TEKTELIC COMMUNICATIONS INC.

Kona Home Sensor

Technical Reference Manual

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†Not applicable to module revisions above Rev C.

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0.2	Dec 22, 2017	D. Smith	Included details of for each configuration.
0.3	Apr 06, 2018	D. Smith	Added missing uplink info.
0.4	Jul 6, 2018	R. Nikjah	Expanded on payload examples. Made some editorial fixes/modifications. This version is in compliant with Rev B of Home Sensor PCBA.
Rev-C 1.0	Aug 23, 2018	R. Nikjah	Added some explanations and clarifications. This version of the document is now only applicable to Kona Home Sensor modules up to and including Rev C.
Rev-C 1.1	Oct 31, 2018	R. Nikjah	Made a minor correction for PIR config registers.

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Acronyms and Glossary

ABP .... activation by personalization
ADR............................ adaptive data rate
Command Field .... The read/write selection bit and register address combination.
CRC .... cyclic redundancy check
DL .... downlink
DR.............................. data rate
EU .... European Union
Flash memory............ Non-volatile memory located on the Home Sensor, which contains application and configuration settings.
g .... gravity (unit of acceleration ≈ 9.8 m/s^2)
Home Sensor............. Any one of the Kona All-In-One Home Sensor Module types
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)
LoRaWAN Commissioning
.... The unique device identifiers and encryption keys used for LoRaWAN communication (see LoRaWAN Specification [1] for more details).
LSB............................. least significant bit
MAC........................... medium access control
MCU .... microcontroller unit
MSB .... most significant bit
NA.............................. North America
NS .... network server
OTA............................ over-the-air
OTAA .... OTA activation
PIR .... passive infrared
Reg .... Register
RFU .... reserved for future use
RH.............................. relative humidity
RMS .... root mean square
RO.............................. read-only
R/W .... read/write
Rx............................... receiver
Sensor........................ = Home Sensor

Temp .... temperature
transducer .... The sensing element attached to the Home Sensor, e.g. PIR transducer, humidity transducer.
TRM .... technical reference manual
Tx............................... transmitter
UL .... uplink

1 Overview

This TRM describes the user accessible configuration settings (pseudo registers) supported by the Home Sensor. This document is intended for a technical audience, such as application developers, with an understanding of the Network Server and its command interfaces.

The Kona All-in-One Home Sensor is a multi-purpose LoRaWAN IoT sensor packed into a very small form factor. The Home Sensor is ideal for monitoring and reporting temperature, humidity, light, shock, and open/closed doors and windows in the home environment. Additional sensing features such as leak and motion detection, as well as counting pulses from an external device are also supported with the appropriate Home Sensor model. Table 2-1 presents the currently available Kona All-in-One Home Sensor models and RF Regions.

Table 2-1: Kona All-in-One Home Sensor Module Models

Product Code	Description	RF Region
T0004893 Rev C	Home Sensor Module, NA, Base	US 902-928MHz ISM Band
T0004885 Rev C	Home Sensor Module, NA, PIR	US 902-928MHz ISM Band
T0004886 Rev C	Home Sensor Module, NA, External Connector	US 902-928MHz ISM Band
T0004895 Rev C	Home Sensor Module, EU, Base	EU 863-870MHz ISM Band
T0004896 Rev C	Home Sensor Module, EU, PIR	EU 863-870MHz ISM Band
T0004897 Rev C	Home Sensor Module, EU, External Connector	EU 863-870MHz ISM Band

The default configuration on the Home Sensor is:

- Report Temperature and RH every 1 (one) hour.
- Report Battery Voltage every 24 (twenty-four) hours.
- Report actuation of the digital input element every one 1 (one) actuation.

There are two information streams that need to be supported by applications:

- Data from the Sensor (UL Data) contains readings from the various on-board transducers.
- Data from the Server (DL Data) contains configuration commands that can be used to change the Sensor's behavior.

In the following sections, the UL (departing from the Sensor) and DL (destined to the Sensor) payload formats are explained. Refer to the *Kona Home Sensor Uplink and Downlink Payload Formation* spreadsheet [2] for a thorough tool to build any UL or DL payload by varying parameter values, toggling read/write actions, and enabling/disabling different fields as desired.

2 UL Data Format

Each data field from the Sensor is encoded in a frame format shown in Figure 2-1.

Data Channel (1 byte)	Data Type (1 byte)	Data (N bytes)

Figure 2-1: The frame format in an UL payload.

A Sensor message payload can include multiple transducer data frames. The ordering of frames is not guaranteed (they can be in any order). A single payload may include data from any given transducer. The Home Sensor payload frame values are shown in Table 2-1. Transducer data in the UL are sent through LoRaWAN Port 10.

Table 2-1: Home Sensor Payload Frame Values

Type Information	Data Channel ID	Data Type ID	Data Size [bytes]	Data Type	Data Format
Battery Voltage	0x00	0xFF	2	Analog	10 mV / LSB (signed)
Input	0x01	0x00	1	Digital	0x00: Low—Connector short-circuited, or magnet present 0xFF: High—Connector open-circuited, or magnet absent
Light Detected	0x02	0x00	1	Digital	0x00: Dark 0xFF: Bright
Temperature	0x03	0x67	2	Temperature	0.1°C / LSB (signed)
RH	0x04	0x68	1	RH	0.5% / LSB
Impact Magnitude	0x05	0x02	2	Analog	1 milli-g / LSB (signed)
Break-in	0x06	0x00	1	Digital	0x00: No break-in 0xFF: Break-in event
Accelerometer Data	0x07	0x71	6	Accelerometer	2-byte X, 2-byte Y, 2-byte Z (1 milli-g / LSB, signed)
Input Count	0x08	0x04	2	Counter	Number (MSB first)
Moisture	0x09	0x00	1	Digital	0x00: Dry 0xFF: Wet
Motion Detected (PIR)	0x0A	0x00	1	Digital	0x00: No motion 0xFF: Motion detected
MCU Temperature	0x0B	0x67	2	Temperature	0.1°C / LSB (signed)

Impact Alarm	0x0C	0x00	1	Digital	0x00: No impact alarm 0xFF: Impact alarm
Motion Event Count	0x0D	0x04	2	Counter	Number (MSB first)

2.1 Example UL Payloads

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

- 0x **03 67** 00 0A **04 68** 28
  - 0x **03 67** (Temperature) = (0x 00 0A) × 0.1°C = 1°C
  - 0x **04 68** (RH) = (0x 28) × 0.5% = 20%
- 0x **04 68** 14 **01 00** FF **08 04** 00 05
  - 0x **04 68** (RH) = (0x 14) × 0.5% = 10%
  - 0x **01 00** (Input) = 0x FF = High
  - 0x **08 04** (Input Count) = 0x 00 05 = 5 switch triggers
- 0x **04 68** 2A **03 67** FF FF **00 FF** 01 2C
  - 0x **04 68** (RH) = (0x 2A) × 0.5% = 21%
  - 0x **03 67** (Temperature) = (0x FF FF) × 0.1°C = −0.1°C
  - 0x **00 FF** (Battery Voltage) = (0x 01 2C) × 0.01 V = 3.00 V
- 0x **02 00** FF **07 71** 00 3A 00 07 00 53 **01 00** FF
  - 0x **02 00** (Light Detected) = 0x FF = Bright
  - 0x **07 71** (Accelerometer Data) = [X-axis: (0x 00 3A) × 0.01g, Y-axis: (0x 00 07) × 0.01g, Z-axis: (0x 00 53) × 0.01g] = [X-axis: 0.58g, Y-axis: 0.07g, Z-axis: 0.83g]
  - 0x **01 00** (Input) = 0x FF = High
- 0x **0D 04** 00 02 **06 00** FF
  - 0x **0D 04** (Motion Event Count) = 0x 00 02 = 2 motion events
  - 0x **06 00** (Break-in) = 0x FF = break-in detected

3 DL Command Format

All DL messages follow the same format. Each configuration option has a 1-byte “register” address that is used to access various configuration parameters. These addresses are bound between 0x00 and 0x7F.

A single DL message can contain multiple command blocks, with a mix of read and write commands. Each block is formatted as shown in Figure 3-1.

<table>
<tr><td colspan="2">Command Field (1 byte)</td><td rowspan="2">Data (N bytes): Only used for WRITE commands</td></tr>
<tr><td>$\overline{R}$ / W (Bit 7)</td><td>Address (Bits 6–0)</td></tr>
</table>

Figure 3-1: Format of a DL message.

All configuration commands (i.e. in the DL), as well as all responses to those commands (i.e. in the UL), are sent through LoRaWAN Port 100.

3.1 Read and Write Access

Bit 7 of the Command Field determines whether a read or write action is being performed. To write to a register, the R/W Access bit must be set to 1 (one). All read commands are one-byte long. Data following a read access command will be interpreted as a new command block.

To read a register, the R/W Access bit must be set to 0 (zero). 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.

Examples:

In the following examples, the Command Field is boldfaced:

- Read Registers 0x00, 0x01, and 0x02:
    - DL command: { 0x **00 01 02** }
- Read Register 0x05 and Write value 0x8000 to Register 0x10:
    - DL command: { 0x **05 90** 80 00 }

When a write command is sent to the Sensor, the Sensor will immediately respond with a CRC32 of the entire DL payload as the first 4 bytes of the UL frame.

Note: Undefined bits/addresses are RFU and must be set to 0 (zero) when performing any write operation.

3.2 LoRaWAN Commissioning

LoRaWAN Commissioning values can be read back from the Sensor using DL commands. These registers are RO. See LoRaWAN 1.0.3 specification [1] for description of values. Table 3-1 shows a list of these registers.

Table 3-1: LoRaWAN Commissioning Registers

Address	Access	Value	Size [bytes]	Description	Format
0x00	RO	DevEUI	8	DevEUI of Device	MSB First
0x01	RO	AppEUI	8	AppEUI of Device	MSB First
0x02	RO	AppKey	16	AppKey of Device	MSB First
0x03	RO	DevAddr	4	4-Byte DevAddr	MSB First
0x04	RO	NwkSKey	16	16-Byte NwkSKey	MSB First
0x05	RO	AppSKey	16	16-Byte AppSKey	MSB First

Note 1: Commissioning values need to be kept secure at all times.

Note 2: Registers 0x02, 0x04, and 0x05 may not be able to be read back in some regions if the DR is too low. For example, in the NA region, the maximum payload size with DR0 is 11 bytes.

3.3 LoRaWAN MAC Configuration

LoRaWAN MAC options can be configured using the LoRaWAN DL. These configuration options change the default MAC configuration that the Sensor loads on start-up. They can also change certain run-time parameters. Table 3-2 shows the MAC configuration registers.

Table 3-2: LoRaWAN MAC Configuration Registers

Address	Access	Value	Size [bytes]	Description
0x10	R/W	Join Mode	2	Bit 15: 0=ABP, 1=OTAA
0x11	R/W	Disable/Enable ADR Disable/Enable Duty Cycle Private/Public Networks Unconfirmed/Confirmed UL	2	Bit 0: 0=unconfirmed UL, 1=confirmed UL Bit 1: 0=private networks, 1=public networks Bit 2: 0=disable duty cycle, 1=enable duty cycle Bit 3: 0=disable ADR, 1=enable ADR
0x12	R/W	Default DR number Default Tx Power number	2	Bits 3–0: default Tx power number (see *LoRaWAN Regional Specification* [3]) Bits 11–8: default DR number (see *LoRaWAN Regional Specification* [3])
0x13	R/W	Rx2 window channel number Rx2 window DR number	2	Bits 3–0: DR number in Rx2 window Bits 11–8: Channel number in Rx2 window
0x19	R/W	Net ID MSB	2	MSBs of Net ID
0x1A	R/W	Net ID LSB	2	LSBs of Net ID

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

3.3.1 LoRa Config Examples

In the following example payloads, the Command Field is boldfaced:

- Switch Device to ABP Mode:
  - DL payload: { 0x **90** 00 00 }
- Set ADR On, No Duty Cycle, Public Network, and Confirmed UL Payloads:
  - DL payload: { 0x **91** 00 0B }
- Set default DR number to 15, default Tx Power number to 15, Rx2 DL channel number to 4, and Rx2 DR number to 2:
  - DL payload: { 0x **92** 0F 0F **93** 04 02 }

3.4 Sensor Application Configuration

Note: Care must be taken to avoid stranding the Sensor during reconfiguration. If all Sensor transducers are disabled, the Sensor cannot be reconfigured.

3.4.1 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.

Note: Certain transducer types, such as accelerometer and light, need to be enabled for periodic reporting. Details are available in each transducer's respective section. Table 3-3 shows a list of registers used to configure the Sensor's periodic transmissions.

Table 3-3: Periodic Transmission Configuration Registers

Address	Access	Value	Size [bytes]	Description
0x20	R/W	Seconds per *tick*	4	Sets the *tick* for periodic events. A value of 0 disables all periodic transmissions.
0x21	R/W	*Ticks* per Battery Tx	2	*Ticks* between Battery reports. A value of 0 disables periodic battery reports.
0x22	R/W	*Ticks* per Temperature Tx	2	*Ticks* between Temp reports. A value of 0 disables periodic Temp reports.
0x23	R/W	*Ticks* per RH Tx	2	*Ticks* between Humidity reports. A value of 0 disables periodic Humidity reports.
0x24	R/W	*Ticks* per Digital Input Tx	2	*Ticks* between Digital Input reports. A value of 0 disables periodic Digital Input reports.
0x25	R/W	*Ticks* per Light Tx	2	*Ticks* between Light reports. A value of 0 disables periodic Light reports.
0x26	R/W	*Ticks* per Accelerometer Tx	2	*Ticks* between Accelerometer reports. A value of 0 disables periodic Accelerometer reports.
0x27	R/W	*Ticks* per MCU Temp Tx	2	*Ticks* between MCU Temp reports. A value of 0 disables periodic MCU Temp reports.
0x28	R/W	*Ticks* per PIR Tx	2	*Ticks* between PIR reports. A value of 0 disables periodic PIR reports.

3.4.1.1 Seconds per Tick

All periodic Tx events are scheduled in *ticks*. This allows for transducer reads to be synchronized, reducing the total number of ULs required to transmit Sensor data. The minimum seconds per *tick* is 30 seconds. Values from 1 to 29 are clipped to 30 seconds. If the Seconds per *Tick* is set to 0 (zero), all periodic reporting is disabled.

3.4.1.2 Ticks per <Transducer>

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

3.4.1.3 Default Configuration

Table 3-4 shows the default values for the periodic transmission configuration registers.

Table 3-4: Default Values of Periodic Transmission Configuration Registers

Seconds per *tick*	3600 seconds (1 hour)
***Ticks* per Battery**	24 ticks (24 hours)
***Ticks* per Temperature†**	1 tick (1 hour)
***Ticks* per RH†**	1 tick (1 hour)
***Ticks* per other transducers**	0 *ticks* (periodic Tx disabled)

† Temperature and RH are only compatible with Home Sensor Base and External Connector models. In Home Sensor PIR, they should be disabled for the PIR function to operate properly (i.e. the Temperature and RH ticks should be set to 0). This limitation is only applicable to Home Sensor modules **before Rev D**.

3.4.1.4 Example DL Messages

In the following example payloads, the Command Field is boldfaced:

- Disable all periodic events:
    - DL payload: { 0x **A0** 00 00 00 00 }
        - Reg 20 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** }
        - Reg 20 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 }
        - Reg 22 and Reg 23 with their write bits set to true
        - Temperature *Ticks* set to 1 (one)

- RH *Ticks* set to 2 (two)

3.4.2 Digital Input Configuration

The Digital Input transducer type varies between different Home Sensor models. The type used in each model is listed in Table 3-5.

Table 3-5: Digital Input Transducer Type for Different Home Sensor Models

Home Sensor Model	Digital Input Transducer Type
Base	Magnetic Reed Switch
External Connector	2-Wire External Connector
PIR	Magnetic Reed Switch

In fact, as Table 3-5 shows, the External Connector and Magnetic Reed Switch are mutually exclusive, i.e. not both exist in the same module, such that the Digital Input is either the External Connector or the Magnetic Reed Switch depending on the module type.

Table 3-6 shows a list of Digital Input configuration registers.

Table 3-6: Digital Input Configuration Registers

Address	Access	Value	Size [bytes]	Description
0x2A	R/W	Mode	1	Bit 0: Rising Edge Enable Bit 1: Falling Edge Enable Other bits are ignored.
0x2B	R/W	Count Threshold	2	# of Triggers for event transmission. A value of 0 disables event transmission
0x2C	R/W	Value to Transmit	1	Bit 0: Input State Bit 1: Counter Value Other bits are ignored.

3.4.2.1 Mode

The Digital Input is edge-triggered and can be set to trigger to rising-edge trigger (Low or Closed to High or Open), falling-edge triggered (High or Open to Closed or Low) or both. An attempt to set the Mode to 0x00 (i.e. to disable both rising and falling edges) is ignored by the Sensor.

Application Examples:

- 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).

3.4.2.2 Count Threshold

The Count Threshold determines when the Sensor transmits after seeing an event on the 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.

Application Example:

- 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.

3.4.2.3 Value to Tx

The Value to Tx 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 Digital Input 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).

3.4.2.4 Default Configuration

Table 3-7 shows the default values for the Digital Input configuration registers.

Table 3-7: Default Values of Digital Input Configuration Registers

Mode	Rising and Falling Edge Enabled
Threshold	1 (one)
Value to Tx	State and Count Enabled

3.4.2.5 Example DL Messages

In the following example payloads, the Command Field is boldfaced:

- Have Digital Input be triggered only on rising edges:
  - DL payload: { 0x **AA** 01 }
    - Reg 2A with write bit set to true
    - "Rising Edge" enabled, "Falling Edge" disabled

- Read current value of Count Threshold:
    - DL payload: { 0x **2B** }
        - Reg 2B with write bit set to false
- Transmit the Digital Input 'state' as soon as the Digital Input is tripped 10 times:
    - DL payload: { 0x **AB** 00 0A **AC** 01 }
        - Reg 2B and Reg 2C with their write bits set to true
        - Count Threshold set to 10 (ten)
        - Value to Tx set to 'Input State'
- Disable the Digital Input event-driven transmission, but periodically report the number of times the Digital Input is triggered:
    - DL payload: { 0x **AB** 00 00 **AC** 02 }
        - Count Threshold set to 0 (zero)
        - Value to Tx set to 'Counter Value'

3.4.3 Accelerometer Configuration

The Accelerometer transducer offers two thresholds for event-based break-in and impact detection. It can also be polled periodically for applications where the Sensor orientation may be of interest. Table 3-8 shows a list of Accelerometer configuration registers.

Table 3-8: Accelerometer Configuration Registers

Address	Access	Value	Size [bytes]	Description
0x30	R/W	Break-In Threshold	2	10 milli-g / LSB
0x31	R/W	Impact Threshold	2	10 milli-g / LSB
0x32	R/W	Value to Transmit	1	Bit 0: Alarm On/Off Bit 1: Magnitude Bit 2: Full-Precision Other bits are ignored.
0x33	R/W	Impact Debounce Time	2	Seconds to wait before reporting impacts again.
0x34	R/W	Mode	1	Bit 0: Break-In Threshold On/Off Bit 1: Impact Threshold On/Off Bit 7: Power On/Off Other bits are ignored.
0x35	R/W	Sample Rate	1	Bits 2–0: Values supported by transducer: • 1: 1 Hz • 2: 10 Hz • 3: 25 Hz • 4: 50 Hz • 5: 100 Hz • 6: 200 Hz • 7: 400 Hz A value of 0 (zero) is ignored. Bits 7–3 are ignored.

3.4.3.1 Break-In Threshold

This parameter is the g-threshold used for break-in detection. As soon as the g-threshold is tripped, a timer with a timeout is started. The timeout period is defined via Impact Debounce Time (see Section 3.4.3.4). Within the timeout period, if the g-threshold is tripped at least 4 times, a break-in alarm is raised.

3.4.3.2 Impact Threshold

This parameter is the g-threshold for an impact event. Impact events are reported immediately once they are triggered. Impact Threshold is greater than 0 (zero). A value of 0 (zero) is ignored.

3.4.3.3 Value to Transmit

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

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

3.4.3.4 Impact Debounce Time

The accelerometer is disabled for a configurable time frame after an event is registered. This is done to prevent a single impact from transmitting multiple events. The minimum debounce time is 1 (one) second.

3.4.3.5 Mode

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

3.4.3.6 Sample Rate

The Accelerometer is an always on transducer (when powered) and samples the transducer elements at a fixed rate. To capture an impact 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 significantly increases the power usage, impacting battery life.

3.4.3.7 Default Configuration

Table 3-9 shows the default values for the Accelerometer configuration registers.

Table 3-9: Default Values of Accelerometer Configuration Registers

Break-In Threshold	**3000** milli-$\boldsymbol{g}$
Impact Threshold	6000 milli-g
Value to Transmit	Full-Precision
Impact Debounce Time	2 (two) seconds

Mode	Break-In Threshold Disabled, Impact Threshold Disabled, Powered Off
Sample Rate	0x01 (1 Hz)

3.4.3.8 Example DL Messages

In the following example payloads, the Command Field is boldfaced:

- Set Impact Threshold and Impact Debounce Time:
    - DL payload: { 0x **B1** 00 C8 **B3** 00 0A }
        - Reg 31 and Reg 33 with their write bits set to true
        - Impact Threshold set to 2000 milli-g and Impact Debounce Time set to 10 seconds.
- Set Sample Rate and read it back:
    - DL payload: { 0x **B5** 06 **35** }
        - Reg 35 with write bit set to true
        - Reg 35 with write bit set to false
        - Sample rate set to 200 Hz, and then read back
- Power on the transducer with Impact Threshold enabled but Break-In Threshold disabled, and set 'Magnitude' as the Value to Transmit:
    - DL payload: { 0x **B4** 82 **B2** 02 }
        - Reg 34 and Reg 32 with their write bits set to true

3.4.4 Temperature/RH Threshold Configuration

In all Home Sensor modules **before Rev D**, Temperature and RH are only compatible with the Base and External Connector models.

The Home Sensor supports threshold transmission on three different transducer outputs:

- Temperature: Located in the Temp/RH transducer
- RH: Located in the Temp/RH transducer
- MCU Temperature: Located inside the MCU (with lower accuracy compared to Temperature and RH)

When a threshold is enabled, the Home Sensor reports the transducer value when it leaves the configured threshold window, and once again when the transducer value re-enters the threshold window. The Threshold mode is compatible with periodic reporting. Table 3-10 shows a list of configuration registers for the Temperature/RH Threshold setting.

Table 3-10: Temperature/RH Threshold Configuration Registers

Address	**Access**	**Value**	**Size [bytes]**	**Description**
0x39	R/W	Temp/Humid Sample Period: Idle	4	Sample period of external Temperature/RH transducer: Idle state (seconds)
0x3A	R/W	Temp/Humid Sample Period: Active	4	Sample period of external Temperature/RH transducer: Active state (seconds)
0x3B	R/W	Low/High Temperature Thresholds	2	Bits 7–0: Low temperature threshold (signed, 1°C/LSB) Bits 15–8: High temperature threshold (signed, 1°C/LSB)
0x3C	R/W	Temperature Thresholds Enabled	1	Bit 0: 0 = Disabled, 1 = Enabled Other bits are ignored.
0x3D	R/W	Low/High RH Thresholds	2	Bits 7–0: Low RH threshold (unsigned, 1% RH/LSB) Bits 15–8: High RH threshold (unsigned, 1% RH/LSB)
0x3E	R/W	RH Thresholds Enabled	1	Bit 0: 0 = Disabled, 1 = Enabled Other bits are ignored.
0x40	R/W	MCU Temp Sample Period: Idle	4	Sample period of MCU temperature transducer: Idle state (seconds)

0x41	R/W	MCU Temp Sample Period: Active	4	Sample period of MCU temperature transducer: Active state (seconds)
0x42	R/W	Low/High MCU Temperature Thresholds	2	Bits 7–0: Low MCU Temperature Threshold (signed, 1°C/LSB) Bits 15–8: High MCU temperature threshold (signed, 1°C /LSB)
0x43	R/W	MCU Temperature Thresholds Enabled	1	Bit 0: 0 = Disabled, 1 = Enabled Other bits are ignored.

3.4.4.1 Temperature/RH/MCU Temperature Transducer Sample Period: Idle

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

Note: When first enabled, the transducer starts in the Idle state.

3.4.4.2 Temperature/RH/MCU Temperature Transducer Sample Period: Active

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

3.4.4.3 Temperature/MCU Temperature Threshold

Temperature thresholds are stored in a single 2-byte register, with the upper byte storing the 'high' temperature threshold, and the lower byte storing the 'low' temperature threshold with a 1°C per bit precision. Each temperature threshold is stored/transmitted as a 1-byte 2-s complement number. The 'high' temperature threshold must be greater than the 'low' temperature threshold.

3.4.4.4 RH Threshold

The RH threshold is stored in a single 2-byte register, with the upper byte storing the 'high' RH threshold, and the lower byte storing the 'low' RH threshold with a 1% per bit precision. Each RH threshold is stored/transmitted as a 1-byte unsigned number. The "high" RH threshold must be greater than the "low" RH threshold.

3.4.4.5 Temperature/RH/MCU Temperature Transducer Threshold Enabled

The <transducer> Thresholds Enabled register enables and disables the threshold reporting on the specified transducer. Thresholds and Sample Period values can be configured but are not activated unless the Thresholds Enabled bit is set.

3.4.4.6 Default Configuration

Table 3-11 shows the default values for the Temperature/RH threshold configuration registers.

Table 3-11: Default Values of Temperature/RH Threshold Configuration Registers

Temp/Humid Sample Period: Idle	60 seconds
Temp/Humid Sample Period: Active	30 seconds
Temperature Threshold: Low	15°C
Temperature Threshold: High	30°C
Temperature Thresholds Enabled	Off
RH Threshold: Low	15%
RH Threshold: High	80%
RH Thresholds Enabled	Off
MCU Temp Sample Period: Idle	300 seconds
MCU Temp Sample Period: Active	60 seconds
MCU Temperature Threshold: Low	20°C
MCU Temperature Threshold: High	25°C
MCU Temperature Thresholds Enabled	Off

3.4.4.7 Example DL Messages

In the following example payloads, the Command Field is boldfaced:

- Set Temperature Thresholds:
  - DL payload: { 0x **BB** 19 F1 }
    - Reg 3B with write bit set to true
    - High threshold set to 25°C
    - Low threshold set to -15°C
- Read Temperature/RH Sample Periods:
  - DL payload: { 0x **39 3A** }
    - Reg 39 and Reg 3A with their write bits set to false
- Set and enable RH thresholds:
  - DL payload: { 0x **BD** 3C 14 **BE** 01 }
    - Reg 3D and Reg 3E with their write bits set to true
    - High RH thresholds set to 60% RH
    - Low RH threshold set to 20% RH
    - RH thresholds enabled

3.4.5 Light Sensing Configuration

In all Home Sensor modules **before Rev D**, Light Sensing is only compatible with the Base and External Connector models, and should be kept disabled for the PIR model.

The Home Sensor Light sensing allows for the presence or absent of light based of the built-in light sensing transducer. The sensing element light pipe is visible on the top surface of the Home Sensor. The orientation of the Home Sensor relative to the light source impacts the measured level of light intensity. Table 3-12 shows a list of Light transducer configuration registers.

Table 3-12: Light Transducer Configuration Registers

Address	Access	Value	Size [bytes]	Description
0x47	R/W	Sample Period	4	Sample period of the light transducer (seconds)
0x48	R/W	Threshold	1	Threshold from 1 to 64 (darker to brighter)

The Light transducer is held turned off to preserve energy. Whenever light data is needed, it gets turned on by the MCU.

3.4.5.1 Sample Period

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, 10, 11, 12, …. Setting the sample period to 0 (zero) disables the light sensing element. Setting the samples period to anything from 1 to 9 sets the sample period to 10.

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.

3.4.5.2 Threshold

The Light Threshold is used to set the dark/bright transition point for the Sensor. The Home Sensor only transmits when the threshold is crossed, and when first enabled, begins in the 'dark' state. A threshold setting of 1 (one) corresponds to the darkest threshold.

3.4.5.3 Default Configuration

Table 3-13 shows the default values for the Light transducer configuration registers. Light Sensing in Home Sensor modules **before Rev D** is buggy in the sense that any attempt to set the Light Threshold causes the Threshold to be automatically set to 64 such that the transducer status is always “dark” (the Sensor becomes light de-sensitized). However, if the Light Threshold is not touched, the Sensor operates expectedly with the default value given in Table 3-13, which basically means that the slightest amount of light triggers the Sensor (for a “bright” status). Otherwise (i.e. only for absolute darkness), the status is dark.

Table 3-13: Default Values of Light Transducer Configuration Registers

Sample Period	0 (disabled)
Threshold	1 (darkest threshold)

3.4.5.4 Example DL Messages

In the following example payloads, the Command Field is boldfaced:

- Set the Threshold to 32 and check the light condition every half an hour:
    - DL payload: { 0x **C8** 20 **C7** 00 00 07 08 }

3.4.6 Motion Transducer Configuration

The Motion transducer on equipped Home Sensor models uses a PIR array sensor for the detection of human motion in a room. Due to the sensitive electronics used in the PIR motion detector, the Home Sensor PIR model is designed to behave as follows:

- For 2 (two) minutes after power is first applied to the device, the PIR motion detector is disabled. This is required for the PIR transducer output to stabilize and avoids false detections.
- For approximately 5 (five) seconds after a radio transmission, the PIR motion detector is disabled. The operation of the radio causes the PIR transducer to produce false positives so a 'cool down' period is required after each Tx.

The Home Sensor PIR model **before Rev D** is incompatible with Temperature, RH, and Light Sensing operations (i.e. the corresponding transducers should be kept disabled for proper PIR operation).

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

Note: The PIR transducer is designed to detected motion so if a room is occupied but the occupants are not moving, the sensor may report "No Motion" after the Grace Period expires.

Table 3-14 shows a list of Motion transducer configuration registers.

Table 3-14: Motion Transducer Configuration Registers

Address	Access	Value	Size [bytes]	Description
0x50	R/W	Grace Period	2	Grace period in seconds (time before motion is no longer detected)
0x51	R/W	Threshold	2	PIR events before motion is detected
0x52	R/W	Threshold Period	2	Period to count PIR events over for threshold detection
0x53	R/W	Mode	1	Bit 0: Motion State to Tx Bit 1: Motion Event Count to Tx Bit 7: PIR Sensor Enabled/Disabled Other bits are ignored.

3.4.6.1 Grace Period

The Grace Period determines how long the Home Sensor waits before the previously reported PIR motion event is considered clear. For example, a Grace Period of 5 (five) minutes results in the sensor transmitting "Motion Detected" when someone enters the room, and "Motion Not Detected" 5 (five) minutes after the room is empty. Values less than 15 seconds are clipped to 15.

3.4.6.2 Threshold

The PIR transducer generates an event each time it detects motion in its field of view. Depending on customer use case it may be desirable to increase the Motion 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. A value of 0 (zero) for the Threshold is clipped to 1.

3.4.6.3 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) seconds accumulates motion detection events over a 10 (ten)-second 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 clipped to 5.

3.4.6.4 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 Home Sensor. When the PIR transducer is disabled, no events from the PIR are monitored. When enabled, the Motion transducer always reports values in an event-driven method. The 'Event Count' and 'State' determine what values are transmitted when periodic reporting is enabled.

3.4.6.5 Default Configuration

Table 3-15 shows the default values for the Motion transducer configuration registers.

Table 3-15: Default Values of Motion Transducer Configuration Registers

Grace Period	300 seconds (5 minutes)
Threshold	1
Threshold Period	15 seconds
Mode	0x81 (State Enabled, Event Count Disabled, Motion Enabled)

3.4.6.6 Example DL Messages

In the following example payloads, the Command Field is boldfaced:

- Set the Motion transducer such that motion is detected only if two events occur within 10 seconds. Also, motion detection is cleared if there are no events for 10 minutes
    - Threshold set to 2, Threshold Period set to 10 seconds, and Grace Period set to 10 minutes
    - DL payload: { 0x **D0** 02 58 **D1** 00 02 **D2** 00 0A }
- Read the Grace Period, and set the transducer such that the Sensor reports both State and Event Count in periodic transmissions
    - DL payload: { 0x **50** **D3** 83 }

3.4.7 Moisture Configuration

Base and External Connection Home Sensors are equipped with a capacitance-based moisture detection system. This allows the Home Sensor to detect the pooling of water (water line leak, spills, etc.) and report moisture detection events. The Moisture transducer is integrated into the Home Sensor enclosure base (screw side) and can sense moisture without making physical contact with the liquid. This transducer does not measure humidity in air. Table 3-16 shows a list of Moisture transducer configuration registers.

Table 3-16: Moisture Transducer Configuration Registers

Address	Access	Value	Size [bytes]	Description
0x5A	R/W	Sample Period	1	Period of moisture measurement
0x5B	R/W	Threshold	1	Moisture detection threshold
0x5C	R/W	Enable/Disable	1	Moisture sensing enabled/disabled Only Bit 0 is considered. Other bits are ignored.
0x5D	W	Calibrate Baseline	1	Command to calibrate the transducer as "dry"

3.4.7.1 Sample Period

The Moisture transducer is activated periodically to determine if water is present. A smaller sample period results in a faster response from the Sensor in the event of a leak, however it results in higher battery usage than a larger sample period.

Supported Sample Periods are as follows:

- 1: 16 seconds
- 2: 32 seconds
- 3: 64 seconds
- 4: 128 seconds

A value of 0 (zero) or greater than 4 is ignored.

Note: Updates to the Sample Period require the Moisture transducer to be de-initialized and then initialized in order to take effect.

3.4.7.2 Threshold

The Threshold of the Moisture transducer determines the tripping point for various conditions. Nominally, a 1/4" of water below the Home Sensor results in a shift of about 300 units from the dry measurement baseline. The Threshold is tunable to allow the customer to set the desired sensitivity level. However, note that changing the threshold may desensitize the Moisture transducer or increase the likelihood of a false positive.

Any value less than 50 for the Threshold is ignored.

3.4.7.3 Enable/Disable

The Enable/Disable register sets whether the Moisture transducer is initialized (enabled) or de-initialized (disabled). This register is used to determine the default state of the Moisture transducer when first powered on. The possible values are:

- 0: Disable
- 1: Enable

3.4.7.4 Calibrate Baseline

Writing a non-zero value to this register forces the transducer to re-calibrate the dry baseline to the current value regardless of its actual state (wet or dry). It is recommended that this command is run when a Home Sensor is first deployed or relocated to ensure that the baseline is correctly set for the material under the Home Sensor.

Note: The moisture detector is automatically recalibrated for a new dryness baseline whenever the transducer is enabled (see also Section 3.4.7.3).

3.4.7.5 Default Configuration

Table 3-17 shows the default values for the Moisture transducer configuration registers.

Table 3-17: Default Values of Moisture Transducer Configuration Registers

Sample Period	2 (32 seconds)
Threshold	100
Enable/Disable	Disabled (De-initialized)

3.4.7.6 Example DL Messages

In the following example payloads, the Command Field is boldfaced:

- Set the Sample Period to 64 seconds and read the Threshold
  - DL payload: { 0x **DA** 03 **5B** }
- Force the transducer to calibrate as being dry
  - DL payload: { 0x **DD** 01 }

3.5 Sensor Command and Control

Configuration changes are not retained after a power cycle unless they are saved in the Flash memory. Table 3-18 shows the structure of the Command & Control Register.

Ensure that the Sensor is properly configured before sending any of the following messages! Failure to do so may irreparably damage the Sensor.

Table 3-18: Sensor Command & Control Register

Address	Access	Name	Size [Bytes]	Description	Format
0x70	W	Flash Write Command	2	Bit 0: Restart Sensor Bit 13: Write App Config Bit 14: Write LoRa Config	Assert Bit Field: 0 = de-asserted 1 = asserted

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 your NS to continually reboot the Sensor.

3.5.1 Command Examples

In the following examples, the Command Field is boldfaced:

- Write Application Configuration to Flash
  - DL payload: { 0x **F0** 20 00 }
- Write Application and LoRa Configurations to Flash
  - DL payload: { 0x **F0** 60 00 }
- Reboot Device
  - DL payload: { 0x **F0** 00 01 }

References

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

[2] TEKTELIC Communications Inc., "Kona Home Sensor Uplink and Downlink Payload Formation," ver 0.1, Jun 2018.

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