data above are also available as EAGLE library.

In order to ensure good solder quality a solder mask thickness of 150 µm is recommended.

In case a 120 µm solder mask is used, it is recommended to enlarge the solder print. The pads on the solder print should then be 0.1 mm larger than the pad dimensions of the module as specified in chapter 2.3. (not relative to the above drawing).

Nevertheless an application and production specific test regarding the amount of soldering paste should be performed to find optimum parameters.

5.6 Soldering information

TCM 410J shall be soldered according to IPC/JEDEC J-STD-020C standard.

Profile Feature	Pb-Free Assembly
Average Ramp-Up Rate (Ts_{max} to Tp)	3° C/second max.
Preheat – Temperature Min (Ts_{min}) – Temperature Max (Ts_{max}) – Time (ts_{min} to ts_{max})	150 °C 200 °C 60-180 seconds
Time maintained above: – Temperature (T_L) – Time (t_L)	217 °C 60-150 seconds
Peak/Classification Temperature (Tp)	260 °C
Time within 5 °C of actual Peak Temperature (tp)	20-40 seconds
Ramp-Down Rate	6 °C/second max.
Time 25 °C to Peak Temperature	8 minutes max.

Note 1: All temperatures refer to topside of the package, measured on the package body surface.
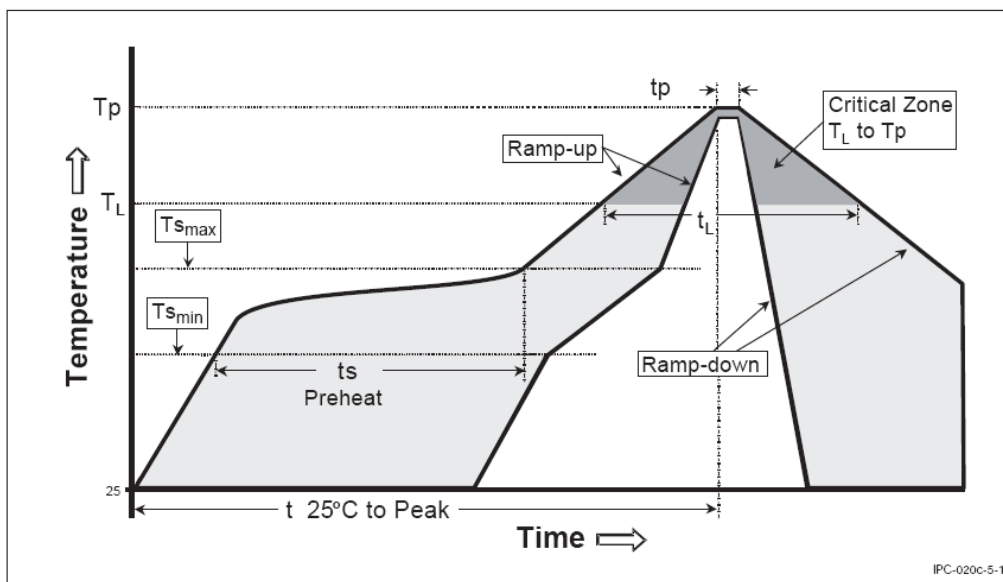
TCM 410J shall be handled according to Moisture Sensitivity Level MSL3 which means a floor time of 168 h. TCM 410J may be soldered only once, since one time is already consumed at production of the module itself.

Once the dry pack bag is opened, the desired quantity of units should be removed and the bag resealed within two hours. If the bag is left open longer than 30 minutes the desiccant should be replaced with dry desiccant. If devices have exceeded the specified floor life time of 72 h, they may be baked according IPC/JEDEC J-STD-033B at max. 90°C for less than 60 h.

Devices packaged in moisture-proof packaging should be stored in ambient conditions not exceeding temperatures of 40 °C or humidity levels of 90% r.H.

TCM 410J modules shall be soldered within 6 months after delivery!

5.7 Tape & Reel specification

Tape running direction

6. AGENCY CERTIFICATIONS

The modules have been tested to fulfil the approval requirements based on the built-in firmware.

⚠️ **When developing customer specific firmware based on the API for this module, special care must be taken not to exceed the specified regulatory limits, e.g. the duty cycle limitations!**

Please find more details in the EnOcean Radio Protocol 2 Specification[2].

6.1 Japanese Type Approval

TCM 410J complies with the Japanese radio law and is certified according to ARIB STD-T108.

When the product is placed on the Japanese market, it must carry the Specified Radio Equipment marking as shown below:
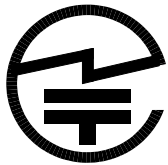
R **206-000372**

If the certification label cannot be recognized from outside (e.g. installation in a host) appropriate information must be referenced in the user manual.

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[2] https://www.enocean.com/fileadmin/redaktion/pdf/tec_docs/EnOceanRadioProtocol2.pdf

EMCC™
DR. RAŠEK

Notified Body Directive 99/5/EC
Notified Body EMC Directive 2014/30/EU
RF CAB under the Japan-EC MRA
FCB under the Canada-EC MRA
TCB under the USA-EC MRA

RF CAB ID No. 206

Designated by the German Regulator Bundesnetzagentur to act as a
Recognised Foreign Conformity Assessment Body in accordance with the Japan-EC MRA

CONSTRUCTION TYPE CONFORMITY CERTIFICATE
for
Specified Radio Equipment

Registration No.	JU000372D Rev.3
Certificate Holder	EnOcean GmbH Kolpingring 18a 82041 Oberhaching Germany
Product Category	Article 2, Paragraph 1, Item 8 (Y)
Product Designation	STM 400J, TCM 410J, USB 400J
Product Description	Scavenger Transceiver Module, Transceiver Module, USB Gateway
Software Release No.	--
Manufacturer	Katek GmbH Bahnhofstraße 108 83224 Grassau Germany

When the product is placed on the
Japanese market, it must carry the
Specified Radio Equipment marking
as shown on the right

R 206-000372

The scope of evaluation relates to the submitted documents only.

This Certificate confirms that the listed product has demonstrated conformity with the relevant
technical regulations defined in the attached Annex. It is only valid in conjunction with the Annex.

Annex to Certificate Registration No. JU000372D Rev.3
Date 2016-05-12
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Technical Construction File (TCF) Details

Technical Standards and Specifications

The product complies with:

Ordinance Regulating Radio Equipment (Radio Regulatory commission No.18, 1950)

Chapter I	General Provisions
Chapter II	Transmitting Equipment
Chapter III	Receiving Equipment
Chapter IV	Article 49.14

Documentation submitted for the Type Certification

Test Report No.	Issue Date	Issued by
16/02-0005	2016-04-05	pkm electronic GmbH

Product documentation
  Antenna specifications
  Block diagram
  Component layout
  Internal & external photographs
  Label sample
  Schematic diagrams
  User manual

Quality System documentation
  ISO 9001 Certificate for manufacturer

Technical characteristics

Type of modulation:	FSK
Emission designator:	F1D
Operating frequency range:	928.35 MHz
Rated transmitter output power:	1 mW
Maximum antenna gain:	2.15 dBi

Other information

The device is certified for operation with the following antenna(s):
  ANT 300, helical antenna, 2.15 dBi gain
  ANT 300J, helical antenna, 2.15 dBi gain
  Whip antenna, 64mm, -3.89 dBi gain
  USB 400J, top loaded PCB spiral antenna, 1.14 dBi gain
  ANT-GXM602, "758-0965", monopole antenna, 2.14 dBi gain
  2J520, "758-0961", dipole antenna, 2.14 dBi gain
  MC0114033, "758-0910", monopole antenna, 1 dBi gain