EMDC

EnOcean Motion Detector And Light Level Sensor

Observe precautions! Electrostatic sensitive devices!

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WO98/36395, DE 100 25 561, DE 101 50 128,
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The following major modifications and improvements have been made to this document:

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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.

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 868.3 MHz (EMDCA), 902.875 MHz (EMDCU) or 928.35 MHz (EMDCJ) versions of the EnOcean radio standard.

EMDC uses a passive infrared (PIR) sensor to detect motion and a dedicated illumination sensor to measure the amount of ambient light.

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 (e.g. 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 can 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 requires 50 lux illumination for 6 hours per day directly at the solar cell which typically is equivalent 200 lux for 6 hours per day to at room level. EMDC is fully self-powered (no batteries required) under these lighting conditions.

For cases where sufficient ambient light is not available, EMDC provides the option to mount 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 and authenticity of the transmitted telegrams and prevents telegram replay (retransmission of previously transmitted telegrams).

1.2 Technical data

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)	200 m free range 30 m for indoor 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
Light Level Sensor Range / Accuracy	0 … 65000 Lux / +- 10 %
Update Rate With / Without Detected Motion	Approximately every 2 minutes / every 1 minute Configurable via NFC Initial motion detection is reported immediately
Supported EEP (Selectable Via NFC)	A5-07-03 (default) A5-07-01 A5-08-01, A5-08-02, A5-08-03
User interface	LRN button Sensitivity selection switch 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 from empty to first transmission	5 minutes at 400 Lux
Operating time in darkness	96 hours (after full charge)
Backup power supply (optional)	CR2032
Backup battery life Infrequent bright light (200 lux for 2 hrs every day) Consistent low light (65 lux for 5 hrs every day) Total Darkness	 Up to 15 years Up to 12.5 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)	0 … 60°C / 32 … 140 F (indoor use only)
Recommended Operating Temperature(1)	0 … 30°C / 32 … 85 F (indoor use only)
Humidity	20% to 85% r.h. (non-condensing)

Note 1: PIR detection requires that the moving object to be detected is significantly warmer than its environment. For the case of human motion, this means that the environment needs to be 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	863.300 MHz
EMDCU	E6251-K515	902.875 MHz
EMDCJ	E6261-K515	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 EnOcean Equipment Profiles (EEP).

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

Figure 1 – EMDC external view

2.2 Basic functionality

EMDC devices contain a passive infrared sensor that detects changes in the received infrared radiation which are characteristic for the movement of persons. In addition, EMDC measures the ambient light level via a dedicated sensor and the temperature using its 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 LED to provide user feedback. Configuration of 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.

2.3 External product interface

The external product interface consists of the following items:

- Infrared lens in conjunction with a passive infrared sensor for motion detection
- Ambient light sensor for light measurement
- Solar cell can for powering the device in normal lighting conditions
- User interface. With one button (LRN) and one LED simple configuration and test
- Internal NFC antenna (not visible) providing access to the NFC configuration
- Wall mount plate (with opening slot for removal) for product mounting

Figure 2 below shows the location of these items.

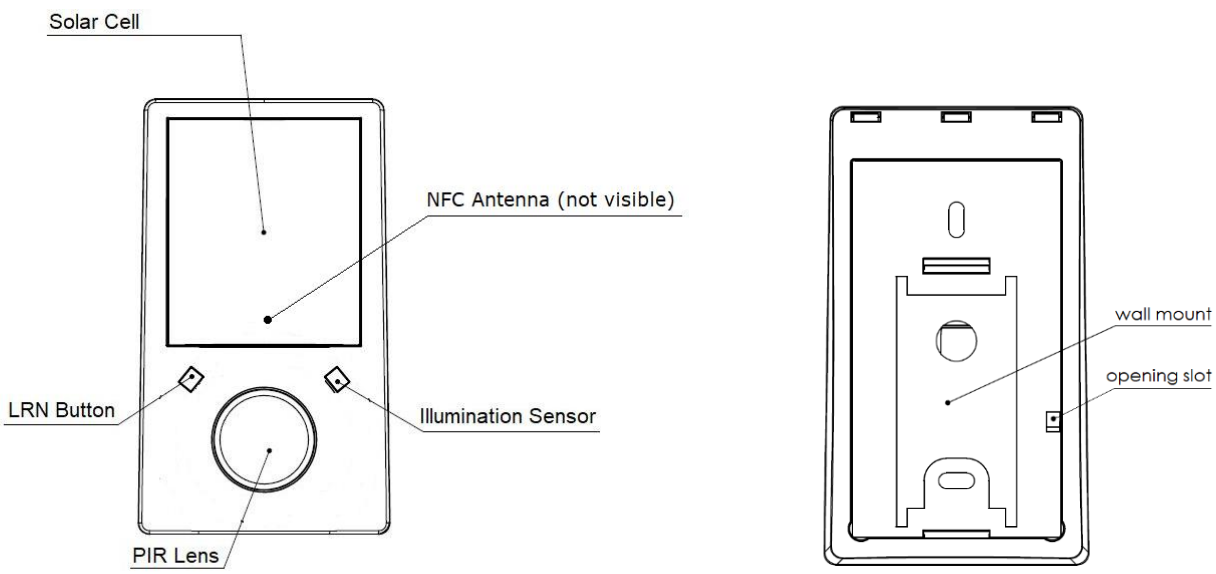

Figure 2 – EMDC front and rear view

2.4 Internal product interface

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

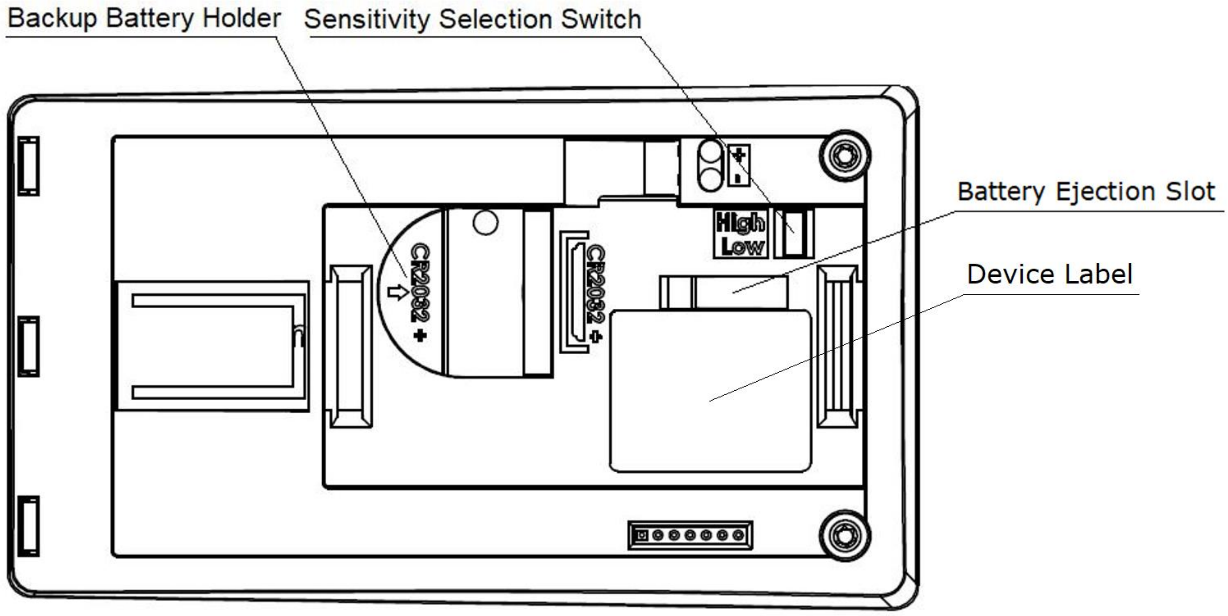

Figure 3 – EMDC internal view

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.

2.5 Functional modes

EMDC supports six types of functional modes:

- Standard operation mode
- Standby (sleep) mode
- Learn mode
- Walk test mode
- Ambient light test mode
- Factory reset mode

These modes are described below.

2.5.1 Standard operation mode

During standard operation, EMDC wakes up periodically and reports the motion detection status and – depending on the selected EEP also the current light level and the temperature status - using data telegrams.

The motion detection functionality is described in chapter 3.1 and the light level sensing functionality in chapter 3.2 and chapter 3.3 respectively.

The EMDC wake-up timer is configured to wake-up EMDC approximately every 2 minutes during periods without detected motion and approximately every 1 minute during periods with detected motion. 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 in order 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) has to be considered.

2.5.2 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 can be selected using the LRN button as described in chapter 4.1 or using the NFC interface as described in chapter 9.5.11.

2.5.3 Walk test mode

Walk test mode is used to verify the motion detection coverage of the device via visual feedback from the LED which will blink whenever motion is detected.

Walk test mode can be selected using the LRN button as described in chapter 4.1 or using the MODE field of the FUNCTIONAL_MODE NFC register as described in chapter 9.5.11.

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.

2.5.4 Learn mode

In learn mode, EMDC will transmit a Teach-in telegram to communicate the device source address, the security key and the EnOcean Equipment Profile (EEP) used by EMDC to a receiver. After that transmission, EMDC will return back to standard operation mode.

Learn mode can be selected using the LRN button as described in chapter 4.1 or using the MODE field of the FUNCTIONAL_MODE NFC register as described in chapter 9.5.11.

2.5.5 Ambient light test mode

During installation, EMDC can measure and report the amount of ambient light available at its solar cell in order to determine a suitable installation location as discussed in chapter 10.4.

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.

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. The computed average illumination is then available in the NFC register ILLUMINATION_TEST_RESULT as described in chapter 9.5.21.

Illumination test mode can be selected using the MODE field of the FUNCTIONAL_MODE NFC register as described in chapter 9.5.11.

2.5.6 Factory reset mode

EMDC can be reset to its standard settings using factory reset mode. Upon entering this mode, EMDC will reset all 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 MODE field of the FUNCTIONAL_MODE NFC register as described in chapter 9.5.11.

2.6 Reporting interval

EMDC will always report the initial motion detection after a period without detected motion immediately. The rate of subsequent updates (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.

2.6.1 Energy considerations

The default reporting interval of 120 seconds (one update every two minutes) when unoccupied (no motion detected) and 60 seconds (one update every minute) when occupied (motion detected) is adjustable using the NFC interface as discussed in the subsequent chapters.

Lowering the reporting interval will increase its power consumption since EMDC will measure and transmit more often. Likewise, increasing the reporting interval will reduce power consumption since it will measure and transmit less often.

To select the right reporting interval, it is essential to determine the amount of harvestable energy. EMDC harvests energy from the available ambient light; therefore, the amount of available energy is determined mainly by the intensity of the available light and the amount of time during which the light is available.

The amount of available ambient light can be determined by executing an ambient light test as described in chapter 2.5.5. The light availability period (the time during which the ambient light is available) has to be determined based on the lighting scheme used for the environment where EMDC is installed.

EMDC is designed to provide one update per minute while a room is occupied based on 200 lux of ambient light available for 6 hours per day.

The minimum supported update interval (for the case of a room being occupied) for self-supplied operation based on other conditions is summarized in Table 1 below. This table assumes that the update interval for the case of an unoccupied room will be double this value.

	6 hrs / day	8 hrs / day	10 hrs / day	12 hrs / day
50 lux	Not supported	Not supported	180 s	120 s
100 lux	120 s	90 s	90 s	60 s
150 lux	90 s	60 s	60 s	45 s
200 lux	60 s	45 s	45 s	30 s
300 lux	45 s	30 s	30 s	20 s
400 lux	30 s	25 s	25 s	15 s
500 lux	25 s	20 s	20 s	15 s

Table 1 – Minimum self-supplied reporting intervals

2.6.2 Standard reporting interval

The standard reporting interval determines the longest interval between two status updates of EMDC, i.e. the minimum update rate.

EMDC can be configured to use a lower reporting interval, i.e. a higher update rate, based on occupancy and available light as described below. But under no circumstances will EMDC report with a longer reporting interval, i.e. a lower update rate, than the standard reporting interval.

The default setting for the standard reporting interval is one status update once every 120 seconds (2 minutes). This means that under all conditions, EMDC will at least report its status once every 120 seconds.

The standard reporting interval can be adjusted using the STANDARD_TX_INTERVAL NFC register as described in chapter 9.5.12.

Figure 4 below illustrates the use of the standard reporting interval.

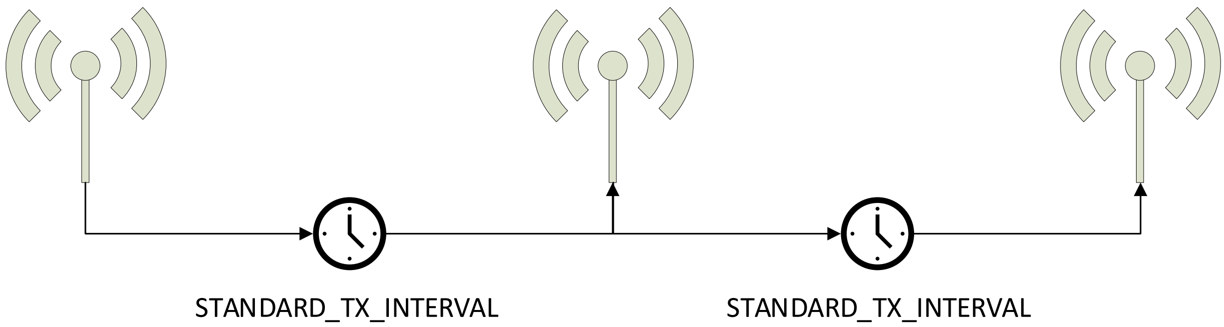

Figure 4 – Standard reporting interval

2.6.3 Occupancy-controlled reporting interval

If a room is occupied, then it might be desirable to receive status updates more often to determine the current light level. EMDC can therefore be configured to use a lower reporting interval, i.e. a higher update rate, while motion is detected.

The default setting of the occupied reporting interval is 60 seconds. This setting can be changed using the OCCUPIED_TX_INTERVAL NFC register as described in chapter 9.5.13.

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

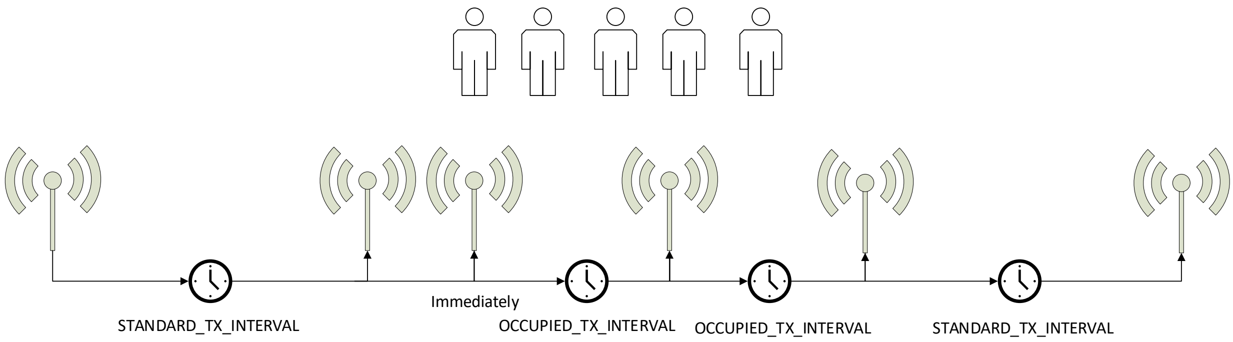

Figure 5 – Occupancy-controlled reporting interval

2.6.4 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 defined in chapter 9.5.

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

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

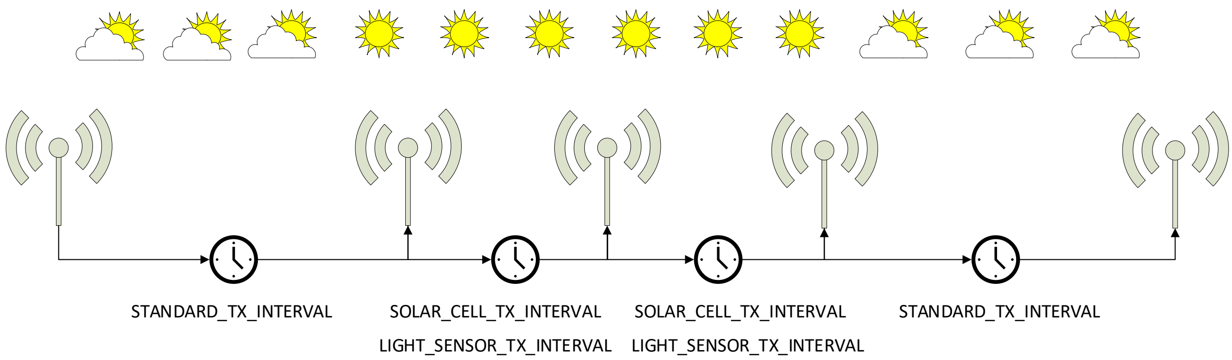

Figure 6 – Illumination-controlled reporting interval

2.6.5 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 using the passive infrared sensor (PIR)
- Illumination measurement using the light level sensor
- Illumination measurement using the solar cell
- Energy level 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.

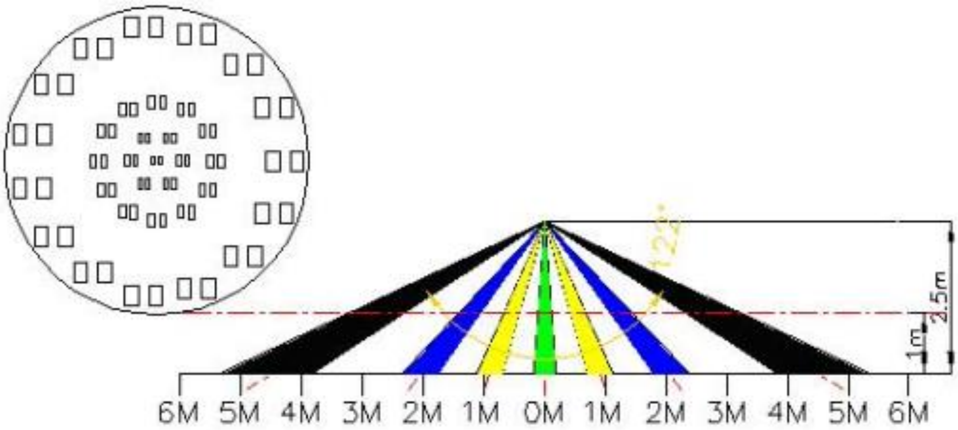

Figure 7 – EMDC PIR detection pattern

3.2 Illumination measurement (light level sensor)

EMDC integrates a dedicated illumination sensor used to accurately measure and report the light level directly underneath (e.g. on the desk surface).

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.

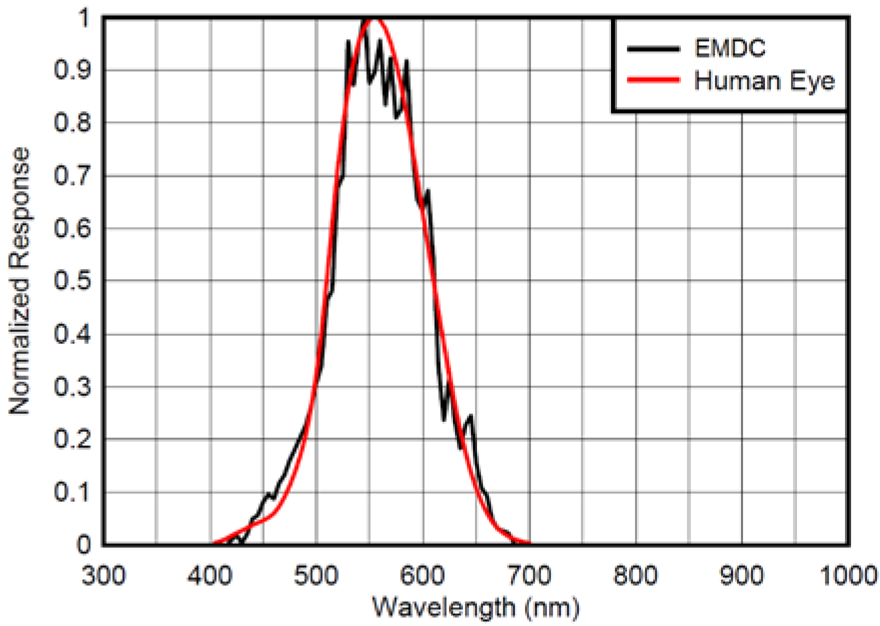

Figure 8 – Spectrum response of the illumination sensor

3.3 Illumination measurement (solar cell)

EMDC can use SIGNAL telegrams - as described in chapter 5.2 - to report the light level by measuring the energy generated by the solar cell. This functionality can be used both to ensure that sufficient ambient light is available to power the device and to measure incoming light if the solar cell is oriented towards the window.

Reporting of the solar cell light level can be enabled and disabled via SIGNAL register of the NFC interface as described in chapter 9.5.9. By default, the reporting is disabled.

In addition, the light level of the solar cell can be reported instead of the light level of the ambient light level sensor. The selection is done using the LIGHT_SENSOR_CFG register of the NFC interface as described in chapter 9.5.15.

3.4 Temperature

EMDC uses the temperature monitor within the microcontroller to detect abnormal temperature conditions (very hot, very cold, quick change of temperature). Due to the limited accuracy of the sensor itself and the temperature offset typically resulting from the installation location (ceiling), this temperature reporting is not suitable for high accuracy HVAC control.

EMDC provide the option for offset calibration of the temperature sensor to account for these effects as described in chapter 9.5.16.

3.5 Energy level

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 will estimate the energy level (amount of remaining energy) and report this as a percentage between 0% (empty) and 100% (fully charged).

The calculated energy level can be reported using SIGNAL telegrams as described in chapter 5.2. The measurement and reporting can be enabled and disabled via the SIGNAL register of the NFC interface as described in chapter 9.5.9. By default, the reporting of the remaining energy is enabled and will be executed once for every 32 data telegrams.

Note that the reported energy level can only provide rough guidance as the actual energy level depends on several factors (most notably the ambient temperature).

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 enabled and disabled via the SIGNAL register of the NFC interface as described in chapter 9.5.9. By default, the reporting is disabled.

4 User interface

The user interface of EMDC consists of the following items:

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

Please refer to chapter 2.3 and 2.4 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 9.5. Some of the most common parameters or states can additionally be configured using the LRN button with the LED providing visual feedback.

Table 2 below lists those configuration actions.

Type	Timing	EMDC Response	LED Response
Single Short	< 1s Press	Exit from Sleep Mode Send Learn Telegram	Success: 1 short blink Error: No feedback
Double Short	< 1s Press, < 1s Release, < 1s Press	Start Walk Test (End after 2 min or upon any button press)	1 short blink every time motion is detected
Triple Short	< 1s Press, < 1s Release, < 1s Press, < 1s Release, < 1s Press	Toggle LED indication	LED enabled: 4 short blinks LED disabled: No feedback
Single Long	3s < Press < 5s	Enter Sleep Mode (Disable LED and Radio)	Success: 3 short blinks Error: No feedback
Double Long	3s < Press < 5s, < 1s Release, 3s < Press < 5s	Enter Secure Mode Send Secure Teach-in Telegram	Success: 2 short blinks Error: No feedback
Very Long	> 8s Press	Factory Reset	Success: 5 short blinks Error: No feedback

Table 2 – EMDC LRN button actions

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.

4.3 Backup battery interface

The backup batter 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.

⚠ 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!

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 EDMCx 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).

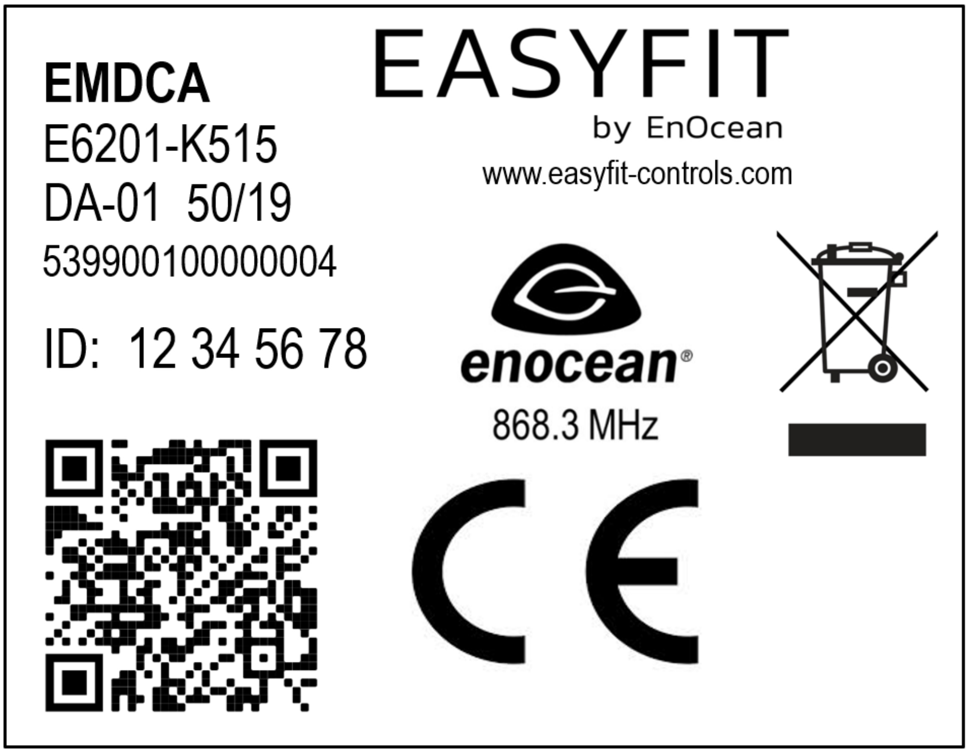

Figure 9 – EMDCA Device Label

The label in this example identifies the following parameters:

- Device type: EMDCA
- Product Revision: DA-01
- Manufacturing Date: Week 50, 2019
- Radio address (EURID): 12345678
- Operating frequency: 868.3 MHz

In addition to that, the QR code in the bottom left corner that 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).

5.1 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.

5.1.1 ERP1 frame format

The ERP1 radio frame format is shown in Figure 10 below.

RORG	DATA	SENDER EURID	STATUS	CRC

Figure 10 – 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)

5.1.2 ERP2 frame format

The ERP2 radio frame format is shown in below.

LENGTH	HEADER	EXT_HEADER	SENDER EURID	DATA	CRC

Figure 11 – 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)

5.2 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.

5.2.1 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 12 below shows the structure of the EEP identifier.

RORG	FUNC	VARIANT
0x00 ... 0xFF	0x00 ... 0x3F	0x00 ... 0x7F
8 bit	6 bit	7 bit

Figure 12 – 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.

5.2.2 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 (Bit0 … Bit31).

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 Bit28. If this bit is set to 0 then the telegram is a 4BS Teach-in Telegram; if this bit is set to 1 then the telegram is a 4BS Data Telegram.

5.2.3 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 13 below shows the structure of a SIGNAL telegram.

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

Figure 13 – SIGNAL Telegram Structure

5.2.4 Supported EEP types

EMDC supports a wide range of EEP suitable for different use cases. Table 3 below lists the supported EEP.

Profile	Type	Reported Parameters	Parameter Range	Size / Resolution
A5-07-01	4BS	Motion Detection Status	Motion Detected Motion Not Detected	1 Bit
A5-07-03 (Default)	4BS	Motion Detection Status	Motion Detected Motion Not Detected	1 bit
		Light Level	0 … 1000 lx	10 bit
A5-08-01	4BS	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	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	Motion Detection Status	Motion Detected Motion Not Detected	1 bit
		Light Level	0 … 1530 lx	8 bit
		Temperature	-30 … 50 °C	8 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 EEP register of the NFC configuration interface described in chapter 9.5.8.

5.2.5 Supported SIGNAL types

Table 4 below lists the SIGNAL types supported by EMDC together with their reported data.

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)
0x10	Backup battery status Disabled by default	1 byte integer value (expressing %) Valid values: 0 … 100

Table 4 – Supported SIGNAL Types

The transmission of each supported SIGNAL telegram can be individually enabled and disabled using the via the SIGNAL configuration register of the NFC interface as described in chapter 9.5.9. By default, the transmission of SIGNAL telegram type 0x06 (energy status) is enabled while the transmission of SIGNAL telegram type 0x0D (energy delivery) and 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 SIGNAL configuration register of the NFC interface as described in 9.5.9.

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 meaning that the transmission interval is approximately 32 minutes when a room is occupied and approximately 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 within the selected transmission interval.

6 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/.

6.1 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.

6.2 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 14 below shows the concept.

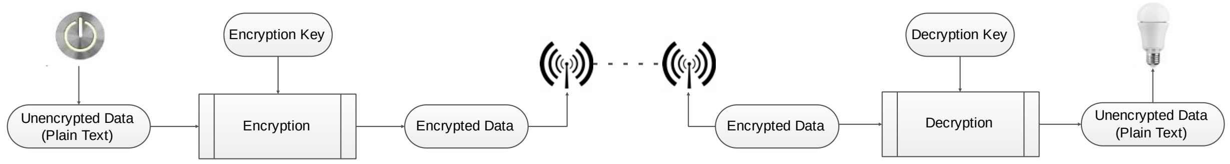

Figure 14 – Telegram encryption

6.2.1 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 one approximately in 4 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 15 below illustrates the content authorization via a CMAC signature.

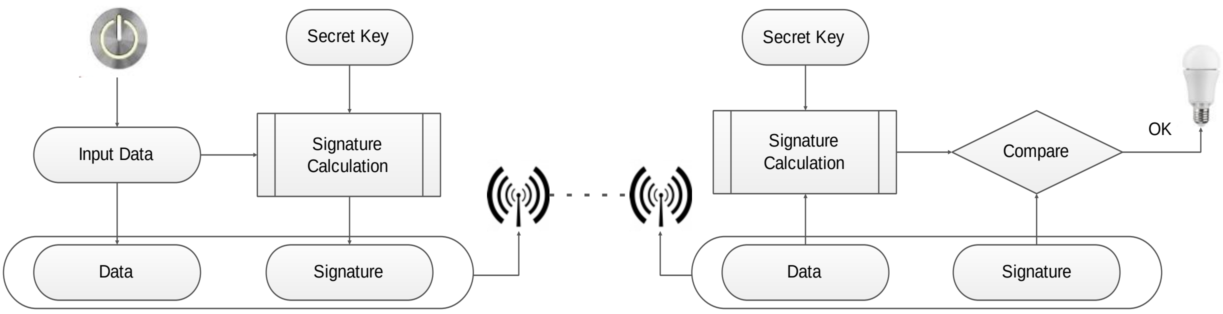

Figure 15 – Telegram authentication

6.2.2 Dynamic security key modification

One fundamental problem with both content protection and content authorization is that using the same input data (plain text) with the same key always yields 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 used data telegrams.

In order to prevent this type of attack, either the telegram data or the security key must change to ensure that identical input data does not create identical encrypted radio telegrams. The mechanism used by the transmitter to change the telegram data or the security key has to be known to the receiver in order to correctly decrypt and authenticate received data telegrams.

The change of telegram data or security key is typically ensured by means of monotonously incrementing counters (often called Rolling Code or RLC in short).

The value of such counter is then used to either modify the telegram payload (usually by appending it to the payload) or the security key. EnOcean systems use the latter approach.

Figure 16 below illustrates the concept of dynamic key modification used by EnOcean radio systems.

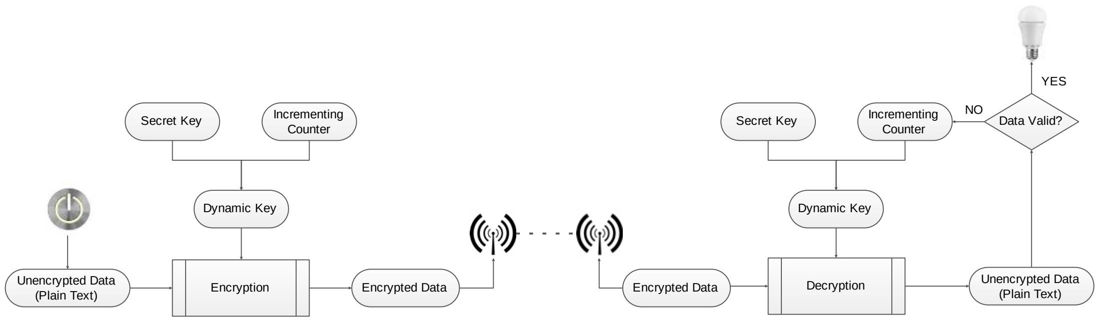

Figure 16 – Dynamic security key modification

6.3 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.

6.3.1 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.

6.3.2 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.

6.3.3 Rolling code

The rolling code is a monotonously incrementing counter used to modify the encryption key of secure telegrams as described in chapter 6.2.2. 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.

6.3.4 Security algorithm

EMDC uses variable AES based on AES-128 to encrypt and authenticate its telegrams.

6.4 Secure teach-in telegram

Teach-in is the process by which EMDC communicates to a remote device all parameters required to establish secure communication using a radio telegram with a specific payload. This radio telegram is called a secure 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 individual telegrams and reassembled at the receiver.

Figure 17 below 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 17 – Secure teach-in telegram structure (first telegram)

The structure for the second of the two telegrams is shown in Figure 18 below.

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

Figure 18 – Secure teach-in telegram structure (second telegram)

6.4.1 Security level format (SLF)

The security level format (SLF) defines the security parameters used for communication between two devices. Figure 19 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 19 – SLF structure

6.5 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 use a 32 bit sequence counter to generate a 32 bit signature using VAES (AES-128) as algorithm.
The security level format for this mode is 0xF3.

For backwards compatibility with legacy systems, EMDC provides the option to use 24 bit RLC with 24 bit CMAC using VAES (AES-128) as algorithm. The security level format for that mode is 0xAB.

The switch between default and legacy security mode is done using the SECURITY_MODE register of the NFC interface as described in chapter 9.5.7.

7 EMDC commissioning

Commissioning is the process by which EMDC 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 EMDC device. This is achieved by using a unique 48 Bit ID (Source Address) for 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 authenticate radio telegrams from EMDC in order to ensure that they originate from this specific device and have not been modified. This is achieved by exchanging a 128 bit random security key used by EMDC to 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 as described in chapter 6.4 to the intended receiver. 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.
  The QR code identifies the EURID and the security key used by EMDC and can be read by a by a suitable commissioning tool (e.g. smartphone) which is already part of the network into which EMDC will be commissioned.
  The commissioning tool then communicates these parameters together with information about the selected EEP to the intended receiver of EMDC radio telegrams.

- NFC commissioning
  Each EMDC device contains an NFC interface allowing to read 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 a dedicated radio telegram (a so-called commissioning telegram).

To do so, EMDC can transmit a dedicated commissioning telegram identifying its relevant parameters according to EnOcean Alliance standard. The transmission of the commissioning telegram is triggered by pressing the LRN button.

Radio-based commissioning mode is intended for applications where NFC commissioning cannot be used. Radio-based commissioning can be disabled via NFC.

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 20 shows an example of such QR code.

Figure 20 – EMDC Commissioning QR code

Note that the EnOcean Equipment Profile used by EMDC has to be communicated to the receiver as well. See chapter 5.2.4 for a description of the supported 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 20 above encodes the following string:

```
30S000012345678+Z9E0DE9C25386B6C4F070642E19E03680+30PE6201-K515+2PDA01+S012345567890123
```

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.

Identi-fier	Length of data (excluding identifier)	Value
30S	12 characters	Device Address EURID (hex)
Z	32 characters	Security Key (hex)
30P	10 characters	Ordering Code (E6201-K515)
2P	4 characters	Step Code - Revision (DA-01)
S	14 characters	Serial Number

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 as described in chapter 9.5.

8 NFC interface

EMDC implements an NFC configuration interface that can be used to access (read and write) the EMDC configuration memory and thereby configure the device as described in the following chapters.

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 actively connected to the NFC interface of EMDC. EMDC operation will automatically resume operation once 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. It is implemented using an NXP NT3H2111 Mifare Ultralight tag.

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. This can be done by unlocking the NFC interface with the old PIN code and then writing the new PIN code to page `0x4B`.

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 recommends the TWN4 Multitech 2 HF NFC Reader (order code T4BT-FB2BEL2-SIMPL) from Elatec RFID Systems (sales-rfid@elatec.com).
This reader is shown in Figure 21 below.

Figure 21 – Elatec TWN4 MultiTech Desktop NFC Reader with CDC interface

8.3.2 Smartphones with NFC

NFC functionality is available in certain Android (e.g. Samsung Galaxy S7 / S8 / S9 / S10) and iOS (iPhone7 or newer, 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

8.4 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.

8.4.1 NFC interface state machine

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

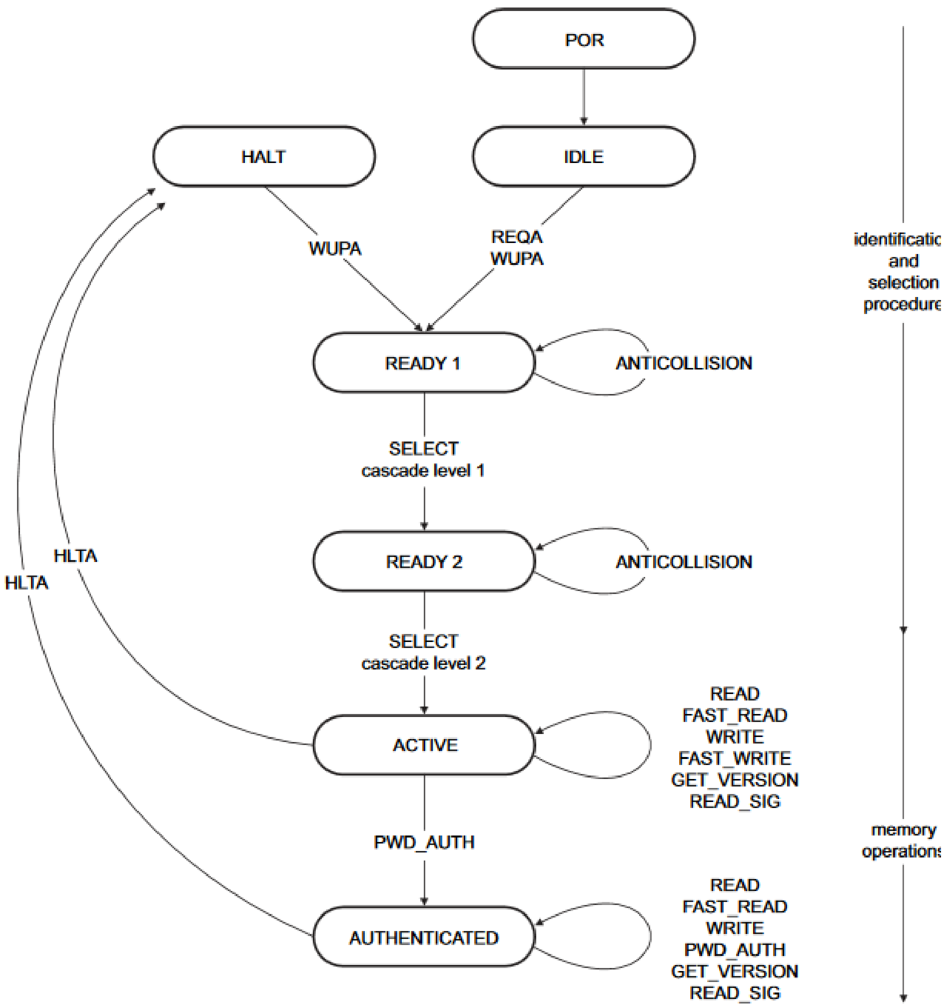

Figure 22 – NFC interface state machine

8.4.2 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.

8.4.3 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.

8.4.4 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.

8.4.5 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.

8.4.6 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.

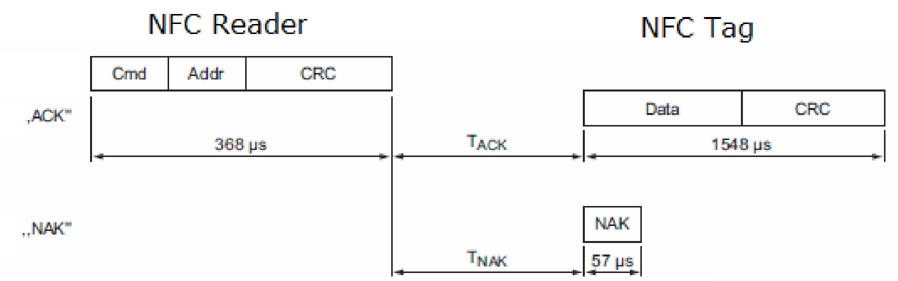

Figure 23 – NFC read command sequence

8.4.7 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.

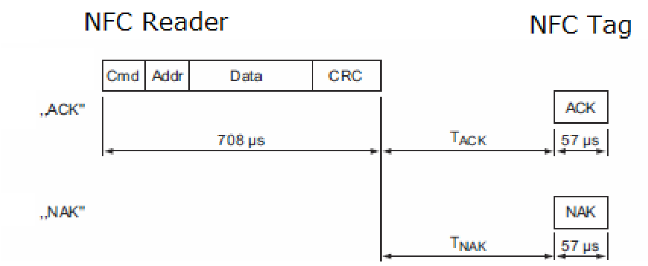

Figure 24 – NFC write command sequence

8.4.8 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.

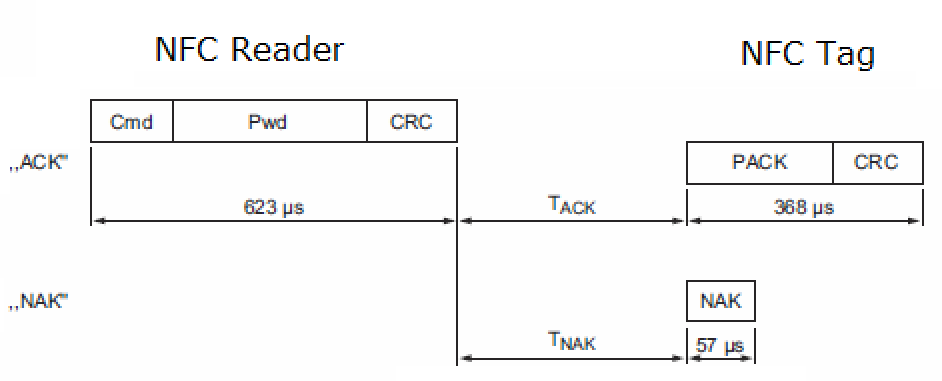

Figure 25 – Password authentication sequence

9 NFC registers

The NFC memory is organized in pages (smallest addressable unit) where each page contains 4 byte of data. Several pages with similar functionality form a NFC memory area.

9.1 NFC memory areas

These NFC pages are allocated into the following areas:

- PRODUCT NDEF string (Public read-only access; no PIN required)
  This area contains an NDEF string identifying key device parameters
- USER NDEF string (Public read / write access; no PIN required)
  This area allows any user to read or write information about the device such as the intended installation location or additional instructions
- PUBLIC INFO (Public read-only access; no PIN required)
  This area contains key device parameters in binary format
- NFC HEADER (Public read-only access; no PIN required)
  This area contains information about the NFC revision
- INTERNAL DATA (Non-accessible)
  This area contains calibration values and internal parameters and cannot be used
- CONFIGURATION (Read and Write access, PIN required)
  This area contains device configuration registers
- USER DATA (Read and Write access, PIN required)
  This area allows the user to store up to 64 byte of data such as information about the installation or any other data that the user deems relevant.
  EMDC does not use this area and does not interpret its content in any way.

The organization of the EMDC NFC memory map is shown in Table 6 below.

NFC Address	Memory Area	Content
0x00 … 0x1D	PRODUCT NDEF	Device identification NDEF string (read-only)
0x1E … 0x30	USER NDEF	User information NDEF string (read / write access)
0x31 … 0x33	NFC HEADER	NFC memory revision (read-only)
0x34 … 0x3F	INTERNAL DATA	Internal data (Do not use)
0x40 … 0x54	CONFIGURATION	Configuration registers (Read / Write, PIN protected)
0x55 … 0xCF	INTERNAL DATA	Internal data (Do not use)
0xD0 … 0xDF	USER DATA	User data (64 byte read / write access, PIN protected)
0xE0 … 0xEB	INTERNAL DATA	Internal data (Do not use)

Table 6 – EMDC NFC memory areas

9.2 PRODUCT NDEF

The PRODUCT NDEF area contains a device identification string using the NDEF (NFC Data Exchange Format) standard that is readable by most NFC-capable reader devices (including smartphones).

An example device identification string from the NDEF area of EMDC could be:

```
6PENO+30S000012345678+1P000B0000004C+30PS6221-K516+2PDA04+2Z01234567891234
+3C31+16S01000000
```

This NDEF string encodes the parameters shown in Table 7 below.

Identifier	Length of data (excl. identifier)	Value
6P	3 characters	Standard: "ENO"
30S	12 characters	EURID (6 byte, variable)
1P	12 characters	EnOcean Alliance Product ID STM 550: „000B0000004C" STM 550U: „000B0000004D" STM 550J: „000B0000004E"
30P	10 characters	Ordering Code STM 550: "S6201-K516" STM 550U: "S6251-K516" STM 550J: "S6261-K516"
2P	4 characters	Step Code and Revision ("DA04")
2Z	14 characters	NFC UID (14 byte, globally unique)
3C	2 characters	Header Start Address ("31" = 0x31)
16S	8 characters	SW Version Example: 01000000 = 01.00.00.00

Table 7 – NDEF Parameters

9.3 USER NDEF

The USER NDEF area allows the user to store a string of up to 64 characters starting at page 0x20 and ending at page 0x2F. The remaining pages in this area (0x1E, 0x1F, 0x30) provide the required NDEF formatting information and cannot be changed by the user.

9.4 NFC HEADER

The NFC HEADER area contains information about the NFC memory structure and can therefore be used to distinguish between different NFC memory layouts.

9.4.1 NFC HEADER area structure

The structure of the NFC HEADER area is shown in Figure 26 below.

NFC Address	Content			
	Byte 0	Byte 1	Byte 2	Byte 3
0x31	START (0xE0)	LENGTH (0x0A)	VERSION (0x01)	OEM MSB (0x00)
0x32	OEM LSB (0x0B)	DEVICE_IDENTIFIER (0x000002)		
0x33	REVISION (0x03)	END (0xFE)	UNUSED (0x0000)	

Figure 26 – NFC HEADER area structure

The NFC HEADER contains the following fields:

- START
  This field identifies the start of the NFC header and is always set to 0xE0
- LENGTH
  This field identifies the length of the NFC header.
  For EMDC, this field is set to 0x0A since the header structure is 10 bytes long
- VERSION
  This field identifies the major revision and is set to 0x01 currently
- OEM
  The 16 bit OEM field identifies the manufacturer of the device so that manufacturer-specific layout implementations can be determined.
  For EnOcean GmbH this field is set to 0x000B
- DEVICE_IDENTIFIER
  The 24 bit DEVICE_IDENTIFIER field identifies an individual device from the range of devices manufactured by the manufacturer specified in the OEM field.
  For EMDC, the DEVICE_IDENTIFIER is set to 0x000002
- REVISION
  The REVISION field identifies the exact revision of the NFC layout. This REVISION will be incremented whenever a change to the NFC layout is made.
- END
  The END field identifies the end of the NFC header and is always set to 0xFE. The number of bytes from START to END must equal LENGTH, otherwise the NFC header is invalid.

9.5 CONFIGURATION

The CONFIGURATION area allows configuring the device parameters and is therefore the most important part of the NFC memory. Configuration registers larger than 8 bit use big endian format, i.e. the most significant byte comes first.

Read or write access to the CONFIGURATION area is only possible after issuing a PWD_AUTH command as described in chapter 8.4.8 using the correct 32 bit PIN code.

9.5.1 Using the NFC configuration functionality

Before making any changes to the default configuration, be sure to familiarize yourself with the functionality of the device and the effect of the intended changes. EMDC will not accept the setting of non-valid values for its parameters. If any parameter is non-valid then all changes made will be rejected and the previous configuration will be restored.

9.5.2 CONFIGURATION area structure

The structure of the CONFIGURATION area is shown in Figure 27 below.

NFC Address	Content			
	Byte 0	Byte 1	Byte 2	Byte 3
0x40 0x41 0x42	PRODUCT_ID (as characters in ASCII format) Will be copied to NDEF Header			
0x43	RFU			
0x44 … 0x47	USER_KEY (128 Bit) (Write Only - Will be reset to zero after it has been copied to internal memory) Can be used as alternative security key instead of FACTORY_KEY			
0x48	SECURITY_KEY_MODE	SECURITY_CFG	RFU	
0x49	EEP	SIGNAL	LED_MODE	FUNCTIONAL_MODE
0x4A	STANDARD_TX_INTERVAL		OCCUPIED_TX_INTERVAL	
0x4B	NFC_PIN_CODE			
0x4C	THRESHOLD_CFG	RFU	LIGHT_SENSOR_CFG	TEMP_SENSOR_CFG
0x4D	SOLAR_ THRESHOLD		SOLAR_ TX_INTERVAL	
0x4E	LIGHT_THRESHOLD		LIGHT_ TX_INTERVAL	
0x4F … 0x53	RFU			
0x54	AMBIENT_LIGHT_TEST_RESULT		RFU	

Figure 27 – CONFIGURATION area structure

9.5.3 NFC_PIN_CODE

The PIN code used to protect access to the NFC CONFIGURATION memory area should be changed from the default value to a user-specific value to avoid unauthorized access to the device configuration.

To do so, first authenticate with the current PIN code and then write the new PIN code (32 bit value) to the NFC_PIN_CODE register.

9.5.4 PRODUCT_ID

The EnOcean Alliance Product ID uniquely identifies each product within the EnOcean Alliance ecosystem. The Product ID consists of a 2 byte manufacturer identification code (assigned by EnOcean Alliance) and a 4 byte product identification code (assigned by the manufacturer.

EnOcean has been assigned the manufacturer identification code 0x000B. EnOcean has assigned the following product identification codes to EMDC:

EMDCA: 0000004F
EMDCU: 00000050
EMDCJ: 00000051

The PRODUCT_ID register contains the Product ID in ASCII format (12 characters) and allows changing both manufacturer and product identification. Changing the PRODUCT_ID will also cause the PRODUCT ID field in the NDEF string (described in chapter 9.2) to be updated.

Figure 28 below shows the structure of the PRODUCT_ID register.

PRODUCT_ID											
CH0	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8	CH9	CH10	CH11
Manufacturer (“000B”)				Product ID (“0000004F”, “00000050” or “00000051”)							

Figure 28 – PRODUCT_ID

9.5.5 USER_KEY

Each EMDC module is pre-programmed at the factory with a randomly generated 128 bit security key (FACTORY_KEY). This key will by default be used to encrypt and authenticate EMDC radio telegrams when operating in high security mode.

In certain applications it might be desirable to assign a different (user-defined) security key (USER_KEY) during commissioning to EMDC. This can be done by writing the user-defined security key to the USER_KEY register and setting KEY SELECTION field of the SECURITY_KEY_MODE to 0b01 as described below.

Note that the USER_SECURITY_KEY register is a write-only register meaning that it is not possible to read back a user-defined security key.

9.5.6 SECURITY_KEY_MODE

The register SECURITY_KEY_MODE allows selecting if FACTORY_KEY or USER_KEY should be used to encrypt and authenticate EMDC radio telegrams in high security mode. In addition, it allows disabling the transmission of Secure Teach-in telegrams in order to protecting the security key.

Note that if the transmission of a secure teach-in telegram has been disabled and is subsequently re-enabled then USER_KEY will be reset to FACTORY_KEY.

Figure 29 below shows the structure of the SECURITY_KEY_MODE register.

SECURITY_KEY_MODE (Default: 0x00)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU				SECURE LRN TELEGRAM		KEY SELECTION	

Figure 29 – SECURITY_KEY_MODE register

The encoding for the KEY SELECTION bit field is shown in Table 8 below.

KEY SELECTION	Security key used
`0b00 (Default)`	FACTORY_KEY is used
`0b01`	USER_KEY is used
`0b10, 0b11`	Reserved, do not use

Table 8 – KEY SELECTION bit field encoding

The encoding for the SECURE LRN TELEGRAM bit field is shown in Table 9 below.

SECURE LRN TELEGRAM	Secure LRN telegram
0b00 (Default)	Secure LRN Telegram (containing security key) enabled
0b01	Secure LRN Telegram (containing security key) disabled
0b10, 0b11	Reserved, do not use

Table 9 – SECURE LRN TELEGRAM bit field encoding

9.5.7 SECURITY_MODE

The register SECURITY_MODE identifies the security settings used by EMDC. Figure 30 below shows the structure of the SECURITY_MODE register.

SECURITY_MODE (Default: 0x00)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU				SECURITY FORMAT		SECURITY MODE	

Figure 30 – SECURITY_MODE register

The encoding for the SECURITY MODE bit field is shown in Table 10 below.

SECURITY MODE	Security Mode
0b00 (Default)	Standard, can be changed by the user with the LRN button
0b01	High Security, can be changed by the user with the LRN button
0b10	Standard, cannot be changed by the user with the LRN button
0b11	High Security, cannot be changed by the user with the LRN button

Table 10 – SECURITY MODE bit field encoding

The encoding for the SECURITY FORMAT bit field is shown in Table 11 below.

SECURITY FORMAT	Advertising Interval
0b00 (Default)	32 bit RLC and 32 bit CMAC
0b01	24 bit RLC and 24 bit CMAC
0b10, 0b11	Reserved, do not use

Table 11 – SECURITY FORMAT bit field encoding

9.5.8 EEP

The EEP register determines the EnOcean Equipment Profile (EEP) used by EMDC for the transmission of data telegrams. Figure 31 below shows the structure of the EEP register.

EEP (Default: 0x00)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU				EEP			

Figure 31 – EEP register

The encoding used by the SIZE bit field is shown in Table 12 below.

EEP	EnOcean Equipment Profile
0b0000 (Default)	A5-07-03
0b0001	A5-07-01
0b0010	A5-08-01
0b0011	A5-08-02
0b0100	A5-08-03
Others	Reserved, do not use

Table 12 – EEP bit field encoding

9.5.9 SIGNAL

EMDC supports reporting its energy status, the current energy delivery of the harvester and the backup battery status via SIGNAL telegrams as described in chapter 5.2.

The type and the transmission rate of SIGNAL telegrams are controlled by the SIGNAL register shown in Figure 32 below.

SIGNAL (Default: 0x31)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
TRANSMISSION RATE				RFU	BACKUP BATTERY	ENERGY DELIVERY	ENERGY STATUS

Figure 32 – SIGNAL register

EMDC supports the following SIGNAL types:
- ENERGY STATUS (MID 0x06)
- ENERGY DELIVERY (MID 0x0D)
- BACKUP BATTERY STATUS (MID 0x10)

Transmission of these supported SIGNAL types can be enabled by setting the associated configuration bit in the SIGNAL register to 0b1 and disabled by setting the associated configuration bit to 0b0.

By default, the reporting of the energy status (MID 0x06) is enabled while the reporting of energy delivery (MID 0x0D) and backup battery status (MID 0x10) is disabled.

EMDC allows additionally to configure at what rate each enabled SIGNAL telegram will be sent using the TRANSMISSION RATE bit field as shown in Table 13 below. If more than one SIGNAL telegram is enabled, then this rate will apply to all enabled telegrams. The SIGNAL telegrams will be transmitted at different times (i.e. not all at the same time one after another) in that case.

TRANSMISSION RATE	Transmission rate for SIGNAL telegrams
`0b0000`	One SIGNAL telegram every 8 data telegrams
`0b0001`	One SIGNAL telegram every 16 data telegrams
`0b0010`	One SIGNAL telegram every 24 data telegrams
`0b0011 (Default)`	One SIGNAL telegram every 32 data telegrams
…	
`0b1111`	One SIGNAL telegram every 128 data telegrams

Table 13 – TRANSMISSION RATE bit field encoding

9.5.10 LED_MODE

The LED_MODE register determines the brightness of the LED. Figure 33 below shows the structure of the LED_MODE register.

LED_MODE (Default: 0x02)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU						LED	

Figure 33 – LED_MODE register

The encoding used by the LED bit field is shown in Table 14 below.

LED	**LED Intensity**
`0b00`	OFF
`0b01`	Low
`0b10 (Default)`	Medium
`0b11`	High

Table 14 – LED bit field encoding

9.5.11 FUNCTIONAL_MODE

The FUNCTIONAL_MODE register can be used to switch between the different operation modes of EMDC as described in chapter 2.5.

Figure 34 below shows the structure of the FUNCTIONAL_MODE register.

FUNCTIONAL_MODE (Default: 0x00, OOB: 0x01)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU				MODE			

Figure 34 – FUNCTIONAL_MODE register

The encoding used by the MODE bit field is shown in Table 15 below.

MODE	Functional Mode
`0b0000 (Default)`	Standard Operation Mode
`0b0001`	Standby (Sleep) Mode
`0b0010`	Learn Mode
`0b0011`	Walk Test Mode
`0b0100`	Illumination Test Mode
`0b0111`	Factory Reset
`Others`	Reserved (Do not use)

Table 15 – MODE bit field encoding

Note that the default configuration (after factory reset) is standard operation mode while the out of box configuration (for new devices) is standby (sleep) mode.

9.5.12 STANDARD_TX_INTERVAL

EMDC uses a standard reporting interval which can be automatically adjusted based on sensor readings as described in chapter 2.6.

The standard reporting interval is set by the register STANDARD_TX_INTERVAL shown in Figure 35 below. The default setting of the standard reporting interval is 120 seconds.

STANDARD_TX_INTERVAL (Default: 0x0078)				
Bit 15	Bit 14	…	Bit 1	Bit 0
STANDARD INTERVAL				

Figure 35 – STANDARD_TX_INTERVAL register

The encoding used by the STANDARD INTERVAL bit field is shown in Table 16 below.

STANDARD INTERVAL	**Standard Reporting Interval**
0x0000, 0x0001, 0x0002	Not supported (Do not use)
0x0003	3 seconds (minimum setting)
…	…
0x0078 (Default)	120 seconds (default setting)
…	…
0xFFFF	65535 seconds (maximum setting)

Table 16 – STANDARD INTERVAL bit field encoding

9.5.13 OCCUPIED_TX_INTERVAL

EMDC can use a different (lower) reporting interval in case motion is detected. The default setting of the reporting interval for the case of detected motion is 60 seconds.

This reporting interval is set by the register OCCUPIED_TX_INTERVAL shown in Figure 36 below.

OCCUPIED_TX_INTERVAL (Default: 0x003C)				
Bit 15	Bit 14	…	Bit 1	Bit 0
OCCUPIED INTERVAL				

Figure 36 – OCCUPIED_TX_INTERVAL register

The encoding used by the OCCUPIED INTERVAL bit field is shown in Table 17 below.

OCCUPIED INTERVAL	**Occupied Reporting Interval**
`0x0000, 0x0001, 0x0002`	Not supported (Do not use)
`0x0003`	3 seconds (minimum setting)
…	…
`0x003C (Default)`	60 seconds (default setting)
…	…
`0xFFFF`	65535 seconds (maximum setting)

Table 17 – OCCUPIED INTERVAL bit field encoding

9.5.14 THRESHOLD_CFG

EMDC can reduce the reporting interval based on the illumination of the solar cell or the illumination of the light level sensor as described in chapter 2.6.

The use of these reduced reporting intervals is enabled by the THRESHOLD_CFG register shown in Figure 37 below.

THRESHOLD_CFG (Default: 0x00)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU				LIGHT SENSOR		SOLAR CELL	

Figure 37 – THRESHOLD_CFG register

The encoding used by the SOLAR CELL bit field is shown in Table 18 below.

SOLAR CELL	Reporting interval reduction based on solar cell illumination
`0b00 (Default)`	Disabled (No reporting interval reduction)
`0b01`	Reserved (Do not use)
`0b10`	Enabled, Reporting interval reduction if light above threshold
`0b11`	Reserved (Do not use)

Table 18 – SOLAR CELL bit field encoding

The encoding used by the LIGHT SENSOR bit field is shown in Table 19 below.

LIGHT SENSOR	Reporting interval reduction based on light sensor illumination
`0b00 (Default)`	Disabled (No reporting interval reduction)
`0b01`	Reserved (Do not use)
`0b10`	Enabled, Reporting interval reduction if light above threshold
`0b11`	Reserved (Do not use)

Table 19 – LIGHT SENSOR bit field encoding

9.5.15 LIGHT_SENSOR_CFG

EMDC allows the user to select if the reported light level is the one measured by the ambient light sensor or the one measured by the solar cell.

Refer to chapter 3.2 for a description of the ambient light sensor and to chapter 3.3 for a description of the solar cell functionality.

The selection between these two options is made by using the LIGHT_SENSOR_CFG register shown in Figure 38 below.

LIGHT_SENSOR_CFG (Default: 0x00)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU							INPUT SELECTION

Figure 38 – LIGHT_SENSOR_CFG register

The encoding used by the INPUT SELECTION bit field is shown in Table 20 below.

INPUT SELECTION	Input value used for illumination reporting
`0b0 (Default)`	Ambient light sensor
`0b1`	Solar cell

Table 20 – INPUT SELECTION bit field encoding

9.5.16 TEMP_SENSOR_CFG

As discussed in chapter 3.4, type and location of the temperature sensor are not suitable for high accuracy temperature measurements. The accuracy can be improved by configuring an offset between measured temperature (measured by EMDC at ceiling level) and the actual temperature.

The offset is expressed as 1 byte signed number with 0.1K increments can be configured using the TEMP_SENSOR_CFG registers shown in Figure 39 below.

TEMP_SENSOR_CFG (Default: 0x14)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
TEMP OFFSET							

Figure 39 – TEMP_SENSOR_CFG register

The encoding used by the OFFSET bit field is shown in Table 21 below.

TEMP OFFSET	Full scale value of the acceleration sensor
0x00 (Default)	No offset
0x01	+ 0.1 K Offset (reported value higher than measured value)
0x02	+ 0.2 K Offset (reported value higher than measured value)
…	
0x7F	+ 12.7 K Offset (reported value higher than measured value)
0x80	- 12.8 K Offset (reported value lower than measured value)
0x81	- 12.7 K Offset (reported value lower than measured value)
…	
0xFF	- 0.1 K Offset (reported value lower than measured value)

Table 21 – TEMP OFFSET bit field encoding

9.5.17 SOLAR_THRESHOLD

If reduction of the reporting interval based on the solar cell light level has been enabled then the light level threshold is defined by SOLAR_THREHOLD register as shown in Figure 40 below.

SOLAR_THRESHOLD				
Bit 15	Bit 14	…	Bit 1	Bit 0
SOLAR CELL THRESHOLD				

Figure 40 – SOLAR_THRESHOLD register

The encoding used by the SOLAR CELL THRESHOLD bit field is shown in Table 22 below.

SOLAR CELL THRESHOLD	Threshold
0x0000	0 lux (minimum setting)
…	…
0x00C8 (Default)	200 lux seconds (default setting)
…	…
0xFFFF	65535 lux (maximum setting)

Table 22 – SOLAR CELL THRESHOLD bit field encoding

The default setting for the solar cell threshold is 200 lux which corresponds to good availability of ambient light for harvesting.

9.5.18 SOLAR_TX_INTERVAL

If solar cell illumination-controlled reporting has been enabled and the solar cell illumination is above the defined threshold then the resulting reporting interval will be determined by the register SOLAR_TX_INTERVAL shown in Figure 41 below.

SOLAR_TX_INTERVAL				
Bit 15	Bit 14	…	Bit 1	Bit 0
SOLAR CELL INTERVAL				

Figure 41 – SOLAR_TX_INTERVAL register

The encoding used by the SOLAR CELL INTERVAL bit field is shown in Table 23 below.

SOLAR CELL INTERVAL	Solar cell illumination-based reporting interval
`0x0000, 0x0001, 0x0002`	Not supported (Do not use)
`0x0003`	3 seconds (minimum setting)
…	…
`0x003C (Default)`	60 seconds (default setting)
…	…
`0xFFFF`	65535 seconds (maximum setting)

Table 23 – SOLAR CELL INTERVAL bit field encoding

The default reporting interval while solar cell illumination is above the solar cell illumination threshold is 60 seconds. This can be reduced according to user requirements keeping in mind the energy balance.

9.5.19 LIGHT_THRESHOLD

If reduction of the reporting interval based on the light level measured by the light sensor has been enabled then the light level threshold is defined by LIGHT_THREHOLD register as shown in Figure 42 below.

LIGHT_THRESHOLD				
Bit 15	Bit 14	…	Bit 1	Bit 0
LIGHT SENSOR THRESHOLD				

Figure 42 – LIGHT_SENSOR_THRESHOLD register

The encoding used by the LIGHT SENSOR THRESHOLD bit field is shown in Table 24 below.

LIGHT SENSOR THRESHOLD	Threshold
0x0000	0 lux (minimum setting)
…	…
0x00C8 (Default)	200 Lux seconds (default setting)
…	…
0xFFFF	65535 lux (maximum setting)

Table 24 – LIGHT SENSOR THRESHOLD bit field encoding

The default setting for the light sensor threshold is 200 lux.

9.5.20 LIGHT_TX_INTERVAL

If solar cell illumination-controlled reporting has been enabled and the solar cell illumination is above the defined threshold then the resulting reporting interval will be determined by the register LIGHT_TX_INTERVAL shown in Figure 43 below.

<table>
<tr><td colspan="5">LIGHT_TX_INTERVAL</td></tr>
<tr><td>Bit 15</td><td>Bit 14</td><td>…</td><td>Bit 1</td><td>Bit 0</td></tr>
<tr><td colspan="5">LIGHT SENSOR INTERVAL</td></tr>
</table>

Figure 43 – LIGHT_TX_INTERVAL register

The encoding used by the LIGHT SENSOR INTERVAL bit field is shown in Table 25 below.

LIGHT SENSOR INTERVAL	Light sensor illumination-based reporting interval
0x0000, 0x0001, 0x0002	Not supported (Do not use)
0x0003	3 seconds (minimum setting)
…	…
0x003C (Default)	60 seconds (default setting)
…	…
0xFFFF	65535 seconds (maximum setting)

Table 25 – LIGHT SENSOR INTERVAL bit field encoding

The default reporting interval while the light level measured by the light sensor is above the light sensor illumination threshold is 60 seconds. This can be reduced according to user requirements keeping in mind the energy balance.

9.5.21 AMBIENT_LIGHT_TEST_RESULT

If EMDC has executed an ambient light test as described in chapter 2.5.5 then the result (the measured average light level at the solar cell) will be stored in the ILLUMINATION_TEST_RESULT register shown in Figure 44 below.

AMBIENT_LIGHT_TEST_RESULT (Default Setting: 0x0000)				
Bit 15	Bit 14	…	Bit 1	Bit 0
AMBIENT LIGHT TEST RESULT				

Figure 44 – AMBIENT_LIGHT_TEST_RESULT register

The field AMBIENT LIGHT TEST RESULT will provide the measured average light level expressed as integer value between 1 lux and 65535 lux. This field will be set to zero if the test is in progress or has not been executed yet.

9.6 USER DATA

The USER DATA area allows the user to read and write up to 64 byte of data after entering the correct PIN code. Typical use cases include storing information about the configuration or the installation of the device (by whom, when, what).

EMDC does not use this area and does not interpret its content in any way.

10 Installation recommendations

10.1 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.

10.2 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.

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.

10.3 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 as described in chapter 9.5.15.

By default, the ambient light sensor is used for light level measurements.

10.3.1 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)

Consider using the light level reported by the solar cell as an alternative approach if measuring a light level over a wider area is desired.

10.3.2 Solar cell

The solar cell has a much larger area and aperture compared to the ambient light sensor. Therefore, the light level measured by the solar cell is typically more representative of the average illumination within a wider area.

Note that the solar cell does not apply a spectral response curve close to the human eye's perception of ambient light to the received illumination. The illumination reported by the solar cell will therefore typically be larger than that reported by the ambient light sensor depending on the spectral properties of the ambient light. Calibration at the receiver is suggested to obtain best results for the given lighting situation.

10.4 Energy harvesting

EMDC is powered by ambient light using its integrated solar cell. For best performance it is therefore 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 exact amount of available light can be determined by executing an illumination test as described in chapter 2.5.5.

Lower levels of available light can be addressed by configuring a lower reporting rate via NFC as discussed in chapter 2.6. If the available light is insufficient, then EMDC offers the option for a CR2032 backup battery as described in chapter 4.3.

10.5 NFC configuration

EMDC can be flexibly configured for a wide range of application scenarios using the NFC configuration interface as described in chapters 8 and 9.

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 2.6.1. 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 2.5.6 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 PIN code is properly noted down.

11 Regulatory notes

11.1 European Union

11.1.1 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

11.1.2 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

11.2 FCC (United States)

EMDCU uses the TCM 515U module which has been tested against and is in compliance with FCC Part 15 Subpart B Class B.

11.2.1 FCC Grant Of Equipment Authorization

TCB

GRANT OF EQUIPMENT AUTHORIZATION

TCB

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

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.

11.2.2 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.

11.3 ISED (former Industry Canada) Certification

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

11.3.1 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

11.3.2 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.

12 Product history

Table 26 below lists the product history of EMDC.

Revision	Release date	Key changes versus previous revision
DA-03	March 2020	First public release

Table 26 – Product History