Smart Cities PRO

Technical Guide

libelium

wasp mote

Document version: v7.1 - 02/2017

INDEX

1. General

1.1. General and safety information

- In this section, the term "Waspmote" encompasses both the Waspmote device itself and its modules and sensor boards.
- Read through the document "General Conditions of Libelium Sale and Use".
- Do not allow contact of metallic objects with the electronic part to avoid injuries and burns.
- NEVER submerge the device in any liquid.
- Keep the device in a dry place and away from any liquid which may spill.
- Waspmote consists of highly sensitive electronics which is accessible to the exterior, handle with great care and avoid bangs or hard brushing against surfaces.
- Check the product specifications section for the maximum allowed power voltage and amperage range and consequently always use a current transformer and a battery which works within that range. Libelium is only responsible for the correct operation of the device with the batteries, power supplies and chargers which it supplies.
- Keep the device within the specified range of temperatures in the specifications section.
- Do not connect or power the device with damaged cables or batteries.
- Place the device in a place only accessible to maintenance personnel (a restricted area).
- Keep children away from the device in all circumstances.
- If there is an electrical failure, disconnect the main switch immediately and disconnect that battery or any other power supply that is being used.
- If using a car lighter as a power supply, be sure to respect the voltage and current data specified in the "Power Supplies" section.
- If using a battery in combination or not with a solar panel as a power supply, be sure to use the voltage and current data specified in the "Power supplies" section.
- If a software or hardware failure occurs, consult the Libelium Web Development section.
- Check that the frequency and power of the communication radio modules together with the integrated antennas are allowed in the area where you want to use the device.
- Waspmote is a device to be integrated in a casing so that it is protected from environmental conditions such as light, dust, humidity or sudden changes in temperature. The board supplied "as is" is not recommended for a final installation as the electronic components are open to the air and may be damaged.

1.2. Conditions of use

- Read the "General and Safety Information" section carefully and keep the manual for future consultation.
- Use Waspmote in accordance with the electrical specifications and the environment described in the "Electrical Data" section of this manual.
- Waspmote and its components and modules are supplied as electronic boards to be integrated within a final product. This product must contain an enclosure to protect it from dust, humidity and other environmental interactions. In the event of outside use, this enclosure must be rated at least IP-65.
- Do not place Waspmote in contact with metallic surfaces; they could cause short-circuits which will permanently damage it.

Further information you may need can be found at http://www.libelium.com/development/waspmote

The "General Conditions of Libelium Sale and Use" document can be found at:
http://www.libelium.com/development/waspmote/technical_service

2. New version: Smart Cities PRO v3.0

This guide explains the new Smart Cities Sensor Board v3.0. This board was designed for our new product lines Waspmote v15 and Plug & Sense! v15, released on October 2016.

The previous version of this board (Smart Cities v2.0) was designed for Waspmote v12 and Plug & Sense! v12, and it is NOT recommended to mix product generations. If you are using previous versions of our products, please use the corresponding guides, available on our Development website.

You can get more information about the generation change on the document "New generation of Libelium product lines".

Differences of Smart Cities PRO v3.0 with the previous version:

- Added the new Noise Level Sensor, able to read LeqA (integrated equivalent continuous sound level, A-weighted) in dBA. The sensor achieves high accuracy in a wide range of frequencies.
- I2C sockets allow the connection of digital sensors, even gas sensors from Gases PRO, Temperature, Humidity and Pressure sensor or Luxes and Ultrasound sensors.
- The Particle Matter – Dust Sensor (PM1 / PM2.5 / PM10) is now available on this board.
- New connectors to improve the Plug & Sense! wiring, making it more robust.
- Added an I2C isolator chip to avoid affecting to the Waspmote I2C bus.

3. Waspmote Plug & Sense!

The Waspmote Plug & Sense! line allows you to easily deploy Internet of Things networks in an easy and scalable way, ensuring minimum maintenance costs. The platform consists of a robust waterproof enclosure with specific external sockets to connect the sensors, the solar panel, the antenna and even the USB cable in order to reprogram the node. It has been specially designed to be scalable, easy to deploy and maintain.

> ***Note:*** *For a complete reference guide download the "Waspmote Plug & Sense! Technical Guide" in the Development section of the Libelium website.*

3.1. Features

- Robust waterproof IP65 enclosure
- Add or change a sensor probe in seconds
- Solar powered with internal and external panel options
- Radios available: 802.15.4, 868 MHz, 900 MHz, WiFi, 4G, Sigfox and LoRaWAN
- Over the air programming (OTAP) of multiple nodes at once (via WiFi or 4G radios)
- Special holders and brackets ready for installation in street lights and building fronts
- Graphical and intuitive programming interface Code Generator (coming in 2017)
- Built-in, 3-axes accelerometer
- External, contactless reset with magnet
- External SIM connector for the 4G models
- Fully certified: CE (Europe), FCC (USA), IC (Canada), ANATEL (Brazil), RCM (Australia), PTCRB (USA, cellular connectivity), AT&T (USA, cellular connectivity)

Figure: Waspmote Plug & Sense!

3.2. General view

This section shows main parts of Waspmote Plug & Sense! and a brief description of each one. In later sections all parts will be described deeply.

3.2.1. Specifications

- **Material:** polycarbonate
- **Sealing:** polyurethane
- **Cover screws:** stainless steel
- **Ingress protection:** IP65
- **Impact resistance:** IK08
- **Rated insulation voltage AC:** 690 V
- **Rated insulation voltage DC:** 1000 V
- **Heavy metals-free:** Yes
- **Weatherproof:** true - nach UL 746 C
- **Ambient temperature (min.):** -10 °C
- **Ambient temperature (max.):** 50 °C
- **Approximated weight:** 800 g

In the pictures included below it is shown a general view of Waspmote Plug & Sense! main parts. Some elements are dedicated to node control, others are designated to sensor connection and other parts are just identification elements. All of them will be described along this guide.

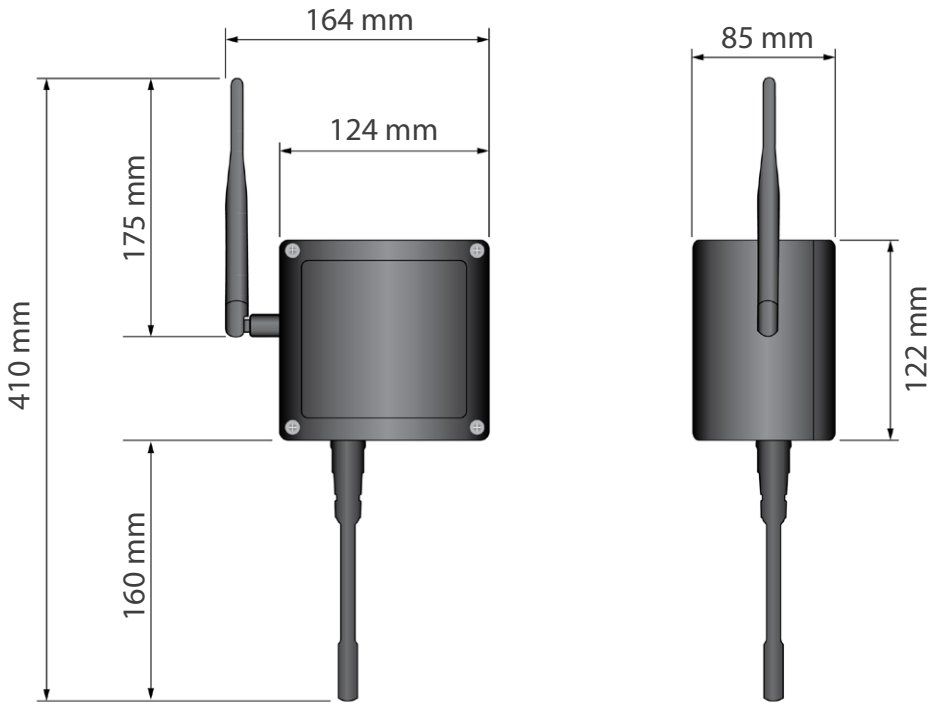


Figure : Main view of Waspmote Plug & Sense!

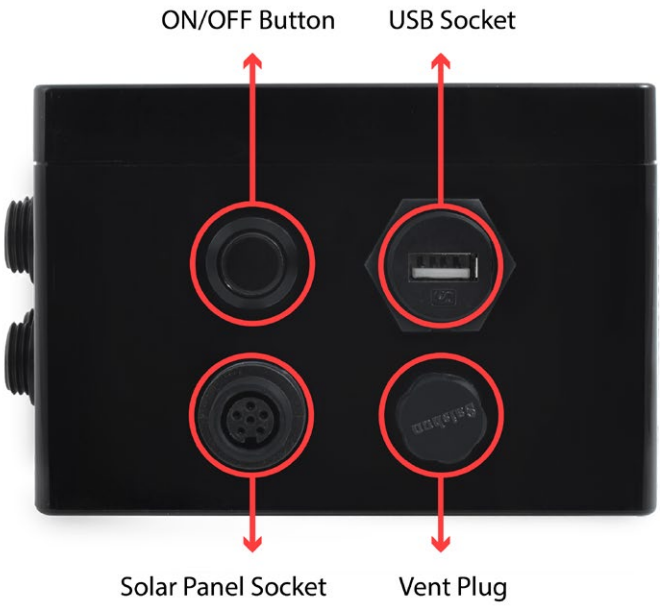


Figure : Control side of the enclosure

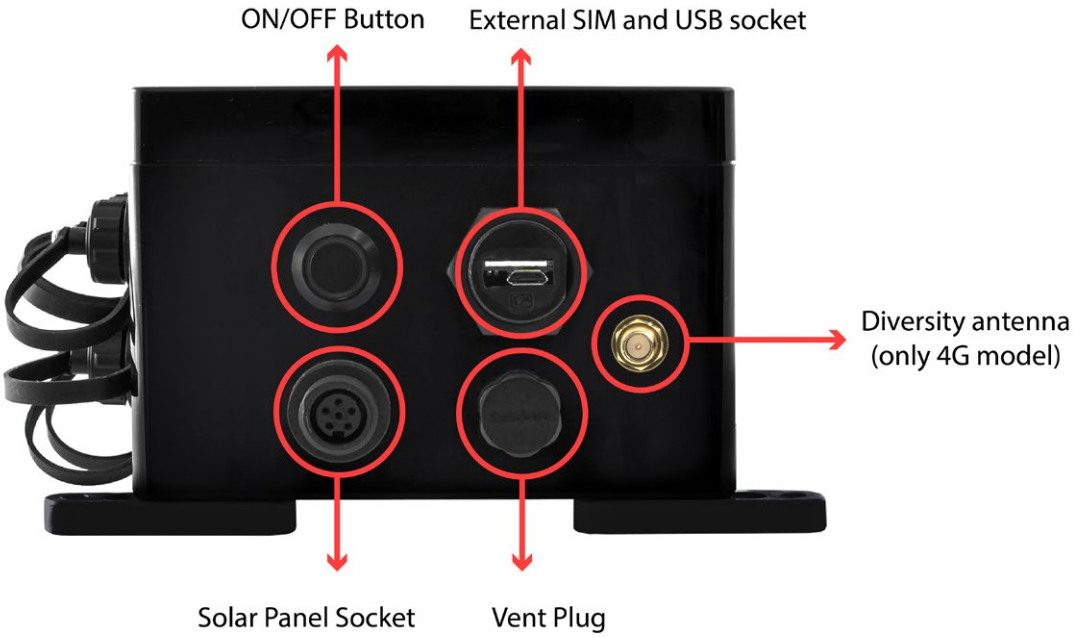


Figure : Control side of the enclosure for 4G model

Figure : Sensor side of the enclosure

Figure : Antenna side of the enclosure

Figure : Front view of the enclosure

Figure : Back view of the enclosure

Figure : Warranty stickers of the enclosure

***Important note:** Do not handle black stickers seals of the enclosure (Warranty stickers). Their integrity is the proof that Waspmote Plug & Sense! has not been opened. If they have been handled, damaged or broken, the warranty is automatically void.*

3.3. Parts included

Next picture shows Waspmote Plug & Sense! and all of its elements. Some of them are optional accessories that may not be included.

Figure : Waspmote Plug & Sense! accessories: 1 enclosure, 2 sensor probes, 3 external solar panel, 4 USB cable, 5 antenna, 6 cable ties, 7 mounting feet (screwed to the enclosure), 8 extension cord, 9 solar panel cable, 10 wall plugs & screws

3.4. Identification

Each Waspmote model is identified by stickers. Next figure shows front sticker.

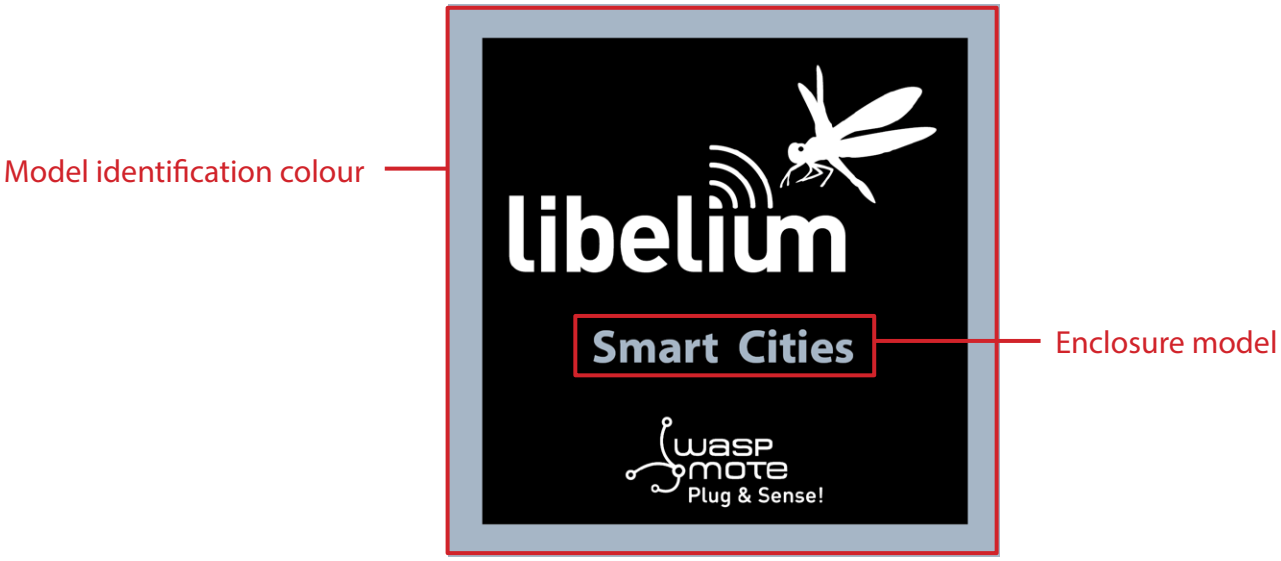


Figure : Front sticker of the enclosure

There are many configurations of Waspmote Plug & Sense! line, all of them identified by one unique sticker. Next image shows all possibilities.

Figure : Different front stickers

Moreover, Waspmote Plug & Sense! includes a back sticker where it is shown identification numbers, radio MAC addresses, etc. It is highly recommended to annotate this information and save it for future maintenance. Next figure shows it in detail.

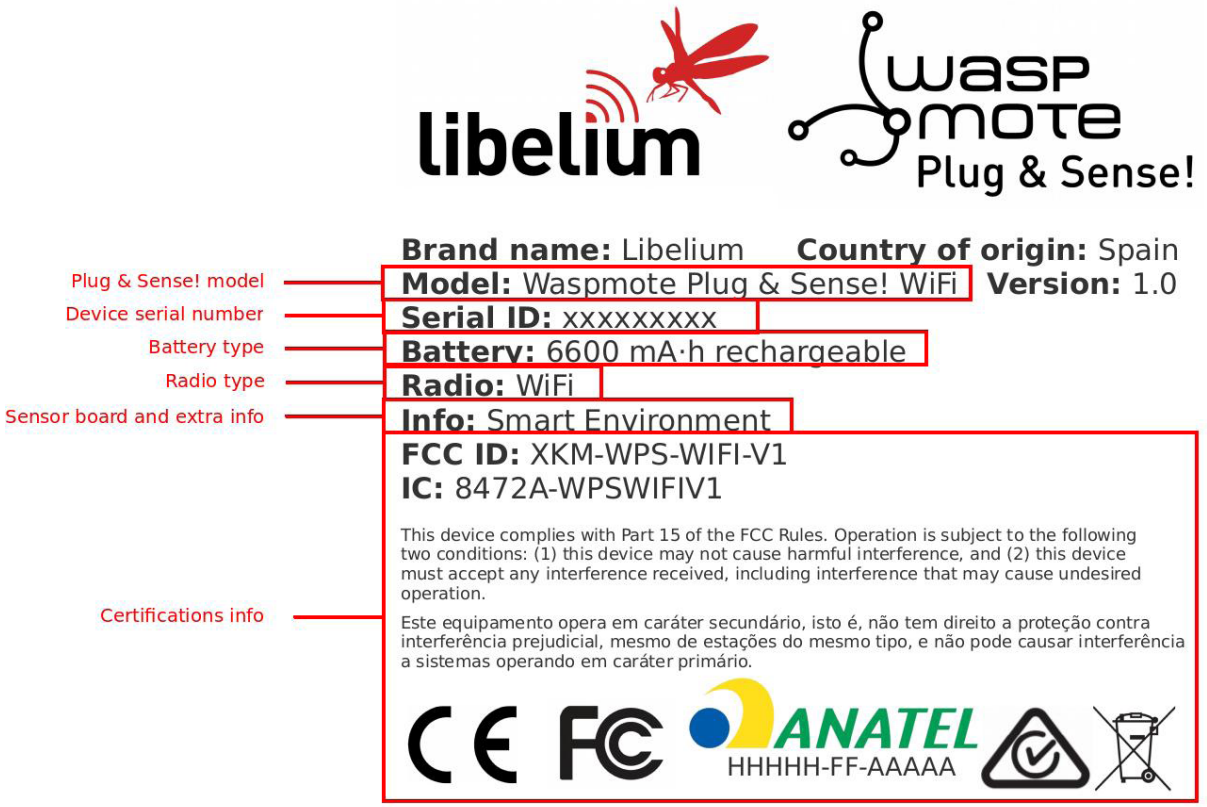


Figure : Back sticker

Sensor probes are identified too by a sticker showing the measured parameter and the sensor manufacturer reference.

Figure : Sensor probe identification sticker

3.5. Sensor probes

Sensor probes can be easily attached by just screwing them into the bottom sockets. This allows you to add new sensing capabilities to existing networks just in minutes. In the same way, sensor probes may be easily replaced in order to ensure the lowest maintenance cost of the sensor network.

Figure : Connecting a sensor probe to Waspmote Plug & Sense!

Go to the Plug & Sense! Sensor Guide to know more about our sensor probes.

3.6. Solar powered

The battery can be recharged using the waterproof USB cable but also the internal or external solar panel options.

The external solar panel is mounted on a 45º holder which ensures the maximum performance of each outdoor installation.

Figure : Waspmote Plug & Sense! powered by an external solar panel

For the internal option, the solar panel is embedded on the front of the enclosure, perfect for use where space is a major challenge.

Figure : Internal solar panel

Figure : Waspmote Plug & Sense! powered by an internal solar panel

3.7. Programming the Nodes

Waspmote Plug & Sense! can be reprogrammed in two ways:

The basic programming is done from the USB port. Just connect the USB to the specific external socket and then to the computer to upload the new firmware.

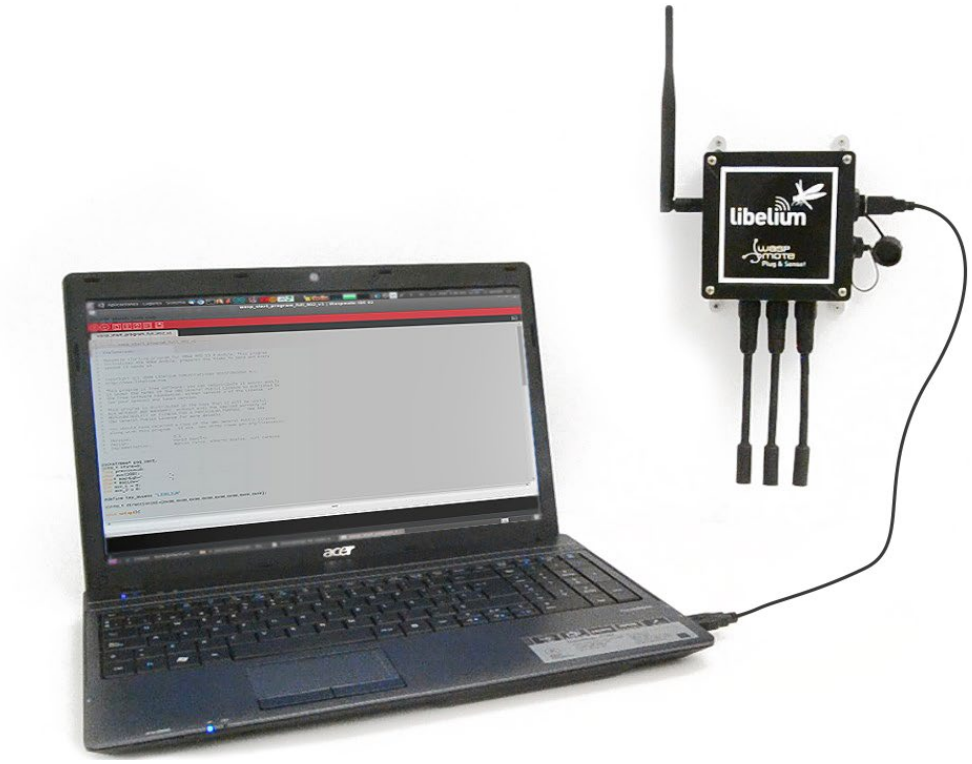


Figure : Programming a node

Besides, Libelium is developing a graphical and intuitive programming interface, the Code Generator (coming in 2017).

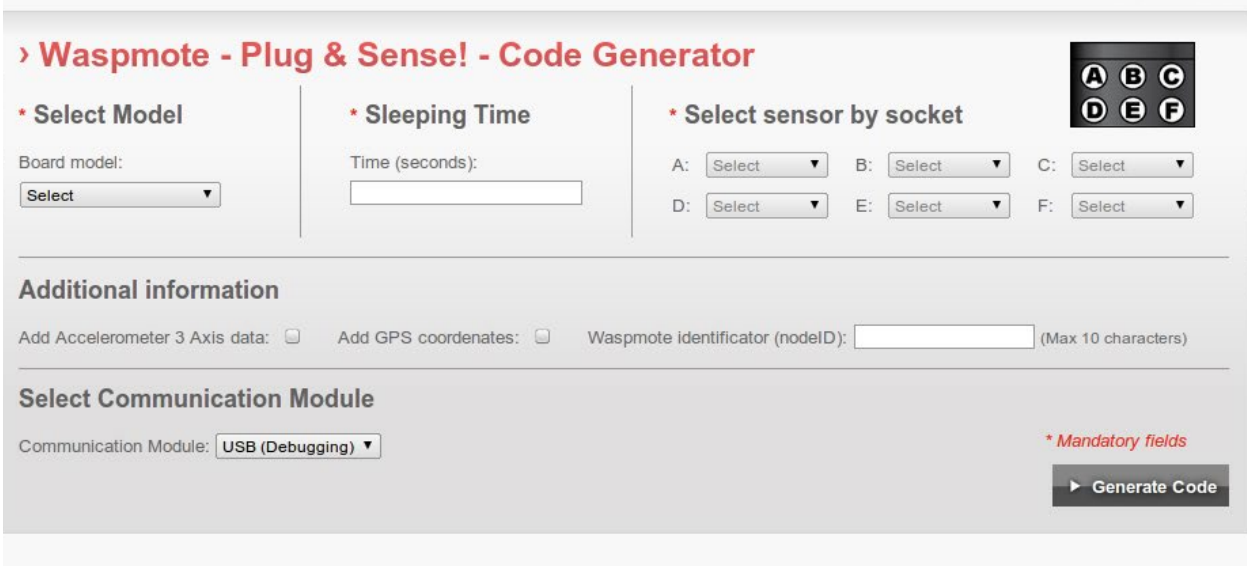


Figure: Code Generator web application

Over the Air Programming (OTAP) is also possible once the node has been installed (via WiFi or 4G radios). With this technique you can reprogram, wireless, one or more Waspmote sensor nodes at the same time by using a laptop and Meshlium.

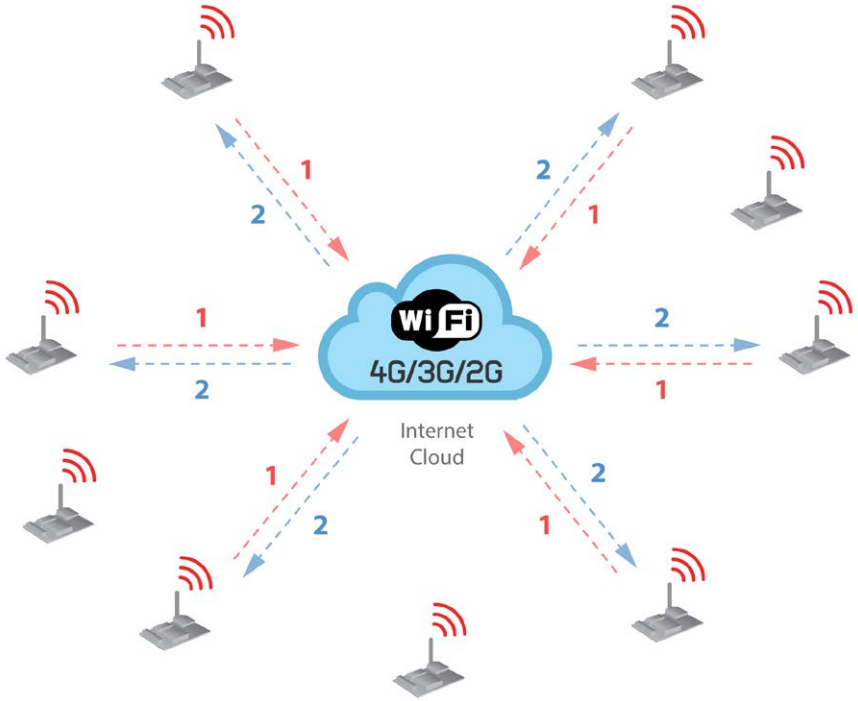


Figure : Typical OTAP process

3.8. Radio interfaces

Radio	Protocol	Frequency bands	Transmission power	Sensitivity	Range*	Certification
XBee-PRO 802.15.4 EU	802.15.4	2.4 GHz	10 dBm	-100 dBm	750 m	CE
XBee-PRO 802.15.4	802.15.4	2.4 GHz	18 dBm	-100 dBm	1600 m	FCC, IC, ANATEL, RCM
XBee 868LP	RF	868 MHz	14 dBm	-106 dBm	8.4 km	CE
XBee 900HP US	RF	900 MHz	24 dBm	-110 dBm	15.5 km	FCC, IC
XBee 900HP BR	RF	900 MHz	24 dBm	-110 dBm	15.5 km	ANATEL
XBee 900HP AU	RF	900 MHz	24 dBm	-110 dBm	15.5 km	RCM
WiFi	WiFi (HTTP(S), FTP, TCP, UDP)	2.4 GHz	17 dBm	-94 dBm	500 m	CE, FCC, IC, ANATEL, RCM
4G EU/BR	4G/3G/2G (HTTP, FTP, TCP, UDP) GPS	800, 850, 900, 1800, 2100, 2600 MHz	4G: class 3 (0.2 W, 23 dBm)	4G: -102 dBm	- km - Typical base station range	CE, ANATEL
4G US	4G/3G/2G (HTTP, FTP, TCP, UDP) GPS	700, 850, 1700, 1900 MHz	4G: class 3 (0.2 W, 23 dBm)	4G: -103 dBm	- km - Typical base station range	FCC, IC, PTCRB, AT&T
4G AU	4G (HTTP, FTP, TCP, UDP)	700, 1800, 2600 MHz	4G: class 3 (0.2 W, 23 dBm)	4G: -102 dBm	- km - Typical base station range	RCM
Sigfox EU	Sigfox	868 MHz	16 dBm	-126 dBm	- km - Typical base station range	CE
Sigfox US	Sigfox	900 MHz	24 dBm	-127 dBm	- km - Typical base station range	FCC, IC
LoRaWAN EU	LoRaWAN	868 MHz	14 dBm	-136 dBm	> 15 km	CE
LoRaWAN US	LoRaWAN	900 MHz	18.5 dBm	-136 dBm	> 15 km	FCC, IC

** Line of sight and Fresnel zone clearance with 5dBi dipole antenna.*

3.9. Models

There are some defined configurations of Waspmote Plug & Sense! depending on which sensors are going to be used. Waspmote Plug & Sense! configurations allow to connect up to six sensor probes at the same time.

Each model takes a different conditioning circuit to enable the sensor integration. For this reason each model allows to connect just its specific sensors.

This section describes each model configuration in detail, showing the sensors which can be used in each case and how to connect them to Waspmote. In many cases, the sensor sockets accept the connection of more than one sensor probe. See the compatibility table for each model configuration to choose the best probe combination for the application.

It is very important to remark that each socket is designed only for one specific sensor, so **they are not interchangeable**. Always be sure you connected probes in the right socket, otherwise they can be damaged.

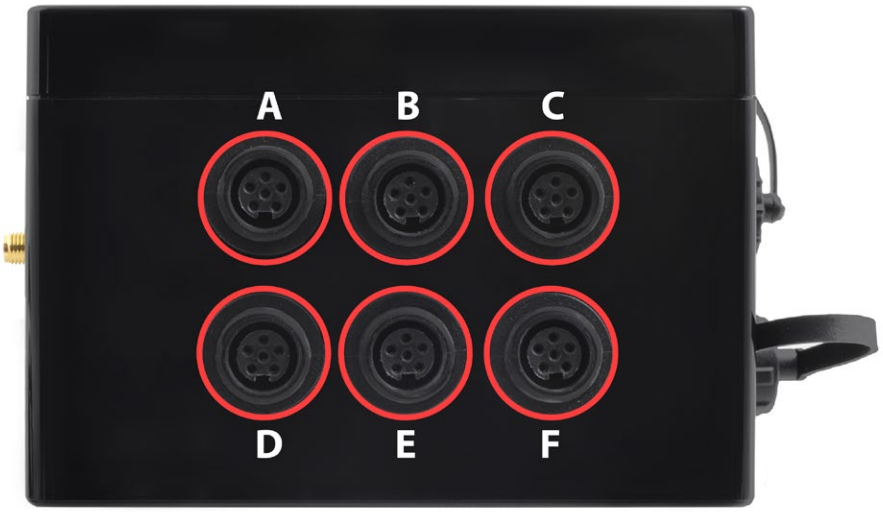


Figure : Identification of sensor sockets

3.9.1. Smart Cities PRO

The main applications for this Waspmote Plug & Sense! model are noise maps (monitor in real time the acoustic levels in the streets of a city), air quality, waste management, smart lighting, etc. Refer to Libelium website for more information.

Figure: Smart Cities PRO Waspmote Plug & Sense! model

Sensor sockets are configured as shown in the figure below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	Reference
A	Noise level sensor	NLS
	Temperature + Humidity + Pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P
B, C and F	Carbon Monoxide (CO) for high concentrations [Calibrated]	9371-P
	Carbon Monoxide (CO) for low concentrations [Calibrated]	9371-LC-P
	Carbon Dioxide (CO_2) [Calibrated]	9372-P
	Oxygen (O_2) [Calibrated]	9373-P
	Ozone (O_3) [Calibrated]	9374-P
	Nitric Oxide (NO) for low concentrations [Calibrated]	9375-LC-P
	Nitric Dioxide (NO_2) high accuracy [Calibrated]	9376-HA-P
	Sulfur Dioxide (SO_2) high accuracy [Calibrated]	9377-HA-P
	Ammonia (NH_3) [Calibrated]	9378-P
	Methane (CH_4) and Combustible Gas [Calibrated]	9379-P
	Hydrogen (H_2) [Calibrated]	9380-P
	Hydrogen Sulfide (H_2S) [Calibrated]	9381-P
	Hydrogen Chloride (HCl) [Calibrated]	9382-P
	Phosphine (PH_3) [Calibrated]	9384-P
	Ethylene (ETO) [Calibrated]	9385-P
	Chlorine (Cl_2) [Calibrated]	9386-P
	Temperature + Humidity + Pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P
D	Particle Matter (PM1 / PM2.5 / PM10) - Dust	9387-P
E	Temperature + Humidity + Pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P

Figure: Sensor sockets configuration for Smart Cities PRO model

Note: *For more technical information about each sensor probe go to the Development section in Libelium website.*

Calibrated gas sensors are manufactured once the order has been placed to ensure maximum durability of the calibration feature. The manufacturing process and delivery may take from 4 to 6 weeks. The lifetime of calibrated gas sensors is 6 months working at maximum accuracy. We strongly encourage our customers to buy extra gas sensors to replace the original ones after that time to ensure maximum accuracy and performance.

4. Hardware

4.1. General description

The purpose of the Waspmote Smart Cities PRO board is to extend the monitoring functionalities from indoor environments to outdoor locations, in order to perform IoT projects in Smart Cities and urban environments. Most of the sensors available for Smart Cities PRO are available for the Gases PRO Sensor Board. Also, the Smart Cities PRO board adds support for the Noise Level Sensor.

4.2. Specifications

- Weight: 20 g
- Dimensions: 73.5 x 51 x 22 mm (without sensors)
- Temperature range: [-20 ºC, 65 ºC]

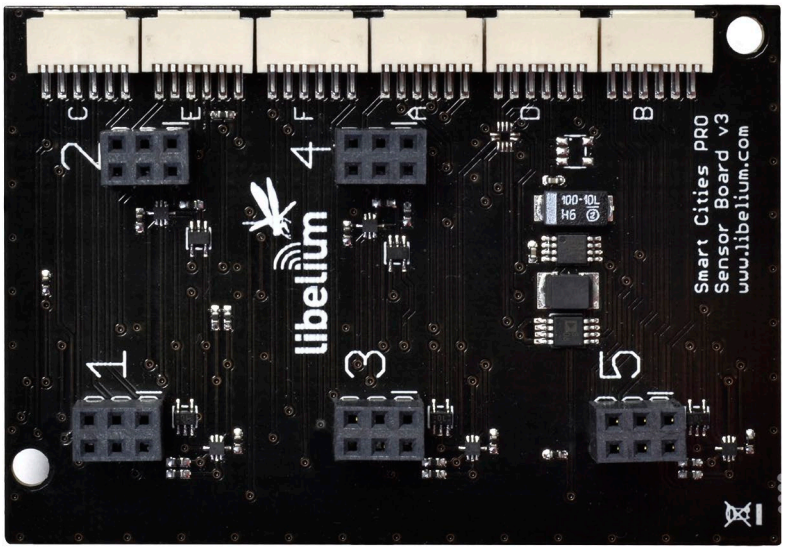


Figure : Top side of the Smart Cities PRO Sensor Board

4.3. Electrical characteristics

- Board power voltages: 3.3 V and 5 V
- Sensor power voltages: 3.3 V and 5 V
- Maximum admitted current (continuous): 200 mA
- Maximum admitted current (peak): 400 mA

5. Sensors

5.1. Temperature, Humidity and Pressure Sensor

The BME280 is a digital temperature, humidity and atmospheric pressure sensor developed by Bosch Sensortec.

5.1.1. Specifications

Electrical characteristics
Supply voltage: 3.3 V
Sleep current typical: 0.1 µA
Sleep current maximum: 0.3 µA

Figure : Temperature, Humidity and Pressure Sensor

Temperature sensor
Operational range: -40 ~ +85 ºC
Full accuracy range: 0 ~ +65 ºC
Accuracy: ±1 ºC (range 0 ºC ~ +65 ºC)
Response time: 1.65 seconds (63% response from +30 to +125 °C).
Typical consumption: 1 µA measuring

Humidity sensor
Measurement range: 0 ~ 100% of relative humidity (for temperatures < 0 °C and > 60 °C see figure below)
Accuracy: < ±3% RH (at 25 ºC, range 20 ~ 80%)
Hysteresis: ±1% RH
Operating temperature: -40 ~ +85 ºC
Response time (63% of step 90% to 0% or 0% to 90%): 1 second
Typical consumption: 1.8 µA measuring
Maximum consumption: 2.8 µA measuring

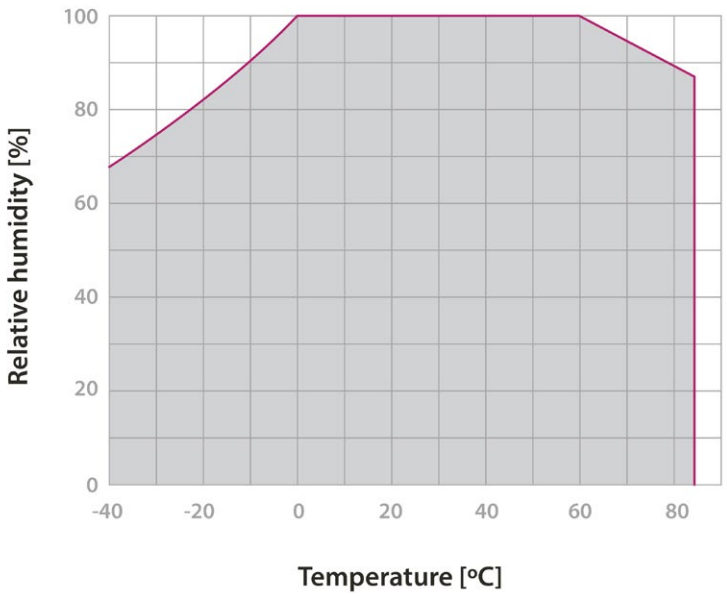


Figure : Humidity sensor operating range

Pressure sensor

Measurement range: 30 ~ 110 kPa

Operational temperature range: -40 ~ +85 ºC

Full accuracy temperature range: 0 ~ +65 ºC

Absolute accuracy: ±0.1 kPa (0 ~ 65 ºC)

Typical consumption: 2.8 µA measuring

Maximum consumption: 4.2 µA measuring

5.1.2. Measurement process

The BME280 is as combined digital humidity, pressure and temperature sensor based on proven sensing principles. The humidity sensor provides an extremely fast response time for fast context awareness applications and high overall accuracy over a wide temperature range.

The pressure sensor is an absolute barometric pressure sensor with extremely high accuracy and resolution and drastically lower noise.

The integrated temperature sensor has been optimized for lowest noise and highest resolution.

Its output is used for temperature compensation of the pressure and humidity sensors and can also be used for estimation of the ambient temperature.

When the sensor is disabled, current consumption drops to 0.1 µA.

You can find a complete example code for reading the BME280 sensor in the following link:
http://www.libelium.com/development/waspmote/examples/scp-v30-05-temperature-humidity-and-pressure-sensor

5.1.3. Socket

This sensor can be connected in sockets 1, 2, 3, 4 and 5 in Waspmote OEM and sockets A, B, C, E and F in Plug & Sense!.

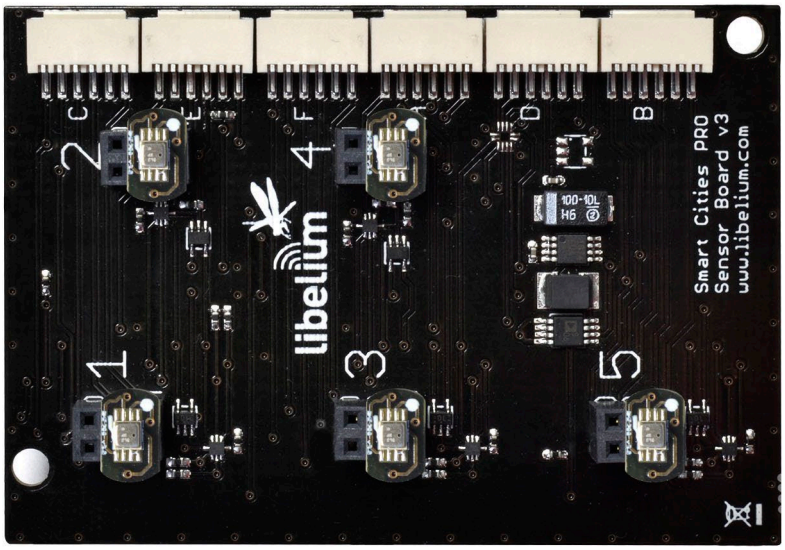


Figure : Temperature, Humidity and Pressure Sensors in sockets 1, 2, 3, 4 and 5

In the image above we can see highlighted the four pins of the terminal block where the sensor must be connected to the board. The white dot on the luxes board, must match the mark of the Smart Cities PRO Sensor Board. Please mind that each socket has 3 rows, but only 2 are used for that sensor, because it only has 2x2 pins. A bad connection can cause malfunction or even hardware damage.

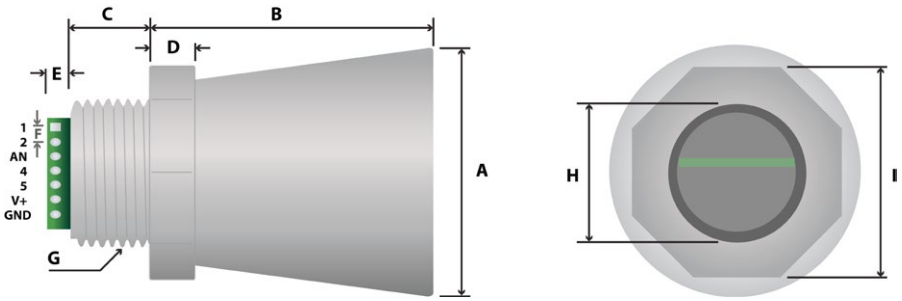
5.2. Ultrasound sensor probe (MaxSonar® from MaxBotix™)

5.2.1. Specifications

I2CXL-MaxSonar®-MB7040™

Operation frequency: 42 kHz
Maximum detection distance: 765 cm
Interface: Digital bus
Power supply: 3.3 V
Consumption (average): 2.1 mA
Consumption (peak): 50 mA
Usage: Indoors and outdoors (IP-67)

Figure : Ultrasonic I2CXL-MaxSonar®-MB7040 from MaxBotix™ sensor



A	1.72″ dia.	43.8 mm dia.
B	2.00″	50.7 mm
C	0.58″	14.4 mm
D	0.31″	7.9 mm
E	0.18″	4.6 mm
F	0.1″	2.54 mm
G	3/4″ *National Pipe Thread Straight*	
H	1.032″ dia.	26.2 dia.
I	1.37″	34.8 mm
weight: 1.76 oz. ; 50 grams		

Figure : Ultrasonic I2CXL-MaxSonar®-MB7040 sensor dimensions

In the figure below we can see a diagram of the detection range of the sensor developed using different detection patterns (a 0.63 cm diameter dowel for diagram A, a 2.54 cm diameter dowel for diagram B, an 8.25cm diameter rod for diagram C and a 28 cm wide board for diagram D):

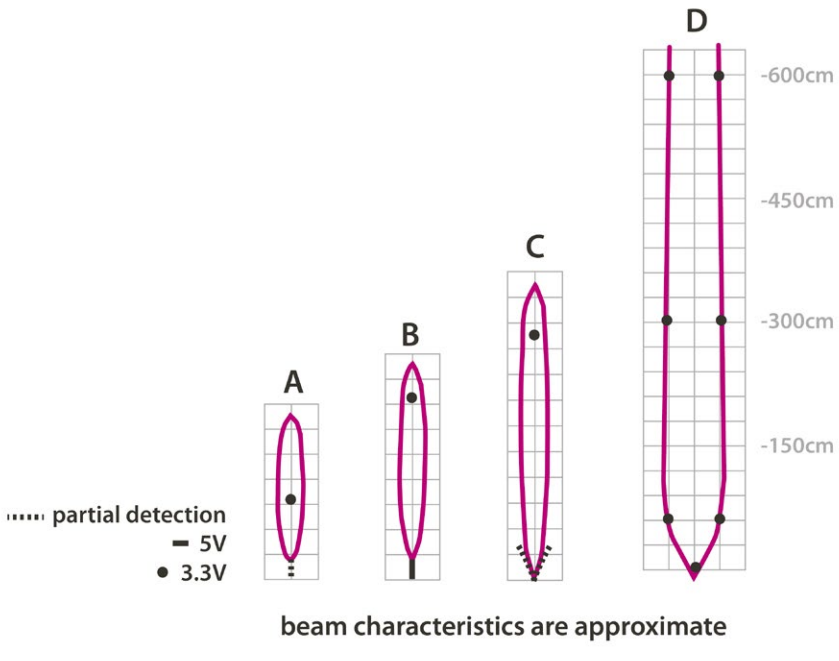
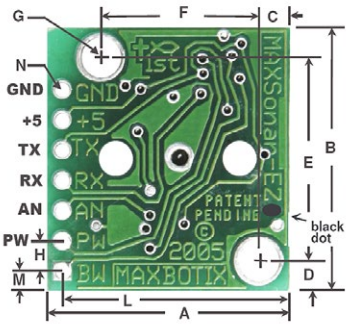


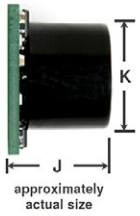
Figure : Diagram of the sensor beam extracted from the data sheet of the XL-MaxSonar®-WRA1™ sensor from MaxBotix

I2CXL-MaxSonar®-MB1202™:

- **Operation frequency:** 42 kHz
- **Maximum detection distance:** 765 cm
- **Consumption (average):** 2 mA
- **Consumption (peak):** 50 mA
- **Usage:** Indoors only

Figure : Ultrasonic I2CXL-MaxSonar®-MB1202 from MaxBotix™ Sensor





A	0.785″	19.9 mm	H	0.100″	2.54 mm
B	0.870″	22.1 mm	J	0.645″	16.4 mm
C	0.100″	2.54 mm	K	0.610″	15.5 mm
D	0.100″	2.54 mm	L	0.735″	18.7 mm
E	0.670″	17.0 mm	M	0.065″	1.7 mm
F	0.510″	12.6 mm	N	0.038″ dia.	1.0 mm dia.
G	0.124″ dia.	3.1 mm dia.	weight: 4.3 grams		

Figure : Ultrasonic I2CXL-MaxSonar®-MB1202 Sensor dimensions

In the figure below we can see a diagram of the detection range of the sensor developed using different detection patterns (a 0.63 cm diameter dowel for diagram A, a 2.54 cm diameter dowel for diagram B, an 8.25 cm diameter rod for diagram C and a 28 cm wide board for diagram D):

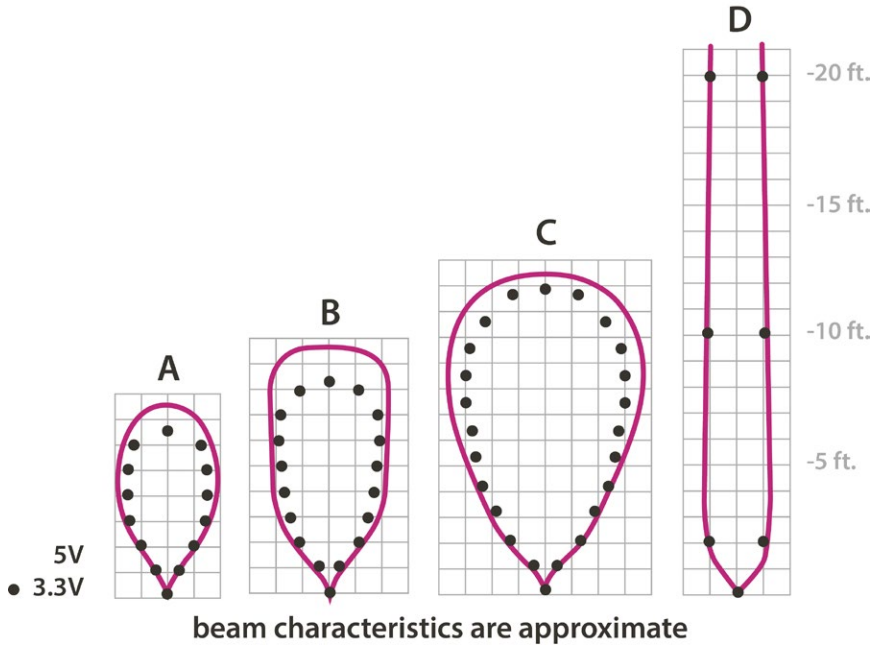


Figure : Diagram of the sensor beam extracted from the data sheet of the Ultrasonic I2CXL-MaxSonar®-MB1202 sensor from MaxBotix

5.2.2. Measurement Process

The MaxSonar® sensors from MaxBotix can be connected through the digital bus interface.

In the next figure, we can see a drawing of two example applications for the ultrasonic sensors, such as liquid level monitoring or presence detection.

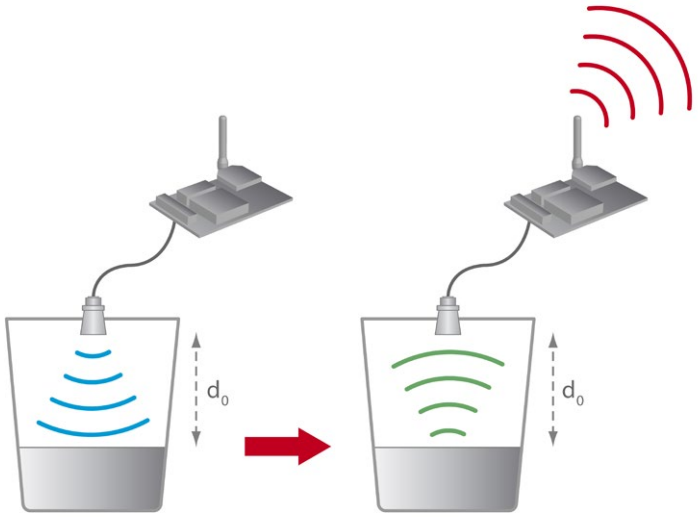


Figure : Examples of application for the MaxSonar® sensors

The MB7040 sensor is endowed with an IP-67 casing, so it can be used in outdoors applications, such as liquid level monitoring in storage tanks.

You can find a complete example code for reading the distance in the following link:
www.libelium.com/development/waspmote/examples/scp-v30-06-ultrasound-sensor

5.2.3. Socket

These sensors can be connected in socket 1, 2, 3, 4 and 5 in Waspmote OEM and sockets A, B, C, E and F in Plug & Sense!.

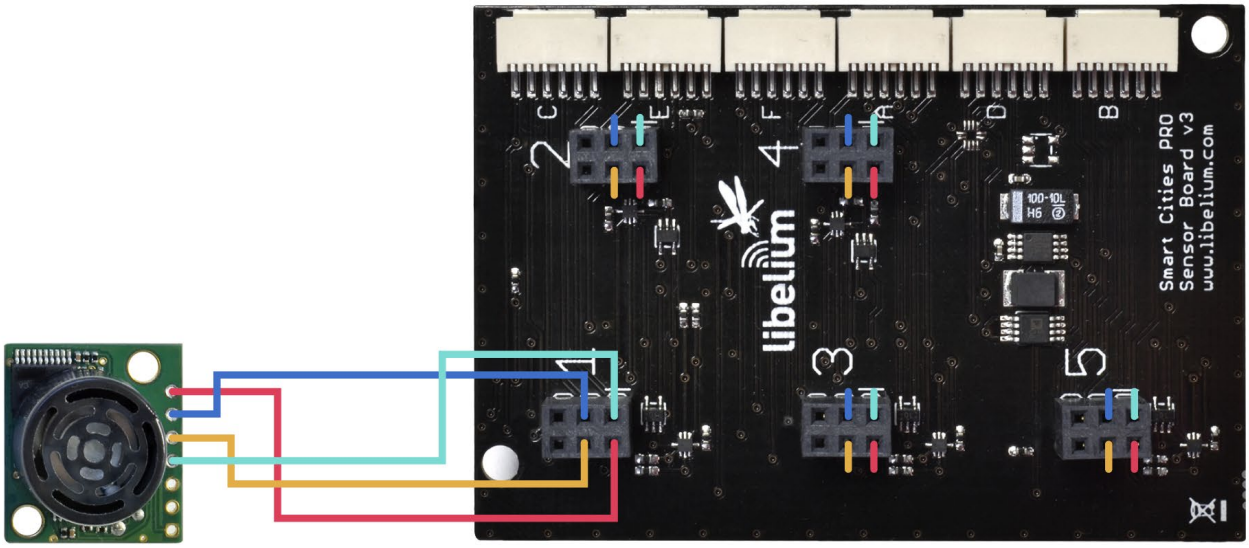


Figure : Images of the sockets for connecting the MaxSonar® Sensors

5.3. Luminosity (Luxes accuracy) Sensor

Figure : Image of the Luminosity Sensor

5.3.1. Specifications

Electrical characteristics

Dynamic range: 0.1 to 40000 lux
Spectral range: 300 ~ 1100 nm
Voltage range: 2.7 ~ 3.6 V
Supply current typical: 0.24 mA
Sleep current maximum: 0.3 µA
Operating temperature: -30 ~ 70 ºC

5.3.2. Measurement process

This is a light-to-digital converter that transforms light intensity into a digital signal output. This device combines one broadband photo-diode (visible plus infrared) and one infrared-responding photo-diode on a single CMOS integrated circuit capable of providing a near-photopic response over an effective 20-bit dynamic range (16-bit resolution). Two integrating ADCs convert the photo-diode currents to a digital output that represents the irradiance measured on each channel. This digital output in lux is derived using an empirical formula to approximate the human eye response.

You can find a complete example code for reading the luminosity in the following link:
www.libelium.com/development/waspmote/examples/scp-v30-07-luxes-sensor

5.3.3. Socket

This sensor can be connected in socket 1, 2, 3, 4 and 5 in Waspmote OEM and sockets A, B, C, E and F in Plug & Sense!

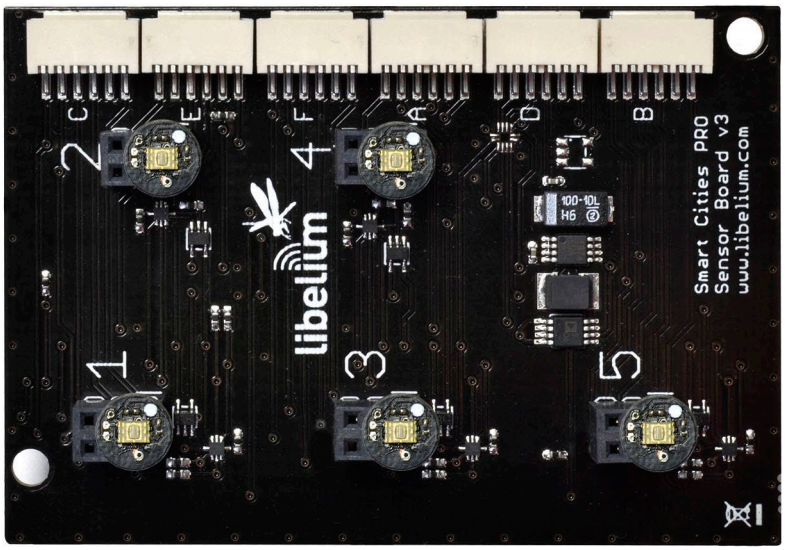


Figure : Luxes sensors connected in sockets 1, 2, 3, 4 and 5

In the image above we can see highlighted the four pins of the terminal block where the sensor must be connected to the board. The white dot on the luxes board, must match the mark of the Smart Cities PRO Sensor Board. Please mind that each socket has 3 rows, but only 2 are used for that sensor, because it only has 2x2 pins. A bad connection can cause malfunction or even hardware damage.

5.4. Particle Matter (PM1 / PM2.5 / PM10) - Dust Sensor

Specifications

Figure : Image of the Particle Matter sensor, encapsulated

Sensor: OPC-N2

Performance Characteristics

Laser classification: Class 1 as enclosed housing
Particle range (um): 0.38 to 17 spherical equivalent size (based on RI of 1.5)
Size categorization (standard): 16 software bins
Sampling interval (seconds): 1 to 10 histogram period
Total flow rate: 1.2 L/min
Sample flow rate: 220 mL/min
Max particle count rate: 10000 particles/second
Max Coincidence probability: 0.91% at 10 particles/L
0.24% at 500 particles/mL

Power Characteristics

Measurement mode (laser and fan on): 250 mA @ 5 Volts (typical)
Voltage Range: 4.8 to 5.2 V DC

Operation Conditions

Temperature Range: -10 ºC to 50 ºC
Operating Humidity: 0 to 99% RH non-condensing

This sensor has a high current consumption. It is very important to turn on the sensor to perform a measure and then, turn it off to save battery. Also, it is advised to operate with a minimum battery level of 40%, just to avoid voltage drops (due to high current peaks) which could lead to resets in the system.

Dust, dirt or pollen may be accumulated inside the dust sensor structure, especially when the sensor is close to possible solid particle sources: parks, construction works, deserts. That is why it is highly recommended to perform maintenance/cleaning tasks in order to have accurate measures. This maintenance/cleaning frequency may vary depending on the environment conditions or amount of obstructing dust. In clean atmospheres or with low particle concentrations, the maintenance/cleaning period will be longer than a place with a high particle concentrations.

Important note: *Do not handle the stickers seals of the enclosure (Warranty stickers). Their integrity is the proof that the sensor enclosure has not been opened. If they have been handled, damaged or broken, the warranty is automatically void.*

DO NOT remove the external housing: this not only ensures the required airflow, also protects the user from the laser light. Removal of the casing may expose the user to Class 3B laser radiation. You must avoid exposure to the laser beam. Do not use if the outer casing is damaged. Return to Libelium. Removal of the external housing exposes the OPC circuitry which contains components that are sensitive to static discharge damage.

Note: *The Particle Matter (PM1 / PM2.5 / PM10) – Dust Sensor is available only for the Plug & Sense! line (socket D).*

5.4.1. Particle matter: the parameter

Particle matter is composed of small solid or liquid particles floating in the air. The origin of these particles can be the industrial activity, exhaust fumes from diesel motors, building heating, pollen, etc. This tiny particles enter our bodies when we breath. High concentrations of particle matter can be harmful for humans or animals, leading to respiratory and coronary diseases, and even lung cancer. That is why this is a key parameter for the Air Quality Index.

Some examples:

- Cat allergens: 0.1-5 µm
- Pollen: 10-100 µm
- Germs: 0.5-10 µm
- Oil smoke: 1-10 µm
- Cement dust: 5-100 µm
- Tobacco smoke: 0.01-1 µm

The smaller the particles are, the more dangerous, because they can penetrate more in our lungs. Many times, particles are classified:

- PM1: Mass (in µg) of all particles smaller than 1 µm, in 1 m^3.
- PM2.5: Mass (in µg) of all particles smaller than 2.5 µm, in 1 m^3.
- PM10: Mass (in µg) of all particles smaller than 10 µm, in 1 m^3.

Many countries and health organizations have studied the effect of the particle matter in humans, and they have set maximum thresholds. As a reference, the maximum allowed concentrations are about 20 µm/m^3 for PM2.5 and about 50 µm/m^3 for PM10.

5.4.2. Measurement process

Like conventional optical particle counters, the OPC-N2 measures the light scattered by individual particles carried in a sample air stream through a laser beam. These measurements are used to determine the particle size (related to the intensity of light scattered via a calibration based on Mie scattering theory) and particle number concentration. Particle mass loading- PM2.5 or PM10, are then calculated from the particle size spectra and concentration data, assuming density and refractive index. To generate the air stream, the OPC-N2 uses only a miniature low-power fan.

The OPC-N2 classifies each particle size, at rates up to ~10,000 particle per second, adding the particle diameter to one of 16 "bins" covering the size range from ~0.38 to 17 µm. The resulting particle size histograms can be evaluated over user-defined sampling times from **1 to 10 seconds duration**, the histogram data being transmitted along with other diagnostic and environmental data (air temperature and air pressure). When the histogram is read, the variables in the library are updated automatically. See the API section to know how to manage and read this sensor.

You can find a complete example code for reading the Particle Matter Sensor in the following link:
http://www.libelium.com/development/waspmote/examples/scp-v30-04-particle-matter-sensor

5.5. Noise / Sound Level Sensor

Figure : Noise / Sound Level Sensor

5.5.1. Specifications of the Sound Level Sensor probe

- **Target parameter:** LeqA
- **Microphone sensitivity:** 12.7 mV / Pa
- **Range of the sensor:** 50 dBA to 100 dBA
- **Accuracy:** +/-0.5dBA (1KHz)
- **Frequency range:** 20 Hz – 20 kHz
- Omni-directional microphone
- **A-weighting** measure
- Sound pressure level measurement (no weighting filter)
- **FAST** mode (125 ms) and **SLOW** mode (1 second), software configurable

5.5.2. Specifications of the enclosure

- **Material:** polycarbonate
- **Sealing:** polyurethane
- **Cover screws:** stainless steel
- **Ingress protection:** IP65
- **Impact resistance:** IK08
- **Rated insulation voltage AC:** 690 V
- **Rated insulation voltage DC:** 1000 V
- **Heavy metals-free**
- **Weatherproof:** true - nach UL 746 C
- **Ambient temperature (min.):** -10 °C
- **Ambient temperature (max.):** 50 °C
- **Approximated weight:** 800 g

5.5.3. Sound pressure level measurement

The sound pressure level or acoustic pressure level is a measure of the effective pressure of a sound relative to a reference value, normally referenced to pressure in air (20 µPa), which is considered as the threshold of the human hearing. The expression of the sound pressure level is defined by:

$$L_p = 20 \times \log\left(\frac{p_1}{p_0}\right)$$

Figure : Sound pressure level expression

Where *p* is the root mean square sound pressure and p_0 is the reference sound pressure (20 µPa). The next table shows some examples of different sound pressure measurements:

Sound sources examples	Sound pressure level (dB)	Sound pressure (Pa = N/m2)	Sound intensity (W/m2)
Threshold of pain	130	63.2	10
Threshold of discomfort	120	20	1
Airport	110	6.3	0.01
Factory	100	2	0.001
Heavy traffic	90	0.63	0.0001
Hair dryer	80	0.2	0.00001
Restaurant	70	0.063	0.000001
Conversation	60	0.02	0.0000001
Background noise	50	0.0063	0.00000001
Refrigerator	40	0.002	0.000000001
Library	30	0.00063	0.0000000001
Recording studio	20	0.0002	0.00000000001
Anechoic camber	10	0.000063	0.000000000001
Threshold of hearing	0	0.00002	0.0000000000001

5.5.4. Equivalent continuous sound level

The sound pressure level parameter, explained in the previous section, is not much used in noise measurements. Instead, an average value called L_{eq}, is used. Equivalent Continuous Sound Level (L_{eq}) is the average of the sound pressure level during a period of time. This value is very used when the noise level is varying quickly. Below the equation to calculate the L_{eq} value in decibels.

$$L_{eq} = 20 \times \log\left[\left(\frac{1}{(t2-t1)}\right)\int_{t1}^{t2}\left(\frac{p_1}{p_0}dt\right)\right]$$

The L_{eq} is the most used parameter by most countries for measuring the exposure to noise levels and earing damage risk. A better approximation to the human ear response is the LA_{eq} (equivalent continuous A-weighted sound pressure level). The A-weighting filter is described in the next section of this guide.

5.5.5. The A-weighting

The A-weighting is the most used curve of the family of curves defined by the IEC 61672 standard. It is very used for measuring environmental and industrial noise, due to the fact that the curve follows the frequency sensitivity of the human ear. Noise measurements made with the A-weighting scale are designated dBA. The A-weighting also predicts quite well the damage risk of the ear. The next graph shows the response of the A-weighting across the frequency range 10 Hz – 20 kHz.

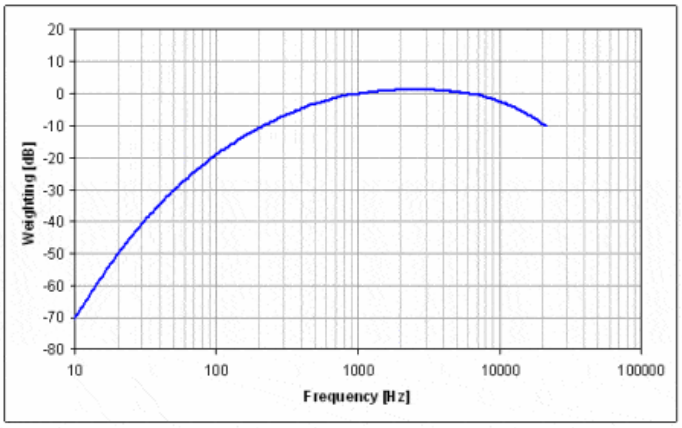


Figure : Graph of the A-weighting curve

5.5.6. International standard IEC 61672-1:2013

The new Noise / Sound Level Sensor has been designed following the specifications of the IEC 61672 standard for sound meters. Specifically with an accuracy of ±2 dBA similar to the Class 2 type devices. The value given is the LeqA (Equivalent continuous sound level, with A weighting) that allows to calculate the average sound pressure level during a period of time. Leq is often described as the average noise level during a noise measurement and it is the magnitude used for many regulations of noise control at work places and the street.

5.5.7. Measurement process

As mentioned previously, the Sound Level Sensor can only be used in combination with a Plug & Sense! Smart Cities PRO device. Once the sensor is connected following the previous steps, the Waspmote Plug & Sense! unit must be programmed for reading the sound pressure values.

You can find a complete example code for reading the temperature sensor in the following link:
http://www.libelium.com/development/waspmote/examples/scp-v30-08-noise-level-sensorg

5.5.8. Calibration Tests

In order to ensure the high quality of the Noise / Sound Level Sensor, each device is verified in an independent test laboratory.

Tests are performed inside an isolated anechoic chamber. The sound sensor probes are exposed to 5 different levels of white noise, created by a specialized sound generator and a cutting-edge, omni-directional speaker: 55, 65, 75, 85 and 95 dBA. The exact level is confirmed by the technician with a certified IEC 61672 soundmeter, placed at the same distance from the sound source than the 16 sensors. For each noise level, the output of each one of the 16 sensors is captured by a software system.

After those tests, an official test report is issued by the laboratory for every Noise / Sound Level Sensor, so the customer can verify the accuracy in dBA at different frequencies for each sound level probe. See below an example of this document.

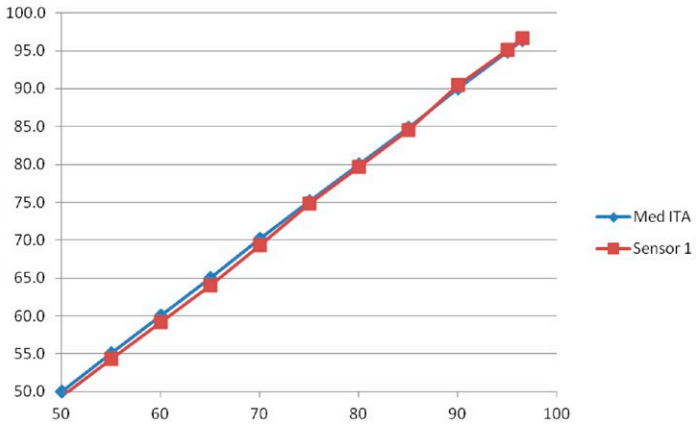


Figure : Example of test report obtained in the laboratory

Sound Level Tests

Test Report

Número: **C/080903I1**
Number

ARAGON INSTITUTE OF TECHNOLOGY
TESTING AND CALIBRATION LABORATORY

Next table shows the results obtained in tests with the sound level sensor probe labeled as: ID-0X0569872

Target reference level (dBA)	Real level, measured by certified soundmeter (dBA)	Measured by sound sensor: ID-0X0569872 (dBA)	Difference (dBA)
55	54.9	54.2	0.7
65	65.9	65.5	0.4
75	75.2	75	0.2
85	85.1	84.8	0.3
95	95.1	94.7	0.4

5.5.9. Mounting and suppling the Noise / Sound Level Sensor

Important: *The Noise Level Sensor has been designed to be used with the Waspmote Plug & Sense! Smart Cities PRO and it cannot be used independently. This sensor cannot be used on a Waspmote OEM with a Smart Cities PRO board, for example.*

The Sound Level Sensor consists of the next items shown in the figure below:

Figure : Noise Level Sensor items: 1 Noise Level Sensor. 2 Noise Level Sensor enclosure. 3 Power supply cable. 4 Data cable. 5 Protection cover

The images below show the different sockets of the Noise Level Sensor.

Figure : Identification of the connectors

Figure : Power supply connector

Figure : Noise Level Sensor probe

To connect the Sound Level Sensor probe to the enclosure, It should be taken into account that the sensor probe connector has only one matching position. The user should align the sensor probe connector looking at the little notch of the connector (see image below). Notice that the sensor connector is male-type and the enclosure sensor connector is female-type.

Figure : Detail of the sensor probe connector

Besides, there is a locking nut which should be screwed till the connector is completely fixed to the enclosure.

Figure : Connecting the sensor probe to the enclosure

After connecting the sensor, connect the the power supply cable to the USB connector, as shown in the picture below and the Noise Level Sensor will power up. Then, connect one end of data cable to the Sound Level Sensor and the other one to the associated Plug & Sense! Smart Cities PRO device.

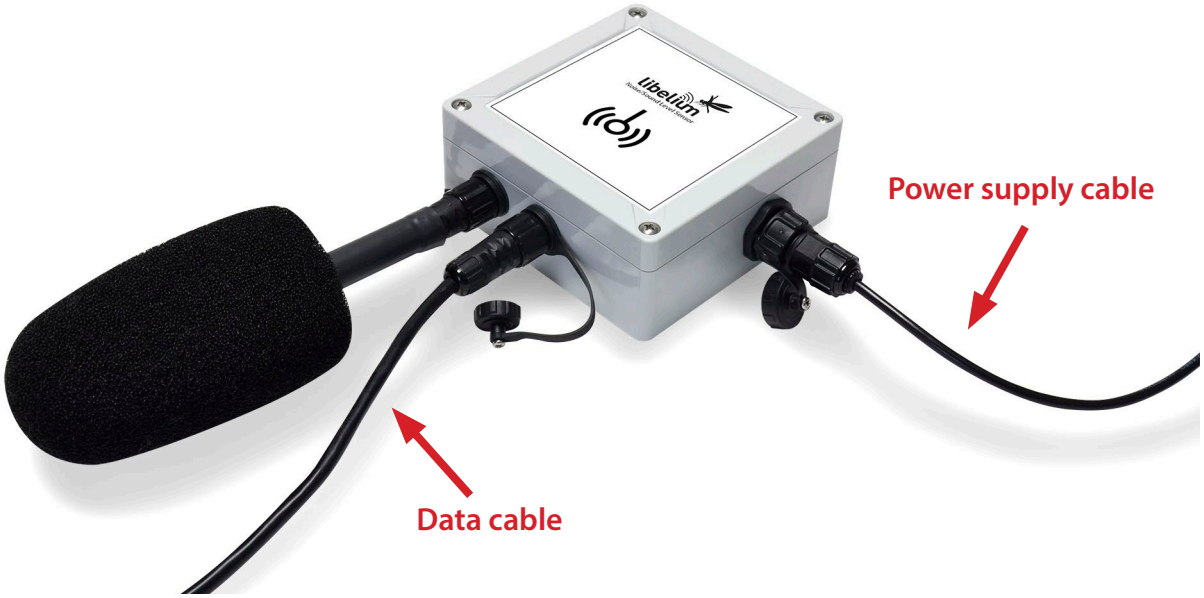


Figure : Connecting the data cable and the power supply cable to the Noise Level Sensor

Figure : Connecting the data cable to the associated Plug & Sense! Smart Cities device

Finally, the Noise Level Sensor can be installed outdoors in a streetlight or directly on a wall. The protection cover should be placed like the pictures below, to protect the Sound Level Sensor probe from the rain.

Figure : Installing the Noise Level Sensor on a wall

Notice that the power supply cable has a waterproof end, suitable for outdoor applications. But, on the other side, it has a non-waterproof end thought to be connected to a USB charger (AC/DC, 5 V output). Bear in mind that this end is not waterproof so it cannot be used outdoors. Please protect it accordingly.

A typical application is to power a node placed on the facade of a building; the power supply cables go indoors through a nearby window and the USB ends remain indoors, connected to a wall adapter. Many lampposts also have a 220 V output inside.

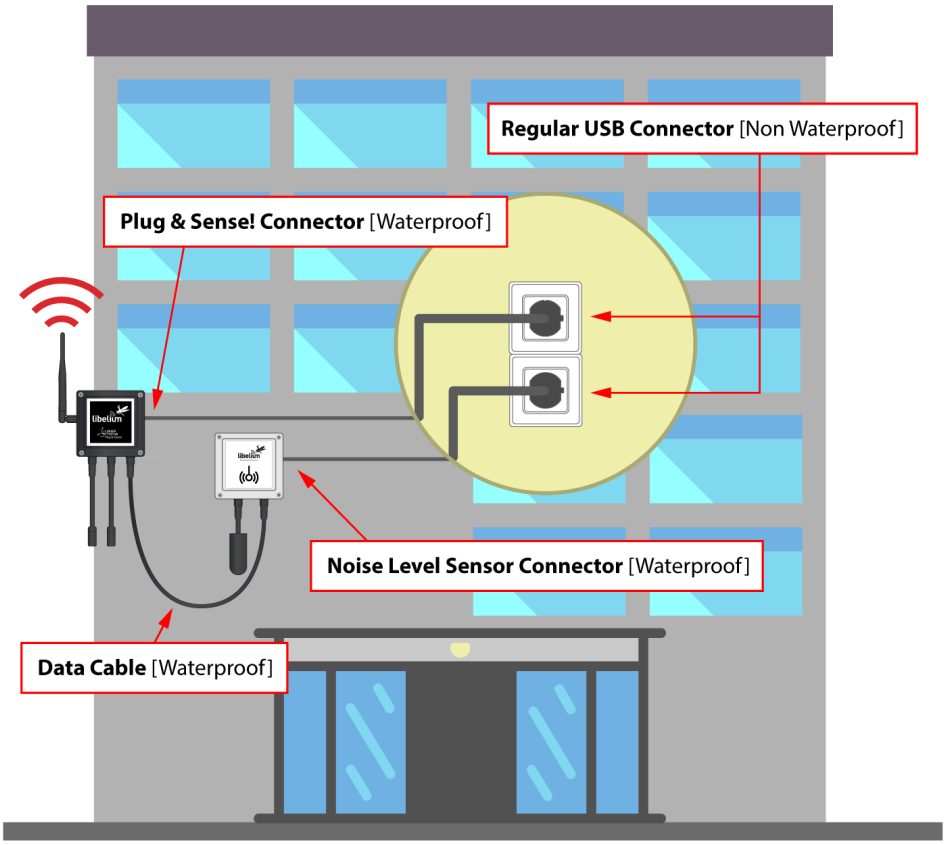


Figure : Typical installation of the Noise Level Sensor

5.6. Carbon Monoxide (CO) Gas Sensor for high concentrations [Calibrated]

5.6.1. Specifications

Figure : Image of the Carbon Monoxide Sensor mounted on its AFE module

Gas: CO
Sensor: 4-CO-500

Performance Characteristics
Nominal Range: 0 to 500 ppm
Maximum Overload: 2000 ppm
Long Term Output Drift: < 2% signal/month
Response Time (T90): ≤ 30 seconds
Sensitivity: 70 ± 15 nA/ppm
Accuracy: as good as ±1 ppm* (ideal conditions)

Operation Conditions
Temperature Range: -20 ºC to 50 ºC
Operating Humidity: 15 to 90% RH non-condensing
Pressure Range: 90 to 110 kPa
Storage Temperature: 0 ºC to 20 ºC
Expected Operating Life: 5 years in air

Sockets for Waspmote OEM:
- SOCKET_1
- SOCKET_3
- SOCKET_5

Sockets for Plug & Sense!:
- SOCKET_B
- SOCKET_C
- SOCKET_F

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. See the "Calibration" chapter in the Gases PRO Technical Guide for more detail.*

5.6.2. Cross-sensitivity data

Gas	Formula	Concentration (ppm)	Output Signal (ppm CO equivalent)
Hydrogen Sulfide	H_2S	24	0
Sulfur Dioxide	SO_2	5	0
Cholrine	Cl_2	10	0-1
Nitric Oxide	O_2	25	0
Nitric Dioxide	NO_2	5	0
Hydrogen	H_2	100	40
Ethylene	C_2H_4	100	16

Table : Cross-sensitivity data for the CO Sensor

You can find a complete example code for reading the CO Sensor in the following link:
www.libelium.com/development/waspmote/examples/scp-v30-01-electrochemical-gas-sensors

5.7. Carbon Monoxide (CO) Gas Sensor for low concentrations [Calibrated]

5.7.1. Specifications

Figure : Image of the Carbon Monoxide Sensor mounted on its AFE module

Gas: CO
Sensor: CO-A4

Performance Characteristics
Nominal Range: 0 to 25 ppm
Maximum Overload: 2000 ppm
Long Term Sensitivity Drift: < 10% change/year in lab air, monthly test
Long Term zero Drift: < ±100 ppb equivalent change/year in lab air
Response Time (T90): ≤ 20 seconds
Sensitivity: 220 to 375 nA/ppm
Accuracy: as good as ±0.1 ppm* (ideal conditions)
H2S filter capacity: 250000 ppm·hrs

Operation Conditions
Temperature Range: -30 ºC to 50 ºC
Operating Humidity: 15 to 90% RH non-condensing
Pressure Range: 80 to 120 kPa
Storage Temperature: 0 ºC to 20 ºC
Expected Operating Life: 3 years in air

Sockets for Waspmote OEM:
- SOCKET_1
- SOCKET_3
- SOCKET_5

Sockets for Plug & Sense!:
- SOCKET_B
- SOCKET_C
- SOCKET_F

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. See the "Calibration" chapter in the Gases PRO Technical Guide for more detail.*

5.7.2. Cross-sensitivity data

Gas	Formula	Concentration (ppm)	Output signal (ppm CO equivalent)
Hydrogen Sulfide	H_2S	5	< 0.1
Nitric Dioxide	NO_2	5	< -2
Chlorine	Cl_2	5	< 0.1
Nitric Oxide	NO	5	< -2
Sulfur Dioxide	SO_2	5	< 0.1
Hydrogen	H_2	100	< 10
Ethylene	C_2H_4	100	< 0.5
Ammonia	NH_3	20	< 0.1

Table : Cross-sensitivity data for the CO Sensor

You can find a complete example code for reading the CO Sensor in the following link:
www.libelium.com/development/waspmote/examples/scp-v30-01-electrochemical-gas-sensors

5.8. Carbon Dioxide (CO_2) Gas Sensor [Calibrated]

5.8.1. Specifications

Figure : Image of the Carbon Dioxide Sensor mounted on its AFE module

Gas: CO_2
Sensor: NE20-CO2P-NCVSP

Performance Characteristics
Nominal Range: 0 to 5000 ppm
Long Term Output Drift: < ± 250 ppm/year
Warm up time: 60 seconds @ 25 ºC
At least 30 min for full specification @ 25 °C
Response Time (T90): ≤ 60 seconds
Resolution: 25 ppm
Accuracy: as good as ±50 ppm*, from 0 to 2500 ppm range (ideal conditions)
as good as ±200 ppm*, from 2500 to 5000 ppm range (ideal conditions)

Operation Conditions
Temperature Range: -40 ºC to 60 ºC
Operating Humidity: 0 to 95%RH non-condensing
Storage Temperature: -40 ºC to 85 ºC
MTBF: ≥ 5 years

Sockets for Waspmote OEM:
- SOCKET_1

Sockets for Plug & Sense!:
- SOCKET_B
- SOCKET_C
- SOCKET_F

Average consumption: 80 mA

Note: *The CO_2 Sensor and the Methane (CH_4) and Combustible Gas Sensor have high power requirements and cannot work together in the same Smart Cities PRO Sensor Board. The user must choose one or the other, but not both.*

** Accuracy values are only given for the **optimum case**. See the "Calibration" chapter in the Gases PRO Technical Guide for more detail.*

You can find a complete example code for reading the CO_2 Sensor in the following link:
http://www.libelium.com/development/waspmote/examples/scp-v30-02-ndir-gas-sensors

5.9. Molecular Oxygen (O_2) Gas Sensor [Calibrated]

5.9.1. Specifications

Figure : Image of the Molecular Oxygen Sensor mounted on its AFE module

Gas: O_2
Sensor: 4-OL

Performance Characteristics
Nominal Range: 0 to 30 Vol.%
Maximum Overload: 90 Vol.%
Long Term Output Drift: < 2% signal/3 months
Response Time (T90): ≤ 30 seconds
Sensitivity: 1.66 ± 0.238 nA/ppm
Accuracy: as good as ± 0.1 % (ideal conditions)

Operation Conditions
Temperature Range: -20 ºC to 50 ºC
Operating Humidity: 5 to 90%RH non-condensing
Pressure Range: 90 to 110 kPa
Storage Temperature: 0 ºC to 20 ºC
Expected Operating Life: 2 years in air

Sockets for Waspmote OEM:
- SOCKET_1
- SOCKET_3
- SOCKET_5

Sockets for Plug & Sense!:
- SOCKET_B
- SOCKET_C
- SOCKET_F

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. See the "Calibration" chapter in the Gases PRO Technical Guide for more detail.*

You can find a complete example code for reading the O_2 Sensor in the following link:
www.libelium.com/development/waspmote/examples/scp-v30-01-electrochemical-gas-sensors

5.10. Ozone (O_3) Gas Sensor [Calibrated]

5.10.1. Specifications

Figure : Image of the Ozone Sensor mounted on its AFE module

Gas: O_3
Sensor: OX-A431

Performance Characteristics
Nominal Range: 0 to 18 ppm
Maximum Overload: 50 ppm
Long Term sensitivity Drift: -20 to -40% change/year
Response Time (T90): ≤ 45 seconds
Sensitivity: -200 to -550 nA/ppm
Accuracy: as good as ±0.2 ppm* (ideal conditions)
High cross-sensitivity with NO_2 gas. Correction could be necessary in ambients with NO_2.

Operation Conditions
Temperature Range: -30 ºC to 40 ºC
Operating Humidity: 15 to 85 %RH non-condensing
Pressure Range: 80 to 120 kPa
Storage Temperature: 3 ºC to 20 ºC
Expected Operating Life: > 24 months in air

Sockets for Waspmote OEM:
- SOCKET_1
- SOCKET_3
- SOCKET_5

Sockets for Plug & Sense!:
- SOCKET_B
- SOCKET_C
- SOCKET_F

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. See the "Calibration" chapter in the Gases PRO Technical Guide for more detail.*

5.10.2. Cross-sensitivity data

Gas	Formula	Concentration (ppm)	Output Signal (ppm CO equivalent)
Hydrogen Sulfide	H_2S	5	< 100
Nitric Dioxide	NO_2	5	70 to 120
Chlorine	Cl_2	5	< 30
Nitric Oxide	NO	5	< 3
Sulfur Dioxide	SO_2	5	< -6
Carbon Monoxide	CO	5	< 0.1
Hydrogen	H_2	100	<0.1
Ethylene	C_2H_4	100	< 0.1
Ammonia	NH_3	20	<0.1
Carbon Dioxide	CO_2	50000	0.1
Halothane	Halothane	100	< 0.1

Table : Cross-sensitivity data for the O_3 Sensor

*This sensor has a **very high cross-sensitivity with NO_2 gas**. So, the output in ambients with NO_2 will be a mix of O_3 and NO_2. A simple way to correct this effect is to subtract NO_2 concentration from O_3 concentration with an NO_2 gas sensor. The measure from the NO_2 sensor must be accurate in order to subtract the right value. **See the related section in the "Board configuration and programming" chapter to use the right function.***

You can find a complete example code for reading the O_3 Sensor in the following link:
www.libelium.com/development/waspmote/examples/scp-v30-01-electrochemical-gas-sensors

5.11. Nitric Oxide (NO) Gas Sensor for low concentrations [Calibrated]

5.11.1. Specifications

Figure : Image of the Nitric Oxide Sensor mounted on its AFE module

Gas: NO
Sensor: NO-A4

Performance Characteristics
Nominal Range: 0 to 18 ppm
Maximum Overload: 50 ppm
Long Term Sensitivity Drift: < 20% change/year in lab air, monthly test
Long Term zero Drift: 0 to 50 ppb equivalent change/year in lab air
Response Time (T90): ≤ 25 seconds
Sensitivity: 350 to 550 nA/ppm
Accuracy: as good as ±0.2 ppm* (ideal conditions)

Operation Conditions
Temperature Range: -30 ºC to 50 ºC
Operating Humidity: 15 to 85% RH non-condensing
Pressure Range: 80 to 120 kPa
Storage Temperature: 0 ºC to 20 ºC
Expected Operating Life: 2 years in air

Sockets for Waspmote OEM:
- SOCKET_1
- SOCKET_3
- SOCKET_5

Sockets for Plug & Sense!:
- SOCKET_B
- SOCKET_C
- SOCKET_F

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. See the "Calibration" chapter in the Gases PRO Technical Guide for more detail.*

5.11.2. Cross-sensitivity data

Gas	Formula	Concentration (ppm)	Output Signal (ppm NO equivalent)
Carbon Monoxide	CO	300	0
Sulfur Dioxide	SO_2	5	0
Nitric Dioxide	NO_2	5	1.5
Hydrogen Sulfide	H_2S	15	-1.5

Table : Cross-sensitivity data for the NO Sensor

You can find a complete example code for reading the NO Sensor in the following link:
www.libelium.com/development/waspmote/examples/scp-v30-01-electrochemical-gas-sensors

5.12. Nitric Dioxide (NO_2) high accuracy Gas Sensor [Calibrated]

5.12.1. Specifications

Figure : Image of the Nitric Dioxide Sensor mounted on its AFE module

Gas: NO_2
Sensor: NO2-A43F

Performance Characteristics
Nominal Range: 0 to 20 ppm
Maximum Overload: 50 ppm
Long Term Sensitivity Drift: < -20 to -40% change/year in lab air, monthly test
Long Term zero Drift: < 20 ppb equivalent change/year in lab air
Response Time (T90): ≤ 60 seconds
Sensitivity: -175 to -450 nA/ppm
Accuracy: as good as ±0.1 ppm* (ideal conditions)
O3 filter capacity @ 2 ppm: > 500 ppm·hrs

Operation Conditions
Temperature Range: -30 ºC to 40 ºC
Operating Humidity: 15 to 85% RH non-condensing
Pressure Range: 80 to 120 kPa
Storage Temperature: 0 ºC to 20 ºC
Expected Operating Life: 2 years in air

Sockets for Waspmote OEM:
- SOCKET_1
- SOCKET_3
- SOCKET_5

Sockets for Plug & Sense!:
- SOCKET_B
- SOCKET_C
- SOCKET_F

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. See the "Calibration" chapter in the Gases PRO Technical Guide for more detail.*

5.12.2. Cross-sensitivity data

Gas	Formula	Concentration (ppm)	Output Signal (ppm NO_2 equivalent)
Hydrogen Sulfide	H_2S	5	< -80
Nitric Oxide	NO	5	< 5
Chlorine	Cl_2	5	< 75
Sulfur Dioxide	SO_2	5	< -5
Carbon Monoxide	CO	5	< -5
Ethylene	C_2H_4	100	< 1
Ammonia	NH_3	20	< 0.2
Hydrogen	H_2	100	< 0.1
Carbon Dioxide	CO_2	5% vol	0.1
Halothane		100	nd

Table : Cross-sensitivity data for the NO_2 Sensor

You can find a complete example code for reading the NO_2 Sensor in the following link:
www.libelium.com/development/waspmote/examples/scp-v30-01-electrochemical-gas-sensors

5.13. Sulfur Dioxide (SO_2) high accuracy Gas Sensor [Calibrated]

5.13.1. Specifications

Figure : Image of the Sulfur Dioxide Sensor mounted on its AFE module

Gas: SO_2
Sensor: SO2-A4

Performance Characteristics
Nominal Range: 0 to 20 ppm
Maximum Overload: 100 ppm
Long Term Sensitivity Drift: < ±15% change/year in lab air, monthly test
Long Term zero Drift: <±20 ppb equivalent change/year in lab air
Response Time (T90): ≤ 20 seconds
Sensitivity: 320 to 480 nA/ppm
Accuracy: as good as ±0.1 ppm* (ideal conditions)

Operation Conditions
Temperature Range: -30 ºC to 50 ºC
Operating Humidity: 15 to 90% RH non-condensing
Pressure Range: 80 to 120 kPa
Storage Temperature: 0 ºC to 20 ºC
Expected Operating Life: 2 years in air

Sockets for Waspmote OEM:
- SOCKET_1
- SOCKET_3
- SOCKET_5

Sockets for Plug & Sense!:
- SOCKET_B
- SOCKET_C
- SOCKET_F

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. See the "Calibration" chapter in the Gases PRO Technical Guide for more detail.*

5.13.2. Cross-sensitivity data

Gas	Formula	Concentration (ppm)	Output Signal (ppm SO_2 equivalent)
Hydrogen Sulfide	H_2S	5	< 40
Nitric Oxide	NO	5	< -160
Chlorine	Cl_2	5	< -70
Sulfur Dioxide	SO_2	5	< -1.5
Carbon Monoxide	CO	5	< 2
Hydrogen	H_2	100	< 1
Ethylene	C_2H_4	100	< 1
Ammonia	NH_3	20	< 0.1
Carbon Dioxide	CO_2	5% vol.	< 0.1

Table : Cross-sensitivity data for the SO_2 Sensor

You can find a complete example code for reading the SO_2 Sensor in the following link:
www.libelium.com/development/waspmote/examples/scp-v30-01-electrochemical-gas-sensors

5.14. Ammonia (NH_3) Gas Sensor [Calibrated]

5.14.1. Specifications

Figure : Image of the Ammonia Sensor mounted on its AFE module

Gas: NH_3
Sensor: 4-NH3-100

Performance Characteristics
Nominal Range: 0 to 100 ppm
Long Term Output Drift: < 2% signal/month
Response Time (T90): ≤ 90 seconds
Sensitivity: 135 ± 35 nA/ppm
Accuracy: as good as ±0.5 ppm* (ideal conditions)

Operation Conditions
Temperature Range: -20 ºC to 50 ºC
Operating Humidity: 15 to 90%RH non-condensing
Pressure Range: 90 to 110 kPa
Storage Temperature: 0 ºC to 20 ºC
Expected Operating Life: ≥1 year in air

Sockets for Waspmote OEM:
- SOCKET_1
- SOCKET_3
- SOCKET_5

Sockets for Plug & Sense!:
- SOCKET_B
- SOCKET_C
- SOCKET_F

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. See the "Calibration" chapter in the Gases PRO Technical Guide for more detail.*

5.14.2. Cross-sensitivity data

Gas	Formula	Concentration (ppm)	Output Signal (ppm NH_3 equivalent)
Carbon Monoxide	CO	300	0
Hydrogen Sulfide	H_2S	5	1.5
Carbon dioxide	CO_2	5	-3
Hydrogen	H_2	15	30
Isobutylene		35	-1
Ethanol		100	0

Table : Cross-sensitivity data for the NH_3 Sensor

You can find a complete example code for reading the NH_3 Sensor in the following link:
www.libelium.com/development/waspmote/examples/scp-v30-01-electrochemical-gas-sensors

5.15. Methane (CH_4) and Combustible Gas Sensor [Calibrated]

5.15.1. Specifications

Figure : Image of the Methane (CH_4) and Combustible Gas Sensor (pellistor) mounted on its AFE module

Main gas: Methane CH_4
Sensor: CH-A3

Performance Characteristics
Nominal Range: 0 to 100% LEL methane
Long Term Output Drift: < 2% signal/month
Response Time (T90): ≤ 30 seconds
Accuracy: as good as ±0.15% LEL* (ideal conditions)

Operation Conditions
Temperature Range: -40 ºC to 55 ºC
Expected Operating Life: 2 years in air

Inhibition/Poisoning

Gas	Conditions	Effect
Chlorine	12hrs 20ppm Cl_2, 50 % sensitivity loss, 2 day recovery	< 10% loss
Hydrogen Sulfide	12hrs 40ppm H_2S, 50 % sensitivity loss, 2 day recovery	< 50% loss
HMDS	9 hrs @ 10ppm HMDS	50% activity loss

Table : Inhibition and poisoning effects

Sockets for Waspmote OEM:
- SOCKET_1

Sockets for Plug & Sense!:
- SOCKET_B
- SOCKET_C
- SOCKET_F

Average consumption: 68 mA

Note: *The Methane (CH_4) and Combustible Gas Sensor and the CO2 Sensor have high power requirements and cannot work together in the same Smart Cities PRO Sensor Board. The user must choose one or the other, but not both.*

** Accuracy values are only given for the **optimum case**. See the "Calibration" chapter in the Gases PRO Technical Guide for more detail.*

5.15.2. Sensitivity data

Hydrocarbon/Gas	% Sensitivity relative to Methane	% LEL Sensitivity to Methane
Hydrogen	130 to 140	160 to 175
Propane	150 to 190	350 to 450
Butane	150 to 180	420 to 500
n-Pentane	180 to 200	600 to 670
Nonane	150 to 170	800 to 950
Carbon Monoxide	42 to 44	17 to 18
Acetylene	150 to 170	300 to 340
Ethylene	150 to 170	270 to 320
Isobutylene	180 to 200	450 to 500

Table : Sensitivity data for the CH_4 and Combustible Gases Sensor

You can find a complete example code for reading the Methane (CH_4) and Combustible Gases Sensor in the following link:
http://www.libelium.com/development/waspmote/examples/scp-v30-03-pellistor-gas-sensors

5.16. Molecular Hydrogen (H_2) Gas Sensor [Calibrated]

5.16.1. Specifications

Figure : Image of the Molecular Hydrogen Sensor mounted on its AFE module

Gas: H_2
Sensor: 4-H2-1000

Performance Characteristics
Nominal Range: 0 to 1000 ppm
Maximum Overload: 2000 ppm
Long Term Output Drift: < 2% signal/month
Response Time (T90): ≤ 70 seconds
Sensitivity: 20 ± 10 nA/ppm
Accuracy: as good as ±10 ppm* (ideal conditions)

Operation Conditions
Temperature Range: -20 ºC to 50 ºC
Operating Humidity: 15 to 90%RH non-condensing
Pressure Range: 90 to 110 kPa
Storage Temperature: 0 ºC to 20 ºC
Expected Operating Life: 2 years in air

Sockets for Waspmote OEM:
- SOCKET_1
- SOCKET_3
- SOCKET_5

Sockets for Plug & Sense!:
- SOCKET_B
- SOCKET_C
- SOCKET_F

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. See the "Calibration" chapter in the Gases PRO Technical Guide for more detail.*

5.16.2. Cross-sensitivity data

Gas	Formula	Concentration (ppm)	Output Signal (ppm H_2 equivalent)
Hydrogen Sulfide	H_2S	24	0
Sulfur Dioxide	SO_2	5	0
Nitric Oxide	NO	35	10
Nitric Dioxide	NO_2	5	0
Carbon Monoxide	CO	50	200
Ethylene	C_2H_4	100	80
Chlorine	Cl_2	10	0

Table : Cross-sensitivity data for the H_2 Sensor

You can find a complete example code for reading the H_2 Sensor in the following link:
www.libelium.com/development/waspmote/examples/scp-v30-01-electrochemical-gas-sensors

5.17. Hydrogen Sulfide (H_2S) Gas Sensor [Calibrated]

5.17.1. Specifications

Gas: H_2S
Sensor: 4-H2S-100

Figure : Image of the Hydrogen Sulfide Sensor mounted on its AFE module

Performance Characteristics
Nominal Range: 0 to 200 ppm
Maximum Overload: 50 ppm
Long Term Output Drift: < 2% signal/month
Response Time (T90): ≤ 20 seconds
Sensitivity: 800 ± 200 nA/ppm
Accuracy: as good as ±0.1 ppm* (ideal conditions)

Operation Conditions
Temperature Range: -20 ºC to 50 ºC
Operating Humidity: 15 to 90%RH non-condensing
Pressure Range: 90 to 110 kPa
Storage Temperature: 0 ºC to 20 ºC
Expected Operating Life: 2 years in air

Sockets for Waspmote OEM:
- SOCKET_1
- SOCKET_3
- SOCKET_5

Sockets for Plug & Sense!:
- SOCKET_B
- SOCKET_C
- SOCKET_F

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. See the "Calibration" chapter in the Gases PRO Technical Guide for more detail.*

5.17.2. Cross-sensitivity data

Gas	Formula	Concentration (ppm)	Output Signal (ppm H_2S equivalent)
Carbon Monoxide	CO	50	≤6
Sulfur Dioxide	SO_2	5	1
Nitric Oxide	NO	35	1
Nitric Dioxide	NO_2	5	-1
Hydrogen	H_2	10000	25
Ethylene	C_2H_4	100	0
Ethanol	C_2H_6O	5000	±1.5

Table : Cross-sensitivity data for the H_2S Sensor

You can find a complete example code for reading the H_2S Sensor in the following link:
www.libelium.com/development/waspmote/examples/scp-v30-01-electrochemical-gas-sensors

5.18. Hydrogen Chloride (HCl) Gas Sensor [Calibrated]

5.18.1. Specifications

Figure : Image of the Hydrogen Chloride Sensor mounted on its AFE module

Gas: HCl
Sensor: 4-HCl-50

Performance Characteristics
Nominal Range: 0 to 50 ppm
Maximum Overload: 100 ppm
Long Term Output Drift: < 2% signal/month
Response Time (T90): ≤ 70 seconds
Sensitivity: 300 ± 100 nA/ppm
Accuracy: as good as ±1 ppm* (ideal conditions)

Operation Conditions
Temperature Range: -20 ºC to 50 ºC
Operating Humidity: 15 to 90%RH non-condensing
Pressure Range: 90 to 110 kPa
Storage Temperature: 0 ºC to 20 ºC
Expected Operating Life: 2 years in air

Sockets for Waspmote OEM:
- SOCKET_1
- SOCKET_3
- SOCKET_5

Sockets for Plug & Sense!:
- SOCKET_B
- SOCKET_C
- SOCKET_F

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. See the "Calibration" chapter in the Gases PRO Technical Guide for more detail.*

5.18.2. Cross-sensitivity data

Gas	Formula	Concentration (ppm)	Output Signal (ppm HCl equivalent)
Hydrogen	H_2	2000	0
Carbon Monoxide	CO	100	0
Nitric Oxide	NO	20	50
Nitric Dioxide	NO_2	10	1
Hydrogen Sulfide	H_2S	25	130
Sulfur Dioxide	SO_2	20	35
Nitrogen	N	1000000	0

Table : Cross-sensitivity data for the HCl Sensor

You can find a complete example code for reading the HCl Sensor in the following link:
www.libelium.com/development/waspmote/examples/scp-v30-01-electrochemical-gas-sensors

5.19. Hydrogen Cyanide (HCN) Gas Sensor [Calibrated]

5.19.1. Specifications

Figure : Image of the Hydrogen Cyanide Sensor mounted on its AFE module

Gas: HCN
Sensor: 4-HCN-50

Performance Characteristics
Nominal Range: 0 to 50 ppm
Maximum Overload: 100 ppm
Long Term Output Drift: < 2% signal/month
Response Time (T90): ≤ 120 seconds
Sensitivity: 100 ± 20 nA/ppm
Accuracy: as good as ±0.2 ppm* (ideal conditions)

Operation Conditions
Temperature Range: -20 ºC to 50 ºC
Operating Humidity: 15 to 90%RH non-condensing
Pressure Range: 90 to 110 kPa
Storage Temperature: 0 ºC to 20 ºC
Expected Operating Life: 2 years in air

Sockets for Waspmote OEM:
- SOCKET_1
- SOCKET_3
- SOCKET_5

Sockets for Plug & Sense!:
- SOCKET_1
- SOCKET_3
- SOCKET_5

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. See the "Calibration" chapter in the Gases PRO Technical Guide for more detail.*

5.19.2. Cross-sensitivity data

Gas	Formula	Concentration (ppm)	Output Signal (ppm HCN equivalent)
Carbon Monoxide	CO	300	0
Sulfur Dioxide	SO_2	5	1.5
Nitric Dioxide	NO_2	5	-3
Hydrogen Sulfide	H_2S	15	30
Nitric Oxide	NO	35	-1
Ethylene	C_2H_4	100	0

Table : Cross-sensitivity data for the HCN Sensor

You can find a complete example code for reading the HCN Sensor in the following link:
www.libelium.com/development/waspmote/examples/scp-v30-01-electrochemical-gas-sensors

5.20. Phosphine (PH_3) Gas Sensor [Calibrated]

5.20.1. Specifications

Figure : Image of the Phosphine Gas Sensor mounted on its AFE module

Gas: PH_3
Sensor: 4-PH3-20

Performance Characteristics
Nominal Range: 0 to 20 ppm
Maximum Overload: 100 ppm
Long Term Output Drift: < 2% signal/month
Response Time (T90): ≤ 60 seconds
Sensitivity: 1400 ± 600 nA/ppm
Accuracy: as good as ±0.1 ppm* (ideal conditions)

Operation Conditions
Temperature Range: -20 ºC to 50 ºC
Operating Humidity: 15 to 90%RH non-condensing
Pressure Range: 90 to 110 kPa
Storage Temperature: 0 ºC to 20 ºC
Expected Operating Life: 2 years in air

Sockets for Waspmote OEM:
- SOCKET_1
- SOCKET_3
- SOCKET_5

Sockets for Plug & Sense!:
- SOCKET_B
- SOCKET_C
- SOCKET_F

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. See the "Calibration" chapter in the Gases PRO Technical Guide for more detail.*

5.20.2. Cross-sensitivity data

Gas	Formula	Concentration (ppm)	Output Signal (ppm PH_3 equivalent)
Carbon Monoxide	CO	1000	0
Hydrogen Sulfide	H_2S	15	12
Sulfur Dioxide	SO_2	5	0.9
Hydrogen	H_2	1000	0
Ethylene	C_2H_4	100	0
Ammonia	NH_3	50	0

Table : Cross-sensitivity data for the PH_3 Sensor

You can find a complete example code for reading the PH_3 Sensor in the following link:
www.libelium.com/development/waspmote/examples/scp-v30-01-electrochemical-gas-sensors

5.21. Ethylene Oxide (ETO) Gas Sensor [Calibrated]

5.21.1. Specifications

Figure : Image of the Ethylene Oxide Sensor mounted on its AFE module

Gas: ETO
Sensor: 4-ETO-100

Performance Characteristics
Nominal Range: 0 to 100 ppm
Long Term Sensitivity Drift: < 2% signal/month
Response Time (T90): ≤ 120 seconds
Sensitivity: 250 ± 125 nA/ppm
Accuracy: as good as ±1 ppm* (ideal conditions)

Operation Conditions
Temperature Range: -20 ºC to 50 ºC
Operating Humidity: 15 to 90%RH non-condensing
Pressure Range: 90 to 110 kPa
Storage Temperature: 0 ºC to 20 ºC
Expected Operating Life: 5 years in air

Sockets for Waspmote OEM:
- SOCKET_1
- SOCKET_3
- SOCKET_5

Sockets for Plug & Sense!:
- SOCKET_B
- SOCKET_C
- SOCKET_F

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. See the "Calibration" chapter in the Gases PRO Technical Guide for more detail.*

5.21.2. Cross-sensitivity data

Gas	Formula	Sensitivity of ETO/Sensitivity of test gas
Ethylene Oxide	ETO	1.0
Carbon Monoxide	CO	2.5
Ethanol	C_2H_6O	2.0
Methanol	CH_4O	0.5
Isopropanol	C_3H_8O	5.0
i-Butylene		2.5
Butadiene	C_4H_6	0.9
Ethylene	C_2H_4	0.8
Propene	C_3H_6	1.7
Vinyl Chloride	C_2H_3Cl	1.3
Vinyl Acetate	$C_4H_6O_2$	2.0
Formic Acid	CH_2O_2	3.3
Ethyl ether	$(C_2H_5)_2O$	2.5
Formaldehyde	CH_2O	1.0

Table : Cross-sensitivity data for the ETO Sensor

You can find a complete example code for reading the ETO Sensor in the following link:
www.libelium.com/development/waspmote/examples/scp-v30-01-electrochemical-gas-sensors

5.22. Chlorine (Cl_2) Gas Sensor [Calibrated]

5.22.1. Specifications

Figure : Image of the Chlorine Sensor mounted on its AFE module

Gas: Cl_2
Sensor: 4-Cl2-50

Performance Characteristics
Nominal Range: 0 to 50 ppm
Maximum Overload: 100 ppm
Long Term Output Drift: < 2% signal/month
Response Time (T90): ≤ 30 seconds
Sensitivity: 450 ± 200 nA/ppm
Accuracy: as good as ±0.1 ppm* (ideal conditions)

Operation Conditions
Temperature Range: -20 ºC to 50 ºC
Operating Humidity: 15 to 90%RH non-condensing
Pressure Range: 90 to 110 kPa
Storage Temperature: 0 ºC to 20 ºC
Expected Operating Life: 2 years in air

Sockets for Waspmote OEM:
- SOCKET_1
- SOCKET_3
- SOCKET_5

Sockets for Plug & Sense!:
- SOCKET_B
- SOCKET_C
- SOCKET_F

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. See the "Calibration" chapter in the Gases PRO Technical Guide for more detail.*

5.22.2. Cross-sensitivity data

Gas	Formula	Concentration (ppm)	Output Signal (ppm Cl_2 equivalent)
Hydrogen Sulfide	H_2S	20	-4
Carbon Monoxide	CO	100	0
Sulfur Dioxide	SO_2	20	0
Nitric Oxide	NO	35	0
Nitric Dioxide	NO_2	10	12
Hydrogen	H_2	3000	0
Ammonia	NH_3	100	0
Carbon Dioxide	CO_2	10000	0
Chlorine Dioxide	ClO_2	1	3.5

Table : Cross-sensitivity data for the Cl_2 Sensor

You can find a complete example code for reading the Cl_2 Sensor in the following link:
www.libelium.com/development/waspmote/examples/scp-v30-01-electrochemical-gas-sensors

5.23. Important notes for Calibrated Sensors

1º - Calibrated gas sensors are manufactured once the order has been placed to ensure maximum durability of the calibration feature. Libelium keeps a minimum stock of calibrated gas sensors to ensure the maximum durability. Ensambling process and delivery time takes from 1 to 2 weeks in case the current stock is enough for the order and from 4 to 6 weeks in case the order is higher than the stock available and new sensors units need to be manufactured and calibrated. Please inform as soon as possible of your sensor requirements to our Sales agents so that they can order the units needed to factory.

2º - Lifetime of calibrated gas sensors is 6 months working at its maximum accuracy as every sensor looses a small percentage of its original calibration monthly in a range that may go from 0.5% to 2% (depending on the external conditions: humidity, temperature, measured gas concentration, if there are another type of gas present which corrode the sensor, etc). We strongly encourage our customers to buy extra gas sensor probes to replace the originals after that time to ensure maximum accuracy and performance. Any sensor should be understood as a disposable item; that means that after some months it should be replaced by a new unit.

3º - Electrochemical calibrated gas sensors are a good alternative to the professional metering gas stations however they have some limitations. The most important parameters of each sensor are the nominal range and the accuracy. If you need to reach an accuracy of ±0.1 ppm remember not to choose a sensor with an accuracy of ±1 ppm. Take a look in the chapter dedicated to each sensor in the Gases PRO Guide (Development section on the Libelium website). We show a summary table at the end of the current document for quick reference.

4º - Libelium indicates an accuracy for each sensor just as an **ideal reference** (for example, "±0.1 ppm"). This theoretical figure has been calculated as the best error the user could expect, the optimum case. In real conditions, the measurement error **may be bigger** (for example, "±0.3 ppm"). The older the sensor is, the more deteriorated it is, so the accuracy gets worse. Also, the more extreme the concentration to meter is, the worse the accuracy is. And also, the more extreme the environmental conditions are, the quicker the sensor decreases its accuracy.

5º - In order to increase the accuracy and reduce the response time we strongly recommend to keep the gas sensor board ON as electrochemical sensors have a very low consumption (less than 1 mA). So these sensors should be left powered ON while Waspmote enters into deepsleep mode. Latest code examples implement in the new API of Waspmote v15 follow this strategy. If you are using the old version of the API and boards (v12) write in our Forum and we will help you to modify your code.

6º - These sensors need a stabilization time to work properly, in some cases hours. We recommend wait 24hours of functioning (always with the gas sensor board ON) to ensure that the values of the sensors are stable.

7º - AFE boards for electrochemical gas sensors have different gain options. The system integrator must choose the adequate gain according to the concentration range to measure. For low concentrations, higher gains are recommended. To know how choosing the right gain, see the chapter "How to choose the right gain resistor" from the Gases PRO Guide.

8º - A digital smoothing filter based on previous values is interesting to reduce noise. It will increase the accuracy of the gases PRO sensors. The filter adequate for its application (note that every sample given by the library has already been filtered inside Waspmote) means from 4 to 8 values.

A simple moving average can be used to increase the accuracy and reduce the noise.

$$\text{Filtered value} = \frac{\text{sample}_t + \text{sample}_{t-1} + \text{sample}_{t-2} + \ldots + \text{sample}_{t-(n-1)}}{n}$$

Where:

- Filtered value are the concentration value with the mean filter applied
- sample are the measurements taken by the gas sensors being $sample_t$ the last measurement, $sample_{t-1}$ the penultimate measurement, etc.
- *n* are the number of samples to calculate the moving mean.

Other filters can be applied according to the project requirements.

9º - Take into account that developing a robust application for gases detection or measurement may take an important effort of testing and knowing the insights of the sensor probes and code that reads them.

6. Board configuration and programming

6.1. Hardware configuration

The Smart Cities PRO board does not require of any handling of the hardware by the user except for placing the sensors in their corresponding position. In the section dedicated to each connector we can see an image of the connections between the socket and its corresponding sensor.

6.2. API

6.2.1. Before starting to program

When using the Smart Cities PRO Sensor Board on Waspmote, remember it is mandatory to include the WaspSensorCities_Pro library by introducing the next line at the beginning of the code:

```
#include <WaspSensorCities_PRO.h>
```

The library manages the power supply and communication lines between Waspmote and the sockets. To manage each sensor the user must use the specific library and guide for each sensor.

6.2.2. Turning on the sockets

Before to use a sensor, the user must switch on the socket where the sensor is placed. To do that, function `ON(SOCKET)` must be used. The input parameters for the function are: `SOCKET_1`, `SOCKET_2`, `SOCKET_3`, `SOCKET_4`, `SOCKET_5`, `SOCKET_A`, `SOCKET_B`, `SOCKET_C`, `SOCKET_E`, `SOCKET_F`. This function powers on the power supply lines (3.3 V) and enables the communication with the sensor.

```
{
  // Turns ON the socket 2
  SensorCitiesPRO.ON(SOCKET_2);
```

Once the socket has been enabled, the sensor can be used. The Noise Level and Particle Matter sensors are exceptions and do not need to turn on any socket.

6.2.3. Turning off the sockets

To switch off the power supply lines (3.3 V) and the comunication with socket, the user must use the function `OFF(SOCKET)`. The input parameters for the function are: `SOCKET_1`, `SOCKET_2`, `SOCKET_3`, `SOCKET_4`, `SOCKET_5`, `SOCKET_A SOCKET_B`, `SOCKET_C`, `SOCKET_E`, `SOCKET_F`.

```
{
  // Turns off the socket A
  SensorCitiesPRO.OFF(SOCKET_A);
```

The Noise Level and the Particle Matter sensors are exceptions and do not need to turn off any socket.

7. Consumption

7.1. Consumption table

In the following table, the consumption shown by the board when active is detailed, the minimum consumption (constant, fixed by the permanently active components, such as the adaptation electronics) and the individual consumptions of each of the sensors connected alone to the board (the total consumption of the board with a determined sensor will be calculated as the sum of the constant minimum consumption of the board plus the minimum consumption of the group to whom the sensor belongs plus the consumption of the sensor).

Remember that the board's power can be completely disconnected, reducing the consumption to zero, powering off all the sensors.

Sensor	Switch on
Minimum (constant, due to the Sensor Board)	4-6 µA
Temperature, Humidity and Pressure	2.8 – 4.2 µA
Luminosity	240 µA
Ultrasound	2 mA (50 mA peaks)
Carbon Monoxide (CO) for high concentrations	351 µA
Carbon Monoxide (CO) for low concentrations	312 µA
Carbon Dioxide (CO2)	85 mA
Molecular Oxygen (O2)	332 µA
Ozone (O3)	<1 mA
Nitric Oxide (NO) for low concentrations	392 µA
Nitric Dioxide high accuracy (NO2)	330 µA
Sulfur Dioxide high accuracy (SO2)	280 µA
Ammonia (NH3)	338 µA
Methane (CH4) and other combustible gases	68 mA
Molecular Hydrogen (H2)	520 µA
Hydrogen Sulfide (H2S)	352 µA
Hydrogen Chloride (HCl)	341 µA
Hydrogen Cyanide (HCN)	327 µA
Phosphine (PH3)	361 µA
Ethylene Oxide (ETO)	360 µA
Chlorine (Cl2)	353 µA
Particle Matter – Dust	260 mA @ 5 V

Table : Consumption for each sensor

8. API changelog

Keep track of the software changes on this link:
www.libelium.com/development/waspmote/documentation/changelog/#SmartCities

9. Documentation changelog

From v7.0 to v7.1:

- Added references to the integration of Industrial Protocols for Plug & Sense!

10. Maintenance

- In this section, the term "Waspmote" encompasses both the Waspmote device itself as well as its modules and sensor boards.
- Take care with the handling of Waspmote, do not drop it, bang it or move it sharply.
- Avoid putting the devices in areas of high temperatures since the electronic components may be damaged.
- The antennas are lightly threaded to the connector; do not force them as this could damage the connectors.
- Do not use any type of paint for the device, which may damage the functioning of the connections and closure mechanisms.

11. Disposal and recycling

- In this section, the term "Waspmote" encompasses both the Waspmote device itself as well as its modules and sensor boards.
- When Waspmote reaches the end of its useful life, it must be taken to a recycling point for electronic equipment.
- The equipment has to be disposed on a selective waste collection system, different to that of urban solid waste. Please, dispose it properly.
- Your distributor will inform you about the most appropriate and environmentally friendly waste process for the used product and its packaging.

12. Certifications

Libelium offers 2 types of IoT sensor platforms, Waspmote OEM and Plug & Sense!:

- **Waspmote OEM** is intended to be used for research purposes or as part of a major product so it needs final certification on the client side. More info at: www.libelium.com/products/waspmote
- **Plug & Sense!** is the line ready to be used out-of-the-box. It includes market certifications. See below the specific list of regulations passed. More info at: www.libelium.com/products/plug-sense

Besides, Meshlium, our multiprotocol router for the IoT, is also certified with the certifications below. Get more info at:

www.libelium.com/products/meshlium

List of certifications for Plug & Sense! and Meshlium:

- CE (Europe)
- FCC (US)
- IC (Canada)
- ANATEL (Brazil)
- RCM (Australia)
- PTCRB (cellular certification for the US)
- AT&T (cellular certification for the US)

Figure : Certifications of the Plug & Sense! product line

You can find all the certification documents at:

www.libelium.com/certifications