TEKTELIC COMMUNICATIONS INC.

Kona Home Sensor

Technical Reference Manual

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†Only applicable to module revisions above Rev C. Some new features are not backward compatible with modules Rev C and below. Module revisions above Rev C only include Base and PIR models (Base model and External Connector model Rev C have been merged into a single Base model Rev D).

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0.3	Apr 06, 2018	D. Smith	Added missing uplink info.
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1.0	Aug 23, 2018	R. Nikjah	Added some explanations and clarifications. This version of the document is only applicable to Kona Home Sensor modules above Rev C.
1.1	Oct 31, 2018	R. Nikjah	Made a minor correction for PIR config registers.
1.2	April 3, 2019	R. Nikjah	Fixed typos.

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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
EIRP .... effective isotropic radiated power
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 D	Home Sensor Module, NA, Base	US 902-928MHz ISM Band
T0004885 Rev D	Home Sensor Module, NA, PIR	US 902-928MHz ISM Band
T0004895 Rev D	Home Sensor Module, EU, Base	EU 863-870MHz ISM Band
T0004896 Rev D	Home Sensor Module, EU, PIR	EU 863-870MHz ISM Band

The default configuration on the Home Sensor is:

- Report Battery Voltage, Temperature, and RH every hour.
- Report actuation (an open-to-close or close-to-open event) of the Reed Switch and the External Input every 1 (one) actuation.
- PIR model only:
  - Report motion after one PIR event
  - Clear motion after 5 minutes of no motions.

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

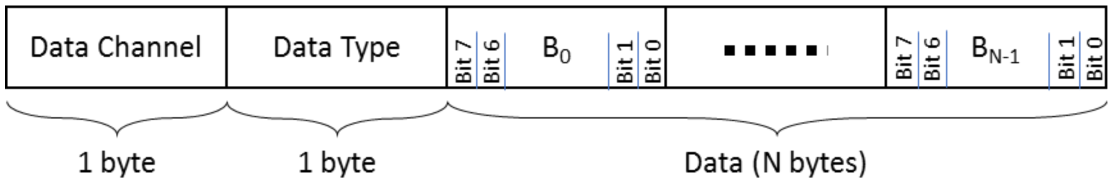

Figure 2-1: The frame format in an UL payload.

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. In this table, B_i refers to data byte indexed *i* as shown in Figure 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	# Bytes	Data Type	Data Format
Battery Voltage	0x00	0xFF	2	Analog	10 mV / LSB (signed)
Reed Switch	0x01	0x00	1	Digital	0x00: Low—Magnet present 0xFF: High—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	1 milli-g / LSB (signed) B_0-B_1: X data B_2-B_3: Y data B_4-B_5: Z data
Reed Switch Count	0x08	0x04	2	Counter	Number
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
External Input	0x0E	0x00	1	Digital	0x00: Low—Connector short-circuited 0xFF: High—Connector open-circuited
External Input Count	0x0F	0x04	2	Counter	Number

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
  - $0x\ \mathbf{03\ 67}$ (Temperature) $= (0x\ 00\ 0A) \times 0.1°C = 1°C$
  - $0x\ \mathbf{04\ 68}$ (RH) $= (0x\ 28) \times 0.5\% = 20\%$
- 0x **04 68** 14 **01 00** FF **08 04** 00 05
  - $0x\ \mathbf{04\ 68}$ (RH) $= (0x\ 14) \times 0.5\% = 10\%$
  - $0x\ \mathbf{01\ 00}$ (Reed Switch) $= 0x\ FF =$ Magnet Absent
  - $0x\ \mathbf{08\ 04}$ (Reed Switch Count) $= 0x\ 00\ 05 = 5$ switch triggers
- 0x **04 68** 2A **03 67** FF FF **00 FF** 01 2C
  - $0x\ \mathbf{04\ 68}$ (RH) $= (0x\ 2A) \times 0.5\% = 21\%$
  - $0x\ \mathbf{03\ 67}$ (Temperature) $= (0x\ FF\ FF) \times 0.1°C = -0.1°C$
  - $0x\ \mathbf{00\ FF}$ (Battery Voltage) $= (0x\ 01\ 2C) \times 0.01\ V = 3.00\ V$
- 0x **02 00** FF **07 71** 00 3A 00 07 00 53 **0E 00** 00
  - $0x\ \mathbf{02\ 00}$ (Light Detected) $= 0x\ FF =$ Bright
  - $0x\ \mathbf{07\ 71}$ (Accelerometer Data) $=$ [X-axis: $(0x\ 00\ 3A) \times 0.01g$, Y-axis: $(0x\ 00\ 07) \times 0.01g$, Z-axis: $(0x\ 00\ 53) \times 0.01g$] $=$ [X-axis: $0.58g$, Y-axis: $0.07g$, Z-axis: $0.83g$]
  - $0x\ \mathbf{0E\ 00}$ (External Input) $= 0x\ 00 =$ Connector Short- Circuited
- 0x **0D 04** 00 02 **06 00** FF
  - $0x\ \mathbf{0D\ 04}$ (Motion Event Count) $= 0x\ 00\ 02 = 2$ motion events
  - $0x\ \mathbf{06\ 00}$ (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. A big-endian format (MSB first) is always followed.

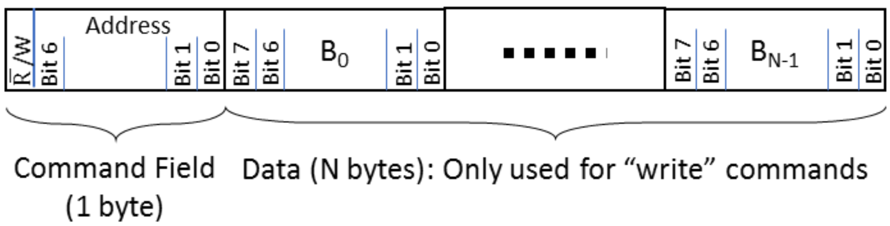

Figure 3-1: Format of a DL message.

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 ignored.

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	# Bytes
0x00	R	DevEUI	8
0x01	R	AppEUI	8
0x02	R	AppKey	16
0x03	R	DevAddr	4
0x04	R	NwkSKey	16
0x05	R	AppSKey	16

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

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

3.3 LoRaMAC Configuration

LoRaMAC 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. In this table, B_i refers to data byte indexed *i* as defined Figure 3-1.

Table 3-2: LoRaMAC Configuration Registers

Address	Access	Value	# Bytes	Description
0x10	R/W	Join Mode	2	B_0-bit 7: 0 = ABP, 1 = OTAA B_1: RFU
0x11	R/W	• Unconfirmed/Confirmed UL • Disable/Enable Duty Cycle • Disable/Enable ADR	2	B_0: RFU B_1-bit 0: 0 = Unconfirmed UL, 1 = Confirmed UL B_1-bit 2: 0 = Disable duty cycle, 1 = Enable duty cycle B_1-bit 3: 0 = Disable ADR, 1 = Enable ADR
0x12	R/W	• Default DR number • Default Tx Power number	2	B_0-bits 3–0: Default DR number [3] B_1-bits 3–0: Default Tx power number [3]
0x13	R/W	• Rx2 window DR number • Rx2 window channel frequency	5	B_0-B_1-B_2-B_3: Channel frequency in Hz for Rx2 B_4: DR for Rx2
0x19	R/W	Net ID MSBs	2	Bytes B_0-B_1 in the Net ID (B_0-B_1-B_2-B_3)
0x1A	R/W	Net ID LSBs	2	Bytes B_2-B_3 in the Net ID (B_0-B_1-B_2-B_3)

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.

3.3.1.1 Default Configuration

Table 3-3 and Table 3-5 show the default values for the LoRaMAC configuration registers (cf. [1], [3]).

Table 3-3: Default Values of LoRaMAC Configuration Registers

Address	Default Value
0x10	0x 80 00 (OTAA mode)
0x11	0x 00 0C (Unconfirmed UL, enabled duty cycle, enabled ADR)
0x12	0x 00 04 (DR0, Tx Power 0—max power, see Table 3-4)
0x13	As per Table 3-5
0x19	0x 00 00
0x1A	0x 00 00

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

RF Region	Max Tx EIRP [dBm]
EU868	16
US915	30
AS923	16
AU915	30
IN865	30
CN470	19.15
KR920	14
RU864	16

Table 3-5: Default Values of Rx2 Channel Frequency and DR Number in Different Regions

RF Region	Default Value	Channel Frequency	DR Number
EU868	0x 33 D3 E6 08 00	869.525 MHz	DR0
NA915	0x 37 08 70 A0 08	923.3 MHz	DR8
AS923	0x 37 06 EA 00 02	923.2 MHz	DR2
AU915	0x 37 08 70 A0 08	923.3 MHz	DR8
IN865	0x 33 A6 80 F0 02	866.55 MHz	DR2
CN470	0x 1E 1E 44 20 00	505.3 MHz	DR0
KR920	0x 36 F3 13 E0 00	921.9 MHz	DR0
RU864	0x 33 CD 69 E0 00	869.1 MHz	DR0

3.3.2 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, 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 }

3.4 Sensor Application Configuration

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 3-6 shows a list of registers used to configure the Sensor's periodic transmissions.

Table 3-6: Periodic Transmission Configuration Registers

Address	Access	Value	# 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 Reed Switch Tx	2	*Ticks* between Reed Switch reports. A value of 0 disables periodic Reed Switch 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 / Ticks per Moisture Tx	2	*Ticks* between PIR reports. A value of 0 disables periodic PIR reports.
0x29	R/W	*Ticks* per External Input Tx	2	*Ticks* between External Input reports. A value of 0 disables periodic External Input 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 60 seconds, and the maximum is 86400 seconds (one day). Values from 1 to 59 are clipped to 60 seconds. Values above 86400 are clipped to 86400. A value of 0 (zero) disables all periodic reporting.

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 3-7 shows the default values for the periodic transmission configuration registers.

Table 3-7: Default Values of Periodic Transmission Configuration Registers

Seconds per *tick*	3600 (1 hour)
***Ticks* per Battery**	1 (thus 1-hour period)
***Ticks* per Temperature**	1 (thus 1-hour period)
***Ticks* per RH**	1 (thus 1-hour period)
***Ticks* per other transducers**	0 (periodic Tx disabled)

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)

3.4.1.5 Preventing Sensor Bricking

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

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

After the reconfiguration is applied, if all event-based reporting (as explained in subsequent sections) is disabled, then periodic reporting is checked. If all periodic reporting is disabled or the minimum non-zero period is greater than a week, then to avoid bricking the Sensor, the core *tick* is set to 86400 (i.e. one day), and the battery voltage *tick* is set to 1 (one).

3.4.2 Reed Switch Configuration

Table 3-8 shows a list of Reed Switch configuration registers.

Table 3-8: Reed Switch Configuration Registers

Address	Access	Value	# 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 Reed Switch 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 Example:

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

3.4.2.2 Count Threshold

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

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 Reed Switch 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 3-9 shows the default values for the Reed Switch configuration registers.

Table 3-9: Default Values of Reed Switch 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 Reed Switch 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 Reed Switch “state” as soon as the Reed Switch 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
        - Value to Tx set to “Input State”
- Disable the Reed Switch event-driven transmission, but report the number of times the Reed Switch 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)
        - Value to Tx set to “Counter Value”

3.4.3 External Input Configuration

Table 3-10 shows a list of External Input configuration registers.

Table 3-10: External Input Configuration Registers

Address	Access	Value	# Bytes	Description
0x2D	R/W	Mode	1	Bit 0: Rising Edge Enable Bit 1: Falling Edge Enable Other bits are ignored.
0x2E	R/W	Count Threshold	2	# of Triggers for event transmission. A value of 0 disables event transmission
0x2F	R/W	Value to Transmit	1	Bit 0: Input State Bit 1: Counter Value Other bits are ignored.

3.4.3.1 Mode

The External 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).

3.4.3.2 Count Threshold

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

3.4.3.3 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 External 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).

3.4.3.4 Default Configuration

Table 3-11 shows the default values for the External Input configuration registers.

Table 3-11: Default Values of External Input Configuration Registers

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

3.4.3.5 Example DL Messages

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

- Have External Input be triggered only on falling edges:

- DL payload: { 0x **AD** 02 }
  - Reg 2D with write bit set to true
  - "Rising Edge" disabled, "Falling Edge" enabled
- Read current value of Count Threshold:
  - DL payload: { 0x **2E** }
    - Reg 2E with write bit set to false
- Transmit the External Input "state" as soon as the External Input is tripped 20 times:
  - DL payload: { 0x **AE** 00 14 **AF** 01 }
    - Reg 2E and Reg 2F with their write bits set to true
    - Count Threshold set to 20
    - Value to Tx set to "Input State"
- Disable the External Input event-driven transmission, but report the number of times the External 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 }
    - Count Threshold set to 0 (zero)
    - Value to Tx set to "Counter Value"

3.4.4 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 3-12 shows a list of accelerometer configuration registers.

Table 3-12: Accelerometer Configuration Registers

Address	Access	Value	# Bytes	Description
0x30	R/W	Break-In Threshold	2	Unsigned, 1 milli-g / LSB
0x31	R/W	Impact Threshold	2	Unsigned, 1 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.

3.4.4.1 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 3.4.4.4). Within the timeout period, if the g-threshold is tripped at least 4 times, a break-in alarm is raised.

3.4.4.2 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.

3.4.4.3 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.

3.4.4.4 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.

3.4.4.5 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.

3.4.4.6 Sample Rate

The accelerometer is always turned on (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.

3.4.4.7 Default Configuration

Table 3-13 shows the default values for the accelerometer configuration registers.

Table 3-13: Default Values of Accelerometer Configuration Registers

Break-In Threshold	**3000** milli-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)

3.4.4.8 Example DL Messages

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

- Set Impact Threshold and Impact Debounce Time:
  - DL payload: { 0x **B1** 07 D0 **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

3.4.5 Temperature/RH Threshold Configuration

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 3-14 shows a list of configuration registers for the Temperature/RH Threshold setting. In this table, B_i refers to data byte indexed *i* as defined Figure 3-1.

Table 3-14: Temperature/RH Threshold Configuration Registers

Address	Access	Value	# 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	B_0: High temperature threshold (signed, 1°C / LSB) B_1: Low 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	B_0: High RH threshold (unsigned, 1% RH / LSB) B_1: Low 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	B_0: High MCU temperature threshold (signed, 1°C / LSB) B_1: Low 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.

3.4.5.1 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. When first enabled, the transducer starts in the Idle state.

3.4.5.2 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.

3.4.5.3 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.

3.4.5.4 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.

3.4.5.5 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.

3.4.5.6 Default Configuration

Table 3-15 shows the default values for the Temperature/RH threshold configuration registers.

Table 3-15: Default Values of Temperature/RH Threshold Configuration Registers

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

3.4.5.7 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

3.4.6 Light Sensing Configuration

The Home Sensor light sensing allows for the detection of the presence or absent of light based on 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 3-16 shows a list of light transducer configuration registers.

Table 3-16: Light Transducer Configuration Registers

Address	Access	Value	# Bytes	Description
0x47	R/W	Sample Period	4	Sample period of the light transducer (seconds)
0x48	R/W	Threshold	1	Threshold level from 1 to 63 (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.

3.4.6.1 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, 60, 61, 62, …. Setting the sample period to 0 (zero) disables the light sensing element. Setting the samples period to anything from 1 to 59 sets the sample period to 60.

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.

3.4.6.2 Threshold

The Threshold is used to set the dark/bright transition point for the Sensor, and can be set to any value from 1 to 63. A value of 0 is clipped to 1, and values greater than 63 are clipped 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, and only transmits when the threshold is crossed.

3.4.6.3 Default Configuration

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

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

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

3.4.6.4 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 }

3.4.7 Motion Transducer Configuration

The motion transducer (detector) is on PIR Home Sensor models only and 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 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 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 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 3.4.7.1) expires.

Table 3-18 shows a list of motion transducer configuration registers.

Table 3-18: Motion Transducer Configuration Registers

Address	Access	Value	# 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.

3.4.7.1 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.

3.4.7.2 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 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.

3.4.7.3 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.

3.4.7.4 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.

3.4.7.5 Default Configuration

Table 3-19 shows the default values for the motion transducer configuration registers.

Table 3-19: 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)

3.4.7.6 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 }

3.4.8 Moisture Configuration

The Base Home Sensor is 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 (detector) 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 3-20 shows a list of moisture transducer configuration registers.

Table 3-20: Moisture Transducer Configuration Registers

Address	Access	Value	# 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”

3.4.8.1 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: For the updates to the Sample Period to take effect, the moisture transducer requires to be de-initialized and then initialized.

3.4.8.2 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.

3.4.8.3 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 for bit 0 are:

- 0: Disable
- 1: Enable

3.4.8.4 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. Any issued recalibration is performed as soon as the next moisture sample is taken. Therefore, as an example, if the sample period is 16 seconds, it may take up to 16 seconds for a recalibration command to be executed.

3.4.8.5 Default Configuration

Table 3-21 shows the default values for the moisture transducer configuration registers.

Table 3-21: Default Values of Moisture Transducer Configuration Registers

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

3.4.8.6 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 }

3.4.8.7 Operation Algorithm

1. Whenever the moisture detector is enabled, it is recalibrated for a new dryness baseline.
2. In every sample, if the measured value goes up from the baseline by more than 10 counts (not user configurable), the moisture detector is recalibrated for a new dryness baseline.
3. In every sample, if the measured value goes down from the baseline by more than the Threshold (user configurable, see Section 3.4.8.2), the detector is tripped (signaling wetness).
4. Every 60 samples, if humidity changes by more than 10% (up or down–not user configurable), the moisture detector gets recalibrated for a new dryness baseline.

3.5 Sensor Command and Control

Configuration changes are not retained after a power cycle unless they are saved in the Flash memory. Table 3-22 shows the structure of the Command & Control Register. In this table, B_i refers to data byte indexed *i* as defined Figure 3-1.

Table 3-22: Sensor Command & Control Register

Address	Access	Name	# Bytes	Description
0x70	W	Flash Write Command	2	B_0-bit 5: Write App Config B_0-bit 6: Write LoRa Config B_1-bit 0: Restart Sensor In all cases: 0 = De-asserted, 1 = Asserted Other bits are ignored.
0x71	R	FW Version	7	B_0: App version major B_1: App version minor B_2: App version revision B_3: LoRaMAC version major B_4: LoRaMAC version minor B_5: LoRaMAC version revision B_6: LoRaMAC region number
0x72	W	Reset Config Registers to Factory Defaults†	1	0x0A: Reset App Config 0xB0: Reset LoRa Config 0xBA: Reset both App and LoRa Configs Any other value is ignored.

†Resetting to factory defaults takes effect on the next power-cycle.

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 the NS to continually reboot the Sensor.

3.5.1 LoRaMAC Region

The LoRaMAC region is indicated by B_6 in the FW Version register (Reg 0x71). Current LoRaMAC regions and corresponding region numbers are listed in Table 3-23.

Table 3-23: LoRaMAC Regions and Region Numbers

LoRaMAC Region	Region Number
EU868	0
NA915	1
AS923	2

AU915	3
IN865	4
CN470	5
KR920	6
RU864	7

3.5.2 Command Examples

In the following examples, the Command Field is boldfaced:

- 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 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.