



# Willow Sensors Industrial Outdoor Modbus Sensor User Manual

Document Revision: 1.01



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## Overview

WS-O-8-AE-MB-1 is an industrial wireless LoRaWAN MODBUS module with RS485 interface. WS-O-8-AE-MB-1 uses the popular STM32WL Cortex-M4 microcontroller from ST Micro. This microcontroller combines a computer unit and a LoRaWAN radio on a single chip. WS-O-8-AE-MB-1 is fully backed by a 3-year warranty, technical support, and application assistance from BiPOM Electronics, Inc.

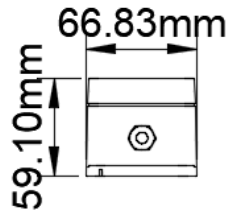


## Industrial Modbus Sensor Features

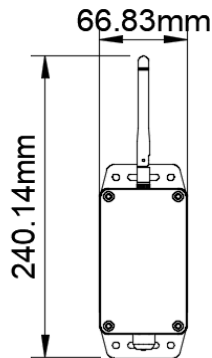
### Dimensions



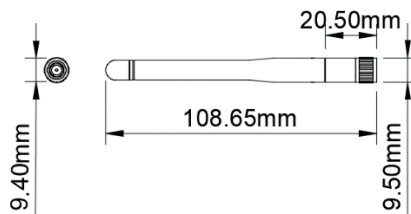
Side view with antenna



Front View without antenna



Top View

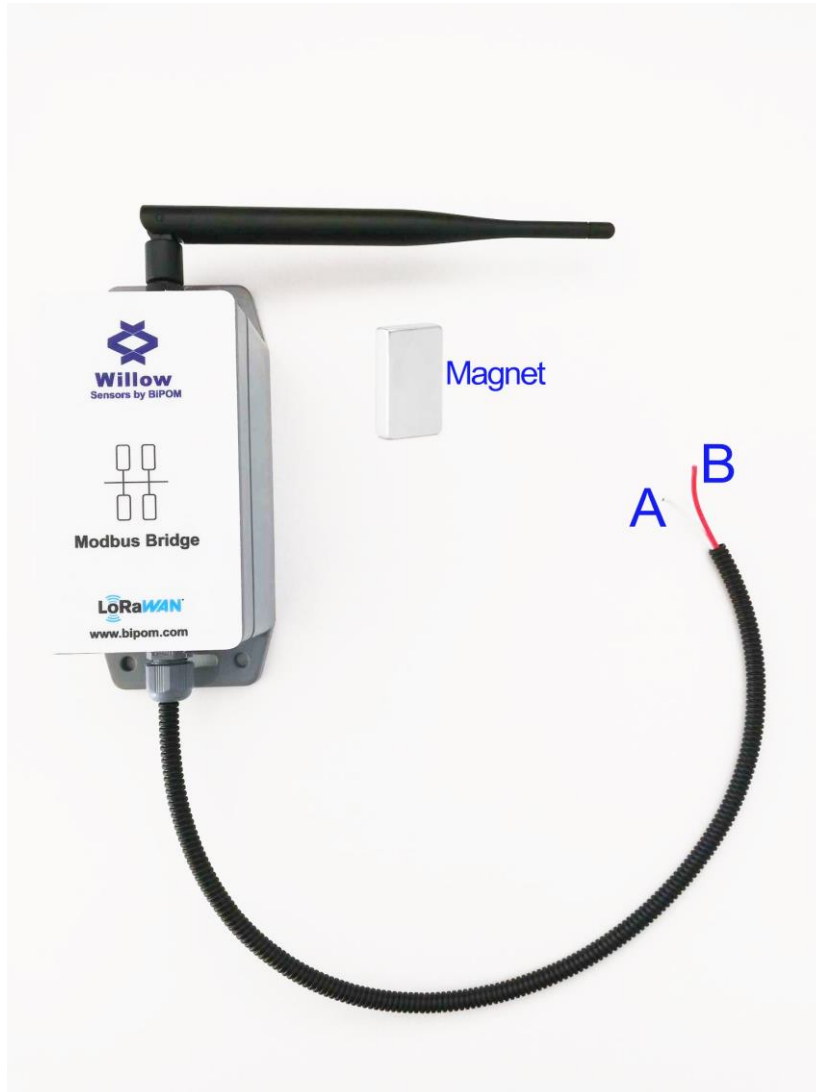


Antenna Dimensions



### Sensor Accessories

The sensor consists of 3 parts: External antenna, 2-wire RS485 cable, magnet and main LoRaWAN sensor module:



Accessories



## Specifications

### LoRaWAN Features:

- Built-in LoRaWAN 1.1.0 Stack
- Ultra-Low Power
- Suitable for battery operation
- User-programmable
- Configurable power output
- Maximum output power: 22 dBm
- Frequency Bands: US915 /AS915/ AU915/ EU868/CN779/EU433/KR920/IN865/RU86  
(Supported but not officially certified in all regions)
- 64 KB of RAM and 256 KB of Flash available for user applications

### Modbus Sensor Features:

- 868/915 MHz LoRaWAN protocol
- Up to 15 km communications distance
- Up to 10 years of battery life
- Low power consumption; sleep current 1.5uA
- Customizable instant status notification
- Wall mountable IP67 Enclosure
- LoRaWAN Downlink Support
- 19000 mAh Battery Capacity
- Up to Reading 20 Modbus Registers
- 300 to 115200 Baud rate Options
- Support Modbus RTU Protocol



## Power Consumption

Sleep mode power consumption: 1.5uA

Data transmission power consumption: 120 mA

## Storage and Operation Temperature

-40 °C, + 85°C

## Applications

- Industry
- Factory
- Warehouse
- Greenhouse
- Energy Monitoring
- PLC Applications
- Gas/Water Meters



## Operating Modes

The sensor has two modes: Deep Sleep Mode and Run Mode.

### Deep Sleep Mode

In Deep Sleep mode, the sensor does not have any LoRaWAN activity. This mode is used for storage and shipping to save battery life.

### Run Mode

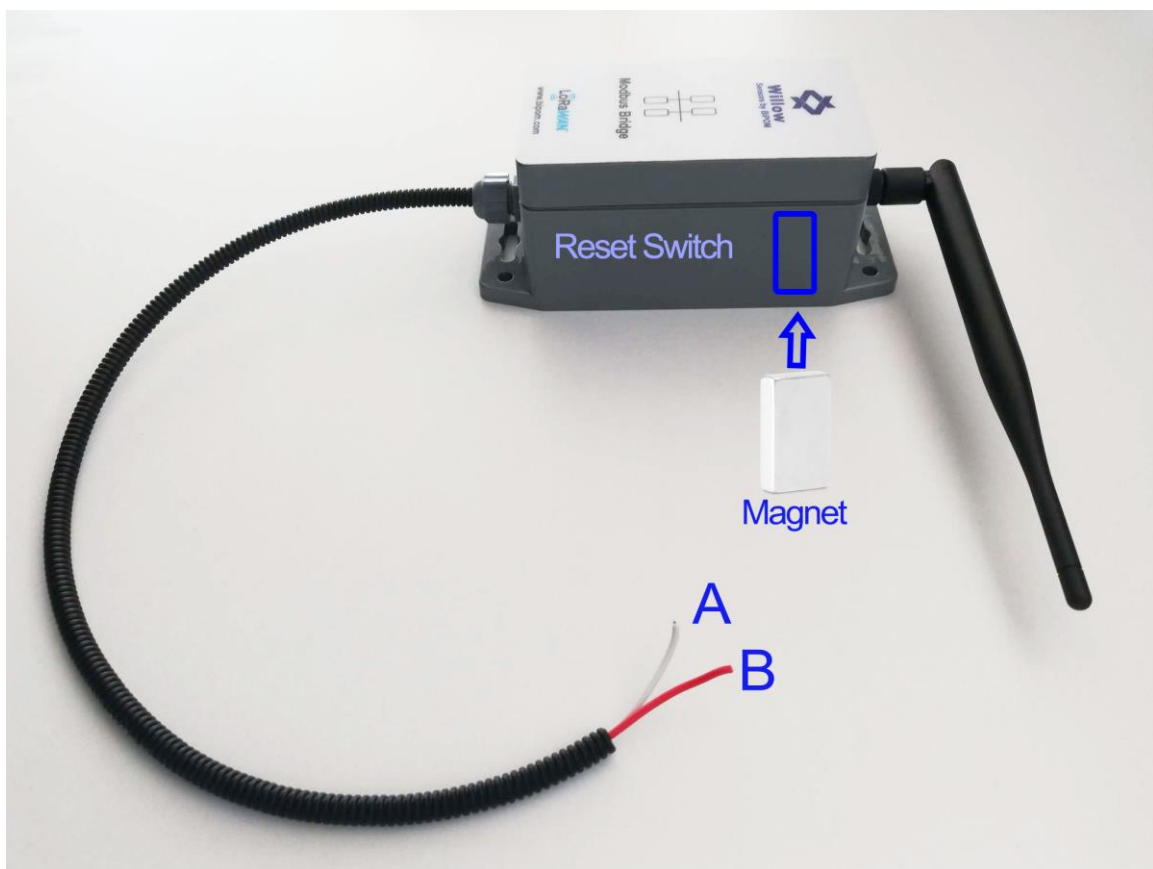
In this mode, the sensor operates as a LoRaWAN sensor node to Join a LoRaWAN network and sends the sensor data to the LoRaWAN server. Between each periodic RS485 activity, the sensor will be in STOP mode. In STOP mode, the sensor will consume the same current (1.5uA) as Deep Sleep Mode.



## Sensor Activation

The sensor does not send any LoRaWAN packets after shipping. The user first wakes up the sensor with a magnet. Then, the sensor starts sending LoRaWAN join-request every minute until it joins the LoRaWAN network. If the sensor cannot join the LoRaWAN network for 5 minutes, the sensor will switch to Deep Sleep mode to save battery.

If the sensor fails to join the LoRaWAN network, touch the magnet to the highlighted blue area on the side of the sensor.



**Note:** There is no sign or text on the module to show reset switch position. This is for avoiding accidental reset by end users.

**Note:** Antenna should be plugged before activating the module otherwise, the module can be damaged due to excessive radio frequency current.





## Activation Methods

The sensor supports both OTAA and ABP activation methods.

### OTAA Mode

The sensor requests OTAA join to the server after device wakes up and goes into the normal operation mode.

### ABP Mode:

In ABP Mode, the sensor networks keys are hardcoded inside the sensor. In ABP mode, there is no join-request. To get the sensors with pre-programmed ABP, please contact BiPOM.

## Sensor Deactivation

The module can be deactivated only if the module has already joined a LoRaWAN network. The user first removes the sensor keys on the LoRaWAN network and then resets the module with the magnet.



### Uplink Message Structure

The device starts sending uplink messages after joining the LoRaWAN network. The first uplink message is sent in 5 minutes after joining to the LoRaWAN network.

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte X
Battery Level	Internal Temp.	Modbus Data	Modbus Data	Modbus Data	Modbus Data	Modbus Data	Modbus Data	Modbus Data

The payload size changes according to the number of the Modbus Registers that is defined in the Downlink messages.

**Byte 0** - Battery level between: 0 and 255.

- 0 – Battery Minimum Level
- 255 – Battery Maximum Level

**Byte 1** - Sensor internal temperature in Celsius.

**Byte 2** – Modbus Register Data

**Byte 3** – Modbus Register Data

**Byte 4** – Modbus Register Data

**Byte 5** – Modbus Register Data

**Byte 6** – Modbus Register Data

**Byte 7** – Modbus Register Data

The number of the Modbus Register data changes according to number of the Modbus register that is set by downlink message.



If the user configures the sensor only to read two Modbus registers as 16-bit size then, the sensor sends the payload as follows:

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
Battery Level	Internal Temp.	Reg. Addr. High Byte	Reg. Addr. Low Byte	Reg. Addr. High Byte	Reg. Addr. Low Byte

**Byte 0** represents the battery level.

**Byte 1** represents internal temperature in Celsius.

**Byte 2** represents Modbus register 0 High Byte

**Byte 3** represents Modbus register 0 Low Byte

**Byte 4** represents Modbus register 1 High Byte

**Byte 5** represents Modbus register 1 Low Byte



### Downlink Message Structure

The sensor supports the downlink messages to set the Modbus parameters and the sensor states. The sensor can receive downlink messages only after the sensor sends an uplink message to the LoRaWAN server.

#### Data Interval Downlink

The following downlink message sets the sensor data interval time:

Data Interval Downlink Message Structure				
Port	Payload			
0x08	Byte 0	Byte 1	Byte 2	Byte 3

Data interval between 60 seconds and 65535 seconds.

**Example Data:** 5-minute time interval

0000012C

5 minutes is 300 seconds and it is represented as 12C in hexadecimal format.

**Note:** The minimum data interval is 60 seconds. If the user sets data interval under 60 seconds, then, the sensor rejects the data interval that is set under 60 seconds.



### Reset Sensor Downlink

The following downlink message resets the sensor. The sensor sends the join-request after the reset by downlink.

Reset Sensor Downlink Message Structure	
Port	Payload
0x0A	0x11



**Modbus Register Address**

The following downlink message shows how to set the sensor Modbus Register Address and communication parameters by downlink.

Modbus Register Address						
Port	Payload					
Port	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
Port	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1

**Byte 0** - RTU Number of the Modbus device. The RTU number can be between 1 and 255. The default RTU number is 0.

**Byte 1** – Baud rate of the sensor. Allowed values:

- 0 – 300
- 1 – 600
- 2 – 1200
- 3 – 2400
- 4 – 4800
- 5 – 9600
- 6 – 19200
- 7 – 38400
- 8 – 57600
- 9 – 115200



**Byte 2-** Serial Parameters. Allowed values:

- 0 – Data Bit 8, Parity None, Stop Bit 1
- 1 – Data Bit 7, Parity None, Stop Bit 1
- 2 – Data Bit 8, Parity Odd, Stop Bit 1
- 3 – Data Bit 8, Parity Even, Stop Bit 1
- 4 – Data Bit 7, Parity Odd, Stop Bit 1
- 5 – Data Bit 8, Parity Even, Stop Bit 1
- 6 – Data Bit 8, Parity None, Stop Bit 1.5
- 7 – Data Bit 7, Parity None, Stop Bit 1.5
- 8 – Data Bit 8, Parity Odd, Stop Bit 1.5
- 9 – Data Bit 8, Parity Even, Stop Bit 1.5
- 10 – Data Bit 7, Parity Odd, Stop Bit 1.5
- 11 – Data Bit 8, Parity Even, Stop Bit 1.5
- 12 – Data Bit 8, Parity None, Stop Bit 2
- 13 – Data Bit 7, Parity None, Stop Bit 2
- 14 – Data Bit 8, Parity Odd, Stop Bit 2
- 15 – Data Bit 8, Parity Even, Stop Bit 2
- 16 – Data Bit 7, Parity Odd, Stop Bit 2
- 17 – Data Bit 8, Parity Even, Stop Bit 2

**Byte 3 -** Register Size. Allowed Values:

- 0 – Signed Integer ( 16-bit )
- 1 – Unsigned Integer ( 16-bit )
- 2 – Signed Integer ( 16-bit )
- 3 – Unsigned Integer ( 16-bit )
- 4 – Floating Point ( 32-bit )
- 5 – Double ( 64-bit )

**Byte 4 -** Register Address Byte 0

**Byte 5 -** Register Address Byte 1



### Modbus Register 0 Address

The following downlink message shows how to set the sensor Modbus Register 0 Address and communication parameters by downlink. The downlink port for Modbus register is 0x0B.

Modbus Register Address						
Port	Payload					
0x0B	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x0B	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1

Example Data: RTU number 2, Baud rate 115200, Serial 7N1, Size Double, Modbus Register 40001

020901059C41

- 02 – reflects RTU number as 2
- 09 – reflects Baudrate as 115200 kbps
- 01 – reflects serial configuration as 7N1
- 05 – reflects register size as Double
- 9C41 – reflects 40001 register size in hex

### Modbus Register 1 Address

The following downlink message shows how to set the sensor Modbus Register 1 Address and communication parameters by downlink. The downlink port for Modbus register is 0x0C.

Modbus Register Address						
Port	Payload					
0x0C	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x0C	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1





### Modbus Register 2 Address

The following downlink message shows how to set the sensor Modbus Register 2 Address and communication parameters by downlink. The downlink port for Modbus register is 0x0D.

Modbus Register Address						
Port	Payload					
0x0D	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x0D	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1

### Modbus Register 3 Address

The following downlink message shows how to set the sensor Modbus Register 3 Address and communication parameters by downlink. The downlink port for Modbus register is 0x0E.

Modbus Register Address						
Port	Payload					
0x0E	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x0E	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1



### Modbus Register 4 Address

The following downlink message shows how to set the sensor Modbus Register 4 Address and communication parameters by downlink. The downlink port for Modbus register is 0x0F.

Modbus Register Address						
Port	Payload					
0x0F	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x0F	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1

### Modbus Register 5 Address

The following downlink message shows how to set the sensor Modbus Register 5 Address and communication parameters by downlink. The downlink port for Modbus register is 0x10.

Modbus Register Address						
Port	Payload					
0x10	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x10	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1



**Modbus Register 6 Address**

The following downlink message shows how to set the sensor Modbus Register 6 Address and communication parameters by downlink. The downlink port for Modbus register is 0x11.

Modbus Register Address						
Port	Payload					
0x11	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x11	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1

**Modbus Register 7 Address**

The following downlink message shows how to set the sensor Modbus Register 7 Address and communication parameters by downlink. The downlink port for Modbus register is 0x12.

Modbus Register Address						
Port	Payload					
0x12	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x12	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1



**Modbus Register 8 Address**

The following downlink message shows how to set the sensor Modbus Register 8 Address and communication parameters by downlink. The downlink port for Modbus register is 0x13.

Modbus Register Address						
Port	Payload					
0x13	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x13	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1

**Modbus Register 9 Address**

The following downlink message shows how to set the sensor Modbus Register 9 Address and communication parameters by downlink. The downlink port for Modbus register is 0x14.

Modbus Register Address						
Port	Payload					
0x14	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x14	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1



**Modbus Register 10 Address**

The following downlink message shows how to set the sensor Modbus Register 10 Address and communication parameters by downlink. The downlink port for Modbus register is 0x15.

Modbus Register Address						
Port	Payload					
0x15	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x15	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1

**Modbus Register 11 Address**

The following downlink message shows how to set the sensor Modbus Register 11 Address and communication parameters by downlink. The downlink port for Modbus register is 0x16.

Modbus Register Address						
Port	Payload					
0x16	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x16	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1



**Modbus Register 12 Address**

The following downlink message shows how to set the sensor Modbus Register 12 Address and communication parameters by downlink. The downlink port for Modbus register is 0x17.

Modbus Register Address						
Port	Payload					
0x17	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x17	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1

**Modbus Register 13 Address**

The following downlink message shows how to set the sensor Modbus Register 13 Address and communication parameters by downlink. The downlink port for Modbus register is 0x18.

Modbus Register Address						
Port	Payload					
0x18	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x18	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1



**Modbus Register 14 Address**

The following downlink message shows how to set the sensor Modbus Register 14 Address and communication parameters by downlink. The downlink port for Modbus register is 0x19.

Modbus Register Address						
Port	Payload					
0x19	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x19	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1

**Modbus Register 15 Address**

The following downlink message shows how to set the sensor Modbus Register 15 Address and communication parameters by downlink. The downlink port for Modbus register is 0x1A.

Modbus Register Address						
Port	Payload					
0x1A	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x1A	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1



**Modbus Register 16 Address**

The following downlink message shows how to set the sensor Modbus Register 16 Address and communication parameters by downlink. The downlink port for Modbus register is 0x1B.

Modbus Register Address						
Port	Payload					
0x1B	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x1B	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1

**Modbus Register 17 Address**

The following downlink message shows how to set the sensor Modbus Register 17 Address and communication parameters by downlink. The downlink port for Modbus register is 0x1C.

Modbus Register Address						
Port	Payload					
0x1C	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x1C	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1





**Modbus Register 18 Address**

The following downlink message shows how to set the sensor Modbus Register 18 Address and communication parameters by downlink. The downlink port for Modbus register is 0x1D.

Modbus Register Address						
Port	Payload					
0x1D	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x1D	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1

**Modbus Register 19 Address**

The following downlink message shows how to set the sensor Modbus Register 19 Address and communication parameters by downlink. The downlink port for Modbus register is 0x1E.

Modbus Register Address						
Port	Payload					
0x1E	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x1E	RTU Number	Baud rate	Serial Parameters	Register size	Reg. Addr. Byte 0	Reg. Addr. Byte 1



## Battery Life

The sensor hourly current consumption is 0.83 uAh with 10 min data interval at SF12 with 11 bytes of data:

Data Rate	Payload Size (Byte)	Interval (minute)	Battery life (25 °C)
DR_0 (SF-12 EU868)	11 Byte	1 minutes	4 Years
DR_0 (SF-12 EU868)	11 Byte	2.5 minutes	10 Years
DR_0 (SF-12 EU868)	11 Byte	5 minutes	10 Years
DR_0 (SF-12 EU868)	11 Byte	10 minutes	10 Years