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Breeze/Breeze-V/Vivid+

Technical Reference Manual (Sensor)

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Revision History

Version	Date	Editor	FW Version	Comments
0.1	Sept. 14, 2021	Shania Stewart, Reza Nikjah	1.0.1	Initial draft based on T0007525_TRM_ver0.3 and demo FW version 1.0.1.
0.2	Sept. 15, 2021	Shania Stewart	1.0.2	Updated default configurations for registers 0x31 and 0x54 in demo FW version 1.0.2.
0.3	Oct. 18, 2021	Shania Stewart	1.0.x	• Updated TRM for features intended to be included in full FW version 1.X.X. • Minor formatting changes throughout the document. • Included more details on the Display in Section 1. • Added the Dynamic Reporting Mode feature specification intended primarily for school use cases (Section 1.2). • Changed default reporting configurations to support multiple reporting modes (Section 1.2.2). • Changed default value of CO_2 sampling parameters register (0x30). • Restructured format of LoRaWAN DL Payload Format subsections. • Added tables with UL/DL information streams. • Included specifications on UL formats for local timestamp acquisition requests and sensor timestamp responses. • Included specifications on DL formats for local timestamp acquisition responses and sensor timestamp requests. • Added DL configuration registers for BLE Display Configuration (Section 7) and Dynamic Reporting Mode Configuration (Section 13.2). • Changed the Report Options register (register 0x40) in so that the ability to report the remaining battery capacity of the Sensor and/or Display can be selected independently.
0.4	Nov. 30, 2021	Shania Stewart	App: 1.0.5 LoRaMAC: 4.4.1 BLE Stack (Gecko): 2.7	• Edited for demo FW version 1.0.5. Changes made in this TRM are with respect to TRM version 0.2, so changes made in TRM version 0.3 do not apply unless listed below. • Minor formatting changes throughout the document. • Included more details on Display in Section 1. • Specified features that are exclusive to Sensors that come with Displays throughout the document. • Updated

				• **Error! Reference source not found.** to include order codes for all regional variants that come with and without Displays. • Added a DL configuration to enable/display BLE Display whitelisting.
0.5	Jan. 13, 2022	Shania Stewart	App: 2.0.0 LoRaMAC: 4.4.1 BLE Stack (STM): 1.12.1	• Updated TRM to reflect design changes for new MCU and school use case in FW version 2.0.0. Changes made in this TRM are with respect to TRM version 0.3, so changes made in TRM version 0.4 do not apply unless listed below. • Updated Abbreviations and Acronyms as necessary. • Updated BLE description to reflect new MCU and include the Bluetooth SDK version. • Updated references to Barometer due to new part, as measurements are in units of mbar. • Changed references to “atmospheric pressure” to “barometric pressure”. • Included references to the BLE Implementation Specification. • Specified features that are exclusive to Sensors that come with Displays throughout the document. • Updated T-Codes. • Updated • **Error! Reference source not found.** to include order codes for all regional variants that come with and without Displays. • Added CO_2 push button protocol. • Added LED specification. • Minor edits to clarify timestamp acquisition behavior. • Removed byte to indicate local offset in payloads containing timestamps. The offset is now factored directly into the transmitted/received timestamp. • Edited examples of DL response to timestamp acquisition requests. • Changed the names of timestamp acquisition sections. • Changed lowest accepted non-zero Core Tick (active and inactive) to 10 seconds. • Removed ability to disable BLE communication with Display via downlink commands. • Removed light transducer support. • Changed the added random delay between timestamp update requests to be between 0 and 5 minutes.
0.6	May 5, 2022	Shania Stewart	App: 2.0.12	• Updated in preparation for customer release based on T0007805_Sensor_TRM_ver0.5.

			LoRaMAC: 4.4.1 BLE Stack (STM): 1.13.1	• Minor edits based on feedback. • Added note in overview about the FW version. • Updated product marketing names. • Minor grammar, typo, and wording fixes. • Reformatted document structure based on LoRaWAN information streams and ports rather than by UL/DL. • Updated STM32CubeWB SDK version from 1.12.1 to 1.13.1 and reference to the BLE Implementation Specification (internal copy only). • Removed product family table and reformatted product code table to include module T-codes and PCBA T-codes. • Edited descriptions of features like dynamic reporting, CO_2/barometer sampling, CO_2 calibrations, and remaining battery capacity reporting. • Consolidated button and LED placements into Figure External Interfaces-2. • Fixed typo regarding LED behavior. • Changed pressure unit back to hPa for consistency in the Sensor FW. • Removed detailed explanation of the advantages and disadvantages to using the CRC32 vs port 101 response to downlink commands feature. • Minor edits to JSON variables. • Included information about colour inversion on the Display when temperature, RH, and battery level thresholds are crossed. • Updated citations.
1.0	May 9, 2022	Shania Stewart	App: 2.0.12 LoRaMAC: 4.4.1 BLE Stack (STM): 1.13.0	• Release based on T0007805_Sensor_TRM_ver0.6.
1.1	Sept. 30, 2022	Shania Stewart	App: 2.0.20 LoRaMAC: 4.4.1 BLE Stack (STM): 1.13.0	• Added Sensor FW versions to document revision history. • Minor wording and formatting fixes. • Clarified how the value of register 0x33 changes when the CO_2 calibration button is used. • Added light transducer support for Rev B and onwards. • Added PIR support for the Breeze-V. • Fixed issue with limits on register 0x68 so that active mode can end at 12:00 AM.

1.2	Feb 15, 2023	Shania Stewart	App: 2.0.20 LoRaMAC: 4.4.1 BLE Stack (STM): 1.13.0	• Minor typo and formatting fixes. • Added notes about light transducer support for sensors with module revisions A and B. • Updated uplink payload examples.
1.3	Apr 27, 2023	Shania Stewart	**LW 1.0.2:** App: 2.1.x LoRaMAC: 4.4.1 BLE Stack (STM): 1.16.0 **LW 1.0.4:** App: 2.2.x LoRaMAC: 4.6.0 BLE Stack (STM): 1.16.0	• INTERNAL COPY ONLY: Specified which FW versions implement which LoRaWAN versions in revision history. Only the production version (likely LoRaWAN 1.0.4) will be included in the customer copy. • INTERNAL COPY ONLY: Included BLE stack version in revision history. • Added LoRaMAC versions to revision history. • Added information about LoRaWAN 1.0.4 support [TBD]. • Updates notes about light transducer support to specify module A and B FW versions. • Updated table of order codes for additional region support [TBD]. • Added the following additional features: ○ Added BLE Display configuration option (register 0x2B) to show the temperature in either degrees Celsius or Fahrenheit [TBD]. ○ Changed the name of configuration register 0x2B from Language Options to [new name] [TBD]. ○ Added BLE Display configuration option (register 0x2C) to change the address of the paired Display [TBD].
2.0	Dec 18, 2024	Emma Tholl	**LW 1.0.4:** App: 2.3.x LoRaMAC: 4.6.0 BLE Stack (STM): 1.16.0	• Updated TRM to match release version. • Updated to include appendix 0 and 1. • Include sensor activation and management section. • Updated to reference LW 1.0.4 material. • Made improvements based on design team feedback.

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Acronyms and Glossary

ABC .... automatic baseline correction
ABP .... activation by personalization
ADR .... adaptive data rate
BLE .... Bluetooth Low Energy
CO_2 .... carbon dioxide
CRC .... cyclic redundancy check
DL .... downlink
DR .... data rate
EIRP .... effective isotropic radiated power
Flash memory .... Non-volatile memory on the Sensor (contains application & configuration settings)
FW .... firmware
hr .... hour
ID .... identity
IIR .... infinite impulse response
IoT .... Internet of things
LED .... light emitting diode
LoRa .... a patented "long-range" IoT technology acquired by Semtech
LoRAMAC .... LoRaWAN MAC
LoRaWAN .... LoRa wide area network (a network protocol based on LoRa)
LSB .... least significant bit
MAC .... medium access control
MCU .... microcontroller unit
min .... minute(s)
MSb .... most significant bit
MSB .... most significant byte
NS .... network server
OTA .... over-the-air
OTAA .... OTA activation
PIR .... passive infrared
POST .... power on self-test
RH .... relative humidity
RF .... radio frequency
RO .... read-only
RTC .... real time clock
R/W .... read/write
Rx .... receiver
SDK .... software development kit

sec .... second(s)
Sensor .... Breeze/Breeze-V/Vivid+ Sensor
SW .... software
transducer............................. sensing element on the Sensor (e.g. PIR or temperature transducers)
TRM...................................... technical reference manual (this document)
Tx.. transmitter
UL .... uplink
UTC....................................... universal coordinated time
WO .... write-only

1 Overview

IMPORTANT: Not all features described in this manual may be available on devices programmed with older FW versions. Refer to the Revision History table to verify which FW versions included the addition of new features. To check the FW version of your device, send a command to query your device as described in Section **Error! Reference source not found.**.

This document contains technical information about the supported functionally of the TEKTELIC Breeze/Breeze-V/Vivid+ Sensor variants, referred to as the Sensor henceforth. In particular, this TRM describes the LoRa IoT uplink and downlink payload structures user accessible configuration settings (pseudo registers) in detail. This document is intended for a technical audience, such as application developers, with an understanding of the LoRaWAN NS and its command interfaces.

The Breeze/Breeze-V/Vivid+ are all multi-purpose LoRaWAN IoT sensors packed into a very small form factor. The Breeze, Breeze-V, and Vivid+ are all variants in the same sensor family, which differ in some of their sensing features. The Sensor is ideal for monitoring and reporting CO_2, human motion, ambient temperature and relative humidity, light,[1] and barometric air pressure in a home/office environment.

Sensors can also be ordered to come with a 2.9″ wireless e-Ink BLE Display that allows room occupants to locally view the latest measurements from select transducers taken in real-time. The Display will show the most recent CO_2[2], temperature, and humidity measurements taken from the Sensor, as well as the remaining battery capacity of the Sensor and Display. The Sensor and Display communicate wirelessly over BLE. The Sensor's MCU is based on the STM32CubeWB version 1.16.0 device drivers and follows Bluetooth 5.2. The Sensor is designed to only communicate with the BLE Display that is shipped with the Sensor.

Sensors may also be ordered without a BLE Display. The only functional differences between a Sensor that comes with or without a Display is that a Sensor that is not programmed to communicate with a Display will not perform any BLE communication or report the remaining battery capacity of the Display. Details concerning the BLE communication between the Sensor and e-Ink Display, beyond select configuration options, are outside the scope of this document. The BLE communication specification for the e-Ink Display can be found in the e-Ink Display BLE Specification [1].

Table Overview-1 presents the available Breeze/Breeze-V/Vivid+ HW variants. Sensors programmed with or without Displays at the factory are determined based on the order, as shown in

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[1] Light transducer support is not available on sensors with module revision A or B. If the module revision is unknown and the device's label is not accessible, query the device's FW version. If the module is programmed with application FW version 2.0.x, then the light transducer is not supported.

[2] The Display will show the pressure compensated CO_2 for Breeze and Breeze-V models only. The spot at which the CO_2 concentration is normally shown will be blank for Vivid+ models.

Error! Reference source not found.. The Breeze/Breeze-V/Vivid+ is available for most regions identified by the LoRa Alliance [2]—see [2] for the Tx and Rx bands in each LoRaWAN region. The different regional variants shown in

Error! Reference source not found. use the same HW, but are distinguished through different parameters in the FW.

Table Overview-1: Breeze/Breeze-V/Vivid+ HW Variants

Functional Variant	PCBA Level T-Code	Module Level T-Code
Breeze With Display	T0007938	T0007838
Breeze Without Display		
Vivid+ With Display	T0007939	T0007848
Vivid+ Without Display		
Breeze-V With Display	T0007937	T0007806
Breeze-V Without Display		

Table Overview-2: Breeze/Breeze-V/Vivid+ Order Codes for Region Specific Variants

LoRaWAN Region	Breeze – T0007838		Vivid+ – T0007848		Breeze-V – T0007806	
	With Display	No Display	With Display	No Display	With Display	No Display
EU868	SMTBCDEU868	SMTBCNEU868	SMTBPDEU868	SMTBPNEU868	SMTBMDEU868	SMTBMNEU868
US915	SMTBCDUS915	SMTBCNUS915	SMTBPDUS915	SMTBPNUS915	SMTBMDUS915	SMTBMNUS915

1.1 Information Streams

The main LoRaWAN UL and DL information streams supported by the Sensor are summarized in Table Overview-3.

Table Overview-3: Breeze/Breeze-V/Vivid+ Information Streams

Stream Direction	Stream Name	Data Type	Sent on LoRaWAN Port
UL (Sensor to NS)	Reported Transducer Data Stream	Readings obtained from on-board transducers	**10**
	Timestamp Acquisition Stream	Local timestamp acquisition requests and response from the Sensor	**20**
	Sensor Application Configuration Stream	Response to read commands from the NS	**100**
		Response to write commands from the NS	**101**
DL (NS to Sensor)	Timestamp Acquisition Stream	Local timestamp acquisition requests and response from the Application Server	**20**
	Sensor Application Configuration Stream	Configuration and control commands from the NS used to change the Sensor's behavior or inquire the Sensor for the values of configuration registers	**100**

1.2 Dynamic Reporting Modes

The Sensor supports multiple reporting modes so that transducer measurements can be reported to the LoRaWAN NS (and BLE Display, if applicable) at different configurable frequencies based on the time of day.

This feature is best suited for applications where rooms are expected to be occupied or vacant during specific hours of the day and days of the week, such as in a school. The Sensor can be configured to report transducer measurements at a different frequency during the expected active hours than at other times where rooms are expected to be vacant. For example, the Sensor can be configured with an active period of 9:00 AM to 5:00 PM from Monday to Friday in which it reports the CO_2 concentration every 5 minutes. Outside of that active period, including the entirety of Saturday and Sunday, the Sensor reports the CO_2 concentration every 1 hour.

The Sensor will periodically request timestamps in order to obtain and maintain an accurate time reference. An external application is required to send downlinks to the Sensor in response to uplinks containing timestamp requests. Uplink and downlink frame formats for local timestamp acquisition and current sensor timestamp requests/responses are detailed in Section 5. Additional details concerning application design are outside the scope of this document.

The DL configuration registers used to configure the dynamic reporting modes and timestamp acquisition behavior OTA are defined in Section 13.2.

> **NOTE:** It is highly recommended that this feature be used to achieve optimum battery life. If this feature is not used, users may want to modify the default reporting and transducer sampling periods (if applicable) to ensure a long battery life for the Sensor.

1.2.1 Active and Inactive Modes

The Sensor supports two different reporting modes: Active and Inactive mode. Active mode is intended to be used when the Sensor should report more frequently than when it is in Inactive mode. If dynamic reporting mode is enabled and the Sensor acquires a time reference, it will alternate between Active and Inactive mode configurations based on the Sensor's perceived time of day and configured active hour settings (configured according to Section 13). When the Sensor first joins the LoRaWAN network, it will assume Active mode configurations until it can verify that it is outside the configured Active mode time period using an acquired time reference. If dynamic reporting mode is disabled, the Sensor will only use the registers associated with Active mode configurations, regardless of the date and time.

The Active and Inactive reporting periods are controlled by two separate time synchronization registers. Active mode uses the Seconds per Core *Tick* register defined in Section 6.2 (0x20), while Inactive mode uses the Seconds per Core *Tick* register defined in Section 13.2 (0x69). Additionally, the CO_2 Sampling Parameters register defined in Section 0 (0x30) are used in Active mode, while the CO_2 Sampling Parameters register defined in Section 13.2 (0x6A) are used in Inactive Mode. The reporting frequencies of individual transducers are determined by the *tick* registers presented in Section 6.2 for both Active and Inactive modes. However, the *tick* registers are synchronized with the Seconds per Core *Tick* register associated with the current mode.

1.2.2 Default Reporting Configuration

The default reporting configurations are specified in Table Overview-4 for active and inactive reporting modes when dynamic reporting mode is enabled. Since the dynamic reporting mode feature is disabled by default, the Sensor will act as if it is exclusively in active mode.

NOTE 1: CO_2 concentration and pressure are reported by Breeze and Breeze-V models only. For the Vivid+ model, the Sensor will update the Display such that the CO_2 concentration field will be blank.

NOTE 2: Motion is reported by Vivid+ and Breeze-V models only.

Table Overview-4: Breeze/Breeze-V/Vivid+ Default Reporting Behavior

Parameter	Report Destination	Default Reporting Frequency	
		During Active Mode	During Inactive Mode
Remaining Battery Capacity of the Sensor	NS and Display	Every 5 (five) minutes	Every 1 (one) hour
Remaining Battery Capacity of the Display	NS and Display	Every 5 (five) minutes	Every 1 (one) hour
Ambient Temperature	NS and Display	Every 5 (five) minutes	Every 1 (one) hour
Ambient Relative Humidity	NS and Display	Every 5 (five) minutes	Every 1 (one) hour
CO_2 Concentration	NS and Display	Every 5 (five) minutes	Every 1 (one) hour
Pressure	NS only	Every 5 (five) minutes	Every 1 (one) hour
Motion	NS only	Report motion after 1 (one) PIR event Clear motion after 5 (five) minutes of no motion	Report motion after 1 (one) PIR event Clear motion after 5 (five) minutes of no motion

2 Sensor Activation and Management

This section outlines the steps required to set up the Breeze/Breeze-V/Vivid+ sensors and manage the Sensor thereafter.

2.1 Unpacking

The following items are included with every Breeze/Breeze-V/Vivid+ sensor package:

- One Breeze/Breeze-V/Vivid+ sensor module with two AA-cell LTC batteries installed and a battery tab for each that prevent the Sensor from turning on.
- A Quick Start Guide

When unpacking the package, please follow these precautions:

- Inspect the shipping carton and report any significant damage to TEKTELIC.
- Conduct unpacking in a clean and dry location.
- Store the package box in a safe and dry location after unpacking. This will be required for returns if the need arises.

2.2 Commissioning

Each Breeze/Breeze-V/Vivid+ sensor package box contains a sticker with the necessary commissioning values for registering the Sensor on a network server. The commissioning keys provided for each sensor include the following:

- Sensor T-code, Revision Number, and Serial Number: These unique identifiers ensure accurate tracking and maintenance of the specific sensor unit.
- DEVEUI (Device EUI): A globally unique 16-byte identifier for the device, used in the network server to identify the device.
- APPEUI (Application EUI): 16-byte key that Identifies the owner or the application provider of the device, ensuring it connects to the correct application.
- APPKEY (Application Key): A 32-byte security key used to authenticate the device during the join process with the network server.

Ensure to keep this information secure and accessible for future reference and troubleshooting.

2.3 Activation

The Breeze/Breeze-V/Vivid+ sensor is shipped in a sealed enclosure with two AA-cell batteries installed and engaged, but with a battery tab preventing the batteries from turning the device on. To start the Sensor, pull out both of the battery tabs and observe the LED activities as described in Section 3.3.

2.4 Mounting

On the battery side of the enclosure, there are two clip holes designed for attaching the Breeze/Breeze-V/Vivid+ sensor to a support structure, as shown Figure Sensor Activation and Management-1 below. The recommended screws for this purpose are stainless steel screws.

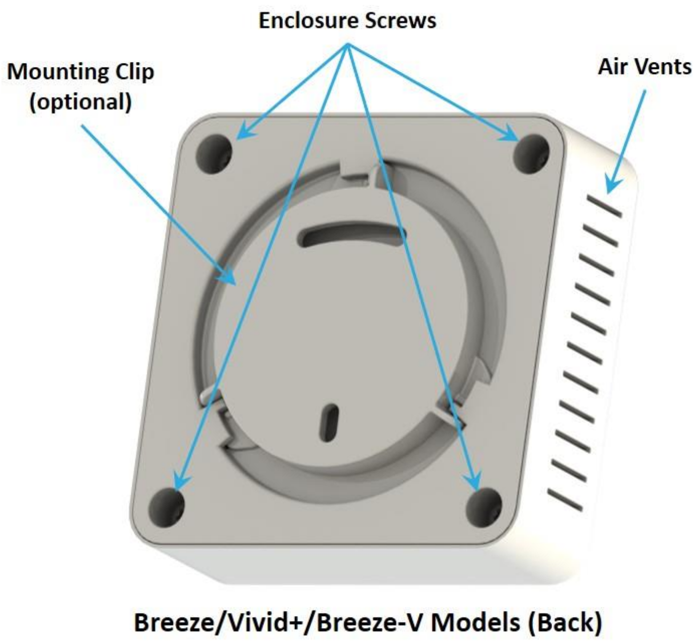


Figure Sensor Activation and Management-1: Breeze/Breeze-V/Vivid+ showing the mounting bracket screws

2.5 Battery Replacement

The Breeze/Breeze-V/Vivid+ sensor requires two AA-cell LTC batteries for operation. When replacing the batteries, ensure the correct polarity according to the markings on the enclosure.

Follow these steps to replace the batteries in the Breeze/Breeze-V/Vivid+ sensor:

1. Locate the battery compartment at the back of the Breeze/Breeze-V/Vivid+ module and use a Phillips screwdriver to carefully open the battery compartment. Keep the screws in a safe place.
2. Remove the existing batteries from the compartment and dispose of it in accordance with local regulations.
3. Insert the replacement batteries.
4. Ensure the correct polarity by aligning the batteries with the polarity markings inside the compartment.
5. Carefully close the battery compartment, tightening each screw to 2.5 lbs-in (30 N-cm) to prevent moisture or debris from entering.

6. The Sensor will start up as soon as the batteries make contact with the terminals.

Remember to handle batteries with care and avoid mixing old and new batteries or different types of batteries, as this can affect device performance and battery life.

3 External Interfaces

The Breeze/Breeze-V/Vivid+ include two push-buttons and four onboard LEDs. Figure External Interfaces-2 shows the location of the push-buttons and LEDs relative to a user facing the Sensor. The buttons can be pressed by applying gentle pressure with a pin, such as a paperclip.

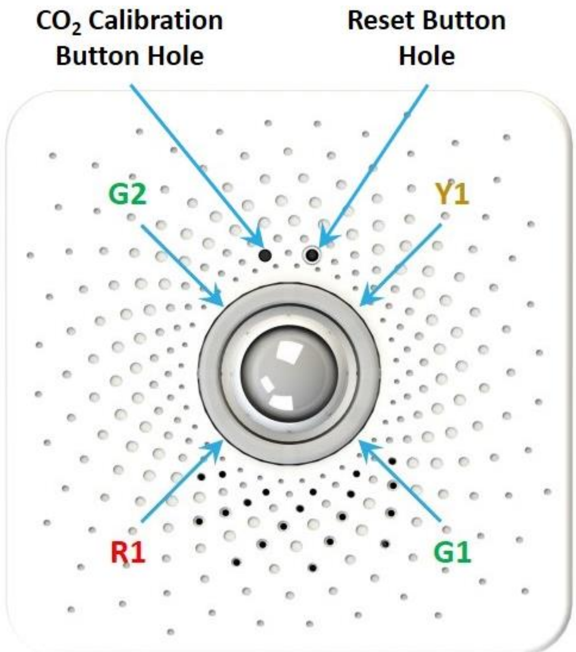


Figure External Interfaces-2: Breeze-V with Marked Push-Button and LED Positions

3.1 CO_2 Calibration Button

The Sensor features a push-button that can be used to manually calibrate the CO_2 transducer when it is exposed to fresh air. The CO_2 calibration button must be pressed and held for 2 to 10 seconds, then released. Around 30 seconds after the button is released, the Sensor performs a background CO_2 calibration with a target of 400 ppm.

For optimal results, users should ensure that the Sensor is exposed to fresh air for several minutes before the calibration occurs. It is also recommended that users move away from the Sensor after pressing the button so as to reduce the risk of an inaccurate calibration. More information on how to calibrate the CO_2 transducer can be found in Section 8.

3.2 Reset Button

There is a reset button on the device that will restart the Sensor's MCU. All the configuration parameters saved in the Flash memory are remembered during the reset.

3.3 LED Behavior

The Sensor is equipped with four LEDs: two green (G1 and G2), one yellow (Y1), and one red (R1) as shown in Figure External Interfaces-2.

Table External Interfaces-5 shows the LED behavior defined for the Sensor in certain situations.

Table External Interfaces-5: List of Breeze/Breeze-V/Vivid+ LED Behaviors

Situation	Behavior Description

Sensor Startup	1. **R1** is turned on when the POST begins.
	2. When the POST ends, depending on the POST result:
	    a. If the POST passed, **G1** and **G2** flashes 3 times for 0.6 sec.
	    b. If the POST failed, **R1** flashes 3 times for 0.6 sec.
	3. **R1** is turned off when the POST and subsequent LED flashing specified in item 2 end.

LoRaWAN Join	**Y1** is toggled on and off every 50 ms for the first hour. But after that, it flashes 2 times (on: time 50 ms, off time: 50 ms) every 10 seconds.
LoRa Tx/Rx (During and After Join)	1. **G1** flashes once for 25 ms right after transmitting a LoRa UL. 2. **G1** flashes once for 100 ms right after receiving a LoRa DL.

BLE Tx/Rx	1. **G2** flashes once for 25 ms every 0.5 seconds while the Sensor is attempting to communicate with the Display. This ends when the connection between the Sensor and Display is either closed or unsuccessful.
	2. When the BLE Display event ends, depending on the result:
	    a. If the Sensor successfully communicated with the Display, **G2** flashes 2 times for 0.2 sec right after the BLE connection has been closed.
	    b. If the BLE connection has been unsuccessful or closed prematurely, **R1** flashes 2 times for 0.2 seconds right after the BLE connection has been closed.

CO_2 Calibration (Regardless of Type)	1. If the CO_2 calibration push button is pressed and released, **Y1** flashes 3 times for 0.6 seconds. 2. After any CO_2 calibration is successfully complete, **G2** flashes 3 times for 0.6 seconds. 3. After any CO_2 calibration fails, **R1** flashes 3 times for 0.6 seconds.

4 General Sensor and LoRaWAN Communication Information

The Breeze/BreezeV/Vivid+ devices communicate with the Network Server (NS) using LoRaWAN packets. When the device sends data to the NS, it's referred to as an UPLINK, whereas communication from the NS to the device is termed a DOWNLINK. By default, LoRaWAN communications for Breeze/BreezeV/Vivid+ devices are Class A or one-way, implying that the device is either transmitting data to the NS or receiving data from it, but not both simultaneously. However, these and other sensor behaviors can be configured differently to suit various types of applications.

The subsequent sub-sections outline the general format of uplinks and downlinks, communication streams, and packet formats supported by Breeze/BreezeV/Vivid+ devices. For comprehensive packet codec functionality, an online application called KONA ATLAS is available [3]. This tool supports the encoding of Downlink (DL) payloads and decoding of Uplink (UL) payloads specifically for Breeze/BreezeV/Vivid+ devices.

4.1 Uplink Payloads

Uplinks are LoRaWAN packets sent from the Breeze/BreezeV/Vivid+ to the NS. Each uplink from the Breeze/BreezeV/Vivid+ is encoded in a frame shown below.

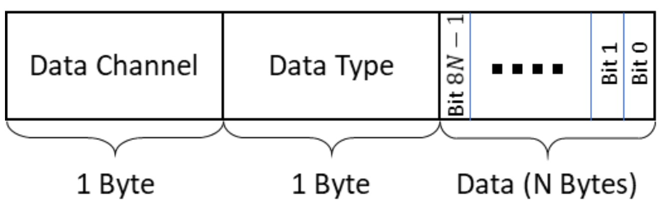


Figure General Sensor and LoRaWAN Communication Information-3: Uplink Payload Format

NOTE: Big-endian format (MSb/MSB first) is always followed.

A Breeze/BreezeV/Vivid+ uplink payload can include multiple blocks of uplinks from the same port and can be arranged in any order. Uplink payloads are generally categorized into the following.

1. Informational data uplinks: These uplinks convey information from the Sensor to the NS regarding specific requests, actions, or sensor status updates. Unlike sensor data uplinks, informational data uplinks do not require transducer measurements. An example is the timestamp acquisition stream, which consists of the requesting local timestamps or the Sensor responding with timestamps.
2. Sensor data uplinks: These uplinks consist of measurement reports obtained from onboard transducers such as the CO_2 transducer, PIR sensor, temperature sensor, etc.

For each of the uplink category above, there are two further sub-divisions based on the event or action that triggers the report. This sub-categorization helps in organizing and understanding the nature of the data being transmitted.

1. Periodic: uplink reports are sent at regular intervals defined by a system time period known as a “tick”.
2. Event based reporting: uplink is triggered by specific actions or events, such as a press of a button.

Table General Sensor and LoRaWAN Communication Information-6 below tabulates the supported uplink streams for Breeze/BreezeV/Vivid+ sensors, their uplink types, and their corresponding port numbers.

Table General Sensor and LoRaWAN Communication Information-6: Breeze/BreezeV/Vivid+ Uplink Streams

Uplink Heading	Information/Sensor Data	Periodic/Event-based	Port
Timestamp Acquisition • Local Timestamp Request • Sensor Timestamp Response	Information	Event-based (if dynamic mode is enabled the Sensor will continue to send timestamp requests until it has either received a timestamp request response from the NS or after 15 minutes have passed without a response)	20
All real-time sensing data • Relative Humidity report • Temperature report • Hall Effect Count and State • Impact Alarm • Motion Count and State • Acceleration vector and magnitude • External Inputs states • MCU Temperature report • Ambient Light intensity and State • Battery life information report	Sensor Data	Periodic	10
Response to downlink commands	Information	Event-based (on any read/write downlink command)	100 (read), 101 (write)

Refer to Appendix 0 for a comprehensive table of all supported uplinks.

4.2 Downlink Payloads

Downlinks, which are LoRaWAN packets transmitted from the Network Server (NS) to the Sensor, play a vital role in communicating instructions or requests to the Breeze/BreezeV/Vivid+ devices. These downlinks can be categorized as follows:

1. Application Request Downlinks: These downlinks are directed to the Sensor to solicit information regarding system status. Notably, these downlink registers are read-only.
    a. Request local timestamps from the Sensor on ***LoRaWAN Port 20*** (Refer to Section 5)

2. Configuration and Control Downlinks (***LoRaWAN Port 100*** downlinks): These downlinks are dispatched to the Sensor to either read, write, or execute other configuration-related actions.

    a. Request to read the current value of a configuration register (R)

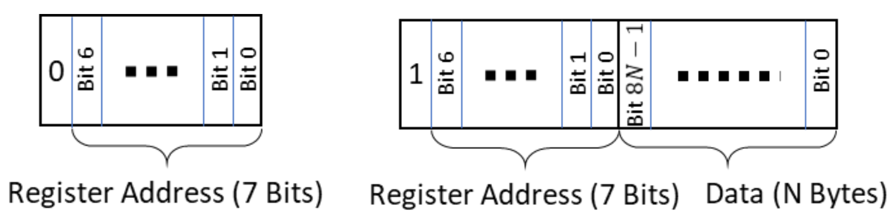
    b. Request to write a value to a configuration register (W)

    c. Request for the Sensor to execute a specific operation, such as resetting to factory defaults (Refer to Section 6.4)

    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 General Sensor and LoRaWAN Communication Information-4. A big-endian format (MSB first) is always followed.

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

    Bit 7 of the first byte determines whether a read or write action is being performed, as shown in Figure General Sensor and LoRaWAN Communication Information-4. 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 block **(b) The write command block.**

Figure General Sensor and LoRaWAN Communication Information-4: Format of a DL configuration and control message block.

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

NOTE: When forming DL payloads with more than 1 command block, sometimes the order of the commands will affect how the Sensor responds overall to the whole payload. Refer to Section 4.3 for a description of how the Sensor processes, executes, and responds to configuration and control commands.

4.3 Response to Downlink Payloads

When the Breeze/BreezeV/Vivid+ receives a downlink containing a request for an action, such as reading the value of a downlink register or writing to a downlink register, it responds with an acknowledgement to the network server. This acknowledgement indicates whether the read or write operation was successful or failed.

Commands received in a downlink (DL) payload are processed sequentially, one at a time, from Most Significant Bit (MSB) to Least Significant Bit (LSB). However, they are typically not executed immediately upon processing. Write commands, if deemed valid, are executed promptly upon processing. Conversely, other types of commands are queued for execution later.

If all commands were processed successfully, the following happens in order:

1. Any queued Command-and-Control (C&C) operations[3] are executed in the following order.
    a. Save configuration settings to flash.
    b. Reset configuration settings to factory default.
    c. Restart sensor.
2. If any read commands were queued, they are executed, and a ***LoRaWAN port 100*** **read response** is sent.
3. If any write commands were executed, a ***LoRaWAN port 101*** **write response** is sent.

As soon as an invalid command[4] is processed, the following happens in order:

1. No further command blocks are processed.
2. If any read commands were queued, they are executed, and a ***LoRaWAN port 100*** **read response** is sent.
3. A ***LoRaWAN port 101*** **write/error response** is sent.

Read Response: In the case of a valid read command block, a UL payload is sent back on ***LoRaWAN port 100*** containing the addresses and values of each of the registers under query. The bit indexing scheme as shown in Figure General Sensor and LoRaWAN Communication Information-5 below

[3] C&C operations are defined as commands accessing register 0x 70 or 0x 72 with bit 7 set to 1 (i.e. if a command block begins with 0x F0 or 0x F2). Refer to section **Error! Reference source not found.** for more details.

[4] An invalid command is one that either tries to access a register designated as RFU or write an invalid value to an accessible register.

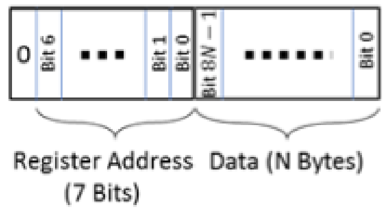


Figure General Sensor and LoRaWAN Communication Information-5: Bit Indexing Scheme for Configuration Registers

If the Sensor receives a read command trying to access a register that is designated as RFU, the address is included in the error response as described below.

Write/Error Response: A message UL is sent on ***LoRaWAN port 101*** with the frame format as shown in Figure General Sensor and LoRaWAN Communication Information-6.

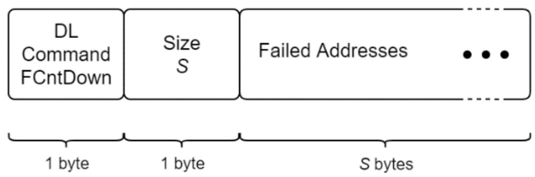


Figure General Sensor and LoRaWAN Communication Information-6: The *LoRaWAN port 101* Write/Error Response UL Frame Format

The contents of the frame include:

- *DL Command FCntDown*: the last byte (LSB) of the LoRaWAN frame count down number of the DL payload which contained the command block that elicited this response [4].
- *Size*: the number of registers, *S*, that were NOT successfully written to, and therefore the size of the rest of the payload. *S* can range from 0 to 255.
- *Failed Addresses*: the address(es) of the register(s) where the command(s) failed.

If all commands were successful, *S* = 0x 00 and no failed addresses are included. This includes if a redundant write command was issued (i.e., the value of that register did not change).

As soon as the Sensor encounters an invalid command block (read or write), the address of that command block is added to the ***LoRaWAN port 101*** response and no further command blocks are processed.

NOTE:

- If anti-bricking is activated, the downlink command is considered unsuccessful and register address 0x 21 will be added to the ***LoRaWAN port 101*** response. See Section 6.2.1.1 for more details about anti-bricking.
- If there were any C&C operations queued to be executed but 1 or more command blocks in the payload were unsuccessful, the C&C commands are ignored, and their addresses are added to the ***LoRaWAN port 101*** response.
- If the DL payload had a mix of read and write command blocks, the read responses are sent separately on ***LoRaWAN port 100*** as described above. In this case, the read responses are sent first

4.4 Configuration Settings

Table General Sensor and LoRaWAN Communication Information-7 shows the downlink response configuration registers.

Table General Sensor and LoRaWAN Communication Information-7: Downlink Response Configuration Registers

Address	Name	Size	Access	Description	JSON Variable	Default
0x6F	Format Option	1 B	R/W	• Bit 0: 0: Invalid-write response format 1: 4-byte CRC • Bits 1-7: Ignored	*resp_to_dl_command_ format: <value> (string/no unit)*	Invalid-write response format selected **0x 00**

4.4.1 Example of Response to DL Command Payloads

- ***LoRaWAN port 101:* 0x 0F 00**
  - 0x 0F → Response to write command in DL with FCntDown ending in 15
  - 0x 00 → Size = 0; no failed write commands

- ***LoRaWAN port 101:* 0x 03 04 15 16 17 18**
  - 0x 03 → Response to write command in DL with FCntDown ending in 3
  - 0x 04 → Size = 4; 4 failed write commands
  - 0x 15 16 17 18 → The write commands attempting to overwrite registers 0x 15, 0x 16, 0x 17, and 0x 18 all failed.

5 Timestamp Acquisition Stream

The timestamp acquisition stream is used to exchange timestamp acquisition data between a Sensor and application server via LoRaWAN. Uplinks and downlinks containing local time acquisition requests/responses and sensor timestamp requests/responses are ***sent on LoRaWAN port 20***.

5.1 Uplink Timestamp Requests and Response from Sensor

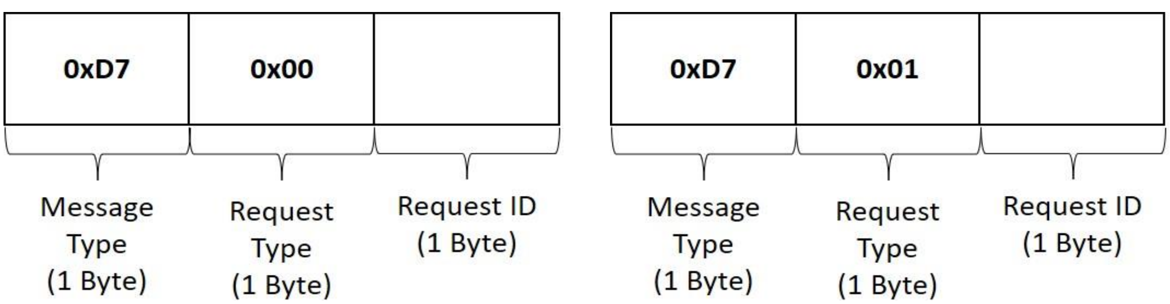
The Sensor uplinks ***sent on LoRaWAN port 20*** contain either a local timestamp acquisition request or a sensor timestamp response. These two types of messages are distinguished by the first byte of the uplink payload:

- **0xD7** for local timestamp acquisition requests
- **0x85** for sensor timestamp responses

5.1.1 Local Timestamp Acquisition Requests

If dynamic reporting mode is enabled and the Sensor does not have an existing[5] time reference, it will send timestamp requests every minute until it receives a timestamp request response from the NS or 15 minutes pass without a response. In the case where the Sensor does not receive a timestamp within 15 minutes, dynamic reporting mode becomes disabled. Users can re-enable dynamic reporting mode through DL configuration register 0x66 (see Section 13.2).

Uplinks containing timestamp acquisition requests are ***sent on LoRaWAN port 20***. The payload formats are shown in Figure Timestamp Acquisition Stream-7 and described in Table Timestamp Acquisition Stream-8.



(a) Acquire initial time reference (b) Update existing time reference

Figure Timestamp Acquisition Stream-7: Frame format of local timestamp acquisition request in an UL payload.

Table Timestamp Acquisition Stream-8: Description of frame format of local timestamp acquisition

Byte	Name	Description
1	Message Type	Local timestamp acquisition requests and responses use 0xD7.

[5] The Sensor loses any previous time reference once it is powered-off/reset or when the dynamic reporting mode is disabled using DL configuration register 0x66 (see Section 13.2).

2	Request Type	Sensor uses 0x00 if it does not have an existing time reference, and it uses 0x01 when it wishes to update its existing time reference.
3	Request ID	Initially a pseudo-random number when the Sensor sends its first timestamp request, and then increments for each subsequent timestamp request. The Request ID wraps to 0 after it reaches the maximum number.

After the Sensor has successfully calculated an initial reference time, it will send periodic timestamp requests (the frequency of which is determined by DL configuration register 0x67) to keep its time reference updated. This is necessary to account for daylight savings time and cumulative timing error due to the inaccuracy of the Sensor's RTC. Periodic timestamp update requests are sent at 3:00 AM (local time) on days determined by the configured timestamp update period. See Section 13 for more information on the timestamp update period. See Section 5.2.1 for more information about how the Sensor calculates and tracks the local time from the acquired timestamp.

5.1.2 Sensor Timestamp Response

The application may request the Sensor's current perceived timestamp by sending DL frames containing sensor timestamp requests as described in Section 5.2.2. If the Sensor receives a sensor timestamp request (***sent on LoRaWAN port 20***), it responds immediately with a UL following the payload format shown in both Figure Timestamp Acquisition Stream-8 and Table Timestamp Acquisition Stream-9. A big-endian format (MSb/MSB first) is always followed.

Figure Timestamp Acquisition Stream-8: Frame format of sensor timestamp response in an UL payload.

If the Sensor does not have an existing time reference, the Sensor will report the local timestamp as 0.

Table Timestamp Acquisition Stream-9: Sensor Timestamp Response Payload Format Description

Value	Size	Description
Message Type	1 B	• Message type to indicate that this is a sensor timestamp response (0x85)
Local Timestamp	4 B	• Seconds in current Epoch since January 1, 1970 (UTC) + local UTC offset (in seconds) • 1 sec / LSB (unsigned)

5.2 Downlink Timestamp Requests and Response from Application

Downlinks containing either a local timestamp acquisition response or a sensor timestamp request are ***sent on LoRaWAN port 20***. These two types of messages are distinguished by the first byte of the downlink payload:

- **0xD7** for local timestamp acquisition responses
- **0x85** for sensor timestamp requests

5.2.1 Local Timestamp Acquisition Response

Once the NS receives a local timestamp acquisition request ***sent on LoRaWAN port 20*** from the Sensor, the application server should queue a DL response *specific to the individual UL request.* The Sensor expects to receive a DL response within the time it takes to send the next two uplinks, regardless of what those two uplinks contain. If the Sensor does not receive a response within this interval, it ignores any future attempts to respond to that specific timestamp request.

The expected downlink payload format is detailed in both Figure Timestamp Acquisition Stream-9 and Table Timestamp Acquisition Stream-10.

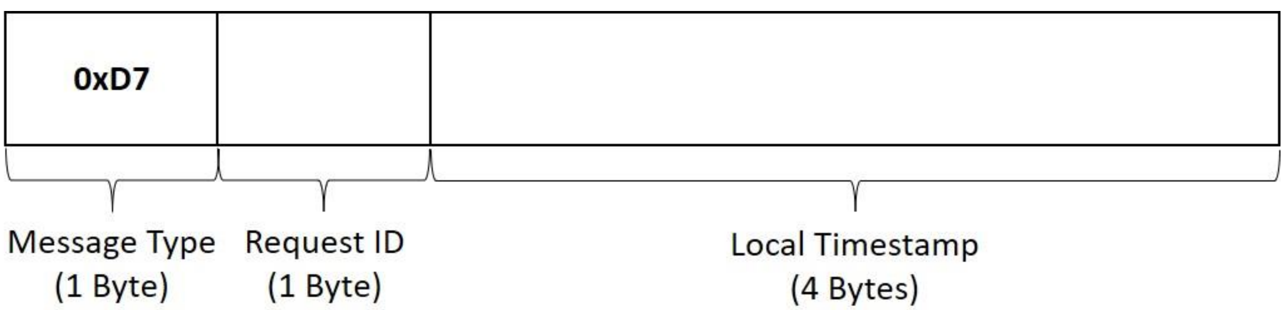


Figure Timestamp Acquisition Stream-9: Frame format of local timestamp acquisition response in a DL payload.

The DL response must begin with the message type corresponding to local timestamp acquisition requests and responses (i.e., 0xD7). The next byte must include the Request ID matching that of the UL timestamp request that the DL is responding to. The last four bytes consist of a local timestamp indicating when the UL timestamp request with the matching Request ID was received by the NS. The application server should send a Unix timestamp that is offset by the local UTC offset (in seconds) so that the Sensor has the correct local time.

Table Timestamp Acquisition Stream-10: Local Timestamp Acquisition Response Payload Format Description

Value	Size	Description
Message Type	1 B	• Message type to indicate that this is a local timestamp acquisition response (0xD7)
Request ID	1 B	• Request ID matching the UL timestamp request associated with timestamp
Local Timestamp	4 B	• Seconds in current Epoch since January 1, 1970 (UTC) + local UTC offset (in seconds) • 1 sec / LSB (unsigned)

Once the Sensor has a time reference, it will track the time of day and alternate between the two independently-configured reporting modes based on this time of day. The Sensor calculates the reference time received from the application according to the following formula:

Current time = Unix timestamp with local offset + time elapsed between request sent and response received

NOTE: It is recommended that the application send a sensor timestamp request (see Section 5.2.2) after the Sensor has successfully received a time reference for the first time in order to verify that the local timestamp has been configured correctly.

Example:

Figure Timestamp Acquisition Stream-10 shows a general example of the transactions between the Sensor, NS, and application.

If the Sensor sends a timestamp request in ULa, it expects to receive a response in either of the LoRa receive windows following ULa or ULb. If a response is not received prior to sending ULc, the Sensor stops tracking the time since it sent ULa. If a response is received prior to sending ULc, the Sensor calculates the elapsed time between when it sent ULa and when it received the response to ULa. The Sensor then calculates the current time to use as its time reference.

Also note that if the response to ULa is not received before the Sensor transmits ULb, ULb can also contain another timestamp request. In that case, the Sensor keeps track of both times since ULa and ULb were sent. If the Sensor does not receive a response to timestamp requests in ULa and ULb prior to receiving ULc, the Sensor stops tracking the time since ULa was sent, and instead begins tracking the time since ULc was sent, and so on.

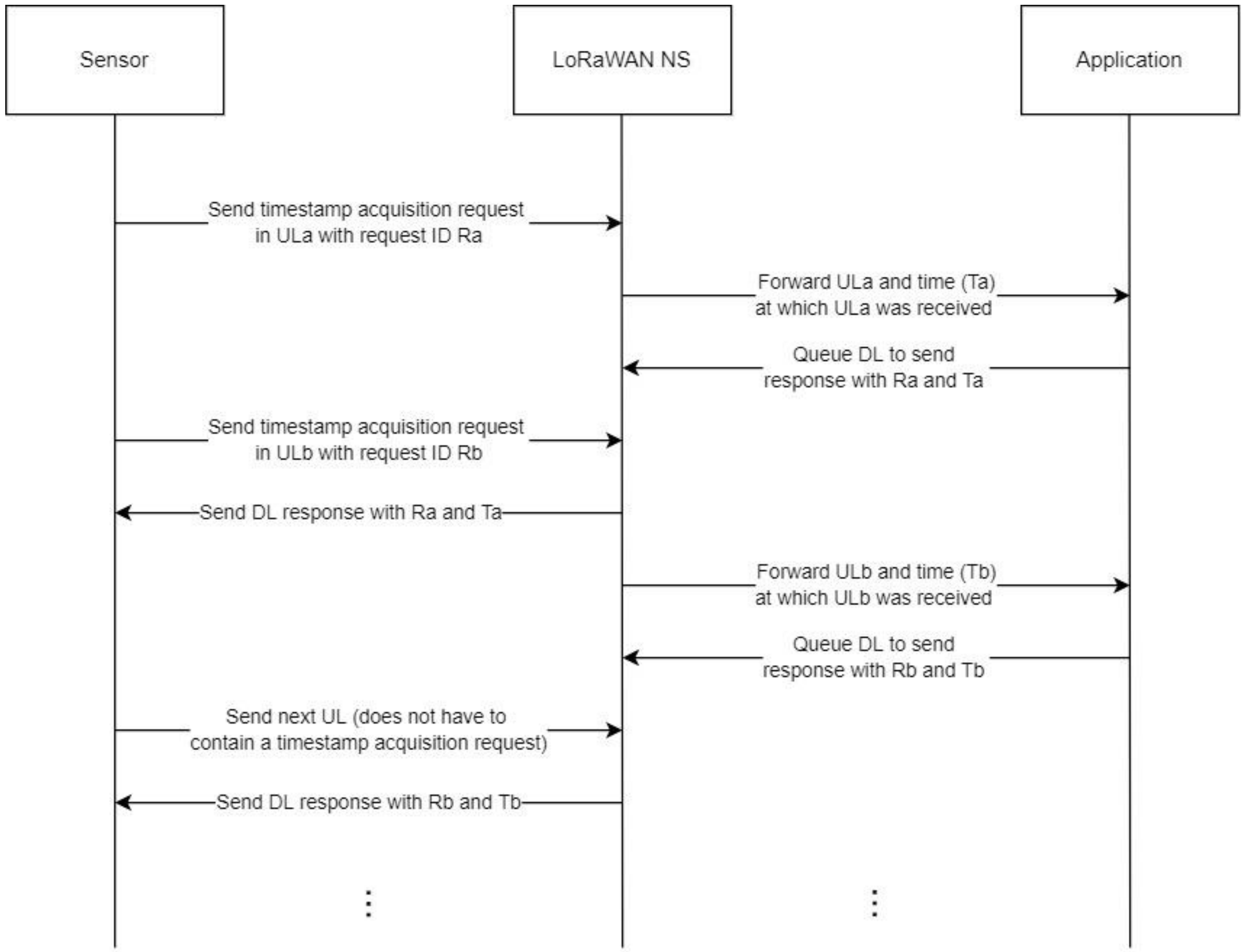


Figure Timestamp Acquisition Stream-10: Example of Sensor, NS, and application timestamp acquisition transactions.

Examples of local timestamp acquisition response payloads:

- Generating a response to UL request with payload: {0x D7 00 1A}
  - Assume the UL was received on the NS at 2027-09-21 19:47:59 (without local offset), or 1821556079 seconds in Unix time and the Sensor is operating in a time zone that uses UTC-7:00 (-25200 sec).
  - DL response payload would be: {0x D7 1A 6C 92 5A FF}
    - Message Type = 0x D7
    - Request ID = 0x 1A
    - Local timestamp calculated as 1821556079 - 25200 = 1821530879 (2027-09-21 12:47:59) or 0x 6C 92 5A FF

- When the Sensor receives this response, it will calculate its perceived time to be 2027-09-21 12:47:59 + time elapsed between UL with Request ID 0x1A sent and response to UL with Request ID 0x1A received.

- Generating a response to UL request with payload: {0x D7 01 FE}
  - Assume the UL was received on the NS at 2021-06-11 14:10:24 (without local offset), or 1623420624 seconds in Unix time and the Sensor is operating in a time zone that uses UTC+9:30 (34200 sec).
  - DL response payload would be: {0x D7 FE 60 C3 F4 68}
    - Message Type = 0x D7
    - Request ID = 0x FE
    - Local timestamp calculated as 1623420624 + 34200 = 1623454824 (2021-06-11 23:40:24) or 0x 60 C3 F4 68
  - When the Sensor receives this response, it will calculate its perceived time to be 2021-06-11 23:40:24 + time elapsed between UL with Request ID 0xFE sent and response to UL with Request ID 0xFE received.

5.2.2 Sensor Timestamp Requests

The application may request the perceived local timestamp of the Sensor with a sensor timestamp request ***sent on LoRaWAN port 20***. The downlink payload format is shown in Figure Timestamp Acquisition Stream-11, where only the message type of sensor timestamp requests and responses (i.e., 0x85) must be sent. The Sensor will then respond with its current perceived timestamp as specified in Section 5.1.2.

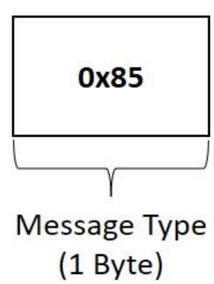


Figure Timestamp Acquisition Stream-11: Frame format of sensor timestamp request in a DL payload.

6 Basic Operation Configuration

The basic functionality of the Breeze/BreezeV/Vivid+ can be broken down into the following categories:

- **LoRaMAC Options**: LoRaWAN general parameters and behaviour as defined by the LoRaWAN Specifications [4].
- **Periodic Report Scheduling**: Scheme for scheduling regular sensor data reports.
- **Battery Management**: Keeping track of consumed battery charge.
- **General Command and Control Operations**: Reading SW metadata, saving configuration settings, resetting to factory default, and sensor restart.

In the following subsections, the operational descriptions, report formats, and configurable settings for each category are explained.

6.1 LoRaMAC Configuration

6.1.1 Operational Description

The LoRaMAC options manage specific LoRaWAN-specified MAC configuration parameters that the Sensor initializes on start-up and utilizes during run-time. The definitions for these parameters are outlined in the LoRaWAN Specifications and Regional Parameters [4], [2]. For detailed descriptions of these parameters and their expected behavior, please refer to these sources, as they are beyond the scope of this Technical Reference Manual (TRM).

6.1.2 Configuration Settings

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 Basic Operation Configuration-11 shows the MAC configuration registers.

Table Basic Operation Configuration-11: LoRaMAC Configuration Registers

Address	Name	Size	Access	Description	JSON Variable	Default
0x10	Join Mode	2 B	R/W	• Bits 0-13: RFU, must be set to 0, otherwise invalid • Bit 14: ABP/OTAA mode	loramac_join_mode: <value> (unsigned/no unit)	OTAA mode **0x 01**
0x11	Options	2 B	See description	• Bits 0 (Read/Write): 0: Unconfirmed 1: Confirmed	*loramac_opts: { confirm_mode: <value>,*	Unconfirmed UL Public Sync

				• Bit 1 (Read Only): 1 0: Private Sync Word 1: Public Sync Word • Bit 2 (Read/Write): 0: Duty Cycle Disabled 1: Duty Cycle Enabled • Bit 3 (Read/Write): 0: ADR Disabled 1: ADR Enabled • Bits 4-15: RFU	*(unsigned/no unit)* *sync_word: <value>,* *(unsigned/no unit)* *duty_cycle: <value>,* *(unsigned/no unit)* *adr: <value>* *(unsigned/no unit)* *}*	Word Duty Cycle Enabled[6] ADR Enabled **0x 00 0E**
0x12	DR and Tx Power[7]	2 B	R/W	• Bits 0-3: Default Tx power • Bits 4-7: RFU • Bits 8-11: Default DR number • Bits 12-15: RFU	*loramac_dr_tx: {* *dr_number: <value>,* *(unsigned/no unit)* *tx_power_number: <value>* *(unsigned/no unit)* *}*	DR4 Tx Power 0 (as per the LoRaWAN Regional Parameters [2])
0x13	Rx2 Window	R/W	5 B	• Bits 0-7: DR for Rx2 • Bits 8-39: Channel frequency in Hz for Rx2	*loramac_rx2: {* *frequency: <value>,* *(unsigned/Hz)* *dr_number: <value>* *(unsigned/no unit)* *}*	As per the LoRaWAN Regional Parameters [2]

NOTE: Modifying these LoRaMAC settings only changes them in the Sensor; LoRaMAC setting in the NS may also need to be changed depending on the desired use case and to ensure a sensor is not stranded without being able to communicate with the network. Modifying configuration parameters in the NS is outside the scope of this document.

6.1.3 LoRaMAC Config Examples

- Disable ADR, keep Duty Cycle enabled, and use confirmed ULs:
    - DL payload: **0x 91 00 07**
        - Register 0x 11 with bit 7 set to 1 = 0x 91

[6] **WARNING**: Disabling the duty cycle in certain regions makes the Sensor non-compliant with the LoRaWAN Specifications [4]. It is recommended that the duty cycle remains enabled. In the LoRa RF regions where there is no duty cycle limitation, the “enabled duty cycle” configuration is invalid.

[7] Tx power number m translates to the maximum Tx power, which is a function of the LoRaWAN RF region, minus $2 \times m$ dBInvalid source specified..

        - Desired options: register value with bit 3 set to 0, bit 2 set to 1, bit 1 set to 1, and bit 0 set to 1 = 0x 00 07
- Set default DR number to 3 and default Tx power number to 4:
    - DL payload: **0x 92 03 04**
        - Register 0x 12 with bit 7 set to 0 = 0x 92
        - DR3 = 0x 03
        - Tx 4 = 0x 04

6.2 Periodic Tx Configuration

6.2.1 Operational Description

All periodic reporting of sensor data is synchronized around ticks. The *core tick* is simply a user-configurable time base unit that is used to schedule sensor measurements. For each transducer or subsystem in the Sensor, the number of elapsed ticks between data transmissions is configurable. These reporting periods are defined by the following equation:

<Data Type> *Reporting Period*   *Seconds per Core Tick* × *Ticks per* <Data Type>

The available options for periodically reported data types are listed below. That is, <Data Type> can be:

- **Battery**: Remaining capacity [%], Battery voltage [volts], or both. See Section 6.3 for battery management details.
- **CO_2 Concentration**: CO_2 of the ambient environment [ppm]. See Section 8 for details.
- **Barometric Pressure**: Pressure of the ambient environment [hPa]. See Section 9 for details.
- **Ambient Temperature**: Temperature of the ambient environment [°C]. See Section 10 for environment sensing details.
- **Relative Humidity**: Relative Humidity of the ambient environment [%]. See Section 10 for environment sensing details.
- **Ambient Light**: State and intensity of the ambient environment. See Section 11 for environment sensing details.
- **Motion Sensor (BreezeV ONLY)**: State and the number of state changes of the motion sensor. See Section 12 for motion sensor operation details.

NOTE: *Seconds per Core Tick* cannot be set to 0; periodic transmissions cannot be globally disabled.

If <Data Type> *Reporting Period* equals 0, it means that periodic reporting is disabled for that data type. Since *Seconds per Core Tick* cannot be set to 0, the above equation can only equal 0 when *Ticks per* <Data Type> is equal to 0. Therefore, to disable the periodic reporting of a specific data type, set its *Ticks per* <Data Type> to 0.

The default reporting behaviour is as tabulated in Table Overview-4. These settings only control the scheduling of reporting data, not *what* is reported; the format and/or content of the reported payloads may depend on other configuration settings. Additionally, the periodic report scheduling settings only affect *periodic* reporting behaviour and do not affect *event-based* reporting behaviour. To configure behaviour not related to the scheduling of reports, refer to the relevant sections for the subsystem or transducer being used.

The second periodic report for any enabled transducer report after the Sensor has successfully joined the network may occur earlier than expected. This is because the core tick timer starts counting immediately after the join process is successful, but the first periodic UL may not happen until after a few seconds. Using the default battery report period of 24 hours as an example, the Sensor sends the first battery report about 5 seconds after join, then the next one 24 hours after join (so 23 hours 59 minutes and 50 seconds after first uplink, and not exactly 24 hours). Every other uplink after the second occur after 24 hours).

6.2.1.1 Anti-bricking Strategy

As a Class-A LoRaWAN end-device, the Breeze/BreezeV/Vivid+ sensor can only receive a DL in the short period after sending an UL. Therefore, if the Sensor is configured to send periodic ULs very infrequently or not at all, it could become impossible to send a DL command. A sensor in a “stranded” state like this is referred to as *bricked*.

The anti-bricking strategy is summarized by the following statement:

The Battery Reporting Period cannot be set to 0 or a value greater than 1 day.

Consequently, it is impossible to completely disable periodic reporting. This is accomplished by restricting acceptable values of the tick registers. Specifically:

1. Register 0x 20: *Seconds per Core Tick* cannot be set to 0.

   This ensures that all periodic reporting cannot be disabled at once.

2. The equation in below must be nonzero and less than or equal to 1 day (86 400 s) for the battery report. This ensures that at a minimum, the Sensor will send a battery report UL once per day. That is, the following must be true:

$$\textit{Battery Reporting Period} \quad \textit{Seconds per Core Tick} \times \textit{Ticks per Battery}$$

$$0 \ \ Battery\ Reporting\ Period \leq 1\ \text{day}$$

$$0 \ \ Battery\ Reporting\ Period \leq 86\,400\ \text{s}$$

If the SW detects that a configuration has been set which does not satisfy the above condition, the *Ticks per Battery* is automatically set to $\lfloor \frac{86400s}{SecondsperCoreTick} \rfloor$.

6.2.2 Configuration Settings

All periodic transducer reporting is synchronized around *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 Basic Operation Configuration-12.

Table Basic Operation Configuration-12: Periodic Transmission Configuration Registers

Address	Name	Size	Access	Description	JSON Variable	Default
0x20	Seconds per Core *Tick*	4 B	R/W	• *Tick* value for periodic events (1 sec / LSB) • Acceptable values: 0, 10, 11, …, 86400 • 0: Disables all periodic transmissions • Other values: Invalid and ignored	*seconds_per_core_tick: <value> (unsigned/sec)*	300 (5 mins) **0x 00 00 01 2C**
0x21	*Ticks* per Battery	2 B	R/W	• Ticks between battery reports • 0: Disables periodic battery reports	*ticks_battery: <value> (unsigned/no unit)*	1 (thus 5-min period) **0x 00 01**
0x22	*Ticks* per Ambient Temperature	2 B	R/W	• Ticks between ambient temperature reports • 0: Disables periodic ambient temperature reports	*ticks_temp: <value> (unsigned/no unit)*	1 (thus 5-min period) **0x 00 01**
0x23	*Ticks* per Ambient RH	2 B	R/W	• *Ticks* between ambient RH reports • 0: Disables periodic ambient RH reports	*ticks_rh: <value> (unsigned/no unit)*	1 (thus 5-min period) **0x 00 01**
0x25	*Ticks* per Ambient Light	2 B	R/W	• *Ticks* between ambient light reports • 0: Disables periodic ambient light reports	*ticks_light: <value> (unsigned/no unit)*	0 (periodic Tx disabled) **0x 00 00**
0x26	*Ticks* per CO_2	2 B	R/W	• *Ticks* between CO_2 reports • 0: Disables periodic CO_2	*ticks_co2: <value> (unsigned/no unit)*	1 (thus 5-min period)

				reports		**0x 00 01**
0x27	*Ticks* per Pressure	2 B	R/W	• *Ticks* between Pressure reports • 0: Disables periodic Pressure reports	*ticks_pressure: <value> (unsigned/no unit)*	1 (thus 5-min period) **0x 00 01**
0x28	*Ticks* per Motion (PIR)	2 B	R/W	• *Ticks* between motion (PIR) reports • 0: Disables periodic motion (PIR) reports	*ticks_motion_pir: <value> (unsigned/no unit)*	0 (periodic Tx disabled) **0x 00 00**

6.2.3 Example DL Payloads

- Disable all periodic events:
  - DL payload: { 0x **A0** 00 00 00 00 }
    - Register 0x20 with the write bit set to true
    - Seconds per *Tick* set to 0 (zero)—i.e., disable periodic transmissions
- Read current value of Seconds per *Tick*:
  - DL payload: { 0x **20** }
    - Register 0x20 with the write bit set to false
- Report Temperature every *tick* and RH every two *ticks*:
  - DL payload: { 0x **A2** 00 01 **A3** 00 02 }
    - Registers 0x22 and 0x23 with their write bits set to true
    - Temperature *Ticks* set to 1 (one)
    - RH *Ticks* set to 2 (two)

6.3 Battery Management

The Breeze/BreezeV/Vivid+ sensor has a battery management system that monitors battery energy depletion and presents the remaining energy in units of percentage and battery voltage.

6.3.1 Operational Description

This section describes tools to monitor and evaluate battery performance for both the Sensor and the Display, ensuring consistent and reliable operation. The Breeze, Breeze-V, and Vivid+ models offer multiple battery reporting options, including voltage monitoring and remaining battery capacity. Only Sensors paired with Displays can report the remaining battery capacity of the Display, enabling a more comprehensive evaluation of system performance.

The Report Options register controls which information is included in periodic transmissions, allowing users to monitor key system metrics. The Sensor can be enabled to report the battery voltage, the remaining battery capacity of the Sensor, and the remaining battery capacity of the Display, respectively. If battery capacity reporting is enabled, the e-Ink Display provides a visual indicator when the battery level of either the Sensor or

Display falls below 10%. In this case, the background and text surrounding the battery level will be inverted until the batteries are replaced.

Remaining battery capacity of Sensor and Display reporting must be enabled in order to update the remaining battery capacity values shown on the e-Ink Display. Since the Sensor tracks the battery level of the Display, it is recommended that the Display be powered off while the Sensor is powered off. The Display is only powered off by removing its batteries.

NOTE: The Sensor assumes that any time batteries are removed and replaced, they are new, resetting the reported battery capacity to 100%. However, performing a soft reset on the Sensor will not reset the battery capacity.

6.3.1.1 Resets and Battery Replacement

The battery management system bases calculations on the average nominal battery voltage of two new AA-cell LTC batteries. When the batteries are replaced, the remaining battery capacity and voltage are automatically reset to reflect fully charged batteries. Any hard reset (i.e., any complete loss of power to the battery contacts) will result in the battery management system resetting.

Battery management data will not reset when a soft reset occurs (i.e. with a reset button press or OTA reset command).

6.3.1.2 Battery Passivation

Due to a phenomenon called battery passivation, it may take some time for the Sensor to begin joining a network after a new set of batteries are inserted. If this occurs, the LEDs will go through the normal power-on patterns and begin the join pattern for about 1s before a reset occurs.

An example of a circumstance which may lead to battery passivation include:

- The batteries are replaced with new ones, including new devices from the factory, where the batteries may have been unused for more than a month.

6.3.2 UL Frame Payload Format

The battery voltage, battery capacity of the Sensor, and battery capacity of the display from the Sensor are sent on ***LoRaWAN Port 10*** and have the frame format as shown in Figure General Sensor and LoRaWAN Communication Information-3. The specific details for the report frame formats are listed in Table Basic Operation Configuration-13. For the general description of sensor data report formats and behavior, see Section 4.1.

Table Basic Operation Configuration-13: Battery Management UL Formats

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Battery Voltage	0x00	0xBA	2 B	Analog Voltage	• 1 mV / LSB (unsigned) • 0x FF FF if unavailable	*battery_voltage: <value> (unsigned/V)*
Remaining Battery Capacity of Sensor	0x00	0xD3	1 B	Percentage	• 1% / LSB (unsigned) • 0x FF if unavailable	*rem_batt_capacity_sensor: <value> (unsigned/%)*
Remaining Battery Capacity of Display	0x11	0xD3	1 B	Percentage	• 1% / LSB (unsigned) • 0x FF if unavailable	*rem_batt_capacity_display: <value> (unsigned/%)*

6.3.2.1 Example UL Payloads

6.3.3 Configuration Settings

Only Sensors that come with Displays can report the remaining battery capacity of the Display. Table Basic Operation Configuration-14 shows the battery management configuration register.

Table Basic Operation Configuration-14: Battery Management Configuration Register

Address	Name	Size	Access	Description	JSON Variable	Default
0x40	Report Options	1 B	R/W	• Bit 0: • 0/1 = Battery voltage not reported/reported • Bit 1: • 0/1 = Remaining battery capacity of Sensor not reported/reported • Bit 2: • 0/1 = Remaining battery capacity of Display not report/reported • Bits 0-2 all set to 0: Invalid and ignored • Bits 3-7: Ignored	*battery_voltage_reported: <value> (string/no unit)* *battery_capacity_sensor_reported: <value> (string/no unit)* *battery_capacity_display_reported: <value> (string/no unit)*	Remaining battery capacity of Sensor and Display reported **0x 06**

6.3.3.1 Example DL Payloads

- Set Report Options:
  - DL Payload: **0x C0 07**
    - Battery Voltage Reported
    - Remaining battery capacity of sensor reported
    - Remaining battery capacity of display reported

6.4 General Command-and-Control Operations

The general command and control operations supported by the Breeze/BreezeV/Vivid+ are:

- Saving the current configuration settings to flash memory.
- Restarting the Sensor (soft reset).
- Reading FW metadata (SW version numbers).
- Factory reset of configuration settings.

To perform a command-and-control operation, the appropriate register must be accessed. Table Basic Operation Configuration-15 lists the details of the command-and-control registers. In this table, the bit indexing scheme is as shown in Figure General Sensor and LoRaWAN Communication Information-4. To access these registers, a command must be formatted and sent according to the details described in the following subsections and in Section 4.2.

Table Basic Operation Configuration-15: Sensor Command & Control Register

Address	Name	Size	Access	Description	JSON Variable	Default
0x70	Flash Write Command	2 B	WO	• 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 Sensor • Bits 1-12, 15: Ignored	*write_to_flash_app_config: <value> (string/no unit)* *write_to_flash_lora_config: <value> (string/no unit)* *restart_sensor: <value> (string/no unit)*	**0x70**
0x71	FW Version	7 B	RO	• Bits 48-55: App version major • Bits 40-47: App version minor • Bits 32-39: App version revision • Bits 24-31: LoRaMAC version major • Bits 16-23: LoRaMAC version minor • Bits 8-15: LoRaMAC version revision • Bits 0-7: LoRaMAC region ID (see Table Basic	*app_ver_major: <value>, (unsigned/no unit)* *app_ver_minor: <value> (unsigned/no unit)* *app_ver_revision: <value> (unsigned/no unit)* *loramac_ver_major: <value> (unsigned/no unit)*	**0x71**

				Operation Configuration-16)	*loramac_ver_minor: <value> (unsigned/no unit)* *loramac_ver_revision: <value> (unsigned/no unit)* *loramac_region_id: <value> (string/no unit)*	
0x72	Reset Config Registers to Factory Defaults[8]	1 B	WO	• 0x0A: Reset App Config • 0xB0: Reset LoRa Config • 0xBA: Reset both App and LoRa Configs • Any other value: Invalid and ignored	*factory_reset_config: <value> (string/no unit)*	**0x72**

6.4.1 Save Current Configuration Settings

Configuration changes are not retained after a power cycle (soft or hard reset) unless they are saved in the non-volatile flash memory. To do so, the *Flash Write Command* register, 0x 70, must be accessed to execute the save-to-flash operation. The DL payload structure is as shown in Figure General Sensor and LoRaWAN Communication Information-4. That is, with the first byte being the register address with bit 7 set to 1 (i.e., 0x F0) and the data indicating which options are selected of those listed in Table Basic Operation Configuration-15. Specifically, the payloads for the different save options (without restarting the Sensor) are:

- **0x F0 20 00**: Save current configuration settings of all FW application registers (0x 20 through 0x 6F) to flash.
- **0x F0 40 00**: Save current configuration settings of all FW LoRaMAC Option registers (0x 11 and 0x 12) to flash.
- **0x F0 60 00**: Save current configuration settings of both FW application and LoRaMAC Options registers to flash.

The save-to-flash command can be sent in a separate DL at any time or be included in the same payload as other read and write command blocks. In the latter case, all other command blocks are always executed first, so that settings can be changed and saved in a single payload.

[8] After sending the reset-to-factory-defaults command, the Sensor is automatically reset with corresponding default configuration values.

6.4.2 Sensor Restart

The *Flash Write Command* register, 0x 70, is used to restart the device via soft reset.

This is done by setting bit 0 to 1. This can be used alone or in conjunction with any of the save-to-flash operation options listed in Section 6.4.1 above. In the former case, the explicit payload is **0x F0 00 01**.

Immediately after receiving the reset command in a DL, the Sensor will reset.

> **NOTE:** Do not send the reset command as a confirmed DL. The reset command causes the Sensor to restart before it can send the acknowledgement UL in response. The Sensor will rejoin the network but then get the command sent again from the NS, causing a loop of continual rebooting[8].

6.4.3 Read FW Metadata

The *FW Metadata* register, 0x 71, can be accessed to read the *application version number*, *LoRaMAC version number*, and *LoRaMAC region number*. The read metadata command is formulated as a regular read command. Explicitly, the command blocks in the payload would be **0x 71** for FW.

After receiving one of these commands, the Sensor will respond with a UL message containing the following:

- For FW metadata:
  - The first byte is the register address: 0x 71.
  - Bits 32 to 55 of the value contain the application revision numbers which define the FW version. The FW version is reported in the format as shown in Figure Basic Operation Configuration-12, which is shown using the example FW v1.0.15 (value 0x 01 00 0F).

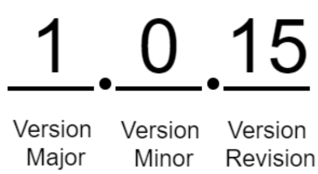


Figure Basic Operation Configuration-12: Example FW Version Format

  - Bits 8 to 31 of the value contain the LoRaMAC version numbers. The format is the same as shown in Figure Basic Operation Configuration-12. This number is not to be confused with the LoRaWAN specification version according to the LoRa Alliance standards.
  - The last byte contains the LoRaMAC region number. Current LoRaMAC regions and corresponding region numbers for the Sensor are listed in Table Basic Operation Configuration-16.

Table Basic Operation Configuration-16: Available LoRaMAC Regions and Channel Plan IDs

LoRaMAC Region	Channel Plan ID

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

6.4.4 Factory Reset

The *Reset Configuration to Factory Defaults* register, 0x 72, is used to reset all the configuration register values (0x 10 to 0x 6F) back to the default settings.

The DL payload structure is as shown in Figure General Sensor and LoRaWAN Communication Information-5. That is, with the first byte being the register address with bit 7 set to 1 (i.e., 0x F2) and the data indicating which options are selected of those listed in Table Basic Operation Configuration-15. Specifically, the payloads for the different factory reset options are:

- **0x F2 0A**: Restore configuration settings of all FW application registers (0x 20 to 0x 5C) to factory default values.
- **0x F2 B0**: Restore configuration settings of all FW LoRaMAC Options registers (0x 10 to 0x 13) to factory default values.
- **0x F2 BA**: Restore configuration settings of both FW application and LoRaMAC Options registers to factory default values.

The factory command can be sent in a separate DL at any time or be included in the same payload as the other read and write command blocks. In the latter case, only the factory command block is executed while all other commands are discarded.

After receiving the factory reset command, the Sensor always restarts immediately.

NOTE: <u>Do not send the factory reset command as a confirmed DL</u>. The command causes the Sensor to restart before it can send the acknowledgement UL in response. The Sensor will rejoin the network but then get the command sent again from the NS, causing a loop of continual rebooting[9].

7 BLE Display Configuration

The BLE Display configuration capabilities provide various configuration options to manage communication, display format, and pairing functionalities between a Sensor and a Display.

7.1 Display Whitelisting

7.1.1 Operational Description

The BLE Communication Options Register controls the Display's whitelisting feature, which, when enabled, restricts BLE connections to the associated Sensor, reducing the risk of unwanted connections. While disabling whitelisting allows other BLE devices to connect, it is strongly recommended to keep whitelisting enabled whenever possible. The Display can only communicate with one BLE device at a time, and removing its batteries clears the whitelisted Sensor address.

7.1.2 Configuration Settings

Table BLE Display Configuration-17 shows the BLE Display whitelisting configuration register.

Table BLE Display Configuration-17: BLE Display Whitelisting Configuration Register

Address	Name	Size	Access	Description	JSON Variable	Default
0x2A	BLE Communication Options	1 B	R/W	• Bit 0: • 0/1 = Sensor whitelisting on Display disabled/enabled • Bits 1-7: Ignored	*ble_display_whitelisting_enabled: <value> (string/no unit)*	Sensor whitelisting on Display enabled **0x 01**

7.1.2.1 Example DL Payloads

- Disable whitelisting on the display:
  - DL payload: **0x AA 00**
    - Register 0x2A with write bit set to true
    - Set whitelisting on the display to disabled

7.2 Display Format Options

7.2.1 Operational Description

The Display Format Options Register allows users to configure the language and temperature unit shown on the Display. Bit 0 selects the language (English or French) with differences in fractional precision formatting, while Bit 4 determines whether temperature values are displayed in Celsius or Fahrenheit[9]. Regardless of the format shown, temperature readings sent to the LoRaWAN network remain in Celsius.

7.2.2 Configuration Settings

Table BLE Display Configuration-18 shows the BLE Display format configuration register.

Table BLE Display Configuration-18: BLE Display Format Configuration Register

Address	Name	Size	Access	Description	JSON Variable	Default
0x2A	BLE Communication Options	1 B	R/W	• Bit 0: • 0/1 = Sensor whitelisting on Display disabled/enabled • Bits 1-7: Ignored	*ble_display_whitelisting_enabled: <value> (string/no unit)*	Sensor whitelisting on Display enabled **0x 01**
0x2B	Display Format Options	1 B	R/W	• Bit 0: Language Setting • 0: English • 1: French • Bits 1-3: Ignored • Bit 4: Temperature Unit Setting • 0: Celsius (°C) • 1: Fahrenheit (F) • Bits 5-7: Ignored	*ble_display_language: <value> (string/no unit)* *ble_display_temperature_unit: <value> (string/no unit)*	English language setting and temperature shown in degrees Celsius **0x 00**
0x2C	BLE Display Address	6 B	R/W	• BLE address of paired e-Ink Display • 0x FF FF FF FF FF FF: Sensor is not paired with an e-Ink Display	*ble_display_address: <value> (unsigned/no unit)*	Dependent on sensor commissioning information

7.2.2.1 Example DL Payloads

- Set Display Format Options:
  - DL payload: **0x AB 11**
    - Register 0x2B with write bit set to true
    - Language setting set to French
    - Temperature unit setting set to Fahrenheit

[9] This feature is only available on Sensors with FW v2.3.0 and higher.

7.3 Display Address

7.3.1 Operational Description

The BLE Display Address Register, available on firmware version 2.1.12 and above, identifies the Display paired with the Sensor and allows users to update the pairing. Writing the default address (0x FF FF FF FF FF FF) disables BLE communication, even if a pairing existed previously. Together, these capabilities provide flexible management of BLE communication and display settings while maintaining system reliability.

7.3.2 Configuration Settings

Table BLE Display Configuration-19 shows the BLE Display address configuration register.

Table BLE Display Configuration-19: BLE Display Address Configuration Register

Address	Name	Size	Access	Description	JSON Variable	Default
0x2C	BLE Display Address	6 B	R/W	• BLE address of paired e-Ink Display • 0x FF FF FF FF FF FF: Sensor is not paired with an e-Ink Display	*ble_display_address: <value> (unsigned/no unit)*	Dependent on sensor commissioning information

7.3.2.1 Example DL Payloads

- Disable BLE communication on the device:
  - DL payload: **0x AC FF FF FF FF FF FF**
    - Register 0x2C with write bit set to true
    - Disable BLE communication

8 CO_2 Transducer Configuration

The CO2 Transducer Configuration provides flexible control over how CO2 measurements are taken, reported, and filtered, ensuring reliable and accurate readings in various environments.

8.1 CO_2 Sampling and Reporting Options

8.1.1 Operational Description

The Sampling Parameters determine how often the CO2 sensor takes measurements and how many readings are averaged for each reported value. Increasing the number of readings improves accuracy but also consumes more power. To ensure the transducer has enough time to complete measurements, the sampling interval must be set appropriately. If CO2 sampling is disabled, periodic CO2 and pressure updates will not reflect new values, and only the last stored data will be reported.

The Threshold Control feature allows users to set a CO2 threshold for event-based reporting. When enabled, the Sensor sends data whenever CO2 levels cross the defined threshold, ensuring timely updates for significant changes. The e-Ink Display visually highlights threshold breaches by inverting the background color around the CO2 value until levels return below the threshold.

The Report Options allow users to decide whether raw CO2 or pressure-compensated CO2 values are sent in periodic or threshold-based updates. Pressure-compensated values must be enabled to update the e-Ink Display. Together, these configurable features enable precise measurement, reporting, and display of CO2 data while accommodating power and performance needs in a variety of operating conditions.

8.1.2 UL Frame Payload Format

The raw and pressure compensated CO2 concentration from the Sensor are sent on ***LoRaWAN Port 10*** and have the frame format as shown in Figure General Sensor and LoRaWAN Communication Information-3. The specific details for the report frame formats are listed in Table CO2 Transducer Configuration-20. For the general description of sensor data report formats and behavior, see Section 4.1.

Table CO2 Transducer Configuration-20: CO2 Transducer UL Formats

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
CO_2 Concentration (Pressure Compensated)	0x0B	0xE4	2 B	CO_2	• 1 ppm / LSB (unsigned) • 0x FF FF if unavailable	*co2_pressure_compensated: <value> (unsigned/ppm)*
CO_2 Concentration (Raw)	0x0E	0xE4	2 B	CO_2	• 1 ppm / LSB (unsigned) • 0x FF FF if unavailable	*co2_raw: <value> (unsigned/ppm)*

8.1.2.1 *Example UL Payloads*

- **0x 0B E4 01 E0**
    - Channel ID = 0x 0B, Type ID = 0x E4 → Barometric Pressure
        - 0x 01 E0 x 1 ppm = 480 ppm

8.1.3 Configuration Settings

Table CO2 Transducer Configuration-21 shows a list of CO_2 transducer configuration registers for sampling and reporting.

Table CO2 Transducer Configuration-21: CO_2 Transducer Sampling and Reporting Configuration Registers

Address	Name	Size	Access	Description	JSON Variable	Default
0x30	Sampling Parameters	3 B	R/W	• Bits 8-23: Sample period of the CO2 transducer (1 sec / LSB) • Acceptable values: 0, 10, 11, …, 65535 • 0: Disables the CO2 sensing element • 1-9: Invalid and ignored • Bits 0-7: Number of subsamples integrated per reported measurement • Acceptable values: 1, 2, …, 255 • 0: Invalid and ignored • Sample period must be greater than number of subsamples multiplied by 0.2	*co2_sample_period: <value> (unsigned/sec)* *co2_num_subsamples: <value> (unsigned/no unit)*	Sample period of 300 sec 16 subsamples **0x 01 2C 10**
0x31	Threshold Control	2 B	R/W	• Threshold level (1 ppm / LSB) • Acceptable values: 0, 1, …, 65535 • 0: Disables threshold-based reporting	*co2_threshold_level: <value> (unsigned/ppm)*	Threshold-based reporting enabled Threshold level set to 1000 ppm **0x 03 E8**
0x34	Report Options	1 B	R/W	• Bit 0: • 0/1 = Raw CO2 value not reported/reported • Bit 1: • 0/1 = Pressure	*co2_raw_reported: <value> (string/no unit)* *co2_pressure_compensated_reported: <value>*	Pressure compensated CO_2 reported only **0x 02**

				Compensated CO2 not reported/reported • Both bits 0 and 1 set to 0: Invalid and ignored • Bits 2-7: Ignored	*(string/no unit)*	

8.1.3.1 *Example DL Payloads*

- Set CO_2 Sampling Parameters:
  - DL payload: **0x B0 00 1E 04**
    - Register 0x30 with write bit set to true
    - Sampling period set to 30 sec
    - Number of subsamples set to 4

8.2 CO_2 IIR Filter Control

8.2.1 Operational Description

For smoother readings, the IIR Filter Control reduces noise in CO2 measurements. The static filter provides consistent noise suppression for stable conditions, while the dynamic filter adapts more quickly to sudden changes in the environment but may introduce minor fluctuations. Both filters can work together to balance stability and responsiveness based on the specific use case.

8.2.2 Configuration Settings

Table CO2 Transducer Configuration-22 shows the CO_2 IIR filter configuration register.

Table CO2 Transducer Configuration-22: CO_2 IIR Filter Configuration Register

Address	Name	Size	Access	Description	JSON Variable	Default
0x32	IIR Filter Control	1 B	R/W	• Bits 0-3: Static IIR filter "recall factor" • Acceptable values: 0, 1, 2, …, 9 • 0: Disables static IIR filter • 10-15: Invalid and ignored • Bit 4: • 0/1 = Dynamic IIR filter disabled/enabled • Bit 4 set to 1 and bits 0-3 set to 0: Invalid and ignored • Bits 5-7: Ignored	*co2_static_iir_recall_factor: <value>* *(unsigned/no unit)* *co2_dynamic_iir_enabled: <value>* *(string/no unit)*	Static and dynamic IIR filters disabled **0x 00**

8.2.2.1 Example DL Payloads

- Enable the dynamic IIR filter:
  - DL payload: **0x B2 10**
    - Register 0x32 with write bit set to true
    - Dynamic IIR filter set to enabled

8.3 Calibration Control

8.3.1 Operational Description

The Calibration Control offers four methods to keep CO2 readings accurate: Automatic Baseline Correction (ABC), Target, Background, and Zero calibrations. ABC is enabled by default and adjusts measurements automatically in environments where CO2 periodically returns to normal outdoor levels. For spaces with consistently elevated CO2, manual calibrations such as Target (known value) or Background (fresh air) can be performed. Zero calibration, used in controlled environments, ensures the transducer aligns to a complete absence of CO2. Calibration settings are persistent across resets, but ABC will re-enable by default unless another method is written to memory.

8.3.2 Configuration Settings

Table CO2 Transducer Configuration-23 shows the CO_2 calibration control configuration register.

Table CO2 Transducer Configuration-23: CO_2 Calibration Configuration Register

Address	Name	Size	Access	Description	JSON Variable	Default
0x33	Calibration Control	4 B	R/W	• Bits 24-31: • 0: ABC calibration • 1: Target calibration • 2: Background calibration • 3: Zero calibration • 255: No calibration • Other values: Invalid and ignored • Bits 16-23: • 0: System default for ABC-cycle calibration period (180 hours) • Non-zero value: Calibration period for ABC cycle (1 hour / LSB) • Bits 0-15: • 0: System default for calibration target value (400 ppm)	*co2_calibration_type: <value> (string/no unit)* *co2_calibration_period : <value> (unsigned/hrs)* *co2_calibration_target : <value> (unsigned/ppm)*	System default (ABC Calibration enabled with period of 180 hours and target value of 400 ppm) **0x 00 00 00 00**

				• Non-zero value: Target calibration value (1 ppm / LSB)		

8.3.2.1 *Example DL Payloads*

- Perform a manual background CO_2 calibration:
  - DL payload: **0x B3 02 00 01 90**
    - Register 0x33 with write bit set to true
    - Background calibration method selected
    - ABC period set to default value (not used for manual calibration)
    - Target set to 400 ppm

9 Barometer Configuration

9.1 Operational Description

The Breeze and Breeze-V include a barometer capable of measuring the barometric air pressure. *Only the Breeze and Breeze-V models are capable of pressure sensing.*

The IIR Filter in the Sensor helps reduce noise caused by environmental disturbances, such as air turbulence from fans or sudden movements like slamming doors or windows. By adjusting the filter's recall factor, users can control how strictly the filter suppresses fluctuations between measurements. A higher recall factor provides stronger noise suppression, making the measurements more stable, but may also slow the response to sudden changes. If noise suppression is not needed, the filter can be disabled by setting the recall factor to zero. Only values within the valid range are accepted, ensuring the filter functions reliably for accurate CO2 measurements in varying environments.

9.2 UL Frame Payload Format

The barometric pressure from the Sensor is sent on ***LoRaWAN Port 10*** and have the frame format as shown in Figure General Sensor and LoRaWAN Communication Information-3. The specific details for the report frame formats are listed in Table Barometer Configuration-25. For the general description of sensor data report formats and behavior, see Section 4.1.

Table Barometer Configuration-24: Barometer UL Formats

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Barometric Pressure	0x0C	0x73	2 B	Pressure	• 0.1 hPa / LSB (unsigned) • 0x FF FF if unavailable	*barometric_pressure: <value> (unsigned/hPa)*

9.2.1 Example UL Payloads

- **0x 0C 73 23 28**
  - Channel ID = 0x 0C, Type ID = 0x 73 → Barometric Pressure
    - 0x 23 28 x 0.1 hPa = 900 hPa

9.3 Configuration Settings

Table Barometer Configuration-25 shows the barometer configuration register.

Table Barometer Configuration-25: Barometer Configuration Registers

Address	Name	Size	Access	Description	JSON Variable	Default
0x38	IIR Filter Recall Factor	1 B	R/W	• Acceptable values: 0, 1, …, 15 • 0: Equivalent to no IIR	*pressure_iir_recall_factor: <value> (unsigned/no unit)*	2 **0x 02**

				filtering • 16-255: Invalid and ignored		

9.3.1 Example DL Payloads

- Set IIR Filter Recall Factor:
  - DL payload: **0x B8 01**
    - Register 0x38 with write bit set to true
    - IIR Filter Recall Factor set to 1

10 Temperature/RH Threshold Configuration

10.1 Operational Description

The Temperature/RH Configuration allows control over sampling frequency, thresholds, and reporting behavior for temperature and relative humidity (RH) measurements.

The Idle Sample Period determines how often the transducer checks for updates when the measured values remain within the defined threshold range. The sample period in this state can be configured between 10 seconds and one day (86,400 seconds), with any values below 10 seconds being ignored. When the reported values move outside the threshold range, the Active Sample Period takes effect, determining how frequently measurements are taken during this state. Like the idle period, the active sample period has a configurable range between 10 seconds and one day, with invalid lower values being ignored.

The Temperature/RH Thresholds define the upper and lower limits for measurements. These thresholds are stored in a single register, with the upper threshold occupying the most significant byte (MSB) and the lower threshold stored in the least significant byte (LSB). For ambient temperature, the thresholds are represented with a precision of 1°C per bit using two's complement format, while RH thresholds use a precision of 1% per bit and are stored as unsigned values. The configuration is only valid if the upper threshold is greater than the lower threshold; otherwise, it is ignored.

The Thresholds Enabled register activates threshold-based reporting for temperature and RH measurements. Thresholds and sample periods can be configured in advance but will only take effect once the thresholds are enabled. When a threshold is crossed, the Sensor triggers a report, and the e-Ink Display visually highlights the event by inverting the background and text color surrounding the temperature or RH value. This visual indicator remains active until the measured values return to within the configured thresholds, providing a clear signal of out-of-range conditions.

10.2 UL Frame Payload Format

The ambient temperature and relative humidity from the Sensor are sent on ***LoRaWAN Port 10*** and have the frame format as shown in Figure General Sensor and LoRaWAN Communication Information-3. The specific details for the report frame formats are listed in Table Temperature/RH Threshold Configuration-27. For the general description of sensor data report formats and behavior, see Section 4.1.

Table Temperature/RH Threshold Configuration-26: Temperature/Humidity UL Formats

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Ambient Temperature	0x03	0x67	2 B	Temperature	• 0.1°C / LSB (signed)	*temperature: <value> (signed/°C)*
Ambient RH	0x04	0x68	1 B	RH	• 0.5% / LSB	*relative_humidity: <value> (unsigned/%)*

10.2.1 Example UL Payloads

- **0x 03 67 00 0A 04 68 28**
    - Channel ID = 0x 03, Type ID = 0x 67 → Ambient Temperature
        - 0x 00 0A x 0.1°C = 1°C
    - Channel ID = 0x 04, Type ID = 0x 68 → Ambient RH
        - 0x 28 x 0.5% = 20%

10.3 Configuration Settings

Table Temperature/RH Threshold Configuration-27 shows a list of configuration registers for the temperature and RH threshold setting.

Table Temperature/RH Threshold Configuration-27: Temperature/RH Threshold Configuration Registers

Address	Name	Size	Access	Description	JSON Variable	Default
0x39	Temperature/RH Sample Period: Idle	4 B	R/W	• Sample period of ambient temperature/RH transducer: Idle state (1 sec / LSB) • Acceptable values: 10, 11, …, 86400 • Other values: Invalid and ignored	*temp_rh_sample_period_idle: <value> (unsigned/sec)*	60 sec **0x 00 00 00 3C**
0x3A	Temperature/RH Sample Period: Active	4 B	R/W	• Sample period of ambient temperature/RH transducer: Active state (1 sec / LSB) • Acceptable values: 10, 11, …, 86400 • Other values: Invalid and ignored	*temp_rh_sample_period_active: <value> (unsigned/sec)*	30 sec **0x 00 00 00 1E**
0x3B	Low/High Temperature Thresholds	2 B	R/W	• 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	*temp_threshold_high: <value> (signed/°C)* *temp_threshold_low: <value> (signed/°C)*	30°C 15°C **0x 1E 0F**
0x3C	Temperature Thresholds Enabled	1 B	R/W	• Bit 0: • 0/1 Thresholds disabled/enabled • Bits 1-7: Ignored	*temp_thresholds_enabled: <value> (string/no unit)*	Disabled **0x 00**

0x3D	Low/High RH Thresholds	2 B	R/W	• Bits 8-15: High RH threshold (unsigned, 1% RH / LSB) • Bits 0-7: Low RH threshold (unsigned, 1% RH / LSB) • High threshold ≤ Low threshold: Invalid and ignored	*rh_threshold_high: <value> (unsigned/%)* *rh_threshold_low: <value> (unsigned/%)*	80% 15% **0x 50 0F**
0x3E	RH Thresholds Enabled	1 B	R/W	• Bit 0: • 0/1 Thresholds disabled/enabled • Bits 1-7: Ignored	*rh_thresholds_enabled : <value> (string/no unit)*	Disabled **0x 00**

10.3.1 Example DL Payloads

- Set Temperature Thresholds:
  - DL payload: **0x BB 19 0A**
    - Register 0x3B with write bit set to true
    - High threshold set to 25°C
    - Low threshold set to 10°C
- Read Temperature/RH Sample Periods:
  - DL payload: **0x 39 3A**
    - Registers 0x39 and 0x3A with their write bits set to false
- Set and enable RH thresholds:
  - DL payload: **0x BD 3C 14 BE 01**
    - Registers 0x3D and 0x3E with their write bits set to true
    - High RH thresholds set to 60% RH
    - Low RH threshold set to 20% RH
    - RH thresholds enabled

11 Light Transducer Configuration

The Light Sensing Configuration enables accurate and reliable detection of light conditions while balancing energy efficiency and performance.

NOTE: Light transducer support is not available on sensors with module revision A. If the module revision is unknown and the device's label is not accessible, query the device's FW version (see Section 6.4). If the module is programmed with application FW version 2.0.x, then the light transducer is not supported.

11.1 Light Sampling and Reporting Options

11.1.1 Operational Description

The Sampling Parameters control how often the light sensor is powered on to check for light, ensuring energy is conserved during idle periods. The Sensor also supports integrating multiple light readings, or subsamples, for each measurement. This feature helps filter out temporary disturbances, such as flickering lights, and ensures more reliable results. Subsamples are collected in rapid succession, and the Sensor processes them into a single reported value.

The Threshold Control allows users to define a transition point between "dark" and "bright" light states. When enabled, the Sensor begins in the "dark" state and sends an update whenever light conditions cross the configured threshold. This provides a simple yet effective way to monitor significant changes in light levels.

With the Report Options, users can choose to report either the light state (dark or bright) or the measured light intensity, offering flexibility based on specific application needs. The Sensor also includes Subsample Processing, which determines how integrated subsamples are handled. Depending on the configuration, the Sensor can report the maximum, minimum, or average light value, providing further customization for stable or dynamic environments.

11.1.2 UL Frame Payload Format

The ambient light state and intensity from the Sensor are sent on ***LoRaWAN Port 10*** and have the frame format as shown in Figure General Sensor and LoRaWAN Communication Information-3. The specific details for the report frame formats are listed in Table Light Transducer Configuration-28. For the general description of sensor data report formats and behavior, see Section 4.1.

Table Light Transducer Configuration-28: Ambient Light UL Formats

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Ambient Light State†	0x02	0x00	1 B	Digital	• 0x00 = Dark • 0xFF = Bright	*light_state: <value>* *(string/no unit)*
Ambient Light	0x10	0x02	2 B	Analog	• Light intensity (uncalibrated)	*light_intensity: <value>*

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Intensity†					• 0.1 µA / LSB	*(unsigned/µA)*

11.1.2.1 Example UL Payloads

- **0x 02 00 FF 10 02 00 7D**
  - Channel ID = 0x 02, Type ID = 0x 00 → Ambient Light State
    - 0x FF = Bright
  - Channel ID = 0x 10, Type ID = 0x 02 → Ambient Light Intensity
    - 0x 00 7D x 0.1 uA = 12.5 uA

11.1.3 Configuration Settings

Table Light Transducer Configuration-30 shows a list of light transducer sampling and reporting configuration registers.

Table Light Transducer Configuration-29: Light Transducer Configuration Registers

Address	Name	Size	Access	Description	JSON Variable	Default
0x47	Sampling Parameters	3 B	R/W	• Bits 8-23: Sample period of the light transducer (1 sec / LSB) • Acceptable values: 0, 10, 11, …, 65535 • 0: Disables the light sensing element • 1-9: Invalid and ignored • Bits 0-7: Number of subsamples integrated per reported measurement • Acceptable values: 1, 2, …, 255 • 0: Invalid and ignored	*light_sample_period: <value> (unsigned/sec)* *light_num_subsamples : <value> (unsigned/no unit)*	Light transducer disabled 10 subsamples **0x 00 00 0A**
0x48	Threshold Control	2 B	R/W	• Threshold level (0.1 µA / LSB) • Acceptable values: 0, 1, …, 32767 • 0: Disables threshold-based reporting • Other values: Invalid and ignored	*light_threshold_level: <value> (unsigned/µA)*	Threshold-based reporting enabled Threshold level set to 10 µA **0x 00 0A**
0x49	Report Options	1 B	R/W	• Bit 0: • 0/1 = State (dark or	*light_state_reported: <value>*	Light state reported only

				bright) not reported/reported • Bit 1: • 0/1 Intensity (uncalibrated, in units of 0.1 µA) not reported/reported • Both bits 0 and 1 set to 0: Invalid and ignored • Bits 2-7: Ignored	*(string/no unit)* *light_intensity_reported: <value>* *(string/no unit)*	**0x 01**
0x4A	Subsample Processing	1 B	R/W	• Acceptable values: • 0: Max • 1: Min • 2: Average • 3-255: Invalid and ignored	*light_subsample_processing: <value>* *(string/no unit)*	Max **0x 00**

11.1.3.1 Example DL Payloads

- Set Sampling Parameters:
  - DL payload: **0x C7 00 20 0A**
    - Register 0x47 with write bit set to true
    - Sample period is set to 30 seconds
    - 10 subsamples
- Set Threshold Control:
  - DL Payload: **0x C8 00 20**
    - Register 0x48 with write bit set to true
    - Threshold based reporting enabled
    - Threshold level set to 32 uA

11.2 Light IIR Filter Control

11.2.1 Operational Description

To reduce noise and improve measurement consistency, the Sensor incorporates an IIR Filter. This filter smooths out fluctuations caused by environmental factors like shadows or sudden light changes. A stricter filter suppresses noise more effectively but may respond more slowly to sudden shifts in lighting. If filtering is not required, the Sensor allows the filter to be turned off entirely.

11.2.2 Configuration Settings

Table Light Transducer Configuration-30 shows the light transducer IIR filter configuration register.

Table Light Transducer Configuration-30: Light Transducer IIR Filter Configuration Register

Address	Name	Size	Access	Description	JSON Variable	Default
0x4B	IIR Filter Recall Factor	1 B	R/W	• Acceptable values: 0, 1, …, 15 • 0: Equivalent to no IIR filtering • 16-255: Invalid and ignored	*light_iir_recall_factor: <value> (unsigned/no unit)*	2 **0x 02**

11.2.3 Example DL Payloads

- Disable IIR filtering for the light transducer:
    - DL payload: **0x CB 00**
        - Register 0x4B with write bit set to true
        - No IIR filtering

12 Motion Transducer Configuration

The PIR Motion Detection Configuration enables reliable motion detection using a PIR transducer, available exclusively in the Vivid+ and Breeze-V models. Designed to detect human motion in a room, the Sensor incorporates features to manage sensitivity, conserve battery life, and reduce false positives, ensuring dependable operation in a variety of environments.

12.1 Threshold and Reporting Options

12.1.1 Operational Description

To optimize sensitivity, the Threshold Count and Threshold Period can be configured to filter out insignificant motion events. The threshold count defines how many motion detections must occur within a configurable time window, the threshold period, before reporting “Motion Detected.” For example, short, insignificant movements, such as someone briefly passing through a room, can be ignored, while longer, meaningful motion patterns trigger a report.

The Report Options provide control over what motion-related data is transmitted. When enabled, the motion transducer monitors the “motion state” (presence or absence of movement) for event-based reporting. For periodic reporting, users can choose to transmit the motion state, the motion event count, or both, based on application needs. If motion detection is not required, the transducer can be disabled entirely to conserve energy.

12.1.2 UL Frame Payload Format

The PIR state and count from the Sensor are sent on ***LoRaWAN Port 10*** and have the frame format as shown in Figure General Sensor and LoRaWAN Communication Information-3. The specific details for the report frame formats are listed in Table Motion Transducer Configuration-31. For the general description of sensor data report formats and behavior, see Section 4.1.

Table Motion Transducer Configuration-31: PIR UL Formats

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Motion (PIR) Event State	0x0A	0x00	1 B	Digital	• 0x00 = No motion • 0xFF = Motion detected	*motion_event_state: <value> (string/no unit)*
Motion (PIR) Event Count	0x0D	0x04	2 B	Counter	• Number	*motion_event_count: <value> (unsigned/no unit)*

12.1.2.1 Example UL Payloads

- **0x 0A 00 FF 0D 04 00 01**
  - Channel ID = 0x 0A, Type ID = 0x 00 → Motion (PIR) Event State
    - 0x FF = Motion detected
  - Channel ID = 0x 0D, Type ID = 0x 04 → Motion (PIR) Event Count

- 0x 00 01 = 1

12.1.3 Configuration Settings

Table Motion Transducer Configuration-32 shows a list of motion transducer configuration registers.

Table Motion Transducer Configuration-32: Motion Transducer Configuration Registers

Address	Name	Size	Access	Description	JSON Variable	Default
0x51	Threshold Count	2 B	R/W	• Number of PIR events before motion is detected • Acceptable values: 1, 2, …, 65535 • 0: Invalid and ignored	*pir_threshold_count: <value> (unsigned/no unit)*	1 **0x 00 01**
0x52	Threshold Period	2 B	R/W	• Period over which PIR events are counted for threshold detection (1 sec / LSB) • Acceptable values: 5, 6, …, 65535 • Other values: Invalid and ignored	*pir_threshold_period: <value> (unsigned/no unit)*	15 sec **0x 00 0F**
0x53	Report Options	1 B	R/W	• Bit 0 (only applies to periodic Tx): • 0/1 = Motion count not reported/reported • Bit 1 (only applies to periodic Tx): • 0/1 = Motion state not reported/reported • Both bits 0 and 1 set to 0: Invalid and ignored • Bits 2-5: Ignored • Bit 6: • 0/1 = PIR event-based reporting disabled/enabled • Bit 7: • 0/1 = PIR transducer disabled/enabled	*pir_motion_count_reported: <value> (string/no unit)* *pir_motion_state_reported: <value> (string/no unit)* *pir_event_based_reporting_enabled: <value> (string/no unit)* *pir_transducer_enabled: <value> (string/no unit)*	PIR transducer enabled Event-based transmission enabled Motion count reported only, in the case of a periodic transmission **0x C1**

12.1.3.1 Example DL Payloads

- Set Report Options:
  - DL Payload: **0x D3 C3**
    - PIR transducer enabled

- PIR event-based reporting enabled
- Motion state reported
- Motion count reported

12.2 Grace Period

12.2.1 Operational Description

The Grace Period determines how long the Sensor waits after the last motion event before declaring that no motion is detected. For example, if the grace period is set to several minutes, the Sensor will report "Motion Detected" when movement occurs and "No Motion" only after a defined period of inactivity. This design conserves battery life by preventing frequent reporting and ensures the motion state is updated in a controlled manner. However, because the PIR transducer only detects motion, the Sensor may report "No Motion" if occupants remain stationary for too long.

12.2.2 Configuration Settings

Table Motion Transducer Configuration-33 shows a list of motion transducer configuration registers.

Table Motion Transducer Configuration-33: Motion Transducer Configuration Registers

Address	Name	Size	Access	Description	JSON Variable	Default
0x50	Grace Period	2 B	R/W	• Grace period (time before motion is no longer detected) (1 sec / LSB) • Acceptable values: 15, 16, …, 65535 • Other values: Invalid and ignored	*pir_grace_period: <value> (unsigned/sec)*	300 sec (5 min) **0x 01 2C**

12.2.2.1 Example DL Payloads

- Set grace period duration to 1 minute (60 seconds):
  - DL Payload: **0x D0 00 3C**
    - Register 0x50 with write bit set to true
    - Grace period set to 60 seconds

12.3 Hold-Off Intervals

12.3.1 Operational Description

To avoid incorrect detections caused by the sensitive electronics, the Sensor includes two Hold-Off Intervals. The post-turn on hold-off interval temporarily disables motion detection for 120 seconds when power is first applied, allowing the PIR transducer to stabilize. Similarly, the post-disturbance hold-off interval disables the PIR transducer for about 10 seconds after radio transmissions or temperature/RH sampling to prevent false positives caused by internal interference. Both hold-off intervals are configurable, providing flexibility for specific deployment needs.

12.3.2 Configuration Settings

Table Motion Transducer Configuration-34 shows a list of motion transducer configuration registers.

Table Motion Transducer Configuration-34: Motion Transducer Configuration Registers

Address	Name	Size	Access	Description	JSON Variable	Default
0x54	Hold-Off Intervals	2 B	R/W	• Bits 8-15: • 0: Default value (120 sec) • Non-zero value: Post-turn on hold-off interval (1 sec / LSB) • Bits 0-7: • 0: Default value (10 sec) • Non-zero value: Post-disturbance hold-off interval (1 sec / LSB)	*pir_post_turn_on_holdoff: <value> (unsigned/sec)* *pir_post_disturbance_holdoff: <value> (unsigned/sec)*	Post-turn on hold-off interval 120 sec Post-disturbance hold-off interval 10 sec **0x 00 00**

12.3.2.1 Example DL Payloads

- Set Hold-Off Intervals:
  - DL Payload: **0x D4 3C 1E**
    - Register 0x54 with write bit set to true
    - Set post-turn on hold-off interval to 60 seconds
    - Set post-disturbance hold-off interval to 30 seconds

13 Dynamic Reporting Mode Configuration

13.1 Operational Description

The Dynamic Reporting Configuration allows the Sensor to optimize energy usage and data reporting by switching between Active and Inactive modes based on a configurable schedule. This feature is particularly useful for balancing system performance and power efficiency while maintaining accurate time references.

The Dynamic Reporting Mode Enabled setting activates or deactivates the Sensor's ability to use both Active and Inactive modes. When disabled, the Sensor operates exclusively in Active mode and does not track the current date or time. If the Sensor fails to receive a timestamp within 15 minutes of its initial request, dynamic reporting will automatically disable itself. Re-enabling the feature prompts the Sensor to attempt another 15-minute window to acquire a valid time reference.

The Timestamp Update Period controls how often the Sensor synchronizes its internal clock. The Sensor sends timestamp requests at 3:00 AM on the configured days, starting from the day after it first acquired a time reference. Users can configure how many days pass between update requests and the maximum number of attempts made during each update period. If a timestamp response is not received, the Sensor retries every 4 minutes until the configured limit is reached. Regular updates are recommended to ensure the Sensor maintains an accurate time reference.

The Active Mode Options provide precise control over when the Sensor enters Active mode. Users can configure specific time intervals and days of the week for Active operation. The start and end times, set in 24-hour format, define the window when the Sensor operates in Active mode. If a day is enabled, the Sensor will report actively during the specified time interval and switch to Inactive mode outside of that window. Days not enabled remain entirely in Inactive mode, conserving battery and reducing unnecessary activity.

When the Sensor is in Inactive Mode, two registers come into play: Seconds per Core Tick and CO2 Sampling Parameters. The Seconds per Core Tick register determines the timing of core system operations during Inactive mode. This synchronization helps optimize battery life while maintaining basic functionality. For models such as Breeze and Breeze-V, the CO2 Sampling Parameters register specifies how frequently CO2 measurements are taken while the Sensor is in Inactive mode, ensuring monitoring continues without unnecessary energy consumption.

By combining configurable schedules, timestamp management, and mode-specific settings, the Dynamic Reporting Configuration allows the Sensor to adapt its behavior to application needs. This ensures efficient performance, reliable data reporting, and extended battery life in environments requiring varying levels of activity.

13.2 Configuration Settings

Table Dynamic Reporting Mode Configuration-35 shows a list of Dynamic Reporting Mode configuration registers.

Table Dynamic Reporting Mode Configuration-35: Dynamic Reporting Mode Configuration Registers

Address	Name	Size	Access	Description	JSON Variable	Default
0x66	Dynamic Reporting Mode Enabled	1 B	R/W	• Bit 0: • 0/1 = Dynamic Reporting Mode disabled/enabled • Bits 1-7: Ignored	*drm_enabled: <value> (string/no unit)*	Dynamic Reporting Mode disabled **0x 00**
0x67	Timestamp Update Period	1 B	R/W	• Bits 4-7: Timestamp update period (1 day / LSB) • Acceptable values: 0, 1, …, 15 • 0: Disables timestamp update requests • Bits 0-3: Maximum number of timestamp requests per update period • Acceptable values: 1, …, 15 • 0: Invalid and ignored	*drm_request_update_period: <value> (unsigned/day)* *drm_max_update_requests: <value> (unsigned/no unit)*	Timestamp update period of 1 day Maximum 3 timestamp update requests per update period **0x 13**
0x68	Active Mode Options	3 B	R/W	• Bits 16-23: Start of active mode (24-hour format, 1 hour / LSB) • Acceptable values: 0, 1, …, 23 • Other values: Invalid and ignored • Bits 8-15: End of active mode (24-hour format, 1 hour / LSB) • Acceptable values: 1, 2, …, 24 • Other values: Invalid and ignored • End of active mode ≤ Start of active mode: Invalid and ignored • Bit 7: Ignored • Bits 0-6: Toggle individual bits to indicate which days of the week use active mode hours • Bit 0: Sunday	*drm_active_start_hr: <value> (unsigned/hour)* *drm_active_end_hr: <value> (unsigned/hour)* *drm_active_on_sunday: <value> (string/no unit)* *drm_active_on_monday: <value> (string/no unit)* *drm_active_on_tuesday: <value> (string/no unit)* *drm_active_on_wednesday: <value> (string/no unit)* *drm_active_on_thursday: <value> (string/no unit)* *drm_active_on_friday: <value>*	Start of Active Mode set to 9:00 (9:00 AM) End of Active Mode set to 17:00 (5:00 PM) Active mode hours apply on Monday, Tuesday, Wednesday, Thursday, and Friday **0x 09 11 3E**

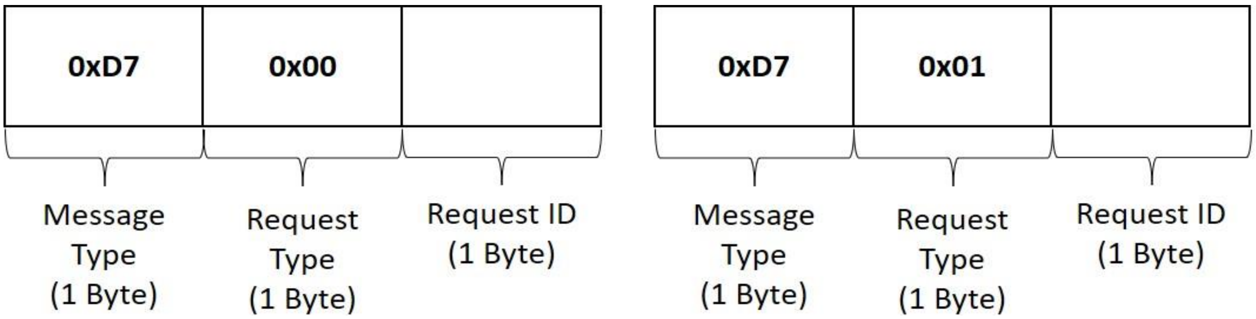
				• Bit 1: Monday • Bit 2: Tuesday • Bit 3: Wednesday • Bit 4: Thursday • Bit 5: Friday • Bit 6: Saturday • 0/1 = Active mode on <day of week> disabled/enabled • Bits 0-6 all set to 0: Invalid and ignored	*(string/no unit)* *drm_active_on_saturday: <value>* *(string/no unit)*	
0x69	Seconds per Core *Tick* (Inactive Mode)	4 B	R/W	• Tick value for periodic events during inactive mode (1 sec / LSB) • Acceptable values: 0, 10, 11, …, 86400 • 0: Disables all periodic transmissions during inactive mode • Other values: Invalid and ignored	*seconds_per_core_tick_inactive: <value>* *(unsigned/sec)*	3600 (1 hour) **0x 00 00 0E 10**
0x6A	CO_2 Sampling Parameters (Inactive Mode)	3 B	R/W	• Bits 8-23: Sample period of the CO2 transducer during inactive mode (1 sec / LSB) • Acceptable values: 0, 10, 11, …, 65535 • 0: Disables the CO2 sensing element • 1-9: Invalid and ignored • Bits 0-7: Number of subsamples integrated per reported measurement during inactive mode • Acceptable values: 1, 2, …, 255 • 0: Invalid and ignored • Sample period must be greater than number of subsamples multiplied by 0.2	*co2_sample_period_inactive: <value>* *(unsigned/sec)* *co2_num_subsamples_inactive: <value>* *(unsigned/no unit)*	Sample period of 3600 sec (1 hour) 32 subsamples **0x 0E 10 20**

13.2.1 Example DL Payloads

- Set Timestamp Update Period:
  - DL payload: **0x E7 34**
    - Register 0x67 with write bit set to true
    - Timestamp update period set to 3 days
    - Maximum number of timestamp requests sent per update to 4
- Enable Dynamic Reporting Mode and set Active Mode hours and days of the week:
  - DL payload: **0x E6 01 E8 07 13 2A**
    - Registers 0x66 and 0x68 with write bits set to true
    - Dynamic Reporting Mode enabled
    - Start of Active Mode set to 7:00 AM
    - End of Active Mode set to 7:00 PM
    - Active mode determined to be during above times on Monday, Wednesday, and Friday
- Set Seconds per Core *Tick* and CO_2 Sampling Parameters for both Active and Inactive modes:
  - DL payload: **0x A0 00 00 02 58 E9 00 00 1C 20 C0 01 2C 10 EA 0E 10 20**
    - Registers 0x20, 0x69, 0x30, and 0x6A with write bits set to true
    - Active Mode: Seconds per Core *Tick* set to 600 sec (10 mins)
    - Inactive Mode: Seconds per Core *Tick* set to 7200 sec (2 hours)
    - Active Mode: CO_2 sampling period set to 300 sec (5 mins) and 16 subsamples
    - Inactive Mode: CO_2 sampling period set to 3600 sec (1 hour) and 32 subsamples

Appendix 0

Port 20 Uplinks



(a) Acquire initial time reference (b) Update existing time reference

Figure Appendix 0-13: Frame format of local timestamp acquisition request in an UL payload.

Figure Appendix 0-14: Frame format of sensor timestamp response in an UL payload.

Table Appendix 0-36: LoRaWAN Port 20 Uplinks

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Initial Time Reference	0xD7	0x00	1 B	Counter	• Number	*initial_time_ref: <value>* *(unsigned/no unit)*
Update Existing Time Reference	0xD7	0x01	1 B	Counter	• Number	*update_time_ref: <value>* *(unsigned/no unit)*
Timestamp Response	0x85	N/A	4 B	Seconds	• Seconds in current Epoch since January 1, 1970 (UTC) + local UTC offset (in seconds) • 1 sec / LSB (unsigned)	*time_response: <value>* *(unsigned/sec)*

Port 100 Uplinks

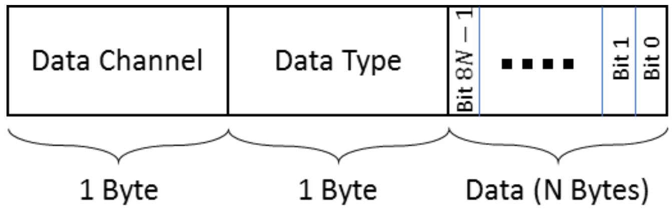


Figure Appendix 0-15: Frame format of transducer data in an UL payload.

Table Appendix 0-37: LoRaWAN Port 100 Uplinks

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Battery Voltage	0x00	0xBA	2 B	Analog Voltage	• 1 mV / LSB (unsigned) • 0x FF FF if unavailable	*battery_voltage: <value> (unsigned/V)*
Remaining Battery Capacity of Sensor	0x00	0xD3	1 B	Percentage	• 1% / LSB (unsigned) • 0x FF if unavailable	*rem_batt_capacity_sensor: <value> (unsigned/%)*
Remaining Battery Capacity of Display	0x11	0xD3	1 B	Percentage	• 1% / LSB (unsigned) • 0x FF if unavailable	*rem_batt_capacity_display: <value> (unsigned/%)*
CO_2 Concentration (Pressure Compensated)	0x0B	0xE4	2 B	CO_2	• 1 ppm / LSB (unsigned) • 0x FF FF if unavailable	*co2_pressure_compensated: <value> (unsigned/ppm)*
CO_2 Concentration (Raw)	0x0E	0xE4	2 B	CO_2	• 1 ppm / LSB (unsigned) • 0x FF FF if unavailable	*co2_raw: <value> (unsigned/ppm)*
Barometric Pressure	0x0C	0x73	2 B	Pressure	• 0.1 hPa / LSB (unsigned) • 0x FF FF if unavailable	*barometric_pressure: <value> (unsigned/hPa)*
Motion (PIR) Event State	0x0A	0x00	1 B	Digital	• 0x00 = No motion • 0xFF = Motion detected	*motion_event_state: <value> (string/no unit)*
Motion (PIR) Event Count	0x0D	0x04	2 B	Counter	• Number	*motion_event_count: <value> (unsigned/no unit)*
Ambient Temperature	0x03	0x67	2 B	Temperature	• 0.1°C / LSB (signed)	*temperature: <value> (signed/°C)*
Ambient RH	0x04	0x68	1 B	RH	• 0.5% / LSB	*relative_humidity: <value> (unsigned/%)*
Ambient Light State[†]	0x02	0x00	1 B	Digital	• 0x00 = Dark • 0xFF = Bright	*light_state: <value> (string/no unit)*
Ambient Light	0x10	0x02	2 B	Analog	• Light intensity	*light_intensity: <value>*

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Intensity†					(uncalibrated) • 0.1 µA / LSB	*(unsigned/µA)*

Port 20 Downlinks

Figure Appendix 0-16: Frame format of local timestamp acquisition response in a DL payload.

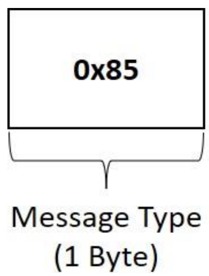
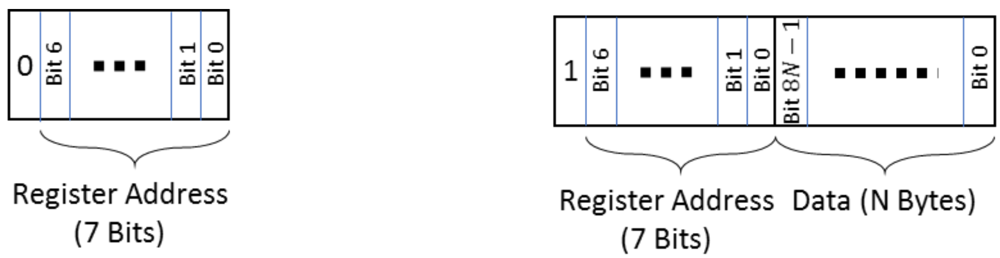


Figure Appendix 0-17: Frame format of sensor timestamp request in a DL payload.

Address	Name	Size	Access	Description	JSON Variable	Default
0xD7	Local Timestamp Acquisition Response	5 B	R/W	• Bits 32-39: Request ID matching the UL timestamp request associated with timestamp • Bits 0-31: Seconds in current Epoch since January 1, 1970 (UTC) + local UTC offset (in seconds) 1 sec / LSB (unsigned)	*timestamp_acquisition_response: <value> (unsigned/sec)*	**0x D7**
0x85	Timestamp Response	0 B	WO		*time_response_req: <value> (unsigned/sec)*	**0x 85**

Port 100 Downlinks



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

Figure Appendix 0-18: The format of a DL configuration and control message block.

Table Appendix 0-38: List of All Port 100 Configuration Registers

Address	Name	Size	Access	Description	JSON Variable	Default
0x10	Join Mode	2 B	R/W	• Bits 0-13: RFU, must be set to 0, otherwise invalid • Bit 14: ABP/OTAA mode	loramac_join_mode: <value> (unsigned/no unit)	OTAA mode **0x 01**
0x11	Options	2 B	See description	• Bits 0 (Read/Write): 0: Unconfirmed 1: Confirmed • Bit 1 (Read Only): 1 0: Private Sync Word 1: Public Sync Word • Bit 2 (Read/Write): 0: Duty Cycle Disabled 1: Duty Cycle Enabled • Bit 3 (Read/Write): 0: ADR Disabled 1: ADR Enabled • Bits 4-15: RFU	*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) }*	Unconfirmed UL Public Sync Word Duty Cycle Enabled[10] ADR Enabled **0x 00 0E**
0x12	DR and Tx Power[11]	2 B	R/W	• Bits 0-3: Default Tx power • Bits 4-7: RFU • Bits 8-11: Default DR number • Bits 12-15: RFU	*loramac_dr_tx: { dr_number: <value>, (unsigned/no unit) tx_power_number: <value> (unsigned/no unit) }*	DR4 Tx Power 0 (as per the LoRaWAN Regional Parameters [2])

[10] **WARNING**: Disabling the duty cycle in certain regions makes the Sensor non-compliant with the LoRaWAN Specifications [4]. It is recommended that the duty cycle remains enabled. In the LoRa RF regions where there is no duty cycle limitation, the “enabled duty cycle” configuration is invalid.

[11] Tx power number *m* translates to the maximum Tx power, which is a function of the LoRaWAN RF region, minus $2 \times m$ dBInvalid source specified..

0x13	Rx2 Window	R/W	5 B	• Bits 0-7: DR for Rx2 • Bits 8-39: Channel frequency in Hz for Rx2	*loramac_rx2: {* *frequency: <value>,* *(unsigned/Hz)* *dr_number: <value>* *(unsigned/no unit)* *}*	As per the LoRaWAN Regional Parameters [2]
0x20	Seconds per Core *Tick*	4 B	R/W	• *Tick* value for periodic events (1 sec / LSB) • Acceptable values: 0, 10, 11, …, 86400 • 0: Disables all periodic transmissions • Other values: Invalid and ignored	*seconds_per_core_tick: <value>* *(unsigned/sec)*	300 (5 mins) **0x 00 00 01 2C**
0x21	*Ticks* per Battery	2 B	R/W	• Ticks between battery reports • 0: Disables periodic battery reports	*ticks_battery: <value>* *(unsigned/no unit)*	1 (thus 5-min period) **0x 00 01**
0x22	*Ticks* per Ambient Temperature	2 B	R/W	• Ticks between ambient temperature reports • 0: Disables periodic ambient temperature reports	*ticks_temp: <value>* *(unsigned/no unit)*	1 (thus 5-min period) **0x 00 01**
0x23	*Ticks* per Ambient RH	2 B	R/W	• *Ticks* between ambient RH reports • 0: Disables periodic ambient RH reports	*ticks_rh: <value>* *(unsigned/no unit)*	1 (thus 5-min period) **0x 00 01**
0x25	*Ticks* per Ambient Light	2 B	R/W	• *Ticks* between ambient light reports • 0: Disables periodic ambient light reports	*ticks_light: <value>* *(unsigned/no unit)*	0 (periodic Tx disabled) **0x 00 00**
0x26	*Ticks* per CO_2	2 B	R/W	• *Ticks* between CO_2 reports • 0: Disables periodic CO_2 reports	*ticks_co2: <value>* *(unsigned/no unit)*	1 (thus 5-min period) **0x 00 01**
0x27	*Ticks* per Pressure	2 B	R/W	• *Ticks* between Pressure reports • 0: Disables periodic Pressure reports	*ticks_pressure: <value>* *(unsigned/no unit)*	1 (thus 5-min period) **0x 00 01**
0x28	*Ticks* per Motion (PIR)	2 B	R/W	• *Ticks* between motion (PIR) reports • 0: Disables periodic motion (PIR) reports	*ticks_motion_pir: <value>* *(unsigned/no unit)*	0 (periodic Tx disabled) **0x 00 00**
0x2A	BLE Communicatio	1 B	R/W	• Bit 0: • 0/1 = Sensor whitelisting	*ble_display_whitelistin g_enabled: <value>*	Sensor whitelisting on

	n Options			on Display disabled/enabled • Bits 1-7: Ignored	*(string/no unit)*	Display enabled **0x 01**
0x2B	Display Format Options	1 B	R/W	• Bit 0: Language Setting • 0: English • 1: French • Bits 1-3: Ignored • Bit 4: Temperature Unit Setting • 0: Celsius (°C) • 1: Fahrenheit (F) • Bits 5-7: Ignored	*ble_display_language: <value> (string/no unit)* *ble_display_temperature_unit: <value> (string/no unit)*	English language setting and temperature shown in degrees Celsius **0x 00**
0x2C	BLE Display Address	6 B	R/W	• BLE address of paired e-Ink Display • 0x FF FF FF FF FF FF: Sensor is not paired with an e-Ink Display	*ble_display_address: <value> (unsigned/no unit)*	Dependent on sensor commissioning information
0x30	Sampling Parameters	3 B	R/W	• Bits 8-23: Sample period of the CO2 transducer (1 sec / LSB) • Acceptable values: 0, 10, 11, …, 65535 • 0: Disables the CO2 sensing element • 1-9: Invalid and ignored • Bits 0-7: Number of subsamples integrated per reported measurement • Acceptable values: 1, 2, …, 255 • 0: Invalid and ignored • Sample period must be greater than number of subsamples multiplied by 0.2	*co2_sample_period: <value> (unsigned/sec)* *co2_num_subsamples: <value> (unsigned/no unit)*	Sample period of 300 sec 16 subsamples **0x 01 2C 10**
0x31	Threshold Control	2 B		• Threshold level (1 ppm / LSB) • Acceptable values: 0, 1, …, 65535 • 0: Disables threshold-based reporting	*co2_threshold_level: <value> (unsigned/ppm)*	Threshold-based reporting enabled Threshold level set to 1000 ppm **0x 03 E8**
0x32	IIR Filter Control	1 B	R/W	• Bits 0-3: Static IIR filter "recall factor"	*co2_static_iir_recall_factor: <value>*	Static and dynamic IIR

				• Acceptable values: 0, 1, 2, …, 9 • 0: Disables static IIR filter • 10-15: Invalid and ignored • Bit 4: • 0/1 = Dynamic IIR filter disabled/enabled • Bit 4 set to 1 and bits 0-3 set to 0: Invalid and ignored • Bits 5-7: Ignored	*(unsigned/no unit)* *co2_dynamic_iir_enabled: <value>* *(string/no unit)*	filters disabled **0x 00**
0x33	Calibration Control	4 B		• Bits 24-31: • 0: ABC calibration • 1: Target calibration • 2: Background calibration • 3: Zero calibration • 255: No calibration • Other values: Invalid and ignored • Bits 16-23: • 0: System default for ABC-cycle calibration period (180 hours) • Non-zero value: Calibration period for ABC cycle (1 hour / LSB) • Bits 0-15: • 0: System default for calibration target value (400 ppm) • Non-zero value: Target calibration value (1 ppm / LSB)	*co2_calibration_type: <value>* *(string/no unit)* *co2_calibration_period : <value>* *(unsigned/hrs)* *co2_calibration_target : <value>* *(unsigned/ppm)*	System default (ABC Calibration enabled with period of 180 hours and target value of 400 ppm) **0x 00 00 00 00**
0x34	Report Options	1 B	R/W	• Bit 0: • 0/1 = Raw CO2 value not reported/reported • Bit 1: • 0/1 = Pressure Compensated CO2 not reported/reported • Both bits 0 and 1 set to 0: Invalid and ignored • Bits 2-7: Ignored	*co2_raw_reported: <value>* *(string/no unit)* *co2_pressure_compensated_reported: <value>* *(string/no unit)*	Pressure compensated CO_2 reported only **0x 02**

0x38	IIR Filter Recall Factor	1 B	R/W	• Acceptable values: 0, 1, …, 15 • 0: Equivalent to no IIR filtering • 16-255: Invalid and ignored	*pressure_iir_recall_factor: <value>* *(unsigned/no unit)*	2 **0x 02**
0x39	Temperature/ RH Sample Period: Idle	4 B	R/W	• Sample period of ambient temperature/RH transducer: Idle state (1 sec / LSB) • Acceptable values: 10, 11, …, 86400 • Other values: Invalid and ignored	*temp_rh_sample_period_idle: <value>* *(unsigned/sec)*	60 sec **0x 00 00 00 3C**
0x3A	Temperature/ RH Sample Period: Active	4 B	R/W	• Sample period of ambient temperature/RH transducer: Active state (1 sec / LSB) • Acceptable values: 10, 11, …, 86400 • Other values: Invalid and ignored	*temp_rh_sample_period_active: <value>* *(unsigned/sec)*	30 sec **0x 00 00 00 1E**
0x3B	Low/High Temperature Thresholds	2 B	R/W	• Bits 8-15: High temperature threshold (signed, 1°C / LSB) • Bits 0-7: Low temperature threshold (signed, 1°C / LSB) • High threshold $\leq$ Low threshold: Invalid and ignored	*temp_threshold_high: <value>* *(signed/°C)* *temp_threshold_low: <value>* *(signed/°C)*	30°C 15°C **0x 1E 0F**
0x3C	Temperature Thresholds Enabled	1 B	R/W	• Bit 0: • 0/1 Thresholds disabled/enabled • Bits 1-7: Ignored	*temp_thresholds_enabled: <value>* *(string/no unit)*	Disabled **0x 00**
0x3D	Low/High RH Thresholds	2 B	R/W	• Bits 8-15: High RH threshold (unsigned, 1% RH / LSB) • Bits 0-7: Low RH threshold (unsigned, 1% RH / LSB) • High threshold $\leq$ Low threshold: Invalid and ignored	*rh_threshold_high: <value>* *(unsigned/%)* *rh_threshold_low: <value>* *(unsigned/%)*	80% 15% **0x 50 0F**

0x3E	RH Thresholds Enabled	1 B	R/W	• Bit 0: • 0/1 Thresholds disabled/enabled • Bits 1-7: Ignored	*rh_thresholds_enabled : <value> (string/no unit)*	Disabled **0x 00**
0x40	Report Options	1 B	R/W	• Bit 0: • 0/1 = Battery voltage not reported/reported • Bit 1: • 0/1 = Remaining battery capacity of Sensor not reported/reported • Bit 2: • 0/1 = Remaining battery capacity of Display not report/reported • Bits 0-2 all set to 0: Invalid and ignored • Bits 3-7: Ignored	*battery_voltage_reported: <value> (string/no unit)* *battery_capacity_sensor_reported: <value> (string/no unit)* *battery_capacity_display_reported: <value> (string/no unit)*	Remaining battery capacity of Sensor and Display reported **0x 06**
0x47	Sampling Parameters	3 B	R/W	• Bits 8-23: Sample period of the light transducer (1 sec / LSB) • Acceptable values: 0, 10, 11, …, 65535 • 0: Disables the light sensing element • 1-9: Invalid and ignored • Bits 0-7: Number of subsamples integrated per reported measurement • Acceptable values: 1, 2, …, 255 • 0: Invalid and ignored	*light_sample_period: <value> (unsigned/sec)* *light_num_subsamples : <value> (unsigned/no unit)*	Light transducer disabled 10 subsamples **0x 00 00 0A**
0x48	Threshold Control	2 B	R/W	• Threshold level (0.1 µA / LSB) • Acceptable values: 0, 1, …, 32767 • 0: Disables threshold-based reporting • Other values: Invalid and ignored	*light_threshold_level: <value> (unsigned/µA)*	Threshold-based reporting enabled Threshold level set to 10 µA **0x 00 0A**
0x49	Report Options	1 B	R/W	• Bit 0: • 0/1 = State (dark or bright) not reported/reported	*light_state_reported: <value> (string/no unit)*	Light state reported only **0x 01**

				• Bit 1: • 0/1 Intensity (uncalibrated, in units of 0.1 µA) not reported/reported • Both bits 0 and 1 set to 0: Invalid and ignored • Bits 2-7: Ignored	*light_intensity_reported: <value>* *(string/no unit)*	
0x4A	Subsample Processing	1 B	R/W	• Acceptable values: • 0: Max • 1: Min • 2: Average • 3-255: Invalid and ignored	*light_subsample_processing: <value>* *(string/no unit)*	Max **0x 00**
0x4B	IIR Filter Recall Factor	1 B	R/W	• Acceptable values: 0, 1, …, 15 • 0: Equivalent to no IIR filtering • 16-255: Invalid and ignored	*light_iir_recall_factor: <value>* *(unsigned/no unit)*	2 **0x 02**
0x50	Grace Period	2 B	R/W	• Grace period (time before motion is no longer detected) (1 sec / LSB) • Acceptable values: 15, 16, …, 65535 • Other values: Invalid and ignored	*pir_grace_period: <value>* *(unsigned/sec)*	300 sec (5 min) **0x 01 2C**
0x51	Threshold Count	2 B	R/W	• Number of PIR events before motion is detected • Acceptable values: 1, 2, …, 65535 • 0: Invalid and ignored	*pir_threshold_count: <value>* *(unsigned/no unit)*	1 **0x 00 01**
0x52	Threshold Period	2 B	R/W	• Period over which PIR events are counted for threshold detection (1 sec / LSB) • Acceptable values: 5, 6, …, 65535 • Other values: Invalid and ignored	*pir_threshold_period: <value>* *(unsigned/no unit)*	15 sec **0x 00 0F**
0x53	Report Options	1 B	R/W	• Bit 0 (only applies to periodic Tx): • 0/1 = Motion count not reported/reported	*pir_motion_count_reported: <value>* *(string/no unit)* *pir_motion_state_repo*	PIR transducer enabled Event-based transmission enabled

				• Bit 1 (only applies to periodic Tx): • 0/1 = Motion state not reported/reported • Both bits 0 and 1 set to 0: Invalid and ignored • Bits 2-5: Ignored • Bit 6: • 0/1 = PIR event-based reporting disabled/enabled • Bit 7: • 0/1 = PIR transducer disabled/enabled	*rted: <value> (string/no unit)* *pir_event_based_reporting_enabled: <value> (string/no unit)* *pir_transducer_enabled: <value> (string/no unit)*	Motion count reported only, in the case of a periodic transmission **0x C1**
0x54	Hold-Off Intervals	2 B	R/W	• Bits 8-15: • 0: Default value (120 sec) • Non-zero value: Post-turn on hold-off interval (1 sec / LSB) • Bits 0-7: • 0: Default value (10 sec) • Non-zero value: Post-disturbance hold-off interval (1 sec / LSB)	*pir_post_turn_on_holdoff: <value> (unsigned/sec)* *pir_post_disturbance_holdoff: <value> (unsigned/sec)*	Post-turn on hold-off interval 120 sec Post-disturbance hold-off interval 10 sec **0x 00 00**
0x66	Dynamic Reporting Mode Enabled	1 B	R/W	• Bit 0: • 0/1 = Dynamic Reporting Mode disabled/enabled • Bits 1-7: Ignored	*drm_enabled: <value> (string/no unit)*	Dynamic Reporting Mode disabled **0x 00**
0x67	Timestamp Update Period	1 B	R/W	• Bits 4-7: Timestamp update period (1 day / LSB) • Acceptable values: 0, 1, …, 15 • 0: Disables timestamp update requests • Bits 0-3: Maximum number of timestamp requests per update period • Acceptable values: 1, …, 15 • 0: Invalid and ignored	*drm_request_update_period: <value> (unsigned/day)* *drm_max_update_requests: <value> (unsigned/no unit)*	Timestamp update period of 1 day Maximum 3 timestamp update requests per update period **0x 13**
0x68	Active Mode Options	3 B	R/W	• Bits 16-23: Start of active mode (24-hour format, 1	*drm_active_start_hr: <value>*	Start of Active Mode set to

				hour / LSB) • Acceptable values: 0, 1, …, 23 • Other values: Invalid and ignored • Bits 8-15: End of active mode (24-hour format, 1 hour / LSB) • Acceptable values: 1, 2, …, 24 • Other values: Invalid and ignored • End of active mode ≤ Start of active mode: Invalid and ignored • Bit 7: Ignored • Bits 0-6: Toggle individual bits to indicate which days of the week use active mode hours • Bit 0: Sunday • Bit 1: Monday • Bit 2: Tuesday • Bit 3: Wednesday • Bit 4: Thursday • Bit 5: Friday • Bit 6: Saturday • 0/1 = Active mode on <day of week> disabled/enabled • Bits 0-6 all set to 0: Invalid and ignored	*(unsigned/hour)* *drm_active_end_hr: <value>* *(unsigned/hour)* *drm_active_on_sunday: <value>* *(string/no unit)* *drm_active_on_monday: <value>* *(string/no unit)* *drm_active_on_tuesday: <value>* *(string/no unit)* *drm_active_on_wednesday: <value>* *(string/no unit)* *drm_active_on_thursday: <value>* *(string/no unit)* *drm_active_on_friday: <value>* *(string/no unit)* *drm_active_on_saturday: <value>* *(string/no unit)*	9:00 (9:00 AM) End of Active Mode set to 17:00 (5:00 PM) Active mode hours apply on Monday, Tuesday, Wednesday, Thursday, and Friday **0x 09 11 3E**
0x69	Seconds per Core *Tick* (Inactive Mode)	4 B	R/W	• Tick value for periodic events during inactive mode (1 sec / LSB) • Acceptable values: 0, 10, 11, …, 86400 • 0: Disables all periodic transmissions during inactive mode • Other values: Invalid and ignored	*seconds_per_core_tick_inactive: <value>* *(unsigned/sec)*	3600 (1 hour) **0x 00 00 0E 10**
0x6A	CO_2 Sampling Parameters (Inactive	3 B	R/W	• Bits 8-23: Sample period of the CO2 transducer during inactive mode (1	*co2_sample_period_inactive: <value>* *(unsigned/sec)*	Sample period of 3600 sec (1 hour)

	Mode)			sec / LSB) • Acceptable values: 0, 10, 11, …, 65535 • 0: Disables the CO2 sensing element • 1-9: Invalid and ignored • Bits 0-7: Number of subsamples integrated per reported measurement during inactive mode • Acceptable values: 1, 2, …, 255 • 0: Invalid and ignored • Sample period must be greater than number of subsamples multiplied by 0.2	*co2_num_subsamples_inactive: <value> (unsigned/no unit)*	32 subsamples **0x 0E 10 20**
0x6F	Format Option	1 B	R/W	• Bit 0: 0: Invalid-write response format 1: 4-byte CRC • Bits 1-7: Ignored	*resp_to_dl_command_format: <value> (string/no unit)*	Invalid-write response format selected **0x 00**
0x70	Flash Write Command	2 B	WO	• 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 Sensor • Bits 1-12, 15: Ignored	*write_to_flash_app_config: <value> (string/no unit)* *write_to_flash_lora_config: <value> (string/no unit)* *restart_sensor: <value> (string/no unit)*	**0x 70**
0x71	FW Version	7 B	RO	• Bits 48-55: App version major • Bits 40-47: App version minor • Bits 32-39: App version revision • Bits 24-31: LoRaMAC version major • Bits 16-23: LoRaMAC version minor • Bits 8-15: LoRaMAC version revision	*app_ver_major: <value>, (unsigned/no unit)* *app_ver_minor: <value> (unsigned/no unit)* *app_ver_revision: <value> (unsigned/no unit)*	**0x 71**

				• Bits 0-7: LoRaMAC region ID (see Table Basic Operation Configuration-16)	*loramac_ver_major: <value> (unsigned/no unit)* *loramac_ver_minor: <value> (unsigned/no unit)* *loramac_ver_revision: <value> (unsigned/no unit)* *loramac_region_id: <value> (string/no unit)*	
0x72	Reset Config Registers to Factory Defaults[12]	1 B	WO	• 0x0A: Reset App Config • 0xB0: Reset LoRa Config • 0xBA: Reset both App and LoRa Configs • Any other value: Invalid and ignored	*factory_reset_config: <value> (string/no unit)*	**0x 72**

[12] After sending the reset-to-factory-defaults command, the Sensor is automatically reset with corresponding default configuration values.

Appendix 1

Breeze/BreezeV/Vivid+ Registers, Default Values, and Category

Table Appendix 1-39: Breeze/BreezeV/Vivid+ Registers, Default Values, and Category

Name	Register Address [Hex]	Default Value [Hex]	Category
Join Mode	10	01	LoRaMAC Configuration
Options	11	00 0E	
DR and Tx Power	12	As per the LoRaWAN Regional Parameters [2]	
Rx2 Window	13	As per the LoRaWAN Regional Parameters [2]	
Seconds per Core *Tick*	20	00 00 01 2C	Periodic Reporting Configuration
Ticks per Battery	21	00 01	
Ticks per Ambient Temperature	22	00 01	
Ticks per Ambient RH	23	00 01	
Ticks per Ambient Light	25	00 00	
Ticks per CO_2	26	00 01	
Ticks per Pressure	27	00 01	
Ticks per Motion (PIR)	28	00 00	
BLE Communication Options	2A	01	BLE Display Configuration
Display Format Options	2B	00	
BLE Display Address	2C	Sensor Dependent	
Sampling Parameters	30	01 2C 10	CO_2 Sensor Configuration
Threshold Control	31	03 E8	
IIR Filter Control	32	00	
Calibration Control	33	00 00 00 00	
Report Options	34	02	
IIR Filter Recall Factor	38	02	Barometer Configuration
Temperature/RH Sample Period: Idle	39	00 00 00 3C	Temperature/Humidity Configuration
Temperature/RH Sample Period: Active	3A	00 00 00 1E	
Low/High Temperature Thresholds	3B	1E 0F	
Temperature Thresholds Enabled	3C	00	
Low/High RH Thresholds	3D	50 0F	
RH Thresholds Enabled	3E	00	
Report Options	40	06	Battery Management Configuration
Sampling Parameters	47	00 00 0A	Light Sensor Configuration
Threshold Control	48	00 0A	

Report Options	49	01	
Subsample Processing	4A	00	
IIR Filter Recall Factor	4B	02	
Grace Period	50	01 2C	PIR Sensor Configuration
Threshold Count	51	00 01	
Threshold Period	52	00 0F	
Report Options	53	C1	
Hold-Off Intervals	54	00 00	
Dynamic Reporting Mode Enabled	66	00	Dynamic Reporting Mode Configuration
Timestamp Update Period	67	13	
Active Mode Options	68	09 11 3E	
Seconds per Core *Tick* (Inactive Mode)	69	00 00 0E 10	
CO_2 Sampling Parameters (Inactive Mode)	6A	0E 10 20	
Format Option	6F	00	Response to Downlinks Configuration
Flash Write Command	70	70	Command and Control Configuration
FW Version	71	71	
Reset Config Registers to Factory Defaults	72	72	

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[3] Tektelic, "ATLAS," Tektelic, [Online]. Available: Atlas.Tektelic.com.

[4] LoRaWAN Alliance, "TS001-1.0.4 LoRaWAN® L2 1.0.4 Specification," October 2020. [Online]. Available: https://lora-alliance.org/wp-content/uploads/2021/11/LoRaWAN-Link-Layer-Specification-v1.0.4.pdf.