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Agriculture Sensor

Technical Reference Manual

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Revision History

Version	Date	Editor	FW Version	Module Revision	Comments
0.1	May 29, 2019	Reza Nikjah	FW v0.0.9 and below	CLOVER: Rev D and below KIWI: Rev E and below	• 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 CLOVER and KIWI modules. • Various changes based on feedback from Reza & Gin. • Change to register 70 descriptions. • 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

Version	Date	Editor	FW Version	Module Revision	Comments
1.1	June 5, 2020	Mark Oevering			• Change to default configuration for CLOVER. • 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)
1.6	May 31, 2021	Mark Oevering			• Added note at the beginning of Section 2.2
1.7	August 27, 2021	Mark Oevering			• Correction to Table 3-6, Register 3F; deleted bits 2, 3 as they are not “ignored”
1.8	June 30, 2022	Mark Oevering			• Added note about blank uplink on page 12
1.9	April 24, 2023	Adedolapo Adegboye	FW v1.0.0 and above	CLOVER: E1 and above KIWI: F1 and above	• Updated product T-code and product names • Updated registers and default values in sections 2 and 3 • Minor formatting changes • Updated conversion table and formula for inputs 1, 2, 3 and 4
2.0	May 05, 2023	Adedolapo Adegboye			• Release

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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 CLOVER Agricultural Sensor and Probe module
SW............................. software
Transducer................ the sensing element attached to the Agricultural 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 Surface Mount Sensor, referred to as CLOVER Sensor henceforth, and by the LoRa IoT Agricultural Elevated Mount Sensor, referred to as KIWI Sensor henceforth.

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

Both the CLOVER Sensor and the KIWI Sensor are LoRaWAN IoT sensors intended for agricultural use cases. They are powered by a C-cell LTC battery, enclosed in a small IP67 casing, and an operating temperature of -40°C to 85°C. The common sensing features on the KIWI and CLOVER are ambient temperature, relative humidity, ambient light, MCU temperature, and an accelerometer (for orientation change detection).

KIWI has two interfaces (inputs 3 and 4) which supports the connection of either an analog thermistor or a digital onewire probe[1] on either interface for remote temperature sensing. The KIWI variant also has an interface for two watermark probes (via Inputs 5 and 6) for measuring soil tension.

Figure 1: KIWI variant of the Agricultural sensor

[1]Not supported on Kiwis with SW less than 1.0.0 and HW version less than F0

The CLOVER variant has two factory fitted prongs interfaced to two inputs - inputs 1 and 2 and provide measurements for soil moisture (Gravimetric Water Content) and soil temperature respectively.

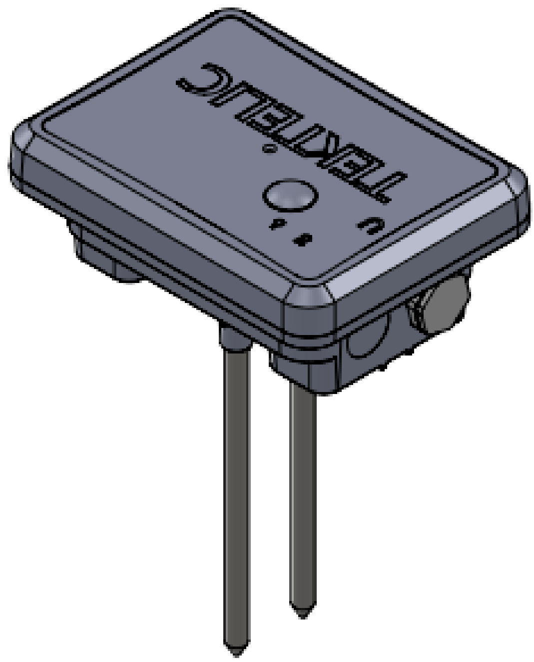

Figure 2: CLOVER variant of the Agricultural sensor showing the metallic prongs.

Both sensors are also equipped with a battery gauge which sends an EoS alarm[2] when the battery capacity left is approximately 5%. The battery lifetime of the CLOVER sensor or the KIWI sensor is expected to be at least 10 years.[3]

Table 1 presents the currently available Agriculture Sensor HW variants. Also, Table 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.

Table 1: Agricultural Sensor Models

Product Code	Description
T0005982	Module, Agriculture Sensor, CLOVER, LoRa

[2] This feature is only supported in SW between 0.3.1 and 0.9.0

[3] This is for transmission of default uplinks 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 -15°C and transmitting at maximum power every minute, the same battery may not last above a year.

T0005986	Module, Agriculture Sensor, KIWI, LoRa

Table 2: Agriculture Sensor Region Specific Variants

Part	Module TCODE	Description
AGRSNNAS92	T0005986	KIWI AGRICULTURE SENSOR ELEVATED MOUNT, AS 923 MHZ
AGRSNNAS922	T0005986	KIWI AGRICULTURE SENSOR ELEVATED MOUNT, AS 923-2 MHZ
AGRSNNA9233	T0005986	KIWI AGRICULTURE SENSOR ELEVATED MOUNT, AS 923-3 MHZ
AGRSNNAS9234	T0005986	KIWI AGRICULTURE SENSOR ELEVATED MOUNT, AS 923-4MHZ
AGRSNNAU915	T0005986	KIWI AGRICULTURE SENSOR ELEVATED MOUNT, AU 915 MHZ
AGRSNNEU868	T0005986	KIWI AGRICULTURE SENSOR ELEVATED MOUNT, EU 868 MHZ
AGRSNNIN865	T0005986	KIWI AGRICULTURE SENSOR ELEVATED MOUNT, IN 865 MHZ
AGRSNNKR920	T0005986	KIWI AGRICULTURE SENSOR ELEVATED MOUNT, KR 920 MHZ
AGRSNNRU864	T0005986	KIWI AGRICULTURE SENSOR ELEVATED MOUNT, RU 864 MHZ
AGRSNNUS915	T0005986	KIWI AGRICULTURE SENSOR ELEVATED MOUNT, NA 915 MHZ
AGRSNPA9234	T0005982	CLOVER AGRICULTURE SENSOR SURFACE MOUNT, AS 923-4 MHZ
AGRSNPAS923	T0005982	CLOVER AGRICULTURE SENSOR SURFACE MOUNT, AS 923 MHZ
AGRSNPAU915	T0005982	CLOVER AGRICULTURE SENSOR SURFACE MOUNT, AU 915 MHZ
AGRSNPEU868	T0005982	CLOVER AGRICULTURE SENSOR SURFACE MOUNT, EU 868 MHZ
AGRSNPIN865	T0005982	CLOVER AGRICULTURE SENSOR SURFACE MOUNT, IN 865 MHZ
AGRSNPKR920	T0005982	CLOVER AGRICULTURE SENSOR SURFACE MOUNT, KR 920 MHZ
AGRSNPRU864	T0005982	CLOVER AGRICULTURE SENSOR SURFACE MOUNT, RU 864 MHZ
AGRSNPUS915	T0005982	CLOVER AGRICULTURE SENSOR SURFACE MOUNT, NA 915 MHZ

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 **CLOVER** variant for reporting transducer readings includes the following:

- Report battery status once every day i.e., 1440 minutes.
- Report ambient temperature once every 15 minutes.
- Report relative humidity once every 15 minutes.
- Report soil moisture (input 1) once every 15 minutes.
- Report soil temperature (input 2) once every 15 minutes.
- Report ambient light intensity once every 15 minutes.

The default configuration of the **KIWI variant** for reporting transducer readings includes the following:

- Report battery status once every day i.e., 1440 minutes
- Report watermark 1 (Input 5) once every 15 minutes
- Report watermark 2 (Input 6) once every 15 minutes
- Report ambient light intensity once every 15 minutes

PLEASE NOTE: If the unit is placed in direct sunlight, the temperature reported will not be ambient temperature of the environment but the sensor case temperature. Temperature and humidity reporting are turned off in the SW by default for this reason in the KIWI module. These functions can be turned on by the user depending on the use case.

1.1 Reed Switch Operation

The KIWI and CLOVER variants are equipped with a magnetic reed switch. This reed switch can be operated by the provided magnet in the product package box. The magnetic patterns supported by the magnetic reed switch are hard coded and not user configurable. A magnet presence is achieved by bringing the magnet to touch the magnet sign on the enclosure and a magnet absence is achieved by taking the magnet away from the enclosure. The magnet sign's position is illustrated in Figure 3 below.

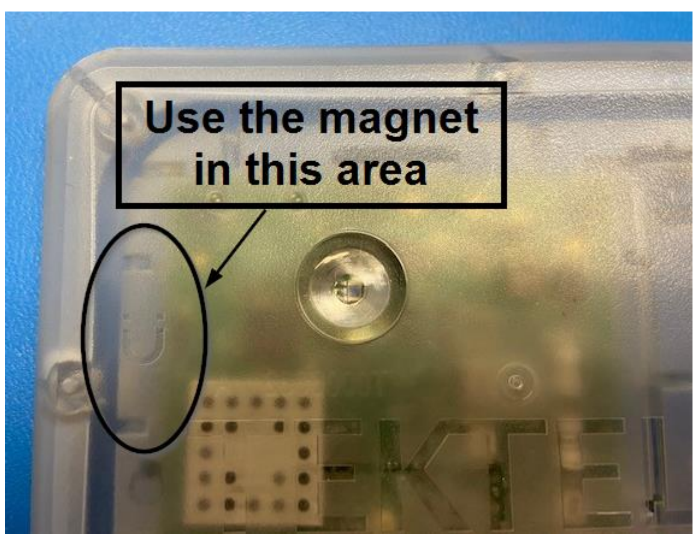

Figure 3: Reed Switch Location on KIWI and CLOVER Enclosure

1) MCU reset upon observing a specified magnetic pattern:

When the module comes out of the factory, it is in the DEEP SLEEP mode,[4] and can be woken up from DEEP SLEEP using the specified magnetic pattern in Figure 4. When this magnetic pattern is applied during the normal sensor operation, the device resets and tries to join the network. Any unsaved configuration changes are lost after this reset.

Here are the steps as illustrated in Figure 4.

1. Bring the magnet to the enclosure at the magnet sign and hold it steady for between 3 to 10 seconds.
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 resets and tries to rejoin 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 included).

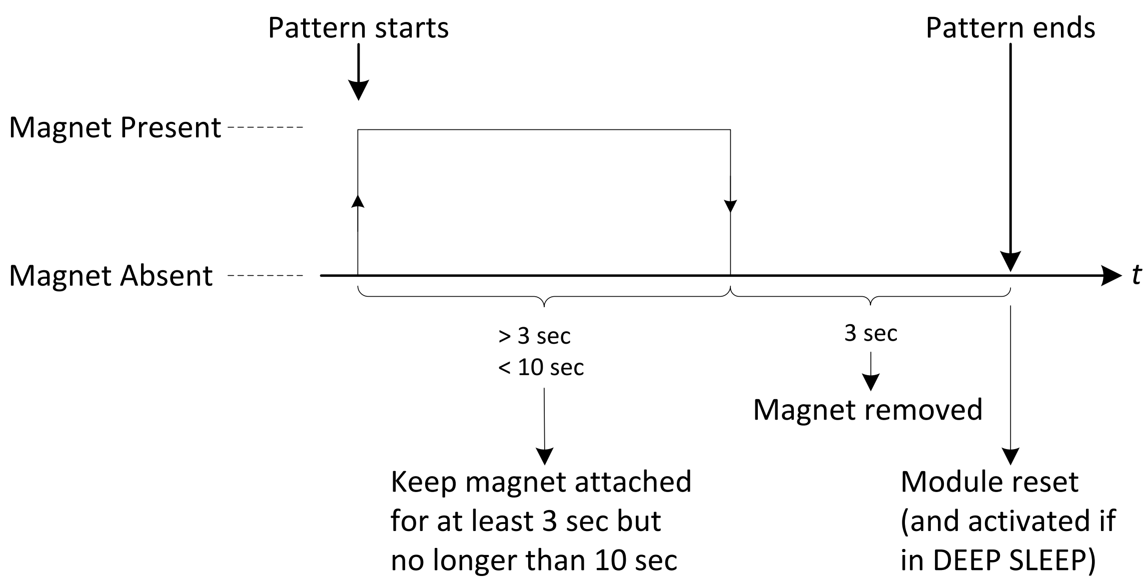

Figure 4: Agriculture Sensor magnetic reset/wake-up pattern

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[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 physically open the enclosure and remove and reinsert the battery.

2) Triggering the Agriculture Sensor to send a blank uplink 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 KIWI/CLOVER sensor to uplink a blank uplink on port 0.

   The magnetic pattern involves holding 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 5 below. It is important to note here that mistakenly holding the magnet attached to the module for more than 2 sec may trigger a module reset, as explained in item 1.

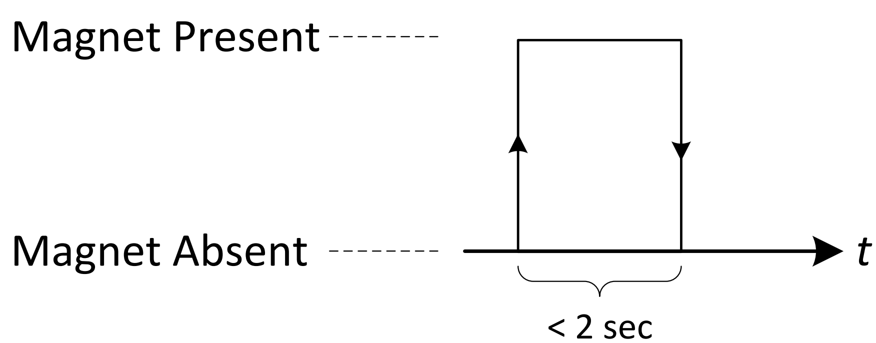

Figure 5: Agriculture Sensor magnetic UL-triggering pattern

Note: Replacing the batteries of the KIWI and CLOVER variants does not cause the Sensors 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:

- Empty uplink sent when the magnet is held to the magnet sign for 2 seconds (sent on **LoRaWAN port 0**).
- 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**)

The first UL stream is explained in Section 1.1 while the other two 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 6. A big-endian format (MSB first) is always followed.

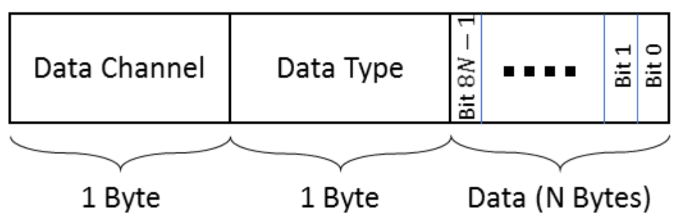

Figure 6: The UL frame payload format

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 KIWI and CLOVER frame payload values for transducers data are shown in Table 3. Transducers data in the UL are sent through ***LoRaWAN port 10***.

Table 3: UL Frame Payload Values for Transducers Data

Information Type	Data Channel ID	Data Type ID	Size (Bytes)	Data Type	Data Format	JSON Variable (Type/Unit)
Battery Voltage[5]	0x00	0xBA[6]	1	Analog	• Bits 0-6: (Voltage∗10mV) + 2.5[7] • Bit 7: EoS Alert (0 = No Alert, 1 = Alert)[8]	*battery_voltage: <value> (unsigned/10mV/LSB)* *eos_alert: <value> (unsigned/no unit)*
Remaining Battery Capacity	0x00	0xD3	1	Percentage	• Unsigned • 1%/LSB	*rem_batt_capacity: <value> (unsigned/%)*
Remaining Battery Lifetime	0x00	0xBD	2	Days	• Unsigned • 1 day/LSB	*rem_batt_days: <value> (Unsigned/days)*
Input 1 (Soil Moisture)[9]	0x01	0x04	2	Frequency	• Unsigned • 1 kHz/LSB	*input1_frequency: <value> (unsigned/Kilohertz)* *input1_frequency_to_moisture: <value> (unsigned/%)*
Input 2 (Soil Temperature)[10]	0x02	0x02	2	Voltage	• Unsigned • 0.001 V/LSB	*input2_voltage: <value> (unsigned/volt)* *input2_voltage_to_temp: <value> (signed/°C)*

[5] Not supported in FW 1.0.0 and above

[6] For SW version 0.2.5, this register is 0x00 FF

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

[8] Not supported in SW version 0.3 or less

[9] The raw reading should be converted to soil moisture for the **CLOVER** sensor provided by Tektelic

[10] The raw reading should be converted to soil temperature for the **CLOVER** sensor provided by Tektelic

Information Type	Data Channel ID	Data Type ID	Size (Bytes)	Data Type	Data Format	JSON Variable (Type/Unit)
Input 3 as thermistor (Analog)[11]	0x03	0x02	2	Voltage	• Unsigned • 0.001V/LSB	*Input3_voltage: <value> (unsigned/volt)* *Input3_voltage_to_temp: <value> (signed/ºC)*
Input 3 as onewire (Digital)[12]	0x03	0x67	2	Temperature	• Signed • 0.1°C /LSB	*Input3_temperature: <value> (signed/ºC)*
Input 4 as thermistor (Analog)[11]	0x04	0x02	2	Voltage	• Unsigned • 0.001V/LSB	*Input4_voltage: <value> (unsigned/volt)* *Input4_voltage_to_temp: <value> (signed/ºC)*
Input 4 as onewire (Digital)[12]	0x04	0x67	2	Temperature	• Signed • 0.1°C /LSB	*Input4_temperature: <value> (signed/ºC)*
Watermark 1 (Soil Water Tension)[13]	0x05	0x04	2	Frequency	• Unsigned • 1 Hz/LSB	*watermark1_frequency: <value> (unsigned/Hz)* *watermark1_tension: <value> (unsigned/kPa)*
Watermark 2 (Soil Water Tension)[13]	0x06	0x04	2	Frequency	• Unsigned • 1 Hz/LSB	*watermark2_frequency: <value> (unsigned/Hz)* *watermark2_tension: <value> (unsigned/kPa)*
Ambient Light Intensity	0x09	0x65	2	Light intensity	• Unsigned • 1 lux/LSB	*light_intensity: <value> (unsigned/lux)*

[11] The raw reading should be converted to probe temperature for the **KIWI** sensor. This will be provided in the data converter provided by Tektelic.

[12] Not supported in SW version less than 1.0.0

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

Information Type	Data Channel ID	Data Type ID	Size (Bytes)	Data Type	Data Format	JSON Variable (Type/Unit)
Ambient Light Alarm	0x09	0x00	1	Digital	• Boolean • 0x00 = No alarm (Light) • 0xFF = Alarm (Dark)	*light_detected: <value> (unsigned/no unit)*
Accelerometer Data	0x0A	0x71	6	Acceleration	• Signed • 1 milli-g/LSB • B_0-B_1: X-axis data • B_2-B_3: Y-axis data • B_4-B_5: Z-axis data •	*accelerometer_data { xaxis: <value>, (signed/g) yaxis: <value>, (signed/g) zaxis: <value> (signed/g) }*
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	Relative Humidity	• Unsigned • 0.5%/LSB	*relative_humidity: <value> (unsigned/%)*
MCU Temperature	0x0C	0x67	2	Temperature	• Signed • 0.1°C/LSB	*mcu_temperature: <value> (signed/celsius)*
					•	

Example Uplink Payloads

- 0x 00 D3 5A 00 BD 0A 0A
    - 0x 00 D3 (Remaining Battery Capacity) = (0x 5A) = 90 x 1% = 90%
    - 0x 00 BD (Remaining Battery Days) = (0x 0A 0A) = 2570 x 1day = 2570days
- 0x 01 04 05 79 02 02 02 D5
    - 0x 01 04 (Soil Moisture) = 0x 05 79 = 1401 x 1kHz = 1401 kHz
    - 0x 02 02 (Soil Temperature) = 0x 02 D5 = 725 x 0.001V = 0.725 V
- 0x 03 02 00 9D 04 67 02 00

- 0x 03 02 (Input 3 as thermistor) = 0x 9D 04 = 157 x 0.001V = 0.157 V
- 0x 02 02 (Input 4 as onewire) = 0x 02 00 = 512 x 0.1°C = 51.2 °C

- 0x 09 65 00 00 0B 67 00 E1 0B 68 92
  - 0x 09 65 (Ambient Light Intensity) = 0x 00 00 = 0 x 1 lux = 0 lux (no light)
  - 0x 0B 67 (Ambient Temperature) = (0x 00 E1) x 0.1°C = 225x 0.1°C = 22.5°C
  - 0x 0B 68 (Ambient RH) = (0x 92) x 0.5% = 146 x 0.5% = 73%

2.2 Data Conversions

NOTE: Sections 2.2.1 and 2.2.2 below apply to CLOVER models (surface mount variant) only.

2.2.1 Soil Moisture (Input 1) Conversion

This section only applies to CLOVER variant. Input 1 measurement is reported as a frequency in kHz. Please refer to below for a conversion from frequency to Gravimetric Water Content (GWC) of the soil.

Table 4: Input 1 GWC Conversion for CLOVER

GWC		Frequency range	
		Upper Limit	Lower Limit
0%	Dry	1402	1399
10%	0.1	1399	1396
20%	0.2	1396	1391
30%	0.3	1391	1386
40%	0.4	1386	1381
50%	0.5	1381	1376
60%	0.6	1376	1371
70%	0.7	1371	1366
80%	0.8	1366	1361
x90%	0.9	1361	1356
100%	1	1356	1351
110%	1.1	1351	1346
120%	1.2	1346	1341
>120%	Wet	1341	1322

Example Uplink Payloads

- 0x 01 04 05 52:
  - 0x 05 52 (Input1_frequency) = 1362 kHz
  - 0x 05 52 (Input1_frequency_to_moisture) = 0.8 or 80% GWC
- 0x 01 04 05 62:

- 0x 05 62 (Input1_frequency) = 1378 kHz
- 0x 05 62 (Input1_frequency_to_moisture) = 0.5 or 50% GWC

- 0x 01 04 05 72:
  - 0x 05 72 (Input1_frequency) = 1394 kHz
  - 0x 05 72 (Input1_frequency_to_moisture) = 0.2 or 20% GWC

2.2.2 Soil Temperature (Input 2) Conversion

This section only applies to the CLOVER variant. Input 2 readings provide voltage readings in units of volts (V). The following formula should be used to convert the voltage reading from input 2 to temperature.

$$\text{Input2\_voltage\_to\_temp} = (-32.46\ x \ln(V\ x\ 1000)) + 236.36$$

where V = voltage measurement in units of volts from input 2

Example Uplink Payloads

- 0x 02 02 06 0A:
  - 0x 06 0A (Input2_voltage) = 1546 x 0.001V = 1.546 V
  - 0x 06 0A (Input2_voltage_to_temp) = -2.0 °C
- 0x 02 02 01 60:
  - 0x 01 60 (Input2_voltage) = 352 x 0.001V = 0.352 V
  - 0x 01 60 (Input2_voltage_to_temp) = 46 °C
- 0x 02 02 02 BC:
  - 0x 02 BC (Input2_voltage) = 700 x 0.001 = 0.7 V
  - 0x 02 BC (Input2_voltage_to_temp) = 23.7 °C

NOTE: Sections 2.2.3 & 2.2.4 below apply to KIWI models (elevated mount variant) only.

2.2.3 Input 3 or 4 – Analog thermistor and Digital Onewire probes

This section only applies to the KIWI variant. Input 3 and 4 provides voltage reading when an analog thermistor probe is connected any of them, and temperature readings when a digital onewire probe[14] is connected to any of them. The supported analog and digital probe types are shown in Table 5 below.

Table 5: Supported Temperature Probes for KIWI variant

Probe type	Part Number	Product T-code
Analog thermistor	TT02-10KC8-T105-1500	T0006993
Digital Onewire	DFR0198	T0008632

[14] One wire probe feature is not supported on SW version less than 1.0.0 and HW revision E0 and below.

The following formula should be used to convert the voltage readings (in unit of volts) from an analog thermistor connected to either input 3 or input 4, to temperature in units of Celsius.

$$\text{Input(3/4)\_voltage\_to\_temp} = \big((-33.01)\ x\ (V^5)\big) + \big((217.4)\ x\ (V^4)\big) + \big((-538.6)\ x\ (V^3)\big) + \ ((628.1)x(V^2) + \big((-378.9)\ x\ (V^1)\big) + 102.9$$

where V = Voltage measurement in units of volts from input 3 or 4

Example Uplink Payloads

- 0x 03 02 01 60:
  - 0x 01 60 (Input3_voltage) = 352 x 0.001V = 0.352 V
  - 0x 01 60 (Input3_voltage_to_temp) = 27 °C
- 0x 03 02 02 BC:
  - 0x 02 BC (Input3_voltage) = 700 x 0.001V = 0.7 V
  - 0x 02 BC (Input3_voltage_to_temp) = 7.3 °C
- 0x 04 02 02 AB:
  - 0x 02 BC (Input4_voltage) = 683 x 0.001V = 0.683 V
  - 0x 02 BC (Input4_voltage_to_temp) = 7.9 °C

2.2.4 Watermark 1 & 2 Conversion

This section only applies to the KIWI variants. Watermark 1 & 2 provides frequency readings for soil tension measurements.

Table 6: Supported Watermark Probe for KIWI variant.

Probe type	Part Number	Product T-code
Watermark	200SS-5	T0005013

A reading of soil temperature from the thermistor will also be considered 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 (data header 0x05 04) or 2 (0x06 04), or both. Figure 7 below can be used to convert the frequencies reported by the watermark probes to soil tension. 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 soil water tension in kPa.

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

Figure 7: Watermark 1 & 2 Conversion to Water Tension

2) Using the temperature reading from either an analog thermistor or digital onewire temperature probes interfaced to input 3 or input 4, record the soil temperature.

   Note: The temperature reading from the onewire is preferred as it is more accurate.

3) Perform this next step only if the soil temperature deviates from 24°C by at least $\pm 6°C$. Using the initial kPa value calculated in step #1 and the soil temperature in step #2 above, calculate a 'temperature adjusted' kPa of soil water tension by using the following formula:

$$kPa_{24} = (initial\ kPa\ from\ step\ 1)\ x\ \big(1 - (0.019\ x\ ((temp\ from\ step\ 2) - 24)\big)$$

Example Uplink Payloads

- 0x 05 04 06 0A:
  - 0x 06 FA (watermark1_frequency) = 1786 Hz
  - 0x 06 FA (watermark1_tension) = 27 kPa
- 0x 06 04 00 3A:
  - 0x 00 3A (watermark1_frequency) = 58 Hz
  - 0x 00 3A (watermark1_tension) = 200 kPa

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 CLOVER and KIWI variants are configuration and control commands used to change the variants' behavior and are sent on **LoRaWAN port 100**.

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 8. A big-endian format (MSB first) is always followed.

The Register Address Field is a 7-bits (bit 0 to 6) address used to access various configuration parameters. These addresses are bound between 0x00 and 0x7F. Bit 7 of the Register Address field determines whether a read or write action is being performed. To write to a register, this bit must be set to 1 (one) and the remaining 7 bits (bits 0-6) represents the register address that's being written to. 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.

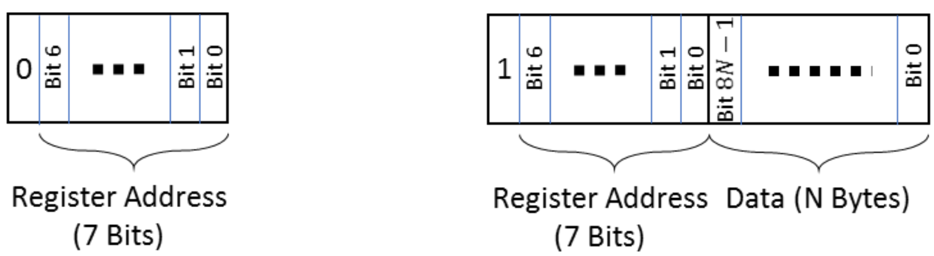

Figure 8: DL configuration and control message block format. Left: READ command block, Right: WRITE command block

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 3 (three) 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 7 shows the MAC configuration registers. In this table, B_i refers to data byte indexed *i* as defined Figure 8.

Table 7: 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	LoRaMAC options	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[15]	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)* *}*

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

Address	Access	Value	Size (Bytes)	Description	JSON Variable (Type/Unit)
0x13	R/W	• Rx2 window channel frequency • Rx2 window DR number	5	• Bits 8-39: Channel frequency in Hz for Rx2 • Bits 0-7: DR for Rx2	*loramac_rx2 {* *frequency: <value>, (unsigned/Hertz)* *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 8, Table 9, and

Table 10 below lists the default values for the LoRaMAC configuration registers (cf. [1], [3]).

Table 8: Default Values of LoRaMAC Configuration Registers

Address	Default Value
0x10	• OTAA mode
0x11	• Unconfirmed UL • Duty cycle enabled[16] • ADR enabled • Class A
0x12	• DR0 • Tx Power 0 (max power; see Table 9)
0x13	• As per Table 10

Table 9: Default Maximum Tx Power in Different Regions

RF Region	Max Tx EIRP [dBm]
EU868	16
US915	30
AS923	16
AU915	30

[16] 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.

RF Region	Max Tx EIRP [dBm]
IN865	30
KR920	14
RU864	16

Table 10: 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 core ticks. 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 11 below.

Table 11: Periodic Transmission Configuration Registers

<table>
<tr><th>Address</th><th>Access</th><th>Value</th><th>Size (Bytes)</th><th>Description</th><th>JSON Variable (Type/Unit)</th></tr>
<tr><td>0x20</td><td>R/W</td><td>Seconds per Core Tick</td><td>4</td><td>Tick value for periodic events
Acceptable values: 0, 30, 31, …, 86400
0 disables all periodic transmissions
Other values: Invalid and ignored</td><td>seconds_per_core_tick: <value> (unsigned/seconds)</td></tr>
<tr><td>0x21</td><td>R/W</td><td>Ticks per Battery</td><td>2</td><td>Ticks between battery reports
0 disables periodic battery reports</td><td>tick_per_battery: <value> (unsigned/no unit)</td></tr>
</table>

Address	Access	Value	Size (Bytes)	Description	JSON Variable (Type/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[17] (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[17] (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[18]	2	• *Ticks* between Input 3 reports • 0 disables periodic Input 3 reports	*tick_per_input3: <value>* *(unsigned/no unit)*
0x28	R/W	*Ticks* per Input 4[18]	2	• *Ticks* between Input 4 reports • 0 disables periodic Input 4 reports	*tick_per_input4: <value>* *(unsigned/no unit)*
0x29	R/W	*Ticks* per Watermark 1 (Soil Water Tension)[18]	2	• *Ticks* between Watermark 1 reports • 0 disables periodic Watermark 1 reports	*tick_per_watermark1: <value>* *(unsigned/no unit)*

[17] Applicable to CLOVER variants only

[18] Applicable to KIWI variants only

Address	Access	Value	Size (Bytes)	Description	JSON Variable (Type/Unit)
0x2A	R/W	*Ticks* per Watermark 2 (Soil Water Tension)[18]	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)*

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 CLOVER and KIWI

Table 12: Default Periodic TX Config for KIWI/CLOVER

Periodic TX configuration	CLOVER	KIWI
Seconds per Core Tick	900 sec (15 min)	900 sec (15 min)
Ticks per Battery	96 (1 day)	96 (1 day)
Ticks per Soil Moisture (input 1)	1 (15 min)	N/A
Ticks per Soil Temperature (input 2)	1 (15 min)	N/A
Ticks per Ambient Light	1 (15 min)	1 (15 min)
Ticks per Ambient RH	1 (15 min)	0 (disabled)
Ticks per Ambient Temperature	1 (15 min)	0 (disabled)
Ticks per Input 3	N/A	0 (disabled)
Ticks per Input 4	N/A	0 (disabled)
Ticks per Watermark 1	N/A	1 (15 min)
Ticks per Watermark 2	N/A	1 (15 min)
Ticks per Accelerometer	0 (disabled)	0 (disabled)
Ticks per Orientation	0 (disabled)	0 (disabled)
Ticks per MCU temperature	0 (disabled)	0 (disabled)

3.1.2.1.4 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)

3.1.2.1.5 Preventing Sensor Bricking

Care has been taken to avoid stranding (hard or soft bricking) the Sensor during reconfiguration. Hard bricking refers to the condition where 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 3.1.2.2, 3.1.2.3, and 3.1.2.4 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).

3.1.2.2 Threshold-Based Configuration

The KIWI and CLOVER Sensors support a total of 11 threshold-based transmissions:

- Ambient Temperature
- Ambient RH
- Input 1 (Soil Moisture in the **CLOVER** module only)
- Input 2 (Soil Temperature in **CLOVER** module only)
- Input 3 as thermistor (Analog input for the **KIWI** module only)
- Input 3 as onewire (Digital input for the **KIWI** module only)
- Input 4 as thermistor (Analog input for the **KIWI** module only)
- Input 4 as onewire (Digital input for the **KIWI** module only)
- Watermark 1 (Soil Water Tension for **KIWI** module only)
- Watermark 2 (Soil Water Tension for **KIWI** module only)
- 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 State.

The threshold mode can be enabled concurrently with periodic reporting. The sensor transducer will be reported at its scheduled periodic interval, and if the threshold is triggered. Table 13 shows configuration parameters for the threshold-based operation of the Sensor (and connected Probes).

Table 13: 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 • Min value: 10s • Max value: 86400s • Values outside this range are invalid and ignored	*temperature_relative_humidity_idle: <value> (unsigned/second)*
0x31	R/W	Ambient Temperature/ RH Sample Period: Active State	4	Sample period of Ambient Temperature/RH in sec in Active State • Min value: 10s • Max value: 86400s • Values outside this range are invalid and ignored	*temperature_relative_humidity_active: <value> (unsigned/second)*
0x32	R/W	Ambient Temperature Thresholds[19]	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)*

[19] Sensor rejects config if high transducer threshold is set to a value lower than the low transducer threshold.

Address	Access	Value	Size [Bytes]	Description	JSON Variable (Type/Unit)
0x34	R/W	RH Thresholds[19]	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/%)* low: <value> *(unsigned/%)* }
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 1/2/3/4/5/6 Sample Period: Idle State	4	Sample period of all inputs in sec in Idle State • Min value: 10s • Max value: 86400s • Values outside this range are invalid and ignored	*input_sample_period_idle: <value>* *(unsigned/second)*
0x37	R/W	Input 1/2 Sample Period: Active State	4	Sample period of Input 1/Input 2 in sec in Active State • Min value: 10s • Max value: 86400s • Values outside this range are invalid and ignored	*input_sample_period_active: <value>* *(unsigned/second)*
0x38	R/W	Input 1 Thresholds[19]	4	• Bits 16-31: High threshold ➢ Unsigned, 1 kHz / LSB • Bits 0-15: Low threshold ➢ Unsigned, 1 kHz / LSB	*input1_threshold {* *high: <value>,* *(unsigned/Kilohertz)* low: <value> *(unsigned/Kilohertz)* }

Address	Access	Value	Size [Bytes]	Description	JSON Variable (Type/Unit)
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/Volts)* low: <value> *(unsigned/Volts)* }
0x3A	R/W	Input 3 as thermistor Thresholds[19]	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 as thermistor Thresholds[19]	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[19]	4	• Bits 16-31: High threshold ➢ Unsigned, 1 Hz / LSB • Bits 0-15: Low threshold ➢ Unsigned, 1 Hz / LSB	*watermark1_threshold {* *high: <value>, (unsigned/Hertz)* low: <value> *(unsigned/Hertz)* }

Address	Access	Value	Size [Bytes]	Description	JSON Variable (Type/Unit)
0x3D	R/W	Watermark 2 Thresholds[19]	4	• Bits 16-31: High threshold ➢ Unsigned, 1 Hz / LSB • 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	• Bit 0: Input 1 ➢ 0 = Disabled ➢ 1 = Enabled • Bit 1: Input 2 ➢ 0 = Disabled ➢ 1 = Enabled • Bit 2: Input 3 ➢ 0 = Disabled ➢ 1 = Enabled • Bit 3: Input 4 ➢ 0 = Disabled ➢ 1 = Enabled • Bit 4: Input 5 (Watermark) ➢ 0 = Disabled ➢ 1 = Enabled • Bit 5: Input 6 (Watermark) ➢ 0 = Disabled ➢ 1 = Enabled • Bit 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)*

Address	Access	Value	Size [Bytes]	Description	JSON Variable (Type/Unit)
0x42	R/W	MCU Temperature Thresholds	2	• 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	*mcu_temperature_threshold {* *high: <value>, (signed/celsius)* low: <value> *(signed/celsius)* }
0x43	R/W	MCU Temperature Threshold Enabled	1	• Bit 0: ➢ 0 = Disabled ➢ 1 = Enabled • Bits 1-7: Ignored	*mcu_temperature_threshold_enabled: <value> (unsigned/no unit)*
0x44	R/W	Input 3 Onewire Temperature Thresholds[19]	2	• Bits 8-15: High temperature threshold ➢ Signed, 1°C/LSB • Bits 0-7: Low temperature threshold ➢ Signed, 1°C/LSB	*input3_onewire_temperature_threshold {* *high: <value>, (signed/celsius)* low: <value> *(signed/celsius)* }
0x45	R/W	Input 4 Onewire Temperature Thresholds[19]	2	• Bits 8-15: High temperature threshold ➢ Signed, 1°C/LSB • Bits 0-7: Low temperature threshold ➢ Signed, 1°C/LSB	*Input4_onewire_temperature_threshold {* *high: <value>, (signed/celsius)* low: <value> *(signed/celsius)* }

3.1.2.2.1 Ambient Temperature/Ambient RH/MCU Temperature/All Inputs Sample Period: Idle State

The Idle State sample period determines how often the sensor transducer is sampled when the sensor is in idle state i.e., when the reported transducer value is within the set 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 device.

Note: When the threshold-based reporting is first enabled, the Sensor assumes it is in an Idle State.

3.1.2.2.2 Ambient Temperature/Ambient RH/MCU Temperature/All Inputs Sample Period: Active State

The active state sample period determines how often the sensor transducer is sampled when the sensor is in active state i.e., when the reported transducer value is outside the set 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 device.

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

Table 14: Default threshold configuration settings for KIWI/CLOVER

Threshold Configuration Setting	Default Value
Ambient Temperature/RH Sample Period: Idle State	60 s
Ambient Temperature/RH Sample Period: Active State	30 s
Ambient Temperature Thresholds: High/Low	30°C/15°C
Ambient Temperature Threshold Enabled	Off
RH Thresholds: High/Low	80%/20%
RH Threshold Enabled	Off
Input 1/2/3/4/5/6 Sample Period: Idle State	60 s
Input 1/2/3/4/5/6 Sample Period: Active State	30 s
Input 1 Thresholds: High/Low	1.370kHz/1.330kHz
Input 1 Threshold Enabled	Off
Input 2 Thresholds: High/Low	1.5 V/0.5 V
Input 2 Threshold Enabled	Off
Input 3 Thresholds - thermistor: High/Low	1.5 V/0.5 V
Input 3 thresholds - onewire: High/Low	30°C/15°C

Input 3 Threshold Enabled	Off
Input 4 Thresholds - thermistor: High/Low	1.5 V/0.5 V
Input 4 thresholds - onewire: High/Low	30°C/15°C
Input 4 Threshold Enabled	Off
Input 5: Watermark 1 Thresholds: High/Low	1500 Hz/575 Hz
Input 5: Watermark 1 Threshold Enabled	Off
Input 6: Watermark 2 Thresholds: High/Low	1500 Hz/575 Hz
Input 6: 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 3A 3B 3C 3D 3F 40 41 42 43 44 45

3.1.2.3 Ambient Light Configuration

The Ambient Light Sensor offers an upper and a lower threshold for event-based light detections. It can also be sampled periodically as explained in Section 3.1.2.1.2. Table 15 shows a list of ALS configuration registers.

Table 15: ALS Configuration Registers

Address	Access	Value	Size [Bytes]	Description	JSON Variable (Type/Unit)
0x48	R/W	Interrupt (Light Alarm) Enabled	1	• Bit 0: ➢ 0 = Interrupt disabled ➢ 1 = Interrupt enabled • Bits 1-7: Ignored	*ALS_interrupt_enabled: <value> (unsigned/no unit)*
0x49	R/W	Upper Threshold	2	• Unsigned • 1 lx/LSB • Min value: 1 • Max value: 65535 • Values outside this range is invalid and ignored by sensor	*ALS_upper_threshold: <value> (unsigned/lx)*

Address	Access	Value	Size [Bytes]	Description	JSON Variable (Type/Unit)
0x4A	R/W	Lower Threshold	2	• Unsigned • 1 lx/LSB • Min value: 0 • Max value: 65535 • Values outside this range is invalid and ignored by sensor.	*ALS_lower_threshold: <value> (unsigned/lx)*
0x4B	R/W	Ambient Light Sample Period in Idle State	4	Sample period of Ambient Light in sec in Idle State • Min value: 10 • Max value: 86400 Values outside this range is invalid and ignored by sensor.	*light_sample_period_idle: <value> (unsigned/second)*
0x4C	R/W	Ambient Light Sample Period in Active State	4	Sample period of Ambient Light in sec in Active State • Min value: 10 • Max value: 86400 Values outside this range is invalid and ignored by sensor.	*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 ➢ 1 = Light intensity reported • Bits 2-7: Ignored	*als_tx {* *light_alarm_reported: <value>, (unsigned/no unit)* light_intensity_reported: <value> *(unsigned/no unit)* }

3.1.2.3.1 Interrupt Enabled

When the Interrupt Enabled bit is set, an event-based light reporting state is enabled such that an alarm is raised when the light intensity value leaves the window set by the upper and lower thresholds (registers 0x49 and 0x4A) i.e., when sensor is in active state. This alarm is cleared once the MCU samples the light transducer and determines that the light value is within the set threshold window i.e., when sensor is in idle state. 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

The MCU samples the light transducer with a sampling period defined in register 0x4C when the light intensity is outside of the threshold window (active range) and samples the light transducer with a sampling period defined in register 0x4B while the light is inside the threshold window (idle range).

The upper threshold and lower threshold values are the maximum value and the minimum value of the threshold window, respectively.

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 3.1.2.3.2 above.

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 Idle 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

In the event of periodic-based or event-based sampling of the ALS, this register can be used to select what type of light data to transmit. The list below contains the possible options that can be enabled when reporting light values.

1. Light Alarm: As explained in 3.1.2.3.1 above, an alarm can be set to go off when the reported light intensity is outside a set threshold window. This alarm is enabled and disabled by toggling the bit 0 of the config register to 1 and 0 respectively.
2. Light Intensity: This is the value of the light intensity readings from the ALS in units of lux.

3.1.2.3.7 Default Configuration

Table 16 shows the default values for the ALS configuration registers.

Table 16: Default ALS Threshold Configuration Settings

ALS Threshold Register	Default Value
Interrupt Enabled	**Interrupt disabled**
Upper Threshold	10000 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

- Read all threshold-based light configuration registers.
    - 0x 48 49 4A 4B 4C 4D

3.1.2.4 Accelerometer Configuration

The accelerometer offers both periodic-based and event-based orientation detection. Table 17 shows a list of accelerometer configuration registers.

Table 17: Accelerometer Configuration Registers

Address	Access	Value	# Bytes	Description	JSON Variable (Type/Unit)
0x50	R/W	Orientation Alarm Threshold	2	• Unsigned, 1° / LSB • Values less than or equal to zero are invalid and ignored by sensor	*orientation_alarm_threshold: <value> (unsigned/degree)*
0x51	R/W	Value to Tx	1	• Bit 0: ➢ 0 = Orientation alarm not reported ➢ 1 = Orientation alarm reported • Bit 5: ➢ 0 = Orientation data not reported ➢ 1 = Orientation data reported ➢ Bits 1-4,6,7: Ignored	*accelerometer_tx {* *orientation_alarm_reported: <value>, (unsigned/no unit)* *orientation_data_reported: <value> (unsigned/no unit)* }

Address	Access	Value	# Bytes	Description	JSON Variable (Type/Unit)
0x52	R/W	Mode	1	• Bit 0: ➢ 0 = Orientation alarm disabled ➢ 1 = Orientation alarm enabled • Bit 1-6: Ignored • Bit 7: ➢ 0 = Accelerometer power off ➢ 1 = Accelerometer power on	*mode {* *orientation_alarm_enabled: <value>, (unsigned/no unit)* *accelerometer_power_on*: <value> *(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. Orientation alarms are reported 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 using this single byte . Available types are:

- Alarm: Bit 0 of the register reports the orientation alarm status
- Orientation data: milli-g values for each X/Y/Z axis of the accelerometer.

3.1.2.4.3 Mode

The accelerometer can be powered on/off to conserve power usage (battery life) for end-user application. Additionally, the Orientation Alarm can be enabled/disabled.

3.1.2.4.4 Default Configuration

Table 18 shows the default values for the accelerometer configuration registers.

Table 18: Default Values of Accelerometer Configuration Registers

Accelerometer Configuration	Default Value
Orientation Alarm Threshold	30°
Value to Tx	Orientation alarm status

Accelerometer Configuration	Default Value
Mode	Orientation alarm enabled, Accelerometer power off

3.1.2.5 Battery Life Configuration

Both variants of the sensor are equipped with a Current Sense Amplifier (CSA) that can sense the power consumption and use this information to estimate the remaining battery capacity and lifetime.

Table 19: Battery Management Configuration Registers

Address	Access	Value	Size [Bytes]	Description	JSON Variable (Type/Unit)
0x61	R/W	Battery Report options	1	• Bit 0: Ignored[20] • Bit 1 ➢ 0 = Remaining battery capacity [%] not reported ➢ 1 = Remaining battery capacity [%] not reported • Bit 2: ➢ 0 = Remaining battery lifetime [days] not reported ➢ 1 = Remaining battery lifetime [days] reported • Bits 0-2 all set to 0: Invalid and ignored. • Bits 3-7: Ignored	*report_capacity_enabled: <value> (unsigned/no unit)* *report_lifetime_enabled: <value>, (unsigned/no unit)*
0x62	R/W	Average Current Trend Window	1	• Bits 0-7: Number of updates [1 update/LSB] • Acceptable values: 1, 2, …, 255 • 0: invalid and ignored	*avg_current_window: <value>* *(unsigned/no unit)*

[20] Deprecated; was used for voltage reporting, which is no longer supported in some devices

3.1.2.5.1 Default Configuration

Table 20: Default Battery Management Configuration for CLOVER and KIWI

Battery Management Config	Default Values
Battery Report Options	Remaining battery capacity [%] and remaining battery lifetime [days] reported
Average Current Trend Window	10 Updates

3.1.3 Command and Control

Configuration changes are not retained after a power cycle unless they are saved in the flash memory. Table 21 shows the structure of the Command-and-Control registers. In this table, B_i refers to data byte indexed *i* as defined in Figure 8.

Table 21: Sensor Command & Control Register

Address	Access	Name	Size [Bytes]	Description	JSON Variable (Type/Unit)
0x70	W	Flash Memory Write Command	2	• Bit 14: ➢ 0 = Do not write LoRaMAC Config ➢ 1 = Write LoRaMAC Config • Bit 13: ➢ 0 = Do not write App Config ➢ 1 = Write App Config • Bit 0: ➢ 0 = Do not restart Sensor ➢ 1 = Restart Sensor • 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)* }

Address	Access	Name	Size [Bytes]	Description	JSON Variable (Type/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 Registers to Factory Defaults[21]	1	• 0x0A = Reset App Config • 0xB0 = Reset LoRa Config • 0xBA = Reset both App and LoRa Configs • Any other value: Invalid and ignored	*configuration_factory_reset:* <value> *(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.

[21] Resetting to factory defaults takes effect on the next reset.

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 22.

Table 22: LoRaMAC Regions and Region Numbers

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

3.1.3.2 Command Examples

- 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}

References

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

[2] LoRa Alliance, "LoRaWAN Regional Parameters," ver. 1.0.2, rev. B, Feb 2017.

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