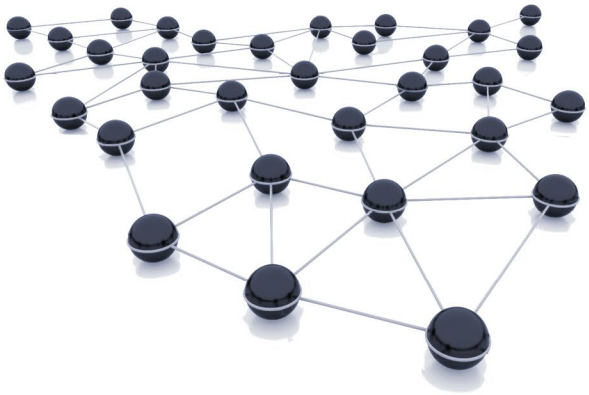
Waspmote Plug & Sense!

Sensor Guide



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wasp mote
Plug & Sense!

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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/plug-sense

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

2. Introduction

In this document, all the possible configurations of the Plug & Sense! line are described, including a general description of all the possible applications and the technical specifications of the sensors associated to each one of them.

For a deep description of the characteristics of the Plug & Sense! line, please refer to the Waspmote Plug & Sense! Technical Guide. You can find it, along with other useful information such as the Waspmote and Sensor boards technical and programming guides, in the Development section of the Libelium website at http://www.libelium.com/development/plug-sense

For detailed info about sensors or probes we do NOT recommend this Guide, but the dedicated guide for the sensor board. Example: if you have a Plug & Sense! Smart Cities PRO, we advise reading the Smart Cities PRO Technical Guide.

Note that no code for reading the sensors has been included in this guide. For programming the Waspmote Plug & Sense! notes, please use the default examples provided for each sensor, available at: http://www.libelium.com/development/plug-sense/examples/

Figure: Waspmote Plug & Sense! line

3. Sensors

Figure: Image of Waspmote Plug & Sense!

3.1. Internal sensors

3.1.1. Accelerometer

Waspmote has a built-in acceleration sensor LIS3331LDH, by STMicroelectronics, which informs the mote of acceleration variations experienced on each one of the 3 axes (X,Y, Z).

The integration of this sensor allows the measurement of acceleration on the 3 axes (X, Y, Z), establishing 4 kinds of events: Free Fall, inertial wake up, 6D movement and 6D position which are explained in the **Interruption Programming Guide**.

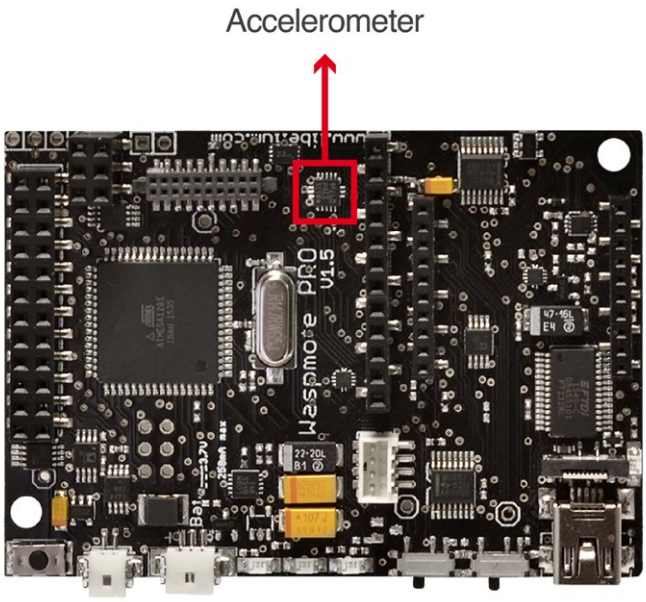


Figure: Accelerometer

The LIS331DLH has dynamically user-selectable full scales of **±2g/±4g/±8g** and it is capable of measuring accelerations with output data rates from **0.5 Hz to 1 kHz**.

The device features ultra low-power operational modes that allow advanced power saving and smart sleep to wake-up functions.

The accelerometer has several power modes, the output data rate (ODR) will depend on the power mode selected. The power modes and output data rates are shown in this table:

Power mode	Output data rate (Hz)
Power down	--
Normal mode	1000
Low-power 1	0.5
Low-power 2	1
Low-power 3	2
Low-power 4	5
Low-power 5	10

This accelerometer has an auto-test capability that allows the user to check the functioning of the sensor in the final application. Its operational temperature range is between -40 ºC and +85 ºC.

The accelerometer communicates with the microcontroller through the I2C interface. The pins that are used for this task are the SCL pin and the SDA pin, as well as another interruption pin to generate the interruptions.

The accelerometer has 4 types of event which can generate an interrupt: free fall, inertial wake up, 6D movement and 6D position.

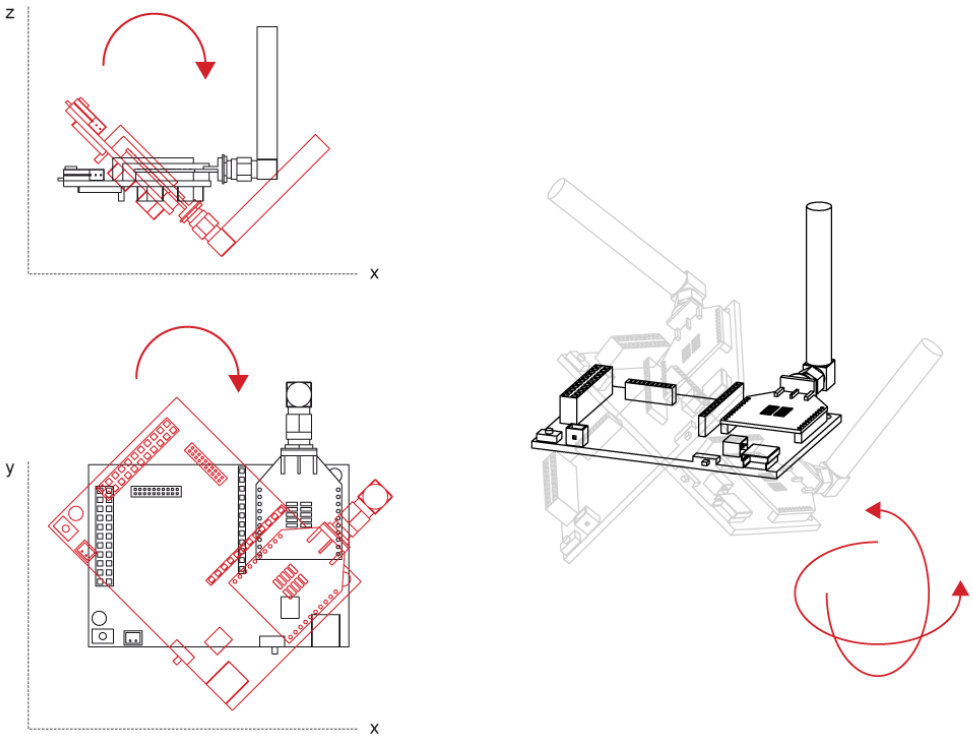
These thresholds and times are set in the WaspACC.h file.

To show the ease of programming, an extract of code about how to get the accelerometer values is included below:

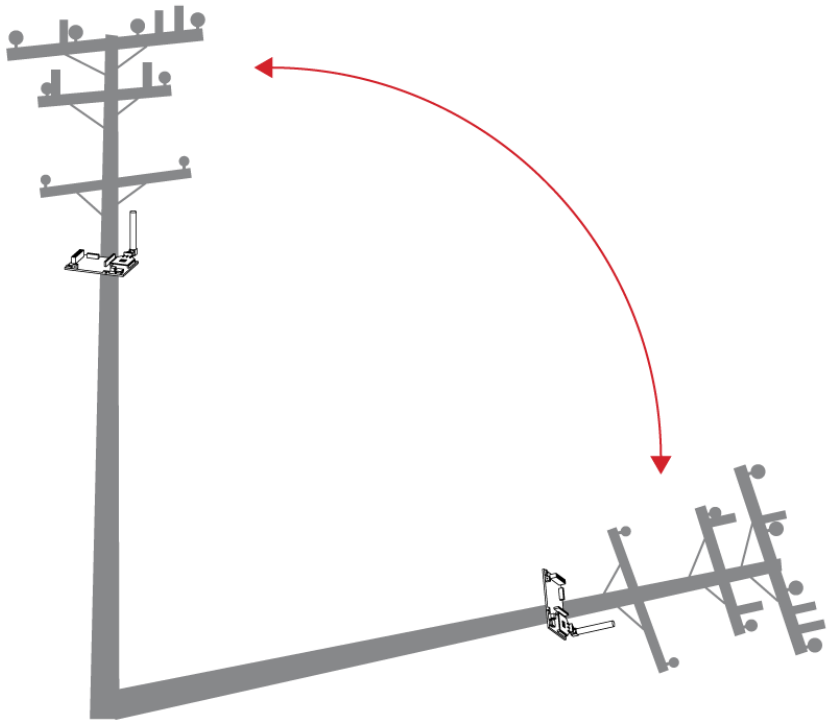
```
{
  ACC.ON();
  ACC.getX();
  ACC.getY();
  ACC.getZ();
}
```

Some figures with possible uses of the accelerometer are shown below:

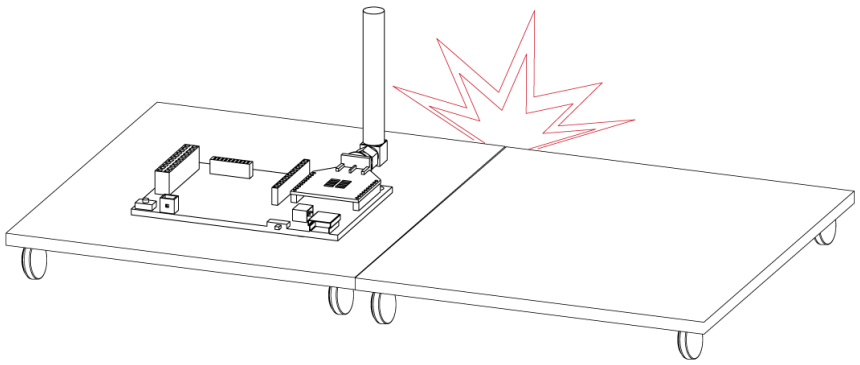
Rotation and twist:



Free fall of objects in which it is installed:



Crash:



More information about interruptions generated by the accelerometer can be found in the chapter "Interruptions" and in the **Interruption Programming Guide**.

Related API libraries: **WaspACC.h, WaspACC.cpp**

All information about their programming and operation can be found in the Accelerometer Programming Guide.

All the documentation is located in the Development section in the Libelium website.

3.2. Sensor probes

All sensing capabilities of Waspmote Plug & Sense! are provided by sensor probes. Each sensor probe contains one sensor, some necessary protections against outdoor environmental conditions and a waterproof male connector.

The standard length of a sensor probe is about 150 mm, including waterproof connector, but it could vary due to some sensors need special dimensions. Weight of a standard probe rounds 20 g, but there are some special cases where this weight can rise.

Sensor probes are designed to be used in vertical position (with the sensor looking to the ground). In this position, the protection cap of each sensor probe is effective against rain.

4. Smart Environment

4.1. General description

Smart Environment model is designed to monitor environmental parameters such as temperature, humidity, atmospheric pressure and some types of gases. The main applications for this Waspmote Plug & Sense! configuration are city pollution measurement, emissions from farms and hatcheries, control of chemical and industrial processes, forest fires, etc. Go to the application section in the Libelium website for a complete list of services.

Figure: Smart Environment 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	Carbon monoxide - CO	9229-P
	Ammonia – NH_3	9233-P
B	Ozone – O_3	9258-PB
	Hydrocarbons – VOC	9201-PB
C (digital bus)	Temperature, humidity and pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P
D	Nitrogen Dioxide – NO_2	9238-PB
E	Carbon Dioxide – CO_2	9230
	Oxygen – O_2	9231-P
F	Methane – CH_4	9232-P
	Liquefied Petroleum Gases: H_2, CH_4, ethanol, isobutene	9234-P
	Air pollutants 1: C_4H_{10}, CH_3CH_2OH, CO, CH_4	9235-P
	Air pollutants 2: $C_6H_5CH_3$, H_2S, CH_3CH_2OH, NH_3, H_2	9236-P
	Alcohol derivatives: CH_3CH_2OH, H_2, C_4H_{10}, CO, CH_4	9237-P

Figure: Sensor sockets configuration for Smart Environment model

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

4.2. Temperature, Humidity and Pressure Sensor Probe

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

Specifications

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

Figure: Image of the Temperature, Humidity and Pressure Sensor Probe

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

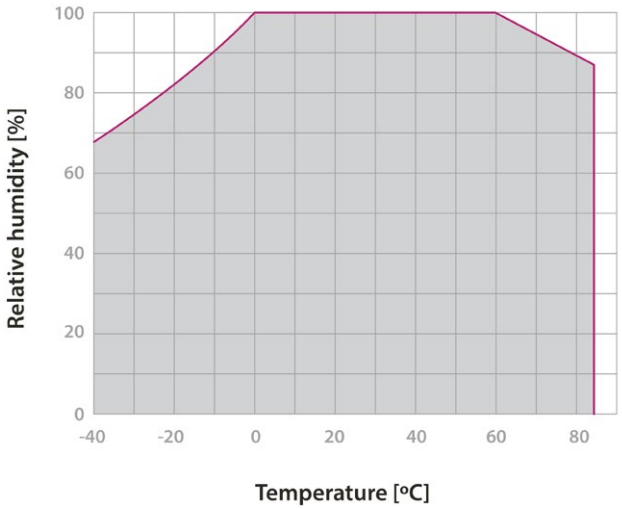


Figure: Humidity sensor operating range

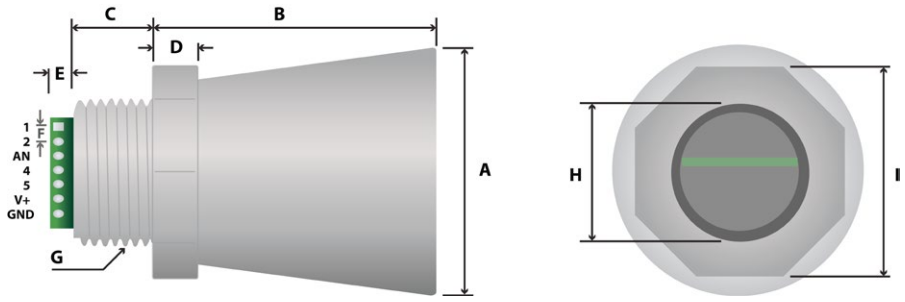
Pressure sensor
Measurement range: 30 ~ 110 kPa
Operational temperature range: -40 ~ +85 ºC
Full accuracy temperature range: 0 ~ +65 ºC
Absolute accuracy: ±0.1 kPa (0 ~ 65 ºC)
Typical consumption: 2.8 µA measuring
Maximum consumption: 4.2 µA measuring

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

I2CXL-MaxSonar®-MB7040™

Operation frequency: 42 kHz
Maximum detection distance: 765 cm
Interface: Digital bus
Power supply: 3.3 V ~ 5 V
Consumption (average): 2.1 mA (powered at 3.3 V) – 3.2 mA (powered at 5 V)
Consumption (peak): 50 mA (powered at 3.3 V) – 100 mA (powered at 5 V)
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 8.25 cm diameter rod for diagram C and a 28 cm wide board for diagram D):

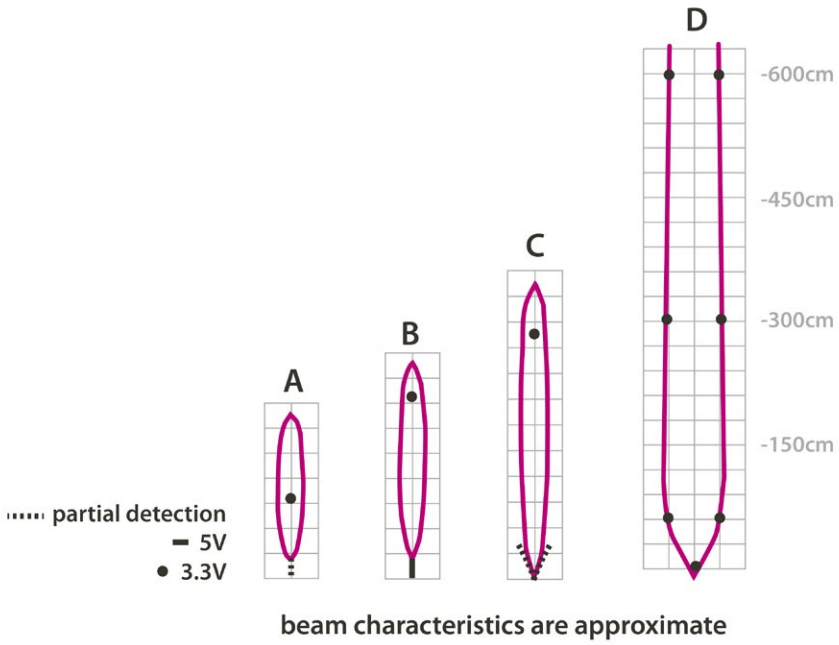


Figure: Diagram of the sensor beam extracted from the data sheet of the XL-MaxSonar®-WRA1™ sensor from MaxBotix

Figure: Image of configurations of the ultrasound sensor probe

As we see in the figure, the ultrasound sensor probe may be placed in different positions. The sensor can be focused directly to the point we want to measure.

4.4. Luminosity sensor probe (Luxes accuracy)

Sensor specifications (Luxes accuracy)

Dynamic range: 0.1 to 40000 Lux
Spectral range: 300 – 1100 nm
Voltage range: 2.7 – 3.6 V
Operating temperature: -30 ºC to +80 ºC
Typical consumption: 0.24 mA
Maximum consumption: 0.6 mA
Usage: Indoors and outdoors

Figure: Image of the Luminosity sensor probe (Luxes accuracy)

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.

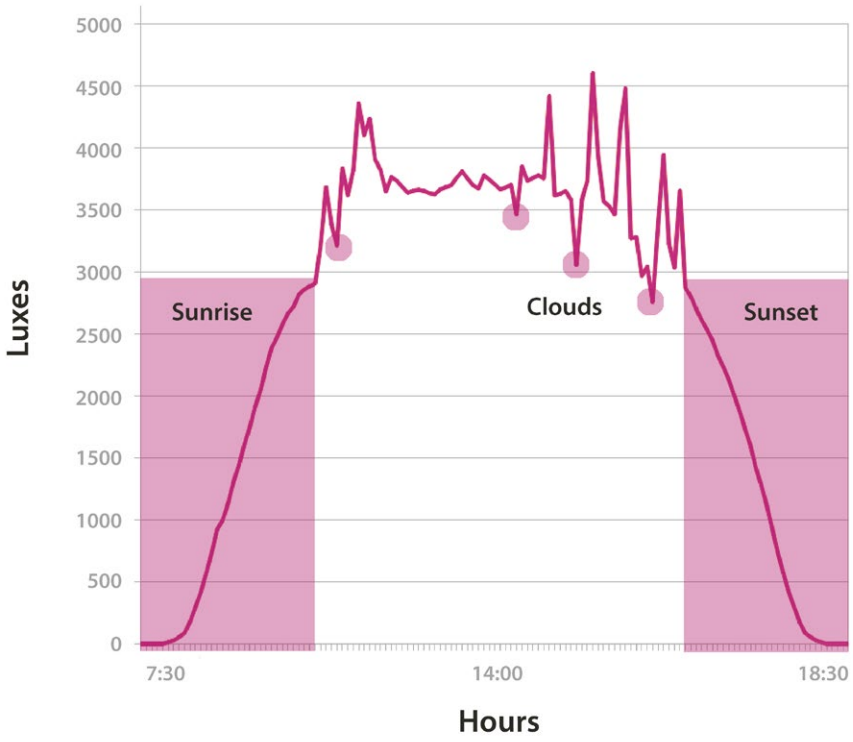


Figure: Image of the Luminosity sensor probe (Luxes accuracy)

4.5. Carbon Monoxide (CO) sensor probe

Sensor specifications (TGS2442)

Gases: CO

Measurement range: 30 ~ 1000 ppm

Resistance at 100ppm: 13.3 ~ 133 kΩ

Sensibility: 0.13 ~ 0.31 (ratio between the resistance at 300 ppm and at 100 ppm)

Supply voltage: 5V ± 0.2 V DC

Operating temperature: -10 ~ +50 ºC

Response time: 1 second

Minimum load resistance: 10 kΩ

Average consumption: 3 mA (throughout the complete power supply cycle in one second)

Figure: Image of the CO sensor probe (TGS2442)

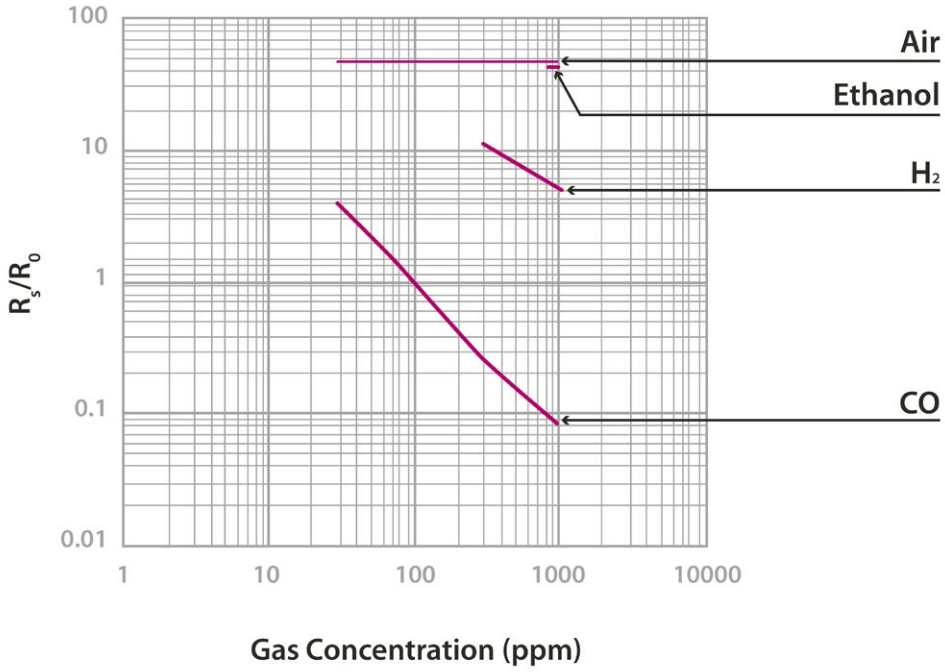


Figure: Graph of the sensitivity of the TGS2442 taken from the Figaro sensor's data sheet

The TGS2442 is a resistive sensor sensitive to the changes in concentration of Carbon Monoxide (CO) and, very slightly, Hydrogen (H_2). The sensor's resistance varies according to the graph in the figure above, which may present significant variations between two different sensors, so it is recommended to consult the sensor's documentation to choose the load resistance and amplification gain and calibrate it before finally inserting it into the application.

4.6. Methane (CH_4) sensor probe

Sensor specifications (TGS2611)

Gases: CH_4, H_2
Measurement range: 500 ~ 10000 ppm
Resistance at 5000ppm: 0.68 ~ 6.8 kΩ
Sensitivity: 0.6 ± 0.06 (ratio between the resistance at 9000 and at 3000 ppm)
Supply voltage: 5 V ± 0.2 V DC
Operating temperature: -10 ~ +40 ºC
Response time: 30 seconds
Minimum load resistance: 0.45 kΩ
Average consumption: 61 mA

Figure: Image of the CH_4 sensor probe (TGS2611)

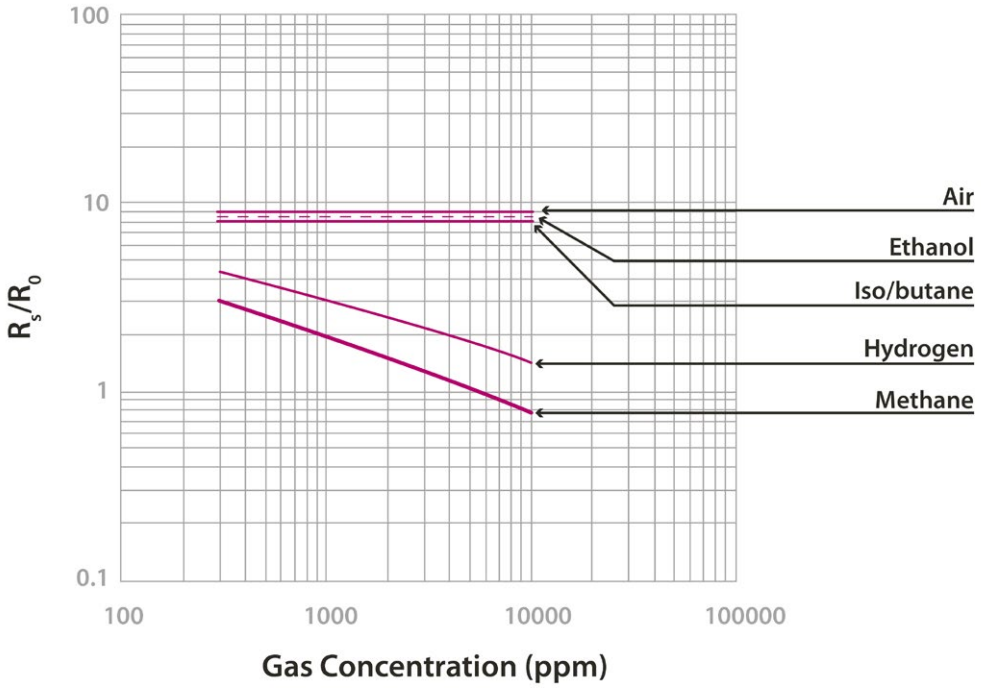


Figure: Graph of sensitivity of the TGS2611 taken from the Figaro sensor's data sheet

The TGS2611 sensor shows a variable resistance with the concentration of CH_4 and to a lesser extent with the concentration of H_2. The sensor's initial resistance (for 5000 ppm) and its sensitivity may show large variations between different sensors of the same model, so it is recommended to consult the manufacturer's documentation and calibrate it before finally inserting it in the application.

4.7. Ammonia (NH_3) sensor probe

Sensor specifications (TGS2444)

Gases: NH_3, H_2S
Measurement range: 10 ~ 100 ppm
Resistance at 10ppm: 3.63 ~ 36.3 kΩ
Sensitivity: 0,063 ~ 0.63 (ratio between the resistance at 3000 and at 1000 ppm)
Supply voltage: 5 V ± 0.2 V DC
Operating temperature: -10 ~ +50 ºC
Response time: 250 ms
Minimum load resistance: 8 kΩ
Average consumption: 12 mA (throughout the complete power supply cycle in 250 ms)

Figure: Image of the NH_3 sensor probe (TGS2444)

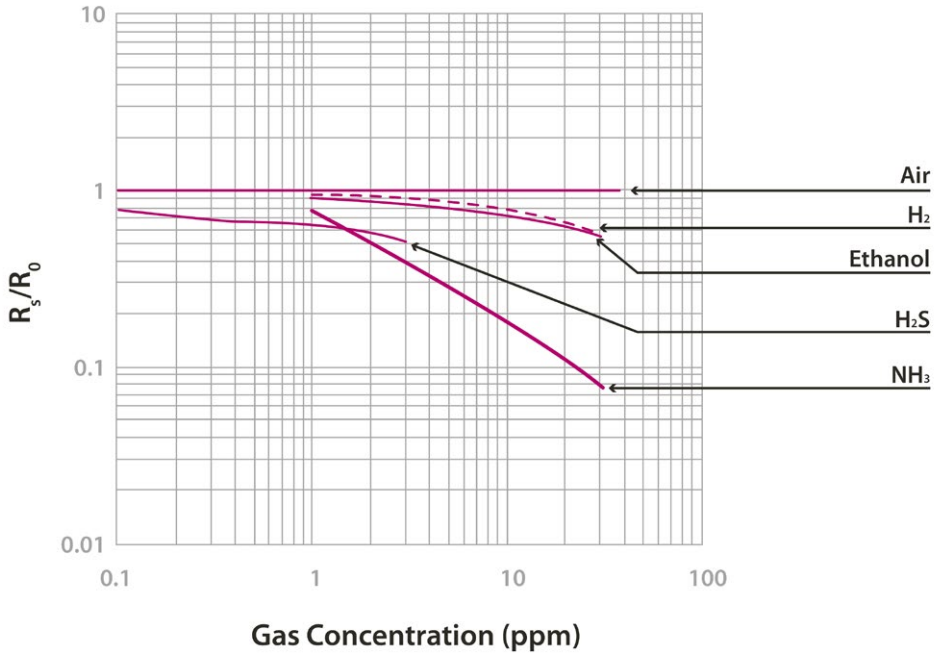


Figure: Graph of the sensitivity of the TGS2444 taken from the Figaro sensor data sheet

The TGS2444 sensor is a resistive sensor which is highly sensitive to variations in the concentration of Ammonia (NH_3) and which shows slight sensitivity to hydrogen sulphide (H_2S) and to a lesser extent, to Hydrogen (H_2) and Ethanol (CH_3CH_2OH). Both the sensor's initial resistance (at 10 ppm) and its sensitivity vary widely between different sensors of the same model, so it is recommended to calibrate each one of them independently before finally including them in the application.

4.8. LPG sensor probe

Sensor specifications (TGS2610)

Gases: CH_3CH_2OH, CH_4, C_4H_{10}, H_2
Measurement range: 500 ~ 10000 ppm
Resistance at 1800ppm (isobutane): 0.68 ~ 6.8 kΩ
Sensitivity: 0.56 ± 0.06 (ratio between the resistance at 3000 and at 1000 ppm)
Supply voltage: 5 V ± 0.2 V DC
Operating temperature: -10 ~ +40 ºC
Response time: 30 seconds
Minimum load resistance: 0.45 kΩ
Average consumption: 61 mA

Figure: Image of the LPG sensor probe (TGS2610)

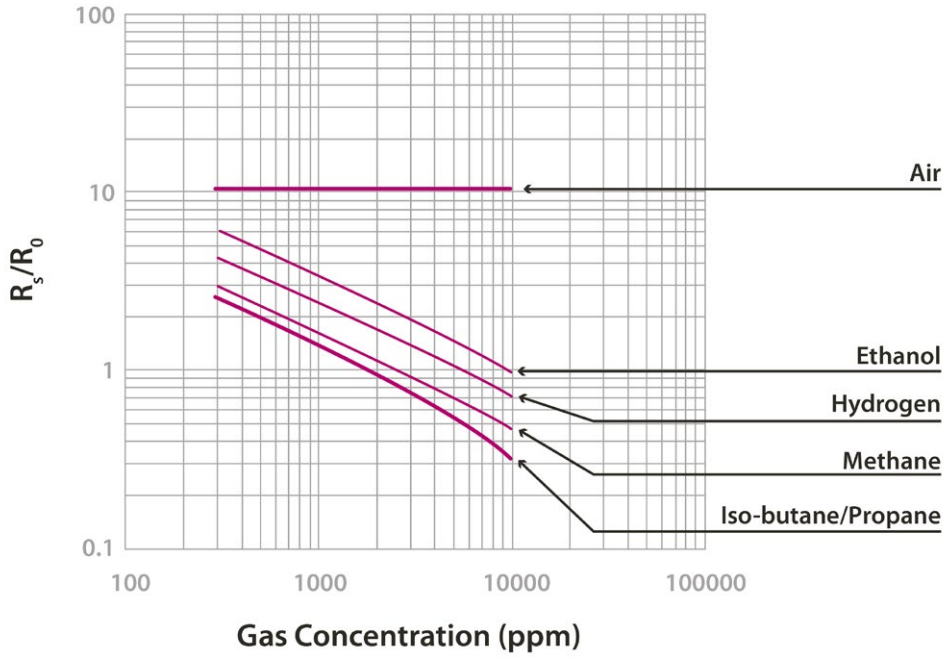


Figure: Graph of the sensitivity of the TGS2610 taken from the Figaro sensor's data sheet

The TGS2610 is a resistive sensor which shows sensitivity to combustible gases and derivatives. Especially reactive to Isobutane (C_4H_{10}), it is also sensitive to Methane (CH_4), Ethanol (CH_3CH_2OH) and Hydrogen (H_2). Because both its resistance and sensitivity show significant variations between different sensors of the same model, it is recommended to consult the manufacturer's documentation and carry out a process of calibration prior to its final inclusion in an application.

4.9. Air Pollutants 1 sensor probe

Sensor specifications (TGS2602)

Gases: $C_6H_5CH_3$, H_2S, CH_3CH_2OH, NH_3, H_2
Measurement range: 1 ~ 30 ppm
Air resistance: 10 ~ 100 kΩ
Sensitivity: 0.15 ~ 0.5 (ratio between the resistance in 10 ppm of Ethanol and in air)
Supply voltage: 5 V ± 0.2 V DC
Operating temperature: +10 ~ +50 ºC
Storage temperature: -20 ~ +60 ºC
Response time: 30 seconds
Minimum load resistance: 0.45 kΩ
Average consumption: 61 mA

Figure: Image of the Air Pollutants 1 sensor probe (TGS2602)

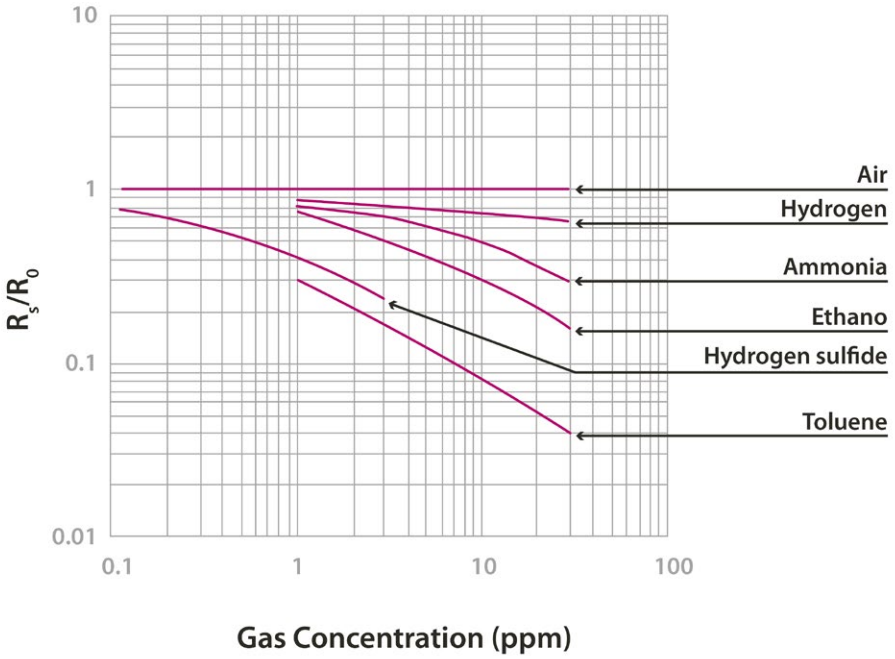


Figure: Graph of the sensitivity of the TGS2602 taken from the Figaro sensor's data sheet

The TGS2602 is a sensor similar to the TGS2600 which reacts varying its resistance in the presence of contaminant gases, mainly Toluene ($C_6H_5CH_3$), Hydrogen Sulphide (H_2S), Ethanol (CH_3CH_2OH), Ammonia (NH_3) and to a lesser extent, Hydrogen (H_2). In air without contaminants the sensor shows a resistance between 10 and 100 kΩ with a variation ratio between 0.15 and 0.5 between the resistance in 10 ppm of CH_3CH_2OH and this one. This variability makes a calibration of the sensor necessary before using it in a final application.

4.10. Air pollutants 2 sensor probe

Sensor specifications (TGS2600)

Gases: C_4H_{10}, CH_3CH_2OH, H_2, CO, CH_4
Measurement range: 1 ~ 100 ppm
Air resistance: 10 ~ 90 kΩ
Sensitivity: 0.3 ~ 0.6 (ratio between the resistance in 10 ppm of H_2 and in air)
Supply voltage: 5 V ± 0.2 V DC
Operating temperature: -10 ~ +40 ºC
Response time: 30 seconds
Minimum load resistance: 0.45 kΩ
Average consumption: 46 mA

Figure: Image of the Air Pollutants 2 sensor probe (TGS2600)

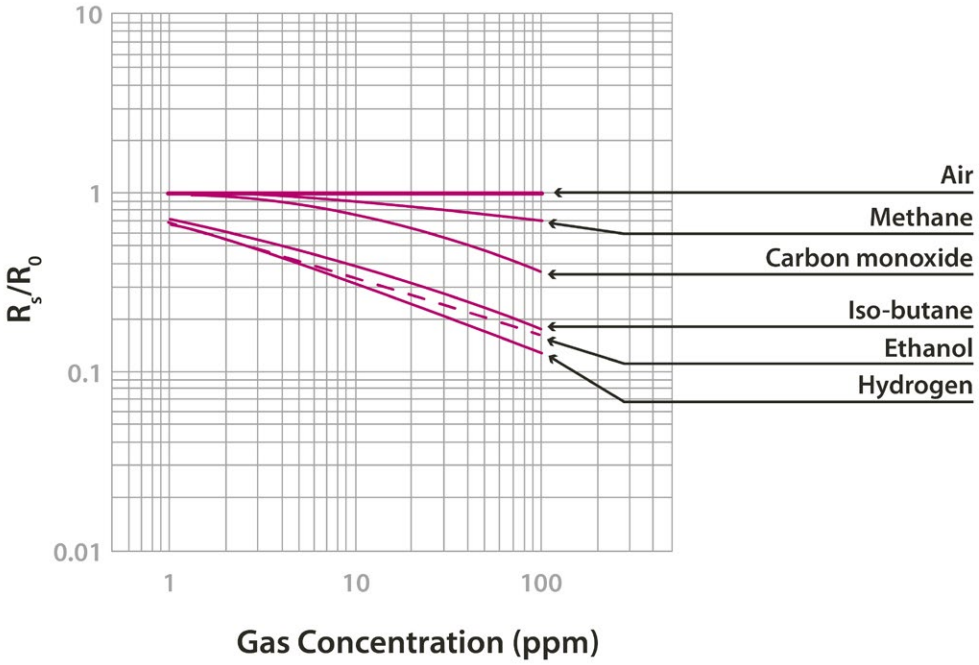


Figure: Graph of the sensitivity of the TGS2600 taken from the Figaro sensor's data sheet

The TGS2600 sensor shows sensitivity to the variation of the concentration of numerous gases that are not usually found in the composition of the atmosphere and which are considered contaminants. Amongst these would be mainly, Ethanol (CH_3CH_2OH) and Isobutane (C_4H_{10}) and, with less response, Carbon Monoxide (CO) and Methane (CH_4). This sensor is also sensitive to variations in the concentration of Hydrogen (H_2). The sensor's resistance in air would vary between 10 and 90 kΩ, with a ratio of sensitivity between 0.3 and 0.6 for an H_2 concentration of 10 ppm. Because of this variability it is recommended to calibrate each one of the sensors prior to their use in a final application.

4.11. Solvent Vapors sensor probe

Sensor specifications (TGS2620)

Gases: CH_3CH_2OH, H_2, C_4H_{10}, CO, CH_4
Measurement range: 50 ~ 5000 ppm
Resistance to 300ppm of Ethanol: 1 ~ 5 kΩ
Sensitivity: 0.3 ~ 0.5 (ratio between the resistance at 300 ppm and at 50 ppm)
Supply voltage: 5 V ± 0.2 V DC
Operating temperature: -10 ~ +40 ºC
Response time: 30 seconds
Load minimum resistance: 0.45 kΩ
Average consumption: 46 mA (throughout the complete power supply cycle in 250 ms)

Figure: Image of the Solvent Vapors sensor probe (TGS2620)

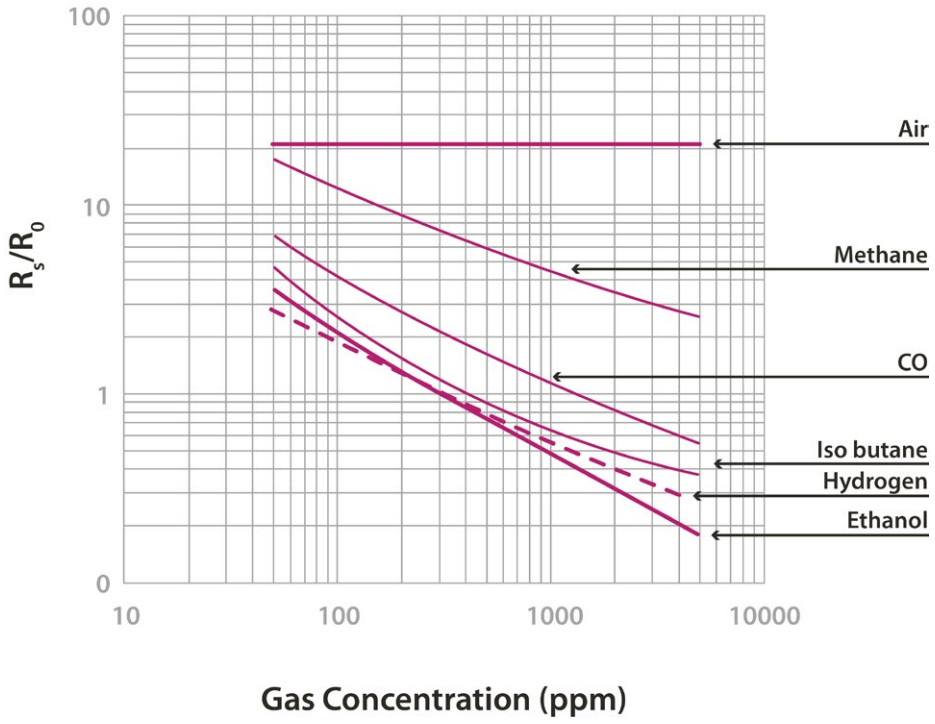


Figure: Graph of the sensitivity of the TGS2620 taken from the Figaro sensor's data sheet

The TGS2620 sensor allows detection of alcohol and organic gases, mainly Ethanol (CH_3CH_2OH), Hydrogen (H_2), Isobutane (C_4H_{10}), Carbon Monoxide (CO) and Methane (CH_4). The resistance the sensor shows in a 300 ppm concentration of Ethanol can vary between 1 and 5 kΩ, while the sensitivity ratio between this and the resistance in 50 ppm varies between 0.3 and 0.5. As a consequence of these variations it is necessary to calibrate each sensor before their insertion into a final application.

4.12. Carbon Dioxide (CO_2) sensor probe

Sensor specifications (TGS4161)

Gases: CO_2
Measurement range: 350 ~ 10000 ppm
Voltage at 350ppm: 220 ~ 490 mV
Sensitivity: 44 ~ 72 mV (variation between the voltage at 350 ppm and at 3500 ppm)
Supply voltage: 5 V ± 0.2 V DC
Operating temperature: -10 ~ +50 ºC
Response time: 1.5 minutes
Average consumption: 50 mA

Figure: Image of the CO_2 sensor probe (TGS4161)

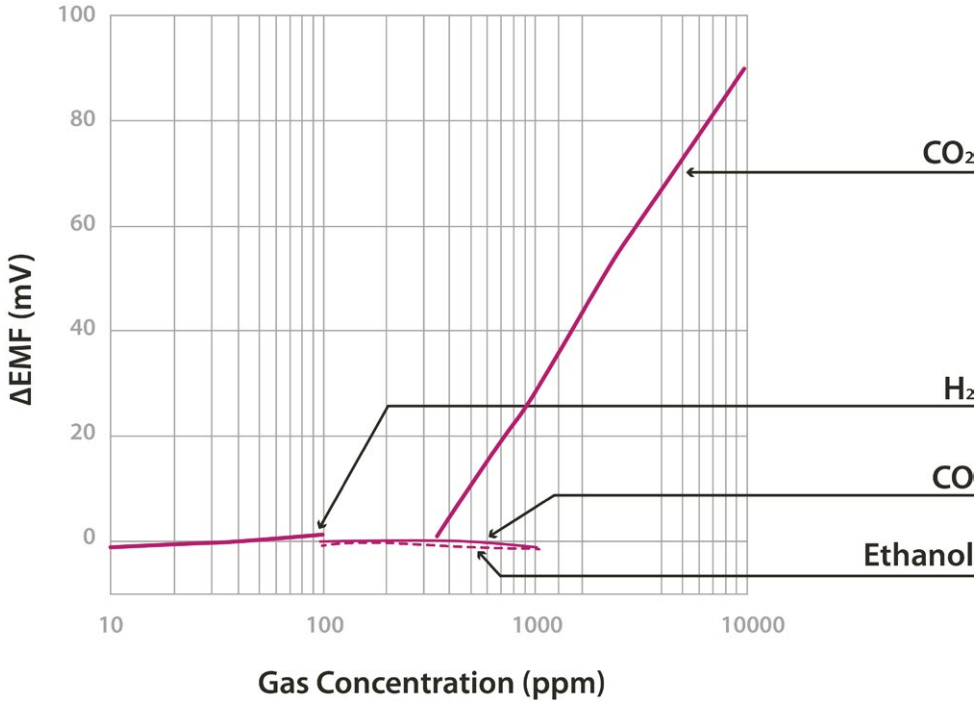


Figure: Graph of the sensitivity of the TGS4161 sensor taken from the Figaro sensor's data sheet

The TGS4161 sensor provides a voltage output proportional to the CO_2 concentration in the atmosphere. It shows a value between 220 and 490 mV for a concentration of 350 ppm (approximately the normal CO_2 concentration in the air) decreasing as the amount of gas increases. Different sensors may show a large variability in the initial voltage values at 350 ppm and sensitivity, so it is recommended to calibrate each sensor before including it in the application.

4.13. Nitrogen Dioxide (NO_2) Sensor probe - MiCS-2714

Specifications

This sensor is the new version for the MiCS-2710 sensor. The new version is provided since June 2014 and has similar specifications:

Figure: Image of the MiCS-2714 sensor probe

Gases: NO_2
Measurement range: 0.05 ~ 5 ppm
Air resistance: 0.8 ~ 8 kΩ (typically 2.2kΩ)
Sensitivity: 6 ~ 100 (typically 55, ratio between the resistance at 0.25 ppm and in air)
Supply voltage: 1.7 ~ 2.5 V DC
Operating temperature: -30 ~ +85 ºC
Response time: 30 seconds
Average consumption: 26 mA (throughout the complete power supply cycle in one second)

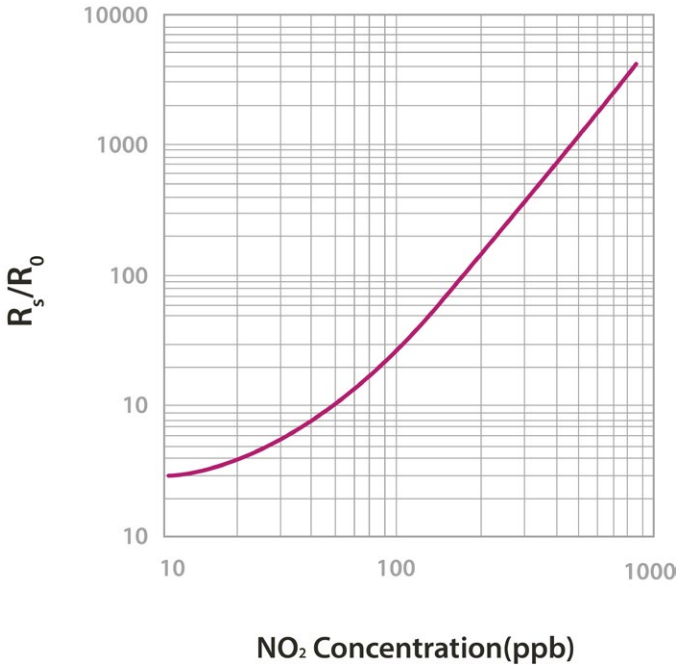


Figure: Graph of the sensitivity of the MiCS-2714 taken from the e2v's sensor data.

The MiCS-2714 is a sensor whose resistance varies in the presence of small concentrations of NO_2. This value varies between 2 kΩ and 2 MΩ approximately, providing high accuracy throughout the output range. Unlike the rest of the board's gas sensors, which operate at a voltage of 5 V, this sensor is powered through a 1.8 V voltage regulator, with consumption of approximately 26 mA. The sensor's resistance in air, as well as its sensitivity, can vary between different units, so it is recommended to calibrate each one of them before finally inserting them in the application.

4.14. VOC sensor probe (MiCS-5524)

Specifications

This sensor is the new version for the MiCS-5521 sensor. The new version is provided since June 2014 and has similar specifications:

Gases: CO, Hydrocarbons, Volatile Organic Compounds *

Measurement range: 30 ~ 400 ppm

Air resistance: 100 ~ 1500 kΩ

Sensitivity: 1.8 ~ 6 (typically 3, ratio between the resistance at 60 ppm and at 200 ppm of CO)

Supply voltage: 2.1 ~ 5 V DC

Operating temperature: -30 ~ +85 ºC

Response time: 30 seconds

Average consumption: 32 mA

Figure: Image of the MiCS-5524 sensor probe

(*) Chlorinated hydrocarbons, aromatic hydrocarbons, aromatic alcohols, aliphatic alcohols, terpenes, glycols, aldehydes, esters and acids. Detailed list can be found at http://www.libelium.com/downloads/voc-sensors.xls

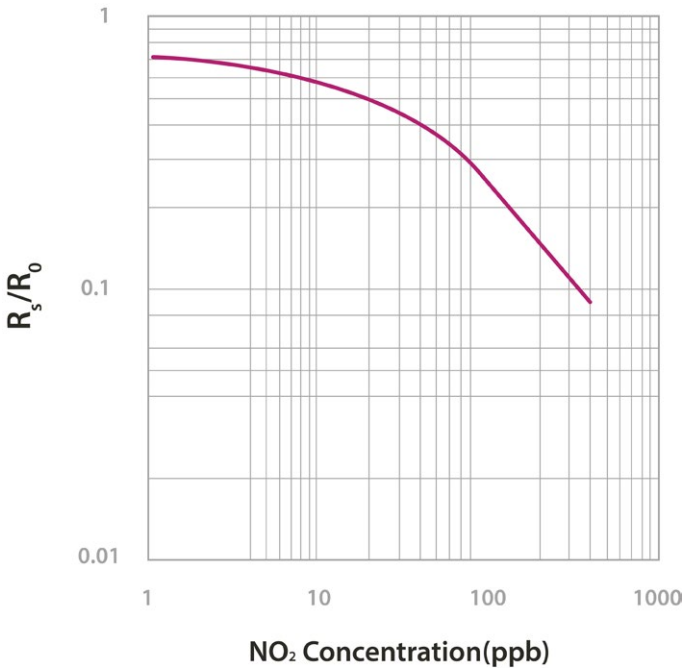


Figure: Graph of the sensitivity of the MiCS-5524 taken from the e2v's sensor data

The MiCS-5524 is a resistive sensor that responds to a great variety of gases, such as Carbon Monoxide (CO), Hydrocarbons and Volatile Organic Compounds. Its resistance varies between 1000 kΩ and 2 kΩ approximately. Like the MiCS-2614, the MiCS-5524 is powered through a 2.5 V voltage regulator, with consumption of approximately 32 mA. The sensor's resistance in air, as well as its sensitivity, can vary between different units, so it is recommended to calibrate each one of them before finally inserting them in the application.

4.15. Oxygen (O_2) sensor probe

Figure: Image of the O_2 sensor probe (SK-25)

Sensor specifications (SK-25)

Gases: O_2
Measurement range: 0 ~ 30%
Output range: Approximately 0 ~ 10 mV
Initial Voltage: 5.5 ~ 8.8 mV
Operating temperature: 5 ~ +40 ºC
Response time: 15 seconds
Consumption: 0 µA

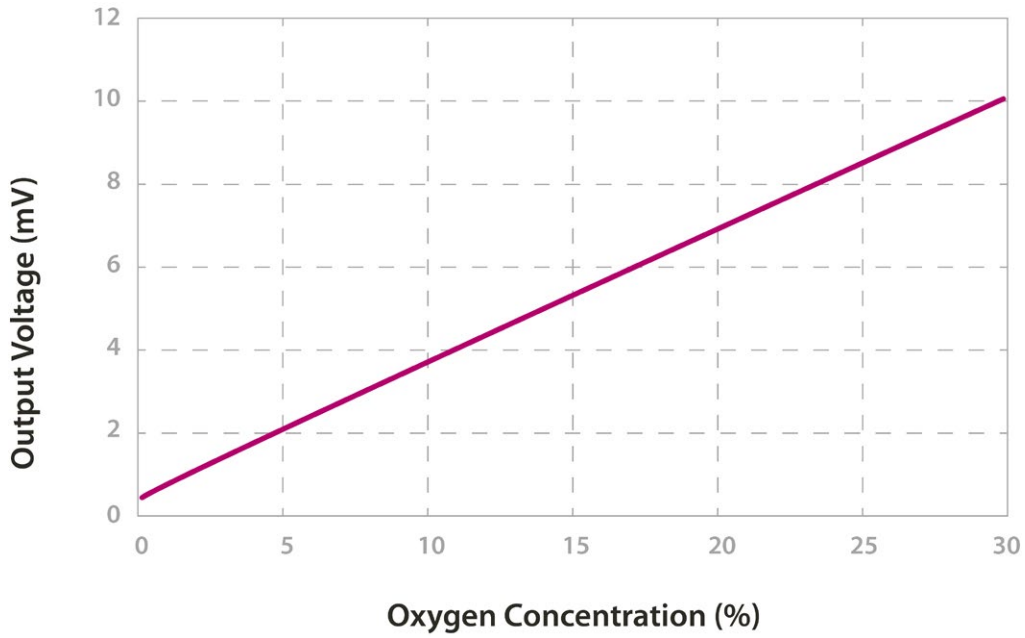


Figure: Graph of the sensitivity of the SK-25 extracted from the Figaro sensor's data sheet

The SK-25 is an analog sensor which provides a voltage output proportional to the O_2 concentration in the atmosphere, without needing power and therefore with zero consumption. It shows an output range between 0 and 10 mV, with voltage in standard conditions (approximately 21% O_2 concentration) of between 5.5 and 8.8 mV. The output response can vary from one sensor to another, so it is recommended to calibrate the sensor before finally inserting it into the application.

5. Smart Enviroment PRO

5.1. General description

The Smart Environment PRO model has been created as an evolution of Smart Enviroment. It enables the user to implement pollution, air quality, industrial, environmental or farming projects with high requirements in terms of high accuracy, reliability and measurement range as the sensors come calibrated from factory.

Figure: Smart Environment 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, B, C or F	Carbon Monoxide (CO) [Calibrated]	9371-P
	Carbon Dioxide (CO_2) [Calibrated]	9372-P
	Oxygen (O_2) [Calibrated]	9373-P
	Ozone (O_3) [Calibrated]	9374-P
	Nitric Oxide (NO) [Calibrated]	9375-P
	Nitric Dioxide (NO_2) [Calibrated]	9376-P
	Sulfur Dioxide (SO_2) [Calibrated]	9377-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
D	Particle Matter (PM1 / PM2.5 / PM10) - Dust	9387-P
E	Temperature, humidity and pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P

Figure: Sensor sockets configuration for Smart Environment PRO model

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

5.2. Temperature, Humidity and Pressure Sensor Probe

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

Specifications

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

Figure: Image of the Temperature, Humidity and Pressure Sensor Probe

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

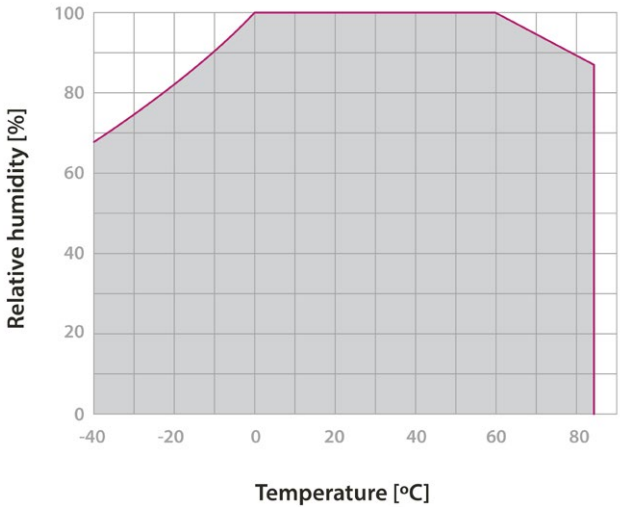


Figure: Humidity sensor operating range

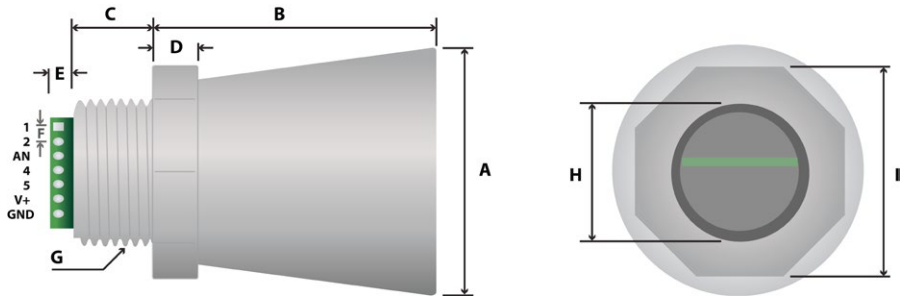
Pressure sensor
Measurement range: 30 ~ 110 kPa
Operational temperature range: -40 ~ +85 ºC
Full accuracy temperature range: 0 ~ +65 ºC
Absolute accuracy: ±0.1 kPa (0 ~ 65 ºC)
Typical consumption: 2.8 µA measuring
Maximum consumption: 4.2 µA measuring

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

I2CXL-MaxSonar®-MB7040™

Operation frequency: 42 kHz
Maximum detection distance: 765 cm
Interface: Digital bus
Power supply: 3.3 V ~ 5 V
Consumption (average): 2.1 mA (powered at 3.3 V) – 3.2 mA (powered at 5 V)
Consumption (peak): 50 mA (powered at 3.3 V) – 100 mA (powered at 5 V)
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 8.25 cm diameter rod for diagram C and a 28 cm wide board for diagram D):

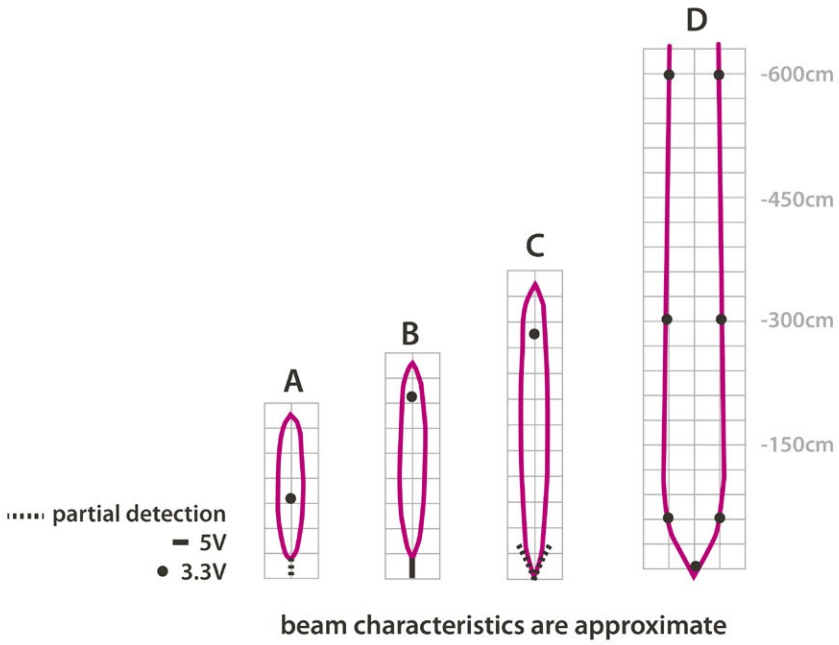


Figure: Diagram of the sensor beam extracted from the data sheet of the XL-MaxSonar®-WRA1™ sensor from MaxBotix

Figure: Image of configurations of the ultrasound sensor probe

As we see in the figure, the ultrasound sensor probe may be placed in different positions. The sensor can be focused directly to the point we want to measure.

5.4. Luminosity sensor probe (Luxes accuracy)

Sensor specifications (Luxes accuracy)

Dynamic range: 0.1 to 40000 Lux
Spectral range: 300 – 1100 nm
Voltage range: 2.7 – 3.6 V
Operating temperature: -30 ºC to +80 ºC
Typical consumption: 0.24 mA
Maximum consumption: 0.6 mA
Usage: Indoors and outdoors

Figure: Image of the Luminosity sensor probe (Luxes accuracy)

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.

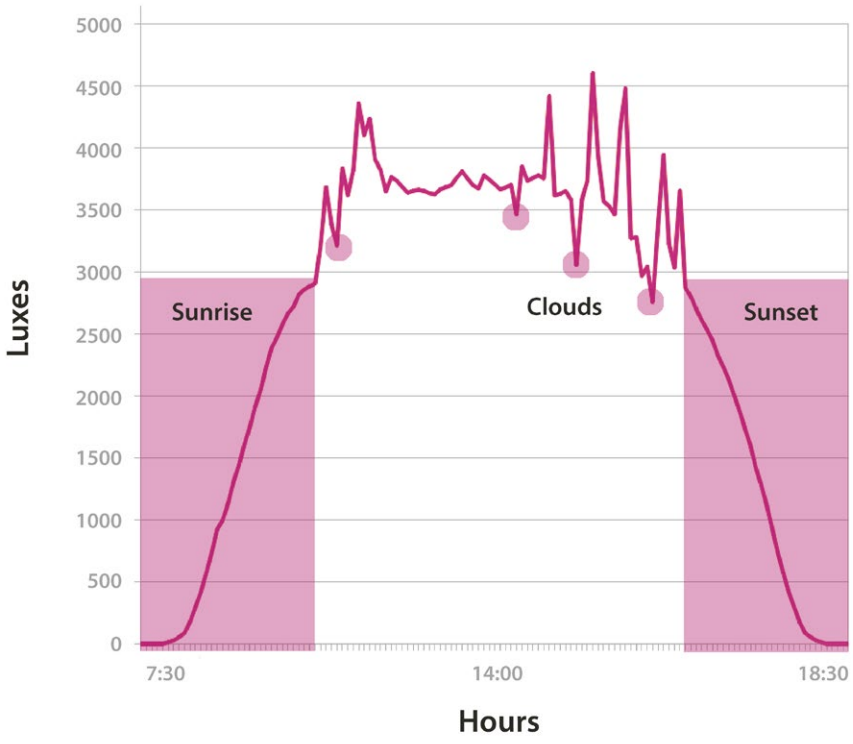


Figure: Image of the Luminosity sensor probe (Luxes accuracy)

5.5. Carbon Monoxide (CO) Gas sensor probe for high concentrations [Calibrated]

Figure: Image of the Carbon Monoxide Sensor Probe for high concentrations

Specifications

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

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. Read the Gases PRO Technical Guide for more details.*

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.

5.6. Carbon Monoxide (CO) Gas sensor probe for low concentrations [Calibrated]

Specifications

Gas: CO
Sensor: CO-A4

Figure: Image of the Carbon Monoxide Sensor Probe for low concentrations

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

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. Read the Gases PRO Technical Guide for more details.*

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.

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

Figure: Image of the Carbon Dioxide Sensor Probe

Specifications

Gas: CO_2
Sensor: INE20-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

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 Gases PRO Sensor Board. The user must choose one or the other, but not both.*

** Accuracy values are only given for the **optimum case**. Read the Gases PRO Technical Guide for more details.*

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.

5.8. Molecular Oxygen (O_2) Gas Sensor probe [Calibrated]

Specifications

Gas: O_2
Sensor: 4-OL

Figure: Image of the Molecular Oxygen Sensor Probe

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

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. Read the Gases PRO Technical Guide for more details.*

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.

5.9. Ozone (O_3) Gas Sensor probe [Calibrated]

Specifications

Gas: O_3
Sensor: O3-A4

Figure: Image of the Ozone Sensor Probe

Performance Characteristics
Nominal Range: 0 to 5 ppm
Maximum Overload: 10 ppm
Long Term sensitivity Drift: -20 to -35% change/year
Response Time (T90): ≤ 15 seconds
Sensitivity: -200 to -400 nA/ppm
Accuracy: as good as ±0.005 ppm* (ideal conditions)

Operation Conditions
Temperature Range: -20 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: > 18 months in air

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. Read the Gases PRO Technical Guide for more details.*

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.

5.10. Nitric Oxide (NO) Gas Sensor Probe for high concentrations [Calibrated]

Figure: Image of the Nitric Oxide Sensor Probe for high concentrations

Specifications

Gas: NO
Sensor: 4-NO-250

Performance Characteristics
Nominal Range: 0 to 250 ppm
Maximum Overload: 1000 ppm
Long Term Output Drift: < 2% signal/month
Response Time (T90): ≤ 30 seconds
Sensitivity: 400 ± 80 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: 2 years in air

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. Read the Gases PRO Technical Guide for more details.*

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.

5.11. Nitric Dioxide (NO_2) Gas Sensor probe [Calibrated]

Specifications

Gas: NO_2
Sensor: 4-NO2-20

Figure: Image of the Nitric Dioxide Sensor Probe

Performance Characteristics
Nominal Range: 0 to 20 ppm
Maximum Overload: 250 ppm
Long Term Output Drift: < 2% signal/month
Response Time (T90): ≤ 30 seconds
Sensitivity: 600 ± 150 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

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. Read the Gases PRO Technical Guide for more details.*

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.

5.12. Sulfur Dioxide (SO_2) Gas Sensor probe [Calibrated]

Specifications

Gas: SO_2
Sensor: 4-SO2-20

Figure: Image of the Sulfur Dioxide Sensor Probe

Performance Characteristics
Nominal Range: 0 to 20 ppm
Maximum Overload: 150 ppm
Long Term Output Drift: < 2% signal/month
Response Time (T90): ≤ 45 seconds
Sensitivity: 500 ± 150 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

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. Read the Gases PRO Technical Guide for more details.*

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.

5.13. Ammonia (NH_3) Gas Sensor probe [Calibrated]

Specifications

Gas: NH_3
Sensor: 4-NH3-100

Figure: Image of the Ammonia Sensor Probe

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

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. Read the Gases PRO Technical Guide for more details.*

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.

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

Specifications

Main gas: Methane CH_4
Sensor: CH-A3

Figure: Image of the Methane (CH_4) and Combustible Gas Sensor Probe

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

Table : Inhibition and poisoning effects

Average consumption: 68 mA

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

** Accuracy values are only given for the **optimum case**. Read the Gases PRO Technical Guide for more details.*

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.

5.15. Molecular Hydrogen (H_2) Gas Sensor probe [Calibrated]

Specifications

Gas: H_2
Sensor: 4-H2-1000

Figure: Image of the Molecular Hydrogen Sensor Probe

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

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. Read the Gases PRO Technical Guide for more details.*

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.

5.16. Hydrogen Sulfide (H_2S) Gas Sensor probe [Calibrated]

Specifications

Gas: H_2S
Sensor: 4-H2S-100

Figure: Image of the Hydrogen Sulfide Sensor Probe

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

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. Read the Gases PRO Technical Guide for more details.*

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.

5.17. Hydrogen Chloride (HCl) Gas Sensor probe [Calibrated]

Specifications

Gas: HCl
Sensor: 4-HCl-50

Figure: Image of the Hydrogen Chloride Sensor Probe

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

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. Read the Gases PRO Technical Guide for more details.*

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.

5.18. Phosphine (PH_3) Gas Sensor probe [Calibrated]

Specifications

Gas: PH_3
Sensor: 4-PH3-20

Figure: Image of the Phosphine Gas Sensor Probe

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

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. Read the Gases PRO Technical Guide for more details.*

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.

5.19. Ethylene Oxide (ETO) Gas Sensor probe [Calibrated]

Specifications

Gas: ETO
Sensor: 4-ETO-100

Figure: Image of the Ethylene Oxide Sensor Probe

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

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. Read the Gases PRO Technical Guide for more details.*

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.

5.20. Chlorine (Cl_2) Gas Sensor probe [Calibrated]

Specifications

Gas: Cl_2
Sensor: 4-Cl2-50

Figure: Image of the Chlorine Sensor Probe

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

Average consumption: less than 1 mA

** Accuracy values are only given for the **optimum case**. Read the Gases PRO Technical Guide for more details.*

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.

5.21. 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.

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

Specifications

Sensor: OPC-N2

Figure: Image of the Particle Matter sensor, encapsulated

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.

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 ton 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.

DO NOT remove the external housing: this not only ensures the required airflow but 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.*

Note: *Libelium also offers the Dust Sensor for the Smart Cities Sensor Board (only available for the "OEM" line, not for Plug & Sense!). This cost-efficient sensor does not feature the excellent characteristics of the Particle Matter Sensor. The Dust Sensor is not calibrated so its measures are not accurate. It does not classify particles per diameter and its range is not really defined. It can be useful for projects where it is important to meter the dust presence (or not) and the approximate amount of dust. Summarizing, it is a qualitative sensor, not quantitative. Besides, the Dust Sensor does not have a fan for generating flow, and no protective enclosure is provided.*

5.22.1. 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 $\mu m/m^3$ for PM2.5 and about 50 $\mu m/m^3$ for PM10.

5.22.2. 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.

5.22.3. Installing the Sensor Probe

Libelium offers the OPC-N2 sensor inside a protective enclosure. The enclosure has special input and output accessories for letting the air flow pass, but always keeping the rain or excessive dirt outside. Fixing accessories and one connection cord are also provided. All the system is called the Particle Matter – Dust Sensor Probe.

Figure: Input and output accessories in the enclosure

The system comes with 4 mounting feet (T's). The enclosure should be firmly fixed to a wall with the provided screws, or fixed to a lamppost or tree with 2 metal cable ties.

Figure: Fixing the Particle Matter – Dust Sensor Probe on a wall

Figure: Connecting the Particle Matter – Dust Sensor Probe to Plug & Sense!

The installation of this Sensor Probe must be similar to any Plug & Sense! installation. Please read the "Installation" chapter in the Plug & Sense! Technical Guide for further details.

Figure: Particle Matter – Dust Sensor Probe finally connected to Plug & Sense!

6. Smart Security

6.1. General description

The main applications for this Waspmote Plug & Sense! configuration are perimeter access control, liquid presence detection and doors and windows openings. Besides, a relay system allows this model to interact with external electrical machines.

Figure: Smart Security Waspmote Plug & Sense! model

Note: *The probes attached in this photo could not match the final location. See next table for the correct configuration.*

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A, C, D or E	Temperature + Humidity + Pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P
	Presence - PIR	9212-P
	Liquid Level	9239-P, 9240-P
	Liquid Presence	9243-P
	Hall Effect	9207-P
B	Liquid Flow	9296-P, 9297-P, 9298-P
F	Relay Input-Output	9270

Figure: Sensor sockets configuration for Smart Security model

As we see in the figure below, thanks to the directional probe, the presence sensor probe (PIR) may be placed in different positions. The sensor can be focused directly to the point we want.

Figure: Configurations of the Presence sensor probe (PIR)

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

6.2. Temperature, Humidity and Pressure Sensor Probe

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

Specifications

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

Figure: Image of the Temperature, Humidity and Pressure Sensor Probe

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

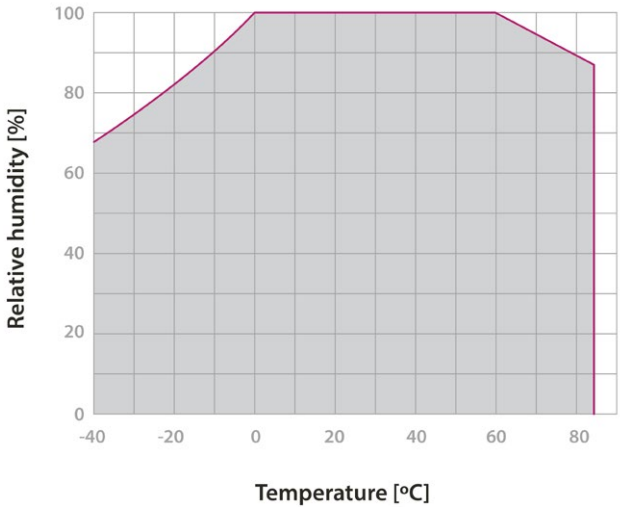


Figure: Humidity sensor operating range

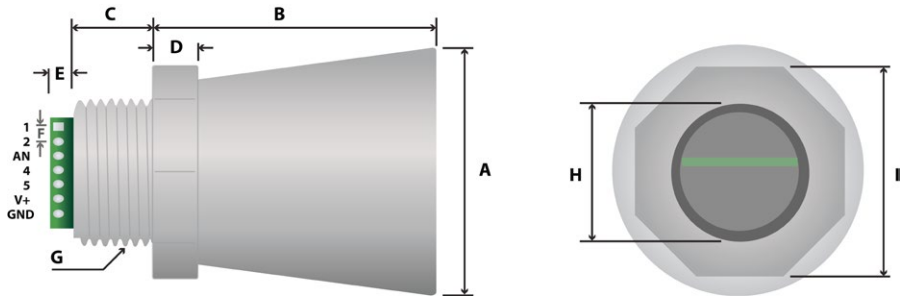
Pressure sensor
Measurement range: 30 ~ 110 kPa
Operational temperature range: -40 ~ +85 ºC
Full accuracy temperature range: 0 ~ +65 ºC
Absolute accuracy: ±0.1 kPa (0 ~ 65 ºC)
Typical consumption: 2.8 µA measuring
Maximum consumption: 4.2 µA measuring

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

I2CXL-MaxSonar®-MB7040™

Operation frequency: 42 kHz
Maximum detection distance: 765 cm
Interface: Digital bus
Power supply: 3.3 V ~ 5 V
Consumption (average): 2.1 mA (powered at 3.3 V) – 3.2 mA (powered at 5 V)
Consumption (peak): 50 mA (powered at 3.3 V) – 100 mA (powered at 5 V)
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 8.25 cm diameter rod for diagram C and a 28 cm wide board for diagram D):

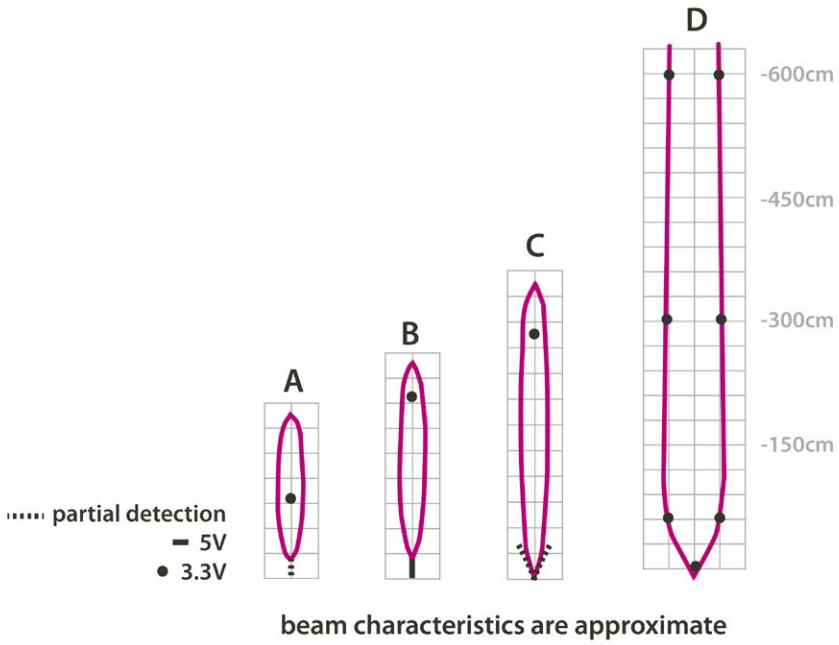


Figure: Diagram of the sensor beam extracted from the data sheet of the XL-MaxSonar®-WRA1™ sensor from MaxBotix

Figure: Image of configurations of the ultrasound sensor probe

As we see in the figure, the ultrasound sensor probe may be placed in different positions. The sensor can be focused directly to the point we want to measure.

6.4. Luminosity sensor probe (Luxes accuracy)

Sensor specifications (Luxes accuracy)

Dynamic range: 0.1 to 40000 Lux
Spectral range: 300 – 1100 nm
Voltage range: 2.7 – 3.6 V
Operating temperature: -30 ºC to +80 ºC
Typical consumption: 0.24 mA
Maximum consumption: 0.6 mA
Usage: Indoors and outdoors

Figure: Image of the Luminosity sensor probe (Luxes accuracy)

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.

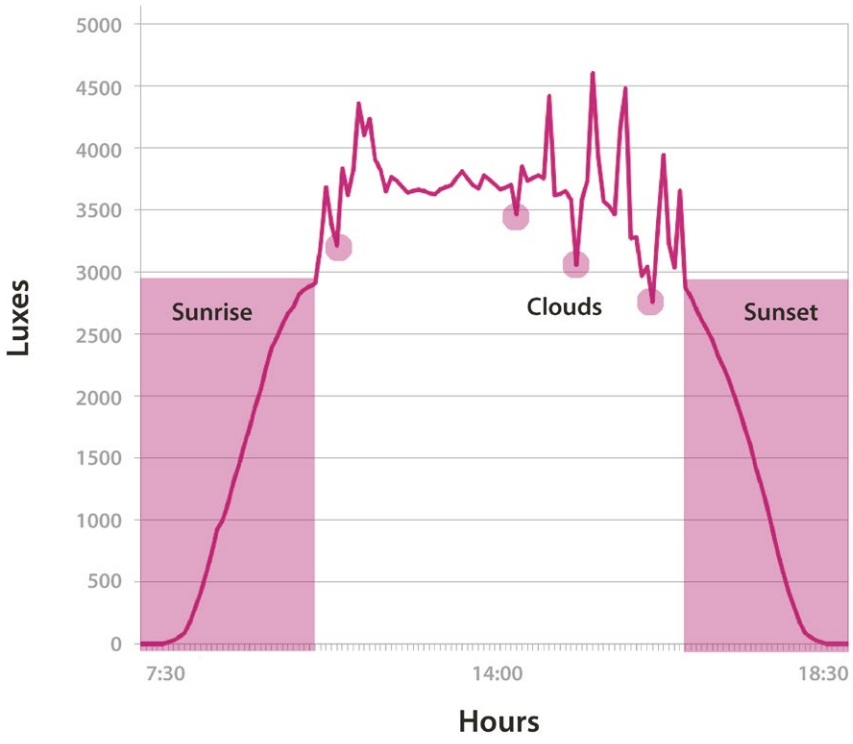


Figure: Image of the Luminosity sensor probe (Luxes accuracy)

6.5. Relay Input-Output (Max: 30VDC, 1A)

6.5.1. Specifications

Contact Ratings VDC: 1 A, 30 VDC
Contact Form: SPDT (1c)
Coil Rated Current: 50 mA

6.5.2. Precautions for Safe Use

- Do not use this feature if you do not have advanced knowledge of electricity and electrical automation.
- The incorrect use of this feature can cause harm to the user or other people and damage any connected equipment.
- The incorrect use of this feature can cause death to the user or other people!
- The incorrect use of this feature can causes fires!
- Use only tools and equipment with non-conducting handles when working on electrical devices.
- Never handle this feature when hands, feet, or body are wet or perspiring, or when standing on a wet floor.
- Do not store highly flammable liquids near this equipment.
- Disconnect the power source before operating on this equipment.
- Do not touch the charged relay terminal area while the power is turned on. Doing so may result in electric shock.
- Do not use a relay for a load that exceeds the relay's switching capacity or other contact ratings. Doing so will reduce the specified performance, causing insulation failure, contact welding, and contact failure, and the relay itself may be damaged or burnt.
- Make sure the number of switching operations is within the permissible range. If a Relay is used after performance has deteriorated, it may result in insulation failure between circuits and burning of the relay itself.
- Do not use Relays where flammable gases or explosive gases may be present. Doing so may cause combustion or explosion due to relay heating or arcing during switching.
- This Limited Warranty does not cover: (a) defects or damage resulting from accident, misuse, abnormal use, abnormal conditions, improper storage, exposure to liquid, moisture, dampness, sand or dirt, neglect, or unusual physical, electrical or electromechanical stress, defects or damage resulting from the use of Product in conjunction or connection with accessories, products, or ancillary/peripheral equipment.

6.5.3. Introduction

The relay that is in Waspmote Events Sensor board v3.0, provides a potential-free contact. This contact can be used to enable low power loads such as relays and contactors, or to enable inputs in a PLC. The IN REL is designed to be used by a potential free contact to join +3v3 with the IN REL, for example in power failure applications.

Its important to remark that the relay Input-Output is not designed for alternate current (VAC), therefore please use only continuous currents (VDC).

NOTE: *the changeover contact is designed to be an auxiliary contact,* ***NEVER TO HANDLE LOADS****. Please never reach the current limitations defined in the relay specifications. The events board can be damaged permanently. The input contact is designed to be used with a relay contact with a 3v3 + IN REL. If you have any question about the usage of the relay, please contact Libelium before any test.*

6.6. Relay Input-Output in Waspmote Plug & Sense!

To provide access to the relay contacts in the Waspmote Plug & Sense! encapsulated line, a waterproof terminal block junction box is provided as a Relay Input-Output probe, making the connections on industrial environments or outdoor applications easier.

Figure: Relay Input-Output probe

It consists of 2 cable glands and 6 terminal block connectors with screw. The junction box can be easily opened by removing the four external screws and the cover. Then, the user is able to make the necessary connections using the terminal block connectors. Finally, the cable glands should be adjusted and the junction box should be closed properly to avoid water ingress.

Figure: Pin-out of the Relay Input-Output junction box

Terminal	Signal
1	Common
2	NC
3	NA
4	3v3
5	Relay Input
6	GND

Note: Please double check the terminal block connections to avoid wrong wirings or short-circuits between poles. The Waspmote Plug & Sense! unit can be seriously damaged. Besides, ensure that the junction box is properly closed to avoid damaged in outdoor applications (because of rain entry, for example). Libelium's warranty will not cover damages caused by a wrong installation.

6.7. Liquid Flow sensor probes (FS100A, FS200A, FS300A, FS400, YF-S401 and YF-G1)

Figure: Image of the Liquid Flow sensor probe (FS400)

Sensor specifications

Water Flow Small, YF-S401:
Flow rate: 0.3 ~ 6 L/Min
Working voltage: +3.3 V ~ +24 V
Working temperature: 0 ºC ~ 80 ºC
Pipe connection: 1/8"
Accuracy: ±3%
Max rated current: 15 mA (DC 5 V)

Figure: Image of the YF-S401, Small Liquid Flow sensor

Water Flow Medium, FS300A:
Flow rate: 1 ~ 60 L/Min
Working voltage: +5 V ~ +24 V (not suitable for +3.3 V)
Working temperature: 0 ºC ~ 80 ºC
Pipe connection: 3/4"
Accuracy: ±3%
Max rated current: 15 mA (DC 5 V)

Figure: Image of the FS-300A, Medium Liquid Flow sensor

Water Flow Large, YF-G1:
Flow rate: 1 ~ 100 L/Min
Working voltage: +3.3 V ~ +24 V
Working temperature: 0 ºC ~ 80 ºC
Pipe connection: 1"
Accuracy: ±3%
Max rated current: 15 mA (DC 5 V)

Figure: Image of the YF-G1, Large Liquid Flow sensor

The liquid flow sensors output a signal that consists of a series of digital pulses whose frequency is proportional to the flow rate of the liquid through the sensor. That digital signal, whose frequency is in the range between 0 Hz and 100 Hz, is directly read through one of the digital input/output pins of the microcontroller.

6.8. Presence sensor (PIR) probe

Sensor specifications (PIR)

Height: 22mm
Diameter: 20.2mm
Consumption: 170µA
Range of detection: 12m
Circuit Stability Time: 30seconds

Figure: Image of the Presence sensor probe (PIR)

The PIR sensor (Passive Infra-Red) is a pyroelectric sensor mainly consisting of an infra-red receiver and a focusing lens that bases its operation on the monitoring of the variations in the levels of reception of detected infra-reds, reflecting this movement by setting its output signal high. The 10µm spectrum corresponds to the radiation of heat from the majority of mammals as they emit temperatures around 36°C.

Figure: Image of configurations of the Presence sensor probe (PIR)

As we see in the figure, the presence sensor probe (PIR) may be placed in different positions. The sensor can be focused directly to the point we want.

6.9. Liquid Level sensor probe

Figure: Image of the Liquid Level sensor probe (PTFA1103)

Sensor specifications

PTFA3415
Measurement Level: Horizontal
Liquids: Water
Material (box): Propylene
Material (float): Propylene
Operating Temperature: -10 ºC ~ +80 ºC

Figure: Image of the PTFA3415 sensor

PTFA0100
Measurement Level: Horizontal
Liquids: Heavy oils and combustibles
Material (box): Polyamide
Material (float): Polyamide
Operating temperature: -10 ºC ~ +80 ºC

Figure: Image of the PTFA0100 sensor

PTFA1103
Measurement Level: Vertical
Liquids: Water
Material (box): Propylene
Material (float): Propylene
Operating temperature: -10 ºC ~ +80 ºC

Figure: Image of the PTFA1103 sensor

There are three liquid level sensors whose operation is based on the status of a switch which can be opened and closed (depending on its placing in the container) as the level of liquid moves the float at its end. The main differences between the three sensors, regarding its use in Waspmote, are to be found in their process for placing them in the container (horizontal in the case of the PTFA3415 and PTFA0100 sensors, vertical for the PTFA1103 sensor) and in the material they are made of (the PTFA1103 and PTFA3415 sensors recommended for edible liquids and certain acids and the PTFA0100 for heavy oils and combustibles, more specific information can be found in the sensors' manual).

6.10. Liquid Presence sensor probe (Point)

Sensor specifications

Maximum Switching Voltage: 100 V
Operating temperature: +5 ºC ~ +80 ºC
Detectable liquids: Water

Figure: Image of the Liquid Presence sensor probe (Point)

This sensor bases its operation on the variation in resistance between its two contacts in the presence of liquid to commute a switch reed from open to closed, commuting to open again when the liquid disappears (take care when it is used to detect liquids of high viscosity which may remain between the terminals blocking its drainage and preventing it from re-opening).

6.11. Liquid Presence sensor probe (Line)

Sensor specifications

Length: 5 meters sensor + 2 meters jumper wire
Material: PE + alloy lend
Weight: 18 g/meter
Pull force limit: 60 kg
Cable diameter: 5.5 mm
Core resistance: 3 ohm/100 meters
Maximum exposed temperature: 75 ºC
Detectable liquids: Water

Figure: Image of the Liquid Presence sensor probe (Line)

This sensor detects conductive liquids anywhere along its length. After it is installed, once the cable senses the leakage of liquids, it will trigger an alarm. The sensor cable can detects the leakage of water.

Installation of this sensor should be in a safe place, far away from high magnetic fields and damp environment. In the installation, let sensor cable keep away from sharp material to avoid scuffing the sensor.

6.12. Hall Effect sensor probe

Sensor specifications

Length: 64 mm
Width: 19 mm
Thickness: 13 mm
Maximum contact resistance (closed): 200 mΩ
Minimum contact resistance (open): 100 GΩ

Figure: Image of the Hall Effect sensor probe

This is a magnetic sensor based on the Hall effect. The sensor's switch remains closed in the presence of a magnetic field, opening up in its absence. Together with its complementary magnet it can be used in applications of monitoring proximity or opening mechanisms.

7. Smart Water

7.1. General description

The Smart Water model has been conceived to facilitate the remote monitoring of the most relevant parameters related to water quality. With this platform you can measure more than 6 parameters, including the most relevant for water control such as dissolved oxygen, oxidation-reduction potential, pH, conductivity and temperature. An extremely accurate turbidity sensor has been integrated as well.

The Smart Water Ions line is complementary for these kinds of projects, enabling the control of concentration of ions like Ammonium (NH_4^+), Bromide (Br^-), Calcium (Ca^{2+}), Chloride (Cl^-), Cupric (Cu^{2+}), Fluoride (F^-), Iodide (I^-), Lithium (Li^+), Magnesium (Mg^{2+}), Nitrate (NO_3^-), Nitrite (NO_2^-), Perchlorate (ClO_4^-), Potassium (K^+), Silver (Ag^+), Sodium (Na^+) and pH. Take a look to the Smart Water Ions line in the next section.

Refer to Libelium website for more information.

Figure: Smart Water 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	pH	9328
B	Dissolved Oxygen (DO)	9327
C	Conductivity	9326
D	Oxidation-Reduction Potential (ORP)	9329
F	Soil/Water Temperature	9255-P (included by default)
	Turbidity	9353-P

Figure: Sensor sockets configuration for Smart Water model

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

7.2. Soil/Water Temperature (Pt-1000) sensor probe

Sensor specifications

Measurement range: 0 ~ 100 ºC
Accuracy: DIN EN 60751
Resistance (0 ºC): 1000 Ω
Diameter: 6 mm
Length: 40 mm
Cable: 3 m

Figure: Image of the Soil/Water Temperature sensor probe

The resistance of the Pt-1000 sensor varies between approximately 920 Ω and 1200 Ω in the range considered useful in agriculture applications (-20 ~ 50 ºC approximately), which results in too low variations of voltage at significant changes of temperature for the resolution of the Waspmote's analog-to-digital converter. The temperature value is returned in Celsius degree (ºC).

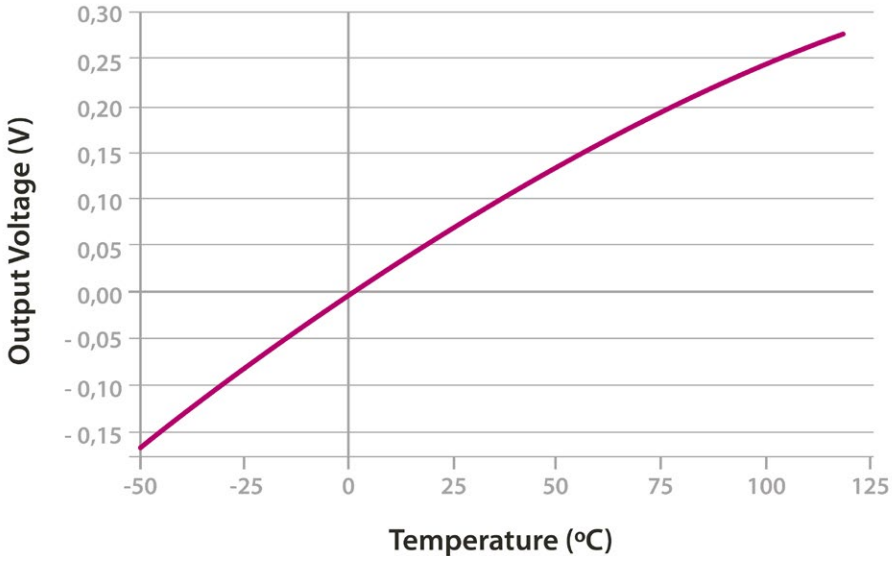


Figure: Output voltage of the PT-1000 sensor with respect to temperature

7.3. Conductivity sensor probe

Sensor specifications

Sensor type: Two electrodes sensor
Electrode material: Platinum
Conductivity cell constant: 1 ± 0.2 cm^{-1}

Figure: Image of the Conductivity sensor probe

The conductivity sensor is a two-pole cell whose resistance varies in function of the conductivity of the liquid it is immersed in. That conductivity will be proportional to the conductance of the sensor (the inverse of its resistance), multiplied by the constant cell, in the case of the Libelium sensor around 1 cm^{-1}, leading to a value in Siemens per centimeter (S/cm). For an accurate measurement, please take a look at section "Calibration Procedure" in the Smart Water Technical Guide, where the calibration procedure is detailed.

To power the conductivity sensor an alternating current circuit has been installed in order to avoid the polarization of the platinum electrodes.

7.4. Dissolved Oxygen sensor probe

Sensor specifications

Sensor type: Galvanic cell
Range: 0~20 mg/L
Accuracy: ±2%
Maximum operation temperature: 50 ºC
Saturation output: 33 mV ± 9 mV
Pressure: 0~100 psig (7.5 Bar)
Calibration: Single point in air
Response Time: After equilibration, 2 minutes for 2 mV

Figure: Image of the Dissolved Oxygen sensor probe

The galvanic cell provides an output voltage proportional to the concentration of dissolved oxygen in the solution under measurement without the need of a supply voltage. This value is amplified to obtain a better resolution and measured with the analog-to-digital converter placed on the Smart Water board.

This sensor should be calibrated with the calibration solution for more accurate measurements.

7.5. pH sensor probe

Sensor specifications

Sensor type: Combination electrode
Measurement range: 0~14 pH
Temperature of operation: 0~80 ºC
Zero electric potential: 7 ± 0.25 p
Response time: < 1 min
Internal resistance: ≤250 MΩ
Repeatability: 0.017
PTS: >98.5
Noise: <0.5 mV
Alkali error: 15 mV
Reader accuracy: up to 0.01 (in function of calibration)

Figure: Image of the pH sensor probe

The pH sensor integrated in the Smart Water board is a combination electrode that provides a voltage proportional to the pH of the solution, corresponding the pH 7 with the voltage reference of 2.048 V of the circuit, with an uncertainty of ±0.25 pH. To get an accurate value from these sensors it is necessary both to carry out a calibration and to compensate the output of the sensor for the temperature variation from that of the calibration moment.

7.6. Oxidation-reduction potential sensor probe

Sensor specifications

Sensor type: Combination electrode
Electric Potential: 245~270 mV
Reference impedance: 10 kΩ
Stability: ±8 mV/24 h

Figure: Image of the Oxidation-reduction potential sensor probe

Like the pH sensor, the ORP probe is a combination electrode whose output voltage is equivalent to the potential of the solution, so it will share the connection sockets with that sensor. The output of the circuitry to which it is connected is directly read from the analog-to-digital converter of the Smart Water sensor board, being the 2.048 V reference subtracted to obtain the actual oxidation-reduction potential in volts (in this case, since this parameter is directly a voltage it is not necessary to call a conversion function).

This sensor should be calibrated with the calibration solution for more accurate measurements.

7.7. Turbidity sensor probe

Specifications

Sensor type: IR optical sensor with optical fibre
Measurement range: 0-4000 NTU
Accuracy: 5% (around 1 NTU in the lower scale)
Robust and waterproof : IP68
Digital output: Modbus RS-485
Power consumption : 820 µA
Power supply: 5 V
Stocking temperature: -10 to +60 ºC
Material: PVC, Quartz, PMMA, Nickel-plated brass

Figure: Turbidity sensor

This sensor is available for Waspmote "OEM" line and for Plug & Sense! line too.

For the Plug & Sense! version, everything comes connected inside the node and the user just needs to plug the probe to the F bottom socket.

The turbidity sensor is extremely sensitive and the user must treat it with especial care in all situations (laboratory tests, development, installation, etc). The sensor must be installed in a solid way and protected from any impact.

Refer to Libelium website for more information.

7.7.1. Turbidity: the parameter

Turbidity is the haziness of a fluid caused by individual solid particles that are generally invisible to the naked eye. The measurement of turbidity is a key test of water quality. Nephelometers, or nephelometric turbidimeters, measure the light scattered at an angle of 90° by one detector from the incident light beam generated by an incandescent light bulb. Readings are reported in Nephelometric Turbidity Units, or NTUs. NTU has been the traditional reporting unit for turbidity and is still recognized by some as the "universal" unit of measure, regardless of the technology used.

The measurement of the turbidity is important in the next scenarios:

- Urban waste water treatment (inlet / outlet controls)
- Sanitation network
- Industrial effluent treatment
- Surface water monitoring
- Drinking water

8. Smart Water Ions

8.1. General description

The Smart Water Ions models specialize in the measurement of ions concentration for drinking water quality control, agriculture water monitoring, swimming pools or waste water treatment.

The Smart Water line is complementary for these kinds of projects, enabling the control of parameters like turbidity, conductivity, oxidation-reduction potential and dissolved oxygen. Take a look to the Smart Water line in the previous section. Refer to Libelium website for more information.

There are 3 variants for Smart Water Ions: Single, Double and PRO. This is related to the type of ion sensor that each variant can integrate. Next section describes each configuration in detail.

Figure: Smart Water Ions Waspmote Plug & Sense! model

Single

This variant includes a Single Junction Reference Probe, so it can read all the single type ion sensors.
Sensor sockets are configured as shown in the table below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A, B, C and D	Calcium Ion (Ca^{2+})	9352
	Fluoride Ion (F^-)	9353
	Fluoroborate Ion ($BF4^-$)	9354
	Nitrate Ion (NO_3^-)	9355
	pH (for Smart Water Ions)	9363
E	Single Junction Reference	9350 (included by default)
F	Soil/Water Temperature	9255 (included by default)

Figure: Sensor sockets configuration for Smart Water Ions model, single variant

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

Double

This variant includes a Double Junction Reference Probe, so it can read all the double type ion sensors.
Sensor sockets are configured as shown in the table below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A, B, C and D	Bromide Ion (Br^-)	9356
	Chloride Ion (Cl^-)	9357
	Cupric Ion (Cu^{2+})	9358
	Iodide Ion (I^-)	9360
	Silver Ion (Ag^+)	9362
	pH (for Smart Water Ions)	9363
E	Double Junction Reference	9351 (included by default)
F	Soil/Water Temperature	9255 (included by default)

Figure: Sensor sockets configuration for Smart Water Ions model, double variant

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

Pro

This special variant integrates extreme quality sensors, with better performance than the Single or Double lines. In this case, there is only one type of reference probe and up to 16 different ion parameters can be analyzed in 4 sockets.

Sensor sockets are configured as shown in the table below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A, B, C or D	Ammonium Ion (NH_4^+) [PRO]	9412
	Bromide Ion (Br^-) [PRO]	9413
	Calcium Ion (Ca^{2+}) [PRO]	9414
	Chloride Ion (Cl^-) [PRO]	9415
	Cupric Ion (Cu^{2+}) [PRO]	9416
	Fluoride Ion (F^-) [PRO]	9417
	Iodide Ion (I^-) [PRO]	9418
	Lithium Ion (Li^+) [PRO]	9419
	Magnesium Ion (Mg^{2+}) [PRO]	9420
	Nitrate Ion (NO_3^-) [PRO]	9421
	Nitrite Ion (NO_2^-) [PRO]	9422
	Perchlorate Ion (ClO_4^-) [PRO]	9423
	Potassium Ion (K^+) [PRO]	9424
	Silver Ion (Ag^+) [PRO]	9425
	Sodium Ion (Na^+) [PRO]	9426
	pH [PRO]	9411
E	Reference Sensor Probe [PRO]	9410 (included by default)
F	Soil/Water Temperature	9255 (included by default)

Figure: Sensor sockets configuration for Smart Water Ions model, PRO variant

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

8.2. Soil/Water Temperature (Pt-1000) sensor probe

Sensor specifications

Measurement range: 0 ~ 100 ºC
Accuracy: DIN EN 60751
Resistance (0 ºC): 1000 Ω
Diameter: 6 mm
Length: 40 mm
Cable: 2 m

Figure: Image of the Soil/Water Temperature sensor probe

The resistance of the Pt-1000 sensor varies between approximately 920 Ω and 1200 Ω in the range considered useful in agriculture applications (-20 ~ 50 ºC approximately), which results in too low variations of voltage at significant changes of temperature for the resolution of the Waspmote's analog-to-digital converter. The temperature value is returned in Celsius degree (ºC).

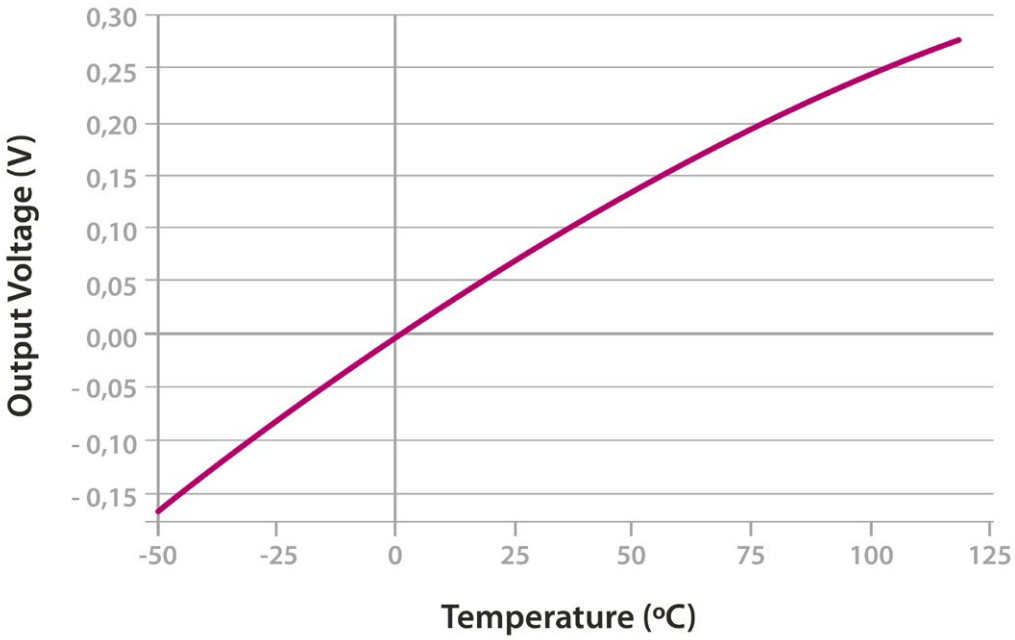


Figure: Output voltage of the PT-1000 sensor with respect to temperature

8.3. Reference probes

A reference electrode is an electrode which has a stable and well-known electrode potential. Reference electrodes are critical to acquiring good electrochemical data. Drift in the reference electrode potential can cause quantitative and qualitative errors in data collection and analysis beyond simple inaccuracies in the measured potential.

Plug & Sense! Smart Water Ions line has two different variants, according to the Reference Probes each Plug & Sense! Includes:

- The Single variant always include a Single Junction Reference.
- The Double variant always include a Double Junction Reference.

Figure: Reference Probe

The next sensors must be used with the Single Junction Reference Probe:

- Calcium Ion (Ca^{2+}) Sensor Probe
- Fluoride Ion (F^{-}) Sensor Probe
- Fluoroborate Ion (BF_4^{-}) Sensor Probe
- Nitrate Ion (NO_3^{-}) Sensor Probe

The next sensors must be used with the Double Junction Reference Probe:

- Bromide Ion (Br^{-}) Sensor Probe
- Chloride Ion (Cl^{-}) Sensor Probe
- Cupric Ion (Cu^{2+}) Sensor Probe
- Iodide Ion (I^{-}) Sensor Probe
- Lead Ion (Pb^{2+}) Sensor Probe
- Silver Ion (Ag^{+}) Sensor Probe

The pH (for Smart Water Ions) Sensor must be always used with the Single **or** the Double Reference Probe.

The Soil/Water Temperature Sensor is the only sensor in this board which does not need any Reference Probe.

One Reference Probe must **always** be connected in the corresponding socket marked as REFERENCE in the Smart Water Ions Sensor Board. **Only one** Reference Probe can be connected at the same time in the Smart Water Ions Sensor Board. One single-type sensor and one double-type sensor can **never be mixed** in the same system at the same time.

8.4. Ion sensors

In this table we can see the main features of the ions sensors. The ion sensors are divided in two groups depending on the required reference (double, or single junction). In the Smart Water Ions Sensor Board, only one reference can be connected at the same time, so is no possible to mix different sensor types.

Species	Construction	Concentration range (mol/L)	pH range	Temperature range (ºC)	Dimensions (mm)	Required Reference
Bromide (Br^-)	Solid State Half-cell	10^{-1}-10^{-6}	2-11	5-60	Ø10x155	Double Junction
Chloride (Cl^-)	Solid State Half-cell	10^{-1}-$5x10^{-5}$	2-12	5-60	Ø10x155	Double Junction
Cupric (Cu^{2+})	Solid State Half-cell	10^{-1}-10^{-6}	2-12	5-60	Ø10x155	Double Junction
Iodide (I^-)	Solid State Half-cell	10^{-1}-$5x10^{-7}$	2-12	5-60	Ø10x155	Double Junction
Lead (Pb^{2+})	Solid State Half-cell	10^{-1}-10^{-6}	4-7	5-60	Ø10x155	Double Junction
Silver (Ag^+)*	Solid State Half-cell	10^{-1}-$3x10^{-7}$	2-8 (Ag^+)	5-60	Ø10x155	Double Junction
Calcium (Ca^{2+})	Plastic Membrane Half-cell	10^{-1}-10^{-5}	2.5-11	5-60	Ø10x155	Single Junction
Fluoride (F^-)	Plastic Membrane Half-cell	10^{-1}-10^{-6}	5-7	5-60	Ø10x155	Single Junction
Fluoroborate (BF_4^-)	Plastic Membrane Half-cell	10^{-1}-$3x10^{-6}$	2.5-11	5-60	Ø10x155	Single Junction
Nitrate (NO_3^-)	Plastic Membrane Half-cell	10^{-1}-10^{-5}	2.5-11	5-60	Ø10x155	Single Junction

* This sensor is also sensitive to Sulfide (S2-) ions; take this into account in terms of cross-sensitivity if the monitored water could contain Sulfide. The user could even use this sensor to meter Sulfide ion if he is able to calibrate the sensor by his own means.

8.5. pH sensor (for Smart Water Ions)

The pH sensor integrated in the Smart Water Ions Sensor Board are specific to be used with this board and in combination with one of the Reference Probes. This pH sensor cannot be used with Smart Water Sensor Board, which integrates another pH sensor, different from the one exposed in this section.

- **pH Range:** 0-14
- **Temp. Range (ºC):** 5-60
- **Internal Reference Type:** Ag/AgCl
- **Dimensions (mm):** Ø12x160
- **Reader accuracy:** in function of calibration

Figure: pH Sensor Probe for Smart Water Ions

9. Smart Cities PRO

9.1. General description

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, structural health, smart lighting, etc. Refer to Libelium website for more information.

Figure: Smart Cities 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
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

* Ask Libelium Sales Department for more information.

As we see in the figure below, thanks to the directional probe, the ultrasound sensor probe may be placed in different positions. The sensor can be focused directly to the point we want to measure.

Figure: Configurations of the ultrasound sensor probe

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

9.2. Noise / Sound Level Sensor sensor probe

Figure: Noise / Sound Level sensor

9.2.1. Specifations of the Noise Level Sensor probe

- **Target parameter:** LeqA
- **Microphone sensitivity:** 12.7 mV / Pa
- **Range of the sensor:** 50 dBA to 100 dBA
- **Accuracy:** ±0.5 dBA (at 1 kHz)
- **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

9.2.2. 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

9.2.3. Calibration tests

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

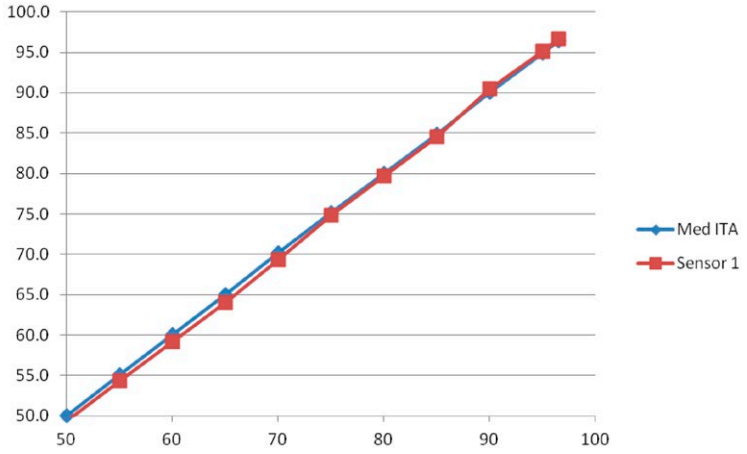


Figure: Example of test report obtained in the laborator

9.3. Smart environment PRO sensors

The Plug & Sense! Smart Cities PRO models allow to connect most of the sensors available on the Plug & Sense! Smart Environment PRO sensors, including gas sensors, the Particle Matter sensor the triple temperature, the humidity and pressure sensor, the Luxes sensor and the ultrasound sensor. You can find detailed info in the chapter "Smart Environment PRO" and also in the Gases PRO Guide for these sensor probes:

- Particle Matter (PM1 / PM2.5 / PM10) - Dust
- Carbon Monoxide (CO) for high concentrations [Calibrated]
- Carbon Monoxide (CO) for low concentrations [Calibrated]
- Carbon Dioxide (CO2) [Calibrated]
- Molecular Oxygen (O_2) [Calibrated]
- Ozone (O_3) [Calibrated]
- Ammonia (NH_3) [Calibrated]
- Methane (CH_4) and Combustible Gases [Calibrated]
- Molecular Hydrogen (H_2) [Calibrated]
- Hydrogen Sulfide (H_2S) [Calibrated]
- Hydrogen Chloride (HCl) [Calibrated]
- Phosphine (PH_3) [Calibrated]
- Ethylene Oxide (ETO) [Calibrated]
- Chlorine (Cl_2) [Calibrated]
- Temperature, Humidity and Pressure
- Ultrasound sensor probe
- Luminosity (Luxes accuracy)

Plug & Sense! Smart Cities PRO has 3 special and exclusive gas sensor probes which are described in the next sections.

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.

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

9.4.1. Specifications

Figure: Image of the Nitric Oxide Sensor for low concentrations 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 Smart Cities PRO Technical Guide for more detail.*

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.

9.5. Nitric Dioxide (NO_2) Gas Sensor [Calibrated]

9.5.1. Specifications

Figure: Image of the Nitric Dioxide high accuracy 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 Smart Cities PRO Technical Guide for more detail.*

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.

9.6. Sulfur Dioxide (SO_2) Gas Sensor [Calibrated]

9.6.1. Specifications

Gas: SO_2
Sensor: SO2-A4

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

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 Smart Cities PRO Technical Guide for more detail.*

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.

10. Smart Parking

10.1. General description

The Smart Parking node allows to detect available parking spots by placing the node on the pavement. It works with a magnetic sensor which detects when a vehicle is present or not.

The node benefits from Sigfox and LoRaWAN technologies (868 and 900 MHz bands), getting ubiquitous coverage with few base stations. The device is very optimized in terms of power consumption, resulting in a long battery life. Its small size and the robust and surface-mount enclosure enables a fast installation, without the need of digging a hole in the ground. Finally, the developer does not need to program the node, but just configure some key parameters. Remote management and bidirectional communication allow to change parameters from the Cloud.

Figure: Smart Parking node

> ***Note:*** *There are specific documents for parking applications on the Libelium website. Refer to the Smart Parking Technical Guide to see typical applications for this model and how to make a good installation.*

11. Smart Agriculture

11.1. General description

The Smart Agriculture models allow to monitor multiple environmental parameters involving a wide range of applications. It has been provided with sensors for air and soil temperature and humidity, solar visible radiation, wind speed and direction, rainfall, atmospheric pressure, etc.

The main applications for this Waspmote Plug & Sense! model are precision agriculture, irrigation systems, greenhouses, weather stations, etc. Refer to Libelium website for more information.

Two variants are possible for this model, normal and PRO. Next section describes each configuration in detail.

Figure: Smart Agriculture Waspmote Plug & Sense! model

Normal

Sensor sockets are configured as shown in the figure below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A	Weather Station WS-3000 (anemometer + wind vane + pluviometer)	9256-P
B	Soil Moisture 1	9248-P, 9324-P, 9323-P
C	Soil Moisture 3	9248-P, 9324-P, 9323-P
D	Soil Temperature	86949*
	Temperature + Humidity + Pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P
E	Leaf Wetness	9249-P
	Soil Moisture 2	9248-P, 9324-P, 9323-P
F (digital bus)	Temperature + Humidity + Pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P

Figure: Sensor sockets configuration for Smart Agriculture model

* Ask Libelium Sales Department for more information.

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

PRO

Sensor sockets are configured as shown in the figure below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A	Weather Station WS-3000 (anemometer + wind vane + pluviometer)	9256-P
B	Soil Mosture 1	9248-P, 9324-P, 9323-P
	Solar Radiation (PAR)	9251-P
	Ultraviolet Radiation	9257-P
C	Soil Mosture 3	9248-P, 9324-P, 9323-P
	Dendrometers	9252-P, 9253-P, 9254-P
D (digital bus)	Soil Temperature (Pt-1000)	9255-P
	Temperature + Humidity + Pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P
E	Leaf Wetness	9249-P
	Soil Moisture 2	9248-P, 9324-P, 9323-P
F (digital bus)	Temperature + Humidity + Pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P

Figure: Sensor sockets configuration for Smart Agriculture PRO model

* Ask Libelium Sales Department for more information.

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

11.2. Temperature, Humidity and Pressure Sensor Probe

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

Specifications

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

Figure: Image of the Temperature, Humidity and Pressure Sensor Probe

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

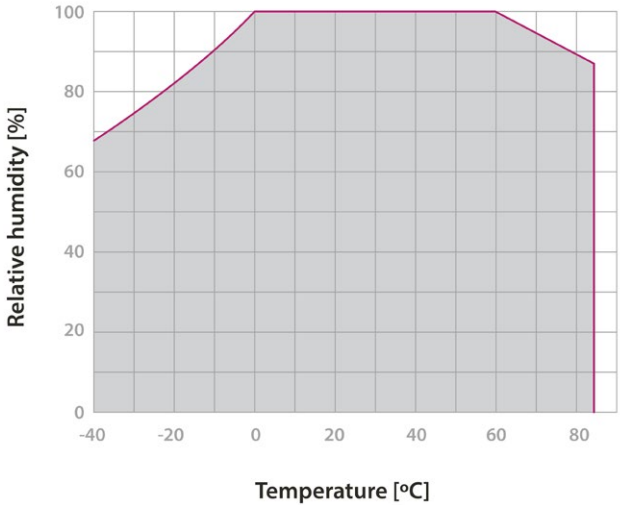


Figure: Humidity sensor operating range

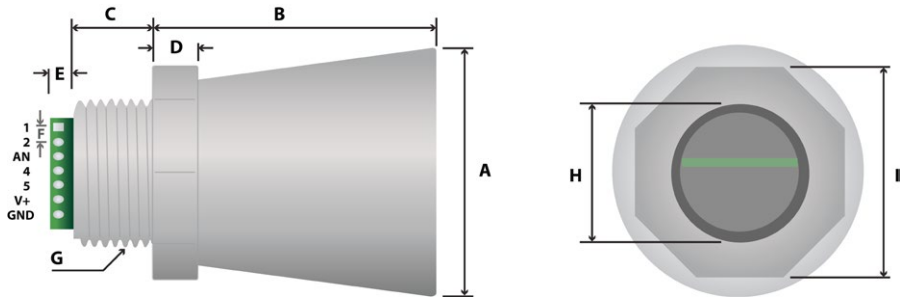
Pressure sensor
Measurement range: 30 ~ 110 kPa
Operational temperature range: -40 ~ +85 ºC
Full accuracy temperature range: 0 ~ +65 ºC
Absolute accuracy: ±0.1 kPa (0 ~ 65 ºC)
Typical consumption: 2.8 µA measuring
Maximum consumption: 4.2 µA measuring

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

I2CXL-MaxSonar®-MB7040™

Operation frequency: 42 kHz
Maximum detection distance: 765 cm
Interface: Digital bus
Power supply: 3.3 V ~ 5 V
Consumption (average): 2.1 mA (powered at 3.3 V) – 3.2 mA (powered at 5 V)
Consumption (peak): 50 mA (powered at 3.3 V) – 100 mA (powered at 5 V)
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 8.25 cm diameter rod for diagram C and a 28 cm wide board for diagram D):

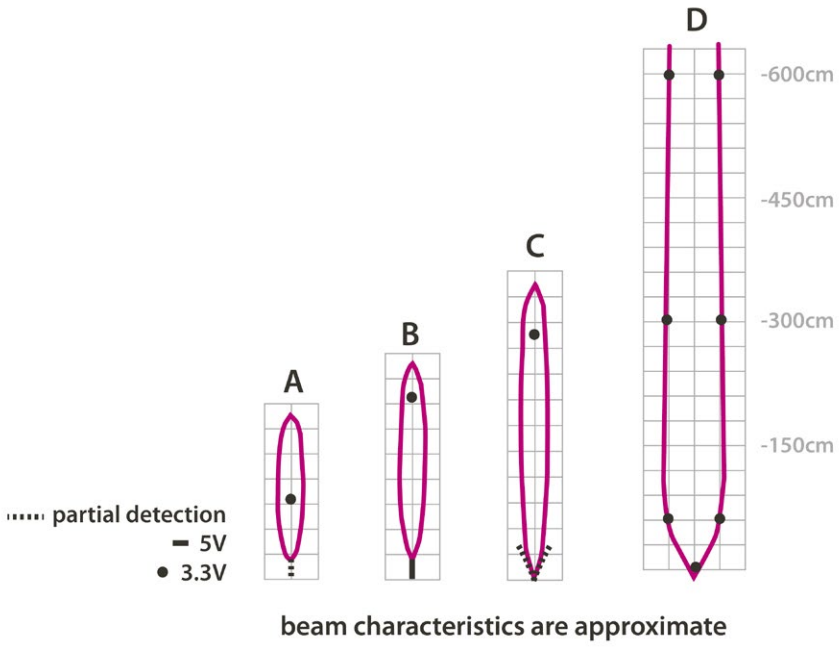


Figure: Diagram of the sensor beam extracted from the data sheet of the XL-MaxSonar®-WRA1™ sensor from MaxBotix

Figure: Image of configurations of the ultrasound sensor probe

As we see in the figure, the ultrasound sensor probe may be placed in different positions. The sensor can be focused directly to the point we want to measure.

11.4. Luminosity sensor probe (Luxes accuracy)

Sensor specifications (Luxes accuracy)

Dynamic range: 0.1 to 40000 Lux
Spectral range: 300 – 1100 nm
Voltage range: 2.7 – 3.6 V
Operating temperature: -30 ºC to +80 ºC
Typical consumption: 0.24 mA
Maximum consumption: 0.6 mA
Usage: Indoors and outdoors

Figure: Image of the Luminosity sensor probe (Luxes accuracy)

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.

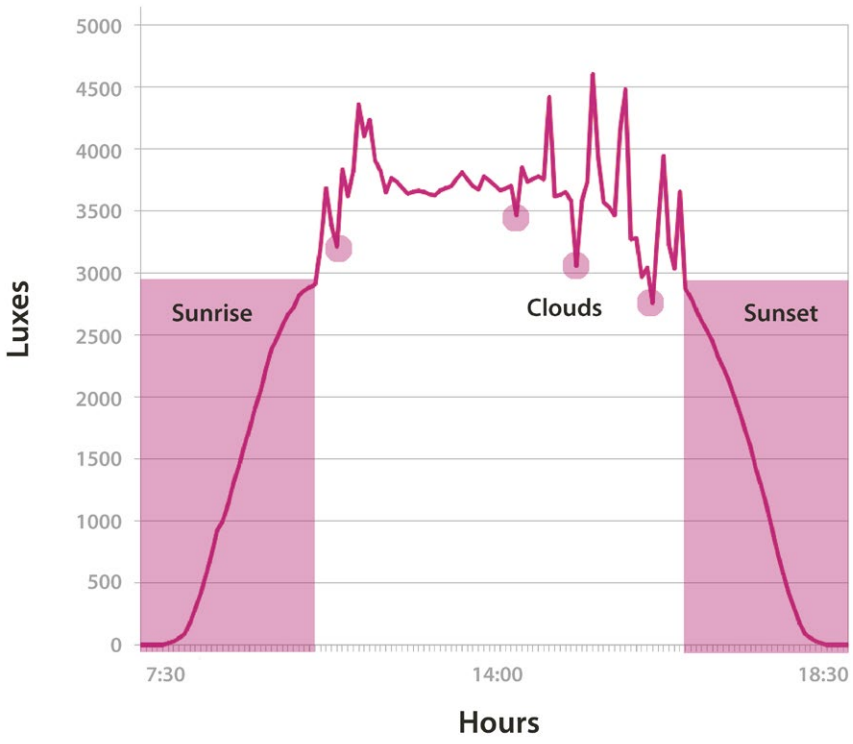


Figure: Image of the Luminosity sensor probe (Luxes accuracy)

11.5. Soil temperature (DS18B20) sensor probe

Sensor specifications (DS18B20)

Measurement range: [-55 ºC,+125 ºC]
Output voltage (0ºC): 500 mV
Resolution: 12 bits (0.0625 ºC)
Accuracy: ±0.5 ºC (range -10 ºC ~ +85 ºC)
Supply voltage: 3.0 ~ 5.5 V
Response time: 1.65 seconds (63% response from +30 to +125 ºC)
Typical consumption: 1 mA
Conversion time: 750 ms

Figure: Image of the Soil Temperature sensor probe (DS18B20)

The DS18B20 is a temperature digital sensor which provides an accurate measurement and a high resolution (of up to 0.065 ºC) which communicates with the Waspmote's microcontroller through the 1-Wire bus. It has been encapsulated in a plastic seal that isolates it from humidity, thus allowing to use it in wet environments as long as for temperature measurement in soil or liquids.

11.6. Soil moisture sensor probe

Sensor specifications (Watermark)

Measurement range: 0 ~ 200 cb
Frequency range: 50 ~ 10000 Hz approximately
Diameter: 22 mm
Length: 76 mm
Terminals: AWG 20

Figure: Image of the Soil Moisture sensor probe (Watermark)

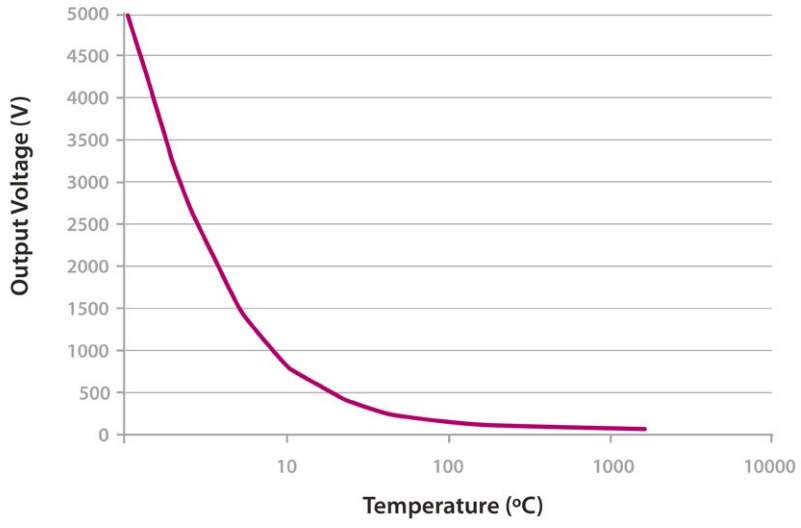


Figure: Output frequency of the Watermark sensor circuit with respect to the resistance of the sensor

The Watermark sensor by Irrometer is a resistive type sensor consisting of two electrodes highly resistant to corrosion embedded in a granular matrix below a gypsum wafer. The resistance value of the sensor is proportional to the soil water tension, a parameter dependent on moisture that reflects the pressure needed to extract the water from the ground. The function of the library `readValue` returns the frequency output of the sensor's adaptation circuit in Hertz (Hz), for more information about the conversion into soil water tension look at Appendix 1 of the Agriculture 3.0 Board technical guide.

11.7. Weather station WS-3000 probe

Sensor specifications (Anemometer)

Sensitivity: 2.4 km/h / turn
Wind Speed Range: 0 ~ 240 km/h
Height: 7.1 cm
Arm length: 8.9 cm
Connector: RJ11

The anemometer chosen for Waspmote consists of a Reed switch normally open that closes for a short period of time when the arms of the anemometer complete a turn, so the output is a digital signal whose frequency will be proportional to the wind speed in kilometers per hour (km/h).

Figure: Image of the Weather Station WS-3000 probe

Sensor specifications (Vane)

Height: 8.9 cm
Length: 17.8 cm
Maximum accuracy: 22.5º
Resistance range: 688 Ω ~ 120 kΩ

The wind vane consists of a basement that turns freely on a platform endowed with a net of eight resistances connected to eight switches that are normally open and are closed (one or two) when a magnet in the basement acts on them, which permits us to distinguish up to 16 different positions (the equivalent to a resolution of 22.5º). The equivalent resistance of the wind vane, along with a 10 kΩ resistance, form a voltage divider, powered at 3.3 V, whose output can be measured in an analog input of the microcontroller. The function of the library `readValue` also stores in variable `vane_direction` an 8 bits value which corresponds with an identifier of the pointing direction. Below, a table with the different values that the equivalent resistance of the wind vane may take is shown, along with the direction corresponding to each value:

Direction (Degrees)	Resistance (kΩ)	Voltage (V)	Identifier
0	33	2.53	SENS_AGR_VANE_N
22.5	6.57	1.31	SENS_AGR_VANE_NNE
45	8.2	1.49	SENS_AGR_VANE_NE
67.5	0.891	0.27	SENS_AGR_VANE_ENE
90	1	0.3	SENS_AGR_VANE_E
112.5	0.688	0.21	SENS_AGR_VANE_ESE
135	2.2	0.59	SENS_AGR_VANE_SE
157.5	1.41	0.41	SENS_AGR_VANE_SSE

Direction (Degrees)	Resistance (kΩ)	Voltage (V)	Identifier
180	3.9	0.92	SENS_AGR_VANE_S
202.5	3.14	0.79	SENS_AGR_VANE_SSW
225	16	2.03	SENS_AGR_VANE_SW
247.5	14.12	1.93	SENS_AGR_VANE_WSW
270	120	3.05	SENS_AGR_VANE_W
292.5	42.12	2.67	SENS_AGR_VANE_WNW
315	64.9	2.86	SENS_AGR_VANE_NW
337.5	21.88	2.26	SENS_AGR_VANE_NNW

Besides, it is recommended to use the function `getVaneFiltered` in order to perform a mean filtered measurement during a specified period of time. Thus, mechanical fluctuations will be avoided and a more accurate measurement will be done.

Sensor specifications (Pluviometer)

Height: 9.05 cm

Length: 23 cm

Bucket capacity: 0.28 mm of rain

The pluviometer consists of a small bucket that, once completely filled (0.28 mm of water approximately), closes a switch, emptying automatically afterwards. The result is a digital signal whose frequency is proportional to the intensity of rainfall in millimeters of rain per minute (mm/min). The sensor is connected directly to a Waspmote digital input through a pull-up resistance and to the interruption pin TXD1, allowing the triggering of an interruption of the microprocessor when the start of the rain is detected.

Tip: the user can apply a little of paraffin on the pluviometer's upper surface in order to help the rain drops to flow down to the inside of the sensor.

11.8. Leaf Wetness sensor probe

Sensor specifications (Leaf Wetness)

Resistance Range: 5 kΩ ~ >2 MΩ
Output Voltage Range: 1 V ~ 3.3 V
Length: 5.5 cm
Width: 4 cm

Figure: Image of the Leaf Wetness sensor probe

The leaf wetness sensor behaves as a resistance of a very high value (infinite, for practical purposes) in absence of condensation in the conductive combs that make it up, and that may fall down to about 5kΩ when it is completely submerged in water. The voltage at its output is inversely proportional to the humidity condensed on the sensor, and can be read at an analog input of Waspmote.

11.9. Soil/Water Temperature (Pt-1000) sensor probe

Sensor specifications

Measurement range: 0 ~ 100 ºC
Accuracy: DIN EN 60751
Resistance (0 ºC): 1000 Ω
Diameter: 6 mm
Length: 40 mm
Cable: 2 m

Figure: Image of the Soil/Water Temperature sensor probe

The resistance of the Pt-1000 sensor varies between approximately 920 Ω and 1200 Ω in the range considered useful in agriculture applications (-20 ~ 50 ºC approximately), which results in too low variations of voltage at significant changes of temperature for the resolution of the Waspmote's analog-to-digital converter. The temperature value is returned in Celsius degree (ºC).

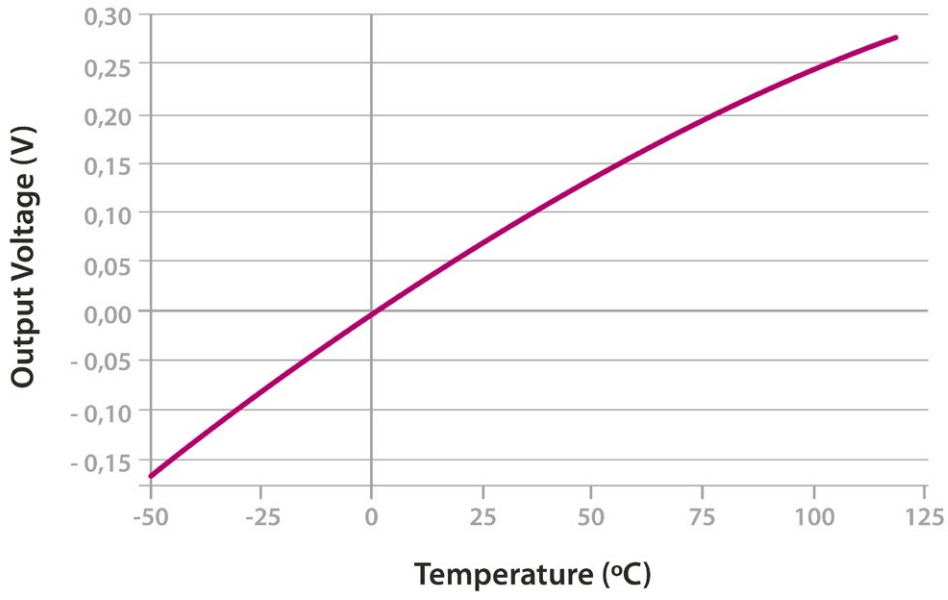


Figure: Output voltage of the PT-1000 sensor with respect to temperature

11.10. Solar Radiation sensor probe

Sensor specifications (SQ-110)

Responsivity: 0.200 mV / µmol·m^{-2}s^{-1}
Maximum radiation output: 400 mV (2000µmol·m^{-2}s^{-1})
Lineal range: 1000 mV (5000 µmol·m^{-2}s^{-1})
Sensibility: 5.00 µmol·m^{-2}s^{-1}/mV
Spectral range: 400 ~ 700 nm
Accuracy: ±5%
Repeatability: ±1%
Diameter: 2.4 cm
Height: 2.75 cm
Cable length: 3 m
Operation temperature: -40 ~ 55 ºC
Operation humidity: 0 ~ 100% RH

Figure: Image of the Solar Radiation sensor probe

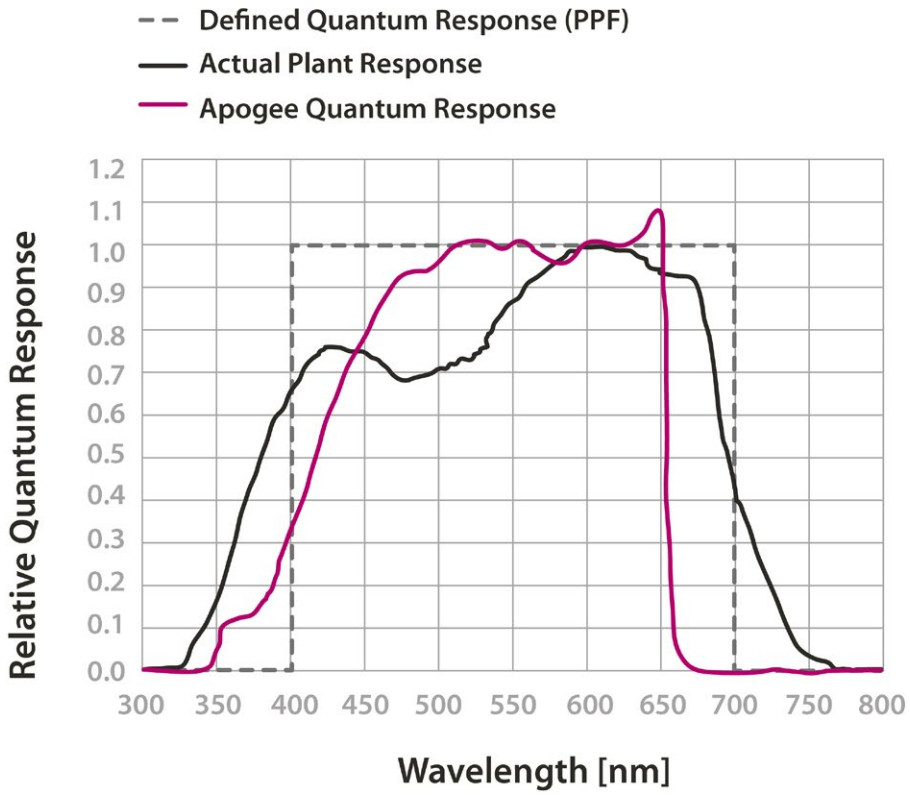


Figure: Graph of the spectral response of the SQ-110 sensor compared to the photosynthetic response of a plant

The SQ-110 sensor, specifically calibrated for the detection of solar radiation, provides at its output a voltage proportional to the intensity of the light in the visible range of the spectrum, a key parameter in photosynthesis processes. It presents a maximum output of 400 mV under maximum radiation conditions and a sensitivity of 5.00 µmol·m^{-2}s^{-1}/mV. In order to improve the accuracy of the reading, this is carried out through a 16 bits analog-to-digital converter that communicates with the microprocessor of the mote through the I2C.

Sensor specifications (SU-100)

Responsivity: 0.15 mV / µmol·m^{-2}s^{-1}
Maximum radiation output: 26 mV (170 µmol·m^{-2}s^{-1})
Lineal range: 60 mV (400 µmol·m^{-2}s^{-1})
Sensibility: 6.5 µmol·m^{-2}s^{-1}/mV
Spectral range: 250 ~ 400 nm
Accuracy: ±10%
Repeatability: ±1%
Diameter: 2.4 cm
Height: 2.75 cm
Cable length: 3 m
Operation humidity: 0 ~ 100% RH

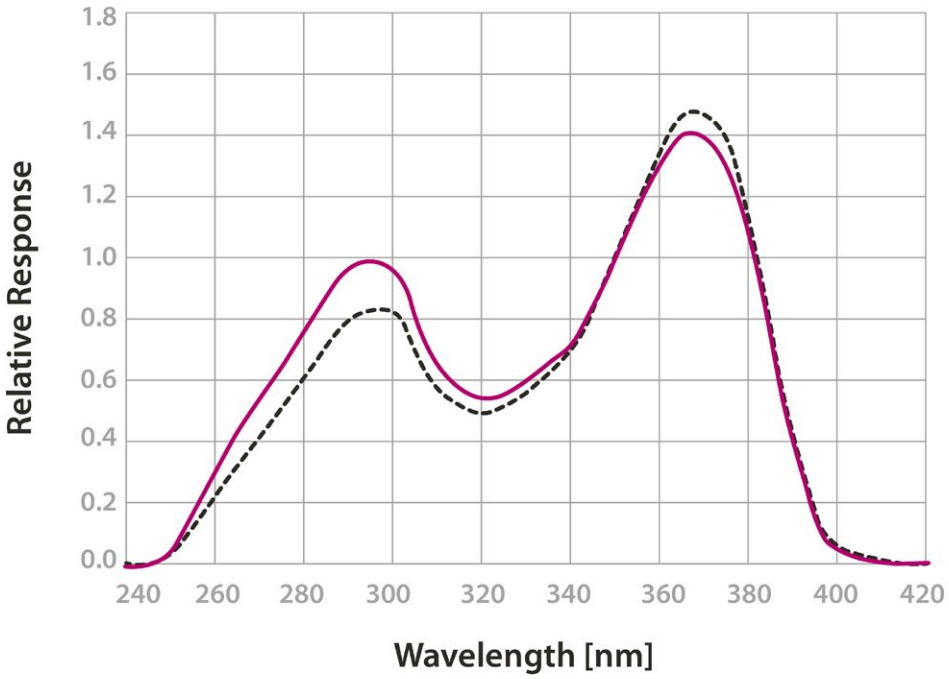


Figure: Graph of the spectral response of the SU-100 sensor compared to the photosynthetic response of a plant

The SU-100 sensor, complementary to the SQ-110 sensor, provides at its output a voltage proportional to the intensity of the light in the ultraviolet range of the spectrum. It presents a maximum output of 26 mV under maximum radiation conditions and a sensitivity of 6.5 µmol·m^{-2}s^{-1}/mV. This sensor is read by the mote through the same 16 bits analog-to-digital converter used with the SQ-110 sensor.

11.11. Dendrometer sensor probe

Figure: Image of the Dendrometer sensor probe

Sensor specifications (Trunk diameter)

Trunk/branch diameter: From 2 cm
Accuracy: ±2 µm
Temperature coefficient: <0.1µm/K
Linearity: <2%
Operation temperature: -30 ~ 40 ºC
Operation humidity: 0 ~ 100% RH
Cable length: 2 m
Output range: 0 ~ 20 kΩ
Range of the sensor: Function of the size of the tree:

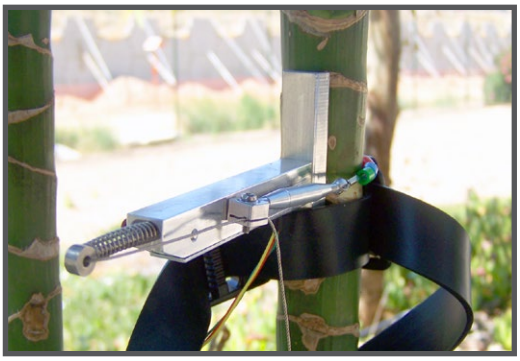


Figure: Ecomatik DC2 sensor

Tree Diameter (cm)	Measuring range in circumference(mm)	Measuring range in diameter (mm)
10	31.25	9.94
40	22.99	7.31
100	16.58	5.27

Sensor specifications (Stem diameter)

Stem/branch diameter: 0 ~ 20 cm
Range of the sensor: 11 mm
Output range: 0 ~ 20 kΩ
Accuracy: ±2 µm
Temperature coefficient: <0.1µm/K
Operation temperature: -30 ~ 40 ºC
Operation humidity: 0 ~ 100% RH
Cable length: 2 m

Figure: Ecomatik DD sensor

Sensor specifications (Fruit diameter)

Fruit diameter: 0 ~ 11 cm
Range of the sensor: 11 mm
Output range: 0 ~ 20 kΩ
Accuracy: ±2 µm
Temperature coefficient: <0.1 µm/K
Operation temperature: -30 ~ 40 ºC
Operation humidity: 0 ~ 100% RH
Cable length: 2 m

Figure: Ecomatik DF sensor

The operation of the three Ecomatik dendrometers, DC2, DD and DF, is based on the variation of an internal resistance with the pressure that the growing of the trunk, stem, branch or fruit exerts on the sensor. The circuit permits the reading of that resistance in a full bridge configuration through a 16 bits analog-to-digital converter whose reference is provided by a high precision 3 V voltage reference in order to acquire the most accurate and stable measurements possible, returning its value in mm.

12. Ambient Control

12.1. General description

This model is designed to monitor the main environment parameters easily. Only three sensor probes are allowed for this model, as shown in next table.

Figure: Ambient Control Waspmote Plug & Sense! model

Sensor sockets are configured as it is shown in figure below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A	Humidity + Temperature (Sensirion)	9247-P
B	Luminosity (LDR)	9205-P
C	Luminosity (Luxes accuracy)	9325-P
D, E and F	Not used	-

Figure: Sensor sockets configuration for Ambient Control model

As we see in the figure below, thanks to the directional probe, the Luminosity (Luxes accuracy) sensor probe may be placed in different positions. The sensor can be focused directly to the light source we want to measure.

Figure: Configurations of the Luminosity sensor probe (luxes accuracy)

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

12.2. Temperature, Humidity and Pressure Sensor Probe

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

Specifications

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

Figure: Image of the Temperature, Humidity and Pressure Sensor Probe

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

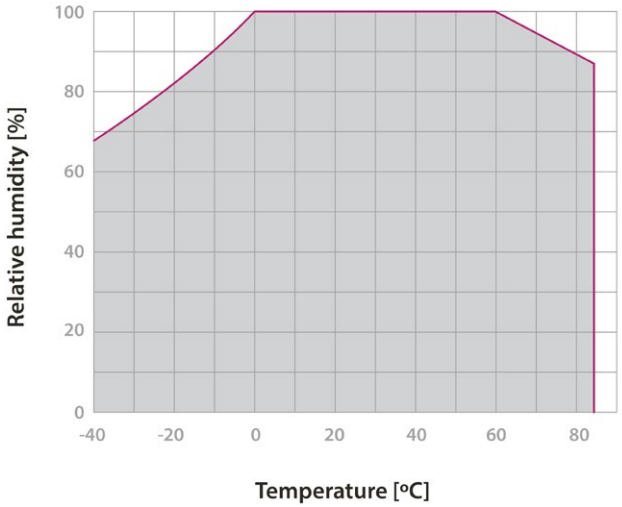


Figure: Humidity sensor operating range

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

12.3. Luminosity (LDR) sensor probe

Sensor specifications (LDR)

Resistance in darkness: 20 MΩ
Resistance in light (10lux): 5 ~ 20 kΩ
Spectral range: 400 ~ 700 nm
Operating temperature: -30 ºC ~ +75 ºC

Figure: Image of the Luminosity sensor probe (LDR)

This is a resistive sensor whose conductivity varies depending on the intensity of light received on its photosensitive part. The measurable spectral range (400 nm – 700 nm) coincides with the human visible spectrum so it can be used to detect light/darkness in the same way that a human eye would detect it.

Note: *The Luminosity sensor probe used in Ambient Control is different from the probe used in the other Plug & Sense! Applications, so they are not interchangeable.*

12.4. Luminosity sensor probe (Luxes accuracy)

Sensor specifications (Luxes accuracy)

Dynamic range: 0.1 to 40000 Lux
Spectral range: 300 – 1100 nm
Voltage range: 2.7 – 3.6V
Operating temperature: -30ºC to +80ºC
Typical consumption: 0.24mA
Maximum consumption: 0.6mA
Usage: Indoors and outdoors

Figure: Image of the Luminosity sensor probe (Luxes accuracy)

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.

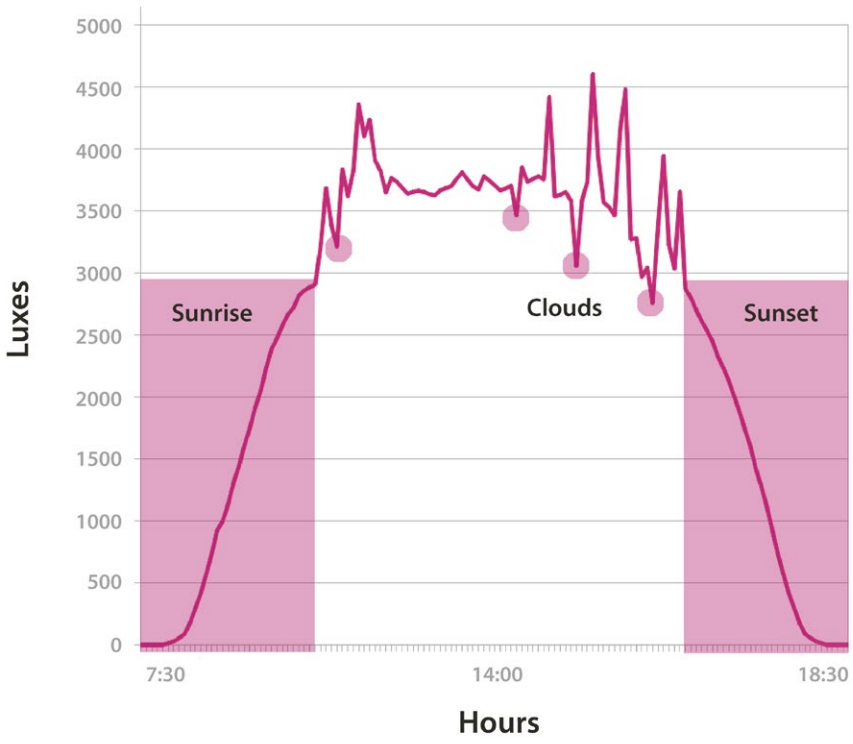


Figure: Image of the Luminosity sensor probe (Luxes accuracy)

Figure: Image of configurations of the Luminosity sensor probe (Luxes accuracy)

As we see in the figure, the luminosity sensor probe may be placed in different positions. The sensor can be focused directly to the light source we want to measure.

If you want to focused it directly to the light source, be sure that it (the sun, a spotlight...) emits less light than the maximum value allowed by the sensor. If we try to measure a higher value the sensor will saturate.

12.5. Comparative between Light and Luminosity sensor

As it is shown in the graph below, the Luminosity sensor probe (LDR) can measure the presence of a light source below or above a certain threshold. Different from the Luminosity sensor probe (Luxes accuracy) that can measure the exact quantity of the light in luxes. It allows us to appreciate different values along the time.

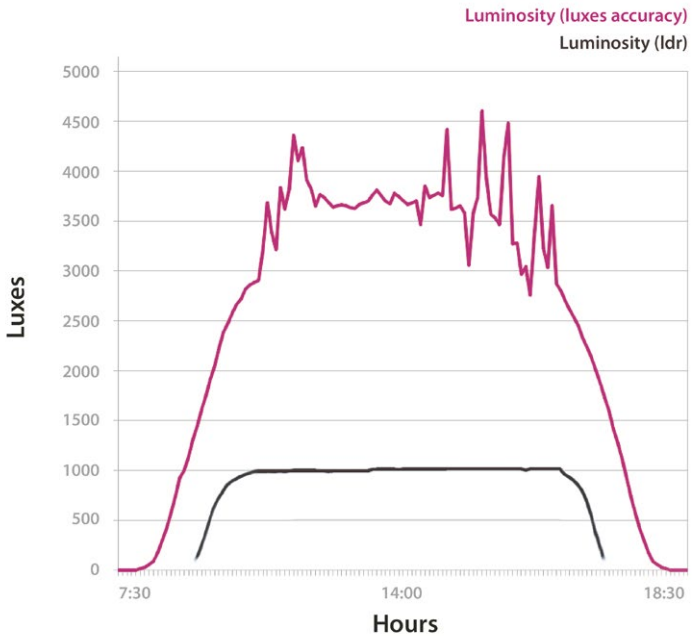


Figure: Comparison of the responses of the Luminosity sensor probe (Luxes accuracy) and the Luminosity sensor probe (LDR)

13. Radiation Control

13.1. General description

The main application for this Waspmote Plug & Sense! configuration is to measure radiation levels using a Geiger sensor. For this model, the Geiger tube is already included inside Waspmote, so the user does not have to connect any sensor probe to the enclosure. The rest of the other sensor sockets are not used.

Figure: Radiation Control Waspmote Plug & Sense! model

Sensor sockets are not used for this model.

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

14. 4-20 mA Current Loop

14.1. General description

The applications for this Plug & Sense! model are focused on adding wireless connectivity to 4-20 mA devices and connecting them to the Cloud.

Figure: 4-20 mA Current Loop Waspmote Plug & Sense! model

Sensor sockets are configured as shown in the figure below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Board channel	**Reference**
A	Channel 1 (type 2)	9270-P, DB9-P
B	Channel 2 (type 2)	9270-P, DB9-P
C	Channel 3 (type 2)	9270-P, DB9-P
D	Channel 4 (type 4)	9270-P, DB9-P

Figure: Sensor sockets configuration for 4-20 mA Current Loop model

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

14.2. Terminal box probe

To provide access to the 4-20 mA current loop board signals on the Waspmote Plug & Sense! encapsulated line, a waterproof terminal block junction box is available as a probe, making the connections on industrial environments or outdoor applications easier.

It consists of 2 cable glands and 6 terminal block connectors with screw. The junction box can be easily opened by removing the four external screws and the cover. Then, the user is able to make the necessary connections using the terminal block connectors. Finally, the cable glands should be adjusted and the junction box should be closed properly to avoid water ingress.

Figure: Terminal box probe

Note: Please double check the terminal block connections to avoid wrong wirings or short circuits between poles. The Waspmote Plug & Sense! Unit can be seriously damaged. Besides, ensure that the junction box is properly closed to avoid damaged in outdoor applications. Libelium warranty will not cover damages caused by a wrong installation.

14.3. DB9 probe

The DB9 connector is commonly used in many applications with data transmission on industrial ambients. Libelium provides this probe with a standard DB9 female connector and a length of 1.5 meters.

Figure: DB9 probe

15. Documentation changelog

From v7.0 to v7.1:

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

16. 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