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Agriculture Sensor

Technical Reference Manual

Document Type:	Technical Reference Manual
Document Number:	T0005978_TRM
Document Version:	1.5
Product Name:	Agriculture Sensor
Product Codes:	T0005982 (Agriculture Sensor, Soil Surface Mount Module, NA)
	T0005983 (Agriculture Sensor, Soil Surface Mount Module, EU)
	T0005986 (Agriculture Sensor, Elevated Mount Module, NA)
	T0005987 (Agriculture Sensor, Elevated Mount Module, EU)
Release Date:	September 23, 2020

Revision History

Version	Date	Editor	Comments
0.1	May 29, 2019	Reza Nikjah	• Initial release
0.2	May 30, 2019	Reza Nikjah	• Edited based on feedback
0.3	Jun 14, 2019	Devin Smith	• Revisions based on implementation
0.4	Nov 21, 2019	Mark Oevering	• Updated PN's for modules
0.5	Jan 15, 2020	Reza Nikjah	• Various updates
0.6	April 21, 2020	Mark Oevering	• Changed ALS thresholds. • Made changes to specify separate information for Soil Surface Mount and Elevated Mount modules. • Various changes based on feedback from Reza & Gin. • Change to register 70 description. • Change to battery status register. • Change to naming of both modules. • Change to default configuration for both sensors; disabled ambient temperature and humidity.
1.0	April 21, 2020	Mark Oevering	• Release
1.1	June 5, 2020	Mark Oevering	• Change to default configuration for Soil Surface Mount • Changed formula for battery voltage, Table 2-1, Page 13 • Added ALS sample period for inactive state, Table 3-7
1.2	June 15, 2020	Mark Oevering	• Change to Input 1 conversion Section 2.2.1
1.3	July 6, 2020	Mark Oevering	• Correction to Table 2-1
1.4	July 31, 2020	Mark Oevering	• Correction to battery calculation, Table 2-1
1.5	September 23, 2020	Mark Oevering	• Fixes in Table 3-6 Description column. • Fixed typo on Register 0x 0C 67, was 1 byte, now 2 bytes (Table 2-1)

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Acronyms and Glossary

ABP .... activation by personalization
ADR .... adaptive data rate
ALS .... ambient light sensor
cbar .... centibar
CRC .... cyclic redundancy check
DL .... downlink
DR .... data rate
EIRP .... effective isotropic radiated power
EoS .... end of service
FALSE .... logical "false"
Flash memory .... Non-volatile memory located on the Home Sensor, which contains application and configuration settings
FW .... firmware
GWC .... gravimetric water content
ID .... identity / identifier
IoT .... Internet of things
ISM .... industrial, scientific, and medical
LoRa .... a patented "long-range" IoT technology acquired by Semtech
LoRAMAC .... LoRaWAN MAC
LoRaWAN .... LoRa wide area network (a network protocol based on LoRa)
LoRaWAN Commissioning the unique device identifiers and encryption keys used for LoRaWAN communication (see LoRaWAN Specification [1] for more details).
LSB .... least significant bit
LTC .... lithium thionyl chloride (the chemistry of LTC batteries)
lx .... lux
MAC .... medium access control
MCU .... microcontroller unit
min .... minute
ms .... millisecond(s)
MSB .... most significant bit
NS ....network server
OTA ....over-the-air
OTAA ....OTA activation
Reg ....register
RH ....relative humidity
RF....... .... radio frequency

RO............................... read-only
R/W............................ read/write
Rx .... receiver
sec .... second
Sensor .... LoRa IoT Agricultural Sensor module
Sensor and Probe....... LoRa IoT Soil Surface Mount Agricultural Sensor and Probe module
SW .... software
Transducer .... the sensing element attached to the Industrial Sensor, e.g. the temperature and RH transducer
TRM............................ technical reference manual
TRUE........................... logical "true"
TX .... transmitter
UL .... uplink

1 Overview

This TRM describes the UL and DL frame payloads supported by the LoRa IoT Agricultural Soil Surface Mount Sensor, referred to as the Soil Surface Mount Sensor henceforth, and by the LoRa IoT Agricultural Elevated Mount Sensor, referred to as the Elevated Mount Sensor henceforth.

This document is intended for a technical audience, such as application developers, with an understanding of the NS and its command interfaces.

This TRM is only applicable to the Agricultural Sensor modules listed in Table 1-1.

Both the Soil Surface Mount Sensor and the Elevated Mount Sensor are LoRaWAN IoT sensors intended for agricultural measurements. They are powered by a C-cell LTC battery and utilize a small IP67 casing. Both sensors features operating temperature of -40°C to 85°C, an ambient temperature and RH transducer, MCU temperature transducer, ALS , and accelerometer (for movement, or orientation change detection). **PLEASE NOTE; if the unit is placed in direct sunlight the temperature reported will not be ambient temperature of the environment but sensor case temperature. Temperature and humidity reporting are turned off in the SW by default for this reason in the Elevated Mount module. These functions can be turned on by the user depending on the use case.**

Both sensors are also equipped with a battery gauge which sends an EoS alarm[1] when the battery capacity left is approximately 5%. The battery lifetime of the Soil Surface Mount sensor or the Elevated Mount sensor is expected to be at least 10 years.[2]

The Elevated Mount Sensor provides an interface to two Watermark probes (Inputs 5 and 6) and two analog inputs (Inputs 3 and 4). Inputs 3 and 4 are intended to be used with the thermistors that are supplied alongside the Watermark probes.

When paired with the probes (metal spikes), the Sensor forms the Soil Surface Mount module. The Probe is interfaced to two inputs of the Sensor and provides measurements for soil moisture (GWC) and soil temperature.

Table 1-1 presents the currently available Agriculture Sensor HW variants. Also, Table 1-2 lists the Agriculture variants for the different RF regions identified by the LoRa Alliance [2]—also see [2] for the Tx and Rx bands in each LoRaWAN region.

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[1] The EoS alarm is not supported in SW prior to version 1.0.

[2] This is for transmission at maximum power every 15 minutes at room temperature, with an LTC battery having a nominal capacity of 8.5 Ah and self-discharge rate of 0.7%. Large variations to this estimate can occur depending on the ambient temperature, amount of usage, battery capacity, and battery self-discharge rate. For example, continuously being at -30°C and transmitting at maximum power every minute, the same battery may not last above a year.

Table 1-1: Agricultural Sensor Models

Product Code	Description	LoRa RF Region and Band
T0005982	Module, Agriculture Sensor, Soil Surface Mount, LoRa, NA	US915: 902-928 MHz (ISM Band)
T0005983	Module, Agriculture Sensor, Soil Surface Mount, LoRa, EU	EU868: 863-870 MHz (ISM Band)
T0005986	Module, Agriculture Sensor, Elevated Mount, LoRa, NA	US915: 902-928 MHz (ISM Band)
T0005987	Module, Agriculture Sensor, Elevated Mount, LoRa, EU	EU868: 863-870 MHz (ISM Band)

Table 1-2: Agriculture Sensor Region Specific Variants

LoRaWAN RF Variant	Corresponding HW Variant	Order Code
EU868	EU T0005983	AGRSNPEU868
EU868	EU T0005987	AGRSNNEU868
US915	NA T0005982	AGRSNPUS915
US915	NA T0005986	AGRSNNUS915
AS923	NA T0005982	AGRSNPAS923
AS923	NA T0005986	AGRSNNAS923
AU915	NA T0005982	AGRSNPAU915
AU915	NA T0005986	AGRSNNAU915
IN865	EU T0005983	AGRSNPIN865
IN865	EU T0005987	AGRSNNIN865
KR920	NA T0005982	AGRSNPKR920
KR920	NA T0005986	AGRSNNKR920
RU864	EU T0005983	AGRSNPRU864
RU864	EU T0005987	AGRSNNRU864

Information streams currently supported by the SW are as follows:

- Readings obtained from on-board transducers (***sent in UL, LoRaWAN port 10***)
- Configuration and control commands from the NS used to change the Sensor's behavior in the DL (***sent in DL, LoRaWAN port 100***)
- Response to configuration and control commands from the NS (***sent in UL, LoRaWAN port 100***)

The default configuration of the **Soil Surface Mount** Sensor for reporting transducer readings includes the following:

- Report battery status every day.
- Report ambient temperature every 15 min.
- Report relative humidity every 15 min.
- Report soil moisture every 15 min.
- Report soil temperature every 15 min.
- Report ambient light every 15 min.

The default configuration of the **Elevated Mount** Sensor for reporting transducer readings includes the following:

- Report battery status every day.
- Report Input 5 every 15 min.
- Report Input 6 every 15 min.
- Report ambient light every 15 min.

1.1 Reed Switch Operation

The Agriculture Sensor is equipped with a magnetic reed switch. The reed switch can be operated by the provided magnet, and is used for the following purposes:

1) MCU reset upon observing a specified magnetic pattern:

   This is mainly used to wake up the module from DEEP SLEEP and having it try to join the network. When the module comes out of the factory, it is in the DEEP SLEEP mode,[4] and can be activated using the specified magnetic pattern. Also, the same magnetic pattern can just be used to reset the Agriculture Sensor during normal operation, getting it to try to rejoin the network.

   The magnetic pattern in this application is hard coded (not user configurable) as illustrated in Figure 5. A magnet presence is achieved by attaching the magnet to the

[4] The Agriculture Sensor will go to DEEP SLEEP whenever the internal sleep button on the PCBA (labeled SW1) is pressed. This is performed as the last step in the factory before closing the enclosure. The only ways to activate the module out of DEEP SLEEP is to apply the specified magnetic pattern or to open the enclosure and remove and reinsert the battery.

enclosure at the magnet sign. A magnet absence is achieved by taking the magnet away from the enclosure. The magnet sign is illustrated in Figure 1-1 below:

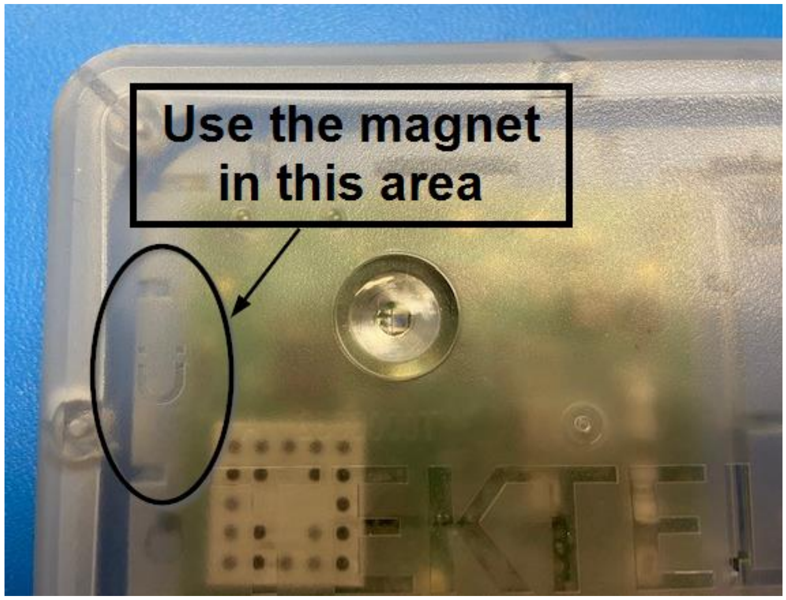


Figure 1-1: Reed Switch Location

Here are the steps as illustrated in Figure 1-2:

1. Attach the magnet to the enclosure at the magnet sign, and hold it for at least 3 sec but less than 10 sec.
2. Keep the magnet away for at least 3 sec.

As soon as the specified magnetic pattern is applied to the Agriculture Sensor, the Agriculture Sensor is reset and tries to join the network. It may take about 10 sec from the Agriculture Sensor reset to seeing the LED activity showing join attempts. Therefore, as step 1 in the above is completed, it takes about 13 seconds before observing the LED activity (if step 2 is respected).

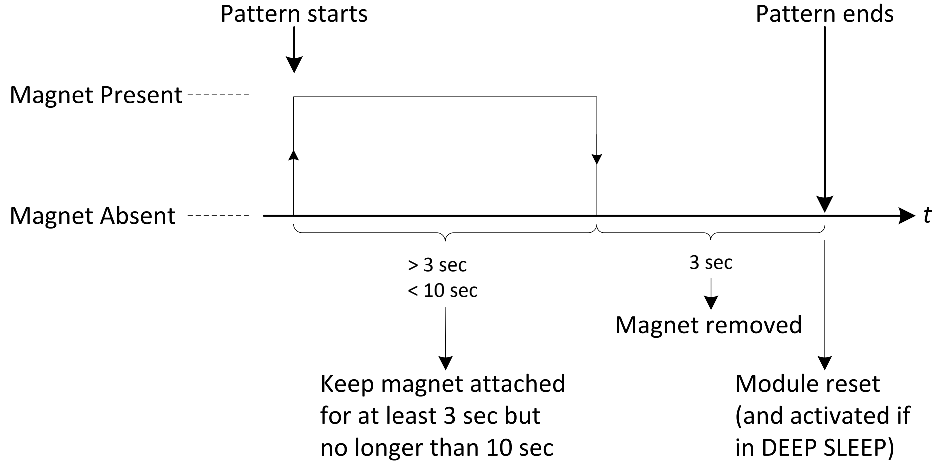


Figure 1-2: Agriculture Sensor magnetic reset/wake-up pattern

2) Triggering the Agriculture Sensor to uplink something upon observing a magnetic pattern:

   This is used to get the LoRaWAN Class-A Agriculture Sensor to open a receive window so it can receive DL commands from the NS, or simply to trigger the Agriculture Sensor to uplink some desired transducer data.

   The magnetic pattern in this case is not user configurable, and involves attaching and taking away the magnet to and from the magnet sign at the top of the enclosure once, all in less than 2 sec, as shown in Figure 6. It is important to note here that mistakenly holding the magnet attached to the module for more than 3 sec may trigger a module reset, as explained in item 1.

   It is configurable what is uplinked when such a reed switch event is registered.

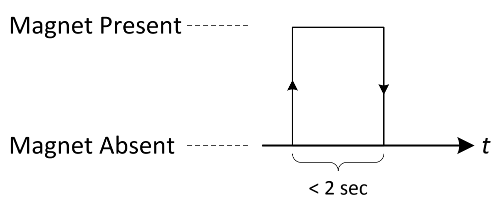


Figure 1-3: Agriculture Sensor magnetic UL-triggering pattern

Note: Replacing the batteries of the Agriculture Sensor does not cause the Agriculture Sensor to go to DEEP SLEEP. As soon as a new battery is inserted, the Agriculture Sensor boots up and tries to join a LoRaWAN network.

2 UL Payload Formats

The UL streams (from the Sensor to the NS) include;

- the readings obtained from on-board transducers (sent on LoRaWAN port 10);
- Response to configuration and control commands from the NS (sent on LoRaWAN port 100)

These are explained in Sections 2.1 & 2.2, respectively.

2.1 Frame Payload to Report Transducers Data

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

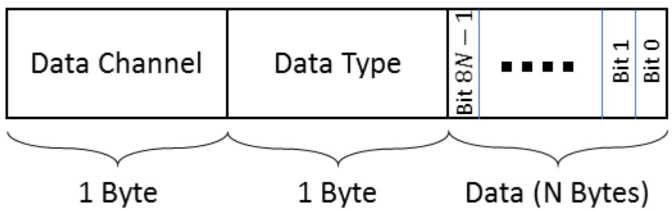


Figure 2-1: The UL frame payload format

A Sensor message payload can include multiple transducer data frames. Frames can be arranged in any order. A single payload may include data from any given transducer. The Agricultural Sensor frame payload values for transducers data are shown in Table 2-1. In this table, B_i refers to data byte indexed *i* as shown in Table 2-1. Transducers data in the UL are sent through ***LoRaWAN port 10***.

Table 2-1: UL Frame Payload Values for Transducers Data

Information Type	Channel ID	Type ID	Size (Bytes)	Data Type	Data Format	JSON Variable (Type/Unit)
Battery Status	0x00	0xBA[5]	1	Analog	• Bits 0-6: $(\text{Voltage} * 10\text{mV}) + 2.5$[6] • Bit 7: EoS Alert (0 = No Alert, 1 = Alert)[7]	*battery_voltage: <value> (unsigned/10mV/LSB)* *eos_alert: <value> (unsigned/no unit)*

[5] For SW version 0.2.5, this register is 0x 00 FF.

[6] For SW version 0.2.5, data format is unsigned, 1%/LSB.

[7] Not supported in software version 0.3 or less.

Input 1 (Soil Moisture)[8]	0x01	0x04	2	Count	• Unsigned • 1 kHz/LSB	*input1_frequency: <value> (unsigned/Hertz)*
Input 2 (Soil Temperature)[9]	0x02	0x02	2	Analog	• Unsigned • 1 mV/LSB	*input2_voltage: <value> (unsigned/volt)*
Input 3 (Analog)	0x03	0x02	2	Analog	• Unsigned • 1mV/LSB	*Input3_voltage: <value> (unsigned/volt)*
Input 4 (Analog)	0x04	0x02	2	Analog	• Unsigned • 1mV/LSB	*Input4_voltage: <value> (unsigned/volt)*
Watermark 1 (Soil Water Tension)[10]	0x05	0x04	2	Count	• Unsigned • 1 Hz/LSB	*watermark1: <value> (unsigned/Hz)*
Watermark 2 (Soil Water Tension)[11]	0x06	0x04	2	Count	• Unsigned 1 Hz/LSB	*watermark2: <value> (unsigned/Hz)*
Ambient Light Intensity	0x09	0x65	2	Illuminance	• Unsigned • 1 lx/LSB	*light_intensity: <value> (unsigned/lux)*
Ambient Light Alarm	0x09	0x00	1	Digital	• Boolean • 0x00 = No alarm 0xFF = Alarm	*light_detected: <value> (unsigned/no unit)*
Accelerometer Data	0x0A	0x71	6	Accelerometer	• B_0-B_1: X data • B_2-B_3: Y data • B_4-B_5: Z data • Signed 1 milli-g/LSB	*acceleration { xaxis: <value>, (signed/g) yaxis: <value>, (signed/g) zaxis: <value> (signed/g) }*

[8] The raw reading should be converted to soil moisture for the **SOIL SURFACE MOUNT** sensor. This will be provided in the data converter provided by Tektelic.

[9] The raw reading should be converted to soil temperature for the **SOIL SUFACE MOUNT** sensor. This will be provided in the data converter provided by Tektelic.

[10] The raw reading should be converted to soil water tension (kPa) for the **ELEVATED MOUNT** sensor. This will be provided in the data converter provided by Tektelic.

[11] The raw reading should be converted to soil water tension (kPa) for the **ELEVATED MOUNT** sensor. This will be provided in the data converter provided by Tektelic.

Orientation Alarm	0x0A	0x00	1	Digital	• Boolean • 0x00 = No orientation alarm • 0xFF = Orientation alarm	*orientation_alarm: <value> (unsigned/no unit)*
Ambient Temperature	0x0B	0x67	2	Temperature	• Signed • 0.1°C/LSB	*ambient_temperature: <value> (signed/celsius)*
Ambient RH	0x0B	0x68	1	RH	• Unsigned • 0.5%/LSB	*relative_humidity: <value> (unsigned/1% percentage)*
MCU Temperature	0x0C	0x67	2	Temperature	• Signed • 0.1°C/LSB	*mcu_temperature: <value> (signed/celsius)*

Example Uplink Payloads

- 0x 01 04 05 79 02 02 02 d5 0a 00 ff
  - 0x 01 04 (Soil Moisture) = 0x 05 79 = 1401kHz
  - 0x 02 02 (Soil Temperature) = 0x 02 d5 = 725mV
  - 0x 0a 00 (Orientation alarm) = 0x ff = orientation alarm
- 0x 00 ff 01 68
  - 0x 00 ff (Battery Report) = (0x 01 68) x 1% = 360 x 0.01 = 3.6V
- 0x 09 65 00 00 0b 67 00 e1 0b 68 92
  - 0x 09 65 (Ambient Light Intensity) = 0x 00 00 = 0 lux (no light)
  - 0x 0b 67 (Ambient Temperature) = (0x 00 e1) x 0.1°C = 22.5°C
  - 0x 0b 68 (Ambient RH) = (0x 92) x 0.5% = 73%

2.2 Data Conversions for Inputs 1, 2, & Watermarks 1, 2

2.2.1 Soil Moisture (Input 1) Conversion

Input 1 readings are a frequency presented in **kHz**. Please refer to Table 2-2 below for a conversion from frequency to GWC.

Table 2-2 Input 1 GWC Conversion

GWC	Frequency range	
Dry	1402	1399
0.1	1399	1396
0.2	1396	1391
0.3	1391	1386
0.4	1386	1381
0.5	1381	1376
0.6	1376	1371
0.7	1371	1366
0.8	1366	1361
0.9	1361	1356
1	1356	1351
1.1	1351	1346
1.2	1346	1341
Wet	1341	1322

2.2.2 Soil Temperature (Input 2) Conversion

Input 2 will provide a voltage reading. This formula can be used to convert the mV reading from Input 2 to a temperature: **-32.46ln(x) + 236.36**
x = mV reading from Input 2 (register 0x 02 02)
The Excel worksheet below acts as a look-up table for the conversion of mV to soil temperature.

Microsoft Excel
Worksheet

2.2.3 Watermark 1 & 2 Conversion

Watermark 1 & 2 will provide frequency readings. A reading of soil temperature from the thermistor will also be taken into account when calculating the final kPa value of soil water tension, for increased accuracy.

Final kPa of soil water tension is calculated by the following steps:

1) Obtain a reading of the frequency from Watermarks 1 or 2 or both. These are registers 0x 05 04 and 0x 06 04 respectively. Table 2-4 below can be used for conversion of the frequencies read from the Watermarks to get an **initial** kPa value. From Table 2-4, use the column on the right to find the appropriate range that the reading from the Watermarks fits into. Then use the formula directly to the left (from the left column) to calculate the kPa of soil water tension.

Table 2-3 Watermark 1 & 2 Conversion

kPa = 0	for Hz > 6430
kPa = 9 - (Hz - 4330) * 0.004286	for 4330 <= Hz <= 6430
kPa = 15 - (Hz - 2820) * 0.003974	for 2820 <= Hz <= 4330
kPa = 35 - (Hz - 1110) * 0.01170	for 1110 <= Hz <= 2820
kPa = 55 - (Hz - 770) * 0.05884	for 770 <= Hz <= 1110
kPa = 75 - (Hz - 600) * 0.1176	for 600 <= Hz <= 770
kPa = 100 - (Hz - 485) * 0.2174	for 485 <= Hz <= 600
kPa = 200 - (Hz - 293) * 0.5208	for 293 <= Hz <= 485
kPa = 200	for Hz < 293

2) Obtain a reading from input 3 or 4 or both. These are registers 0x 03 02, 0x 04 02 respectively. Use the equation below to calculate a temperature from the mV reading.

   Temp = -31.96ln(x)+213.25

   x = mV reading from input 3 or 4

   This calculation represents the **soil temperature.**

3) Perform this next step only if the soil temperature varies from 24°C. Using the initial kPa value calculated in step #1, and the soil temperature calculated in step #2, calculate a 'temperature adjusted' kPa of soil water tension by using this formula:

from step #2

$$kPa_{24} := kPa * (1 - 0.019 * (°C - 24)$$

from step #1

2.3 Response to Configuration and Control Commands

Sensor responses to DL configuration and control commands (which are sent on LoRaWAN port 100; see Section 3.1) are sent in the UL on ***LoRaWAN port 100***. These responses include:

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

In the former case, the Sensor responds by the address and value of each of the registers under inquiry (this can be in one or more consecutive UL packets depending on the maximum frame payload size allowed). In the latter case, the Sensor responds with a CRC32 of the entire DL payload (which may be a combination of read and write commands) as the first four bytes of the UL frame. If the DL payload has also had read commands, the four CRC32 bytes are followed by the address and value of each of the registers under inquiry (similar to the Sensor response in the former case).

3 DL Payload Formats

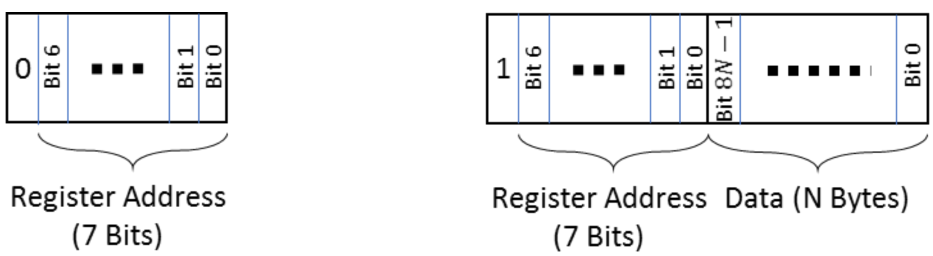
The DL stream (from the NS to the Sensor) supported by the SW includes; Configuration and control commands used to change the Sensor's behavior (sent on LoRaWAN port 100), and is explained in Section 3.1.

3.1 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 3-1. A big-endian format (MSB first) is always followed.

The Command Field has a "register" address that is used to access various configuration parameters. These addresses are bound between 0x00 and 0x7F.

Bit 7 of the Command Field determines whether a read or write action is being performed. To write to a register, this bit must be set to 1 (one), but to read a register, it must be set to 0 (zero). 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 3-1: The format of a DL configuration and control message block

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

When a write command is sent to the Sensor, the Sensor immediately responds with a CRC32 of the entire DL payload as the first 4 bytes of the UL frame on ***LoRaWAN port 100*** (also see Section 2.3).

DL configuration and control commands fall into one of the following 4 (four) categories and are discussed in Sections 3.1.1, 3.1.2, and 3.1.3, respectively:

- LoRaMAC Configuration
- Application Configuration
- Command and Control

3.1.1 LoRaMAC Configuration

LoRaMAC options can be configured using DL commands. These configuration options change the default MAC configuration that the Sensor loads on start-up. They can also change certain run-time parameters. Table 3-1 shows the MAC configuration registers. In this table, B_i refers to data byte indexed *i* as defined Figure 3-1.

Table 3-1: LoRaMAC Configuration Registers

Address	Access	Value	Size (Bytes)	Description	JSON Variable (Type/Unit)
0x10	R/W	Join Mode	2	• Bit 15: 0/1 = ABP/OTAA mode • Bits 0-14: Ignored	*loramac_join_mode: <value>* *(unsigned/no unit)*
0x11	R/W	• Unconfirmed/ Confirmed UL • Disable/Enable Duty Cycle • Disable/Enable ADR	2	• Bit 0: 0/1 = Unconfirmed/Confirmed UL • Bit 1 = 1 (RO): 0/1 = Private/Public Sync Word • Bit 2: 0/1 = Disable/Enable Duty Cycle • Bit 3: 0/1 = Disable/Enable ADR • Bits 4-11: Ignored • Bits 12-15: 0x0: Class A 0xC: Class C	*loramac_opts {* *confirm_mode: <value>,* *(unsigned/no unit)* *sync_word: <value>,* *(unsigned/no unit)* *duty_cycle: <value>,* *(unsigned/no unit)* *adr: <value>* *(unsigned/no unit)* *}*
0x12	R/W	• Default DR number • Default Tx Power number[17]	2	• Bits 8-11: Default DR number • Bits 0-3: Default Tx power number • Bits 4-7, 12-15: Ignored	*loramac_dr_tx {* *dr_number: <value>,* *(unsigned/no unit)* *tx_power_number: <value>,* *(unsigned/no unit)* *}*
0x13	R/W	• Rx2 window channel frequency	5	• Bits 8-39: Channel frequency in Hz for Rx2 • Bits 0-7: DR for Rx2	*loramac_rx2 {* *frequency: <value>,* *(unsigned/Hertz)*

[17] Tx power number m translate to the maximum Tx power, which is a function of the LoRaWAN RF region, minus $2 \times m$ dB.

		• Rx2 window DR number			*dr_number: <value> (unsigned/no unit)* *}*

Note: Modifying these values only changes them in the Sensor device. Options for the Sensor in the NS also need to be changed in order to not strand a Sensor. Modifying configuration parameters in the NS is outside the scope of this document.

3.1.1.1 Default Configuration

Table 3-2 and Table 3-4 list the default values for the LoRaMAC configuration registers (cf. [1], [2]).

Table 3-2: Default Values of LoRaMAC Configuration Registers

Address	Default Value
0x10	• OTAA mode
0x11	• Unconfirmed UL • Duty cycle enabled[18] • ADR enabled • Class A
0x12	• DR0 • Tx Power 0 (max power; see Table 3-3)
0x13	• As per Table 3-4

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

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

[18] In the LoRa RF regions where there is no duty cycle limitation, such as US915, the "enabled duty cycle" configuration of the Sensor is ignored.

Table 3-4: Default Values of Rx2 Channel Frequency and DR Number in Different Regions

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

3.1.2 Application Configuration

This section lists all possible application configurations (as part of DL configuration and control commands), including periodic TX configuration, and threshold configuration.

3.1.2.1 Periodic TX Configuration

All periodic transducer reporting is synchronized around *1*. A *tick* is simply a user configurable time-base that is used to schedule transducer measurements. For each transducer, the number of elapsed *ticks* before transmitting can be defined, as shown in Table 3-5.

Table 3-5: Periodic Transmission Configuration Registers

Address	Access	Value	Size (Bytes)	Description	JSON Variable (Type/Unit)
0x20	R/W	Seconds per Core *Tick*	4	• *Tick* value for periodic events • Acceptable values: 0, 30, 61, …, 86400 • 0 disables all periodic transmissions • Other values: Invalid and ignored	*seconds_per_core_tick: <value>* *(unsigned/no unit)*
0x21	R/W	*Ticks* per Battery	2	• *Ticks* between battery reports • 0 disables periodic battery reports	*tick_per_battery: <value>* *(unsigned/no unit)*
0x22	R/W	*Ticks* per Ambient Temperature	2	• *Ticks* between ambient temperature reports • 0 disables periodic ambient temperature reports	*tick_per_ambient_temperature: <value>* *(unsigned/no unit)*

0x23	R/W	*Ticks* per Ambient RH	2	• *Ticks* between ambient RH reports • 0 disables periodic ambient RH reports	*tick_per_relative_humidity: <value> (unsigned/no unit)*
0x24	R/W	*Ticks* per Ambient Light	2	• *Ticks* between ambient light reports • 0 disables periodic ambient light reports	*tick_per_light: <value> (unsigned/no unit)*
0x25	R/W	*Ticks* per Input 1 (Soil Moisture)	2	• *Ticks* between Input 1 reports • 0 disables periodic Input 1 reports	*tick_per_input1: <value> (unsigned/no unit)*
0x26	R/W	*Ticks* per Input 2 (Soil Temperature)	2	• *Ticks* between Input 2 reports • 0 disables periodic Input 2 reports	*tick_per_input2: <value> (unsigned/no unit)*
0x27	R/W	*Ticks* per Input 3*	2	• *Ticks* between Input 3 reports • 0 disables periodic Input 1 reports	*tick_per_input3: <value> (unsigned/no unit)*
0x28	R/W	*Ticks* per Input 4*	2	• *Ticks* between Input 4 reports • 0 disables periodic Input 1 reports	*tick_per_input4: <value> (unsigned/no unit)*
0x29	R/W	*Ticks* per Watermark 1 (Soil Water Tension)*	2	• *Ticks* between Watermark 1 reports • 0 disables periodic Watermark 1 reports	*tick_per_watermark1: <value> (unsigned/no unit)*
0x2A	R/W	*Ticks* per Watermark 2 (Soil Water Tension)*	2	• *Ticks* between Watermark 2 reports • 0 disables periodic Watermark 2 reports	*tick_per_watermark2: <value> (unsigned/no unit)*
0x2C	R/W	*Ticks* per Accelerometer Data	2	• *Ticks* between accelerometer data reports • 0 disables periodic accelerometer data reports	*tick_per_accelerometer: <value> (unsigned/no unit)*

0x2D	R/W	*Ticks* per Orientation Alarm	2	• *Ticks* between orientation alarm reports • 0 disables periodic orientation alarm reports	*tick_per_orientation_alarm: <value> (unsigned/no unit)*
0x2E	R/W	Ticks per MCU Temperature	2	• *Ticks* between MCU temperature reports. • 0 disables periodic MCU temperature reports	*tick_per_mcu_temperature: <value> (unsigned/no unit)*

* *APPLICABLE ONLY TO THE **ELEVATED MOUNT** MODULE*

3.1.2.1.1 Seconds per Core Tick

All periodic TX events are scheduled in *ticks*. This allows for transducer reads to be synchronized, reducing the total number of ULs required to transmit Sensor data. The minimum seconds per *tick* is 30 seconds and the maximum is 86,400 seconds (one day). Values from 1 to 29 or above 86,400 are invalid and ignored. A value of 0 (zero) disabled all periodic reporting.

3.1.2.1.2 *Ticks* per <Transducer>

This register sets the reporting period for a transducer in terms of *ticks*. Once the configured number of *ticks* has expired, the Sensor polls the specified transducer and reports the data in an UL message. A setting of 0 (zero) disables periodic reporting for the specified transducer.

3.1.2.1.3 Default Configuration for **Soil Surface Mount**

Seconds per Core *Tick*	**900 sec (15 min)**
***Ticks* per Battery**	96 (1 day)
***Ticks* per Soil Moisture**	1 (15 min)
***Ticks* per Soil Temperature**	1 (15 min)
***Ticks* per Ambient Light**	1 (15 min)
***Ticks* per Ambient RH**	1 (15 min)
***Ticks* per Ambient Temperature**	1 (15 min)
***Ticks* per Input 3**	0 (disabled)
***Ticks* per Input 4**	0 (disabled)
***Ticks* per Watermark 1**	0 (disabled)
***Ticks* per Watermark 2**	0 (disabled)
***Ticks* per Accelerometer**	0 (disabled)
***Ticks* per Orientation**	0 (disabled)
***Ticks* per MCU temperature**	0 (disabled)

3.1.2.1.4 Default Configuration for **Elevated Mount**

Seconds per Core *Tick*	**900 sec (15 min)**
***Ticks* per Battery**	96 (1 day)
***Ticks* per Watermark 1**	1 (15 min)
***Ticks* per Watermark 2**	1 (15 min)
***Ticks* per Ambient Light**	1 (15 min)
***Ticks* per Input 3**	0 (disabled)
***Ticks* per Input 4**	0 (disabled)
***Ticks* per Ambient Temperature**	0 (disabled)
***Ticks* per Ambient RH**	0 (disabled)
***Ticks* per Soil Moisture**	0 (disabled)
***Ticks* per Soil Temperature**	0 (disabled)
***Ticks* per Accelerometer**	0 (disabled)
***Ticks* per Orientation**	0 (disabled)
***Ticks* per MCU temperature**	0 (disabled)

3.1.2.1.5 Default Example DL Messages

- Disable all periodic events:
  - 0x: A0 00 00 00 00 (Reg 20, write bit set to TRUE)—Seconds per Core *Tick* = 0 (disabled)
- Read the current “Seconds per Core *Tick*” value:
  - 0x: 20 (Reg 20, write bit set to FALSE)

- Write "Tick per Ambient Temperature" and "Ticks per Ambient RH":
    - 0x: A2 00 01 A3 00 02 (Reg 22 and Reg 23, write bit set to TRUE)—set "Ticks per Ambient Temperature" to 1 (one) and "Ticks per Ambient RH" to 2 (two)

3.1.2.2 Threshold-Based Configuration

The Sensor and the Sensor and Probe modules support a total of 9 threshold-based transmissions:

- Ambient Temperature
- Ambient RH
- Input 1 (Soil Moisture in the **Soil Surface Mount** module)
- Input 2 (Soil Temperature in **Soil Surface Mount** module)
- Input 3 (Analog input for the **Elevated Mount** module)
- Input 4 (Analog input for the **Elevated Mount** module)
- Watermark 1 (Soil Water Tension for **Elevated Mount** module)
- Watermark 2 (Soil Water Tension for **Elevated Mount** module)
- MCU Temperature

When a threshold is enabled, the Sensor (and Probe) reports the transducer value when it leaves the configured threshold window, and once again when the transducer value re-enters the threshold window. Inside the configured threshold window is called the Idle State. Outside the window is the Active Sate.

The threshold mode can be enabled concurrently with periodic reporting. The sensor transducer will be reported at its scheduled periodic interval, and also if the threshold is triggered. Table 3-6 shows configuration parameters for the threshold-based operation of the Sensor (and Probe).

Table 3-6: Threshold-Based Transmission Configuration

Address	Access	Value	Size [Bytes]	Description	JSON Variable (Type/Unit)
0x30	R/W	Ambient Temperature/RH Sample Period: Idle State	4	Sample period of Ambient Temperature/RH in sec in Idle State	*temperature_relative_humidity_idle: <value> (unsigned/second)*
0x31	R/W	Ambient Temperature/R	4	Sample period of Ambient	*temperature_relative_humidity_active: <value>*

		H Sample Period: Active State		Temperature/RH in sec in Active State	*(unsigned/second)*
0x32	R/W	Ambient Temperature Thresholds	2	○ Bits 8-15: High temperature threshold ➢ Signed, 1°C/LSB ○ Bits 0-7: Low temperature threshold ➢ Signed, 1°C/LSB	*ambient_temperature_threshold {* *high: <value>* *(signed/celsius)* low: <value> *(signed/celsius)* }
0x33	R/W	Ambient Temperature Threshold Enabled	1	• Bit 0: ➢ 0 = Disabled ➢ 1 = Enabled • Bits 1-7: Ignored	*ambient_temperature_threshold_enabled: <value>* *(unsigned/no unit)*
0x34	R/W	RH Thresholds	2	○ Bits 8-15: High RH threshold ➢ Unsigned, 1%/LSB ○ Bits 0-7: Low RH threshold ➢ Unsigned, 1%/LSB High threshold ≤ Low threshold: Invalid and ignored	*relative_humidity_threshold {* *high: <value>,* *(unsigned/1% percentage)* low: <value> *(unsigned/1% percentage)* }
0x35	R/W	RH Threshold Enabled	1	○ Bit 0: ➢ 0 = Disabled ➢ 1 = Enabled ○ Bits 1-7: Ignored	*relative_humidity_threshold_enabled: <value>* *(unsigned/no unit)*
0x36	R/W	Input Sample Period: Idle State	4	Sample period of Input 1/Input 2 in sec in Idle State	*input_sample_period_idle: <value>* *(unsigned/second)*
0x37	R/W	Input Sample Period: Active State	4	Sample period of Input 1/Input 2 in sec in Active State	*input_sample_period_active: <value>* *(unsigned/second)*

0x38	R/W	Input 1 Thresholds	4	○ Bits 16-31: High threshold ➢ Unsigned, 1 kHz / LSB • Bits 0-15: Low threshold ➢ Unsigned, 1 kHz / LSB	*input1_threshold {* *high: <value>,* *(unsigned/mV)* low: <value> *(unsigned/mV)* }
0x39	R/W	Input 2 Thresholds	4	○ Bits 16-31: High temperature threshold ➢ Unsigned, 1 mV/LSB ○ Bits 0-15: Low temperature threshold ○ Unsigned, 1 mV/LSB	*input2_threshold {* *high: <value>,* *(unsigned/Hertz)* low: <value> *(unsigned/Hertz)* }
0x3A	R/W	Input 3 Thresholds*	4	○ Bits 16-31: High threshold ➢ Unsigned, 1 mV / LSB • Bits 0-15: Low threshold ○ Unsigned, 1 mV / LSB	*Input3_threshold {* *high: <value>,* *(unsigned/mV)* low: <value> *(unsigned/mV)* }
0x3B	R/W	Input 4 Thresholds*	4	○ Bits 16-31: High threshold ➢ Unsigned, 1 mV / LSB • Bits 0-15: Low threshold ○ Unsigned, 1 mV / LSB	*Input4_threshold {* *high: <value>,* *(unsigned/mV)* low: <value> *(unsigned/mV)* }
0x3C	R/W	Watermark 1 Thresholds	4	○ Bits 16-31: High threshold ➢ Unsigned, 1 Hz / LSB ○ Bits 0-15: Low threshold	*watermark1_threshold {* *high: <value>,* *(unsigned/Hertz)* low: <value> *(unsigned/Hertz)* }

				➢ Unsigned, 1 Hz / LSB	
0x3D	R/W	Watermark 2 Thresholds	4	o Bits 16-31: High threshold ➢ Unsigned, 1 Hz / LSB o Bits 0-15: Low threshold Unsigned, 1 Hz / LSB	*watermark2_threshold {* *high: <value>,* *(unsigned/Hertz)* low: <value> *(unsigned/Hertz)* }
0x3F	R/W	Input Threshold Enabled	1	o Bit 0: Input 1 ➢ 0 = Disabled ➢ 1 = Enabled o Bit 1: Input 2 ➢ 0 = Disabled ➢ 1 = Enabled o Bit 2: Input 3 ➢ 0 = Disabled ➢ 1= Enabled o Bit 3: Input 4 ➢ 0 = Disabled ➢ 1 = Enabled o Bit 4: Input 5 (Watermark) ➢ 0 = Disabled ➢ 1 = Enabled o Bit 5: Input 6 (Watermark) ➢ 0 = Disabled ➢ 1 = Enabled o Bit 2,3,6,7: Ignored	*threshold_enabled {* *input1: <value>,* *(unsigned/no unit)* *input2: <value>* *(unsigned/no unit)* *Input3: <value>* *(unsigned/no unit)* *Input4: <value>* *(unsigned/no unit)* *input5: <value>,* *(unsigned/no unit)* *input6: <value>* *(unsigned/no unit)* }
0x40	R/W	MCU Temperature Sample Period: Idle State	4	Sample rate of MCU Temperature in sec in Idle State	*mcu_temperature_sample_period_idle: <value>* *(unsigned/seconds)*
0x41	R/W	MCU Temperature Sample Period: Active State	4	Sample rate of MCU Temperature in sec in Active State	*mcu_temperature_sample_period_active: <value>* *(unsigned/seconds)*

0x42	R/W	MCU Temperature Thresholds	2	o Bits 8-15: High temperature threshold ➢ Signed, 1°C/LSB o Bits 0-7: Low temperature threshold ➢ Signed, 1°C/LSB High threshold ≤ Low threshold: Invalid and ignored	*mcu_temperature_threshold {* *high: <value>,* *(signed/celsius)* low: <value> *(signed/celsius)* }
0x43	R/W	MCU Temperature Threshold Enabled	1	o Bit 0: ➢ 0 = Disabled ➢ 1 = Enabled o Bits 1-7: Ignored	*mcu_temperature_threshold_enabled: <value>* *(unsigned/no unit)*

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3.1.2.2.1 Ambient Temperature/Ambient RH/Input 1/Input 2/Input 5/MCU Temperature Sample Period: Idle State

The Idle State sample period determines how often the sensor transducer is checked when the reported value is within the threshold window. This value is given in seconds, with a minimum of 10 and a maximum of 86400.

Values smaller than 10 or larger than 86400 are invalid and ignored by the SW.

Note: When the threshold-based reporting is enabled first, the Sensor (and Probe) will start in the Idle State.

3.1.2.2.2 Ambient Temperature/Ambient RH/Input 1/Input 2/Input 5/MCU Temperature Sample Period: Active State

The Active State sample period determines how often the sensor transducer is checked when the reported value is outside the threshold window. This value is given in seconds, with a minimum of 10 and a maximum of 86400.

Values smaller than 10 or larger than 86400 are invalid and ignored by the SW.

3.1.2.2.3 Thresholds

The thresholds for different transducers are stored in a single 2-byte register, with the MSB byte storing the high threshold, and the LSB byte storing the low threshold. The high threshold must be greater than the low threshold.

3.1.2.2.4 Threshold Enabled

The Threshold Enabled register enables and disables the threshold reporting on the specified transducer. The “Thresholds” and “Sample Periods” can be configured, but are **not** activated unless the “Threshold Enabled” bit is set.

3.1.2.2.5 Default Configuration

Ambient Temperature/RH Sample Period: Idle State	60 s
Ambient Temperature/RH Sample Period: Active State	30 s
Ambient Temperature Thresholds	30°C/15°C
Ambient Temperature Threshold Enabled	Off
RH Thresholds	80%/20%
RH Threshold Enabled	Off
Input 1/Input 2 Sample Period: Idle State	60 s
Input 1/Input 2 Sample Period: Active State	30 s
Input 1 Thresholds	61kHz/21kHz
Input 1 Threshold Enabled	Off
Input 2 Thresholds	1.5 V/0.5 V
Input 2 Threshold Enabled	Off
Input 3 Thresholds	1.5 V/0.5 V
Input 3 Threshold Enabled	Off
Input 4 Thresholds	1.5 V/0.5 V
Input 4 Threshold Enabled	Off
Watermark 1 Sample Period: Idle State	60 s
Watermark 1 Sample Period: Active State	30 s
Watermark 1 Thresholds	6 kHz/1 kHz
Watermark 1 Threshold Enabled	Off
Watermark 2 Thresholds	6 kHz/1 kHz
Watermark 2 Threshold Enabled	Off
MCU Temperature Sample Period: Idle State	60 s
MCU Temperature Sample Period: Active State	30 s
MCU Temperature Thresholds	30°C/15°C
MCU Temperature Threshold Enabled	Off

3.1.2.2.6 Example DL Messages

- Read all threshold-based configuration registers
  - 0x 30 31 32 33 34 35 36 37 38 39 3C 3D 3F 40 41 42 43

3.1.2.3 Ambient Light Configuration

The ALS offers an upper and a lower threshold for interrupt-based detections. It can also be polled periodically. The ALS is always on and enabled, but operates at a low-power mode where measurements are automatically taken every 800 ms. The integration time for each measurement is at least 100 ms and at most 800 ms, and is automatically and optimally set by the transducer for the best results. Table 3-7 shows a list of ALS configuration registers.

Table 3-7: ALS Configuration Registers

Address	Access	Value	Size [Bytes]	Description	JSON Variable (Type/Unit)
0x48	R/W	Interrupt Enabled	1	• Bit 0: ➢ 0 = Interrupt disabled ➢ 1 = Interrupt enabled ○ Bits 1-7: Ignored	*interrupt_enabled: <value>* *(unsigned/no unit)*
0x49	R/W	Upper Threshold	2	○ Unsigned ○ 1 lx/LSB	*upper_threshold: <value>* *(unsigned/lx)*
0x4A	R/W	Lower Threshold	2	○ Unsigned ○ 1 lx/LSB	*lower_threshold: <value>* *(unsigned/lx)*
0x4B	R/W	Ambient Light Sample Period in Inactive State	4	Sample period of Ambient Light in sec in Inactive State	*light_sample_period_inactive: <value>* *(unsigned/second)*
0x4C	R/W	Ambient Light Sample Period in Active State	4	Sample period of Ambient Light in sec in Active State	*light_sample_period_active: <value>* *(unsigned/second)*
0x4D	R/W	Value to Tx	1	• Bit 0: ➢ 0 = Light alarm not reported ➢ 1 = Light alarm reported • Bit 1: ➢ 0 = Light intensity not reported	*als_tx {* *light_alarm_reported: <value>,* *(unsigned/no unit)* light_intensity_reported: <value>

				➢ 1 = Light intensity reported ○ Bits 2-7: Ignored	*(unsigned/no unit)* }

3.1.2.3.1 Interrupt Enabled

When the Interrupt Enabled bit is set, an alarm is raised whenever the light value leaves a window set by the upper and lower thresholds (registers 0x49 and 0x4A). The MCU starts sampling the light transducer with a sample period defined in register 0x4C while the light is outside of the threshold window. The MCU starts sampling the light transducer with a sample period defined in register 0x4B while the light is inside the threshold window. The alarm is cleared once the MCU samples the light transducer and determines the light value is within the threshold window. There is a time delay, equivalent to the sampling periods, to see the alarm state change depending on whether the light is entering or leaving the threshold window.

3.1.2.3.2 Upper Threshold

See Section 3.1.2.3.1. Acceptable values for the Upper Threshold are 1, 2… 65535. Any other value is invalid and ignored. Also, any value smaller than or equal to the Lower Threshold is invalid and ignored.

3.1.2.3.3 Lower Threshold

See Section 3.1.2.3.1. Acceptable values for the Lower Threshold are 0, 1… 65535. Any other value is invalid and ignored. Also, any value greater than or equal to the Upper Threshold is invalid and ignored.

3.1.2.3.4 Ambient Light Sample Period in Inactive State

See Section 3.1.2.3.1. Acceptable values for the Sample Period are 10, 11… 86400. Any other value is invalid and ignored.

3.1.2.3.5 Ambient Light Sample Period in Active State

See Section 3.1.2.3.1. Acceptable values for the Sample Period are 10, 11… 86400. Any other value is invalid and ignored.

3.1.2.3.6 Value to TX

When a light alarm is raised or when the light transducer is periodically polled, the data to transmit can be configured by this register.

3.1.2.3.7 Default Configuration

Table 3-8 shows the default values for the ALS configuration registers.

Table 3-8: Default Values of ALS Configuration Registers

Interrupt Enabled	**Interrupt disabled**
Upper Threshold	10,000 lx
Lower Threshold	1000 lx
Ambient Light Sample Period in Inactive State	60 sec
Ambient Light Sample Period in Active State	30 sec
Value to Tx	Only light intensity reported

3.1.2.3.8 Example DL Messages

- 0x 09 65 02 1f 0b 67 00 ec
  - 0x 09 65 (Ambient Light Intensity) = 0x 02 1f = 543 lux
- 0x 09 65 05 ac 0b 67 00 f0
  - 0x 09 65 (Ambient Light Intensity) = 0x 05 ac = 1452 lux

3.1.2.4 Accelerometer Configuration

The accelerometer transducer offers a threshold for event-based orientation detection. It can also be polled periodically for applications where the Sensor (and Probe) orientation may be of interest. Table 3-9 shows a list of accelerometer configuration registers.

Table 3-9: Accelerometer Configuration Registers

Address	Access	Value	# Bytes	Description	JSON Variable (Type/Unit)
0x50	R/W	Orientation Alarm Threshold	2	• Unsigned, 1° / LSB	*orientation_alarm_threshold: <value> (unsigned/degree)*
0x51	R/W	Value to Tx	1	• Bit 0: ➢ 0/1 = Orientation alarm not reported/reported • Bit 5: ➢ 0/1 = Orientation vector not reported/reported ➢ Bits 1-4,6,7: Ignored	*accelerometer_tx {* *orientation_alarm_reported: <value>, (unsigned/no unit)* *orientation_vector_reported*: <value> *(unsigned/no unit)* }
0x52	R/W	Mode	1	• Bit 0: 0/1 = Orientation alarm disabled/enabled • Bit 1-6: Ignored • Bit 7:	*mode {* *orientation_alarm_enabled: <value>, (unsigned/no unit)* *accelerometer_power_on*: <value>

				• 0/1 = Accelerometer power off/on	*(unsigned/no unit)* }

3.1.2.4.1 Orientation Alarm Threshold

This parameter is the tilt threshold for an orientation alarm to be raised. Tilt is measured from the sensors z-axis and the horizontal plane. Tilt events are reported immediately once they are triggered. First when the sensor exceeds the specified tilt, and again when proper orientation is restored. This value is greater than 0 (zero). A value of 0 (zero) is ignored.

3.1.2.4.2 Value to TX

When an orientation event is registered or when the accelerometer is periodically polled, the data to transmit can be configured by the end user. Available types are:

- Alarm: A single data byte to indicate that the Sensor was tripped.
- Full-Precision: milli-g values for each X/Y/Z axis of the accelerometer.

3.1.2.4.3 Mode

The accelerator can be powered on/off to tune power usage (battery life) for end-user application. Additionally, the Orientation Alarm can be enabled/disabled. Disabling a threshold prevents the Sensor from generating the applicable accelerometer event.

3.1.2.4.4 Default Configuration

Table 3-10 shows the default values for the accelerometer configuration registers.

Table 3-10: Default Values of Accelerometer Configuration Registers

Orientation Alarm Threshold	**30°**
Value to Tx	Orientation vector reported
Mode	Orientation alarm enabled, accelerometer power off

3.1.3 Command and Control

Configuration changes are not retained after a power cycle unless they are saved in the flash memory. Table 3-11 shows the structure of the Command and Control registers. In this table, B_i refers to data byte indexed *i* as defined in Figure 3-1.

Table 3-11: Sensor Command & Control Register

Address	Access	Name	Size [Bytes]	Description	JSON Variable (Type/Unit)
0x70	W	Flash Memory Write Command	2	Bit 14: • 0/1 = Do not write/Write LoRaMAC Config Bit 13: • 0/1 = Do not write/Write App Config Bit 0: • 0/1 = Do not restart/Restart Tracker Bits 1-12, 15: Ignored	*write_to_flash {* *app_configuration:* <value>, *(unsigned/no unit)* *lora_configuration:* <value>, *(unsigned/no unit)* *restart_sensor:* <value> *(unsigned/no unit)* }
0x71	R	FW Version	7	B_0: App version major B_1: App version minor B_2: App version revision B_3: LoRaMAC version major B_4: LoRaMAC version minor B_5: LoRaMAC version revision B_6: LoRaMAC region number	*firmware_version {* *app_major_version:* <value>, *(unsigned/no unit)* *app_minor_version:* <value>, *(unsigned/no unit)* *app_revision:* <value>, *(unsigned/no unit)* *loramac_major_version:* <value>, *(unsigned/no unit)* *loramac_minor_version:* <value>, *(unsigned/no unit)* *loramac_revision:* <value>, *(unsigned/no unit)* *region:* <value> *(unsigned/no unit)* }
0x72	W	Reset Config	1	• 0x0A = Reset App Config • 0xB0 = Reset LoRa Config	*configuration_factory_reset:* <value>

		Registers to Factory Defaults[19]		• 0xBA = Reset both App and LoRa Configs • Any other value: Invalid and ignored	*(unsigned/no unit)*

Note: The Flash Memory Write Command is always executed after the full DL configuration message has been decoded. The reset command should always be sent as an "unconfirmed" DL message. Failure to do so may cause the NS to continually reboot the Sensor.

3.1.3.1 LoRaMAC Region

The LoRaMAC region is indicated by B_6 in the FW Version register (Reg 0x71). Current LoRaMAC regions and corresponding region numbers are listed in Table 3-12.

Table 3-12: LoRaMAC Regions and Region Numbers

LoRaMAC Region	Region Number
EU868	0
US915	1
AS923	2
AU915	3
IN865	4
KR920	6
RU864	7

3.1.3.4 Command Examples

In the following examples, the Command Field is boldfaced:

- Write application configuration to flash memory
  - DL payload: { 0x **F0** 20 00 }
- Write application and LoRa configurations to flash memory
  - DL payload: { 0x **F0** 60 00 }
- Reboot Device
  - DL payload: { 0x **F0** 00 01 }
- Read FW versions, and reset application configuration to factory defaults
  - DL payload: { 0x **71 F2** 0A }

[19] Resetting to factory defaults takes effect on the next power cycle.

3.1.4 Preventing Sensor Bricking

Care has been taken to avoid stranding (hard or soft bricking) the Sensor during reconfiguration. Hard bricking refers to the condition that the Sensor does not transmit any more as all periodic and event-based reporting (see subsequent sections) have been disabled and the configuration has been saved to the Flash memory. Soft bricking refers to the condition where the Sensor has been configured such that all event-based reporting is disabled and any periodic reporting is either disabled or has a period of larger than a week. Therefore, transmissions from a soft-bricked Sensor cannot be smaller than a week apart.

To avoid these situations, for any reconfiguration command sent to the Sensor, the following algorithm is automatically executed:

After the reconfiguration is applied, if all event-based reporting (see Sections 3.1.2.1 and 3.1.2.3 for event-based reporting) is disabled, then periodic reporting is checked (see Section 3.1.2.1 for periodic reporting). If all periodic reporting is disabled or the minimum non-zero period is greater than a week, then to avoid bricking the Sensor, the core *tick* is set to 86,400 (i.e. one day), and the battery report *tick* is set to 1 (one).

References

[1] LoRa Alliance, "LoRaWAN Specification," ver. 1.0.3, Jul 2018.

[2] LoRa Alliance, "LoRaWAN Regional Parameters," ver. 1.1, rev. B, Jan 2018.