Level Monitor

Specifications

Version Changes

Version	Comments
0.1	Initial release
0.2	Data payload changed Noted initial transmissions on OTAA join respects duty cycle

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, powers the sensor, and controls the operation of the sensor.

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 100% fill height gives the height of the liquid or solid in the tank or silo.

Enclosure

Two options are available. In both cases, the ultrasonic sensor needs to be placed vertically in the centre of the top cover with at least 30 cm (1 foot) free space above the 100% fill height.

The first enclosure option has separate ultrasonic sensor and communications node. The sensor needs to be fitted to the top of the tank or silo. It is connected by a cable to the separate communications node which can be installed at any convenient location.

The second option is a single enclosure with both the ultrasonic sensor and communications node. The single unit needs to be fitted to the top of the tank or silo as a single unit. The ultrasonic sensor will protrude into the tank or silo and the hole needs to be at least 1 cm in diameter bigger than the sensor to prevent interference.

The first option is better suited for flexibility and ability to separately place the communications unit where the LoRaWAN network signal is strong. For example, in measuring tank levels underground or deep inside buildings. The second option provides the convenience of a single, integrated unit and can be used where the LoRaWAN network signal is strong.

NOTE: THESE ILLUSTRATIONS ARE INDIVICATIVE ONLY. ACTUAL MAY VARY SLIGHTLY

Option 1: Separate sensor and node

Option 2: Single Enclosure

Technical Specifications

General Specifications

Power Supply	Internal battery, 3.6V, Lithium ion
Protection	IP65
Dimensions	145 x 70 x 55 mm (option 2, excluding antenna)
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°C to +60°C
Temperature Compensation	Automatic
Working Relative Humidity	≤80%
Accuracy	±1cm, Measured Reading x 0.3%
Electrostatic Protection	IEC61000-4-2
Blind Zone	0-30 cm
Measuring Distance	30-420 cm

Communications Node

Wireless Protocol	LoRaWAN v1.0.2
Frequency	Any sub-GHz for North America, EU, Asia, Oceania, others
Operating Voltage	3.3V
Battery Life	3-10 years depending on sleep period
Operating Temperature	-20°C to +70°C
Tx Power Maximum	+20 dBm (+14 dBm where limited such as EU)
Sensitivity	To -137 dBm
Chipset	STM32L0 and SX1276

Data Specifications

Data Payload

Hexadecimal in format **AAAABBCCCCDD** where

AAAA Static (unchanging) application identifier
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 Application identifier, 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

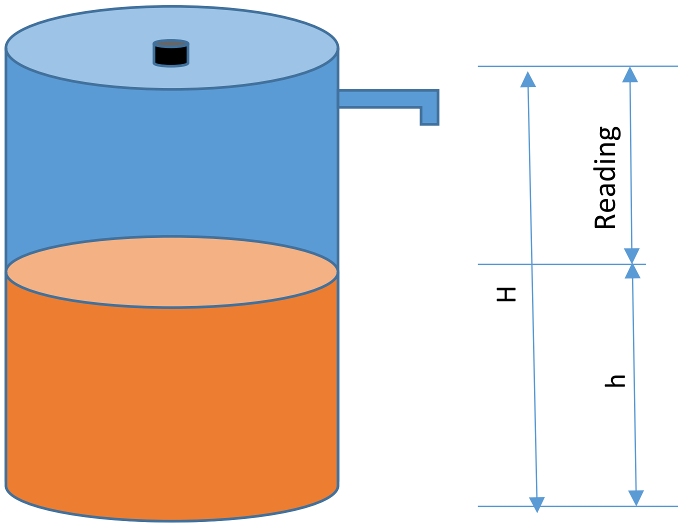
Initial Calibration

Each installation requires a one-off tank calibration after installing and connecting the level monitor.

To do this, measure and note ‘h’ which is the level of liquid or solid in the tank. Also, note the sensor reading, converting CCCC to decimal cm.

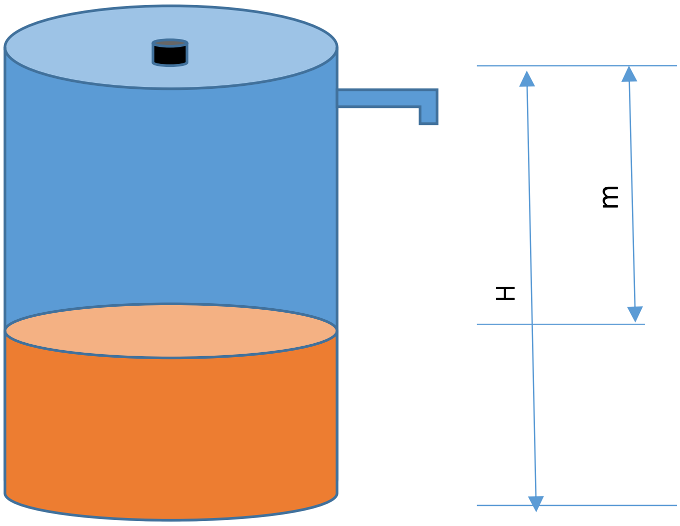
The sum of these two measurements h and sensor reading is called Total Height ‘H’ in the illustration below. Note that CCCC is a signed integer. ‘H’ will initially be set to 0, so the sensor reading as communicated by CCCC will be a number with a negative sign.

The Total Height is a static quantity. It is stored on the sensor using a network command or by the service provider directly.



Tank Level

If the measurement from the ultrasonic sensor is ‘m’, then height of the liquid or solid is H-m. Since H is stored on the sensor, the actual height of the liquid or solid is correctly reported in data payload as CCCC**.**



Converting Measurement to Percentage Full

This requires consideration of any overflow pipe and a safety buffer. If the tank or silo is not a regular shape such as a cylinder, then a separate calculation is applicable based on the specific geometry of the tank or silo.

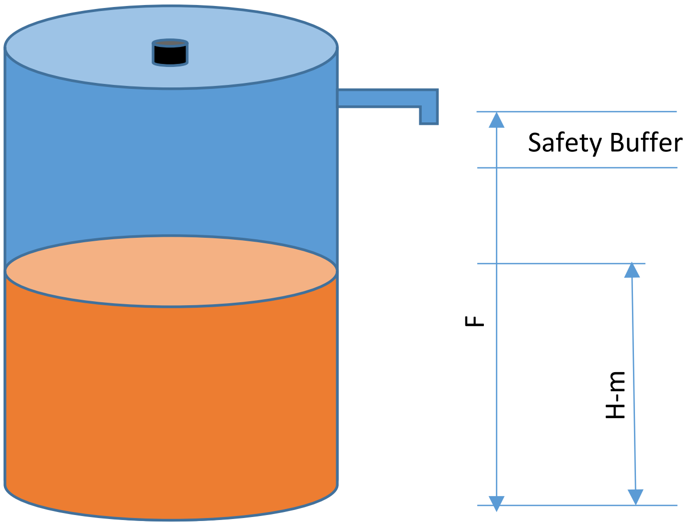
Measure ‘F’ which is the distance from the bottom of the overflow pipe to the tank bottom. If there is no overflow pipe, then F is the same as H calculated previously. Similarly, if there is any filling stop mechanism, then F is the height at which it operates.

There needs to be a safety buffer to prevent overflows, for example 25 cm. The value ‘F-safety buffer’ represents the 100% full tank level. It needs be stored by the service provider as it is not stored on the sensor itself and is to be used in calculations with the sensor reading.

Then percentage tank full is:

$$\frac{\text{Reading CCCC}}{\text{Full tank level}} \times 100\%$$

Calculation and display of percentage full is done by the service provider. The service provider can also choose to show the volume of the liquid or weight of the solid in the tank or silo by using the geometry and density of the liquid or solid.



For example, if
H Total height, say 400 cm
m Measured level, say 187 cm
F Say 360 cm
Safety Buffer is 25 cm

Then,
Height of the liquid in the tank is 400 – 187 or 213 cm (which is reported as CCCC)
Percentage full is 213 / (360 – 25) x 100% or 63.6%

The only variable is 'm' which is measured by the ultrasonic sensor and 'H-m' is communicated periodically.

Blind Zone

All ultrasonic sensors have a 'blind zone'. This is the minimum 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, the unmeasured area (blind zone) must allow for 100% tank full. This requires (H – (F - safety buffer)) to be more than the blind zone of 30 cm. In the example, it is (400-(360-25)) which is 65 cm.

Commands to Level Monitor

Key parameters are stored on the device in non-volatile memory. The value of these parameters can be changed using a downlink, i.e. data (commands) sent to the device from the network server.

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

On data being sent to the device, it is acknowledged by the device sending the data payload below. In addition, the stored parameter value on the device can be queried at any time by sending 0x0FAA where AA is the configuration data identifier in the table below. The device will respond with the same data payload, which in hexadecimal is:

AAAABBCCDD…EE where

AAAA	Static (unchanging) application identifier
BB	01 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:

00 04	Static application identifier
01	Signifies it is in response to downlink
10	Echoed parameter (sleep period)
00 1e	Echoed value of parameter
23	Internal battery level in hex

The following table lists the commands available. It consists of a parameter identifier followed by the value of the new parameter.

Parameter to be changed	Network Command / Data
Device EUI, 16 hex characters	00XXXXXXXXXXXXXXXX
App EUI, 16 hex characters	01XXXXXXXXXXXXXXXX
App Key, 32 hex characters	02XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Network Session Key, 32 hex characters	03XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Application Session Key, 32 hex characters	04XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Device Address, 8 hex characters	05XXXXXXXX
Join Type, 1 unsigned byte, 0 is ABP, 1 is OTAA	06XX
Tx Type, 1 unsigned byte, 0 is Unconfirmed, 1 is Confirmed	07XX
Maximum Retries*, 8 bit unsigned integer	08XX
Device Reset	FF00

Sleep Period**, 16 bit unsigned integer XXXX preceded by minutes (YY is 01) or seconds (YY is 00)	10YYXXXX
‘H’, 16 bit unsigned integer	20XXXX

*Maximum retries is the number of retries before DR is reduced, or if it is at or reached DR0, before message is discarded (in which case the next transmission will occur after the regular sleep period).

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

Note that in OTAA join, the first 5 data transmissions are sent rapidly (15s 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 quickly 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’.