EMDC (Revision DB)

EnOcean Motion Detector And Light Level Sensor

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,
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REVISION HISTORY

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

Version	Author	Reviewer	Date	Major Changes
2.0	MKA	OT, RS	02 Apr 2025	First release for product revision DB

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Recycling information
Components of the modules are considered and should be disposed of as hazardous waste. Please use suitable recycling operators for modules, components or packaging.

TABLE OF CONTENT

1 General description

This user manual describes the functionality of the family of ceiling-mounted motion detectors and light level sensors EMDC in product revision DB. Please contact EnOcean for documentation about the previous revision DA.

The EMDC product family consists of the following members:

- EMDCA using 868.300 MHz radio (main market Europe)
- EMDCU using 902.875 MHz radio (main market US / Canada)
- EMDCJ using 928.350 MHz radio (main market Japan)

The term "EMDC" is used throughout this user manual to describe all three variants unless otherwise noted.

1.1 Basic functionality

EMDC enables the realization of energy harvesting wireless occupancy and light level sensors for light, building or industrial control systems communicating with the 868.300 MHz (EMDCA), 902.875 MHz (EMDCU) or 928.350 MHz (EMDCJ) versions of the EnOcean radio standard.

EMDC uses a passive infrared (PIR) sensor to detect motion and either a dedicated illumination sensor or a calibrated solar cell to measure the ambient light level.

EMDC reports periodically (approximately every 2 minutes when no motion is detected, approximately every 1 minute when motion is detected) the latest motion detection status (motion detected, or no motion detected). EMDC will report immediately if motion is detected for the first time after a period without detected motion (for instance when a person is entering a room).

EMDC will use EnOcean Equipment Profiles (EEP) of the EnOcean radio standard for the reporting of the motion detection status. Depending on the selected EEP, EMDC will additionally report the measured ambient light level and the measured temperature status.

EMDC is self-supplied via an integrated solar cell which generates the energy required for its operation. EMDC operates fully self-powered (no batteries required) if 200 lux of illumination is present for at least 6 hours per day.

For cases where sufficient ambient light is not available, EMDC provides the option to install a CR2032 backup battery.

EMDC supports both standard and high security mode as specified by EnOcean Alliance. In high security mode, radio telegrams transmitted by EMDC are both encrypted and authenticated using AES-128 with a device-unique private key and a sequence counter. This ensures confidentiality, integrity, authenticity and originality of the transmitted telegrams and prevents telegram replay (retransmission of previously transmitted telegrams).

1.2 Technical data

The table below provides the technical data for EMDC. Unless stated otherwise, all values are typical values at room temperature (+25°C / 77 F) using the default product configuration.

Transmission Frequency / Power	EMDCA: 868.300 MHz / +5 dBm EMDCU: 902.875 MHz / + 99dBuV EMDCJ: 928.350 MHz / 0 dBm
Transmission Data Rate	125 kbit / s
Communication Range (For Guidance Only)	Up to 30 m for indoor line-of-sight environment
Recommended Installation	Ceiling-mounted at 2.5 m (8.5 ft) … 3 m (10 ft) height
Motion Detection Radius	typ. 5 m (16 ft.) when mounted 2.5 m (8.5 ft.) high
Illumination Measurement Range	0 … 65000 lux
Update Rate Without / With Detected Motion	Approximately every 2 minutes / every 1 minute Initial motion detection is reported immediately
Supported EEP	A5-07-03 (default) A5-07-01 A5-08-01, A5-08-02, A5-08-03 D2-15-00
User Interface	LRN button Sensitivity selection switch Bi-color (red / green) notification LED
Configuration Interface	NFC (ISO 14443)
Power Supply	Integrated solar cell
Required Illumination To Sustain Operation	200 lux for 6 hours per day
Charge Time (Empty To First Transmission)	5 minutes at 400 lux
Charge Time (Empty To Full Charge)	45 hours at 1000 lux
Start-up Time (Standby to Active)	120 seconds
Operating Time (In Darkness)	Up to 7 days (after full charge)
Backup Power Supply (Optional)	CR2032
Backup Battery Life (CR2032 With 230mAh) Occasional bright light (200 lux for 3 hrs every day) Consistent low light (75 lux for 6 hrs every day) Total darkness	 Up to 10 years Up to 7 years Up to 5 years
Dimensions	113,2 mm L x 65,5 mm W x 30,7 mm H (4.46” L x 2.58” W x 1.21” H)

1.3 Environmental conditions

Maximum Operating Temperature(1)	-5 °C … +45 °C / 25 … 115 F (indoor use only)
Recommended Operating Temperature(1)	0°C … 30 °C / 32 … 85 F (indoor use only)
Humidity	20 % r.h. … 85 % r.h. (non-condensing)

Note 1: PIR detection requires that the environment is significantly colder than the moving object to be detected. Human motion detection therefore requires that the environment is significantly colder than the human body temperature of 36.5 °C / 98 F.

1.4 Packaging information

Packaging Unit	12 units
Packaging Method	Box / pallet

1.5 Ordering information

Type	Ordering Code	Frequency
EMDCA	E6201-K515:DB	863.300 MHz
EMDCU	E6251-K515:DB	902.875 MHz
EMDCJ	E6261-K515:DB	928.350 MHz

2 Functional description

2.1 EMDC product overview

The energy harvesting ceiling-mounted motion and illumination sensor EMDC from EnOcean provides wireless motion and illumination sensing functionality without batteries. Power is provided by a built-in solar cell harvesting available light from the environment.

EMDC transmits sensor data based on the EnOcean radio standard using the selected EnOcean Equipment Profile (EEP) as described in chapter 5 and the selected security mode as described in chapter 6.

The outer appearance of EMDC is shown in Figure 1 below.

Figure 1 – EMDC external view

2.2 Start-up

Upon delivery, EMDC is in Standby (Sleep) mode as described in Chapter 2.7.2 to conserve energy and to comply with regulation prohibiting radio transmission during transport.

To start EMDC operation, follow these steps:

1. Place EMDC under bright light (light source or near to a window)
2. Press the LRN button once to request start of operation
3. Leave under the selected light source for 5 minutes to provide an initial charge for operation

After that, EMDC will be ready for operation and will blink every time when a telegram is transmitted.

2.3 Basic functionality

EMDC devices contain a passive infrared sensor that detects changes in the received infrared radiation which are characteristic for the movement of people.

Starting with product revision DB, EMDC also provides the option to count the amount of detected people movement events (people activity counting).

In addition, EMDC measures ambient light level via a dedicated sensor or via the integrated solar cell and temperature using a sensor in the integrated microcontroller.

EMDC integrates a solar cell that generates the required energy for its operation from available ambient light.

The user interface of EMDC consists of one button for simple configuration tasks and one bicolor (red / green) LED to provide user feedback. Configuration of all EMDC parameters is possible via an integrated NFC (ISO 14443) interface.

EMDC is designed for ceiling mounting; it can be mounted on most ceilings with suitable screws or mounted on dropped ceilings using wire brackets.

2.4 External product interface

The external product interface consists of the following items:

- Infrared lens working together with a passive infrared sensor for motion detection
- Ambient light sensor for narrow beam light measurement
- Solar cell for powering the device and for wide area light measurement
- User interface with one button (LRN) and one LED for simple configuration tasks
- NFC interface with antenna (not visible) providing the configuration interface
- Wall mount plate (with opening slot for removal) for product mounting

Figure 2 below shows the location of these items.

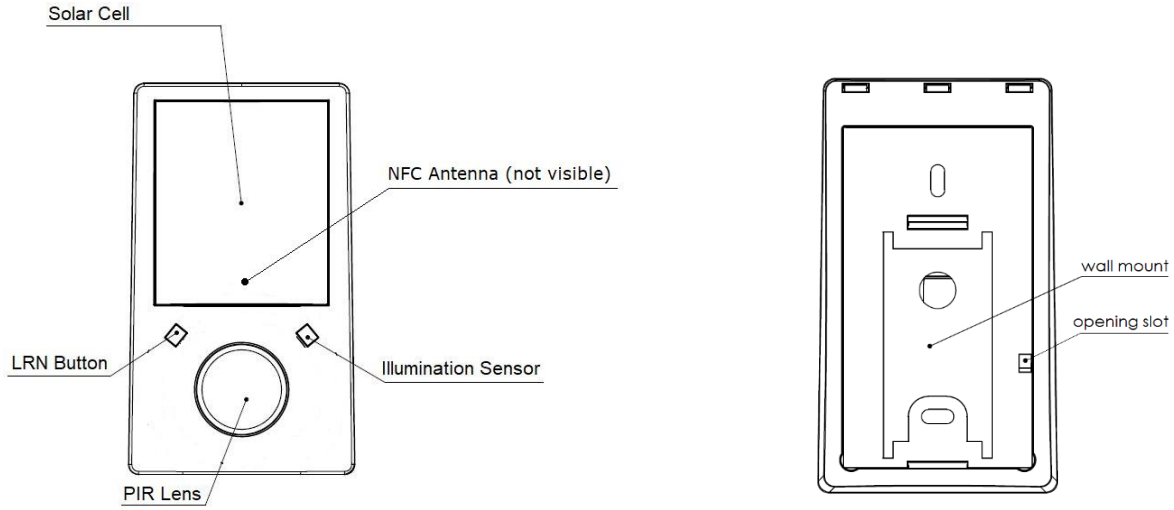

Figure 2 – EMDC front and rear view

2.5 Internal product interface

EMDC contains a holder for a CR2032 battery and a PIR sensitivity selection switch as shown in Figure 3 below.

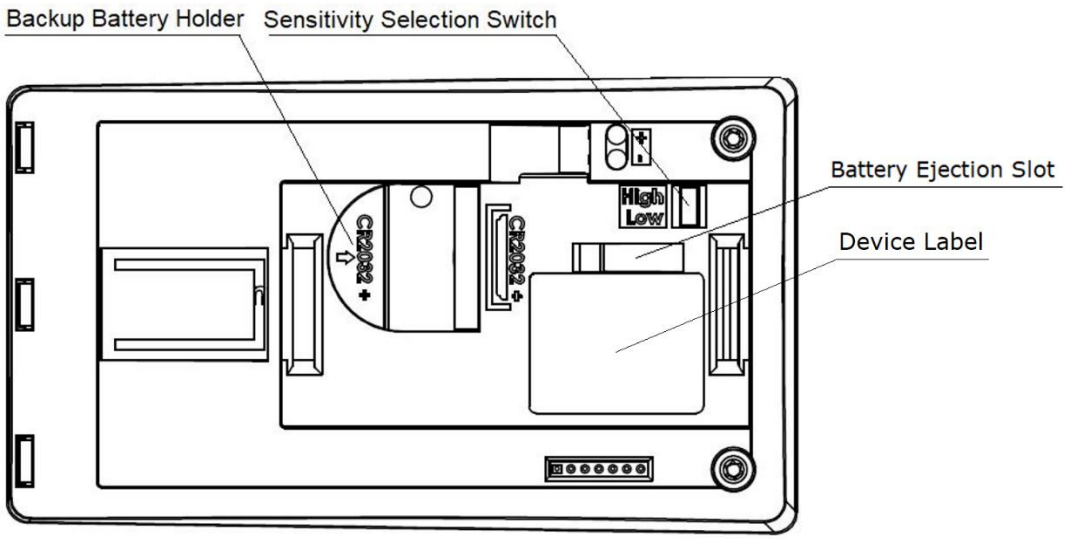

Figure 3 – EMDC internal view

The internal product interface is accessible after removing the wall mount plate.

If EMDC has not yet been mounted onto the ceiling, then the wall mount plate can be removed by inserting a screwdriver (or similar tool) into the opening slot shown in Figure 2 and pushing the wall mount plate outwards.

If the EMDC wall mount plate is already attached to the ceiling, then EMDC can be removed by gently pulling the housing.

A backup battery can be inserted into the backup battery holder and removed by inserting a suitable tool into the battery ejection slot as described in chapter 4.3.

2.6 Energy harvesting functionality

EMDC can generate the energy required for its operation from available ambient light. EMDC will accumulate the energy generated from available ambient light to enable operation in periods without available light.

EMDC is designed to operate for one full day (24 hours) based on 200 lux of ambient light available for 6 hours and a room occupancy of 6 hours during this day. This means that 6 hours of available light will provide enough energy for 24 hours (6 hours with light, 18 hours without light) of operation.

If ambient light is available for more than 6 hours per day, then EMDC will accumulate the additional energy so that it can operate for more than 18 hours without light. EMDC can accumulate energy for up to 7 days of operation without light.

The amount of available ambient light can either be determined by using a suitable lux meter or by executing an ambient light test as described in chapter 2.7.5.

2.7 Functional modes

EMDC supports six types of functional modes:

- Standard Operation mode
- Standby (sleep) mode
- Learn Telegram mode
- Walk Test mode
- Ambient Light Test mode
- Factory Reset mode

These modes are described below.

2.7.1 Standard Operation mode

During standard operation, EMDC wakes up periodically and transmits data telegrams which report the motion detection status and – depending on the selected EEP - also the measured light level and temperature. The motion detection functionality is described in chapter 3.1, the light level sensing functionality in chapter 3.2 and the temperature monitor functionality in chapter 3.3.

The EMDC wake-up timer is configured to wake-up EMDC approximately every 2 minutes during periods without detected motion (unoccupied wake-up interval) and approximately every 1 minute during periods with detected motion (occupied wake-up interval). If motion is detected for the first time after a period without motion, then EMDC wakes up immediately.

Both the occupied and the unoccupied wake-up intervals are affected at random (resulting in slightly larger or smaller intervals) to increase the robustness of the radio transmission and to comply with regulatory requirements.

It is possible to change the wake-up intervals using the NFC interface. In case of reducing the reporting interval, the resulting increase in required energy (provided by the available light or a backup battery) must be considered.

2.7.2 Standby (Sleep) mode

Standby (Sleep) mode is used to conserve as much energy as possible during periods of storage or transport. All functionality – except those needed to return to standard operation mode – is disabled in this mode.

Standby mode is the out of box condition for newly delivered devices. Standby mode can additionally be selected using the LRN button as described in chapter 4.1 or using the NFC interface as described in chapter 8 to account for longer periods without activity.

When exiting Standby mode, EMDC requires an initialization time (from standby mode to first telegram) of 120 seconds.

2.7.3 Walk Test mode

Walk Test mode is used to verify the motion detection coverage of the device via visual feedback from the LED. The LED will blink green if motion has been detected and red if no motion has been detected. Walk Test mode can be selected using the LRN button as described in chapter 4.1 or using the NFC interface as described in chapter 8.

Walk Test mode will be active for a period of 120 seconds; it will end immediately if the LRN button is pressed while walk test mode is active. Walk Test mode can only be executed if the energy store of EMDC is sufficiently charged. If required, a backup battery can be fitted for the purpose of executing Walk Test mode.

2.7.4 Learn Telegram mode

In Learn Telegram mode, EMDC will first transmit a security teach-in telegram to communicate the security parameters used by EMDC (if EMDC operates in high security mode and transmission of a security teach-in telegram is enabled).

After that, EMDC will transmit an EEP teach-in telegram to communicate the EnOcean Equipment Profile (EEP) used by EMDC to a receiver.

Please refer to chapter 7.1 for a description of these telegrams. After the learn telegram transmission is complete, EMDC will return to Standard Operation mode.

Learn Telegram mode can be selected using the LRN button as described in chapter 4.1 or using the NFC interface as described in chapter 8.

2.7.5 Ambient Light Test mode

During installation, EMDC can measure and report the amount of ambient light available at its solar cell to determine a suitable installation location as discussed in chapter 9.4.

Upon activation of Ambient Light Test mode, EMDC will first wait for 15 seconds so that the installer can leave the area to ensure a relevant measurement result. This period is indicated by the LED blinking red.

After that, EMDC will take measurements of the ambient light level using its solar cell every 5 seconds for a period of one minute and compute the average illumination based on those measurements. This period is indicated by the LED blinking green.

Completion of Ambient Light Test mode is indicated by the LED blinking one time green and one time red.

Ambient Light Test mode can be selected, and the computed average illumination can be read using the NFC interface as described in chapter 8. Ambient Light Test mode can be aborted by button press if required.

2.7.6 Factory Reset mode

EMDC can be reset to its standard settings using Factory Reset mode. Upon entering this mode, EMDC will reset its configuration registers to their default settings and then restart operation in Standard Operation mode.

Factory Reset mode can be selected using the LRN button as described in chapter 4.1 or using the NFC interface as described in chapter 8.

2.8 Reporting interval

EMDC will report initial motion detection after a period without detected motion immediately. The rate of subsequent reporting (reporting interval = time between two data telegrams) can be configured by the user based on different conditions.

The minimum configurable reporting interval is 3 seconds, and the maximum possible transmission interval is 65535 seconds.

2.8.1 Standard (Unoccupied) reporting interval

The standard reporting interval (STANDARD_TX_INTERVAL) determines the interval between two status reports of EMDC while it does not detect motion, and the available light level does not exceed a user-defined threshold.

The default setting of STANDARD_TX_INTERVAL is one status report every 120 seconds (2 minutes).

EMDC can be configured to use a lower reporting interval - i.e. a higher reporting rate – if available light exceeds a user-defined threshold or if motion is detected as described in the subsequent chapters.

The standard reporting interval can be adjusted using the NFC interface as described in chapter 8. Figure 4 below illustrates the use of the standard reporting interval.

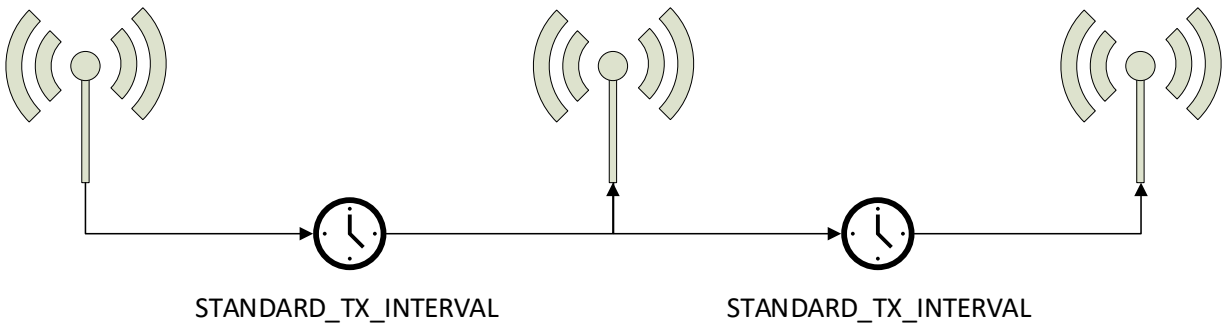

Figure 4 – Standard reporting interval

2.8.2 Occupancy-controlled reporting interval

If motion is detected – i.e. if a room is occupied, then it might be desirable to receive status reports more often to determine the current light level and motion detection status.

To address this requirement, EMDC can be configured to report using a lower reporting interval (OCCUPIED_TX_INTERVAL) while motion is detected. The default setting of OCCUPIED_TX_INTERVAL is 60 seconds. This setting can be changed using the NFC interface as described in chapter 8.

If a room had been occupied and becomes unoccupied, then EMDC will send the first report indicating "unoccupied" status after OCCUPIED_TX_INTERVAL (which is typically shorter than STANDARD_TX_UINTERVAL) has elapsed. This ensures that the receiver is promptly notified about the change in room occupancy.

Subsequent reports without detected motion will be sent using STANDARD_TX_INTERVAL. If motion is detected again, then a report indicating "occupied" status will be sent immediately.

Figure 5 below illustrates the use of the occupancy-controlled reporting interval.

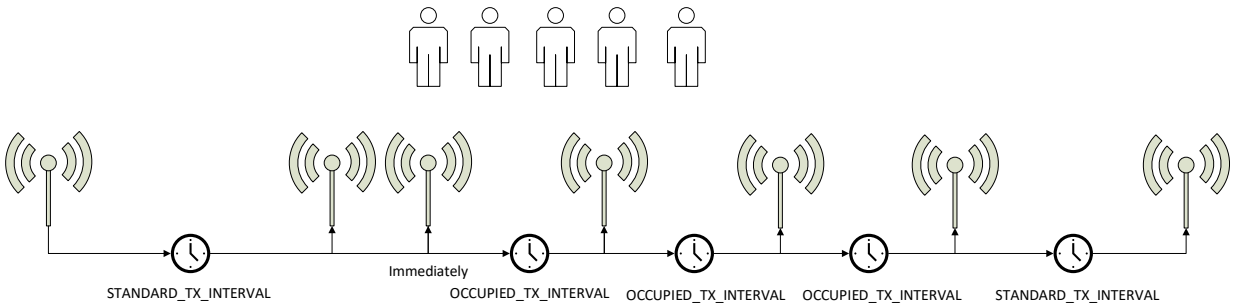

Figure 5 – Occupancy-controlled reporting interval

2.8.3 Illumination-controlled reporting interval

If sufficient ambient light is available, then it might be desirable to receive status updates more often. For this, there are typically two main use cases:

- Adjust the update rate based on the ambient light available for harvesting
- Report more often during daytime (or when an office is lit) and less often during night-time (or when an office is dark) to adapt the reporting to the usage pattern

In both cases, the lower update rate (defined by the standard reporting interval) would be used whenever the ambient light level is below a certain threshold. The higher update rate (defined by the light level-controlled reporting interval) would be used whenever the ambient light level is above a certain threshold.

In EMDC, the light threshold and the reporting interval rate to be used when the measured light level is above the threshold can be configured using the NFC interface as described in chapter 8.

It is possible to define different thresholds and reporting intervals for the solar cell (harvested energy) using SOLAR_TX_THRESHOLD and SOLAR_TX_INTERVAL and the light level sensor (measured light level) using LIGHT_SENSOR_THRESHOLD and LIGHT_SENSOR_INTERVAL.

Figure 6 below illustrated the use of the illumination-controlled reporting interval.

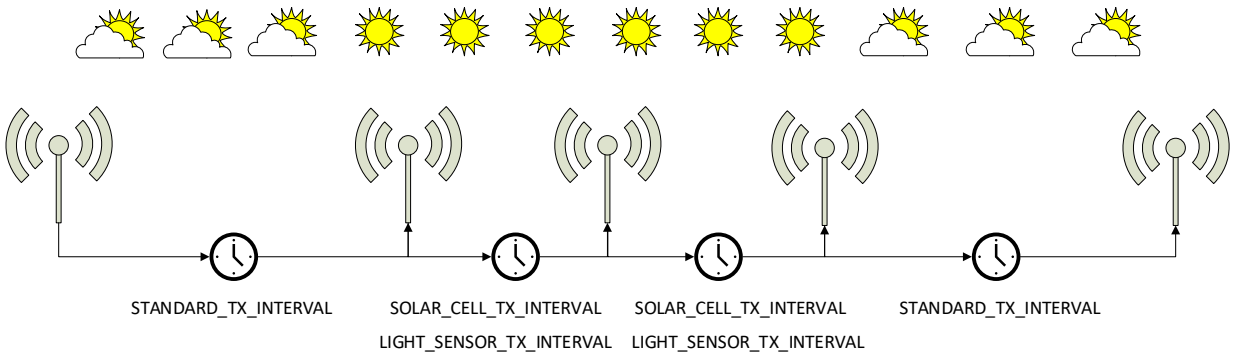

Figure 6 – Illumination-controlled reporting interval

2.8.4 Arbitration between reporting intervals

If more than one condition for a lower reporting interval applies – e.g. if a room is both occupied and brightly lit – then the lowest of the corresponding reporting intervals will be selected.

3 Sensor functionality

EMDC implements the following sensor functions:

- Motion detection (and optionally counting of motion events) using the passive infrared sensor (PIR)
- Illumination measurement using the light level sensor
- Illumination measurement using the solar cell
- Supply voltage of the energy store
- Supply voltage of the backup battery (if present)

These functions are described in detail in the subsequent chapters.

3.1 Motion detection

EMDC contains an integrated passive infrared (PIR) sensor that can detect moving objects based on the temperature difference between the moving object and its environment.

3.1.1 PIR detection characteristics

EMDC is designed to detect movement within a radius of up to 5 m (16 ft.) when mounted at a ceiling of 3 m (10 ft.) height. The recommended coverage area for best detection performance is within a radius of 3 m (10 ft).

Figure 7 shows the PIR detection pattern.

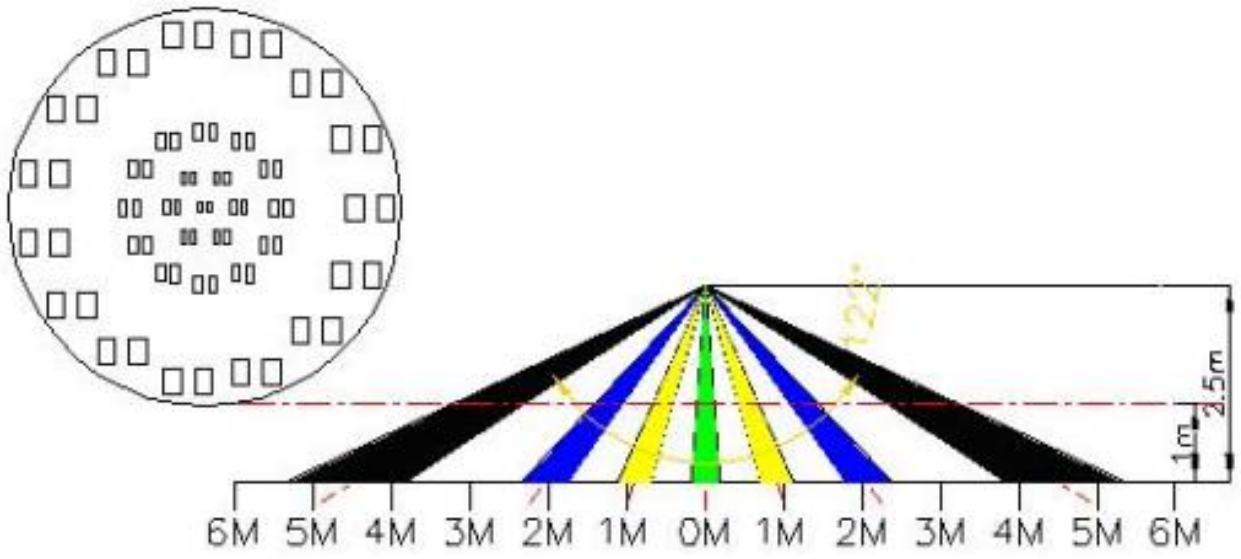

Figure 7 – EMDC PIR detection pattern

3.1.2 Activity counting

Starting with product revision DB, EMDC can count, and report how often motion events were detected during the reporting interval.

The reporting of the number of motion events is done based on a 16-bit activity counter that is incremented based on the number of detected motion events as described below. The activity counter is initialized to 0 upon enabling people activity counting functionality (by selecting the people activity counting EEP D2-15-00 via the NFC interface) and upon exiting standby (sleep) mode. The activity counter will wrap around to 0 upon reaching 65535.

The number of motion events is determined by dividing the reporting interval into sub-intervals with a duration of 6 seconds per sub-interval. This means that an occupied reporting interval of 60 seconds would be sub-divided into 10 sub-intervals of 6 seconds each.

During each such sub-interval, EMDC will determine if motion has been detected or not. If motion has been detected during the duration of a sub-interval, then this sub-interval will be considered as sub-interval with activity. If no motion has been detected during the duration of a sub-interval, then this sub-interval will be considered as sub-interval without activity.

When EMDC is due to report its status, it will count the sub-intervals with activity, increment the activity counter by that value and report the resulting value of the activity counter. The receiver can then determine the number of motion events as difference between the current and the most recently reported activity counter value.

Should the current activity counter value be less than the most recently reported activity counter value, then wrap-around occurred and a value of 65536 must be added to the difference between the current and the most recently reported value.

3.2 Illumination measurement

EMDC offers two user-configurable, alternate options to measure and report the light level in the surrounding area. Each of these option serves different purposes, and their results can be different, depending on the surrounding circumstances. Refer to chapter 9.3 for a discussion about the respective benefits of the two options.

The option used for light level measurement is selected using the NFC interface as described in chapter 8. By default, the light level sensor is used.

3.2.1 Illumination measurement with light level sensor

EMDC integrates a dedicated illumination sensor used to measure and report the light level directly underneath (for instance on the surface of a working desk).

This sensor has a narrow aperture, and a spectral response optimized to mimic the human eye's perception of ambient light. It reports the light level directly underneath the sensor (spot measurement). Figure 8 shows the spectrum response of the EMDC illumination sensor compared to that of the human eye.

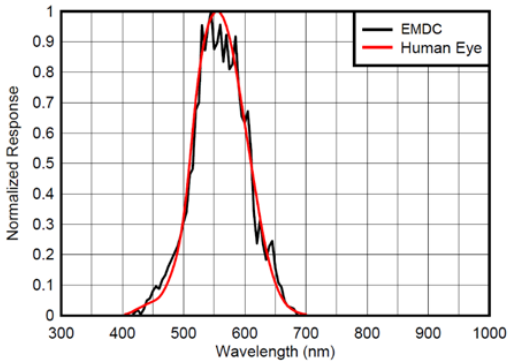

Figure 8 – Spectrum response of the illumination sensor

Note that use cases such as light measurement on desk surfaces always require calibration on the receiver side to account for different light reflection characteristics. Use of the solar cell for illumination measurements – as described below - is recommended for applications where the average light level over a wider area should be measured.

3.2.2 Illumination measurement with solar cell

EMDC can report the light level of the surrounding area based on measurement taken while using the integrated solar cell. The solar cell has been factory calibrated for universal use and offers a wide field of view and a broad spectral sensitivity, covering LED, fluorescent, incandescent and natural light sources.

If mounted close and facing towards a window, it can serve well as a daylight sensor for EnOcean Easyfit lighting controllers.

3.3 Temperature monitor

EMDC uses the temperature monitor within the microcontroller to detect abnormal temperature conditions (very hot, very cold, quick change of temperature). This temperature monitor provides a resolution of 1°C, i.e. it reports only integer values.

EMDC provide the option for offset calibration of the temperature monitor using the NFC interface described in chapter 8.

Due to the limited accuracy of the temperature monitor, the temperature reporting of EMDC is not suitable for high accuracy HVAC control.

3.4 Energy generation

EMDC can measure and report (using SIGNAL telegrams as described in chapter 5.2) the amount of energy generated by the solar cell. Reporting of the solar cell energy generation level can be enabled and disabled via the SIGNAL register of the NFC interface as described in chapter 8. By default, the reporting is disabled.

3.5 Energy level estimation

EMDC can measure the voltage of the internal energy store which stores the harvested energy to supply the device when the ambient light is insufficient to power the device. Based on the measured voltage, EMDC can then estimate the energy level (amount of remaining energy).

The measurement, estimation and reporting functionality can be enabled and disabled via the NFC interface described in chapter 8. By default, this functionality is enabled, and one energy estimation will be executed for every 32 data telegrams. The estimated energy will be reported as a percentage between 0% (empty) and 100% (fully charged) using SIGNAL telegrams as described in chapter 5.2.

Note that the estimated energy level can only provide a rough guidance to determine if the internal energy is increasing, decreasing or stable. The actual energy level depends on several factors (most notably the ambient temperature). In many cases, the estimated energy level will therefore not change linearly from 100% to 0%.

3.6 Backup battery voltage

EMDC can measure the supply voltage level of external backup battery used to supply the device when the available ambient light is insufficient for energy harvesting operation.

The measured backup battery voltage can be reported using SIGNAL telegrams as described in chapter 5.2. The measurement and reporting can be enabled and disabled via the NFC interface as described in chapter 8. By default, the backup battery voltage reporting is disabled.

4 User interface

The user interface of EMDC consists of the following items:

- LRN button and LED
- Backup battery interface
- Sensitivity selection switch
- Device label

Please refer to chapter 2.4 and 2.5 to identify the location of these items. They are described in more detail below.

4.1 LRN button and LED

Most EMDC device parameters can be configured using the NFC interface as described in chapter 8. Some of the most common parameters or states can additionally be configured using the LRN button with the LED providing visual feedback.

Table 1 below lists those configuration actions. Note that the LRN button is locked while EMDC is in Sleep Mode to protect against unintended configuration actions during transport. In this mode, the only supported action is Single Short Press which is used to wake-up the device.

Event / User Action	**Action**	**LED Indication**
Telegram Transmission (No Button Action)	***Data Telegram Transmission*** Indication of data telegram transmission	1 blink red
NFC Configuration (Not Button Action)	***NFC Configuration Event*** Configuration Update via NFC Factory Reset via NFC	Config Success: 4 blink green Config Error: 4 blink red Reset Success: 5 blink green Reset Error: 5 blink red
Single Short Press (Press < 1s)	***LRN Telegram Transmission*** *If in Standard Mode:* Send Standard LRN Telegram *If in High Security Mode:* Send Secure LRN Telegram *If in Sleep Mode:* Wake up to Standard Mode Send Standard LRN Telegram	 2 blink green 3 blink green 2 blink green
Double Short Press (Each Press <1s Pause in between <1s)	***Start Function Test*** Measure and report sensor status every 3 seconds Indicate PIR detection status via LED Function test ends after 2 minutes or upon any button press	Start: 2 blink red-green No motion detected: 1 blink red Motion detected: 1 blink green

Triple Short Press (Each Press <1s Pauses in between <1s)	***Transition to High Security Mode and Send Security LRN Telegram*** *If in Standard Mode:* Enter High Security Mode Send Secure LRN Telegram *If in High Security Mode:* Stay in High Security Mode Send Secure LRN Telegram	 3 blink green 3 blink green
Quad Short Press (Each Press <1s Pauses in between <1s)	***Transition to Standard Mode and Send LRN Telegram*** *If in Standard Mode:* Stay in Standard Mode Send LRN Telegram *If in High Security Mode:* Enter Standard Mode Send LRN Telegram	 2 blink green 2 blink green
Single Long Press (Press 3s … 5s)	***Transition to Sleep Mode*** *If in Sleep Mode:* Stay in Sleep Mode *If in any other mode:* Enter Sleep Mode	 3 blink red 3 blink red
Double Long Press (Each Press 3s … 5s Pause in between <1s)	***Toggle LED Indication*** *If LED Indication is Enabled:* Disable LED Indication *If LED Indication is Disabled:* Enable LED Indication	 4 blink red 4 blink green
Single Very Long Press (Press >= 7s)	***Factory Reset*** Reset device configuration (to default configuration values)	 Success: 5 blink green Insufficient energy: 5 blink red

Table 1 – EMDC LRN button actions

4.1.1 LRN button timing

To guide users regarding the expected duration of long and very long button presses, EMDC will indicate the timing of a long button press by one short red blink and the timing of a very long button press by two red blinks as shown in Table 2.

Type of press	Duration	LED Timing Indication
Short	< 3 seconds	None
Long	> 3 seconds	One short red blink after 3 seconds
Very long	> 7 seconds	One short red blink after 3 seconds Two short red blinks after 7 seconds

Table 2 – LED timing indication

4.2 Factory Reset

The EMDC configuration can be reset to the factory default values by means of a factory reset. Factory reset is triggered by pressing and holding the LRN button for more than 8 seconds as described above.

EMDC will blink 5 times green to indicate successful execution of a factory reset.
Should factory reset fail due to insufficient energy, then EMDC will restart operation after 60 seconds.

4.3 Backup battery interface

The backup battery interface allows supplying EMDC with a CR2032 battery in case the available ambient light is insufficient for energy harvesting operation. EnOcean recommends using Renata batteries due to their low self-discharge characteristics.

The CR2032 backup battery can be inserted by gently pushing it into the backup battery slot. Note that the positive terminal (+) must face upwards (away from the PCB).

The backup battery can be removed (ejected) by using a small, non-conductive item (e.g. wooden toothpick) to push the battery out via the battery ejection slot shown in Figure 2.

4.3.1 Safety remarks

Please familiarize yourself with the following safety remarks before using a backup battery:

Do not insert any tools into the battery slot or the battery ejection slot. Doing so could create a short circuit or damage the PCB resulting in permanent damage.

CAUTION: Risk of damage or explosion if a battery of incorrect type is used.
The battery shall be rated for operation up to 60°C.

This product can contain a coin/button cell battery. If the coin/button cell battery is swallowed, it can cause severe internal burns in just 2 hours and can lead to death.

Keep new and used batteries away from children.

4.4 Sensitivity selection switch

The sensitivity selection switch allows reducing the detection range from its default radius of up to 5 m to a reduced radius of up to 3 m.

Note that the exact detection radius depends on a number of factors including the mounting height and the ambient temperature.

4.5 Device label

Each EMDC device contains a product label identifying the product revision, the manufacturing date, the frequency and the device radio address. Figure 9 below shows the EMDC device label for the case of EMDCA (868.3 MHz).

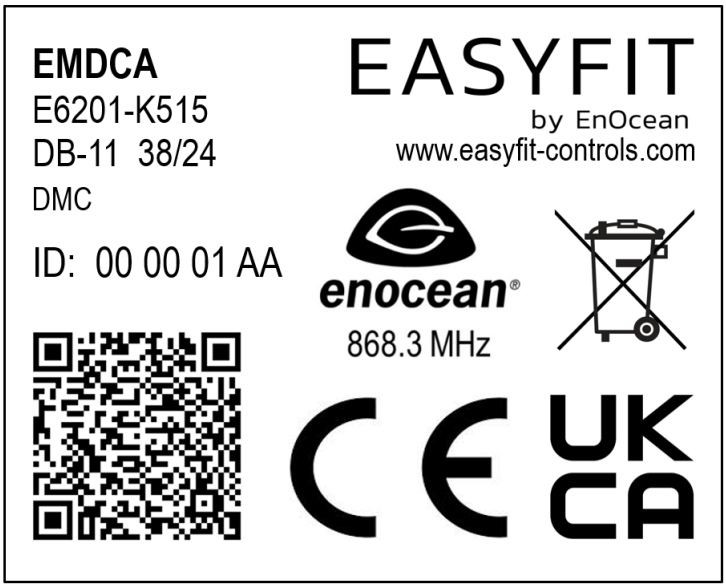

Figure 9 – EMDCA Device Label

The label in this example identifies the following parameters:

- Device type: EMDCA
- Product Revision: DB-11
- Manufacturing Date: Week 38, 2024
- Radio address (EURID): 000001AA
- Operating frequency: 868.3 MHz

In addition to that, the QR code in the bottom left corner can be used for commissioning as described in chapter 7.2.

5 Radio communication

EMDC communicates using radio telegrams encoded according to the EnOcean Equipment Profile (EEP) specification and the EnOcean Alliance Signal Telegram specification on a radio link according to the EnOcean Alliance Radio Protocol (ERP).

Appendix A provides an introduction to EnOcean Alliance radio standard.

5.1 Supported EEP types

EMDC supports a wide range of EEP suitable for different use cases. Table 3 below lists the supported EEP. For a detailed description of these EEP, please refer to [5].

Profile	Type	Reported Parameters	Parameter Range	Size
A5-07-01	4BS	Supply Voltage	0 … 5.0 V (50 mV step size)	8 bit
		Motion Detection Status	Motion Detected Motion Not Detected	1 bit
A5-07-03 (Default)	4BS	Supply Voltage	0 … 5.0V (50mV step size)	8 bit
		Motion Detection Status	Motion Detected Motion Not Detected	1 bit
		Light Level	0 … 1000 lx	10 bit
A5-08-01	4BS	Supply Voltage	0 … 5.0 V (50 mV step size)	8 bit
		Motion Detection Status	Motion Detected Motion Not Detected	1 bit
		Light Level	0 … 510 lx	8 bit
		Temperature	0 … 51 °C	8 bit
A5-08-02	4BS	Supply Voltage	0 … 5.0 V (50 mV step size)	8 bit
		Motion Detection Status	Motion Detected Motion Not Detected	1bit
		Light Level	0 … 1020 lx	8 bit
		Temperature	0 … 51 °C	8 bit
A5-08-03	4BS	Supply Voltage	0 … 5.0 V (50 mV step size)	8 bit
		Motion Detection Status	Motion Detected Motion Not Detected	1 bit
		Light Level	0 … 1530 lx	8 bit
		Temperature	-30 … 50 °C	8 bit

D2-15-00	VLD (3 byte)	Motion Detection Status	Motion Detected Motion Not Detected Motion Detection Error	2 bit
		Energy Status	High, Medium, Low, Critical	2 bit
		Activity Measurement Interval	1 … 16 seconds	4 bit
		Activity Counter Value	0 … 65535	16 bit

Table 3 – Supported EEP types

The default EEP used by EMDC is A5-07-03. It is possible to select a different supported EEP via the NFC configuration interface described in chapter 8.

5.2 Supported SIGNAL types

Table 4 below lists the SIGNAL types supported by EMDC together with their reported data. For a detailed description of these SIGNAL types, please refer to [6].

MID	Content	Data
0x06	Energy status (remaining energy) Enabled by default	1 byte integer value (expressing %) Valid values: 0 … 100
0x0D	Energy delivery of the harvester Disabled by default	1 byte Enumeration Valid values: 0x00 (best) ... 0x04 (worst)
0x0E	Deactivation of radio (Transmitted upon entry to Standby mode)	No data
0x10	Backup battery status Disabled by default	1 byte integer value (expressing %) Valid values: 0 … 100

Table 4 – Supported SIGNAL Types

The SIGNAL telegram with MID 0x0E indicates entry to Standby mode as described in Chapter 2.7.2. It is transmitted once, upon entry to Standby mode, to inform the receiver that EMDC now stops transmission.

The transmission of SIGNAL telegrams using other MID can be individually enabled and disabled using the NFC interface as described in chapter 8.

By default, transmission of SIGNAL telegram with MID 0x06 (Energy Status) is enabled while transmission of SIGNAL telegram with MID 0x0D (Energy Delivery) and MID 0x10 (Backup Battery Status) is disabled.

EMDC will transmit each of the enabled SIGNAL telegram types once for every *n* EEP (data) telegrams with *n* being the configurable transmission interval that can be set via the NFC interface as described in chapter 8.

The default setting is that one SIGNAL telegram per enabled type (energy status, energy delivery or backup battery status) will be transmitted every 32 EEP (data) telegrams. This means that with default timing intervals, a SIGNAL telegram will be transmitted approximately once every 32 minutes when a room is occupied and approximately once every 64 minutes when a room is unoccupied.

If more than one SIGNAL type is enabled, then the individual SIGNAL telegrams will be transmitted at different times in between data telegrams.

6 Security

EMDC supports both standard and high security modes as defined by EnOcean Alliance according to the EnOcean security specification [4].

Appendix B introduces the security mechanisms defined by EnOcean Alliance.

6.1 EMDC security implementation

EMDC supports both standard and high security modes as defined by EnOcean Alliance. The security mode can be selected both via the LRN button and via the NFC interface.

For high security mode, the default security level format (SLF) is set to 0xF3 indicating the use of a 32-bit sequence counter to generate a 32-bit authentication signature using VAES (AES-128) as algorithm.

For backwards compatibility with legacy systems, EMDC provides the option to use the security level format of 0xAB indicating the use of a 24-bit sequence counter to generate a 24-bit authentication signature using VAES (AES-128) as algorithm.

The switch between default and legacy security mode is done using the NFC interface as described in chapter 8.

7 EMDC commissioning

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

The following tasks are required in this process:

- Device identification
  The receiver needs to know how to uniquely identify this specific EMDC device. This is achieved by using a unique Source Address (EURID) of each EMDC device.

- EnOcean Equipment Profile (EEP) identification
  The receiver needs to know which EnOcean Equipment Profile (EEP) is used by EMDC to encode parameters within a data telegram

- Security parameter exchange
  The receiver needs to be able to decrypt and authenticate radio telegrams from EMDC if high security is used. This is achieved by exchanging a 128-bit random security key used by EMDC to encrypt and authenticate its radio telegrams.

EMDC provides the following options for these tasks:

- Radio-based commissioning (LRN Telegram)
  EMDC can communicate its parameters via secure teach-in telegrams (identifying the security parameters) together with an EEP teach-in telegram (identifying the EEP that is used) to the intended receiver as described in chapter 7.1.
  Transmission of such telegrams can be triggered by using the LRN button or via NFC.

- QR code commissioning
  Each EMDC device contains a product label with an optically readable Quick Response (QR) Code as described in chapter 4.5 which identifies the EURID and the security key used by EMDC. This QR code can be read by a by a suitable commissioning tool (e.g. smartphone) which communicates these parameters to the intended receiver of EMDC radio telegrams.

- NFC commissioning
  Each EMDC device contains an NFC interface allowing to read the device parameters and to configure the device.

7.1 Radio-based commissioning

Radio-based commissioning is used to associate EMDC with other devices by sending the following radio telegrams:

- EEP teach-in telegram
  The EEP teach-in telegram provides information about the EEP used by EMDC.
  The structure of a 4BS EEP teach-in telegram is described in Appendix A.2.2.

- Security teach-in telegram
  The security teach-in telegram provides security-specific information such as the device-specific random security key, the security algorithm parameters (SLF) and the most recently used rolling code (RLC) value.
  The structure of the security teach-in telegram is described in Appendix B.3.

The transmission of the commissioning telegram can be triggered by pressing the LRN button or using the NFC interface described in chapter 8.

If EMDC is configured to operate in high security mode, then it will first transmit a security teach-in telegram and then an EEP teach-in telegram. Transmission of the security teach-in telegram can be disabled using the NFC interface described in chapter 8.

If EMDC is configured to operate in standard security mode, then EMDC will only transmit an EEP teach-in telegram.

7.2 QR code commissioning

Each EMDC device contains a product label which can be used to commission EMDC via its commissioning QR code. See chapter 4.5 for a description of the product label.

7.2.1 Commissioning QR code structure

Each device label contains a commissioning QR code that can be scanned to identify source address and security key of EMDC to a receiver. Figure 10 shows an example of such QR code.

Figure 10 – EMDC Commissioning QR code

Note that the EnOcean Equipment Profile used by EMDC must be communicated to the receiver as well. See chapter 5.1 for a description of the supported and the default EEP.

7.2.2 Commissioning 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 10 above encodes the following string:

```
30S000012345678+1P000B0000006D+13Z00112233445566778899AABBCCDDEEFF
+30PE6201-K515+2PDB11+31Z0000E500+S012345678912
```

Table 5 below describes the ANSI/MH10.8.2 data identifiers used by the EMDC device label and shows the interpretation of the data therein.

Identifier	Length of data	Content of data	Data in the example
30S	12 chars	EnOcean Radio Address (EURID)	000012345678
1P	12 characters	EnOcean Alliance Product ID	000B0000006D
13Z	32 characters	Security Key	00112233445566778899AABBCCDDEEFF
30P	10 characters	Ordering Code	E6201-K515
2P	4 characters	Step Code - Revision	DB11
31Z	8 characters	NFC PIN Code	0000E500
S	14 characters	Serial Number	012345678912

Table 5 – QR code format

7.3 Commissioning via NFC interface

EMDC implements NFC Forum Type 2 Tag functionality as specified in the ISO/IEC 14443 Part 2 and 3 standards. This NFC functionality can be used to read the device address and the security key of EMDC using the NFC interface described in chapter 8.

8 NFC interface

EMDC implements an NFC configuration interface that can be used to access (read and write) the EMDC configuration memory.

NFC communication distance is for security reasons set to require direct contact between the NFC reader and the EMDC device.

Note that EMDC temporarily stops operation while the NFC reader is connected to the NFC interface of EMDC to ensure configuration data integrity.

EMDC operation will automatically resume approximately 5 seconds after the NFC reader has been disconnected.

8.1 NFC interface parameters

The NFC interface of EMDC uses NFC Forum Type 2 Tag functionality as specified in the ISO/IEC 14443 Part 2 and 3 standards.

8.2 NFC access protection

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 `0x0000E500`.

The default PIN code shall be changed to a user-defined value as part of the installation process.

8.3 Using the NFC interface

Using the NFC interface requires the following:

- NFC reader
  This can be either a USB NFC reader connected to a PC or a suitable smartphone with NFC functionality

- NFC SW with read, write, PIN lock, PIN unlock and PIN change functionality
  This can be either a PC application or an Android / iOS app

These options are described in more detail below.

8.3.1 PC with dedicated NFC reader

For PC-based applications, EnOcean provides a dedicated PC application called EnOcean NFC Configurator which works in conjunction with the TWN4 Multitech 2 HF NFC Reader.

EnOcean NFC Configurator can be obtained from the EnOcean homepage:
https://www.enocean.com/en/product/enocean-nfc-configurator/

The TWN4 Multitech 2 HF NFC Reader is available from Elatec RFID Systems (sales-rfid@elatec.com) using order code T4BT-FB2BEL2-SIMPL. It is shown in Figure 11 below.

Figure 11 – Elatec TWN4 MultiTech Desktop NFC Reader

8.3.2 Android or iOS smartphone with NFC

NFC functionality is available in most Android (e.g. Samsung Galaxy S7 or newer) and iOS (starting from iPhone7 with firmware version 13 or newer) smartphones.

EnOcean provides the configuration app "EnOcean Tool" for these devices which can be downloaded directly from the respective app store.

At the time of writing, the tool was available from the Google Play Store using this link:
https://play.google.com/store/apps/details?id=de.enocean.easytool&hl=en

Likewise, the tool was available from the Apple Store using this link:
https://apps.apple.com/de/app/enocean-tool/id1497283202

9 Installation recommendations

9.1 Setup instructions

Before installing EMDC into its intended location, a sufficient initial charge should be provided to EMDC, and its correct operation should be verified.

To do so, follow these steps:

1. Place EMDC under bright light (daylight or bright light source) for 5 minutes to provide an initial charge

2. Press the LRN button once so that EMDC will start operation

3. Check that EMDC transmits radio telegrams at the configured update interval (by default once every 60 seconds). The LED will blink every time a telegram is transmitted (unless this has been disabled via NFC).

4. Use a suitable receiver to capture the EMDC data telegrams and verify that all required parameters are reported. Consider disabling the measurement and reporting of non-required parameters to conserve energy.

5. Check the light level reported by EMDC at the intended installation location to verify that sufficient light is available for the energy harvesting functionality. Maximize the amount of light available for energy harvesting as much as possible.

6. Make sure that the installation location is chosen according to the guidelines in the subsequent chapters to maximize the measurement accuracy.

After those steps, EMDC is ready for installation into its intended location.

9.2 Motion detection

Motion detection works based on the temperature difference between a moving object and its environment. Detection accuracy can therefore be affected by the following factors:

- Insufficient temperature difference (leading to no detection)
- Obstructions between PIR detector and moving person (leading to no detection)
- Warm moving objects (leading to false detections)
- Electro-magnetic radiation

For the case of person detection, the temperature of the moving object is the human body temperature (normally around 36.5 °C / 98 F). If under very hot conditions the temperature of the environment approaches the temperature of the human body, then detection performance will be significantly reduced to the point where EMDC might not be able to reliably detect motion anymore.

For the same reason, hot objects within the detection area should be avoided. Examples include standing lights, heaters or electrical equipment generating heat.

To reliably detect motion, an unobstructed line of sight from the sensor to the person(s) in the detection area is required. Walls, room dividers, plants, book shelfs, hanging lights or other obstacles within the line of sight can limit the detection performance.

The following factors should be considered to avoid the unintended detection of other warm moving objects:

- Rapid temperature changes in the vicinity of the PIR detector, e.g. caused by fans or fan heaters being switched on or off
- Lights (especially incandescent or halogen) being switched on or off in the immediate catchment area
- Warm moving objects such as animals, machines (e.g. cleaning robots or toys), hot paper output of fax machines and laser printers, falling flower petals
- Motion in areas adjacent to the intended detection area, e.g. in the floor or in the aisle around the detection area or outside of the window

Strong external electro-magnetic fields might induce noise into the highly sensitive PIR detection circuitry and thereby affect the detection performance. EMDC should therefore not be mounted in close vicinity of electro-magnetic radiation sources such as Wi-Fi access points, gateways, wireless audio or video systems or other wireless devices.

For consistent detection, the mounting site of EMDC should not be exposed to vibrations or motion.

9.3 Light level measurement

EMDC offers the option to measure the ambient light level either via the ambient light sensor or via the solar cell. This can be configured using the LIGHT_SENSOR_CFG register of the NFC interface described in chapter 8. By default, the solar cell is used for light level measurements.

9.3.1 Ambient light sensor

The ambient light sensor measures and reports the light level with a spectral response close to the human eye's perception of ambient light. The following points should be considered when using the ambient light sensor:

- Aperture
  The sensor measures the light level within a small radius around its centre axis. If the lighting conditions within that area are not representative for the overall conditions, then the result might be different from expectation.

- Surface
  The most common application for a ceiling-mounted illumination sensor is to measure the light level at a working desk surface underneath. In this application, the measured light level depends on the reflectivity of the surface. Simply put, a dark desk surface will give a totally different result compared to a white desk surface even when the same luminous flow is directed towards it.

- Obstruction
  Any obstruction between the sensor and the intended measurement area (desk surface, window) will significantly impact the measurement result. Maintaining a clear line of sight between measurement area and illuminations sensor is therefore essential.

- Interference
  To ensure accurate measurement results, it is essential to minimize interference from other light sources not contributing to the illumination at the target measurement area. For instance, when measuring the light level at a desk surface, interference might occur due to direct light from the window or from or upwards emission of indirect light sources (floor lamps etc)

Use of the light sensor is recommended for applications such as the measurement of the light level on a desk surface.

Note that this type of applications always require calibration on the receiver side to account for the relation between available light and reflected (measured) light. The value reported by EMDC will typically be lower than the actual illumination because surfaces never reflect all available light.

This effect must be compensated at the receiver side based on calibration measurements where a correction factor is calculated based on the relation between reported and actual illumination at a given installation location.

9.3.2 Solar cell

The solar cell has a much larger area and aperture compared to the ambient light sensor. Therefore, the solar cell will typically capture both natural light (through windows) and artificial light (from indoor lighting).

The light level measured by the solar cell is therefore more representative for the average illumination within a wider area rather than for the light level at a given point (such as a desk surface).

The solar cell should be used if measuring a light level over a wider area is desired. This is the default configuration of EMDC.

9.4 Energy harvesting

EMDC is powered by ambient light which is converted to energy using the integrated solar cell. For best performance it is essential to maximize the amount of light available for harvesting.

Harvestable light will typically be either natural light (daylight coming in through windows, sky lights, etc) or artificial light (direct or reflected light from indoor luminaires). If natural light is available (e.g. from a window) then the solar cell of EMDC should be oriented as much as possible towards that.

EMDC is designed to operate self-supplied with its standard parameters based on 200 lux of illumination at its solar cell for at least 6 hours per day. The amount of available light can be determined by executing an illumination test as described in chapter 2.7.5.

Lower levels of available light can be addressed by configuring a lower reporting rate via NFC as discussed in chapter 2.8. If the available light is insufficient, then EMDC offers the option to use a backup battery as described in chapter 4.3.

9.5 NFC configuration

EMDC can be flexibly configured for a wide range of application scenarios using the NFC configuration interface described in chapter 8.

Updating the device configuration via the NFC interface requires that EMDC has sufficient energy to read and process the new parameters. It is therefore recommended to provide an initial charge to EMDC by placing it under bright light for 5 minutes before starting the configuration process.

Before making any configuration changes, be sure to familiarize yourself with the device functionality and determine the energy constraints based on the available ambient light as discussed in chapter 2.6. Be especially careful not to configure higher update rates (low reporting intervals) before ensuring that sufficient light is available.

Should you be unsure about the current NFC configuration, then execute a factory reset as described in chapter 2.7.6 to reset all configuration registers to their default setting.

After completing the NFC configuration and ensuring that all functionality works as required, it is recommended to lock the NFC configuration interface by changing the NFC PIN code from its default value to a different (secret) value. Make sure the new NFC PIN code is properly noted down.

10 Regulatory notes

10.1 European Union

10.1.1 Declaration of conformity

Hereby, EnOcean GmbH, declares that this radio equipment is in compliance with the essential requirements and other relevant provisions of Directive 2014/53/EU. A copy of the Declaration of Conformity can be obtained from the product webpage at www.enocean.com

10.1.2 Waste treatment

WEEE Directive Statement of the European Union
The marking below indicates that this product should not be disposed with other household wastes throughout the EU. To prevent possible harm to the environment or human health from uncontrolled waste disposal, recycle it responsibly to promote the sustainable reuse of material resources.
Germany: WEEE-Reg-No.: DE 93770561

BATTERY Directive
This symbol below indicates that batteries must not be disposed of in the domestic waste as they contain substances which can be damaging to the environment and health.
Please dispose of batteries in designated collection points.
Germany: UBA Reg-No.: 21008516

Warning
Do not dispose of the product in fire, at extremely high temperatures or by mechanical crushing!

10.2 FCC (United States)

EMDCU uses TCM 515U which has been tested and is in compliance with FCC Rule Part 15.231.

10.2.1 FCC Grant Of Equipment Authorization

TCB

GRANT OF EQUIPMENT AUTHORIZATION

Certification

Issued Under the Authority of the

Federal Communications Commission

By:

TCB

Timco Engineering, Inc.
849 NW State Road 45
P.O. Box 370,
Newberry, FL 32669

Date of Grant: 08/07/2017

Application Dated: 08/07/2017

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-TCM515U
Name of Grantee:	EnOcean GmbH
Equipment Class:	**Part 15 Security/Remote Control Transmitter**
Notes:	**Transceiver Module**
Modular Type:	**Single Modular**

Grant Notes	FCC Rule Parts	Frequency Range (MHZ)	Output Watts	Frequency Tolerance	Emission Designator
	15.231	**902.875 - 902.875**			

Single Modular Approval. Approval is limited to OEM installation only. Compliance of this device in all final host configurations is the responsibility of the Grantee. Only antennas investigated in the application for Equipment Authorization for this device are allowed. OEM integrators must be provided labeling requirements for finished products. This grant is valid only when the device is sold to OEM integrators and the OEM integrators are instructed to ensure that the end user has no manual instructions to remove or install the device. Separate approval is required for all other operating configurations, including portable configurations with respect to 2.1093 and different antenna configurations. This module can only be used with a host antenna circuit trace layout design in strict compliance with the OEM instructions provided.

10.2.2 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.

To comply with FCC/IC RF exposure limits for general population / uncontrolled exposure, the antenna(s) used for this transmitter must be installed to provide a separation distance of at least 20 cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter

Warning
Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Interference
This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation.

This equipment generates uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation.

If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

10.3 ISED (former Industry Canada) Certification

EMDCU uses TCM 515U which has been tested and meets the requirements of Industry Canada's license-exempt RSSs.

10.3.1 ISED Technical Acceptance Certificate

TIMCO ENGINEERING INC.
849 NW State Road 45
Newberry, Florida 32669
http://www.timcoengr.com
888.472.2424 F 352.472.2030 email: cb@timcoengr.com

No. ➢ 1352IC17

TECHNICAL ACCEPTANCE CERTIFICATE

Certification No. ➢ IC: 5713A-TCM515U

Issued To ➢ EnOcean GmbH
Kolpingring 18A
Oberhaching 82041, Germany

Tested By ➢ VPI LABORATORIES, INC.
Company No: 2041A
29145 Old Lincoln Hwy Wanship, UT 84017
801-260-4056
joej@vpitech.com

Type of Equipment ➢ Low Power Device (902-928 MHz)
➢ Modular Approval (MA)

Type of Service ➢ New Certification (Single)

Hardware Version Id Number (HVIN) ➢ TCM 515U

Product Marketing Name: (PMN) ➢ TCM 515U

Firmware Version Id Number (FVIN) ➢ N/A

Host Marketing (HMN) ➢ N/A

FREQUENCY RANGE	EMISSION DESIGNATIONS NECESSARY BANDWIDTH & EMISSION CLASSIFICATION	R.F. POWER	ANTENNA INFO	SPECIFICATION / ISSUE & DATE	
902.875 MHz	276KF1D	81.8dBuV/@3m	See Note 2	RSS-210	Issue 9; Aug 16

Note 1: This equipment also complies with RSS-102, Issue 5 (March 2015) and RSS-Gen, Issue 4 (Nov 2014)
Note 2: Mitsubishi AM11DP-ST01T, Linx ANT-916-CW-HWR-RPS, EnOcean ANT300 helical, trace antenna, wire whip antenna

Certification of equipment means only that the equipment has met the requirements of the above noted specifications. License applications, where applicable to use certified equipment, are acted on accordingly by the 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 of the radio standards specifications and procedures issued by Industry Canada.

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

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 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'Industrie Canada.

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

ISSUED UNDER THE AUTHORITY OF MINISTER OF INDUSTRY
DÉLIVRÉ AVEC L'AUTORISATION DU MINISTRE DES INDUSTRIES

DATE: August 14, 2017

S. S. Sanders, President

10.3.2 ISED Usage Conditions

This device complies with Industry Canada’s license-exempt RSSs. 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.

10.4 ARIB (Japan)

10.4.1 ARIB construction type conformity certificate

EMCC DR. RAŠEK

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.	JU000605M
Certificate Holder	EnOcean GmbH Kolpingring 18a 82041 Oberhaching Germany
Product Category	Article 2, Paragraph 1, Item 8 (Y)
Product Designation	TCM 500J, TCM 501J, TCM 515J, STM 550J, EMSIJ, EMDCJ
Product Description	Wireless Transceiver
Software Release No.	--
Manufacturer	Katek GmbH Bahnhofstraße 108 83224 Grassau Germany

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

R 206-000605

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,
2020-09-02

Karlheinz Kraft
Recognised Foreign Conformity Assessment Body

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11 Product history

Table 6 below lists the product history of EMDC.

Product	Revision	Release date	Key changes versus previous revision
EMDCA	DA-03	March 2020	Initial release of EMDCA
	DB-11	April 2025	Major functional update - Addition of EPAC functionality - Change from single color to bi-color LED - Extended operation time without light to 7 days
EMDCJ	CA-02	May 2021	Initial release of EMDCJ
	DB-04	April 2025	Major functional update - Addition of EPAC functionality - Change from single color to bi-color LED - Extended operation time without light to 7 days
EMDCU	DA-05	May 2021	Initial release of EMDCU
	DB-08	April 2025	Major functional update - Addition of EPAC functionality - Change from single color to bi-color LED - Extended operation time without light to 7 days

Table 6 – Product History

12 References

Please use below references for an in-depth description of features supported by EMDC.

[1] EnOcean Serial Protocol Version 3 (ESP3)

[2] EnOcean Radio Protocol 1 (ERP1)

[3] EnOcean Radio Protocol 2 (ERP2)

[4] Security of EnOcean Radio Networks

[5] EnOcean Equipment Profiles

[6] SIGNAL Telegram

A Introduction to EnOcean radio communication

This chapter gives a high-level introduction to key aspects of the EnOcean radio protocol to help the understanding of EMDC features. Refer to the EnOcean Radio Protocol 1 (ERP1) [2] specification [2][2]and the EnOcean Radio Protocol 2 (ERP2) specification [3].

Devices within the EnOcean ecosystem communicate using the EnOcean Radio Protocol (ERP). Two versions of this radio protocol are in use today – ERP version 1 (ERP1 in short) is used for 868.3 MHz radio systems in Europe while ERP version 2 (ERP2 in short) is used for 902.875 MHz radio systems in the US / Canada and 928.35 MHz radio systems in Japan.

A.1 Radio frame format

EMDCA uses the ERP1 standard (ISO 14543-3-10) while EMDCU and EMDCJ use the ERP2 (ISO 14543-3-11) standard. Note that EnOcean radio transceivers such as TCM 310 or TCM 515 will convert both ERP1 and ERP2 into the same EnOcean Serial Protocol (ESP3) format so that this difference is normally not noticeable.

A.1.1 ERP1 frame format

The ERP1 radio frame format is shown in Figure 12 below.

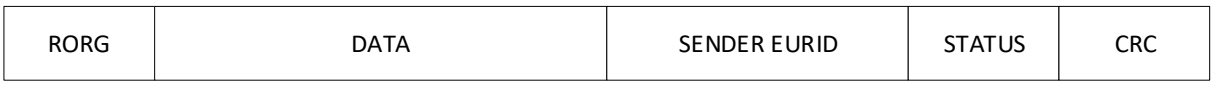

Figure 12 – ERP1 Frame Format

The most relevant fields of the ERP1 frame are the following:
- RORG (containing the EEP or SIGNAL RORG)
- SENDER EURID (Device address of the sender)
- DATA (Telegram payload containing the EEP)

A.1.2 ERP2 frame format

The ERP2 radio frame format is shown in below.

Figure 13 – ERP2 Frame Format

The most relevant fields of the ERP2 frame are the following:
- HEADER (including the EEP or SIGNAL RORG)
- SENDER EURID (Device address of the sender)
- DATA (Telegram payload containing the EEP)

A.2 EnOcean Equipment Profiles (EEP) and SIGNAL telegrams

The data section within EnOcean radio telegrams uses one of the EnOcean Equipment Profiles (EEP) or one of the SIGNAL telegram types defined by EnOcean Alliance to encode sensor information. The EEP used is selected by the sender and must be supported by the receiver.

A.2.1 EEP structure

Each EEP is identified using three fields:

- RORG
  RORG identifies the high-level telegram type, e.g. rocker switch telegram (RPS), one-byte sensor telegram (1BS), four-byte sensor telegram (4BS), variable length telegram (VLD), Universal Teach-in with EEP (UTE), etc.

- FUNC
  FUNC identifies the function group to which this telegram belongs, e.g. the function group of temperature sensors within the four-byte sensor telegram type

- VARIANT (or TYPE)
  VARIANT (which is confusingly also called TYPE) identifies the exact sensor variant within the function group, e.g. a 0 °C – 40 °C temperature sensor that is defined within the function group of temperature sensors

Figure 14 below shows the structure of the EEP identifier.

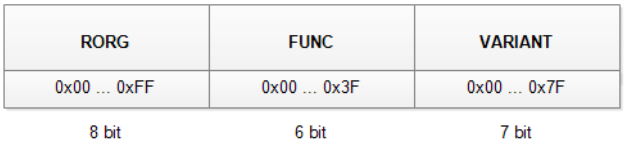

Figure 14 – EEP identifier structure

The EEP identifier is typically only transmitted during the initial teach-in (paring) between devices. For special cases (e.g. devices using more than one EEP), data telegrams might specify the EEP that is used.

A.2.2 4BS telegram structure

4 Byte Sensor (4BS) telegrams are identified by the RORG field being set to 0xA5 which is followed by four bytes of payload (Bit 0 … Bit 31).

The payload of 4BS telegrams encodes either the sensor status (4BS data telegram) during normal operation or identifies EEP and manufacturer of the device during teach-in (4BS Teach-in Telegram). The distinction between data and teach-in telegrams is made based on the status of Bit 28 (Byte 0, Bit 3 in Figure 15 below).

If this bit is set to 1, then the telegram is a 4BS data telegram using the data encoding defined by the selected 4BS EEP.

If this bit is set to 0, then the telegram is a 4BS teach-in telegram using the format shown in Figure 15 below.

4BS Teach-in Telegram PAYLOAD																															
BYTE 3								BYTE 3								BYTE 1								BYTE 0							
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
FUNCTION (6 bit)						VARIANT (7 bit)							MANUFACTURER ID (11 bit)										TEACH_IN_TYPE								

Figure 15 – 4BS Teach-in Telegram Structure

A.2.3 Signal telegram structure

SIGNAL telegrams are used to encode generic system conditions independent of specific sensor functionality of the device. Examples of such system conditions are internal energy level, available ambient energy and backup battery status.

SIGNAL telegrams are identified by having the RORG field of the data telegram set to 0xD0. After that, the SIGNAL type (what is reported) is identified by the 1 byte long MID field which is followed by the data corresponding to this SIGNAL type.

Figure 16 below shows the structure of a SIGNAL telegram.

SIGNAL RORG	SIGNAL Type (MID)	SIGNAL Data
0xD0	0x00 ... 0xFF	Depending on SIGNAL Type

Figure 16 – SIGNAL Telegram Structure

B Security

EMDC supports both standard and high security modes as defined by EnOcean Alliance according to the EnOcean security specification: https://www.enocean-alliance.org/sec/.

B.1 Basic concepts

Security for radio transmission addresses two main issues:

- Unauthorized interception (reception and correct interpretation) of transmitted data
  In doing so, a third (unauthorized) party is able to understand the content of a received content.

- Unauthorized transmission of radio telegrams
  In doing so, a third (unauthorized) party is able to transmit a radio telegram that is treated by a receiver as valid request.

Somewhat loosely speaking, the goal of security has to be preventing an unauthorized person (often referred to as an *Attacker*) both from learning about the current state of a system and from actively changing it.

These goals can be achieved via techniques such as telegram encryption, telegram authorization and dynamic security key modification. All three techniques will be reviewed in the subsequent chapters for reference.

B.1.1 Telegram encryption

The goal of telegram encryption is to prevent unauthorized receivers from correctly interpreting the content of a telegram.

In order to do so, the original (plain text) data is *encrypted* with a *key* thus transforming it into encrypted, unreadable data. Only when the correct key is known it is possible to transform – *decrypt* - the encrypted data into readable data again.

Figure 17 below shows the concept.

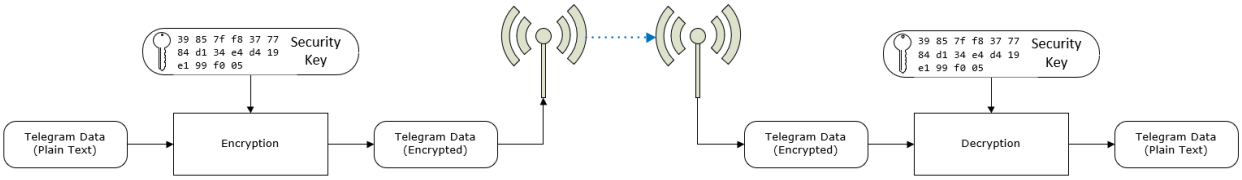

Figure 17 – Telegram encryption

If the same security key is used for encryption at the sender and decryption at the receiver then this is called a *symmetric key* algorithm. AES (AES128 / AES256) and DES / 3DES algorithms are typical examples of this category. EMDC uses this approach.

B.1.2 Telegram authentication

The goal of telegram authentication is to prevent unauthorized senders to transmit apparently valid commands causing the receiver to perform unauthorized actions.

Telegram authentication works by creating a *message signature* (often called *Cipher-based Message Authentication Code* or *CMAC* in short) based on the content of the telegram and the secret key.

Essentially, the telegram data is transformed via a defined algorithm using the secret key into a unique, fixed size signature which identifies this specific message. EMDC by default uses a 32-bit value for this signature; a legacy mode of 24 bit is also supported and can be selected via NFC.

For an optimal signature algorithm, the likelihood of two different messages creating the same message signature is inversely proportional to the signature size, so for instance for 32-bit signatures the likelihood would be approximately one in four billion.

For message authentication purposes, the message signature (CMAC) is typically appended to the message itself and transmitted together with it.

When the receiver receives such a message, it will itself calculate the CMAC based on the secret key and the content of the received message. The receiver then compares the CMAC it calculated with the CMAC it received as part of the message.

If both CMAC are the same, then the receiver can establish two important facts:

1. The message originates from an owner of the secret key
2. The content of the message has not been modified

Figure 18 illustrates the content authorization via a CMAC signature.

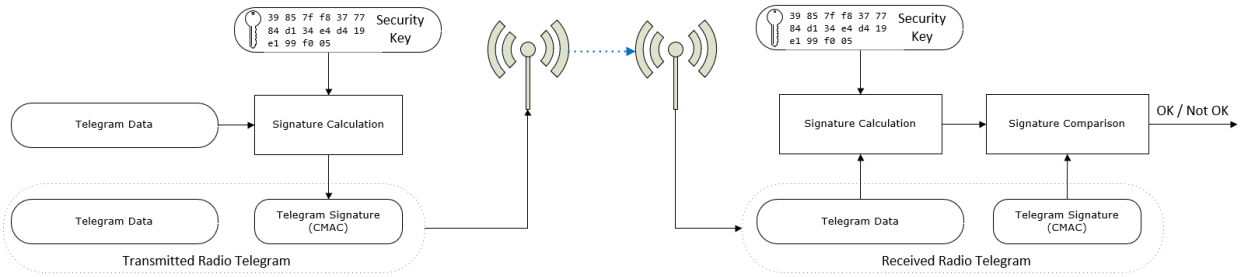

Figure 18 – Telegram authentication

B.1.3 Replay protection

One fundamental problem with both telegram encryption and telegram authorization is that using the same input data (plain text) with the same security key will always result in the same encrypted data and the same signature. This enables attacks based on monitoring previous system behaviour. If an attacker has observed that a certain data telegram results in a certain light being turned on, then he could use this information to identify - or even actively send - similar telegrams in the future. This type of attack is often called *Replay Attack* since it works by reusing (replaying) previously transmitted (valid) data telegrams.

To prevent this type of attack, either the telegram data or the security material (e.g. the security key or the initialization vector / nonce) must change to ensure that identical input data does not create identical encrypted radio telegrams.

The change of telegram data or security material is done based on a sequence of values that are guaranteed to be unique so that the same value will not be used twice. This sequence of changing values is often referred to as *Rolling Code* or *RLC* in short.

To prevent replay of an already received message, the receiver will keep track of the latest received RLC value and will only accept telegrams with an RLC value that comes later (after the last received RLC value) in the sequence.

Both sender and receiver must know the mechanism how to generate the next RLC (the next value in the sequence) based on the current RLC (the current value of the sequence). The easiest - and most common - approach for that is to use the value of a monotonously incrementing counter that is incremented for each telegram.

Such counter is often referred to as *Sequence Counter*; the current value of the sequence counter is the RLC.

Figure 19 below shows the concept of adding an RLC to the telegram data.

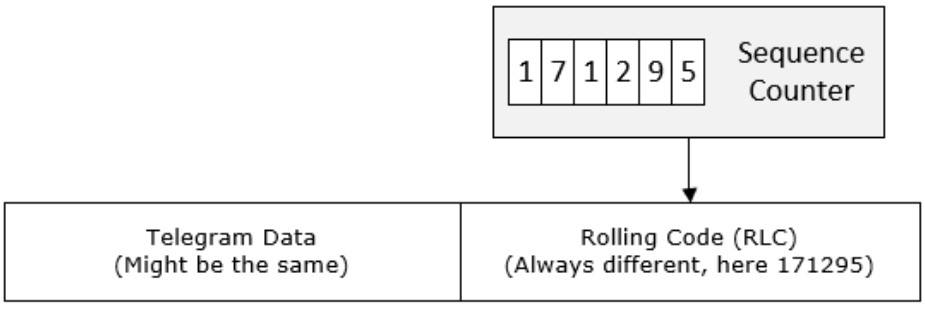

Figure 19 – Addition of an RLC to the telegram data

EnOcean systems use sequence counter and security key both for data encryption and for authentication signature calculation as defined by EnOcean Alliance Security specification [4]. Figure 20 below illustrates this approach.

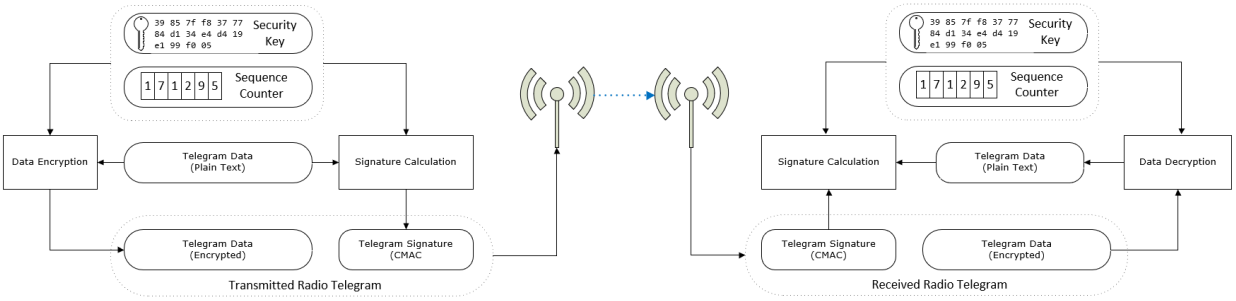

Figure 20 – Encryption and authentication with sequence counter

B.2 Security parameters

The following security parameters are used to define secure communication based on EnOcean Alliance security specification between a sender and a receiver:

- EURID (Device ID of the sender)
- Rolling code size and current value
- Signature (MAC) size
- Security algorithm

Those parameters are communicated from EMDC to the receiver during teach-in either via a secure teach-in telegram, via NFC configuration or via the QR code of EMDC.

B.2.1 EURID

The EURID identifies the sender of each radio telegram using a unique 6 byte value. The EURID of an EnOcean device is assigned at manufacturing and cannot be changed.

B.2.2 Security key

The security key is a random 128 Bit (16 byte) value that is known only to the sender and the receiver(s). It is used to encrypt, decrypt and authenticate telegrams.

B.2.3 Rolling code

The rolling code is a monotonously incrementing counter used to prevent replay of previously transmitted telegrams as described in Appendix B.1.3.

The rolling code is generated by the sender and monitored by the receiver. EMDC uses by default a 32-bit rolling code counter which will be initialized to 0 at the time of production and increment whenever a telegram is transmitted.

The receiver will store the most recently received rolling code value and only accept telegrams with higher rolling code values to avoid retransmission of previously transmitted messages.

B.2.4 Security level format (SLF)

The security level format (SLF) defines the security parameters used for communication between two devices. Figure 21 below shows the supported security parameters options encoded in the SLF field.

7	6	5	4	3	2	1	0
RLC_MODE			**CMAC_SIZE**		**ENCRYPTION_ALGO**		
0b000: No RLC algorithm 0b001: RFU 0b010: 16 bit RLC (not transmitted) 0b011: 16 bit RLC (16 bit transmitted) 0b100: 24 bit RLC (not transmitted) 0b101: 24 bit RLC (24 bit transmitted) 0b110: 32 bit RLC (24 bit transmitted) 0b111: 32 bit RLC (32 bit transmitted)			0b00: No MAC 0b01: 24 bit CMAC 0b10: 32 bit CMAC 0b11: RFU		0b000: No data encryption 0b001: Deprecated 0b010: Deprecated 0b011: VAES using AES128 0b100: AES-CBC using AES128 Others: RFU		

Figure 21 – SLF structure

EMDC by default uses 32-bit RLC with 32-bit CMAC using VAES algorithm for security processing (SLF = 0xF3).

For backwards compatibility with older systems, EMDC can be configured to use 24-bit RLC with 24-bit CMAC using VAES algorithm (SLF = 0xAB).

B.3 Security Teach-in

Teach-in is the process by which one device (the sender) communicates to another device (the receiver) all parameters required to establish secure communication using a radio telegram with a specific payload. This radio telegram is called a Security Teach-in Telegram (abbreviated SEC_TI).

The parameters communicated in such secure teach-in telegram are the following:

- RORG (1 byte)
  Secure teach-in telegrams are identified by the RORG 0x35
- Teach-in Info (1 byte)
  This field is used for the segmentation and reassembly process and also defines the teach-in type (which is always uni-directional for EMDC). The first telegram has this field set to 0x20 while the second telegram has this field set to 0x40.
- Security Level (1 byte)
  The security level specifies the type of encryption and authentication used by for the communication with the remote device as described below.
- Rolling Code (4 byte in default configuration)
  The rolling code is used to constantly modify the security key to avoid message replay. The rolling code is initialized to 0 at the time of production and increases for each transmission of a secure telegram. EMDC uses 4 byte rolling code length by default but supports also a legacy mode with 3 byte rolling code.
- Security key (16 byte)
  The 128-bit AES security key is used in high security mode to encode and / or authenticate radio telegrams

The length of a secure teach-in telegram exceeds the maximum telegram length of EnOcean radio telegrams; therefore, the telegram will be split (fragmented) into two telegrams for transmission which will be reassembled at the receiver.

B.3.1 Secure teach-in telegram structure

Figure 22 shows the first of the two telegrams for the case of the default configuration.

RORG	Teach-In Info	SLF	Rolling Code (4 byte)	Security Key
0x35	0x20	0xF3	Rolling Code (Big Endian)	Security Key (1st part, 8 Byte)

Figure 22 – Secure teach-in telegram structure (first telegram)

The structure for the second of the two telegrams is shown in Figure 23 below.

RORG	Teach-In Info	Security Key
0x35	0x40	Security Key (2nd part, 8 Byte)

Figure 23 – Secure teach-in telegram structure (second telegram)