

Manual

LoRaWAN CO₂ stoplicht



Versioning

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Registry

Understanding:	Definition:
LoRaWAN	Abbreviation for: Long Range Wide Area Network. A Low Power, Wide Area (LPWA) network protocol specifically developed to connect wireless battery-powered 'things' to the Internet in regional, national or global networks. (More information see: www.lora-alliance-org/about-lorawan).
Node	A node is a device equipped with a transmitter. This transmitter uses LoRaWAN modulation, which gives the device the possibility to realize communication via the LoRaWAN network.
Gateway	A device that takes care of the translation and therefore also the connection of two incompatible networks with each other. In this case, the gateway provides the connection between the respective LoRaWAN network and the internet.
Backend	A backend is a program or part of a program that is invisible to the user. It can possibly be addressed via a command-line interface. The interaction with users does not take place directly with the backend but via the graphical user interface or frontend of the program.
OTAA	Abbreviation for Over the Air Activation. OtAA uses a join procedure to activate a node on a network.
Uplink	A LoRaWAN message sent by the node to the gateway.
Downlink	A LoRaWAN message sent from the gateway to the node.
Hexadecimal	Sixteen-part system with numbers 0 to F is indicated by 0x before the number. Example: 0xFF is a hexadecimal notation of the decimal number 255.

1. Foreword

This document is intended as a user manual for the LoRaWAN CO₂ Stoplicht from Teneo Sales B.V. The purpose of this document is to provide a clear overview of how the LoRaWAN CO₂ Stoplicht can be installed, used and maintained.

In addition, any hazards and/or risks are pointed out in order to inform the user as well as possible about the LoRaWAN CO₂ Stoplicht.

In addition to this user manual, a 'Quick Start Guide' can also be used; this user manual always prevails over the Quick Start Guide.

The Quick Start Guide and all other documents referred to in this guide can be downloaded from: www.co2-stoplicht.online/downloads .



Figure 1: Product photo LoRaWAN CO₂ Stoplicht.

2. Introduction

2.1. Product description

The LoRaWAN CO₂ stoplicht is a product that measures CO₂ level, temperature and humidity and transmits these measured values via the LoRaWAN wireless communication network.

In addition, the CO₂ stoplicht has LEDs that change color when the measured CO₂ value exceeds a certain threshold.

On the basis of this direct feedback by the LEDs, (extra) can then be ventilated, to ensure that the air quality in the measured room returns to the desired level.

The thresholds are based on the requirements for CO₂ meters according to Article 3.5 of the Bouwbesluit 2012 from the Netherlands¹, but can also be adjusted remotely by means of a downlink.


2.2. Product specifications

Category:	Part:	Specification:
Physically	Dimensions:	H: 166 mm, Ø: 85 mm
	Material:	ABS
	Weight:	310 grams
	IP-rating:	IP 20
Conditions of use	Temperature:	- 20 °C to 50 °C
LoRaWAN	Transmission power:	14 dBm
	Class:	A (baseline)
	Activation method	OTAA
	Frequency	EU 868 MHz (863 – 870 MHz)
	Encryption	AES128
Power Supply		5V DC
CO₂ sensor	Sensor:	SCD30 (Sensirion)
	Measuring range	400 ppm – 10,000 ppm
	Accuracy	± 30 ppm
Humidity sensor	Measuring range	0% - 100% RH
	Accuracy	± 3% RH
Temperature sensor	Unit	Celsius
	Measuring range	- 20 °C - + 50 °C
	Accuracy	± 0.5°C

¹ Source: https://rijksoverheid.bouwbesluit.com/Inhoud/docs/wet/bb2012_reg/hoofdstuk-3/artikel-3.5

3. Operation

3.1. Preparation

	Warning!
	<p>In case of extreme heat (temperature > 70 °C), the node may be damaged. Therefore, do not use hot air heating sources near (< 1.5 meters) of the sensor.</p>

The CO₂ stoplicht is supplied with USB-A to micro USB cable. A 5 V USB power supply can then be used for this, this 5V power supply is not included with the stoplicht.

In the photo below you can see the contents of one box of CO₂ stoplicht.



Figure 2: Contents box CO₂ stoplicht.

3.2. Installation/Assembly

The CO₂ stoplicht can be placed on the tables or surfaces, but in addition, the CO₂ stoplicht with the supplied wall mounting bracket can also be attached to walls or other surfaces.

For mounting the wall bracket and attaching the stoplicht there is a square hole in the back of the stoplicht, through this square hole the CO₂ stoplicht can be hooked to the wall bracket.

On the next page of this manual we see with photos an explanation of how exactly the stoplicht can be fixed.



Figure 3 and 4 : Mounting wall mounting bracket correctly.

In order to secure the stoplicht, it is important that the wall bracket is fixed in such a way that the hook points upwards; as also shown in Figure 4.

The stoplicht can then be attached to this. This will look like the one shown below in Figure 5.



Figure 5: Example of CO₂ stoplicht attached to the wall by wall bracket.

It is also possible to equip the wall bracket with an anti-theft protection. This security can be purchased at an additional cost.

3.3. Usage

The CO₂ stoplicht can be put into operation by plugging the power supply into the wall socket.

Then the stoplicht starts up and immediately starts performing the first CO₂ measurement. It may take a while (± 20 seconds) for the LEDs to light up.

3.4. Error messages

The sensor is equipped with the functionality to send status messages. The node does this by sending a status message on Port 223; as also described in Chapter 5.1 of this Manual.

3.5. De-commissioning

When the sensor is replaced or removed, for example because the sensor no longer functions, the CO₂ stoplicht must be replaced in its entirety.

For other information see also section 6.1.2. WEEE 2012/19/EU.

4. LoRaWAN

The sensor is equipped with LoRaWAN for the communication of the sensor data to the user (other than through the LEDs). The sensor is configured at the EU 863-870 MHz bandwidth.

At LoRaWAN, the node has a so-called 'join procedure' in which the node logs on to the LoRaWAN network in question. There are two ways in which a node can join the network; by means of Over the Air Activation (OTAA) or Activation by Personalization (ABP). Teneo's nodes only support the OTAA's procedure. OTAA is generally seen within the LoRa protocol as the most robust and secure way of joining the network.

For the purpose of being able to set up the sensors in a LoRaWAN backend and for the unique identification of each sensor on the LoRaWAN network, a set of unique 'keys' is used: namely the DeviceEUI, AppKey and AppEUI.

The DeviceEUI and AppKey differ for each device individually, while the AppEUI may be the same per set of sensors.

These different keys are structured and recognizable as follows:

- DeviceEUI, for example: 00FBE52F1ECD66C5 (EUI-64);
- AppKey, for example: C56A32026BD0FDDAB93DA22FA87623A0;
- AppEUI, for example: 00FBE52F1ECD66C6 (EUI-64);

These three keys are all preconfigured by Teneo and cannot be changed by the user. These keys are made available to the user to connect the sensors with a specific back-end.

The DeviceEUI of each sensor also appears on each sticker, as shown in the example below.



Legenda:

- 1) Model/type nummer;
- 2) Device EUI;
- 3) Firmware versie;

Furthermore, (from CO₂ stoplichts with firmware version V1.20 onwards) a model/type number can be found on the label with the relevant firmware version (which is programmed in the CO₂ stoplicht) is mentioned and a QR code can optionally be displayed.

This QR code can be scanned for any other information. For the AppKey and AppEUI, your supplier can be contacted if necessary. If your product has been delivered directly by Teneo, it can be further consulted in Teneo's client portal via <https://www.clientportal.teneo-iot.nl>.

In addition, other information can be mentioned in this QR code, but it only serves for internal reference and is not necessary for the commissioning of the sensor in question.

5. Payload

5.1. In advance

In this document, all bits are read as "Little-endian". This means that all bits are read from right to left. Bytes are read from left to right. Both bytes and bits start from the number 0.

Example with the decimal number 279716668:

In hexadecimal:

```
Byte 0      Byte 3
  |          |
0x10 AC 23 3C
```

Binary:

```
Bit7 Bit0 Bit7 Bit0 Bit7 Bit0 Bit7 Bit0
|     |     |     |     |     |     |     |
00010000 10101100 00100011 00111100
```

5.1.1. Definitions:

- Node: The device with the microcontroller developed by Teneo.
- Uplink: A message from the node to the LoRaWAN network.
- Downlink: A message from the LoRaWAN network to the node.
- Payload: The data sent or received by the node.
- 0xA3: The hexadecimal number A3, decimal is 163 and binary this is 1010 0011.
- Unsigned int: A positive integer.
- Int: An integer (positive or negative).
- RFU: Reserved For Future Use.
- Float: A decimal number (positive and negative).

5.2. Firmware versions

Since the launch of the CO₂ stoplicht, several firmware improvements have been made. The following is a table with a brief overview of the different firmware versions, the release date of this firmware and a brief description of the changes/improvements.

Firmware version:	Release date:	Content:
V1.10	19-11-2020	Initial release/launch.
V1.20	17-12-2020	Improved measurement of temperature and humidity.
V1.30	21-01-2021	Automatic calibration default enabled Manual calibration option added Added downlinks for setting air pressure and altitude above sea level Default thresholds LEDs adjusted(green: up to 1000 ppm, orange: 1001 to 1400 ppm, red: 1401 ppm or higher).

5.3. Uplinks

Uplink messages from a Teneo LoRaWAN sensor consist of two components: the port and the payload. Each uplink payload starts with one header byte.

5.3.1. Port:

The port is a number with a range of 1 to 223. The value of the port indicates the type of message.

5.3.2. Header byte:

Our software gives a header with each message as the last byte of the payload. The header consists of a type and parameters:

Bit	Description
7..6	Header Type
5..0	Parameters

The following types are defined:

Value (bit 7..6)	Name	Description
00	Default	If there is nothing to report, this header type is used. This type has no parameters.
01	MultiMessage	LoRa messages have a limited length. With MultiMessage, a full message is distributed across multiple uplinks because it doesn't fit in 1 uplink. The current version of the program will not go over that. MultiMessage does not occur.
10	Status	Status messages are given when the node starts up or something has gone wrong. These messages always go to port 223.
11	Power	When battery protection is used, these messages indicate the state in which it is located. These messages always go to port 223 .

Default message:

Bit number	Name	Description
3..0	System voltage	Indicates the tension of the node. Calculation: System voltage = 2 + Batterydisplay/ 10.

The most commonly used header is a standard header with a battery display. This header will be used unless otherwise described. For example, the default header looks like this: 0000 1100 or 0x0C.

The first two bits(0000 1100) indicate that it is a default message.

The second two bits (0000 1100) have no meaning in this case.

The last four bits (0000 **1100**) contain the battery display. These first four bits represent the number 12. This means that the system voltage is: $2 + (12/10) = 3,2$ Volts.

Other header types:

The MultiMessage is not explained because no large messages are sent. Also, the Status messages are not explained further in this documentation.

5.3.3. Message (according to V1.10 and V1.20):

With firmware versions V1.10 and V1.20, the node can send the following uplink messages:

Port	Message type	Description
1	CO2 Measurement	This message displays the calibration option and CO2 measurement, along with an optional temperature and humidity measurement.
223	Status	Port 223 sent status messages.

Port 1: CO₂ Measurement:

Byte	Length	Description
0	1	Header
1	1	RFU
2..5	4	CO ₂ display
6..7	2	Temperature display
8..9	2	Humidity display

These values are not the actual values of the measurements, they must first be converted. For this calculation see the relevant chapters.

The CO₂ sensor controls the current measurement values.
This message is sent with an adjustable interval (period time).

For example, this message looks like this: **0x0F 00 00 01 53 3B 07 53 11 4D**
The meaning of this post is:

Byte 0:0x0F = System voltage: 3.5 V
 Byte 1:0x00 = RFU
 Byte 2..5:0x0001 53 3B = 868.43 PPM
 Byte 6..7:0x0753 = 18.75 degrees Celsius
 Byte 8..9:0x114D = 44.29% RH

Header:

Bit number	Description
3..0	Battery view

The system voltage is calculated as follows:
2+ (Battery display/10)

If the battery display in the message is 0x0C (12), the system voltage calculation becomes: 2 + (12/10) = 3.2 V.

Measured CO₂ value:

Byte number	Length	Description
2..5	4	CO ₂ display

This byte shows the measured CO₂ value. To convert this value to the actual measured value, this calculation must be used:

$$\text{CO}_2 \text{ in PPM} = \text{CO}_2 \text{ value} / 100$$

0x0001533B: This has a decimal value of 86843.
86843/100 = 868.43 PPM

Measured temperature:

Byte number	Length	Description
6..7	2	Temperature value

The temperature can be negative, to convert it, the MSB must be looked at.

If this MSB is 1 then the temperature is: - (65536 – temperature value) /100.
If this MSB is 0 then the temperature is: temperature value /100.

For example, at value 0x0753: is binary: **0001 0001 0100 1101**, last bit is **0** so:
0x0753 = decimal 1875: the temperature = 1875/100 = 18.75 degrees Celsius.

For example, at value 0xFCE0: is binary: **1111 1100 1110 0000**, last bit is **1** so:
0xFCE0 = decimal 64736: temperature = - (65536 - 64736) / 100 = -8.00 degrees Celsius.

Humidity measured:

Byte number	Length	Description
8..9	2	Humidity value

This byte shows the measured humidity value. To convert this to the actual value, this calculation must be used:

Humidity % RH = Humidity value / 100

For example, the display = 0x114D = 4429.
Humidity = 4429/100 = 44.29% RH.

5.3.4. Message (according to firmware version V1.30):

The node can send the following uplink messages:

Port	Message type	Description
1	CO2 Measurement	This message displays the calibration option and CO2 measurement, along with an optional temperature and humidity measurement.
223	Status	Port 223 sent status messages.

Port 1: CO₂ Meting:

Byte	Length	Description
0	1	Header
1	1	Calibration option & Automatic self-calibration
2..5	4	CO2 display
6..7	2	Temperature display*
8..9	2	Humidity display*

This value is not the actual values of the measurements, they must first be converted. For this calculation see the relevant chapters.

The CO₂ sensor controls the current measured values, along with a calibration option in byte 1 to indicate whether the CO₂ value is derived from an additional calibration. In addition to this option, it is also indicated whether automatic calibration is on, this can be seen by whether bit 3 is on 1.

Byte 1 = 0x09 = 0000 1001 : Air pressure calibration option, automatic calibration on.
Byte 1 = 0x02 = 0000 0010 : Height calibration option, automatic calibration off.

*The temperature and humidity are optionally controlled, see "downlinks FPORT 10" for more information. If **both** are not sent along, the message is 4 bytes shorter.

This message is sent with an adjustable interval (period time).

For example, this message looks like this: **0x0F 08 00 01 53 3B 07 53 11 4D**

The meaning of this post is:

Byte 0:0x0F = Systemvoltage: 3.5V.

Byte 1:0x0 8 = No additional calibration option, automatic calibration is on

Byte 2..5 0x00 01 53 3B = 868.43 PPM

Byte 6..7 0x07 53 = 18,75 C;

Byte 8..9 0x11 4D = 44.29 %RH

Header:

Bit number	Description
3..0	Battery view

The system voltage is calculated as follows:

$2 + (\text{Battery display}/10)$

If the battery display in the message is 0x0C (12), the battery voltage calculation becomes: $2 + (12/10) = 3.2$ V.

Calibration option:

Byte number	Length	Description
1	1	Calibration option

This byte indicates which calibration option is set.

0x00 (binary 0000 0000) = No calibration option, automatic calibration off.

0x01 (binary 0000 0001) = Air pressure calibration, automatic calibration off.

0x02 (binary 0000 0010) = Altitude compared to sea level calibration, automatic calibration off.

0x08 (binary 0000 1000) = No calibration option, automatic calibration on.

0x09 (binary 0000 1001) = Air pressure calibration option, automatic calibration on.

0x0 A (binary 0000 1010) = Altitude compared to sea level calibration option, automatic calibration on.

Measured CO₂ value:

Byte number	Length	Description
2..5	4	CO ₂ display

This byte shows the measured CO₂ display. To convert this display to the measured value, this calculation must be used: $\text{CO}_2 \text{ in PPM} = \text{CO}_2 \text{ display}/100$

0x0001533B: This has a decimal value of 86843.

$86843/100 = 868.43$ PPM

Measured Temperature:

Byte number	Length	Description
6..7	2	Temperature display

The temperature can be negative, to convert it, the MSB must be looked at.

If this MSB is 1, the temperature is: $-(65536 \text{ temperature display})/100$.

If this MSB is 0 then the temperature is: $\text{temperature display} /100$.

For example, at value 0x0753: is binary: **0001 0001 0100 1101**, last bit is **0** so:
 0x0753 = decimal 1875: the temperature = 1875/100 = 18.75 degrees Celsius.

For example, at value 0xFCE0: is binary: **1111 1100 1110 0000**, last bit is **1** so:
 0xFCE0 = decimal 64736: temperature = -(65536-64736)/100 = -8.00 degrees Celsius.

Measured Humidity:

Byte number	Length	Description
8..9	2	Humidity display

This byte shows the measured humidity display. To convert this to the actual value, this calculation must be used:

Humidity %RH = Humidity display/100

For example, the display = 0x114D = 4429.
 Humidity = 4429/100 = 44,29 %RH.

5.4. Downlinks

In order to change the settings of the node, downlinks can be sent to the node. As with the uplinks, the FPort indicates what type of message it is, but no header needs to be sent.

The following downlinks can be sent:

FPort	Message type	From version:	Description
1	Period time	V1.10	Adjusts the time between two standard downlink messages.
8	Air pressure compensation	V1.30	An air pressure compensation for the CO ₂ measurements, expressed in millibar.
9	Height compared to sea level compensation	V1.30	The height of the CO ₂ stoplicht specified for the CO ₂ sensor for compensation relative to the sea level, expressed in meters.
10	Display temperature/humidity	V1.30	Setting for displaying temperature, humidity or both.
11	LED Borders Green/Orange/Red	V1.10	Specify the limit values for when the red, orange, and green LEDs should turn on/off.
12	Automatic and manual calibration	V1.30	Turning the automatic calibration and/or manual calibration function of the CO ₂ sensor on/off.
13	Settings behavior	V1.10	Setting whether the LEDs should be used

In the table above, version indicates **from** which firmware version this downlink is incorporated into the CO₂ stoplicht. So when it says "V1.10" here, this means that this downlink can be used at all stoplichts with V1.10 or newer. When "V1.30" is displayed here, this means that this downlink can be used at all stoplichts with V1.30 or newer.

FPort 1: Period time

Byte	Length	Description
0..3	4	Period time in seconds

The period time message is used to set how much time (in seconds) there is between two default messages. This set time is the desired time, it can vary by several percent. The minimum period time will always be LoRaWAN's waiting time (derived from the duty cycle).

Payload = 0x00 00 0E 10 = 3600 seconds (A message every hour)

FPort 8: Air pressure compensation

Byte	Length	Description
0..1	2	Air pressure in millibar

Here an air pressure can be specified that the CO₂ sensor uses to make a more accurate measurement. The air pressure must be specified in millibar. If set, the calibration option of the CO₂ Measurement uplink will be set to 0x01. The sensor can never take into account both air pressure and height. If these are both set, **this** setting will be used.

If the value 0 is set, this calibration will not be used.

Payload: 0x0411: 0411 = 1041 so there is a compensation of 1041 millibars

FPort 9: Altitude relative to sea level

Byte	Length	Description
0..1	2	Altitude above sea level in meters

Here the height of the sensor can be adjusted (in meters above sea level). This will be used as an additional calibration value when calculating the CO₂ value. If this calibration is set, the calibration option in the CO₂ measurement uplink will be on 0x02. If air pressure compensation is set, this setting will not be used, so only if air pressure is set to 0 will this calibration be calculated.

If the value 0 is set, this calibration will not be used. Negative values are not possible.

Payload: 0x0342: 0342 = 834 so there is an altitude compensation of 834 meters above sea level

FPort 10: Temperature/humidity display

Byte	Length	Description
0	1	Display byte of temperature and humidity.

Here it can be adjusted whether the sensor sends the temperature and/or humidity.

If they are both not sent along, the CO₂ measurement will be 4 bytes shorter. If 1 of the 2 is set, the other value will be at its default value.

This default value is for temperature: 0x7FFF and for humidity 0xFFFF.

Bit number	Name	Description
7..2	RFU	-
1	Humidity display	Indicates whether the humidity is controlled.
0	Temperature display	Indicates whether the temperature is controlled.

Humidity display:

This bit indicates whether the humidity is given, if it is set to 0 together with temperature display, the uplink will be 4 bytes shorter.

If it is at 0 but temperature at 1, then the humidity sent will always be 0xFFFF.

Bit 1 = 1: control humidity.

Bit 1 = 0: Do not control humidity.

Temperature display:

This bit indicates whether the humidity is given, if it is set to 0 together with temperature display, the uplink will be 4 bytes shorter.

If it is at 0 but humidity at 1, then the controlled temperature will always be 0x7FFF.

Bit 0 = 1: control the temperature.

Bit 0 = 0: Do not send temperature.

Payload: 0x03(binary:00000011): temperature and humidity are sent along with the CO₂ value.

FPort 11: LED borders Green/Orange/Red:

Byte	Length	Description	Default V1.20:	Default V1.30:
0..1	2	Minimum value green	0x0000	0x0000
2..3	2	Maximum value green	0x041A	0x03E8
4..5	2	Minimum value orange	0x041B	0x03E9
6..7	2	Maximum value orange	0x060D	0x0578
8..9	2	Minimum value red	0x060E	0x0579
10..11	2	Maximum value red	0xFFFF	0xFFFF

Here the limit values of the green/orange/red LEDs can be set, if the CO₂ measurement is equal or between these 2 values, the corresponding LED will turn on *.

If both values of a certain LED are set to 0, the LED will never be on.

The example below uses the default values.

Example:

Payload 0x0000 03E8 03E9 0578 0579 FFFF:

* This setting only has an effect if the LED indicator in the behavior setting is turned on see "**FPort 13 Behavior Settings**".

FPort 12: Automatic and manual calibration

Byte number	Length	Description
0	1*	Automatic calibration on/off
0..2	3*	Manual calibration incl. reference value of manual calibration in ppm

* The length of this downlink is 1 byte when automatic calibration is turned on or off and 3 bytes when manual calibration is used.

With this downlink, the automatic calibration or manual calibration can be turned on. How these can be set is described here.

Byte 0 = 0x00: Automatic calibration off
 Byte 0 = 0x01: Automatic calibration on
 Byte 0..2= 0x02 nnnn: Re-forced (manual) calibration; nnnn is the calibration CO₂ value in PPM, converted to hex.

Automatic calibration:

By turning on automatic calibration, the sensor will recalibrate itself in a week. It is important that the sensor remains on continuously, otherwise the calibration may take longer.

The automatic calibration continues until it is switched off again with 0x00.

A manual calibration does not affect the on or off of the automatic calibration.

Note: When switching on/using automatic calibration, the CO₂ stoplicht must be in fresh air (400 ppm) for at least 1 hour a day.

Most buildings have their air quality in order in such a way that usually once a day (during the night) the air quality level is at/around 400 ppm.

Manual calibration:

With the manual calibration, a new calibration value can be set, this can be done by setting byte 0 to 0x02 and then setting a ppm value in byte 1..2.

Payload 0x01: The automatic calibration is turned on, can be turned off with 0x00

Payload 0x020190: The manual calibration is set with a value of 400ppm(0x0190).

FPort 13: Settings behavior

Byte	Length	Description
0	1	Behavior settings

With this setting, the 'behavior' of the sensor can be determined.

The byte has a limited meaning:

0x01: LEDs are off

0x02: LEDs are on. **This is the default setting**

Example:

Payload: 0x02 (binary:00000010): stoplicht mode is on and the LEDs are used.

6. Regulations

6.1. CE Certification

6.1.1. EU Declaration of Conformity

Manufacturer: Teneo Sales B.V.
Product: LoRaWAN CO₂ Stoplicht
Type designation: 01COS
Batch/serial number: TBV20-01COS-01LR

Teneo Sales B.V. hereby declares that the "LoRaWAN CO₂ stoplicht" complies with the Radio Equipment Directive (2014/53/EU).

The full text of the Declaration of Conformity is available on our website: www.co2-stoplicht.online/downloads .

6.1.2. WEEE 2012/19/EU:

The node, including all components, must not be disposed of in household and/or industrial waste. Users are obliged to dispose of the end-of-life node in accordance with the requirements of the WEEE Regulation (waste electronic and electrical equipment) in order to contribute to the protection of the environment and the reduction of waste (recycling).

For further information on how this can be done, please contact a certified collection party.

Teneo Sales B.V. is a member of Wecycle and Stibat in order to fulfil its obligations as a producer, following the WEEE Regulations.