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Comfort/Vivid

Technical Reference Manual

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Revision History

Version	Date	Editor	Module Revision and FW Version	Comments
0.1	Jun 10, 2019	Reza Nikjah	• Module Revs A-C • FW v1.3.0 and below	Initial draft for Smart Room Sensors (Gen 3 Home Sensors).
0.2	Jun 13, 2019	Reza Nikjah		Modified based on feedback, including, • typos and oversights; • 2 bytes instead of 1 byte for analog input threshold; • moving Accelerometer Configuration section ahead of Threshold Configuration section, so the register addresses appear in a reasonable order; • change of “Sample Rate & Measurement Range” for the Accelerometer to “Sensitivity” • change of register name “Threshold” to “Threshold Control” for Light; • change of bitmapping of the Light “Threshold Control” register; • change of bitmapping of the PIR “Mode” register.

0.3	Jun 19, 2019	Reza Nikjah		• Minor edits:
				  ○ Categorized accelerometer events into “acceleration events” and “impact alarm events”
				  ○ Corrected description of the accelerometer events debounce time
				  ○ Corrected possible light threshold values and number of bits devoted to the light threshold
				  ○ Corrected Rx2 frequency for DN915
				  ○ Removed the default register value for configuration registers, and instead, *described* the default values

0.4	Jul 10, 2019	Reza Nikjah		• Edits based on feedback, including,
				  ○ Clarified the grouping in Table 2-1
				  ○ Clarified the External Connector configuration
				  ○ Clarified Accelerometer configuration
				  ○ showed current draws for different accelerometer sample rates and moisture sample periods

0.5	Jul 15, 2019	Reza Nikjah		• Corrected typos
				• Edits based on feedback, including,
				  ○ Added register 0x11 Sync Word bit
				  ○ Corrected Acceleration Event Debounce Time description
				  ○ Explained limits on the Sample Periods

0.6	Oct 16, 2019	Reza Nikjah		• Minor edits (Table 2-1)

				• Clarified that moisture detection is specific to Base
1.0	Jan 2, 2020	Reza Nikjah, Mark Oevering		• Updated acceleration vector example • Updated the document format • Changed the bit indexing scheme from bytes and bits to only bits, with the rightmost bit indexed 0, for more clarity • Minor edits to read/write examples • Added acceptable values, wherever applicable, to the tables of configuration registers
1.1	May 6, 2020	Reza Nikjah		• Added Jason variables for UL and DL encoding and decoding • Some editorial changes
1.2	Nov 23, 2020	Lukas Morrison		• Updated expected current draws for moisture transducer sampling.
1.3	Nov 24, 202	Reza Nikjah		• Added description of register 0x54 to control PIR hold-off intervals.
2.0	Nov 26, 2020	Reza Nikjah	• Module Revs A-C • FW v2.1.0	• Enhanced accelerometer configuration to support the toilet leakage use case.
2.1	Dec 7, 2020	Reza Nikjah		• Removed analytical event (AE) alarm uplinks. In the case of threshold being exceeded, the AE value is just reported (i.e. a threshold-based reporting, rather than an alarm reporting). • Rearranged bits and bytes in registers 0x64 and 0x65.
2.2	Jan 4, 2021	Reza Nikjah		• Redefined register 0x32 to decouple reporting values for accelerometer periodic reporting and acceleration event reporting
2.3	Mar 26, 2021	Reza Nikjah		• Added configuration commands for the water flow detection use case. • Removed duration median from enhanced accelerometer configuration due to its limited use and challenging calculation for streaming data. • Removed duration range from enhanced accelerometer configuration due to its redundancy in view of duration min and duration max. • Removed duration mean from enhanced accelerometer configuration due to its redundancy in view of duration total and duration count. • Replaced CIC filter with a simple IIR filtering that only has a single recall factor parameter.

3.0	Nov. 7, 2022	Shania Stewart	• Module Rev D • FW v3.0.10	• Added FW versions and module revisions to document revision history. • Updated product names from Smart Room Sensor Base and PIR to Comfort and Vivid, respectively. • Reformatted document structure based on LoRaWAN information streams and ports rather than by UL/DL. • Removed product family table and reformatted product code table to include module and PCBA T-codes. • Removed DN and CN-specific region support. • Consolidated regional module T-codes to T0006115 and T0006116 based on the new HW. • Replaced reed switch configuration with hall effect transducer configuration. • Removed moisture sensing configuration due to limitations with the new HW. • Temporarily removed support for the enhanced accelerometer configuration. • Updated UL frame payload format for battery voltage to be consistent with other TEKTELIC sensors. • Lowered limit of acceptable values for the Seconds per Core Tick downlink configuration register (0x20). • Added invalid value limit on register 0x32. • Updated accelerometer current draws. • Added the alternative response to DL commands on port 101 feature and the associated downlink configuration register (0x6F).
3.1	Dec. 5, 2022	Shania Stewart	• Module Rev D • FW v3.0.12	• Minor typo and wording fixes. • Added port 5 uplink and downlink formats for system diagnostics and examples. • Added description of the sensor behavior once it has joined a LoRaWAN network. • Changed the name of “Value to Tx” downlink configuration registers to “Report Options” throughout the document. • Added new features and configuration options for the Comfort’s external connector. ○ Added a port 10 uplink format for the 4-byte total digital input count.

				○ Modified configuration register 0x2F to include the option to report the relative or total digital input count. ○ Added a configuration register 0x5A to reset the total digital input count to any value. ○ Updated downlink configuration examples. • Removed invalid value limit on bits 4-5 of register 0x32. • Added a footnote about the accelerometer event-based reporting exception in the anti-bricking strategy.

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Acronyms and Glossary

ABP .... activation by personalization
ADC .... analog-to-digital converter
ADR .... adaptive data rate
CRC .... cyclic redundancy check
DL .... downlink
DR .... data rate
EIRP .... effective isotropic radiated power
Flash memory .... Non-volatile memory on the Sensor (contains application & configuration settings)
g .... gravity (unit of acceleration ≈ 9.8 m/s^2)
ID .... identity
IoT .... Internet of things
LoRa .... a patented "long-range" IoT technology acquired by Semtech
LoRAMAC .... LoRaWAN MAC
LoRaWAN .... LoRa wide area network (a network protocol based on LoRa)
LSB .... least significant bit
MAC .... medium access control
MCU .... microcontroller unit
min .... minute(s)
MSB .... most significant bit
NS .... network server
OTA .... over-the-air
OTAA .... OTA activation
PIR .... passive infrared
RH .... relative humidity
RFU .... reserved for future use
RO .... read-only
R/W .... read/write
Rx .... receiver
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 .... write-only

1 Overview

IMPORTANT: Not all features described in this manual may be available on devices programmed with older FW versions or different module revisions. Refer to the Revision History table to verify which module revisions and FW versions included different features. To check the FW version of your device, send a command to query your device as described in Section 4.2.10.

This document contains technical information about the supported functionally of the TEKTELIC Comfort/Vivid sensor variants[1], referred to as the Sensor henceforth. This TRM describes the LoRa IoT uplink and downlink payload structures user accessible configuration settings (pseudo registers) in detail. This document is intended for a technical audience, such as application developers, with an understanding of the LoRaWAN NS and its command interfaces.

The Comfort/Vivid are both multi-purpose LoRaWAN IoT sensors packed into a very small form factor. The Comfort and Vivid are both variants in the same sensor family, which differ in some of their sensing features. Comfort/Vivid sensors are ideal for monitoring and reporting temperature, (ambient, remote through a probe, or MCU), humidity, light, shock, and open/closed doors and windows in a home/office environment. Additional sensing features, such as motion detection or the ability to integrate an external probe, are also supported by the appropriate Sensor variant.

Table 1-1 lists the Sensor variants for regions identified by the LoRa Alliance [1]—see [1] for the Tx and Rx bands in each LoRaWAN region. The different RF variants shown in Table 1-1 use the same HW, but are distinguished through different parameters in FW. *Note that this table is only applicable to sensors with module revision D and onwards.*

Table 1-1: Comfort/Vivid Order Codes for Region Specific Variants

LoRaWAN RF Variant	Functional Variant	Product Code, Module-Level T-Code	Product Code, PCBA-Level T-Code	Order Code
US915	Comfort	T0006115	T0008168	SMTBBUS915
US915	Vivid	T0006116	T0008169	SMTPBUS915
EU868	Comfort	T0006115	T0008168	SMTBBEU868
EU868	Vivid	T0006116	T0008169	SMTPBEU868
AS923	Comfort	T0006115	T0008168	SMTBBAS923
AS923	Vivid	T0006116	T0008169	SMTPBAS923
AU915	Comfort	T0006115	T0008168	SMTBBAU915
AU915	Vivid	T0006116	T0008169	SMTPBAU915
IN865	Comfort	T0006115	T0008168	SMTBBIN865

[1] The Comfort and Vivid were formerly known as the Smart Room Sensor Base and PIR variants, respectively.

LoRaWAN RF Variant	Functional Variant	Product Code, Module-Level T-Code	Product Code, PCBA-Level T-Code	Order Code
IN865	Vivid	T0006116	T0008169	SMTPBIN865
KR920	Comfort	T0006115	T0008168	SMTBBKR920
KR920	Vivid	T0006116	T0008169	SMTPBKR920
RU864	Comfort	T0006115	T0008168	SMTBBRU864
RU864	Vivid	T0006116	T0008169	SMTPBRU864

1.1 Information Streams

The main LoRaWAN UL and DL information streams supported by the Sensor are summarized in Table 1-2.

Table 1-2: Comfort/Vivid Information Streams

Stream Direction	Stream Name	Data Type	Sent on LoRaWAN Port
UL (Sensor to NS)	System Diagnostics Stream	Sensor system diagnostic information	**5**
	Reported Transducer Data Stream	Readings obtained from on-board transducers	**10**
	Sensor Application Configuration Stream	Response to read commands from the NS	**100**
		Response to write commands from the NS	**101**
DL (NS to Sensor)	System Diagnostics Stream	Codes sent from the NS to query the Sensor's diagnostic information	**5**
	Sensor Application Configuration Stream	Configuration and control commands from the NS used to change the Sensor's behavior or inquire about the values of the Sensor's configuration registers	**100**

1.2 Default Reporting Configuration

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

- Report the battery voltage every hour
- Report the ambient temperature every hour
- Report the ambient RH every hour
- Report actuation (an open-to-close or close-to-open event) of the hall effect transducer every 1 (one) actuation
- Report actuation (an open-to-close or close-to-open event) of the digital input every 1 (one) actuation (Comfort model only)
- Report motion after one PIR event (Vivid model only)
- Clear motion after 5 min of no motion detected (Vivid model only)

2 System Diagnostics Stream

The system diagnostics stream is used to exchange system diagnostic information between a Sensor and an application Server via LoRaWAN. Uplinks containing system diagnostics from a Sensor are ***sent on LoRaWAN port 5***. Downlinks containing query codes to a Sensor are ***sent on LoRaWAN port 5***.

2.1 Uplink System Diagnostic Information

Each data field from the Sensor is encoded in a frame format shown in Figure 2-1. A big-endian format (MSB first) is always followed. Uplinks containing system diagnostic information ***sent on LoRaWAN port 5*** use the same frame payload format as uplinks containing transducer data ***sent on LoRaWAN port 10***.

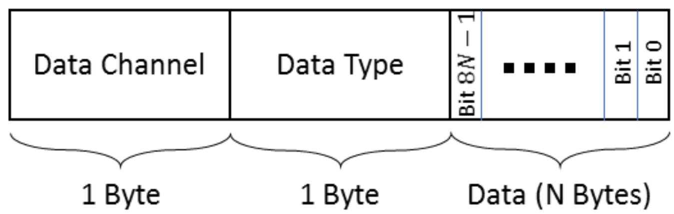


Figure 2-1: The port 5 UL frame payload format.

The Sensor's payload frame values are shown in Table 2-1. In this table, the bit indexing scheme is as shown in Figure 2-1. While only sensor reset diagnostic data is currently available, more options may be included in the future. If this occurs, a Sensor message payload may include multiple system diagnostic data frames, but the frames can be in any order. A single payload may include data from any given type of system diagnostic.

Table 2-1: UL Frame Payload Values for System Diagnostic Information

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 32-39: Latest reset reason code 0x01 = Push-button reset 0x02 = DL command reset 0x04 = Independent watchdog reset 0x08 = Power loss reset • Bits 24-31: Power loss reset counter • Bits 16-23: Independent watchdog reset counter • Bits 8-15: DL command reset counter	*reset_diagnostics {* *reset_reason: <value>, (string/no unit)* *power_loss_reset_count: <value>, (unsigned/no unit)* *watchdog_reset_count: <value>, (unsigned/no unit)* *dl_reset_count: <value>, (unsigned/no unit)*

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
					• Bits 0-7: Push-button reset counter	*button_reset_count: <value> (unsigned/no unit)* }

Examples:

In the following example payloads, the data channel ID and data type ID are boldfaced:

- 0x **40 06** 02 01 00 03 04
  - 0x **40 06** (Sensor Reset Diagnostics) = 0x 02 01 00 03 04:
    - Reset Reason Code = 0x 02 = DL command reset
    - Power Loss Reset Count = 0x 01 = 1 power loss reset
    - Independent Watchdog Reset Count = 0x 00 = 0 independent watchdog resets
    - DL Command Reset Count = 0x 03 = 3 DL command resets
    - Push-Button Reset Count = 0x 04 = 4 push-button resets

2.1.1 Sensor Reset Diagnostics

The Sensor tracks and reports the reason for its most recent reset and the number of times it has been reset by each of the four reset types. The four types of resets include:

- **Push-Button Reset:** occurs when the reset button is pressed and released.
- **DL Command Reset:** occurs when the sensor receives a downlink (***sent on LoRaWAN port 100***) containing the sensor reset command (see Section 4.2.10 for more details).
- **Independent Watchdog Reset:** occurs when the system gets locked up due to an unforeseen circumstance.
- **Power Loss Reset:** occurs when the Sensor's battery is removed or experiences a brown-out.

The Sensor will increment the respective reset counter(s) right before it begins attempting to join a LoRaWAN network. As a result, resets that occur between when a sensor first boots and when a sensor sends its first join request may not be counted. The Sensor stores the reset counter values in reset-safe RAM to retain this information over "soft" resets (e.g., push-button, DL command, or independent watchdog resets). However, all four reset counters will be reset to zero when a power loss reset occurs, and the power loss reset counter will be set to 1.

The Sensor will send an uplink containing the Sensor Reset Diagnostics in the following situations:

1. Shortly after the Sensor joins a LoRaWAN network, which always occurs after a reset.
2. In response to receiving a downlink (***sent on LoRaWAN port 5***) containing the appropriate query code (0x40) as described in Section 2.2.

2.2 Downlink System Diagnostic Query Commands

The application may query the Sensor's system diagnostic information using downlink messages containing one or more query codes ***sent on LoRaWAN port 5.*** The Sensor will then respond with one or more uplinks ***sent on LoRaWAN port 5*** containing the data associated with the received query code(s).

The Sensor supports the query code listed in Table 2-2. Query codes are used to poll the matching information type shown in Table 2-1. While only sensor reset diagnostic data is currently available, more options may be added in the future. If this occurs, one or more query codes can be included in a single downlink payload. A big-endian format (MSB first) is always followed.

Table 2-2: DL Frame Payload Format for System Diagnostic Queries

Query Code	Queried Information Type	Description
0x40	Sensor Reset Diagnostics	• Query sensor reset diagnostic information from the sensor

Examples:

- Determine how many times the Sensor has been reset:
  - DL payload: { 0x 40 }
    - Send query code 0x40 to query the Sensor Reset Diagnostics

3 Reported Transducer Data Stream

The reported transducer data stream is used to exchange transducer data between a Sensor and an application server via LoRaWAN. Uplinks containing measurement data from the on-board transducers are ***sent on LoRaWAN port 10***.

3.1 Uplink Frame Payload to Report Transducers Data

Each data field from the Sensor is encoded in a frame format shown in Figure 3-1. A big-endian format (MSB first) is always followed. Uplinks ***sent on LoRaWAN port 10*** use the same frame payload format as uplinks ***sent on LoRaWAN port 5***.

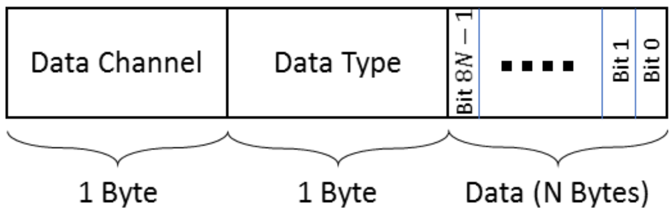


Figure 3-1: The port 10 UL frame payload format.

A Sensor message payload can include multiple transducer data frames, but the frames can be in any order. A single payload may include data from any given transducer. The Sensor's payload frame values are shown in Table 3-1. In this table, the bit indexing scheme is as shown in Figure 3-1. Payload frame values in Table 3-1 has been grouped by bolded boundaries. This grouping is only to indicate which payloads are related to the same physical transducer; it *does not imply* that the payloads within the same group are uplinked together.

Table 3-1: UL Frame Payload Values for Transducer Data

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Battery Voltage	0x00	0xBA	2 B	Analog	• 1 mV / LSB (unsigned)	*battery_voltage: <value> (signed/volt)*
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)*
Impact Alarm	0x0C	0x00	1 B	Digital	• 0x00 = Impact alarm inactive • 0xFF = Impact alarm active	*impact_alarm: <value> (unsigned/no unit)*
Acceleration Magnitude	0x05	0x02	2 B	Analog	• 1 milli-g/LSB (unsigned)	*impact_magnitude: <value> (unsigned/g)*

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Acceleration Vector	0x07	0x71	6 B	Acceleration	• 1 milli-g/LSB (signed) • Bits 32-47: X-axis acceleration • Bits 16-31: Y-axis acceleration • Bits 0-15: Z-axis acceleration	*acceleration {* *xaxis: <value>, (signed/g)* *yaxis: <value>, (signed/g)* *zaxis: <value> (signed/g)* *}*
External Connector: Digital Input State	0x0E	0x00	1 B	Digital	• 0x00 = Low—Connector short-circuited • 0xFF = High—Connector open-circuited	*extconnector_state: <value> (unsigned/no unit)*
External Connector: Relative Digital Input Count	0x0F	0x04	2 B	Counter	• Number	*extconnector_count: <value> (unsigned/no unit)*
External Connector: Total Digital Input Count	0x12	0x04	4 B	Counter	• Number	*extconnector_total_count: <value> (unsigned/no unit)*
External Connector: Analog Input[2]	0x11	0x02	2 B	Analog	• 1 mV/LSB (signed)	*extconnector_analog: <value> (signed/V)*
MCU Temperature	0x0B	0x67	2 B	Temperature	• 0.1°C / LSB (signed)	*mcu_temperature: <value> (signed/°C)*
Ambient Temperature	0x03	0x67	2 B	Temperature	• 0.1°C / LSB (signed)	*ambient_temperature: <value> (signed/°C)*
Ambient RH	0x04	0x68	1 B	RH	• 0.5% / LSB	*relative_humidity: <value> (unsigned/1%)*
Ambient Light State	0x02	0x00	1 B	Digital	• 0x00 = Dark • 0xFF = Bright	*light_detected: <value> (unsigned/no unit)*

[2] 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)
Ambient Light Intensity	0x10	0x02	1 B	Analog	• Uncalibrated digitized light intensity • Values: 0, 1, …, 64	*light_intensity: <value> (unsigned/no unit)*
Motion (PIR) Event State	0x0A	0x00	1 B	Digital	• 0x00 = No motion • 0xFF = Motion detected	*motion_event_state: <value> (unsigned/no unit)*
Motion (PIR) Event Count	0x0D	0x04	2 B	Counter	• Number	*motion_event_count: <value> (unsigned/no unit)*

When the Sensor is powered on or been reset, it will go through its standard startup procedure and then attempts to join the LoRaWAN network. Once the Sensor has successfully joined the LoRaWAN network, it will first send a confirmed UL frame on ***LoRaWAN port 0*** with an empty payload (UL0).[3] Shortly thereafter, the Sensor will send a UL frame ***on LoRaWAN port 5*** containing the latest Sensor Reset Diagnostics[4] (UL1). After about two minutes, if periodic reporting is enabled, the Sensor will send its first periodic report ***on LoRaWAN port 10*** containing transducer data (UL2).

The Sensor supports both periodic and event-based transmissions of transducer data. Periodic transmissions can be configured as shown in Section 4.2.2, where the Sensor will send transducer data according to configured time intervals. Event-based transmissions are supported by select transducers, in which the Sensor will transmit transducer data in response to specific triggers (e.g., waving a hand in front of the Sensor in order to trigger the PIR transducer).

Examples:

In the following example payloads, the data channel ID and data type ID are boldfaced:

- 0x **03 67** 00 0A **04 68** 28
  - $0\text{x}\ \mathbf{03\ 67}\ (\text{Ambient Temperature}) = (0\text{x}\ 00\ 0\text{A}) \times 0.1°\text{C} = 1°\text{C}$
  - $0\text{x}\ \mathbf{04\ 68}\ (\text{Ambient RH}) = (0\text{x}\ 28) \times 0.5\% = 20\%$
- 0x **04 68** 14 **01 00** FF **08 04** 00 05
  - $0\text{x}\ \mathbf{04\ 68}\ (\text{Ambient RH}) = (0\text{x}\ 14) \times 0.5\% = 10\%$
  - $0\text{x}\ \mathbf{01\ 00}\ (\text{Hall Effect State}) = 0\text{x FF} = \text{Magnet absent}$

[3] "ULn" represents the UL with associated FCount (frame counter) number n (e.g., UL0 has FCount 0, UL1 has FCount 1, etc.).

[4] Applicable to sensors programmed with FW versions 3.0.12 and above.

- 0x **08 04** (Hall Effect Count) = 0x 00 05 = 5 switch triggers

- 0x **04 68** 2A **03 67** FF FF **00 BA** 0B B8
  - 0x **04 68** (Ambient RH) = (0x 2A) × 0.5% = 21%
  - 0x **03 67** (Ambient Temperature) = (0x FF FF) × 0.1°C = −0.1°C
  - 0x **00 BA** (Battery Voltage) = (0x 0B B8) × 0.001 V = 3.00 V
- 0x **02 00** FF **0E 00** 00
  - 0x **02 00** (Light State) = 0x FF = Bright
  - 0x **0E 00** (Digital Input State) = 0x 00 = Connector short–circuited
- 0x **0D 04** 00 02
  - 0x **0D 04** (Motion Event Count) = 0x 00 02 = 2 motion events

4 Sensor Application Configuration Stream

The sensor application configuration stream is used to exchange configuration and control command data between a Sensor and an application server via LoRaWAN. Downlinks containing configuration and control commands to a Sensor are ***sent on LoRaWAN port 100***. Uplinks containing responses to configuration and control commands from a Sensor are ***sent on LoRaWAN port 100*** and/or ***LoRaWAN port 101*** (see Section 4.1 for more details).

4.1 Uplink Response to DL Configuration and Control Commands

Sensor responses to DL configuration and control commands (which are sent on ***LoRaWAN port 100***; see Section 4.2) are sent in the UL on ***LoRaWAN port 100*** and/or ***LoRaWAN port 101***. These responses include the following:

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

In the first case, the Sensor responds with the address and value of each of the registers under inquiry on ***LoRaWAN port 100***. The response can be in one or more consecutive UL packets depending on the maximum frame payload size allowed.

In the second case, the Sensor responds by immediately sending the last byte of the LoRaWAN DL frame counter value followed by a size byte indicating the number of registers that were **NOT** successfully written to, and then the addresses of the failed registers on ***LoRaWAN port 101***. The intent is to both inform the user which set of commands the end-device is referring to, and which (if any) of the write commands were seen as invalid. As a result, if a redundant write command is issued (i.e., the value of that register is not changing), then the Sensor will not report its address, because it was not an invalid command. In the case where all the write commands are performed successfully, the Sensor will send back a frame with only the last byte of the DL frame counter value and a size indication byte of “00” on ***LoRaWAN port 101***.

If the DL payload also had read commands, the address and value of each of the registers under inquiry are reported separately on ***LoRaWAN port 100***. In this case, the UL response to read commands on ***LoRaWAN port 100*** is handled before the UL response to write commands on ***LoRaWAN port 101***. The Sensor will respond this way to all read and/or write commands, except for the special case where the anti-bricking strategy is performed. See Section 4.2.2.4 for more details.

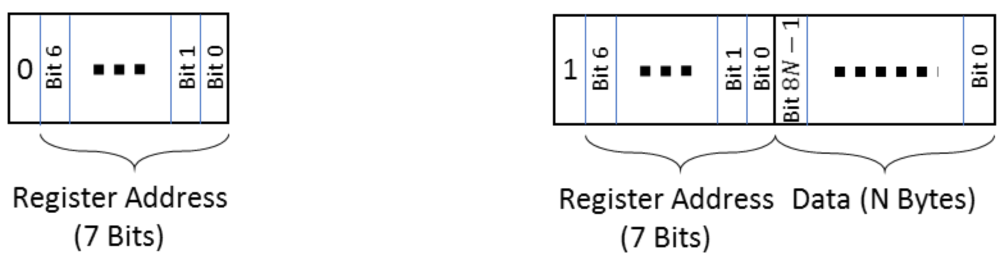
The default method in which the Sensor responds to write commands differs from previous iterations of TEKTELIC Sensors. Previously, the Sensor would respond with a CRC32 of the entire DL payload as the first 4 bytes of the UL frame. Users now have the option to select the desired response format through the configuration register detailed in Section 4.2.9. This option has been included to accommodate applications designed for previous iterations of TEKTELIC Sensors that can decode the CRC. However, it is strongly recommended that users update their data encoders and decoders to accommodate the new response format.

4.2 Downlink Configuration and Control Commands

A single DL configuration and control message can contain multiple command blocks, with a possible mix of read and write commands. Each message block is formatted as shown in Figure 4-1. A big-endian format (MSb/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 4-1. All read commands are one-byte long. Data following a read access command will be interpreted as a new command block. Read commands are processed last. For example, in a single DL message, if there is a read command from a register and a write command to the same register, the write command is executed first.



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

Figure 4-1: The format of a DL configuration and control message block.

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

When a write command is sent to the Sensor, the Sensor immediately responds by sending a UL containing the last byte of the LoRaWAN DL frame counter value followed by a size byte indicating the number of appended addresses, and the addresses of the registers that were not successfully written to on ***LoRaWAN port 101*** (see Section 4.1).

DL configuration and control commands fall into one of the following four categories and are discussed in Sections 4.2.1 to 4.2.10.

- LoRaMAC Configuration
- Periodic Tx Configuration
- Hall Effect Configuration
- External Connector Configuration
- Accelerometer Configuration
- Temperature/RH/Analog Input Threshold Configuration
- Light Sensing Configuration

- Motion Transducer Configuration
- Response to DL Commands Configuration
- Command and Control

4.2.1 LoRaMAC Configuration

LoRaMAC options can be configured using DL commands. These configuration options change the default MAC configuration that the Sensor loads on start-up. They can also change certain run-time parameters. Table 4-1 shows the MAC configuration registers. All the registers have R/W access.

Table 4-1: LoRaMAC Configuration Registers

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

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

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

4.2.1.1 Default Configuration

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

Table 4-2: Default Values of LoRaMAC Configuration Registers

Address	Default Value
0x10	• OTAA mode
0x11	• Unconfirmed UL • Duty cycle enabled[6] • ADR enabled
0x12	• DR0 • Tx Power 0 (max power; see Table 4-3)
0x13	• As per Table 4-4

Table 4-3: Default Maximum Tx Power in Different Regions

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

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

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

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

RF Region	Channel Frequency [Hz]	DR Number
RU864	869100000	0

Examples:

- Switch Sensor to ABP Mode:
  - DL payload: { 0x **90** 00 00 }
- Set ADR enabled, no duty cycle, and confirmed UL payloads:
  - DL payload: { 0x **91** 00 0B }
- Set default DR number to 1 and default Tx power number to 2:
  - DL payload: { 0x **92** 01 02 }

4.2.2 Periodic Tx Configuration

All periodic transducer reporting is synchronized around *ticks*. A *tick* is simply a user configurable time-base that is used to schedule transducer measurements. For each transducer, the number of elapsed *ticks* before transmitting can be defined as shown in Table 4-5. All the registers in this table have R/W access.

Note: Certain transducers, such as accelerometer and light, need to be enabled for periodic reporting. Details are available in each transducer's respective section.

Table 4-5: Periodic Transmission Configuration Registers

Address	Value	Size	Description	JSON Variable (Type/Unit)
0x20	Seconds per Core *Tick*	4 B	• *Tick* value for periodic events • Acceptable values: 0, 10, 11, …, 86400 • 0: Disables all periodic transmissions • Other values: Invalid and ignored	*seconds_per_core_tick: <value>* *(unsigned/sec)*
0x21	*Ticks* per Battery	2 B	• *Ticks* between battery reports • 0 disables periodic battery reports	*tick_per_battery: <value>* *(unsigned/no unit)*
0x22	*Ticks* per Ambient Temperature	2 B	• *Ticks* between ambient temperature reports • 0 disables periodic ambient temperature reports	*tick_per_ambient_temperature: <value>* *(unsigned/no unit)*
0x23	*Ticks* per Ambient RH	2 B	• *Ticks* between ambient RH reports • 0 disabled periodic ambient RH reports	*tick_per_relative_humidity: <value>* *(unsigned/no unit)*
0x24	*Ticks* per Hall Effect	2 B	• *Ticks* between hall effect transducer reports • 0 disables periodic hall effect transducer reports	*tick_per_reed_switch: <value>* *(unsigned/no unit)*
0x25	*Ticks* per Ambient Light	2 B	• *Ticks* between ambient light reports • 0 disables periodic ambient light reports	*tick_per_light: <value>* *(unsigned/no unit)*

Address	Value	Size	Description	JSON Variable (Type/Unit)
0x26	*Ticks* per Accelerometer (both Acceleration and Impact Alarm)	2 B	• *Ticks* between accelerometer reports • 0 disables periodic accelerometer reports	*tick_per_accelerometer: <value>* *(unsigned/no unit)*
0x27	*Ticks* per MCU Temperature	2 B	• *Ticks* between MCU temperature reports • 0 disables periodic MCU temperature reports	*tick_per_mcu_temperature: <value>* *(unsigned/no unit)*
0x28	*Ticks* per Motion (PIR)	2 B	• *Ticks* between motion (PIR) reports • 0 disables periodic motion (PIR) reports	*tick_per_pir: <value>* *(unsigned/no unit)*
0x29	*Ticks* per External Connector (Digital/Analog Input)	2 B	• *Ticks* between external connector (digital/analog input) reports • A value of 0 disables periodic external connector (digital/analog input) reports	*tick_per_external_connector: <value>* *(unsigned/no unit)*

4.2.2.1 Seconds per Core Tick

All periodic Tx events are scheduled in *ticks*. This allows for transducer reads to be synchronized, reducing the total number of ULs required to transmit Sensor data. The minimum seconds per *tick* is 10 sec, and the maximum is 86,400 sec (one day). Values from 1 sec to 9 sec and values above 86,400 sec are invalid and ignored. A value of 0 (zero) disables all periodic reporting.

Note: While the seconds per core *tick* can be set as low as 10 seconds, it is recommended that the Core *Tick* and *Ticks* per <Transducer> registers be configured such that the Sensor transmits only as frequently as is reasonably necessary for the use case and environment.

4.2.2.2 Ticks per <Transducer>

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

4.2.2.3 Default Configuration

Table 4-6 shows the default values for the periodic transmission configuration registers.

Table 4-6: Default Values of Periodic Transmission Configuration Registers

Seconds per Core *tick*	3600 (1 hour)
***Ticks* per Battery**	1 (thus 1-hour period)
***Ticks* per Ambient Temperature**	1 (thus 1-hour period)

***Ticks* per Ambient RH**	1 (thus 1-hour period)
***Ticks* per Hall Effect**	0 (periodic Tx disabled)
***Ticks* per Ambient Light**	0 (periodic Tx disabled)
***Ticks* per Accelerometer**	0 (periodic Tx disabled)
***Ticks* per MCU Temperature**	0 (periodic Tx disabled)
***Ticks* per PIR**	0 (periodic Tx disabled)
***Ticks* per Digital/Analog Input**	0 (periodic Tx disabled)

Examples:

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

4.2.2.4 Anti-Bricking Strategy

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

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

After the reconfiguration is applied, if all event-based reporting (as explained in subsequent sections) is disabled,[7] then periodic reporting is checked. If all periodic reporting is disabled or the minimum non-zero period is greater than a day, then to avoid bricking the Sensor, the core *tick* is set to 86,400 (i.e., one day), and

[7] Since the Sensor can be configured to simultaneously disable both acceleration magnitude and vector reporting for accelerometer events (via downlink configuration register 0x32), the anti-bricking strategy can apply even if event-based accelerometer reporting is enabled.

the battery *tick* is set to 1 (one). The Sensor will first respond on ***LoRaWAN port 100*** with the value of the registers it has had to change internally to inform the application server of these changes. Then, the sensor will respond to the attempted reconfiguration on ***LoRaWAN port 101*** with the LoRaWAN DL frame counter value followed by what registers it has been unable to change as per normal (see Section 4.1).[8]

4.2.3 Hall Effect Configuration

Note: The reed switch has been replaced with a hall effect transducer on sensors with module revision D and above. The hall effect transducer and reed switch are functionally identical.

Table 4-7 shows a list of Hall Effect configuration registers. All registers have R/W access.

Table 4-7: Hall Effect Configuration Registers

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x2A	Mode	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 and ignored Bits 2-7: Ignored	*reed_mode {* *rising_edge_enabled: <value>, (unsigned/no unit)* *falling_edge_enabled: <value> (unsigned/no unit)* *}*
0x2B	Count Threshold	2 B	• Number of triggers for event transmission • 0 disables event transmission	*reed_switch_count_threshold: <value> (unsigned/no unit)*
0x2C	Report Options	1 B	• Bit 0: 0/1 = Input state not reported/reported • Bit 1: 0/1 = Counter value not reported/reported • Both bits 0 and 1 set to 0: Invalid and ignored • Bits 2-7: Ignored	*reed_tx {* *report_state_enabled: <value>, (unsigned/no unit)* *report_count_enabled: <value>, (unsigned/no unit)* *}*

[8] This assumes that the response format is set to the default method (i.e., invalid-write response format). If the CRC method is selected, the Sensor will respond with the 4-byte CRC in response to the configuration command as per normal.

4.2.3.1 Mode

The hall effect transducer is edge-triggered and can be set to trigger on a rising-edge (Low/Closed to High/Open) and/or a falling-edge (High/Open to Closed/Low). An attempt to set the Mode to 0x00 (i.e. to disable both rising and falling edges) is ignored by the Sensor.[9]

Application Example:

Door Open/Close detection would use both rising and falling triggers to detect when the door was opened and when it was closed.

4.2.3.2 Count Threshold

The Count Threshold determines when the Sensor transmits after seeing an event on the hall effect transducer. A value of 0 (zero) disables the event driven transmission, while a value of 1 (one) or greater triggers an event-based transmission after the configured number of events has occurred, which is when the event "counter" reaches the value of the Count Threshold. Whenever such event-based transmission occurs, the event counter is automatically reset to 0 and starts incrementing as events occur until the counter reaches the threshold again and another event-based transmission occurs.

Application Example:

If a sensor is intended to monitor room utilization, it may be configured either to disable event-based transmission in favor of getting hourly reports from the sensor, or to only transmit after 50 "events" logged in the room. The latter may be useful for alerting cleaning staff that room requires attention.

4.2.3.3 Report Options

The Report Options determines what information is transmitted whenever an event or periodic digital transmission is required. If the value is "Counter Value", the transmission contains the number of times the hall effect transducer was triggered since the last transmission, while the value of "Input State" causes a transmission of the current input state of the switch (i.e. Open or Closed).

4.2.3.4 Default Configuration

Table 4-8 shows the default values for the Hall Effect configuration registers.

Table 4-8: Default Values of Hall Effect Configuration Registers

Mode	Rising and falling edges enabled
Threshold	1 (one)
Report Options	State and count reported

[9] Input pulse frequency must be less than 5 Hz.

Examples:

- Have hall effect transducer be triggered only on rising edges:
  - DL payload: { 0x **AA** 01 }
    - Register 0x2A with write bit set to true
    - “Rising Edge” enabled, “Falling Edge” disabled
- Read current value of Count Threshold:
  - DL payload: { 0x **2B** }
    - Register 0x2B with write bit set to false
- Transmit the hall effect “state” as soon as the hall effect transducer is tripped 10 times:
  - DL payload: { 0x **AB** 00 0A **AC** 01 }
    - Registers 0x2B and 0x2C with their write bits set to true
    - Count Threshold set to 10
    - Report Options set to “Input State”
- 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 }
    - Count Threshold set to 0 (zero)
    - Report Options set to “Counter Value”

4.2.4 External Connector Configuration

The Sensor features an external connector that allows users to connect an analog or digital external sensing probe. *Only the Comfort model is equipped with an external connector.* This connector can be configured as either a digital input (having only two values or states of “open” and “closed”), or analog input. The input mode (digital or analog) is determined by bit 7 of register 0x2D (see Table 4-9). The input mode is digital by default.

In the digital input mode, the external connector has only two values or states: open (open-circuited) with a value of 0xFF, and closed (short-circuited) with a value of 0x00. For example, the external connector can be used for leak detection in this mode of operation. This mode of operation supports periodic (Section 4.2.2) and event-based (edge triggered) reporting (see the following subsections).

In the analog input mode, one pin is grounded, and the other pin is pulled up to VDD_MPU (1.9 V) by a 68.1-*k*Ω resistor. The analog input has values in units of mV from 0 to VDD_MPU (the precision is 1 mV[10]), and is suitable for connection to a thermistor (recommended 10-*k*Ω) as a remote temperature probe. The actual temperature can be obtained from the value of the analog input and a conversion table or formula (see [3] for

[10] The actual ADC output has a resolution of 0.61 mV.

such conversion methods and formulas). This mode of operation supports periodic (Section 4.2.2) and threshold-based reporting (Section 4.2.6).

Table 4-9 shows a list of External Connector configuration registers. All registers have R/W access, except for register 0x5A, which has write-only (WO) access.

Table 4-9: External Connector Configuration Registers

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x2D	Mode	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 and ignored • Bits 2-6: Ignored • Bit 7: 0/1 = Digital/Analog Input mode	*external_connector {* *rising_edge_enabled: <value>, (unsigned/no unit)* *falling_edge_enabled: <value>, (unsigned/no unit)* *mode: <value> (unsigned/no unit)* *}*
0x2E	Count Threshold	2 B	• Number of triggers for event transmission • 0: disables event transmission	*external_connector_count_threshold: <value>* *(unsigned/no unit)*
0x2F	Report Options	1 B	• Bit 0: 0/1 = Digital Input state not reported/reported • Bit 1: 0/1 = Digital Input count not reported/reported • Both bits 0 and 1 set to 0: Invalid and ignored • Bits 4: 0: Report Relative Digital Input count 1: Report Total Digital Input count • Bits 2-3, 5-7: Ignored	*external_connector_tx {* *report_state_enabled: <value>, (unsigned/no unit)* *report_count_enabled: <value>, (unsigned/no unit)* *count_type: <value> (unsigned/no unit)* *}*
0x5A (WO)	Reset Total Count	4 B	• Counter value (1/LSB) • Acceptable values: 0, 1, …, 4,294,967,295	*external_connector_reset_count: <value>* *(unsigned/no unit)*

4.2.4.1 Mode

In the Digital Input mode (bit 7 = 0), the input is edge-triggered and can be set to be triggered by the rising edge (Low/Closed to High/Open) and/or the falling edge (High/Open to Closed/Low). An attempt to set the Mode to 0x00 (i.e. to disable both rising and falling edges) is ignored by the Sensor.[11]

In the Analog Input mode (bit 7 = 1), bits 0-6 of register 0x2D, and the entire registers 0x2E and 0x2F are irrelevant and ignored. The configuration registers in the Analog Input mode only include 0x29 (see Section 4.2.2), 0x44, 0x45, 0x46, and 0x4A (see Section 4.2.5).

Application Examples for Digital Input Mode:

- Door Open/Close detection would use both rising and falling triggers to detect when the door was opened and when it was closed.
- Pulse counting from a water meter would use a single edge trigger, depending on the resting state of the connected device (positive pulse would use rising edge, negative pulse would use falling edge).

4.2.4.2 Count Threshold

The Count Threshold is only applicable in the Digital Input mode, and determines when the Sensor transmits after seeing an event on Digital Input. A value of 0 (zero) disables the event driven transmission, while a value of 1 (one) or greater triggers an event-based transmission after the configured number of events has occurred, which is when the event "counter" reaches the value of the Count Threshold. Whenever such event-based transmission occurs, the event counter is automatically reset to 0 and starts incrementing as events occur until the counter reaches the threshold again and another event-based transmission occurs.

Application Examples:

- If a sensor is intended to pulse count from a high-volume water meter, it may be configured to disable event-based transmission in favor of getting hourly reports from the sensor.
- If a sensor is intended to monitor room utilization it may be configured to only transmit after 100 "events" logged in the room. This may be useful for alerting cleaning staff that room requires attention.

4.2.4.3 Report Options

The Report Options register determines what information is transmitted whenever a Digital Input event or periodic transmission is required. Digital Input events can only be tracked and reported when the external connector is configured in Digital Input mode.

Bit 0 (Digital Input state) controls whether the transmission contains the current Digital Input state of the switch (i.e., 0xFF for open or 0x00 for closed). Bit 1 (Digital Input count) controls whether the transmission

[11] Input pulse frequency must be less than 3 Hz.

contains the number of times that the Digital Input has been triggered, either represented as the Relative or Total Digital Input count. Bit 4 controls whether the Sensor reports the Relative or Total Digital Input count while Digital Input count reporting (controlled by Bit 1) is enabled. The Relative count represents the number of times that the Digital Input has been triggered since the last transmission, while the Total count represents the current total number of Digital Input triggers that have occurred.

The Total count can always be incremented while in Digital Mode, even if the Sensor is configured to report the Relative count and/or if Digital Input count reporting is disabled. The Sensor will also retain the Total count over soft resets (e.g., push-button, DL command, and independent watchdog resets). However, the Total count is lost when the Sensor loses power.

4.2.4.4 Reset Total Count

The Total Digital Input count can be reset to any value written to the Reset Total Count register. This register has write-only (WO) access.

Application Example:

- If a sensor is intended to pulse count from a water meter that is already running, the Total count may be reset to match the value shown on the meter when the sensor is first connected. This makes it easier to synchronize sensors with existing devices.
- If a sensor has been pulse counting from a water meter for some time, but the Total count is lost due to a battery replacement, the application could reset the Total count to the last known value reported by a sensor.

4.2.4.5 Default Configuration

Table 4-10 shows the default values for the External Connector configuration registers.

Table 4-10: Default Values of External Connector Configuration Registers

Mode	Digital Input mode with rising and falling edges enabled
Threshold	1 (one)
Report Options	• Digital Input state and count reported • Relative counter reported

Examples:

- Have Digital Input be triggered only on falling edges:
  - DL payload: { 0x **AD** 02 }
    - Register 0x2D with write bit set to true
    - “Rising edge” disabled, “Falling edge” enabled
- Read current value of Count Threshold:
  - DL payload: { 0x **2E** }

        - Register 0x2E with write bit set to false
- Transmit the Digital Input state as soon as the Digital Input is tripped 20 times:
    - DL payload: { 0x **AE** 00 14 **AF** 01 }
        - Registers 0x2E and 0x2F with their write bits set to true
        - Count Threshold set to 20
        - Report Options set to "Digital Input state"
- Disable the Digital Input event-driven transmission, but report the relative number of times the Digital Input has been triggered whenever a report is inquired (i.e., in the case of periodic reporting):
    - DL payload: { 0x **AE** 00 00 **AF** 02 }
        - Registers 0x2E and 0x2F with their write bits set to true
        - Count Threshold set to 0 (zero)
        - Report Options set to "Digital Input count" and "Report Relative Digital Input count"
- Reset the total number of Digital Input events to 0 and report the Digital Input state and total number of times the Digital Input has been triggered:
    - DL payload: { 0x **AF** 13 **DA** 00 00 00 00 }
        - Registers 0x2F and 0x5A with their write bits set to true
        - Report Options set to "Digital Input state," "Digital Input count," and "Report Total Digital Input count"
        - Reset Total Count set to 0

4.2.5 Accelerometer Configuration

The accelerometer transducer offers a threshold for an "impact alarm event,"[12] and a threshold for an "acceleration event." It can also be polled periodically for applications where the Sensor orientation may be of interest. Table 4-11 shows a list of accelerometer configuration registers. All registers have R/W access.

Some terminology in this section is as follows:

- Accelerometer (transducer) refers to the accelerometer transducer component.
- Impact alarm (event) refers to an accelerometer event based on exceeding an impact alarm event threshold. Impact alarm events are reported with an impact alarm.
- Acceleration (event) refers to an accelerometer event, independent of the impact alarm event, and based on exceeding an acceleration event threshold. Acceleration events are reported with the acceleration magnitude, acceleration vector, or both.

[12] Here "impact" generally refers to a Sensor motion event (i.e., not necessarily an *impact* to the Sensor).

Table 4-11: Accelerometer Configuration Registers

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x30	Impact Alarm Event Threshold	2 B	• Unsigned, 1 milli-g/LSB	*impact_event_threshold (unsigned/g)*
0x31	Acceleration Event Threshold	2 B	• Unsigned, 1 milli-g/LSB	*acceleration_event_threshold: <value> (unsigned/g)*
0x32	Report Options	1 B	• Bit 0 (applicable to periodic reporting[13]): 0/1 = Impact alarm not reported/reported • Bit 1 (applicable to periodic reporting): 0/1 = Acceleration magnitude not reported/reported • Bit 2 (applicable to periodic reporting): 0/1 = Acceleration vector not reported/reported • Bits 0-2 all set to 0: Invalid and ignored • Bit 4 (applicable to acceleration event reporting): 0/1 = Acceleration magnitude not reported/reported • Bit 5 (applicable to acceleration event reporting): 0/1 = Acceleration vector not reported/reported • Bits 3, 6, 7: Ignored	*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)* *}*
0x33	Acceleration Event Debounce Time	2 B	• Seconds to wait before possibly reporting an acceleration event again • Acceptable values: 1, 2, …, 65535 • 0: Invalid and ignored	*acceleration_impact_grace_period: <value> (unsigned/seconds)*
0x34	Mode	1 B	• Bit 0: 0/1 = Impact alarm event threshold disabled/enabled	*accelerometer {* *impact_threshold_enabled: <value>,*

[13] This bit only controls whether the impact alarm status (i.e., raised or cleared) will be present in periodic reporting when such accelerometer periodic reporting is enabled (see Section 4.2.2). This bit does not control reporting of the impact alarm status for impact alarm events. If the impact alarm event threshold is enabled (register 0x34, bit 0), an impact alarm is always raised (reported) when the impact alarm event threshold (register 0x30) is exceeded, and is cleared after an impact alarm event grace period (register 0x36) elapses without any impact alarm events (see Section 4.2.5.7).

Address	Name	Size	Description	JSON Variable (Type/Unit)
			• Bit 1: 0/1 = Acceleration event threshold disabled/enabled • Bits 2, 3: Ignored • Bit 4/5/6: 0/1 = X/Y/Z-axis disabled/enabled • Bit 7: 0/1 = Accelerometer power off/on	*(unsigned/no unit)* *acceleration_threshold_enabled : <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)* *}*
0x35	Sensitivity	1 B	• Bits 0-2 (Sample Rate): 0: Invalid and ignored 1/2/3/4/5/6/7 = 1/10/25/50/100/200/400 Hz • Bits 4-5 (Measurement Range[14]): 0/1/2/3 = ±2 *g*/±4 *g*/±8 *g*/±16 *g* • Bits 3, 6, 7: Ignored	*sensitivity {* *accelerometer_sample_rate: <value>,* *(unsigned/Hz)* *accelerometer_measurement_range: <value>,* *(unsigned/g)* *}*
0x36	Impact Alarm Event Grace Period	2 B	• Impact alarm grace period in sec (time to pass after the last impact alarm before the alarm can be cleared) • Acceptable values: 15, 16, …, 65535 • Other values: Invalid and ignored	*impact_alarm_grace_period: <value>* *(unsigned/seconds)*
0x37	Impact Alarm Event Threshold Count	2 B	• Number of impact alarm events before an impact alarm is raised • Acceptable values: 1, 2, …, 65535	*impact_alarm_threshold_count: <value>* *(unsigned/no unit)*

[14] Measurement ranges ±2 *g*, ±4 *g*, ±8 *g*, ±16 *g* correspond to typical transducer output precisions of 16 mg, 32 mg, 64 mg, 192 mg, respectively. Note that if a threshold configured in register 0x30 or register 0x31 is equal to or greater than the configured measurement full scale (2 *g*, 4 *g*, 8 *g*, 16 *g*), then the corresponding event (impact alarm or acceleration event) will never be triggered.

Address	Name	Size	Description	JSON Variable (Type/Unit)
			• 0: Invalid and ignored	
0x38	Impact Alarm Event Threshold Period	2 B	• Period in sec over which impact alarm events are counted for threshold detection • Acceptable values: 5, 6, …, 65535 • Other values: Invalid and ignored	*impact_alarm_threshold_period: <value> (unsigned/seconds)*

4.2.5.1 Impact Alarm Event Threshold

This parameter is the g-threshold for an impact alarm event. Impact alarm events are reported only if both of the following conditions are met:

- The impact alarm event threshold (bit 0 of register 0x34) is enabled.
- The impact alarm event threshold is exceeded on at least one of the enabled axes (X, Y, Z) within a period (Impact Alarm Event Threshold Period—register 0x38) more than the configured number of times (Impact Alarm Event Threshold Count—register 0x37).

4.2.5.2 Acceleration Event Threshold

This parameter is the g-threshold for an acceleration event. Provided that the acceleration threshold is enabled (bit 1 of register 0x34), acceleration events are reported as soon as the Acceleration Event Threshold is exceeded on at least one of the enabled axes (X, Y, Z). However, acceleration event interrupts are completely ignored (not registered) for a time period equal to the Acceleration Event Debounce Time (register 0x33) after a registered (and thus reported) acceleration event.

4.2.5.3 Report Options

The Report Options register determines what is reported (transmitted) in the case of accelerometer periodic transmission or an acceleration event. The parameters to report include the status of the impact alarm (alarm on/off), the acceleration magnitude $||\langle x, y, z\rangle|| = \sqrt{x^2 + y^2 + z^2}$, and the acceleration vector $\langle x, y, z\rangle$.

4.2.5.4 Acceleration Event Debounce Time

Interrupts caused by acceleration events are disabled for a configurable duration, called the Acceleration Event Debounce Time, after an acceleration event is registered. This is to prevent a single acceleration event from being transmitted as multiple events. The minimum debounce time is 1 (one) sec. A value 0 (zero) is invalid and ignored.

4.2.5.5 Mode

The accelerometer can be put in the power-down mode to save battery life when it is not being used in an end-user application. Otherwise, the accelerometer can be enabled in a low-power mode, in which it is active and operational.

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

4.2.5.6 Sensitivity

When powered on, the accelerometer always 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 a shorter period and can therefore resolve shorter impacts.

However, sampling the transducer at a larger rate increases the power usage, impacting the battery life. Table 4-12 shows how much continuous current draw is expectable to be drawn from a 3.0-V battery for the different sample rates when the accelerometer is powered on. For example, the sample rate of 1 Hz would translate to about 10 mAh/year battery usage, while a sample rate of 50 Hz would over triple that usage.

Table 4-12: 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

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

4.2.5.7 Impact Alarm Event Grace Period

The Grace Period determines how long the Sensor waits before the previously reported impact alarm event is considered clear. For example, a Grace Period of 5 (five) min results in the sensor transmitting “Impact Detected” when there is movement, and “Impact Alarm Cleared” 5 (five) min after the Sensor has been still.

The minimum acceptable value for this register is 15. Values smaller than 15 are invalid and ignored.

4.2.5.8 Impact Alarm Event Threshold Count

The accelerometer generates an impact alarm event each time it detects movement. Depending on the customer use case, it may be desirable to increase the threshold count to reduce sensitivity. This feature is to allow customers to filter out short impact events, while still allowing longer impact events to be reported.

The minimum acceptable value for this register is 1. Value 0 is invalid and ignored.

4.2.5.9 Impact Alarm Event Threshold Period

The Impact Alarm Event Threshold Period is the amount of time that impact alarm events are accumulated for threshold detection. For example, an Impact Alarm Event Threshold Period of 10 (ten) sec accumulates impact alarm events over a 10 (ten)-sec period from the time of first detection. If the Impact Alarm Event Threshold Count is reached before the time expires, the sensor reports "Impact Detected", otherwise it does not report.

The minimum acceptable value for this register is 5. Values smaller than 5 are invalid and ignored.

4.2.5.10 Default Configuration

Table 4-13 shows the default values for the accelerometer configuration registers.

Table 4-13: Default Values of Accelerometer Configuration Registers

Impact Alarm Event Threshold	1500 milli-g
Acceleration Event Threshold	3000 milli-g
Report Options	Acceleration vector for periodic and acceleration-event reports
Acceleration Event Debounce Time	2 sec
Mode	• Impact alarm threshold disabled • Acceleration threshold disabled • X-axis, Y-axis, and Z-axis enabled • Accelerometer power off
Sensitivity	• Sample rate 1 Hz • Measurement range ±8 g
Impact Alarm Event Grace Period	300 sec (5 min)
Impact Alarm Event Threshold Count	1
Impact Alarm Event Threshold Period	15 sec

4.2.6 Temperature/RH/Analog Input Threshold Configuration

The Comfort/Vivid supports threshold transmission on four different transducer values:

- Ambient temperature: Measured by the Temperature/RH transducer
- Ambient RH: Measured by the Temperature/RH transducer
- MCU Temperature: Measured by the MCU (with lower accuracy compared to the Ambient Temperature)
- Analog Input Voltage: When the External Connector is in the Analog Input mode (*Comfort model only)*.

When a threshold on a transducer is enabled, the Sensor reports the transducer value when it leaves the configured threshold window, and once again when the transducer value re-enters the threshold window[15]. The Threshold mode is compatible with periodic reporting. Table 4-14 shows a list of configuration registers for the temperature/RH/Analog Input threshold setting. All the registers have R/W access.

Table 4-14: Temperature/RH/Analog Input Threshold Configuration Registers

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x39	Ambient Temperature/RH Sample Period: Idle	4 B	• Sample period of Ambient Temperature/RH transducer: Idle state (sec) • Acceptable values: 30, 31, …, 86400 • Other values: Invalid and ignored	*temperature_relative_humidity_sample_period_idle: <value> (unsigned/sec)*
0x3A	Ambient Temperature/RH Sample Period: Active	4 B	• Sample period of Ambient Temperature/RH transducer: Active state (sec) • Acceptable values: 30, 31, …, 86400 • Other values: Invalid and ignored	*temperature_relative_humidity_sample_period_active: <value> (unsigned/sec)*
0x3B	Low/High Ambient Temperature Thresholds	2 B	• Bits 8-15: High temperature threshold (signed, 1°C / LSB) • Bits 0-7: Low temperature threshold (signed, 1°C / LSB) • High threshold ≤ Low threshold: Invalid and ignored	*ambient_temperature_threshold { high: <value> (signed/°C) low: <value> (signed/°C) }*
0x3C	Ambient Temperature Thresholds Enabled	1 B	• Bit 0: 0/1 = Thresholds disabled/enabled • Bits 1-7: Ignored	*ambient_temperature_threshold_enabled: <value> (unsigned/no unit)*
0x3D	Low/High Ambient RH Thresholds	2 B	• Bits 8-15: High RH threshold (unsigned, 1% RH / LSB) • Bits 0-7: Low RH threshold (unsigned, 1% RH / LSB) • High threshold ≤ Low threshold: Invalid and ignored	*relative_humidity_threshold { high: <value>, (unsigned/%) low: <value> (unsigned/%) }*
0x3E	Ambient RH Thresholds Enabled	1 B	• Bit 0: 0/1 = Thresholds disabled/enabled • Bits 1-7: Ignored	*relative_humidity_threshold_enabled: <value> (unsigned/no unit)*

[15] Note that the threshold window here is defined as the open interval "(Low Threshold, High Threshold)", not e.g. the closed interval "[Low Threshold, High Threshold]"; i.e. even if the transducer value is equal to Low Threshold or High Threshold, the Sensor is considered to have left the threshold window.

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x40	MCU Temperature Sample Period: Idle	4 B	• Sample period of MCU temperature transducer: Idle state (sec) • Acceptable values: 30, 31, …, 86400 • Other values: Invalid and ignored	*mcu_temperature_sample_period_idle: <value>* *(unsigned/sec)*
0x41	MCU Temperature Sample Period: Active	4 B	• Sample period of MCU temperature transducer: Active state (sec) • Acceptable values: 30, 31, …, 86400 • Other values: Invalid and ignored	*mcu_temperature_sample_period_active: <value>* *(unsigned/sec)*
0x42	Low/High MCU Temperature Thresholds	2 B	• Bits 8-15: High MCU temperature threshold (signed, 1°C / LSB) • Bits 0-7: Low MCU temperature threshold (signed, 1°C / LSB) • High threshold ≤ Low threshold: Invalid and ignored	*mcu_temperature_threshold* *{* *high: <value>,* *(signed/°C)* *low: <value>* *(signed/°C)* *}*
0x43	MCU Temperature Thresholds Enabled	1 B	• Bit 0: 0/1 = Thresholds disabled/enabled • Bits 1-7: Ignored	*mcu_temperature_threshold_enabled: <value>* *(unsigned/no unit)*
0x44	Analog Input Sample Period: Idle	4 B	• Sample period of analog input: Idle state (sec) • Acceptable values: 30, 31, …, 86400 • Other values: Invalid and ignored	*analog_sample_period_idle: <value>* *(unsigned/sec)*
0x45	Analog Input Sample Period: Active	4 B	• Sample period of analog input: Active state (sec) • Acceptable values: 30, 31, …, 86400 • Other values: Invalid and ignored	*analog_sample_period_active: <value>* *(unsigned/sec)*
0x46	Low/High Analog Input Thresholds	4 B	• Bits 16-31: High analog input threshold (unsigned, 1 mV/LSB) • Bits 0-15: Low analog input threshold (unsigned, 1 mV/LSB) • High threshold ≤ Low threshold: Invalid and ignored	*analog_input_threshold {* *high: <value>,* *(unsigned/V)* *low: <value>* *(unsigned/V)* *}*
0x4A	Analog Input Thresholds Enabled	1 B	• Bit 0: 0/1 = Thresholds disabled/enabled • Bits 1-7: Ignored	*analog_input_threshold_enabled: <value>* *(unsigned/no unit)*

4.2.6.1 Temperature/RH/Analog Input Sample Period: Idle

The idle sample period determines how often the transducer is checked when the reported value is within the threshold window. When first enabled, the transducer starts in the Idle state.

The minimum Sample Period in the Idle state is 30 sec, and the maximum is 86,400 sec (one day). Values smaller than 30 for this register are invalid and ignored.

4.2.6.2 Temperature/RH/Analog Input Sample Period: Active

The active sample period determines how often the transducer is checked when the reported value is outside the threshold window.

The minimum Sample Period in the Active state is 30 sec, and the maximum is 86,400 sec (one day). Values smaller than 30 for this register are invalid and ignored.

4.2.6.3 Temperature/RH/Analog Input Thresholds

The thresholds are stored in a single 2-byte register, with the MSB storing the upper threshold, and the LSB storing the lower threshold. Ambient or MCU Temperature thresholds have a precision of 1°C per bit, and are stored/transmitted as 2-s complement numbers. The RH thresholds have a precision of 1% per bit, and are stored/transmitted as unsigned numbers. The Analog Input thresholds are also unsigned numbers, and have a precision of 1 mV per bit.

In all cases, the upper threshold must be greater than the lower threshold. Otherwise, the configuration is considered invalid and ignored.

4.2.6.4 Temperature/RH/Analog Input Thresholds Enabled

The Thresholds Enabled registers enable and disable the threshold reporting on the specified transducer. Thresholds and Sample Periods can be configured but are not activated unless the Thresholds Enabled bit is set.

4.2.6.5 Default Configuration

Table 4-15 shows the default values for the threshold configuration registers.

Table 4-15: Default Values of Threshold Configuration Registers

Ambient Temperature/RH Sample Period: Idle	60 sec
Ambient Temperature/RH Sample Period: Active	30 sec
Ambient Temperature Threshold: High	30°C
Ambient Temperature Threshold: Low	15°C
Ambient Temperature Thresholds Enabled	Disabled
Ambient RH Threshold: High	80%
Ambient RH Threshold: Low	15%
Ambient RH Thresholds Enabled	Disabled

MCU Temperature Sample Period: Idle	300 sec
MCU Temperature Sample Period: Active	60 sec
MCU Temperature Threshold: High	30°C
MCU Temperature Threshold: Low	15°C
MCU Temperature Thresholds Enabled	Disabled
Analog Input Sample Period: Idle	60 sec
Analog Input Sample Period: Active	30 sec
Analog Input Threshold: High	1200 mV
Analog Input Threshold: Low	600 mV
Analog Input Thresholds Enabled	Disabled

Examples:

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

4.2.7 Light Sensing Configuration

The light transducer on the Comfort/Vivid allows for the detection of the presence or absence of light based on the built-in light sensing transducer. The sensing element light pipe is visible on the top surface of the Sensor's enclosure. The orientation of the Sensor relative to the light source impacts the measured level of light intensity. The light sensing capability supports both periodic and threshold-based transmissions. Table 4-16 shows a list of light transducer configuration registers. All the registers have R/W access.

Table 4-16: Light Transducer Configuration Registers

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x47	Sample Period	4 B	• Sample period of the light transducer (sec) • Acceptable values: 0, 30, 31, …, 86400 • 0: Disables the light sensing element	*light_sample_period: <value>* *(unsigned/second)*

Address	Name	Size	Description	JSON Variable (Type/Unit)
			• 1, 2, …, 29: Invalid and ignored	
0x48	Threshold Control	1 B	• Bits 0-5: 0: Invalid and ignored 1-63: Threshold level (1: darkest, 63: brightest) • Bit 6: Ignored • Bit 7: • 0/1 = Threshold-based reporting disabled/enabled	*light {* *threshold: <value>, (unsigned/no unit)* *threshold_enabled: <value> (unsigned/no unit)* *}*
0x49	Report Options	1 B	• Bit 0: 0/1 = State (dark or bright) not reported/reported • Bit 1: 0/1 = Intensity (a value between 0 and 64, inclusive) not reported/reported • Both bits 0 and 1 set to 0: Invalid and ignored • Bits 2-7: Ignored	*light_tx {* *state_reported: <value>, (unsigned/no unit)* *intensity_reported: <value> (unsigned/no unit)* *}*

4.2.7.1 Sample Period

The light transducer is held off to preserve energy, but turned on periodically by the MCU to take samples. The light sensing sample period determines how often the light sensing transducer is powered on and checked for the presence of light. Shorter sample periods result in an improved detection time but result in additional battery usage.

Acceptable values for the sample period are 0, 30–86,400 sec. Setting the sample period to 0 (zero) disables the light sensing element. Values 1 to 29 sec or values greater than 86,400 sec are invalid and ignored.

Note: The light sensing sample period needs to be enabled for periodic transmission. Otherwise, in every transmission a repetitive light value residing in the MCU memory is reported.

4.2.7.2 Threshold Control

Bits 0-5 of the Threshold Control register is used to set the dark/bright transition point for the Sensor, and can be set to any value from 1 to 63. A light value smaller than or equal to the threshold is interpreted as “dark”, and values greater than the threshold as “bright”. Therefore, a threshold setting of 1 (one) corresponds to the darkest threshold, and 63 to the brightest threshold. When first enabled, the Sensor begins in the “dark” state.

Bit 7 of the Threshold is used to enable or disable the threshold-based reporting. If the threshold-based reporting is enabled, the Sensor transmits whenever the threshold is crossed (i.e. when the current and previous samples lie both sides of the threshold). If the threshold-based reporting is disabled, the threshold defined in bits 0-5 is only used to determine the “state” (dark or bright) in possible periodic transmissions.

4.2.7.3 Report Options

The Report Options determines the value that is reported in periodic or threshold-based transmissions. The light state is either dark or bright (based on a comparison of the light intensity value with the light threshold). The light intensity is a value between 0 and 64, inclusive.

4.2.7.4 Default Configuration

Table 4-17 shows the default values for the light transducer configuration registers.

Table 4-17: Default Values of Light Transducer Configuration Registers

Sample Period	Light transducer disabled
Threshold Control	• Threshold-based reporting enabled • Light threshold = 32 (i.e. a mid-range threshold)
Report Options	Light state reported only

4.2.8 Motion Transducer Configuration

The Sensor features a motion transducer (detector) that uses a PIR transducer for the detection of human motion in a room. *Only the Vivid model is capable of motion detection.* Due to the sensitive electronics used in the PIR motion detector, the Sensor is designed to behave as follows:

- For **120 sec** after power is first applied to the device, the PIR motion detector is disabled (*post-turn on hold-off interval*). This is required for the PIR transducer output to stabilize and avoids false detections. The post-turn on hold-off interval is configurable through register 0x54 (see Table 4-18).
- For approximately **15 sec** after a radio transmission or after sampling the temperature/RH transducer, the PIR motion detector is disabled (*post-disturbance hold-off interval*). The operation of the radio or the temperature/RH transducer causes the PIR transducer to produce false positives so a “cool down” period is required after each Tx. The post-disturbance hold-off interval is also configurable through register 0x54 (see Table 4-18).

The Vivid runs a simple state machine for reporting whether motion is detected. To conserve battery usage, motion is reported only when it is first detected and when motion has not been detected for a configurable Grace Period.

Note: The PIR transducer is designed to detect motion so if a room is occupied but the occupants are not moving, the sensor may report “No Motion” after the Grace Period (see Section 4.2.8.1) expires.

Table 4-18 shows a list of motion transducer configuration registers. All the registers have R/W access.

Table 4-18: Motion Transducer Configuration Registers

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x50	Grace Period	2 B	• Grace period in sec (time before motion is no longer detected) • Acceptable values: 15, 16, …, 65535 • Other values: Invalid and ignored	*pir_grace_period: <value>* *(unsigned/second)*
0x51	Threshold Count	2 B	• Number of PIR events before motion is detected • Acceptable values: 1, 2, …, 65535 • 0: Invalid and ignored	*pir_threshold: <value>* *(unsigned/no unit)*
0x52	Threshold Period	2 B	• Period over which PIR events are counted for threshold detection • Acceptable values: 5, 6, …, 65535 • Other values: Invalid and ignored	*pir_threshold_period: <value>* *(unsigned/no unit)*
0x53	Mode	1 B	• Bit 0 (only applies to periodic Tx): 0/1 = Motion count not reported/reported • Bit 1 (only applies to periodic Tx): 0/1 = Motion state not reported/reported • Both bits 0 and 1 set to 0: Invalid and ignored • Bits 2-5: Ignored • Bit 6: 0/1 = PIR event-based transmission disabled/enabled • Bit 7: 0/1 = PIR transducer disabled/enabled	*pir_mode {* *motion_count_reported: <value>,* *(unsigned/no unit)* *motion_state_reported: <value>,* *(unsigned/no unit)* *event_transmission_enabled: <value>,* *(unsigned/no unit)* *transducer_enabled: <value>* *(unsigned/no unit)* *}*
0x54	Hold-Off Intervals	2 B	• Bits 8-15: Post-turn on hold-off interval (unsigned, 1 sec / LSB) 0 = Default value (120 sec) • Bits 0-7: Post-disturbance hold-off interval (unsigned, 1 sec / LSB) 0 = Default value (15 sec)	*pir_holdoff {* *post_turn_on: <value>,* *(unsigned/sec)* *Post_disturbance: <value>,* *(unsigned/sec)* *}*

4.2.8.1 Grace Period

The Grace Period determines how long the Sensor waits before the previously reported PIR motion event is considered clear. For example, a Grace Period of 5 (five) min results in the sensor transmitting “Motion

Detected" when someone enters the room, and "Motion Not Detected" 5 (five) min after the room is empty. Values less than 15 sec are invalid and ignored.

4.2.8.2 Threshold Count

The PIR transducer generates an event each time it detects motion in its field of view. Depending on the customer use case it may be desirable to increase the Threshold to reduce sensitivity. This feature was designed to allow customers to filter out short motion events (such as a person quickly entering a room to pick-up a notebook), while still allowing longer motion events (a team meeting) to be reported.

4.2.8.3 Threshold Period

The Threshold Period is the amount of time that motion events will be accumulated for Threshold detection. For example, a Threshold Period of 10 (ten) sec accumulates motion detection events over a 10 (ten)-sec period from the time of first detection. If the Threshold is exceeded before the time expires, the sensor reports "Motion Detected", otherwise it does not report. Values less than 5 for the Threshold Period are invalid and ignored.

4.2.8.4 Mode

The Mode register allows the customer to disable/enable the motion transducer, as well as change the type of data that is transmitted by the Sensor. When the PIR transducer is disabled, no events from the PIR are monitored. When enabled, the motion transducer always reports the "motion state" (i.e. only the presence or absence of movement) in event-based reporting, if the event-based reporting is enabled. Bit 0 (motion count) and bit 1 (motion state) bits determine what values are transmitted when periodic reporting is enabled.

4.2.8.5 Hold-Off Intervals

PIR has two configurable hold-off intervals, post-turn on and post-disturbance, where the PIR is temporarily disabled to avoid false positives. This has been explained in more details at the beginning of Section 4.2.8.

The MSB of register 0x54 controls the post-turn on hold-off interval while the LSB controls the post-disturbance interval. A value of 0 for any of these intervals is equivalent to the default value of that interval (120 sec for the post-turn on and 15 sec for the post-disturbance hold off).

Note: It is recommended that transducer sampling and reporting periods are configured with the PIR hold-off interval in mind. For example, if the idle active temperature sampling periods is configured for every 30 seconds, and the old-off interval is 15 seconds, then the PIR will only be enabled 50% of the time.

4.2.8.6 Default Configuration

Table 4-19 shows the default values for the motion transducer configuration registers.

Table 4-19: Default Values of Motion Transducer Configuration Registers

Grace Period	300 sec (5 min)

Threshold	1
Threshold Period	15 sec
Mode	• PIR transducer enabled • Event-based transmission enabled • Motion count reported only, in the case of a periodic transmission
Hold-Off Intervals	• Post-turn on hold-off interval 120 sec (2 min) • Post-disturbance hold-off interval 15 sec

4.2.9 Response to DL Commands Configuration

The Comfort and Vivid include the ability for the user to select the format of UL responses to DL commands. Details on the response formats can be found in Section 4.1. Table 4-20 shows the response to DL commands register. This register has R/W access.

Table 4-20: Response to DL Command Configuration Register

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x6F	Format Option	1 B	• Bit 0: 0: Invalid-write response format 1: 4-byte CRC • Bits 1-7: Ignored	*resp_to_dl_command_format: <value> (unsigned/no unit)*

4.2.9.1 Format Option

The value of the Format Option register determines how the Sensor responds to DL commands. Setting Bit 0 to 0 (zero) selects the invalid-write response format, while a value of 1 (one) selects the 4-byte CRC method. Please refer to Section 4.1 for more details.

4.2.9.2 Default Configuration

Table 4-21 shows the default value for the response to DL commands configuration register.

Table 4-21: Default Value of Response to DL Commands Configuration Register

Format Option	Invalid-write response format selected

4.2.10 Command and Control

Configuration changes are not retained after a power cycle unless they are saved in the Flash memory. Table 4-22 shows the structure of the Command & Control Register.

Table 4-22: Sensor Command & Control Register

Address	Access	Name	Size	Description	JSON Variable (Type/Unit)
0x70	WO	Flash Write Command	2 B	• Bit 14: • 0/1 = Do not write/Write LoRaMAC Config	*write_to_flash { app_configuration: <value>, (unsigned/no unit)*

Address	Access	Name	Size	Description	JSON Variable (Type/Unit)
				• Bit 13: • 0/1 = Do not write/Write App Config • Bit 0: • 0/1 = Do not restart/Restart Sensor • Bits 1-12, 15: Ignored	*lora_configuration: <value>, (unsigned/no unit)* *restart_sensor: <value> (unsigned/no unit)* *}*
0x71	RO	FW Version	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 number (see Section 4.2.10.1)	*firmware_version {* *app_major_version: <value>, (unsigned/no unit)* *app_minor_version: <value>, (unsigned/no unit)* *app_revision: <value>, (unsigned/no unit)* *loramac_major_version: <value>, (unsigned/no unit)* *loramac_minor_version: <value>, (unsigned/no unit)* *loramac_revision: <value>, (unsigned/no unit)* *region: <value> (unsigned/no unit)* *}*
0x72	WO	Reset Config Registers to Factory Defaults[16]	1 B	• 0x0A = Reset App Config • 0xB0 = Reset LoRa Config • 0xBA = Reset both App and LoRa Configs • Any other value: Invalid and ignored	*configuration_factory_reset: <value> (unsigned/no unit)*

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

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

4.2.10.1 LoRaWAN Region ID

The LoRaMAC region is indicated by B_6 in the FW Version register (register 0x71). Current LoRaMAC regions and corresponding region numbers are listed in Table 4-23.

Table 4-23: LoRaMAC Regions and Region Numbers [1]

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

Examples:

- Write Application Configuration to Flash memory
  - DL payload: { 0x **F0** 20 00 }
- Write Application and LoRa Configurations to Flash memory
  - DL payload: { 0x **F0** 60 00 }
- Reboot Device
  - DL payload: { 0x **F0** 00 01 }
- Get FW version, and reset App Config to factory defaults
  - DL payload: { 0x **71 F2** 0A}

References

[1] LoRa Alliance, "LoRaWAN Regional Parameters," ver 1.0.2, Rev B, Feb 2017.

[2] LoRa Alliance, "LoRaWAN Specification," ver. 1.0.2, Jul 2016.

[3] TEKTELIC Communications Inc., "Smart Room Sensor User Guide," ver 1.5, Jan 2020.