

PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE

PTM 215B Dolphin Bluetooth® Pushbutton Transmitter Module

22.06.2018



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

PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE

REVISION HISTORY

The following major modifications and improvements have been made to this document:

Version	Author	Reviewer	Date	Major Changes
1.0	MKA	MK	14.10.2016	First release for DA-3 status
1.1	MKA	MKA	15.12.2016	Update for DB-4 status
1.2	MKA	MKA	25.01.2017	Added NFC reader information Added instructions for validating the authentication signature
1.3	MKA	MKA	17.03.2017	Added note on receiver configuration
1.4	MKA	MKA	30.03.2017	Added telegram parsing examples
1.5	MK	MKA	17.07.2017	R&TTE -> RED, max. transmit power
1.6	MK	MKA	11.10.2017	Added note regarding magnets or ferromagnetic materials near PTM 215B
1.7	MKA	MKA	21.12.2017	Added Australia certification
1.8	MKA	MKA	22.06.2018	Added Japan certification and changes introduced in version DC-06

**Published by EnOcean GmbH, Kolpingring 18a, 82041 Oberhaching, Germany
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1. General description

1.1 Basic functionality

PTM 215B enables the realization of energy harvesting wireless switches for building or industrial automation systems communicating based on Bluetooth® low energy technology.

PTM 215B is mechanically compatible with the established PTM 210 form factor enabling quick integration into a wide range of designs. Key applications are wall-mounted or portable switches either with up to two rockers or up to four push buttons.

PTM 215B pushbutton transmitters are self-powered (no batteries) and fully maintenance-free. They can therefore be used in all environments including locations that are difficult to reach or within hermetically sealed housings. The required energy is generated by an electro-dynamic energy transducer actuated by an energy bow located on the left and right of the module. This energy bow which can be pushed from outside the module by an appropriate pushbutton or switch rocker.

When the energy bow is pushed down or released, electrical energy is created and a radio telegram according to the Bluetooth® low energy standard is transmitted. This radio telegram transmits the status of all four contact nipples at the moment when the energy bow was pushed down or released.

PTM 215B radio telegrams are protected with AES-128 security based on a device-unique private key.



Figure 1 – PTM 215B Product Outline

PTM 215B is available in the following variants:

- PTM 215B
Stand-alone module without additional components
- EWSSB / EWSDB
PTM 215B integrated into European-style single / double rocker wall switch housing
- ESRPB / EDRPB
PTM 215B integrated into US-style single or double rocker pad housing

The term “PTM 215B” as used in this document applies to all product variants unless otherwise mentioned.

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1.2 Technical data

Antenna	Integrated PCB antenna
Max. transmit power measured	0.4dBm / 1.1mW
Communication Range (Guidance Only)	75 m ideal line of sight / 10 m indoor environment
Communication Standard	Bluetooth Low Energy (BLE)
Radio Frequency (min / max)	2402 MHz / 2480 MHz
Default Radio Channels	CH 37 / 38 / 39 (2402 MHz / 2426 MHz / 2480 MHz)
Advertising Events per press or release (min / max)	2 / 3
Data Rate and Modulation	1 Mbit/s GFSK
Configuration Interface	NFC Forum Type 2 Tag (ISO/IEC 14443 Part 2 and 3)
Device Identification	Unique 48 Bit Device ID (factory programmed)
Security	AES128 (CBC Mode) with Sequence Code
Power Supply	Integrated Kinetic Energy Harvester
Button Inputs	Up to four buttons or two rockers

1.3 Physical dimensions

Module Dimensions	40.0 x 40.0 x 11.2 mm
Module Weight	20 g +/- 1g

1.4 Environmental conditions

Operating Temperature	-25°C ... 65°C
Storage Temperature	-25°C ... 65°C
Humidity	0% to 95% r.h. (non-condensing)

1.5 Packaging information

Packaging Unit	100 units
Packaging Method	Tray / Box (10 units per tray, 10 trays per box)

1.6 Ordering information

Type	Ordering Code	Frequency
PTM 215B	S3221-A215	2.4 GHz (Bluetooth Low Energy)

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2. Functional information

2.1 Device Overview

The pushbutton transmitter module PTM 215B from EnOcean enables the implementation of wireless remote controls without batteries. It transmits Bluetooth Low Energy (BLE) data telegrams where the required energy is provided by a built-in electro-dynamic energy generator.

The outer appearance of PTM 215B is shown on the picture below.

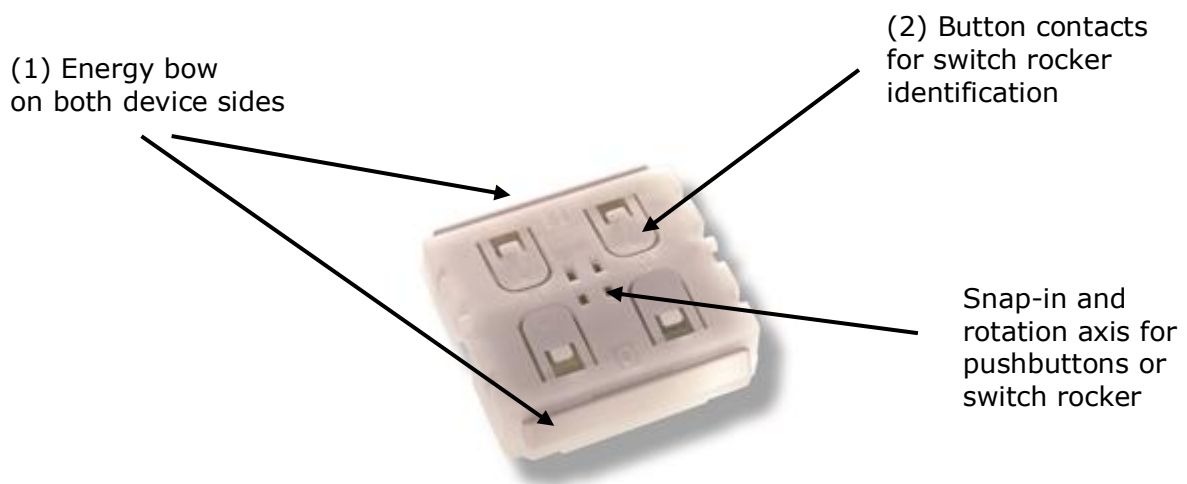


Figure 2 – Electro-dynamic powered pushbutton transmitter module PTM 215B

2.2 Basic Functionality

PTM 215B devices contain an electro-dynamic energy converter which is actuated by an energy bow (1). This bow is pushed by an appropriate push button, switch rocker or a similar construction mounted onto the device. An internal spring will release the energy bow as soon as it is not pushed down anymore.

When the energy bow is pushed down, electrical energy is created and a BLE radio telegram is transmitted which identifies the action (pressed or not pressed) and the status of the four button contacts (2). Releasing the energy bow similarly generates energy which is used to transmit a different radio telegram.

It is therefore possible to distinguish between radio telegrams sent when the energy bar was pushed and radio telegrams sent when the energy bar was released.

By identifying these different telegram types and measuring the time between pushing and releasing of the energy bar, it is possible to distinguish between “Long” and “Short” button contact presses. This enables simple implementation of applications such as dimming control or blinds control including slat action.

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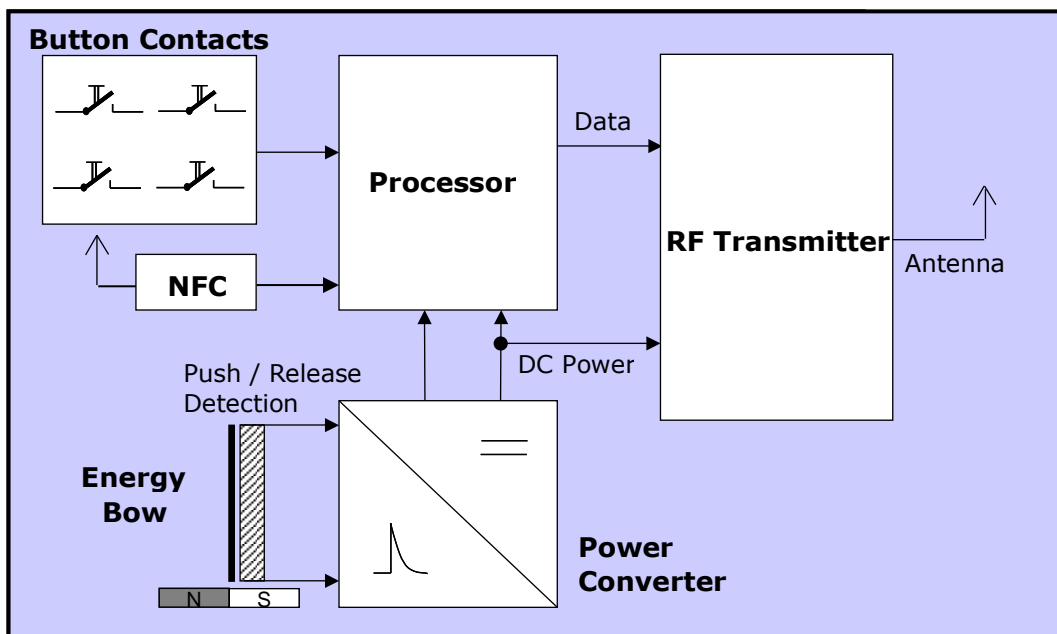
2.3 **Block Diagram**

Figure 3 – Functional block diagram of PTM 215B

Energy Bow / Power Generator

Converts the motion of the energy bow into electrical energy

Power Converter

Converts the energy of the power generator into a stable DC supply voltage for the device electronics

Processor

Determines the status of the button contacts and the energy bow, encodes this status into a data word, generates the proper radio telegram structure and sends it to the radio transmitter

RF transmitter

Transmits the data in the form of a series of short 2.4 GHz Bluetooth Low Energy radio telegrams using the integrated antenna

NFC interface

Allows reading and writing certain product parameters using an NFC compliant reader / writer supporting NFC Forum Type 2 tags (as specified by ISO/IEC 14443 Part 2 and 3).

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2.4 User Interface

PTM 215B devices provide four button contacts. They are grouped into two channels (Channel A and Channel B) each containing two button contacts (State O and State I).

The state of all four button contacts (pressed or not pressed) is transmitted together with a unique device identification (48 Bit device ID) whenever the energy bow is pushed or released.

Figure 4 below shows the arrangement of the four button contacts and their designation:

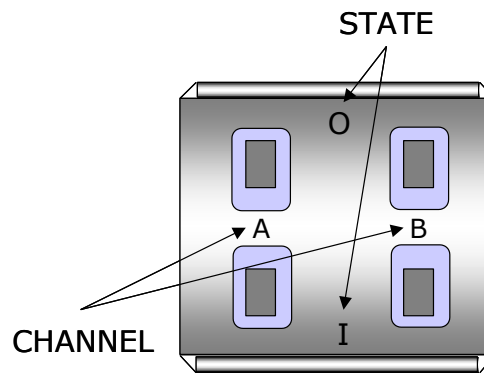


Figure 4 – Button contact designation

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3. Telegram transmission

3.1 Radio channel parameters

PTM 215B transmits Bluetooth Low Energy (BLE) advertising telegrams within the 2.4 GHz radio frequency band (2402MHz ... 2480MHz).

By default, PTM 215B will use the three BLE advertising channels (BLE Channel 37, 38 and 39) defined for transmission. The transmission of a radio telegram on these three advertising channels is called an Advertising Event.

Use of different radio channels within the frequency band from 2402 MHz to 2480 MHz is possible, see chapter 6.7.9.

The initialization value for data whitening is set as follows:

- For BLE channels is set according to specification (value = radio channel)
- For the custom radio channels the initialization value is equal to the offset from 2400 MHz (e.g. value = 3 for 2403 MHz)

Table 1 below summarizes radio channels supported by PTM 215B.

Radio Channel	Frequency	Channel Type
BLE Radio Channels		
37	2402 MHz	BLE Advertising Channel
0	2404 MHz	BLE Data Channel
1	2406 MHz	BLE Data Channel
...		
10	2424 MHz	BLE Data Channel
38	2426 MHz	BLE Advertising Channel
11	2428 MHz	BLE Data Channel
12	2430 MHz	BLE Data Channel
...		
36	2478 MHz	BLE Data Channel
39	2480 MHz	BLE Advertising Channel
Custom Radio Channels		
40	2403 MHz	Custom Radio Channel
41	2405 MHz	Custom Radio Channel
...		
77	2477 MHz	Custom Radio Channel
78	2479 MHz	Custom Radio Channel

Table 1 – PTM 215B supported radio channels

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3.2 Default radio transmission sequence

PTM 215B transmits telegrams in its standard configuration by using so-called Advertising Events.

An advertising event is defined as the transmission of the same radio telegram on all selected radio channels (by default this would be on BLE Channel 37, 38 and 39) one after another with minimum delay in between.

For reliability reasons, PTM 215B will send several (minimum two, maximum three) advertising events for each button input. The resulting transmission sequence is shown in Figure 5 below.

The default pause between the advertising events is 20 ms. Starting with product version DC-06 it will be possible to reduce this pause to 10 ms via the NFC configuration interface. See chapter 6.7.8 for details.

CH 37	CH 38	CH 39	Pause	CH 37	CH 38	CH 39	Pause	CH 37	CH 38	CH 39
----------	----------	----------	-------	----------	----------	----------	-------	----------	----------	----------

Figure 5 – Default radio transmission sequence

3.3 User-defined radio transmission sequences

In certain situations it might be desirable to transmit radio telegrams on channels other than the three advertising channels.

PTM 215B therefore allows to select the radio channels to be used for the transmission of data telegrams and commissioning telegrams. The following transmission modes are supported:

- Both commissioning telegrams and data telegrams are transmitted on the advertising channels as three advertising events. This is the default configuration and described in chapter 3.2 above.
- Commissioning telegrams are transmitted on the advertising channels as three advertising events while data telegrams are transmitted in a user-defined sequence as described below.
- Both commissioning and data telegrams are transmitted in a user-defined sequence as described below.

The selection of the transmission mode is done using the CUSTOM_VARIANT register of the NFC configuration interface as described in chapter 6.7.8.

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3.3.1 Supported radio transmission sequences

PTM 215B supports the following user-defined sequences:

- **Three channel sequence**
This sequence is similar to the default Advertising Event with the difference that the user can select the radio channels to be used. The three channel sequence is described in chapter 3.3.2 below.
- **Two channel sequence**
In this sequence the radio telegram is transmitted using four transmissions on two radio channels. It is described in chapter 3.3.3 below.
- **One channel sequence**
In this sequence the radio telegram is transmitted using six transmissions on one radio channel. It is described in chapter 3.3.4 below.

The selection of user-defined radio transmission sequences is made via the CUSTOM VARIANT register of the NFC configuration interface, please see chapter 6.7.8.

3.3.2 Three channel radio transmission sequence

The three channel radio transmission sequence is similar to the default transmission sequence. The difference is that the radio channels (BLE Channel 37, 38 and 39 in the default transmission sequence) can be selected using the registers CH_REG1, CH_REG2 and CH_REG3.

The PTM 215B telegram will in this mode be transmitted on the radio channel selected by CH_REG1 first, immediately followed by a transmission on the radio channel selected by CH_REG2 and a transmission on the radio channel selected by CH_REG3.

This transmission sequence will be sent three times in total as shown in Figure 6 below.

The default pause between the advertising events is 20 ms. Starting with product version DC-06 it will be possible to reduce this pause to 10 ms via the NFC configuration interface. See chapter 6.7.8 for details.

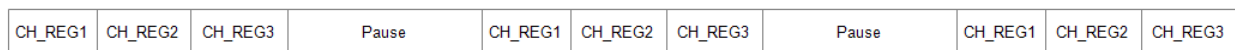


Figure 6 – Three channel radio transmission sequence

The format of CH_REG1, CH_REG2 and CH_REG3 is described in chapter 6.7.9.

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3.3.3 Two channel radio transmission sequence

The two channel radio transmission sequence removes transmission on the third radio channel (selected by CH_REG3) and instead repeats the transmission once more (four times in total).

The PTM 215B telegram will in this mode be transmitted on the radio channel selected by CH_REG1 first, immediately followed by a transmission on the radio channel selected by CH_REG2.

This transmission sequence will be sent four times in total as shown in Figure 7 below.

The default pause between the advertising events is 20 ms. Starting with product version DC-06 it will be possible to reduce this pause to 10 ms via the NFC configuration interface. See chapter 6.7.8 for details.

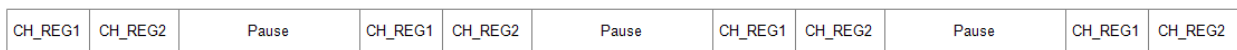


Figure 7 – Two channel radio transmission sequence

The format of CH_REG1 and CH_REG2 is described in chapter 6.7.9.

3.3.4 Single channel radio transmission sequence

The single channel radio transmission sequence removes transmission on the second and third radio channel (selected by CH_REG2 and CH_REG3 respectively), i.e. all transmissions will be on the radio channel selected by CH_REG1.

The PTM 215B telegram will be sent six times on this radio channel as shown in Figure 8 below.

The default pause between the advertising events is 20 ms. Starting with product version DC-06 it will be possible to reduce this pause to 10 ms via the NFC configuration interface. See chapter 6.7.8 for details.

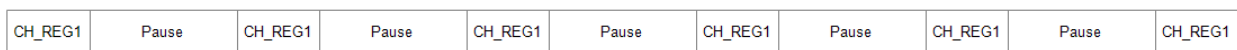


Figure 8 – Single channel radio transmission sequence

The format of CH_REG1 is described in chapter 6.7.9.

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4. Telegram format

PTM 215B transmits Bluetooth Low Energy (BLE) radio telegrams in the 2.4 GHz band. For detailed information about the Bluetooth Low Energy standard, please refer to the applicable specifications.

Figure 9 below summarizes the BLE frame structure.

Preamble 0xAA	Access Address 0x8E89BED6	Header (2 Byte)	Source Address (6 Byte)	Payload (0 ... 31 Byte)	Check Sum (3 Byte)
------------------	------------------------------	--------------------	----------------------------	----------------------------	-----------------------

Figure 9 – BLE frame structure

The content of these fields is described in more detail below.

4.1 Preamble

The BLE Preamble is 1 byte long and identifies the start of the BLE frame. The value of the BLE Preamble is always set to 0xAA.

4.2 Access Address

The 4 byte BLE Access Address identifies the radio telegram type. For advertising frames, the value of the Access Address is always set to 0x8E89BED6.

4.3 Header

The BLE Header identifies certain radio telegram parameters. Figure 10 below shows the structure of the BLE header.

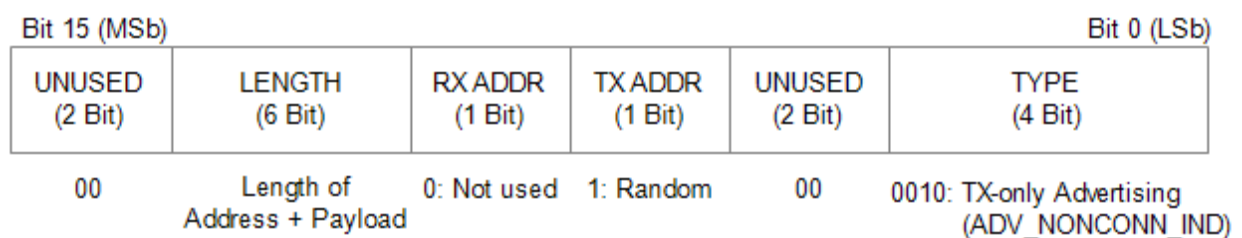


Figure 10 – BLE header structure

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4.4 Source address

The 6 byte BLE Source Address (MAC address) uniquely identifies each PTM 215B product.

PTM 215B supports two source address modes:

- **Static Source Address mode (default)**
In this mode, the source address is constant (but its lower 32 bit can be configured via NFC interface)
- **Private Resolvable Address mode (NFC configurable)**
In this mode, the source address changes for each transmission

PTM 215B uses by default Static Source Address mode.

Private Resolvable Address mode can be selected by setting the Private Source Address flag in the Configuration register (see chapter 6.7.7) to 0b0.

These two address modes are described in the following chapters.

4.4.1 Static source address mode

By default, PTM 215B uses static source addresses meaning that the source address is constant during normal operation. The static source address can be read and configured (written) via NFC as described in chapter 6.

The structure of PTM 215B static addresses is as follows:

- The upper 2 bytes of the source address are used to identify the device type and set to 0xE215 for all PTM 215B devices (to designate EnOcean PTM 215 device type). These two bytes cannot be changed.
- The lower 4 bytes are uniquely assigned to each device. They can be changed using the NFC configuration interface as described in chapter 6.7.3

Figure 11 below illustrates the static address structure used by PTM 215B.

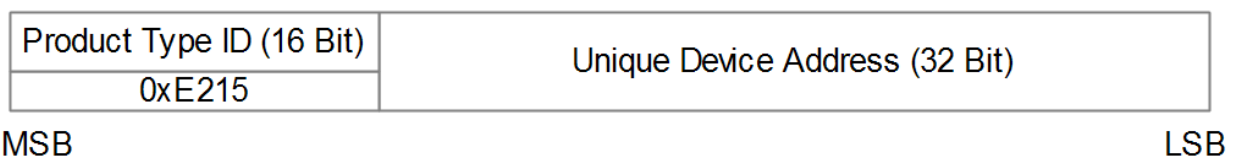


Figure 11 – BLE static source address structure

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4.4.2 Private resolvable source address mode

For some applications it is desirable to modify (rotate) the source address used by PTM 215B in order to prevent tracking of its radio transmissions. At the same time, each PTM 215B device must remain uniquely identifiable by the receiver.

To achieve these goals, PTM 215B can be configured via NFC to use random resolvable private addresses.

Using random resolvable private addresses requires that both PTM 215B and the receiver both know a common key – the so-called Identity Resolution Key (IRK). PTM 215B uses its device-unique random key as identity resolution key. This key can be configured via the NFC configuration interface as described in chapter 6.

For resolvable private addresses, the 48 bit address field is split into two sub-fields:

- prand
This field contains a random number which always starts (two most significant bits) with 0b10. The prand value is changed for each telegram that is transmitted. Individual advertising events used to transmit one telegram (as described in chapter 0) use the same prand value.
- hash
This field contains a verification value (hash) generated from prand using the IRK

The structure of a random resolvable private address is shown in Figure 12 below.

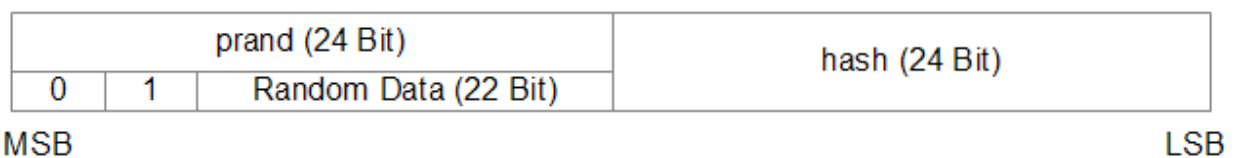


Figure 12 – BLE private resolvable source address structure

The prand value is encrypted using the IRK. The lowest 24 bit of the result (encrypted value) are then used as hash.

The concatenation of 24 bit prand and 24 bit hash will be transmitted as 48 bit private resolvable source address.

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The receiving device maintains a list of IRK for all transmitters that have been commissioned to work with it.

Whenever the receiving device receives a radio telegram with private resolvable source address (identified by the most significant bits being set to 0b10), it will itself generate a 24 bit hash from the 24 bit prand sequentially using the IRK of each device that it has been learned into it.

If an IRK matches (i.e. when prand is encoded with this specific IRK then the result matches hash), then the receiver has established the identity of the transmitter.

So conceptually the IRK takes the role of the device source address while prand and hash provide a mechanism to select the correct IRK among a set of IRK.

This mechanism is illustrated in Figure 13 below.

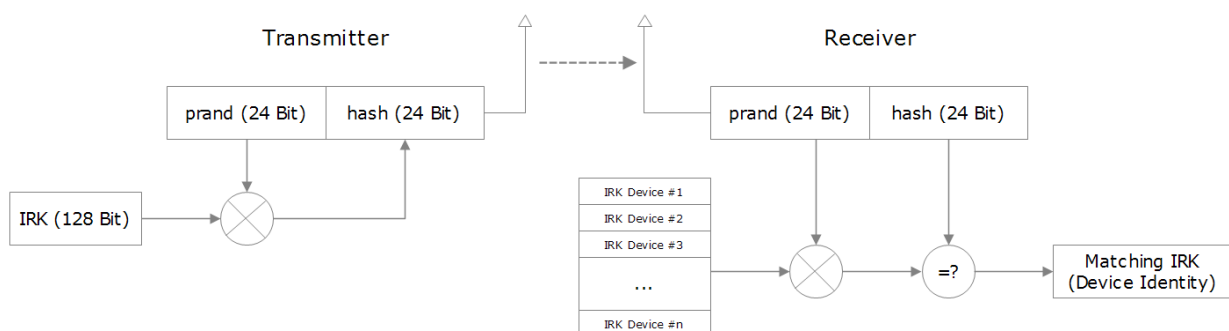


Figure 13 – Resolving private source addresses

4.5 Check Sum

The 3 byte BLE Check Sum is used to verify data integrity of received BLE radio telegrams. It is calculated as CRC (cyclic redundancy check) of the BLE Header, Source Address and Payload fields.

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4.6 Payload

The payload of data telegrams is 13 ... 17 bytes long (depending on the size of the Optional Data field) and consists of the following fields:

- Length (1 byte)
 The Length field specifies the combined length of the following fields. The content of the field depends on the size of the Optional Data field (which can be 0 / 1 / 2 or 4 byte).
 The resulting Length setting would be 12 / 13 / 14 or 16 byte (0x0C / 0x0D / 0x0E / 0x10) respectively
- Type (1 byte)
 The Type field identifies the data type used for this telegram. For PTM 215B data telegrams, this field is always set to 0xFF to designate manufacturer-specific data field
- Manufacturer ID (2 byte)
 The Manufacturer ID field is used to identify the manufacturer of BLE devices based on assigned numbers. EnOcean has been assigned 0x03DA as manufacturer ID code. The Manufacturer ID can be changed via the NFC configuration interface as described in chapter 6.7.5.
- Sequence Counter (4 byte)
 The Sequence Counter is a continuously incrementing counter used for security processing. It is initialized to 0 at the time of production and incremented for each telegram (data telegram or commissioning telegram) sent.
- Switch Status (1 byte)
 The Switch Status field reports the button action. The encoding of this field is described in chapter 4.7.
- Optional Data (0 / 1 / 2 or 4 byte)
 PTM 215B provides the option to transmit additional user-defined data within each data telegram. This data can be used to identify user-specific properties.
 The length of the Optional Data field is defined in the Configuration register as described in chapter 6.7.7.
- Security Signature (4 byte)
 The Security Signature is used to authenticate PTM 215B radio telegrams as described in chapter 4.8

Figure 14 below illustrates the data telegram payload.

0x0C ... 0x10	0xFF	Manufacturer ID 0x03DA	Sequence Counter (4 Byte)	Switch Status	Optional Data (0/1/2/4 Byte)	Security Signature (4 Byte)
LEN		TYPE				

Figure 14 – Data telegram payload structure

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4.7 Switch status encoding

The Switch Status field within the Payload data identifies the PTM 215B action (button push or release). PTM 215B uses the following sequence to identify and transmit button contact status:

1. Determine direction of the energy bar movement (Push Action or Release Action)
2. Read input status of all button contacts
3. Calculate data payload
4. Calculate security signature

In PTM 215B, the type of action (Press Action or Release Action) is indicated by Bit 0 (Energy Bar). If a button contact has been actuated during Press Action or Release Action then this is indicated by the according status bit set to '1'.

Note that all contacts that were pressed during Press Action will be released during Release Action. The case of continuing to hold one (or several) button contacts during Release Action is mechanically not possible.

The switch status encoding used by PTM 215B is shown Figure 15 in below.

Switch Status							
Reserved			B1	B0	A1	A0	ACTION TYPE
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Shall be 0b000			0 = No Action 1 = Action	0 = No Action 1 = Action	0 = No Action 1 = Action	0 = No Action 1 = Action	0 = Release Action 1 = Press Action

Figure 15 - PTM 215B button action encoding

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4.8 PTM 215B telegram authentication

PTM 215B implements telegram authentication to ensure that only telegrams from senders using a previously exchanged security key will be accepted. Authentication relies on a 32 bit telegram signature which is calculated as shown in Figure 16 below and exchanged as part of the radio telegram.

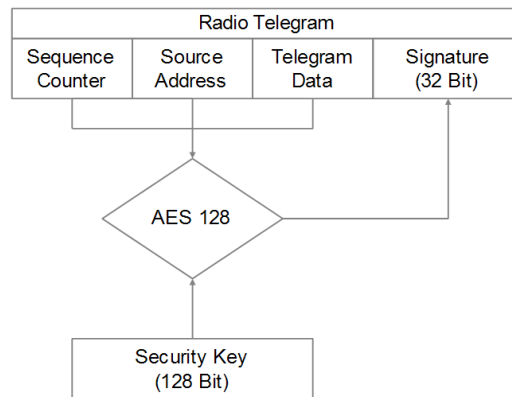


Figure 16 – Telegram authentication flow

Sequence counter, source address and the remaining telegram data together form the input data for the signature algorithm. This algorithm uses AES128 encryption based on the device-unique random security key to generate a 32 bit signature which will be transmitted as part of the radio telegram.

The signature is therefore dependent both on the current value of the sequence counter, the device source address and the telegram payload. Changing any of these three parameters will therefore result in a different signature.

The receiver performs the same signature calculation based on sequence counter, source address and the remaining telegram data of the received telegram using the security key it received from PTM 215B during commissioning.

The receiver then compares the signature reported as part of the telegram with the signature it has calculated. If these two signatures match then the following statements are true:

- Sender (PTM 215B) and receiver use the same security key
- The message content (address, sequence counter, data) has not been modified

At this point, the receiver has validated that the message originates from a trusted sender (as identified by its security key) and that its content is valid.

In order to avoid message replay (capture and retransmission of a valid message), it is required that the receiver tracks the value of the sequence counter used by PTM 215B and only accepts messages with higher sequence counter values (i.e. not accepts equal or lower sequence counter values for subsequent telegrams).

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4.8.1 Authentication implementation

PTM 215B implements telegram authentication based on AES128 in CCM (Counter with CBC-MAC) mode as described in IETF RFC3610. At the time of writing, the RFC3610 standard could be found here: <https://www.ietf.org/rfc/rfc3610.txt>

The 13 Byte CCM Nonce (number used once – unique) initialization value is constructed as concatenation of 6 byte Source Address, 4 byte Sequence Counter and 3 bytes of value 0x00 (for padding).

Note that both Source Address and Sequence Counter use little endian format (least significant byte first).

Figure 17 below shows the structure of the AES128 Nonce.

AES128 Nonce (13 Byte)												
Source Address						Sequence Counter				Padding		
Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 0	Byte 1	Byte 2	Byte 3	0x00	0x00	0x00

Figure 17 – AES128 Nonce structure

The AES128 Nonce and the 128 bit device-unique security key are then used to calculate a 32 bit signature of the authenticated telegram payload shown in Figure 18 below.

Authenticated Payload								
LEN	TYPE	MANUFACTURER	Sequence Counter				STATE	Optional Data
Byte 0	0xFF	0x03DA	Byte 0	Byte 1	Byte 2	Byte 3	Byte 0	0 / 1 / 2 / 4 byte

Figure 18 – Authenticated payload

The calculated 32 bit signature is then appended to the data telegram payload as shown in Figure 14 in chapter 4.6.

In addition to the RFC3610 standard itself, please consult also Appendix A for a step by step description of the authentication process.

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5. Commissioning

Commissioning is the process by which PTM 215B is learned into a receiver (actuator, controller, gateway, etc.).

The following two tasks are required in this process:

- **Device identification**
The receiver needs to know how to uniquely identify this specific PTM 215B device. This is achieved by using a unique 48 Bit ID (Source Address) for each PTM 215B device as described in chapter 4.4. In addition, up to 4 byte of Optional Data can be configured as described in chapter 6.7.6
- **Security parameter exchange**
The receiver needs to be able to authenticate radio telegrams from PTM 215B in order to ensure that they originate from this specific device and have not been modified as described in chapter 4.8. This is achieved by exchanging a 128 Bit random security key used by PTM 215B to authenticate its radio telegrams.

PTM 215B provides the following options for these tasks:

- **NFC-based commissioning**
The PTM 215B parameters are read by a suitable commissioning tool (e.g. NFC smartphone with suitable software) which is already part of the network into which PTM 215B will be commissioned. The commissioning tool then communicates these parameters to the intended receiver of PTM 215B radio telegrams. NFC-based commissioning is described in chapter 6
- **Camera-based commissioning**
Each PTM 215B module contains an optically readable Data Matrix Code (DMC) which identifies its ID and its security key. This DMC can be read by a suitable commissioning tool (e.g. smartphone) which is already part of the network into which PTM 215B will be commissioned. The commissioning tool then communicates these parameters to the intended receiver of PTM 215B radio telegrams. The DMC structure is described in chapter 8.1.1
- **Radio-based commissioning**
PTM 215B can communicate its parameters via special radio telegrams (commissioning telegrams) to the intended receiver. To do so, PTM 215B can be temporarily placed into radio-based commissioning mode as described in chapter 5.3

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5.1 NFC-based commissioning

All required PTM 215B parameters can be read via a suitable NFC reader and writer supporting the ISO/IEC 14443 Part 2 and 3 standards. The actual NFC implementation in PTM 215B uses a Mifare Ultralight tag.

Commissioning via NFC should follow these steps:

1. Unlock PTM 215B using the default NFC PIN code `0x0000E215`
2. Read the PTM 215B Source Address, Security Key and Sequence Counter and configure the receiver accordingly
3. **Important:** The pre-programmed random security key used by PTM 215B can be obtained both from the product DMC code as described in chapter 5.2, from received commissioning telegrams as described in chapter 5.3 and via the NFC interface. For security-critical applications where unauthorized users could have physical access to the switch it is therefore strongly recommended to change the security key to a new security key as part of the NFC-based commissioning process. To do so, follow the procedure outlined in chapter 6.7.4.
For additional security, NFC read-out of the new security key can be disabled by setting the Private Security Key flag in the Configuration register before setting the new security key.
This ensures that even persons knowing the correct PIN code to configure this specific switch cannot read out the programmed new security key. Please verify that you have properly documented the new security key as there is no possibility to retrieve this after it has been written.
4. **Important:** It is strongly recommended to disable radio-based commissioning after programming a new security key. This ensures that the new security key cannot be read out by triggering a commissioning telegram as described in chapter 5.3. To disable radio-based commissioning, set the Disable Radio Commissioning flag in the Configuration register to `0b1`, see chapter 6.7.7.
5. **Important:** You should always change the NFC PIN code from its default setting to a new NFC PIN code and lock the NFC configuration interface. This step is mandatory to avoid access to the PTM 215B configuration using the default PIN code. Should you lose the new NFC PIN code then PTM 215B can be reset to factory mode (with the default NFC PIN code) by means of a factory reset as described in chapter 0. For security reasons, this factory reset will always reset the security key to its pre-programmed value.

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5.2 Camera-based commissioning

Each PTM 215B module contains an optically readable Commissioning Code implemented either as Data Matrix Code or as QR Code depending on the device revision.

This Commissioning Code on the device label can be scanned by a suitable commissioning tool (e.g. smartphone or PC with DMC / QR code reader) to read the static source address and the security key of the device.

The commissioning tool can use this information to configure the intended receiver of PTM 215B radio telegrams.

See chapter 8 for details of the commissioning code structure.

5.3 Radio-based commissioning

For cases where both NFC and camera-based commissioning are not feasible it is possible to set PTM 215B into a specific mode where it transmits commissioning telegrams.

This functionality can be disabled via the NFC configuration interface by setting the Disable Radio Commissioning flag in the Configuration register to 0b1 (see chapter 6.7.7).

Starting from product version DC-06, this functionality can also be disabled by means of a specific button press (long press of A0 + A1 + B1), see chapter 5.3.4.

5.3.1 Commissioning mode entry

Commissioning mode is entered using a special button contact sequence. This is illustrated in Figure 19 below.

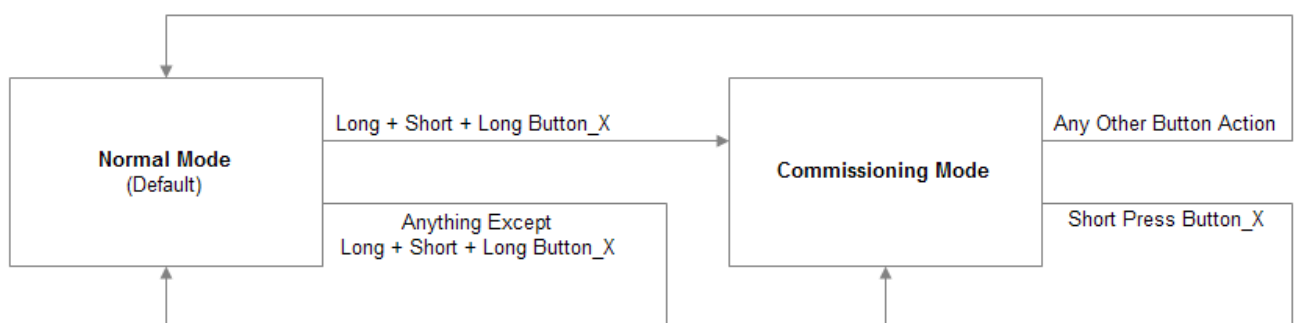


Figure 19 – Button sequence to enter radio-based commissioning mode

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To enter commissioning mode, start by selecting one button contact of PTM 215B. Any button of PTM 215B (A0, A1, B0, B1) can be used. This button is referred to as Button_X in Figure 19 above.

Next, execute the following long-short-long sequence:

1. Press and hold the selected button together with the energy bar for more than 7 seconds before releasing it
2. Press the selected button together with the energy bar quickly (hold for less than 2 seconds)
3. Press and hold the selected button together with the energy bar again for more than 7 seconds before releasing it

Upon detection of this sequence, PTM 215B will enter commissioning mode if the Disable Radio Commissioning flag in the Configuration register of the NFC interface is set to 0b0 (default state).

5.3.2 Commissioning telegram transmission

PTM 215B will transmit a commissioning telegram (on the radio channels selected as described in chapter 3.1) upon entering commissioning mode.

PTM 215B will continue to transmit commissioning telegrams whenever the button used for entry into commissioning mode (Button_X) is pressed or released again.

The payload of commissioning telegrams is 30 bytes long and consists of the following fields:

- Length (1 byte)
The Length field specifies the combined length of the following fields. For PTM 215B commissioning telegrams, this field is set to 0x1D to indicate 29 byte of manufacturer-specific data.
Note: In product versions prior to DC-06 this field was incorrectly set to 0x1E.
- Type (1 byte)
The Type field identifies the data type used for this telegram. This field is set to 0xFF to indicate a "Manufacturer-specific Data" field
- Manufacturer ID (2 byte)
The Manufacturer ID field is used to identify the manufacturer of BLE devices based on assigned numbers. By default, this field is set to 0x03DA (EnOcean GmbH). This field can be changed via the NFC configuration interface as described in chapter 6.7.5.
- Sequence Counter (4 byte)
The Sequence Counter is a continuously incrementing counter used for security processing. It is initialized to 0 at the time of production and incremented for each telegram (data telegram or commissioning telegram) sent.

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- **Security Key (16 byte)**
Each PTM 215B device contains its own 16 byte device-unique random security key which is generated and programmed during manufacturing. It is transmitted during commissioning to enable the receiver to authenticate PTM 215B data telegrams

- **Static Source Address (6 byte)**
The Static Source Address is used to uniquely identify each BLE device. It is transmitted as part of the BLE frame as described in chapter 4.4.1. Some devices (most notable all iOS-based products) however do not expose this address to their applications. This makes it impossible to use such applications to commission PTM 215B. The Static Source Address is therefore again transmitted as part of the payload.

Figure 20 below illustrates the commissioning telegram payload.

LEN	TYP	Manufacturer ID	Manufacturer-specific Data		
0x1D	0xFF	0x03DA	Sequence Counter (4 Byte)	Security Key (16 Byte)	Static Source Address (6 Byte)

Figure 20 – Commissioning telegram payload structure

5.3.3 Exit from commissioning mode

Pressing any key except the button used for entry into commissioning mode (Button_X) will cause PTM 215B to stop transmitting commissioning telegrams and return to normal data telegram transmission.

5.3.4 Disable commissioning mode

Starting with product version DC-06 it will be possible to disable commissioning mode also by means of a specific button input.

To do so, press buttons A0, A1 and B1 together with the energy bar and hold them for at least 10 seconds before releasing them.

Commissioning mode can be re-enabled by means of a factory reset as described below.

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5.4 Factory Reset

PTM 215B can be reset to its default settings by means of a factory reset.

This ensures that PTM 215B can be reset to a known configuration in case the PIN for the NFC access has been lost or NFC access is not possible for other reasons

In order to execute such factory reset, the rocker(s) and the switch housing have to be removed from the PTM 215B module. Then, all four button contacts (A0, A1, B0 and B1) have to be pressed at the same time while the energy bow is pressed down.

The energy bow must then be held at the down position for at least 10 seconds before being released. The button contacts A0, A1, B0 and B1 can be released at any time after pressing the energy bow down, i.e. it is no requirement to hold them as well for at least 10 seconds.

Upon detecting this input, PTM 215B will restore the default settings of the following items:

- Static Source Address
- Security Key and Security Key Write register
Both registers will be restored to the value of the factory-programmed security key
- Manufacturer ID
The manufacturer ID will be reset to 0x03DA (EnOcean GmbH)
- NFC PIN Code
The NFC PIN Code will be reset to 0x0000E215

After such factory reset, Source Address and Security Key will again match the content of the DMC code on the unit label as described in chapter 8.

In addition, PTM 215B will reset the following registers:

- Configuration register (to 0x00)
- Custom Variant Register (to 0x00)

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6. NFC interface

PTM 215B implements NFC Forum Type 2 Tag functionality as specified in the ISO/IEC 14443 Part 2 and 3 standards using an NXP NT3H2111 Mifare Ultralight tag.

This NFC functionality can be used to access (read and write) the PTM 215B configuration memory and thereby configure the device as described in the following chapters.

Chapter 6.1 below gives an introduction to the NFC functionality and options to use the NFC interface.

For in-depth support for integrating the NXP NT3H2111 NFC functionality into PC or smartphone SW please contact NXP technical support.

6.1 Using the NFC interface

Using the NFC interface requires the following:

- NFC reader (either PC USB accessory or suitable smartphone / tablet)
- NFC SW with read, write, PIN lock, PIN unlock and PIN change functionality

EnOcean recommends TWN4 from Elatec RFID Systems (<https://www.elatec-rfid.com/en/>) as USB NFC reader. This reader is shown in Figure 21 below.



Figure 21 – Elatec TWN4 MultiTech Desktop NFC Reader

TWN4 can be configured as CDC / Virtual COM port and can then be accessed like any serial interface. It provides all necessary commands for the NFC interface, specifically to:

- Read data from configuration memory and write data to configuration memory
- Authenticate the user (to allow read / write of protected memory) via 32 bit PIN

NFC functionality is also available in certain Android smartphones and tablets. NXP provides a SW framework that can be used with Android devices and can advise regarding suitable tablets and smartphones.

NFC communication distance is for security reasons set to require direct contact between reader and switches based on PTM 215B.

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6.2 NFC interface functions

For a detailed description about the NFC functionality, please refer to the ISO/IEC 14443 standard.

For specific implementation aspects related to the NXP implementation in NT3H2111, please refer to the NXP documentation which at the time of writing was available under this link:

http://cache.nxp.com/documents/data_sheet/NT3H2111_2211.pdf

The following chapters summarize the different functions for reference purposes.

6.2.1 NFC interface state machine

Figure 22 below shows the overall state machine of the NFC interface.

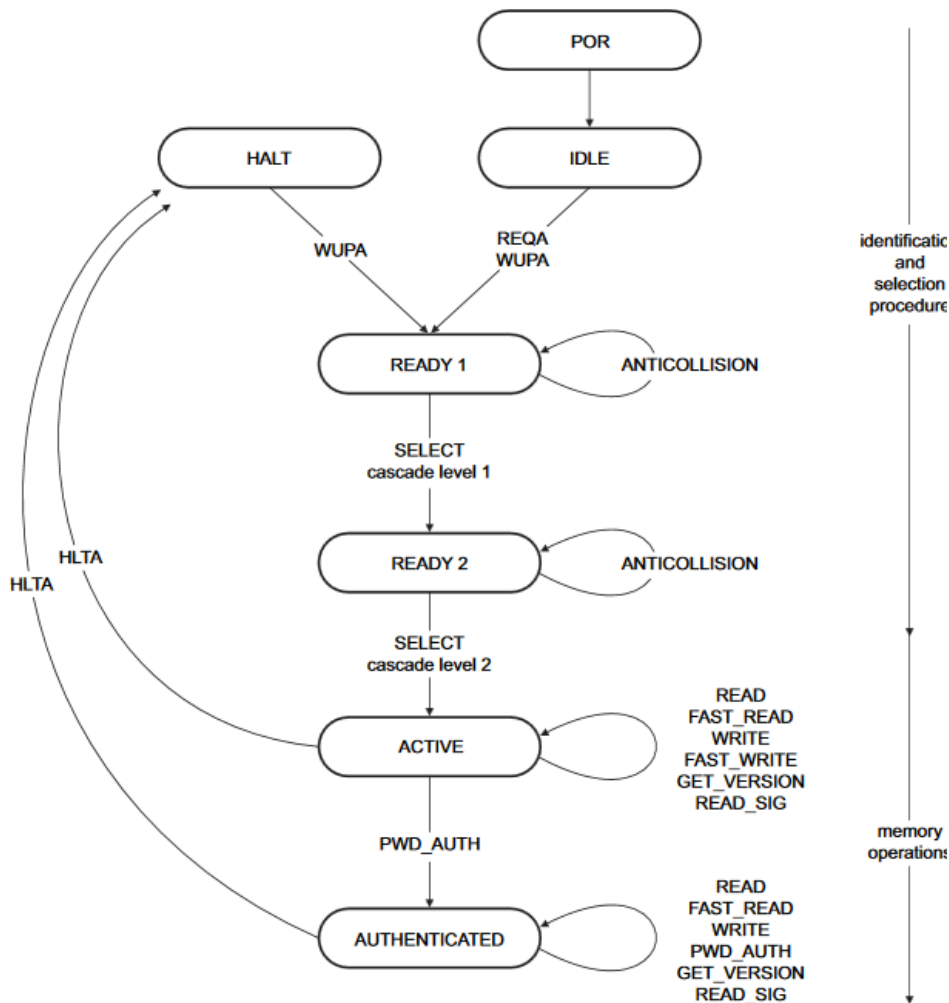


Figure 22 – NFC interface state machine

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6.2.2 IDLE state

IDLE is the waiting state after a Power-On Reset (POR), i.e. after the NFC tag has been introduced into the magnetic field of the NFC reader.

The NFC tag exits the IDLE state towards the READY 1 state when either a REQA or a WUPA command is received from the NFC reader. REQA and WUPA commands are transmitted by the NFC reader to determine whether any cards are present within its working range.

Any other data received by the NFC tag while in IDLE state is discarded and the NFC tag will remain in IDLE state.

6.2.3 READY 1 state

READY 1 is the first UID resolving state where the NFC tag resolves the first 3 bytes of the 7 byte UID using the ANTICOLLISION or SELECT commands for cascade level 1.

READY 1 state is exited after the SELECT command from cascade level 1 with the matching complete first part of the UID has been executed. The NFC tag then proceeds into READY 2 state where the second part of the UID is resolved.

6.2.4 READY 2 state

READY 2 is the second UID resolving state where the NFC tag resolves the remaining 4 bytes of the 7 byte UID using the ANTICOLLISION or SELECT commands for cascade level 2.

READY 2 state is exited after the SELECT command from cascade level 2 with the matching complete part of the UID has been executed. The NFC tag then proceeds into ACTIVE state where the application-related commands can be executed.

6.2.5 ACTIVE state

ACTIVE state enables read and write accesses to unprotected memory.

If access to protected memory is required then the tag can transition from the ACTIVE state to AUTHENTICATED state by executing the PWD_AUTH command in conjunction with the correct 32 bit password.

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6.2.6 Read command

The READ command requires a start page address, and returns the 16 bytes of four NFC tag pages (where each page is 4 byte in size).

For example, if the specified address is 03h then pages 03h, 04h, 05h, 06h are returned. Special conditions apply if the READ command address is near the end of the accessible memory area.

Figure 23 below shows the read command sequence.

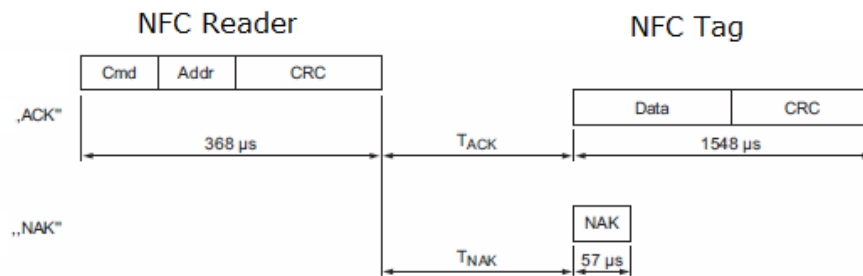


Figure 23 – NFC read command sequence

6.2.7 Write command

The WRITE command requires a start page address and returns writes 4 bytes of data into that page.

Figure 24 below shows the read command sequence.

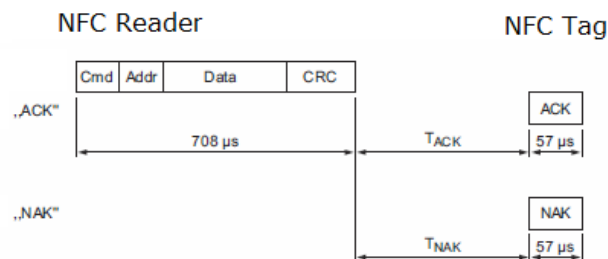


Figure 24 – NFC write command sequence

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6.2.8 Password authentication (PWD_AUTH) command

The protected memory area can be accessed only after successful password verification via the PWD_AUTH command.

The PWD_AUTH command takes the password as parameter and, if successful, returns the password authentication acknowledge, PACK.

Figure 25 below shows the password authentication sequence.

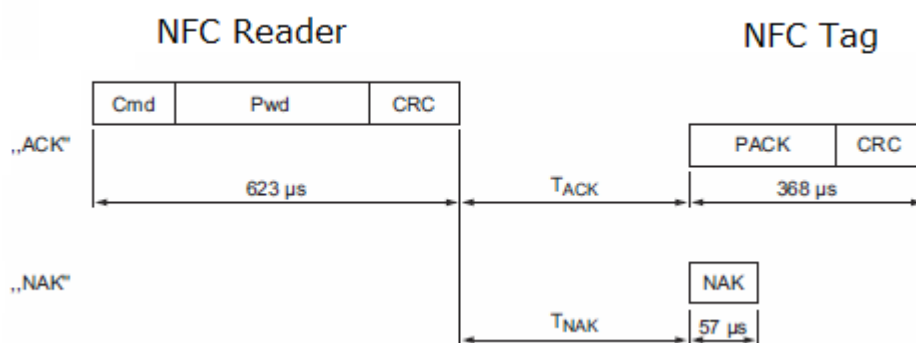


Figure 25 – Password authentication sequence

After successful authentication, the password can be changed by writing the new password to memory page 0xE5.

Note that a read access to page 0xE5 always return 0x00000000, i.e. it is not possible to read out the current PIN code.

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6.3 Using TWN4 as USB NFC reader

Elatec RFID Systems provides a PC software called “Director” as part of their software support package. At the time of writing, this was available from this address: <https://www.elatec-rfid.com/en/download-center/contact-form-twn4-devpack-sdk/>

Figure 26 below shows the user interface of this software.

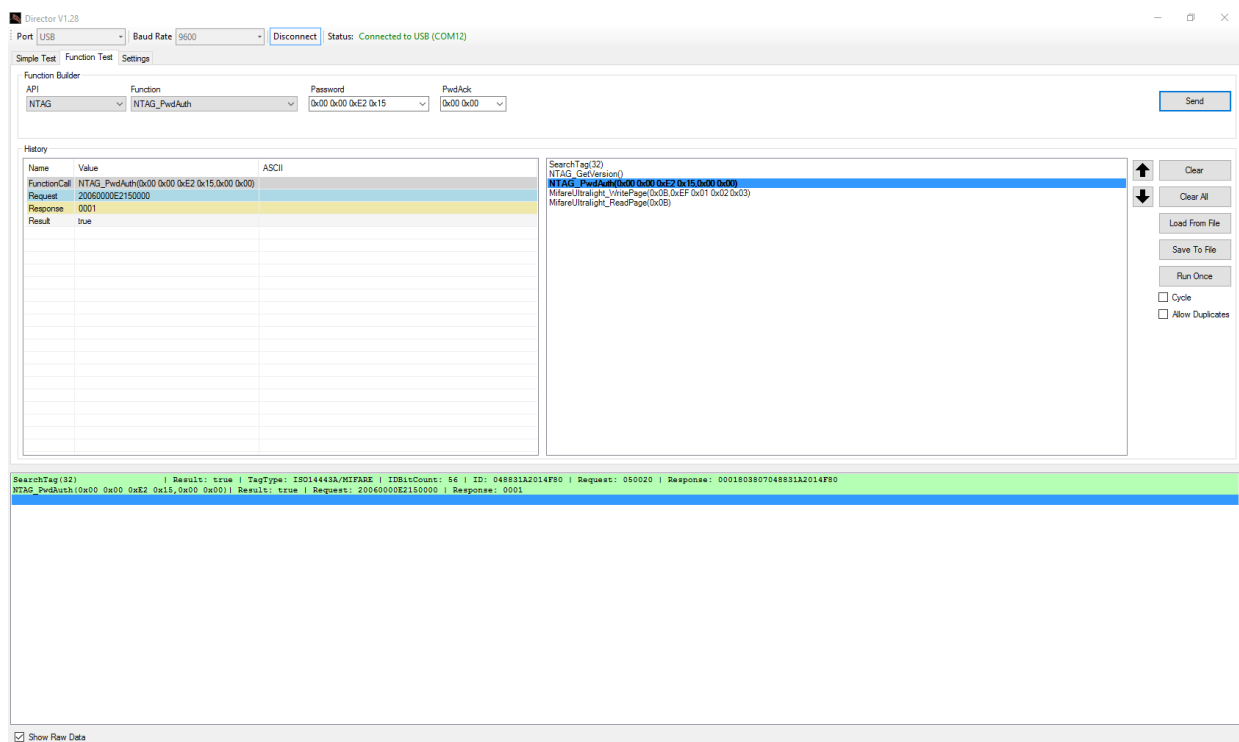


Figure 26 – User interface of TWN4 Director

By using this software, it is easily possible to generate the required serial commands that have to be sent via CDC / Virtual COM port to TWN4 and understand the structure of the response that will be received back.

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6.3.1 Useful commands

The following commands are especially useful:

- **SearchTag(maximum ID bytes)**
Used to search for a connected tag and identify type and ID of such tag. This should always be used as first operation ahead of any read / write / authenticate actions.
Example: SearchTag(32)
- **NTAG_PwdAuth(32 bit password as hex bytes, 16 bit password_ack as hex bytes)**
Used to authenticate access to the protected memory area
Example: NTAG_PwdAuth(0x00 0x00 0xE2 0x15, 0x00 0x00)
- **NTAG_Read(page)**
Used to read one page of data
Example: NTAG_Read(0x04)
- **NTAG_Write(page, data)**
Used to write one page of data
Example: NTAG_Write(0x40, 0x12 0x34 0x56 0x78)
- **NTAG_Write(0xE5, PIN Code)**
Used to set a new pin code by writing to page 0xE5
Example: NTAG_Write(0xE5, 0x12 0x34 0x56 0x78)

6.3.2 Translation into binary data

In order to use these commands within a user application, they have to be translated into raw data. This can be done by enabling the "Show Raw Data" feature in the command log of the Director software as shown in Figure 27 below.

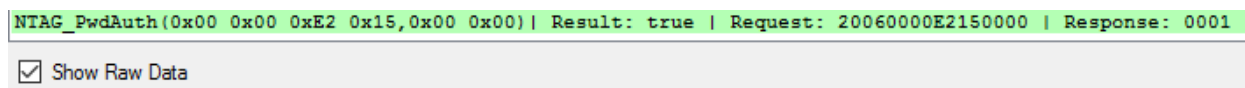


Figure 27 – Enabling raw data display

This raw data can then be transmitted to TWN4 via a virtual COM port. TWN4 will respond to the request with the corresponding response as shown in Figure 28 below.



Figure 28 – Binary data exchange

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6.4 Configuration memory organization

The PTM 215B configuration memory is divided into the following areas:

- Public data
- Protected data

In addition to that, PTM 215B maintains a private configuration memory region used to store default parameters and confidential information which is not accessible to the user.

Figure 29 below illustrates the configuration memory organization used by PTM 215B.

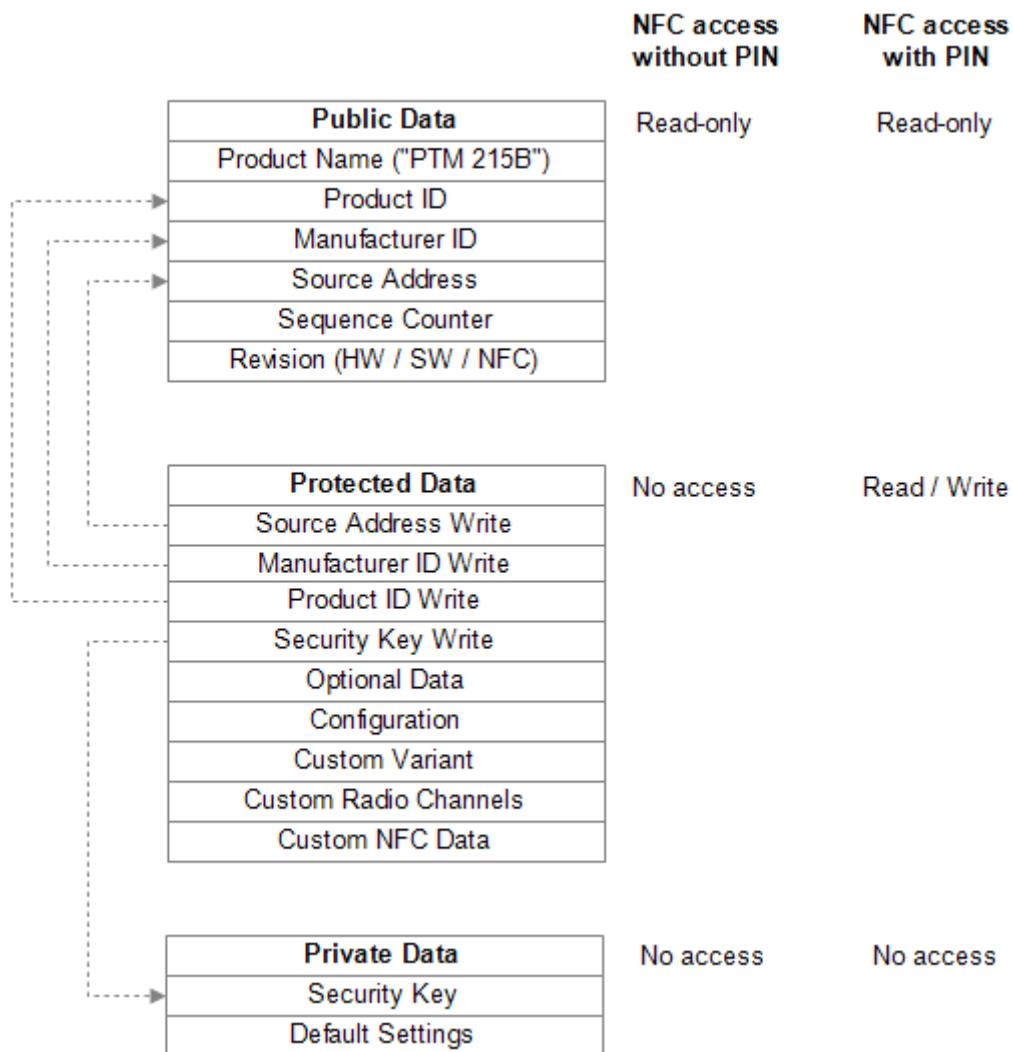


Figure 29 – Configuration memory organization

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6.5 Memory Address Map

The NFC-accessible configuration memory is organized in memory pages where each memory page is 4 byte wide. An NFC access reads 16 bytes (4 pages) or writes 4 bytes (one page). The addresses map of the configuration memory is shown in Table 2 below. The byte order is little endian, i.e. byte 0 will be read first and byte 3 last.

Area	NFC Page	Byte Offset	Byte 0 (LSB)	Byte 1	Byte 2	Byte 3 (MSB)
Public Memory Area						
Public	0 (0x00)	0	Reserved			
Public	...	...		
Public	3 (0x03)	12				
Public	4 (0x04)	16	Product Name "PTM 215B"			
Public	5 (0x05)	20				
Public	6 (0x06)	24	Product ID			
Public	7 (0x07)	28				
Public	8 (0x08)	32	NFC Revision		Manufacturer ID	
Public	9 (0x09)	36	Reserved			
Public	10 (0x0A)	40	Hardware Revision			
Public	11 (0x0B)	44	Software Revision			
Public	12 (0x0C)	48	Static Source Address			
Public	13 (0x0D)	52	Sequence Counter			
Protected Memory Area						
Protected	14 (0x0E)	56	Configuration	Variant	Reserved	
Protected	15 (0x0F)	60	Opt Data 0	Opt Data 1	Opt Data 2	Opt Data 3
Protected	16 (0x10)	64	Product ID Write			
Protected	17 (0x11)	68				
Protected	18 (0x12)	72	Source ID Write			
Protected	19 (0x13)	76	Manufacturer ID Write		Reserved	
Protected	20 (0x14)	80	Security Key Write			
Protected	...	...		
Protected	23 (0x17)	92				
Protected	24 (0x18)	96	CH_REG1	CH_REG2	CH_REG3	Reserved
Protected	25 (0x19)	100	Reserved			
Protected	...	...		
Protected	31 (0x1F)	124				
Protected	32 (0x20)	128	Customer NFC Data			
Protected	...	...		
Protected	95 (0x5F)	380				
Protected	96 (0x60)	384	Reserved			
Protected	...	...		
Protected	225 (0x10)	900				
Protected	229 (0xE5)	916	PIN Code (Write Only)			

Table 2 – Configuration memory address map

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6.6 Public data

Public data can be read by any NFC-capable device supporting the ISO/IEC 14443 Part 2 and 3 standards. No specific security measures are used to restrict read access to this data.

The following items are located in the public data area:

- **PTM 215B Product Name**
This is always "PTM 215B"
- **PTM 215B Product ID**
This is an 8 byte field which is by default set to 0x0000000000000000.
Product ID and Manufacturer ID can be configured by the customer as required to identify his PTM 215B based product, see chapter 6.7.5
- **PTM 215B Manufacturer ID**
This is an 2 byte field used to identify the manufacturer of a BLE product, see chapter 4.6. This field is by default set to 0x03DA (EnOcean GmbH).
Product ID and Manufacturer ID can be configured by the customer as required to identify his PTM 215B based product, see chapter 6.7.5
- **PTM 215B Static Source Address**
This is a 4 byte field used to identify the static source address used by PTM 215B, see chapter 4.4.1. Each PTM 215B is pre-programmed with an individual static source address.
The Static Source Address can be configured by the customer as required to identify his PTM 215B based product, see chapter 6.7.3
- **Hardware Revision, Software Revision and NFC Revision**
These fields identify the device revision
- **Telegram sequence counter**
This is a 4 byte field which is initialized to 0 during manufacturing and incremented for each transmitted telegram. Receivers shall never accept telegrams containing sequence counter values equal or less than previously received values to avoid replay attacks.

Changing the Static Source Address, Manufacturer ID and Product ID fields is only possible via protected data access as described below to prevent unauthorized modification.

For security reasons, the telegram sequence counter cannot be written or reset by any mechanism.

PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE

6.7 Protected Data

The following items are located in the protected data area:

- **Source Address Write register**
This 4 byte register is used to update the lower 4 byte of the Static Source Address, see chapter 6.7.3
- **Product ID Write register**
This 8 byte register is used to update the Product ID, see chapter 6.7.5
- **Manufacturer ID Write register**
This 4 byte register is used to update the Manufacturer ID, see chapter 6.7.5
- **Security Key Write register**
This 16 byte register is used to update the security key used by PTM 215B, see chapter 6.7.4
- **Optional Data register**
This 4 byte register contains optional data that can be transmitted as part of all data telegrams, see chapter 4.6. Optional Data 0 is sent first, Optional Data 3 last.
- **Configuration register**
This 1 byte register is used to configure the functional behavior of PTM 215B, see chapter 6.7.7
- **Custom Variant register**
This 1 byte register is used to configure the transmission behavior of PTM 215B, see chapter 6.7.8
- **Custom Radio Channel registers (CH_REG1, CH_REG2 and CH_REG3)**
These 1 byte registers are used to configure the radio channels in custom transmission mode of PTM 215B, see chapter 6.7.9
- **Custom NFC Data**
PTM 215B reserves 64 byte for customer-specific NFC data, see chapter 6.7.10

PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE

6.7.1 PIN Code

Protected data access is only possible after unlocking the configuration memory with the correct 32 bit PIN code. By default, the protected area is locked and the default pin code for unlocking access is 0x0000E215.

The default pin code shall be changed to a user-defined value as part of the installation process. This can be done by unlocking the NFC interface with the old PIN code and then writing the new PIN code to page 0xE5 as described in chapter 6.3.1.

6.7.2 Configuration of product parameters

PTM 215B allows no direct modification of the following parameters:

- Static Source Address
- Product ID
- Manufacturer ID
- Security Key

In order to modify these parameters, the user has to write the new value into specific registers (Source Address Write, Product ID Write, Manufacturer ID Write and Security Key Write) in the protected data area and set the according Update flag in the Configuration register.

After that, the user has to push and release the energy bar of the PTM 215B module.

6.7.3 Source Address Write register

The Source Address Write register is 4 byte wide and can be used to modify the lower 32 bit of the PTM 215B Static Source Address. The upper 16 bit of the PTM 215B Static Source Address are always fixed to 0xE215 to identify the device type.

In order to do change the lower 32 bit of the Static Source Address, follow these steps:

1. Write new source address into the Source Address Write register
2. Set the Update Source Address flag in the Configuration register to 0b1
3. Actuate (press and release) the energy bar of PTM 215B

PTM 215B will determine that it should modify the Static Source Address based on the setting of the Update Source Address flag and copy the value of the Source Address Write register to the lower 32 bit of the Source Address register.

After successful execution, PTM 215B will clear the Update Source Address flag to 0b0.

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6.7.4 Security Key Write register

The Security Key Write register is 16 byte wide and contains the device-unique random security key.

The factory programmed key can be replaced with a user defined key by following these steps:

1. Write new security key into the Security Key Write register
Note that for security reasons, setting the Security Key to the following values is not possible:
 - 0x00000000000000000000000000000000
 - 0xFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFIf the Security Key Write register is set to one of these values then no update of the Security Key will occur.
2. Set the Update Security Key flag in the Configuration register to 0b1
3. If the key should be write-only (not readable after the key update) then set the Private Security Key flag in the Configuration register to 0b1
4. Actuate (press and release) the energy bar of PTM 215B

PTM 215B will determine that it should modify the security key based on the setting of the Update Security Key flag and copy the value of the Security Key Write register to the Security Key register in private memory.

After successful execution, PTM 215B will clear the Update Security Key flag to 0b0.

If the Private Key flag in the Configuration register is set to 0b0 then the content of the Security Key Write register will be maintained at its current value. This addresses use cases where the security key shall be readable for users having the correct PIN code.

If the Private Key flag in the Configuration register is set to 0b1 then the content of the Security Key Write register will be cleared to 0x00000000000000000000000000000000 after successful execution. This addresses use cases where the security key shall never be readable (even for users having the correct PIN code).

The Security Key Write register will maintain this value of 0x00000000000000000000000000000000 even if the Private Key flag in the Configuration register is subsequently cleared to 0b0. This ensures that it is not possible to read a security key which was written with the Private Key flag in the Configuration register being set.

Note that it is not possible to read the current security key via NFC if the Security Key Write register has been accidentally overwritten or cleared via NFC write. In this case it is necessary to write a new security key (as described above) or to reset the device to its default security key by means of a factory reset.

The protected memory is designed to support 1000 modifications of the security key.

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6.7.5 Product ID and Manufacturer ID Write register

The Product ID register is 8 byte wide and can be used to specify a publicly-accessible parameter (e.g. a user-specific ID or name) that can be read by an NFC commissioning tool in order to determine the specific product type.

The Manufacturer ID is 2 byte wide and specifies the manufacturer of a BLE product and is transmitted as part of each BLE telegram. By default, the manufacturer ID is set to 0x03DA (EnOcean GmbH) but it can be changed to a different OEM identifier.

Product ID and Manufacturer ID can be changed by following these steps:

1. Write the desired Product ID (8 byte using HEX or ASCII encoding according to user choice) into the Product ID Write register. Setting the Product ID register to 0x0000000000000000 will cause PTM 215B not to update the Product ID.
2. Write the desired Manufacturer ID (2 byte) into the Manufacturer ID Write register. Setting the Manufacturer ID Write register to 0x0000 will cause PTM 215B not to update the Manufacturer ID.
3. Set the Update Product and Manufacturer ID flag in the Configuration register to 0b1
4. Actuate (press and release) the energy bar of PTM 215B

PTM 215B will determine that it should update the Product ID and Manufacturer ID based on the setting of the Update Product and Manufacturer ID flag and copy any non-zero value of the Product ID Write register to the Product ID register and any non-zero value of the Manufacturer ID Write Register to the Manufacturer ID register.

After that, PTM 215B will clear the Update Product and Manufacturer ID flag to 0b0.

6.7.6 Optional Data register

The Optional Data register can be used to specify up to 4 byte of custom data that will be transmitted as part of each data telegram. This optional data can store user-specific or application-specific information.

The size of the Optional Data field is specified in the Configuration register and can be 0 byte (not present, default), 1 byte, 2 byte or 4 byte.

If the size of the Optional Data field is set to a non-zero value in the Configuration register then PTM 215B will read the corresponding amount of data from the Optional Data register beginning with the least significant byte (Byte 0 – Optional Data 0).

Note that using the optional data feature requires additional energy for the radio telegram transmission and might therefore reduce the total number of redundant telegrams which are transmitted.

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6.7.7 Configuration register

The Configuration register is 1 byte wide and contains configuration flags. Figure 30 below shows the structure of the Configuration register.

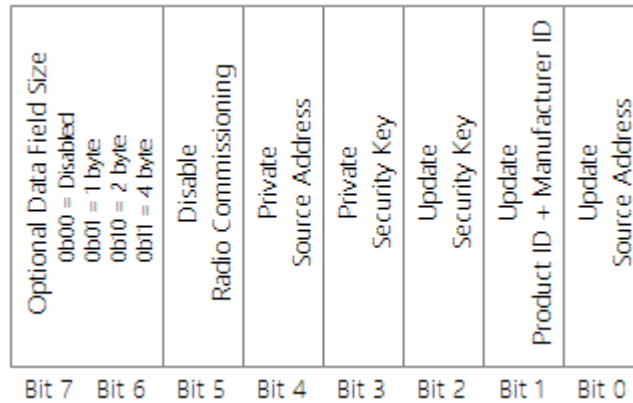


Figure 30 – Configuration register structure

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6.7.8 Custom Variant register

The Custom Variant register is 1 byte wide and allows selection of the custom radio transmission modes as described in chapter 3.3.

Table 3 below shows the supported custom radio transmission settings.

Setting	Meaning
0x00	Commissioning and data telegrams in standard Advertising Mode (Default configuration) Note: This is equivalent to 0x04 with the radio channels set to BLE CH37, CH38 and CH39
0x01	Commissioning telegrams in standard Advertising Mode Data telegrams on 3 user-defined radio channels
0x02	Commissioning telegrams in standard Advertising Mode Data telegrams on 2 user-defined radio channels
0x03	Commissioning telegrams in standard Advertising Mode Data telegrams on 1 user-defined radio channel
0x04	Commissioning and Data telegrams on 3 user-defined radio channels
0x05	Commissioning and Data telegrams on 2 user-defined radio channels
0x06	Commissioning and Data telegrams on 1 user-defined radio channel
0x07 ... 0xFF	Unused, will be treated as 0x00

Table 3 – Custom Variant register settings

Starting with version DC-06 it will be possible to reduce the transmission interval from the default setting of 20 ms to a reduced value of 10 ms by means of setting bit 4 of the Custom Variant register.

This means that the settings 0x08 ... 0x0E will provide the same transmission channel mode as the settings 0x00 ... 0x06 but with 10 ms intervals between the transmissions.

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6.7.9 Radio channel selection registers

If the Custom Variant register is set to a value other than 0x00 then the radio channels for transmission are selected using the CH_REG1, CH_REG2 and CH_REG3 registers as described in chapter 3.3. Each of these registers is 1 byte wide and uses the encoding shown in Table 4 below.

Note that two channel types can be used:

- Standard BLE radio channels (BLE Channel 0 ... BLE Channel 39 using the even frequencies from 2402 MHz to 2480 MHz as described in chapter 3)
- Custom radio channels in between the standard BLE channels (odd frequencies from 2403 MHz to 2479 MHz)

CH_REGn Value	Frequency	Channel Type
BLE Radio Channels		
37	2402 MHz	BLE Advertising Channel
0	2404 MHz	BLE Data Channel
1	2406 MHz	BLE Data Channel
...		
10	2424 MHz	BLE Data Channel
38	2426 MHz	BLE Advertising Channel
11	2428 MHz	BLE Data Channel
12	2430 MHz	BLE Data Channel
...		
36	2478 MHz	BLE Data Channel
39	2480 MHz	BLE Advertising Channel
Custom Radio Channels		
40	2403 MHz	Custom Radio Channel
41	2405 MHz	Custom Radio Channel
...		
77	2477 MHz	Custom Radio Channel
78	2479 MHz	Custom Radio Channel

Table 4 – Radio Channel Selection register settings

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6.7.10 Customer Data

PTM 215B allocates 64 pages (256 byte) for customer data that can be read and written via the NFC interface in protected mode.

The main intention is to enable storing OEM-specific information such as product type, revision, date code or similar. There is however no restriction (other than the maximum size of 256 byte) on the type of content that can be stored in this memory region.

PTM 215B will not access or modify this memory region.

Users should keep in mind that the content of this memory region will not be affected by a factory reset. This means that after a factory reset, the content of this memory region can be read using the default PIN code. This region should therefore not be used to store sensitive data.

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6.8 Private Data

The private data area stores the following items:

- Security Key
- Default settings

The content of the private data area is not externally accessible.

6.8.1 Security Key

The Security Key field contains the 128 bit private key used for authenticating PTM 215B telegrams and for resolving private source addresses.

This register is programmed with a random value during manufacturing. It can be changed using the Security Key Write feature described in chapter 6.7.4.

6.8.2 Default Settings

The Default Settings field contains a backup of the following PTM 215B factory settings:

- Static Source Address
- Security Key
- Manufacturer ID
- NFC PIN Code

These default settings can be restored by means of a factory reset as described in chapter 5.4.

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7. Device integration

PTM 215B is designed for integration into button or rocker based switches. It implements the established PTM 2xx mechanical form factor and can therefore be used with a wide variety of existing designs.

7.1 Mechanical Interface Characteristics

Energy bow travel / operating force	1.8 mm / typ. 9 N At room temperature Only one of the two energy bows may be actuated at the same time!
Restoring force at energy bow	typ. 0.7 N Minimum restoring force of 0.5 N is required for correct operation
Number of operations at 25°C	typ. 100.000 actuations tested according to VDE 0632 / EN 60669
Cover material	Hostaform (POM)
Energy bow material	PBT (50% GV)

7.2 Mechanical Interface Drawings

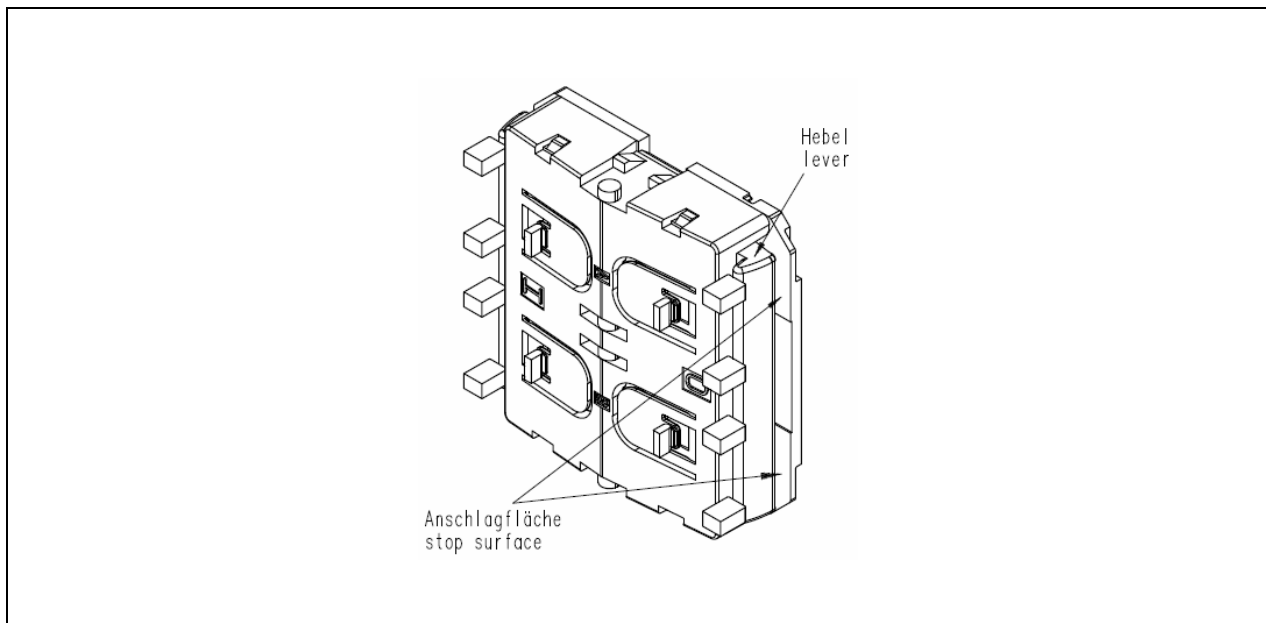
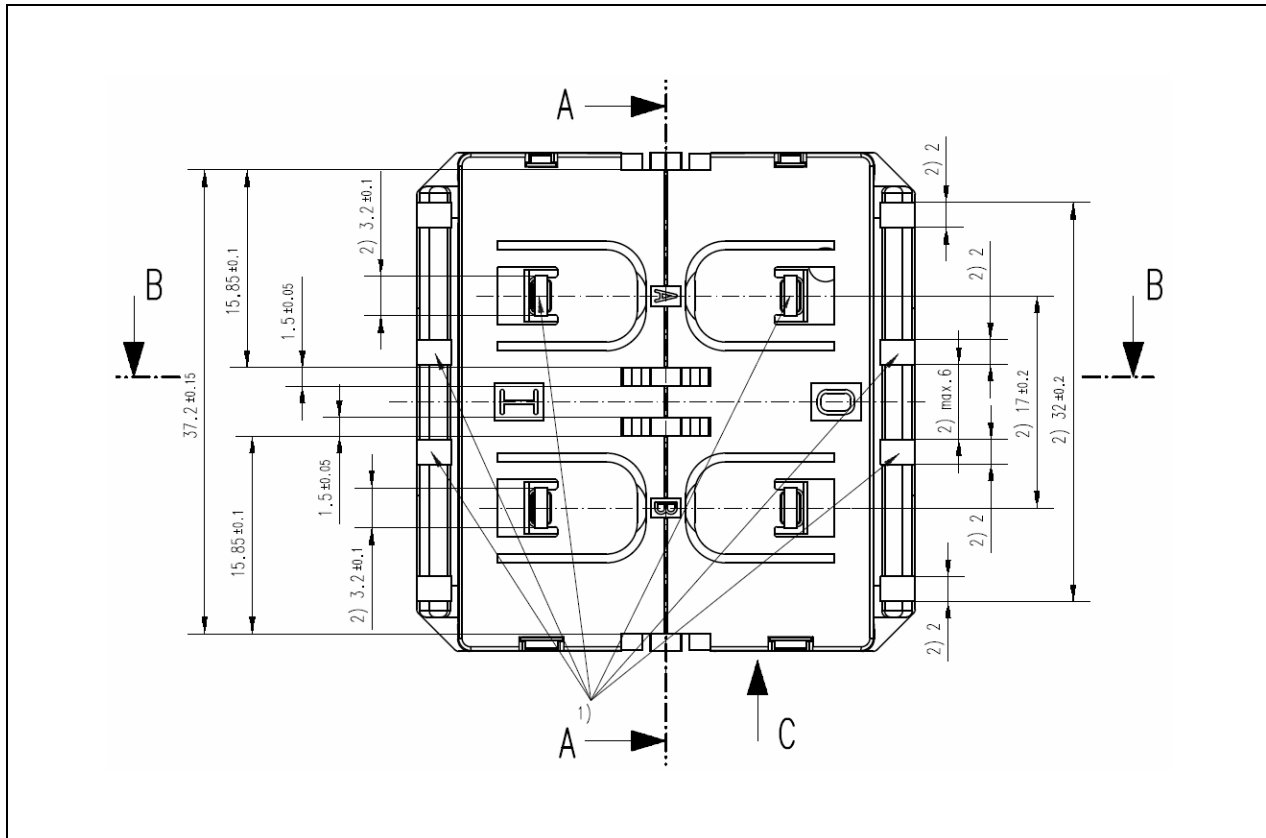


Figure 31 – PTM 215B, tilted view (including rocker catwalks)

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1) these catwalks are not needed when using one single rocker only 2) dimensions of rocker part

Figure 32 – PTM 215B, top view (note cut A, B and C marking)

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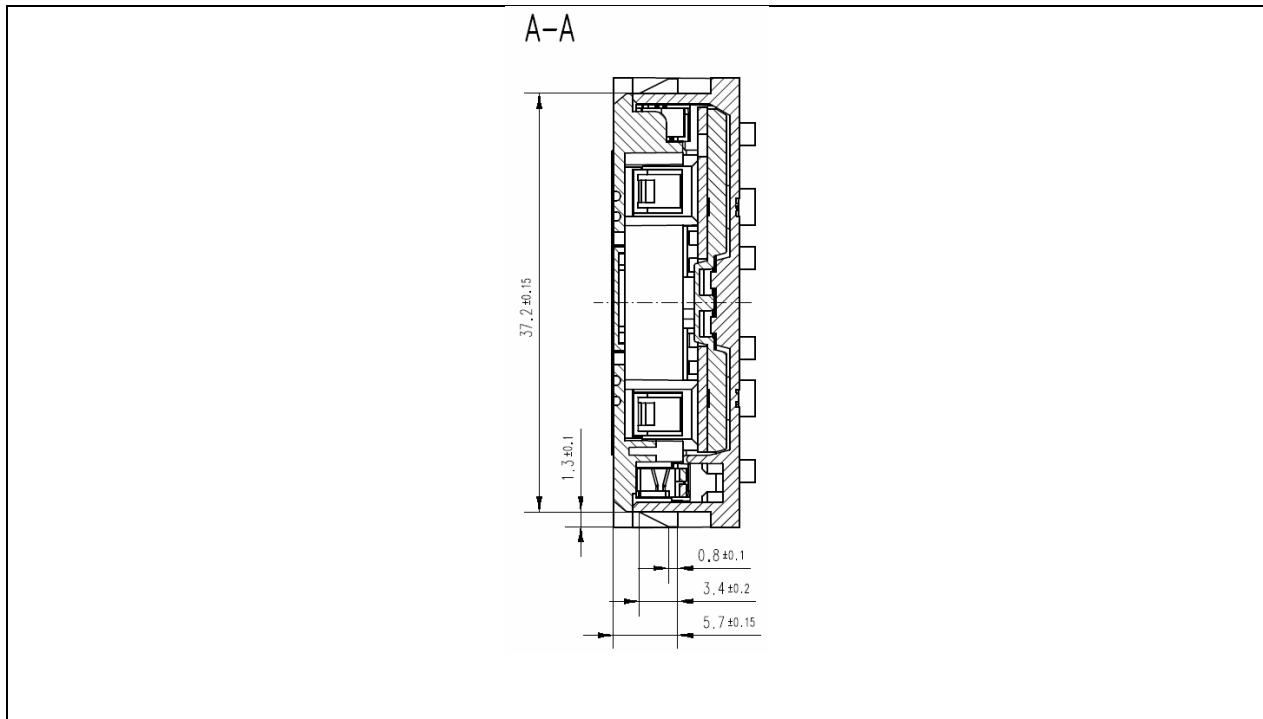
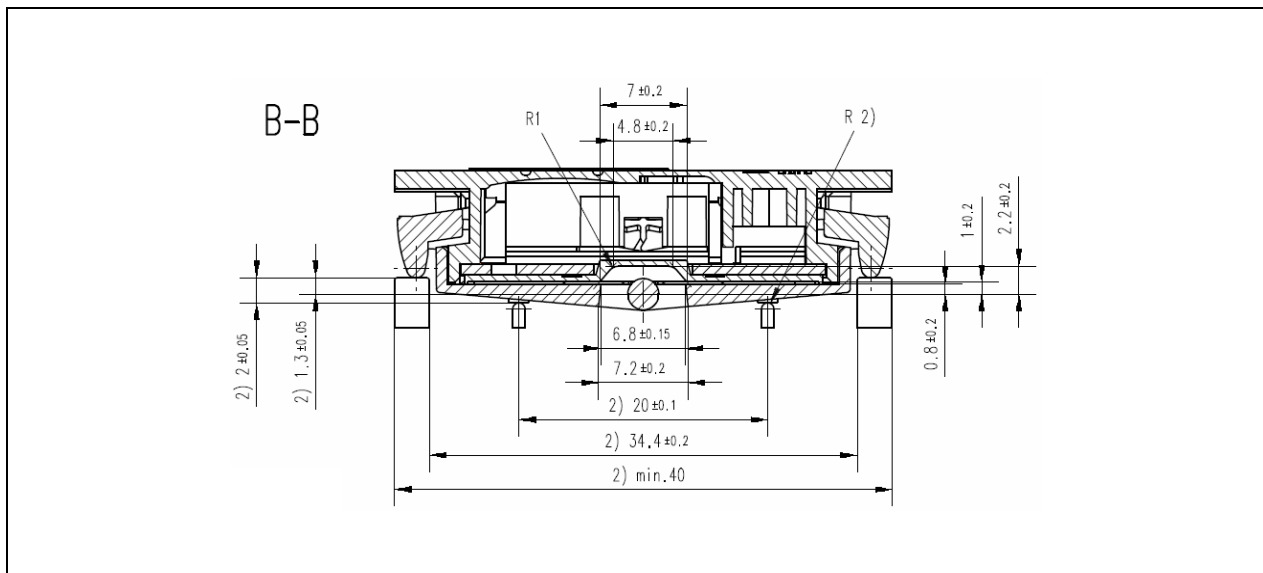


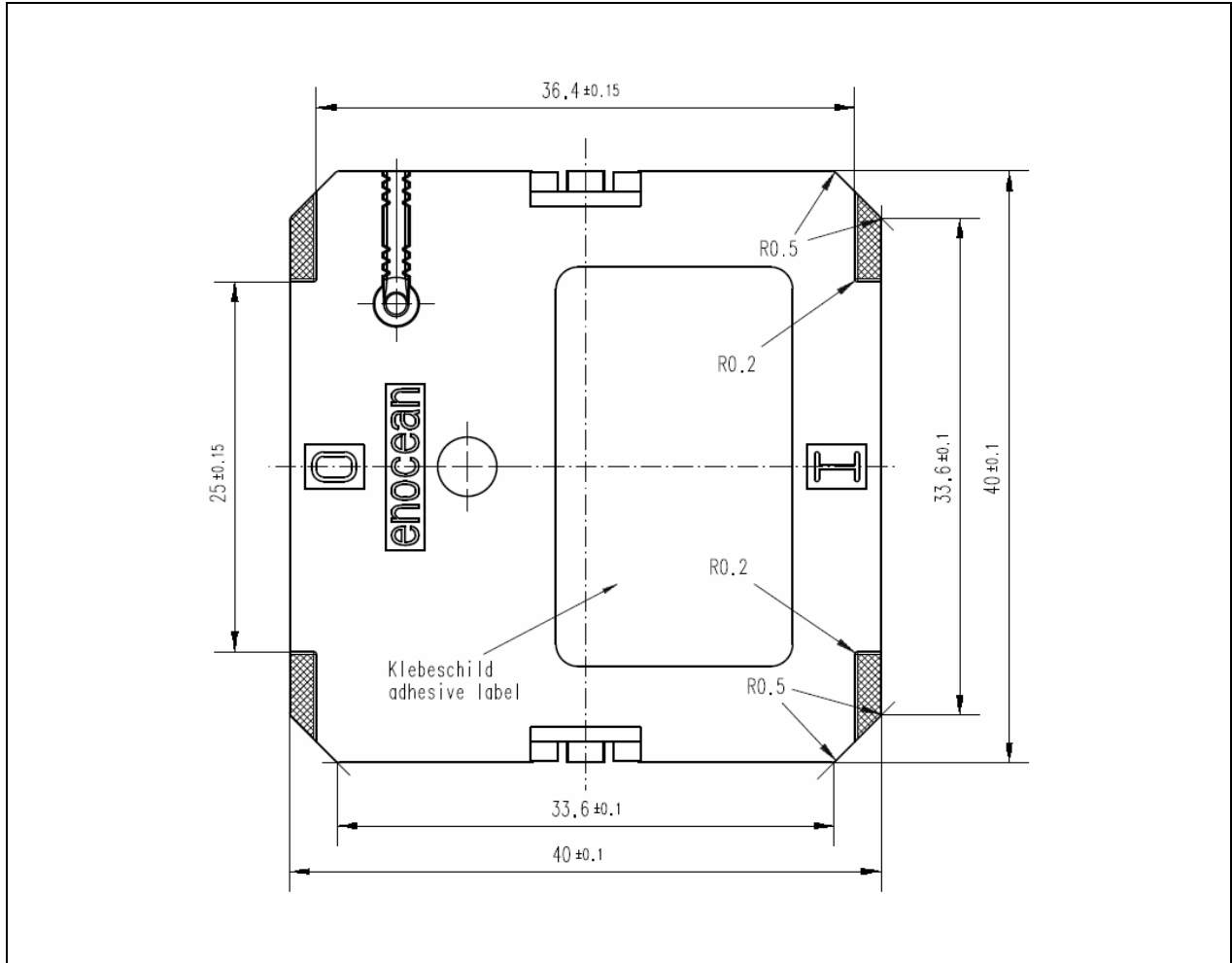
Figure 33 – PTM 215B, cut A



2) dimensions of rocker part

Figure 34 – PTM 215B, cut B and C

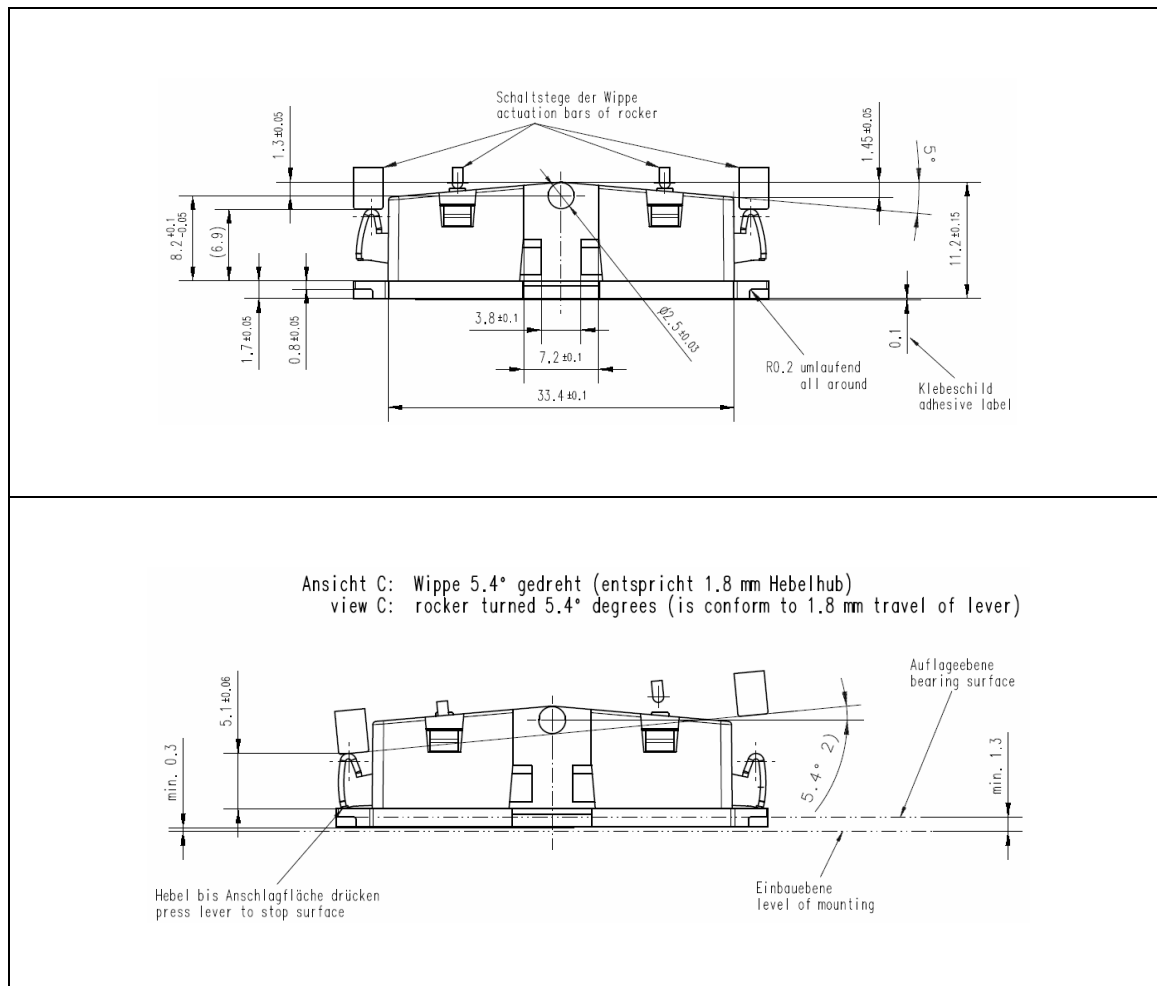
PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE



Hatched areas: support planes

Figure 35 – PTM 215B rear view

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2) dimensions of rocker part

Figure 36 – PTM 215B, side view



If the rocker is not mounted on the rotation axis of PTM 215B several tolerances have to be considered! The measure from support plane to top of the energy bow is 7.70 mm +/- 0.3 mm!



The movement of the energy bow must not be limited by mounted rockers!



Catwalks of the switch rocker must not exert continuous forces on the button contacts!

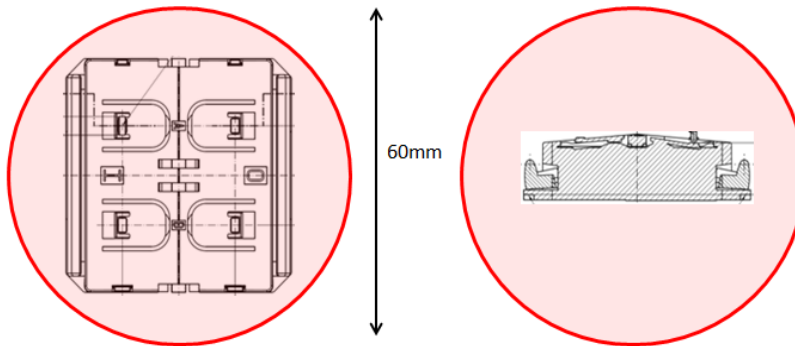
PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE



It is required to use non-conductive material (no metal or plastic with metal or graphite elements) for the rockers, the frame and the base plate to ensure best transmission range.



PTM 215B is powered by the electromagnetic generator ECO 200. For proper function there has to be a keep out zone of 60mm for magnets or ferromagnetic materials around the center of PTM 215B.



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7.3 Product label

Customer products integrating PTM 215B modules should include a QR code on their product label for the purpose of commissioning as described in chapter 5.2. This QR code can then be scanned by commissioning tools to automatically extract the required product parameters.

The format of the QR code has to be according to the ANSI/MH10.8.2-2013 industry standard using the syntax described in chapter 8.2.1. The QR code should at a minimum contain the two fields listed in Table 5 below.

Identifier	Length of data (excluding identifier)	Value
30S	12 characters	Static Source Address (hex)
Z	32 characters	Security Key (hex)

Table 5 – Required fields for the product QR code

7.3.1 Example for a product QR code

For this example we consider a product using the following parameters:

- Static Source Address: E21501500100
- Security Key: 0123456789ABCDEF0123456789ABCDEF

The resulting ANSI/MH10.8.2-2013 string would be:

```
30SE21501500100+Z0123456789ABCDEF0123456789ABCDEF
```

Figure 37 below shows the QR code corresponding to this example. This QR code should be part of the customer product label with a size and resolution that enables easy scanning using a mobile phone or tablet.



Figure 37 – Example for a product QR code

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8. PTM 215B device label

Each PTM 215B module contains a device label. Note that the finished switches (EWSSB, EWSDB, ESRPB and EDRPB) use a different product label as described in their user manuals and the information given in the subsequent chapters applies only to the PTM 215B module itself.

The format of the PTM 215B device label depends on the revision of the device:

- Revisions up to DB-05 (produced before July 2018) use a device label with two DMC codes
- Revisions starting with DC-06 (produced after July 2018) use a new label with only one QR code

Both versions are described in the following chapters.

8.1 PTM 215B device label for products up to version DB-05

PTM 215B products up to version DB-05 (PTM 215B produced before July 2018) contain the label shown in Figure 38 below.



Figure 38 – PTM 215B device label (for versions up to DB-05)

The device label identifies the following parameters relevant for customer use:

- Order number (S3221-A215) and revision (DA-2)
- Manufacturing date (week 20, 2017)
- Static Source Address (0xE2:15:01:50:01:00)

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The device label additionally contains two DMC codes:

- The smaller DLC on the left side (Manufacturer DMC) is used for manufacturing only and not relevant for customers
- The larger DMC code on the right side (Commissioning DMC) specifies Source Address and Security Key and can be used for commissioning the switch into a network.

The structure of the Commissioning DMC is described in the next chapter.

8.1.1 Commissioning DMC structure

The commissioning DMC uses the ECC200 standard to encode the following data string:
 <PRODUCT_NAME>ID<SOURCE_ID>00B<DEVICE_KEY>

This data string identifies the following product parameters:

- Product name (always "PTM215B")
- 48 bit Static Source Address (unique for each device, starts with "E215" Prefix)
- 128 bit device-unique random security key (different for each device)

Figure 39 below shows the Commissioning DMC from the label in Figure 38.



Figure 39 – Commissioning DMC (for PTM 215B versions up to DB-05)

The Commissioning DMC shown above encodes the following string:
 PTM215BIDE2150150010000B0123456789ABCDEF0123456789ABCDEF

For better readability, the same reading is shown below coloured red, green and orange to identify the different parts:

PTM215BIDE2150150010000B0123456789ABCDEF0123456789ABCDEF

This particular DMC reading would identify the following parameters:

- Product name = PTM215B
- Static Source Address = E21501500100
- Device-unique random security key = 0123456789ABCDEF0123456789ABCDEF

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8.2 PTM 215B device label for products starting with version DC-06

PTM 215B products starting with version DB-05 (PTM 215B produced after May 2018) use a new label as shown in Figure 40 below.

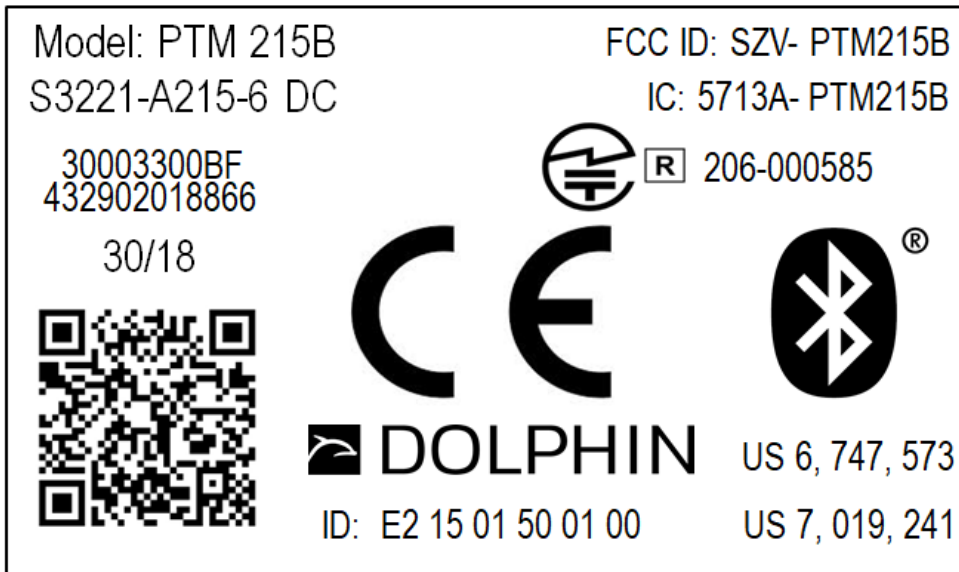


Figure 40 – PTM 215B device label (for versions starting with DC-06)

This label adds the required ARIB (Japan) certification logo and ID (206-000585) and merges the two DMC used previously into one QR code. Other fields remain unchanged.

8.2.1 QR Code format

The QR code used in the new product label encodes the product parameter according to the ANSI/MH10.8.2-2013 industry standard. The QR code shown in Figure 40 above encodes the following string:

30SE21501500100+Z0123456789ABCDEF0123456789ABCDEF+30PS3221-A215+2PDC06+S01234567890123

Table 6 below describes the ANSI/MH10.8.2 data identifiers used by the PTM 215B device label and shows the interpretation of the data therein.

Identifier	Length of data (excluding identifier)	Value
30S	12 characters	Static Source Address (hex)
Z	32 characters	Security Key (hex)
30P	10 characters	Ordering Code (S3221-A215)
2P	4 characters	Step Code - Revision (DC-06)
S	14 characters	Serial Number

Table 6 – QR code format (for PTM 215B versions starting with DC-06)

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9. Application information

9.1 Transmission range

The main factors that influence the system transmission range are:

- Type and location of the antennas of receiver and transmitter
- Type of terrain and degree of obstruction of the link path
- Sources of interference affecting the receiver
- “Dead spots” caused by signal reflections from nearby conductive objects.

Since the expected transmission range strongly depends on this system conditions, range tests should always be performed to determine the reliably achievable range under the given conditions.

The following figures should be treated as a rough guide only:

- Line-of-sight connections
Typically 10 m range in corridors, up to 30 m in halls
- Plasterboard walls / dry wood
Typically 10 m range, through max. 2 walls
- Ferro concrete walls / ceilings
Typically 5 m range, through max. 1 ceiling (depending on thickness)
- Fire-safety walls, elevator shafts, staircases and similar areas should be considered as shielded

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 include:

- Switch mounting on metal surfaces (up to 30% loss of transmission range)
- Hollow lightweight walls filled with insulating wool on metal foil
- False ceilings with panels of metal or carbon fibre
- Lead glass or glass with metal coating, steel furniture

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

Note that interference from other radio equipment operating in the 2.4 GHz band (WiFi routers, smartphones, wireless audio and video systems, etc.) can have major impact on radio performance.

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9.2 Receiver configuration

PTM 215B communicates user actions (rocker push / release) using a sequence of advertising telegrams as described in chapter 0.

In order to maximize the likelihood of reception of these telegrams, it is necessary that the receiver is either permanently in receive mode on the selected radio channels or – if this is not possible – is in receive mode periodically on one of the chosen radio channels for a certain minimum period of time.

The two key timing parameters for the periodical reception case are the scan interval (time between the start of two consecutive scanning cycles) and the scan duration (for how long will the receiver scan within each scanning cycle).

PTM 215B transmits the advertising events with a pause interval of 20 ms between two transmissions. The transmission of the advertising event itself requires approximately 1 ms per radio channel (meaning approximately 3 ms in total when using 3 radio channels) which means that the total time between the start of two advertising events is approximately 23 ms.

Considering that the receiver might start scanning directly after the start of one transmission, we can therefore determine that it should remain active (scan duration) for at least 23 ms to check for the start of the next transmission.

Likewise, we need to ensure that the receiver will become active (scan period) no later than right before the beginning of the third advertising event. So the longest period for which the receiver can be inactive is given by the time from the beginning of the first advertising events until the beginning of the third advertising event, meaning approximately 46 ms in total.

The likelihood of correct reception obviously increases if more than one of the redundant advertising events is received. It should also be considered that the receiver is typically scanning on different radio channels. Therefore the theoretical maximum of 46 ms should be significantly reduced to increase the likelihood of correct reception.

It is therefore recommended to use a setting of 30 ms scan period and 23 ms scan interval for cases where continuous reception is not possible.

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10. Regulatory information

PTM 215B has been certified according to FCC (US), ISED (CA) and RED (EU) regulations. Changes or modifications not expressly approved by EnOcean could void the user's authority to operate the equipment.

10.1 RED for European Market

The Radio Equipment Directive (2014/53/EU, typically referred to as RED) replaces R&TTE directive as regulatory framework for radio products in the European Union. All products sold final customers within the European Union have to be compliant to RED. At the time of writing, the text of the RED legislation was available from this link: <http://eur-lex.europa.eu/eli/dir/2014/53/oj>

Dolphin radio modules are components which are delivered to OEM manufacturers for their use/integration in final or combined products. It is the responsibility of the OEM manufacturer to demonstrate compliance to all applicable EU directives and standards. The EnOcean attestation of conformity can be used as input to the declaration of conformity for the full product.

At the time of writing, guidance on the implementation of EU product rules – the so called “Blue Guide” – was available from this link: <http://ec.europa.eu/DocsRoom/documents/18027/>

Specifically within the new RED framework, all OEM manufacturers have for instance to fulfill the following additional requirements:

- Provide product branding (on the product) clearly identifying company name or brand and product name as well as type, charge or serial number for market surveillance
- Include (with the product) documentation containing full postal address of the manufacturer as well as radio frequency band and max. transmitting power
- Include (with the product) user manual, safety information and a declaration of conformity for the final product in local language
- Provide product development and test documentation upon request

Please contact an accredited test house for detailed guidance.

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10.2 **FCC (United States) Certificate**

TCB

**GRANT OF EQUIPMENT
AUTHORIZATION**

TCB

**Certification
Issued Under the Authority of the
Federal Communications Commission
By:**

**EMCCert Dr. Rasek GmbH
Stoernhofer Berg 15
91364 Unterleinleiter,
Germany**

**Date of Grant: 09/26/2016
Application Dated: 09/26/2016**

**EnOcean GmbH
Kolpingring 18a
Oberhaching, 82041
Germany**

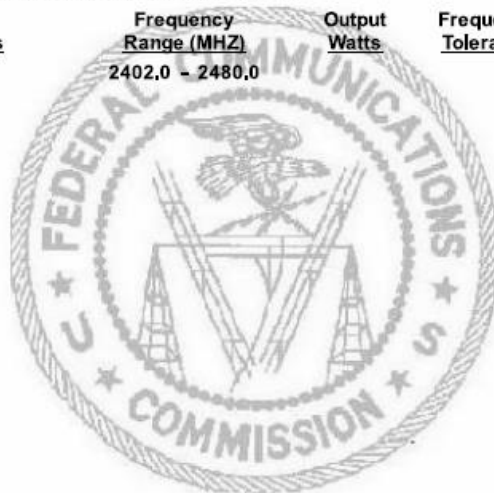
Attention: Armin Anders , Director Product Marketing

NOT TRANSFERABLE

EQUIPMENT AUTHORIZATION is hereby issued to the named GRANTEE, and is VALID ONLY for the equipment identified hereon for use under the Commission's Rules and Regulations listed below.

FCC IDENTIFIER: SZV-PTM215B
Name of Grantee: EnOcean GmbH
Equipment Class: Part 15 Low Power Communication Device Transmitter
Notes: 2402 MHz - 2480 MHz transmitter

<u>Grant Notes</u>	<u>FCC Rule Parts</u>	<u>Frequency Range (MHZ)</u>	<u>Output Watts</u>	<u>Frequency Tolerance</u>	<u>Emission Designator</u>
	15C	2402,0 - 2480,0			



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10.2.1 FCC (United States) Regulatory Statement

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

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

PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE

10.3 IC (Industry Canada) Certificate



FCB under the Canada-EC MRA
TCB under the USA-EC MRA
RFCAB under the Japan-EC MRA
Notified Body R&TTE Directive 99/5/EC
Notified Body RED Directive 2014/53/EU
Notified Body EMC Directive 2014/30/EU
No. CA001711G

**TECHNICAL ACCEPTANCE
CERTIFICATE
CANADA**

**CERTIFICAT D'ACCEPTABILITÉ
TECHNIQUE
CANADA**

CERTIFICATION No. **▶ 5713A-PTM215B**
No. DE CERTIFICATION

ISSUED TO **▶ EnOcean GmbH**
DELIVRE A

Street Address **Kolpingring 18 a**
Numéro et rue
Province or State **Germany**
Province ou Etat

City **Oberhaching**
Ville
Postal Code **82041**
Code postal

TYPE OF EQUIPMENT **▶ Low Power Device (2400–2483.5 MHz)**
GENRE DE MATERIEL

PMN **▶ PTM 215B**

ANTENNA **▶ Integrated** ANTENNA GAIN **▶**
ANTENNE **Incorporé** GAIN D'ANTENNE

HVIN **▶ PTM 215B**

FVIN **▶**

FREQUENCY RANGE BANDE DE FRÉQUENCES	EMISSION TYPE GENRE D'ÉMISSION	RF POWER PUISSANCE H.F.	SPECIFICATION / ISSUE / DATE SPÉCIFICATION / ÉDITION / DATE
2402 - 2480 MHz	947KG1D	96.6 dBµV/m	RSS-210 / 9 / August 2016

TEST LABORATORY **▶ EMCCons DR. RASEK GmbH & Co. KG**
LABORATOIRE D'ESSAY

Street Address **Stoernhofer Berg 15**
Numéro et rue
Province or State **Germany**
Province ou Etat

CN **3464C** OATS **3464C-1**

City **Unterleinleiter**
Ville

Postal Code **91364**
Code Postal

Name **Ludwig Kraft**
Nom

Tel **+49 9194 7263-301**

E-mail **Lkraft@emcc.de**

Fax **+49 9194 7263-309**

Certification of equipment means only that the equipment has met the requirements of the above-noted specification. Licence applications, where applicable to use certified equipment, are acted on accordingly by the ISED issuing office and will depend on the existing radio environment, service and location of operation. This certificate is issued on condition that the holder complies and will continue to comply with the requirements and procedures issued by ISED. The equipment for which this certificate is issued shall not be manufactured, imported, distributed, leased, offered for sale or sold unless the equipment complies with the applicable technical specifications and procedures issued by ISED.

La certification du matériel signifie seulement que le matériel a satisfait aux exigences de la norme indiquée ci-dessus. Les demandes de licences nécessaires pour l'utilisation du matériel certifié sont traitées en conséquence par le bureau de délivrance d'ISDE et dépendent des conditions radio ambiantes, du service et de l'emplacement d'exploitation. Le présent certificat est délivré à la condition que le titulaire satisfasse et continue de satisfaire aux exigences et aux procédures d'ISDE. Le matériel à l'égard duquel le présent certificat est délivré ne doit pas être fabriqué, importé, distribué, loué, mis en vente ou vendu à moins d'être conforme aux procédures et aux spécifications techniques applicables publiées par ISDE.

I hereby attest that the subject equipment was tested and found in compliance with the above-noted specification.

J'atteste par la présente que le matériel a fait l'objet d'essai et jugé conforme à la spécification ci-dessus.

DATE **26 September 2016**



Certification Officer

PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE

10.3.1 IC (Industry Canada) Regulatory Statement

This device complies with Industry Canada licence-exempt RSS standard(s).
Operation is subject to the following two conditions:

- (1) this device may not cause interference, and
- (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence.

L'exploitation est autorisée aux deux conditions suivantes :

- (1) l'appareil ne doit pas produire de brouillage, et
- (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement."

PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE

10.4 **ACMA (Australia) Declaration of Conformity**

Supplier's Declaration of Conformity



As required by the following Notices:

- > *Radiocommunications (Compliance Labelling - Devices) Notice 2014* made under section 182 of the *Radiocommunications Act 1992*;
- > *Radiocommunications Labelling (Electromagnetic Compatibility) Notice 2008* made under section 182 of the *Radiocommunications Act 1992*
- > *Radiocommunications (Compliance Labelling – Electromagnetic Radiation) Notice 2014* made under section 182 of the *Radiocommunications Act 1992* and
- > *Telecommunications (Labelling Notice for Customer Equipment and Customer Cabling) Instrument 2015* made under section 407 of the *Telecommunications Act 1997*.

Instructions for completion

- > **Do not return this form to the ACMA.** This completed form must be retained by the supplier as part of the documentation required for the compliance records and must be made available for inspection by the ACMA when requested.

Supplier's details (manufacturer, importer or authorised agent)

Company Name (OR INDIVIDUAL)

ACN/ARBN

Compliance Folder Management Pty Ltd
On behalf of: EnOcean GmbH

ABN 75 082 447 194



Street Address (AUSTRALIAN)

Unit 1, 570 City Road
South Melbourne
Victoria, 3205

Product details and date of manufacture

Product description – brand name, type, current model, lot, batch or serial number (if available), software/firmware version (if applicable)

Brand:	Dolphin
Model:	PTM 215B
Description:	Bluetooth (LE) Pushbutton Transmitter Module
Manufacturer:	EnOcean GmbH Kolpingring 18a, 82041 Oberhaching, Germany
Date of manufacture or importation of the original/modified item	

PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE

Compliance – applicable standards and other supporting documents

Evidence of compliance with applicable standards may be demonstrated by test reports, endorsed/accredited test reports, certification/competent body statements.

Having had regard to these documents, I am satisfied the above mentioned product complies with the requirements of the relevant ACMA Standards made under the *Radiocommunications Act 1992* and the *Telecommunications Act 1997*.

List the details of the documents the above statement was made, including the standard title, number and, if applicable, number of the test report/endorsed test report or certification/competent body statement

<p>Radiocommunications (Short Range Devices) Standard 2014 (Amnt 1 : 2015) Radiocommunications (Low Interference Potential Devices) Class Licence 2015</p> <p>AS/NZS 4268: 2017 WLAN 2.4GHz : EN 300 328 V1.9.1 Bluetooth (LE) - Report No.: 16/06-0033, Dated: 18 August 2016, PKM electronic GmbH</p>
<p>Radiocommunications (Electromagnetic Compatibility) Standard 2008</p> <p>EN 55022: 2010 Report No.: 16/06-0033 Dated: 16 August 2016, PKM electronic GmbH</p>
<p>Radiocommunications (Electromagnetic Radiation – Human Exposure) Standard 2014</p> <p>Maximum Exposure Levels to Radio Frequency Fields – 3 kHz to 300 GHz (2002) RPS 3, ARPANSA Exemption– Fixed Station Exemption, ARPANSA Schedule 5, General Public Exposure, <20mW Mean Power.</p>

OEM products that this module may be installed may also be required to show compliance with Radiocommunications (Short Range Devices) Standard 2014 (Amnt 1 : 2015), Radiocommunications (Electromagnetic Compatibility) Standard 2008, the Radiocommunications (Electromagnetic Radiation – Human Exposure) Standard 2014 and the requirements of the Telecommunications Labelling Notice.


Declaration

I hereby declare that:

1. I am authorised to make this declaration on behalf of the Company mentioned above,
2. the contents of this form are true and correct, and
3. the product mentioned above complies with the applicable above mentioned standards and all products supplied under this declaration will be identical to the product identified above.

Note: Under section 137.1 of the *Criminal Code Act 1905*, it is an offence to knowingly provide false or misleading information to a Commonwealth entity.

Penalty: 12 months Imprisonment

 Signature of Supplier or Agent <p style="text-align: center;">Robert Norris</p> Print Name	<p style="text-align: center;">General Manager</p> Position In Organisation <p style="text-align: center;">28th November 2017</p> Date
---	--

The *Privacy Act 1988* (Cth) (the *Privacy Act*) imposes obligations on the ACMA in relation to the collection, security, quality, access, use and disclosure of personal information. These obligations are detailed in the Australian Privacy Principles.

The ACMA may only collect personal information if it is reasonably necessary for, or directly related to, one or more of the ACMA's functions or activities.

The purpose of collecting the personal information in this form is to ensure the supplier is identified in the 'Declaration of conformity'. If this Declaration of Conformity is not completed and the requested information is not provided, a compliance label cannot be applied.

Further information on the Privacy Act and the ACMA's Privacy Policy is available at www.acma.gov.au/privacypolicy. The Privacy Policy contains details about how you may access personal information about you that is held by the ACMA, and seek the correction of such information. It also explains how you may complain about a breach of the Privacy Act and how we will deal with such a complaint.

Should you have any questions in this regard, please contact the ACMA's privacy contact officer on telephone on 1800 226 667 or by email at privacy@acma.gov.au.

PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE

10.5 **ARIB (Japan) Construction Type Conformity Certification**



Notified Body EMC Directive 2014/30/EU
 Notified Body Directive 2014/53/EU
 RF CAB under the Japan-EC MRA
 FCB under the Canada-EC MRA
 TCB under the USA-EC MRA

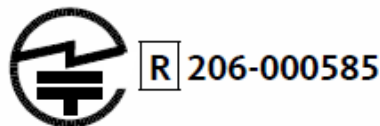
RF CAB ID No. 206

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.	JU000585K
Certificate Holder	EnOcean GmbH Kolpingring 18a 82041 Oberhaching Germany
Product Category	Article 2, Paragraph 1, Item 19 (WW)
Product Designation	PTM 215B, ESRPB, EDRPB, EWSSB, EWSDB
Product Description	Bluetooth Low Energy Transmitter
Software Release No.	1.1.0.0
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



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.

Unterleinleiter,
2018-03-15



 Günther Proß
 Recognised Foreign Conformity Assessment Body

PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE

11. Product history

Table 7 below lists the product history of PTM 215B.

Revision	Release date	Key changes versus previous revision
DA-03	October 2016	First release for lead customers
DB-04	February 2017	Broad market release incorporating lead customer feedback <ul style="list-style-type: none"> • Added option to change Manufacturer ID • Added option to use custom radio channels • Changed NFC memory organization to include additional configuration registers • Changed format of commissioning telegram: <ul style="list-style-type: none"> ○ Addition of Static Source Address ○ Removal of Product Name ('PTM215B')
DB-05	March 2018	<ul style="list-style-type: none"> • Internal version (component update), no customer change
DC-06	July 2018	<ul style="list-style-type: none"> • Corrected length field in commissioning telegram (now correctly set to 0x1D) • Addition of option to reduce interval between advertising events from 20 ms to 10 ms • Addition of option to disable transmission of commissioning telegrams via long press A0+A1+B1 • Modification of product label <ul style="list-style-type: none"> ○ Addition of ARIB approval sign ○ Merge of the two DMC into one QR code with parameter encoding according to ANSI/MH10.8.2 standard

Table 7 – Product History

PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE

A. Parsing PTM 215B radio telegrams

This appendix is intended as an example of how start to parse received PTM 215B radio telegrams. Please refer to chapter 4 first for a description of the BLE frame structure

A.1 Data telegram example

We consider the following raw data telegram data captured from an EnOcean PTM 215B device:

```
D6 BE 89 8E 42 13 9F 1B 00 00 15 E2 0C FF DA 03 69 01 00 00 10 8A D6 C1 7E 16 EE 23
```

A.1.1 BLE frame structure

The message shown above can be parsed into the following components (keep in mind the little endian byte order):

BLE Access Address (4 byte):	0x8E89BED6
BLE Frame Control (2 byte):	0x1342 Size of source address + payload: 0x13 (19 byte) Telegram type: Non-connectable Advertising
BLE Source Address (6 byte):	0xE21500001B9F
Length of payload (1 byte):	0x0C (12 byte)
Type of payload (1 byte):	0xFF (manufacturer-specific data)
Manufacturer ID (2 byte):	0x03DA (EnOcean GmbH)
EnOcean Payload (9 byte):	69 01 00 00 10 8A D6 C1 7E
CRC (3 byte):	16 EE 23

A.1.2 EnOcean data telegram payload structure

The EnOcean data telegram payload can now be parsed as follows:

Sequence Counter (4 byte):	0x00000169
Switch Status:	10 (Release of button B1)
Telegram Signature:	C7 24 EA F0

PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE

A.2 Commissioning telegram example

We consider the following raw commissioning telegram data captured from an EnOcean PTM 215B device:

```
D6 BE 89 8E 42 24 9F 1B 00 00 15 E2 1E FF DA 03 71 01 00 00 AB 4B 9A 91 85 2B 70 B8
A6 52 A0 5E 92 BB 12 A0 9F 1B 00 00 15 E2 9E 6D 7C
```

A.2.1 BLE frame structure

The message shown above can be parsed into the following components (keep in mind the little endian byte order):

BLE Access Address (4 byte):	0x8E89BED6
BLE Frame Control (2 byte):	0x2442 Size of source address + payload: 0x24 (36 byte) Telegram type: Non-connectable Advertising
BLE Source Address (6 byte):	0xE21500001B9F
Length of payload (1 byte):	0x1E (30 byte) Note that this field should correctly be set to 0x1D This issue has been corrected in product version DC-06
Type of payload (1 byte):	0xFF (manufacturer-specific data)
Manufacturer ID (2 byte):	0x03DA (EnOcean GmbH)
EnOcean Payload (27 byte):	71 01 00 00 AB 4B 9A 91 85 2B 70 B8 A6 52 A0 5E 92 BB 12 A0 9F 1B 00 00 15 E2
CRC (3 byte):	0x7C6D9E

A.2.2 EnOcean commissioning telegram payload structure

The EnOcean commissioning telegram payload can now be parsed as follows:

Sequence Counter (4 byte):	0x00000171
Security Key:	AB 4B 9A 91 85 2B 70 B8 A6 52 A0 5E 92 BB 12 A0
Static Source Address:	0xE21500001B9F

PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE

B. Authentication of PTM 215B data telegrams

PTM 215B provides the option to authenticate its data telegrams as described in chapter 4.8. The authentication mechanism used by PTM 215B is standardized as RFC3610. The full RFC3610 specification could be found here at the time of writing and should be used as primary source of information: <https://www.ietf.org/rfc/rfc3610.txt>

The following description aims to summarize the security processing steps for users not deeply familiar with cryptography in general or RFC3610 in particular.

B.1 Algorithm input parameters

The purpose of the security processing in PTM 215B is to calculate a unique signature that can be used to verify authenticity (telegram has not been modified) and originality (telegram comes from the assumed sender) of a telegram.

To do so, two types of algorithm parameters are required:

- Constant algorithm input parameters
These parameters identify high level algorithm and telegram properties and are the same for any PTM 215B telegram
- Variable algorithm input parameters
These parameters identify telegram-specific parameters and therefore depend on the specifics of the transmitted telegram

B.1.1 Constant input parameters

The RFC3610 implementation in PTM 215B requires two constant input parameters:

- Length field size
This is the size (in byte) of the field used to encode the length of the input data (which is the payload to be authenticated).
The maximum size of PTM 215B payload to be authenticated is 13 byte; therefore one byte would be easily sufficient to encode the payload size. The minimum value permitted by the standard is however 2 bytes which is therefore chosen.
- Signature size
This is the desired size of the generated signature which is 4 byte for PTM 215B

Table 8 below summarizes these constant algorithm parameters.

Parameter	Comment / Description	Example
Length Field Size	Size (in bytes) of the field used to encode the input length	2 (always, minimum permissible size)
Signature Size	Desired size (in byte) of the signature generated by the algorithm	4 (always)

Table 8 – Constant algorithm input parameters

PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE

B.1.2 Variable input parameters

The RFC3610 implementation in PTM 215B requires four variable input parameters:

- **Source address**
The 6 byte source address used to identify the sender of an authenticated message. The source address is required in little endian (least significant byte first) format.
- **Input data (Payload to be authenticated)**
The authenticated payload contains source address, sequence counter, switch status and optional data (if present). See chapter 4.8 for a description of the authenticated payload.
- **Input length (Size of the payload to be authenticated)**
The length of the payload to be authenticated depends on the amount of optional data used in the telegram. This is configured via the Configuration register, see chapter 6.7.7.
By default, no optional data is present and the length of the authenticated payload is 9 byte.
- **Sequence counter**
Each PTM 215B contains a sequence counter which is initialized to zero during production and increased for each telegram that is sent.
The sequence counter is transmitted as part of the input data.
The receiver of PTM 215B telegrams keeps track of this counter and will accept only telegrams with counter values higher than the highest previously used value. This eliminates the possibility of reusing previously transmitted telegrams.
Note that the individual (identical) advertising telegrams used to encode the same data telegram use the same sequence counter value.
- **Security key**
Each PTM 215B is programmed with a random 16 byte security key during manufacturing. This key can be modified using the NFC interface, see chapter 6.7.4.

Table 9 below summarizes these parameters.

Parameter	Comment / Description	Example
Source Address	Unique source address of the PTM 215B module (little endian)	B819000015E2 (little endian representation of E215000019B8)
Input Data	Telegram data to be authenticated	0CFFDA035D04000011
Input Length	Length of input data (in bytes, encoded using 2 bytes)	0x0009 (if optional data size = 0, default) 0x000A (if optional data size = 1) 0x000B (if optional data size = 2) 0x000D (if optional data size = 4)
Sequence Counter	Incrementing counter to avoid replay Part of the input data (byte 4 ... 7)	5D040000 (little endian representation of the counter value 000045D)
Security Key	128 bit random key that is known both to sender and receiver	3DDA31AD44767AE3CE56DCE2B3CE2ABB

Table 9 – Variable input parameters

B.1.3 Obtaining the security key

PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE

All required parameters except the security key can be directly extracted from the received message that shall be authenticated.

The security key –the common secret shared between sender and receiver – has to be obtained via specific mechanisms. As described in chapter 5, there are three different ways to obtain the security key of a given PTM 215B module:

- Obtaining the key via the NFC configuration interface
- Obtaining the key via the product DMC code
- Obtaining the key via a dedicated commissioning telegram

Each option is described now in detail.

B.1.3.1 Obtaining the security key via NFC interface

Using the Elatec TWN4 reader (as described in chapter 6.3), the security key can be read using the following command sequence:

```
SearchTag(32)
NTAG_PwdAuth(0x00 0x00 0xE2 0x15,0x00 0x00)
NTAG_Read(0x14)
```

This is equivalent to the following binary command sequence:

```
Request: 050020
Response: 0001803807048831A2014F8020060000E2150000

Request: 20060000E2150000
Response: 0001

Request: 200014
Response: 00013DDA31AD44767AE3CE56DCE2B3CE2ABB
```

The tag response to the last command - NTAG_Read(0x14) - contains the password:

```
NTAG_Read(0x14) Result: true Page: 3DDA31AD44767AE3CE56DCE2B3CE2ABB
```

The password of this device is therefore: 3DDA31AD44767AE3CE56DCE2B3CE2ABB

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B.1.3.2 Obtaining the security key via the product DMC code

Each PTM 215B module contains a DMC code on its product label which identifies source address and security key of the module, see chapter 5.2.

The DMC code of the device used for this tutorial is shown in Figure 41 below.



Figure 41 – Example DMC code

This DMC code can be read using a suitable DMC code reader (e.g. QRbot smartphones). The content of this example DMC code is:

PTM215BIDE215000019B800B3DDA31AD44767AE3CE56DCE2B3CE2ABB

The structure of the DMC code is described in chapter 8.1.1. The location of the security key in above DMC string is marked red for reference. This means that the security key of this device is:

3DDA31AD44767AE3CE56DCE2B3CE2ABB

Note that the device label will be updated starting with product version DC-06 as described in chapter 8.2. The security key can then be obtained from the “Z” field as described there.

B.1.3.3 Obtaining the security key via a commissioning telegram

PTM 215B modules can send dedicated commissioning telegrams that identify their security key. Transmission of such commissioning telegrams can be triggered by means of a specific button sequence as described in chapter 5.3.

Note that this feature can be disabled via the NFC commissioning interface by setting the Disable Radio Commissioning flag in the Configuration register to 0b1 (see chapter 6.7.7).

The resulting commissioning telegram has the following payload:

1D FF DA 03 56 04 00 00 3D DA 31 AD 44 76 7A E3 CE 56 DC E2 B3 CE 2A BB B8 19 00 00
15 E2

Please see Figure 20 in chapter 5.3.2 for a description of the commission telegram structure. The location of the security key is for reference highlighted red above. This means that the security key of this device is:

3DDA31AD44767AE3CE56DCE2B3CE2ABB

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B.2 Internal parameters

The RFC3610 implementation in PTM 215B derives a set of internal parameters for further processing from the provided input parameters.

Again, there are two types of internal parameters:

- Constant internal parameters
These parameters are based on the high level algorithm and telegram properties and are the same for any PTM 215B telegram
- Variable input parameters
These parameters are based on the telegram-specific parameters and therefore depend on the specifics of the transmitted telegram

B.2.1 Constant internal parameters

The RFC3610 implementation in PTM 215B derives two internal parameters – M' and L' – based on the input data and uses them to construct $A0_Flag$ and B_0_Flag which – together with the iteration counter i – are required for subsequent processing.

The value of these internal parameters - listed in Table 10 below - is the same for all PTM 215B telegrams.

Parameter	Comment / Description	Example
M'	Binary encoded output length $M' = (\text{Output length} / 2) - 1$	0b001 (always)
L'	Binary encoded length field size $L' = \text{length field size} - 1$	0b001 (always)
$A0_Flag$	L'	0x01 (always)
$B0_Flag$	$(0b01 \ll 6) + (M' \ll 3) + L'$	0x49 (always)
i	Iteration counter	0x0000 (always)

Table 10 – Constant internal parameters

PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE

B.2.2 Variable internal parameters

The RFC3610 implementation in PTM 215B derives four internal parameters – Nonce, A0, B0 and B1 – based on the telegram specific input data and the constant internal parameters.

These variable internal parameters - listed in Table 11 below - are then used together with the security key to calculate the actual signature.

Parameter	Comment / Description	Example
Nonce	13 byte initialization vector based on concatenation of source address, sequence counter and padding, see 4.8.1	FE19000015E2D00A000000000000
A0	A0_Flag followed by Nonce followed by 2 byte 0x00	01FE19000015E2D00A00000000000000
B0	B0_Flag followed by Nonce followed by 2 byte 0x00 (no message to encode)	49FE19000015E2D00A00000000000000
B1	Input Length followed by Input Data followed by 5 / 4 / 3 / 1 byte of 0x00 padding (for optional data size = 0 / 1 / 2 / 4 byte)	00090CFFDA03D00A0000030000000000

Table 11 – Variable internal parameters

B.3 Algorithm execution sequence

The algorithm uses the variable internal parameters A_0, B_0, B_1 together with the private key to generate the authentication vector T_0 using three AES-128 and two XOR operations. The algorithm execution sequence is shown in Figure 42 below.

The first four bytes of T_0 are then used to authenticate PTM 215B telegrams.

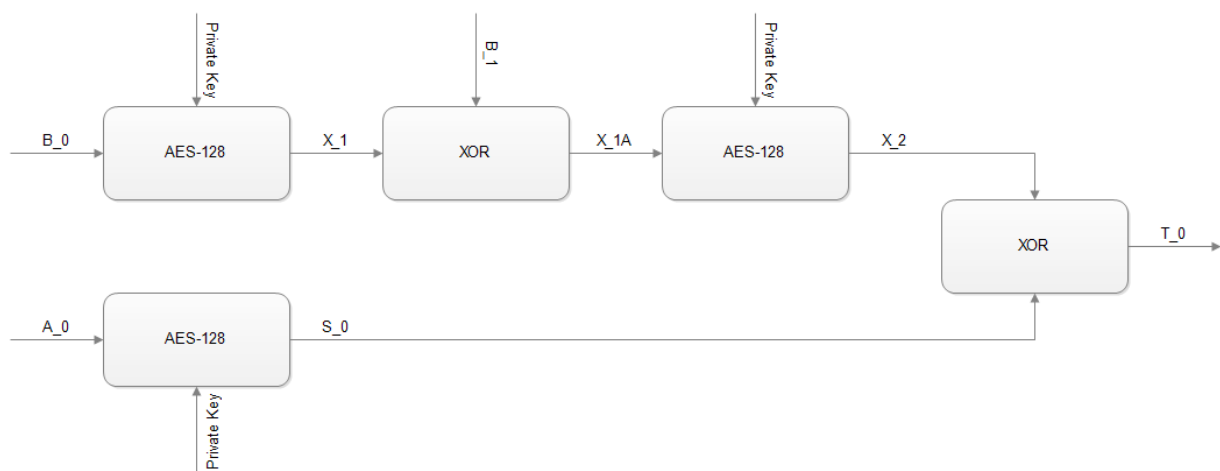


Figure 42 – Authentication algorithm sequence

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B.4 Examples

The following four chapters give step by step examples based on one actual device and 0 / 1 / 2 or 4 byte of optional data.

B.4.1 Data telegram without optional data

For this example, we consider the following telegram payload received from a PTM 215B with the source address E215000019B8 and security key 3DDA31AD44767AE3CE56DCE2B3CE2ABB:

```
0C FF DA 03 5D 04 00 00 11 B2 FA 88 FF
```

The last four bytes of this payload (B2 FA 88 FF) are the sender-provided signature which has to be authenticated (compared against the signature the receiver calculates based on its own security key).

The variable input parameters are therefore the following:

Parameter	In this example
Source Address	B819000015E2 (little endian representation of E215000019B8)
Input Data	0CFFDA035D04000011
Input Length	0x0009
Sequence Counter	5D040000
Security Key	3DDA31AD44767AE3CE56DCE2B3CE2ABB

The constant internal parameters are always the same:

Parameter	In this example
A0_Flag	0x01 (always)
B0_Flag	0x49 (always)
i	0x0000 (always)

Based on variable input data and constant internal algorithm parameters, we can now derive the following variable internal parameters:

Parameter	In this example
Nonce	B819000015E25D04000000000000
A0	01B819000015E25D0400000000000000
B0	49B819000015E25D0400000000000000
B1	00090CFFDA035D040000110000000000

We can now calculate the signature using AES128 and XOR operations.

At the time of writing, a suitable online AES calculator could be found here:
<http://testprotect.com/appendix/AEScalc>

Likewise, a suitable XOR calculator could be found here:
<http://xor.pw/>

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```
X_1 = AES128(B0, Key)
X_1 = AES128(49B819000015E25D0400000000000000, 3DDA31AD44767AE3CE56DCE2B3CE2ABB)
X_1 = 41ef09792ae152ae52c671435c1f247d
```

```
X_1A = XOR(X_1, B_1)
X_1A = XOR(41ef09792ae152ae52c671435c1f247d, 00090CFFDA035D040000110000000000)
X_1A = 41e60586f0e20faa52c660435c1f247d
```

```
X_2 = AES128(X1A, Key)
X_2 = AES128(41e60586f0e20faa52c660435c1f247d, 3DDA31AD44767AE3CE56DCE2B3CE2ABB)
X_2 = 8d89e733da516ae3e08f9e30184909fc
```

```
S_0 = AES128(A0, Key)
S_0 = AES128(01B819000015E25D0400000000000000, 3DDA31AD44767AE3CE56DCE2B3CE2ABB)
S_0 = 3f736fcc8bcaf2d4aabca0260fab7976
```

```
T_0 = XOR(X_2, S_0)
T_0 = XOR(8d89e733da516ae3e08f9e30184909fc, 3f736fcc8bcaf2d4aabca0260fab7976)
T_0 = b2fa88ff519b98374a333e1617e2708a
```

The calculated signature is formed by the first four bytes of T_0, i.e. it is B2 FA 88 FF. The calculated signature matches the signature that was transmitted as part of the payload. This proves that the telegram originates from a sender that possesses the same security key and the telegram content has not been modified.

PTM 215B – DOLPHIN BLUETOOTH® PUSHBUTTON TRANSMITTER MODULE

B.4.2 Data telegram with 1 byte optional data

For this example, we consider the following telegram payload received from a PTM 215B with the source address E215000019B8 and security key 3DDA31AD44767AE3CE56DCE2B3CE2ABB:

0D FF DA 03 62 04 00 00 10 12 B9 FE AC C1

The last four bytes of this payload (B9 FE AC C1) are the sender-provided signature which has to be authenticated. The variable input parameters are therefore the following:

Parameter	In this example
Source Address	B819000015E2 (little endian representation of E215000019B8)
Input Data	0DFFDA03620400001012
Input Length	0x000A
Sequence Counter	62040000
Security Key	3DDA31AD44767AE3CE56DCE2B3CE2ABB

Based on variable input data and constant internal algorithm parameters, we can now derive the following variable internal parameters:

Parameter	In this example
Nonce	B819000015E262040000000000
A0	01B819000015E2620400000000000000
B0	49B819000015E2620400000000000000
B1	000A0DFFDA0362040000101200000000

We can now calculate the signature as follows:

X₁ = AES128(B0, Key)
 X₁ = AES128(49B819000015E2620400000000000000, 3DDA31AD44767AE3CE56DCE2B3CE2ABB)
 X₁ = dc8d685f968e795b23f4370b3091f33f

X_{1A} = XOR(X₁, B₁)
 X_{1A} = XOR(dc8d685f968e795b23f4370b3091f33f, 000A0DFFDA0362040000101200000000)
 X_{1A} = dc8765a04c8d1b5f23f427193091f33f

X₂ = AES128(X_{1A}, Key)
 X₂ = AES128(dc8765a04c8d1b5f23f427193091f33f, 3DDA31AD44767AE3CE56DCE2B3CE2ABB)
 X₂ = 231be2ff54ca62fb38d32eaaaf1b447d

S₀ = AES128(A0, Key)
 S₀ = AES128(01B819000015E2620400000000000000, 3DDA31AD44767AE3CE56DCE2B3CE2ABB)
 S₀ = 9ae54e3e95de9f91a0c279537bc25b00

T₀ = XOR(X₂, S₀)
 T₀ = XOR(231be2ff54ca62fb38d32eaaaf1b447d, 9ae54e3e95de9f91a0c279537bc25b00)
 T₀ = b9feacc1c114fd6a981157f9d4d91f7d

The calculated signature is formed by the first four bytes of T₀, i.e. it is B9 FE AC C1.

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B.4.3 Data telegram with 2 byte optional data

For this example, we consider the following telegram payload received from a PTM 215B with the source address E215000019B8 and security key 3DDA31AD44767AE3CE56DCE2B3CE2ABB:

```
0E FF DA 03 63 04 00 00 11 12 34 52 E0 51 16
```

The last four bytes of this payload (52 E0 51 16) are the sender-provided signature which has to be authenticated. The variable input parameters are therefore the following:

Parameter	In this example
Source Address	B819000015E2 (little endian representation of E215000019B8)
Input Data	0EFFDA0363040000111234
Input Length	0x000B
Sequence Counter	62040000
Security Key	3DDA31AD44767AE3CE56DCE2B3CE2ABB

Based on variable input data and constant internal algorithm parameters, we can now derive the following variable internal parameters:

Parameter	In this example
Nonce	B819000015E263040000000000
A0	01B819000015E2630400000000000000
B0	49B819000015E2630400000000000000
B1	000B0EFFDA0363040000111234000000

We can now calculate the signature as follows:

```
X_1 = AES128(B0, Key)
X_1 = AES128(49B819000015E2630400000000000000, 3DDA31AD44767AE3CE56DCE2B3CE2ABB)
X_1 = ab5ec24beabc9ddeeb73751c7734cc64
```

```
X_1A = XOR(X_1, B_1)
X_1A = XOR(ab5ec24beabc9ddeeb73751c7734cc64, 000B0EFFDA0363040000111234000000)
X_1A = ab55ccb430bffedaeb73640e4334cc64
```

```
X_2 = AES128(X1A, Key)
X_2 = AES128(ab55ccb430bffedaeb73640e4334cc64, 3DDA31AD44767AE3CE56DCE2B3CE2ABB)
X_2 = d33e96d7a105c4e8543207f9e75e6cfe
```

```
S_0 = AES128(A0, Key)
S_0 = AES128(01B819000015E2630400000000000000, 3DDA31AD44767AE3CE56DCE2B3CE2ABB)
S_0 = 81dec7c16915c6647d92b0668f65e9c9
```

```
T_0 = XOR(X_2, S_0)
T_0 = XOR(d33e96d7a105c4e8543207f9e75e6cfe, 81dec7c16915c6647d92b0668f65e9c9)
T_0 = 52e05116c810028c29a0b79f683b8537
```

The calculated signature is formed by the first four bytes of T_0, i.e. it is 52 E5 11 16.

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B.4.4 Data telegram with 4 byte optional data

For this example, we consider the following telegram payload received from a PTM 215B with the source address E215000019B8 and security key 3DDA31AD44767AE3CE56DCE2B3CE2ABB:

```
10 FF DA 03 6A 04 00 00 10 12 34 56 78 2C 9E 10 95
```

The last four bytes of this payload (2C 9E 10 95) are the sender-provided signature which has to be authenticated. The variable input parameters are therefore the following:

Parameter	In this example
Source Address	B819000015E2 (little endian representation of E215000019B8)
Input Data	10FFDA036A0400001012345678
Input Length	0x000D
Sequence Counter	6A040000
Security Key	3DDA31AD44767AE3CE56DCE2B3CE2ABB

Based on variable input data and constant internal algorithm parameters, we can now derive the following variable internal parameters:

Parameter	In this example
Nonce	B819000015E26A040000000000
A0	01B819000015E26A0400000000000000
B0	49B819000015E26A0400000000000000
B1	000D10FFDA036A040000101234567800

We can now calculate the signature as follows:

```
X_1 = AES128(B0, Key)
X_1 = AES128(49B819000015E26A0400000000000000, 3DDA31AD44767AE3CE56DCE2B3CE2ABB)
X_1 = 434fa5855b8a8a8ae99bf1cb114a51b7
```

```
X_1A = XOR(X_1, B_1)
X_1A = XOR(434fa5855b8a8a8ae99bf1cb114a51b7, 000D10FFDA036A040000101234567800)
X_1A = 4342b57a8189e08ee99be1d9251c29b7
```

```
X_2 = AES128(X1A, Key)
X_2 = AES128(4342b57a8189e08ee99be1d9251c29b7, 3DDA31AD44767AE3CE56DCE2B3CE2ABB)
X_2 = 12c78b85a4ecb6f34daff7651db8e386
```

```
S_0 = AES128(A0, Key)
S_0 = AES128(01B819000015E2630400000000000000, 3DDA31AD44767AE3CE56DCE2B3CE2ABB)
S_0 = 3e599b103f33447e6b46eec4a042d0bc
```

```
T_0 = XOR(X_2, S_0)
T_0 = XOR(12c78b85a4ecb6f34daff7651db8e386, 3e599b103f33447e6b46eec4a042d0bc)
T_0 = 2c9e10959bdf28d26e919a1bdfa333a
```

The calculated signature is formed by the first four bytes of T_0, i.e. it is 2C 9E 10 95.