

STM 550 / EMSI – ENOCEAN MULTISENSOR FOR IOT APPLICATIONS

EnOcean Multisensor For IoT Applications

STM 550 / EMSI

24 March 2023



Observe precautions! Electrostatic sensitive devices!

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STM 550 / EMSI – ENOCEAN MULTISENSOR FOR IOT APPLICATIONS

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

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1.0	MKA	TM, EM, MH, MF	19.02.2020	First public release
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Packing: Please use the recycling operators known to you.

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1 General description

This user manual describes the functionality of the STM 550 EnOcean multisensor in the following frequency variants and revisions:

- STM 550 (Revision DC)
868.3 MHz radio (main market Europe)
- STM 550U (Revision DB)
902.875 MHz radio (main market US)
- STM 550J (Revision DB)
928.35 MHz radio (main market Japan)

For documentation regarding previous revisions, please contact EnOcean GmbH. The term “STM 550” is used throughout this user manual to describe all variants unless otherwise noted.

1.1 Basic functionality

STM 550 is a flexible self-powered multisensor module family capable of measuring temperature, humidity, illumination, magnet contact status and acceleration. It enables the realization of energy harvesting wireless sensors for light, building or industrial control systems communicating using the EnOcean radio standard.

STM 550 uses the same mechanical form factor as the industry standard PTM 21x modules from EnOcean.

STM 550 integrates the following sensors:

- Temperature
- Humidity
- Illumination
- Acceleration
- Magnet contact

STM 550 will report periodically (by default approximately every 60 seconds, configurable via NFC) the latest measurements of these sensors. In addition, STM 550 can also report its internal energy level and the amount of light available at the solar cell.

STM 550 will report immediately if the status (open / closed) of the magnet contact changes or if a change in acceleration measured by the acceleration sensor exceeds a user-defined threshold for the first time.

Radio telegrams transmitted by STM 550 can be encrypted and authenticated using AES-128 security based on a device-unique private key and a sequence counter in accordance to the EnOcean Alliance Security Specification. This ensures integrity, confidentiality and authenticity of the transmitted telegrams and prevents telegram replay (retransmission of previously transmitted telegrams).

STM 550 is self-supplied via an integrated solar cell which generates the energy required for its operation. For cases where ambient light is not sufficiently available, STM 550 provides the option to mount a CR1632 backup battery.

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1.2 Product variants

STM 550 is available in two different product variants:

- STM 550 is the multisensor module in original PTM module form factor intended for integration into OEM housings. It is delivered in tray and box packaging of 100 units per box.
- EMSI (Easyfit Multisensor for IOT) is the combination of the STM 550 multisensor module with a design frame, a wall mount, a magnet (for magnet sensor functionality) and an adhesive mounting tape into a ready to use product.

EMSI is delivered as installation kit (STM 550 KIT) consisting of one box with 100 units of STM 550 modules and one box with 100 units of housing and installation material.

Figure 1 below shows the STM 550 module on the left and EMSI on the right.



Figure 1 – STM 550 module (left) and EMSI finished product (right)

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1.3 Technical data

Antenna	Integrated helix antenna
Transmission frequency / power	STM 550: 868.300 MHz / +5 dBm STM 550U: 902.875 MHz / + 99 dBμV STM 550J: 928.350 MHz / 0 dBm
Transmission data rate	125 kbit/s
Communication range (for guidance only)	200 m free field 30 m indoor environment
Temperature measurement range / accuracy	-20 °C ... +60 °C / +- 0.3 K ⁽¹⁾
Humidity measurement range / accuracy	0 ... 100 % r.h. / +- 3% r.h. ⁽¹⁾
Illumination measurement range	0 ... 65000 lux
Acceleration measurement range	+ - 2 g (default, configurable via NFC)
Acceleration threshold for immediate report	0.03 g (default, configurable via NFC)
Update rate (excl. random offset)	Every 60 seconds (configurable via NFC)
Device configuration	LRN button and NFC interface
User notification	LED (red)
Supported EEP (selectable via NFC)	D2-14-41 (default) D2-14-40, A5-02-05, A5-04-01, A5-04-03 A5-06-02, A5-06-03, A5-14-05, D5-00-01
Power supply	Integrated solar cell
Minimum light level for self-supplied operation	200 lux for 6 hours per day ⁽²⁾
Operating time in darkness	4 days (after full charge)
Backup power supply (optional)	CR1632
Operation time with backup battery	Renata CR1632 (137 mAh)
Infrequent bright light (200 lux for 2 hrs per day)	7 years
Consistent low light (50 lux for 6 hrs per day)	6 years
Total Darkness	4.5 years
Dimensions (STM 550 module)	40 mm x 40 mm x 13 mm
Dimensions (EMSI finished product)	49 mm x 49 mm x 13 mm

Note 1: STM 550 is designed for indoor use only and should only be used in the environmental conditions specified below

Note 2: Minimum light level required for self-supplied operation with the default product configuration. See chapter 3.2 for other scenarios

1.4 Environmental conditions

Operating Temperature	-5 °C ... +45 °C (indoor use in dry rooms only)
Humidity	0% to 90% r.h. (non-condensing)

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1.5 Packaging information

1.5.1 STM 550

STM 550 is delivered in a box of 100 units packed onto 10 trays of 10 units each.

Packaging Unit	100 units
Packaging Method	10 modules per tray, 10 trays per box
Tray Dimensions	205 mm x 166 mm x 20 mm
Box Dimensions	205 mm x 176 mm x 174 mm

1.5.2 EMSI (STM 550 KIT)

EMSI is delivered as installation kit consisting of one box with 100 units STM 550 modules (as described above) together with one box of 100 units of housings and installation material.

Packaging Unit	100 units
Packaging Method	1 large outer box containing 2 smaller inner boxes Inner box 1: 100 units STM 550 (same as STM 550) Inner box 2: 100 units housing and installation material
Outer Box Dimensions	360 mm x 234 mm x 178 mm
Inner Box Dimensions	232 mm x 176 mm x 174 mm

1.6 Ordering information

Product	Type	Ordering Code	Frequency
STM 550 STM 550U STM 550J	Module only 100 unit packaging	S6201-K516 S6251-K516 S6261-K516	868.300 MHz 902.875 MHz 928.350 MHz
STM 550 KIT STM 550U KIT STM 550J KIT	Module with installation material 100 unit packaging	B6201-K516 B6251-K516 B6261-K516	868.300 MHz 902.875 MHz 928.350 MHz

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2 Functional overview

2.1 Product overview

The energy-harvesting multisensor module STM 550 provides wireless sensing functionality without batteries.

STM 550 operates fully self-powered (no batteries required) when sufficient available ambient light (200 Lux for 6 hours per day) is available. The required energy for operation is harvested by an integrated solar cell. In this configuration, STM 550 operates fully maintenance-free.

For cases where sufficient ambient light is not available there is the option to mount a CR1632 backup battery.

STM 550 integrates high performance sensors to measure temperature, humidity, ambient light level, magnet contact status and acceleration. STM 550 periodically reports the status of these sensors using radio telegrams according to EnOcean Alliance radio specification.

Radio telegrams transmitted by STM 550 can be authenticated and encrypted using AES-128 security based on a device-unique private key and a sequence counter in accordance to the EnOcean Alliance Security Specification.

The user interface of STM 550 consists of one button for simple configuration tasks and one LED to provide user feedback. Configuration of STM 550 parameters is also possible via an integrated NFC (ISO 14443) interface.

2.2 Product interface

The STM 550 product interface consists of the following elements:

- LRN button and LED
- Solar cell harvesting energy from ambient light
- Ambient light sensor (co-located with the LED)
- Magnet contact sensor
- Ventilation slots to ensure airflow to the temperature and humidity sensor
- Backup battery slot for a CR1632 battery
- Backup battery ejector slot (on the back side)
- Product label (on the back side)

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2.2.1 Front side (STM 550)

Figure 2 below shows the external interfaces on the front side of the STM 550 module.

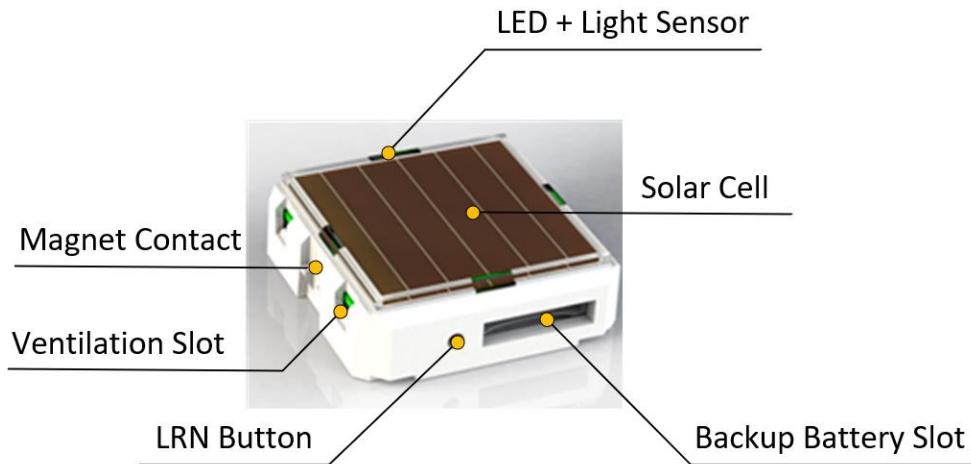


Figure 2 – STM 550 product interface (front side)

2.2.2 Front side (EMSI)

Figure 4 below shows the external interfaces on the front side of the assembled EMSI product (STM 550 module combined with the design frame and the wall mount provided by STM 550 KIT).

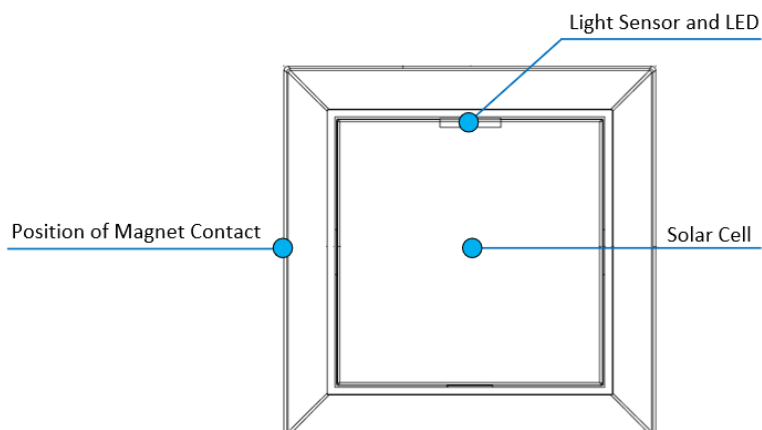


Figure 3 – EMSI product interface (front side)

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2.2.3 Back side (STM 550)

Figure 4 below shows the external interfaces on the back side of the STM 550 module. The orientation indicator points towards the side where the magnet contact is located.

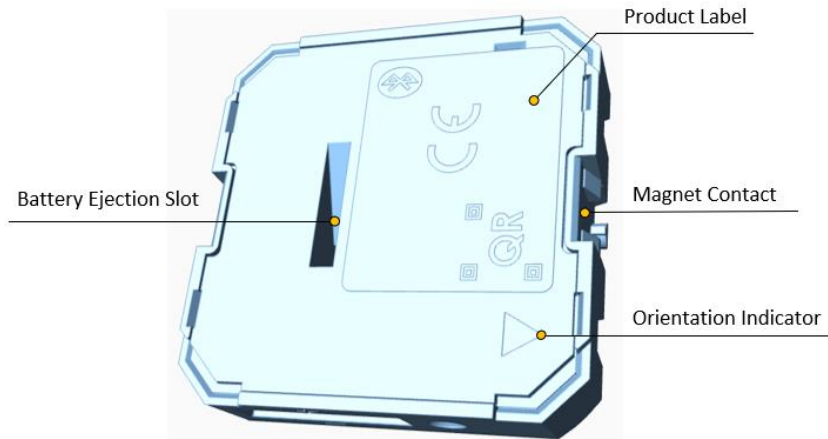


Figure 4 – STM 550 product interface (back side)

2.2.4 Back side (EMSI)

Figure 5 below shows the external interfaces on the back side of the assembled EMSI product. The orientation indicator points towards the side where the magnet contact is located. The ventilation slots ensure air flow towards the temperature and humidity sensor and should not be obstructed if EMSI is used to measure temperature or humidity.

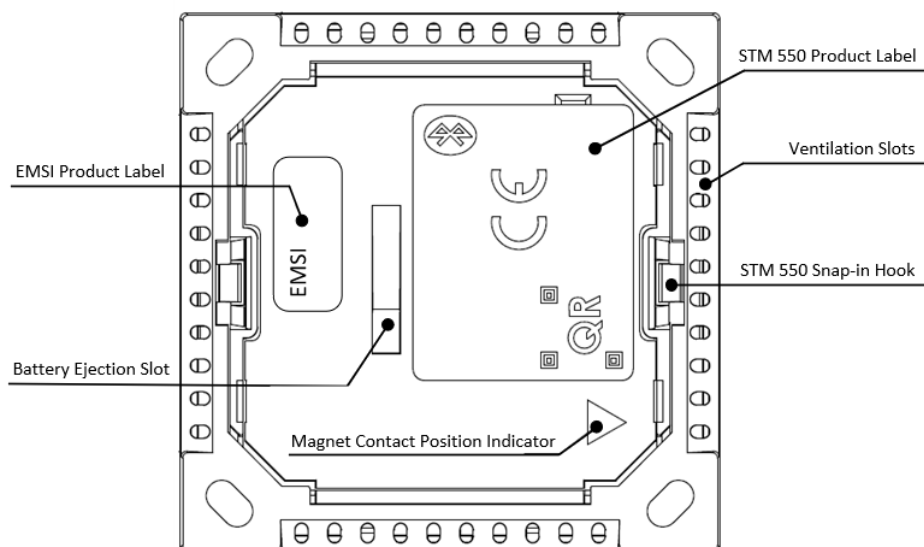


Figure 5 – STM 550 housing interface (back side)

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2.3 Functional modes

STM 550 supports seven functional modes:

- Standard operation mode
- Standby (Sleep) mode
- Learn mode
- Function test mode
- Illumination test mode
- Acceleration test mode
- Factory reset mode



Factory-new (out of the box) STM 550 are configured to be in standby mode to conserve energy during transport and storage. Upon initial setup, STM 550 has to be set to standard operation mode by pressing the LRN button shortly as described in chapter 11.1 or via the NFC interface as described in chapter 9.8.11

2.3.1 Standard operation mode

During standard (normal) operation, STM 550 wakes up periodically and reports the current sensor status using data telegrams. The STM 550 wake-up timer is by default configured to wake-up STM 550 approximately every 60 seconds. The wake-up intervals are affected at random (meaning that a small random offset is added to the timing interval) to increase the robustness of the radio transmission and to comply with regulatory requirements.

If acceleration exceeding the configured threshold is detected for the first time after a period without exceeding this threshold, then STM 550 wakes up immediately (wake on acceleration event). Likewise, if the status of the magnet contact changes (from open to closed or vice versa) then this is reported immediately as well (wake on magnet contact event).

2.3.2 Standby (Sleep) mode

Standby (sleep) mode is the lowest power mode of STM 550 and is the out of the box state of STM 550 upon delivery. It is intended to be used during extended periods without operation such as device storage or transport. In standby mode, STM 550 stops operation and conserves as much energy as possible. All functionality – except those needed to return to standard operation mode – are disabled in this mode.

Standby mode can be selected using the LRN button as described in chapter 5.2 or using the MODE field of the FUNCTIONAL_MODE NFC register as described in chapter 9.8.11. Upon entering standby mode, STM 550 will send a SIGNAL telegram of type 0x0E as described in chapter A.5.2.5.

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2.3.3 Learn mode

In Learn mode, STM 550 will transmit a Teach-in telegram to communicate its source address (EURID), the EnOcean Equipment Profile (EEP) that it currently uses and – if applicable - security mode and security information to a receiver. After that transmission, STM 550 will return to standard operation mode.

Learn mode can be selected using the LRN button as described in chapter 5.2 or using the MODE field of the FUNCTIONAL_MODE NFC register as described in chapter 9.8.11.

2.3.4 Function test mode

In Function Test mode, STM 550 will measure and report the status of the integrated sensors at the highest possible rate to verify the sensor functionality.

STM 550 can be set into function test mode via the LRN button as described in chapter 5.2 or via the MODE field of the FUNCTIONAL_MODE NFC register as described in chapter 9.8.11.

Function Test Mode will be active for approximately 2 minutes; it will be stopped immediately if the LRN button is pressed or if the functional mode is changed via the NFC interface.

2.3.5 Illumination test mode

During installation, STM 550 can measure and report the amount of ambient light available at its solar cell in to select a suitable installation location as discussed in chapter 11.7.

Upon activation of illumination test mode, STM 550 will first wait for 15 seconds so that the installer can vacate the area in front of the sensor to ensure an accurate measurement result.

After that, STM 550 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 9.8.28.

Illumination test mode can be selected using the MODE field of the FUNCTIONAL_MODE NFC register as described in chapter 9.8.11.

2.3.6 Acceleration test mode

During installation, STM 550 can visually indicate if detected acceleration exceeds the configured threshold. This provides quick visual feedback about the correct installation as discussed in chapter 11.5.

Acceleration test mode can be selected using the MODE field of the FUNCTIONAL_MODE NFC register as described in chapter 9.8.11 or using the LRN button as described in chapter 5.2.

Upon activation of acceleration test mode, STM 550 will periodically (approximately every 3 seconds) measure acceleration vector changes and blink the LED whenever this change exceeds the threshold configured using the ACCELERATION_THRESHOLD register as described in chapter 9.8.21.

Acceleration Test Mode will be active for approximately 2 minutes; it will be stopped immediately if the LRN button is pressed or if the functional mode is changed via the NFC interface.

2.3.7 Factory reset mode

STM 550 can be reset to its standard settings using factory reset mode. Upon entering this mode, STM 550 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 5.2 or using the MODE field of the FUNCTIONAL_MODE NFC register as described in chapter 9.8.11.

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2.4 Reporting interval

STM 550 will transmit its status as data telegram at a regular interval, the so-called reporting interval. By default, the reporting interval is 60 seconds, i.e. STM 550 will measure and report its status approximately once per minute.

STM 550 is designed to add a random timing offset of up to 10% to the configured reporting interval to increase transmission reliability and meet regulatory requirements.

If STM 550 is configured to report acceleration, then it will always report the initial acceleration detection after a period without detected acceleration immediately. Likewise, if STM 550 is configured to report magnet contact status, then it will report any change in the status of the magnet contact sensor (open -> closed or closed -> open) immediately.

2.4.1 Standard reporting interval

The standard reporting interval determines the default interval between two status updates of STM 550.

The standard reporting interval can be adjusted using the `STANDARD_TX_INTERVAL` NFC register as described in chapter 9.8.12. Consider the available energy before lowering the reporting interval as discussed in chapter 3.2.

The default setting for the standard reporting interval is one status update once every 60 seconds (1 minute).

Figure 6 below illustrates the use of the standard reporting interval.

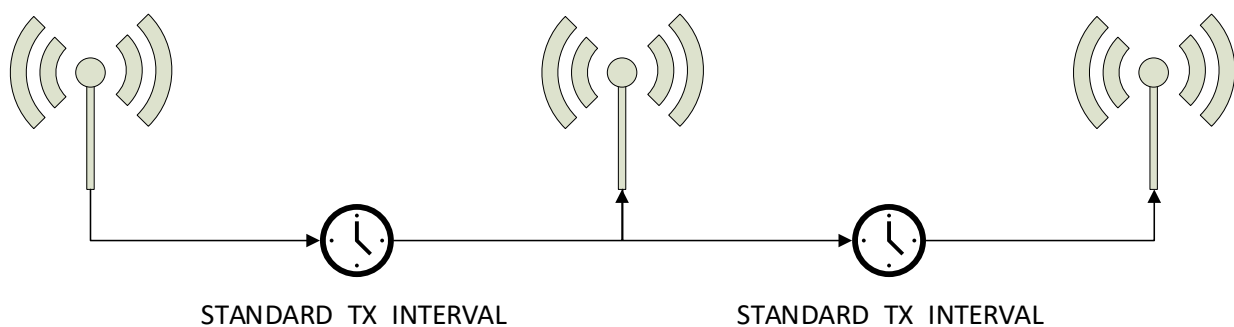


Figure 6 – Standard reporting interval

STM 550 can be configured to use a lower reporting interval, i.e. provide updates more often, based on certain conditions as described below.

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2.4.2 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 higher update rate would be used whenever the ambient light level is above a certain threshold. Figure 7 below illustrated the use of the illumination-controlled reporting interval.

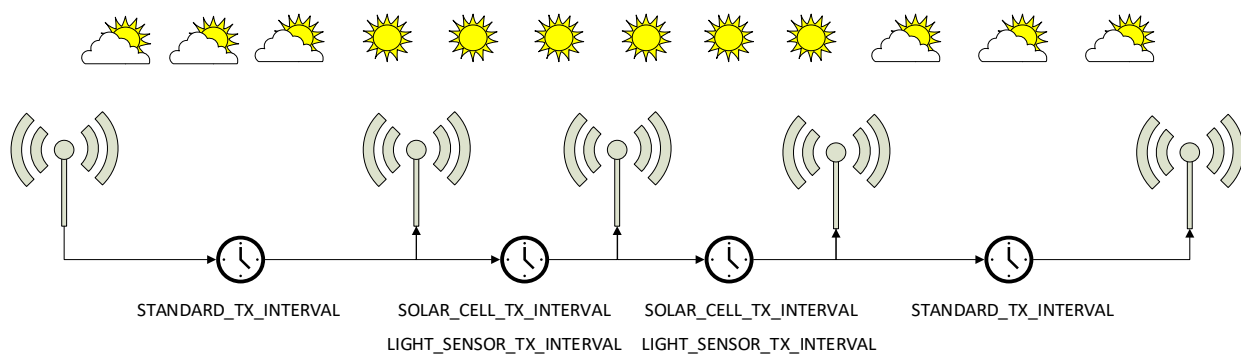


Figure 7 – Illumination-controlled reporting interval

STM 550 can use either the light level at the solar cell (harvested energy) or the light level at the ambient light sensor to trigger a higher update rate. To enable this feature, use the following steps:

1. Configure the desired light level threshold either for the solar cell or the ambient light sensor using either the `SOLAR_THRESHOLD` or `LIGHT_THRESHOLD` registers described in chapters 9.8.17 and 9.8.19 respectively
2. Configure the desired reporting interval using either the `SOLAR_TX_INTERVAL` or the `LIGHT_TX_INTERVAL` registers described in chapters 9.8.18 and 9.8.20 respectively
3. Enable the use of the defined parameters using the `SOLAR CELL` and `LIGHT SENSOR` bit fields in the `THRESHOLD_CFG1` register of the NFC interface as defined in chapter 9.8.13.

Consider the available energy before lowering the reporting interval as discussed in chapter 3.2.

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2.4.3 Temperature-controlled reporting interval

In HVAC (heating, ventilation, air conditioning) applications it might be desirable to receive status updates more often if the measured temperature is significantly above or below the target value.

Figure 8 below illustrates the use of the temperature-controlled reporting interval.

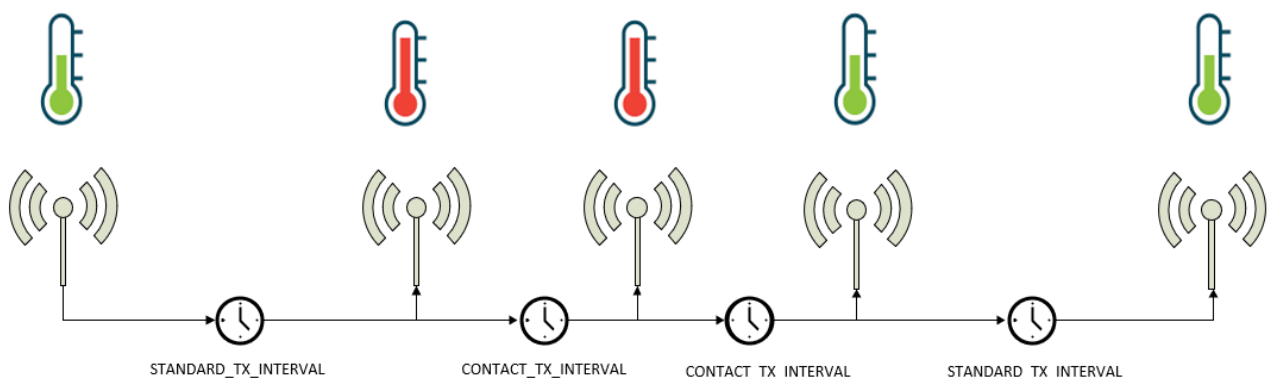


Figure 8 – Temperature-controlled reporting interval

STM 550 can use the temperature measured by the temperature and humidity sensor to trigger a higher update rate. To enable this feature, use the following steps:

1. Make sure that the EEP selected using the EEP register as described in chapter 9.8.8 reports the measured temperature
2. Configure the desired temperature threshold using the `TEMPERATURE_THRESHOLD` register described in chapter 9.8.23
3. Configure the desired reporting interval using the `TEMPERATURE_TX_INTERVAL` register described in chapter 9.8.24
4. Enable the use of the defined parameters using the `TEMP SENSOR` bit field in the `THRESHOLD_CFG1` register of the NFC interface as defined in chapter 9.8.13.

Consider the available energy before lowering the reporting interval as discussed in chapter 3.2.

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2.4.4 Humidity-controlled reporting interval

In HVAC (heating, ventilation, air conditioning) applications it might be desirable to receive status updates more often if the measured humidity is significantly above or below the target value.

Figure 9 below illustrates the use of the humidity-controlled reporting interval.

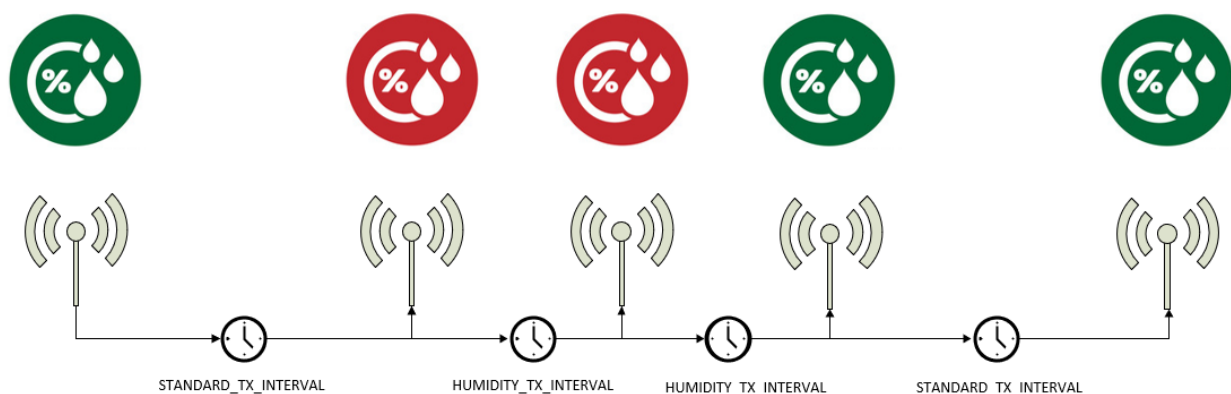


Figure 9 – Humidity-controlled reporting interval

STM 550 can use the humidity measured by the temperature and humidity sensor to trigger a higher update rate. To enable this feature, use the following steps:

1. Make sure that the EEP selected using the EEP register as described in chapter 9.8.8 reports humidity
2. Configure the desired humidity threshold using the HUMIDITY_THRESHOLD register described in chapter 9.8.25
3. Configure the desired reporting interval using the HUMIDITY_TX_INTERVAL register described in chapter 9.8.26
4. Enable the use of the defined parameters using the HUMIDITY SENSOR bit field in the THRESHOLD_CFG1 register of the NFC interface as defined in chapter 9.8.13.

Consider the available energy before lowering the reporting interval as discussed in chapter 3.2.

2.4.5 Acceleration-controlled reporting interval

If an asset is in operation or it is being moved, then it might be desirable to receive status updates more often to determine its status or location.

Figure 10 below illustrates the use of the acceleration-controlled reporting interval.

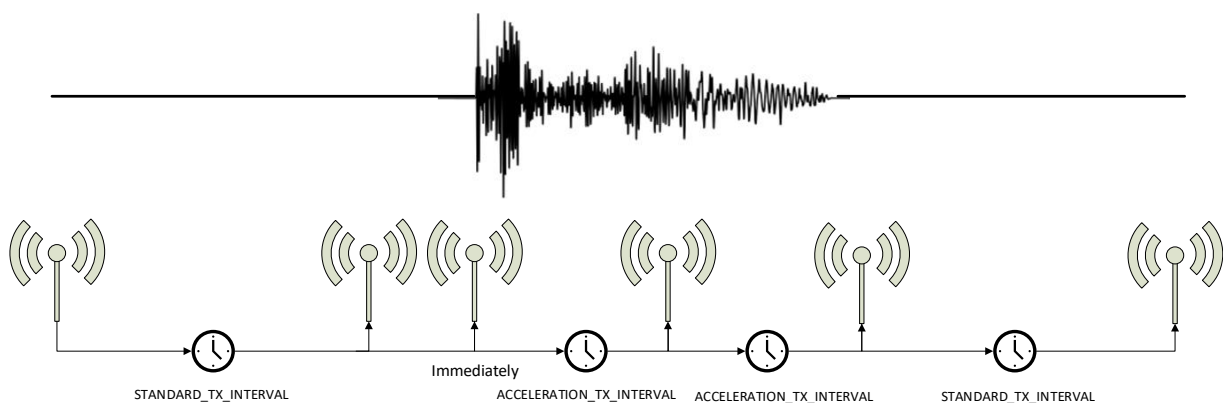


Figure 10 – Acceleration-controlled reporting interval

STM 550 can use acceleration events detected by the acceleration sensor to trigger a higher update rate. To enable this feature, use the following steps:

1. Make sure that the EEP selected using the EEP register as described in chapter 9.8.8 reports acceleration
2. Configure the acceleration sensor parameters (full scale value and sampling frequency) and enable the wake-on-acceleration feature using the ACC_SENSOR_CFG register described in chapter 9.8.16
3. Configure the desired acceleration threshold using the ACCELERATION_THRESHOLD register described in chapter 9.8.21
4. Configure the desired reporting interval using the ACCELERATION_TX_INTERVAL register described in chapter 9.8.22
5. Enable the use of the defined parameters using the ACCELERATION SENSOR bit field in the THRESHOLD_CFG2 register of the NFC interface as defined in chapter 9.8.14.

Consider the available energy before lowering the reporting interval as discussed in chapter 3.2.

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2.4.6 Magnet contact sensor-controlled reporting interval

If a door or a window is opened when it normally should be closed (or vice versa), then it might be desirable to receive status updates more often to monitor its status. STM 550 can therefore be configured to use a lower reporting interval, i.e. a higher update rate, for one of the two magnet contact sensor status options (open or closed).

Figure 11 below illustrates the use of the magnet contact sensor-controlled reporting interval.

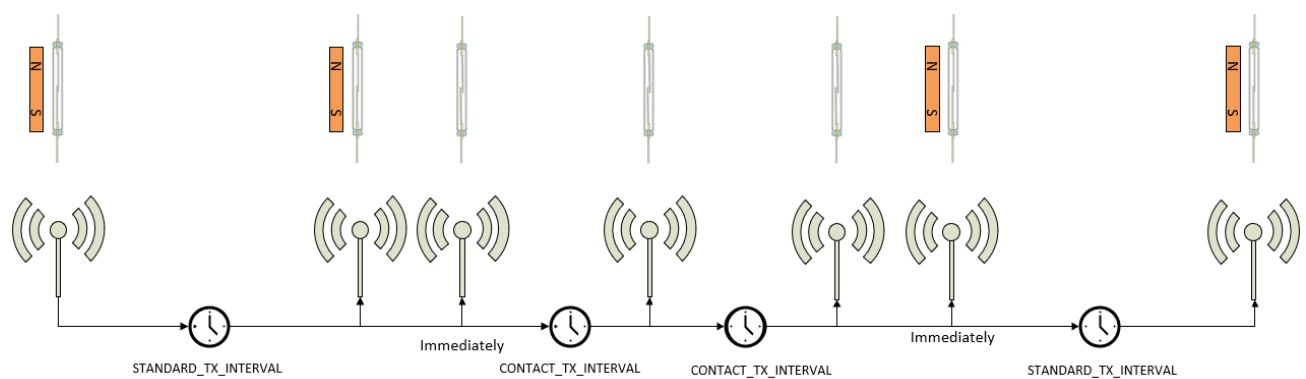


Figure 11 – Magnet contact sensor-controlled reporting interval

STM 550 can use the status of the magnet contact to trigger a higher update rate. To enable this feature, use the following steps:

1. Make sure that the EEP selected using the EEP register as described in chapter 9.8.8 reports the magnet contact status
2. Configure the desired reporting interval using the MAGNET_CONTACT_TX_INTERVAL register described in chapter 9.8.22
3. Select the state of the magnet contact (open or closed) where the lower update interval should be active using the MC SENSOR bit field in the THRESHOLD_CFG2 register as defined in chapter 9.8.14.

Consider the available energy before lowering the reporting interval as discussed in chapter 3.2.

2.4.7 Arbitration between reporting intervals

If more than one condition for a lower reporting interval applies – e.g. both an acceleration exceeding the acceleration threshold is detected and the room is brightly lit in excess of the light level threshold – then the lowest of the corresponding reporting intervals will be selected.

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3 Energy harvesting

Under normal operating conditions, STM 550 generates all energy required for its operation from available ambient light. Under these conditions, the amount of generated energy equals the amount of consumed energy; this state is called “energy balance”. STM 550 is designed to achieve energy balance - i.e. to operate fully self-supplied - in its default configuration based on a light level of at least 200 lux available for at least 6 hours per day.

3.1 Energy generation

STM 550 generates energy from the ambient light using an integrated solar cell. The amount of generated by this solar cell energy depends on the ambient light level, the availability of the ambient light and – to a much lesser extend – also the type of light as described in the next chapters.

3.1.1 Light level

STM 550 uses an integrated solar cell which is optimized for indoor lighting conditions. It is designed to achieve best performance for light levels between 50 lux and 2000 lux.

Table 1 below provides a summary of the minimum required light level for typical work and school areas in Germany as a reference for typical light levels.

Area type	Required light level
Common office areas such as entrance halls, floors, break rooms, changing rooms, toilets and canteens Automated production areas without regular presence	200 lux
Work areas without special requirements School areas without special requirements Sales areas in stores	300 lux
Office work areas for reading, writing and data processing Specialized work areas for measuring, inspecting, testing and packaging Specialized school areas	500 lux
Quality inspection workplaces	1000 lux

Table 1 – Required lighting conditions for work and school areas

The actual ambient light level at an installation location can be determined by executing an illumination test as described in chapter 2.3.5.



STM 550 is intended for indoor use only. Operation in light levels above 10000 lux (outdoor operation, especially in direct sunlight) is not permitted. The solar cell performance might degrade after extended exposure to direct sunlight.

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3.1.2 Light availability

Light availability defines the amount of time for which a certain ambient light level is available.

Taking the example of a workplace, ambient light will usually be available for eight hours or more if the workplace is occupied during standard working hours. On the other hand, ambient light might not be available at all during the weekend if the interior lighting system is not in operation and the window shutters are closed.

The amount of generated energy is directly proportional to the availability of the light, meaning that for instance 200 lux of ambient light available for 12 hours per day will provide twice the amount of energy compared to 200 lux of ambient light available for 6 hours per day.

3.1.3 Light characteristics

STM 550 uses an integrated solar cell which is optimized for typical ambient indoor lighting over a wide spectral range. Energy will be generated both from artificial lighting (such as LED lighting) or from natural lighting (from the sun) with comparable efficiency.

Special windows (which protect against infrared ultraviolet radiation) will slightly reduce the amount of energy that is generated from the incoming natural light. This impact of this effect can however be neglected in relation the impact of changing light intensity or availability.

3.2 Energy consumption

STM 550 uses the generated energy for its operation; excess energy will be stored in the integrated energy storage element. Understanding the energy consumption is important to determine the energy balance.

STM 550 is designed to operate for one full day (24 hours) based on 200 lux of ambient light available for 6 hours. This means that 6 hours of available light will provide enough energy for 24 hours (6 hours with light, 18 hours without light) of operation.

If ambient light is available for more than 6 hours per day, then STM 550 will accumulate the additional energy so that it can operate for more than 18 hours without light. STM 550 can accumulate energy for up to 14 days of operation without light.

It is suggested to select an installation location which provides at least 25% margin (e.g. 250 lux instead of 200 lux for 6 hours per day or 200 lux for 8 hours per day) to account for these factors. As reference, the required minimum light level at most working places is more than 300 lux.

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4 Sensor functionality

STM 550 integrates a set of sensors used to measure environmental parameters. The following chapters described their characteristics in detail.

4.1 Light level sensor

STM 550 integrates a dedicated light level sensor with narrow aperture and a spectral response optimized to mimic the human eye's perception of ambient light. This light sensor reports the light level directly in front of the sensor (spot measurement with narrow aperture).

Figure 12 shows the spectrum response of the STM 550 illumination sensor compared to that of the human eye.

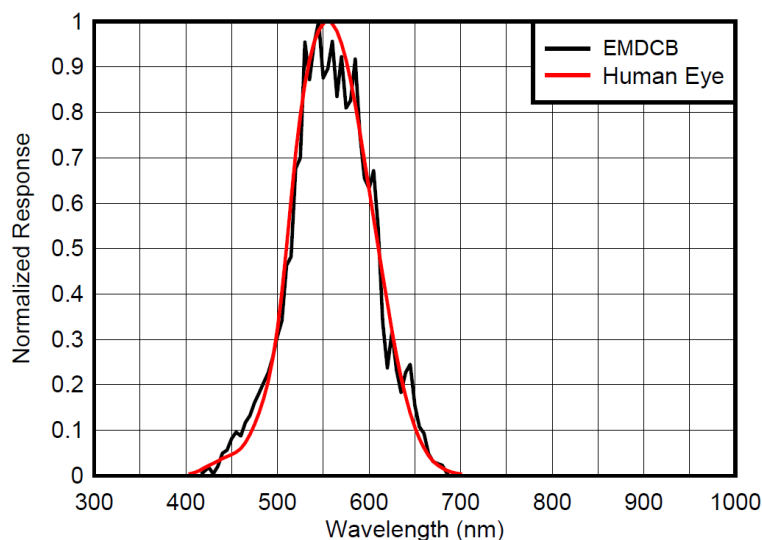


Figure 12 – Spectrum response of the light level sensor

4.2 Solar cell

STM 550 can use SIGNAL telegrams - as described in chapter A.5.2.5 - to report the energy generated by the solar cell. Reporting of the solar cell energy generation level can be enabled and disabled via the SIGNAL register of the NFC interface as described in chapter 9.8.9. By default, the reporting is disabled.

In addition, STM 550 provides the option to use the calibrated solar cell response to report wide area illumination instead of the narrow angle spot measurement of the ambient light level sensor. This can be selected using the LIGHT_SENSOR_CFG register of the NFC interface as described in chapter 9.8.15.

Refer to Chapter 11.6 for a discussion about the respective benefits of the two options.

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4.3 Temperature sensor

STM 550 integrates a high-performance temperature sensor achieving accuracy of better than ± 0.3 °C throughout the entire operation temperature range and an accuracy of better than ± 0.2 °C for the typical indoor temperature range. Figure 13 below shows the typical accuracy of the STM 550 temperature sensor as a function of the ambient temperature.

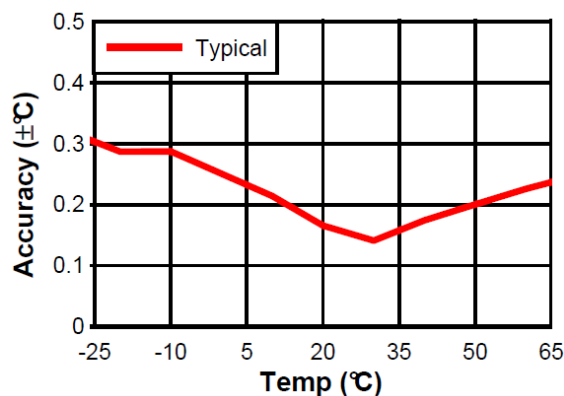


Figure 13 – Temperature sensor accuracy

To determine the overall system accuracy, the quantization error (reporting step size) determined by the selected EnOcean Equipment Profile (EEP) has to be added to this value.

4.4 Humidity sensor

STM 550 integrates a high-performance humidity sensor achieving accuracy of better than ± 3 % r.h. throughout the entire operation temperature range and an accuracy of better than ± 2 % r.h. for the typical indoor humidity range. Figure 14 below shows the typical accuracy of the STM 550 humidity sensor as a function of the ambient humidity.

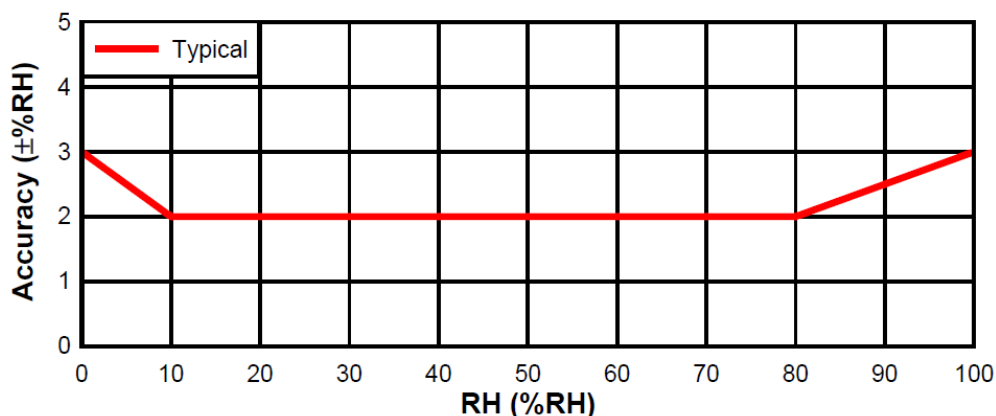


Figure 14 – Humidity sensor accuracy

To determine the overall system accuracy, the quantization error (reporting step size) determined by the selected EnOcean Equipment Profile (EEP) has to be added to this value.

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4.5 Acceleration sensor

STM 550 integrates an acceleration sensor which provides two types of data:

- Acceleration vector orientation
This allows determining the direction into which STM 550 is either accelerated (moved) or permanently oriented (positioned relative to the earth gravity vector). See Chapter 11.5.1 for an example.
- Acceleration vector change
This allows determining if STM 550 is moved or shaken

The second case (acceleration vector change) can be used to determine the presence or absence of small vibrations (acceleration vector changes). Examples use cases causing such small vibrations include asset utilization (e.g. a motor to which STM 550 is attached is running) or asset movement (e.g. an asset to which STM 550 is attached changes its location).

If such change in acceleration is above a certain threshold, then this will be reported as part of the regular data telegram. If the acceleration exceeds this threshold for the first time, then this will be reported immediately (wake-on-acceleration).

Figure 15 below shows the orientation of the acceleration vector relative to STM 550. This means that:

- If STM 550 was be positioned stationary on a flat surface parallel to the earth surface with the solar cell oriented away from the earth surface (STM 550 “laying” on the device label side, like in the illustration below), then STM 550 would report:
 $x = 0g$; $y = 0g$; $z = 1g$ (earth gravity)
- If STM 550 was be positioned stationary on a flat surface parallel to the earth surface with the battery insertion slot oriented towards the earth surface (STM 550 “standing” on the battery insertion slot), then STM 550 would report:
 $x = 0g$; $y = -1g$ (earth gravity); $z = 0g$

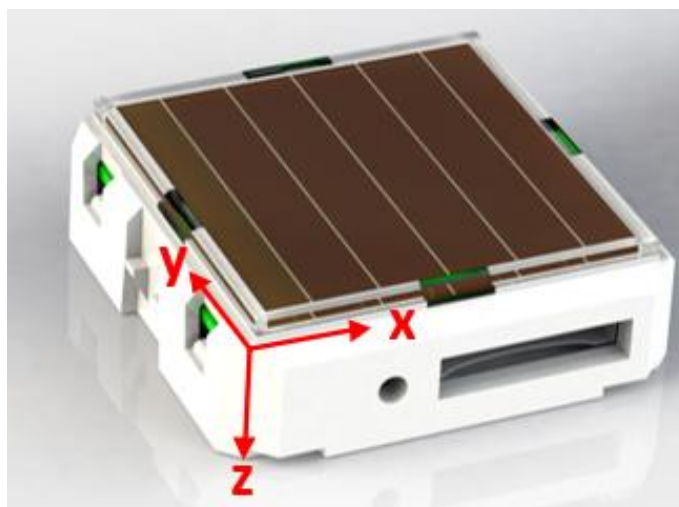


Figure 15 – Acceleration sensor orientation

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4.5.1 Wake on acceleration

If acceleration exceeding the configured threshold is detected for the first time after a period without exceeding this threshold, then STM 550 wakes up immediately (wake on acceleration event).

Wake-on acceleration can be used to immediately trigger the transmission of a message when an item is moved or starts to vibrate. The threshold for the wake on acceleration feature is adjustable as described below.

4.5.2 Acceleration sensor parameters

The acceleration sensor integrated in STM 550 allows configuring the following parameters:

- **Full-scale magnitude**
The full-scale magnitude determines the maximum acceleration magnitude that will be reported. Higher settings allow reporting higher magnitudes but will result in less resolution and thereby less sensitivity. The default full scale magnitude of $\pm 2g$ should be appropriate for most use cases.
- **Acceleration threshold**
The acceleration threshold determines the threshold of acceleration vector change required to trigger a wake-on vibration event as described above or to reduce the transmission interval as described in chapter 2.4.5.
Setting a lower acceleration threshold results in a higher sensitivity to acceleration vector changes. STM 550 uses by default the minimum possible threshold corresponding to $1/64$ of its full-scale magnitude.
- **Sampling rate**
The sampling rate determines how often the acceleration vector will be measured. Higher sampling rates allow detecting shorter vibrations but require more energy to do so. Higher sampling rates should only be used if minor vibrations are not detected when using the minimum acceleration threshold.

Table 2 below shows the supported configuration options for each of these parameters and their default settings in STM 550.

Parameter	Supported Options (bold = default)
Full-scale magnitude	$\pm 2g$, $\pm 4g$, $\pm 8g$, $\pm 16g$
Acceleration threshold	$1/64$... $63/64$ of full scale
Sampling rate	1.6 Hz , 12.5 Hz , 25 Hz , 50 Hz
Measurement resolution	10 bit for each (x, y, z) direction

Table 2 – Acceleration sensor parameters



Note that increasing the sampling rate will proportionally increase the power consumption of STM 550. The sampling rate should only be increased if sufficient ambient light is available or if a backup battery is used.

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4.6 Magnet contact sensor

STM 550 integrates a magnet contact sensor detecting presence or absence of a magnetic field in the proximity of the it. Refer to Chapter 2.2 for the location of the magnet contact sensor within STM 550 and to Chapter 11.7 for mounting instructions.

The STM 550 installation kit includes a block magnet suitable for use with its magnet contact sensor. Figure 16 shows the outer appearance of this magnet.

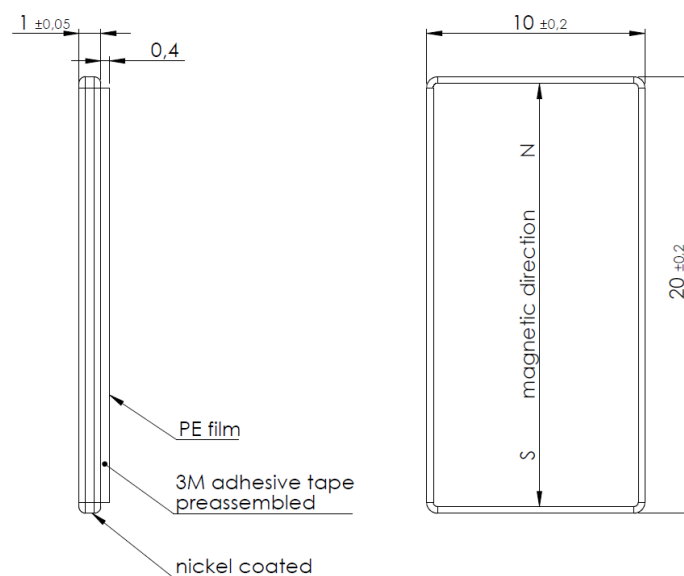


Figure 16 – Magnet outline

The magnet is made from N35 grade Neodymium material. Table 3 below lists the key parameters of this material for reference if use of alternative magnets is planned.

	Br		Hcb		Hcj		(BH) _{max}		TW
	T	KGs	KA/m	KOe	KA/m	KOe	KJ/m ³	MGOe	°C
N35	1.17-1.21	11.7-12.1	876-899	11.0-11.3	≥955	≥12	263-279	33-35	≤80

Table 3 – N35 material parameters

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5 User interface

The STM 550 product interface contains an LED, a LRN button and a backup battery interface as described in chapter 2.2.

5.1 LED

STM 550 contains an indication LED used to provide user feedback. By default, the LED will blink shortly whenever a telegram is transmitted. This indication can be disabled using the LED_MODE register of the NFC interface as described in chapter 9.8.10. In addition to that, the LED provides a response to LRN button inputs as described below.

5.2 LRN button

Most STM 550 device parameters can be configured using the NFC interface as described in chapter 9. Some of the most common parameters or states can additionally be configured using the LRN button. Table 4 below lists those LRN button actions with the corresponding STM 550 response and LED feedback.

Type	LRN Button Action	STM 550 Response	LED Feedback
1 x Short	< 1s Press	Exit from Sleep Mode Send Learn Telegram	Success: 1 short blink Error: No feedback
2 x Short	< 1s Press,	Start Function Test (End after ~2 min or upon any button press)	Sensor status is transmitted with higher update rate, LED blinks for every transmission
	< 1s Release,		
	< 1s Press		
3 x Short	< 1s Press,	Toggle LED indication	LED enabled: 2 short blinks LED disabled: No feedback
	< 1s Release,		
	< 1s Press,		
	< 1s Release,		
	< 1s Press		
4 x Short	< 1s Press,	Start Acceleration Test (End after ~2 min or upon any button press)	1 short blink during test interval if acceleration above threshold is detected
	< 1s Release,		
	< 1s Press,		
	< 1s Release,		
	< 1s Press		
	< 1s Release,		
	< 1s Press		
1 x Long	3s < Press < 5s	Enter Sleep Mode	Success: 3 short blinks Error: No feedback
2 x Long	3s < Press < 5s,	Enter High Security Mode	Success: 2 short blinks Error: No feedback
	< 1s Release,		
	3s < Press < 5s		
Very Long	> 8s Press	Execute Factory Reset	Success: 5 short blinks Error: No feedback

Table 4 – STM 550 user interface actions

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5.3 Backup battery

STM 550 provides a backup battery interface to mount a CR1632 battery for cases with insufficient ambient light. The backup battery has to be installed with the negative pole pointing upwards (i.e. towards the side of the solar cell). Check the '+' and '-' polarity markings on the housing for correct battery orientation as shown in Figure 17 below.

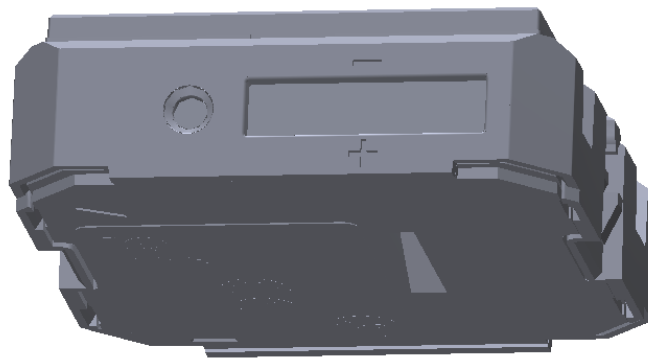


Figure 17 – Backup battery slot with polarity markings

EnOcean recommends Renata CR1632 due to its low self-discharge and high capacity. Gloves should be used when installing a backup battery to avoid contamination of the isolation area between the contacts that could lead to a higher self-discharge.

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 ejector slot on the back side of STM 550 as shown in chapter 2.2.

5.3.1 Safety remarks

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



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



CAUTION: Risk of damage or explosion if a battery of incorrect type is used.



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



Keep new and used batteries away from children.

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5.4 Product label

5.4.1 STM 550

Each STM 550 module contains a product label with a commissioning QR code. Figure 18 shows the STM 550 product label. STM 550U and STM 550J use the same label structure. Note the commissioning QR code (described in chapter 8.2) on the bottom left side.

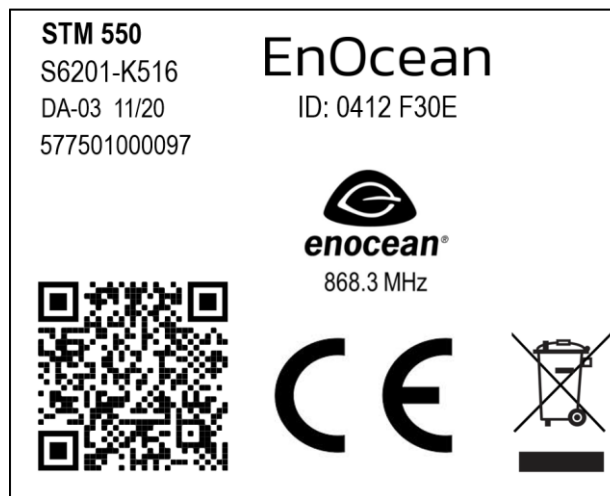


Figure 18 – STM 550 product label

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6 Radio communication

STM 550 devices communicate 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).

STM 550 uses the ERP1 standard (ISO 14543-3-10) while STM 550U and STM 550J use the ERP2 (ISO 14543-3-11) standard. Refer to Appendix A for a description of EnOcean Radio Protocol and EnOcean Equipment Profiles.

6.1 Supported EEP

STM 550 supports a wide range of EEP suitable for different use cases. Table 5 below lists the supported EEP. For details about the data format used by these EEP, see:

<http://tools.enocean-alliance.org/EEPViewer/#1>

Profile	Type	Reported Parameters	Parameter Range	Size / Resolution
D5-00-01	1BS	Magnet Contact	Open / Closed	1 Bit
A5-02-05	4BS	Temperature	0°C ... 40°C	8 bit
A5-04-01	4BS	Temperature	0°C ... 40°C	8 Bit
		Humidity	0% ... 100% r.h.	8 Bit
A5-04-03	4BS	Temperature	-20°C ... 60°C	10 Bit
		Humidity	0% ... 100% r.h.	8 Bit
A5-06-02	4BS	Light Sensor	0 lx ... 1020 lx	8 Bit
A5-06-03	4BS	Light Sensor	0 lx ... 1000 lx	10 Bit
A5-14-05	4BS	Vibration Detector	Above / Below threshold	1 Bit
D2-14-40	VLD (9 Byte)	Temperature	-40°C ... 60°C	10 Bit
		Humidity	0% ... 100% r.h.	8 Bit
		Illumination	0 ... 100000 lx	17 Bit
		Acceleration x-axis	+/- 2.5g	10 Bit
		Acceleration y-axis	+/- 2.5g	10 Bit
		Acceleration z-axis	+/- 2.5g	10 Bit
		Acceleration Status	Above / Below threshold	2 Bit
D2-14-41 (Default)	VLD (9 Byte)	Temperature	-40°C ... 60°C	10 Bit
		Humidity	0% ... 100% r.h.	8 Bit
		Illumination	0 ... 100000 lx	17 Bit
		Acceleration x-axis	+/- 2.5g	10 Bit
		Acceleration y-axis	+/- 2.5g	10 Bit
		Acceleration z-axis	+/- 2.5g	10 Bit
		Acceleration Status	Above / Below threshold	2 Bit
		Magnet Contact	Open / Closed	1 Bit

Table 5 – Supported EEP

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6.1.1 Default EEP

The default EEP used by STM 550 is D2-14-41 (VLD with 9 byte payload). It is possible to select another one of the supported EEP via the EEP register of the NFC configuration interface described in chapter 9.8.8.

6.2 Supported SIGNAL telegram types

Table 6 below lists the SIGNAL types supported by STM 550 together with their reported data.

MID	Content	Data
0x06	Energy status (remaining energy)	1 byte integer value (expressing %) Valid values: 0 ... 100
0x0D	Energy delivery of the harvester	1 byte Enumeration Valid values: 0x00 (best) ... 0x04 (worst)
0x0E	Radio disabled	Transmitted upon entering standby mode No additional data
0x10	Backup battery status	1 byte integer value (expressing %) Valid values: 0 ... 100

Table 6 – Supported SIGNAL telegram types

6.2.1 Enabled SIGNAL telegram types

The reporting of the supported SIGNAL types by STM 550 can be enabled and disabled using the SIGNAL register of the NFC interface as described in chapter 9.8.9.

By default, SIGNAL 0x06 (Energy Status) and SIGNAL 0x0E (Radio Disabled) are enabled while SIGNAL 0x0D (Energy Delivery of Harvester) and 0x10 (Backup Battery Status) are disabled.

6.2.2 SIGNAL telegram transmission rate

STM 550 will transmit each of the enabled SIGNAL telegram types once for every n EEP (data) telegrams with n being a configurable parameter that can be set via the SIGNAL configuration register of the NFC interface as described in chapter 9.8.9.

The default setting is that each enabled SIGNAL telegram type will be transmitted once every 32 EEP (data) telegrams, i.e. STM 550 will provide an update about the enabled internal parameters approximately once every 32 minutes.

7 Security

STM 550 implements the security handling functions as specified in the EnOcean security specification: <https://www.enocean-alliance.org/sec/> Please refer to Appendix B for a description of EnOcean security mechanisms.

7.1 STM 550 security implementation

STM 550 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 4 byte sequence counter to generate a 4 byte signature.

For backwards compatibility with legacy systems, it is possible to select via NFC a legacy mode using a 3 byte sequence counter to generate a 3 byte signature.

STM 550 will use secure chained telegrams (SEC_CDM) if high security mode is used and the telegram payload (including rolling code and CMAC) exceeds 14 byte.

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8 Commissioning

Commissioning is the process by which STM 550 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 STM 550 device. This is achieved by using a unique 48 Bit ID (Source Address) for each STM 550 device.
- **Security parameter exchange**
The receiver needs to be able to authenticate radio telegrams from STM 550 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 STM 550 to authenticate its radio telegrams.

STM 550 provides the following options for these tasks:

- **Radio-based commissioning**
STM 550 can communicate its parameters via special radio telegrams (teach-in telegrams) to the intended receiver. Transmission of such telegrams can be triggered by using the LRN button.
- **QR code commissioning**
Each STM 550 device contains an optically readable Quick Response (QR) Code which identifies its ID and its security key. This QR code can be read by a suitable commissioning tool (e.g. smartphone) which is already part of the network into which STM 550 will be commissioned. The commissioning tool then communicates these parameters to the intended receiver of STM 550 radio telegrams.
- **NFC commissioning**
Each STM 550 device contains an NFC interface allowing to read device parameters and to configure a user-defined security key.

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8.1 Radio-based commissioning (LRN telegram)

Radio-based commissioning is used to associate STM 550 with other devices by sending a dedicated radio telegram (a so-called commissioning telegram).

To do so, STM 550 can transmit a dedicated teach-in telegram identifying its relevant parameters. Transmission of the teach-in telegram is triggered by pressing the LRN button or via the NFC interface by setting the function mode to Learn Mode as described in chapter 9.8.11.

Radio-based commissioning mode is intended for applications where NFC commissioning cannot be used. Radio-based commissioning can be disabled via NFC if the device is operating in high security mode to prevent transmission of the security key over the air.

8.2 QR code commissioning

QR code-based commissioning reads the required parameters from a dedicated QR code in the product label (described in chapter 5.4). The parameters are encoded according to the ANSI/MH10.8.2-2013 industry standard.

The QR code on the product label in chapter 5.4 encodes the following string:

```
30S0412F30E+1P000B0000004C+13ZF9714BC5E8345CA72DFC78DB7514624F+30PS6201-K516  
+2PDA03+S01577501000097
```

Identifier	Length of data (excluding identifier)	Value
30S	8 characters	EURID (hex)
13Z	32 characters	Security Key (hex)
30P	Up to 10 characters	Ordering Code (E6201-K516)
2P	4 characters	Step Code - Revision (CA-01)
S	14 characters	Serial Number

Table 7 – QR code format

From this content, it is possible to extract the device address (000012345678) and the security key (0123456789ABCDEF0123456789ABCDEF) which can then be used to commission STM 550 into a receiver and to decrypt and authenticate STM 550 data telegrams as described in chapter 7.

8.3 Commissioning via NFC interface

STM 550 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 to configure the security key of STM 550 as described in chapter 9.

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9 NFC interface

STM 550 implements an NFC configuration interface that can be used to access (read and write) the STM 550 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 STM 550 device.



Note that STM 550 temporarily stops operation to ensure configuration data integrity while the NFC reader is connected to the NFC interface of STM 550.

STM 550 will automatically resume operation approximately 5 seconds after the NFC reader has been disconnected.

Care has to be taken not to configure unsupported values as product behavior is undefined in that case.

9.1 NFC interface parameters

The NFC interface of STM 550 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.

9.2 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.

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9.3 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.

9.3.1 PC with dedicated NFC reader

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

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

The TWN4 Multitech 2 HF NFC Reader is available from Elatec RFID Systems (sales-rfid@elatec.com) using order code T4BT-FB2BEL2-SIMPL. It is shown in Figure 19 below.



Figure 19 – Elatec TWN4 MultiTech Desktop NFC Reader

9.3.2 Android or iOS smartphone with NFC

NFC functionality is available in certain Android (e.g. Samsung Galaxy S7 or newer) 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>

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9.4 NFC memory areas

These NFC pages are allocated into the following areas:

- **Device Identification NDEF string** (Public read-only access; no PIN required)
This area contains an NDEF string identifying key device parameters
- **User Information 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.
STM 550 does not use this area and does not interpret its content in any way.

The organization of the STM 550 NFC memory map is shown in Table 8 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 8 – STM 550 NFC memory areas

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9.5 Device identification NDEF

The 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 STM 550 could be:

```
6PEN0+30S0000012345678+1P000B00000004C+30PS6221-K516+2PDB06+12Z01234567891234
+3C31+01000000
```

This NDEF string encodes the parameters shown in Table 9 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: „000B00000004C“ STM 550U: „000B00000004D“ STM 550J: „000B00000004E“
30P	10 characters	Ordering Code STM 550: "S6201-K516" STM 550U: "S6251-K516" STM 550J: "S6261-K516"
2P	4 characters	Step Code and Revision ("DB06")
12Z	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 9 – NDEF Parameters

9.6 User information NDEF

The 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.

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9.7 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.

9.7.1 NFC HEADER area structure

The structure of the NFC HEADER area is shown in Figure 20 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 (0x000003)		
0x33	REVISION (0x03)	END (0xFE)	UNUSED (0x0000)	

Figure 20 – 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 STM 550, 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 STM 550, the DEVICE_IDENTIFIER is set to 0x000003
- **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.

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9.8 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 using the correct 32-bit PIN code.

9.8.1 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. STM 550 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.

9.8.2 CONFIGURATION area structure

The structure of the CONFIGURATION area is shown in Figure 21 below.

NFC Address	Content			
	Byte 0	Byte 1	Byte 2	Byte 3
0x40	PRODUCT_ID (as characters in ASCII format) Will be copied to NDEF Header			
0x41				
0x42				
0x43	RFU			
0x44	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			
...				
0x47				
0x48	SECURITY_KEY_MODE	SECURITY_CFG	RFU	
0x49	EEP	SIGNAL	LED_MODE	FUNCTIONAL_MODE
0x4A	STANDARD_TX_INTERVAL		RFU	
0x4B	NFC_PIN_CODE			
0x4C	THRESHOLD_CFG1	THRESHOLD_CFG2	LIGHT_SENSOR_CFG	ACC_SENSOR_CFG
0x4D	SOLAR_THRESHOLD		SOLAR_TX_INTERVAL	
0x4E	LIGHT_THRESHOLD		LIGHT_TX_INTERVAL	
0x4F	ACCELERATION_THRESHOLD		ACCELERATION_TX_INTERVAL	
0x50	TEMPERATURE_THRESHOLD		TEMPERATURE_TX_INTERVAL	
0x51	HUMIDITY_THRESHOLD		HUMIDITY_TX_INTERVAL	
0x52	RFU		MAGNET_CONTACT_TX_INTERVAL	
0x53	RFU		RFU	
0x54	LIGHT_TEST_RESULT		RFU	

Figure 21 – CONFIGURATION area structure

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9.8.3 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.

9.8.4 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 STM 550:

STM 550: 0000004C
STM 550U: 0000004D
STM 550J: 0000004E

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 9.5) to be updated.

Figure 22 below shows the structure of the PRODUCT_ID register. This register contains the sequence of 12 ASCII characters (1 byte each) starting with CH0 and ending with CH11.

PRODUCT_ID											
CH0	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8	CH9	CH10	CH11
Manufacturer ("000B")				Product ID ("0000004C", "0000004D" or "0000004E")							

Figure 22 – PRODUCT_ID

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9.8.5 USER_KEY

Each STM 550 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 STM 550 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 STM 550. 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.

9.8.6 SECURITY_KEY_MODE

The register SECURITY_KEY_MODE allows selecting if FACTORY_KEY or USER_KEY should be used to encrypt and authenticate STM 550 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 23 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 23 – SECURITY_KEY_MODE register

The encoding for the KEY SELECTION bit field is shown in Table 10 below.

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

Table 10 – KEY SELECTION bit field encoding

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The encoding for the SECURE LRN TELEGRAM bit field is shown in Table 11 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 11 – SECURE LRN TELEGRAM bit field encoding

9.8.7 SECURITY_MODE

The register SECURITY_MODE identifies the security settings used by STM 550. Figure 24 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 24 – SECURITY_MODE register

The encoding for the SECURITY MODE bit field is shown in Table 12 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 12 – SECURITY MODE bit field encoding

The encoding for the SECURITY FORMAT bit field is shown in Table 13 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 13 – SECURITY FORMAT bit field encoding

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9.8.8 EEP

The EEP register determines the EnOcean Equipment Profile (EEP) used by STM 550 for the transmission of data telegrams. Figure 25 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 25 – EEP register

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

EEP	EnOcean Equipment Profile
0b0000 (Default)	D2-14-41
0b0001	D2-14-40
0b0010	A5-02-05
0b0011	A5-04-03
0b0100	A5-06-03
0b0101	A5-06-02
0b0110	D5-00-01
0b0111	A5-14-05
0b1000	A5-04-01
Others	Reserved, do not use

Table 14 – EEP bit field encoding

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9.8.9 SIGNAL

STM 550 supports reporting its energy status, the current energy delivery of the harvester and the backup battery status via SIGNAL telegrams as described in chapter A.5.2.5.

The type and the transmission rate of SIGNAL telegrams is controlled by the SIGNAL register shown in Figure 26 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 26 – SIGNAL register

STM 550 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.

STM 550 allows additionally to configure at what rate each enabled SIGNAL telegram will be sent using the TRANSMISSION RATE bit field as shown in Table 15 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 15 – TRANSMISSION RATE bit field encoding

9.8.10 LED_MODE

The LED_MODE register determines the brightness of the LED. Figure 27 below shows the structure of the LED_MODE register.

LED_MODE (Default: 0x01)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU						LED	

Figure 27 – LED_MODE register

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

LED	LED Intensity
0b00	LED is disabled
0b01 (Default)	LED is enabled
0b10, 0b11	Reserved (Do not use)

Table 16 – LED bit field encoding

9.8.11 FUNCTIONAL_MODE

The FUNCTIONAL_MODE register can be used to switch between the different functional modes of STM 550 as described in chapter 2.2.

Figure 28 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 28 – FUNCTIONAL_MODE register

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

MODE	Functional Mode
0b0000 (Default)	Standard Operation Mode
0b0001	Standby (Sleep) Mode
0b0010	Learn Mode
0b0011	Function Test Mode
0b0100	Illumination Test Mode
0b0101	Acceleration Test Mode
0b0111	Factory Reset
Others	Reserved (Do not use)

Table 17 – 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.

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9.8.12 STANDARD_TX_INTERVAL

STM 550 uses a standard reporting interval which can be automatically adjusted based on sensor readings as described in chapter 2.4. The standard reporting interval is set by the register STANDARD_TX_INTERVAL shown in Figure 29 below.

STANDARD_TX_INTERVAL (Default: 0x003C)				
Bit 15	Bit 14	...	Bit 1	Bit 0
STANDARD INTERVAL				

Figure 29 – STANDARD_TX_INTERVAL register

The encoding used by the STANDARD INTERVAL bit field is shown in Table 18 below.

STANDARD INTERVAL	Standard 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 18 – STANDARD INTERVAL bit field encoding

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9.8.13 THRESHOLD_CFG1

STM 550 can reduce the reporting interval based on the illumination of the solar cell, the light illumination of the light level sensor, the temperature or the humidity as described in chapter 2.4.

The use of these reduced reporting intervals is enabled by the THRESHOLD_CFG1 register shown in Figure 30 below.

THRESHOLD_CFG1 (Default: 0x00)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
HUMIDITY SENSOR		TEMP SENSOR		LIGHT SENSOR		SOLAR CELL	

Figure 30 – THRESHOLD_CFG1 register

The encoding used by the SOLAR CELL bit field is shown in Table 19 below.

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

Table 19 – SOLAR CELL bit field encoding

The encoding used by the LIGHT SENSOR bit field is shown in Table 20 below.

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

Table 20 – LIGHT SENSOR bit field encoding

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

TEMP SENSOR	Reporting interval reduction based on temperature
0b00 (Default)	Disabled (No reporting interval reduction)
0b01	Enabled, Reporting interval reduction if temperature below threshold
0b10	Enabled, Reporting interval reduction if temperature above threshold
0b11	Reserved (Do not use)

Table 21 – TEMP SENSOR bit field encoding

The encoding used by the HUMIDITY SENSOR bit field is shown in Table 22 below.

HUMIDITY SENSOR	Reporting interval reduction based on temperature
0b00 (Default)	Disabled (No reporting interval reduction)
0b01	Enabled, Reporting interval reduction if humidity below threshold
0b10	Enabled, Reporting interval reduction if humidity above threshold
0b11	Reserved (Do not use)

Table 22 – HUMIDITY SENSOR bit field encoding

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9.8.14 THRESHOLD_CFG2

STM 550 can reduce the reporting interval based on the acceleration sensor status and the magnet contact status as described in chapter 2.4.

The use of these reduced reporting intervals is enabled by the THRESHOLD_CFG2 register shown in Figure 31 below.

THRESHOLD_CFG2 (Default: 0x00)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU				MC SENSOR		ACC SENSOR	

Figure 31 – THRESHOLD_CFG2 register

The encoding used by the ACC SENSOR bit field is shown in Table 23 below.

ACC SENSOR	Reporting interval reduction based on acceleration
0b00 (Default)	Disabled (No reporting interval reduction)
0b01	Reserved (Do not use)
0b10	Enabled, Reporting interval reduction if acceleration above threshold
0b11	Reserved (Do not use)

Table 23 – ACC SENSOR bit field encoding

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

MC SENSOR	Reporting interval reduction based on magnet contact status
0b00 (Default)	Disabled (No reporting interval reduction)
0b01	Enabled, Reporting interval reduction if contact is open
0b10	Enabled, Reporting interval reduction if contact is closed
0b11	Reserved (Do not use)

Table 24 – MC SENSOR bit field encoding

9.8.15 LIGHT_SENSOR_CFG

STM 550 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 4.1 for a description of the ambient light sensor and to chapter 4.2 for a description of the solar cell functionality.

The selection between these two options is made using the LIGHT_SENSOR_CFG register shown in Figure 32 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 32 – LIGHT_SENSOR_CFG register

The encoding used by the INPUT SELECTION bit field is shown in Table 25 below.

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

Table 25 – INPUT SELECTION bit field encoding

9.8.16 ACC_SENSOR_CFG

The operation parameters of the acceleration sensor in STM 550 can be configured using the ACC_SENSOR_CFG registers shown in Figure 33 below. Refer to chapter 4.5 for a description of the acceleration sensor function.

ACC_SENSOR_CFG (Default: 0x14)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU			WAKE	SAMPLING RATE		FULL SCALE	

Figure 33 – ACC_SENSOR_CFG register

The encoding used by the FULL SCALE bit field is shown in Table 23 below.

FULL SCALE	Full scale value of the acceleration sensor
0b00 (Default)	+2 g
0b01	+4 g
0b10	+8 g
0b11	+16 g

Table 26 – FULL SCALE bit field encoding

The encoding used by the SAMPLING RATE bit field is shown in Table 27 below.

SAMPLING RATE	Sampling rate of the acceleration sensor
0b00	1.6 Hz
0b01 (Default)	12.5 Hz
0b10	25 Hz
0b11	50 Hz

Table 27 – SAMPLING RATE bit field encoding

The wake-on-acceleration function can be enabled and disabled using the WAKE bit field as shown in Table 28 below.

WAKE	Wake-on-acceleration
0b0	Disabled
0b1 (Default)	Enabled

Table 28 – WAKE bit field encoding

9.8.17 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_THRESHOLD register as shown in Figure 34 below.

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

Figure 34 – SOLAR_THRESHOLD register

The encoding used by the SOLAR CELL THRESHOLD bit field is shown in Table 29 below.

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

Table 29 – 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.

9.8.18 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 35 below.

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

Figure 35 – SOLAR_TX_INTERVAL register

The encoding used by the SOLAR CELL INTERVAL bit field is shown in Table 30 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 30 – 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.

9.8.19 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_THRESHOLD register as shown in Figure 36 below.

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

Figure 36 – LIGHT_SENSOR_THRESHOLD register

The encoding used by the LIGHT SENSOR THRESHOLD bit field is shown in Table 31 below.

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

Table 31 – LIGHT SENSOR THRESHOLD bit field encoding

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

9.8.20 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 37 below.

LIGHT_TX_INTERVAL				
Bit 15	Bit 14	...	Bit 1	Bit 0
LIGHT_SENSOR_INTERVAL				

Figure 37 – LIGHT_TX_INTERVAL register

The encoding used by the LIGHT SENSOR INTERVAL bit field is shown in Table 32 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 32 – 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.

9.8.21 ACCELERATION_THRESHOLD

If reduction of the reporting interval based on acceleration has been enabled, then the acceleration threshold is defined by ACCELERATION_THRESHOLD register as shown in Figure 38 below.

Note that this threshold is also used for the wake-on-acceleration function as described in chapter 4.5.

ACCELERATION_THRESHOLD				
Bit 15	Bit 14	...	Bit 1	Bit 0
ACCELERATION_THRESHOLD				

Figure 38 – ACCELERATION_THRESHOLD register

The encoding used by the ACCELERATION_THRESHOLD bit field is shown in Table 33 below.

ACCELERATION_THRESHOLD	Threshold
0b000000	Reserved (Do not use)
0b000001 (Default)	1/64 * Full scale
0b000010	2/64 * Full scale
...	
0b111110	62/64 * Full scale
0b111111	63/64 * Full scale

Table 33 – ACCELERATION_THRESHOLD bit field encoding

9.8.22 ACCELERATION_TX_INTERVAL

If acceleration-controlled reporting has been enabled and the acceleration exceeds the defined acceleration threshold, then the resulting reporting interval will be determined by the register ACCELERATION_TX_INTERVAL shown in Figure 39 below.

ACCELERATION_TX_INTERVAL				
Bit 15	Bit 14	...	Bit 1	Bit 0
ACCELERATION INTERVAL				

Figure 39 – ACCELERATION_TX_INTERVAL register

The encoding used by the ACCELERATION INTERVAL bit field is shown in Table 34 below.

ACCELERATION INTERVAL	Acceleration-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 34 – ACCELERATION INTERVAL bit field encoding

The default reporting interval when the acceleration meets the defined threshold criteria is 60 seconds. This can be reduced according to user requirements keeping in mind the energy balance.

9.8.23 TEMPERATURE_THRESHOLD

If reduction of the reporting interval based on the temperature has been enabled, then the temperature threshold is defined by TEMPERATURE_THRESHOLD register as shown in Figure 40 below.

TEMPERATURE_THRESHOLD					
Bit 15	Bit 14	...		Bit 1	Bit 0
TEMPERATURE THRESHOLD					

Figure 40 – TEMPERATURE_THRESHOLD register

The encoding used by the TEMPERATURE_THRESHOLD bit field is shown in Table 35 below.

TEMPERATURE_THRESHOLD	Threshold
0x0000	0.0°C
0x0001	0.1°C
...	
0x028A	65.0°C
Reserved	
0xFF38	-20.0°C
...	
0xFFFF	-0.1°C

Table 35 – TEMPERATURE_THRESHOLD bit field encoding

9.8.24 TEMPERATURE_TX_INTERVAL

If temperature-controlled reporting has been enabled and the temperature meets the defined threshold criteria, then the resulting reporting interval will be determined by the register TEMPERATURE_TX_INTERVAL shown in Figure 41 below.

TEMPERATURE_TX_INTERVAL					
Bit 15	Bit 14	...		Bit 1	Bit 0
TEMPERATURE INTERVAL					

Figure 41 – TEMPERATURE_TX_INTERVAL register

The encoding used by the TEMPERATURE INTERVAL bit field is shown in Table 36 below.

TEMPERATURE INTERVAL	Temperature-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 36 – TEMPERATURE INTERVAL bit field encoding

The default reporting interval when the temperature meets the defined threshold criteria is 60 seconds. This can be reduced according to user requirements keeping in mind the energy balance.

9.8.25 HUMIDITY_THRESHOLD

If reduction of the reporting interval based on the humidity has been enabled, then the humidity threshold is defined by HUMIDITY_THRESHOLD register as shown in Figure 42 below.

HUMIDITY_THRESHOLD					
Bit 15	Bit 14	...		Bit 1	Bit 0
HUMIDITY THRESHOLD					

Figure 42 – HUMIDITY_THRESHOLD register

The encoding used by the HUMIDITY_THRESHOLD bit field is shown in Table 37 below.

HUMIDITY_THRESHOLD	Threshold
0x0000	0.0 % r.h.
0x0001	0.5 % r.h.
...	
0x00C7	99.5 %r.h.
0x00C8	100.0 %r.h.
Others	Reserved (Do not use)

Table 37 – HUMIDITY_THRESHOLD bit field encoding

9.8.26 HUMIDITY_TX_INTERVAL

If humidity-controlled reporting has been enabled and the humidity meets the defined threshold criteria, then the resulting reporting interval will be determined by the register HUMIDITY_TX_INTERVAL shown in Figure 43 below.

HUMIDITY_TX_INTERVAL				
Bit 15	Bit 14	...	Bit 1	Bit 0
HUMIDITY INTERVAL				

Figure 43 – HUMDITY_TX_INTERVAL register

The encoding used by the HUMIDITY INTERVAL bit field is shown in Table 38 below.

HUMIDITY INTERVAL	Humidity-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 38 – HUMIDITY INTERVAL bit field encoding

The default reporting interval when the humidity meets the defined threshold criteria is 60 seconds. This can be reduced according to user requirements keeping in mind the energy balance.

9.8.27 MAGNET_CONTACT_TX_INTERVAL

If magnet contact-controlled reporting has been enabled and the magnet contact state matches the state configured in the THRESHOLD_CFG2 register, then the resulting reporting interval will be determined by the register MAGNET_CONTACT_TX_INTERVAL shown in Figure 44 below.

MAGNET_CONTACT_TX_INTERVAL					
Bit 15	Bit 14	...		Bit 1	Bit 0
MAGNET CONTACT INTERVAL					

Figure 44 – MAGNET_CONTACT_TX_INTERVAL register

The encoding used by the MAGNET CONTACT INTERVAL bit field is shown in Table 39 below.

MAGNET CONTACT INTERVAL	Magnet contact-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 39 – MAGNET CONTACT INTERVAL bit field encoding

The default reporting interval when the magnet contact state meets the defined state is 60 seconds. This can be reduced according to user requirements keeping in mind the energy balance.

9.8.28 ILLUMINATION_TEST_RESULT

If STM 550 has executed an illumination test as described in chapter 2.3.5 then the result (the measured average light level at the solar cell) will be stored in the ILLUMINATION_TEST_RESULT register shown in Figure 45 below.

ILLUMINATION_TEST_RESULT (Default Setting: 0x0000)				
Bit 15	Bit 14	...	Bit 1	Bit 0
ILLUMINATION TEST RESULT				

Figure 45 – ILLUMINATION_TEST_RESULT register

9.9 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).

STM 550 does not use this area and does not interpret its content in any way.

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10 Mechanical interface

10.1 STM 550

STM 550 implements the mechanical interface of the PTM 21x module which is described in more detail in this chapter. All dimensions and tolerances given are in millimetres unless otherwise noted.

10.1.1 Top view

Figure 46 below shows the STM 550 module seen from the top. The cut view along the A-A line is shown in chapter 10.1.3.

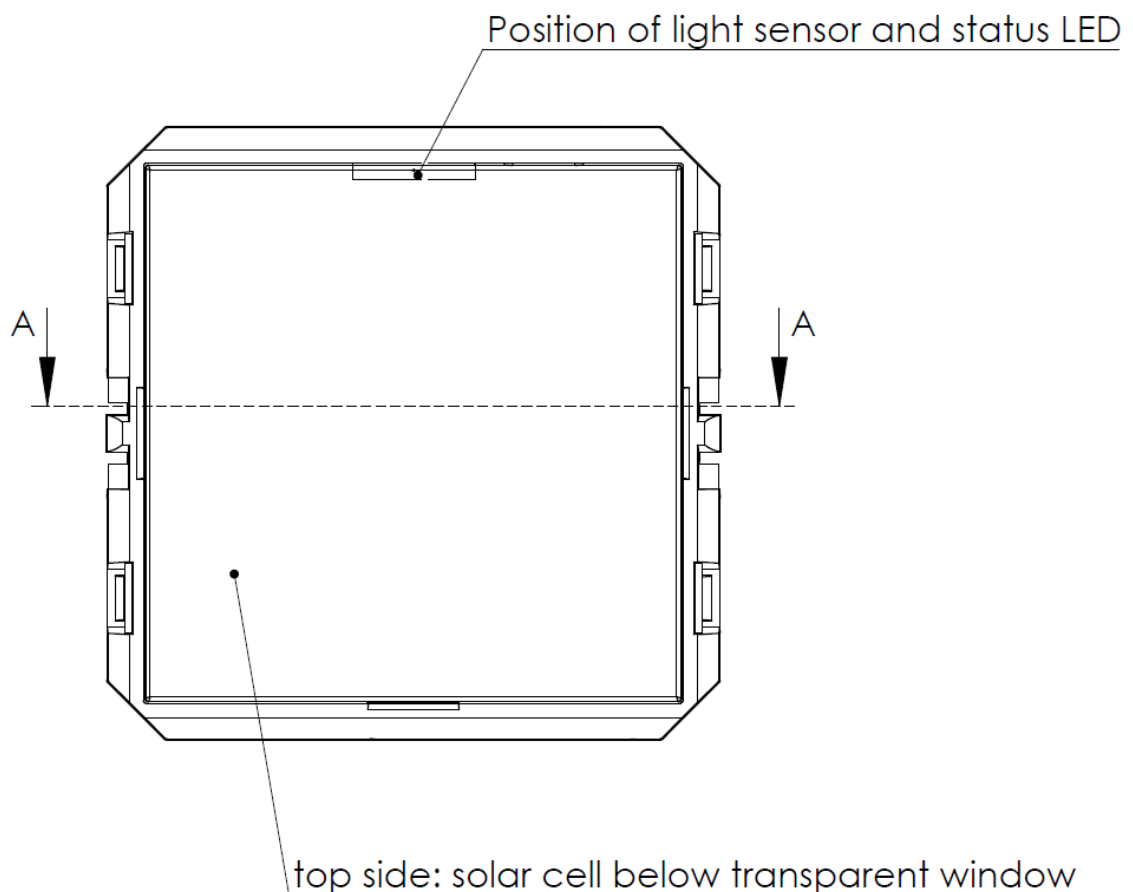


Figure 46 – Top view of STM 550 module

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10.1.2 Bottom view

Figure 47 below shows the STM 550 module seen from the bottom.

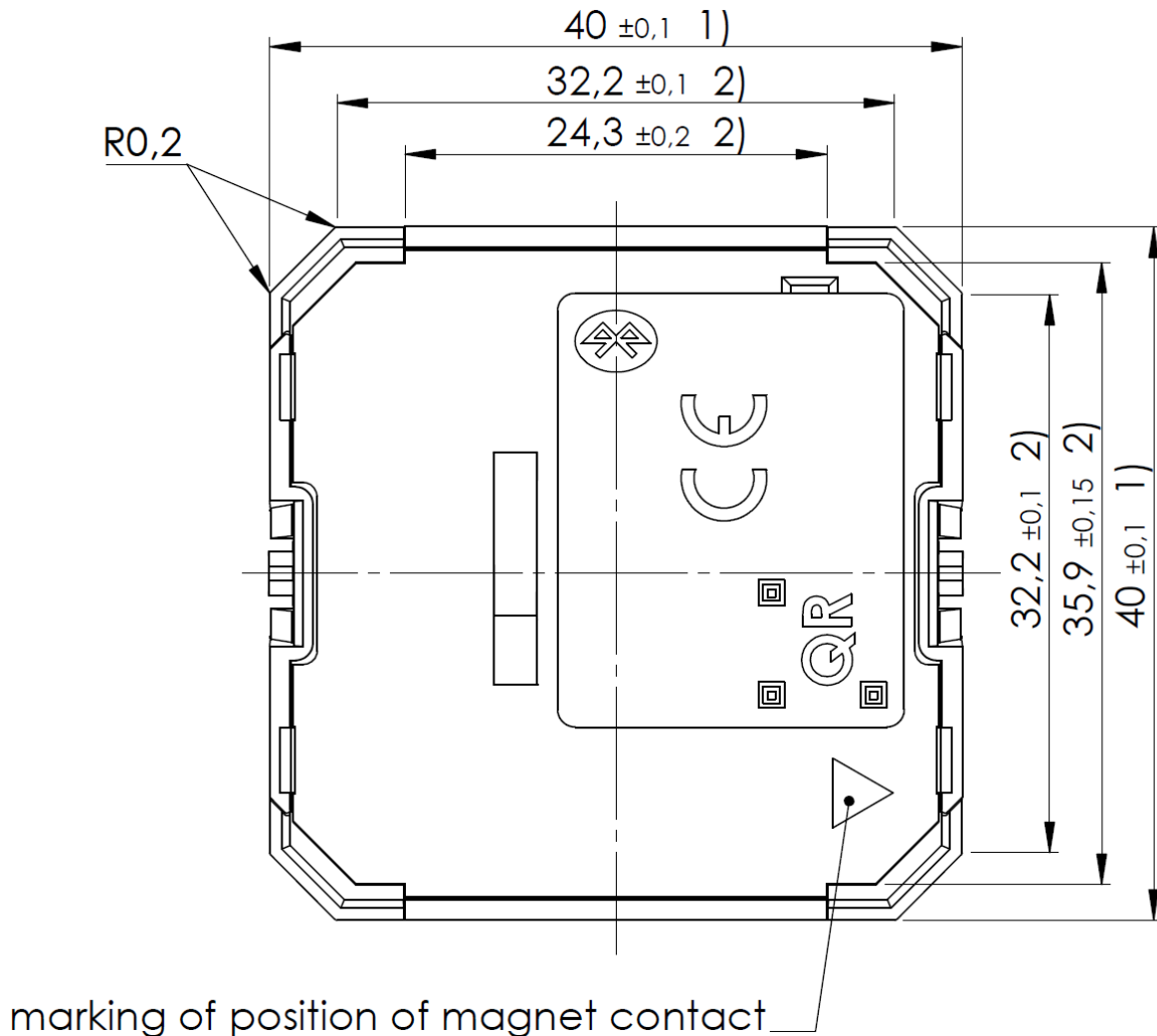


Figure 47 – Bottom view of STM 550 module

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10.1.3 Cut view (A-A)

Figure 48 below shows a cut along the A-A line of Figure 46 and highlights the area of the mounting structure (B region) in more detail.

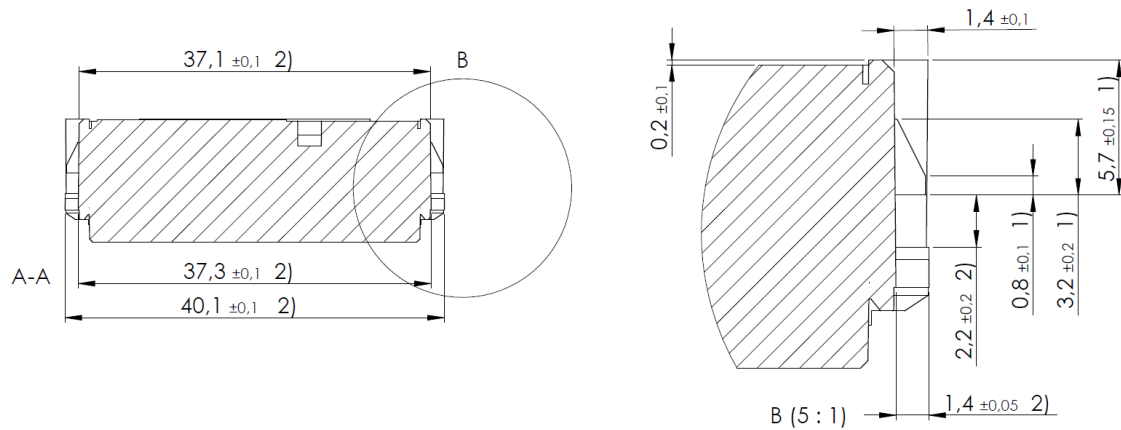


Figure 48 – Cut view (A-A) of STM 550 module

10.1.4 Front view

Figure 49 below shows the STM 550 module seen from the front.

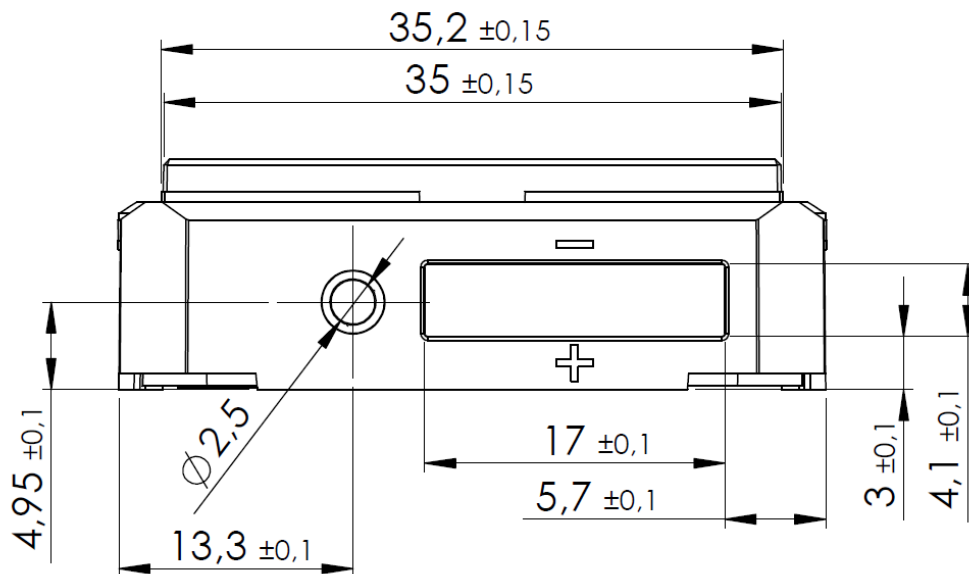


Figure 49 – Front view of STM 550 module

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10.1.5 Side view

Figure 50 below shows the STM 550 module seen from the side.

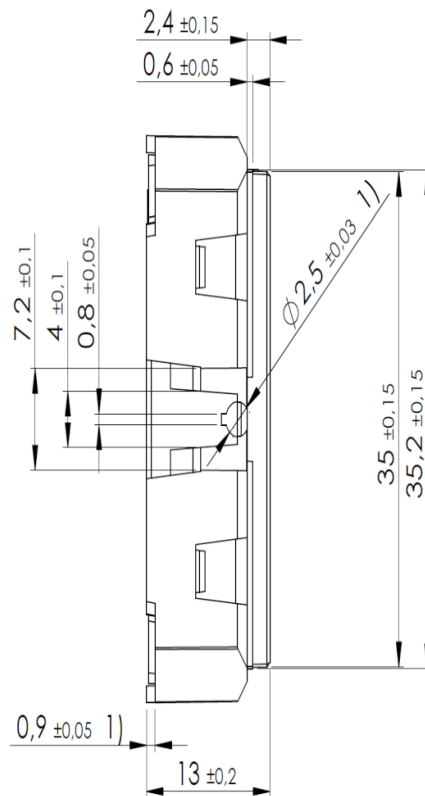


Figure 50 – Side view of STM 550 module

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10.2 Housing

The STM 550 installation kit provides a housing for integration of the STM 550 module. Figure 51 below shows the mechanical interface of this housing.

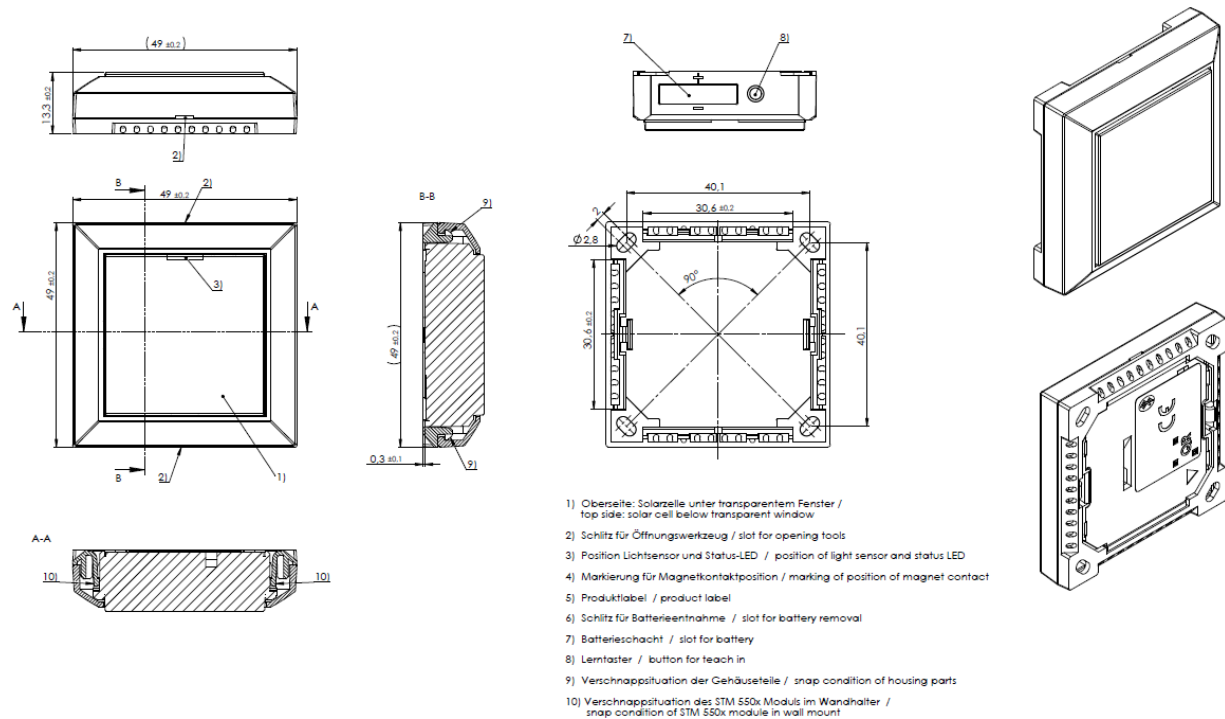


Figure 51 – Mechanical interface of STM 550 in housing

The housing can be attached to a variety of surfaces using the provided adhesive pad. Figure 52 below shows the dimensions of this pad.

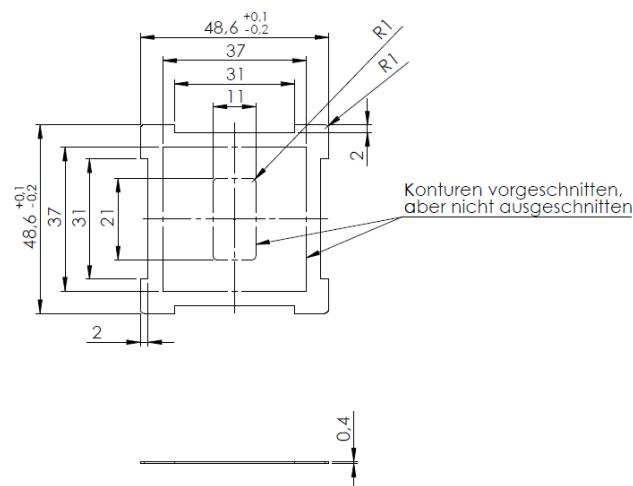


Figure 52 – Adhesive pad

11 Installation recommendations

11.1 Setup instructions

Before installing STM 550 into its intended location, a sufficient initial charge should be provided to STM 550 and its correct operation should be verified.

To do so, follow these steps:

1. Place STM 550 under bright light (daylight or bright light source) for 5 minutes to provide an initial charge
2. Press the LRN button once so that STM 550 will start operation
3. Check that STM 550 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 (for instance a PC with EnOcean USB 300 receiver running DolphinView visualization SW) to capture the STM 550 data telegrams and verify that all required parameters are reported. Consider disabling the measurement and reporting of non-required parameters (especially acceleration) to conserve energy.
5. Check the light level reported by STM 550 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, STM 550 is ready for installation into its intended location.

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11.2 Installation location

Before selecting the installation location for STM 550, please consider the following general guidance:

- STM 550 is designed for indoor use only
- STM 550 should be operated within a temperature range of -5°C ... +45°C
Avoid excessive heat-up due to direct exposure to sun light
- STM 550 should be used within a humidity range of 0% ... 90% r.h.
Avoid environments with condensation (for instance the area around entry doors to air-conditioned rooms)
- STM 550 should not be used on fast moving or strongly vibrating parts.
If used as a door sensor, STM 550 should be attached to the stationary door frame

Additional, application-specific guidance (for specific use cases) is provided in subsequent chapters.

11.3 Mounting options (Housing only)

STM 550 installation kit provides the STM 550 module together with a wall mount and a design frame as ready-to-use product. The wall mount can be attached to most surfaces either by screws (using the four screw holes) or via an adhesive pad. Mounting via an adhesive pad is the recommended approach.

The STM 550 installation kit includes a suitable two-zone adhesive pad as shown in below. Use of the outer adhesive zone (marked blue) is sufficient for most applications and enables easy removal of STM 550 from the mounting surface. The inner adhesive zone (marked green) can be additionally used if firm attachment to the mounting surface is desired.

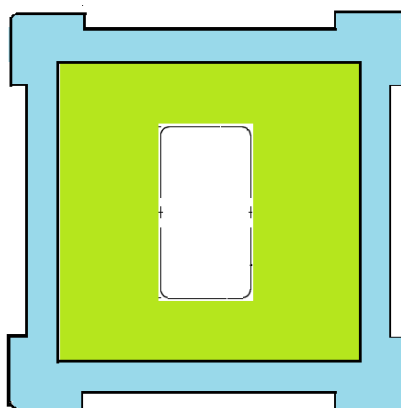


Figure 53 – Adhesive zones

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11.4 Temperature and humidity sensor

The dedicated temperature and humidity sensor integrated into STM 550 accurately measures and reports temperature and humidity present at its surface. To achieve the best possible accuracy, it is important to consider the following points:

- **Installation height**
The sensor should be installed at a height that is representative for the use case. For the case of an office, the sensor should be mounted at desk level.
- **Sun light or heat exposure**
The sensor should be mounted such that it is not directly exposed to sunlight or heat (e.g. close to a radiator)
- **Disturbances**
The sensor should be mounted such that the influence from disturbances such as the air stream from air condition units is minimized. Consider also the possible temperature gradient between wall and room when mounting the sensor directly onto a wall.
- **Air flow**
The sensor should be mounted such that the airflow from the target measurement area towards the air inlets is maximized. This will ensure the lowest possible response time of the sensor. Avoid mounting the sensor in niches or slots with little air flow. The sensor should be mounted such that the airflow from the target measurement area towards the air inlets is maximized. This will ensure the lowest possible response time of the sensor. Avoid mounting the sensor in niches or slots with little air flow. When designing your own housing around an STM 550 module, consider the location of the ventilation slots (there are four of them in total) as shown in Figure 54. Housing design has to maximize the airflow towards these slots focusing especially on the two slots nearest to the sensor which are marked with a green dot.

Figure 54 below shows the location of the temperature and relative humidity (TRH) sensor and of the ventilation slots.

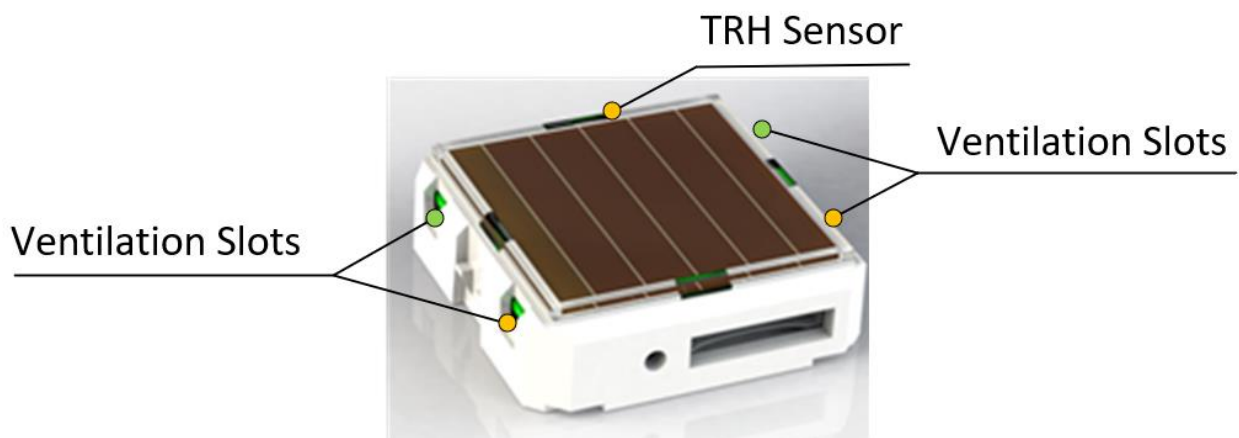


Figure 54 – Location of temperature / humidity sensor and ventilation slots

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11.5 Acceleration sensor

Acceleration sensors measure the acceleration vector in all three dimensions $\{x; y; z\}$. This sensor can be used both to determine the device orientation (relative to the earth gravity vector) and the device acceleration (e.g. if a device is moved or shaken). Both cases will be discussed below.

11.5.1 Device orientation use cases

If an object is at rest or continuously moving at the same speed, then the magnitude of the vector will be $1g$ (i.e. the magnitude of the measured acceleration vector will be equivalent to the magnitude of the earth gravity vector at the location of the device which will be approximately $1g$).

Measuring the magnitude in all three dimensions allows determining the orientation of an object relative to the earth gravity as shown in Figure 55 below. This illustration assumes that STM 550 is placed flat onto a surface parallel to the earth surface (e.g. a table).

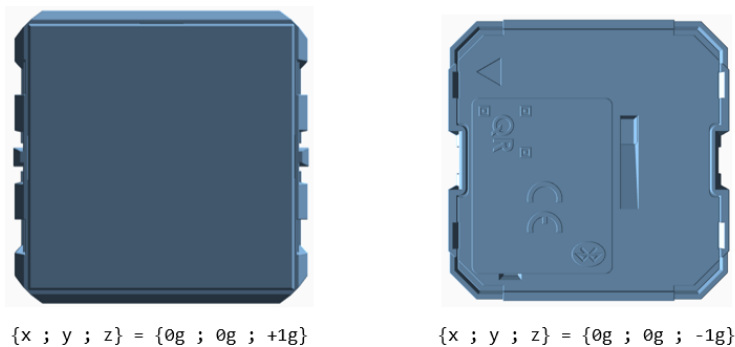


Figure 55 – Acceleration vector based on device orientation

Note that it is not possible to distinguish cases where STM 550 is rotated but its orientation relative to the direction of earth gravity remains the same. This is shown in Figure 56 below for the case of device rotation across the earth gravity vector axis.

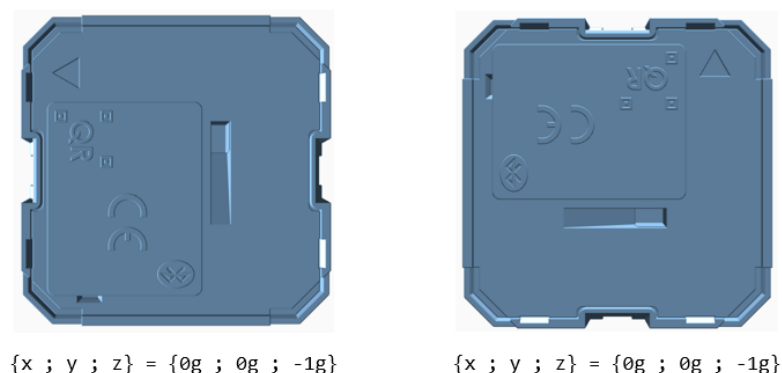


Figure 56 – Device rotation across earth gravity vector axis

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Figure 57 below illustrates this issue in a practical use case:

- The position of the window in the left case (window tilt) could be detected if STM 550 is attached to the window part that is tilted since the orientation of STM 550 relative to the gravity vector would change
- The position of the window in the right case (window open / rotation) could not be detected if STM 550 is attached to the window part that is rotated since the orientation of STM 550 relative to the gravity vector would remain the same.
STM 550 would however report that the window was moved due to the resulting acceleration and deceleration.

The surface towards which STM 550 is attached should therefore be chosen to maximize orientation changes relative to the gravity vector.

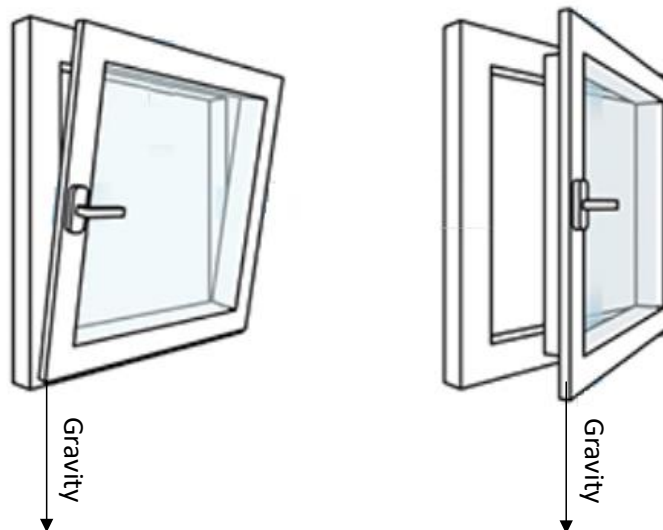


Figure 57 – Tilt versus gravity vector

11.5.1.1 Temperature effects on acceleration vector

For device orientation use cases requiring high resolution (for instance inclination measurements), the effect of temperature changes onto the actual device orientation might need to be considered.

For most materials, an increase of temperature will lead to an expansion while a decrease of temperature will lead to a contraction. This effect applies both to the material onto which STM 550 is mounted and to the material within STM 550 itself (housing and PCB) and might slightly alter the reported orientation.

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11.5.2 Device acceleration use cases

If an object vibrates or is moved after being, then the acceleration vector measured by the acceleration sensor will change. Figure 58 below illustrates this.

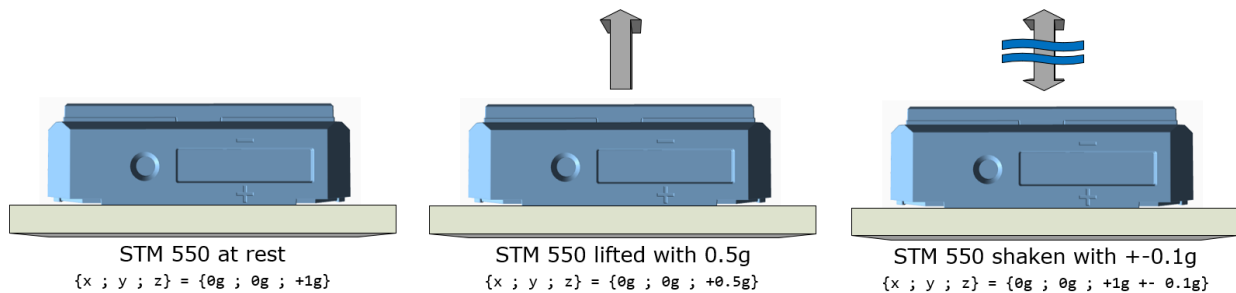


Figure 58 – Acceleration vector changes based on motion or vibration

This principle can be used for two major use cases:

- The approximate location of an object can be tracked based on the strength of the received periodic data telegrams. Movement of the object (e.g. from one room to another) can be detected based on the reported acceleration vector change.
- The utilization of an object (a machine that is running, a chair that is occupied, ...) can be tracked based on the characteristic vibrations associated with this utilization.

In both cases, STM 550 should be attached to the object for which location or utilization shall be monitored. The following chapter gives general guidelines how to do so.

11.5.3 Installation suggestions

The following points should be considered to maximize the reliability of acceleration measurement:

- STM 550 should be firmly attached to the asset without any damping to ensure that any vibration of the asset will be properly propagated to STM 550
- STM 550 should be attached to the asset at the location where the vibration is maximized. For instance, when tracking the utilization of office chairs, the highest acceleration is typically observed at the back rest.
- The acceleration threshold for wake-on-acceleration should be selected such that utilization / motion is reliably detected without false triggers due to spurious vibration (e.g. people walking by)
- Should the default sensitivity be insufficient even at the lowest threshold then the sampling rate should be increased

Use function test mode or acceleration test mode as described in Chapter 2.3 to verify correct installation.

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11.6 Illumination measurement

STM 550 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 9.8.15. By default, the ambient light sensor is used.

11.6.1 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)

11.6.2 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.

11.7 Magnet contact sensing

If STM 550 is used to detect the presence of a magnet using its magnet contact sensor (e.g. for door or window monitoring), then the magnet has to be in close proximity to the STM 550 magnet contact sensor for the case where a “Magnet Present” (or “Closed”) condition shall be detected. Refer to Chapter 2.2 for the location of the sensor.

Attach the magnet to the intended surface (e.g. door or window) such that the centre of the large side of the magnet is oriented towards the location of the magnet contact sensor in STM 550 and that the distance between magnet and STM 550 housing is less than 1 cm for the “Magnet Present” condition. Verify that the state (e.g. door open or closed) is reported as expected.

11.8 Energy harvesting

STM 550 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 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 STM 550 should be oriented as much as possible towards that.

STM 550 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. STM 550 can operate for 4 days without available energy after being exposed to 200 lux for 2 days.

Lower levels of available light can be addressed by configuring a lower reporting rate via NFC as discussed in chapter 3.2. If the available light is insufficient, then STM 550 offers the option for a CR1632 backup battery as described in chapter 5.3.

The exact amount of available light can be determined by executing an illumination test as described in chapter 2.3.5.

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11.9 NFC configuration

STM 550 can be flexibly configured for a wide range of application scenarios using the NFC configuration interface as described in chapter 9.



Updating the device configuration via the NFC interface requires that STM 550 has sufficient energy to read and process the new parameters. It is therefore recommended to provide an initial charge to STM 550 by placing it under bright light for 5 minutes before starting the configuration process.

Before making any configuration changes, be sure to familiarize yourself with the device functionality and determine the energy constraints based on the available ambient light as discussed in chapter 3.2. 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 2.3.5 to reset all configuration registers to their default setting.

After writing the new NFC configuration, remove the device from the NFC reader (or disconnect the NFC interface) to trigger the read and update process. STM 550 will indicate the successful completion of this process by two short blinks of the LED.

Once STM 550 has been configured to the intended parameters and correct functionality has been verified, 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.

12 Regulatory notes

12.1 European Union

12.1.1 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

12.1.2 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

The 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



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12.2 FCC (United States)**12.2.1 FCC Grant Of Equipment Authorization****TCB****GRANT OF EQUIPMENT
AUTHORIZATION****TCB**

Certification

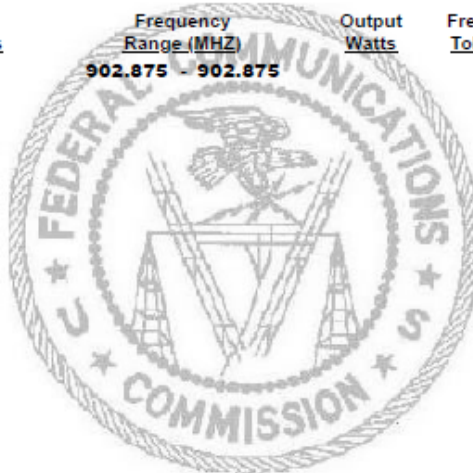
Issued Under the Authority of the
Federal Communications Commission

By:

Timco Engineering, Inc.
849 NW State Road 45
Newberry, FL 32669

Date of Grant: 02/04/2021

Application Dated: 02/04/2021

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-STM550U
Name of Grantee: EnOcean GmbH
Equipment Class: Part 15 Security/Remote Control
Transmitter
Notes: Temperature and Humidity Sensor with
transmitterGrant NotesFCC Rule Parts
15.231Frequency
Range (MHZ)
902.875 – 902.875Output
WattsFrequency
ToleranceEmission
Designator

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12.2.2 FCC OEM requirements

In order to use EnOcean's FCC ID number, OEM integrating STM 550U into own products must ensure that the following conditions are met:

- The Original Equipment Manufacturer (OEM) must ensure that FCC labeling requirements are met. This includes a clearly visible label on the outside of the final product. Attaching a label to a removable portion of the final product, such as a battery cover, is not permitted.
- The label must include the following text:
Contains FCC ID: SZV-STM550U
The enclosed device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (i.) this device may not cause harmful interference and (ii.) this device must accept any interference received, including interference that may cause undesired operation.
- The FCC identifier or the unique identifier, as appropriate, must be displayed on the device.
- The user manual for the end product must also contain the text given above.

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12.3 ISED (Industry Canada)

12.3.1 ISED Technical Acceptance Certificate

TIMCO ENGINEERING, INC.

849 NW State Road 45
Newberry, Florida 32669
www.timcoengr.com
(352) 472-5500 CB@timcoengr.com

Job No. ➤ 0564-21

TECHNICAL ACCEPTANCE CERTIFICATE

Certification No. ➤ IC: 5713A-STIM550U

Issued To ➤ EnOcean GmbH
Kolpingring 18A
Oberhaching 82041
Germany

Tested By ➤ VPI Laboratories, Inc.
Company No.: 2041B
313 W 12800 S., Suite 311
Draper, UT 84020, USA
801-260-4056; jasons@vpitech.com

Type of Equipment ➤ Low Power Device (902–928 MHz)

Type of Service ➤ New Certification (Single)

Hardware Version Id Number (HVIN) ➤ STM 550U

Firmware Version Id Number (FVIN) ➤ N/A

Product Marketing Name: (PMN) ➤ STM 550U

Host Marketing (HMN) ➤ N/A

FREQUENCY RANGE	EMISSION DESIGNATIONS NECESSARY BANDWIDTH & EMISSION CLASSIFICATION	R.F. POWER	ANTENNA INFO	SPECIFICATION/ ISSUE & DATE
902.875 MHz	275KF1D	73.0 dBuV@3m	Wire, 0dBi	RSS-210 Issue 10; Dec.2019

Note 1: This equipment also complies with RSS-102, Issue 5 (March 2015) and RSS-Gen, Issue 5 (March 2019)

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

La certification de l'équipement signifie uniquement que l'équipement a satisfait aux exigences de la spécification susmentionnée. Les demandes de licence, le cas échéant pour utiliser un équipement certifié, sont traitées en conséquence par le bureau émetteur d'ISED et dépendront de l'environnement radio, du service et du lieu d'exploitation existants. Ce certificat est délivré à condition que le titulaire se conforme et continuera de se conformer aux exigences et procédures émises par ISED. L'équipement pour lequel ce certificat est délivré ne doit pas être fabriqué, importé, distribué, loué, mis en vente ou vendu à moins que l'équipement ne soit conforme aux spécifications et procédures techniques applicables émises par ISED.

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

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
DELIVRÉ AVEC L'AUTORISATION DU MINISTRE DES INDUSTRIES

DATE: February 5, 2021


Bruno Clavier, General Manager

Canadian Certification

12.3.2 ISED (Industry Canada) regulatory statement

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

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

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes :

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

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12.4 ARIB (Japan)**12.4.1 ARIB construction type conformity certificate**

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

RF CAB ID No. 206

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

CONSTRUCTION TYPE CONFORMITY CERTIFICATE
for
Specified Radio Equipment

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

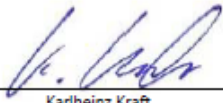
When the product is placed on the
 Japanese market, it must carry the
 Specified Radio Equipment marking as
 shown on the right

**R 206-000605**

The scope of evaluation relates to the submitted documents only.

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

Unterleinleiter,
 2020-09-02


 Karlheinz Kraft
 Recognised Foreign Conformity Assessment Body

EMCCons DR. RAŠEK GmbH & Co. KG • Stoernhofer Berg 15, 91364 Unterleinleiter, Germany
 Tel.: +49 9194 7263-888 • Fax: +49 9194 7263-889 • E-mail: emc.cert@emcc.de • Web: www.emcc.de

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13 Product history

Table 40 below lists the product history of STM 550.

Revision	Release	Key changes versus previous revision
STM 550 DA-05	Jun 2020	Market release (868.300 MHz)
STM 550J DA-02	Aug 2020	Market release (902.350 MHz)
STM 550 DB-06	Nov 2020	Product update - Increase of transmission power to +10 dBm - Improved supply voltage reporting
STM 550 DB-07 STM 550J DA-03	Mar 2021	Product update - Corrected issues with EEP support and backup battery
STM 550U DA-05	May 2021	Market Release (902.875 MHz)

Table 40 – Product History

STM 550 / EMSI – ENOCEAN MULTISENSOR FOR IOT APPLICATIONS

A. Introduction to EnOcean radio protocol

This chapter gives a high-level introduction to key aspects of the EnOcean radio protocol to help the understanding of STM 550 radio transmission features. Refer to the EnOcean Radio Protocol 1 (ERP1) specification and the EnOcean Radio Protocol 2 (ERP2) specification for detailed information.

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

A.1 ERP1 telegram format

The ERP1 telegram format is shown in Figure 59 below for the case of a broadcast telegram.

RORG	DATA	SENDER EURID	STATUS	HASH
1 Byte	1 ... 14 Byte	4 Byte	1 Byte	1 Byte

Figure 59 – ERP1 telegram format for broadcast telegrams

An ERP1 telegram contains the following fields:

- RORG specifies the EEP or SIGNAL type used by this telegram
- DATA contains the telegram payload
- SENDER EURID specifies the address of the sender
- STATUS specifies transmission properties such as the repeater hop count
- HASH is used to verify the integrity of the telegram

It is possible to specify the intended receiver (the destination) of a telegram by prefixing the telegram content with the R-ORG 0xA6 (ADT = Addressed Data Telegram) to indicate that a destination address is present and including the DESTINATION EURID before the SENDER EURID as shown in Figure 60 below.

ADT	RORG	DATA	DESTINATION EURID	SENDER EURID	STATUS	HASH
0xA6	1 Byte	1 ... 9 Byte	4 Byte	4 Byte	1 Byte	1 Byte

Figure 60 – ERP1 telegram format for addressed telegrams

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A.2 ERP2 telegram format

The ERP2 radio telegram format is shown in Figure 61 below.

LENGTH	HEADER	EXT_HEADER	EXT_TYPE	DESTINATION EURID	SENDER EURID	DATA	OPTIONAL_DATA	CRC
1 Byte	1 Byte	1 Byte	1 Byte	4 Byte	3 / 4 / 6 Byte	Variable	Variable	1 Byte

Figure 61 – ERP2 Telegram Format

The ERP2 telegram contains the following fields:

- LENGTH specifies the total length of the ERP2 radio telegram
- HEADER specifies the EURID types and sizes, the RORG that is used (based on a selection of the most common EEP) and specifies if EXT_HEADER is present
- EXT_HEADER specifies the repeater count and the length of OPTIONAL_DATA. It is an optional field that might be omitted by energy-constrained devices
- EXT_TYPE specifies less common RORG which are not available within the HEADER field
- SENDER EURID specifies the device address of the sender
- DESTINATION EURID can be used to specify the device address of the intended recipient of a data telegram (optional)
- DATA contains the telegram data
- OPTIONAL_DATA can be used to transmit additional data that should be treated separately from the main telegram data (optional)
- CRC is used to verify the integrity of the telegram

A.3 Subtelegrams

EnOcean radio systems use the concept of redundant subtelegrams in order to increase the communication reliability. In addition to using redundant transmissions, first and second level repeaters can be used to increase communication distance.

Within this scheme, telegrams are transmitted redundantly with random (but small) delays between them. The total number of redundant subtelegrams can be either two or three. Certain telegram types (e.g. those used in very limited energy scenarios such as SMART_ACK) do not support redundant transmission, i.e. they are transmitted only once.

If a telegram is transmitted redundantly as set of two or three subtelegrams then the first subtelegram is sent immediately upon receiving and processing the ESP3 command for telegram transmission.

The timing offset between this first subtelegram and the remaining (second or third) subtelegrams is random within pre-defined time intervals.

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A.3.1 Subtelegram timing

EnOcean Radio Protocol 1 (ERP1) and EnOcean Radio Protocol 2 (ERP2) uses a repeater-level dependent time slot mechanism for the subtelegram timing during transmission.

The sender of a radio telegram will transmit the first telegram immediately upon receiving the request for transmission. After that, the time offset (interval) between the first subtelegram and the second subtelegram is a random value between 1 ms and 9 ms. Likewise, the time offset (interval) between the first subtelegram and the third subtelegram is a random value between 20 ms and 39 ms.

For the first-level repeater (which received the telegram from the sender), the time offset (interval) between the reception of the telegram and the transmission of the first subtelegram is a random value between 10 ms and 19 ms. Likewise, the time offset (interval) between the reception of the telegram and the second subtelegram is a random value between 20 ms and 29 ms.

For the second-level repeater (which received the telegram from the first-level repeater), the time offset (interval) between the reception of the telegram and the transmission of the first subtelegram is a random value between 0 ms and 9 ms. Likewise, the time offset (interval) between the reception of the telegram and the second subtelegram is a random value between 20 ms and 29 ms.

Both first and second level repeaters do not transmit a third subtelegram. The standard subtelegram timing is summarized in Table 41 below.

Repeater Level	Time Offset [ms] First Subtelegram	Time Offset [ms] Second Subtelegram	Time Offset [ms] Third Subtelegram
0 (Original Telegram)	0	1 ... 9	20 ... 39
1 (Repeated for the first time)	10 ... 19	20 ... 29	No 3rd Subtelegram
2 (Repeated for the second time)	0 ... 9	20 ... 29	No 3rd Subtelegram

Table 41 – Standard subtelegram timing

Certain countries have regulatory limitations for the total duration of a radio transmission in certain frequency bands including those used by EnOcean products. For these cases, a compressed subtelegram timing has been defined. This would for instance be used in Japan which requires that all transmissions related to one event have to be finished after 50 ms.

Table 42 below summarizes the compressed subtelegram timing.

Repeater Level	Time Offset [ms] First Subtelegram	Time Offset [ms] Second Subtelegram	Time Offset [ms] Third Subtelegram
0 (Original Telegram)	0 ... 1	4 ... 12	14 ... 22
1 (Repeated for the first time)	0 ... 1	4 ... 12	14 ... 22
2 (Repeated for the second time)	0 ... 1	4 ... 12	14 ... 22

Table 42 – Compressed subtelegram timing

A.3.2 TX maturity time

The maximum time between the request for transmission and the end of transmission of all subtelegrams is called the TX Maturity Time.

In radio systems using standard subtelegram timing, the TX maturity time is 40 ms because the transmission of the last telegram will start no later than 39 ms after the transmission request. In radio systems using compressed subtelegram timing, the TX maturity time is 25 ms.

After the TX maturity time has elapsed, the host can be sure that all subtelegrams corresponding to the telegram have been transmitted. In practical applications this means for instance that an external controller can power down the transmitter after the TX maturity time has elapsed.

A.3.3 RX maturity time

The maximum time allowed for reception of a radio telegram is called the RX Maturity Time. Identical subtelegrams from the same sender are considered to belong to the same telegram if they are received within the RX maturity time.

In EnOcean radio systems, the RX maturity time is 100 ms.

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A.4 Addressing

Each radio transmission within an EnOcean radio network will contain information about the originator (sender) of the transmitted radio telegram.

In addition, the intended receiver of a transmitted telegram can optionally be specified as well. Telegrams where the intended receiver is designated are called Addressed Data Telegram or ADT in short. Telegrams where the intended receiver is not designated are called Broadcast Telegrams.

Different types of addresses can be used to designate sender and receiver of an EnOcean radio telegram.

A.4.1 Address types

EnOcean radio systems support three different types of addresses:

- EnOcean Unique Radio ID (EURID)
- Base ID
- Broadcast ID

Each of these three address types corresponds to a specific address or address range as shown Figure 62 below.

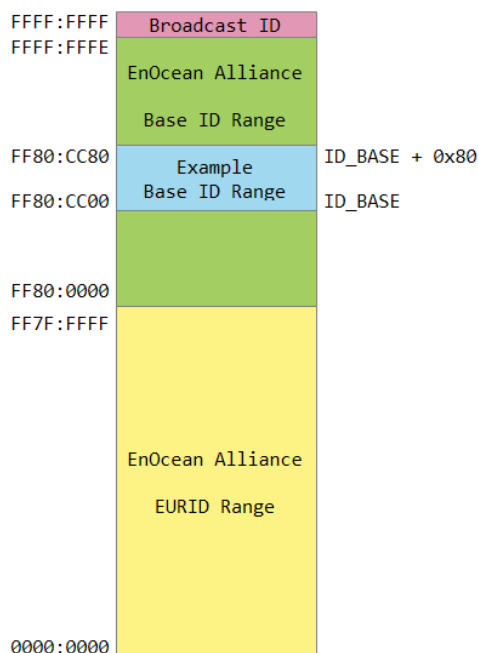


Figure 62 – Address map of EnOcean radio systems

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A.4.2 EURID (Radio ID)

Each device communicating within an EnOcean radio network contains its own EnOcean Unique Radio ID (EURID) which is assigned by EnOcean Alliance. The EURID uniquely identifies each EnOcean device; no two EnOcean devices can have the same EURID.

When transmitting a radio telegram, the sender might either use the EURID or a selected Base ID (as described below) to identify itself as the originator of the telegram.

In addition, the sender might use the EURID of the intended receiver to designate this as the intended recipient of the telegram. If no receiver is designated, then the radio telegram will be transmitted as a broadcast. In this case, the receivers of such broadcast telegram decide if they accept this telegram.

A.4.3 Broadcast ID

The Broadcast ID can be used as destination address instead of the EURID of the intended receiver if a telegram should be received by more than one receiver or if the EURID of the intended receiver is unknown.

Telegrams where the destination address is the Broadcast ID are called "Broadcast Telegrams" and are commonly used by sensors and switches. The Broadcast ID is 0xFFFF:FFFF. Note that the broadcast ID is not transmitted as part of the radio telegram.

Receivers of broadcast telegrams can decide based on the EURID of the sender (originator) of the telegram if this telegram is relevant for them or not.

A.4.4 Base ID

Normally, EnOcean devices will use their own EURID in order to identify themselves as the originator of transmitted telegrams. For very specific use cases, they can instead choose to use an address (ID) from within a defined range of 128 addresses. These 128 addresses are called the Base ID Range of the device.

The Base ID Range (128 addresses) of a device can be allocated anywhere in between 0xFF80:0000 and 0xFFFF:FFFE (which represents a total range of approximately 8 million addresses). The location of the Base ID Range is defined by the start (lowest) address of the range which will always be aligned on a 7 bit (128) boundary, i.e. the last byte of the start address can be either 0x00 or 0x80.

Note that Base ID - unlike EURID - are not guaranteed to be globally unique. Many devices with the same Base ID might exist within the EnOcean ecosystem. Having several devices using the same Base ID within a system might lead to undefined system behaviour.

Note also that the use of Base ID is not defined within the scope of secure communication, remote management or smart acknowledge. STM 550 does not support the use of Base ID.

A.5 Data payload

EnOcean radio systems encode the data using so called EEP (EnOcean Equipment Profile). Each transmitter might choose one (or sometimes several) EEP for data transmission depending on the type of transmitted data.

A.5.1 EnOcean Equipment Profiles (EEP) structure

EnOcean Equipment Profiles (EEP) are identified using three fields:

- **RORG**
RORG identifies the high-level telegram type, e.g. rocker switch telegram, four-byte sensor telegram, variable length telegram 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 (sometimes 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 63 below shows the structure of the EEP identifier.

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

Figure 63 – EEP identifier structure

The complete EEP identifier is typically only transmitted during the initial teach-in (paring) between devices. After that, only the RORG which identifies the high-level telegram is transmitted. Transmission of the RORG allows distinguishing between different telegram types (e.g. data and signal telegrams) originating from the same sender.

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A.5.2 Common RORG

Within EnOcean radio telegrams, the RORG field identifies the telegram type as described in the previous chapter. Table 43 below lists common RORG used for communication in EnOcean systems.

RORG	Description	Typical Use
0x30	Encrypted telegram without RORG of the original telegram	Encrypted switch or magnet contact telegrams
0x31	Secure message that does identify the type (RORG) of the encrypted telegram	Encrypted sensor telegrams
0x32	Decrypted telegram without RORG	Decrypted telegrams from switches or magnet contacts
0x33	Secure chained messages (SEC_CDM)	Encrypted sensor telegrams requiring chaining due to length
0x35	Secure teach-in telegram (SEC_TI)	Setup of a secure communication channel
0xA5	4 Byte Sensor Telegram (4BS)	Common (simple) sensor telegrams expressed with 4 byte payload
0xA6	Addressed data telegram (ADT)	Telegrams that specify the intended receiver
0xC5	Remote management telegram (SYS_EX)	Configuration of functional parameters in the receiver
0xD0	Signal telegram (SIGNAL)	Reporting of system parameters
0xD1	Manufacturer-specific content (MSC)	Manufacturer-defined telegrams
0xD2	Variable length telegram (VLD)	Variable length telegrams requiring more than 4 byte of payload
0xD5	1 Byte sensor telegram (1BS)	Simple sensors with 1 byte payload such as magnet contact sensors
0xF6	Rocker and pushbutton switches (RPS)	Rocker switches or push buttons

Table 43 – Common RORG used in EnOcean radio systems

For full details about EnOcean Equipment Profiles (EEP) please refer to the EnOcean Equipment Profiles specification.

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A.5.2.1 1BS telegram

1 Byte Sensor (1BS) telegrams are identified by the RORG field being set to 0xD5 which is followed by one byte of payload (Bit0 ... Bit7. 1BS telegrams are used exclusively to encode the status (open / closed) of a binary contact (typically a magnet contact)

The payload of 1BS telegrams encodes either the contact status (1BS Data Telegram) during normal operation or identifies a teach-in telegram (1BS Teach-in Telegram).

The distinction between data and teach-in telegrams is made based on the status of Bit4. If this bit is set to 0 then the telegram is a 1BS Teach-in Telegram; if this bit is set to 1 then the telegram is a 1BS Data Telegram.

A.5.2.2 4BS telegram

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 EEPROM 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.

A.5.2.3 VLD telegram

Variable Length Data (VLD) telegrams are identified by the RORG field being set to 0xD2. They carry a variable length payload which can be between 1 and 14 byte long.

A.5.2.4 UTE (Universal Teach-in) telegram

Variable Length Data (VLD) telegrams carry a variable length payload, therefore it is not possible to use one bit at a pre-defined location to distinguish between data and teach-in telegrams.

Devices communicating using VLD data telegrams therefore use the generic Universal Teach-in with EEPROM (UTE) format when transmitting a teach-in telegram. The format of such UTE telegram is shown in Figure 64 below.

UTE RORG	UTE DATA						
BYTE0	BYTE0	BYTE1	BYTE2	BYTE3	BYTE4	BYTE5	BYTE5
0xD4	CTRL	CHANNEL	MANUFACTURER_ID		FUNC	TYPE	RORG

Figure 64 – UTE Telegram Structure

A.5.2.5 SIGNAL telegram

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 65 below shows the structure of a SIGNAL telegram.

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

Figure 65 – SIGNAL Telegram Structure

A.5.3 Data payload size

The maximum telegram data payload size used by EnOcean radio telegrams is 14 byte of data payload for the case of standard broadcast telegrams. For the case of standard addressed telegrams, the maximum length of the data payload is 9 byte.

If the radio telegram contains security information such as the RLC value or the authentication signature, then the maximum data payload of one EnOcean radio telegram is reduced further according to the size of the security information.

If the telegram data payload exceeds the maximum available data payload then it has to be transmitted as a chain of radio telegrams which together transfer the message payload.

The type of chaining that is used depends on the type of telegram that is transmitted. Standard telegrams are transmitted as Chained Data Messages (CDM) while secure telegrams are transmitted as Secure Chained Data Messages (SEC_CDM).

A.6 Telegram chaining

Telegram chaining is a feature that allows transmission of a payload that is larger than the maximum supported DATA payload.

For the transmission of a telegram with a data payload larger than 14 byte, the payload is distributed (segmented) across several telegrams using the telegram structure shown below. Upon reception, the payload of the received telegrams is combined (reassembled) into the original telegram and forwarded to the host via the ESP3 interface once the last telegram in the chain has been received.

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A.6.1 Telegram chaining for broadcast telegrams

Chained broadcast telegrams can be identified by the R-ORG 0x40 (CDM). The first telegram in a chain (with $IDX = 0b000000$) uses the CHAIN_LEN field to specify the total length of the DATA payload that is transported by this chain. Figure 66 below shows the structure of the first telegram in a chain of broadcast telegrams.

0x40 (CDM)	CHAIN_CTRL		CHAIN_LEN	RORG	DATA	SENDER EURID	STATUS	CRC / HASH
	ID	IDX						
1 Byte	1 Byte		2 Byte	1 Byte	10 Byte	4 Byte	1 Byte	1 Byte

Figure 66 – Structure of the first telegram in a chain of broadcast telegrams

Subsequent telegrams in the chain (with $IDX > 0b000000$) omit the CHAIN_LEN field as shown in Figure 67 below.

0x40 (CDM)	CHAIN_CTRL		RORG	DATA	SENDER EURID	STATUS	CRC / HASH
	ID	IDX					
1 Byte	1 Byte		1 Byte	1 ... 12 Byte	4 Byte	1 Byte	1 Byte

Figure 67 – Structure of subsequent telegrams in a chain of broadcast telegrams

Up to 4 telegram chains from the same sender can be in progress at any time. The individual chains are identified by the 2 bit wide ID field. Telegrams having the same ID field setting are considered to be part of the same chain.

The order of the telegrams within each chain are identified by the 6 bit IDX field with the first telegram using $IDX = 0b000000$, the second telegram $IDX = 0b000001$ and so on. The maximum length of a telegram chain is therefore 64 telegrams.

The theoretical maximum DATA length within a chain of telegrams is 766 byte ($63 * 12 \text{ byte} + 1 * 10 \text{ byte}$).

A.6.2 Telegram chaining for addressed telegrams (ADT)

Chained addressed telegrams extend the format of chained broadcast telegrams by adding the RORG 0xA6 (Addressed Data Telegram) at the begin of the message and EURID of the intended receiver of the message before the EURID of the sender.

Figure 68 below shows the structure for the first telegram in a chain of addressed telegrams.

0xA6 (ADT)	0x40 (CDM)	CHAIN_CTRL		CHAIN_LEN	RORG	DATA	DESTINATION EURID	SENDER EURID	STATUS	CRC / HASH
		ID	IDX							
1 Byte	1 Byte	1 Byte		2 Byte	1 Byte	5 Byte	4 Byte	4 Byte	1 Byte	1 Byte

Figure 68 – Structure of the first telegram in a chain of addressed telegrams

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Subsequent telegrams in a chain of addressed telegrams omit both the CHAIN_LEN and the RORG field as shown in Figure 69 below.

0xA6 (ADT)	0x40 (CDM)	CHAIN_CTRL		DATA	DESTINATION EURID	SENDER EURID	STATUS	CRC / HASH
		ID	IDX					
1 Byte	1 Byte	1 Byte		1 ... 8 Byte	4 Byte	4 Byte	1 Byte	1 Byte

Figure 69 – Structure of subsequent telegrams in a chain of addressed telegrams

A.6.3 Telegram chaining for secure telegram (SEC_CDM)

Chained secure telegrams – identified by RORG 0x33 (SEC_CDM) - extend the format of chained broadcast telegrams by defining three different telegram structures – one for the first telegram in a chain, one for the last telegram in a chain and one for all telegrams in between the first and the last.

Figure 70 shows the structure for the first telegram in a chain of secure telegrams.

0x33 (SEC_CDM)	CHAIN_CTRL		CHAIN_LEN	RORG	DATA	SENDER EURID	STATUS	CRC / HASH
	ID	IDX						
1 Byte	1 Byte		2 Byte	1 Byte	10 Byte	4 Byte	1 Byte	1 Byte

Figure 70 – Structure of the first telegram in a chain of secure telegrams

Intermediary telegrams in a chain of secure telegrams omit both the CHAIN_LEN and the RORG field as shown in Figure 71 below.

0x33 (SEC_CDM)	CHAIN_CTRL		DATA	SENDER EURID	STATUS	CRC / HASH
	ID	IDX				
1 Byte	1 Byte		1 ... 13 Byte	4 Byte	1 Byte	1 Byte

Figure 71 – Structure of intermediary telegrams in a chain of secure telegrams

The last telegram of the chain contains the rolling code (RLC) value and the message signature (CMAC) as shown in Figure 72 below. Note that the last telegram in a chain of secure telegrams might have no data payload (if the data exactly fits into the previous telegram in the chain).

0x33 (SEC_CDM)	CHAIN_CTRL		DATA	CMAC	RLC	SENDER EURID	STATUS	CRC / HASH
	ID	IDX						
1 Byte	1 Byte		0 ... 5 / 7 Byte	3 / 4 Byte	3 / 4 Byte	4 Byte	1 Byte	1 Byte

Figure 72 – Structure of the last telegram in a chain of secure telegrams

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A.6.4 Telegram chaining for addressed secure telegram (ADT SEC_CDM)

Chained secure telegrams may also be transmitted as addressed telegram (ADT) to identify the intended receiver of this telegram chain.

Chained addressed secure telegrams extend the format of chained secure telegrams by adding the RORG 0xA6 (Addressed Data Telegram) at the begin of the message and EURID of the intended receiver of the message before the EURID of the sender.

Figure 73 below shows the structure for the first telegram in a chain of secure telegrams.

0xA6 (ADT)	0x33 (SEC_CDM)	CHAIN_CTRL		CHAIN_LEN	RORG	DATA	DESTINATION EURID	SENDER EURID	STATUS	CRC / HASH
		ID	IDX							
1 Byte	1 Byte	1 Byte		2 Byte	1 Byte	5 Byte	4 Byte	4 Byte	1 Byte	1 Byte

Figure 73 – First telegram in a chain of addressed secure telegrams

Intermediary telegrams in a chain of secure telegrams omit both the CHAIN_LEN and the RORG field as shown in Figure 74 below.

0xA6 (ADT)	0x33 (SEC_CDM)	CHAIN_CTRL		DATA	DESITNATION EURID	SENDER EURID	STATUS	CRC / HASH
		ID	IDX					
1 Byte	1 Byte	1 Byte		1 ... 8 Byte	4 Byte	4 Byte	1 Byte	1 Byte

Figure 74 – Intermediary telegrams in a chain of addressed secure telegrams

The last telegram of the chain contains the rolling code (RLC) value and the message signature (CMAC) as shown in Figure 75 below.

0xA6 (ADT)	0x33 (SEC_CDM)	CHAIN_CTRL		DATA	CMAC	RLC	DESTINATION EURID	SENDER EURID	STATUS	CRC / HASH
		ID	IDX							
1 Byte	1 Byte	1 Byte		0 ... 5 / 7 Byte	3 / 4 Byte	3 / 4 Byte	4 Byte	4 Byte	1 Byte	1 Byte

Figure 75 – Last telegram in a chain of addressed secure telegrams

Note that the encapsulation as addressed (ADT) telegram is applied after the SEC_CDM telegram has been formed. The last SEC_CDM telegram might therefore be split into two addressed SEC_CDM telegrams due to the addition of the RORG and DESTINATION EURID addressing fields resulting in a telegram size larger than the maximum size of EnOcean radio telegrams.

B. Introduction to EnOcean security protocol

This chapter gives a high-level introduction to key aspects of the security protocol used in EnOcean radio networks to help the understanding of security-related features of STM 550.

Refer to the EnOcean Alliance Security Specification for a detailed up to date description of all features.

B.1 Goals of secure radio communication

Secure radio communication aims to address 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 is to prevent 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 modification. All three techniques will be reviewed in the subsequent chapters for reference.

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B.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 *security 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 76 below shows the concept.

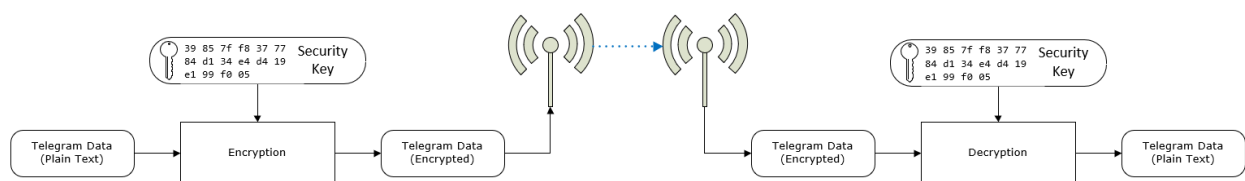


Figure 76 – Telegram encryption

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

If different security keys are used for encryption at the sender and decryption at the receiver then this is called an *asymmetric key* algorithm or a *public key* algorithm. Public / private key algorithms such as PGP, GPG or TLS fall into this category. EnOcean radio systems do not support asymmetric key algorithms.

B.3 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 is typically used in conjunction with telegram encryption.

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

Essentially, the telegram data is transformed via a defined algorithm using the security key into a unique, fixed size signature (where typical signature lengths include 24 bit, 32 bit, 512 bit and 1024 bit) which identifies this specific message.

For an optimal signature algorithm, the likelihood of two different telegrams creating the same telegram signature should be inversely proportional to the signature size, so for instance for 24 bit signatures the likelihood should be one in 16 million and for 32 bit signatures it should be one in 4 billion.

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Conceptually the correspondence between telegram content and telegram signature is like the one between a person and a fingerprint:

- Each person has a unique fingerprint. Based on a given person one can determine her or his fingerprint
- Based on a given fingerprint one can check if it originated from a given person
- Based on the fingerprint one cannot determine any other properties of the person

For telegram authentication purposes, the telegram signature (CMAC) is usually appended to the telegram content so that the telegram content and the telegram signature are transmitted together.

When the receiver receives such a telegram, it will itself calculate the telegram signature (CMAC) based on the security key and the telegram content. The receiver then compares the signature that it calculated with the signature it received as part of the telegram.

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

1. The telegram originates from a sender knowing the security key
2. The content of the telegram has not been modified after the sender added the signature to it

Figure 77 below illustrates the concept of telegram authorization via a telegram signature.

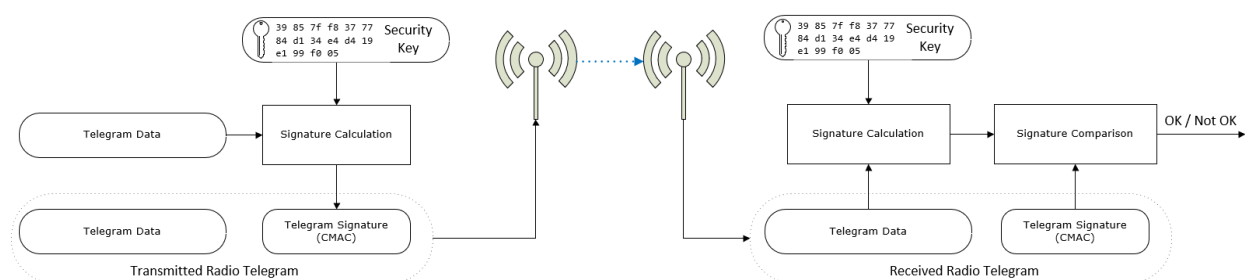


Figure 77 – Telegram authentication via telegram signature

B.4 Replay protection

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

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

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

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

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

Such counter is often referred to as *Sequence Counter*; the current value of the sequence counter is the RLC. Figure 78 shows the concept of adding an RLC to the telegram data.

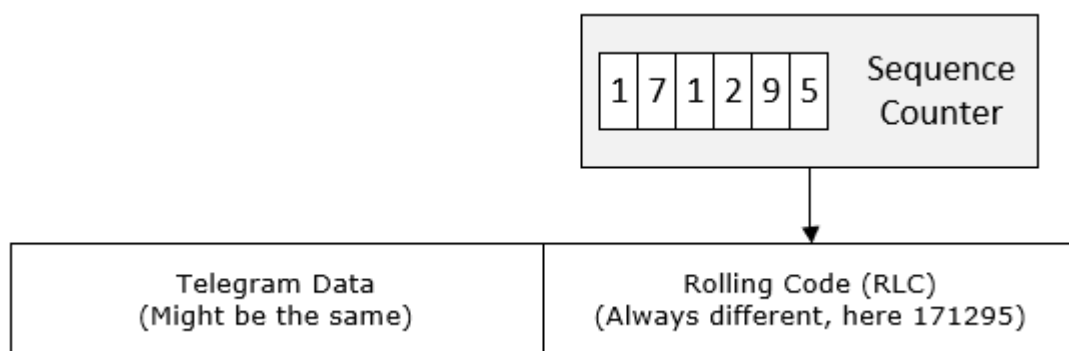


Figure 78 – Addition of an RLC to the telegram data

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EnOcean radio systems use an approach where the RLC is used to change the security material (specifically, the initialization vector – often called *Nonce* - used by the security algorithms together with the security key) to ensure that the encrypted telegram payload and the telegram signature change even when the content of the telegram itself stays the same.

Figure 79 below illustrates this approach.

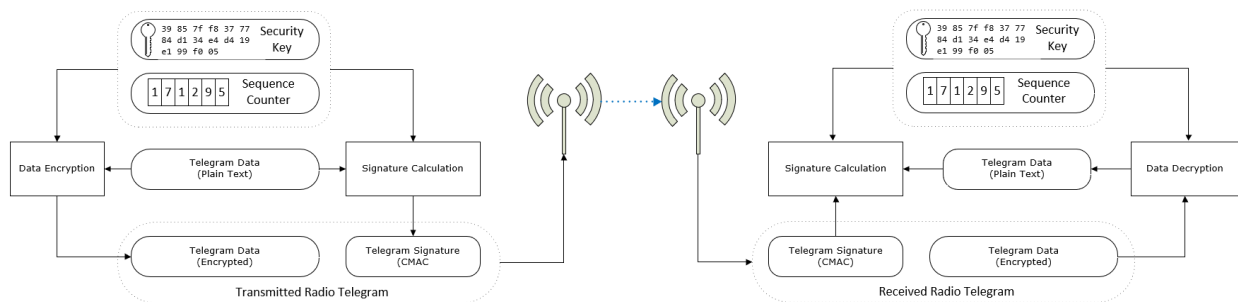


Figure 79 – Encryption and authentication

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B.4.1 RLC and security key in bi-directional communication

If the communication between two devices (*Device1* and *Device2*) is bi-directional, i.e. each device can either transmit or receive telegrams, then two independent RLC (*RLC1* and *RLC2*) have to be used (since the number of telegrams one direction might be different from the number of telegrams in the other direction) and two different security Keys (*Key1* and *Key2*) might be used (using the same key in both directions would also be possible).

The first pair (*RLC1*, *Key1*) will be used for the telegram transmission from *Device1* to *Device2* while the second pair (*RLC2*, *Key2*) will be used for the telegram transmission from *Device2* to *Device1*.

Device1 will store *RLC1* and *Key1* together with the address of *Device2* in its so-called *out-bound secure link table* since they are used for transmission of telegrams to the remote device. *RLC2* and *Key2* together with the address of *Device2* will be stored in its so-called *inbound secure link table* since they are used for reception of telegrams from the remote device.

Conversely, *Device2* will store *RLC1* and *Key1* together with the address of *Device1* in its inbound secure link table and *RLC2* and *Key2* together with the address of *Device1* in its outbound secure link table. Figure 80 below illustrates that.

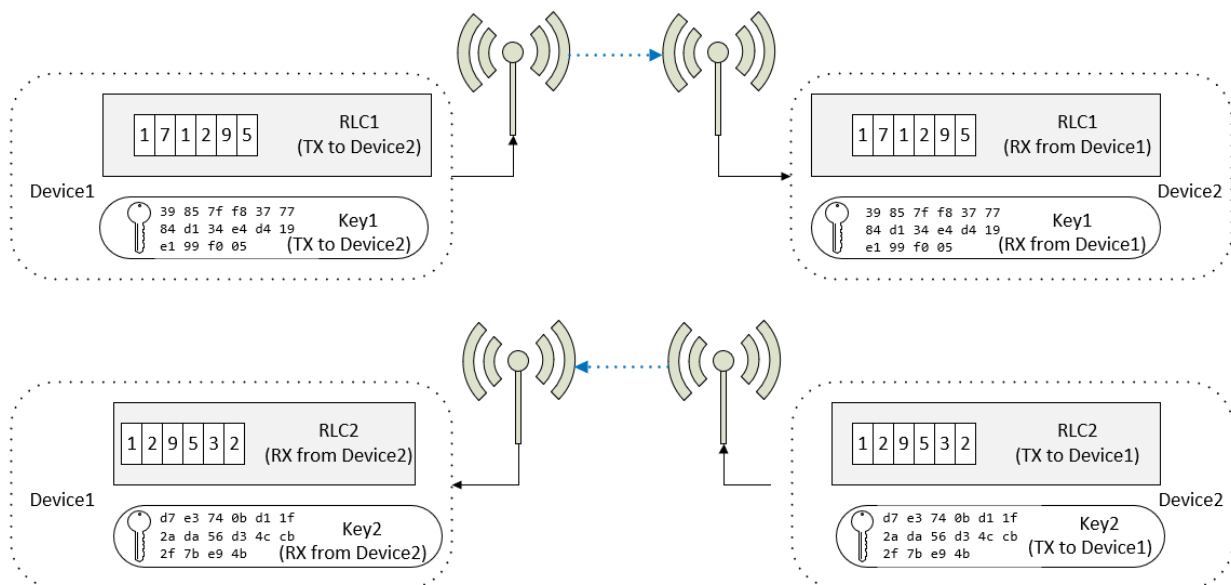


Figure 80 – Security key and RLC usage in bi-directional communication

B.4.2 RLC synchronization between sender and receiver

For encryption and authentication using RLC, it is important that the RLC on the transmitter side and the RLC on the receiver side remain synchronized, i.e. that they always have the same value.

This can be ensured either by transmitting the RLC as part of the telegram (this is called *explicit RLC mode*) or by tracking the expected RLC when it is not transmitted as part of the telegram (this is called *implicit RLC mode*).

Explicit RLC mode is the recommended procedure since it ensures that the receiver always knows the current RLC used by the sender; it requires however to increase the size of the telegram in order to transmit this RLC.

Implicit RLC mode might be used in energy-constrained systems where there might not be enough energy to additionally transmit the current RLC as part of the telegram.

For implicit RLC mode, the initial value of the RLC at the sender and at the receiver will be aligned during the establishment of the secure communication so that the receiver knows the current RLC used by the sender.

After that, both sender and receiver will adjust (increment for the case of using a sequence counter to generate the RLC) the RLC for each telegram that is transmitted to this specific receiver (RLC adjustment in the sender) or received from this specific sender (RLC adjustment in the receiver).

In order to guard against the case of telegrams being lost (not received by the receiver), the receiver will check if the RLC it assumes is used in the received telegram will result in a matching message signature (CMAC) when executing telegram authentication using this RLC together with the security key.

If this is the case, then the receiver will decrypt the telegram content using this RLC together with the security key. If this is not the case, then the receiver can retry using the next RLC in the sequence and so on. Typically, a maximum number of future RLC values to be tried will be defined. This parameter is often referred to as the *Rolling Code Window Size*.

If message decryption based on a future RLC is successful then the RLC used by the receiver will be updated to this value, thereby re-synchronizing the transmitter and receiver RLC. If no matching RLC is found within the rolling code window, then the message cannot be decrypted and authenticated and might be forwarded to the host for further analysis.

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B.4.3 Secure telegram types

Secure communication is based on two telegram types:

- Secure teach-in telegrams are used to establish a secure communication channel by providing the receiver with the required information to decrypt and authenticate received secure data telegrams
- Secure data telegrams are used to securely transmit data

The format of these two telegram types is described in the subsequent chapters.

B.4.3.1 Secure teach-in telegram

Teach-in is the process by which a sender communicates to a receiver the parameters required to decrypt and authenticate received secure telegrams. These parameters can be communicated from the sender to the receiver by transmitting a secure teach-in telegram with the structure shown in Figure 81 below.

RORG (0x35: SEC_TI)	TEACH-IN INFO	SECURITY FORMAT (SLF)	CURRENT RLC VALUE	SECURITY KEY
1 byte	1 byte	1 byte	2 / 3 / 4 byte	16 byte

Figure 81 – Secure teach-in telegram structure

The secure teach-in telegram contains the following parameters:

- RORG 0x35 (SEC_TI)
Secure teach-in telegrams are identified by the RORG 0x35 (SEC_TI)
- Teach-in Info
This field contains information about the secure teach-in telegram allowing the receiver to properly it. The structure of the Teach-in Info field is shown below.
- SLF
The SLF specifies the type of encryption and authentication used by for the communication with the remote device as described in chapter B.4.3.3.
- RLC
This field contains the current value of the RLC used by the sender.
- Key
The 128 bit security key is used by the sender to encrypt and authenticate the transmitted telegram and by the receiver to decrypt and authenticate the received telegram

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B.4.3.2 Teach-in Info

Figure 82 below shows the structure of the Teach-in Info field.

TEACH IN INFO							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
IDX		CNT		PSK	TYPE	INFO	
0b00: 1st segment 0b01: 2nd segment 0b10, 0b11: Unused		If IDX = 0b00: Total number of segments 0b00: 1 segment 0b01: 2 segments 0b10, 0b11: Unused		If IDX = 0b00: 0b0: PSK not used 0b1: PSK used	If IDX = 0b00: 0b0: Is not PTM 0b1: Is PTM	If IDX = 0b00 and TYPE = 0b0: 0b00: Unidirectional teach-in 0b01: Bi-directional teach-in If IDX = 0b00 and TYPE = 0b1: 0b00: Rocker A used for teach-in 0b01: Rocker B used for teach-in	

Figure 82 – Teach-in Info structure**B.4.3.3 Security level format (SLF)**

The security level format (SLF) defines the security parameters used for communication between two devices. If the communication is bi-directional (send and receive) then the same SLF setting has to be used in both directions.

Figure 83 below shows the supported security parameter options of 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: 3 byte CMAC 0b10: 4 byte CMAC 0b11: RFU		0b000: No data encryption 0b001: Deprecated 0b010: Deprecated 0b011: VAES using AES128 0b100: AES-CBC using AES128 Others: RFU		

Figure 83 – SLF structure