
SEAL/SEAL-Ex Wearable GPS Tracker

User Guide

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Acronyms and Glossary

BeiDou	BeiDou Navigation Satellite System (BDS), a Chinese satellite navigation system
BER	bit error rate
BLE	Bluetooth Low Energy
bps	bits per second
DL	downlink
EIRP ...	equivalent isotropically radiated power
FCC	Federal Communications Commission
GLONASS	GLObal NAVigation Satellite System
GNSS ...	Global Navigation Satellite System
GPS	Global Positioning System
IoT	Internet of Things
IP	Ingress Protection
LED	light emitting diode
LID	lithium-iron disulfide (chemistry of LTC batteries)
LoRa ..	a patented “long-range” IoT technology acquired by Semtech
LoRaWAN	LoRa wide area network (a network protocol based on LoRa)
MCU ..	microcontroller unit
NS	network server
OTA	over the air
PCBA ..	printed circuit board assembly
QZSS ..	Quasi-Zenith Satellite System
RF	radio frequency
RSS	Radio Standards Specifications
RSSI	received signal strength indicator
Rx	receiver, receive
SBAS ..	Satellite-Based Augmentation System
Tracker	any variant of the SEAL Wearable GPS Tracker
TTF ...	time to first fix
TRM ...	technical reference manual
Tx	transmitter, transmit
UG	user guide (this document)
UTC	Coordinated Universal Time
UV	ultraviolet
ver.	version

1 Product Description

1.1 Overview

This document is the official user manual for *the SEAL Wearable GPS Tracker* designed and developed by Tektelic Communications, henceforth referred to as *SEAL/SEAL-Ex*.

The SEAL/SEAL-Ex is a light, small factor, long battery lifetime, low-cost LoRaWAN sensor used for tracking people (as a wearable device) or equipment, based on GNSS and BLE technologies. The SEAL/SEAL-Ex comes both as an ATEX/IECEX certified version (henceforth referred to as *SEAL-Ex*), certified to operate in potentially hazardous and explosive atmospheres, and as a regular non-ATEX/IECEX version (henceforth referred to as *SEAL*).

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, 1 at the top 1 and one at the front, to indicate emergency status, low battery, and the system going into or out of DEEP SLEEP, are among other features.

Table 1-1: SEAL Wearable GPS Tracker Model

Product Code	Description	RF Region	Tx Band (MHz)	Rx Band (MHz)
T0008766	SEAL, ATEX with no Safety Clip	US915 EU868	923-928 863-870	902-915 863-870
T0008767	SEAL, ATEX with Safety Clip			
T0008768	SEAL, non-ATEX with no Safety Clip			
T0008769	SEAL, non-ATEX with Safety Clip			

Each of the ATEX/IECEX certified and the non-ATEX/IECEX versions have two functional 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 alarm if the user is to be warned.

The supported features of the different SEAL/SEAL-Ex variants are tabulated below

Table 1-2: Functional features of SEAL/SEAL-Ex variants

Feature	SEAL/SEAL-Ex Functional Variants			
	SEAL with clip	SEAL without clip	SEAL-EX with clip	SEAL-EX without clip
Battery Lifetime info (Percentage and days remaining)	X	X	X	X
GNSS Fix Position and time stamp	X	X	X	X
GNSS Danger zone	X	X	X	X
GNSS datalogging	X	X	X	X
Groundspeed	X	X	X	X
Discovered BLE devices	X	X	X	X
BLE Danger zone	X	X	X	X
Emergency button	X	X	X	X
Fall detection	X	X	X	X
Safety Harness detection	X		X	
Elevation detection	X	X	X	X
Atmospheric Pressure	X	X	X	X
Acceleration Vector Report	X	X	X	X
Temperature	X	X	X	X
GNSS Diagnostics info	X	X	X	X

Figure 1-1 and Figure 1-2 below illustrates the clip and the non-clip variants of the SEAL/SEAL-Ex respectively.

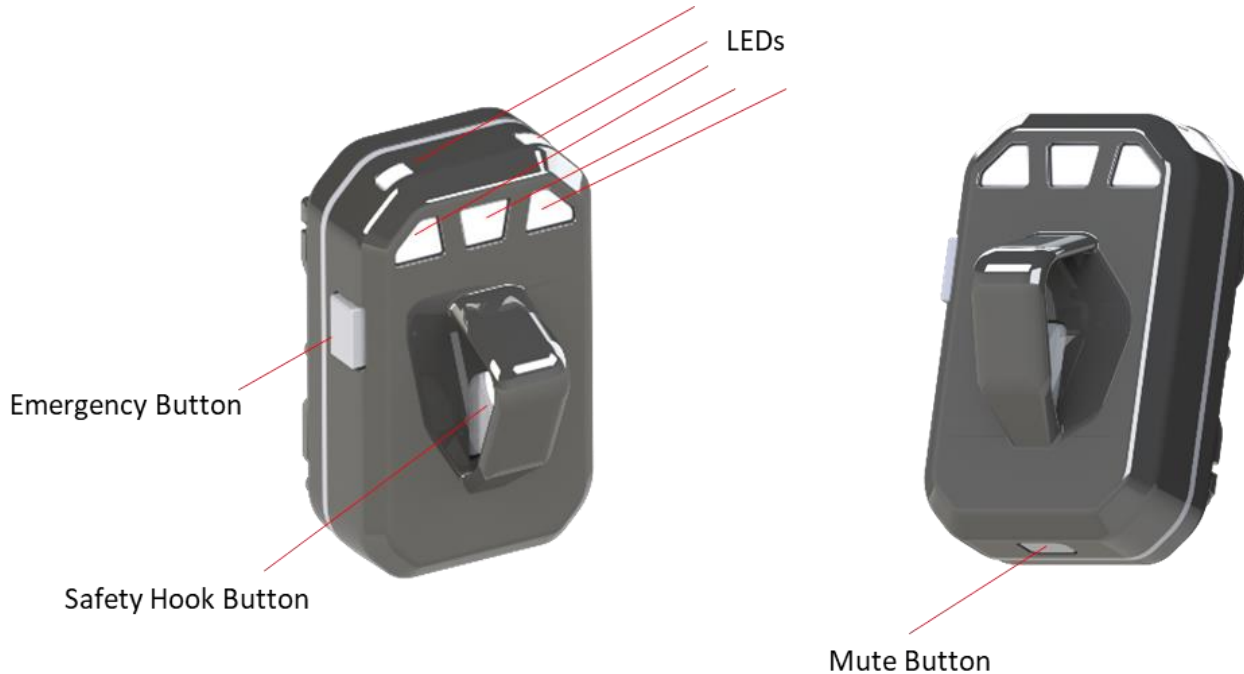


Figure 1-1: The SEAL Wearable GPS Tracker – Clip Variant.



Figure 1-2: The SEAL Wearable GPS Tracker – Non-Clip Variant.

Figure 1-3: SEAL Wearable GPS Tracker – LEDs and buttons



1.2 Specifications

The SEAL/SEAL-Ex specifications are listed in Table 1-.

Table 1-2: SEAL Wearable GPS Tracker Specifications

Parameter	Specification
Use Environment	Indoor/outdoor explosive atmospheres
Form Factor	Wearable, clipped to overalls, harness (carabiner)
Environmental Rating	IP67
Enclosure size	≤ 85mm x 55mm
Humidity Vent	Acrylic Self Adhesive, EPTFE, VE8 SERIES, 7.6mm OD Self adhesive patch, IP-67
Operating Temperature/RH	-20°C–60°C/5-100%
Storage Temperature/RH for Optimal Battery Life	-25°C–55°C/5-100%
Size	Clip variant: 101.9 mm x 62.7 mm x 31.8 mm non-clip variant: 101.9 mm x 62.7 mm x 54.8 mm
Weight	100 g without battery; add 15 g per battery.
Power Source	Battery powered: 2x (SEAL-EX) or 3x (SEAL) AA-cell LID with reverse polarity protection
Network technology/Frequency band	LoRaWAN EU868/US915/AS923/AU915/IN865/KR920/RU864
Air Interface	LoRa
Maximum Tx Power	15 dBm
Sensing Functions	GNSS, Accelerometer, BLE, Temperature, Pressure, Battery Gauge
GNSS Features	Support of GPS/QZSS, GLONASS, Galileo, BeiDou Support of up to 4 concurrent GNSSs

Parameter	Specification
	Data logging up to 3,000 entries Geofencing up to 4 circular geofences 2.5 m position accuracy (CEP 50%) TTFF: <ul style="list-style-type: none"> • 60 sec cold start • 5 sec hot start Sensitivity: <ul style="list-style-type: none"> • -160 dBm tracking and navigation • -148 dBm cold start • -157 dBm hot start
Accelerometer Sensitivity	Sample rate: 1 Hz, 10 Hz, 25 Hz, 50 Hz, 100 Hz, 200 Hz, 400 Hz Measurement range: $\pm 2 g$, $\pm 4 g$, $\pm 8 g$, $\pm 16 g$ Precision: 16 mg, 32 mg, 64 mg, 192 mg
Bluetooth Compatibility	BLE base on Bluetooth 5
BLE horizontal accuracy	$\leq 5 m$
BLE Sensitivity (0.1% BER)	125 kbps: -103 dBm 500 kbps: -98 dBm 2 Mbps: -91 dBm
BLE Danger Zones	Supports geofencing of up to 4 BLE mac address ranges
Temperature Measurement Accuracy	Accuracy: $< \pm 0.5^{\circ}C$
Barometric Pressure	Range: 300 to 1200 hPa Precision: $< \pm 0.002 hPa$ (or $\pm 0.02m$) Relative accuracy: $< \pm 0.06 hPa$ (or $\pm 0.5m$) Absolute accuracy: $< \pm 1 hPa$ ($\pm 8m$)
Event detection	Accelerometer for: <ol style="list-style-type: none"> 1. Fall detection 2. Motion detection to trigger device wakeup for sleep
Safety Harness Detection	Safety clip for tracking safety harness usage Elevation detection using onboard barometer for precise elevation tracking
Function button	1 panic button on side, easily accessible when worn. The button can: <ol style="list-style-type: none"> 1. trigger a panic report 2. trigger rapid reporting of location information 3. be acknowledged on the SEAL/SEAL-Ex by buzzing 4. be acknowledged on the SEAL/SEAL-Ex by LED flashing
LED	Total of five (5) amber colored LEDs All LEDs are used <ol style="list-style-type: none"> 1. As an indicator to confirm SEAL/SEAL-Ex is in any form of emergency (e.g., periodic flashing when emergency states are active) 2. As an indicator of Low battery warning (e.g., periodic flashing when battery low) 3 front LEDs used <ol style="list-style-type: none"> 1. As a Lora uplink indicator 2. As an Indication of the SEAL/SEAL-Ex going into DEEP SLEEP

Parameter	Specification
Audio/mechanical indicator	1 buzzer to provide physical feedback when panic button is pressed
Battery Fuel Gauge Features	1 current sense system for measuring battery current and estimating battery lifetime
Battery Lifetime	1.5 years for non-ATEX version, 11 months for ATEX version

1.3 Transducer Details

The SEAL/SEAL-Ex is equipped with a number of different transducers. A general overview of the transducers is given below.

- GNSS: 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. 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
 - Position accuracy (50% CEP): 2.5m¹
 - Time to first fix: Cold start: 1-minute, Hot start: 5s
- BLE: 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.
- Accelerometer: 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 $\pm 2g/\pm 4g/\pm 8g/\pm 16g$ and is capable of measuring accelerations with output data rates from 1 Hz to 5.3 kHz.
- 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

¹ Calculated from 6 hours of continuous multi-constellation fixes in static open and clear sky.

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

- a. Operation range: Pressure: 300 –1200 hPa, temperature: -40 – 85 °C
 - b. Pressure sensor precision: ± 0.002 hPa (or ± 0.02 m) (high precision mode).
 - c. Relative accuracy: ± 0.06 hPa (or ± 0.5 m)
 - d. Absolute accuracy: ± 1 hPa (or ± 8 m)
 - e. Temperature accuracy: $\pm 0.5^\circ\text{C}$.
5. Current Sense Resistor: The 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.

2 Installation

2.1 Included Product and Installation Material

The following items are shipped with each Tracker:

- SEAL/SEAL-Ex in a ruggedized IP67 enclosure with two LID AA batteries and three LID batteries installed for ATEX and non-ATEX versions respectively. The Tracker comes with a belt and harness clip for clipping the SEAL to overalls, harness or hard hat.

2.2 Safety Precautions

The following safety precautions should be observed:

- Use only LID cells.
- Should the SEAL/SEAL-Ex be opened and powered externally, do not exceed the maximum specified terminal voltages – 3v for ATEX versions and 4.5v for non-ATEX versions
- All installation practices must be in accordance with the local and national electrical codes.

2.3 Unpacking and Inspection

The following should be considered during the unpacking of a new SEAL/SEAL-Ex:

- Inspect the shipping carton and report any significant damage to TEKTELIC.
- Unpacking should be conducted in a clean and dry location.
- Do not discard the shipping box or inserts as they will be required if a unit is returned for repair or re-configuration.

2.4 Commissioning and Activation

The SEAL/SEAL-Ex is shipped in closed enclosure with the batteries installed and engaged. However, the SEAL/SEAL-Ex is in a state of DEEP SLEEP where it draws infinitesimal current, until it is woken up (activated) by a button pattern.

The SEAL/SEAL-Ex does not need to get opened for activation. Assuming that the SEAL/SEAL-Ex has been commissioned on the NS using the commissioning info provided with the SEAL/SEAL-Ex, use the button pattern to wake up the Tracker as listed below. A button press is achieved by pressing the mute button and feeling a click. A mute button release is achieved by releasing the mute button.

Here are the steps required to activate the button pattern:

1. Press the mute button for 1s, then release the mute button.
2. Press the mute button for at least 3 sec but less than 10 sec, then release the mute button.

As soon as the specified mute button press is applied to the SEAL/SEAL-Ex, the SEAL/SEAL-Ex wakes up from the DEEP-SLEEP state and tries to join the network. See Section 4.3 for the expected LED behaviour of the Tracker during the join process. It may take about 5 sec from the SEAL/SEAL-Ex wake-up to seeing the LED activity showing join attempts.

Note that the specified button press pattern always triggers a module reset, even during normal operation. The mute button is located on the base of all the SEAL/SEAL-Ex variants as shown below.



Figure 2-1: SEAL/SEAL-Ex with clip showing the mute button.

The SEAL/SEAL-Ex can be put into DEEP SLEEP at anytime by applying the pattern described above while the device is trying to join the network (this is indicated by rapid flashing of the top LEDs). If put to DEEP SLEEP, the SEAL/SEAL-Ex can be woken up (re-activated) again using the same procedure explained above. Removing and reinserting the batteries can also reset the SEAL/SEAL-Ex.

Note: Removing and replacing the batteries of the SEAL/SEAL-Ex does not cause the Tracker to go to DEEP SLEEP. As soon as new batteries are inserted, the SEAL/SEAL-Ex boots up and tries to join the network.

2.5 Mounting

On the battery side of the enclosure, there are four clip holes that can be used to clip the SEAL/SEAL-Ex to a belt or harness clip as shown in see Figure 2-2 below. The recommended clipping screw type is M3 5mm stainless steel screws. Separate mounting screws are not provided with the SEAL/SEAL-Ex.



Figure 2-2: The Tracker clipped to a belt clip (Left) and harness clip (Right).

2.6 Battery Replacement

Open up the SEAL/SEAL-Ex using a 1.5mm internal hex screwdriver. The SEAL/SEAL-Ex has 6x 1.5mm hex enclosure screws at the battery-side of the enclosure. Be careful not to misplace the back-cover or any of the screws and washers.

To replace the batteries, use AA-size, 1.5 V, LID batteries. The SEAL/SEAL-Ex can operate with two or three batteries, depending on the type of variant it is (2x for ATEX, 3x for non-ATEX).

Once the batteries make contact with the terminals, the SEAL/SEAL-Ex is powered ON and tries to join the network, with its LEDs behaving as described in Section 4.34.3. Fit the back cover and tighten the screws to keep the batteries in place. Make sure the screws are properly aligned with the screw inserts before tightening the screws. Tighten the 6 cover screws to 2.5 lbf-in (30 N-cm).

3 Power up, Commissioning, and Monitoring

3.1 Required Equipment

No special equipment is required to power on the SEAL/SEAL-Ex.

3.2 Power Up/Down Procedure

Once the sensor information has been added to the Network Server, press the mute button pattern explained in Section 2.4. The batteries must be removed to turn off the device, but the mute button pattern can be pressed to simply reset the device.

4 Operation, Alarms, and Management

4.1 Configuration

The SEAL/SEAL-Ex supports a full range of OTA configuration options. Specific technical details are available in the SEAL/SEAL-Ex TRM [1]. All configuration commands need to be sent OTA during a SEAL/SEAL-Ex's receive windows.

4.2 Default Configuration

The default configuration on the Tracker is:

- Report the remaining battery capacity in percentage once every day.
- Report GNSS position fix coordinates, time stamp and groundspeed once every 15 mins in NORMAL mode and once every minute in EMERGENCY mode
- Report the Safety status once every 5 minutes in NORMAL mode and once every minute in EMERGENCY mode

4.3 LED Behaviour

See Figure 1-3 for the location and identification of the SEAL/SEAL-Ex LEDs.

During the boot and join process:

- All LEDs are turned OFF when power is first applied.
- All three front LEDs are turned on when the device health self-check begins
 - If the front LED flashes rapidly after they were turned off, then the self checks have failed. Consider replacing the batteries, or moving the SEAL/SEAL-Ex to an environment within the temperature range.
 - If the top LED flashes rapidly after the front LEDs are turned off, then the self checks have passed. The SEAL/SEAL-Ex moves to the net step below.
- After a small delay (< 10 seconds) the top LEDs start blinking rapidly indicating the SEAL/SEAL-Ex is trying to join the network. During this time the SEAL/SEAL-Ex sends join request uplinks at least once every 10s, with the front LED blinking every time a join request is sent. If the SEAL/SEAL-Ex is not successful in joining the network after one hour, the SEAL/SEAL-Ex backs off the joining process by reducing the rate at which it sends the join request to a significantly lower rate to conserve battery. The flash rate of the LEDs is also reduced to once every 10s.
- During normal operation, the front LED blinks whenever LoRa uplink activity occurs on the Tracker (transmitting packets).

4.4 Push Buttons

The SEAL/SEAL-Ex has two common push buttons: one on the side called the emergency/panic button used for activating and deactivating the emergency mode, and another on the base of the SEAL/SEAL-Ex called the mute button used for muting and unmuting the buzzer, and resetting and putting the SEAL/SEAL-Ex to and out of deep sleep (check Section 2.4 for more information)

SEAL and SEAL-Ex with clip variants have a third button at the front of the device, used for detecting safety harness connection. See Figure 1-3 for an illustration of where all the buttons are positioned.

4.5 Activation, Putting to DEEP SLEEP, Resetting, and Shutting Down

Table 4-1 shows how to activate, put to DEEP SLEEP, reset, or completely turn off the SEAL/SEAL-Ex.

Table 4-1: How to Activate, Put to DEEP SLEEP, Reset, or Shut Down SEAL/SEAL-Ex

Desired Action	What to Do
Activate out of DEEP SLEEP	<ul style="list-style-type: none">Apply the specified mute button pattern described in Section 2.4 to a SEAL/SEAL-Ex in deep sleep (this step does not require opening the SEAL/SEAL-Ex)
Put to DEEP SLEEP	<ul style="list-style-type: none">Apply the specified mute button pattern described in Section 2.4 while the SEAL/SEAL-Ex is trying to join the network
Reset	Apply the specified mute button pattern described in Section 2.4 to the SEAL/SEAL-Ex in operation (this step does not require opening the SEAL/SEAL-Ex) OR: <ul style="list-style-type: none">Remove and reinsert the batteries
Completely power off	<ul style="list-style-type: none">Remove the batteries

NOTE: Shutting down or resetting the SEAL/SEAL-Ex will cause all unsaved user configurations to be lost. Save your desired configuration to the flash before powering off, putting to DEEP SLEEP, or resetting the SEAL/SEAL-Ex.

5 Compliance Statements

Federal Communications Commission:

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

1. This device may not cause harmful interference, and
2. This device must accept any interference received, including interference that may cause undesired operation.

To comply with FCC exposure limits for general population / uncontrolled exposure, this device has lowered its maximum power to comply with SAR limits for wearable devices and must not be co-located or operating in conjunction with any other transmitter.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment. This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one of the following measures:

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

Innovation, Science and Economic Development Canada


This device contains licence-exempt transmitter(s)/receiver(s) that comply with Innovation, Science and Economic Development Canada's licence-exempt RSS(s). Operation is subject to the following two conditions:

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

L'émetteur/récepteur exempt de licence contenu dans le présent appareil est conforme aux CNR d'Innovation, Sciences et Développement économique Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes:

- a. L'appareil ne doit pas produire de brouillage.*
- b. L'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.*

California Proposition 65:

 **WARNING:** This product can expose you to chemicals including lead, nickel, and carbon black, which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information, go to www.P65Warnings.ca.gov.

References

- [1] Tektelic Communications, T0007705_TRM_v1.0.
- [2] LoRa Alliance, "LoRaWAN Specification," ver. 1.0.2, July 2016.
- [3] LoRa Alliance, "LoRaWAN 1.0.2 Regional Parameters," rev. B, Feb 2017.