TEKTELIC Communications Inc.
7657 10th Street NE Calgary, Alberta
Canada, T2E 8X2

COMFORT/VIVID v2

Technical Reference Manual

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4.0	July 18, 2024	Ade Adegboye	• Initial draft based on COMFORT/VIVID TRM v3.3.
4.1	November 29, 2024	Emma Tholl	• Updated to match new configuration for external connectors and PIR. • Added vibration analysis. • Updated formatting.
4.2	December 24, 2024	Emma Tholl	• Added Appendix 2 for data converter development. • Updated Sections 1 and 2 to be reflective of COMFORT/VIVID v2 battery installation.
4.3	June 10, 2025	Emma Tholl	• Updated register 0x4E to correct description and new default values. • Reviewed by design team.

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Acronyms and Glossary

ABP ...... activation by personalization
ADC ...... analog-to-digital converter
ADR ...... adaptive data rate
AE ...... analytical event
AI ...... artificial intelligence
CRC ...... cyclic redundancy check
DL ...... downlink
DLim ...... duration limit
DR ...... data rate
DRan ...... duration range
DS1 ...... display 1 (LED)
DS2 ...... display 2 (LED)
EIRP ...... effective isotropic radiated power
Flash memory ...... Non-volatile memory on the Sensor (contains application & configuration settings)
HPF ...... high-pass filter
ID ...... identity
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)
LPF ...... low-pass filter
LSB ...... least significant bit
MAC ...... medium access control
MCU ...... microcontroller unit
mg ...... millig-unit
min ...... minute(s)
ML ...... magnitude level
ms ...... millisecond
MSB ...... most significant bit
NS ...... network server
OTA ...... over-the-air
OTAA ...... OTA activation
PIR ...... passive infrared
POST ...... power-on self-test
R/W ...... read/write
RFU ...... reserved for future use
RH ...... relative humidity
RO ...... read-only
Rx ...... receiver
SD ...... standard deviation
sec ...... second(s)
Sensor ...... COMFORT/VIVID
transducer ...... sensing element on the Sensor (e.g. PIR or temperature transducers)
TRM ...... technical reference manual (this document)
Tx ...... transmitter
UL ...... uplink
WO ...... writes-only
g ...... gravity (unit of acceleration ≈ 9.8 m/s^2)

1 Introduction

NOTE: For details specific to COMFORT/VIVID v1 sensors, please refer to TRM v3.3.

This document provides technical information about the functionalities supported by the TEKTELIC COMFORT/VIVID v2 sensor variants, referred to as the Sensors henceforth. The v2 version of the COMFORT/VIVID sensors is a redesigned version of the v1, featuring significant enhancements in the mechanical housing, improved leak detection capabilities for COMFORT v2, and enhanced Passive Infrared (PIR) features for VIVID v2.

This technical reference manual (TRM) document includes comprehensive descriptions of the LoRa IoT uplink and downlink payload structures, as well as user-accessible configuration settings. For effective comprehension, it is assumed that the reader has prior familiarity with the hexadecimal number system, LoRaWAN network architecture, the Network Server (NS), and its command interfaces.

1.1 Overview

LoRaWAN, the LoRa wireless communications standard protocol, offers a solution for transmitting small data packets over long distances with low power consumption. This technology, designed with wireless sensing applications in mind, facilitates the gathering of telemetry data in various environments. The COMFORT/VIVID v2 sensors support both LoRa and (G)FSK modulations in accordance with the LoRaWAN 1.0.4 Specification [1]. Utilizing the 150 MHz-960 MHz ISM bands, the sensors cater to diverse application requirements across different regions, accommodating both standard and proprietary protocols.

The COMFORT/VIVID v2 is an IP65-rated, ultra-low-power, cost-effective LoRa sensor designed for both commercial and residential applications, suitable for indoor and outdoor use. It leverages Semtech's LoRa wireless communication technology, which is based on the chirp spread spectrum technique implemented in the Semtech SX1261. This technology provides low bandwidth, low power, and long-range (up to 2 km NLOS and over 22 km LOS) data transmission capabilities. The LoRa protocol is specifically developed for wireless sensing, enabling innovative methods of gathering telemetry in diverse environments.

The COMFORT/VIVID v2 sensor integrates a Semtech SX1261 LoRa modem, a low-energy STM32 MCU, and various on-board sensing inputs. Its primary function is to collect data from connected transducers and transmit it via LoRa to an application server, which then processes the data for meaningful use. In LoRaWAN terminology, the COMFORT/VIVID v2 functions as an end-point or remote device, communicating with network and application servers through gateways.

Designed for low-power operation and unobtrusive deployment, the COMFORT/VIVID v2 is adaptable to a wide range of sensing applications. The module features a minimal footprint and offers a long operating life (5+ years[1]) powered by replaceable CR2477 coin-cell batteries.

[1] Estimation used with default configurations

1.2 Features and Functions

The COMFORT and VIVID sensors are multi-purpose LoRaWAN IoT devices designed with a compact form factor, making them highly versatile and unobtrusive. Although they belong to the same family, these sensors differ in some of their sensing features, catering to a variety of monitoring needs in home and office environments.

COMFORT/VIVID sensors excel at monitoring and reporting a range of environmental conditions. They can measure temperature in multiple ways, including ambient temperature, remote temperature via a probe, and the temperature of the microcontroller unit (MCU). In addition to temperature, these sensors also track humidity levels and light intensity. Enhanced by a low-power 3-axis MEMS accelerometer, the sensors can detect acceleration and shock, enabling comprehensive data collection and analysis. The COMFORT/VIVID v2 sensors also incorporate a battery life estimation algorithm, providing estimates of the remaining battery capacity in percentage and the battery voltage in volts.

Beyond these standard features, the COMFORT/VIVID sensors offer additional functionalities depending on the specific variant. The VIVID v2 variant is equipped with presence detection capabilities, useful for occupancy and automation applications. Conversely, the COMFORT v2 variant supports the integration of external probes, allowing for expanded monitoring capabilities tailored to specific requirements such as leak detection (including valve shutoff), digital pulse counting, and external magnetic switch integration. These diverse features make the COMFORT and VIVID sensors flexible solutions for a wide range of IoT applications, ensuring comprehensive environmental monitoring and reporting.

The COMFORT/VIVID v2 is equipped with various user interface elements, including two LEDs (one green and one red), a light pipe for the light sensor, two USB-C type connectors (exclusive to COMFORT v2 variants), and a PIR lens (exclusive to VIVID variants).

In the event of unforeseen critical component or system failures, the COMFORT/VIVID v2 sensors are equipped with self-recovery capabilities designed to address the issue. These self-recovery mechanisms target the affected components with precision to restore operations. If these targeted recovery efforts are unsuccessful, the sensors initiate a system reset. Following the reset, logs detailing the reset event and any associated failures are transmitted as the first uplink, providing administrators with crucial information about the events leading to the reset.

Table 1-1 below summarizes all supported features and functions and the applicable variant across the two generations (v1 and v2).

Table 1-1: Supported functions and applicable variants

Features and Functions	Section #	COMFORT v1	COMFORT v2	VIVID v1	VIVID v2
Operating Temperature	-	0°C - 60°C	0°C - 60°C	0°C - 60°C	0°C - 60°C
Operating Humidity	-	5% to 95%	5% to 95%	5% to 95%	5% to 95%
Environmental Rating	-	IP30	IP65	IP30	IP65
Accessible Reset Button	-	Yes	No	Yes	No
Hall Effect Transducer	6	Yes	Yes	Yes	Yes
External Connector (s)	7	One (1) 2-pin connector	Two (2) UBC-C type connectors A and B	N/A	N/A

Features and Functions	Section #	COMFORT v1	COMFORT v2	VIVID v1	VIVID v2
Leak detection via rope/cable		Yes	Yes, on Connectors A and B	N/A	N/A
Leak detection via enclosure screws	7.1	N/A	Yes	N/A	N/A
Digital Pulse Counter	7.2	Yes, on Connector A ONLY	Yes, on Connectors A and B	N/A	N/A
Magnetic Probe Switch	7.2	Yes, on Connector A ONLY	Yes, on Connectors A and B	N/A	N/A
Analog Temperature Probe	7.3	Yes, on Connector A ONLY	Yes, on Connector B ONLY	N/A	N/A
Valve Shut Off	7.1	No	Yes	N/A	N/A
PIR feature: Presence Detection	8	N/A	N/A	Yes	Yes
Accelerometer feature: Orientation	9	Yes	Yes	Yes	Yes
Accelerometer feature: Impact Alarm	9.2	Yes	Yes	Yes	Yes
Accelerometer feature: Acceleration Event	9.3	Yes	Yes	Yes	Yes
Accelerometer feature: Vibration Analysis	14	Yes	Yes	Yes	Yes
Critical Data Delivery Assurance	13	No	Yes	No	Yes
Temperature	10	Yes	Yes	Yes	Yes
Humidity	10	Yes	Yes	Yes	Yes
Ambient Light	11	Yes	Yes	Yes	Yes
Battery Life Estimation	5.3	In volts ONLY	In volts and %	In volts ONLY	In volts and %
System Diagnostics	12	Yes	Yes	Yes	Yes

1.3 Hardware Models, Data Streams, and Default Behavior

Table 1-2 and Table 1-3 below shows more information on the supported HW models and the supported data streams.

Table 1-2: COMFORT/VIVID v2 HW Models

Part Number			Description
Level 1 (Module)	Level 2 (PCBA)	Level 3 (PCB)	
T0006115			HOME SENSOR MODULE, GEN3+, BASE
T0006116			HOME SENSOR MODULE, GEN3+, PIR
	T0008998		PCBA, COMFORT (BASE), NA-EU, 2024 UPDATE

Part Number			Description
Level 1 (Module)	Level 2 (PCBA)	Level 3 (PCB)	
	T0008999		PCBA, VIVID (PIR), NA-EU, 2024 UPDATE
		T0008997	PCB, COMFORT-VIVID NA-EU, 2024 UPDATE

Table 1-3: COMFORT/VIVID v2 Information Streams

Stream Direction	Data Type	Sent on LoRaWAN Port
Uplinks (Sensor to NS)	Systems Diagnostics Information • Component errors • System errors • Reset types and counts	**5**
	All Real-time sensing data • External connector data/status • PIR • Accelerometer vector • Temperature • Humidity • Light intensity • Light State • Battery life capacity (%) • Battery voltage (volts)	**10**
	Response to read/write commands from the NS	**100**
		101
Downlinks (NS to Sensor)	Query for sensor's diagnostics report	**5**
	Configuration and Control Commands	**100**

The default configuration on the COMFORT/VIVID v2 sensors for periodic reports is outlined in Table 1-4 below.

Table 1-4: COMFORT/VIVID v2 Default Reporting Behavior

Report type	Report Type	Occurrence
Remaining Battery Capacity in percentage	Periodic	Once every hour
Battery Voltage in volts	Periodic	Once every hour
Ambient Temperature (°C)	Periodic	Once every hour
Relative Humidity (%)	Periodic	Once every hour
Hall Effect State	Event-based	On any change in the actuation state
External Connector A digital state (COMFORT v2 ONLY)	Event-based	On any change in the actuation state
External Connector B digital state (COMFORT v2 ONLY)	Event-based	On any change in the actuation state
PIR Presence state (VIVID v2 ONLY)	Event-based	On any detected presence
Detected PIR Presence Cleared (VIVID v2 ONLY)	Event-based	300s (5 minutes) of no presence after presence is detected

2 Sensor Activation and Management

This section outlines the steps required to set up the COMFORT/VIVID v2 sensors and manage the sensor thereafter.

2.1 Unpacking

The following items are included with every COMFORT/VIVID v2 sensor package:

- One COMFORT v2 or VIVID v2 sensor module with a CR2477 coin cell battery installed and a battery sticker preventing the sensor from turning on.
- Mounting Bracket Kit

The following should be considered during the unpacking of a new COMFORT/VIVID v2 Sensor:

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

2.2 Commissioning

Each COMFORT/VIVID v2 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:

- 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 COMFORT/VIVID v2 sensor is shipped in a sealed enclosure with a CR2477 coin cell battery installed and engaged, but with a battery sticker on the negative terminal preventing the battery from turning the device on. Once the sensor information has been added to the Network Server, the sensor can be turned on by removing the battery from the enclosure and taking off the sticker attached to the negative terminal. Reinsert the battery and observe the LED activities as described in Section 3.4.

2.4 Mounting

On the battery side of the enclosure, there are four clip holes designed for attaching the COMFORT/VIVID v2 sensor to a support structure, as shown Figure 2-1 below. The recommended screws for this purpose are stainless steel screws.

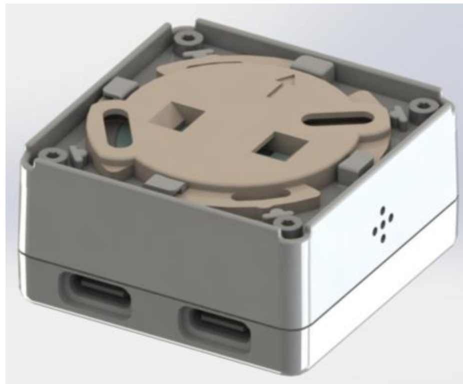


Figure 2-1: COMFORT v2 showing the enclosure screws

2.5 Battery Replacement

The COMFORT/VIVID v2 sensor is powered by a standard CR2477 coin cell.

Warning

The COMFORT/VIVID v2 Sensor contains a coin cell battery.

Do not ingest battery, Chemical Burn Hazard.

If a battery is swallowed, it can cause severe internal burns in just 2 hours and can lead to death.

Keep new and used batteries away from children.

If the battery compartment does not close securely, stop using the product and keep it away from children.

If you think batteries might have been swallowed or placed inside any part of the body, seek immediate medical attention.

Use only approved CR2477 cells when replacing the battery. The following are approved replacement cells:

- Panasonic (model CR2477)
- Sony (model CR2477)
- EVE Energy (model CR2477)
- Jauch (model CR2477)

To access the battery, please follow the steps listed below:

1. Turn the battery lid counterclockwise until the arrow on the battery lid aligns with the unlock symbol, using a flat tool, such as a coin.

2. While holding the sensor with the bottom facing up, remove the battery lid from the device.
3. With the battery lid removed, the coin cell battery is accessible.
4. Remove the coin cell from the holder.
5. Place the new cell in the holder. The top of the coin cell is marked with a + symbol indicating the positive terminal. This positive terminal must face outward from the device, meaning it is visible after insertion.
6. Check for LED activity. If the LEDs are lit, the battery replacement was successful.
7. Replace the battery lid and turn it clockwise until the arrow on the battery lid aligns with the lock symbol, using a flat tool.

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 COMFORT/VIVID v2 enclosure is shown in Figure 3-1, with the locations of the external user interfaces identified.

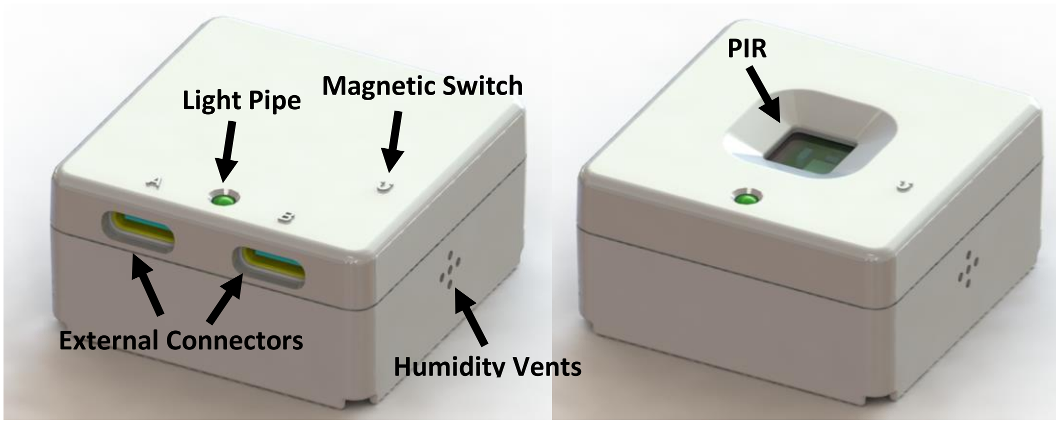


Figure 3-1: Top and Side view of the Comfort and VIVID v2 Sensors

3.1 Hall Effect Sensor

The hall effect sensor (location indicated by a magnet symbol on the enclosure) is triggered by the presence of a nearby magnet. The magnet can be detected at a maximum distance of 15mm. For more information on the hall effect operation, see Section 6.

3.2 Vents and Pipes

The light and PIR pipes enable ambient light sensing and presence detection (VIVID v2 ONLY) respectively, while the humidity vents allow for air circulation, resulting in better ambient temperature and relative humidity (RH) measurements.

3.3 External Connectors (COMFORT v2 ONLY)

There are two USB-C type external connectors which allow for use in the following modes:

- Digital Input
    - Connection to an external open-closed or open-drain type switch (e.g. a manual switch/ a “dry contact” switch, or an on-off (reed) switch activated by an external magnetic field, or an externally controlled open-drain transistor); or
    - Connection to a leak detection rope; or
    - Connection to an external digital input signal [0V to 1.8V (or float) logic levels, 3.3V maximum] with a pulse frequency of 20Hz or less.
- Digital Output
    - Connection to a flow valve for shutoff via energization of an onboard solid-state relay
- Analog input

- Connection to a 10$k\Omega$ thermistor for remote temperature sensing

The length of any external cable connected to any of the connectors should be less than 3 meters. For more information on the external connectors, see Section 7.

3.4 LEDs

The COMFORT/VIVID v2 sensor is equipped with two on-board LEDs: **GREEN** and **RED**. They are visible through holes in the sensor enclosure at the locations shown in Figure 3-1. The LED behaviour is not user configurable.

The LEDs are normally off. Their blinking patterns reflect different actions and states of the sensor. At a high level, the main patterns are summarized in Table 3-1. The detailed sequence and timings for each are described in the following subsections.

Table 3-1: Summary of LED Patterns

LED Pattern	Meaning
GREEN blinking rapidly and a single **RED** flash every time a JOIN REQUEST is sent (~40 s)	JOIN mode; attempting to join the network
Single **RED** flash	UL sent
Single **GREEN** flash	DL received

3.4.1 Power-On and Network Join Patterns

When the sensor is activated or reset:

1. Both **GREEN** and **RED** are OFF for approximately 0.5 s after any reset occurs.
2. Upon startup, the SW conducts its POST. Both **GREEN** and **RED** are turned on when the POST begins.
3. When the POST ends (about 2 s), both **GREEN** and **RED** are turned off. Immediately following, the sensor will do 1 of 2 things, depending on the POST result:
   a. If the POST passes, **GREEN** is toggled ON and OFF 3 times: every 100 ms for 0.6 s, as shown in Figure 3-2. In this case, the LED pattern proceeds to step 4.
   b. If the POST fails, **RED** is toggled ON and OFF 3 times: every 100 ms for 0.6 s, as shown in Figure 3-2. In this case, the device restarts and the LED pattern begins again at step 1 after approximately 4 s.

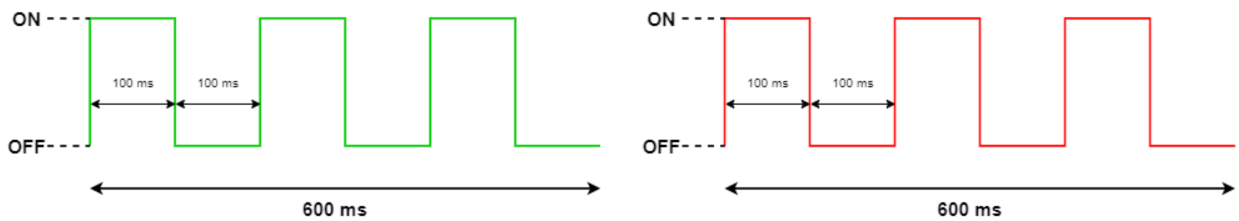


Figure 3-2: The GREEN POST Pass (left) and RED POST Failure (right) LED Patterns

4. After a successful POST, both **GREEN** and **RED** are turned off. Immediately following this, the sensor will enter JOIN mode and begin attempting to join the network. For the first hour[2]:
   a. **GREEN** is toggled ON and OFF every 50 ms.
   b. **RED** flashes just once:
      i. with a pulse duration of 25 ms right after transmitting a JOIN REQUEST. This occurs at approximately 40 s intervals at the beginning of the join process, but at decreasing regularity the longer the join process continues due to battery saving measures and possible duty-cycle limitations in certain regions [2].
      ii. with a pulse duration of 100 ms right after receiving a JOIN ACCEPT. This will occur once, after which, the device will have joined the network and normal operation begins.

   If the sensor has been unsuccessfully trying to join for more than an hour, it enters *join back-off* to conserve power. While the sensor still attempts to join, **GREEN** stops flashing and **RED** flashes twice (ON time: 10 ms, OFF time: 10 ms) every 8 s. The JOIN LED pattern is shown in Figure 3-3

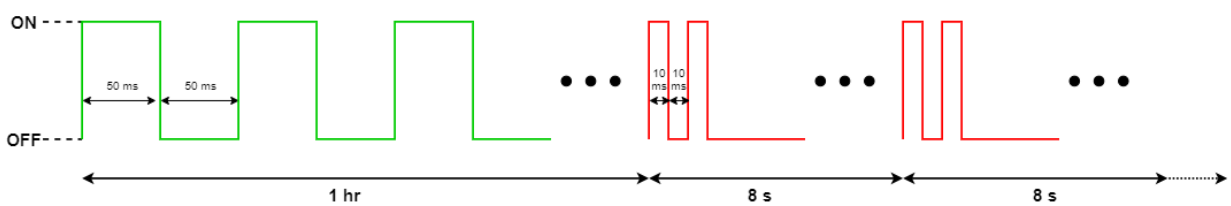


Figure 3-3: The LED Patterns During JOIN Mode

3.4.2 Normal Operation Patterns

After the sensor has joined the network:

a. **RED** flashes just once with a pulse duration of 25 ms right after transmitting an uplink.
b. **GREEN** flashes just once with a pulse duration of 100 ms right after receiving a downlink.

[2] The very first time a sensor is activated out of the box or after a battery replacement, there might be some ramp-up time required due to battery passivation. See section 5.3.1.2 for details.

4 General Sensor and LoRaWAN Communication Information

The COMFORT/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 COMFORT/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 COMFORT/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 COMFORT/VIVID devices.

4.1 Uplink Payloads

Uplinks are LoRaWAN packets sent from the COMFORT/VIVID to the NS. Each uplink from the COMFORT/VIVID is encoded in a frame shown below.

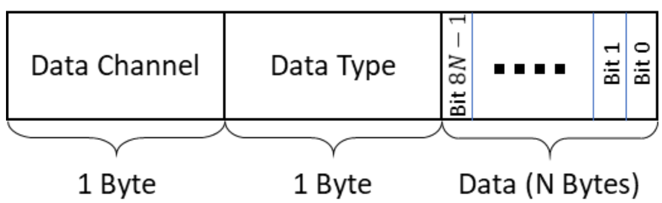


Figure 4-1: Uplink Payload Format

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

A COMFORT/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 system diagnostics uplink, which contains information such as reset/restart counters, communication bus failures, component failures, and more.
2. Sensor data uplinks: These uplinks consist of measurement reports obtained from onboard transducers such as the accelerometer, 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 exceeding a threshold.

Table 4-1 below tabulates the supported uplink streams for COMFORT/VIVID sensors, their uplink types, and their corresponding port numbers.

Table 4-1: COMFORT/VIVID Uplink Streams

Uplink Heading	Information/Sensor Data	Periodic/Event-based	Port
System diagnostics • Reset counters • Most recent reset type • Components health status	Information	Event-based (second uplink on successful network JOIN) and after a query DL	5
All real-time sensing data • Relative Humidity report • Temperature report • Hall Effect Count and State • Impact Alarm • Presence Count, State, and Value • Acceleration vector and magnitude • External Inputs states • MCU Temperature report • Ambient Light intensity and State • Battery life information report	Sensor Data	Periodic and event-based	10
Response to downlink commands	Information	Event-based (on any read/write downlink command)	100 (read), 101 (write)

Refer to Appendix 1 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 COMFORT/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 system diagnostics status on **port 5** (Refer to Section 12)

2. Configuration and Control Downlinks (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)

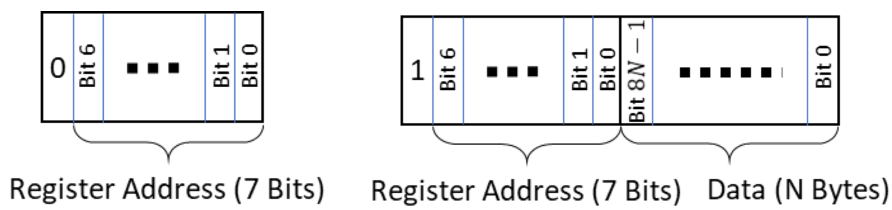
    b. Request to write a value to a configuration register (W)

    c. Request for the sensor to execute a specific operation, such as resetting to factory defaults (Refer to Section 5.4)

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 4-2. 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 4-2. 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 4-2: 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 COMFORT/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 4-3 below

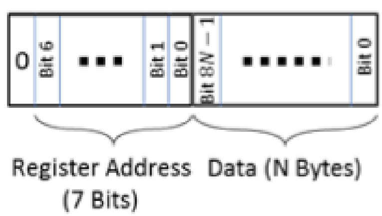


Figure 4-3: Bit Indexing Scheme for Configuration Registers

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 4-4.

[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 5.4 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.

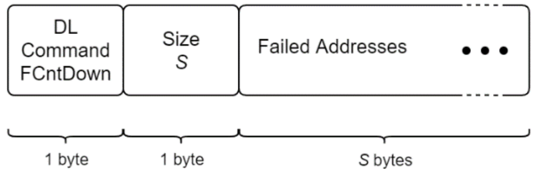


Figure 4-4: The *LoRaWAN port 101* Write/Error Response UL Frame Format

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, this is considered an unsuccessful command and register address 0x 21 will be added to the ***LoRaWAN port 101*** response. See Section 5.2.1.1 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 not executed, 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 and the write/error responses after.

4.4 Configuration Settings

Address	Name	Access	Size	Description	JSON Variable	Default
0x6F	Format Options	R/W	1 B	• Bit 0: 0: Invalid write-response format 1: 4-byte CRC • Bit 1-7: Ignored	*resp_to_dl_command_ format: <value> (unsigned/no unit)*	Invalid write-response format **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 Basic Operation Configuration

The basic functionality of the COMFORT/VIVID can be broken down into the following categories:

- **LoRaMAC Options**: LoRaWAN general parameters and behaviour as defined by the LoRaWAN Specifications [5].
- **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.

5.1 LoRaMAC Configuration

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 [5], [6]. 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).

5.1.1 Configuration Settings

Table 5-1 shows the MAC configuration registers. In this table, the bit indexing scheme is as shown in Figure 4-2. To access these registers, a command must be formatted and sent according to the details described in Section 4.2.

Table 5-1: LoRaMAC Options Configuration Registers

Address	Name	Access	Size	Description	JSON Variable	Default
0x11	Options	See Description	2 B	• 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[5] ADR Enabled **0x 00 0E**
0x12	DR and Tx Power[6]	R/W	2 B	• 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 [6])

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.

5.1.1.1 *Example DL Payloads*

- 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

[5] **WARNING**: Disabling the duty cycle in certain regions makes the sensor non-compliant with the LoRaWAN Specifications [5]. 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.

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

- Bit 3 set to 0 (ADR disabled), bit 2 set to 1 (duty cycle enabled), bit 1 set to 1 (public sync word), and bit 0 set to 1 (confirmed ULs) = 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 1 = 0x 92
    - DR3 = 0x 03
    - Tx 4 = 0x 04

5.2 Periodic Reporting Scheduling

5.2.1 Operation 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*** $\times$ ***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 5.3 for battery management details.
- **Hall Effect**: Open/Close state and the number of state changes of the Hall Effect sensor. See Section 6 for Hall Effect Sensor operation details.
- **Accelerometer**: Acceleration vector [*g*] in three axes and all other acceleration-based uplinks. See Section 9 for accelerometer operation details.
- **External Connectors (COMFORT v2 ONLY)**: State and the number of state changes of the externally connected probes in digital mode, and the measurement from the analog thermistor probe in analog mode. See Section 7 for external connector operation 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.
- **MCU Temperature**: Temperature of the microcontroller unit [°C]. See Section 10 for environment sensing details.
- **Ambient Light**: State and intensity of the ambient environment. See Section 11 for environment sensing details.
- **Presence Sensor (VIVID v2 ONLY)**: State and the number of state changes of the presence sensor. See Section 8 for PIR 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 are as tabulated in Table 1-4. 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).

5.2.1.1 Anti-bricking Strategy

As a Class-A LoRaWAN end-device, the COMFORT/VIVID sensor can only be receptable to 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*.

COMFORT/VIVID can manually force a UL by bringing a magnet close to the “U” sign on the enclosure, so it is technically impossible to *completely* brick the sensor. However, there are use cases in which using the magnet to trigger the sensor may not be a convenient option, e.g., due to remote installation constraints. In this use-case, a strategy to avoid bricking the sensor is beneficial and therefore included as a SW feature.

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: S*econds 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:

$$\boldsymbol{Battery\ Reporting\ Period} = \boldsymbol{Seconds\ per\ Core\ Tick} \times \boldsymbol{Ticks\ per\ Battery}$$

$$\boldsymbol{0 < Battery\ Reporting\ Period \leq 1\ \mathbf{day}}$$

$$\boldsymbol{0 < Battery\ Reporting\ Period \leq 86\,400\ \mathbf{s}}$$

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 $\left\lfloor \frac{86\,400\ \mathrm{s}}{Seconds\ per\ Core\ Tick} \right\rfloor$.

5.2.2 Configuration Settings

Table 5-2 lists the registers used to configure the periodic reporting periods. *Seconds per Core Tick* is configured using register 0x 20, and the *Ticks per* <Data Type> are configured using registers 0x 21 through 0x 29. In this table, the bit indexing scheme is as shown in Figure 4-1. To access these registers, a command must be formatted and sent according to the details described in Section 4.1.

Table 5-2: Periodic Report Scheduling Configuration Registers

Address	Name	Access	Size	Description	JSON Variable	Default
0x20	Seconds per Core Tick	R/W	4 B	• Ticks value for periodic events • Acceptable values: 15,16, 17, …, 86400 • 0, Other values: Invalid	*seconds_per_core_tick: <value> (number/sec)*	3600 s = 1 hr **0x 00 00 0E 10**
0x21	Ticks per Battery	R/W	2 B	• Ticks between battery reports • Acceptable values: 1,2…65535 • 0, Other values: Invalid	*ticks_per_battery: <value> (number/no unit)*	1 tick = 1 hr **0x 00 01**
0x22	Ticks per Ambient Temperature	R/W	2 B	• Ticks between ambient temperature report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic ambient temperature reports • Other values: Invalid	*ticks_per_ambient_temperature: <value> (number/no unit)*	1 tick = 1 hr **0x 00 01**
0x23	Ticks per Relative Humidity	R/W	2 B	• Ticks between Relative Humidity report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic Relative Humidity reports • Other values: Invalid	*ticks_per_relative_humidity: <value> (number/no unit)*	1 tick = 1 hr **0x 00 01**

Address	Name	Access	Size	Description	JSON Variable	Default
0x24	Ticks per Hall Effect	R/W	2 B	• Ticks between Hall Effect report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic Hall Effect reports • Other values: Invalid	*ticks_per_hall_effect: <value> (number/no unit)*	0 tick = Disabled by default **0x 00 00**
0x25	Ticks per Ambient Light	R/W	2 B	• Ticks between Ambient Light report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic Ambient Light reports • Other values: Invalid	*ticks_per_ambient_light: <value> (number/no unit)*	0 tick = Disabled by default **0x 00 00**
0x26	Ticks per Accelerometer	R/W	2 B	• Ticks between Accelerometer report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic Accelerometer reports • Other values: Invalid	*ticks_per_ccelerometer: <value> (number/no unit)*	0 tick = Disabled by default **0x 00 00**
0x27	Ticks per MCU Temperature	R/W	2 B	• Ticks between MCU Temperature report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic MCU Temperature reports • Other values: Invalid	*ticks_per_mcu_temperature: <value> (number/no unit)*	0 tick = Disabled by default **0x 00 00**
0x28	Ticks per PIR	R/W	2 B	• Ticks between periodic PIR sensor reports • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic reports • Other values: Invalid	*ticks_per_pir: <value> (number/no unit)*	0 ticks = PIR report is disabled by default **0x 00 00**
0x55	Ticks per Externally Connector A (Digital ONLY)	R/W	2 B	• Ticks between Externally Connector A report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic Externally Connector A reports • Other values: Invalid	*ticks_per_external_connector_a: <value> (number/no unit)*	0 tick = Disabled by default **0x 00 00**

Address	Name	Access	Size	Description	JSON Variable	Default
0x29	Ticks per Externally Connector B (Digital/Analog)	2 B	2 B	• Ticks between Externally Connector B report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic Externally Connector B reports • Other values: Invalid	*ticks_per_external_connector_b: <value> (number/no unit)*	0 tick = Disabled by default **0x 00 00**

5.2.2.1 Example DL Payloads

- Change core tick to 1 hour:
    - DL payload: 0x **A0** 00 00 0E 10
        - Register 0x 20 with bit 7 set to 1 = 0x A0
        - Seconds per Core Tick = 3600 = 0x 00 00 0E 10

- Read current value of Seconds per Core Tick:
    - DL payload: 0x **20**
        - Register 0x 20 with bit 7 set to 0 = 0x 20

- Change settings to report the ambient temperature every 5 mins
    - DL payload: 0x **A0** 00 00 00 3C **A2** 00 05
        - Register 0x 20 with bit 7 set to 1 = 0x A0
        - Seconds per core tick set to 60s = 0x 00 00 00 3C
        - Register 0x 22 with bit 7 set to 1 = 0x A3
        - Ticks per ambient temperature set to 5 = 5 ticks = 0x 00 05

5.3 Battery Management

The COMFORT/VIVID has a battery management system that monitors battery energy depletion and presents the remaining energy in units of percentage and battery voltage.

5.3.1 Operation Description

The measured battery voltage refers to the most recent voltage reading taken by an onboard voltmeter at the battery terminals. This voltage measurement is subject to fluctuations due to the sensor's normal operational activities, which can cause the voltage to momentarily drop and then recover. The software (SW) records the lowest voltage measurement observed during these fluctuations. This recorded value is crucial as it helps to build a historical record (hysteresis) that is used for estimating the battery percentage accurately over time.

The remaining battery capacity represents the percentage of battery energy still available for the sensor's use, relative to a fully charged battery. The software continuously monitors and updates this value to provide a real-time estimate of the sensor's battery life. The rate at which the remaining battery capacity decreases depends on the sensor's configuration and usage patterns.

For example, if a sensor is configured to send ten (10) uplink (UL) reports every 15 minutes, it will consume energy at a higher rate compared to a sensor configured to send a single UL report every 60 minutes. This is because more frequent data transmissions require more power, thereby accelerating the depletion of the battery. Consequently, the configuration settings, such as the frequency of data reports, play a significant role in determining the sensor's energy consumption rate and, ultimately, the longevity of its battery life.

5.3.1.1 Resets and Battery Replacement

The battery management system bases calculations on the average nominal battery voltage of a new coin cell battery. When the battery is replaced, the remaining battery capacity and voltage are automatically reset to reflect a fully charged battery. 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 OTA reset command).

5.3.1.2 Battery Passivation

Due to the chemistry of batteries, a *passivation layer* can build up internally during periods when the battery has little to no charge flowing out. This layer can prevent high pulse current draws for a few minutes at the time of first use. As the sensor begins drawing current from the battery, the passivation begins to break down. The longer the dormant state of the battery, the longer it takes to break the passivation layer down.

At the user-level, passivation means that the first time a sensor is woken up or powered on with a new battery, it is possible that there is some ramp-up time required before it can complete the join procedure. Until the device detects that it can get enough current from the battery, it will constantly reset in attempt to break the passivation layer down. 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 battery is replaced with a new one, including new devices from the factory, where the battery may have been unused for more than a month.

5.3.2 UL Report Frame Formats

Battery reports are sent on ***LoRaWAN port 10*** and have the frame format as shown in Table 5-3. For the general description of sensor data report formats and behaviour, see Section 4.1.

Table 5-3: Battery Report UL Frame Formats

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Battery Voltage	0x00	0xBA	2 B	Volts	• 1 millivolt / LSb	*battery_voltage: <value> (unsigned/volts)*
Remaining Battery Capacity	0x00	0xD3	1 B	Percentage	• 1% / LSb (unsigned)	*rem_batt_capacity: <value> (unsigned/%)*

5.3.2.1 *Example UL Payloads*

- 0x **00 D3** 32 **00 BA** 01 E6
    - Channel ID = 0x 00, Type ID = 0x D3 → Remaining battery capacity data report
    - 0x 32 = 50 × 1% = 50%
    - Channel ID = 0x 00, Type ID = 0x BA → Battery Voltage
    - 0x 0B B8 = 3000 × 1 mV = 3.0 V

5.3.3 Configuration Settings

All configuration registers that control battery management behaviour are listed Table 5-4. In this table, the bit indexing scheme is as shown in Figure 4-2. To access these registers, a command must be formatted and sent according to the details described in section 4.2.

Table 5-4: Battery Management Configuration Registers

Address	Name	Access	Size	Description	JSON Variable	Default
0x20	Seconds per Core Tick	R/W	4 B	• Ticks value for periodic events • Acceptable values: 15,16, 17, …, 86400 • 0, Other values: Invalid	*seconds_per_core_tick: <value>* *(number/sec)*	3600 s = 1 hr **0x 00 00 0E 10**
0x21	Ticks per Battery	R/W	2 B	• Ticks between battery reports • Acceptable values: 1,2…65535 • 0, Other values: Invalid	*ticks_per_battery: <value>* *(number/no unit)*	1 tick = 1 hr **0x 00 01**
0x5C	Battery Report Options	R/W	1 B	• Bit 0: 0/1 = Battery Voltage [V] not reported/reported • Bit 1: 0/1 = Remaining battery capacity [%] not reported/reported • Bits 0-1 all set to 0: Invalid • Bits 2-7:0, otherwise Invalid	*battery_options: {* *battery_voltage_report: <value>* *(string/no unit)* *battery_lifetime_pct_report: <value>* *(string/no unit)* *}*	Only battery voltage report enabled **0x 01**

5.3.3.1 *Example DL Payloads*

- Schedule battery reports every 24 hours:
    - DL payload: 0x **A0** 00 00 0E 10 **A1** 00 18
        - Register 0x 20 with bit 7 set to 1 = 0x A0
        - 3600 s/core tick = 0x 00 00 0E 10
        - Register 0x 21 with bit 7 set to 1 = 0x A1

        - Report every 24 ticks = 0x 00 18

- Include remaining battery capacity and battery voltage in battery reports:
    - DL payload: 0x **DC** 03
        - Register 0x 5C with bit 7 set to 1 = 0x DC
        - Bits 0 and 1 set to 1 = 0x 03

5.4 General Command-and-Control Operations

The general command and control operations supported by the COMFORT/VIVID are:

- Saving the current configuration settings to flash memory.
- Restarting the sensor (soft reset).
- Reading firmware metadata (software version numbers).
- Factory reset of configuration settings.

To perform a command-and-control operation, the appropriate register must be accessed. Table 5-5 lists the details of the command-and-control registers. In this table, the bit indexing scheme is as shown in Figure 4-2. 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 5-5: Command & Control Register Details

Address	Name	Access	Size	Description and Options	JSON Variable (Type/Unit)
0x 70	Flash Write Command	WO	2 B	• Bit 14: 0/1 = Do not write/Write LoRaMAC Configuration • Bit 13: 0/1 = Do not write/Write App Configuration • Bit 0: 0/1 = Do not restart/Restart Sensor • Bits 1-12, 15: RFU, must be 0, otherwise invalid	*write_to_flash {* *app_config: <value>, (unsigned/no unit)* *lora_config: <value>, (unsigned/no unit)* *restart_sensor: <value> (unsigned/no unit)* *}*

Address	Name	Access	Size	Description and Options	JSON Variable (Type/Unit)
0x 71	FW Metadata	RO	7 B	• 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 number7	*data {* *app_major_version: <value>, (unsigned/no unit)* *app_minor_version: <value>, (unsigned/no unit)* *app_revision: <value>, (unsigned/no unit)* *loramac_major_version: <value>, (unsigned/no unit)* *loramac _minor_version: <value>, (unsigned/no unit)* *loramac_revision: <value>, (unsigned/no unit)* *region: <value> (unsigned/no unit)* *}*
0x 72	Reset Configuration to Factory Defaults	WO	1 B	• 0x 0A: Reset app configuration • 0x B0: Reset LoRaMAC configuration • 0x BA: Reset both App and LoRaMAC configurations • Any other value: Invalid	*config_factory_reset {* *app_config: <value>, (unsigned/no unit)* *loramac_config: <value> (unsigned/no unit)* *}*

5.4.1 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 4-2. 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 5-5. 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.

[7] Defined by Table 5-6.

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.

Register 0x 70 also supports a reset option, described in Section 5.4.2. When this option is not selected, the sensor will send a write response (as described in Section 4.3) after receiving the flash write command.

5.4.2 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 5.4.1 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].

5.4.3 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 fist 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 5-1, which is shown using the example FW v1.0.15 (value 0x 01 00 0F).

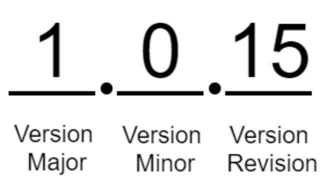


Figure 5-1: Example FW Version Format

- Bits 8 to 31 of the value contain the LoRaMAC version numbers. The format is the same as shown in Figure 5-1. 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 5-6.

Table 5-6: Available LoRaMAC Regions and Channel Plan IDs

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

5.4.4 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 4-3. 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 5-5. 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:** Do not send the factory reset command as a confirmed DL. 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].

6 Hall Effect Sensor

The hall effect sensor, indicated by a magnet symbol on the enclosure, is triggered by the presence of a nearby magnet, with a detection range of up to 15 mm. Both COMFORT and VIVID v2 sensors are equipped with this hall effect sensor.

6.1 Operation Description

The hall effect transducer is edge-triggered and can be configured to trigger on a rising-edge (Low/Closed to High/Open) and/or a falling-edge (High/Open to Closed/Low). Attempting to disable both rising and falling edges by setting the Mode to 0x00 is invalid and the command is rejected by the sensor.

In simple terms, a hall effect sensor detects the presence of a magnetic field. The terms "rising edge" and "falling edge" refer to how the sensor responds to changes in the magnetic field.

- Rising Edge Trigger: This happens when the sensor detects a change from a low magnetic field (or no magnetic field) to a high magnetic field. In other words, it's triggered when a magnet moves close to the sensor.
- Falling Edge Trigger: This happens when the sensor detects a change from a high magnetic field to a low magnetic field (or no magnetic field). In other words, it's triggered when a magnet moves away from the sensor.

So, a rising edge trigger signals that a magnet is approaching the sensor, while a falling edge trigger signals that a magnet is moving away from the sensor.

The Count Threshold determines when the sensor transmits data after detecting an event on the hall effect transducer. A value of 0 disables event-driven transmission, while a value of 1 or greater triggers a transmission after the specified number of events occurs. When the event counter reaches the Count Threshold, an event-based transmission is triggered, and the event counter resets to 0, starting the count anew until the next threshold is reached.

The Report Options setting determines the information transmitted during an event or periodic transmission. If set to “Counter Value,” the transmission includes the number of times the hall effect transducer was triggered since the last transmission. If set to “Input State” the transmission includes the current input state of the switch (i.e., Open or Closed).

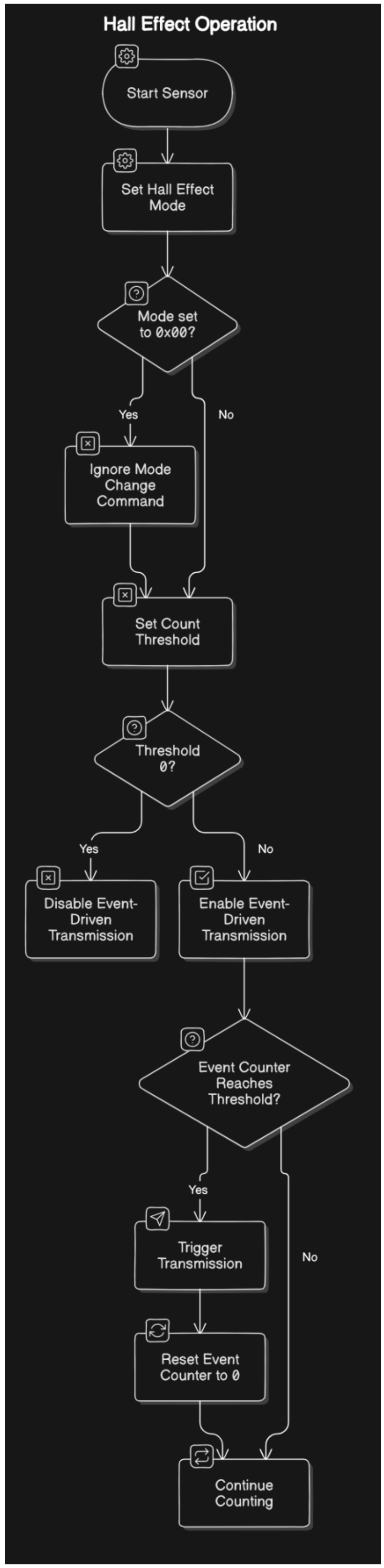


Figure 6-1: Hall Effect Sensor Operation

6.2 Application Examples

For open/close detection, the sensor can use both rising and falling triggers to detect when doors are opened and closed. This can be configured to either disable event-based transmission in favor of hourly reports or to transmit after logging a specific number of events, such as 50. This setup is particularly useful for monitoring room utilization and can notify cleaning staff when a room requires attention.

Other applications that can utilize this mechanism include refrigerator door monitoring, mailbox activity tracking, and industrial access panel monitoring.

6.3 UL Frame Payload Format

Hall Effect Sensor's State and Count are sent on *LoRaWAN port 10* and have the frame format as shown in Figure 4-1. The specific details for the safety report frame formats are listed in Table 6-1. For the general description of sensor data report formats and behaviour, see Section 4.1.

Table 6-1: Hall Effect UL Formats

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Hall Effect State	0x01	0x00	1 B	Digital	• 0x00 = Low—magnet present • 0xFF = High—magnet absent	*hall_effect_state: <value> (unsigned/no unit)*
Hall Effect Count	0x08	0x04	2 B	Counter	• Number	*hall_effect_count: <value> (unsigned/no unit)*

6.3.1 Example UL Payloads

- 0x **01 00** FF
  - Channel ID = 0x 01, Type ID = 0x 00 → Hall Effect State
  - 0x FF = High – magnet absent
- 0x **08 04** 05
  - Channel ID = 0x 08, Type ID = 0x 04 → Hall Effect Count
  - 0x 05 = 5 counts of hall effect activations

6.4 Configuration Settings

All user-configurable registers for the Hall Effect Sensor are listed in Table 6-2. In this table, the bit indexing scheme is as shown in Figure 4-2. To access these registers, a command must be formatted and sent according to the details described in Section 4.2.

Table 6-2: Hall Effect Configuration Registers

Address	Name	Access	Size	Description	JSON Variable	Default
0x20	Seconds per Core Tick	R/W	4 B	• Tick value for periodic events • Acceptable values: 15, 16, 17, …, 86400 • Other values: Invalid	*seconds_per_core_tick: <value> (number/sec)*	60 s = 1 min **0x 00 00 00 3C**
0x24	Tick per Hall Effect	R/W	2 B	• Ticks between periodic hall effect reports • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic reports • Other values: Invalid	*ticks_per_hall_state: <value> (number/no unit)*	0 ticks = Hall Effect is disabled by default **0x 00 00**
0x2A	Hall Effect Mode	R/W	1 B	• Bit 0: 0/1: Rising Edge disabled/enabled • Bit 1: 0/1: Falling edge disabled/enabled • Both bits 0 and 1 set to 0: Invalid • Bits 2 - 7: RFU, must be set to 0, otherwise Invalid	*hall_effect_mode: { rising_edge_enabled: <value> (unsigned/no unit) falling_edge_enabled: <value> (unsigned/no unit) }*	Rising and falling edges enabled **0x 03**
0x2B	Hall Effect Count Threshold	R/W	2 B	• Bit 0-13: Number of triggers required for event transmission • 0: disables event transmission	*hall_effect_count_threshold: <value> (number/no unit)*	Count Threshold = 1 **0x 00 01**
0x2C	Hall Effect Report Options	R/W	1 B	• Bit 0: 0/1: State report disabled/enabled • Bit 1: 0/1: Counter value disabled/enabled • Both bits 0 and 1 set to 0: Invalid • Bits 2 - 7: RFU, must be set to 0, otherwise Invalid	*hall_effect_report_options: { report_state_enabled: <value> (unsigned/no unit) report_count_enabled: <value> (unsigned/no unit) }*	State and count reported **0x 03**

6.4.1 Example DL Payloads

- Have hall effect transducer be triggered only on rising edges:
  - DL payload: 0x **AA** 01
    - Register 0x 2A with bit 7 set to 1 = 0x AA

        - Rising Edge enabled and Falling Edge disabled = 0x 01

- Read current value of Count Threshold:
    - DL payload: 0x **2B**
        - Register 0x 2B with write bit set to 0 = 0x 2B

- Transmit the hall effect “state” as soon when the hall effect sensor is activated 10 times:
    - DL payload: 0x **AB** 00 0A **AC** 01
        - Register 0x 2B with bit 7 set to 1 = 0x AB
        - Count threshold set to 10 = 0x 00 0A
        - Register 0x 2C with bit 7 set to 1 = 0x AC
        - Only state report enabled = 0x 01
- Disable the hall effect event-driven transmission, but report the number of times the hall effect transducer has been triggered whenever a report is inquired (i.e. in the case of periodic reporting):
    - DL payload: 0x **AB** 00 00 **AC** 02
        - Register 0x 2B with bit 7 set to 1 = 0x AB
        - Count threshold set to 0 = 0x 00 00
        - Register 0x 2C with bit 7 set to 1 = 0x AC
        - Only counter value report enabled = 0x 02

7 External Connectors (COMFORT v2 ONLY)

The COMFORT v2 Sensor features two external connectors, referred to as Connector A and Connector B henceforth, that allow users to connect either an analog or digital external sensing probes.

- Connector A:
  - Supports connection of digital input probe (with two possible states: "open" and "closed")
  - Supports connection of digital output probe for closing a flow valve
- Connector B:
  - Supports connection of digital input probe (with two possible states: "open" and "closed")
  - Supports connection of digital output probe for closing a flow valve
  - Supports connection of analog input probe for remote temperature measurement

Figure 7-1 below, illustrates the configurability options for both connectors.

NOTE: The connectors operate independently of each other.

Both connectors are USB-C type with custom pin connections and must be used with custom digital input, digital output, and analog input cables only. These custom probes are sold separately; please contact TEKTELIC for more information on purchasing supported probes.

Important Note 1: The connectors are not compliant with USB standards or specifications in any way. Do not connect the COMFORT sensor to a laptop or other electronic devices.

Important Note 2: The COMFORT v1 only supported Connector B via a 2-pin type connector, with digital output and analog input functionalities only—no digital output.

In digital input mode, the external connectors have two states depending on its electrical conductivity state:

- Open (open-circuited) if the probe is not electrically conductive, such as a dry leak cable or an open-ended magnetic probe
- Closed (short-circuited) if the probe is electrically conductive via an external source, such as water (as in a wet leak cable) or an external magnet (as in a remote magnetic probe).

In digital output mode, the COMFORT sensor is capable of controlling an externally powered electric flow valve with open-close functionality. When a water leak is detected, COMFORT v2, if enabled, activates an onboard normally-open solid-state relay. This relay then triggers the externally powered valve to shift from an open position (allowing flow) to a closed position (stopping flow).

In analog input mode, COMFORT v2 can be configured to measure temperature by voltage conversion through the use of a 10-kΩ thermistor.

The following subsections explain the use-cases and applications of these modes in greater detail.

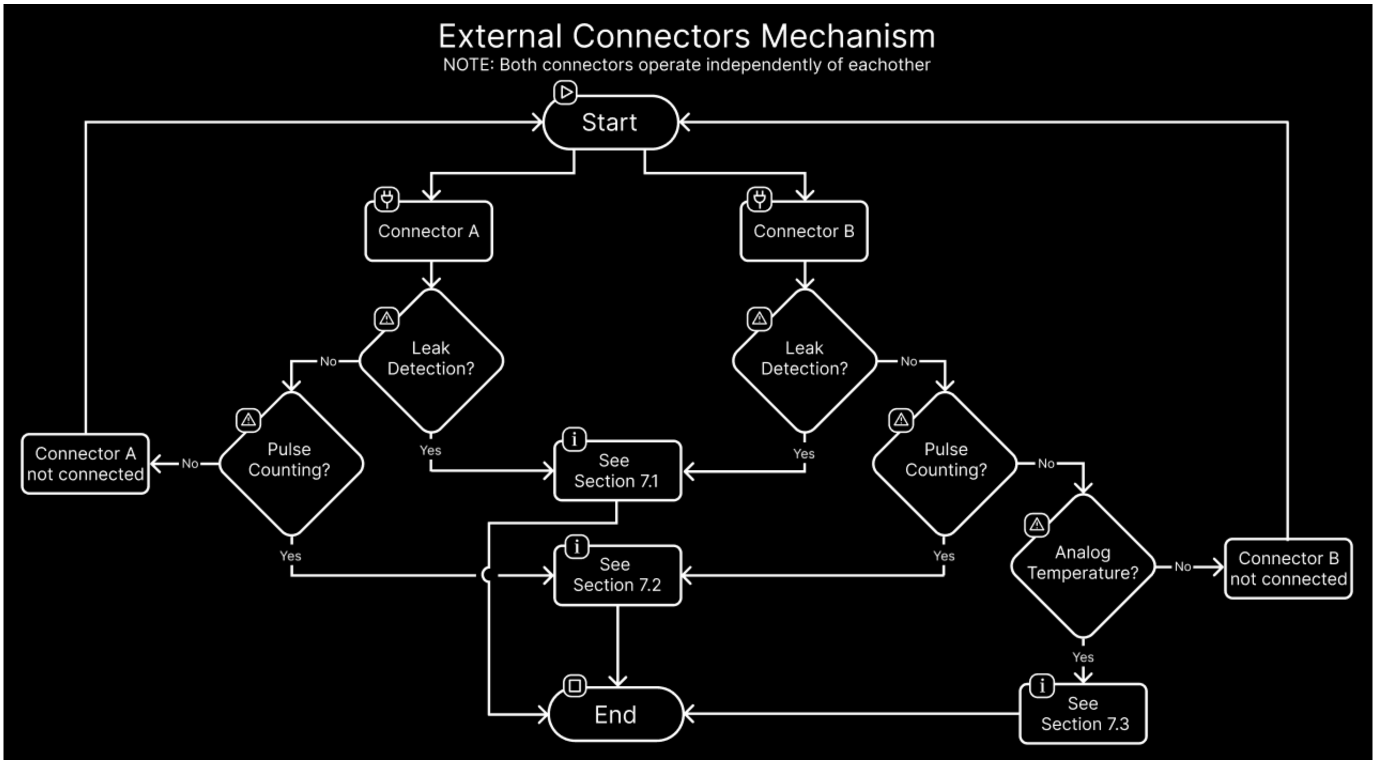


Figure 7-1: External Connectors Mechanism

7.1 Digital Input and Output Modes: Leak Detection Solution

The COMFORT v2 is specifically optimized for leak detection, featuring several enhancements compared to COMFORT v1. These include the following:

- Support for USB-C type connectors for more rugged applications
- Support for a second connector to allow dual independent leak monitoring
- Integration of enclosure screws for leak detection
- An upgraded IP rating to enhance resilience against water and dust ingress
- The implementation of a flow valve shut off feature upon leak detection.

NOTE: The use-case described in this section is supported on both CONNECTORS A and B.

7.1.1 Operation Description

In order to detect a leak through any of the supported connectors, a conductive fluid leak detection cable must be connected to at least one of the connectors on the COMFORT v2 device. If both connectors are of interest for leak detection, then each connector should be connected with separate cables.

NOTE: The connectors operate independently of each other in digital mode.

The leak detection cable features a custom USB-C connector (with SBU-1 and SBU-2 pins connected ONLY) that connects to the COMFORT sensor. The core of the cable consists of two conductive wires that either extend the entire length of the cable (as in a fabric cable) or are positioned at the tip of the cable (as in leak prongs). These wires are electrically isolated by insulating materials to ensure there is no continuity between them.

When conductive liquid comes into contact with any part of the fabric leak cable length or both prongs of the leak prongs, the sensing wires become electrically connected through the liquid. The COMFORT v2 detects this electrical conductivity via the connectors and registers it as a leak. The corresponding connector then sends an uplink to the network server, indicating the change in the leak state of its connected cable. It is possible for both connectors to have different states as they operate independently of each other.

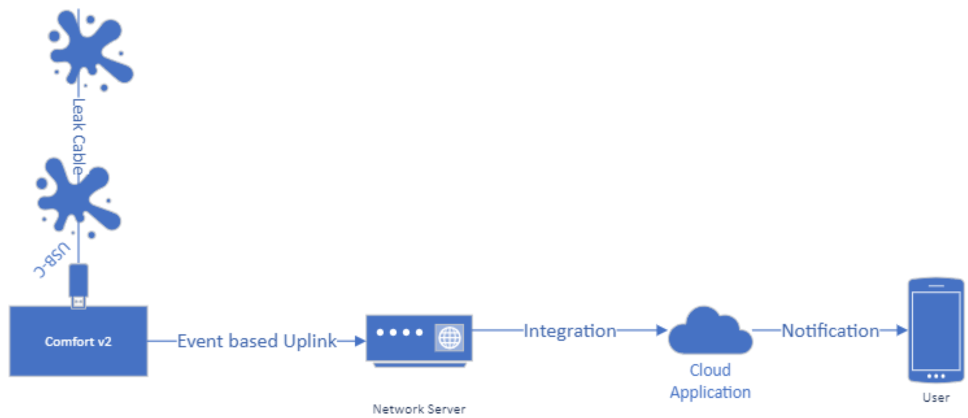


Figure 7-2: Leak detection end-to-end solution

Additionally, leak detection functionality extends to the enclosure, with the screws acting as sensing elements. Similar to the rope sensing mechanism, this approach uses electrical conductivity, leveraging the enclosure screws as sensors. All four enclosure screws serve this purpose, with two designated as "signal screws" and the remaining two as "ground" screws.

If there is a connection between any "signal" screw and any "ground" screw, as seen in Figure 7-3, COMFORT v2 identifies it as a leak. This feature shares the same activation mechanism as Connector A, so when the enclosure screws are shorted, the Connector A state is reported as an active leak.

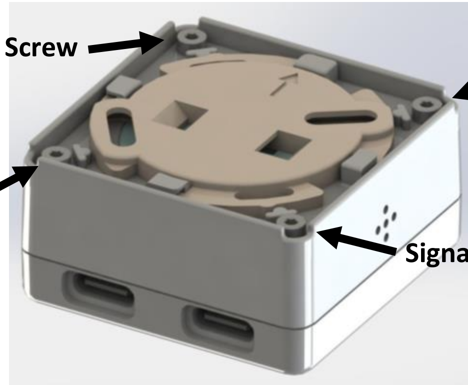


Figure 7-3: COMFORT v2 Enclosure Screws

In COMFORT v2, a new digital output mode is introduced to control a single open-close externally powered electric flow valve. The concept is straightforward: upon detecting a water leak, COMFORT v2 can, if enabled, activate a normally-open solid-state relay on the PCB. This relay, in turn, triggers the externally powered valve to transition from an open (allowing flow) to a closed (stopping flow) state via a custom-made USB-C type digital output cable with only the VBUS and GND pins connected.

To conserve the limited power supplied by the coin cell battery on COMFORT, only "latching" type valves are supported. These valves require only a brief energization period, typically around 10 seconds, to effectuate the transition from open to close. COMFORT v2 only activates the switch in one direction: from open to close. Reverting the valve to its flow-enabled state necessitates user intervention.

The onboard relay, specifically a TLP3122A type, requires approximately 3mA of activation current, which is drawn from the coin cell battery. Flexible user configurability is supported to allow variability in the duration of relay energization. The relay can also be energized on demand by sending a downlink command to the COMFORT v2.

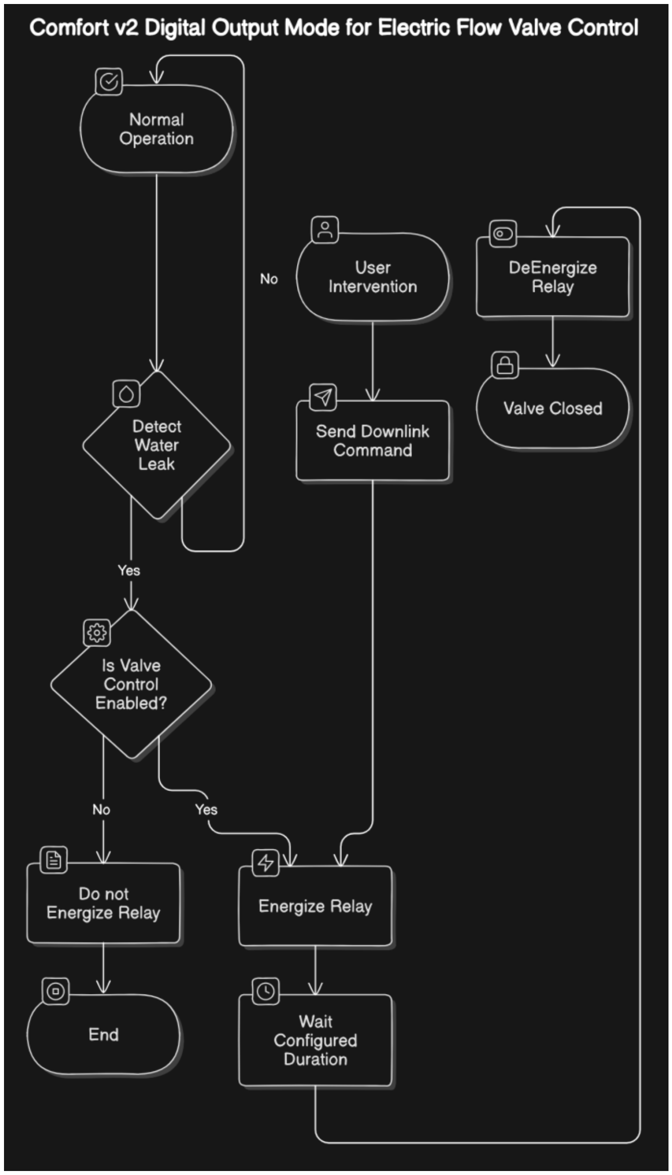


Figure 7-4: COMFORT v2 Digital Output Mode for Flow Valve Control

The relay switches the "VBUS" and "GND" pins on both the "A" and "B" connectors. Consequently, when the relay is closed, VBUS is shorted to GND on both connectors. This configuration renders it unsuitable to connect COMFORT to a conventional USB charger or any other electrical device. Electrically, the valve that can be controlled is rated for a maximum of 24VAC or VDC and a maximum current of 300mA.

Important Note 1: The COMFORT v2 supports only one solid-state relay (SSR), so only one connector can act as a valve controller at any given time. Therefore, enabling or disabling the SSR will affect both connectors simultaneously. The digital output feature is disabled by default.

Important Note 2: Since the digital output uses different pins on the USB compared to the digital input, there is no interference in operation between the input and output modes. When a leak is detected or a downlink is sent to energize the SSR, the SSR energizes both connectors. However, only the connector with the custom-made digital output cable with the corresponding pins connected will respond to the energization.

In summary, the leak detection solution can be used to efficiently perform the following operations independently

- Detect leak either via leak detection rope connected to Connection A or via enclosure corner screws
- Independently detect leak via leak detection rope connected to Connection B
- Activate the solid-state relay to initiate closure of flow valve for a configurable period of time in response to an active leak detection event or via a downlink command

7.1.2 UL Report Frame Format

All Digital input and Output Reports are sent on *LoRaWAN port 10* and have the frame format as shown in Figure 4-1. The specific details for the safety report frame formats are listed in Table 7-1. For the general description of sensor data report formats and behaviour, see Section 4.1.

Table 7-1: Digital Input and Output Uplink Formats

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
External Connector A: Digital Input State	0x1E	0x00	1 B	Digital	• 0x00 = Low—Connector short-circuited • 0xFF = High—Connector open-circuited	*extconnector_a_state: <value> (unsigned/no unit)*
External Connector B: Digital Input State	0x0E	0x00	1 B	Digital	• 0x00 = Low—Connector short-circuited • 0xFF = High—Connector open-circuited	*extconnector_b_state: <value> (unsigned/no unit)*
External Connector A: Relative Digital Input Count	0x1F	0x04	2 B	Counter	• Bits 0 – 13: Relative Digital Count for Connector A since last transmission	*extconnector_a_relative_count: <value> (unsigned/no unit)*

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
External Connector B: Relative Digital Input Count	0x0F	0x04	2 B	Counter	• Bits 0 – 13: Relative Digital Count for Connector B since last transmission	*extconnector_b_relative_count: <value>* *(unsigned/no unit)*
External Connector A: Total Digital Input Count	0x22	0x04	4 B	Counter	• Bits 0 – 13: Cumulative Total Digital Count for Connector A	*extconnector_a_total_count: <value>* *(unsigned/no unit)*
External Connector B: Total Digital Input Count	0x12	0x04	4 B	Counter	• Bits 0 – 13: Cumulative Total Digital Count for Connector B	*extconnector_b_total_count: <value>* *(unsigned/no unit)*
External Connectors A and B: Digital Output State	0x0D	0x 00	1 B	Digital	• 0x00 = Low—SSR non-conducting • 0xFF = High—SSR conducting	*extconnectors_output_state: <value>* *(unsigned/no unit)*

The "Digital Connection state" uplink register indicates the electrical conductivity status of the rope or cable connected to corresponding connector. In the context of leak detection, a low state indicates a detected leak, whereas a high state signifies no leak. For other digital input contexts, such as water meter pulse counting or door open/close detection, the state may have different meanings (e.g., "open" as the event and "closed" as the resting/normal state).

Relative Count denotes the number of times the Digital Connection has been triggered since the last transmission.

Total Count represents the cumulative total of Digital Connection triggers since the last reset.

The digital output (SSR) state indicates the conducting state of the solid-state relay (SSR). A low state means the SSR is non-conducting, so the flow valve is open. A high state means the SSR is conducting, so the flow valve is closed.

7.1.2.1 Example UL Payloads

- 0x **1E 00** FF **0E 00** 00 **1F 04** 00 0A **0F 04** 00 0A **22 04** 00 00 00 64 **12 04** 00 00 00 64
  - Channel ID = 0x 1E, Type ID = 0x 00 → External Connector A: Digital State
  - 0x FF = Connector A short-circuited
  - Channel ID = 0x 0E, Type ID = 0x 00 → External Connector B: Digital State
  - 0x 00 = Connector B short-circuited
  - Channel ID = 0x 1F, Type ID = 0x 04 → External Connector A: Relative Count

- 0x 00 0A = 10 counts since last transmission
- Channel ID = 0x 0F, Type ID = 0x 04 → External Connector B: Relative count
- 0x 00 0A = 10 counts since last transmission
- Channel ID = 0x 22, Type ID = 0x 04 → External Connector A: Total count since last reset
- 0x 00 00 00 64 = 100 counts since last reset
- Channel ID = 0x 12, Type ID = 0x 04 → External Connector B: Total count since last reset
- 0x 00 00 00 64 = 100 counts since last reset

- 0x **0D 00** 00
  - Channel ID = 0x 0D, Type ID = 0x 00 → Digital Output State
  - 0x 00 = SSR non-conducting

7.1.3 Configuration Settings

All user-configurable registers for Digital Input and output modes are listed Table 7-2. In this table, the bit indexing scheme is as shown in Figure 4-2. To access these registers, a command must be formatted and sent according to the details described in Section 4.2.

Table 7-2: Digital Input and Digital Output Configuration Settings

Address	Name	Access	Size	Description	JSON Variable	Default
0x20	Seconds per Core Tick	R/W	4 B	• Tick value for periodic events • Acceptable values: 15, 16, 17, …, 86400 • Other values: Invalid	*seconds_per_core_tick: <value> (number/sec)*	3600s = 1 hr **0x 00 00 0E 10**
0x55	Ticks per External Connector A (Digital only)	R/W	2 B	• Ticks between External Connector A report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic Externally Connector A reports • Other values: Invalid	*ticks_per_external_connector_a: <value> (number/no unit)*	0 tick = Disabled by default **0x 00 00**
0x29	Ticks per External Connector B (Digital/Analog)	R/W	2 B	• Ticks between External Connector B report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic Externally Connector B reports • Other values: Invalid	*ticks_per_external_connector_b: <value> (number/no unit)*	0 tick = Disabled by default **0x 00 00**

Address	Name	Access	Size	Description	JSON Variable	Default
0x4D	External Connector A Mode	R/W	1 B	• Bit 0: 0/1: Rising Edge disabled/enabled • Bit 1: 0/1: Falling edge disabled/enabled • Both bits 0 and 1 set to 0: Invalid • Bit 2: 0/1: Disable/Enable Control of Digital Output • Bits 3 - 7: RFU, must be set to 0, otherwise Invalid	*external_connector_a_mode: {* *rising_edge_enabled: <value>, (unsigned/no unit)* *falling_edge_enabled: <value> (unsigned/no unit)* *digital_output_connector_a_enabled: <value> (unsigned/no unit)* *}*	Rising and falling edges enabled Disable control of digital output **0x 03**
0x2D	External Connector B Mode	R/W	1 B	• Bit 0: 0/1: Rising Edge disabled/enabled • Bit 1: 0/1: Falling edge disabled/enabled • Both bits 0 and 1 set to 0: Invalid • Bit 2: 0/1: Disable/Enable Control of Digital Output • Bit 7: 0/1: Digital/Analog mode • Both bits 2 and 7 set to 1: Invalid • Bits 3 - 6: RFU, must be set to 0, otherwise Invalid	*external_connector_b_mode: {* *rising_edge_enabled: <value>, (unsigned/no unit)* *falling_edge_enabled: <value> (unsigned/no unit)* *digital_output_connector_b_enabled: <value> (unsigned/no unit)* *connection_mode: <value> (unsigned/no unit)* *}*	Rising and falling edges enabled Disable control of digital output Digital Connection **0x 03**
0x56	Connector A Count Threshold	R/W	2 B	• Bits 0-15: Number of triggers for event-based transmission (1/LSB) • 0: disables event transmission	*external_connector_a_count_threshold: <value> (unsigned/no unit)*	Connection A count Threshold: 1 **0x 00 01**
0x2E	Connector B Count Threshold	R/W	2 B	• Bits 0-15: Number of triggers for event-based transmission (1/LSB) • 0: disables event transmission	*external_connector_b_count_threshold: <value> (unsigned/no unit)*	Connection B count Threshold: 1 **0x 00 01**

Address	Name	Access	Size	Description	JSON Variable	Default
0x4F	Connector A Report options	R/W	1 B	• Bit 0: 0/1: Digital state report disabled/enabled • Bit 1: 0/1: Digital Input Count report disabled/enabled • Both bits 0 and 1 set to 0: Invalid • Bit 4: 0: Report Relative Digital Input Count 1: Report Total Digital Input Count • Bits 2 - 3, 5 - 7: RFU, must be set to 0, otherwise Invalid	*external_connector_a_tx: {* *report_state_enabled: <value> (unsigned/no unit)* *report_count_enabled: <value> (unsigned/no unit)* *count_type: <value> (unsigned/no unit)* *}*	Digital State and count reported Relative Count Reported **0x 03**
0x2F	Connector B Report options	R/W	1 B	• Bit 0: 0/1: Digital state report disabled/enabled • Bit 1: 0/1: Digital Input Count report disabled/enabled • Both bits 0 and 1 set to 0: Invalid • Bit 4: 0: Report Relative Digital Input Count 1: Report Total Digital Input Count • Bits 2 - 3, 5 - 7: RFU, must be set to 0, otherwise Invalid	*external_connector_b_tx {* *report_state_enabled: <value> (unsigned/no unit)* *report_count_enabled: <value> (unsigned/no unit)* *count_type: <value> (unsigned/no unit)* *}*	Digital State and count reported Relative Count Reported **0x 03**
0x5B	Connector A: Reset Total Count	WO	4 B	• Value to set the Counter value to • Acceptable values: 0, 1, 2, …, 4,294,967,295 • Other values: Invalid	*external_connector_a_reset_count: <value> (unsigned/no unit)*	N/A
0x5A	Connector B: Reset Total Count	WO	4 B	• Value to set the Counter value to • Acceptable values: 0, 1, 2, …, 4,294,967,295 • Other values: Invalid	*external_connector_b_reset_count: <value> (unsigned/no unit)*	N/A

Address	Name	Access	Size	Description	JSON Variable	Default
0x57	Digital Output (SSR) Mode	R/W	1 B	• Bit 0: 0/1: Disable/Enable Digital Output mode • Bits 1 - 7: RFU must be 0, otherwise Invalid	*digital_output_mode: <value> (unsigned/no unit)*	Digital output disabled **0x 00**
0x58	Energization (SSR) State	R/W	1 B	• Bit 0: 0/1: Disable/Enable Energization of SSR • Bits 1 - 7: RFU must be 0, otherwise Invalid	*ssr_state: <value> (unsigned/no unit)*	Energization of SSR disabled **0x 00**
0x59	Digital Output (SSR) Energization Duration	R/W	1 B	• Number of seconds to energize SSR for • Acceptable values: 1 – 254: number of seconds 255: infinity 0: Invalid	*ssr_energization_duration: <value> (unsigned/no unit)*	SSR energization: 10s **0x 0A**

The "Ticks per External Connector 'A' and 'B'" registers set the reporting frequency for the states of connectors A and B in ticks. After the specified number of ticks, the sensor checks the states (open/close) of the connectors and sends the data in an uplink (UL) message. Setting these registers to 0 disables periodic reporting for the designated connectors.

Both external connectors A and B operate on an edge-triggered basis. They can be configured to trigger on the rising edge (transition from Low/Closed to High/Open) and/or the falling edge (transition from High/Open to Low/Closed). Any attempt to set the Mode of any of the connectors to 0x00 (disabling both rising and falling edges) is invalid and will be rejected by the sensor. Connector A does not support analog connections.

The Count Threshold configuration parameter is relevant only in Digital Connection mode. It determines when the sensor will transmit data after detecting an event on the corresponding digital connections. Setting it to 0 disables event-driven transmission for that digital connection. A value of 1 or higher triggers transmission based on the configured number of events, which is useful for applications like door usage monitoring and pulse counting described in Section 7.2.

The Report Options register specifies the information (state, count, or both) transmitted during a digital connection event or periodic transmission. The state can be either low or high, and the count can be either relative or total. The relative count represents the number of times the digital connection has been triggered since the last transmission, while the total count represents the cumulative total of digital connection triggers.

The total digital connection count for any digital connection can be set to a specific value by writing to the Reset Total Count register, useful for integrating a COMFORT v2 sensor into an existing counter system.

Register 0x57 controls enabling or disabling the digital output (SSR) on the connectors. The SSR is linked to both connectors A and B; thus, enabling this register activates the SSR on both connectors, and disabling it deactivates the SSR on both connectors. The digital output is disabled by default.

The digital output (SSR) state can be toggled remotely between conducting and non-conducting via over-the-air commands. When set to the conducting state, the SSR remains conducting for the duration specified in register 0x59. This register only functions if the SSR mode is enabled using register 0x57. If the SSR mode is disabled, any command to change the SSR state will be of no effect.

The digital output energization duration determines how long the SSR remains energized. The acceptable range for this duration is between 1 second and 254 seconds. Setting the register to 255 indicates infinite energization time. The register does not accept a duration of 0, as a minimum time interval is required for proper operation.

7.1.3.1 Example DL Payloads

- Set core tick to 60s, ticks per external Connector A to 10, and ticks per external Connector B to 15:
  - DL payload: 0x **A0** 00 00 00 3C **D5** 00 0A **A9** 00 0F
    - Register 0x 20 with bit 7 set to 1 = 0x A0
    - Core tick set to 60 s = 0x 00 00 00 3C
    - Register 0x 55 with bit 7 set to 1 = 0x D5
    - Ticks per External Connector A set to 10 = 0x 00 0A
    - Register 0x 29 with bit 7 set to 1 = 0x A9
    - Ticks per External Connector B set to 15 = 0x 00 0F

- Have Digital Input be triggered only on falling edges for both connectors:
  - DL payload: 0x **AD** 02 **CD** 02
    - Register 0x 2D with bit 7 set to 1 = 0x AD
    - Rising edge disabled, falling edge enabled = 0x 02
    - Register 0x 4D with bit 7 set to 1 = 0x CD
    - Rising edge disabled, falling edge enabled = 0x 02

- Transmit the Digital Input state when the relative digital Input is tripped 20 times on both connectors:
  - DL payload: 0x **AE** 00 14 **D6** 00 14 **AF** 01 **CF** 01
    - Register 0x 2E with bit 7 set to 1 = 0x AE
    - Count threshold for Connector B set to 20 = 0x 00 14
    - Register 0x 56 with bit 7 set to 1 = 0x D6
    - Count threshold for Connector A set to 20 = 0x 00 14
    - Register 0x 2F with bit 7 set to 1 = 0x AF
    - Only digital state report enabled = 0x 01
    - Register 0x 4F with bit 7 set to 1 = 0x CF
    - Only digital state report enabled = 0x 01

- Reset the total number of Digital Input events to 0 for Connector A and 10 for Connector B
  - DL payload: 0x **DB** 00 00 00 00 **DA** 00 00 00 0A
    - Register 0x 5B with bit 7 set to 1 = 0x DB
    - Reset the total number of events to 0 for Connector A = 0x 00 00 00 00

        - Register 0x 5A with bit 7 set to 1 = 0x DA
        - Set the total number of events to 10 for Connector B = 0x 00 00 00 0A

- Enable digital output and set energization duration to 100s, then send downlink to energize SSR
    - DL payload: 0x **D7** 01 **D9** 64 **D8** 01
        - Register 0x 57 with bit 7 set to 1 = 0x D7
        - Enable SSR = 0x 01
        - Register 0x 59 with bit 7 set to 1 = 0x D9
        - Set energization duration to 100 seconds = 0x 64
        - Register 0x 58 with bit 7 set to 1 = 0x D8
        - Energize the SSR = 0x 01

7.2 Digital Input Mode: Digital Switch/Pulse Detection

The COMFORT v2 sensor can also be utilized in various other digital pulse detection applications, such as remote magnetic field detection and pulse counting from a water meter.

> **NOTE:** The use-case described in this section is supported on both CONNECTORS A and B.

7.2.1 Operation description

The operational principle for these use cases is similar to that of leak detection, where the sensor monitors continuity on the connected custom cable for state changes. In these scenarios, an external mechanism, like a magnetic field or a pulse from a water meter, creates an electrical continuity in the otherwise electrically discontinuous cable. This continuity is detected by the sensor, which registers the event as a "count." Users can configure the sensor with a threshold value, which triggers an event-based transmission when exceeded.

For example, in remote magnetic field detection, the sensor can be used to monitor the open or closed state of doors or windows equipped with magnetic contacts. Each time the magnetic contact is broken (door/window opened) and/or restored (door/window closed), the sensor detects this state change and increments the count, depending on the configured edge control.

Similarly, in pulse counting for a water meter, each pulse generated by the meter, indicating water usage, is detected by the sensor. As the pulses accumulate, the sensor keeps a count of the total water usage. This application uses a single edge trigger, which is determined by the resting state of the connected device. A positive pulse would use a rising edge trigger, while a negative pulse would use a falling edge trigger.

When the configurable threshold is reached, the sensor performs an event-based transmission. This transmission can initiate various application-level actions, such as generating maintenance requests or logging the event in a cloud-based system for further analysis and record-keeping.

7.2.2 UL Report Frame Format

See Section 7.1.2

7.2.2.1 Example UL Payloads

See Section 7.1.2.1

7.2.3 Configuration Settings

See Section 7.1.3

7.2.3.1 Example DL Payloads

See Section 7.1.3.1

Important Note on the Usage of Digital Input and Digital Output on COMFORT v2:

As previously discussed, either connector on the COMFORT device can be configured as an input channel (with a leak, magnetic, or pulse cable connected) or as an output (with a valve control cable connected). However, caution must be exercised to prevent false triggers of the digital output due to events from the input connector.

Here is an example to illustrate this point:

If Connector A is configured to detect door open/close events with a digital input cable connected, and Connector B is configured with a valve control cable to serve as a digital output, the open/close events on Connector A could inadvertently trigger the valve on Connector B. For instance, if the threshold for the door open/close events is set to 10, the solid-state relay (SSR) will be energized after the 10th door open/close event, causing the valve connected to Connector B to close.

While this scenario may be unlikely in practical terms, careful consideration is necessary when configuring input and output modes. An input event could unintentionally trigger an output action, leading to unintended behavior.

7.3 Analog Input Mode: Remote Temperature Sensing

When the Connector B is set to analog mode, an external thermistor may be used to perform remote temperature sensing in conditions where the sensor itself may be unsuitable due to temperature restrictions or inaccessible locations e.g. under electrical machines.

NOTE: The mode described in this section is supported on Connector B ONLY.

7.3.1 Operation Description

TEKTELIC recommends using a 10-kΩ thermistor for remote temperature sensing in the Analog mode. A 10-kΩ thermistor is a type of resistor whose resistance changes significantly with temperature. Specifically, it is a Negative Temperature Coefficient (NTC) thermistor, meaning its resistance decreases as the temperature increases.

At a given reference temperature of 25°C, the thermistor has a specified resistance, which in this case is 10 kΩ. As the temperature rises above the reference temperature, the resistance of the thermistor decreases. Conversely, as the temperature falls below the reference temperature, the resistance of the thermistor increases. The thermistor is part of a voltage divider circuit. This circuit converts the resistance change into a measurable voltage change. A constant voltage is applied across a series combination of the thermistor and another resistor. The voltage across the thermistor is then measured. This measured voltage varies with temperature because the resistance of the thermistor changes with temperature.

To obtain the actual temperature, the voltage or resistance value measured needs to be converted using a calibration curve or a mathematical formula specific to the thermistor. The relationship between resistance and temperature is often non-linear and is typically described using a Steinhart-Hart equation or a look-up table.

In addition to periodic temperature data reporting, the COMFORT v2 supports sending additional data reports based on crossing configurable voltage thresholds.

When a voltage threshold is enabled, the sensor reports the voltage data when it leaves the configured *threshold window*, and once again when it re-enters the threshold window. The threshold window is an open interval, meaning that even if the voltage data is equal to the *low threshold* or *high threshold*, the sensor is considered to have left the threshold window.

When the voltage report is inside the threshold window, the COMFORT v2 is in the *idle* sampling state. When outside, the COMFORT v2 is in the *active* sampling state. This is illustrated using the default configurations in Figure 7-5 below.

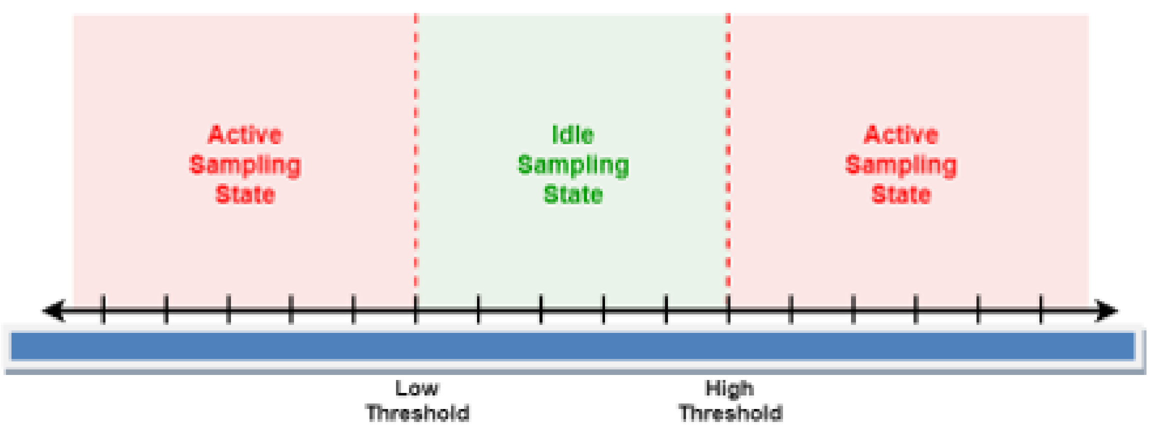


Figure 7-5: Voltage Threshold Window

The sampling periods are configurable and determine how often the thermistor is checked when the reported value is inside/outside the threshold window. When first enabled, the thermistor starts in the idle sampling state.

By default, threshold-based reporting is disabled.

Threshold-based reporting is compatible with periodic reporting of the temperature data; both can be disabled and enabled independently.

7.3.2 UL Report Frame Format

Analog Input Reports are sent on *LoRaWAN port 10* and have the frame format as shown in Figure 4-1. The specific details for the safety report frame formats are listed in Table 6-1. For the general description of sensor data report formats and behaviour, see Section 4.1.

Table 7-3: Analog Input on External Connector B UL Report Formats

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
External Connector B: Analog Input[8]	0x11	0x02	2 B	Voltage	• Bits 0-13: 1mv/LSB	*extconnector_b_analog: <value> (signed/V)*

7.3.2.1 Example UL Payloads

- Report 1000mV as Analog Input Measurement
  - 0x **11 02** 03 E8
    - Channel ID = 0x 11, Type ID = 0x 02 → External Connector B: Analog Input
    - 0x 03 E8 = 1000 x 1mV = 1000mV

7.3.3 Configuration Settings

All user-configurable registers for Analog Input mode are listed in Table 7-4. In this table, the bit indexing scheme is as shown in Figure 4-2. To access these registers, a command must be formatted and sent according to the details described in Section 4.2.

Table 7-4: Analog Mode Configuration Settings

Address	Name	Access	Size	Description	JSON Variable	Default
0x20	Seconds per Core Tick	R/W	4 B	• Tick value for periodic events • Acceptable values: 15, 16, 17, …, 86400 • Other values: Invalid	*seconds_per_core_tick: <value> (number/sec)*	3600s = 1 hr **0x 00 00 0E 10**

[8] Voltage value, to be converted to temperature for a remote temperature probe using a conversion table or formula.

Address	Name	Access	Size	Description	JSON Variable	Default
0x29	Ticks per External Connector B (Digital/Analog)	R/W	2 B	• Ticks between External Connector B report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic Externally Connector B reports • Other values: Invalid	*ticks_per_external_connector_b: <value> (number/no unit)*	0 tick = Disabled by default **0x 00 00**
0x2D	External Connector B Mode	R/W	1 B	• Bit 0: 0/1: Rising Edge disabled/enabled • Bit 1: 0/1: Falling edge disabled/enabled • Both bits 0 and 1 set to 0: Invalid • Bit 7: 0/1: Digital/Analog mode • Bits 2 - 7: RFU, must be set to 0, otherwise Invalid	*external_connector_b_mode: {* *rising_edge_enabled: <value> (unsigned/no unit)* *falling_edge_enabled: <value> (unsigned/no unit)* *connection_mode: <value> (unsigned/no unit)* *}*	Rising and falling edges enabled Digital Connection **0x 03**
0x44	Analog Input Sample Period in Idle State	R/W	4 B	• Bits 0 – 31: Sample period of Analog Input in sec in Idle state (1s/LSB) • Acceptable values: 30, 31, …, 86400 • Other values: Invalid	*analog_input_sample_period_idle: <value> (number/sec)*	Idle state sample period: 60s **0x 00 00 00 3C**
0x45	Analog Input Sample Period in Active State	R/W	4 B	• Bits 0-31: Sample period of Analog Input in sec in Active state (1s/LSB) • Acceptable values: 30, 31, …, 86400 • Other values: Invalid	*analog_input_sample_period_active: <value> (number/sec)*	Active state sample period: 30s **0x 00 00 00 1E**
0x46	Analog Input High/Low Thresholds	R/W	4 B	• Bits 16-31: High threshold (unsigned, 1mV/LSb) • Bits 0-15: Low threshold (unsigned, 1mV/LSb) • High threshold ≤ Low threshold: Invalid	*analog_input_thresholds {* *high_threshold: <value> (number/mV)* *low_threshold: <value> (number/mV)* *}*	High Threshold: 1200 mV Low Threshold: 600 mV **0x 04 B0 02 58**

Address	Name	Access	Size	Description	JSON Variable	Default
0x4A	Analog Input Thresholds Status	R/W	1 B	• Bit 0: 0/1 = Analog Input thresholds disabled/enabled • Bits 1-7: RFU, must be 0, otherwise invalid	*analog_input_thresholds_status: <value> (string/no unit)*	Threshold disabled **0x 00**

7.3.3.1 Example DL Payloads

- Set core tick to 60s, and ticks per external Connector B to 15:
    - DL payload: 0x **A0** 00 00 00 3C **A9** 00 0F
        - Register 0x 20 with bit 7 set to 1 = 0x A0
        - Core tick set to 60 s = 0x 00 00 00 3C
        - Register 0x 29 with bit 7 set to 1 = 0x A9
        - Tick per External Connector B set to 15 = 0x 00 0F
- Enable Analog mode on external Connector B and rising edge activation only
    - DL payload: 0x **AD** 81
        - Register 0x 2D with bit 7 set to 1 = 0x AD
        - Analog mode and Rising Edge only = Bits 0 and 7 only set to 1 = 0x 81

- Set idle sampling period to 120s and active sampling period to 30s:
    - DL payload: 0x **C4** 00 00 00 78 **C5** 00 00 00 1E
        - Register 0x 44 with bit 7 set to 1 = 0x C4
        - Idle sampling period set to 120 s = 0x 00 00 00 78
        - Register 0x 45 with bit 7 set to 1 = 0x C5
        - Active sampling period set to 30s = 0x 00 00 00 1E

- Enable threshold-based analog reporting with a window between 100 mV and 500 mV:
    - DL payload: 0x **C6** 01 F4 00 64 **CA** 01
        - Register 0x 46 with bit 7 set to 1 = 0x C6
        - High threshold set to 500 mV = 0x 01 F4
        - Low threshold set to 100 mV = 0x 00 64
        - Register 0x 4A with bit 7 set to 1 = 0x CA
        - Threshold enabled = Bit 0 set to 1 = 0x 01

8 PIR (VIVID v2 ONLY)

The Vivid v2 Sensor features advanced capabilities, including presence detection and Field-of-View (FoV) temperature sensing, powered by a digital Passive Infrared (PIR) transducer. This functionality is facilitated by the built-in PIR transducer, which operates through a lens visible on the top surface of the VIVID sensor's enclosure.

8.1 PIR Initialization

The PIR sensor is designed to operate with high performance and reliability. However, for it to function correctly, it is crucial that its Field of View (FoV) is entirely clear of any foreign heat source when the device boots up. If there are foreign heat sources within the FoV during the boot process, the sensor's accuracy and dependability for presence detection may be compromised.

8.1.1 Operation Description

When the PIR sensor is initialized for the first time or after any power reset, it requires a calibration process for its FoV baseline parameters. If this calibration occurs with a heat source, such as a human body, within the PIR coverage area, the baseline will be skewed, negatively impacting the accuracy of presence detection.

The following lists the terms and terminologies used in the PIR initialization operation. All listed items are user-configurable.

- PIR Initialization Retries: Allows for control over the number of automatic retries the system will attempt during PIR initialization. This register is particularly useful in scenarios where PIR initialization might fail due to transient conditions, allowing the system to retry automatically without manual intervention.
- PIR Initialization Mode: Controls the mode of PIR initialization. This register directly influences the state of the PIR initialization process.

8.1.2 UL Frame Payload Format

PIR initialization reports are sent on *LoRaWAN port 10* and have the frame format as shown in Figure 4-1. The specific details for the safety report frame formats are listed in Table 8-1**.** For the general description of sensor data report formats and behaviour, see Section 4.1.

Table 8-1: PIR Initialization UL Formats

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
PIR initialization Status	0x2A	0x00	1 B	Digital	• 0x00 = PIR initialization successful • 0xFF = PIR initialization unsuccessful	*pir_init_state: <value> (unsigned/no unit)*

8.1.2.1 Example UL Payloads

- 0x **2A 00** 00
  - Channel ID = 0x 2A, Type ID = 0x 00 → PIR Initialization State
  - 0x 00 = PIR initialization successful
- 0x **2A 00** FF
  - Channel ID = 0x 2A, Type ID = 0x 00 → PIR Initialization State
  - 0x FF = PIR initialization unsuccessful

8.1.3 Configuration Settings

All user-configurable registers for the PIR initialization are listed in Table 8-2. In this table, the bit indexing scheme is as shown in Figure 4-2. To access these registers, a command must be formatted and sent according to the details described in Section 4.2.

Table 8-2: PIR Initialization Configuration Settings

Address	Name	Access	Size	Description	JSON Variable	Default
0x6A	PIR initialization Retries	R/W	1 B	• Bit 0 - 7: Number of automatic PIR init retries 0: Disable automatic PIR init retries	*pir_init_retries: <value> (number/no unit)*	PIR init retry 5 times **0x 05**
0x6B	PIR initialization mode	WO	1 B	• Bits 0 - 7: 00: Deactivate PIR Initialization FF: Activate PIR initialization	N/A	N/A

8.1.3.1 Example DL Payloads

- Set the number of PIR initialization retries to 1:
  - DL payload: 0x **EA** 01
    - Register 0x6A with bit 7 set to 1 = 0x EA
    - PIR initialization retries set to 1 = 0x 01

8.2 Presence Detection

The PIR transducer detects infrared (IR) radiation emitted by warm objects, such as human bodies, within its field of view. Presence detection recognizes sustained IR levels, indicating occupancy.

8.2.1 Operation Description

The PIR operates by sensing infrared radiation emitted by warm objects in its field-of-view (FoV), such as human bodies. When a person moves in the sensors FoV, the PIR transducer detects the change in infrared radiation and triggers the presence detection function.

The PIR transducer is enabled by default, but no reports are transmitted periodically. The reporting option can be customized to transmit the state, count, and/or value. When threshold-based transmission is enabled, the VIVID v2 sensor generates a report if the presence count exceeds the defined threshold within the specified period.

To enhance the efficiency of the presence sensor and minimize false positives, several configurable restrictions are available, including the grace period, post-turn-on hold-off interval, post-disturbance hold-off interval, and sensitivity. During these restricted times, or when the PIR transducer is disabled, the sensor does not monitor for presence.

The following lists the terms and terminologies used in the PIR operation. All listed items are user-configurable.

- Grace Period: The Grace Period determines how long the Sensor waits before the previously reported PIR presence event is considered clear. For instance, if the Grace Period is set to 5 minutes, the sensor will transmit "Presence Detected" when someone enters the room and "Presence Not Detected" 5 minutes after the room becomes empty. This ensures that brief absences do not trigger unnecessary notifications.

- PIR Threshold Count: The PIR transducer generates an event each time it detects presence within its field of view. Depending on the specific use case, customers may find it beneficial to increase the presence detection threshold to reduce sensitivity. This adjustment allows for filtering out short presence events, such as someone quickly entering a room to pick up a notebook, while still accurately reporting longer presence events, like a team meeting.

- PIR Threshold Period: The Threshold Period defines the duration over which presence events are accumulated for threshold detection. For instance, a Threshold Period of 10 seconds means that the sensor will accumulate presence detection events over a 10-second window starting from the first detection. If the number of detected events exceeds the threshold within this period, the sensor will report "Presence Detected." If the threshold is not met within this timeframe, no presence detection report is sent.

- Post-Turn-On Hold-Off Interval: For a default value of 10 seconds after power is first applied to the device, the PIR transducer is disabled. This interval allows the PIR transducer output to stabilize and prevents false detections.

- Post-Disturbance Hold-Off Interval: For approximately 1 second after a radio transmission or after sampling the temperature/RH transducer, the PIR presence detector is disabled. The operation of the radio or the temperature/RH transducer can cause the PIR transducer to produce false positives, so a "cool down" period is necessary after each transmission.

- Sensitivity: Sensitivity involves two configurations, threshold and hysteresis. Threshold is the value that the sensor's output must surpass to indicate that presence has been detected. This value can be adjusted to control the sensitivity of the detection system. Hysteresis is a buffer zone around the threshold value to prevent rapid toggling or oscillation of the system's state due to minor fluctuations in the input signal. This value can be adjusted to help prevent false triggers and rapid switching between states.

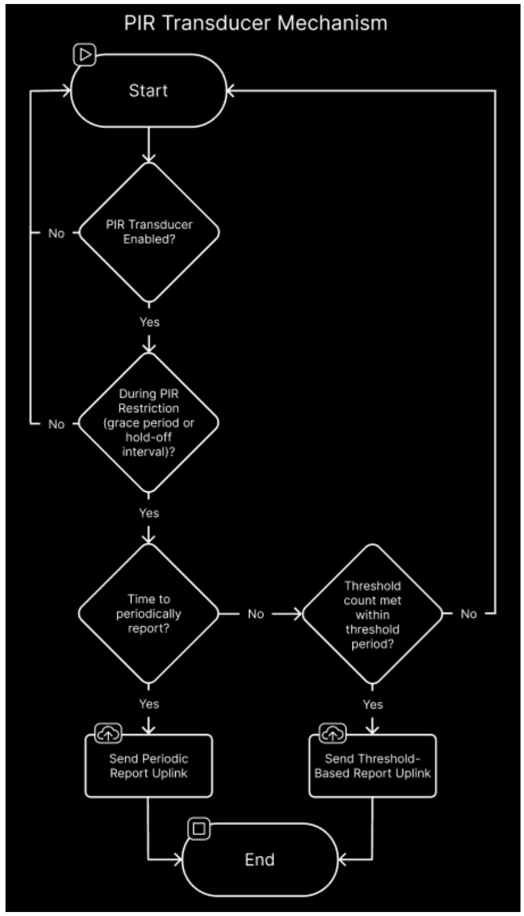


Figure 8-1: PIR Transducer Mechanism

8.2.2 Application Examples

The VIVID v2 sensor's PIR feature can be utilized to monitor the occupancy of desks in office environments. By detecting presence, the sensor provides real-time data on whether a desk is currently in use, which can help in efficient space management. Adjusting the sensitivity settings will allow the system to distinguish between brief entries and longer stays, ensuring that the data accurately reflects desk usage. This information can be used to optimize desk booking systems, reduce energy consumption by controlling lighting and HVAC systems based on occupancy, and enhance overall office efficiency.

8.2.3 UL Frame Payload Format

Presence sensor reports are sent on *LoRaWAN port 10* and have the frame format as shown in Figure 4-1. The specific details for the safety report frame formats are listed in Table 8-3. For the general description of sensor data report formats and behaviour, see Section 4.1.

Table 8-3: Presence Detection UL Formats

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Presence Event State	0x0A	0x00	1 B	Digital	• 0x00 = No presence detected • 0xFF = Presence detected	*pir_event_state: <value> (unsigned/no unit)*

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Presence Event Count	0x0D	0x04	2 B	Counter	• Number	*pir_event_count: <value> (unsigned/no unit)*
Presence Event Value	0x09	0x03	2 B	Counter	• Raw PIR presence value	*pir_event_value: <value> (signed/no unit)*

8.2.3.1 Example UL Payloads

- 0x **0A 00** FF
  - Channel ID = 0x 0A, Type ID = 0x 00 → Presence state
  - 0x FF = Presence detected
- 0x **0D 04** 00 05
  - Channel ID = 0x 0D, Type ID = 0x 04 → Presence event count
  - 0x 00 05 = 5 counts of presence
- 0x **09 03** 03 6C
  - Channel ID = 0x 09, Type ID = 0x 03 → Presence event value
  - 0x 03 6C = Raw PIR presence value of 876

8.2.4 Configuration Settings

All user-configurable registers for presence detection are listed in Table 8-4. In this table, the bit indexing scheme is as shown in Figure 4-2. To access these registers, a command must be formatted and sent according to the details described in Section 4.2.

Table 8-4: Presence Detection Configuration Registers

Address	Name	Access	Size	Description	JSON Variable	Default
0x20	Seconds per Core Tick	R/W	4 B	• Tick value for periodic events • Acceptable values: 15, 16, 17, …, 86400 • Other values: Invalid	*seconds_per_core_tick: <value> (number/sec)*	3600 s = 1 hr **0x 00 00 0E 10**
0x28	Ticks per PIR	R/W	2 B	• Ticks between periodic PIR sensor reports • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic reports • Other values: Invalid	*ticks_per_pir: <value> (number/no unit)*	0 ticks = PIR report is disabled by default **0x 00 00**
0x50	Grace Period	R/W	2 B	• Bit 0-15: Grace period of presence sensor in seconds • Acceptable values: 15, 16, 17, …, 65535 • Other values: Invalid	*pir_grace_period: <value> (unsigned/second)*	Grace period: 300s **0x 01 2C**

Address	Name	Access	Size	Description	JSON Variable	Default
0x51	Presence Threshold Count	R/W	2 B	• Bit 0-15: Number of PIR events required for event-based presence transmission • Acceptable values: 1, 2, 3, …, 65535 • 0: Invalid	*pir_threshold_count: <value> (unsigned/no unit)*	PIR threshold count: 1 **0x 01**
0x52	Presence Threshold Period	R/W	2 B	• Bit 0-15: Period over which presence events are counted for threshold detection • Acceptable values: 5, 6, 7, …, 65535 • 0-4: Invalid	*pir_threshold_period: <value> (unsigned/no unit)*	PIR threshold period: 15s **0x 0F**
0x53	Presence (PIR) Mode	R/W	1 B	• Bit 0 {Periodic Tx only}: 0/1: Count report disabled/enabled • Bit 1 {Periodic Tx only}: 0/1: State report disabled/enabled • Bit 2 {Periodic Tx only}: 0/1: Value report disabled/enabled • Both bits 0, 1, and 2 set to 0: Invalid • Bits 3-5: RFU, must be set to 0, otherwise Invalid • Bit 6: 0/1: PIR threshold-based transmission disabled/enabled • Bit 7: PIR sensor disabled/enabled	*pir_mode: { pir_count_reported: <value> (unsigned/sec) pir_state_reported: <value> (unsigned/no unit) pir_value_reported: <value> (unsigned/no unit) event_transmission_enabled: <value> (unsigned/no unit) transducer_enabled: <value> (unsigned/no unit) }*	Presence Count Reported Only PIR threshold-based transmission enabled PIR sensor enabled **0x C1**
0x54	Hold-Off intervals	R/W	2 B	• Bit 8 - 15: Post turn-on hold-off interval (unsigned, 1s/LSB) 0: Default value of 10s • Bit 0 - 7: Post disturbance hold-off interval (unsigned, 1s/LSB) 0: Default value of 1s	*pir_holdoff: { post_turn_on: <value> (unsigned/sec) post_disturbance: <value> (unsigned/sec) }*	Post turn-on: 10s Post disturbance: 1s **0x 0A 01**

Address	Name	Access	Size	Description	JSON Variable	Default
0x4E	Presence Sensitivity	R/W	3 B	• Bit 8 - 23: Threshold of PIR sensor (unsigned, 1/LSB) Acceptable values: 0 to 65535 0: most sensitive 65535: least sensitive • Bit 0 - 7: Hysteresis of PIR sensor (unsigned, 1/LSB) Acceptable values: 0 to 255 0 (no hysteresis): most sensitive 255: least sensitive	*pir_sensitivity: {* *pir_sens_threshold: <value> (unsigned/sec)* *pir_sens_hysteresis: <value> (unsigned/sec)* *}*	Threshold: 1000 Hysteresis: 100 **0x 03 E8 64**

8.2.4.1 Example DL Payloads

- Transmit the PIR "state", "count", and "value" every 60s and as soon as the count crosses 30 within 30s seconds:
  - DL payload: 0x **A0** 00 00 00 3C **A8** 00 01 **D1** 00 1E **D2** 00 1E **D3** C7
    - Register 0x 20 with bit 7 set to 1 = 0x A0
    - Seconds per core tick set to 60 = 0x 00 00 00 3C
    - Register 0x 28 with bit 7 set to 1 = 0x A8
    - Ticks per PIR set to 1 = 0x 00 01
    - Register 0x 51 with bit 7 set to 1 = 0x D1
    - Threshold count set to 30 = 0x 00 1E
    - Register 0x 52 with bit 7 set to 1 = 0x D2
    - Threshold period set to 30 seconds = 0x 00 1E
    - Register 0x 53 with bit 7 set to 1 = 0x D3
    - PIR state, count, and value reported, PIR enabled and threshold-based transmission set to true = 0x C7

- Set the grace period to 60s, post turn on hold off to 30s, and post disturbance hold off to 100s
  - DL payload: 0x **D0** 00 3C **D4** 1E 64
    - Register 0x 50 with bit 7 set to 1 = 0x D0
    - Grace period set to 60 seconds = 0x 00 3C
    - Register 0x 54 with bit 7 set to 1 = 0x D4
    - Post turn-on hold-off set to 30 seconds and post disturbance hold-off set to 100 seconds = 0x 1E 64

9 Accelerometer

The COMFORT/VIVID v2 sensor is equipped with an accelerometer that can measure the direction and magnitude of acceleration on up to 3 individual axes: ±X, ±Y, and ±Z.

The accelerometer is disabled by default and when enabled, it operates in a configurable power mode in the background during system operations, making measurements at a configurable *sample rate*.

The accelerometer measurement can be used for 3 main sensor functions:

- **Orientation Detection:** the accelerations on each axis can be reported periodically or on predefined acceleration event
- **Impact Alarms:** Refers to an event triggered by the accelerometer when it exceeds a specified impact alarm threshold. These events are reported as an impact alarm.
- **Acceleration Event:** Refers to an accelerometer event triggered independently of the impact alarm when it exceeds a specified acceleration threshold. These events are reported with the acceleration magnitude, acceleration vector, or both.

By default, all threshold-based and periodic accelerometer reports are disabled, and the accelerometer is powered off.

The general behaviour and configuration, as well as the descriptions of the supported accelerometer functions described above are detailed in the following subsections.

9.1 General Accelerometer Sampling

9.1.1 Operational Description

Regardless of which accelerometer function is used, the basic measurement scheme remains consistent. A single accelerometer measurement sample consists of the direction and magnitude of acceleration on up to three individual axes: ±X, ±Y, and ±Z. The acceleration magnitude is measured in units of acceleration due to gravity, g, where 1 g is equivalent to 9.810 m/s^2, the acceleration experienced by a body at rest on the Earth's surface. Measuring acceleration means detecting changes in movement.

The accelerometer can be set to power-down mode to conserve battery life when not in use. Alternatively, it can be enabled in low-power, normal, or high-resolution sampling modes, balancing power efficiency and data resolution. Power consumption is the same in normal and high-resolution modes but is higher compared to low-power mode. The resolution for each mode is specified Table 8-5.

Table 8-5: Accelerometer Mode Resolutions

Accelerometer Sampling Mode	Resolution (mg)	Bandwidth [Hz]
Low-power	16	Sampling Rate/2
Normal	4	Sampling Rate/2
High-resolution	1	Sampling Rate/9

The measurement range is configurable and defines the full dynamic range of accelerations that can be monitored on any enabled axis. Since the accelerometer output is always an 8-bit signed number, a larger measurement range results in less precision (i.e., a larger g unit per LSb). The supported measurement ranges of ±2 g, ±4 g, ±8 g, ±16 g correspond to typical output precisions of 16 mg, 32 mg, 64 mg, and 192 mg, respectively. If the physical acceleration magnitude is outside the current measurement range at the time of sampling, it will not be registered.

Additionally, impact alarm and acceleration event thresholds can be enabled or disabled. Disabling a threshold prevents the sensor from generating the corresponding event. It is also possible to independently enable or disable the X, Y, and Z axes. Any disabled axis is not considered in monitoring impact alarms or acceleration events.

When powered on, the accelerometer samples the transducer element at a fixed rate, called the Sample Rate. To capture an impact alarm or acceleration event, the physical event needs to last longer than the sample period. Larger sample rates have shorter periods and can therefore detect shorter impacts. However, sampling at a larger rate increases power usage, impacting battery life. Table 5-13 shows the expected continuous current draw from a 3.0-V battery for different sample rates when the accelerometer is powered on.

The Sensitivity register sets the measurement range or full scale, indicating the dynamic range of accelerations that can be monitored on any enabled axis. Note that when active, the accelerometer is always in its low power mode, meaning the output acceleration values on any given axis (X, Y, or Z) are 8-bit signed numbers. Therefore, a measurement range of ±2 g implies a precision of 4/256 g/LSB.

Table 8-6: Typical Current Draws at 3.0 V for Different Accelerometer Sample Rates

Sample Rate [Hz]	1	10	25	50	100	200	400
Current Draw [μA]	1.0	1.4	2.2	3.5	6.2	11.4	21.8

9.1.2 Configuration Settings

Table 8-7 shows the list of configuration registers which control general accelerometer behaviour. In this table, the bit indexing scheme is as shown in Figure 4-2 .To access these registers, a command must be formatted and sent according to the details described in Section 4.2.

Table 8-7: General Accelerometer Configuration Registers

Address	Name	Access	Size	Description	JSON Variable	Default
0x34	Accelerometer Mode	R/W	1 B	• Bit 0: 0/1 = Impact alarm event threshold disabled/enabled • Bit 1: 0/1 = Acceleration event threshold disabled/enabled • Bit 2-3: 0 = Low power mode 1 = Normal mode 2 = High resolution mode 3 = Invalid • Bits 4/5/6: 0/1 =X/Y/Z-axis disabled/enabled • Bit 7: Accelerometer power OFF/ON	*accelerometer_mode: {* *impact_threshold_enabled: <value> (unsigned/no unit)* *acceleration_threshold_enabled: <value> (unsigned/no unit)* *accel_power_mode: <value> (unsigned/no unit)* *xaxis_enabled: <value> (unsigned/no unit)* *yaxis_enabled: <value> (unsigned/no unit)* *zaxis_enabled: <value> (unsigned/no unit)* *poweron: <value> (unsigned/no unit)* *}*	Impact Alarm disabled Acceleration event disabled Low power mode XYZ axis enabled Accelerometer OFF **0x 70**
0x35	Accelerometer Sensitivity	R/W	1 B	• Bits 0-2: Sample Rate 0: Invalid 1/2/3/4/5/6/7 = 1/10/25/50/100 /200/400 Hz • Bit 3: RFU, must be 0, otherwise invalid • Bits 4-5: Measurement Range 0/1/2/3 = ±2/±4/±8/±16 g • Bits 6-7: RFU, must be 0, otherwise invalid	*accelerometer_sensitivity: {* *accelerometer_sample_rate: <value> (unsigned/Hz)* *accelerometer_measurement_range: <value> (unsigned/g)* *}*	Accelerometer measurement range: +/-8 g, Accelerometer sample rate: 1 Hz **0x 21**

9.1.2.1 Example DL Payloads

- Enable both impact alarm and acceleration event thresholds, use high resolution mode, enable X/Y/Z-axis, and power on the accelerometer:
  - DL payload: 0x **B4** FB
    - Register 0x 34 with bit 7 set to 1 = 0x B4
    - Enable impact alarm event threshold, enable acceleration event threshold, high resolution mode, X/Y/Z-axis enabled, accelerometer power ON = 0x FB
      - Bit 0: 1 = Impact alarm event threshold enabled
      - Bit 1: 1 = Acceleration event threshold enabled
      - Bit 2/3: 2 = High Resolution mode
      - Bits 4/5/6: 1/1/1 =X/Y/Z-axis enabled
      - Bit 7: Accelerometer power ON

- Set sample rate to 400 Hz and measurement range to ±2:
  - DL payload: 0x **B5** 07
    - Register 0x 35 with bit 7 set to 1 = 0x B5
    - Sample rate option 7, measurement range option 0 = 0x 07

9.2 Impact Alarm

The impact alarm functionality of the accelerometer is a robust system designed to detect and report significant and sustained impacts. By configuring thresholds, counts, and periods, users can tailor the sensitivity and responsiveness of the sensor to meet specific application requirements, ensuring that only relevant events are logged and reported.

9.2.1 Operational Description

Impact alarms are critical events triggered by the accelerometer when the measured acceleration surpasses a predefined impact alarm threshold a predefined number of times over a predefined period of time. When this threshold is exceeded, the sensor registers the event and reports it as an impact alarm. This mechanism is essential for applications requiring the detection of significant impacts, ensuring that only relevant and substantial movements are logged. For an impact alarm event to be reported, two key conditions must be met:

1. The impact alarm event threshold (bit 0 of register 0x34) must be enabled. This setting activates the sensor's capability to monitor for impact events.
2. The threshold must be exceeded on at least one of the enabled axes (X, Y, Z) within a specified period (Impact Alarm Event Threshold Period—register 0x38) more than the configured number of times (Impact Alarm Event Threshold Count—register 0x37). This ensures that the sensor only reports sustained and significant impacts, filtering out brief and insignificant movements.

The impact alarm threshold is the g-threshold for triggering an impact alarm event. The Report Options register determines what data is reported during accelerometer periodic transmissions or acceleration events. For Impact alarm events, only the status is transmitted on activation and deactivation of the event.

The Grace Period register defines the time in seconds the sensor waits before considering a previously reported impact alarm event as cleared. For example, a Grace Period of 5 minutes results in the sensor transmitting "Impact Detected" upon impact event and "Impact Alarm Cleared" 5 minutes after the impact event, if no other events were registered within the 5 minutes duration. The minimum acceptable value for the Grace Period register is 15, and values smaller than 15 are invalid.

The accelerometer generates an impact alarm event each time it satisfies the impact event conditions, and the threshold count can be adjusted to reduce sensitivity based on customer use cases. This feature allows customers to filter out short impact events while ensuring longer impact events are reported. The minimum acceptable value for the Impact Alarm Event Threshold Count is 1, with 0 being invalid.

The Impact Alarm Event Threshold Period is the time frame over which impact alarm events are accumulated for threshold detection. For example, an Impact Alarm Event Threshold Period of 10 seconds accumulates impact alarm events over a 10-second period from the first detection. If the Impact Alarm Event Threshold Count is reached before the period expires, the sensor reports "Impact Detected." Otherwise, it does not report. The minimum acceptable value for this register is 5 seconds, and values smaller than 5 are invalid.

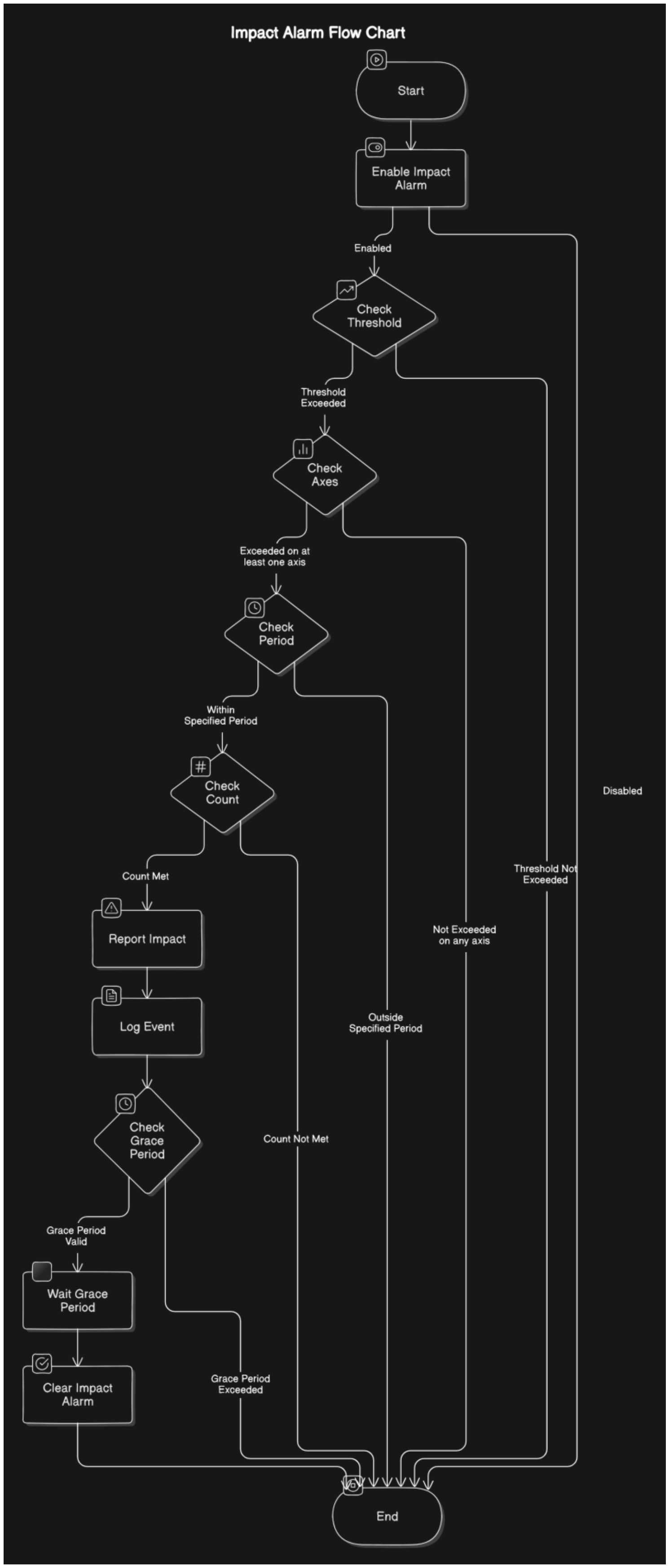


Figure 8-2: Impact Alarm Flow Chart

9.2.2 UL Report Frame Format

Impact alarm status reports are sent on *LoRaWAN port 10* and have the frame format as shown in Figure 4-1. The specific details for the safety report frame formats are listed in Table 8-8. For the general description of sensor data report formats and behaviour, see Section 4.1.

Table 8-8: Impact Alarm UL Report Formats

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Accelerometer Impact Alarm	0x0C	0x00	1 B	Digital	• Bits 0-7: 0x 00: Impact Alarm Inactive 0x FF: Impact Alarm Active	*impact_alarm: <value> (unsigned/no unit)*
Acceleration Magnitude	0x05	0x02	2 B	Magnitude	• Bits 0-15: Magnitude of all enabled axis	*accelerometer_magnitude: <value> (unsigned/g)*
Acceleration Vector	0x07	0x71	6 B	Acceleration	• Bits 32-47: X-axis acceleration • Bits 16-31: Y-axis acceleration • Bits 0-15: Z-axis acceleration [1 mg/LSb] (signed)	*acceleration_vector { acceleration_x: <value> (signed/g) acceleration_y: <value> (signed/g) acceleration_z: <value> (signed/g) }*

9.2.2.1 Example UL Payloads

- Report Active Impact Alarm
  - 0x **0C 00** FF
    - Channel ID = 0x 0C, Type ID = 0x 00 → Accelerometer Impact Alarm Status
    - 0x FF = Alarm Active

- Report acceleration vector for x, y and z
  - 0x **07 71** 00 00 FB 50 00 00
    - Channel ID = 0x 07, Type ID = 0x 71 → acceleration vector data report
    - 0x 00 00 = 0 × 1 mg = 0.000 g in X-direction
    - 0x FB 50 = -1200 × 1 mg = -1.200 g in Y-direction
    - 0x 00 00 = 0 × 1 mg = 0.000 g in Z-direction

- Report acceleration magnitude of 1000mg
  - 0x **05 02** 03 E8
    - Channel ID = 0x 05, Type ID = 0x 02 → Accelerometer magnitude
    - 0x 03 E8 = 1000 mg

9.2.3 Configuration Settings

All user-configurable registers for accelerometer impact alarm are listed on Table 8-9. In this table, the bit indexing scheme is as shown in Figure 4-2. To access these registers, a command must be formatted and sent according to the details described in Section 4.2.

Table 8-9: Acceleration Impact Alarm Configuration Settings

Address	Name	Access	Size	Description	JSON Variable	Default
0x20	Seconds per Core Tick	R/W	4 B	• Tick value for periodic events • Acceptable values: 15, 16, 17, …, 86400	*seconds_per_core_tick: <value> (number/sec)*	3600s = 1 hr **0x 00 00 0E 10**
0x26	Ticks per Accelerometer	R/W	2 B	• Ticks between Accelerometer report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic Accelerometer reports • Other values: Invalid	*tick_per_accelerometer: <value> (number/no unit)*	0 tick = Disabled by default **0x 00 00**
0x30	Impact Alarm Event Threshold	R/W	2 B	• Bits 0 – 15: Acceleration threshold in milli-g (1mg/LSB) • Acceptable values: 0, 1, …, 65535 • Other values: Invalid	*impact_event_threshold : <value> (unsigned/g)*	Threshold: 1500mg **0x 05 DC**

Address	Name	Access	Size	Description	JSON Variable	Default
0x32	Accelerometer Report Options	R/W	1 B	• Bit 0: {Periodic Reporting Only} • 0/1: Impact alarm status report disabled/enabled • Bit 1: {Periodic Reporting Only} 0/1: Acceleration magnitude report disabled/enabled • Bit 2: {Periodic Reporting Only} 0/1: Acceleration vector report disabled/enabled • Bits 0 to 2 set to 0: Invalid • Bit 4: {Acceleration Event Only} 0/1: Acceleration magnitude report disabled/enabled • Bit 5: {Acceleration Event Only} 0/1: Acceleration vector report disabled/enabled • Bits 3, 6 - 7: RFU, must be set to 0, otherwise Invalid	*accelerometer_tx {* *report_periodic_alarm_enabled: <value>, (unsigned/no unit)* *report_periodic_magnitude_enabled: <value>, (unsigned/no unit)* *report_periodic_vector_enabled: <value> (unsigned/no unit)* *report_event_magnitude_enabled: <value>, (unsigned/no unit)* *report_event_vector_enabled: <value> (unsigned/no unit)* *}*	Acceleration vector ONLY for periodic and event reports **0x 24**

Address	Name	Access	Size	Description	JSON Variable	Default
0x34	Accelerometer Mode	R/W	1 B	• Bits 0: 0/1 = Impact alarm event disabled/enabled • Bit 1: 0/1 = Acceleration event disabled/enabled • Bit 2-3: 0 = Low power mode 1 = Normal mode 2 = High Resolution mode 3 = Invalid • Bits 4/5/6: 0/1 =X/Y/Z-axis disabled/enabled • Bit 7: Accelerometer power OFF/ON	*accelerometer_mode {* *impact_threshold_enabled: <value>, (unsigned/no unit)* *acceleration_threshold_enabled: <value>, (unsigned/no unit)* *accel_power_mode: <value>, (unsigned/no unit)* *xaxis_enabled: <value>, (unsigned/no unit)* *yaxis_enabled: <value>, (unsigned/no unit)* *zaxis_enabled: <value>, (unsigned/no unit)* *poweron: <value> (unsigned/no unit)* *}*	Impact Alarm disabled Acceleration event disabled Low power mode XYZ axis enabled Accelerometer OFF **0x 70**
0x36	Impact alarm Grace Period	R/W	2 B	• Bit 0 - 15: • Period after which an impact alarm is cleared, if no other impact alarm event were recorded • Acceptable values: 15, 16, …, 65535 • 0 – 14: invalid	*impact_alarm_grace_period: <value> (unsigned/seconds)*	Impact Alarm Grace Period: 300s **0x 01 2C**
0x37	Impact alarm Event Threshold Count	R/W	2 B	• Bit 0 - 15: • The number of impact alarm events within the threshold period required to trigger an impact alarm • Acceptable values: 1, 2, …, 65535 • 0: invalid	*impact_alarm_threshold_count: <value> (unsigned/no unit)*	Impact Alarm threshold Count: 1 **0x 00 01**

Address	Name	Access	Size	Description	JSON Variable	Default
0x38	Impact alarm Event Threshold Period	R/W	2 B	• Bit 0 - 15: • The time span in seconds during which impact alarm events are tallied for threshold detection • Acceptable values: 5, 6, …, 65535 • 0 - 4: invalid	*impact_alarm_threshold_period: <value> (unsigned/seconds)*	Impact alarm Event Threshold Period: **0x 00 0F**

9.2.3.1 Example DL Payloads

- Set core tick to 60s, and ticks per accelerometer to 15:
    - DL payload: 0x **A0** 00 00 00 3C **A6** 00 0F
        - Register 0x 20 with bit 7 set to 1 = 0x A0
        - Core tick set to 60 seconds = 0x 00 00 00 3C
        - Register 0x 26 with bit 7 set to 1 = 0x A6
        - Ticks per accelerometer set to 15 = 00 0F

- Set Impact alarm threshold to 2000mg, grace period to 100s, threshold count to 10, and threshold period to 60s
    - DL payload: **0**x **B0** 07 D0 **B6** 00 64 **B7** 00 0A **B8** 00 3C
        - Register 0x 30 with bit 7 set to 1 = 0x B0
        - Threshold to 2000 mg = 0x 07 D0
        - Register 0x 36 with bit 7 set to 1 = 0x B6
        - Grace period to 100 seconds = 0x 00 64
        - Register 0x 37 with bit 7 set to 1 = 0x B7
        - Threshold count to 10 = 0x 00 0A
        - Register 0x 38 with bit 7 set to 1 = 0x B8
        - Threshold period to 60 s = 0x 00 3C

- Enable all possible report options for periodic and event-based reports
    - DL payload: 0x **B2** 37
        - Register 0x 32 with bit 7 set to 1 = 0x B2
        - Enable all periodic and event-based reports = 0x 37
            - Bit 0: 1 = Impact alarm status report enabled for periodic reports
            - Bit 1: 1 = Acceleration magnitude report enabled for periodic reports
            - Bit 2: 1 = Acceleration vector report enabled for periodic reports
            - Bit 4: 1 = Acceleration magnitude report enabled for event-based reports
            - Bit 5: 1 = Acceleration vector report enabled for event-based reports.

9.3 Acceleration Event

Acceleration events are triggered by the accelerometer when the measured acceleration surpasses a predefined acceleration threshold. Unlike impact alarm events, acceleration events do not require count, period, or grace period conditions for the events to be registered.

Acceleration events are triggered by the accelerometer when the measured acceleration surpasses a predefined acceleration threshold outside of the acceleration debounce period. For an Acceleration event to be registered, two conditions must be met:

1. The acceleration of the enabled accelerometer axis exceeds the acceleration threshold.
2. The event occurs outside of the configurable acceleration debounce period.

For example, if the acceleration threshold is set to 2000mg and the debounce period is set to 10 seconds, an acceleration exceeding 2000mg is registered as an acceleration event by the accelerometer. An event-based uplink, consisting of the magnitude, vector, or both, is sent to the network server in response to this event. If another acceleration event occurs within 10 seconds of the first event, it is not recorded, as it falls within the debounce period.

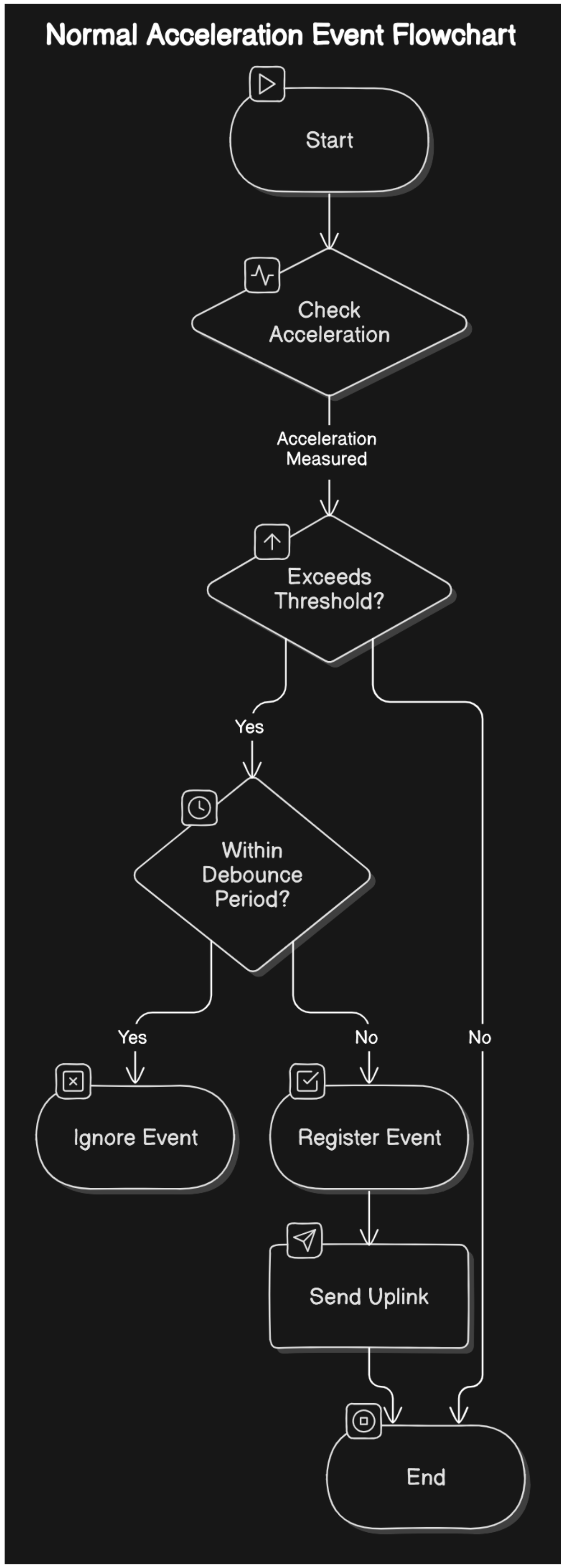


Figure 8-3: Acceleration Event Algorithm

9.3.1 UL Report Frame Format

Refer to Section 9.2.2

9.3.1.1 Example UL Payloads

Refer to Section 9.2.2.1

9.3.2 Configuration Settings

All user-configurable registers for Acceleration events are listed Table 8-10. In this table, the bit indexing scheme is as shown in Figure 4-2. To access these registers, a command must be formatted and sent according to the details described in Section 4.2.

Table 8-10: Acceleration Event Configuration Settings

Address	Name	Access	Size	Description	JSON Variable	Default
0x20	Seconds per Core Tick	R/W	4 B	• Tick value for periodic events • Acceptable values: 15, 16, 17, …, 86400	*seconds_per_core_tick: <value> (number/sec)*	3600s = 1 hr **0x 00 00 0E 10**
0x26	Ticks per Accelerometer	R/W	2 B	• Ticks between Accelerometer report. • Acceptable values: 0, 1, 2, …, 65535 0: Disables periodic Accelerometer reports • Other values: Invalid	*tick_per_accelerometer: <value> (number/no unit)*	0 tick = Disabled by default **0x 00 00**
0x31	Acceleration Event Threshold	R/W	2 B	• Bits 0 – 15: Acceleration threshold in milli-g (1mg/LSB) • Acceptable values: 0, 1, …, 65535	*acceleration_event_threshold: <value> (unsigned/g)*	Threshold: 3000 mg **0x 0B B8**

Address	Name	Access	Size	Description	JSON Variable	Default
0x32	Accelerometer Report Options	R/W	1 B	• Bit 0: {Periodic Reporting Only} 0/1: Impact alarm status report disabled/enabled • Bit 1: {Periodic Reporting Only} 0/1: Acceleration magnitude report disabled/enabled • Bit 2: {Periodic Reporting Only} 0/1: Acceleration vector report disabled/enabled • Bits 0 to 2 set to 0: Invalid • Bit 4: {Acceleration Event Only} 0/1: Acceleration magnitude report disabled/enabled • Bit 5: {Acceleration Event Only} 0/1: Acceleration vector report disabled/enabled • Bits 3, 6 - 7: RFU, must be set to 0, otherwise Invalid	*accelerometer_tx {* *report_periodic_alarm_enabled: <value>, (unsigned/no unit)* *report_periodic_magnitude_enabled: <value>, (unsigned/no unit)* *report_periodic_vector_enabled: <value> (unsigned/no unit)* *report_event_magnitude_enabled: <value>, (unsigned/no unit)* *report_event_vector_enabled: <value> (unsigned/no unit)* *}*	Acceleration vector ONLY for periodic and event reports **0x 24**
0x33	Acceleration Event Debounce Period	R/W	2 B	• Bit 0 - 15: • The duration to wait before potentially reporting another acceleration event. • Acceptable values: 1, 2, …, 65535 • 0: invalid	*acceleration_impact_grace_period: <value> (unsigned/seconds)*	Acceleration Debounce Period: 2s **0x 00 02**

9.3.2.1 Example DL Payloads

- Set acceleration threshold to 5000mg and debounce interval to 60s:
    - DL payload: 0x **B1** 13 88 **B3** 00 3C
        - Register 0x 31 with bit 7 set to 1 = 0x B1
        - Acceleration magnitude threshold set to 5000 mg = 0x 13 88
        - Register 0x 33 with bit 7 set to 1 = 0xB3
        - Debounce interval set to 60 seconds = 0x 00 3C

10 Ambient Environmental Sensing

The COMFORT/VIVID v2 is equipped with an onboard transducer that functions as both a thermometer and hygrometer. The vents in the enclosure allow the ambient air to flow through the sensor so that the temperature [°C] and relative humidity (RH) [%] data can be reported in a LoRaWAN UL on port 10. Threshold ranges can also be set such that moving in or out of range causes additional ambient data reports. In the following subsections, periodic and threshold-based reporting are described.

10.1 Temperature and RH Periodic Reporting

10.1.1 Operational Description

The COMFORT/VIVID v2 samples the temperature and humidity readings during the background of normal operation. It can be configured to periodically report the temperature in [°C] and RH in [%] in a LoRaWAN UL. Sampling cannot be disabled, but reporting can be disabled.

By default, both temperature and RH are reported once every hour.

NOTE: During ambient temperature or RH changes, it may take some time for the sensor to report the new ambient values because the air takes some time to flow through the enclosure vents. Results may vary depending on the mounting orientation with respect to air flow direction.

10.1.2 UL Report Frame Formats

Temperature and Relative Humidity reports are sent on *LoRaWAN port 10* and have the frame format as shown in Figure 4-1. The specific details for the safety report frame formats are listed in Table 10-1. For the general description of sensor data report formats and behaviour, see Section 4.1.

Table 10-1: Ambient Environment Data Report UL Frame 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 Relative Humidity	0x04	0x68	1 B	Humidity	• [0.5%/LSb] (unsigned)	*relative_humidity: <value> (unsigned/%)*
MCU Temperature	0x0B	0x67	2 B	Temperature	• [0.1°C/LSb] (signed)	*mcu_temperature: <value> (signed/°C)*

10.1.2.1 Example UL Payloads

- 0x **03 67** 00 96
  - Channel ID = 0x 03, Type ID = 0x 67 → ambient temperature data report
  - 0x 00 96 = 150 × 0.1°C = 15°C

- 0x **04 68** 54

- Channel ID = 0x 04, Type ID = 0x 68 → ambient RH data report
    - 0x 54 = 84 × 0.5% = 42%

- 0x **0B 67** 00 96
    - Channel ID = 0x 0B, Type ID = 0x 67 → MCU temperature data report
    - 0x 00 96 = 150 × 0.1°C = 15°C

10.1.3 Configuration Settings

All user-configurable registers for periodic ambient environmental data are listed on Table 10-2. In this table, the bit indexing scheme is as shown in Figure 4-2. To access these registers, a command must be formatted and sent according to the details described in Section 4.2.

Table 10-2: Ambient Environment Report Configuration Registers

Address	Name	Access	Size	Description and Options	JSON Variable (Type/Unit)	Default Value
0x20	Seconds per Core Tick	R/W	4 B	• Ticks value for periodic events • Acceptable values: 15,16, 17, …, 86400 • 0, Other values: Invalid	*seconds_per_core_tick: <value>* *(number/sec)*	3600 s = 1 hr **0x 00 00 0E 10**
0x22	Ticks per Ambient Temperature	R/W	2 B	• Ticks between ambient temperature report • Acceptable values: 0, 1, 2, …, 65535 0: Disables periodic ambient temperature reports • Other values: Invalid	*ticks_per_ambient_temperature: <value>* *(number/no unit)*	1 tick = 1 hr **0x 00 01**
0x23	Ticks per Relative Humidity	R/W	2 B	• Ticks between Relative Humidity report. • Acceptable values: 0, 1, 2, …, 65535 0: Disables periodic Relative Humidity reports • Other values: Invalid	*ticks_per_relative_humidity: <value>* *(number/no unit)*	1 tick = 1 hr **0x 00 01**

Address	Name	Access	Size	Description and Options	JSON Variable (Type/Unit)	Default Value
0x27	Ticks per MCU Temperature	R/W	2 B	• Ticks between MCU temperature reports. • Acceptable values: 0, 1, 2, …, 65535 0: Disables periodic MCU Temperature reports • Other values: Invalid	*ticks_per_mcu_temperature: <value>* *(number/no unit)*	0 tick = MCU temperature disabled by default **0x 00 00**

10.1.3.1 Example DL Payloads

- Schedule ambient temperature and MCU temperature reports every 48 hours:
    - DL payload: 0x **A0** 00 00 0E 10 **A2** 00 30 **A7** 00 30
        - Register 0x 20 with bit 7 set to 1 = 0x A0
        - Core tick set to 3600 seconds = 0x 00 00 0E 10
        - Register 0x 22 with bit 7 set to 1 = 0x A2
        - Ticks per ambient temperature report set to 48 = 0x 00 30
        - Register 0x 27 with bit 7 set to 1 = 0x A7
        - Ticks per MCU temperature report set to 48 = 0x 00 30

- Disable RH reporting:
    - DL payload: 0x **A3** 00 00
        - Register 0x 23 with bit 7 set to 1 = 0x A3
        - Disable periodic reporting of relative humidity = 0x 00 00

10.2 Temperature and RH Threshold-Based Reporting

10.2.1 Operational Description

In addition to periodic ambient environment data reporting, the COMFORT/VIVID v2 supports sending additional data reports based on crossing configurable thresholds. Both temperature and RH thresholds can be set.

When an environmental temperature threshold is enabled, the sensor reports the environment data when it leaves the configured *threshold window*, and once again when it re-enters the threshold window. The threshold window is an open interval, meaning that even if the environment data is equal to the *low threshold* or *high threshold*, the sensor is considered to have left the threshold window.

When the environment data is inside the threshold window, the COMFORT/VIVID V2 is in the *idle* sampling state. When outside, the COMFORT/VIVID v2 is in the *active* sampling state. This is illustrated using the default configurations in Figure 10-1.

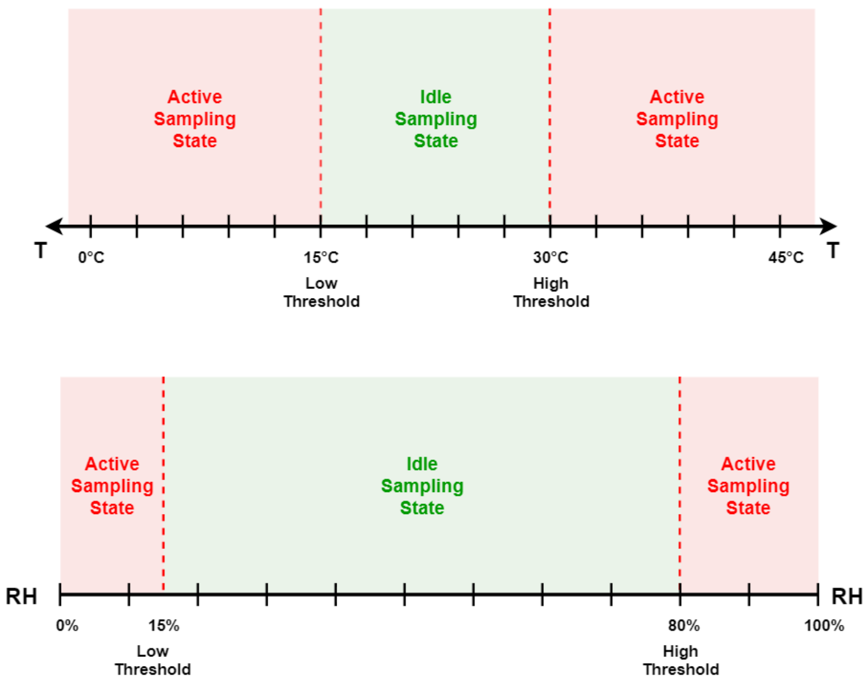


Figure 10-1: Default Ambient Temperature and RH Threshold Windows

The sampling periods are configurable and determine how often the temperature and RH transducer is checked when the reported value is inside/outside the threshold window. When first enabled, the temperature transducer starts in the idle sampling state.

By default, threshold-based reporting is disabled.

Threshold-based reporting is compatible with periodic reporting of the ambient environment data; both can be disabled and enabled independently[9].

10.2.2 UL Report Frame Formats

Refer to Section 10.1.2

10.2.3 Configuration Settings

All user-configurable registers for event based ambient environmental data are listed on Table 10-3. In this table, the bit indexing scheme is as shown in Figure 4-2. To access these registers, a command must be formatted and sent according to the details described in Section 4.2.

[9] See Section 10.1 for details about periodic ambient environment data reporting configuration.

Table 10-3: Ambient Environment Data Threshold Configuration Registers

Address	Name	Access	Size	Description and Options	JSON Variable (Type/Unit)	Default Value
0x39	Temperature/RH Sample Period: Idle	R/W	4 B	• Sample period of ambient temperature/RH data when in idle state [1 s/LSB] • Acceptable values: 30, 31, …, 86400 • Other values: Invalid	*temp_rh_sample_period_idle: <value> (unsigned/sec)*	Sample period in idle state: 60 s **0x 00 00 00 3C**
0x3A	Temperature/RH Sample Period: Active	R/W	4 B	• Sample period of ambient temperature/RH data when in active state [1 s/LSB] • Acceptable values: 30, 31, …, 86400 • Other values: Invalid	*temp_rh_sample_period_active : <value> (unsigned/sec)*	Sample period in active state: 30 s **0x 00 00 00 1E**
0x3B	Low/High Temperature Thresholds	R/W	2 B	• Bits 8-15: High ambient temperature threshold (signed) [1°C/LSb] • Bits 0-7: Low ambient temperature threshold (signed) [1°C/LSb] • High threshold ≤ Low threshold: Invalid	*temp_threshold_high: <value> (signed/°C)* *temp_threshold_low: <value> (signed/°C)*	High threshold = 30°C Low threshold = 15°C **0x 1E 0F**
0x3C	Temperature Thresholds Enabled	R/W	1 B	• Bit 0: 0/1: Ambient temperature thresholds disabled/enabled • Bits 1-7: RFU, must be set to 0, otherwise invalid	*temp_thresholds_enabled: <value> (string/no unit)*	Disabled **0x 00**
0x3D	Low/High RH Thresholds	R/W	2 B	• Bits 8-15: High ambient RH threshold (unsigned) [1%/LSb] • Bits 0-7: Low ambient RH threshold (unsigned) [1%/LSb] • High threshold ≤ Low threshold: Invalid	*rh_threshold_high: <value> (unsigned/%)* *rh_threshold_low: <value> (unsigned/%)*	High threshold = 80% Low threshold = 15% **0x 50 0F**
0x3E	RH Thresholds Enabled	R/W	1 B	• Bit 0: 0/1: Ambient RH thresholds disabled/enabled • Bits 1-7: RFU, must be set to 0, otherwise invalid	*rh_thresholds_enabled: <value> (string/no unit)*	Disabled **0x 00**
0x40	MCU Temperature Sample Period: Idle	R/W	4 B	• Sample period of MCU Temperature data when in idle state [1 s/LSB] • Acceptable values: 30, 31, …, 86400 • Other values: Invalid	*mcu_temp_sample_period_idle: <value> (unsigned/sec)*	300 s **0x 00 00 01 2C**

Address	Name	Access	Size	Description and Options	JSON Variable (Type/Unit)	Default Value
0x41	MCU Temperature Sample Period: Active	R/W	4 B	• Sample period of MCU Temperature data when in active state [1 s/LSB] • Acceptable values: 30, 31, …, 86400 • Other values: Invalid	*mcu_temp_sample_period_active: <value> (unsigned/sec)*	60 s **0x 00 00 00 3C**
0x42	Low/High MCU Temperature Thresholds	R/W	2 B	• Bits 8-15: High ambient MCU Temperature threshold (signed) [1°C/LSb] • Bits 0-7: Low ambient MCU Temperature threshold (signed) [1°C/LSb] • High threshold ≤ Low threshold: Invalid	*mcu_temp_threshold_high: <value> (signed/°C)* *temp_threshold_low: <value> (signed/°C)*	High threshold = 30°C Low threshold = 15°C **0x 1E 0F**
0x43	MCU Temperature Thresholds Enabled	R/W	1 B	• Bit 0: 0/1: Ambient MCU Temperature thresholds disabled/enabled • Bits 1-7: RFU, must be set to 0, otherwise invalid	*mcu_temp_thresholds_enabled: <value> (string/no unit)*	Disabled **0x 00**

10.2.3.1 Example DL Payloads

- Enable temperature threshold-based reporting with a window between -10°C and 35°C:
  - DL payload: 0x **BB** 23 F6 **BC** 01
    - Register 0x 3B with bit 7 set to 1 = 0x BB
    - High ambient temperature threshold set to 35°C = 0x 23
    - Low ambient temperature threshold set to -10°C = 0x F6
    - Register 0x 3C with bit 7 set to 1 = 0x BC
    - Thresholds enabled = 0x 01

- Read current sample periods:
  - DL payload: 0x **39 3A 40 41**
    - Register 0x 39 with bit 7 set to 0 = 0x 39
    - Register 0x 3A with bit 7 set to 0 = 0x 3A
    - Register 0x 40 with bit 7 set to 0 = 0x 40
    - Register 0x 41 with bit 7 set to 0 = 0x 41

11 Ambient Light Sensor

The COMFORT/VIVID v2 sensor is equipped with a light transducer that enables the detection of light presence or absence. This functionality is facilitated by the built-in light sensing transducer, which operates through a light pipe that is visible on the top surface of the sensor's enclosure.

11.1 Operation Description

The COMFORT/VIVID sensor's light sensing capability supports two types of transmissions: periodic and threshold-based. Periodic transmissions involve the sensor regularly reporting the light data at set intervals, irrespective of changes in light levels. In contrast, threshold-based transmissions are triggered when the light intensity crosses predefined threshold level.

NOTE: The orientation of the sensor relative to the light source significantly impacts the measured light intensity levels. This is because the sensor's position and angle can affect the amount of light reaching the transducer.

To conserve energy, the light transducer is typically powered off. However, if periodic reporting is enabled, it is periodically powered by the MCU to take samples of the ambient light. The light sensing sample period determines how often this transducer is powered on and checked for the presence and intensity of light. Shorter sample periods improve detection time but increase battery usage. Acceptable values for the sample period range from 30 to 86,400 seconds. Setting the sample period to 0 disables the light sensing element, while values between 1 to 29 seconds or values greater than 86,400 seconds are invalid.

NOTE: The light sensing sample period must be enabled for periodic transmission. Otherwise, each transmission will report a repetitive light value stored in the MCU memory, rather than an updated measurement. This ensures accurate and timely reporting of light conditions.

The Threshold Control register is used to set the dark/bright transition point for the sensor. Bits 0-5 can be configured to any value from 1 to 63. A light value smaller than or equal to the threshold is interpreted as "dark," while values greater than the threshold is interpreted as "bright." Consequently, a threshold setting of 1 corresponds to the darkest threshold, and 63 corresponds to the brightest threshold. When first enabled, the sensor starts in the "dark" state.

Bit 7 of the Threshold Control register is used to enable or disable threshold-based reporting. When threshold-based reporting is enabled, the sensor transmits data whenever the threshold is crossed, meaning when the current and previous samples lie on opposite sides of the threshold. If threshold-based reporting is disabled, the threshold defined by bits 0-5 is only used to determine the "state" (dark or bright) for periodic transmissions, without triggering any immediate transmissions when the threshold is crossed.

The Report Options register determines the value that is reported during periodic or threshold-based transmissions. This value can represent the light state, which is either "dark" or "bright" based on a comparison of the light intensity value with the light threshold. Alternatively, the light intensity itself can be reported as a value between 0 and 64, inclusive.

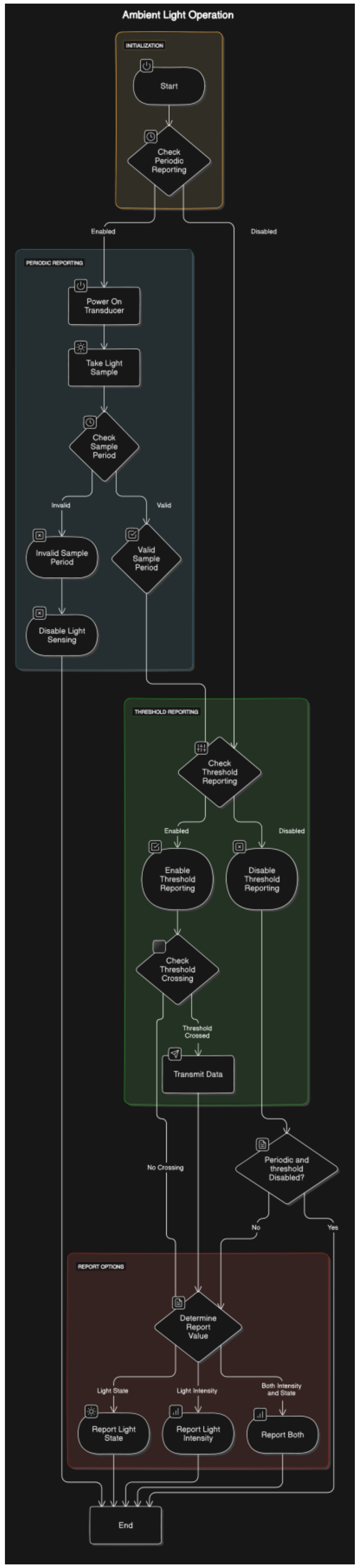


Figure 11-1: Ambient Light Sensor Operation

11.2 Application Examples

For automatic lighting control, the ambient light sensor can detect light levels and trigger indoor lights to turn on when it gets dark or turn off when it is bright, ensuring optimal lighting conditions in smart home systems. In commercial buildings, the sensor can be used in daylight harvesting systems to adjust artificial lighting based on natural light availability, thus reducing energy consumption.

In security systems, the sensor can control outdoor security lighting, turning it on at dusk and off at dawn to enhance safety. In agricultural settings, the sensor can automate greenhouse lighting to ensure plants receive the necessary light levels for growth, adapting to changing light conditions throughout the day.

11.3 UL Frame Payload Format

Ambient light sensor's intensity and state are sent on *LoRaWAN port 10* and have the frame format as shown in Figure 4-1. The specific details for the safety report frame formats are listed in Table 11-1. For the general description of sensor data report formats and behaviour, see section 4.1.

Table 11-1: Ambient Light Sensor 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_detected: <value> (unsigned/no unit)*
Ambient Light Intensity	0x10	0x02	1 B	Counter	• Uncalibrated Digitized Ambient Light Intensity • Values: 0, 1, … 63	*light_intensity: <value> (unsigned/no unit)*

11.3.1 Example UL Payloads

- 0x **02 00** FF
  - Channel ID = 0x 02, Type ID = 0x 00 → Ambient Light State
  - 0x FF = Bright
- 0x **10 02** 05
  - Channel ID = 0x 10, Type ID = 0x 02 → Ambient Light Intensity
  - 0x 05 = Intensity level of 5

11.4 Configuration Settings

All user-configurable registers for the Ambient Light Sensor are listed Table 11-2. In this table, the bit indexing scheme is as shown in Figure 4-2. To access these registers, a command must be formatted and sent according to the details described in section 4.2.

Table 11-2: Light Sensor Configuration Registers

Address	Name	Access	Size	Description	JSON Variable	Default
0x20	Seconds per Core Tick	R/W	4 B	• Tick value for periodic events • Acceptable values: 15, 16, 17, …, 86400 • Other values: Invalid	*seconds_per_core_tick: <value>* *(number/sec)*	3600 s = 1 hr **0x 00 00 0E 10**
0x25	Tick per Ambient Light	R/W	2 B	• Ticks between periodic ambient light reports • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic reports • Other values: Invalid	*ticks_per_light: <value>* *(number/no unit)*	0 ticks = Light report is disabled by default **0x 00 00**
0x47	Sample Period	R/W	4 B	• Bit 0-31: Sample period of ambient light sensor in seconds 0: Disables light sensor • Acceptable values: 0, 30, 31, …, 86400	*light_sample_period: <value>* *(unsigned/second)*	Light Transducer Disabled **0x 00 00 00 00**
0x48	Ambient Light Threshold	R/W	1 B	• Bit 0-5: Threshold level required for event-based light transmission • Acceptable values: 1, 2, 3, …, 63 0: Invalid • Bit 6: RFU, must be set to 0, otherwise Invalid • Bit 7: 0/1: disable/enable threshold-based transmission	*light_threshold: {* *threshold: <value>* *(unsigned/no unit)* *threshold_enabled : <value>* *(unsigned/no unit)* *}*	Threshold based reporting enabled Light threshold: 32 **0x A0**
0x49	Ambient Light Report Options	R/W	1 B	• Bit 0: 0/1: State report disabled/enabled • Bit 1: 0/1: Intensity value disabled/enabled • Both bits 0 and 1 set to 0: Invalid • Bits 2 - 7: RFU, must be set to 0, otherwise Invalid	*ambient_light_report_options: {* *report_state_enabled: <value>* *(unsigned/no unit)* *report_intensity_enabled: <value>* *(unsigned/no unit)* *}*	Light State Reported Only **0x 01**

11.4.1 Example DL Payloads

- Transmit the light “state” and “intensity” every 60s and as soon as the light intensity crosses 30 with a sample period of 30 seconds:
    - DL payload: 0x **A0** 00 00 00 3C **A5** 00 01 **C7** 00 00 00 1E **C8** 9E **C9** 03
        - Register 0x 20 with bit 7 set to 1 = 0x A0
        - Core tick set to 60 seconds = 0x 00 00 00 3C
        - Register 0x 25 with bit 7 set to 1 = 0x A5
        - Ticks per ambient light set to 1 = 0x 00 01
        - Register 0x 47 with bit 7 set to 1 = 0x C7
        - Sample period set to 30 seconds = 0x 00 00 00 1E
        - Register 0x 48 with bit 7 set to 1 = 0x C8
        - Threshold based transmission enabled, and threshold set to 30 = 0x 9E
        - Register 0x 49 with bit 7 set to 1 = 0x C9
        - State and intensity reports enabled = 0x 03

12 System Diagnostics

The COMFORT/VIVID v2 has a system diagnostics mechanism for managing and recording resets, transducer failures, and other unexpected operational issues that may arise during sensor usage.

12.1 Operation Description

The system is designed to continue functioning in the event of non-critical failures while attempting to surgically recover from system errors and failures. Regardless of the recovery outcome, a log is maintained and can be retrieved by sending a DL command. Additionally, the log keeps track of the reset count to monitor the number of disruptions the system experiences.

The supported component error diagnostics counters are described below

- Barometer Failure: occurs when system is unable to communicate with the barometer
- I2C Bus Failure: occurs when the system is unable to communicate with its I2C peripherals

The sensor will increment the respective error counter immediately after the error occurs and before it takes remediate action, such as forcing the failed peripheral/component to restart or rebooting the system.

The supported reset error diagnostics counters are described below

- Programmer Reset: occurs when the sensor is reset by the programmer.
- SW Command Reset: occurs when a SW reset occurs (including if the sensor receives a downlink (sent on LoRaWAN port 100) containing the sensor reset command (see section 5.4.2).
- Independent Watchdog Reset: occurs when the system gets locked up due to a SW bug.
- Power Loss Reset: occurs when the Sensor's battery is removed or experiences a brown-out.
- Other resets: refers to all other types of reset causes not covered within the scope of this document.

Upon a successful JOIN event, the COMFORT/VIVID v2 sends the diagnostics reports as part of the first set of uplinks.

12.2 UL Frame Report Format

System diagnostics reports are sent on ***LoRaWAN port 5*** and have the frame format as shown in section 5.3.2. The specific details for the uplink frame formats are listed in Table 12-1. For the general description of sensor data report formats and behaviour, see section 4.1.

Table 12-1: Ambient Environment Data Report UL Frame Formats

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Sensor Reset Diagnostics	0x40	0x06	5 B	Reset History	• Bits 0-7: Programmer reset counter • Bits 8-15: SW reset counter • Bits 16-23: Independent watchdog reset counter • Bits 24-31: Power loss reset counter • Bits 32-39: Latest reset reason code 0x01 = Programmer reset 0x02 = SW reset (incl. DL request) 0x04 = Independent watchdog reset 0x10 = Power loss reset 0x80 = Other resets	*reset_diagnostics: {* *reset_reason: <value> (string/no unit)* *power_loss_reset_count: <value> (unsigned/no unit)* *watchdog_reset_count: <value> (unsigned/no unit)* *sw_reset_count: <value> (unsigned/no unit)* *programmer_reset_count: <value> (unsigned/no unit)* *}*
Sensor Error Diagnostics	0x40	0x07	5 B	Error History	• Bits 0-7: I2C Bus Failure • Bits 8-15: Barometer Failure • Bits 16-23: RFU • Bits 24-31: RFU • Bits 32-39: RFU	*error_diagnostics: {* *barometer_failure: <value> (string/no unit)* *i2c_failure: <value> (string/no unit)* *}*
Sensor Assertion Diagnostics	0x40	0x08	8 B	Assertion Info	• Bits 32-63: LR • Bits 0-31: PC	*assertion_diagnostics: {* *lr_failure: <value> (string/no unit)* *pc_failure: <value> (string/no unit)* *}*

12.2.1 Example UL Payloads

- 0x **40 06** 02 01 00 03 04
  - Channel ID = 0x 40, Type ID = 0x 06 → sensor reset diagnostics
  - 0x 02 = latest reset reason code: SW reset,
  - 0x 01 = power loss reset count: 1,
  - 0x 00 = watchdog reset count: 0,
  - 0x 03 = SW reset count: 3,

- 0x 04 = programmer reset count: 4

- 0x **40 07** 00 00 00 03 01
  - Channel ID = 0x 40, Type ID = 0x 07 → sensor error diagnostics
  - 0x 00 = RFU,
  - 0x 03 = barometer failure: 3,
  - 0x 01 = i2c bus failure: 1

12.3 Configuration Settings

The read-only register for querying the system diagnostics report is tabulated in Table 12-2. This query code must be sent on *port 5* to request for the latest systems diagnostics report.

Table 12-2: Systems Diagnostics Configuration Registers

Address	Name	Access	Description
0x40	Systems Diagnostics Query	RO	Query systems diagnostics information from sensor

12.3.1 Example DL Payloads

- Read latest systems diagnostics report
  - DL payload: 0x **40**

13 Critical Data Delivery Assurance (CDDA)

By default, all event-based reports are transmitted on port 10, just like the periodic reports. This can make it challenging to distinguish between periodic and event-based reports because both types of uplink frames have identical formats and are sent on the same LoRaWAN uplink ports. When both reporting types are enabled simultaneously for any transducer, it becomes difficult for an application to determine whether an event occurred or if the information was periodically reported based solely on the uplink. Although the content or timestamps of the uplink can sometimes help identify if it is an event-based or periodic report, CDDA offers an alternative method to ensure that event-based reports are not missed or ignored by the application.

This method provides a clear distinction between event-based and periodic reports, enhancing the application's ability to accurately interpret and respond to the data received. The feature also supports retransmission of event-based uplinks and allows the application to acknowledge the receipt of event transmissions.

13.1 Operation Description

Each event is reported in an event block, and each event-based uplink is made up of one or more event blocks. Figure 13-1 shows the frame format of an event block, where each field is summarized in Table 13-1.

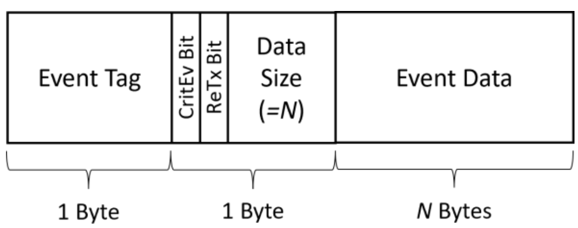


Figure 13-1: Frame Format of a CDDA Event Block

Table 13-1: CDDA Event Block Frame Description

Value	Size	Description
Event Tag	1 B	• Event Tag counter that increments every time an event of any kind occurs
Data Size	1 B	• Bit 7: Critical Event Bit 0 = Event is not critical 1 = Event is critical • Bit 6: Retransmission Bit 0 = This is the first time the event with this Event Tag is transmitted 1 = This is a retransmission of the event with this Event Tag • Bits 0-5: Event Data size (*N*) (1 byte / LSB)
Event Data	*N* B	• One or more event data chunks to be reported, which follow the port 10 uplink formats from the sensor's TRM

Event Tag:

Each event to be reported is associated with an event tag, which is carried in the first byte of an event block. The event tag is a wraparound counter that increments with every unique event occurrence, regardless of type. This includes subsequent events of the same type (e.g., two accelerometer events happening consecutively would have two different event tags).

Retransmissions (if enabled) should contain the same event tag as the original event they are retransmitting. When the event tag counter reaches its maximum value of 255 (0xFF), it wraps around to zero. Additionally, the event tag counter resets to zero upon a sensor restart, as the sensor does not retain information about past events in reset-safe RAM or non-volatile memory (NVM).

Data Size:

Bits 0-5 of the data size field, also known as N, indicate the number of bytes to follow in the event data field of the event block. The data size always equals N for the event data associated with the event block, even if the event data must be split into data chunks as described in Section 13.1.1.

> **NOTE:** N represents the size of each event block, not the total payload size. An uplink may contain more than one event block, each with its own N values.

Bit 6 of the data size field indicates whether the event is being retransmitted according to the CDDA protocol detailed in Section 13.1.2.1 (Bit 6 = 1), or if this is the first time the event is being reported (Bit 6 = 0).

Bit 7 of the data size field indicates whether the event is critical (Bit 7 = 1) or not critical (Bit 7 = 0). More information on critical events can be found in Section 13.1.2.

Event Data:

The event data field of a single event block contains the sensing data that would otherwise be reported for the specific event on port 10. For each reported data type (or data chunk), this includes a 2-byte data header (Channel ID and Type ID) that allows the decoder to distinguish between different types of sensing data traditionally reported on LoRaWAN port 10.

For example, if a sensor is configured to report both the acceleration magnitude and acceleration vector when an acceleration event occurs, the event data field for that acceleration event would contain both the acceleration magnitude and acceleration vector values. For the COMFORT v2 sensor, this means that if both data types are to be reported, the event data field would include two data chunks, totaling 12 bytes in length (4 bytes for the acceleration magnitude + 8 bytes for the acceleration vector).

13.1.1 Event-Based ULs with Event Block Format

Enabling CDDA allows event-based uplinks to be transmitted on LoRaWAN port 11. If data fragmentation is required, they can also be transmitted on LoRaWAN port 12, following the event block format described in Section 13.1.

Generally, the sensor always attempts to incorporate as much of the event data as possible into one uplink (UL) packet. However, due to payload size limitations imposed by certain LoRaWAN data rates (DRs), the sensor may need to fragment the event data chunks in an event block across multiple UL packets. The following subsections describe the CDDA behavior for both fragmented and unfragmented transmissions.

13.1.1.1 Unfragmented Transmissions

This is the case where the sensor transmits one or more event blocks in a single UL on ***LoRaWAN port 11***. The packet format is shown in Figure 13-2 for up to *k* event blocks.

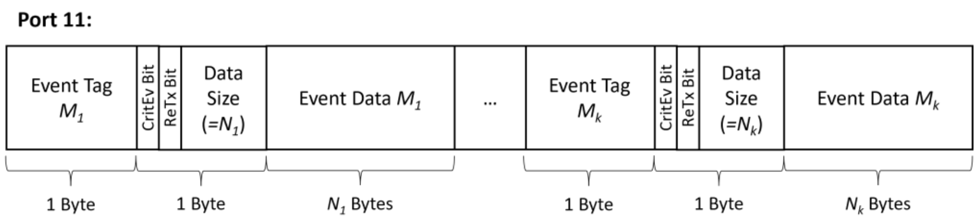


Figure 13-2: Frame Format of Unfragmented ULs sent on LoRaWAN Port 11

The payload can consist of one or more consecutive event blocks. Each event block's data is separated by data size bytes that indicate their respective lengths, allowing the application to easily distinguish each event block included in the UL payload.

13.1.1.2 Fragmented Transmissions

When the sensor must split an event block into multiple ULs due to payload size restrictions, the event data field may be divided into one or more data chunks. Each data chunk consists of sensing data that is typically reported by the sensor on LoRaWAN port 10. Each data chunk must be independently decodable in each payload.

The UL sent on ***LoRaWAN port 11*** can contain up to D_{11} number of data chunks (1 to *d*), while the UL sent on ***LoRaWAN port 12*** will then contain the D_{12} remaining data chunks (*d*+1 to *D*) to transmit. Both payload formats are shown in Figure 13-3 for up to *k* event blocks.

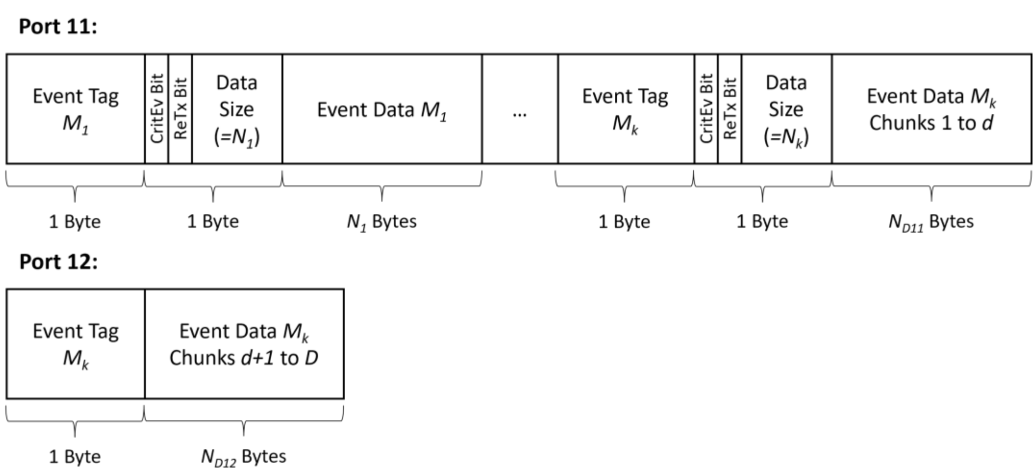


Figure 13-3: Frame Format of Fragmented ULs sent on LoRaWAN Ports 11 and 12

> **NOTE:** Only one event block should be fragmented into a UL ***sent on LoRaWAN port 12***. Any consecutive event blocks should be transmitted in a separate UL ***sent on LoRaWAN port 11 and/or LoRaWAN port 12*** as needed.

The application knows it has received all the fragments as intended only when the following three conditions are satisfied:

1. It has received the first *d* data chunks of the *k*-th event block ***sent on LoRaWAN port 11***.
2. The data chunk(s) in the UL ***sent on LoRaWAN port 12*** brings the total size of the fragmented event data of the respective event block to N_k bytes (i.e., $N_k = N_{D11} + N_{D12}$).

If either of the above conditions are not satisfied, the application should assume that the *k*-th event block has not been completely received, and as such, it should not send an application layer acknowledgement (ALA) for the *k*-th event block (if required). However, if the UL ***sent on LoRaWAN port 11*** contains multiple event blocks, then the application may ALA the unfragmented event blocks contained in the payload.

13.1.2 Critical Events

The Critical Data Delivery Assurance (CDDA) protocol allows users to designate certain events as critical, which requires an Application Layer Acknowledgment (ALA). If an ALA is not received, the event will be retransmitted a specified number of times. The types of events available will depend on the sensor model, so the critical event mechanism should be implemented according to the sensor's event-based reporting capabilities. For instance, since the COMFORT v2 does not support PIR capabilities, PIR-based events should not be configured for the COMFORT v2 using CDDA.

13.1.2.1 Retransmissions

Critical events are retransmitted based on a set retransmission period and retransmission count. Here's how it works:

1. Retransmission Period:
   - This determines the time interval between retransmissions.
2. Retransmission Count:
   - If indefinite retransmission is disabled, the sensor will stop retransmitting after the maximum number of retransmissions set by the retransmission count.
   - If indefinite retransmission is enabled, the sensor will continue retransmitting until an ALA is received. Once the retransmission count is reached, the event will no longer follow the retransmission period but will instead synchronize with all future periodic reporting periods.

This retransmission configuration applies whether or not the critical event uplink is fragmented. Therefore, if the event is sent on both LoRaWAN port 11 and LoRaWAN port 12, both uplinks will be retransmitted.

If a new critical event occurs before the previous critical event of the same type has stopped retransmitting, the sensor will:

- Reset the retransmission count to zero.
- Begin retransmitting the most recent critical event based on the set retransmission period, retransmission count, and indefinite retransmission configuration.
- Consider the previous critical event of the same type expired, and it will no longer be retransmitted.

When multiple critical events of different types occur at different times, the sensor will include all active critical events in each retransmission, if possible. The retransmission period will be relative to the first event that occurred.

For example:

- If unique event 1 occurs and is to be retransmitted every 1 minute, and then unique event 2 occurs 32 seconds later, both event 1 and event 2 will be retransmitted 28 seconds after event 2 occurred.

This ensures that all active critical events are retransmitted effectively and acknowledged promptly.

13.1.2.2 Application Layer Acknowledgments (ALAs)

If an ALA is required for retransmissions to end, meaning indefinite retransmissions are enabled, the application server/end-user must send a downlink command to the sensor on ***LoRaWAN Port 11*** to ALA one or more critical events. The downlink payload can include one or more event tags associated with events that are to be Acknowledged. The resulting downlink payload frame format is shown in Figure 13-4 for up to *k* event blocks.

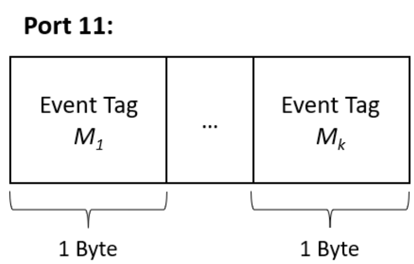


Figure 13-4: Frame Format of ALA DLs sent on LoRaWAN Port 11

If the sensor receives a downlink (DL) on LoRaWAN port 11 containing an event tag, it considers the event acknowledged and will cease retransmission of that event. The sensor ignores any expired or unrecognized event tags it receives. Since each event tag is of a fixed length, the sensor can accurately distinguish every event tag in the DL.

13.1.2.2.1 Retransmission Algorithm Examples

Figure 13-5 illustrates how the algorithm works when an ALA is required for retransmissions to stop while Figure 13-6 illustrates how the algorithm works when an ALA is not required for retransmissions to stop.

Sensor Settings:

- Fastest Core Tick Interval: 1 hour
- Critical Event Retransmission Period: 3 minutes (180 seconds)
- Critical Event Retransmission Count: 5
- **Indefinite retransmission is enabled (ALA is required to stop retransmission)**

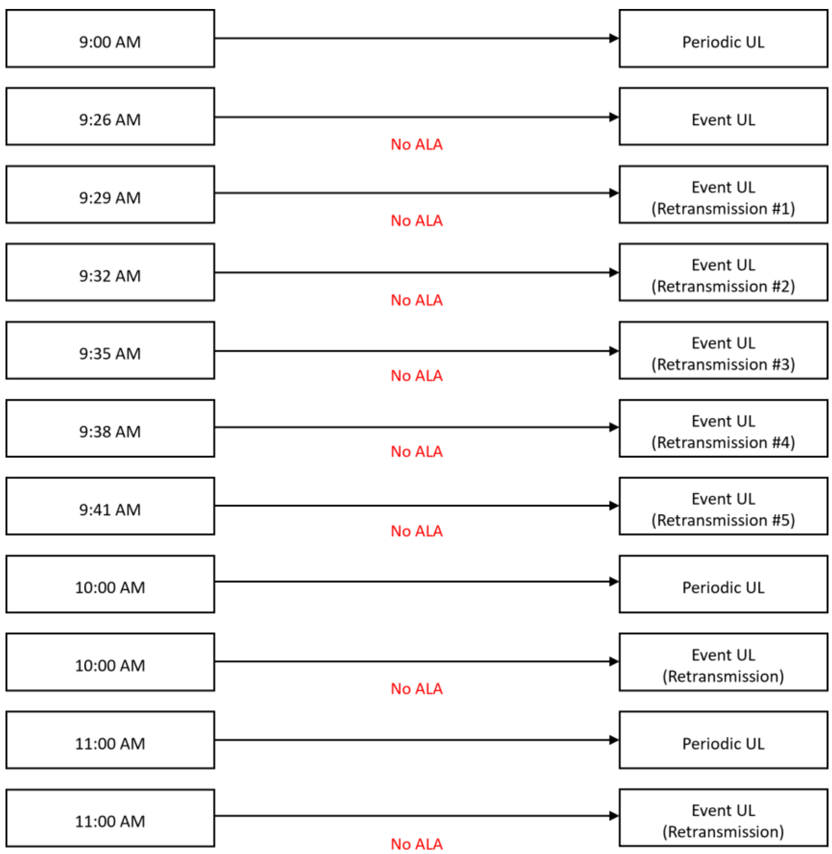


Figure 13-5: Retransmission Algorithm when ALA is required

Sensor Settings:

- Fastest Core Tick Interval: 1 hour
- Critical Event Retransmission Period: 3 minutes (180 seconds)
- Critical Event Retransmission Count: 5
- **Indefinite retransmission is disabled (ALA is not required to stop retransmission)**

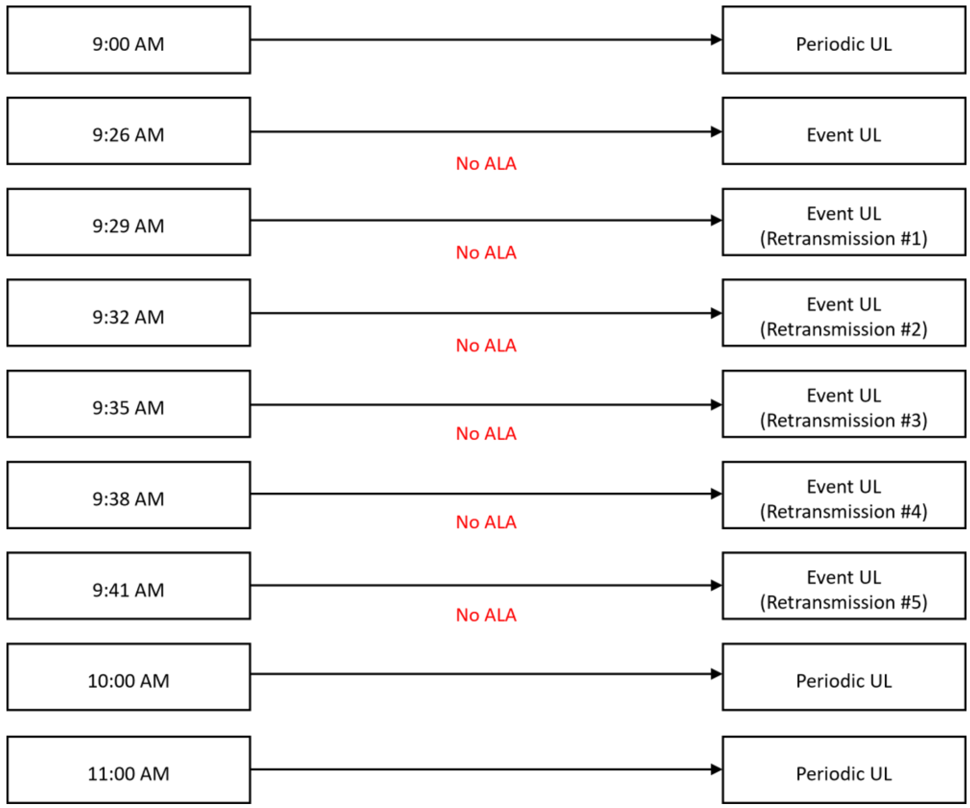


Figure 13-6: Retransmission Algorithm when ALA is not required

13.2 UL Frame Payload Format

The critical event options for the COMFORT and VIVID are as shown in Table 13-2 to match all the events supported by the COMFORT/VIVID v2. Note that not all listed reported data options must (or can) be reported for each event type simultaneously, as that depends on the sensor's capabilities and configuration options.

Table 13-2: Critical Events on COMFORT and VIVID v2 Sensor

Value to Enable	Critical Event Type	Description of Event	Event Data Options and UL Sizes (2-Byte Header Included)
1	Hall Effect Event	Detect the presence/absence of a magnet. Uses a configurable threshold to determine how many events must occur to trigger a UL.	• Hall Effect State (3 bytes) • Hall Effect Count (4 bytes)
2	Impact Alarm Event	Event triggers when acceleration crosses the configurable threshold. Event is cleared after the grace period has elapsed without threshold being crossed.	• Impact Alarm (3 bytes)

Value to Enable	Critical Event Type	Description of Event	Event Data Options and UL Sizes (2-Byte Header Included)
3	Acceleration Event[10]	Event triggers when acceleration crosses the configurable threshold.	• Acceleration Magnitude (4 bytes) • Acceleration Vector (8 bytes)
4	MCU Temperature Event	Event triggers when MCU temperature crosses the configurable high or low threshold.	• MCU Temperature (4 bytes)
5	Ambient Temperature Event	Event triggers when ambient temperature crosses the configurable high or low threshold.	• Ambient Temperature (4 bytes)
6	Ambient Relative Humidity Event	Event triggers when RH crosses the configurable high or low threshold.	• Ambient RH (3 bytes)
7	Ambient Light Event	Event triggers when light crosses the configurable threshold.	• Ambient Light State (3 bytes) • Ambient Light Intensity (3 bytes)
8	Presence (PIR) Event	Event triggers when PIR sees human presence. Event is cleared after the grace period has elapsed without human presence detected.	• Presence (PIR) Event State (3 bytes) • Presence (PIR) Event Count (4 bytes)
9	External Connector A – Digital Input Event Only	• Digital Input: Event triggers when digital input A is shorted/opened. Uses a configurable threshold to determine how many events must occur to trigger a UL. • Analog Input is not supported on Connector A	• Digital Input A State (3 bytes) • Relative Digital Input A Count (4 bytes) • Total Digital Input A Count (6 bytes)
10	External Connector B – Analog or Digital Input Event	• Digital Input: Event triggers when digital input is shorted/opened. Uses a configurable threshold to determine how many events must occur to trigger a UL. • Analog Input: Event triggers when analog input voltages cross the configurable high or low threshold. • Digital and Analog Inputs cannot be enabled simultaneously.	• Digital Input B State (3 bytes) • Relative Digital Input B Count (4 bytes) • Total Digital Input B Count (6 bytes) • Analog Input (4 bytes)

[10] While the impact alarm and acceleration events are both determined by the accelerometer, each feature can be independently enabled and configured and should be considered separate.

Value to Enable	Critical Event Type	Description of Event	Event Data Options and UL Sizes (2-Byte Header Included)
11	External Connectors – Digital Output Event	• Digital Output: Event and UL triggers when digital output is energized. Uses a configurable energization duration to determine how long the energization event lasts for.	• Digital Output State (3 bytes)

CDDA event-based reports are sent on LoRaWAN port 11 and 12, and have the frame format as shown in Figure 13-1. The specific details for the uplink frame formats are explained in Section 13.1.

13.2.1 Example UL Payloads

1. A COMFORT sensor is to transmit an event:
   - One accelerometer event with event tag 0x 09 (9)
     - Event is not a retransmission and does not require an ALA
     - Sensor reports acceleration magnitude as part of the event:
       - Value to transmit: 1000 m*g*
       - Event data chunk (4 bytes): 0x **05 02** 03 E8
     - Sensor reports acceleration vector as part of the event:
       - Value to transmit: X-axis = 0 m*g*, Y-axis = 0 m*g*, Z-axis = 1000 m*g*.
       - Event data chunk (8 bytes): 0x **07 71** 00 00 00 00 03 E8
     - Event block payload (14 bytes): 0x 09 0C **05 02** 03 E8 **07 71** 00 00 00 00 03 E8
   - **If unfragmented:** Port 11 UL payload (14 bytes): 0x 09 0C **05 02** 03 E8 **07 71** 00 00 00 00 03 E8

Port 11:

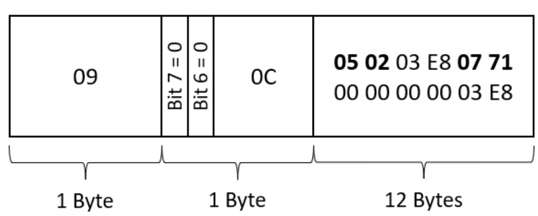


Figure 13-7: Example 1 – Unfragmented Case

- **If fragmented due to payload size limit of *11 bytes*:**
  - Port 11 UL payload (6 bytes): 0x 09 0C **05 02** 03 E8
  - Port 12 UL payload (9 bytes): 0x 09 **07 71** 00 00 00 00 03 E8

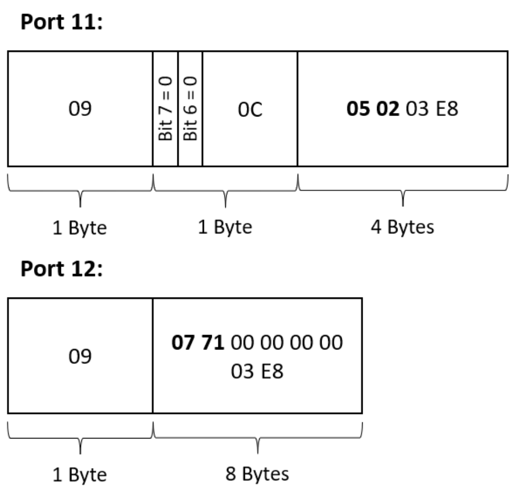


Figure 13-8: Example 1 – Fragmented Case

2. A COMFORT sensor is to transmit two events:
   - One ambient temperature event with event tag 0x 0A (10)
     - Event is a retransmission and requires an ALA
     - Sensor reports ambient temperature as part of the event:
       - Value to transmit: 23.4°C
       - Event data chunk (4 bytes): 0x **03 67** 00 EA
     - Event block payload (6 bytes): 0x <u>0A</u> C4 **03 67** 00 EA
   - One accelerometer event with event tag 0x 0B (11)
     - Event is a retransmission and requires ALA
     - Sensor reports acceleration magnitude as part of the event:
       - Value to transmit: 1000 m*g*
       - Event data chunk (4 bytes): 0x **05 02** 03 E8
     - Sensor reports acceleration vector as part of the event:
       - Value to transmit: X-axis = 0 m*g*, Y-axis = 0 m*g*, Z-axis = 1000 m*g*.
       - Event data chunk (8 bytes): 0x **07 71** 00 00 00 00 03 E8
     - Event block payload (14 bytes): 0x <u>0B</u> CC **05 02** 03 E8 **07 71** 00 00 00 00 03 E8
   - **If unfragmented:** Port 11 UL payload (20 bytes): 0x <u>0A</u> C4 **03 67** 00 EA <u>0B</u> CC **05 02** 03 E8 **07 71** 00 00 00 00 03 E8

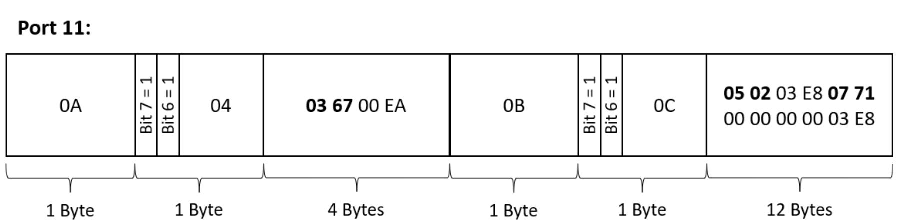


Figure 13-9: Example 2 – Unfragmented Case

- **If fragmented due to payload size limit of *15 bytes*:**
  - Port 11 UL payload (12 bytes): 0x <u>0A</u> C4 **03 67** 00 EA <u>0B</u> CC **05 02** 03 E8

- Port 12 UL payload (9 bytes): 0x 0B **07 71** 00 00 00 00 03 E8

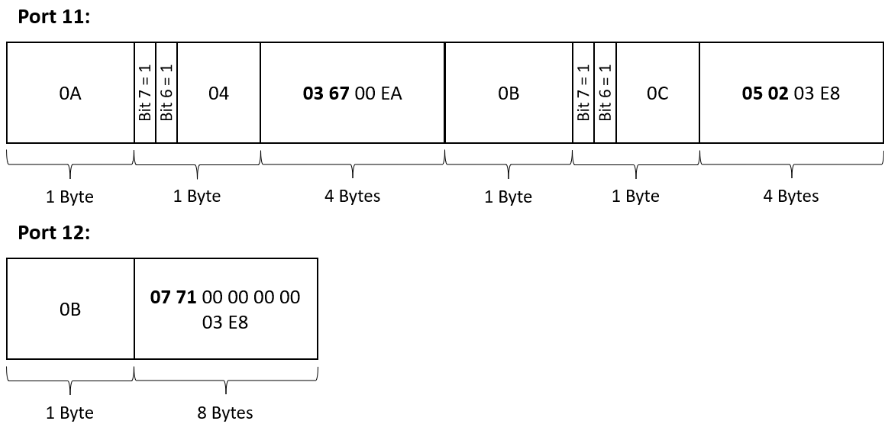


Figure 13-10: Example 2 – Fragmented Case

If an ALA is required for retransmissions to stop, the sensor must receive an ALA for each active critical event in order to stop retransmitting said critical events. Downlinks sent on ***LoRaWAN port 11*** may contain one or more critical event ALAs. As a result, the sensor should accept the following DL examples:

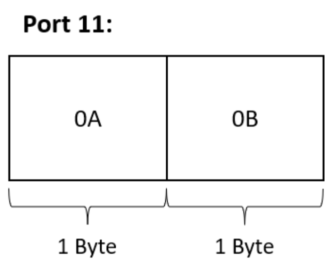


Figure 13-11: Example 2 – Multiple ALAs in One DL

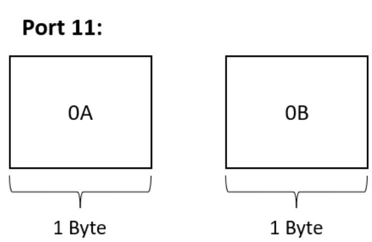


Figure 13-12: Example 2 – ALAs in Separate DLs

Assume the sensor previously transmitted an accelerometer event with event tag 0x 09 (see Example 1), which was superseded by the accelerometer event with event tag 0x 0B before it received an ALA. The application server may queue the following DL:

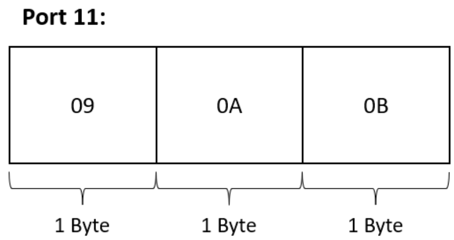


Figure 13-13: Example 2 – ALAs for Active and Expired Events

The sensor accepts this DL then ignore the expired/unknown event tag (0x 09) and consider events 0x 0A and 0x 0B ALAed.

3. A COMFORT v2 sensor is to transmit one event:
   - One accelerometer event with event tag 0x 0C (12)
     - Event is not a retransmission, but it does require an ALA
     - Sensor reports acceleration vector as part of the event:
       - Value to transmit: X-axis = 0 m*g*, Y-axis = 0 m*g*, Z-axis = 1000 m*g*.
       - Event data chunk (8 bytes): 0x **07 71** 00 00 00 00 03 E8
     - Event block payload (10 bytes): 0x 0C 88 **07 71** 00 00 00 00 03 E8
   - **If unfragmented:** Port 11 UL payload (10 bytes): 0x 0C 88 **07 71** 00 00 00 00 03 E8

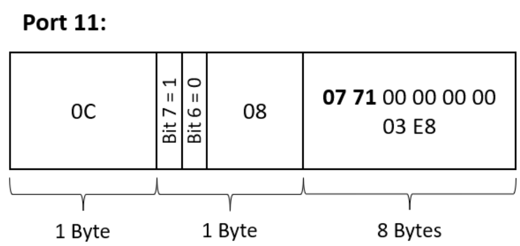
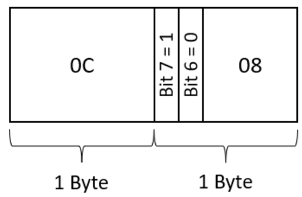


Figure 13-14: Example 3 – Unfragmented Case

   - **If fragmented due to payload size limit of *9 bytes*:**
     - Port 11 UL payload (2 bytes): 0x 0C 88
     - Port 12 UL payload (9 bytes): 0x 0C **07 71** 00 00 00 00 03 E8

Port 11:



Port 12:

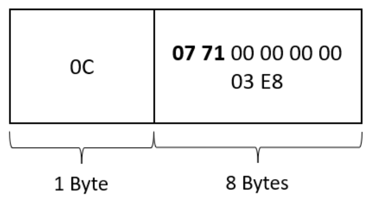


Figure 13-15: Example 3 – Fragmented Case

4. A COMFORT sensor is to transmit three events:
    - One ambient temperature event with event tag 0x 0D (13)
        - Event is a retransmission and requires an ALA
        - Sensor reports ambient temperature as part of the event:
            - Value to transmit: 23.4°C
            - Event data chunk (4 bytes): 0x **03 67** 00 EA
        - Event block payload (6 bytes): 0x 0D C4 **03 67** 00 EA
    - One digital input event with event tag 0x 0E (14)
        - Event is a retransmission and requires ALA
        - Sensor reports digital input state as part of the event:
            - Value to transmit: Low–Connector short-circuited (0x00)
            - Event data chunk (3 bytes): 0x **0E 00** 00
        - Sensor reports relative digital input count as part of the event:
            - Value to transmit: 32
            - Event data chunk (4 bytes): 0x **0F 04** 00 20
        - Event block payload (9 bytes): 0x 0E C7 **0E 00** 00 **0F 04** 00 20
    - One hall effect event with event tag 0x 0F (15)
        - Event is a retransmission and requires ALA
        - Sensor reports hall effect state as part of the event:
            - Value to transmit: High–Magnet absent (0xFF)
            - Event data chunk (3 bytes): 0x **01 00** FF
        - Sensor reports hall effect count as part of the event:
            - Value to transmit: 15
            - Event data chunk (4 bytes): 0x **08 04** 00 0F
        - Event block payload (9 bytes): 0x 0F C7 **01 00** FF **08 04** 00 0F
    - **If unfragmented:** Port 11 UL payload (24 bytes): 0x 0D C4 **03 67** 00 EA 0E C7 **0E 00** 00 **0F 04** 00 20 0F C7 **01 00** FF **08 04** 00 0F

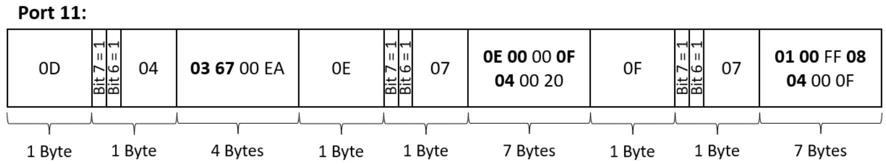


Figure 13-16: Example 4 – Unfragmented Case

- **If fragmented due to payload size limit of *11 bytes*:**
  - Port 11 UL payload (11 bytes): 0x 0D C4 **03 67** 00 EA 0E C7 **0E 00** 00
  - Port 12 UL payload (5 bytes): 0x 0E **0F 04** 00 20
  - Port 11 UL payload (9 bytes): 0x 0F C7 **01 00** FF **08 04** 00 0F

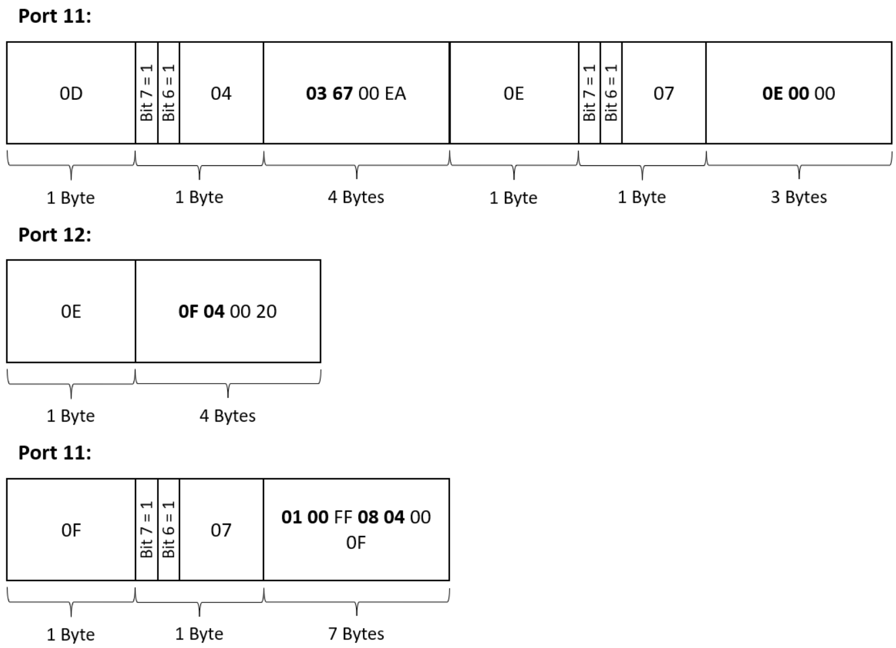


Figure 13-17: Example 4 – Fragmented Case

13.3 Configuration Settings

The supported downlink configuration commands ***sent on LoRaWAN port 100*** for CDDA configuration are summarized in Table 13-3. The commands listed in 0x6D are specific to the COMFORT and VIVID sensors, and should be adapted to the event-based capabilities of each sensor.

Table 13-3: Downlink (Port 100) Event Configuration Registers

Address	Name	Access	Size	Description	JSON Variable	Default
0x6C	Event Mode	R/W	1 B	• Bit 0: 0: Event-based data sent on Port 10 (legacy) 1: Event-based data sent on Port 11/12 with event-block format • Bits 1-7: RFU, must be 0, otherwise invalid	*cdda_event_mode: <value> (number/no unit)*	Event-based reports sent on port 10 **0x 00**
0x6D	Critical Event Options	R/W	2 B	• Toggle whether each event is critical or not • For each bit: 0/1 = <event type> is not a critical event/is a critical event • Bit 0: Hall Effect Event • Bit 1: Impact Alarm Event • Bit 2: Acceleration Event • Bit 3: MCU Temperature Event • Bit 4: Ambient Temperature Event • Bit 5: Ambient Relative Humidity Event • Bit 6: Ambient Light Event • Bit 7: External Connector A – Digital Input Event (COMFORT v2 only) • Bit 8: External Connector B –Analog or Digital Input Event (COMFORT v2 only) • Bit 9: External Connectors – Digital Output Event (COMFORT v2 only) • Bit 10: Presence (PIR) Event (VIVID v2 only) • Bit 11: PIR Initialization Event (VIVID v2 only) • Bits 12-15: RFU, must be 0, otherwise invalid	*cdda_critical_event_options: <value> (number/no unit)*	No critical events enabled **0x 00 00**

Address	Name	Access	Size	Description	JSON Variable	Default
0x6E	Retransmission Period and Retransmission Count	R/W	3 B	• Bits 0-15: Critical event retransmission period (s) • Acceptable values: 10, 11, …, 65535 • Other values: invalid • Bits 16-22: Critical event retransmission count (number of times to retransmit) • Bit 23: Indefinite Retransmission disabled/enabled • 0: Sensor will only retransmit the event the set number of times (ALA not required to stop retransmissions) 1: Sensor will retransmit the event the set number of times and synchronously with all future periodic events (ALA required to stop retransmissions)	*cdda_retransmission: <value> (number/no unit)*	Critical event retransmit period is 300 seconds (5 mins) Critical event retransmission count is 3 and will not retransmit indefinitely (does not require an ALA to stop retransmissions) **0x 03 01 2C**

NOTE: The sensor must be configured to report event-based data on port 11/12 via register 0x6C in order to use the CDDA feature. Configuring one or more events as critical via register 0x6D will not change the sensor behavior if the port 10 legacy behavior is enabled.

14 Accelerometer Enhanced Configuration

This section introduces enhanced configuration to expand the functionality of the accelerometer, as needed by some applications, such as toilet leakage or water flow detection. The enhanced functionality allows the user to configure Sample Analysis from when an **acceleration event** is registered **until the end of the event** OR when the **acceleration event debounce time** is expired (see Section 9.3.2)

14.1 Operation Description

The block diagram of such an analysis has been shown in Figure 14-1. The magnitudes of the accelerometer samples are low-pass filtered, then binned into a number of *magnitude levels (MLs)*, ML_0, ML_1, …, ML_p, where $1 \le p \le 15$. ML_0 is always the zero level, and not counted or kept track of for event reporting.

A whole run of the same ML is called an *ML event*, which has a length (duration) associated with it; e.g. a run of 3 ML_1 is an ML_1 event of duration 3. ML events can have length 1. That can happen due to noisy and quick jumps between MLs. Enabled hysteresis in binning can reduce noise.

An *analytical event (AE)* is defined by an ML (ML_1 to ML_{15}) and a *duration range (DRan)*. In other words, an AE is an ML event with a duration within some range. To avoid complexity, from 1 to only 4 DRans can be defined, and only for ML_1 and ML_2; ML_3 to ML_{15} always have 1 DRan. The case of 1 DRan, $DRan_0$, for ML_p ($1 \le p \le 15$) means there is no duration limits for ML_p and any ML_p event (i.e. any whole run of ML_p) is considered an AE, denoted by $AE_{p,0}$, where index 0 means $DRan_0$.

The case of 2 DRans for ML_1 or ML_2 is defined by 1 *duration limit (DLim)*, $DLim_0$, where durations below $DLim_0$ constitute $DRan_0$ and those above $DLim_0$ constitute $DRan_1$, thus having 2 DRans below and above a single DLim. Similarly, the cases of 3 and 4 DRans for ML_1 or ML_2 ($DRan_0$ to $DRan_2$, and $DRan_0$ to $DRan_3$) are defined by 2 DLims ($DLim_0$ and $DLim_1$) and 3 DLims ($DLim_0$, $DLim_1$, and $DLim_2$), respectively. Now, $AE_{1,q}$ ($0 \le q \le 3$) simply denotes an ML_1 event with the duration inside $DRan_q$ of ML_1. Similarly, $AE_{2,q}$ ($0 \le q \le 3$) is an ML_2 event with the duration inside $DRan_q$ of ML_2.

The Count & Group block in Figure 14-1 counts and keeps track of statistics of all defined AEs. For example, it is possible that 15 MLs, ML_1 or ML_{15}, each with only one DRan, $DRan_0$, have been defined, e.g. during application training where DLims are not known yet. In this case, we have a total of 15 AEs, $AE_{1,0}$ to $AE_{15,0}$. After the training, the application may learn a DLim, and only define $AE_{1,0}$ and $AE_{1,1}$ for the sensor, i.e. AEs associated with a single ML, ML_1, and 2 DRans, $DRan_0$ and $DRan_1$, which are defined by only 1 DLim, $DLim_0$, for ML_1.

Simply put, $AE_{p,q}$ denotes an ML_p event ($p > 0$) with duration within $DRan_q$, where $DRan_q$ is the DRan between $DLim_{q-1}$ and $DLim_q$. The Count & Group block in Figure 14-1 keeps track of all defined $AE_{p,q}$'s within the acceleration event debounce time, and update statistics for these AEs at the end of each debounce interval. At the periodic reporting time, the statistics asked for are reported for all defined $AE_{p,q}$'s. These statistics include total duration, min duration, max duration, duration SD, and count. All the statistics and counters for all defined AEs are cleared when an acceleration event stop is detected OR a periodic report is made.

It is also possible to enable threshold-based reporting on one of the statistics, the duration total and duration count. As soon as that statistic for a defined $AE_{p,q}$ exceeds the $AE_{p,q}$'s corresponding threshold, the value of that statistic is reported for the $AE_{p,q}$. Such a threshold-based report does not reset the counters or statistics. It is just for periodic reports, and the detection of an acceleration stop event, that all counters are reset.[11]

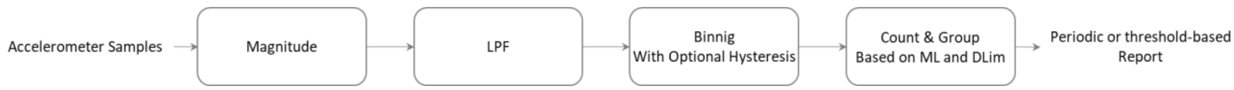


Figure 14-1: Block diagram of the Sample Analysis after an acceleration event

14.2 Application Examples

Example: 8 MLs, ML_1 to ML_8, with 1 DRan ($DRan_0$) have been defined for the sensor. In a debounce time, the following MLs come out of the binning block:

ML_4 ML_4 ML_4 ML_0 ML_0 ML_5 ML_3 ML_3 ML_0 ML_7 ML_6 ML_3 ML_8 ML_8 ML_8 ML_8 ML_0 ML_0 ML_0 ML_0 ML_1 ML_1 ML_1 ML_1 ML_3 ML_6 ML_5 ML_5 ML_3 ML_6 ML_4 ML_7 ML_5 ML_2 ML_2 ML_2 ML_2 ML2 ML_2 ML_2 ML_0

Table 14-1 the AE analysis results for this example. It shows there are one $AE_{1,0}$, one $AE_{2,0}$, four $AE_{3,0}$, two $AE_{4,0}$, three $AE_{5,0}$, three $AE_{6,0}$, two $AE_{7,0}$, and one $AE_{8,0}$.

> **NOTE:** ML_0 is the zero level and does not define an AE.

Table 14-1: Example of AEs and Their Statistics in an Acceleration Debounce Time

	ML1	ML2	ML3	ML4	ML5	ML6	ML7	ML8
AE Runs	4	7	2	3	1	1	1	4
			1	1	2	1	1	
			1		1	1		
			1					
Total Duration	4	7	5	4	4	3	2	4
Min Duration	4	7	1	1	1	1	1	4
Max Duration	4	7	2	3	2	1	1	4
Duration SD	0	0	0.5	1.4	0.6	0	0	0
Count	1	1	4	2	3	3	2	1

[11] However, if counters are not reset after a threshold-based report, the threshold keeps getting triggered. To avoid this issue, SW increases the thresholds appropriately each time a threshold is exceeded, but then resets all the thresholds to their original values at the time of a periodic report.

14.3 Configuration Settings

The supported downlink configuration commands ***sent on LoRaWAN port 100*** for the enhanced accelerometer configuration are summarized in Table 14-2. To access these registers, a command must be formatted and sent according to the details described in Section 4.2.

Table 14-2: Enhanced Accelerometer Configuration Registers

Address	Name	Access	Size	Description	JSON Variable	Default
0x60	Sample Analysis Mode	R/W	1 B	• Bits 0-3: IIR filter recall factor • Bit 7: 0/1: Sample analysis disabled/enabled • Bit 4-6: Ignored	*sample_analysis_mode: {* *iir_recall_factor: <value> (unsigned/no unit)* *analysis_enabled: <value> (unsigned/no unit)* *}*	IIR filter recall factor set to 4 Sample analysis disabled **0x 04**
0x61	HPF Configuration	R/W	1 B	• Bits 0: 0/1: HPF disabled/enabled on accelerometer outputs • Bit 1: 0/1: HPF disabled/enabled on accelerometer outputs • Bit 2: 0/1 = HPF disabled/enabled on Sample Analysis • Bit 4-5: HPF cutoff frequency selector • Acceptable values: 0, 1, 2, 3 Larger number = smaller cutoff • Bit 3, 6, 7: Ignored	*hpf_mode: {* *enabled_on_outputs: <value> (unsigned/no unit)* *enabled_on_interrupts: <value> (unsigned/no unit)* *enabled_on_sample_analysis: <value> (unsigned/no unit)* *cutoff: <value> (unsigned/no unit)* *}*	HPF disabled on accelerometer interrupts HPF enabled on accelerometer interrupts HPF enabled on Sample Analysis HPF cutoff frequency selector set to 0 **0x 06**

Address	Name	Access	Size	Description	JSON Variable	Default
0x62	Acceleration Event Stop Thresholds	R/W	4 B	• Bits 16-31: Stop Threshold, unsigned 1 milli-/LSB, 0 = disabled • Bits 0-15: Minimum Report Duration, unsigned, 1 s-/LSB, 0 = report all events	*acceleration_event_stop_thresholds: {* *acceleration_event_stop_threshold: <value> (unsigned/g)* *acceleration_event_report_duration_min:<value>, (unsigned/s)* *}*	Stop threshold disabled Minimum report duration set to 5 s **0x 00 00 00 05**
0x63	ML Configuration	R/W	7 B	• Bits 48-55: Number of nonzero MLs (1 ≤ · ≤ 15) • Bits 32-47: ML1 upper limit, 1 mg/LSB • Bits 16-31: ML1 lower limit, 1 mg/LSB • Bits 0-15: ML step, 1 mg/LSB • Number of nonzero MLs = 0 or > 15: Invalid and ignored • ML1 upper limit < ML1 lower limit: Invalid and ignored • ML1 upper limit = ML1 lower limit: Hysteresis disabled • Number of nonzero MLs > 1 & ML step = 0: Invalid and ignored	*ml_config: {* *num: <value> (unsigned/no unit)* *ml1upper: <value> (unsigned/g)* *ml1lower: <value> (unsigned/g)* *ml_step: <value>, (unsigned/g)* *}*	Number of nonzero MLs = 8 ML1 upper limit = 40 mg ML1 lower limit = 20 mg ML step = 30 mg **0x 08 00 28 00 14 00 1E**
0x64	ML_1 DLim Configuration	R/W	5 B	• Bits 32-39: Number of DLims (0 ≤ · ≤ 3) • Bits 16-31: DLim0, 1 sec/LSB • Bits 0-15: DLim step, 1 sec/LSB • Number of DLims > 3: Invalid and ignored • Number of DLims > 1 & DLim step = 0: Invalid and ignored	*ml1_dlim_config: {* *num_dlims: <value> (unsigned/no unit)* *dlim0: <value> (unsigned/sec)* *dlim_step: <value> (unsigned/sec)* *}*	Number of DLims = 0 $DLim_0$ = 0 DLim step = 0 **0x 00 00 00 00 00**

Address	Name	Access	Size	Description	JSON Variable	Default
0x65	ML_2 DLim Configuration	R/W	5 B	• Bits 32-39: Number of DLims (0 ≤ · ≤ 3) • Bits 16-31: DLim0, 1 sec/LSB • Bits 0-15: DLim step, 1 sec/LSB • Number of DLims > 3: Invalid and ignored • Number of DLims > 1 & DLim step = 0: Invalid and ignored	*ml2_dlim_config: {* *num_dlims: <value> (unsigned/no unit)* *dlim0: <value> (unsigned/sec)* *dlim_step: <value> (unsigned/sec)* *}*	Number of DLims = 0 $DLim_0$ = 0 DLim step = 0 **0x 00 00 00 00 00**
0x66	$AE_{1, x}$ Thresholds	R/W	9 B	• Bits 64-71: 0: Thresholds disabled 1: Thresholds enabled on duration total 2: Thresholds enabled on count 3-255: Invalid and ignored • Bits 48-63: AE1, 0 threshold, unsigned 1 sec or 1 count/LSB • Bits 32-47: AE1, 1 threshold, unsigned, 1 sec or 1 count/LSB • Bits 16-31: AE1, 2 threshold, unsigned, 1 sec or 1 count/LSB • Bits 0-15: AE1, 3 threshold, unsigned, 1 sec or 1 count/LSB	*AE1_thresholds: {* *thresholds_enabled: <value> (unsigned/no unit)* *ae10_threshold: <value> (unsigned/sec)* *ae11_threshold: <value> (unsigned/sec)* *ae12_threshold: <value> (unsigned/sec)* *ae13_threshold: <value> (unsigned/sec)* *}*	Thresholds disabled $AE_{1, 0}$, $AE_{1, 1}$, $AE_{1, 2}$, $AE_{1, 3}$ thresholds set to 0 **0x 00 00 00 00 00 00 00 00 00**

Address	Name	Access	Size	Description	JSON Variable	Default
0x67	$AE_{2, x}$ Thresholds	R/W	9 B	• Bits 64-71: 0: Thresholds disabled 1: Thresholds enabled on duration total 2: Thresholds enabled on count 3-255: Invalid and ignored • Bits 48-63: AE2, 0 threshold, unsigned 1 sec or 1 count/LSB • Bits 32-47: AE2, 1 threshold, unsigned, 1 sec or 1 count/LSB • Bits 16-31: AE2, 2 threshold, unsigned, 1 sec or 1 count/LSB • Bits 0-15: AE2, 3 threshold, unsigned, 1 sec or 1 count/LSB	*AE2_thresholds: {* *thresholds_enabled: <value> (unsigned/no unit)* *ae20_threshold: <value> (unsigned/sec)* *ae21_threshold: <value> (unsigned/sec)* *ae22_threshold: <value> (unsigned/sec)* *ae23_threshold: <value> (unsigned/sec)* *}*	Thresholds disabled $AE_{2, 0}$, $AE_{2, 1}$, $AE_{2, 2}$, $AE_{2, 3}$ thresholds set to 0 **0x 00 00 00 00 00 00 00 00 00**
0x68	Sample Analysis Report Options (applicable to both periodic and event-based transmissions)	R/W	1 B	• Bits 0: 0/1: AE duration total disabled/enabled • Bit 1: 0/1: AE duration min disabled/enabled • Bit 2: 0/1: AE duration max disabled/enabled • Bit 3: 0/1: AE duration SD disabled/enabled • Bit 4: 0/1: AE count disabled/enabled • Bit 5-7: Ignored	*accelerometer_analysis_tx: {* *duration_total_enabled: <value> (unsigned/no unit)* *duration_min_enabled: <value> (unsigned/no unit)* *duration_max_enabled: <value> (unsigned/no unit)* *duration_sd_enabled: <value> (unsigned/no unit)* *count_enabled: <value> (unsigned/no unit)* *}*	AE duration total enabled **0x 01**

14.3.1 Example DL Payloads

14.3.1.1 Water Flow Detection Use Case (Without Sensor Learning)

In the water flow detection use case, the application server configures the sensor in a way that allows the sensor to collect data using a Sample Analysis, and report it in the form of a configurable histogram as well as acceleration vector data. This prepares data for use in a statistical physics model or training an AI model for flow detection.

The main components involved in the Use Case and their recommended configuration is described in Table 14-3. These can be reconfigured to further customize the application. See the register corresponding to each output for details on configuration.

Table 14-3: Recommended Use-Case Configuration

Register (Hex)	Write Command (Hex)	Output
20	A0 00 00 38 40	Set periodic uplink configuration (Core Tick) to 4 hours
21	A1 00 00	Disables periodic Battery reports
22	A2 00 00	Disables periodic Ambient Temperature reports
23	A3 00 00	Disables periodic Ambient RH reports
26	A6 00 01	Enables periodic Accelerometer reports (once per Core Tick)
31	B1 00 32	Sets Acceleration Event Threshold set to 50 m*g*
32	B2 04	Enables periodic Acceleration Vector reports
34	B4 F6	Enables Acceleration Event Threshold, Normal mode, X/Y/Z axes, and power Accelerometer on
35	B5 03	Sets Sample Rate and Measurement Range to 25 Hz and ±2 *g*
60	E0 84	Sets recall factor of IIR filter to 4, and enables Sample Analysis mode
61	E1 06	Enables HPF on Accelerometer Interrupts and Sample Analysis
62	E2 00 0a 00 03	Sets the Stop Threshold to 10 m*g* and Minimum Report Duration to 3s
63	E3 0f 00 32 00 32 00 0a	Configures MLs [E3 [ML] [ML_1_High] [ML_1_Low] [ML_Step]] to ML = 15 bins, lower and upper limits = 50 m*g*, and step to 10 m*g.* Hysteresis is disabled.
68	E8 01	Reports the AE duration total (duration at each ML, $AE_{p,0}$)
70	F0 20 00	Save configuration to flash

The write commands can be sent separately, or as one downlink: A0 00 00 38 40 A1 00 00 A2 00 00 A3 00 00 A6 00 01 B1 00 32 B2 04 B4 F6 B5 03 E0 84 E1 06 E2 00 0a 00 03 E3 0f 00 32 00 32 00 0f E8 01 F0 20 00

The uplink format reported by the sensor includes Analytical Event data as well as the Acceleration Vector. Details are provided in Table 8-8.

14.3.1.2 Water Flow Detection Use Case (With Sensor Learning)

In the water flow detection use case, the application server configures the sensor in a way that allows the sensor to collect data and uplink it to the application so the application learns how to set the sensor configuration to detect toilet leakages. We call this the training stage.

The training stage starts after the sensor joins the network, or after it gets triggered by a magnet so it sends an alarm, from which the application understands the sensor is ready and sends the sensor the proper training configuration.

The training configuration has two parts. The first part includes the following:

1. Set the core tick to 10 min, and accelerometer tick to 1 hour, but the other ticks to 0:

   0x A0 00 00 02 58 A1 00 00 A2 00 00 A3 00 00 A6 00 01

2. Set the acceleration event threshold to 0:

   0x B1 00 00

3. Enable the periodic accelerometer vector:

   0x B2 04

4. Se the acceleration event debounce time to 90 sec:

   0x B3 00 5A

5. Power on the accelerometer and enable the acceleration event threshold:

   0x B4 F2

6. Enable the accelerometer with sample rate of 10 Hz and measurement range of ±2 *g*:

   0x B5 02

7. Enable Sample Analysis and IIR filtering with recall factor of 4:

   0x E0 84

8. Disable HPF for periodic accelerometer vector reporting, but enable HPF with cutoff index 0 for accelerometer triggers and Sample Analysis:

   0x E1 06

9. Define 8 (nonzero) MLs with upper and lower limits of 20 m*g* to 160 m*g* in steps of 20 m*g:*

   0x E3 08 00 14 00 14 00 14

10. Enable AE duration total reporting:

    0x E8 01

The above configuration can be sent in one DL command as:

0x A0 00 00 02 58 A1 00 00 A2 00 00 A3 00 00 A6 00 01 B1 00 00 B2 04 B3 00 3C B4 F2 B5 02 E0 84 E1 06 E3 08 00 14 00 14 00 14 E8 01

or “oAAAAlihAACiAACjAACmAAGxAACyBLMAPLTytQLghOEG4wgAFAAUABToAQ==” in Base64.

With the above configuration, the application receives a histogram for 8 bins from the sensor after a few report periods. With this histogram, the application finds a suitable acceleration event threshold and ML_1 for leakage detection. In the second part of the training, the application tries to configure the sensor with only one (nonzero) ML and derives statistics on the durations of runs of ML_1. To this end, the application reconfigures the sensor as follows:

1. 1 ML with a hysteresis of 20 m*g* is defined for the sensor, with the ML upper limit derived from the histogram obtained from the first part of the training stage:

   0x E3 01 <xx xx> <xx xx - 20> 00 00

   where <xx xx> is the threshold in hex.

2. AE duration total and AE duration count are enabled for periodic reporting:

   0x E8 11

The above configuration can be sent in one DL command as:

0x E3 01 <xx xx> <xx xx - 20> 00 00 E8 11.

After a few reports of the sensor data, the application finds out the average duration range of a normal flush, thus determining $DLim_0$ and $DLim_1$, and defining 3 DRans for ML_1 ($DRan_0$ corresponding to hiccup flushes, $DRan_1$ corresponding to normal flushes, and $DRan_2$ corresponding to water running events). Now, the application configures the sensor as follows for normal operation:

1. Set the acceleration event threshold to the threshold obtained from the histogram analysis in the training stage, part 1:

   0x B1 <xx xx>

   where <xx xx> is the threshold.

2. Set the acceleration event debounce time 10 sec above the estimated average time of a normal flush:

   0x B3 <yy yy + 10>

   where <yy yy> is the estimated average of the duration of a normal flush.

3. Define two DLims with the obtained values from the training for ML_1, and enable threshold-based reporting on $AE_{1,0}$, $AE_{1,1}$, or $AE_{1,2}$, as desired:

   0x E4 02 <zz zz> <tt tt> 01 <aa aa> <bb bb> <cc cc> 00 00

   where <zz zz>, <tt tt>, <aa aa>, <bb bb>, and <cc cc> are $DLim_0$, DLim step, $AE_{1,0}$ threshold, $AE_{1,1}$ threshold, and $AE_{1,2}$ threshold, respectively.

The above configuration can be sent in one DL command as:

0x B1 <xx xx> B3 <yy yy + 10> E4 02 <zz zz> <tt tt> 01 <aa aa> <bb bb> <cc cc> 00 00.

Appendix 1

Port 10 Uplinks

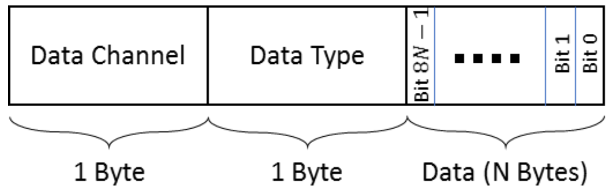


Figure 0-1: The UL Frame Format for port 10 uplinks

Table 0-1: Port 10 uplinks

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Battery Voltage	0x00	0xBA	2 B	Volts	• 1 millivolt / LSb	*battery_voltage: <value> (unsigned/volts)*
Remaining Battery Capacity	0x00	0xD3	1 B	Percentage	• 1% / LSb (unsigned)	*rem_batt_capacity: <value> (unsigned/%)*
Hall Effect State	0x01	0x00	1 B	Digital	• 0x00 = Low—magnet present • 0xFF = High—magnet absent	*hall_effect_state: <value> (unsigned/no unit)*
Hall Effect Count	0x08	0x04	2 B	Counter	• Bits 0-15: Number	*hall_effect_count: <value> (unsigned/no unit)*
External Connector A: Digital Input State	0x1E	0x00	1 B	Digital	• 0x00 = Low—Connector A short-circuited • 0xFF = High—Connector A open-circuited	*extconnector_a_state: <value> (unsigned/no unit)*
External Connector B: Analog Input[12]	0x11	0x02	2 B	Voltage	• Bits 0-15: 1mv/LSB	*extconnector_b_analog: <value> (signed/V)*
External Connector B: Digital Input State	0x0E	0x00	1 B	Digital	• 0x00 = Low—Connector B short-circuited • 0xFF = High—Connector B open-circuited	*extconnector_b_state: <value> (unsigned/no unit)*
External Connector A: Relative Digital Input Count	0x1F	0x04	2 B	Counter	• Bits 0 – 15: Relative Digital Count for Connector A since last transmission	*extconnector_a_relative_count: <value> (unsigned/no unit)*

[12] Voltage value, to be converted to temperature for a remote temperature probe using a conversion table or formula.

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
External Connector B: Relative Digital Input Count	0x0F	0x04	2 B	Counter	• Bits 0 – 15: Relative Digital Count for Connector B since last transmission	*extconnector_b_relative_count: <value>* *(unsigned/no unit)*
External Connector A: Relative Total Input Count	0x22	0x04	4 B	Counter	• Bits 0 – 15: Cumulative Total Digital Count for Connector A	*extconnector_a_total_count: <value>* *(unsigned/no unit)*
External Connector B: Total Digital Input Count	0x12	0x04	4 B	Counter	• Bits 0 – 15: Cumulative Total Digital Count for Connector B	*extconnector_b_total_count: <value>* *(unsigned/no unit)*
External Connectors A and B: Digital Output State	0x0D	0x00	1 B	Digital	• 0x00 = Low—SSR non-conducting • 0xFF = High—SSR conducting	*extconnectors_output_state: <value>* *(unsigned/no unit)*
PIR initialization Status	0x2A	0x00	1 B	Digital	• 0x00 = PIR initialization successful • 0xFF = PIR initialization unsuccessful	*pir_init_state: <value>* *(unsigned/no unit)*
Presence Event State	0x0A	0x00	1 B	Digital	• 0x00 = No presence detected • 0xFF = Presence detected	*pir_event_state: <value>* *(unsigned/no unit)*
Presence Event Count	0x0D	0x04	2 B	Counter	• Number	*pir_event_count: <value>* *(unsigned/no unit)*
Presence Event Value	0x09	0x03	2 B	Counter	• Raw presence value	*pir_event_value: <value>* *(signed/no unit)*
Accelerometer Impact Alarm	0x0C	0x00	1 B	Digital	• 0x 00: Impact Alarm Inactive • 0x FF: Impact Alarm Active	*impact_alarm: <value>* *(unsigned/no unit)*
Acceleration Magnitude	0x05	0x02	2 B	Magnitude	• Bits 0-15: Magnitude of all enabled axis	*accelerometer_magnitude: <value>* *(unsigned/g)*
Acceleration Vector	0x07	0x71	6 B	Acceleration	• Bits 32-47: X-axis acceleration • Bits 16-31: Y-axis acceleration • Bits 0-15: Z-axis acceleration • [1 m*g*/LSb] (signed)	*acceleration_vector {* *acceleration_x: <value> (signed/g)* *acceleration_y: <value> (signed/g)* *acceleration_z: <value> (signed/g)* *}*
Ambient Temperature	0x03	0x67	2 B	Temperature	• 0.1oC/LSb (signed)	*temperature: <value>* *(signed/ºC)*
Ambient Relative Humidity	0x04	0x68	1 B	Humidity	• 0.5%/LSb (unsigned)	*relative_humidity: <value>* *(unsigned/%)*

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
MCU Temperature	0x0B	0x67	2 B	Temperature	• 0.1oC/LSb (signed)	*mcu_temperature: <value> (signed/ºC)*
Ambient Light State	0x02	0x00	1 B	Digital	• 0x00 = Dark • 0xFF = Bright	*light_detected: <value> (unsigned/no unit)*
Ambient Light Intensity	0x10	0x02	1 B	Counter	• Uncalibrated Digitized Ambient Light Intensity with values: 0, 1, … 63	*light_intensity: <value> (unsigned/no unit)*

Port 5 Uplinks

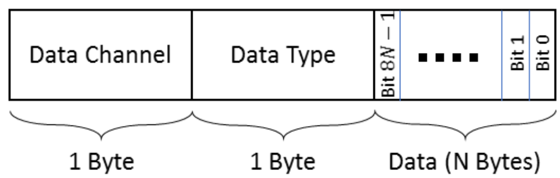


Figure 0-2: The UL Frame Format for port 5 uplinks

Table 0-2: Port 5 Uplinks

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Sensor Reset Diagnostics	0x40	0x06	5 B	Reset History	• Bits 0-7: Programmer reset counter • Bits 8-15: SW reset counter • Bits 16-23: Independent watchdog reset counter • Bits 24-31: Power loss reset counter • Bits 32-39: Latest reset reason code 0x01 = Programmer reset 0x02 = SW reset (incl. DL request) 0x04 = Independent watchdog reset 0x10 = Power loss reset 0x80 = Other resets	*reset_diagnostics: {* *reset_reason: <value> (string/no unit)* *power_loss_reset_count: <value> (unsigned/no unit)* *watchdog_reset_count: <value> (unsigned/no unit)* *sw_reset_count: <value> (unsigned/no unit)* *programmer_reset_count: <value> (unsigned/no unit)* *}*
Sensor Error Diagnostics	0x40	0x07	5 B	Error History	• Bits 0-7: I2C Bus Failure • Bits 8-15: Barometer Failure • Bits 16-23: RFU • Bits 24-31: RFU • Bits 32-39: RFU	*error_diagnostics: {* *barometer_failure: <value> (string/no unit)* *i2c_failure: <value> (string/no unit)* *}*

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Sensor Assertion Diagnostics	0x40	0x08	8 B	Assertion Info	• Bits 32-63: LR • Bits 0-31: PC	*assertion_diagnostics: {* *lr_failure: <value> (string/no unit)* *pc_failure: <value> (string/no unit)* *}*

LoRaWAN Port 100 and 101 UL Frame Formats

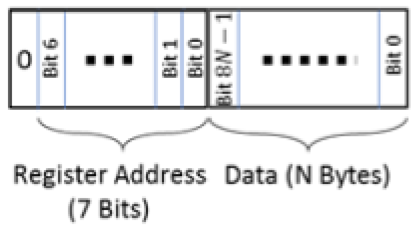


Figure 0-3: The *LoRaWAN Port 100* Read Response Format

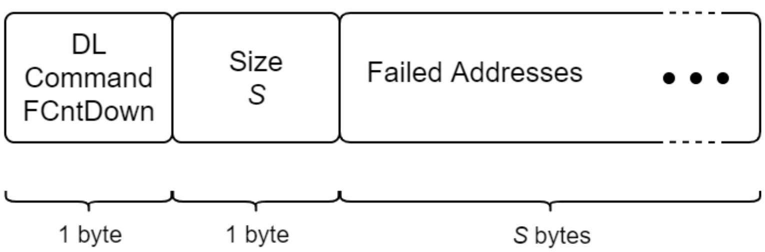
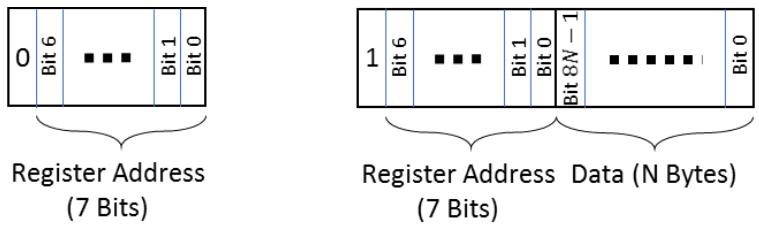


Figure 0-4: The *LoRaWAN port 101* Write Response Format

Port 100 and Port 5 Downlinks



a) Read Command Block (b) Write or Executable Command Block

Figure 0-5: The *LoRaWAN Port 100* DL Formats for Configuration and Control Message Blocks

Port 100 Downlinks

Table 0-3: List of All Configuration Registers

Address	Name	Access	Size	Description	JSON Variable	Default
0x10	Join Mode	R/W	2 B	• 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	See description	2 B	• 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[13] ADR Enabled **0x 00 0E**

[13] **WARNING**: Disabling the duty cycle in certain regions makes the sensor non-compliant with the LoRaWAN Specifications [5]. 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.

Address	Name	Access	Size	Description	JSON Variable	Default
0x12	DR and Tx Power[14]	R/W	2 B	• 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 [6])
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 [6])
0x20	Seconds per Core Tick	R/W	4 B	• Ticks value for periodic events • Acceptable values: 15,16, 17, …, 86400 • 0, Other values: Invalid	*seconds_per_core_tick: <value> (number/sec)*	3600 s = 1 hr **0x 00 00 0E 10**
0x21	Ticks per Battery	R/W	2 B	• Ticks between battery reports • Acceptable values: 1,2…65535 • 0, Other values: Invalid	*ticks_per_battery: <value> (number/no unit)*	1 tick = 1 hr **0x 00 01**
0x22	Ticks per Ambient Temperature	R/W	2 B	• Ticks between ambient temperature report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic ambient temperature reports • Other values: Invalid	*ticks_per_ambient_temperature: <value> (number/no unit)*	1 tick = 1 hr **0x 00 01**
0x23	Ticks per Relative Humidity	R/W	2 B	• Ticks between Relative Humidity report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic Relative Humidity reports • Other values: Invalid	*ticks_per_relative_humidity: <value> (number/no unit)*	1 tick = 1 hr **0x 00 01**
0x24	Ticks per Hall Effect	R/W	2 B	• Ticks between Hall Effect report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic Hall Effect reports • Other values: Invalid	*ticks_per_hall_effect: <value> (number/no unit)*	0 tick = Disabled by default **0x 00 00**

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

Address	Name	Access	Size	Description	JSON Variable	Default
0x25	Ticks per Ambient Light	R/W	2 B	• Ticks between Ambient Light report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic Ambient Light reports • Other values: Invalid	*ticks_per_ambient_light: <value> (number/no unit)*	0 tick = Disabled by default **0x 00 00**
0x26	Ticks per Accelerometer	R/W	2 B	• Ticks between Accelerometer report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic Accelerometer reports • Other values: Invalid	*ticks_per_ccelerometer: <value> (number/no unit)*	0 tick = Disabled by default **0x 00 00**
0x27	Ticks per MCU Temperature	R/W	2 B	• Ticks between MCU Temperature report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic MCU Temperature reports • Other values: Invalid	*ticks_per_mcu_temperature: <value> (number/no unit)*	0 tick = Disabled by default **0x 00 00**
0x28	Ticks per PIR	R/W	2 B	• Ticks between periodic PIR sensor reports • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic reports • Other values: Invalid	*ticks_per_pir: <value> (number/no unit)*	0 ticks = PIR report is disabled by default **0x 00 00**
0x55	Ticks per Externally Connector A (Digital ONLY)	R/W	2 B	• Ticks between Externally Connector A report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic Externally Connector A reports • Other values: Invalid	*ticks_per_external_connector _a: <value> (number/no unit)*	0 tick = Disabled by default **0x 00 00**
0x29	Ticks per Externally Connector B (Digital/Analog)	R/W	2 B	• Ticks between Externally Connector B report. • Acceptable values: 0, 1, 2, …, 65535 • 0: Disables periodic Externally Connector B reports • Other values: Invalid	*ticks_per_external_connector _b: <value> (number/no unit)*	0 tick = Disabled by default **0x 00 00**

Address	Name	Access	Size	Description	JSON Variable	Default
0x5C	Battery Report Options	R/W	1 B	• Bit 0: 0/1 = Battery Voltage [V] not reported/reported • Bit 1: 0/1 = Remaining battery capacity [%] not reported/reported • Bits 0-1 all set to 0: Invalid • Bits 2-7:0, otherwise Invalid	*battery_options: {* *battery_voltage_report: <value>* *(string/no unit)* *battery_lifetime_pct_report: <value>* *(string/no unit)* *}*	Only battery voltage report enabled **0x 01**
0x2A	Hall Effect Mode	R/W	1 B	• Bit 0: 0/1: Rising Edge disabled/enabled • Bit 1: 0/1: Fallin edge disabled/enabled • Both bits 0 and 1 set to 0: Invalid • Bits 2 - 7: RFU, must be set to 0, otherwise Invalid	*hall_effect_mode: {* *rising_edge_enabled: <value>* *(unsigned/no unit)* *falling_edge_enabled: <value>* *(unsigned/no unit)* *}*	Rising and falling edges enabled **0x 03**
0x2B	Hall Effect Count Threshold	R/W	2 B	• Bit 0-13: Number of triggers required for event transmission • 0: disables event transmission	*hall_effect_count_threshold: <value>* *(number/no unit)*	Count Threshold = 1 **0x 00 01**
0x2C	Hall Effect Report Options	R/W	1 B	• Bit 0: 0/1: State report disabled/enabled • Bit 1: 0/1: Counter value disabled/enabled • Both bits 0 and 1 set to 0: Invalid • Bits 2 - 7: RFU, must be set to 0, otherwise Invalid	*hall_effect_report_options: {* *report_state_enabled: <value>* *(unsigned/no unit)* *report_count_enabled: <value>* *(unsigned/no unit)* *}*	State and count reported **0x 03**
0x4D	External Connector A Mode	R/W	1 B	• Bit 0: 0/1: Rising Edge disabled/enabled • Bit 1: 0/1: Falling edge disabled/enabled • Both bits 0 and 1 set to 0: Invalid • Bits 2 - 7: RFU, must be set to 0, otherwise Invalid	*external_connector_a_mode: {* *rising_edge_enabled: <value>* *(unsigned/no unit)* *falling_edge_enabled: <value>* *(unsigned/no unit)* *}*	Rising and falling edges enabled **0x 03**

Address	Name	Access	Size	Description	JSON Variable	Default
0x2D	External Connector B Mode	R/W	1 B	• Bit 0: 0/1: Rising Edge disabled/enabled • Bit 1: 0/1: Falling edge disabled/enabled • Both bits 0 and 1 set to 0: Invalid • Bit 7: 0/1: Digital/Analog mode • Bits 2 - 6: RFU, must be set to 0, otherwise Invalid	*external_connector_b_mode: {* *rising_edge_enabled: <value> (unsigned/no unit)* *falling_edge_enabled: <value> (unsigned/no unit)* *connection_mode: <value> (unsigned/no unit)* *}*	Rising and falling edges enabled Digital Connection **0x 03**
0x56	Connector A Count Threshold	R/W	2 B	• Bits 0-15: Number of triggers for event-based transmission (1/LSB) • 0: disables event transmission Invalid	*external_connector_a_count_threshold: <value> (unsigned/no unit)*	Connection A count Threshold: 1 **0x 00 01**
0x2E	Connector B Count Threshold	R/W	2 B	• Bits 0-15: Number of triggers for event-based transmission (1/LSB) • 0: disables event transmission Invalid	*external_connector_b_count_threshold: <value> (unsigned/no unit)*	Connection B count Threshold: 1 **0x 00 01**
0x4F	Connector A Report options	R/W	1 B	• Bit 0: 0/1: Digital state report disabled/enabled • Bit 1: 0/1: Digital Input Count report disabled/enabled • Both bits 0 and 1 set to 0: Invalid • Bit 4: 0: Report Relative Digital Input Count 1: Report Total Digital Input Count • Bits 2 - 3, 5 - 7: RFU, must be set to 0, otherwise Invalid	*external_connector_a_tx: {* *report_state_enabled: <value> (unsigned/no unit)* *report_count_enabled: <value> (unsigned/no unit)* *count_type: <value> (unsigned/no unit)* *}*	Digital State and count reported Relative Count Reported **0x 03**

Address	Name	Access	Size	Description	JSON Variable	Default
0x2F	Connector B Report options	R/W	1 B	• Bit 0: • 0/1: Digital state report disabled/enabled • Bit 1: 0/1: Digital Input Count report disabled/enabled • Both bits 0 and 1 set to 0: Invalid • Bit 4: 0: Report Relative Digital Input Count 1: Report Total Digital Input Count • Bits 2 - 3, 5 - 7: RFU, must be set to 0, otherwise Invalid	*external_connector_b_tx: {* *report_state_enabled: <value> (unsigned/no unit)* *report_count_enabled: <value> (unsigned/no unit)* *count_type: <value> (unsigned/no unit)* *}*	Digital State and count reported Relative Count Reported **0x 03**
0x5B	Connector A: Reset Total Count	WO	4 B	• Value to set the Counter value to • Acceptable values: 0, 1, 2, …, 4,294,967,295 • Other values: Invalid	*external_connector_a_reset_count: <value> (unsigned/no unit)*	N/A
0x5A	Connector B: Reset Total Count	WO	4 B	• Value to set the Counter value to • Acceptable values: 0, 1, 2, …, 4,294,967,295 • Other values: Invalid	*external_connector_b_reset_count: <value> (unsigned/no unit)*	N/A
0x57	Digital Output (SSR) Mode	R/W	1 B	• Bit 0: 0/1: Disable/Enable Digital Output mode • Bits 1 - 7: RFU must be 0, otherwise Invalid	*digital_output_mode: <value> (unsigned/no unit)*	Digital output disabled **0x 00**
0x58	Energization (SSR) State	R/W	1 B	• Bit 0: 0/1: Disable/Enable Energization of SSR • Bits 1 - 7: RFU must be 0, otherwise Invalid	*ssr_state: <value> (unsigned/no unit)*	Energization of SSR disabled **0x 00**
0x59	Digital Output (SSR) Energization Duration	R/W	1 B	• Number of seconds to energize SSR for • Acceptable values: 1 – 254: number of seconds • 255: infinity • 0: Invalid	*ssr_energization_duration: <value> (unsigned/no unit)*	SSR energization: 10s **0x 0A**
0x44	Analog Input Sample Period in Idle State	R/W	4 B	• Bits 0 – 31: Sample period of Analog Input in sec in Idle state (1s/LSB) • Acceptable values: 30, 11, …, 86400 • Other values: Invalid	*analog_input_sample_period_idle: <value> (number/sec)*	Idle state sample period: 60s **0x 00 00 00 3C**

Address	Name	Access	Size	Description	JSON Variable	Default
0x45	Analog Input Sample Period in Active State	R/W	4 B	• Bits 0-31: Sample period of Analog Input in sec in Active state (1s/LSB) • Acceptable values: 30, 11, …, 86400 • Other values: Invalid	*analog_input_sample_period _active: <value> (number/sec)*	Active state sample period: 30s **0x 00 00 00 1E**
0x46	Analog Input High/Low Thresholds	R/W	4 B	• Bits 16-31: High threshold (unsigned, 1mV/LSb) • Bits 0-15: Low threshold (unsigned, 1mV/LSb) • High threshold ≤ Low threshold: Invalid	*analog_input_thresholds: { high_threshold: <value> (number/mV) low_threshold: <value> (number/mV) }*	High Threshold: 1200 mV Low Threshold: 600 mV **0x 04 B0 02 58**
0x4A	Analog Input Thresholds Status	R/W	1 B	• Bit 0: 0/1 = Analog Input thresholds disabled/enabled • Bits 1-7: RFU, must be 0, otherwise invalid	*analog_input_thresholds_status: <value> (string/no unit)*	Threshold disabled **0x 00**
0x50	Grace Period	R/W	2 B	• Bit 0-15: Grace period of presence sensor in seconds • Acceptable values: 15, 16, 17, …, 65535 • Other values: Invalid	*pir_grace_period: <value> (unsigned/second)*	Grace period: 300s **0x 01 2C**
0x51	Presence Threshold Count	R/W	2 B	• Bit 0-15: Number of PIR events required for event-based presence transmission • Acceptable values: 1, 2, 3, …, 65535 • 0: Invalid	*pir_threshold_count: <value> (unsigned/no unit)*	PIR threshold count: 1 **0x 01**
0x52	Presence Threshold Period	R/W	2 B	• Bit 0-15: Period over which presence events are counted for threshold detection • Acceptable values: 5, 6, 7, …, 65535 • 0-4: Invalid	*pir_threshold_period: <value> (unsigned/no unit)*	PIR threshold period: 15s **0x 0F**

Address	Name	Access	Size	Description	JSON Variable	Default
0x53	Presence (PIR) Mode	R/W	1 B	• Bit 0 {Periodic Tx only}: 0/1: Count report disabled/enabled • Bit 1 {Periodic Tx only}: 0/1: State report disabled/enabled • Bit 2 {Periodic Tx only}: 0/1: Value report disabled/enabled • Both bits 0, 1, and 2 set to 0: Invalid • Bits 3-5: RFU, must be set to 0, otherwise Invalid • Bit 6: 0/1: PIR threshold-based transmission disabled/enabled • Bit 7: PIR sensor disabled/enabled	*pir_mode: {* *pir_count_reported: <value> (unsigned/sec)* *pir_state_reported: <value> (unsigned/no unit)* *pir_value_reported: <value> (unsigned/no unit)* *event_transmission_enabled: <value> (unsigned/no unit)* *transducer_enabled: <value> (unsigned/no unit)* *}*	Presence Count Reported Only PIR threshold-based transmission enabled PIR sensor enabled **0x C1**
0x54	Hold-Off intervals	R/W	2 B	• Bit 8-15: Post turn-on hold-off interval (unsigned, 1s/LSB) 0: Default value of 10s • Bit 0-7: Post disturbance hold-off interval (unsigned, 1s/LSB) 0: Default value of 1s	*pir_holdoff: {* *post_turn_on: <value> (unsigned/sec)* *post_disturbance: <value> (unsigned/sec)* *}*	Post turn-on: 10s Post disturbance: 1s **0x 0A 01**
0x4E	Presence Sensitivity	R/W	3 B	• Bit 8 - 23: Threshold of PIR sensor (unsigned, 1/LSB) Acceptable values: 0 to 65535 0: most sensitive 65535: least sensitive • Bit 0 - 7: Hysteresis of PIR sensor (unsigned, 1/LSB) Acceptable values: 0 to 255 0 (no hysteresis): most sensitive 255: least sensitive	*pir_sensitivity: {* *pir_sens_threshold: <value> (unsigned/sec)* *pir_sens_hysteresis: <value> (unsigned/sec)* *}*	Threshold: 1000 Hysteresis: 100 **0x 03 E8 64**
0x6A	PIR initialization Retries	R/W	1 B	• Bit 0 - 7: Number of automatic PIR init retries 0: Disable automatic PIR init retries	*pir_init_retries: <value> (number/no unit)*	PIR Initialization Retries = 5 **0x 05**

Address	Name	Access	Size	Description	JSON Variable	Default
0x6B	PIR initialization mode	WO	1 B	• Bits 0 - 7: 00: Deactivate PIR Initialization FF: Activate PIR initialization	N/A	N/A
0x34	Accelerometer Mode	R/W	1 B	• Bits 0: 0/1 = Impact alarm event threshold disabled/enabled • Bit 1: 0/1 = Acceleration event threshold disabled/enabled • Bit 2-3: 0 = Low power mode 1 = Normal mode 2 = High Resolution mode 3 = Invalid • Bits 4/5/6: 0/1 =X/Y/Z-axis disabled/enabled • Bit 7: Accelerometer power OFF/ON	*accelerometer_mode: {* *impact_threshold_enabled: <value> (unsigned/no unit)* *acceleration_threshold_enabled: <value> (unsigned/no unit)* *accel_power_mode: <value> (unsigned/no unit)* *xaxis_enabled: <value> (unsigned/no unit)* *yaxis_enabled: <value> (unsigned/no unit)* *zaxis_enabled: <value> (unsigned/no unit)* *poweron: <value> (unsigned/no unit)* *}*	Impact Alarm disabled Acceleration event disabled Low power mode XYZ axis enabled Accelerometer OFF **0x 70**
0x35	Accelerometer Sensitivity	R/W	1 B	• Bits 0-2: Sample Rate • 0: Invalid • 1/2/3/4/5/6/7 = 1/10/25/50/100/200/400 Hz • Bit 3: RFU, must be 0, otherwise invalid • Bits 4-5: Measurement Range[15] • 0/1/2/3 = ±2/±4/±8/±16 *g* • Bits 6-7: RFU, must be 0, otherwise invalid	*accelerometer_sensitivity: {* *accelerometer_sample_rate: <value> (unsigned/Hz)* *accelerometer_measurement_range: <value> (unsigned/g)* *}*	Accelerometer measurement range: +/-8 g Accelerometer sample rate: 1 Hz **0x 21**

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

Address	Name	Access	Size	Description	JSON Variable	Default
0x30	Impact Alarm Event Threshold	R/W	2 B	• Bits 0 – 15: Acceleration threshold in milli-g (1mg/LSB) • Acceptable values: 0, 1, …, 65535 • Other values: Invalid	*impact_event_threshold: <value> (unsigned/g)*	Threshold: 1500mg **0x 05 DC**
0x32	Accelerometer Report Options	R/W	1 B	• Bit 0: {Periodic Reporting Only} 0/1: Impact alarm status report disabled/enabled • Bit 1: {Periodic Reporting Only} 0/1: Acceleration magnitude report disabled/enabled • Bit 2: {Periodic Reporting Only} 0/1: Acceleration vector report disabled/enabled • Bits 0 to 2 set to 0: Invalid • Bit 4: {Event-based Only} 0/1: Acceleration magnitude report disabled/enabled • Bit 5: {Event-based Only} 0/1: Acceleration vector report disabled/enabled • Bits 3, 6 - 7: RFU, must be set to 0, otherwise Invalid	*accelerometer_tx: { report_periodic_alarm_enabled: <value> (unsigned/no unit) report_periodic_magnitude_enabled: <value> (unsigned/no unit) report_periodic_vector_enabled: <value> (unsigned/no unit) report_event_magnitude_enabled: <value> (unsigned/no unit) report_event_vector_enabled: <value> (unsigned/no unit) }*	Acceleration vector ONLY for periodic and event reports **0x 24**
0x36	Impact alarm Grace Period	R/W	2 B	• Bit 0 - 15: Period after which an impact alarm is cleared, if no other impact alarm event were recorded • Acceptable values: 15, 16, …, 65535 • 0 – 14: invalid	*impact_alarm_grace_period: <value> (unsigned/seconds)*	Impact Alarm Grace Period: 300s **0x 01 2C**
0x37	Impact alarm Event Threshold Count Period	R/W	2 B	• Bit 0 - 15: The number of impact alarm events within the threshold period required to trigger an impact alarm • Acceptable values: 1, 2, …, 65535 • 0: invalid	*impact_alarm_threshold_count: <value> (unsigned/no unit)*	Impact Alarm threshold Count: 1 **0x 00 01**

Address	Name	Access	Size	Description	JSON Variable	Default
0x38	Impact alarm Event Threshold Period	R/W	2 B	• Bit 0 - 15: The time span in seconds during which impact alarm events are tallied for threshold detection • Acceptable values: 5, 6, …, 65535 • 0 - 4: invalid	*impact_alarm_threshold_period: <value> (unsigned/seconds)*	Impact alarm Event Threshold Period: **0x 00 0F**
0x31	Acceleration Event Threshold	R/W	2 B	• Bits 0 – 15: Acceleration threshold in milli-g (1mg/LSB) • Acceptable values: 0, 1, …, 65535	*acceleration_event_threshold: <value> (unsigned/g)*	Threshold: 3000 mg **0x 0B B8**
0x33	Acceleration Event Debounce Period	R/W	2 B	• Bit 0 - 15: The duration to wait before potentially reporting another acceleration event. • Acceptable values: 1, 2, …, 65535 • 0: invalid	*acceleration_debounce_period: <value> (unsigned/seconds)*	Acceleration Debounce Period: 2s **0x 00 02**
0x39	Temperature/RH Sample Period: Idle	R/W	4 B	• Sample period of ambient temperature/RH data when in idle state [1 s/LSB] • Acceptable values: 30, 31, …, 86400 • Other values: Invalid	*temp_rh_sample_period_idle: <value> (unsigned/sec)*	Sample period in idle state: 60 s **0x 00 00 00 3C**
0x3A	Temperature/RH Sample Period: Active	R/W	4 B	• Sample period of ambient temperature/RH data when in active state [1 s/LSB] • Acceptable values: 10, 11, …, 86400 • Other values: Invalid	*temp_rh_sample_period_active: <value> (unsigned/sec)*	Sample period in active state: 30 s **0x 00 00 00 1E**
0x3B	Low/High Temperature Thresholds	R/W	2 B	• Bits 8-15: High ambient temperature threshold (signed) [1°C/LSb] • Bits 0-7: Low ambient temperature threshold (signed) [1°C/LSb] • High threshold ≤ Low threshold: Invalid	*temp_threshold_high: <value> (signed/°C)* *temp_threshold_low: <value> (signed/°C)*	High threshold = 30°C Low threshold = 15°C **0x 1E 0F**
0x3C	Temperature Thresholds Enabled	R/W	1 B	• Bit 0: 0/1: Ambient temperature thresholds disabled/enabled • Bits 1-7: RFU, must be set to 0, otherwise invalid	*temp_thresholds_enabled: <value> (string/no unit)*	Disabled **0x 00**

Address	Name	Access	Size	Description	JSON Variable	Default
0x3D	Low/High RH Thresholds	R/W	2 B	• Bits 8-15: High ambient RH threshold (unsigned) [0.5%/LSb] • Bits 0-7: Low ambient RH threshold (unsigned) [0.5%/LSb] • High threshold ≤ Low threshold: Invalid	*rh_threshold_high: <value> (unsigned/%)* *rh_threshold_low: <value> (unsigned/%)*	High threshold = 80% Low threshold = 15% **0x 50 0F**
0x3E	RH Thresholds Enabled	R/W	1 B	• Bit 0: 0/1: Ambient RH thresholds disabled/enabled • Bits 1-7: RFU, must be set to 0, otherwise invalid	*rh_thresholds_enabled: <value> (string/no unit)*	Disabled **0x 00**
0x40	MCU Temperature Sample Period: Idle	R/W	4 B	• Sample period of MCU Temperature data when in idle state [1 s/LSb] • Acceptable values: 30, 31, …, 86400 • Other values: Invalid	*mcu_temp_sample_period_idle: <value> (unsigned/sec)*	300 s **0x 00 00 01 2C**
0x41	MCU Temperature Sample Period: Active	R/W	4 B	• Sample period of MCU Temperature data when in active state [1 s/LSB] • Acceptable values: 10, 11, …, 86400 • Other values: Invalid	*mcu_temp_sample_period_active: <value> (unsigned/sec)*	60 s **0x 00 00 00 3C**
0x42	Low/High MCU Temperature Thresholds	R/W	2 B	• Bits 8-15: High ambient MCU Temperature threshold (signed) [1°C/LSb] • Bits 0-7: Low ambient MCU Temperature threshold (signed) [1°C/LSb] • High threshold ≤ Low threshold: Invalid	*mcu_temp_threshold_high: <value> (signed/°C)* *temp_threshold_low: <value> (signed/°C)*	High threshold = 30°C Low threshold = 15°C **0x 1E 0F**
0x43	MCU Temperature Thresholds Enabled	R/W	1 B	• Bit 0: 0/1: Ambient MCU Temperature thresholds disabled/enabled • Bits 1-7: RFU, must be set to 0, otherwise invalid	*mcu_temp_thresholds_enabled: <value> (string/no unit)*	Disabled **0x 00**
0x47	Ambient Light Sample Period	R/W	4 B	• Bit 0-31: Sample period of ambient light sensor in seconds • 0: Disables light sensor • Acceptable values: 0, 30, 31, …, 86400	*light_sample_period: <value> (unsigned/second)*	Light Transducer Disabled **0x 00**

Address	Name	Access	Size	Description	JSON Variable	Default
0x48	Ambient Light Threshold	R/W	1 B	• Bit 0-5: Threshold level required for event-based light transmission • Acceptable values: 1, 2, 3, …, 63 • 0: Invalid • Bit 6: RFU, must be set to 0, otherwise Invalid • Bit 7: 0/1: disable/enable threshold-based transmission	*light_threshold: {* *threshold: <value> (unsigned/no unit)* *threshold_enabled: <value> (unsigned/no unit)* *}*	Threshold based reporting enabled Light threshold: 32 **0x A0**
0x49	Ambient Light Report Options	R/W	1 B	• Bit 0: 0/1: State report disabled/enabled • Bit 1: 0/1: Intensity value disabled/enabled • Both bits 0 and 1 set to 0: Invalid • Bits 2 - 7: RFU, must be set to 0, otherwise Invalid	*ambient_light_report_options: {* *report_state_enabled: <value> (unsigned/no unit)* *report_intensity_enabled: <value> (unsigned/no unit)* *}*	Light State Reported Only **0x 01**
0x60	Sample Analysis Mode	R/W	1 B	• Bits 0-3: IIR filter recall factor • Bit 7: 0/1: Sample analysis disabled/enabled • Bit 4-6: Ignored	*sample_analysis_mode: {* *iir_recall_factor: <value> (unsigned/no unit)* *analysis_enabled: <value> (unsigned/no unit)* *}*	IIR filter recall factor set to 4 Sample analysis disabled **0x 04**
0x61	HPF Configuration	R/W	1 B	• Bits 0: 0/1: HPF disabled/enabled on accelerometer outputs • Bit 1: 0/1: HPF disabled/enabled on accelerometer outputs • Bit 2: 0/1 = HPF disabled/enabled on Sample Analysis • Bit 4-5: HPF cutoff frequency selector • Acceptable values: 0, 1, 2, 3 Larger number = smaller cutoff • Bit 3, 6, 7: Ignored	*hpf_mode: {* *enabled_on_outputs: <value> (unsigned/no unit)* *enabled_on_interrupts: <value> (unsigned/no unit)* *enabled_on_sample_analysis: <value> (unsigned/no unit)* *cutoff: <value> (unsigned/no unit)* *}*	HPF disabled on accelerometer interrupts HPF enabled on accelerometer interrupts HPF enabled on Sample Analysis HPF cutoff frequency selector set to 0 **0x 06**

Address	Name	Access	Size	Description	JSON Variable	Default
0x62	Acceleration Event Stop Thresholds	R/W	4 B	• Bits 16-31: Stop Threshold, unsigned 1 milli-/LSB, 0 = disabled • Bits 0-15: Minimum Report Duration, unsigned, 1 s-/LSB, 0 = report all events	*acceleration_event_stop_thresholds: {* *acceleration_event_stop_threshold: <value> (unsigned/g)* *acceleration_event_report_duration_min:<value> (unsigned/s)* *}*	Stop threshold disabled Minimum report duration set to 5 s **0x 00 00 00 05**
0x63	ML Configuration	R/W	7 B	• Bits 48-55: Number of nonzero MLs (1 ≤ · ≤ 15) • Bits 32-47: ML1 upper limit, 1 mg/LSB • Bits 16-31: ML1 lower limit, 1 mg/LSB • Bits 0-15: ML step, 1 mg/LSB • Number of nonzero MLs = 0 or > 15: Invalid and ignored • ML1 upper limit < ML1 lower limit: Invalid and ignored • ML1 upper limit = ML1 lower limit: Hysteresis disabled • Number of nonzero MLs > 1 & ML step = 0: Invalid and ignored	*ml_config: {* *num: <value> (unsigned/no unit)* *ml1upper: <value> (unsigned/g)* *ml1lower: <value> (unsigned/g)* *ml_step: <value> (unsigned/g)* *}*	Number of nonzero MLs = 8 ML1 upper limit = 40 mg ML1 lower limit = 20 mg ML step = 30 mg **0x 08 00 28 00 14 00 1E**
0x64	ML_1 DLim Configuration	R/W	5 B	• Bits 32-39: Number of DLims (0 ≤ · ≤ 3) • Bits 16-31: DLim0, 1 sec/LSB • Bits 0-15: DLim step, 1 sec/LSB • Number of DLims > 3: Invalid and ignored • Number of DLims > 1 & DLim step = 0: Invalid and ignored	*ml1_dlim_config: {* *num_dlims: <value> (unsigned/no unit)* *dlim0: <value> (unsigned/sec)* *dlim_step: <value> (unsigned/sec)* *}*	Number of DLims = 0 $DLim_0$ = 0 DLim step = 0 **0x 00 00 00 00 00**
0x65	ML_2 DLim Configuration	R/W	5 B	• Bits 32-39: Number of DLims (0 ≤ · ≤ 3) • Bits 16-31: DLim0, 1 sec/LSB • Bits 0-15: DLim step, 1 sec/LSB • Number of DLims > 3: Invalid and ignored • Number of DLims > 1 & DLim step = 0: Invalid and ignored	*ml2_dlim_config: {* *num_dlims: <value> (unsigned/no unit)* *dlim0: <value> (unsigned/sec)* *dlim_step: <value> (unsigned/sec)* *}*	Number of DLims = 0 $DLim_0$ = 0 DLim step = 0 **0x 00 00 00 00 00**

Address	Name	Access	Size	Description	JSON Variable	Default
0x66	$AE_{1, x}$ Thresholds	R/W	9 B	• Bits 64-71: 0: Thresholds disabled 1: Thresholds enabled on duration total 2: Thresholds enabled on count 3-255: Invalid and ignored • Bits 48-63: AE1, 0 threshold, unsigned 1 sec or 1 count/LSB • Bits 32-47: AE1, 1 threshold, unsigned, 1 sec or 1 count/LSB • Bits 16-31: AE1, 2 threshold, unsigned, 1 sec or 1 count/LSB • Bits 0-15: AE1, 3 threshold, unsigned, 1 sec or 1 count/LSB	*AE1_thresholds: {* *thresholds_enabled: <value> (unsigned/no unit)* *ae10_threshold: <value> (unsigned/sec)* *ae11_threshold: <value> (unsigned/sec)* *ae12_threshold: <value> (unsigned/sec)* *ae13_threshold: <value> (unsigned/sec)* *}*	Thresholds disabled $AE_{1, 0}$, $AE_{1, 1}$, $AE_{1, 2}$, $AE_{1, 3}$ thresholds set to 0 **0x 00 00 00 00 00 00 00 00 00**
0x67	$AE_{2, x}$ Thresholds	R/W	9 B	• Bits 64-71: 0: Thresholds disabled 1: Thresholds enabled on duration total 2: Thresholds enabled on count 3-255: Invalid and ignored • Bits 48-63: AE2, 0 threshold, unsigned 1 sec or 1 count/LSB • Bits 32-47: AE2, 1 threshold, unsigned, 1 sec or 1 count/LSB • Bits 16-31: AE2, 2 threshold, unsigned, 1 sec or 1 count/LSB • Bits 0-15: AE2, 3 threshold, unsigned, 1 sec or 1 count/LSB	*AE2_thresholds: {* *thresholds_enabled: <value> (unsigned/no unit)* *ae20_threshold: <value> (unsigned/sec)* *ae21_threshold: <value> (unsigned/sec)* *ae22_threshold: <value> (unsigned/sec)* *ae23_threshold: <value> (unsigned/sec)* *}*	Thresholds disabled $AE_{2, 0}$, $AE_{2, 1}$, $AE_{2, 2}$, $AE_{2, 3}$ thresholds set to 0 **0x 00 00 00 00 00 00 00 00 00**

Address	Name	Access	Size	Description	JSON Variable	Default
0x68	Sample Analysis Report Options (applicable to both periodic and event-based transmissions)	R/W	1 B	• Bits 0: 0/1: AE duration total disabled/enabled • Bit 1: 0/1: AE duration min disabled/enabled • Bit 2: 0/1: AE duration max disabled/enabled • Bit 3: 0/1: AE duration SD disabled/enabled • Bit 4: 0/1: AE count disabled/enabled • Bit 5-7: Ignored	*accelerometer_analysis_tx: {* *duration_total_enabled: <value> (unsigned/no unit)* *duration_min_enabled: <value> (unsigned/no unit)* *duration_max_enabled: <value> (unsigned/no unit)* *duration_sd_enabled: <value> (unsigned/no unit)* *count_enabled: <value> (unsigned/no unit)* *}*	AE duration total enabled **0x 01**
0x6C	Event Mode	R/W	1 B	• Bit 0: 0: Event-based data sent on Port 10 (legacy) 1: Event-based data sent on Port 11/12 with event-block format • Bits 1-7: RFU, must be 0, otherwise invalid	*cdda_event_mode: <value> (number/no unit)*	Event-based reports sent on port 10. **0x 00**

Address	Name	Access	Size	Description	JSON Variable	Default
0x6D	Critical Event Options	R/W	2 B	• Toggle whether each event is critical or not • For each bit: 0/1 = <event type> is not a critical event/is a critical event • Bit 0: Hall Effect Event • Bit 1: Impact Alarm Event • Bit 2: Acceleration Event • Bit 3: MCU Temperature Event • Bit 4: Ambient Temperature Event • Bit 5: Ambient Relative Humidity Event • Bit 6: Ambient Light Event • Bit 7: External Connector A – Digital Input Event (COMFORT v2 only) • Bit 8: External Connector B – Analog or Digital Input Event (COMFORT v2 only) • Bit 9: External Connectors – Digital Output Event (COMFORT v2 Only) • Bit 10: Presence (PIR) Event (VIVID only) • Bit 11: PIR Initialization Event (VIVID v2 only) • Bits 12-15: RFU, must be 0, otherwise invalid	*cdda_critical_event_options: <value> (number/no unit)*	No critical events enabled **0x 00 00**
0x6E	Retransmission Period and Retransmission Count	R/W	3 B	• Bits 0-15: Critical event retransmission period (s) • Acceptable values: 10, 11, …, 65535 • Other values: invalid • Bits 16-22: Critical event retransmission count (number of times to retransmit) • Bit 23: Indefinite Retransmission disabled/enabled • 0: Sensor will only retransmit the event the set number of times (ALA not required to stop retransmissions) 1: Sensor will retransmit the event the set number of times and synchronously with all future periodic events (ALA required to stop retransmissions)	*cdda_retransmission: <value> (number/no unit)*	Critical event retransmit period is 300 seconds (5 mins) Critical event retransmission count is 3 and will not retransmit indefinitely (does not require an ALA to stop retransmissions). **0x 03 01 2C**

Address	Name	Access	Size	Description	JSON Variable	Default
0x6F	Format Options	1 B	R/W	• Bit 0: 0: Invalid write-response format 1: 4-byte CRC • Bit 1-7: Ignored	*resp_to_dl_command_format : <value> (unsigned/no unit)*	Invalid write-response format **0x 00**
0x70	Flash Write Command	2 B	WO	• Bit 14: 0/1 = Do not write/Write LoRaMAC Configuration • Bit 13: 0/1 = Do not write/Write App Configuration • Bit 0: 0/1 = Do not restart/Restart Sensor • Bits 1-12, 15: RFU, must be set to 0, otherwise Invalid	*write_to_flash: {* *app_config: <value> (unsigned/no unit)* *lora_config: <value> (unsigned/no unit)* *restart_sensor: <value> (unsigned/no unit)* *}*	**0x 70**
0x71	FW Metadata	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 number[16]	*metadata: {* *app_ver_major: <value> (unsigned/no unit)* *app_ver_minor: <value> (unsigned/no unit)* *app_ver_revision: <value> (unsigned/no unit)* *modem_ver_major: <value> (unsigned/no unit)* *modem_ver_minor: <value> (unsigned/no unit)* *modem_ver_revision: <value> (unsigned/no unit)* *loramac_region: <value> (unsigned/no unit)* *}*	**0x 71**

[16] Defined by Table 5-6.

Address	Name	Access	Size	Description	JSON Variable	Default
0x72	Reset Configuration to Factory Defaults	1 B	WO	• 0x 0A: Reset app configuration • 0x B0: Reset LoRaMAC configuration • 0x BA: Reset both App and LoRaMAC configurations • Any other value: Invalid	*config_factory_reset: {* *app_config: <value> (unsigned/no unit)* *loramac_config: <value> (unsigned/no unit)* *}*	**0x 72**

Port 5 Downlinks

Table 0-4: Systems Diagnostics Configuration Registers

Address	Name	Access	Description
0x40	Systems Diagnostics Query	R only	Query systems diagnostics information from sensor

Appendix 2

COMFORT/VIVD v2 Registers, Default Values, and Category

Table 0-5: COMFORT/VIVID v2 Registers, Default Values, and Category

Name	Register Address [Hex]	Default Value [Hex]	Category
Join Mode	0x10	0x 01	LoRaMAC Configuration
Options	0x11	0x 00 0E	
DR and Tx Power[17]	0x12	As per the LoRaWAN Regional Parameters [6]	
Rx2 Window	0x13	As per the LoRaWAN Regional Parameters [6]	
Seconds per Core Tick	0x20	0x 00 00 0E 10	Periodic Reporting Configuration
Ticks per Battery	0x21	0x 00 01	
Ticks per Ambient Temperature	0x22	0x 00 01	
Ticks per Relative Humidity	0x23	0x 00 01	
Ticks per Hall Effect	0x24	0x 00 00	
Ticks per Ambient Light	0x25	0x 00 00	
Ticks per Accelerometer	0x26	0x 00 00	
Ticks per MCU Temperature	0x27	0x 00 00	
Ticks per PIR	0x28	0x 00 00	
Ticks per Externally Connector A (Digital ONLY)	0x55	0x 00 00	
Ticks per Externally Connector B (Digital/Analog)	0x29	0x 00 00	
Battery Report Options	0x5C	0x 01	Battery Management Configuration
Hall Effect Mode	0x2A	0x 03	Hall Effect Configuration
Hall Effect Count Threshold	0x2B	0x 00 01	
Hall Effect Report Options	0x2C	0x 03	
External Connector A Mode	0x4D	0x 03	External Connectors/External Output Configuration
External Connector B Mode	0x2D	0x 03	
Connector A Count Threshold	0x56	0x 00 01	
Connector B Count Threshold	0x2E	0x 00 01	
Connector A Report options	0x4F	0x 03	
Connector B Report options	0x2F	0x 03	
Connector A: Reset Total Count	0x5B	N/A	
Connector B: Reset Total Count	0x5A	N/A	
Digital Output (SSR) Mode	0x57	0x 00	

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

Energization (SSR) State	0x58	0x 00	
Digital Output (SSR) Energization Duration	0x59	SSR 0x 0A	
Analog Input Sample Period in Idle State	0x44	0x 00 00 00 3C	
Analog Input Sample Period in Active State	0x45	0x 00 00 00 1E	
Analog Input High/Low Thresholds	0x46	0x 04 B0 02 58	
Analog Input Thresholds Status	0x4A	0x 00	
Grace Period	0x50	0x 01 2C	PIR Configuration
Presence Threshold Count	0x51	0x 01	
Presence Threshold Period	0x52	0x 0F	
Presence (PIR) Mode	0x53	0x C1	
Hold-Off intervals	0x54	0x 0A 01	
Presence Sensitivity	0x4E	0x 03 E8 64	
PIR initialization Retries	0x6A	0x 05	
PIR initialization mode	0x6B	N/A	
Accelerometer Mode	0x34	0x 70	Accelerometer Configuration
Accelerometer Sensitivity	0x35	0x 21	
Impact Alarm Event Threshold	0x30	0x 05 DC	
Accelerometer Report Options	0x32	0x 24	
Impact alarm Grace Period	0x36	0x 01 2C	
Impact alarm Event Threshold Count Period	0x37	0x 00 01	
Impact alarm Event Threshold Period	0x38	0x 00 0F	
Acceleration Event Threshold	0x31	0x 0B B8	
Acceleration Event Debounce Period	0x33	0x 00 02	
Temperature/RH Sample Period: Idle	0x39	0x 00 00 00 3C	Temperature/Humidity Configuration
Temperature/RH Sample Period: Active	0x3A	0x 00 00 00 1E	
Low/High Temperature Thresholds	0x3B	0x 1E 0F	
Temperature Thresholds Enabled	0x3C	0x 00	
Low/High RH Thresholds	0x3D	0x 50 0F	
RH Thresholds Enabled	0x3E	0x 00	
MCU Temperature Sample Period: Idle	0x40	0x 00 00 01 2C	
MCU Temperature Sample Period: Active	0x41	0x 00 00 00 3C	
Low/High MCU Temperature Thresholds	0x42	0x 1E 0F	
MCU Temperature Thresholds Enabled	0x43	0x 00	
Sample Period	0x47	0x 00	Light Sensor Configuration
Ambient Light Threshold	0x48	0x A0	
Ambient Light Report Options	0x49	0x 01	
Sample Analysis Mode	0x60	0x 04	Enhanced Accelerometer Configuration
HPF Configuration	0x61	0x 06	
Acceleration Event Stop Thresholds	0x62	0x 00 00 00 05	
ML Configuration	0x63	0x 08 00 28 00 14 00 1E	
ML_1 DLim Configuration	0x64	0x 00 00 00 00 00	
ML_2 DLim Configuration	0x65	0x 00 00 00 00 00	

$AE_{1,x}$ Thresholds	0x66	0x 00 00 00 00 00 00 00 00 00	
$AE_{2,x}$ Thresholds	0x67	0x 00 00 00 00 00 00 00 00 00	
Sample Analysis Report Options (applicable to both periodic and event-based transmissions)	0x68	0x 01	
Event Mode	0x6C	0x 00	Critical Data Delivery Assurance (CDDA) Configuration
Critical Event Options	0x6D	0x 00 00	
Retransmission Period and Retransmission Count	0x6E	0x 03 01 2C	
Format Options	0x6F	0x 00	Response to Downlinks Configuration
Flash Write Command	0x70	0x 70	Command and Control Configuration
FW Metadata	0x71	0x 71	
Reset Configuration to Factory Defaults	0x72	0x 72	

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