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SEAL Wearable GPS Tracker

Technical Reference Manual

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Acronyms and Glossary

ABP .... activation by personalization
ADR .... adaptive data rate
B .... byte
BeiDou. .... BeiDou Navigation Satellite System (BDS)
BD_ADDR .... Bluetooth Device Address
BLE .... Bluetooth Low Energy
CRC .... cyclic redundancy check
DC .... data converter
DL .... downlink
DR .... data rate
DZ .... designated/danger zone
EAR .... EMERGENCY App Request
EB .... emergency button
EIRP .... effective isotropically radiated power
EU .... European Union
flash .... a non-volatile memory, referring to either the MCU (internal) flash—containing application and configuration settings—or the GNSS receiver (external) flash memory—containing GNSS logs
FSM .... finite state machine
FW .... firmware
g .... gravity (unit of acceleration ≈ 9.8 m/s^2)
Galileo . ... EU GNSS
GLONASS .... GLObal NAvigation Satellite System
GNSS .... Global Navigation Satellite System
GPS .... Global Positioning System
ID .... identity/identifier
IoT .... Internet of Things
IP .... Ingress Protection
JSON .... JavaScript Object Notation
LAP .... lower address part
LED .... light-emitting diode
LID .... lithium-iron disulfide
LoRa .... a patented "long-range" IoT technology acquired by Semtech
LoRAMAC .... LoRaWAN MAC
LoRaWAN .... LoRa wide area network (a network protocol based on LoRa)
LoS .... line-of-sight
LSb .... least significant bit
LSB .... least significant byte
MAC .... Medium Access Control
MB .... Mute Button
MCU .... microcontroller unit

min .... minute(s)
MSb .... most significant bit
MSB .... most significant byte
NA .... North America
NAR .... NORMAL App Request
NS .... network server
OTA .... over-the-air
OTAA ... . OTA activation
OUI .... organizationally unique identifier
POST .... power-on self-test
QZSS .... Quasi-Zenith Satellite System, Japanese SBAS for GPS
RF .... radio frequency
RFU .... reserved for future use
RO .... read-only
R/W .... read/write
RSSI .... received signal strength indicator
Rx .... receiver
SB .... sleep button
SBAS .... Satellite-Based Augmentation System
sec .... second(s)
SH .... safety hook
SW .... software
transducer .... a sensing element in the SEAL, such as the accelerometer
TRM .... technical reference manual (this document)
Tx .... transmitter
UL .... uplink
UTC .... Coordinated Universal Time
ver. .... Version
SEAL .... Wearable GPS Tracker

1 Overview

This document describes the LoRa IoT uplink and downlink payloads and user accessible configuration settings supported by the SEAL and SEAL ATEX wearable tracker developed by TEKTELIC Communications Inc, henceforth collectively referred to as the SEAL/SEAL-Ex device. This document assumes a reasonable understanding of the Network Server (NS) and its command interfaces.

The SEAL/SEAL-Ex is a **light**, **small**, **long battery lifetime, low-cost LoRaWAN sensor** used for tracking people (as a **wearable device**) or equipment, based on **GNSS** and **BLE** technologies. It has a **wide operating temperature range of -20°C to +60°C**. The SEAL comes both as an **ATEX/IECEx certified** unit to operate in potentially hazardous and explosive atmospheres, and as a regular non-ATEX/IECEx unit. Each of the ATEX/IECEx certified and the non- ATEX/IECEx models has two variants: **with and without a safety clip harness**. The safety clip harness detects whether a safety hook is placed on the unit or not, triggering a local buzz if the user is to be warned.

The SEAL/SEAL-Ex uses **Semtech SX1261 modem** for LoRaWAN communication, and a low-power, IoT targeted MCU, **STM32 from STMicroelectronics** with **built-in BLE** module, **256 kB of RAM**, and **512 kB of flash**. Other hardware features include a high-sensitivity GNSS receiver from u-blox (**MAX-M10S)**, a low power 3-axis MEMS accelerometer from STMicroelectronics (**LIS3DH**), and a digital barometric air pressure sensor from Infineon (**DPS310**). There is also a push button used as an **emergency/SOS/panic button**, 1 buzzer (**GT-0601A** from Soberton Inc.) to locally indicate the emergency button (EB) press or safety hook (SH) disconnection, 1 mute button (MB) to manually mute (disable) or unmute (enable) the buzzer, and **2 sets of LEDs**, one set at the top containing two high-intensity amber color LEDs, and another set at the front containing three high-intensity amber color LEDs. These LEDs are used to indicate emergency status, low battery, and the system going into or out of DEEP SLEEP, among other features – See section 1.10 for more information on LED operations.

The GNSS receiver of the SEAL supports GPS, Galileo, GLONASS, BeiDou, QZSS, and SBAS. The SEAL/SEAL-Ex also supports BLE as a positioning system, and is capable of scanning and reporting neighboring BLE devices to provide location information to a cloud location resolver. This can be particularly helpful in indoor environments with poor GNSS satellite coverage. The SEAL/SEAL-Ex is also equipped with a barometer that can be used for estimating a user's elevation at the application level. This is performed by evaluating the pressure report relative to that of a reference SEAL device place on the ground level.

The SEAL/SEAL-Ex accelerometer is used to **detect (emergency) human fall** by comparing the orientation and acceleration measured by the onboard accelerometer with a defined number of human fall conditions such as free-fall acceleration and fall-time. The accelerometer output vector can also be reported periodically if knowledge of the SEAL/SEAL-Ex orientation is of interest.

Under certain emergency conditions, including pressing the EB, a human fall event, and entering danger zones, as determined from the GNSS receiver localization or BLE scan results, the SEAL goes from the **NORMAL state** to an **EMERGENCY state** with local LED indication. By default, location information and alarm statuses are reported five (5) times faster than the **NORMAL** state. The SEAL can also go to a **SLEEP state** to reserve power, and wake up upon observing motion, using the accelerometer as a motion detector.

Another important SEAL/SEAL-Ex feature is **GNSS Datalogging**, which means it can store up to 3000 valid GNSS location fixes and their UTC timestamps. This is helpful in keeping track of location data when the SEAL goes outside LoRa coverage.

When it returns to the coverage zone, it can forward the location data collected during the outage upon request from the cloud application.

Additional sensing functions on the SEAL/SEAL-Ex include **temperature** (from the barometer), the **battery remaining capacity**, and **remaining battery capacity**— calculated using current measurement by an onboard current sense amplifier (CSA) in percentage and number of days respectively. Low battery threshold can be defined in days or percentage, and is visibly indicated to the user by distinctly periodic LEDs flashes when the reported battery level goes below the set threshold.

The SEAL/SEAL-Ex supports remote configuration of all the features described above by the cloud application.

The SEAL/SEAL-Ex has an **IP67** enclosure, and runs on **2 AA LID** batteries for the ATEX/IECEx certified version with an expected lifetime of **10 months** in the NORMAL default state, or on **3 AA LID** batteries for the non-ATEX/IECEx version with an expected lifetime of **16 months** in the NORMAL default state (please see Section 1.1 for the explanation of the NORMAL default state). There is an onboard current sense circuitry measuring the consumed power to estimate the remaining battery lifetime (in percentage or number of days).

Table 1-1: SEAL HW Models

Part Number			Description
Level 1 (module)	**Level 2 (PCBA)**	**Level 3 (PCB)**	
T0008766			SEAL Module, 2x AA-Cell (ATEX) With Safety Clip
T0008767			SEAL Module, 2x AA-Cell (ATEX) With No Safety Clip
T0008768			SEAL Module, 3x AA-Cell with Safety Clip
T0008769			SEAL Module, 3x AA-Cell with No Safety Clip
	T0007706		SEAL PCBA, non-ATEX
	T0008211		SEAL PCBA, ATEX
		T0008189	SEAL PCB

Table 1-2: SEAL Region Specific Variants

LoRaWAN Region	Corresponding HW Variant	Order Code
EU868	T0008766, T0008767, T0008768, T0008769	SEALW0EU868 SEALWCEU868
US915		SEALW0US915 SEALWCUS915

Note: Other LoRaWAN regions are available on request.

Information streams supported by the SW is shown in Table 1-3.

Table 1-3: SEAL Information Streams

Stream Direction	Data Type	Sent on LoRaWAN Port
UL (SEAL/SEAL-Ex to NS)	All Real-time sensing data • GNSS location fix • GNSS and BLE DZ status updates • Accelerometer vector report • Barometric pressure • Temperature • Battery life information • Periodic Safety Status (EB, Fall, and SH status)[1]	**10**
	Report GNSS logged position and timestamp (UTC)	**15**
	Report GNSS Diagnostics Information	**16**
	Report discovered BLE devices	**25**
	Response to read/write commands from the NS	**101**
DL (NS to SEAL/SEAL-Ex)	Request behavior change (Emergency -> Normal and vice versa)	**10**
	Request GNSS logged (historical) time and position	**15**
	Configuration and Control Commands	**100**

The default configuration on the SEAL/SEAL-Ex for reporting transducer readings has been shown in Table 1-4.

Table 1-4: SEAL/SEAL-Ex Default Reporting Behavior

Report	Occurrence
Battery remaining capacity in percentage	Once every day (1440 minutes) • Every 15 min in the NORMAL state
GNSS position fix and UT timestamp GNSS Groundspeed	• Every 15 min in the NORMAL state • Every min in the EMERGENCY state
Safety Status (EB, Fall, SH, and EAR status)[2]	• Every 5 min in the NORMAL state • Every 1 min in the EMERGENCY state • With any status change in EB, Fall, or SH[3]

1.1 Finite State Machine Description

Figure 1-1 shows the state machine of the SEAL/SEAL-Ex with the glossary and notes. The following states are defined in the state machine:

[1] The SH status is always OFF (= 0) for HW models not equipped with the safety clip.

[2] Ditto Footnote 1.

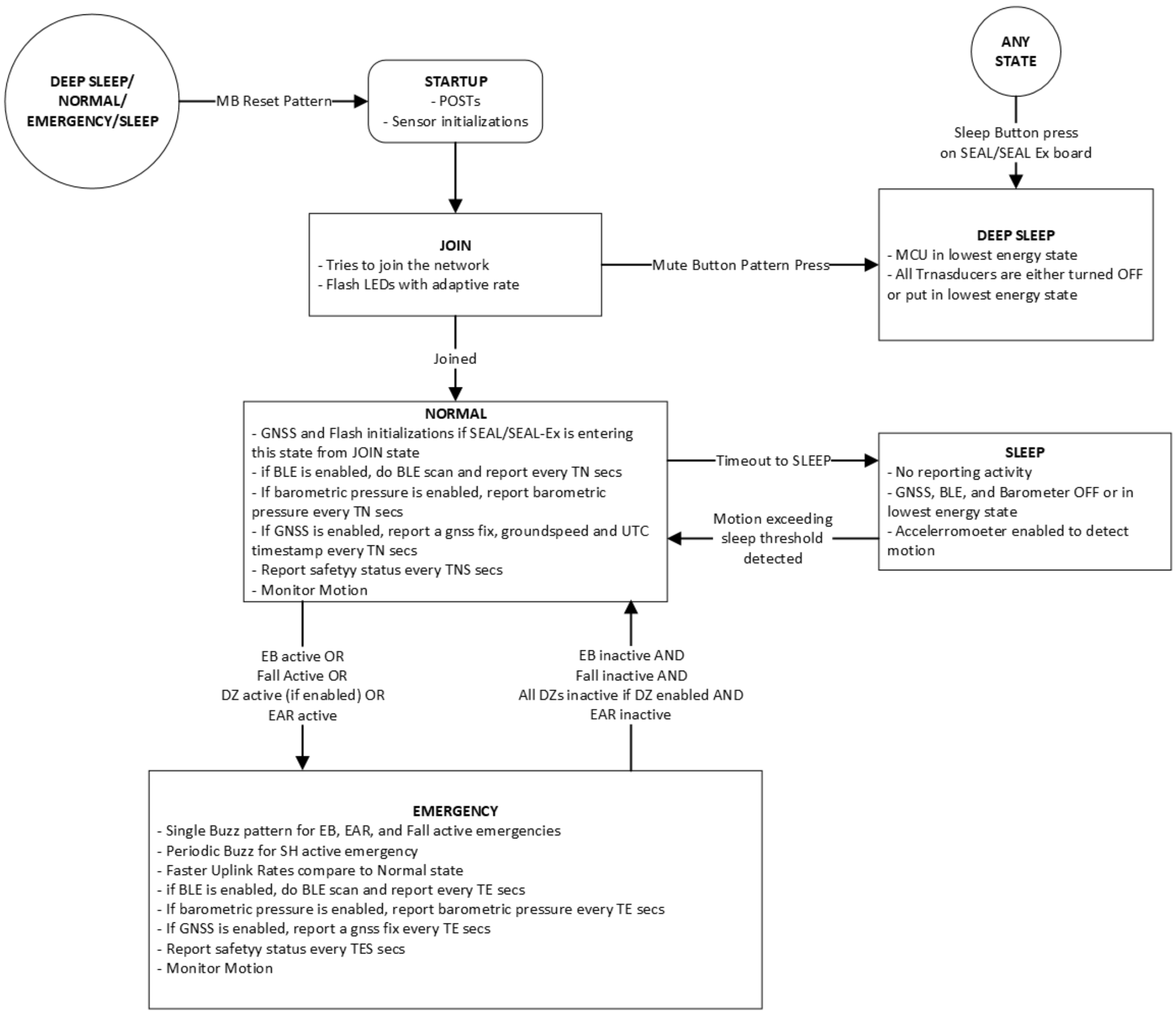
[3] Ditto Footnote 1.

- STARTUP: When the SEAL is booting up, doing POSTs and other initializations, and getting ready to start LoRa network join attempts.
- DEEP SLEEP: The state where the MCU is in deep sleep (lowest energy state). It is possible to go to this state from any other state by pressing the sleep button on the SEAL board. The SEAL always comes out of the factory in DEEP SLEEP. Applying a specific Mute Button (MB) pattern will wake up the SEAL into STARTUP. Applying the same Mute Button (MB) pattern during join will cause a transition back to DEEP SLEEP, while applying the pattern in any other state will reset the SEAL. See section 1.9 for more information on how to apply the DEEP SLEEP pattern using the MB.
- JOIN: When the SEAL is attempting to join a LoRa network. In this state, the LEDs flash at a faster rate for the first hour, but with a much slower rate after that.
- NORMAL: The SEAL periodically reports GNSS fixes, ground speed, and Safety Status (status of Emergency Button (EB), Fall, Safety Hook (SH), and Emergency App request (EAR))[4]. The SEAL also monitors motion from time to time so it can go to SLEEP if no motion is detected for some amount of time (default sleep timeout is fifteen (15) minutes).
- EMERGENCY: Pushing the EB or safety hook (for models equipped with safety hook), a human fall event, entering a GNSS or BLE designated/danger zone (DZ), or a specific DL command, called an EMERGENCY App Request (EAR), will cause transitioning to this state. EAR becomes inactive by a specific DL command, called a NORMAL App Request (NAR). The following is observed upon transition to the EMERGENCY state
    - a Safety Status report is generated and uplinked to the cloud application.
    - A local buzz by the buzzer is also used as a local acknowledgement of the EB and safety hook presses.
    - All LEDs start flashing rapidly and periodically to indicate the EMERGENCY state.
    - The SEAL periodically reports GNSS and Safety Status with a higher rate compared with the NORMAL state.

  A transition to the NORMAL state occurs when all emergency situations are cleared. No transition to the SLEEP state is possible from the EMERGENCY state.
- SLEEP: When the SEAL enters this battery-conservation mode when motionless in the NORMAL state for fifteen minutes. In this state, all transducers, except the accelerometer, are put to their lowest energy states, and nothing is reported from the SEAL. The accelerometer monitors motion events. As soon as motion exceeding the sleep threshold acceleration is detected, the SEAL is woken up into the NORMAL state.

NOTE: The front LEDs provide indications for LoRa uplink events and low battery events.

[4] Ditto Footnote 1.



GLOSSARY

Safety Status: Comprises of EB, Fall, SH, and EAR statuses. For non-clip SEAL/ SEAL-EX variants, SH status bits are always OFF (i.e. 00)

DZ: (BLE or GNSS) Designated/Danger Zone

EAR: EMERGENCY App Request

EB: Emargency Button

MB: Mute button

SB: Sleep Button (reset button on the board)

SH: Safety Hook

TNS: Report Period in NORMAL state

TES: Report Period in EMERGENCY state

NOTES:

The MB reset pattern, explaained inn Section 1.3, is not user configurable.

When a sensor is disabled or turned off (e.g. GNSS, BLE, barometer), no report (periodic or event-based) is transmitted for it.

Battery periodic reporting, temperature periodic and threshold-bassed reporting, and accelerometer periodic reporting are all handled in the same way in both NORMAL and EMERGENCY states, based on their corresponding configurations.

Figure 1-1: The SEAL/SEAL-Ex Finite State Machine.

1.2 GNSS Operation

The SEAL/SEAL-Ex uses the MAX-M10S module for GNSS localization and other GNSS-related features such as GNSS danger zone and GNSS datalogging.

1.2.1 GNSS Position fixes

The MAX-M10S is a low power, high precision module that supports concurrent receptions of up to four GNSS constellations (GPS, GLONASS, Galileo, and BeiDou). The high number of visible satellites enables the receiver to select the best signals. This maximizes the position availability, in particular under challenging conditions such as in deep urban canyons. The typical and maximum accuracies of the GNSS position fixes for the SEAL/SEAL-Ex is listed below

1. Position accuracy (50% CEP): 2.5m[5]
2. Time to first fix: Cold start: 1-minute, Hot start: 5s

1.2.2 GNSS Datalogging

SEAL/SEAL-Ex has the capability to store up to 3000 position fixes and their timestamps in its flash at a time. These log entries can be requested for OTA using any of the supported request methods (see Section 3.2 for more information). SEAL can dump up to 255 log entries at a time.

1.2.3 GNSS Danger zones

Up to four circular danger zones can be set up by providing the coordinates of the danger zone's center coordinates and the radius of the danger. SEAL/SEAL-Ex will transition to emergency mode when it gets a position fix that falls within any of the defined danger zones. Active GNSS danger zones can also be used as a standalone criterion for the activation of the Safety hook alarm, or in combination with the BLE danger zones. See Section 3.3.5.3 for more information on how to set up GNSS danger zones

1.3 BLE Operation

The SEAL/SEAL-Ex's MCU is an ultra-low power IoT targeted module with in-built support for Bluetooth low energy SIG 5.2 technology. The SEAL/SEAL-Ex ONLY supports the use of this technology as a TRACKER. This means that the SEAL/SEAL-Ex can track and discover BLE devices nearby, but it can't be discovered by other BLE trackers. By default, the BLE scanning functionality of the SEAL/SEAL-Ex is disabled. However, this can easily be changed by sending a simple OTA command to enable the BLE mode. The SEAL/SEAL-Ex can track and report up to 128 devices per scan.

1.3.1 BLE Scans

There are generally two types of BLE modes – Tracker and Beacon modes. SEAL/SEAL-Ex can only be used in tracker mode and not in beacon mode, which means it is not discoverable by other BLE-capable devices. During each scan, other advertising BLE devices can be discovered. Each discovered device has its data (MAC address and the RSSI of the advertisement packet) saved by the SEAL/SEAL-Ex to then be reported in a LoRa UL. This UL is normally reported

[5] Calculated from 6 hours of continuous multi-constellation fixes in static open and clear sky.

immediately after the scan concludes, but may be delayed due to duty cycle limitations (LoRa Alliance, Feb 2017). If a new BLE scan occurs before the results of the previous scan have been sent, the old scan results will be discarded.

The BLE scan can be disabled or enabled at any time by sending the required configuration downlink via the cloud application. Figure 1-2 shows the BLE scan scheme overview when the BLE scan is enabled. As shown in the figure, BLE scans are performed periodically, with the period being T_N (in the NORMAL state) or T_E (in the EMERGENCY state). Also, each scan duration is divided into scan intervals. The BLE scan is performed only in a scan window portion of the scan interval. The ratio of the scan window to the scan interval shows the scan duty cycle. The scan window being equal to the scan interval represents a scan duty cycle of 100%, or a continuous scan, over each scan duration. This is the default behavior as it maximizes the chance of discovering BLE beacons for a given scan duration. Reducing the duty cycle saves some amount of power at the expense of possibly missing some BLE beacons.

The scan period, duration, interval, and window are all configurable (see Sections 3.3.2 and 0).

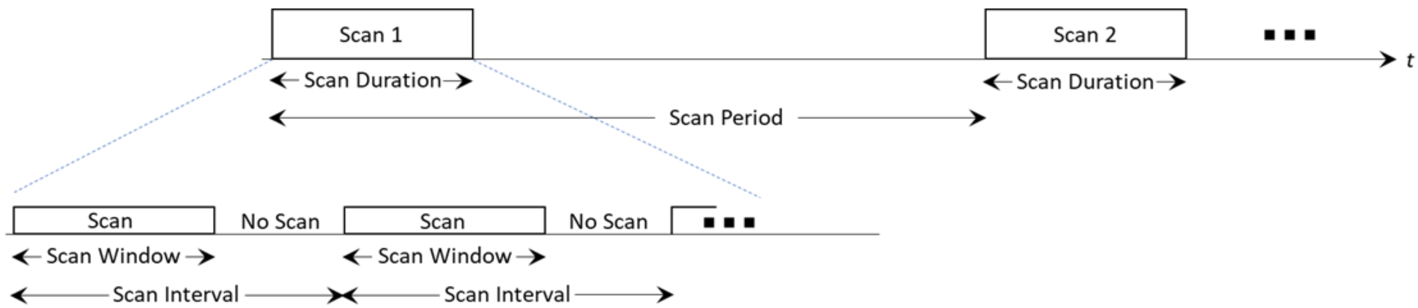


Figure 1-2: The BLE scan scheme.

Following each scan, there are two different modes for reporting the discovered BLE device data:

A. **Averaging Mode (Default)**: It is often the case that more than one packet from the same BLE device is received during a single scan. When averaging mode is enabled, the RSSIs for each device are averaged, then the devices are sorted and uplinked in order from strongest average RSSI to weakest, up to *N* distinct devices (*N* is a user-configurable value; see section 3.3.10).

B. **Raw Mode:** The packets received during each scan are neither averaged nor sorted before getting uplinked; the *N* last discovered devices are sent. This means it is possible to have repeated devices in the same UL. When the averaging mode is disabled, the device uses the raw mode to process its BLE uplinks.

Furthermore, there is the option to send device data with *basic* reporting or *filtered/whitelisting* reporting. In the basic (default) reporting, at the end of each scan duration, up to a maximum *N* discovered BLE devices are reported over LoRaWAN. In filtered/whitelisting reporting, up to maximum *N* discovered BLE from a user-specified range of MAC addresses are reported. This allows for keeping out undesired devices from the OTA report, and thus reducing the OTA time and saving battery life. An example application of this is for an indoor Beacon network; only the Beacon signals are of interest and no other devices like smartphones are of value. In either reporting type, if no devices are found, an empty list is uplinked.

Averaging/raw modes and basic/filtered reporting are mutually compatible; that is, any combination of the four options is acceptable.

SEAL/SEAL-Ex supports BLE of Bluetooth 5.0. The BLE scan is performed in the passive mode only; i.e., the Tracker listens to surrounding beacons, but does not transmit to them to request additional information.

NOTE: The BLE scan is exclusive to LoRa radio transmission; i.e., they do not overlap. If any reporting becomes due at the same time as a BLE scan, the reporting will be done after the BLE scan is complete.

1.3.2 BLE Danger Zones

SEAL/SEAL-Ex supports the definition of danger zones using mac addresses of discovered BLE devices. Users can define up to four BLE MAC address ranges and the required RSSI threshold to set up as danger zones. If a discovered BLE device with a MAC address that falls within a defined danger zone MAC address range has a RSSI value lower than the defined RSSI threshold, SEAL/SEAL-Ex triggers a danger zone alarm. See Section 3.3.10 for more information on how to configure BLE danger zones.

1.4 Accelerometer Operation

The SEAL/SEAL-Ex has a 3-axis MEMS digital accelerometer (LIS3DH) for motion detection to wake the device up from inactivity sleep, and free-fall detection. The LIS3DH is an ultra-low-power high performance three-axis linear accelerometer belonging to the “nano” family, with digital I2C/SPI serial interface standard output. The device features ultra-low-power operational modes that allow advanced power saving and smart embedded functions. The LIS3DH has dynamically user-selectable full scales of ±2g/±4g/±8g/±16g and is capable of measuring accelerations with output data rates from 1 Hz to 5.3 kHz.

1.4.1 Motion detection

The SEAL/SEAL-Ex uses the accelerometer to continuously monitor motion for the purpose of putting the device to sleep when there is an extended period of inactivity. By default, the device is put to sleep after the accelerometer measure 10 minutes of inactivity. The default sensitivity threshold is set to 250mg – a threshold low enough to ignore small and insignificant vibrations but sensitive enough to human movements or motion.

1.4.2 Fall detection operation

SEAL/SEAL-Ex features a free-fall detection mechanism using the on-board accelerometer. See Section 3.3.9 for more information on how SEAL/SEAL-Ex detects human fall.

1.5 Current Sense Resistor

SEAL/SEAL-EX features a current sense resistor that continuously monitor and record the system current usage and use this information to compute the remaining battery lifetime of the unit.

1.6 Barometer

The SEAL/SEAL-Ex has an onboard barometer from Infineon (DPS310) used for measuring barometric pressure and temperature. The DPS310 is a miniaturized Digital Barometric Air Pressure Sensor with a high accuracy and a low current consumption, capable of measuring both pressure and temperature. The pressure sensor element is based on a capacitive sensing principle which guarantees high precision during temperature changes. The typical and maximum accuracies specified across the operating relative humidity and temperature range of the sensor are listed below

1. Operation range: Pressure: 300 –1200 hPa, temperature: -40 – 85 °C
2. Pressure sensor precision: ± 0.002 hPa (or ±0.02 m) (high precision mode).
3. Relative accuracy: ± 0.06 hPa (or ±0.5 m)
4. Absolute accuracy: ± 1 hPa (or ±8 m)
5. Temperature accuracy: ± 0.5°C.

1.7 Safety Hook Button (SH) Operation

The Clip variants of the SEAL/SEAL-Ex are equipped with a SB. The SB is used for the following purposes:

1) SB Active event: Pressing and holding the EB for at least 1 sec sounds the emergency active buzz pattern if the buzzer is enabled, flashes the top LEDs periodically, sends a Safety Status (combination of EB, Fall, SH, and EAR statuses),[6] and makes a system state transition to the EMERGENCY state (if not already in that state).
2) SB Inactive Event: Pressing and holding the EB for at least 5 secs in the EMERGENCY state sounds the emergency inactive buzz pattern if the buzzer is enabled, stops the periodic LED flashes, sends a Safety Status, and makes a system state transition to NORMAL state if no other emergency condition (i.e., EAR, Fall or being inside designated/danger zones (DZs)) is active.

1.8 Emergency Button (EB) Operation

The SEAL/SEAL-Ex is equipped with an EB. The EB is used for the following purposes:

3) EB Active event: Pressing and holding the EB for at least 1 sec sounds the emergency active buzz pattern if the buzzer is enabled, flashes the top LEDs periodically, sends a Safety Status (combination of EB, Fall, SH, and EAR statuses),[7] and makes a system state transition to the EMERGENCY state (if not already in that state).
4) EB Inactive Event: Pressing and holding the EB for at least 5 secs in the EMERGENCY state sounds the emergency inactive buzz pattern if the buzzer is enabled, stops the periodic LED flashes, sends a Safety Status, and makes a system state transition to NORMAL state if no other emergency condition (i.e., EAR, Fall or being inside designated/danger zones (DZs)) is active.

[6] Ditto Footnote 1.

[7] Ditto Footnote 1.

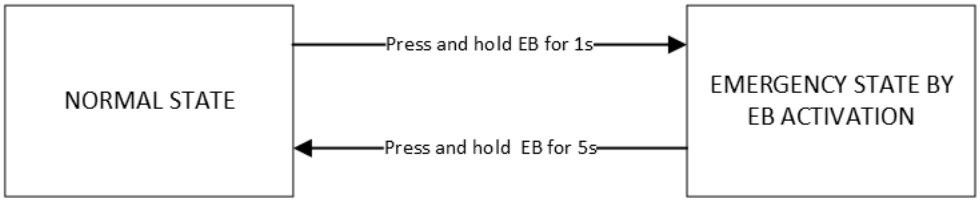


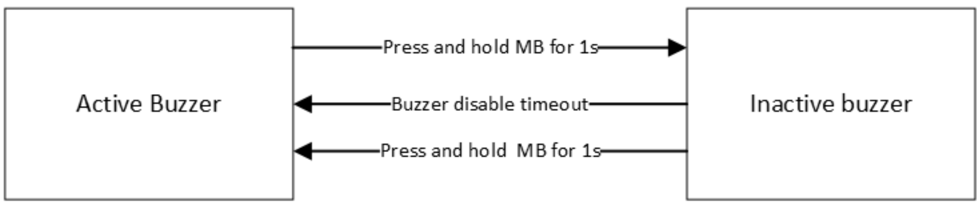
Figure 1-3: EB activation and deactivation block diagram

1.9 Mute Button (MB) Operation

The SEAL is equipped with a MB. The MB is used for the following purposes:

1) Muting the buzzer: Pressing the MB for at least 1 sec mute the buzzer if the buzzer is enabled
2) Unmuting the buzzer: Pressing the MB for at least 1 sec unmutes a muted buzzer. Also, the buzzer is automatically re-enabled after Buzzer Disable Timer has elapsed (see Section 3.3.13 for more information).

Figure 1-4: MB activation and deactivation block diagram



3) Clicking the MB once, then pressing and holding it for at least 3 sec, resets the SEAL. This can be used to take the SEAL out of DEEP SLEEP when received from the factory. If the same pattern is applied while the SEAL is trying to join before joining is complete, it takes the SEAL back to DEEP SLEEP. If the pattern is applied in any other state, it simply causes a system reset, which is then followed by the SEAL trying to join the network. See Figure 1-1 for more information.

1.10 LEDs Behavior

The SEAL/SEAL-Ex is equipped with two LED sets: Two Top-Set LEDs (TS) and Three Front-Set LEDs (FS). Table 1-5 shows a list of LEDs behaviors defined for the SEAL/SEAL-Ex. Only one LED pattern at a time is run by the SEAL/SEAL-Ex.

Table 1-5: List of Possible SEAL LEDs Behaviors

Status	LEDs Behavior
Startup	1. Both **TS** and **FS** are turned off when the SEAL is powered on. 2. **FS** is turned on when the POST begins. 3. When the POST ends, depending on the POST result: a) If the POST passes, **TS** is toggled on and off every 50 msec for 0.5 sec. b) If the POST fails, **FS** is toggled on and off every 50 msec for 0.5 sec.

	4. Both **TS** and **FS** are turned off when the POST and the subsequent LED flashing specified in item 3 end.
Join	**TS** is toggled on and off every 50 msec for the first hour. But after that, it flashes 5 times (on time: 50 msec, off time: 50 msec) every 10 sec.
Going to DEEP SLEEP	**FS** is toggled on and off three times with on and off times being 0.1 sec.
Waking up from DEEP SLEEP	**TS** is toggled on and off three times with on and off times being 0.5 sec.
LoRa uplink	**FS** is toggled ON for 50ms
EMERGENCY	All LEDs flash periodically in pattern configured in Register 0x39 (Section
Low-Battery	Periodic **TS** LEDs pattern configured in Register 0x6A (Section

1.11 Buzzer Behavior

The SEAL/SEAL-Ex is equipped with a buzzer, which is enabled by default, but can be disabled/re-enabled by a mute button (see Section 3.3.13). Table 1-6 shows a list of buzzer behaviors defined for the SEAL/SEAL-Ex. Only one buzzer pattern at a time is run by the SEAL/SEAL-Ex. The priority column shows which pattern prevails in cases of concurrent buzzer patterns.

Table 1-6: List of Possible SEAL Buzzer Behaviors

Status	Buzzer Behavior
EB Active and Inactive Events	Single buzz pattern (non-periodic) configured in Registers 0x28 and 0x29.
SH Buzz[8]	Periodic buzz pattern configured in Register 0x2D.

1.12 Safety Status Behavior

Safety Status refers to the uplink message with header 0x02 95 and payload consisting of the EB, Fall, SH, and EAR statuses,[9] as shown in Table 2-2. As shown in the SEAL/SEAL-Ex state machine (Figure 1-1), the Safety Status is periodically reported in the NORMAL and EMERGENCY states with respective configurable report periods. However, SEAL/SEAL-Ex also triggers a Safety Status report upon any change in any of its reported EMERGENCY statuses. In other words, Safety Status reporting can either be periodic or event-based.

[8] Ditto Footnote 1.

[9] Ditto Footnote 1.

2 UL Payload Formats

The UL streams (from the SEAL/SEAL-Ex to the NS) supported by the SW are shown in Table 2-1, and are explained in Sections 2.1 to 2.4.

Table 2-1: UL Information Streams

Data Type	Sent on LoRaWAN Port
All Real-time sensing data • GNSS location fix ○ "0x 00 00 00" means "no fix found" after GNSS scan • GNSS and BLE DZ status updates • Accelerometer vector report • Barometric pressure • Temperature • Battery life information Periodic Safety Status (EB, Fall, and SH status)[10]	**10**
Report GNSS logged position and timestamp (UTC) UL containing "00" from port 15 means the requested GNSS logged entry is invalid	**15**
Report GNSS Diagnostics Information	**16**
Report discovered BLE devices	**25**
Response to read/write commands from the NS	**101**

2.1 Frame Payload to Report Real-Time Sensing Data

Each data field from the SEAL/SEAL-Ex is encoded in a frame format shown in Figure 2-1. A big-endian format (MSb/MSB first) is always followed.

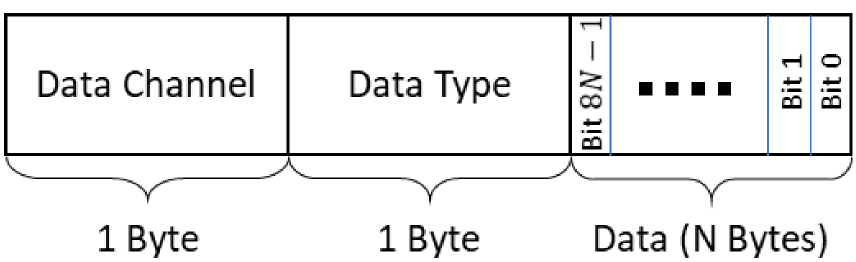


Figure 2-1: The frame format in an UL payload.

A SEAL/SEAL-Ex message payload can include multiple data frames from different sensing entities in the SEAL/SEAL-Ex. Frames can also be arranged in any order. The SEAL/SEAL-Ex frame payload values for real-time sensor data are shown in Table 2-2. In this table, the bit indexing scheme is as shown in Figure 2-1. Real-time sensor data in the UL are sent through ***LoRaWAN port 10*** and GNSS diagnostics information are sent on ***LoRaWAN port 16.***

[10] The SH status is always OFF (= 0) for HW models not equipped with the safety clip.

Table 2-2: UL Frame Payload Values for Present SEAL Data

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Battery Lifetime in Percentage	0x00	0xD3	1 B	Percentage	• 1%/LSB (Unsigned)	*battery_lifetime_pct: <value> (number/%)*
Battery Lifetime in Days	0x00	0xBD	2 B	Days	• 1 day/LSB (Unsigned)	*battery_lifetime_dys: <value> (number/days)*
UTC	0x00	0x85	4 B	Timestamp	• Bits 26-31: Year—2020 • Bits 22-25: Month [1-12] • Bits 17-21: Day [1-31] • Bits 12-16: Hour [0-23] • Bits 6-11: Minute [0-59] • Bits 0-5: Second [0-60][11]	• *year: <value> (number/202(<value>))* • *month: <value> (number/year)* • *day: <value> (number/day)* • *hour: <value> (number/hour)* • *minute: <value> (number/min)* • *second: <value> (number/s)*
Position Coordinates	0x00	0x88	8 B	Coordinate	• Bits 40-63: Latitude (signed, $\frac{90^{\circ}}{2^{23}}$/LSB) • Bits 16-39: Longitude (signed, $\frac{180^{\circ}}{2^{23}}$/LSB) • Bits 0-15: Altitude+500m (unsigned, $\frac{9500}{2^{16}}$ m/LSB)	• *latitude: <value> (number/°)* • *longitude: <value> (number/°)* • *altitude: <value> (number/m)*
Ground Speed	0x00	0x92	1 B	Speed	• 0.27778 m/s/LSB	*ground_speed: <value> (number/m/s)*
No GNSS position fix	0x00	0x00	1B	Bitmap Input	• 0x 00: invalid GNSS fix	*gnss_fix: invalid <value> (string/no unit)*
GNSS DZ Status	0x00	0x95	1 B	Bitmap Input	• Bits 0-1 (DZ 0): 0 = Unknown 1 = Inside 2 = Outside	• *gnss_status_dz0: <value> (string/no unit)*

[11] The maximum possible value for "second" is 60 to allow for leap seconds.

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
					• Bits 2-3 (DZ 1): 0 = Unknown 1 = Inside 2 = Outside • Bits 4-5 (DZ 2): 0 = Unknown 1 = Inside 2 = Outside • Bits 6-7 (DZ 3): 0 = Unknown 1 = Inside 2 = Outside	• *gnss_status_dz1: <value> (string/no unit)* • *gnss_status_dz2: <value> (string/no unit)* • *gnss_status_dz3: <value> (string/no unit)*
BLE DZ Status	0x01	0x95	1 B	Bitmap Input	• Bits 0-1 (DZ 0): 0 = Unknown 1 = Inside 2 = Outside 3 = Near • Bits 2-3 (DZ 1): 0 = Unknown 1 = Inside 2 = Outside 3 = Near • Bits 4-5 (DZ 2): 0 = Unknown 1 = Inside 2 = Outside 3 = Near • Bits 6-7 (DZ 3): 0 = Unknown 1 = Inside 2 = Outside 3 = Near	• *ble_status_dz0: <value> (string/no unit)* • *ble_status_dz1: <value> (string/no unit)* • *ble_status_dz2: <value> (string/no unit)* • *ble_status_dz3: <value> (string/no unit)*
Atmospheric Pressure	0x00	0x73	2 B	Barometric Pressure	• 0.1 hPa/LSB (unsigned)	*atmospheric_pressure: <value> (number/hPa)*
Acceleration Vector	0x00	0x71	6 B	Acceleration	• 1 mg/LSB (signed) • Bits 32-47: X-axis acceleration • Bits 16-31: Y-axis acceleration • Bits 0-15: Z-axis acceleration	• *acceleration_x: <value> (number/g)* • *acceleration_y: <value>*

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
						(number/g) • *acceleration_z: <value> (number/g)*
Temperature	0x00	0x67	2 B	Temperature	• 0.1°C/LSB (signed)	*temperature: <value> (number/°C)*
Safety Status	0x02	0x95	1 B	Bitmap Input	• Bit 0: 0/1 = EB Inactive/Active • Bit 1: 0/1 = Fall Cleared/Active • Bit 2: 0/1 = SH OFF/ON Always = 0 for HW models not equipped with the safety clip. • Bits 3: 0/1 = EAR Alert Inactive/Active • Bits 4-7: Ignored	• *safety_status_eb: <value> (string/no unit)* • *safety_status_fall: <value> (string/no unit)* • *safety_status_sh: <value> (string/no unit)* • *safety_status_ear: <value> (string/no unit)*
(GNSS Diagnostics Information) Number of Visible Satellites	0x0D	0x3C	1 B	Integer	• Bits 0-7: Number of satellites used to calculate the GNSS fix. If no fix was obtained, this value is the total number of visible satellites (unsigned, 1/LSB)	• *num_satellites: <value> (unsigned/no unit)*
(GNSS Diagnostics Information) Average Satellite SNR	0x0D	0x64	2 B	Generic (signed)	• Bits 0-15: Average SNR of all satellites used in getting the GNSS fix (0.1 dB/LSB) • 0x 00 00 = No satellites visible for calculating average	• *avg_satellite_snr: <value> (signed/dB)*
(GNSS Diagnostics Information) Most recent log entry number	0x0D	0x0F	2 B	Integer (unsigned)	• Bits 0-15: Most recent log entry number (unsigned, 1/LSB)	• *log_num: <value> (unsigned/ no unit)*
(GNSS Diagnostics	0x0D	0x95	1 B	Bitmap Input	• Bits 0-1: The type of fix acquired by the receiver (unsigned) Possible types are:	• *fix_type: <value> (unsigned/ no unit)*

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Information) GNSS Fix Type					0 = No fix available 1 = 2D fix 2 = 3D fix • Bits 2-7: ignored	
(GNSS Diagnostics Information) GNSS Time-to-fix	0x0D	0x96	2 B	Stopwatch	• Bits 0-15: The total time that the GNSS receiver has spent scanning for a fix since the last fix was obtained. (Unsigned, 1s/LSB)	• *time_to_fix: <value> (unsigned/s)*
(GNSS Diagnostics Information) GNSS Fix Accuracy	0x0D	0x97	4 B	Fix Accuracy	• Bit 0-15: Horizontal fix accuracy (unsigned, 1m/LSB) • Bits 16-31: Vertical fix accuracy (unsigned, 1m/LSB)	• *gnss_horizontal_accuracy: <value> (unsigned/m)* • *gnss_vertical_accuracy: <value> (unsigned/m)*
(GNSS Diagnostics Information) Ground Speed Accuracy	0x0D	0x98	4 B	Speed Accuracy	• Bits 0-31: Ground speed accuracy (unsigned, 0.001m/s/LSB)	• *ground_speed_accuracy: <value> (unsigned/m/s)*
(GNSS Diagnostics Information) Number of fixes per scan	0x0D	0x99	1 B	Integer (unsigned)	• Bits 0-7: Number of fixes per scan (unsigned, 1/LSB)	• *num_of_fixes: <value> (unsigned/no unit)*

Table 2-3: Examples of Decoded Uplinks

Uplinks	Decoded Information
0x 00 D3 64 00 BD 01 99	{"raw": "00 D3 64 00 BD 01 99", "fport": 10, "battery_lifetime_pct": 100, "battery_lifetime_dys": 409}
0x 00 85 0D C3 5A 85 00 92 00	{"raw": "00 85 0D C3 5A 85 00 92 00", "fport": 10, "year_utc": 3, "month_utc": 7, "day_utc": 1,

Uplinks	Decoded Information
	"hour_utc": 21, "minute_utc": 42, "second_utc": 5, "ground_speed": "0.0"}
0x 00 88 48 C4 C7 AE DE 6B 2B E5	{“raw": "00 88 48 C4 C7 AE DE 6B 2B E5", "fport": 10, "latitude": "51.1654651", "longitude": "-114.0907216", "altitude": "1129"}
0x 00 95 02 01 95 55 02 95 02	{ “raw": "00 95 02 01 95 55 02 95 02", "fport": 10, "gnss_status_dz0": "Outside", "gnss_status_dz1": "Unknown", "gnss_status_dz2": "Unknown", "gnss_status_dz3": "Unknown", "ble_status_dz0": "Inside", "ble_status_dz1": "Inside", "ble_status_dz2": "Inside", "ble_status_dz3": "Inside", "safety_status_eb": "Inactive", "safety_status_fall": "Active", "safety_status_sh": "Off", "safety_status_ear": "Inactive"}
0x 00 73 23 56 00 71 01 01 01 01 01 01 00 67 01 2A	{ “raw": "00 73 23 56 00 71 01 01 01 01 01 01 00 67 01 2A", "fport": 10, "atmospheric_pressure": "904.6", "acceleration_x": "0.257", "acceleration_y": "0.257", "acceleration_z": "0.257", "temperature": "29.8"}
0x 0D 3C 08 0D 64 01 83 0D 95 03 0D 96 00 08 0D 97 00 1E 00 11 0D	{“raw": "0D 3C 08 0D 64 01 83 0D 95 03 0D 96 00 08 0D 97 00 1E 00 11 0D 98 00 00 03 3F 0D 99 02 0D 0F 05 2F",

Uplinks	Decoded Information
98 00 00 03 3F 0D 99 02 0D 0F 05 2F	"fport": 16, "num_satellites": 8, "avg_satellite_snr": 38.7, "fix_type": "3D fix", "time_to_fix": 8, "gnss_vertical_accuracy": "30.00", "gnss_horizontal_accuracy": "17.00", "ground_speed_accuracy": "0.8", "num_of_fixes": 2, "log_num": 1327}

2.2 Reporting GNSS Logged UTC and Position Data

Position fixes and their respective timestamp (UTC) are logged using a mechanism similar to store and forward mechanism implemented in the Tektelic BLE Trackers. These fixes can be retrieved later from the flash memory and reported OTA on ***LoRaWAN port 15***. The GNSS log to be reported could be a single log entry, or combination of several log entries. Each log entry consists of a pair of corresponding UTC (as the timestamp) and position coordinates.

The payloads to report these log entries are in one of three formats shown in Figure 2-2. The UTC and Position Coordinates are logged in the exact same format as mentioned in rows 3 and 4 in Table 2-2, respectively.

Formats (a) and (b) are suitable for payloads that contain only one timestamp or one set of position coordinates. Corresponding timestamp and position coordinates have the same log fragment number. Using formats (a) and (b), two payloads, one of format (a) and one of format (b), are needed to report one log entry. These formats are especially helpful when the device is operating in a low data rate state.

For example, successive payloads “0x 01 00 U0”, “0x 02 00 P0”, “0x 01 01 U1”, “0x 02 01 P1”, “0x 01 02 U2”, “0x 02 02 P2” can be sent to report log entries (U0, P0), (U1, P1), (U2, P2), where U denotes UTC timestamp, P denotes position fixes information, (00, 01, 02) represents the fragment number, data type 0x 01 reports UTC time, and data type 0x 02 reports position fixes. Notice how the fragment number remains the same for both uplinks reporting the UTC and position fix pair.

Format (c) is suitable for instances where the data rate allows uplink of payloads that contains one or more log entries. Depending on the UL DR, a GNSS log may be reported only by payloads of formats (a) and (b), or only by payloads of format (c), or by a combination of these formats. Log fragment numbers help the NS to reconstruct the log in its original order.

For example, payload “0x 03 00 U0 P0 U1 P1 U2 P2” can be sent to report log entries (U0, P0), (U1, P1), (U2, P2), where U denotes UTC, P denotes position information, and 00 is the one-byte log fragment number

A payload consisting of only a one-byte Data Type 0x00 is transmitted to indicate there is no log entry available to report.

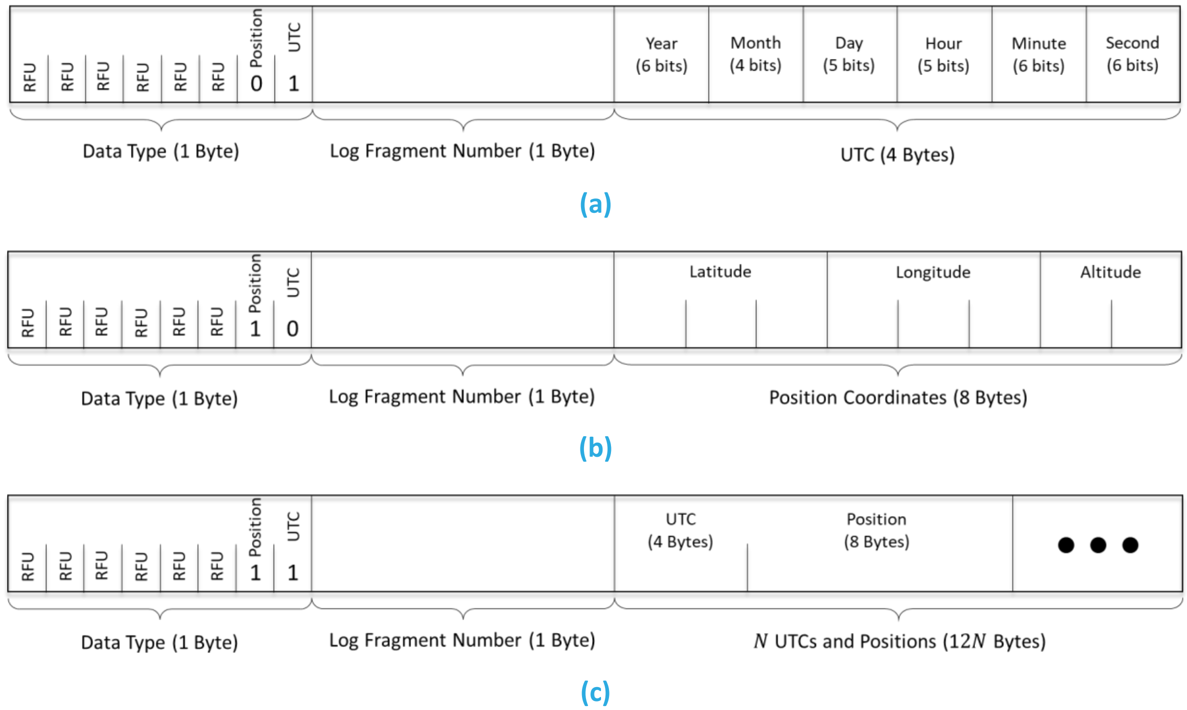


Figure 2-2: The UL payload formats to report GNSS logs.

Table 2-4: Examples of decoded log reports

Raw UL	Decoded Log UL Information
Format (a) 0x 01 01 0D C3 5A 85	{ “raw": "01 01 0D C3 5A 85", "fport": 15, "fragment_number_1": 1, "year_1": 3, "month_1": 7, "day_1": 1, "hour_1": 21, "minute_1": 42, "second_1": 5}
Format (b) 0x 02 01 48 C4 C7 AE DE 6B 2B E5	{ “raw": "02 01 48 C4 C7 AE DE 6B 2B E5", "fport": 15, "fragment_number_2": 1, "latitude_2": "51.1654651", "longitude_2": "-114.0907216", "altitude_2": "1129"}

Raw UL	Decoded Log UL Information
Format(c) 0x 03 01 0D C3 5A 85 48 C4 C7 AE DE 6B 2B E5	{ "raw": "03 01 0D C3 5A 85 48 C4 C7 AE DE 6B 2B E5", "fport": 15, "fragment_number_3": 1, "year_3": 3, "month_3": 7, "day_3": 1, "hour_3": 21, "minute_3": 42, "second_3": 5, "latitude_3": "51.1654651", "longitude_3": "-114.0907216", "altitude_3": "1129"}

2.3 Reporting Discovered BLE Devices

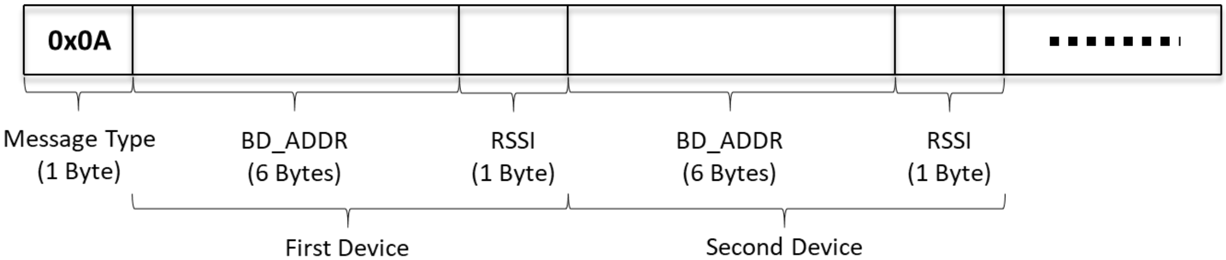
Discovered BLE devices are reported on ***LoRaWAN port 25***. The payload format to report such devices has been shown in Figure 2-3.

In the Basic mode of reporting (Figure 2-3-(a)), the header is **0x0A**. The BD_ADDR for each discovered device is a full 6-byte address, and is followed by the device RSSI, which is a signed 1-byte number. If no devices are found, an empty list consisting of only the header **(0x 0A)** is reported.

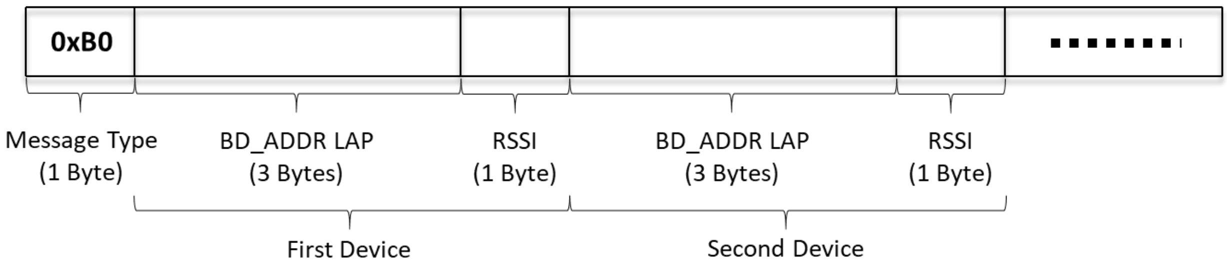
In the Whitelisting mode of reporting (Figure 2-3-(b-d)), up to 4 ranges of BD_ADDR can be defined for whitelisting discovered devices. The message type headers **0xB0, 0xB1, 0xB2, 0xB3** correspond to Ranges 0, 1, 2, and 3 respectively. A BD_ADDR consists of an Organizationally-Unique Identifier (OUI) comprising the 3 MSBs followed by a Lower Address Part (LAP) comprising the 3 LSBs. Each BD_ADDR range is a 9-byte OUI:LAPstart-LAPend that determines the range of BD_ADDRs as OUI:LAPstart to OUI:LAPend. Therefore, OUI is the same and known for all devices in each range. The message type header determines the range, and thus the OUI for all devices in the message, such that the devices in each message can be uniquely identified by their LAPs only.

For example, if the only discoverable BLE devices of interest all have MAC addresses that begin with AC233F (OUI) and only the last 3 bytes are different for each device (LAPs), the BD_ADDR range to filter for only these devices would be AC233F:000000-FFFFFF. In other words, this BD_ADDR range means that the Tracker will filter the discovered devices to include only those with MAC addresses from AC233F000000 to AC233FFFFFFF, **inclusive.**

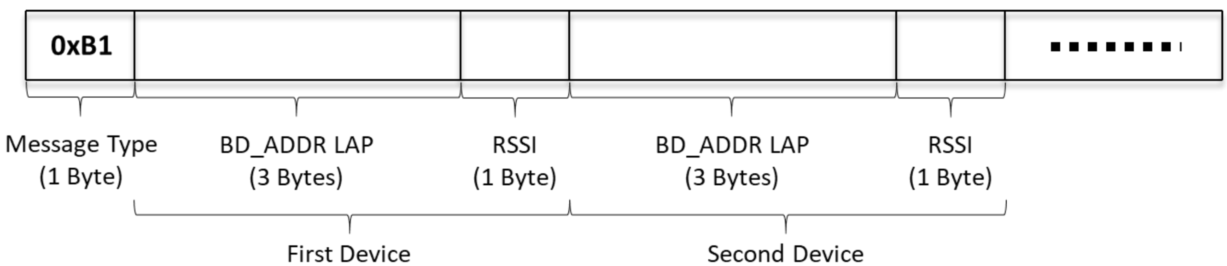
Note that in the Whitelisting mode, the devices from more than one range cannot be reported within the same packet. This is because the number of the devices for each range is not given in the corresponding header. Zero, one, or more devices can be reported in a single message, depending on the number of devices available to report and payload size limitation as determined by LoRaWAN regional restrictions. If the devices to be reported do not fit into one packet, more than one packet will be transmitted to report the devices.



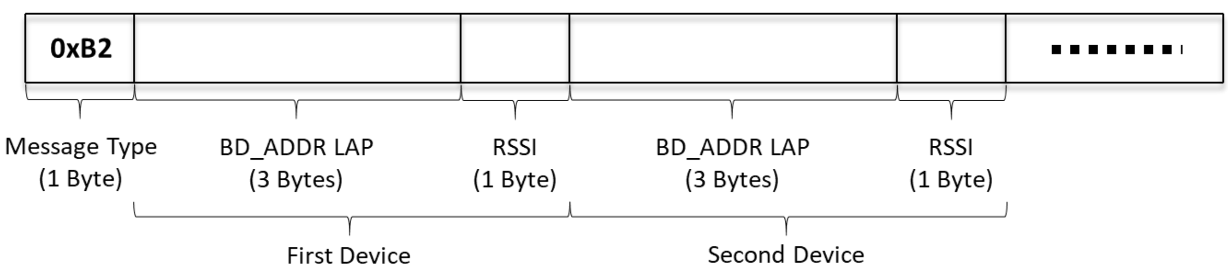
(a) Basic mode.



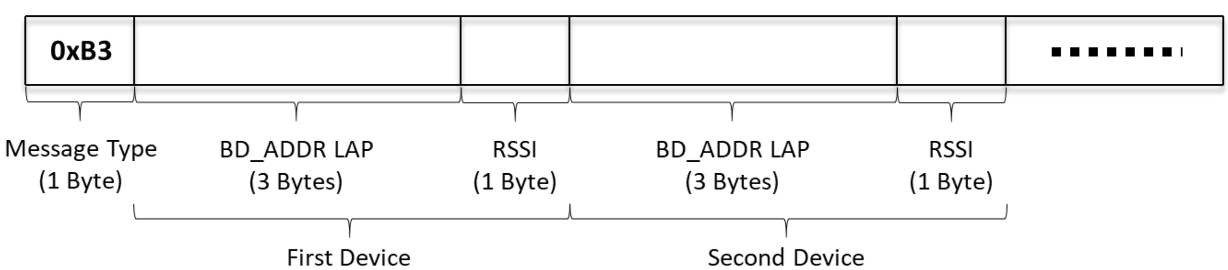
(b) Whitelisting mode, Range 0.



(c) Whitelisting mode, Range 1.



(d) Whitelisting mode, Range 2.



(e) Whitelisting mode, Range 3.

Figure 2-3: The UL payload format to report discovered BLE devices.

Table 2-5: Examples of BLE decoded ULs

Raw UL	Decoded Log UL Information

Basic mode
 	
0x 0A AC 23 3F 8F 96 B1 AA AC 23 3F 8F 96 B2 AB
	{
	"data": {
	"raw": "0A AC 23 3F 8F 96 B1 AA AC 23 3F 8F 96 B2 AB",
	"fPort": 25,
	"basic_report": [
	{
	"BD_ADDR_0": "ac 23 3f 8f 96 b1",
	"RSSI_0": -86
	},
	{
	"BD_ADDR_0": "ac 23 3f 8f 96 b2",
	"RSSI_0": -85
	}
	]
	},
	"errors": [],
	"warnings": []
	}

Filter Range 0
 	
0x B0 8F 97 B3 AC 8F 97 B4 AD
	{
	"data": {
	"raw": "B0 8F 97 B3 AC 8F 97 B4 AD",
	"fPort": 25,
	"filter_report_0": [
	{
	"BD_ADDR_1": "8f 97 b3",
	"RSSI_1": -84
	},
	{
	"BD_ADDR_1": "8f 97 b4",
	"RSSI_1": -83
	}
	]

Raw UL	Decoded Log UL Information
	}, "errors": [], "warnings": [] }

Filter Range 1
 	
0x B1 8F 96 BE AE 8F 96 BF AF 8F 96 B0 B1
	{
	"data": {
	"raw": "B1 8F 96 BE AE 8F 96 BF AF 8F 96 B0 B1",
	"fPort": 25,
	"filter_report_1": [
	{
	"BD_ADDR_2": "8f 96 be",
	"RSSI_2": -82
	},
	{
	"BD_ADDR_2": "8f 96 bf",
	"RSSI_2": -81
	},
	{
	"BD_ADDR_2": "8f 96 b0",
	"RSSI_2": -79
	}
	]
	},
	"errors": [],
	"warnings": []
	}

Filter Range 2
 	
0x B2 8F 96 C3 B2 8F 96 C4 B3 8F 96 B9 B4 8F 96 F4 B5
	{
	"data": {
	"raw": "B2 8F 96 C3 B2 8F 96 C4 B3 8F 96 B9 B4 8F 96 F4 B5",
	"fPort": 25,
	"filter_report_2": [
	{

Raw UL	Decoded Log UL Information

	"BD_ADDR_3": "8f 96 c3",
	"RSSI_3": -78
	},
	{
	"BD_ADDR_3": "8f 96 c4",
	"RSSI_3": -77
	},
	{
	"BD_ADDR_3": "8f 96 b9",
	"RSSI_3": -76
	},
	{
	"BD_ADDR_3": "8f 96 f4",
	"RSSI_3": -75
	}
	]
	},
	"errors": [],
	"warnings": []
	}

Filter Range 3
 	
0x B3 8F 96 B7 B6 8F 96 B8 B7 8F 96 B9 B8 96 B4 AD B9 96 B4 AA BA
	{
	"data": {
	"raw": "B3 8F 96 B7 B6 8F 96 B8 B7 8F 96 B9 B8 96 B4 AD B9 96 B4 AA BA",
	"fPort": 25,
	"filter_report_3": [
	{
	"BD_ADDR_4": "8f 96 b7",
	"RSSI_4": -74
	},
	{
	"BD_ADDR_4": "8f 96 b8",
	"RSSI_4": -73
	},

Raw UL	Decoded Log UL Information
	{ "BD_ADDR_4": "8f 96 b9", "RSSI_4": -72 }, { "BD_ADDR_4": "96 b4 ad", "RSSI_4": -71 }, { "BD_ADDR_4": "96 b4 aa", "RSSI_4": -70 }] }, "errors": [], "warnings": [] s

2.4 Response to Configuration and Control Commands

SEAL/SEAL-Ex responses to DL configuration and control commands (DL sent on LoRaWAN port 100; see Section 3.3) are sent in the UL on ***LoRaWAN port 100*** and/or ***LoRaWAN port 101***. These responses include the following:

- Returning the value of (a) configuration register(s) in response to an inquiry from the NS.
- Writing to (a) configuration register(s).

In the first case, SEAL/SEAL-Ex responds with the address and value of each of the registers under inquiry on **LoRaWAN port 100.** The response can be in one or more consecutive UL packets depending on the maximum frame payload size allowed.

In the second case, SEAL/SEAL-Ex responds by immediately sending the last byte of the LoRaWAN DL frame counter value followed by a size byte indicating the number of registers that were **NOT** successfully written to, and then the addresses of the failed registers on **LoRaWAN port 101**. The intent is to both inform the user which set of commands the SEAL/SEAL-Ex is referring to, and which (if any) of the write commands were seen as invalid. As a result, if a redundant write command is issued (i.e., the value of that register is not changing), then SEAL/SEAL-Ex will not report its address, because it was not an invalid command. In the case where all the write commands are performed successfully, Seal will send back a frame with only the last byte of the DL frame counter value and a size indication byte of "00" on **LoRaWAN port 101,** implying that all registers were successfully written to**.**

If the DL payload also had read commands, the address and value of each of the registers under inquiry are reported separately on **LoRaWAN port 100**. In this case, the UL response to read commands on **LoRaWAN port 100** is handled before the UL response to write commands on LoRaWAN port 101. SEAL/SEAL-Ex will respond this way to all read and/or write commands, except for the special case where the anti-bricking strategy is performed.

The default method in which SEAL/SEAL-Ex responds to write commands differs from previous iterations of TEKTELIC Sensors. Previously, Tektelic Sensors would respond with a CRC32 of the entire DL payload as the first 4 bytes of the UL frame. Users now have the option to select the desired response format through the configuration register detailed in Section 3.3.14. This option has been included in an attempt to accommodate applications designed for previous iterations of TEKTELIC Sensors that can decode the CRC. However, it is strongly recommended that users update their data encoders and decoders to accommodate the new response format.

Table 2-6: Example of response to config commands

DL command	Decoded Log UL Information

Response to Read Command on port 100
 	
DL: 0x 20 21 22
	{
	"raw": "20 00 00 00 3C 21 05 A0 22 00 0F",
	"port": 100,
	"seconds_per_core_tick": 60,
	"ticks_battery": 1440,
	"ticks_normal_state": 15
	}

Response to successful Write command on port 101
 	
0x A0 00 00 00 3C
 	
DL above is expected to set the seconds per tick to 60s successfully
	{
	"0": "All write commands from DL:1 were successfull",
	"raw": "04 00",
	"port": 101
	}

Response to unsuccessful Write command on port 101
 	
Attempt to write invalid command to register 0x20
 	
0xA0 00 00
 	
Error: register 0x20 expects 4 bytes of data
	{
	"0": "1 Invalid write command(s) from DL:1 for register(s): 0x20",
	"raw": "01 01 20",
	"port": 101
	}

3 DL Payload Formats

The DL streams (from the NS to the SEAL/SEAL-Ex) supported by the SW are shown in Table 3-1, and are explained in details in this Section.

Table 3-1: DL Information Streams

Data Type	Sent on LoRaWAN Port
Request behavior change	**10**
Request GNSS logged Position fix and UTC timestamp	**15**
Configuration and Control Commands	**100**

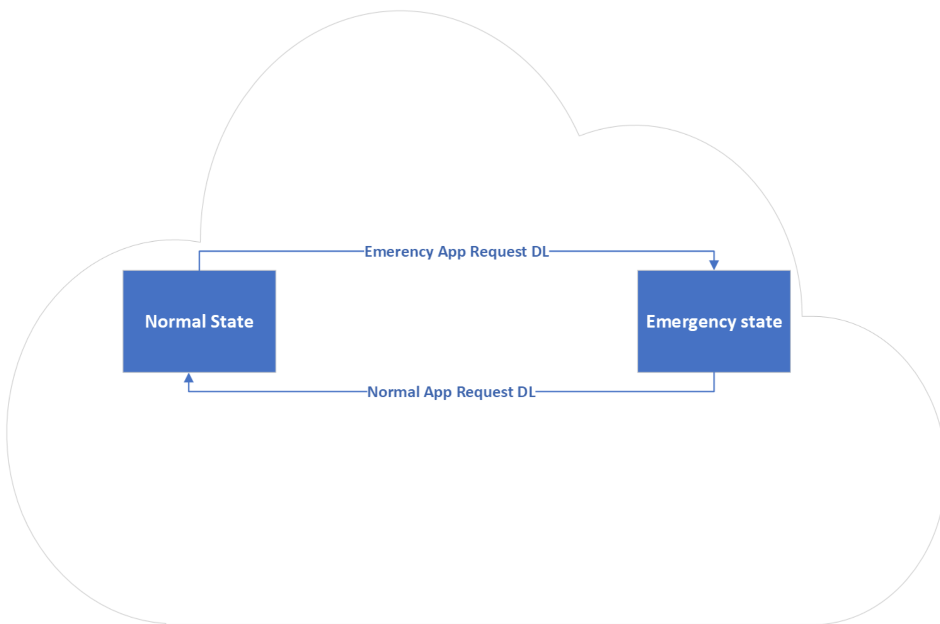
3.1 Application Requests for Behavioral Change

The cloud application can request the SEAL/SEAL-Ex to change from Normal state to Emergency state and vice versa by sending the EMERGENCY App Request (EAR) and Normal App Request (NAR) DL commands respectively on **LoRaWAN port 10**. If the SEAL/SEAL-Ex is already in Normal state, the NAR command does not trigger a state change since the device is already in Normal state. However, if the device is in any type of EMERGENCY state other than one triggered by an EAR command, an EAR DL command will activate the Emergency by EAR. In other words, the Emergency state triggered by EAR DL command is independent of all other Emergency triggers (EB, SH, and Fall) and can only cleared by a NAR DL command. Table 3-2 lists the set of such requests from the application.

Table 3-2: List of DL Behavior-Change Requests

Request on Port 10	Action
0x 00 01 00 (called NORMAL App Request or NAR)	**Go to, or stay in NORMAL**
0x 00 01 FF (called EMERGENCY App Request or EAR)	**Go to, or stay in EMERGENCY** **Reset EAR Active timer (see Section 3.3.6)**

Figure 3-1: EAR and NAR DL Commands



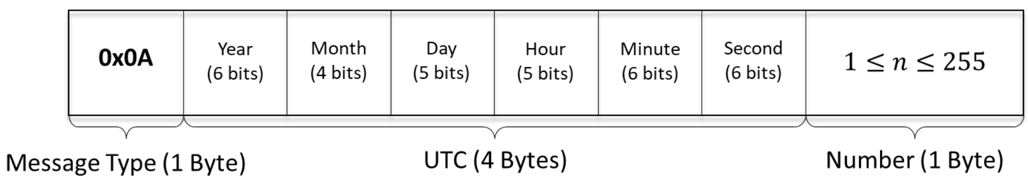
3.2 Request GNSS Log

The request from the cloud application to receive the GNSS log is sent on ***LoRaWAN port 15***. This request can be sent in two types, Type A and Type B. Figure 3-2 shows the payload format in each request type. The first byte in each payload is the request type (i.e., 0x0A or 0x0B).

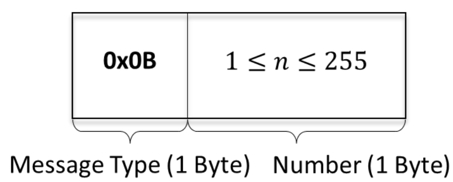
In the Type A request, a UTC timestamp t, and a number n, where $1 \leq n \leq 255$, as shown in Figure 3-2 is provided to the SEAL/SEAL-Ex. The UTC has the same format as in Table 2-2. By sending this request, the cloud application is asking for the last (most recent) n GNSS log entries (position fixes, altitude and time) by time t, **inclusive**. In other words, SEAL/SEAL-Ex counts 'n' steps backward from the provided timestamp and returns the log entries within the range.

In the Type B request, only a number n, where $1 \leq n \leq 255$ is provided to the SEAL/SEAL-Ex. By sending this request, the cloud application is asking for the last (most recent) n GNSS log entries (position fixes, altitude and time).

Upon receiving a GNSS log request, the SEAL/SEAL-Ex responds with the requested GNSS log on port 15, as explained in Section 2.2. If there is no log as per the request, the zero-byte 0x00 is uplinked by the SEAL/SEAL-Ex, as specified in Section 2.2.



(a) Type A request.



(b) Type B request.

Figure 3-2: The DL payload format to request GNSS log.

NOTE: If an invalid log is requested using any of the log request methods explained above, SEAL/SEAL-Ex responds with '00' on port 15 to indicate that the log is invalid.

Table 3-3: GNSS Log Request and Response Example

DL command	Decoded Log UL Information
Type A DL: 0x 0A 0D C3 5A C2 02 Expect last two entries from the following time stamp, inclusive of the timestamp.	Response via type (a) and (b) as explained in Section 2.2 Log entry 1 { "raw": "01 00 0D C3 5A C2", "port": 15, "fragment_number_1": 0,

DL command	Decoded Log UL Information
{ "raw": "00 85 0D C3 5A C2", "port": 10, "year_utc": 3, "month_utc": 7, "day_utc": 1, "hour_utc": 21, "minute_utc": 43, "second_utc": 2} Date: 01/07/2023 Time: 21:43:02	"year_1": 3, "month_1": 7, "day_1": 1, "hour_1": 21, "minute_1": 43, "second_1": 2} { "raw": "02 00 48 C4 C7 AE DE 72 2C 01", "port": 15, "fragment_number_2": 0, "latitude_2": "51.1654651", "longitude_2": "-114.0905714", "altitude_2": "1133"} Date: 01/07/2023 Time: 21:43:02 Log entry 2 { "raw": "01 01 0D C3 5A 85", "port": 15, "fragment_number_1": 1, "year_1": 3, "month_1": 7, "day_1": 1, "hour_1": 21, "minute_1": 42, "second_1": 5} { "raw": "02 01 48 C4 C7 AE DE 6B 2B E5", "port": 15, "fragment_number_2": 1, "latitude_2": "51.1654651", "longitude_2": "-114.0907216", "altitude_2": "1129"}

DL command	Decoded Log UL Information
	Date: 01/07/2023 Time: 21:42:05
<u>Type B</u> 0x 0B 02 We expect last two entries in the log	Response via type (a) and (b) as explained in Section 2.2 <u>Log entry 1</u> { "raw": "01 00 0D C3 5C 03", "port": 15, "fragment_number_1": 0, "year_1": 3, "month_1": 7, "day_1": 1, "hour_1": 21, "minute_1": 48, "second_1": 3} { "raw": "02 00 48 C4 C2 AE DE 79 2C 10", "port": 15, "fragment_number_2": 0, "latitude_2": "51.1654115", "longitude_2": "-114.0904212", "altitude_2": "1135"} Date: 01/07/2023 Time: 21:48:03 <u>Log entry 2</u> { "raw": "01 01 0D C3 5B C3", "port": 15, "fragment_number_1": 1, "year_1": 3, "month_1": 7, "day_1": 1, "hour_1": 21, "minute_1": 47,

DL command	Decoded Log UL Information
	"second_1": 3} { "raw": "02 01 48 C4 C7 AE DE 6C 2B D3", "port": 15, "fragment_number_2": 1, "latitude_2": "51.1654651", "longitude_2": "-114.0907001", "altitude_2": "1126"} Date: 01/07/2023 Time: 21:47:03

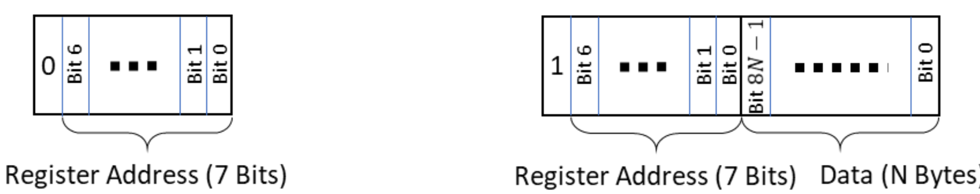
Invalid GNSS log requests
Req (a) DL: 0x 0A 0D C3 5A C2 02
Req (b) DL: 0x 0B 00
 	
SEAL/SEAL-Ex responds with ‘00’ to signify invalid entry
	{
	"raw": "00",
	"port": 15,
	"log_entry": "invalid"
	}

3.3 Configuration and Control Commands

A single DL configuration and control message can contain multiple command blocks, with a possible mix of read and write commands. Each message block is formatted as shown in Figure 3-3. A big-endian format (MSB first) is always followed.

The Register Address is used to access various configuration parameters. These addresses are bound between 0x00 and 0x7F.

Bit 7 of the first byte determines whether a read or write action is being performed, as shown in Figure 3-3. All read commands are one-byte long. Data following a read access command will be interpreted as a new command block. Read commands are processed last. For example, in a single DL message, if there is a read command from a register and a write command to the same register, the write command is executed first.



(a) The read command. (b) The write command.

Figure 3-3: Format of a DL configuration and control message block.

All DL configuration and control commands are sent on ***LoRaWAN port 100***.

Examples:

- Read Registers 0x10, 0x11, and 0x12:
    - DL command: {0x 10 11 12}
- Read Register 0x13 and Write value 0x8000 to Register 0x10:
    - DL command: {0x 13 90 80 00}

When a read or write or write-and-read command is sent to the SEAL/SEAL-Ex, the SEAL/SEAL-Ex immediately responds on port 100 with the format described in Section 2.4.

DL configuration and control commands fall into one of the following categories and are discussed in Sections 3.3.1–3.3.13:

- LoRaMAC Configuration
- Periodic Tx Configuration
- Emergency Button (EB) Configuration
- Safety Hook (SH) Configuration (applicable to HW models equipped with the safety clip)
- GNSS Configuration
- EMERGENCY State Configuration
- Barometer Configuration
- Accelerometer Configuration
- Fall Configuration
- BLE Configuration
- Temperature Threshold Configuration
- Battery Configuration
- Buzzer Muting Configuration
- Command and Control

3.3.1 LoRaMAC Configuration

LoRaMAC options can be configured using the LoRaWAN DL. These configuration options change the default MAC configuration that the SEAL loads on start-up. They can also change certain run-time parameters. Table 3-4 shows the MAC configuration registers. In this table, the bit indexing scheme is as shown in Figure 3-3. All the registers have R/W access.

Table 3-4: LoRaMAC Configuration Registers

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x10	LoRaMAC Join Mode	2 B	• Bit 15: 0/1 = ABP/OTAA mode • Bits 0-14: Ignored	*loramac_join_mode: <value> (string/no unit)*
0x11	LoRaMAC Options	2 B	• Bits 4-15: Ignored • Bit 3: 0/1 = ADR disabled/enabled	• *loramac_adr: <value> (string/no unit)* • *loramac_duty_cycle: <value> (string/no unit)*

			• Bit 2: 0/1 = Duty Cycle disabled/enabled • Bit 1 = 1 (RO): 0/1 = Private/Public Sync Word • Bit 0: 0/1 = Unconfirmed/Confirmed UL	• *loramac_ul_type: <value> (string/no unit)*
0x12	LoRaMAC DR and Tx Power[12]	2 B	• Bits 12-15: Ignored • Bits 8-11: Default DR • Bits 4-7: Ignored • Bits 0-3: Default Tx power	• *loramac_default_dr: <value> (number/no unit)* • *loramac_default_tx_pwr: <value> (number/no unit)*
0x13	LoRaMAC Rx2 Window	5 B	• Bits 8-39: Channel frequency in Hz for Rx2 • Bits 0-7: DR for Rx2	• *loramac_rx2_freq: <value> (number/MHz)* • *loramac_rx2_dr: <value> (number/no unit)*

Note: Modifying these values only changes them in the SEAL/SEAL-Ex. Options for the SEAL/SEAL-Ex in the NS may also need to be changed to not strand a SEAL/SEAL Ex. Modifying configuration parameters in the NS is outside the scope of this document.

3.3.1.1 LoRa Configuration DL Examples

- Switch Device to ABP Mode:
  - DL payload: {0x 90 00 00}
- Set ADR On, No Duty Cycle, and Confirmed UL Payloads:
  - DL payload: {0x 91 00 0B}
- Set default DR number to 3, default Tx power number to 4:
  - DL payload: {0x 92 03 04}

3.3.1.2 Default Configuration

Table 3-5 shows the default values for the LoRaMAC configuration registers (cf. (LoRa Alliance, Feb 2017), (LoRa Alliance, July 2016)).

Table 3-5: Default Values of LoRaMAC Configuration Registers

Address	Default Value
0x10	• OTAA mode
0x11	• ADR enabled • Duty cycle enabled[13] • LoRaMAC Uplink Type: Public

[12] Tx power m translates to the maximum Tx power, which is a function of the LoRaWAN region, minus $2 \times m$ dB.

[13] In the LoRaWAN regions where there is no duty cycle limitation, such as US915, the “enabled duty cycle” configuration of the SEAL/SEAL-EX is ignored.

	• Unconfirmed UL
0x12	• DR0 • Tx Power 0 (max power; see Table 3-6)
0x13	• As per Table 3-6

Table 3-6: Default Maximum Tx Power in Different LoRaWAN Regions

LoRaWAN Region	Max Tx EIRP [dBm]
EU868	16
US915	30
AS923	16
AU915	30
IN865	30
KR920	14
RU864	16

Table 3-7: Default Values of Rx2 Channel Frequency and DR in Different LoRaWAN Regions

LoRaWAN Region	Channel Frequency [Hz]	DR
EU868	869525000	0
US915	923300000	8
AS923	923200000	2
AU915	923300000	8
IN865	866550000	2
KR920	921900000	0
RU864	869100000	0

3.3.1.3 LoRa Config Examples

- Enable ADR, disable the duty cycle, and set UL payloads to be confirmed:
  - DL payload: {0x 91 00 0B}
- Set default DR to 3, default Tx power to 4:
  - DL payload: {0x 92 03 04}

3.3.2 Periodic Tx Configuration

All periodic reporting is synchronized around ticks. A tick is simply a user configurable time base that is used to schedule SEAL/SEAL-Ex measurements. Table 3-8 shows a list of registers used to configure the SEAL/SEAL-EX periodic transmissions. All the registers have R/W access.

The reporting period in each case (e.g., Battery, Accelerometer, Temperature) is obtained as "Ticks" in that case multiplied by "Seconds per Core Tick". A reporting period being 0 means that the corresponding periodic report is disabled.

<Transducer> ***Reporting Period*** = ***Seconds per Core Tick*** × ***Ticks per*** **<Transducer>***,*

Table 3-8: Periodic Transmission Configuration Registers

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x20	Seconds per Core Tick	4 B	• Tick value for periodic events • Acceptable values: 3, 4, …, 86400 • Other values: Invalid and ignored	*seconds_per_core_tick: <value>* *(number/sec)*
0x21	Ticks per Battery	2 B	• Ticks between battery reports • Acceptable values: TBD	*ticks_battery: <value>* *(number/no unit)*
0x22	Ticks in NORMAL State	2 B	• Ticks between GNSS, barometer (if enabled), and BLE (if enabled) reports in NORMAL state. • Acceptable values: 0, 1, …, 65535 0: Disables periodic reports in NORMAL state	*ticks_normal_state: <value>* *(number/no unit)*
0x23	Ticks in EMERGENCY State	2 B	• Ticks between GNSS reports, barometer (if enabled), and BLE (if enabled) in EMERGENCY state. • Acceptable values: 0, 1, …, 65535 0: Disables periodic reports in EMERGENCY state	*ticks_emergency_state: <value>* *(number/no unit)*
0x24	Ticks per Accelerometer	2 B	• Ticks between accelerometer reports • Acceptable values: 0, 1, …, 65535 0: Disables periodic accelerometer reports	*ticks_accelerometer: <value>* *(number/no unit)*
0x25	Ticks per Temperature	2 B	• Ticks between temperature reports • Acceptable values: 0, 1, …, 65535 0: Disables periodic temperature reports	*ticks_temperature: <value>* *(number/no unit)*
0x26	Ticks for Safety Status in NORMAL State	2 B	• Ticks between Safety Status reports in NORMAL state • Acceptable values: 0, 1, …, 65535 0: Disables periodic Safety Status reports in NORMAL state	*ticks_safety_status_normal: <value>* *(number/no unit)*
0x27	Ticks for Safety Status in EMERGENCY State	2 B	• Ticks between Safety Status reports in EMERGENCY state • Acceptable values: 0, 1, …, 65535 0: Disables periodic Safety Status reports in EMERGENCY state	*ticks_safety_status_emergency: <value>* *(number/no unit)*

3.3.2.1 Default Configuration

Table 3-9Table 3-9 shows the default values for the periodic transmission configuration registers.

Table 3-9: Default Values of Periodic Transmission Configuration Registers

Seconds per Core Tick	60 (1 min)
Ticks per Battery	1440 (1-day period)
Ticks in NORMAL State	15 (15-min period)
Ticks in EMERGENCY State	1 (1-min period)
Ticks per Accelerometer	0
Ticks per Temperature	0
Ticks for Safety Status in NORMAL State	5 (5-min period)
Ticks for Safety Status in EMERGENCY State	1 (1-min period)

Examples:

- Read current value of Seconds per Core Tick:
  - DL payload: {0x 20}
    - Register 20 with the write bit set to false
- Report Temperature every core tick:
  - DL payload: {0x A5 00 01}
    - Register 25 with its write bits set to true
    - Ticks per Temperature set to 1 (one)

3.3.3 Emergency Button (EB) Configuration

All EB operations are summarized in Section 1.4. Configurable EB operations are discussed in this section.

An EB Active event is registered when the EB is pressed for at least 5 secs. When an EB Active event is registered, a buzz goes off as a local confirmation/alert to the user. The buzz happens once per registered EB Active event, and is configurable with the following parameters:

EB Active Buzz ON time: The buzz on time.

EB Active Buzz OFF time: The buzz off time.

EB Active Buzz Number of ON-OFFs: Number of times the on-off pattern is repeated.

The EB Active buzz pattern (which is non-periodic as it occurs once) has been shown in Figure 3-4.

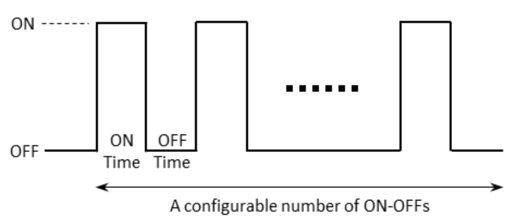


Figure 3-4: The non-periodic indication pattern.

When an EB Active event is registered from an EB Inactive status, a Safety Status report is generated and sent on port 10, a transition occurs to the EMERGENCY state, with an accelerated UL rate compared to the Normal state. If the SEAL/SEAL-EX is already in EMERGENCY, a registered EB Active event does not trigger any state change.

An EB Inactive event is registered manually when the EB is pressed and held for at least 5 secs in the EMERGENCY state. When an EB Inactive event occurs, the buzzer sounds as a local indication to the user (if the buzzer is enabled). Also, a transition to the NORMAL state occurs if no other emergency conditions, i.e., Fall, SH, EAR, and DZs are active. Also, a Safety Status is sent on port 10 when the EB status changes (i.e., Active to Inactive). The buzz happens once per registered EB Inactive event, with the pattern as shown in Figure 3-4, and is configurable with the following parameters:

EB Inactive Buzz ON time: The buzz on time.

EB Inactive Buzz OFF time: The buzz off time.

EB Inactive Buzz Number of ON-OFFs: Number of times the on-off pattern (sub-buzz) is repeated.

All the mechanism explained above has been summarized in Figure 3-5.

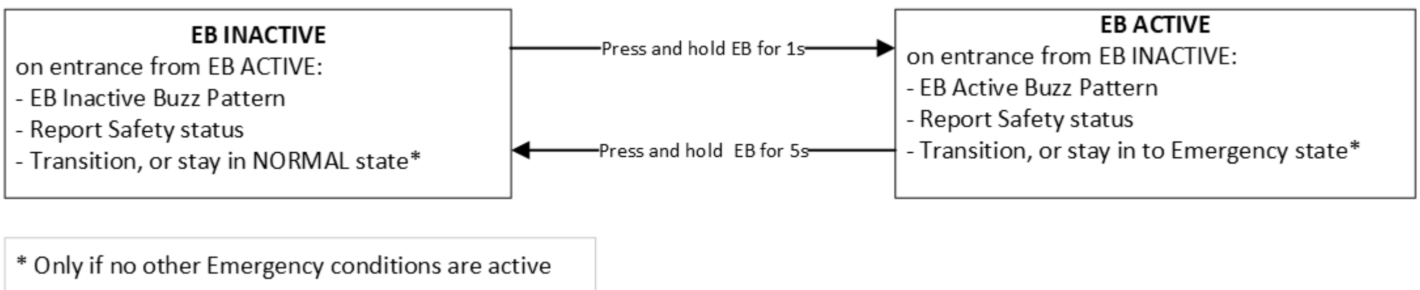


Figure 3-5: The EB state machine.

Table 3-10 shows the configuration registers for the EB. In this table, the bit indexing scheme is as shown in Figure 3-3. These registers have R/W access.

Table 3-10: EB Configuration Registers

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x28	EB Active Buzz Config	3 B	• Bits 16-23: EB Active Buzz ON time (0.1 sec/LSB) 0: Invalid and ignored • Bits 8-15: EB Active Buzz OFF time (0.1 sec/LSB) • Bits 0-7: EB Active Buzz Number of ON-OFFs 0: Invalid and ignored	• *eb_buzz_active_on_time: <value> (number/sec)* • *eb_buzz_active_off_time: <value> (number/sec)* • *eb_buzz_active_num_on_offs: <value> (number/no unit)*
0x29	EB Inactive Buzz Config	3 B	• Bits 16-23: EB Inactive Buzz ON time (0.1 sec/LSB) 0: Invalid and ignored • Bits 8-15: EB Inactive Buzz OFF time (0.1 sec/LSB) • Bits 0-7: EB Inactive Buzz Number of ON-OFFs 0: Invalid and ignored	• *eb_buzz_inactive_on_time: <value> (number/sec)* • *eb_buzz_inactive_off_time: <value> (number/sec)* • *eb_buzz_inactive_num_on_offs: <value>* *(number/no unit)*

3.3.3.1 Default Configuration

Table 3-11 shows the default values for the EB configuration registers.

Table 3-11: Default Values of EB Configuration Registers

EB Active Buzz Config	EB Active Buzz ON time 0.5 sec EB Active Buzz OFF time 1.0 sec EB Active Buzz Number of ON-OFFs = 3
EB Inactive Buzz Config	EB Inactive Buzz ON time 0.2 sec EB Inactive Buzz OFF time 0.2 sec EB Inactive Buzz Number of ON-OFFs = 3

3.3.4 Safety Hook (SH) Configuration[14]

SH OFF/ON status monitoring is a safety feature of the SEAL/SEAL-Ex to ensure that the user connects the SH (a carabiner) to the support structure whenever needed. SH OFF is when the SH is off the SEAL/SEAL-EX (and by implication, connected to the support structure). SH is ON when the SH is on the SEAL/SEAL-EX (and by implication, not connected to any support structure.

SH status is monitored through the SH button on the SEAL/SEAL-Ex. When the SH is placed on the safety clip harness SEAL/SEAL-Ex, the SH button is pressed, and when the SH is removed from the SEAL/SEAL-Ex, the SH button is released. In order to debounce the SH button, SH Debounce Interval is considered as follows. The SH status becomes ON as soon as a falling edge is detected on the SH button.[15] However, the SH status becomes OFF when a rising edge is detected on the SH button with no falling edge detected for a Debounce Interval after the rising edge.

The initial (default) SH status after power-up or waking up from SLEEP is OFF.

The SH status is part of the Safety Status, and therefore, can be reported periodically or on status change (see Section 1.11).

When the SH status is ON (SH is on the SEAL/SEAL-Ex) for a time longer than the debounce interval, there are three configurable options to register the SH button press as an emergency event.

a. Trigger the SH emergency state always
b. Trigger the SH emergency state ONLY IF any GNSS DZ is entered; or
c. Trigger the alarm ONLY IF any BLE DZ is entered; or
d. Trigger the SH emergency state if any of either the BLE or GNSS DZ is entered.

Naturally, non-definition of GNSS or BLE DZs is equivalent to no such DZs are entered. For example, if the buzzer is set to buzz only when a GNSS DZ is entered but no such DZ has been defined, the buzzer will not buzz for the SH.

The periodic buzz is configurable as follows, and can also be disabled:

SH Buzz ON time: The buzz on time.

---

[14] Applicable to HW models equipped with the safety clip. In HW models with no safety clip, the SH status is assumed to be always OFF (= 0). Also, see Table 2-2.

[15] The SH button is a "normally closed" switch.

SH Buzz OFF time: The buzz off time.

SH Buzz Number of ON-OFFs: Number of times the on-off pattern (sub-buzz) is repeated.

SH Buzz Period: Period of the buzz.

The periodic SH buzz pattern has been shown in Figure 3-6.

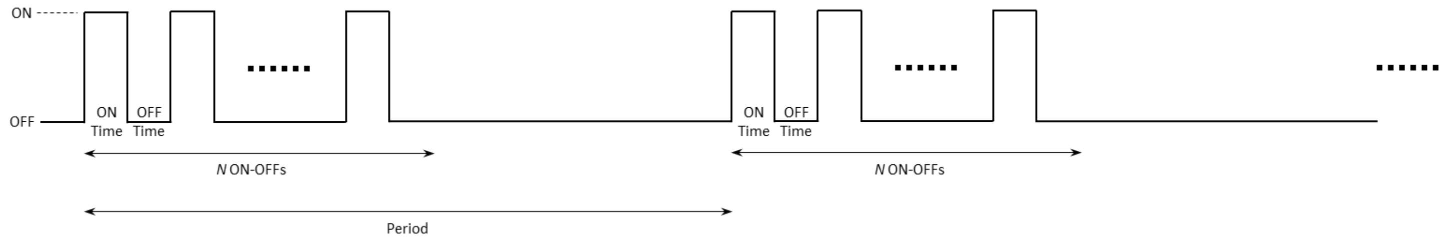


Figure 3-6: The periodic indication pattern.

Table 3-12 shows the configuration registers for the SH. In this table, the bit indexing scheme is as shown in Figure 3-3. These registers have R/W access.

Table 3-12: SH Configuration Registers

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x2C	SH Debounce Interval	1 B	• The Debounce Interval in secs • Acceptable values: 0…255 • Other values: invalid and ignored	*sh_debounce_interval: <value> (number/sec)*
0x2D	SH Buzz Config	5 B	• Bits 34-39: Ignored • Bits 32-33: 0: Buzz whenever SH ON 1: Buzz whenever SH ON and any GNSS DZ entered 2: Buzz whenever SH ON and any BLE DZ entered 3: Buzz whenever SH ON and any designated GNSS or BLE DZ entered • Bits 24-31: SH Buzz ON time (0.1 sec/LSB) 0: Disables buzz accepted values: other values: ignored • Bits 16-23: SH Buzz OFF time (0.1 sec/LSB) accepted values: other values: ignored • Bits 8-15: SH Buzz Number of ON-OFFs	• *sh_buzz_when_to: <value> (string/no unit)* • *sh_buzz_on_time: <value> (number/sec)* • *sh_buzz_off_time: <value> (number/sec)* • *sh_buzz_num_on_offs: <value> (number/no unit)* • *sh_buzz_period: <value> (number/sec)*

Address	Name	Size	Description	JSON Variable (Type/Unit)
			0: Disables buzz accepted values: other values: ignored • Bits 0-7: SH Buzz Period (0.1 sec/LSB) 0: Invalid and ignored accepted values: other values: ignored **For a valid config command:** $(ON\ time + OFF\ time) * \ Counts \leq Period$ **Otherwise:** Config command is invalid and ignored	

3.3.4.1 Default Configuration

Table 3-13 shows the default values for the SH configuration registers.

Table 3-13: Default Values of SH Configuration Registers

SH Debounce Interval	10 sec
SH Buzz Config	Buzz whenever SH ON and any GNSS or BLE DZ entered SH Buzz ON time 0.4 sec SH Buzz OFF time 0.1 sec SH Buzz Number of ON-OFFs = 2 SH Buzz Period = 10 sec

3.3.5 GNSS Configuration

Table 3-14 shows a list of configuration registers for the SEAL/SEAL-Ex's GNSS receiver. In this table, the bit indexing scheme is as shown in Figure 3-3. All the registers have R/W access.

Table 3-14: GNSS Receiver Configuration Registers

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x30	GNSS Mode	1 B	• Bit 7: 0/1 = GNSS receiver disabled/enabled • Bits 0-6: Ignored	*gnss_receiver: <value>* *(string/no unit)*
0x31	GNSS Report Options	1 B	• Bits 3-7: Ignored • Bit 2: 0/1 = GNSS DZ Status report disabled/enabled • Bit 1:	• *gnss_dz_status_report: <value>* *(string/no unit)* • *gnss_ground_speed_report: <value>* *(string/no unit)*

Address	Name	Size	Description	JSON Variable (Type/Unit)
			0/1 = Ground Speed report disabled/enabled • Bit 0: 0/1 = UTC and Position Coordinates report disabled/enabled ❖ Bits 0-2 = 0: Invalid and ignored	• *gnss_utc_coordinates_report: <value>* *(string/no unit)*
0x32	GNSS DZ 0 Definition	8 B	• Bits 40-63: Center Latitude ($\frac{90^{\circ}}{2^{23}}$/LSB) • Bits 16-39: Center Longitude ($\frac{180^{\circ}}{2^{23}}$/LSB) • Bits 0-15: Radius (10 m/LSB)	• *gnss_dz0_latitude: <value> (number/°)* • *gnss_dz0_longitude: <value> (number/°)* • *gnss_dz0_radius: <value> (number/m)*
0x33	GNSS DZ 1 Definition	8 B	• Bits 40-63: Center Latitude ($\frac{90^{\circ}}{2^{23}}$/LSB) • Bits 16-39: Center Longitude ($\frac{180^{\circ}}{2^{23}}$/LSB) • Bits 0-15: Radius (10 m/LSB)	• *gnss_dz1_latitude: <value> (number/°)* • *gnss_dz1_longitude: <value> (number/°)* • *gnss_dz1_radius: <value> (number/m)*
0x34	GNSS DZ 2 Definition	8 B	• Bits 40-63: Center Latitude ($\frac{90^{\circ}}{2^{23}}$/LSB) • Bits 16-39: Center Longitude ($\frac{180^{\circ}}{2^{23}}$/LSB) • Bits 0-15: Radius (10 m/LSB)	• *gnss_dz2_latitude: <value> (number/°)* • *gnss_dz2_longitude: <value> (number/°)* • *gnss_dz2_radius: <value> (number/m)*
0x35	GNSS DZ 3 Definition	8 B	• Bits 40-63: Center Latitude ($\frac{90^{\circ}}{2^{23}}$/LSB) • Bits 16-39: Center Longitude ($\frac{180^{\circ}}{2^{23}}$/LSB) • Bits 0-15: Radius (10 m/LSB)	• *gnss_dz3_latitude: <value> (number/°)* • *gnss_dz3_longitude: <value> (number/°)* • *gnss_dz3_radius: <value> (number/m)*
0x36	GNSS Diagnostics Report Options	1 B	• Bit 0: 0/1 = Number of Visible Satellites report disabled/enabled • Bit 1: 0/1 = Average Satellite SNR report disabled/enabled • Bit 2: 0/1 = Fix Type report disabled/enabled • Bit 3: 0/1 = Time-To-Fix report disabled/enabled	• *gnss_diagnostics_tx {* *num_satellites: <value>,* *(unsigned/no unit)* *avg_satellite_snr: <value>,* *(unsigned/no unit)* *fix_type: <value>,* *(unsigned/no unit)* *time_to_fix: <value>* *(unsigned/no unit)* *log_num: <value>*

Address	Name	Size	Description	JSON Variable (Type/Unit)
			• Bit 4: 0/1 = Most Recent Log Entry # report disabled/enabled • Bit 5: 0/1 = GNSS fix accuracy, groundspeed accuracy, and number of fixes report disabled/enabled • Bits 6 and 7: Ignored	*(unsigned/no unit)* *acc_and_num_fixes_report: <value>* *(unsigned/no unit)*

3.3.5.1 Mode

The GNSS receiver can be powered off/on to tune power usage (battery life) for end-user applications.

NOTE: If the GNSS receiver is disabled, no periodic or event-based report related to GNSS is produced.

3.3.5.2 Report Options

When the GNSS receiver is periodically polled, the data to transmit can be configured by the end user. Available types are:

- UTC and Position Coordinates: UTC time fix in year, month, day, hour, minute, and second, plus latitude, longitude, and altitude of the obtained fix.
- Ground Speed: Ground speed of the SEAL/SEAL-EX in multiples of 1 m/s.
- DZ Status: Obtained fix status as being “unknown”, “inside”, or “outside” relative to each GNSS DZ—DZ Status for undefined GNSS DZs returns 0 (equivalent to “unknown”).

3.3.5.3 GNSS Designated/Danger Zone (DZ) Definition Registers

These registers are used to define up to 4 GNSS DZs. Each DZ is a circle defined by the latitude and longitude of its center, and its radius.

By default, the values of these registers are 0 (all DZs are inactive). Whenever the user defines one or more DZs by updating the value of one or more of these registers, the SEAL/SEAL-Ex SW sets ALL the active DZs (out of the available four) in the GNSS receiver. Whenever the GNSS receiver is polled to return the DZ status, it will return the status of the active DZs, which the SEAL/SEAL-Ex subsequently reports OTA (using the header 0x 00 95 followed by 1 byte data, as indicated in Table 2-2).

3.3.5.4 GNSS Diagnostics Report Options

When the GNSS receiver subsystem is periodically polled, the user can choose which, if any, diagnostic information is transmitted. The periods for reporting depend on the current motion state of the device and are controlled by registers 0x 22 and 0x 23. Available diagnostics value options to report are:

- Number of Visible Satellites: number of satellites detected by the GNSS antenna during the last GNSS SEARCH. If a fix is obtained following the search, this value only represents the number of satellites used to calculate the fix data that is reported (ref. §3.2.4.4). If a fix cannot be obtained, this value represents all visible satellites.

- Average Satellite SNR: the average signal-to-noise ratio of all satellites used to calculate the fix in the last GNSS SEARCH. If no satellites were visible, a value of 0x 00 00 is transmitted.
- Fix Type: whether the reported fix was a 2D or 3D fix. If no fix was available, a value of 0x 00 is transmitted.
- Time-To-Fix (TTF): the time, in seconds, that it took to obtain the fix; i.e.: the length of time between the beginning of the GNSS SEARCH and the moment a fix could be obtained. Each time a valid fix is obtained, the TTF value is reset to 0 after reporting the fix data in a LoRa UL. If no fix is obtained before the search is cut off (210 s), then the TTF value is not reset to 0. That is, at the time the next GNSS SEARCH begins after a search that resulted in no fix, the TTF during the new search is added to the existing value.
- Most recent log entry number: The device stores every fix obtained during a GNSS SEARCH state in the GNSS log under an incrementing log number. If this option is enabled, the most recent log entry number is transmitted, even if no new fixes were acquired during the last GNSS SEARCH.
- GNSS fix accuracy, groundspeed accuracy, and number of fixes report: Sometimes the GNSS reports inaccurate fixes and ground speed due to poor GNSS signal environment. The accuracy values are used to determine these inaccurate fixes. Fixes marked as inaccurate are rescanned to get a more accurate fix with acceptable accuracy values. This cycle is repeated until an acceptable fix is achieved, or the GNSS scan timeout is exceeded, whichever comes first. Possible accuracy options that can be reported are
    - GNSS fix Horizontal accuracy (m)
    - GNSS fix vertical accuracy (m)
    - Ground speed accuracy (m/s)

3.3.5.5 Default Configuration

Table 3-15 shows the default values for the GNSS configuration registers.

Table 3-15: Default Values of GNSS Configuration Registers

GNSS Mode	GNSS receiver enabled
GNSS Report Options	Only UTC and Position Coordinates reports enabled
GNSS DZ 0/1/2/3 Definition	0x 00 00 00 00 00 00 00 00
GNSS Diagnostics Report Options	No Diagnostics Reported

3.3.6 EMERGENCY State Configuration

A transition occurs from the NORMAL state to the EMERGENCY state (if not already in EMERGENCY) if *any* of the following holds:

1. Emergency by EB Active
2. Emergency by Fall Active
3. Emergency by SH active (see section 3.3.4 for Emergency by SH configurations)
4. Enter any GNSS DZ: *Can be disabled or enabled*
5. Enter any BLE DZ: *Can be disabled or enabled*
6. EMERGENCY App Request (EAR) Active: DL “0x 00 01 FF” received on port 10.

A transition occurs from the EMERGENCY to NORMAL state if *all* of the following hold:

1. EB Inactive
2. Fall Cleared

3. SH cleared (see section 3.3.4 for Emergency by SH configurations)
4. Exit all GNSS DZs: *Can be disabled or enabled*
5. Exit all BLE DZ: *Can be disabled or enabled*
6. EAR Inactive: A NORMAL App Request (NAR)—DL "0x 00 01 00" on port 10—is received or EAR Active Timer times out

The EMERGENCY state has a configurable, periodic LED indication, where both *top and front LEDs* blink synchronously with the following configuration:

1. EMERGENCY LED ON time: The LED on time.
2. EMERGENCY LED OFF time: The LED off time.
3. EMERGENCY LED Number of ON-OFFs: Number of times the on-off pattern (sub-flash) is repeated.
4. EMERGENCY LED Period: Period of flashes.

The periodic EMERGENCY LED pattern are as shown in Figure 3-6.

Table 3-16 shows a list of configuration registers for the EMERGENCY state. In this table, the bit indexing scheme is as shown in Figure 3-3. All the registers have R/W access.

Table 3-16: EMERGENCY State Configuration Registers

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x38	EMERGENCY State Trigger	1 B	• Bit 2-7: Ignored • Bit 1: 0/1 = BLE DZs disabled/enabled • Bit 0: 0/1 = GNSS DZs disabled/enabled	• *emergency_trigger_by_ble_dz: <value> (string/no unit)* • *emergency_trigger_by_gnss_dz: <value> (string/no unit)*
0x39	EMERGENCY State LED Config	4 B	• Bits 24-31: EMERGENCY LED ON time (0.01 sec/LSB) 0: Invalid and ignored • Bits 16-23: EMERGENCY LED OFF time (0.01 sec/LSB) • Bits 8-15: EMERGENCY LED Number of ON-OFFs 0: Invalid and ignored • Bits 0-7: EMERGENCY LED Period (1 sec/LSB) 0: Invalid and ignored **For a valid config command:** $(ON\ time + OFF\ time) * \ Counts \leq Period$ **Otherwise:** Config command is invalid and ignored	• *emergency_led_on_time: <value> (number/sec)* • *emergency_led_off_time: <value> (number/sec)* • *emergency_led_num_on_offs: <value> (number/no unit)* • *emergency_led_period: <value> (number/sec)*

3.3.6.1 Default Configuration

Table 3-17 shows the default values for the GNSS configuration registers.

Table 3-17: Default Values of EMERGENCY State Registers

EMERGENCY State Trigger	Both BLE and GNSS DZs enabled
EMERGENCY State LED Config	EMERGENCY LED ON time 0.5 sec EMERGENCY LED OFF time 1.0 sec EMERGENCY LED Number of ON-OFFs = 3 EMERGENCY LED Period = 6 sec

3.3.7 Barometer Configuration

The SEAL/SEAL-Ex includes a barometer capable of measuring the barometric air pressure. This barometric pressure can then be used to develop an elevation estimation as described in section 1 above.

The barometer is set to take pressure samples in its low precision mode by default. The barometer periodic report in the NORMAL and EMERGENCY states can be disabled or enabled. Table 3-18 shows the barometer configuration register. This register has R/W access.

Table 3-18: Barometer Configuration Registers

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x3C	Barometer Mode	1 B	• Bit 7: 0/1 = Barometer report disabled/enabled • Bits 4-6: Ignored • Bits 0-3: Barometer IIR filter recall factor 0: Equivalent to no IIR filtering	• *barometer_report_enabled: <value>* *(string/no unit)* • *barometer_iir_recall_factor: <value>* *(number/no unit)*

3.3.7.1 IIR Filter Recall Factor

An IIR filter is implemented in the SEAL/SEAL-Ex as it is particularly useful for suppressing noise introduced by environmental disturbances, such as air turbulence from a fan or a slamming door or window. A higher recall factor will result in a stricter filter that is better for noise suppression between measurements. A value of 0 (zero) disables the IIR filter, while values from 1 to 15 determine the recall factor.

3.3.7.2 Barometric Report Enabled

When considered relative to the atmospheric pressure of a reference SEAL/SEAL-Ex, atmospheric pressure reporting can help estimating the height (elevation) of the SEAL/SEAL-Ex more accurately. Barometric report is periodic, and occurs along with the BLE and GNSS reports, with the periods configured in Registers 0x22 and 0x23 in the NORMAL and EMERGENCY states, respectively. The barometric report can be disabled/enabled independently of the BLE and GNSS report.

3.3.7.3 Default Configuration

Table 3-19 shows the default value for the barometer configuration register.

Table 3-19: Default Value of Barometer Configuration Register

Barometer Mode	Barometric report disabled IIR Filter Recall Factor = 2

3.3.8 Accelerometer Configuration

The main uses of the accelerometer in the SEAL/SEAL-Ex are as follows:

1. To detect motion so the SEAL/SEAL-Ex can go to SLEEP in the case of no motion detected for a period of time, and wake up from SLEEP in the event of a detected motion.
   In this usage, high-pass filtered X, Y, and Z components are monitored for interrupts. If any filtered axis magnitude exceeds the SLEEP Acceleration Threshold, the motion interrupts are disabled for 10% of the Timeout to Sleep, but then re-enabled with the SLEEP timer being reset. Whenever the SLEEP timer hits the Timeout to SLEEP, the SEAL/SEAL-EX goes to SLEEP. While the SEAL/SEAL-EX is in SLEEP, if the SLEEP Acceleration Threshold is exceeded by any of the high-pass filtered axis' magnitude, the SEAL/SEAL-Ex wakes up from SLEEP and resets the SLEEP timer. Figure 3-7 illustrates how the above feature works.

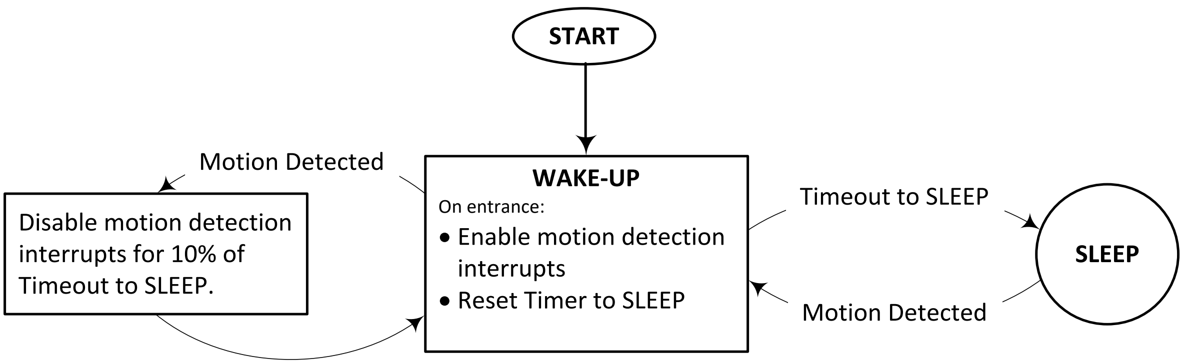
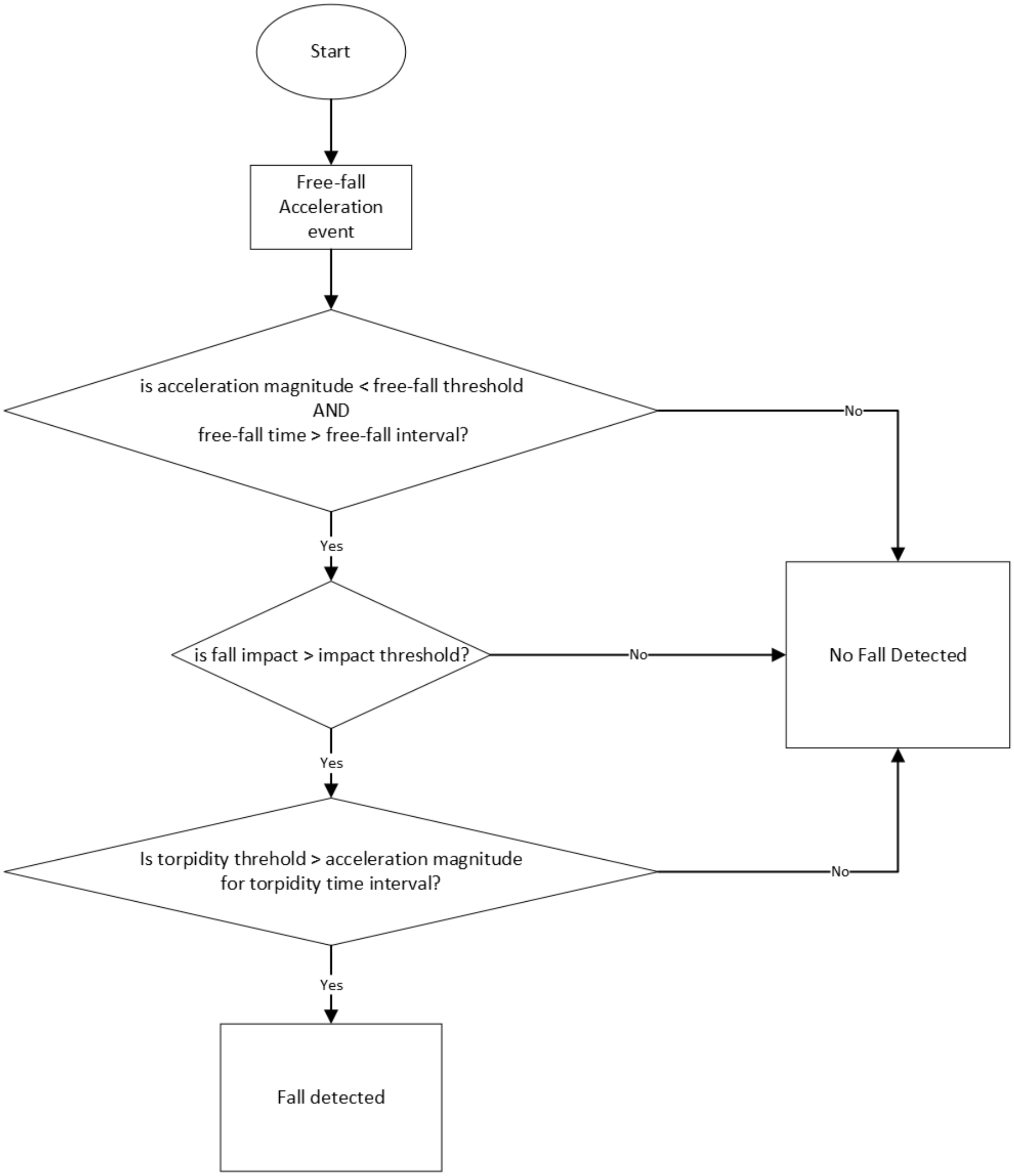


Figure 3-7: The motion detection state machine to support the SLEEP state.

2. To detect human fall event, the SEAL/SEAL-Ex uses the accelerometer and its internal timer to check for the following conditions. The summary of the fall detection feature is shown in Figure 3-8.
   a. Free Fall Event: the accelerometer is first triggered by a free fall event. This occurs when the magnitudes of all unfiltered axis X, Y, and Z go below certain threshold for a short duration known as the free-fall interval.
   b. Fall Impact: after the free fall event is registered, the accelerometer needs to detect an impact where the magnitude of any unfiltered axis exceeds another threshold known as impact threshold. The impact is followed first by an impact blackout duration, where no impact or activity is monitored as after the impact, there may be some random vibrations or impacts on the user wearing the SEAL/SEAL-Ex that we would like to ignore as they do not represent an important human motion.
   c. Torpidity: this is a short period of inactivity following the impact. For the torpidity condition to be met, the acceleration magnitude must stay below the torpidity threshold for a short period of time known as the torpidity Interval time.

Figure 3-8: Fall detection flow chart



The accelerometer can also be polled periodically (Register 0x24) for its raw (unfiltered) acceleration vector (X, Y, Z), useful for the applications where the SEAL/SEAL-Ex orientation is of interest.

Table 3-20 shows a list of accelerometer configuration registers. In this table, the bit indexing scheme is as shown in Figure 3-3. All the registers have R/W access.

Table 3-20: Accelerometer Configuration Registers

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x41	Accelerometer Sensitivity	1 B	• Bits 6-7: Ignored • Bits 4-5 (Measurement Range)[16]: 0/1/**2**/3 = ±2/±4/**±8**/±16 *g* • Bit 3: Ignored • Bits 0-2 (Sample Rate): 0: Invalid and ignored 1/2/**3**/4/5/6/7 = 1/10/**25**/50/100/200/400 Hz	• *accelerometer_measurement_range : <value> (number/g)* • *accelerometer_sample_rate: <value> (number/Hz)*
0x42	SLEEP Acceleration Threshold	2 B	• 1 m*g*/LSB (unsigned)	*sleep_acceleration_threshold: <value> (number/g)*
0x43	Timeout to SLEEP	1 B	• No-motion duration, in min, before the SEAL/SEAL-EX goes to SLEEP 0: Disables going to SLEEP	*timeout_to_sleep: <value> (number/min)*

3.3.8.1 Sensitivity

When enabled (powered on), the accelerometer always samples the transducer element at a fixed rate, called the Sample Rate. To capture an acceleration event, the physical event needs to last longer than the sample period. Larger sample rates have a shorter period and can therefore resolve shorter acceleration events. However, sampling the transducer at a larger rate increases the power usage, impacting the battery life. Table 3-21 and Table 3-22 shows typical current draw deltas (with respect to the background current at sleep) for the different sample rates when the accelerometer is enabled.

Table 3-21: Typical Current Draw Deltas (3.0v) for Different Accelerometer Sample Rates (ATEX)

Sample Rate [Hz]	TBU	TBU	TBU	TBU	TBU	TBU	TBU
Current Draw [μA]	TBU	TBU	TBU	TBU	TBU	TBU	TBU

Table 3-22: Typical Current Draw Deltas (4.5v) for Different Accelerometer Sample Rates (non-ATEX)

Sample Rate [Hz]	TBU	TBU	TBU	TBU	TBU	TBU	TBU
Current Draw [μA]	TBU	TBU	TBU	TBU	TBU	TBU	TBU

Furthermore, the Sensitivity register sets the measurement range or full-scale, which shows the dynamic range of accelerations that can be monitored on any enabled axis. In the SEAL/SEAL-Ex, the accelerometer is put into the low-

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[16] Measurement ranges ±2 *g*, ±4 *g*, ±8 *g*, ±16 *g* correspond to typical transducer output precisions of 16 m*g*, 32 m*g*, 64 m*g*, 192 m*g*, respectively. Note that if an acceleration threshold for an event is set equal to or greater than the configured measurement full-scale (2 *g*, 4 *g*, 8 *g*, 16 *g*), then no such acceleration event will be triggered.

power mode, which means the output acceleration values on any given axis (X, Y, Z), is an 8-bit signed number. Therefore, a measurement range of ±2 *g* implies a precision of 4/256 *g*/LSB.

3.3.8.2 SLEEP Acceleration Threshold

As explained above in Section 3.3.8 (Item 1).

3.3.8.3 Timeout to SLEEP

As explained above in Section 3.3.8 (Item 1).

3.3.8.4 Default Configuration

Table 3-23 shows the default values for the accelerometer configuration registers.

Table 3-23: Default Values of Accelerometer Configuration Registers

Sensitivity	Measurement Range ±8 *g* Sample Rate 25 Hz
SLEEP Acceleration Threshold	0.250 *g*
Timeout to SLEEP	10 min

3.3.9 Fall Configuration

A human fall event is detected and registered through a combination of accelerometer events. See Section 3.3.8 for how a fall event is detected on SEAL/SEAL-Ex.

Under a Fall Active event status, a Fall Cleared event is registered (and therefore, the Fall Active event is cleared) if the emergency button is pressed for more than 5 seconds.

A Fall Active event triggers transition to the EMERGENCY state (if not already in the EMERGENCY state). A Fall Cleared event triggers transition to the NORMAL state if the SEAL/SEAL-Ex is in EMERGENCY not due to any emergency events other than falling. The Fall status is part of the Safety Status, and therefore, can be reported periodically or on status change (see Sections 1.9).

Table 3-24 shows a list of fall configuration registers. In this table, the bit indexing scheme is as shown in Figure 3-3. All the registers have R/W access.

Table 3-24: Fall Configuration Registers

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x48	Free Fall	4 B	• Bits 16-31: Free Fall Acceleration Threshold (the threshold all acceleration axes must go below, to detect a free fall). 1 m*g*/LSB (unsigned) Acceptable values: 0-800 • Bits 0-15: Free Fall Acceleration Interval (the interval over which all acceleration axes remain	• *free_fall_acceleration_threshold: <value> (number/g)* • *free_fall_acceleration_interval: <value> (number/sec)*

Address	Name	Size	Description	JSON Variable (Type/Unit)
			below Free Fall Acceleration Threshold, to detect a free fall). 1 msec/LSB (unsigned) 0: Invalid and ignored	
0x49	Impact	4 B	• Bits 16-31: Impact Threshold (the threshold the acceleration magnitude must go above, to detect the impact portion of a human fall). 1 mg/LSB (unsigned) Acceptable values: 1500-8000 • Bits 0-15: Impact Blackout Duration (the duration to wait after the impact before looking for torpidity). 1 msec/LSB (unsigned) Acceptable values: 0-65535	• *impact_threshold: <value> (number/g)* • *impact_blackout_duration: <value> (number/sec)*
0x4A	Torpidity	3 B	• Bits 8-23: Torpidity Threshold (the threshold the acceleration magnitude must stay below for Torpidity Interval time, to detect the torpidity portion of a human fall). 1 mg/LSB (unsigned) Acceptable values: 100-3000 • Bits 0-7: Torpidity Interval (the interval over which the acceleration magnitude must remain below Torpidity Threshold, to detect the torpidity portion of a human fall). 1 sec/LSB (unsigned) Acceptable values: 0-255	• *torpidity_threshold: <value> (number/g)* • *torpidity_interval: <value> (number/sec)*

3.3.9.1 Default Configuration

Table 3-25 shows the default values for the fall configuration registers.

Table 3-25: Default Values of Fall Configuration Registers

Free Fall	Threshold = 0.350 *g* Interval = 0.350 sec
Impact	Threshold = 5 *g* Blackout Duration = 2 sec
Torpidity	Threshold = 2 *g* Interval = 2 sec

3.3.10 BLE Configurations

The BLE module is embedded in the MCU. It plays the role of a BLE tracker device that periodically search to discover nearby BLE peripherals. A location resolver on the cloud can be used to estimate the position of the user using the RSSI values of these discovered BLE devices. The discovered nearby BLE devices can also be used to set up danger zones such that when a discovered BLE device falls withing the defined RSSI-threshold of a danger zone, SEAL/SEAL-Ex raises an alarm to warn the user of the danger.

Figure 1-2 shows how periodic BLE scans are performed; also see Section 1.2 for how BLE operates in the SEAL/SEAL-EX. Furthermore, Section 2.3 explains how discovered BLE devices are reported by the SEAL/SEAL-EX.

3.3.10.1 BLE Discovered Devices Configurations

As explained in Section 1.2, it is typically the case that in a single scan, one device is observed more than once. There is an averaging mode in the configuration that can be enabled or disabled. When the averaging mode is on, only the average readings of a device is recorded and considered for later processing. When the averaging mode is off, all instances of a device discovery are considered for possible reporting.

Also as explained in Section 1.2, there are two BLE scan report modes, Basic and Whitelisting. In the Basic mode, (up to) n RSSI-strongest beacons are reported, but in the Whitelisting mode, (up to) n RSSI-strongest beacons with BD_ADDRs within one of configured BD_ADDR ranges are reported. Up to 4 BD_ADDR ranges can be defined. Each BD_ADDR range has 9 bytes: B_0 (MSB) to B_8 (LSB). The corresponding BD_ADDR range is defined as B_0:B_1:B_2:B_3:B_4:B_5 to B_0:B_1:B_2:B_6:B_7:B_8. In other words, in each BD_ADDR range, the first 3 MSBs represent the OUI, and the 6 LSBs represent the LAP range. Therefore, a BD_ADDR range is given as OUI-LAP_{start}-LAP_{end} and represents the address range OUI:LAP_{start} to OUI:LAP_{end}.

In the Whitelisting mode, after a scan is complete, first, the list of the discovered devices is filtered to just include those lying in one of the 4 BD_ADDR ranges. Then, (up to) n RSSI-strongest devices in the filtered list are reported using the format described in Section 2.3. Devices falling under each range are reported with their respective range headers, as illustrated in Figure 2-3. Only LAPs of the devices followed by their RSSIs are reported in the Whitelisting mode, as explained in Section 2.3.

The following are the rules around using the 4 BD_ADDR ranges:

1. A range set to all 0's: An inactive range; otherwise, an active range.
2. All 4 ranges inactive: The Basic mode is enabled (the reporting shall be performed with message type header 0xFF as per Section 2.3). Otherwise, the Whitelisting mode is enabled.
3. In the Whitelisting mode, in every round of BLE scanning, there will be reports corresponding to each active range. If no devices are found to be reported for an active range, an empty list with the header corresponding to that active range is reported. An example has been given in Section 2.3.

4. A range with $LAP_{start} > LAP_{end}$: The range is active, but empty (i.e., always an empty list is reported with its corresponding header).
5. An active range with $LAP_{start} = LAP_{end}$: The range has only one BD_ADDR in it.
6. It is possible that the ranges overlap. A beacon that is in at least one of the ranges and is to be reported, is always reported under the first range (from Range 0 to 3) that it falls into.

Table 3-26: BLE discovered devices configuration

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x50	BLE Mode	1 B	• Bit 7: 0/1 = Averaging mode off/on • Bit 6: 0/1 = Report BLE DZ status disabled/enabled • Bits 0-5: Number of reported devices 0: Disables BLE	• *ble_avg_mode: <value> (string/no unit)* • *ble_dz_status_report: <value> (string/no unit)* • *ble_num_reported_devices: <value> (number/no unit)*
0x51	BLE Scan Duration	1 B	• Scan duration for periodic reports (1 sec/LSb) 0: Invalid and ignored	*ble_scan_duration_periodic: <value> (number/sec)*
0x52	BLE Scan Interval	2 B	• Scan interval (1 msec/LSb) • Acceptable values: 3, …, 10000 • Other values: Invalid and ignored	*ble_scan_interval: <value> (number/msec)*
0x53	BLE Scan Window	2 B	• Scan window (1 msec/LSb) • Acceptable values: 3, …, “Scan Interval” • Other values: Invalid and ignored	*ble_scan_window: <value> (number/msec)*
0x54	BLE Range 0 Definition	9 B	• Range 0 for whitelisted BD_ADDRs • $B_0:B_1:B_2:B_3:B_4:B_5$ to $B_0:B_1:B_2:B_6:B_7:B_8$ • Bits 48-71: OUI = $B_0:B_1: B_2$ • Bits 24-47: $LAP_{start} = B_3:B_4:B_5$ • Bits 0-23: $LAP_{end} = B_6:B_7:B_8$	• *ble_range0_bd_addr_oui: <value> (string/no unit)* • *ble_range0_bd_addr_start: <value> (string/no unit)* • *ble_range0_bd_addr_end: <value> (string/no unit)*
0x55	BLE Range 1 Definition	9 B	• Range 1 for whitelisted BD_ADDRs • $B_0:B_1:B_2:B_3:B_4:B_5$ to $B_0:B_1:B_2:B_6:B_7:B_8$ • Bits 48-71: OUI = $B_0:B_1: B_2$ • Bits 24-47: $LAP_{start} = B_3:B_4:B_5$ • Bits 0-23: $LAP_{end} = B_6:B_7:B_8$	• *ble_range1_bd_addr_oui: <value> (string/no unit)* • *ble_range1_bd_addr_start: <value> (string/no unit)* • *ble_range1_bd_addr_end: <value>*

Address	Name	Size	Description	JSON Variable (Type/Unit)
				(string/no unit)
0x56	BLE Range 2 Definition	9 B	• Range 2 for whitelisted BD_ADDRs • $B_0:B_1:B_2:B_3:B_4:B_5$ to $B_0:B_1:B_2:B_6:B_7:B_8$ • Bits 48-71: OUI = $B_0:B_1: B_2$ • Bits 24-47: $LAP_{start} = B_3:B_4:B_5$ • Bits 0-23: $LAP_{end} = B_6:B_7:B_8$	• *ble_range2_bd_addr_oui: <value>* *(string/no unit)* • *ble_range2_bd_addr_start: <value>* *(string/no unit)* • *ble_range2_bd_addr_end: <value>* *(string/no unit)*
0x57	BLE Range 3 Definition	9 B	• Range 3 for whitelisted BD_ADDRs • $B_0:B_1:B_2:B_3:B_4:B_5$ to $B_0:B_1:B_2:B_6:B_7:B_8$ • Bits 48-71: OUI = $B_0:B_1: B_2$ • Bits 24-47: $LAP_{start} = B_3:B_4:B_5$ • Bits 0-23: $LAP_{end} = B_6:B_7:B_8$	• *ble_range3_bd_addr_oui: <value>* *(string/no unit)* • *ble_range3_bd_addr_start: <value>* *(string/no unit)* • *ble_range3_bd_addr_end: <value>* *(string/no unit)*

3.3.10.2 BLE Danger Zone Configurations

Another BLE configuration for the SEAL/SEAL-Ex is the definition of BLE designated/danger zones (DZs). Up to 4 BLE DZs can be defined. Each DZ consists of a BD_ADDR range and an RSSI threshold for the DZ range defined as seen in Table 3-27 below.

For example, to set the RSSI threshold for all DZs to "-100 dBm" and define each of the four BLE DZs to include all possible BLE_ADDR with OUI "AA AA AA", "BB BB BB", "CC CC CC", and "DD DD DD" respectively, we follow the format explained in Section 3.3.10 as seen in the example below.

BLE DZ 0: D8 AA AA AA 00 00 00 FF FF FF 9C

BLE DZ 1: D9 BB BB BB 00 00 00 FF FF FF 9C

BLE DZ 2: DA CC CC CC 00 00 00 FF FF FF 9C

BLE DZ 3: DB DD DD DD 00 00 00 FF FF FF 9C

Where:

D (8 ,9, A, B): BLE DZ 0, 1, 2 and 3 config register with its read/write bit to 1 to write the configuration
OUIs: AA AA AA, BB BB BB, CC CC CC, and DD DD DD
00 00 00: the smallest possible address in the DZ BD_ADDR range, i.e., the LAP_{start}
FF FF FF: the biggest possible address in the DZ BD_ADDR range, i.e., the LAP_{end}

Similar to the 'Whitelist mode' explained in section 3.3.10, after a BLE scan is complete, the list of the discovered devices is filtered to just include those lying in one of the 4 DZ BD_ADDR ranges. If any of the BLE_ADDR has an RSSI value that falls above the defined RSSI threshold for their respective DZ BD_ADDR ranges, the BLE DZ emergency is triggered for that DZ BD_ADDR range, and a status report indicating the change in emergency status is sent as shown in Table 2-2. The following explains in greater detail the possible BLE DZ statuses

1. The SEAL/SEAL-Ex is considered to be *inside* a given DZ if the average RSSI values of any BLE_ADDR in the range exceeds the DZ RSSI threshold.
2. If the SEAL/SEAL-Ex sees any BD_ADDR in the range but the average RSSI from the DZ BD_ADDR is below the DZ RSSI threshold, the SEAL/SEAL-Ex is considered to be *near* the given DZ.
3. If the SEAL/SEAL-Ex cannot discover any DZ BD_ADDR from the range, the SEAL/SEAL-Ex is said to be *outside* the given DZ.
4. If any of the four BLE DZs is not set or set incorrectly, the SEAL/SEAL-Ex reports that particular DZ to be *unknown*

It is possible to disable or enable the report of the BLE DZ status in the BLE periodic reports. The following are the rules around using the 4 BD_ADDR ranges:

1. A BLE DZ range set to all 0's: An inactive range; otherwise, an active range.
2. A BLE DZ range with $LAP_{start} > LAP_{end}$: The range is active, but empty (i.e., BLE DZ status always reports *unknown*).
3. A BLE DZ active range with $LAP_{start} = LAP_{end}$: The BLE DZ range has only one BD_ADDR in it.
4. It is possible that the ranges overlap. A BD_ADDR that is in at least one of the ranges and is to be reported, is always reported under the first range (from BLE DZ Range 0 to 3) that it falls into.

Table 3-27 shows the list of BLE configuration registers. In this table, the bit indexing scheme is as shown in Figure 3-3. All the registers have R/W access.

Table 3-27: BLE Danger Zone Configuration

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x58	BLE DZ 0 Definition	10 B	• $B_0:B_1:B_2:B_3:B_4:B_5$ to $B_0:B_1:B_2:B_6:B_7:B_8$ • Bits 56-79: OUI = $B_0:B_1:B_2$ • Bits 32-55: $LAP_{start} = B_3:B_4:B_5$ • Bits 8-31: $LAP_{end} = B_6:B_7:B_8$ • Bits 0-7: RSSI Threshold (1 dBm/LSB, signed)	• *ble_dz_range0_bd_addr_oui: <value> (string/no unit)* • *ble_dz_range0_bd_addr_start: <value> (string/no unit)* • *ble_dz_range0_bd_addr_end: <value> (string/no unit)* • *ble_dz_range0_rssi: <value> (number/dBm)*
0x59	BLE DZ 1 Definition	10 B	• $B_0:B_1:B_2:B_3:B_4:B_5$ to $B_0:B_1:B_2:B_6:B_7:B_8$ • Bits 56-79: OUI = $B_0:B_1:B_2$ • Bits 32-55: $LAP_{start} = B_3:B_4:B_5$	• *ble_dz_range1_bd_addr_oui: <value> (string/no unit)*

Address	Name	Size	Description	JSON Variable (Type/Unit)
			• Bits 8-31: $LAP_{end} = B_6:B_7:B_8$ • Bits 0-7: RSSI Threshold (1 dBm/LSB, signed)	• *ble_dz_range1_bd_addr_start: <value> (string/no unit)* • *ble_dz_range1_bd_addr_end: <value> (string/no unit)* • *ble_dz_range1_rssi: <value>* • *(number/dBm)*
0x5A	BLE DZ 2 Definition	10 B	• $B_0:B_1:B_2:B_3:B_4:B_5$ to $B_0:B_1:B_2:B_6:B_7:B_8$ • Bits 56-79: OUI = $B_0:B_1:B_2$ • Bits 32-55: $LAP_{start} = B_3:B_4:B_5$ • Bits 8-31: $LAP_{end} = B_6:B_7:B_8$ • Bits 0-7: RSSI Threshold (1 dBm/LSB, signed)	• *ble_dz_range2_bd_addr_oui: <value> (string/no unit)* • *ble_dz_range2_bd_addr_start: <value> (string/no unit)* • *ble_dz_range2_bd_addr_end: <value> (string/no unit)* • *ble_dz_range2_rssi: <value> (number/dBm)*
0x5B	BLE DZ 3 Definition	10 B	• $B_0:B_1:B_2:B_3:B_4:B_5$ to $B_0:B_1:B_2:B_6:B_7:B_8$ • Bits 56-79: OUI = $B_0:B_1:B_2$ • Bits 32-55: $LAP_{start} = B_3:B_4:B_5$ • Bits 8-31: $LAP_{end} = B_6:B_7:B_8$ • Bits 0-7: RSSI Threshold (1 dBm/LSB, signed)	• *ble_dz_range3_bd_addr_oui: <value> (string/no unit)* • *ble_dz_range3_bd_addr_start: <value> (string/no unit)* • *ble_dz_range3_bd_addr_end: <value> (string/no unit)* • *ble_dz3_rssi: <value> (number/dBm)*

NOTE: If BLE is disabled through Register 0x50, no periodic or event-based report related to BLE is reported.

3.3.10.3 Default Configuration

Table 3-28 shows the default values for the BLE configuration registers.

Table 3-28: Default Values of BLE Configuration Registers

BLE Mode	Averaging mode on Report DZ status disabled

	0 BLE devices reported
BLE Scan Duration	3 sec
BLE Scan Interval	0.030 sec
BLE Scan Window	0.030 sec
BLE Range 0/1/2/3 Definition	0x 00 00 00 00 00 00 00 00 00 (Whitelisting mode disabled)
BLE DZ 0/1/2/3 Definition	0x 00 00 00 00 00 00 00 (no BLE DZs defined)

3.3.10.4 Guidelines on BLE Scan Configuration

Although the BLE scan duration and number of devices to report can be freely configured to different values, a bad combination can result in the SEAL/SEAL-Ex not responding as desired, as the report period could be too small (e.g., the report period T_E in the EMERGENCY state). The general rule of thumb is that the scan duration plus the time to report the discovered devices should be smaller than the scan period. The report time is a function of the UL DR and number of devices to report. For example, while a larger DR takes fewer packets to report a number of devices, a smaller DR would require more packets for the same number. Moreover, due to LoRaWAN standard requirements, the packets cannot be sent out faster than about every 3 sec.

Table 3-29 shows the maximum number of BLE devices that can be accommodated in a single packet, as a function of the LoRaWAN region and DR. In the table entries, the first number is for the Basic mode, where each device is reported using 7 bytes, and the second number is for the Whitelisting mode where 4 bytes is needed per device. For example, from Table 3-29, to report 10 discovered beacons using DR0 of US915, it takes (at least) $\frac{10}{1} = 10$ and $\frac{10}{2} = 5$ packets in the Basic and Whitelisting mode, respectively. But the same 10 devices can be reported in 1 packet using DR3 of EU868.

Table 3-29: Maximum Number of Reported BLE Devices per LoRaWAN Packet in Different Regions

Region	DR0	DR1	DR2	DR3	DR4	DR5	DR6
EU868	7/12	7/12	7/12	16/28	34/60	34/60	34/60
US915	1/2	7/13	17/31	34/60	34/60	N/A	N/A
AS923	7/12	7/12	7/12	16/28	34/60	34/60	34/60
AU915	7/12	7/12	7/12	16/28	34/60	34/60	34/60
IN865	7/12	7/12	7/12	16/28	34/60	34/60	N/A
KR920	7/12	7/12	7/12	16/28	34/60	34/60	N/A
RU864	7/12	7/12	7/12	16/28	34/60	34/60	34/60

Whenever the DR is not certain (e.g., due to enabled ADR, which can change the DR used by the SEAL/SEAL-Ex), it is recommended enough margin for the report time be considered between the scan duration and scan period.

3.3.11 Temperature Threshold Configuration

The SEAL/SEAL-Ex supports threshold transmission on the temperature. The temperature is measured from the barometer. When the temperature thresholds are enabled, the SEAL/SEAL-Ex reports the temperature when it leaves the configured threshold window, defined as the open interval "(Low Threshold, High Threshold)", and once again when the temperature re-enters the threshold window. The Idle and Active Sample Periods determine how often the temperature is checked (sampled) when the reported value is inside and outside the threshold window, respectively. When first enabled, the temperature transducer starts in the Idle state. Table 3-30 shows a list of configuration registers for the temperature threshold setting. In this table, the bit indexing scheme is as shown in Figure 3-3. All the registers have R/W access.

Table 3-30: Temperature Threshold Configuration Registers

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x60	Temperature Sample Period in Idle State	4 B	• Sample period of temperature in sec in Idle state • Acceptable values: 10, 11, …, 86400 • Other values: Invalid and ignored	*temperature_sample_period_idle: <value> (number/sec)*
0x61	Temperature Sample Period in Active State	4 B	• Sample period of temperature in sec in Active state • Acceptable values: 10, 11, …, 86400 • Other values: Invalid and ignored	*temperature_sample_period_active: <value> (number/sec)*
0x62	Temperature High/Low Thresholds	2 B	• Bits 8-15: High temperature threshold (signed, 1°C/LSb) • Bits 0-7: Low temperature threshold (signed, 1°C/LSb) • High threshold ≤ Low threshold: Invalid and ignored	• *temperature_threshold_high: <value> (number/°C)* • *temperature_threshold_low: <value> (number/°C)*
0x63	Temperature Thresholds Status	1 B	• Bits 1-7: Ignored • Bit 0: 0/1 = Temperature thresholds disabled/enabled	*temperature_thresholds_status: <value> (string/no unit)*

3.3.11.1 Default Configuration

Table 3-31 shows the default values for the temperature threshold configuration registers.

Table 3-31: Default Values of Temperature Threshold Configuration Registers

Temperature Sample Period in Idle State	300 sec
Temperature Sample Period in Active State	60 sec
Temperature High Threshold	30°C
Temperature Low Threshold	15°C
Temperature Thresholds Status	Disabled

3.3.11.2 Example DL Messages

- Set Temperature Thresholds:
  - DL payload: {0x E2 23 F6}
    - Register 62 with write bit set to true
    - High threshold set to 35°C
    - Low threshold set to -10°C
- Read Sample Periods:
  - DL payload: {0x 60 61}

- Register 60 and Register 61 with their write bits set to false

3.3.12 Battery Management Configuration

The battery status can be checked and reported periodically (see Section 3.3.2). It is configurable what to report for the battery: battery remaining capacity in percentage, or battery remaining capacity in days. It is also configurable to set a threshold for the battery capacity, in percentage or days, below which a configurable low-battery periodic LED indication starts to blink periodically. For this LED indication, only *top LEDs* blink with the following configuration:

1. Low-Battery LED ON time: The LED on time.
2. Low-Battery LED OFF time: The LED off time.
3. Low-Battery LED Number of ON-OFFs: Number of times the on-off pattern (sub-flash) is repeated.
4. Low-Battery LED Period: Period of flashes.

The periodic low-battery LED pattern has been shown in Figure 3-6.

While the remaining battery capacity in percentage gradually drops throughout during normal operation of the SEAL/SEAL-Ex, the remaining battery capacity in days may go up or down, depending on the energy consumption of the device. For example, a SEAL/SEAL-EX configured to send an UL report every 15 minutes will consume more energy than one that is configured to send an UL report every 60 minutes. And since the SEAL/SEAL-Ex can be reconfigured at any time during normal operation and change their energy consumption rate, the remaining lifetime will in-turn change as well.

The SEAL/SEAL-Ex handles this by monitoring the average energy consumption trend over a certain time; the *Average Energy Trend Window.* The SEAL/SEAL-Ex updates how much energy it has consumed at each core tick (register 0x 20). The average energy trend window specifies the number of preceding core ticks over which the energy consumption trend is calculated. This average energy consumption trend is then used to estimate the remaining battery lifetime in days.

Note that the JOIN procedure consumes energy at a higher rate than normal default operation, so the remaining lifetime value reported will take some time to stabilize after the SEAL/SEAL-Ex joins the network. It will take '***w***' core ticks over which "steady-state" energy consumption occurs before the remaining battery lifetime value will stabilize.

It is recommended that the core tick settings and average energy trend window be configured in relation to each other. For example, a large core tick setting and large window will result in a long time for the remaining battery lifetime in days to be calculated accurately and will take a long time to respond to changes in energy consumption. A small core tick setting and small window will result in more fluctuations in consecutive battery reports.

Note: The algorithm is based on the average nominal battery capacity of a new battery, so when the battery is replaced, the remaining capacity is automatically reset. However, the remaining battery capacity will not be reset when the device is soft-reset for any reason, including an OTA reboot or switching between Beacon and Tracker modes.

Table 3-32 shows a list of battery configuration registers. In this table, the bit indexing scheme is as shown in Figure 3-3. All the registers have R/W access.

Table 3-32: Battery Configuration Registers

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x68	Battery Report Options	1 B	• Bits 0,3-7: Ignored • Bit 2:	• *battery_lifetime_dys_report: <value>* *(string/no unit)*

			0/1 = Battery lifetime report in days disabled/enabled • Bit 1: 0/1 = Battery lifetime report in percentage disabled/enabled	• *battery_lifetime_pct_report: <value>* *(string/no unit)*
0x69	Low-Battery Threshold	2 B	• Bits 14-15 (threshold type): 1: Threshold on remaining capacity in percentage 2: Threshold on remaining capacity in days 0,3: Invalid and ignored • Bits 0-13 (threshold value): In case of percentage: 1%/LSB In case of days: 1 day/LSB	• *low_battery_threshold_type: <value>* *(string/no unit)* • *low_battery_threshold_value: <value>* *(number/%-days)*
0x6A	Low-Battery LED Config	4 B	• Bits 24-31: Low-Battery LED ON time (0.01 sec/LSB) 0: Invalid and ignored • Bits 16-23: Low-Battery LED OFF time (0.01 sec/LSB) • Bits 8-15: Low-Battery LED Number of ON-OFFs 0: Invalid and ignored • Bits 0-7: Low-Battery LED Period (1 sec/LSB) 0: Invalid and ignored	• *low_battery_led_on_time: <value>* *(number/sec)* • *low_battery_led_off_time: <value>* *(number/sec)* • *low_battery_led_num_on_offs: <value>* *(number/no unit)* • *low_battery_led_period: <value>* *(number/sec)*
0x6B	Average Energy Trend Window		• Bits 0-7: Number of core ticks '***w***' per window (1 update/LSB) Acceptable values: 1,2, …, 255 0: Invalid and ignored	• *avg_energy_trend_window: <value>* *(unsigned/no unit)*

3.3.12.1 Default Configuration

Table 3-33 shows the default values for the battery configuration registers.

Table 3-33: Default Values of Battery Configuration Registers

Battery Report Options	Only battery lifetime report in percentage enabled
Low-Battery Threshold Type	Threshold on remaining capacity in percentage
Low-Battery Threshold	10%
Low-Battery LED Config	Low-Battery LED ON time 0.050 sec Low-Battery LED OFF time 0.180 sec Low-Battery LED Number of ON-OFFs = 10

	Low-Battery LED Period = 180 sec
Average Energy Trend Window	10 updates

3.3.13 Mute Button (MB) Configuration

The SEAL/SEAL-Ex buzzer can be momentarily disabled (so it will not buzz for EB events, SH events, or a DL-triggered event described in Section 3.1) anytime manually by pressing and holding the MB for at least 1 sec. The buzzer can be re-enabled anytime manually by pressing and holding the MB for at least 1 sec.

Essentially, pressing and holding the MB for 1s toggles the muting of the buzzer ON and OFF, depending on the state of the buzzer before the press.

The disabled buzzer is automatically re-enabled after the Buzzer Disable Timeout elapses since the last manual buzzer disabling.

Figure 3-9 shows the buzzer enable-disable state machine.

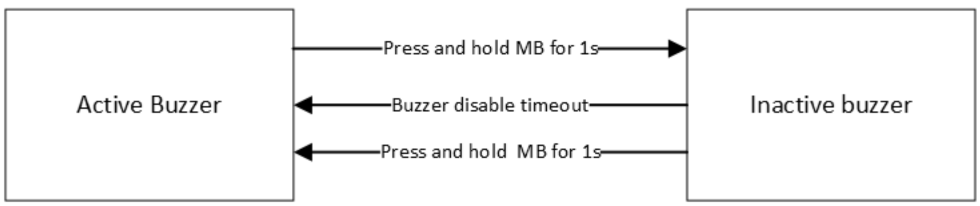

Figure 3-9: The buzzer enable-disable state machine.

Table 3-34 shows the configuration register for the buzzer disabling. In this table, the bit indexing scheme is as shown in Figure 3-3. The register has R/W access.

Table 3-34: Buzzer Disabling Configuration Register

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x6C	Buzzer Disable Timeout	1 B	• The buzzer disable timeout in min. • Acceptable values: 1-255	*buzzer_disable_timeout: <value> (number/min)*

3.3.13.1 Default Configuration

Table 3-35 shows the default value for the buzzer disabling configuration register.

Table 3-35: Default Value of Buzzer Disabling Configuration Register

Buzzer Disable Timeout	60 min

3.3.14 Response to DL Commands Configuration

The SEAL/SEAL-Ex includes the ability for the user to select the format of UL responses to DL commands. Details on the response formats can be found in Section 2.4. Table 3-36 shows the response to DL commands register. This register has R/W access.

Table 3-36: Response to DL Commands Configuration Register

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x6F	Format Option	1 B	• Bit 0: 0: Invalid-write response format 1: 4-byte CRC • Bits 1-7: Ignored	*resp_format: <value>* *(unsigned/no unit)*

3.3.14.1 Format Option

The value of the Format Option register determines how the Sensor responds to DL commands. Setting Bit 0 to 0 (zero) selects the invalid-write response format, while a value of 1 (one) selects the 4-byte CRC method. Please refer to Section 2.4 for more details.

3.3.14.2 Default Configuration

Table 3-37 shows the default value for the response to DL commands configuration register.

Table 3-37: Default Value of Response to DL Commands Configuration Register

Format Option	Invalid-write response format

3.3.15 Command and Control

Configuration changes are not retained after a power cycle unless they are saved in the flash. Table 3-38 shows the structure of the command-and-control registers. In this table, the bit indexing scheme is as shown in Figure 3-3.

Table 3-38: Command and Control Registers

Address	Access	Name	Size	Description	JSON Variable (Type/Unit)
0x70	W	Flash Write Command	2 B	• Bit 15: Ignored • Bit 14: 0/1 = Do not write/Write LoRaMAC Configuration • Bit 13: 0/1 = Do not write/Write App Configuration • Bits 1-12: Ignored • Bit 0: 0/1 = Do not restart/Restart SEAL/SEAL-EX	• *write_to_flash_loramac_config: <value>* *(string/no unit)* • *write_to_flash_app_config: <value>* *(string/no unit)* • *restart_sensor: <value>* *(string/no unit)*
0x71	R	Metadata	7 B	• Bits 48-55: App version major • Bits 40-47: App version minor • Bits 32-39: App version revision	• *app_ver_major: <value>* *(number/no unit)* • *app_ver_minor: <value>* *(number/no unit)* • *app_ver_revision: <value>* *(number/no unit)*

Address	Access	Name	Size	Description	JSON Variable (Type/Unit)
				• Bits 24-31: LoRaMAC version major • Bits 16-23: LoRaMAC version minor • Bits 8-15: LoRaMAC version revision • Bits 0-7: LoRaWAN region ID	• *loramac_ver_major: <value> (number/no unit)* • *loramac_ver_minor: <value> (number/no unit)* • *loramac_ver_revision: <value> (number/no unit)* • *lorawan_region_id: <value> (number/no unit)*
0x72	W	Reset to Factory Defaults[17]	1 B	• 0xB0 = Reset LoRaMAC Configuration • 0x0A = Reset App Configuration • 0xBA = Reset both LoRaMAC and App Configurations • Any other value: Invalid and ignored	• *factory_reset_config_app: <value> (string/no unit)* • *factory_reset_config_loramac: <value> (string/no unit)*

Note: The command-and-control registers are always executed after the full DL configuration message has been decoded. A reset command should always be sent as an unconfirmed DL message. Failure to do so may cause a poorly designed NS to continually reboot the SEAL/SEAL-EX.

The LoRaWAN region is the last byte of the FW Version register (Register 0x71). Current LoRaWAN regions and corresponding region IDs are listed in Table 3-39.

Table 3-39: LoRaWAN Regions and Region IDs

LoRaWAN Region	Region ID
EU868	0
US915	1
AS923	2
AU915	3
IN865	4
KR920	6
RU864	7

Example:

- Write Application and LoRa Configurations to flash and reboot the device:
    - DL payload: 0x F0 60 01
- Get FW version, and reset App Configuration to factory defaults

[17] After sending the reset-to-factory-defaults command, the SEAL/SEAL-Ex is automatically reset with corresponding default configuration values.

- DL payload: 0x 71 F2 0A

Appendix A: Data Converter (DC)

The DC is a piece of SW interfacing to the Application Server, that decodes UL Frame Payloads to what the Application Server understands, and also encodes the Application Server commands into DL Frame Payloads. This section presents decoder and encoder DCs in JavaScript as examples corresponding to this version of the TRM. The DCs use the JSON variables in Table 2-2, Table 3-4, Table 3-8, Table 3-10, Table 3-12, Table 3-14, Table 3-16, Table 3-18, Table 3-20, Table 3-24, Table 3-27, Table 3-30, Table 3-32, Table 3-34, Table 3-36, and Table 3-38.

[TBU]

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