Level Monitor

Specifications & Operations

DRAFT

 v0.6 DRAFT

Introduction

The Level Monitor is a self-contained LoRaWAN device for measuring using sound (ultrasonic) waves and communicating the level of a liquid or solid.

Description

The Level Monitor consists of two components:

- An ultrasonic sensor to measure the distance from the sensor to the top of the liquid or solid to be measured, and
- A battery powered communications node that wirelessly transmits the measurement using LoRaWAN, powers the sensor, and controls the operation of the sensor.

There are two options for the maximum range measured, 4.2m (standard) or 8m (long range). The standard 4.2m level monitor has two horns, one each for the transducer transmitter and receiver. The long-range 8m level monitor has a single, combined transducer with no horns. It is protected by a mesh.

Applications

Measures the free space or “ullage” above the level of a liquid or solid in a tank, silo or flowing such as rivers. Subtracting this reading from the full fill height gives the height of the liquid or solid in the tank or silo.

Enclosure

Two options for the enclosure are available- integrated or separate.

The first, standard option is an integrated ultrasonic sensor and communications node in a single enclosure.

The second enclosure option has separate ultrasonic sensor and communications node. The sensor is connected by a cable to the separate communications node which can be installed at any convenient location outside the tank or silo.

The first, standard option provides the convenience of a single, integrated unit and can be used where the LoRaWAN network signal is strong. The second option of a separate enclosure is better suited when the LoRaWAN network signal is not strong as the communications unit can be placed where the network signal is strong enough. For example, in measuring tank levels underground or deep inside buildings, the second option is better.

Keep Ultrasonic Sensor Dry

The ultrasonic sensor uses sound waves for measurement. Like any “speaker”, the sensor works best when it is dry. While the sensor can withstand some liquid splashing, the ultrasonic level monitor is not suitable for applications where there is significant or continuous liquid splashing on the sensor. In that case, our laser ranging LoRaWAN device is the right choice.

The communications node enclosure is IP65 protection rated and is therefore able to withstand more liquid splashing than the sensor.

Standard Enclosure With Integrated Sensor and Communications Node

Option For Separate Cabled Sensor And Communications Node

Technical Specifications

General Specifications

Power Supply	Internal battery, 3.6V, Lithium ion
Protection	IP65
Dimensions (standard, excluding antenna)	145 x 70 x 55 mm
Certification	Not yet certified. Meets FCC/CE standards

Ultrasonic Sensor

Operating Voltage	5V, powered by the node battery
Centre Frequency	40 kHz
Working Temperature	-15℃ to +60℃
Working Relative Humidity	≤80%
Accuracy	± (1+S*0.5%) cm
Electrostatic Protection	IEC61000-4-2
Blind Zone	0-10 cm
Measuring Distance	10-420 cm / 10-800 cm

Communications Node

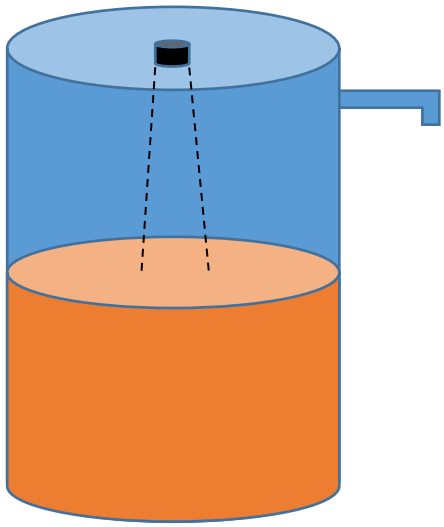
Wireless Protocol	LoRaWAN v1.0.2
Frequency	Any sub-GHz for North America, EU, Asia, Oceania, others
LoRaWAN Joining	OTAA standard, ABP optional
LoRaWAN Device Class	A
Battery Life	3-10 years depending on sleep period
Operating Temperature	-20℃ to +70℃
Tx Power Maximum	+20 dBm (+14 dBm where limited such as EU)
Sensitivity	To -137 dBm
Chipset	STM32L0 and SX1276

Installation

- Register the device on the network server using the OTAA (or ABP optional) join parameters provided
- Firmly attach antenna. Most LoRaWAN networks are vertically polarised so keep antenna vertical.
- Insert battery firmly. Ensure battery positive terminal is on the side marked +ve on the board. The top cover can now be screwed on firmly.
- After inserting battery, if the level monitor will be exposed to liquid splashing, recommend using a sealant (not supplied) along the device cover's edge and antenna connector.
- After inserting the battery, the level monitor will switch on. If the purple LED does not flash, see troubleshooting section.
- The level monitor will join the network and start sending measurements. Please see Initial Calibration and Default Values. Normally, other than initial calibration, nothing further needs to be done. Default values and some other stored parameters on the device can be changed if required. Please see Commands to Level Monitor.

Installation On Tank/Silo

- Attach towards the centre, ensuring there is at least 30 cm distance from the side.
- The sensor should have a clear, unobstructed view of the liquid/solid to be measured.
- For a separately cabled sensor, the sensor needs to be fixed inside the tank or silo as above, while the communications node can be placed outside where the network signal is strong.



Data Specifications

Data Payload

Hexadecimal in format **AAAABBCCCCDD** where

AAAA Static (unchanging) device serial number
BB 00 for normal sensor data
CCCC Tank level in centimetres, 16 bits signed integer
DD Internal battery level in 1/10 volts, 8 bits unsigned integer

For example, 00040000d525 should be interpreted as

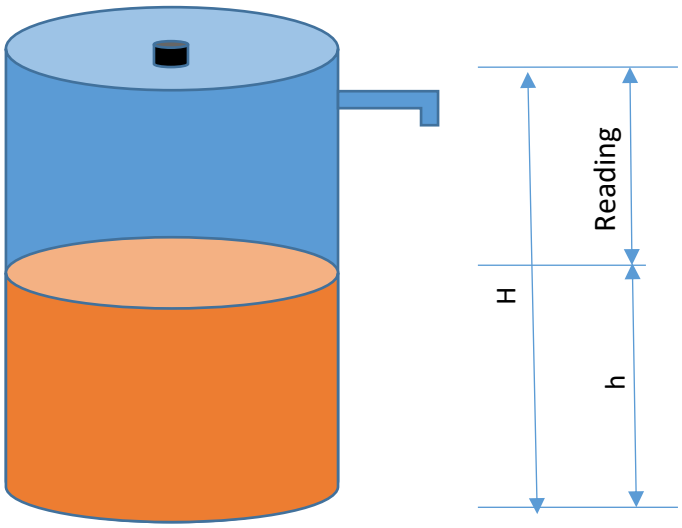
0004 Device serial number, which does not change
00 Signifies it is normal sensor data
00d5 Tank level. Converting to decimal, this is 213 cm
25 Internal battery. Converting to decimal, this is 3.7V

Initial Calibration

Each installation requires a one-off tank calibration after installing and connecting the level monitor. If and while this is not done, the level monitor will report the free space "ullage" above the liquid/solid level as a negative number.

For initial calibration after device installation, measure and note 'h' which is the level of liquid or solid in the tank. At the same time, note the sensor reading, converting CCCC in the data payload to decimal cm and ignoring the negative sign. Note CCCC is a 16 bits signed integer.

The sum of these two measurements, h and sensor reading, is the Total Height 'H' in the illustration below.



The Total Height ‘H’ is an unchanging value. It is to be stored on the level monitor using a network command (see Commands to Level Monitor below). When correctly stored, the level monitor reading is the height of the liquid or solid. When not stored, the default shipped value is 0, and so the level monitor reading is the negative of the free space above the liquid or solid.

As an example, where H is not set, say the first data payload is 00 0b 00 ff 94 21. The level is hexadecimal ff94 which is decimal -108 cm. (One online tool for converting hexadecimal to decimal is http://www.rapidtables.com/convert/number/hex-to-decimal.htm). The free space above the liquid or solid is 108 cm.

Say the measured level of liquid at that time (“h”) is 127 cm. Then “H” is 127 + 108 or 235 cm. Converting decimal 235 to hexadecimal using http://www.rapidtables.com/convert/number/decimal-to-hex.htm, this is EB.

The “H” value needs to be stored on the device so that future readings will directly display the level correctly. Details to do this are in the section Commands to Level Monitor.

In this case, it requires sending data 2000eb to the device on port 5. Once data is sent to the device, which the network server will do after the next transmission from the device, the level monitor will confirm by echoing the command. In this case, it will transmit 00 0b 01 20 00 eb 21. The ‘01’ indicates the level monitor is responding to the command whereas ‘00’ is used for normal level monitor readings.

The easiest way to confirm H has been set correctly on the device is also to check that the next reading from the device, provided the tank level has not changed, is the same as was measured, 127 cm in this case. The data payload in this case will be 00 0b 00 00 7f 21. (Hexadecimal 7f is decimal 127).

Blind Zone

All ultrasonic sensors have a ‘blind zone’. For these level monitors, it is 10cm. This is the distance from the bottom of the sensor within which it cannot measure. If the level of the liquid or solid is anywhere within the blind zone, the level monitor will only report it as full (i.e. a constant measurement reflecting the blind zone), not the actual level.

For accurate readings at all times, device installation must allow for the unmeasured area (blind zone) when the tank is considered “full”.

Commands to Level Monitor

Key parameters are stored on the device in non-volatile memory, i.e. they are retained even when the battery is taken out. The value of these parameters can be changed using downlink data, i.e. data (commands) sent to the device from the network server. The specific way in which data is sent to the device should be checked with the network operator.

All data is sent in hexadecimal and should be sent to port 5.

The data payload to be sent depends on which parameter is to be changed and to what value. See table below.

On data being sent to the device, it is acknowledged by the device sending the data payload below. The device will respond with the same data payload. Format of the data transmitted by the device in response to downlink data (command) in hexadecimal is:

AAAABBCCDD…EE where

AAAA Static (unchanging) device serial number
BB 01 indicates it is in response to downlink data/command
CC Parameter
DD.. Value of the parameter whose length depends on the parameter type
EE Internal battery level in 1/10 volts, 8 bits unsigned integer

For example, if data sent to the device is 1001001E to set sleep period to 30 minutes, after receiving the data it will respond with 00040110001e23 where:

0004 Device serial number
01 Signifies it is in response to downlink
10 Echoed parameter (sleep period)
001e Echoed value of parameter
23 Internal battery level in hex

In addition, the stored parameter value on the device can be queried at any time by sending 0FCC where CC is the parameter identifier in the table below. This does not change the value of the stored parameter. For example, sending 0F07 to the device will cause it to transmit the current value (which is 00 for unconfirmed and 01 for confirmed transmissions).

Parameter to be changed	Network Command / Data
App EUI, 16 hex characters	01XXXXXXXXXXXXXXXX
App Key, 32 hex characters	02XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Network Session Key, 32 hex characters	03XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Application Session Key, 32 hex characters	04XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Device Address, 8 hex characters	05XXXXXXXX
Join Type, 1 unsigned byte, 00 is ABP, 01 is OTAA	06XX
Tx Type, 1 unsigned byte, 00 is Unconfirmed, 01 is Confirmed	07XX
Maximum Retries for OTAA join and confirmed transmissions, 8 bit unsigned integer, e.g. 0A03 is 3 retries	0AXX

Sleep Period*, minutes (YY is 01) or seconds (YY is 00), followed by 16 bit unsigned integer XXXX	10YYXXXX
Minimum period between transmissions in seconds, 16 bit unsigned integer, e.g. default 30 seconds is 11001E	11XXXX
Get configuration by parameter, e.g. 0F10 returns deep sleep period	0FXX
Device Reboot	FF00
'H', 16 bit unsigned integer	20XXXX

*Examples: setting sleep period to 15 minutes, the command will be 1001000F, while for setting to 45 seconds it will be 1000002D.

Note that on joining the network, the first 3-5 data transmissions are sent rapidly (20s apart) before the normal reporting period as set by the sleep period is used. Where duty cycle limits apply, such as for EU 868 band, this is reduced and are sent over a longer time to comply with the limits. Quicker initial transmissions allow for determining if the device is working on start up or reset without waiting for what could be a long sleep period. It also assists in quickly determining and setting 'H'.

Default Values

Unless otherwise specified at the time of placing the order, key parameter settings are:

- Join Type: OTAA
- Sleep Period: 15 minutes
- Uplink Transmissions: Unconfirmed
- Retries (join, confirmed transmissions): 3
- ADR: On (enabled)

Basic Troubleshooting

If Purple LED Does Not Flash

When battery is inserted into device it is switched on. The purple LED should flash within a few seconds. If it does not, this indicates a power issue. Check the following:

- Correct battery is being used, i.e. 3.6V lithium ion AA size.
- The positive terminal of the battery is on the side marked +ve on the board.
- The battery clips are firmly holding the terminal and exposed metal of the battery.

If Purple LED Flashes Every Few Seconds

When battery is inserted into device it is switched on. The purple LED should flash within a few seconds, indicating the device is trying to join the network, and will stop flashing once successfully joined. If the LED flashes again after a few seconds, and continues this cycle, it indicates the device has been unsuccessful in joining the network. Check the following:

- Network server logs will show any issue with join parameters, e.g. incorrect App EUI.
- Device must operate on the same LoRaWAN frequencies and bandwidth that the gateway is listening to.
- Network signal could be too weak. Moving the device outdoors or line-of-sight of the gateway could help.
- Antenna should be firmly attached to the device.

Note: If the device does not join after a number of attempts (each signified by a LED flash), the battery should be removed, wait for a minute, and put back in. If the level monitor still does not join, the battery should be removed and the problem investigated, as otherwise the repeated join attempts can drain the battery permanently. The number of unsuccessful join attempts is limited by the maximum retries parameter (default is 3).

If Purple LED Flashes During Normal Operations

After joining, the device sends measurements after every sleep period. If the purple LED flashes during this normal operations period, it indicates the device is trying to re-send data or a fault. Check the following:

- Check network server logs for errors or, if transmissions from the device are set as confirmed, that the network server is sending acknowledgements to device transmissions.
- Reboot device by taking battery out, waiting a minute, and putting it back in.
- Consider using unconfirmed transmissions from the device.
- Network conditions may have changed with too weak a signal for the data rate set. Moving the device outdoors or line-of-sight of the gateway could help. Check RSSI and SNR levels from network server log for last successful transmission.
- Check battery level in last successful data transmission from the device.
- If sleep period is less than 2 minutes, consider either increasing sleep period or using a battery that is appropriate to deliver sustained drain.