# Ultrasonic LoRaWAN
# User Manual

## Contents

# 1. Product Description

The Ultrasonic LoRaWAN sensor is a flexible and configurable, battery-operated ultrasonic liquid sensor which is configured to connect to a LoRaWAN network.
This sensor will measure and report the distance between the device and the surface of the liquid.
The functionality of the sensor includes various alarm triggers, configurable measurement schedule, reporting schedules & temperature measurement.
Once activated on a LoRaWAN network it will send the measurement data according to its configuration through the network gateways to the endpoint server accessible by end users.
It may be used for applications such as Liquid level monitoring of fuel, water, waste oil on fixed or portable vessels.
See installation instruction for installation and activation guidelines.

## 1.1 Abbreviations/Definitions

The following is a list of terms that may be found in this document.

| | |
|---|---|
| **Ullage** | The unfilled space between the sensor and the top of the liquid being monitored |
| **RSSI** | Received Signal Strength Indicator |
| **SRSSI** | Sonic Received Signal Strength Indicator |
| **SRC** | Sonic Results Code – a performance metric of the ultrasonic measurement. |
| **Ack** | Acknowledgement from the LoRaWAN network server |
| **Message** | The data packet / payload / datagram sent across the network |
| **Payload** | Data transmitted between sensor and LoRaWAN network |
| **Nibble** | Half of a byte |
| **LSB** | The Least Significant Bit is the right-most bit in the string |
| **MSB** | The Most Significant Bit is the left-most bit in the string |
| **Minor** | The right-most bits in the string |
| **Major** | The left-most bits in the string |
| **0x** | Identifies the number as hexadecimal. e.g. 0x3F *Note: numbers are assumed decimal unless specified otherwise.* |
| **0b** | Identifies the number as binary e.g. 0b1101 *Note: numbers are assumed decimal unless specified otherwise.* |
| **Unsigned byte** | Numbers are only represented in the positive range: 0….256 |
| **Signed byte** | Will allow numbers to be represented both in the positive and negative ranges: -127 to +127 |
| **Waveguide** | A waveguide option allows the ultrasonic reading to be measured through a waveguide pipe inserted into the tank to avoid any obstacles/obstructions that may affect the standard ultrasonic reading |
| **IoT** | Internet of Things |
| **Dormant** | Dormant units are inactivated and do not make RF transmissions or measurements to ensure the longest battery service life |

## 2. Description of Data Transmission

### 2.1 Operation Modes

Once the sensor has been successfully activated, it will operate in two modes:

- A manual connection – By pressing the button
- An automatic connection according to the internal connection schedule

### 2.2 Standard Operation

The Ultrasonic LoRaWAN sensor will remain in low power mode for the majority of its lifetime.
It will briefly wake up and make an ultrasonic measurement of the ullage as per the configuration schedule and store the result before reverting to low power mode. The sensor will make a predefined number of transmissions in a time frame defined by the configuration schedule.

### 2.3 Factory Default Operation:

The following are the factory default settings for the sensor but are configurable.
The sensor will briefly wake up and make an ultrasonic measurement of the ullage every 15 minutes, which is compared to an alarm limit (if enabled). Every 6 hours the current ultrasonic measurement is stored before reverting to low power mode. The sensor will make 4 transmissions every 24 hours, one every 6 hours. Every fourth transmission will expect an acknowledgement from the LoRaWAN server, the other 3 transmissions do not require this. For data redundancy, each transmission will include one current ultrasonic measurement as part of the payload as well as last 3 previously uploaded readings. A **status** message is sent once every 7 days.

### 2.4 Manual Operation

The sensor can be forced to connect to the LoRaWAN network server at any time by briefly pressing the button for one second to wake up the sensor. The sensor will take an ultrasonic measurement, connect to the gateway and transmit a status message which includes a current ultrasonic measurement. During the connection, the dual colour LED will turn on solid Green, then flash green to indicate that the connection is complete. The sensor will then revert to low power mode.

### 2.5 Logging Data

The sensor will store 4 measurements internally which contain the following:

- Ullage – Reported in cm
- SRC
- SRSSI
- Internal PCB Temperature in $^{o}$C

### 2.6 Principle of Data Upload

The sensor will connect to the LoRaWAN network server for one of the following reasons:

- **Activation** – The user has pressed the button for 1 second to activate the device from dormant mode and subsequently force a connection to the network.
- **Manual Connection** – The user has pressed the button for 1 second to make a measurement and send a status message.
- **Scheduled** – The sensor will connect to the LoRaWAN network server according to its schedule.
- **Regular Status Update** – Typically once per week as defined in the schedule.
- **Alarm** – Reporting that alarm limit thresholds have been exceeded (if enabled).
- **Configuration Update** – Soft reset – This occurs in response to a configuration settings update. A hard-internal reset would also cause a communication.

***Note:** After a device reset, manual activation or after provisioning, a **status** message will be uploaded to the LoRaWAN network server.*

## 2.7 Alarm Mode

There are up to three separate static alarms levels that can be configured on the sensor. These can be configured to alarm when the measured value is higher or lower than the defined level.
When a static alarm is activated, an immediate message is sent to the LoRaWAN network server.
This message will indicate which of the static limits was exceeded and will also contain two ultrasonic readings, the first ultrasonic reading is the one that exceeded the threshold and the second is the previous reading made as defined by the measurement schedule. In order to avoid false alarms, the ultrasonic measurement reading is tested against programmable quality metrics SRC: SRSSI filter limits as defined in parameter 0x4004. If the ultrasonic measurement does not exceed these limits then an alarm is not triggered.

## 2.8 SRC & SRSSI

In addition to the ullage (represented in CM) there are two additional parameters which can be used to identify the quality and reliability of an ultrasonic reading.

1. **Sonic RSSI:** The SRSSI is simply an integer number between 1 (low level) and 10 (expected level) given to the expected strength of the echo reflected to the transducer. A value of 9 or 10 would normally be expected from a uniformly flat surface such as from a stable fluid level inside a tank. A low value may indicate that the sensor is not mounted perpendicular to the surface or that the surface is irregular (not flat) or of a nature which absorbs ultrasonic signals such as soft furnishings. The SRSSI when used in combination with the SRC is a useful measure of the overall confidence in the measurement.

2. **Sonic Results Code:** The SRC represents the result code of the ultrasonic algorithm which can be used to deduce whether a reading is likely to be valid or not. An SRC of 9 or 10 are optimal.

| Sonic Result Code | Range Near < 80cm Far >= 80cm | Description |
|---|---|---|
| 10 | Near & Far | Good quality ultrasonic echo. |
| 9 | Near | Detected echo indicates operation in 'blind zone'. i.e. <= 24cms. |
| 8 | Near & Far | Best Echo is not the 1st one detected. |
| 7 | Near | The first echo was < 25cm but the subsequent echo was stronger so that one was chosen instead. |
| 6 | Far | Ullage > 50cm & < 80cm. In this range, Near field algorithm should have reported. |
| 5 | Near | Multiple echoes, <= 24 cms. |
| 4 | Far | Best Echo > 400cm limit. 1st echo seen is reported. |
| 3 | Near | Best Echo > 24cm but a high level of noise |
| 2 | Far | Best Echo < 50cms. In this range, Near field algorithm should have reported. |
| 1 | Near | 1st echo is strongest, but High levels of energy bunched up in the very near field <= 24cms. |
| 0 | Near & Far | No echo detected |

# 3. Configuring Device

## 3.1 LoRaWAN Network Server Response

Every time a sensor makes an outgoing status connection to the gateway, the LoRaWAN network server has the option to respond with configuration settings to alter the operation of the device.
Sending responses to the sensor is very useful for tasks such as changing the connection schedule. Care must be taken, as sending the wrong settings could render the device incapable of correct operation.

## 3.2 Message Types

The sensor transmits or receives several packet types.

**Messages Issued by sensor:**

| Message Type | Description | Payload Msg. Type / Port |
|---|---|---|
| **Measurement:** | Sensor sends measurement data to LoRaWAN network server<br>This is setup periodically when configuring the schedule | 0x10 |
| **Status:** | Sensor sends status data to LoRaWAN network server<br>This is setup periodically when configuring the schedule | 0x30 |
| **Parameter Read Response:** | Sensor sends parameter settings to the LoRaWAN network server | 0x43 |
| **Alarm Notification:** | Sensor sends alarm notification to the LoRaWAN network server | 0x45 |
| **Diagnostic Read Response:** | Sensor sends diagnostics data (mostly ultrasonic) to the LoRaWAN network server | 0x47 |

**Messages issued by LoRaWAN network server:**

| Message Type | Description | Payload Msg. Type / Port |
|---|---|---|
| **Response Ack:** | LoRaWAN network server sends a soft "ack" for write request to the LoRaWAN network sensor | 0x40 |
| **Parameter Read Request:** | LoRaWAN network server requests the sensor to send parameter settings to the LoRaWAN network server | 0x41 |
| **Parameter Write Request:** | Update of parameters on LoRaWAN network sensor | 0x42 |
| **Diagnostic Read Request:** | LoRaWAN network server requests the sensor to send diagnostic data to the LoRaWAN network server | 0x46 |

### 3.2.1 Configuration Parameters

| Parameter 0x40 | Read/ Write | Parameter | Data Type | Data Byte Length | Default Value | Description |
|---|---|---|---|---|---|---|
| 0x4000 | R/W | Sonic Control | u32 | 4 | 0x49351928 | Characteristic of the Advanced Sonics routine |
| 0x4001 | R/W | Static Limit1 | u16 | 2 | 0 | Characteristics of the Limit Alarm (Low/High, Threshold etc) |
| 0x4002 | R/W | Static Limit2 | u16 | 2 | 0 | Characteristics of the Limit Alarm (Low/High, Threshold etc) |
| 0x4003 | R/W | Static Limit3 | u16 | 2 | 0 | Characteristics of the Limit Alarm (Low/High, Threshold etc) |
| 0x4004 | R/W | SRC/SRSSI Filter | u8 | 1 | - | Filters whether a measurement can trigger alarm |
| 0x4005 | R/W | Ping Rate | u8 | 1 | 15 | How often (in minutes) ultrasonic ping/LPG sample occurs |
| 0x4006 | R/W | RF_RSSI Threshold | s8 | 1 | -120 | RF RSSI Threshold to generate LED flash response |
| 0x4007 | R/W | Control Byte | u8 | 1 | 0 | Bitwise flags such as bund enable, measurement frame confirmations |

| Scheduler 0x05 | Read/ Write | Scheduler Parameter | Data Type | Data Byte Length | Default Value | Units | Description |
|---|---|---|---|---|---|---|---|
| 0x0500 | R/W | TX Period | u32 | 4 | 86400 | seconds | Duration of all transmission windows- Default 24hours |
| 0x0502 | R/W | TX randomisation period | u32 | 4 | 3600 | seconds | Duration of one transmission window - randomisation |
| 0x0503 | R/W | Logger Interval Period | u32 | 4 | 21600 | seconds | Time between two index measurements - Default 6hours |
| 0x0505 | R/W | Status frame period | u32 | 4 | 604800 | seconds | Time between two status frame transmissions - Default 7days |

**Data Type:**

- u = unsigned byte, e.g., u32 = unsigned 4 bytes.
- s = signed byte

Configurable parameters listing default, minimum and maximum.

| PARAMETER: | MINIMUM | MAXIMUM | DEFAULT | UNITS |
|---|---|---|---|---|
| Scheduler TX Period | 1 | 720 | 6 | Hours |
| Status TX Period | 1 | 30 | 7 | Days |
| Logger Interval | 2 | 1440 | 360 | Minutes |
| TX Randomisation Period | 1 | 240 | 60 | Minutes |
| Ultrasonic Ping Rate | 1 | 240 | 15 | Minutes |
| Alarm Static Threshold Limits | 22 | 400 | 0 (disabled) | cm |
| Sonic SRC/SRSSI Filter limits | 0:0 | 10:10 | 9:4 | - |

### 3.2.2 Product ID reference

| TEK # | PROD ID field |
|---|---|
| TEK 766 | 00 |
| TEK 586 | 02 |
| TEK 790 | 03 |
| TEK 733 | 05 |
| TEK 643 | 06 |
| TEK 811 | 07 |
| TEK 822 | 08 |
| TEK 733A | 09 |

### 3.2.3 Measurement

This is a standard message that the sensor sends as scheduled to the LoRaWAN network server.
It includes the latest ultrasonic measurement plus 3 previously sent readings (4 readings in total).
The individual readings comprise of a 2-byte ullage - this represents the distance between the ultrasonic transducer and the surface of the liquid. From this a calculation of the tank % full can be calculated. The temperature within the tank is also provided (one byte) and a metric of the quality of the ultrasonic measurement called SRC/ SRSSI (1 Byte) is also provided.
The Alarms byte represents a passive alarm notification (so indicates an alarm if the alarm threshold is set and exceeded, but the alarm is disabled by default).

Sample Payload: (Payloads are Hexadecimal)
1000000001121B7701131BAA01121BA90114F274

| Byte # | Payload | Description | Notes | Results |
|---|---|---|---|---|
| 1 | 10 | Defines the payload type *(See Section 3.2)* | 0x10 = Measurement | Measurement |
| 2 | 00 | Defines the product identification number *(See Section 3.2.2)* | 0x00 = TEK 766 | TEK 766 |
| 3 | 00 | Defines the Alarms *(See Section 3.2.8.1)* | 0x00 -> 0b00000000<br>Lim1: Bit0 = 0<br>Lim2: Bit1 = 0<br>Lim3: Bit2 = 0 | No limits exceeded |
| 4 | 00 | N/A | N/A | |
| 5 | 01 | Defines the ullage reading in cms<br>(Byte 5 x $2^8$) + Byte 6 | (0x01 x $2^8$) + 0x12<br>(1 x $2^8$) + 18<br>256 + 18 = 274 | 274cm |
| 6 | 12 | | | |
| 7 | 1B | Defines the temperature in °C<br>- ([256 or 0] - Byte 7)<br>*(See Section 3.2.3.1)* | [0x1B = 27 -> 0]<br>- (0 - 27) = 27 | 27°C |
| 8 | 77 | SRC: Major nibble of Byte 8<br>SRSSI: Minor nibble of Byte 8 | SRC = 0x7 = 7<br>SRSSI = 0x7 = 7 | SRC=7<br>SRSSI=7 |
| 9 | 01 | Defines the ullage reading in cms<br>(Byte 9 x $2^8$) + Byte 10 | (0x01 x $2^8$) + 0x13<br>(1 x $2^8$) + 19<br>256 + 19 = 275 | 275cm |
| 10 | 13 | | | |
| 11 | 1B | Defines the temperature in °C<br>- ([256 or 0] - Byte 11)<br>*(See Section 3.2.3.1)* | [0x1B = 27 -> 0]<br>- (0 - 27) = 27 | 27°C |
| 12 | AA | SRC: Major nibble of Byte 12<br>SRSSI: Minor nibble of Byte 12 | SRC = 0xA = 10<br>SRSSI = 0xA = 10 | SRC=10<br>SRSSI=10 |
| 13 | 01 | Defines the ullage reading in cms<br>(Byte 13 x $2^8$) + Byte 14 | (0x01 x $2^8$) + 0x12<br>(1 x $2^8$) + 18<br>256 + 18 = 274 | 274cm |
| 14 | 12 | | | |
| 15 | 1B | Defines the temperature in °C<br>- ([256 or 0] - Byte 15)<br>*(See Section 3.2.3.1)* | [0x1B = 27 -> 0]<br>- (0 - 27) = 27 | 27°C |
| 16 | A9 | SRC: Major nibble of Byte 16<br>SRSSI: Minor nibble of Byte 16 | SRC = 0xA = 10<br>SRSSI = 0x9 = 9 | SRC=10<br>SRSSI=9 |
| 17 | 01 | Defines the ullage reading in cms<br>(Byte 17 x $2^8$) + Byte 18 | (0x01 x $2^8$) + 0x14<br>(1 x $2^8$) + 20<br>256 + 20 = 276 | 276cm |
| 18 | 14 | | | |
| 19 | F2 | Defines the temperature in °C<br>- ([256 or 0] - Byte 19)<br>*(See Section 3.2.3.1)* | [0xF2 = 242 -> 256]<br>- (256 - 242) = -14 | -14°C |
| 20 | 74 | SRC: Major nibble of Byte 20<br>SRSSI: Minor nibble of Byte 20 | SRC = 0x7 = 7<br>SRSSI = 0x4 = 4 | SRC=7<br>SRSSI=4 |

#### 3.2.3.1 Temperature

Temperature ranges -20°C to +50°C (Variable range -127 -> 127)

- - ([256 or 0] - Byte)
- If the decimal conversion of the byte is greater than 32 then the number required for the formula is 256 otherwise the number required for the formula is 0.

### 3.2.4 Status

This is a packet that the sensor sends as scheduled to the LoRaWAN network server.
It is also generated by pressing the button on the sensor.

Sample Payload: (Payloads are Hexadecimal)
30000001010636006300630004060018 1BAA

| Byte # | Payload | Description | Notes | Results |
|---|---|---|---|---|
| 1 | 30 | Defines the payload type *(See Section 3.2)* | 0x30 = Status | Status |
| 2 | 00 | Defines the product identification number *(See Section 3.2.2)* | 0x00 = TEK 766 | TEK 766 |
| 3 | 00 | N/A | N/A | |
| 4 | 01 | Defines the Hardware ID | 0x01 = 1 | 1 |
| 5 | 01 | Defines the firmware revision Byte 5 . Byte 6 | 0x01 . 0x06 = 1.6 | 1.6 |
| 6 | 06 | | | |
| 7 | 36 | Defines the reason for the last reset *(See Section 3.2.5.1)* | 0x36 = 0b00110110<br>Contact: Bit0,Bit1 = 0b10 = 2<br>Reset: Bit2,Bit3,Bit4 = 0b101 = 5<br>Active: Bit5 = 0b1 = 1 | Manual Contact<br>System Request Reset<br>Active |
| 8 | 00 | N/A | N/A | |
| 9 | 63 | Defines the sensor RSSI - Byte 9 | - 0x63 = - 99 | -99dBm |
| 10 | 00 | N/A | N/A | |
| 11 | 63 | Defines the remaining battery % | 0x63 = 99 | 99% |
| 12 | 00 | Defines the measurement Sections in minutes (Byte 12 x $2^8$) + Byte 13 | (0x00 x $2^8$) + 0x04<br>(0 x 256) + 4 = 4 | 4 mins |
| 13 | 04 | | | |
| 14 | 06 | Defines the schedule transmit period in hours | 0x06 = 6 | 6 Hours |
| 15 | 00 | Defines the ullage reading in cms (Byte 15 x $2^8$) + Byte 16 | (0x00 x $2^8$) + 0x18<br>0 + 24 = 24 | 24cm |
| 16 | 18 | | | |
| 17 | 1B | Defines the temperature in °C - ([256 or 0] - Byte 17) *(See Section 3.2.3.1)* | [0x1B = 27 -> 0]<br>- (0 - 27) = 27 | 27°C |
| 18 | AA | SRC: Major nibble of Byte 18<br>SRSSI: Minor nibble of Byte 18 | SRC = 0xA = 10<br>SRSSI = 0xA = 10 | SRC=10<br>SRSSI=10 |

The status frame contains some important information, but information which would rarely change and is not required to be transmitted on a daily basis.

Typically, the Status frame will be transmitted once per week and contains information such as the sensor Firmware version, the current Battery level as well as a single ultrasonic measurement (which is useful if the status frame is uploaded during an installation/diagnostic button press). The sensor RSSI is the signal strength of the unit received by the gateway.

**Note:** The scheduled TX period is limited to a single byte and so is limited to representing a maximum of 255 hours.

#### 3.2.4.1 Status Byte

The status byte is contained in the status frame (which is typically sent once per week). It contains information about the connection reason (i.e. was it via a button press or a scheduled connection). Also, if the connection reason was due to a "reset", then the corresponding "LastResetReason" can be extracted.

<table>
<tr><th>Bit7</th><th>Bit6</th><th>Bit5</th><th>Bit4</th><th>Bit3</th><th>Bit2</th><th>Bit1</th><th>Bit0</th></tr>
<tr><td>Reserved</td><td>Reserved</td><td>Active Status</td><td colspan="3">LastResetReason:<br>0 = Power on reset<br>1 = Brown out reset<br>2 = External reset<br>3 = Watchdog reset<br>4 = Cortex-M3 lockup reset<br>5 = Cortex-M3 system request reset<br>6 = EM4 reset<br>7 = System has been in Backup mode</td><td colspan="2">Contact Reason<br>0 = Reset<br>1 = Scheduled<br>2 = Manual<br>3 = Activation</td></tr>
</table>

### *3.2.5 Parameter Read Request*

This is a message issued by the LoRaWAN network server requesting information on current parameter settings of the sensor. This can contain several parameter requests linked together but is limited to a maximum combined size of 45 bytes.

(See Section 3.2.1 for parameters table)

Sample Payload: (Payloads are Hexadecimal)
41000040014002

| Byte # | Payload | Description | Notes | Results |
|---|---|---|---|---|
| 1 | 41 | Defines the payload type *(See Section 3.2)* | 0x41 = Parameter Read Request | Parameter Read Request |
| 2 | 00 | Defines the product identification number *(See Section 3.2.2)* | 0x00 = TEK 766 | TEK 766 |
| 3 | 00 | N/A | N/A | |
| 4 | 40 | Defines the Parameter ID *(See Section 3.2.1)* | 0x4001 = Static Limit1 | Static Limit 1 |
| 5 | 01 | | | |
| 6 | 40 | Defines the Parameter ID *(See Section 3.2.1)* | 0x4002 = Static Limit 2 | Static Limit 2 |
| 7 | 02 | | | |

This can contain several parameter requests concatenated together, though care must be taken not to request settings which combined size would exceed 45 bytes.

### 3.2.6 Parameter Read Response

This is a message that the sensor sends in response to the LoRaWAN network server requesting the aforementioned Parameter Read Request.

(See Section 3.2.1 for parameters table)

Sample Payload: (Payloads are Hexadecimal)
43000002400164480240011600

| Byte # | Payload | Description | Notes | Results |
|---|---|---|---|---|
| 1 | 43 | Defines the payload type *(See Section 3.2)* | 0x43 = Parameter Read Response | Parameter Read Response |
| 2 | 00 | Defines the product identification number *(See Section 3.2.2)* | 0x00 = TEK 766 | TEK 766 |
| 3 | 00 | N/A | N/A | |
| 4 | 02 | Data length after parameters | 0x02 | 02 |
| 5 | 40 | Defines the Parameter ID *(See Section 3.2.1)* | 0x4001 = Static Limit1 | Static Limit 1 |
| 6 | 01 | | | |
| 7 | 64 | Defines the static threshold limits *(See Section 3.3.7)* | LSB First = 0x4864 | Threshold = 100cm<br>Tolerance = 2cm<br>Alarm = Enabled<br>Polarity = Lower than Threshold |
| 8 | 48 | | | |
| 9 | 02 | Data length after parameters | 0x02 | 02 |
| 10 | 40 | Defines the Parameter ID *(See Section 3.2.1)* | 0x4001 = Static Limit1 | Static Limit 1 |
| 11 | 01 | | | |
| 12 | 16 | Defines the static threshold limits *(See Section 3.3.7)* | LSB First = 0x0016 | Threshold = 22cm<br>Tolerance = 0cm<br>Alarm = Not Enabled<br>Polarity = Lower than Threshold |
| 13 | 00 | | | |

A response frame to read parameters response largely resembles a write parameter request i.e. the message contains a setting length field (as different parameters are of different length) as well as the Category, ID and corresponding parameter value.

Please note the byte order of multi-byte parameter responses are LSB first. i.e. a value of 20 in a 4-byte parameter is represented as 0x14000000

**Note:** All ‘parameter read responses’ are ‘confirmed’ packets that is, the sensor will make three attempts to send the data. If unsuccessful, the Application server will have to make another attempt by sending a new ‘parameter read request’. For sensors in areas with weak signal strength – it is recommended to send shorter parameter requests.

#### 3.2.6.1 Response code Byte

This byte is sent in response to a LoRaWAN downlink frame (i.e. to change a parameter). In normal circumstances, a response code of 0 is expected to be returned, indicating the downlink action was a success.

| Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
|---|---|---|---|---|---|---|---|
| *Reserved* | *Reserved* | *Reserved* | *Reserved* | *Reserved* | *Reserved* | *Reserved* | Response Code<br>0 = Write Request successfully received<br>1 = Write request/read request failed.<br>2 = Write command not recognized. |

### 3.2.7 Parameter Write Request

This is a message issued by the LoRaWAN network server to request a change to the parameter settings on the LoRaWAN network sensor.
The data representing the parameter settings may be of variable length as multiple parameters can be sent simultaneously and each parameter is also of variable length.

(See Section 3.2.1 for parameters table)

Sample Payload: (Payloads are Hexadecimal)
42000004050580 3A0900

| Byte # | Payload | Description | Notes | Results |
|---|---|---|---|---|
| 1 | 42 | Defines the payload type *(See Section 3.2)* | 0x42 = Parameter Write Request | Parameter Write Request |
| 2 | 00 | Defines the product identification number *(See Section 3.2.2)* | 0x00 = TEK 766 | TEK 766 |
| 3 | 00 | N/A | N/A | |
| 4 | 04 | Data length after parameters | 0x04 | 04 |
| 5 | 05 | Defines the Parameter ID *(See Section 3.2.1)* | 0x0505 = Status frame period | Status frame period |
| 6 | 05 | | | |
| 7 | 80 | Defines the Parameter Write Request Combination of Byte 7 to Byte 10 *(See Section 3.3)* | 0x803A0900 | 7 Days |
| 8 | 3A | | | |
| 9 | 09 | | | |
| 10 | 00 | | | |

The data representing the S parameters may be of variable length
This is because multiple parameters can be sent simultaneously, and each parameter is of variable length (as indicated by the Data Length field)

**Note:** The byte order of multi-byte parameter responses are LSB first i.e. a value of 20 in a 4-byte parameter is represented as 0x14000000.

### 3.2.8 Alarm Notification

This is a packet that the sensor sends to the LoRaWAN network server if a valid ultrasonic reading exceeds an alarm threshold.
This packet will indicate which of the static limits was exceeded and will also provide two ultrasonic readings.
The first is the reading that exceeded the threshold and the second is the reading logged previously to that.
The alarms are structured similarly to a standard measurement apart from the different message type and that only two readings are sent.

Sample Payload: (Payloads are Hexadecimal)
45000100001E17AA001E16A9

| Byte # | Payload | Description | Notes | Results |
|---|---|---|---|---|
| 1 | 45 | Defines the payload type<br>*(See Section 3.2)* | 0x45 = Alarm Notification | Alarm Notification |
| 2 | 00 | Defines the product identification number<br>*(See Section 3.2.2)* | 0x00 = TEK 766 | TEK 766 |
| 3 | 01 | Defines the reason for Alarm<br>*(See Section 3.2.7.1)* | 0x01 = 0b00000001<br>Lim1: Bit0 = 1<br>Lim2: Bit1 = 0<br>Lim3: Bit2 = 0 | Static Limit 1 Exceeded |
| 4 | 00 | N/A | N/A | |
| 5 | 00 | Defines the ullage reading in cms<br>(Byte 5 x $2^8$) + Byte 6 | (0x00 x $2^8$) + 0x1E<br>(0 x $2^8$) + 30<br>0 + 30 = 30 | 30cm |
| 6 | 1E | | | |
| 7 | 17 | Defines the temperature in °C<br>- ([256 or 0] - Byte 7)<br>*(See Section 3.2.3.1)* | [0x17 = 23 -> 0]<br>- (0 - 23) = 23 | 23°C |
| 8 | AA | SRC: Major nibble of Byte 8<br>SRSSI: Minor nibble of Byte 8 | SRC = 0xA -> 10<br>SRSSI = 0xA -> 10 | SRC=10<br>SRSSI=10 |
| 9 | 00 | Defines the ullage reading in cms<br>(Byte 9 x $2^8$) + Byte 10 | (0x00 x $2^8$) + 0x1E<br>(0 x $2^8$) + 30<br>0 + 30 = 30 | 30cm |
| 10 | 1E | | | |
| 11 | 16 | Defines the temperature in °C<br>- ([256 or 0] - Byte 7)<br>*(See Section 3.2.3.1)* | [0x16 = 22 -> 0]<br>- (0 - 22) = 22 | 22°C |
| 12 | A9 | SRC: Major nibble of Byte 12<br>SRSSI: Minor nibble of Byte 12 | SRC = 0xA -> 10<br>SRSSI = 0x9 -> 9 | SRC=10<br>SRSSI=9 |

The alarms frame is structurally similar to a standard measurement frame apart from the different message type (to indicate an immediate alarm notification as opposed to a scheduled measurement) and that only two readings are sent (the "alarming" reading, plus the previously logged reading).

#### 3.2.8.1 Alarm byte

| Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
|---|---|---|---|---|---|---|---|
| *Reserved* | *Reserved* | *Reserved* | *Reserved* | Bund Alarm | Limit 3 | Limit 2 | Limit 1 |

- Limit 1: Flag is set if most recently measured reading exceeds the "Limit" threshold parameters. The flag is cleared if the reading + hysteresis falls back below the threshold.
- Bund Alarm: Not implemented.

#### 3.2.8.2 Alarms

Each sensor has three static limit alarms that are programmed in centimetres.
An alarm is generated when a valid ultrasonic measurement is recorded that exceeds the static alarm threshold limits.
There is also a polarity flag which can set the direction of the alarm threshold so that an alarm is generated if the ullage is less or greater than these values.
A hysteresis level limit of between 0 and 15cm is allowed. The minimum threshold level alarm allowable is set to 22cm for operational reasons.
A valid ultrasonic measurement is used to test against the static alarm limits. This requires that the ultrasonic reading must exceed the SRC & SRSSI filter to be considered a valid reading. The default values are {9:4} and it is not recommended to change these without guidance from application support.
Once an alarm is generated, it is sent from the sensor and it requires a LoRaWAN network server response over the LoRaWAN network.
The sensor will make three attempts to send an alarm packet if an acknowledgment is not received, if it does not receive an acknowledgment then no further attempts will be made.
A new alarm will only be generated once the existing alarm condition has been cleared.
The device alarms are deactivated as default but may be enabled through a configuration change.

## 3.3 Scheduler

The sensor will upload data at regular intervals. These intervals are defined by the scheduler which sets up the ultrasonic measurements, logging intervals and RF transmission rates.
The scheduler defines the following key parameters: (See Section 3.2.1 for default, maximum and minimum values).

### *3.3.1 TX Period (0500)*

The TX period is the time between packet transmissions to the LoRaWAN network server, measured in hours.
Increasing the frequency of radio transmissions reduces the battery lifetime.
The formula for creating the payload structure for this is as follows:

| Formula | | |
|---|---|---|
| 1. Hours x 60 x 60 = Value in Seconds<br>2. Convert decimal to hexadecimal (Values) = 'XXYYZZ'<br>3. Switch Byte Endianness.<br>4. Pad Word to Bytes length as per 3.2.1 with zeros. | | |
| **Default (6 Hours)** | **Maximum (720 Hours)** | **Minimum (1 Hour)** |
| 1. 6 x 60 x 60 = 21600 Seconds<br>2. 21600 = 0x5460<br>3. = 6054<br>4. **Payload** = 60540000 **[u32]** | 1. 720 x 60 x 60 = 2592000 Seconds<br>2. 2592000 = 0x278D00<br>3. = 008D27<br>4. **Payload** = 008D2700 | 1. 1 x 60 x 60 = 3600 Seconds<br>2. 3600 = 0x0E10<br>3. = 100E<br>4. **Payload** = 100E0000 |

### *3.3.2 TX Randomization level (0502)*

The TX randomization is an additional time interval of random length centred around the TX Period transmission, measured in minutes. The range allowed is from 1 minute to ¼ of the TX period.
The formula for creating the payload structure for this is as follows:

| Formula | | |
|---|---|---|
| 1. Minutes x 60 = Value in Seconds<br>2. Convert decimal to hexadecimal (Values) = 'XXYY'<br>3. Switch Byte Endianness.<br>4. Pad Word to Bytes length as per 3.2.1 with zeros | | |
| **Default (60 Minutes)** | **Maximum (240 Minutes)** | **Minimum (1 Minute)** |
| 1. 60 x 60 = 3600 Seconds<br>2. 3600 = 0x0E10<br>3. = 100E<br>4. **Payload** = 100E0000 | 1. 240 x 60 = 14400 Seconds<br>2. 14400 = 0x3840<br>3. = 4038<br>4. **Payload** = 40380000 | 1. 1 x 60 = 60 Seconds<br>2. = 0x3C<br>3. = 3C<br>4. **Payload** = 3C000000 |

### *3.3.3 Logging interval (0503)*

The Logging interval is the time period during which 4 ultrasonic measurements are made. It should be equal to or greater than the 'ping rate' and evenly divide into the TX period. By default, it's normally set equal to the TX Period.
The formula for creating the payload structure for this is as follows:

| Formula | | |
|---|---|---|
| 1. Minutes x 60 = Value in Seconds<br>2. Convert decimal to hexadecimal (Values) = 'XXYYZZ'<br>3. Switch Byte Endianness.<br>4. Pad Word to Bytes length as per 3.2.1 with zeros | | |
| **Default (360 Minutes)** | **Maximum (1440 Minutes)** | **Minimum (2 Minute)** |
| 1. 360 x 60 = 21600 Seconds<br>2. 21600 = 0x5460<br>3. = 6054<br>4. **Payload** = 60540000 | 1. 1440 x 60 = 86400 Seconds<br>2. 86400 = 0x015180<br>3. = 805101<br>4. **Payload** = 80510100 | 1. 2 x 60 = 120 Seconds<br>2. 120 = 0x78<br>3. = 78<br>4. **Payload** = 78000000 |

### 3.3.4 *Status Message TX period (0505)*

The Status message TX period is the time between each status packet radio transmission, measured in days. The status period should be set to a minimum of twice the scheduler TX period for correct operation.
The formula for creating the payload structure for this is as follows:

| Formula | | |
|---|---|---|
| 1. Days x 24 x 60 x 60 = Value in Seconds<br>2. Convert decimal to hexadecimal (Values) = 'XXYYZZ'<br>3. Switch Byte Endianness.<br>4. Pad Word to Bytes length as per 3.2.1 with zeros | | |
| **Default (7 Days)** | **Maximum (30 Days)** | **Minimum (1 Day)** |
| 1. 7 x 24 x 60 x 60 = 604800 Secs<br>2. 604800 = 0x093A80<br>3. = 803A09<br>4. **Payload =** 803A0900 | 1. 30 x 24 x 60 x 60 = 2592000 Secs<br>2. 2592000 = 0x278D00<br>3. = 008D27<br>4. **Payload =** 008D2700 | 1. 1 x 24 x 60 x 60 = 86400 Secs<br>2. 86400 = 0x015180<br>3. = 805101<br>4. **Payload =** 80510100 |

### 3.3.5 *Ultrasonic "Ping rate" (4005)*

The Ultrasonic "Ping rate" is how often an ultrasonic measurement is taken, measured in minutes. A faster ping rate allows for a more responsive performance when the alarm functionality is enabled, but at a cost of reduced battery life.
The formula for creating the payload structure for this is as follows:

| Formula | | |
|---|---|---|
| 1. Convert decimal to hexadecimal (Values) = 'XX'<br>2. Pad Word to Bytes length as per 3.2.1 | | |
| **Default (15 Minutes)** | **Maximum (240 Minutes)** | **Minimum (1 Minute)** |
| 5. 15 = 0x0F<br>6. **Payload** = 0F | 5. 240 = 0xF0<br>6. **Payload** = F0 | 5. 1 = 0x01<br>6. **Payload** = 01 |

### 3.3.6 *Combined Payload message*

#### 3.3.6.1 Default Schedule

| Parameter | Schedule | Measurement | Values (DEC) | Payload (HEX) |
|---|---|---|---|---|
| TX Period (0500) | 6 | hours | 21600 | 60540000 |
| TX Randomization level (0502) | 60 | mins | 3600 | 100E0000 |
| Logging interval (0503) | 360 | mins | 21600 | 60540000 |
| Status message TX period (0505) | 7 | days | 604800 | 803A0900 |
| Ultrasonic "Ping rate"(4005) | 15 | mins | 15 | 0F |

"Payload Message Type" & "Data Length" & Parameter & Payload

↓

"420000" & "04" & 0500 & 60540000 & "04" & 0502 & 100E0000 & "04" & 0503 & 60540000 & "04" & 0505 & 803A0900 & "04" & 0507 & 80510100 & "01" & 4005 & 0F

↓

Payload:
42000004050060540000045021 00E0000040503605400000405058 03A090000405078051010001 40050F

### 3.3.6.2 Custom Schedules

| Parameter | Schedule | Measurement | Values (DEC) | Payload (HEX) |
|---|---|---|---|---|
| TX Period (0500) | 1 | hours | 3600 | 100E0000 |
| TX Randomization level (0502) | 5 | mins | 300 | 2C010000 |
| Logging interval (0503) | 60 | mins | 3600 | 100E0000 |
| Status message TX period (0505) | 1 | days | 86400 | 80510100 |
| Ultrasonic "Ping rate"(4005) | 15 | mins | 15 | 0F |
| Payload: 420000040500100E0000040502 2C010000040503100E00000405058051010004050780510100 0140050F | | | | |

| Parameter | Schedule | Measurement | Values (DEC) | Payload (HEX) |
|---|---|---|---|---|
| TX Period (0500) | 3 | hours | 10800 | 302A0000 |
| TX Randomization level (0502) | 15 | mins | 900 | 84030000 |
| Logging interval (0503) | 180 | mins | 10800 | 302A0000 |
| Status message TX period (0505) | 7 | days | 604800 | 803A0900 |
| Ultrasonic "Ping rate"(4005) | 15 | mins | 15 | 0F |
| Payload: 420000040500302A00000405028403000004050330 2A0000040505803A09000405078051010001 40050F | | | | |

| Parameter | Schedule | Measurement | Values (DEC) | Payload (HEX) |
|---|---|---|---|---|
| TX Period (0500) | 12 | hours | 43200 | C0A80000 |
| TX Randomization level (0502) | 30 | mins | 1800 | 08070000 |
| Logging interval (0503) | 720 | mins | 43200 | C0A80000 |
| Status message TX period (0505) | 7 | days | 604800 | 803A0900 |
| Ultrasonic "Ping rate"(4005) | 15 | mins | 15 | 0F |
| Payload: 420000040500C0A8000004050208070000040503C0A80000040505803A0900040507805101000140050F | | | | |

| Parameter | Schedule | Measurement | Values (DEC) | Payload (HEX) |
|---|---|---|---|---|
| TX Period (0500) | 24 | hours | 86400 | 80510100 |
| TX Randomization level (0502) | 60 | mins | 3600 | 100E0000 |
| Logging interval (0503) | 1440 | mins | 86400 | 80510100 |
| Status message TX period (0505) | 7 | days | 604800 | 803A0900 |
| Ultrasonic "Ping rate"(4005) | 15 | mins | 15 | 0F |
| Payload: 42000004050080510100040502100E000004050380510100040505803A09000405078051010001 40050F | | | | |

| Parameter | Schedule | Measurement | Values (DEC) | Payload (HEX) |
|---|---|---|---|---|
| TX Period (0500) | 168 | hours | 604800 | 803A0900 |
| TX Randomization level (0502) | 240 | mins | 14400 | 40380000 |
| Logging interval (0503) | 1440 | mins | 86400 | 80510100 |
| Status message TX period (0505) | 14 | days | 1209600 | 00751200 |
| Ultrasonic "Ping rate"(4005) | 15 | mins | 15 | 0F |
| Payload: 420000040500803A090004050240380000040503805101000405050075120004050780510100 0140050F | | | | |

**Note:** It is possible, due to the flexibility of the scheduler, to use parameter values that might give unexpected behaviour – for example if the Logging interval or TX randomisation is longer than recommended values. For this reason, it is preferred to use the above profiles.

It is only possible to change a sensor configuration when the sensor wakes up to perform measurement and transmits to the LoRaWAN network or manually by pressing the sensor button.

(See Section 3.2.1 for parameters table)

Sample Payload (Default Schedule): (Payloads are Hexadecimal)
4200000405006054000004050210 0E00000405036054000004050580 3A090004050780510100014 0050F

| Byte # | Payload | Description | Notes | Results |
|---|---|---|---|---|
| 1 | 42 | Defines the payload type *(See Section 3.2)* | 0x42 = Parameter Write Response | Parameter Write Response |
| 2 | 00 | Defines the product identification number *(See Section 3.2.2)* | 0x00 = TEK 766 | TEK 766 |
| 3 | 00 | N/A | N/A | |
| 4 | 04 | Data length after parameters | 0x04 | 04 |
| 5 | 05 | Defines the Parameter ID *(See Section 3.2.1)* | 0x0500 = TX Period | TX Period |
| 6 | 00 | | | |
| 7 | 60 | Defines the Parameter Write Request Combination of Byte 7 to Byte 10 *(See Section 3.3.1)* | 0x60540000 | 6 Hours Daily |
| 8 | 54 | | | |
| 9 | 00 | | | |
| 10 | 00 | | | |
| 11 | 04 | Data length after parameters | 0x04 | 04 |
| 12 | 05 | Defines the Parameter ID *(See Section 3.2.1)* | 0x0502 = TX Randomisation Period | TX Randomisation Period |
| 13 | 02 | | | |
| 14 | 10 | Defines the Parameter Write Request Combination of Byte 14 to Byte 17 *(See Section 3.3.2)* | 0x100E0000 | 60 Minutes |
| 15 | 0E | | | |
| 16 | 00 | | | |
| 17 | 00 | | | |
| 18 | 04 | Data length after parameters | 0x04 | 04 |
| 19 | 05 | Defines the Parameter ID *(See Section 3.2.1)* | 0x0503 = Logger Interval Period | Logger Interval Period |
| 20 | 03 | | | |
| 21 | 60 | Defines the Parameter Write Request Combination of Byte 21 to Byte 24 *(See Section 3.3.3)* | 0x60540000 | 360 Minutes |
| 22 | 54 | | | |
| 23 | 00 | | | |
| 24 | 00 | | | |
| 25 | 04 | Data length after parameters | 0x04 | 04 |
| 26 | 05 | Defines the Parameter ID *(See Section 3.2.1)* | 0x0505 = Status Frame Period | Status Frame Period |
| 27 | 05 | | | |
| 28 | 80 | Defines the Parameter Write Request Combination of Byte 28 to Byte 31 *(See Section 3.3.4)* | 0x803A0900 | 7 Days |
| 29 | 3A | | | |
| 30 | 09 | | | |
| 31 | 00 | | | |
| 39 | 01 | Data length after parameters | 0x01 | 01 |
| 40 | 40 | Defines the Parameter ID *(See Section 3.2.1)* | 0x4005 = Ping Rate | Ping Rate |
| 41 | 05 | | | |
| 45 | 0F | Defines the Parameter Write Response *(See Section 3.3.5)* | 0x0F = 15 | 15 Minutes |

### 3.3.7 Static Alarm Threshold Limits

Each sensor can have up to three static alarms, so depending on the polarity an alarm is generated if the ullage is greater, or less than these values. The alarm threshold must be 22cm or greater. The device has 2cm of in-built hysteresis.

| Description | Notes | Example |
|---|---|---|
| **Limit Polarity Flag:** | 1=Reading Higher than Threshold, 0=Lower. | 0 |
| **Enable alarm:** | 1=Enabled, 0=Disable (Alarm Status flags will be set, irrespectively) | 1 |
| **Hysteresis: cm** | The "tolerance" to be exceeded before clearing alarm (15cm max) | 2 |
| **Threshold: cm** | The threshold for level alarm | 100 |
| | lim n (hex) = | **4864** |

**Formula:**

1. Threshold + (Tolerance x 2^10) + (Alarm: 1=Enabled, 0=Disabled x 2^14) + (Polarity: 1=Higher, 0=Lower x 2^15) = Result
2. Convert the result to HEX

**Example:**

100 + (2 x 1024) + (1 x 16384) + (0 x 32768)
100 + 2048 + 16384 + 0
18532 = 0x4864

(See Section 3.2.1 for parameters table)

Sample Payload (All alarms): (Payloads are Hexadecimal)
420000024001644802400216000240031600

| Byte # | Payload | Description | Notes | Results |
|---|---|---|---|---|
| 1 | 42 | Defines the payload type *(See Section 3.2)* | 0x42 = Parameter Write Response | Parameter Write Response |
| 2 | 00 | Defines the product identification number *(See Section 3.2.2)* | 0x00 = TEK 766 | TEK 766 |
| 3 | 00 | N/A | N/A | |
| 4 | 02 | Data length after parameters | 0x02 | 02 |
| 5 | 40 | Defines the Parameter ID *(See Section 3.2.1)* | 0x4001 = Static Limit 1 | Static Limit 1 |
| 6 | 01 | | | |
| 7 | 64 | Defines the Parameter Write Response *(See Section 3.3.7)* | 0x6448 | Lower than Threshold<br>Alarm Enabled<br>Tolerance = 2cm<br>Threshold = 100cm |
| 8 | 48 | | | |
| 9 | 02 | Data length after parameters | 0x02 | 02 |
| 10 | 40 | Defines the Parameter ID *(See Section 3.2.1)* | 0x4002 = Static Limit 2 | Static Limit 2 |
| 11 | 02 | | | |
| 12 | 16 | Defines the Parameter Write Response *(See Section 3.3.7)* | 0x1600 | Lower than Threshold<br>Alarm Not Enabled<br>Tolerance = 0cm<br>Threshold = 22cm |
| 13 | 00 | | | |
| 14 | 02 | Data length after parameters | 0x02 | 02 |
| 15 | 40 | Defines the Parameter ID *(See Section 3.2.1)* | 0x4003 = Static Limit 3 | Static Limit 3 |
| 16 | 03 | | | |
| 17 | 16 | Defines the Parameter Write Response *(See Section 3.3.7)* | 0x1600 | Lower than Threshold<br>Alarm Not Enabled<br>Tolerance = 0cm<br>Threshold = 22cm |
| 18 | 00 | | | |

## 3.4 Miscellaneous Parameters

Configuration bytes for miscellaneous parameters allow for setting of confirmation messages.
Bit 1 & 2 of the *Configuration flags* set the '*Measurement Frame Confirmation*' – this is how frequently measurement messages are 'confirmed' or acknowledged by the LoRaWAN network server. (The parameter 0x4007 allows the user to write the appropriate value.)
There is a network cost of sending acknowledgment packets to sensors hence there are four options allowed:

| Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
|---|---|---|---|---|---|---|---|
| *Reserved* | *Reserved* | *Reserved* | *Reserved* | *Reserved* | Measurement Frame Confirmations<br>0 = No confirmed transmissions - ACK is OFF<br>1= Confirm every transmission<br>2 = Confirm every 4th transmission<br>3 = Confirm every 8th transmission | | Bund Enable |

### *3.4.1 SRC/SRSSI Filter*

This byte is divided into two nibbles. The Ultrasonic Sonic Result Code/Sonic RSSI values must exceed this filter before any limit alarm testing occurs.

| Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
|---|---|---|---|---|---|---|---|
| SRC Filter: 0 - A (Hex) | | | | SRSSI Filter: 0 - A (Hex) | | | |
| A | | | | A | | | |

(See Section 3.2.1 for parameters table)

Sample Command: (Payloads are Hexadecimal)
420000014004AA

| Byte # | Payload | Description | Notes | Results |
|---|---|---|---|---|
| 1 | 42 | Defines the payload type<br>*(See Section 3.2)* | 0x42 = Parameter Write Response | Parameter Write Response |
| 2 | 00 | Defines the product identification number<br>*(See Section 3.2.2)* | 0x00 = TEK 766 | TEK 766 |
| 3 | 00 | N/A | N/A | |
| 4 | 01 | Data length after parameters | 0x01 | 01 |
| 5 | 40 | Defines the Parameter ID<br>*(See Section 3.2.1)* | 0x4004 = SRC/RSSI Filter | SRC/RSSI Filter |
| 6 | 04 | | | |
| 7 | AA | SRC: Major nibble of Byte 7<br>SRSSI: Minor nibble of Byte 7 | SRC = 0xA -> 10<br>SRSSI = 0xA -> 10 | SRC=10<br>SRSSI=10 |

### 3.4.2 Sonic Control

The ultrasonic measurement allows for different configurations depending on the physical setup of the tank. The default value allows for sensors to operate in non-waveguide mode.
A waveguide option is used where there are obstructions in tanks that would cause problems with the ultrasonic signal propagating in the tank. It involves the use of a waveguide pipe as shown in the Installation Guide.

***Note:*** *Do not modify these profiles without consulting manufacturer.*

| | |
|---|---|
| Standard Profile | 0x49351928 |
| Waveguide Profile | 0x14FF3C3C |

(See Section 3.2.1 for parameters table)

Sample command: (Payloads are Hexadecimal)
4200000440003C3CFF14

| Byte # | Payload | Description | Notes | Results |
|---|---|---|---|---|
| 1 | 42 | Defines the payload type *(See Section 3.2)* | 0x42 = Parameter Write Response | Parameter Write Response |
| 2 | 00 | Defines the product identification number *(See Section 3.2.2)* | 0x00 = TEK 766 | TEK 766 |
| 3 | 00 | N/A | N/A | |
| 4 | 04 | Data length after parameters | 0x04 | 04 |
| 5 | 40 | Defines the Parameter ID *(See Section 3.2.1)* | 0x4000 = Sonic Control | Sonic Control |
| 6 | 00 | | | |
| 7 | 3C | Defines the Parameter Write Response. Combination of Byte 7 to Byte 10 (LSB First) | 0x3C3CFF14 LSB First = 14FF3C3C | Waveguide Profile |
| 8 | 3C | | | |
| 9 | FF | | | |
| 10 | 14 | | | |

### 3.4.3 RF-RSSI Threshold

The Ultrasonic LoRaWAN sensor has an LED interface to give an approximate indication of the LoRaWAN RSSI signal strength. The RSSI limit, which is reflected by the LED flashing sequence in 6.1, sets the point where the LED flash code is alternate green / red flashing. ***Note:*** *Do not modify without consulting manufacturer.*

Sample Command: (Payloads are Hexadecimal)
42000001400688

| Byte # | Payload | Description | Notes | Results |
|---|---|---|---|---|
| 1 | 42 | Defines the payload type *(See Section 3.2)* | 0x42 = Parameter Write Response | Parameter Write Response |
| 2 | 00 | Defines the product identification number *(See Section 3.2.2)* | 0x00 = TEK 766 | TEK 766 |
| 3 | 00 | N/A | N/A | |
| 4 | 01 | Data length after parameters | 0x01 | 01 |
| 5 | 40 | Defines the Parameter ID *(See Section 3.2.1)* | 0x4006 = RF_RSSI Threshold | RF_RSSI Threshold |
| 6 | 06 | | | |
| 7 | 88 | Defines the Parameter Write Response *(See Section 3.4.3.1)* | 0x88 = -120dbm | -120 dbm |

#### 3.4.3.1 RF-RSSI Data Value

Byte 7 is determined by the rightmost 2 Nibbles from the HEX conversion of the dbm.
Examples:

- -120 dbm = 0xFFFFFFFFFFFFFF88 → 88
- 50dbm = 0x32 → 32

# 4. Technical Specifications

## 4.1 Radio interface

The Ultrasonic LoRaWAN sensor has an integrated antenna. This antenna allows the RF communication with the LoRaWAN IoT Station.

## 4.2 External Antenna

There is an external antenna option available with a detachable antenna to allow for easier installations in the case of underground tanks (additionally the RF signal may be too weak for the internal antenna in underground tanks and may require the external antenna to be mounted above ground). See Installation Guide for more info.

## 4.3 Pushbutton switch

The pushbutton switch is used to force the unit to make a measurement and deliver the data to the server endpoint. It is also used to wake a unit from dormant state and force it to connect to a LoRaWAN network.

## 4.4 LED output

The Ultrasonic LoRaWAN sensor status feedback will be provided via a bicolour LED. (See Sections 6.1 & 6.2)

# 5. On-site maintenance checks

## 5.1 Mounting

During on-site maintenance, the operator must ensure that the Ultrasonic LoRaWAN sensor is still securely tightened.

## 5.2 External antenna

During on-site maintenance, where an external antenna is in use, the operator must check the connection between the Ultrasonic LoRaWAN sensor and the external antenna:

- No degradation of the cable
- To prevent water ingress - mount the cable above any likely water line.

### *5.2.1 RF antenna*

During on-site maintenance, where an external antenna is in use, the operator must check that the antenna is still in optimal conditions to have an efficient RF transmission or reception:

- The antenna tip is at least at 20 cm from any metallic part
- The cable between the meter and the Ultrasonic LoRaWAN sensor is not close to the antenna.
- The RF antenna is in vertical position
- The Ultrasonic LoRaWAN sensor, when placed in underground, is located as close as possible to the ground surface. Raising the antenna elevation generally improves performance.

## 5.3 Environment

During on-site maintenance, the operator must check that external environment does not degrade the performance of the Ultrasonic LoRaWAN sensor, such as clay, dust, water, etc.

# 6. Trouble Shooting

## 6.1 LED Radio Signal Strength Flash Code

| LED Pattern | Function |
|---|---|
| Green X 3 Flashes | Excellent signal strength |
| Green X 2 Flashes | Good signal strength |
| Green X 1 Flash | Adequate signal strength |
| Alternate Green/Red Flash | Weak signal strength |
| Weak signal strength: Try 5 times and if this response is stable then it's deemed adequate. If the sensor shows some double red flashes during this signal strength test - then an external antenna should be tried. It may need to be elevated for best performance. | |

## 6.2 LED Error Flash Code

| LED Pattern | Function |
|---|---|
| Red X 1 Flash | Device registered with an incorrect AppKey. |
| Red X 2 Flashes | No response from LoRaWAN network |
| Red X 3 Flashes | General Error. Please try again. If the error persists, contact the supplier for support. |
| Red X 5 Flashes | Maximum number of allowed button presses exceeded (up to 6 button presses per hour allowed). |

## 6.3 Manually Testing Sensor

Once the sensor has been installed successfully, it is recommended to force a manual connection 4-5 times to test the communications strength of the radio signal.

1. Press and hold the button for approximately 1 second, until the LED turns green.
2. Wait approximately 10-20 seconds and observe if the LED flashes green or red.
3. Green flashes indicate a successful test connection and data transmission.
4. Red flashes mean an unsuccessful connection.

See previous, LED Flash codes for description of Green/Red LED flashes.

## 6.4 Button Press

The button and LED can appear unresponsive occasionally, for example if the sensor is active performing a join request to the LoRaWAN network. This is a consequence of internal activity and the user is advised to wait for a few minutes before retrying.
Note: There is a regulatory limit to the number of button presses allowed per hour. After ten button presses the sensor will not respond to further button presses until an hour has elapsed.

## 6.5 Dormant Mode

The device may be put back into dormant mode (whereby it becomes inactive) by:

1. Press and hold the button for approximately 10 seconds, until the LED starts flashing red rapidly.
2. Release button and then press it again for 1 second and release.

The unit will make a final transmission and become dormant (the status packet can be checked to show it's inactive).

**For further details please see additional documents:**

- *DS-5043-XX TEK 766 Ultrasonic LoRaWAN Datasheet*
- *9-5848-XX TEK 766 Ultrasonic LoRaWAN Installation Guide*
- *9-5962-XX TEK 766 Ultrasonic LoRaWAN Installation Guide – French*
- *9-5966-XX TEK 766 Ultrasonic LoRaWAN PC Application Guide*

## 7. FAQ:

**Q.** Are the batteries user-replaceable?

**A.** *No, as the battery is soldered in place. The projected battery life is such that the battery should exceed the working life of the sensor.*

**Q.** Can the cable for external antenna be extended?

**A.** *Yes, using standard SMA RF pigtails (Male-Female). Note that the RF signal is also attenuated in cables, so there is typically a diminishing return in performance from any increase in cable length.*

**Q.** Can I fit an external antenna to a unit that has an internal antenna?

**A.** *No, installers should have a supply of both types of units and choose the external antenna version where the LoRaWAN network is not strong enough for the internal antenna version.*

**Q.** Will it work indoors?

**A.** *Yes, but LoRa signal strength depends on distance from the nearest base station (LoRaWAN gateway). Always check using a LoRaWAN tester and using the LEDs on the unit before installing. Place the unit as near as possible to its installation point for testing and remove hands.*

**Q.** Will it work underground?

**A.** *Yes, but LoRaWAN signal strength depends on distance from and angle to the nearest base station (LoRaWAN gateway). A unit with an external antenna may often be required for underground installations. Always check using a LoRaWAN tester and using the LEDs on the unit before installing, as close to the installation point as possible (and with any cover back in place if possible).*