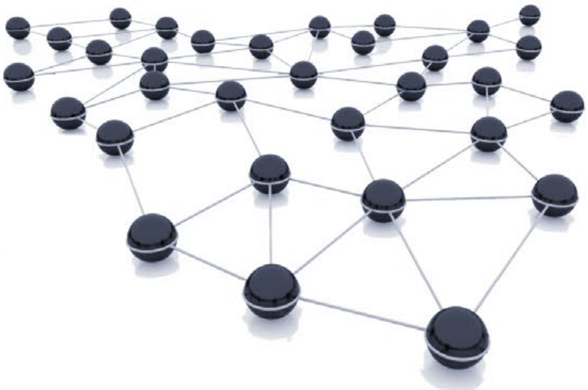
Waspmote Plug & Sense!

Sensor Guide



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

For a deep description of the characteristics of the Plug & Sense! line please refer to the Plug & Sense! Waspmote 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

Note that no code for reading the sensors has been included in this guide. For programming the Waspmote Plug & Sense! Motes please use the Libelium Code Generator that you can find at:
http://www.libelium.com/development/plug-sense/sdk_applications

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 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, as mentioned in the Waspmote Technical Guide.

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 7 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 -40ºC and +85ºC.

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 INT 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.

Please refer to the Waspmote Technical Guide for more information about how to handle the accelerometer in the Development section of the Libelium Website.

3.1.2. RTC temperature sensor

The Waspmote RTC (DS3231SN from Maxim) has a built in internal temperature sensor which it uses to **recalibrate itself**. Waspmote can access the value of this sensor through the I2C bus.

The sensor is shown in a 10-bit two's complement format. It has a resolution of **0.25ºC**. The measurable temperature range is between **-40ºC and +85ºC**.

The sensor is prepared to measure the temperature of the board itself and can thereby compensate for oscillations in the quartz crystal it uses as a clock. As it is a sensor built in to the RTC, for any application that requires a probe temperature sensor, this must be integrated from the micro's analog and digital inputs, as has been done in the case of the sensor boards designed by Libelium.

Please refer to the Waspmote Technical Guide for more information about how to handle the accelerometer in the Development section of 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 (gases probes, temperature and humidity (Sensirion), etc), but there are some special cases which can rise this weight.

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

New sensor probes

According to the feedback received from customers and as a part of Libelium Quality Service Policy, Libelium has designed new rigid sensor probes. They consist of a solid tube protecting the sensor to get them always straight and standardize as maximum as possible the size and shape of the probes. This avoids bending and deliver a more professional finish to each node. The result is more esthetic and probes are uniform.

Figure: New sensor probes

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	Temperature	9203
	Carbon monoxide - CO	9229
	Methane - CH_4	9232
	Ammonia – NH_3	9233
	Liquefied Petroleum Gases: H_2, CH_4, ethanol, isobutene	9234
	Air pollutants 1: C_4H_{10}, CH_3CH_2OH, H_2, CO, CH_4	9235
	Air pollutants 2: $C_6H_5CH_3$, H_2S, CH_3CH_2OH, NH_3, H_2	9236
	Alcohol derivates: CH_3CH_2OH, H_2, C_4H_{10}, CO, CH_4	9237
B	Humidity	9204
	Atmospheric pressure	9250
C	Carbon dioxide - CO_2	9230
D	Nitrogen dioxide - NO_2	9238 , 9238 -B
E	Ozone - O_3	9258 , 9258 -B
	Hydrocarbons - VOC	9201 , 9201-B
	Oxygen - O_2	9231
F	Carbon monoxide - CO	9229
	Methane - CH_4	9232
	Ammonia – NH_3	9233
	Liquefied Petroleum Gases: H_2, CH_4, ethanol, isobutene	9234
	Air pollutants 1: C_4H_{10}, CH_3CH_2OH, H_2, CO, CH_4	9235
	Air pollutants 2: $C_6H_5CH_3$, H_2S, CH_3CH_2OH, NH_3, H_2	9236
	Alcohol derivates: CH_3CH_2OH, H_2, C_4H_{10}, CO, CH_4	9237

Figure: Sensor sockets configuration for Smart Environment model

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

4.2. Temperature sensor probe

Sensor specifications (MCP9700A)

Measurement range: [-40ºC ,+125ºC]
Output voltage (0ºC): 500mV
Sensitivity: 10mV/ºC
Accuracy: ±2ºC (range 0ºC ~ +70ºC), ±4ºC (range -40 ~ +125ºC)
Supply voltage: 2.3 ~ 5.5V
Response time: 1.65 seconds (63% response from +30 to +125°C).
Typical consumption: 6µA
Maximum consumption: 12µA

Figure: Image of the Temperature sensor probe (MCP9700A)

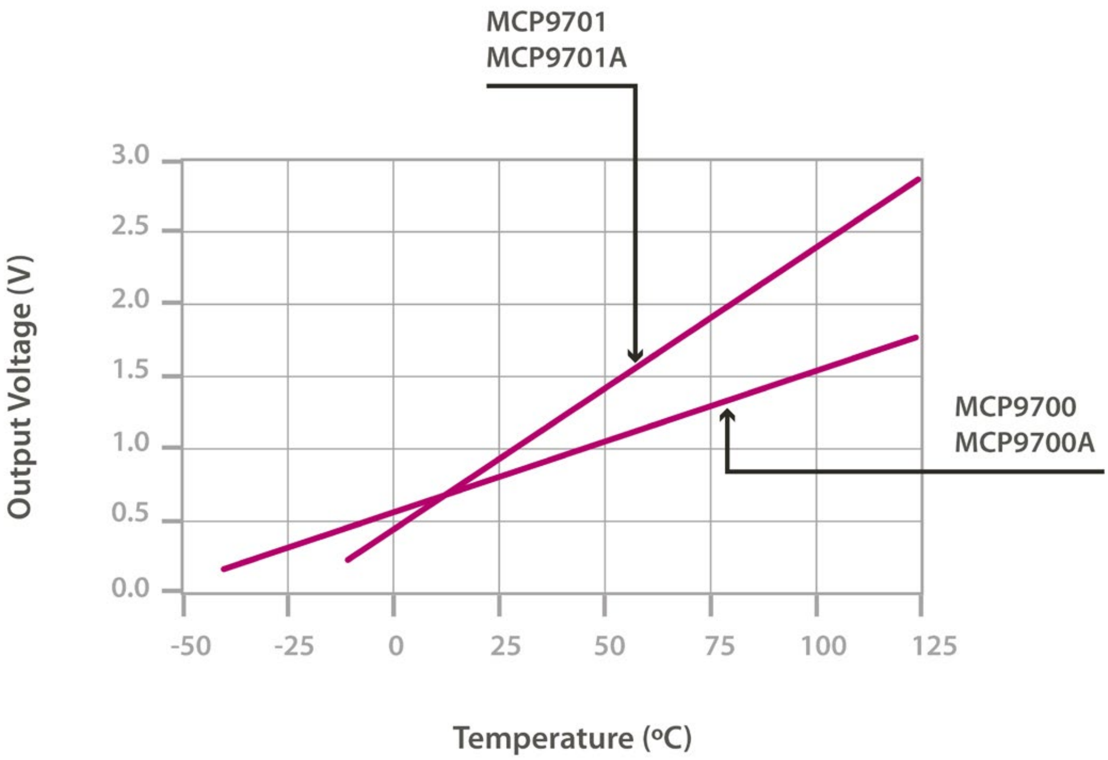


Figure: Graph of the MCP9700A sensor output voltage with respect to temperature, taken from the Microchip sensor's data sheet

The MCP9700A is an analog sensor which converts a temperature value into a proportional analog voltage. The range of output voltages is between 100mV (-40°) and 1.75V (125°C), resulting in a variation of 10mV/°C, with 500mV of output for 0°C.

4.3. Humidity sensor probe

Sensor specifications (808H5V5)

Measurement range: 0 ~ 100%RH
Output signal: 0.8 ~ 3.9V (25ºC)
Accuracy: <±4%RH (at 25ºC, range 30 ~ 80%), <±6%RH (range 0 ~ 100)
Supply voltage: 5VDC ±5%
Operating temperature: -40 ~ +85ºC
Response time: <15 seconds
Typical consumption: 0.38mA
Maximum consumption: 0.5mA

Figure: Image of the Humidity sensor probe (808H5V5)

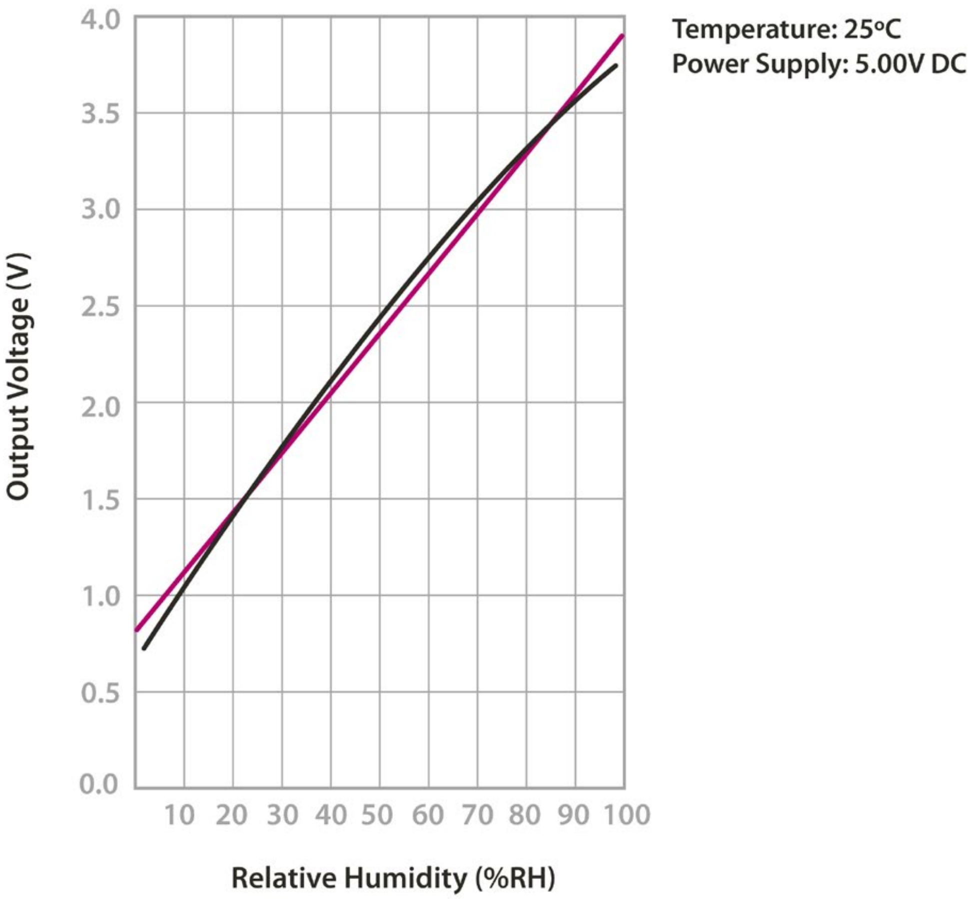


Figure: 808H5V5 humidity sensor output taken from the Sencera Co. Ltd sensor data sheet

This is an analog sensor which provides a voltage output proportional to the relative humidity in the atmosphere. As the sensor's signal range is outside of that permitted to the Waspmote's input, a voltage divider has been installed which converts the output voltage to values between 0.48 ~ 2.34V.

4.4. Atmospheric Pressure sensor probe

Sensor specifications (MPX4115A)

Measurement range: 15 ~ 115kPa
Output signal: 0,2 ~ 4,8V (0 ~ 85ºC)
Sensitivity: 46mV/kPa
Accuracy: <±1,5%V (0 ~ 85ºC)
Typical consumption: 7mA
Maximum consumption: 10mA
Supply voltage: 4.85 ~ 5.35V
Operation temperature: -40 ~ +125ºC
Storage temperature: -40 ~ +125ºC
Response time: 20ms

Figure: Image of the Atmospheric Pressure sensor probe (MPX4115A)

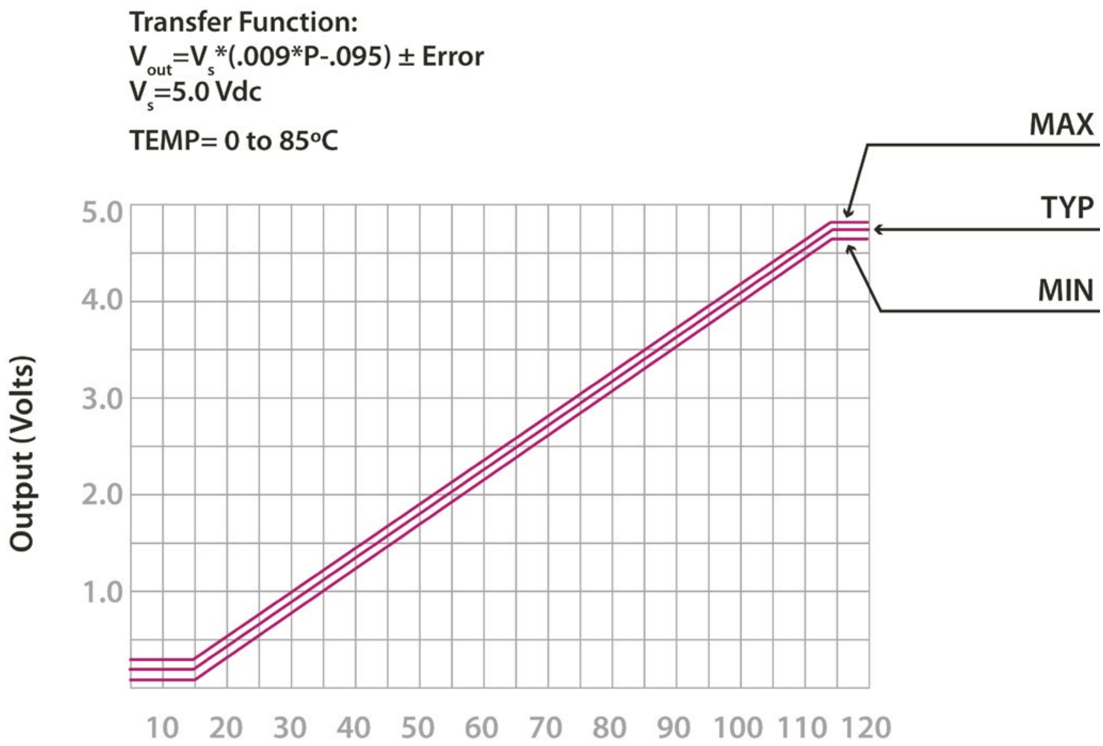


Figure: Graph of the MPX4115A sensor's output voltage with regard to pressure taken from the Freescale sensor's data sheet

The MPX4115A sensor converts atmospheric pressure to an analog voltage value in a range covering between 0.2V and 4.8V. As this is a range which exceeds the maximum value admitted by Waspmote, its output has been adapted to fit in a range between 0.12V and 2.88V.

4.5. Carbon Monoxide (CO) sensor probe

Sensor specifications (TGS2442)

Gases: CO
Measurement range: 30 ~ 1000ppm
Resistance at 100ppm: 13.3 ~ 133kΩ
Sensibility: 0.13 ~ 0.31 (ratio between the resistance at 300ppm and at 100ppm)
Supply voltage: 5V ±0.2V DC
Operating temperature: -10 ~ +50ºC
Response time: 1second
Minimum load resistance: 10kΩ
Average consumption: 3mA (throughout the complete power supply cycle in one second)

Figure: Image of the CO sensor probe (TGS2442)

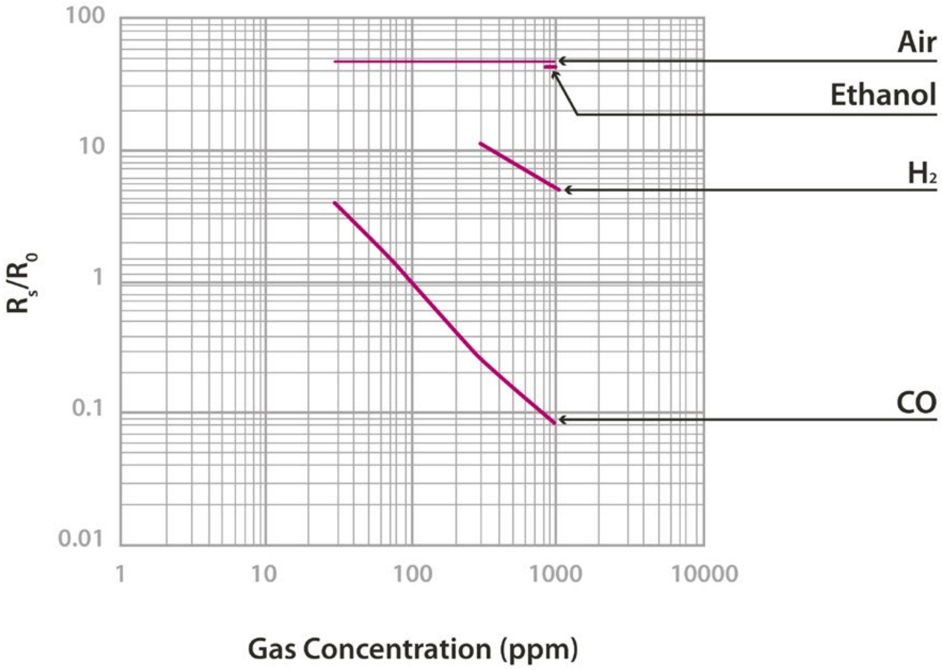


Figure: Graph of the sensitivity of the TGS2442 taken from the Figaro sensor's data sheet

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

Figure: Image of the CH_4 sensor probe (TGS2611)

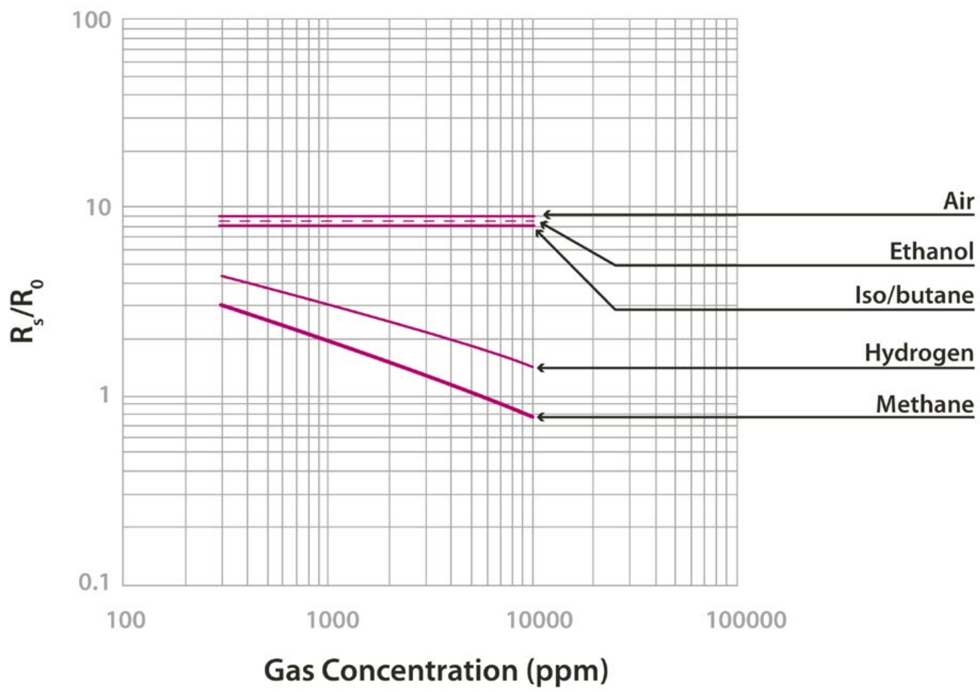


Figure: Graph of sensitivity of the TGS2611 taken from the Figaro sensor's data sheet

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 5000ppm) 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 ~ 100ppm
Resistance at 10ppm: 3.63 ~ 36.3kΩ
Sensitivity: 0,063 ~ 0.63 (ratio between the resistance at 3000 and at 1000ppm)
Supply voltage: 5V ±0.2V DC
Operating temperature: -10 ~ +50ºC
Response time: 250ms
Minimum load resistance: 8kΩ
Average consumption: 12mA (throughout the complete power supply cycle in 250ms)

Figure: Image of the NH_3 sensor probe (TGS2444)

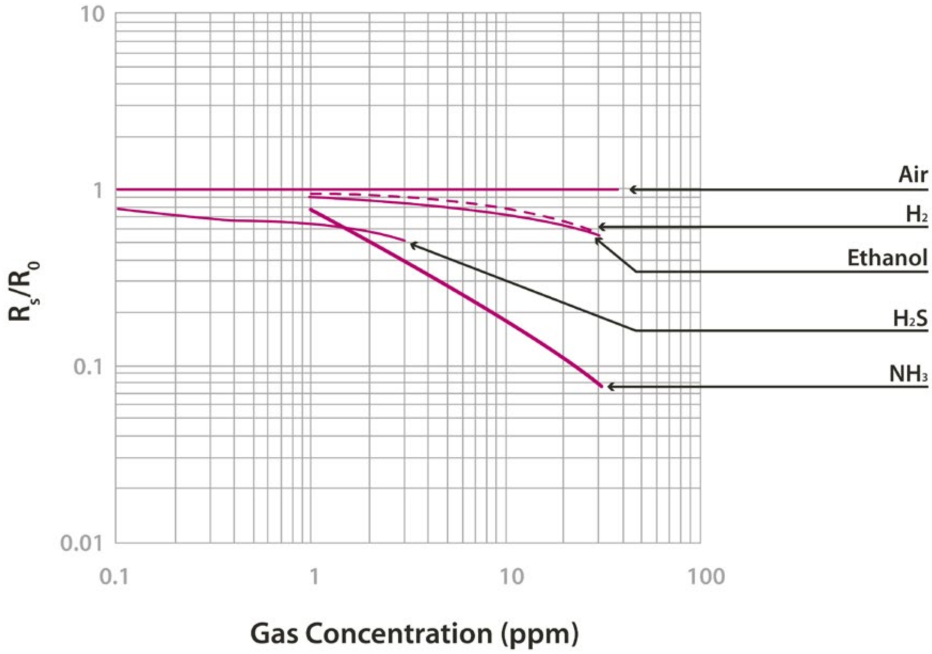


Figure: Graph of the sensitivity of the TGS2444 taken from the Figaro sensor data sheet

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

Figure: Image of the LPG sensor probe (TGS2610)

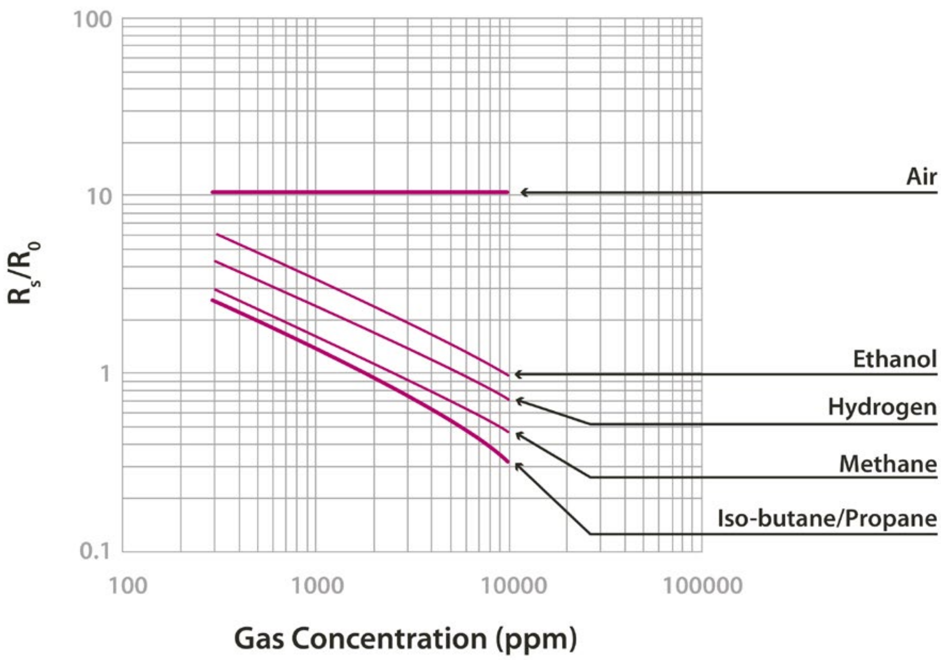


Figure: Graph of the sensitivity of the TGS2610 taken from the Figaro sensor's data sheet

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

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

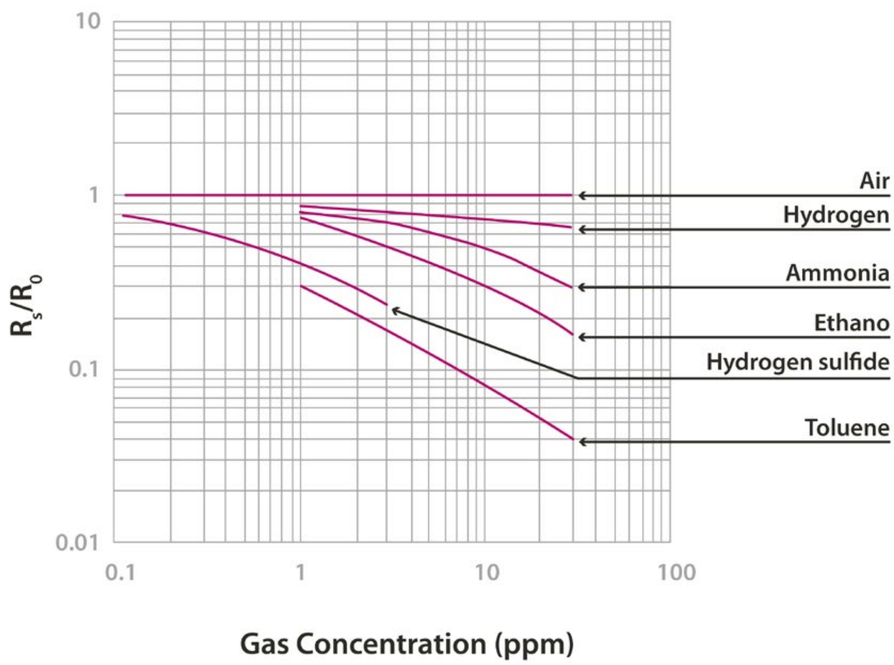


Figure: Graph of the sensitivity of the TGS2602 taken from the Figaro sensor's data sheet

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 100kΩ with a variation ratio between 0.15 and 0.5 between the resistance in 10ppm 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 ~ 100ppm
Air resistance: 10 ~ 90kΩ
Sensitivity: 0.3 ~ 0.6 (ratio between the resistance in 10ppm of H_2 and in air)
Supply voltage: 5V ±0.2V DC
Operating temperature: -10 ~ +40ºC
Response time: 30 seconds
Minimum load resistance: 0.45kΩ
Average consumption: 46mA

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

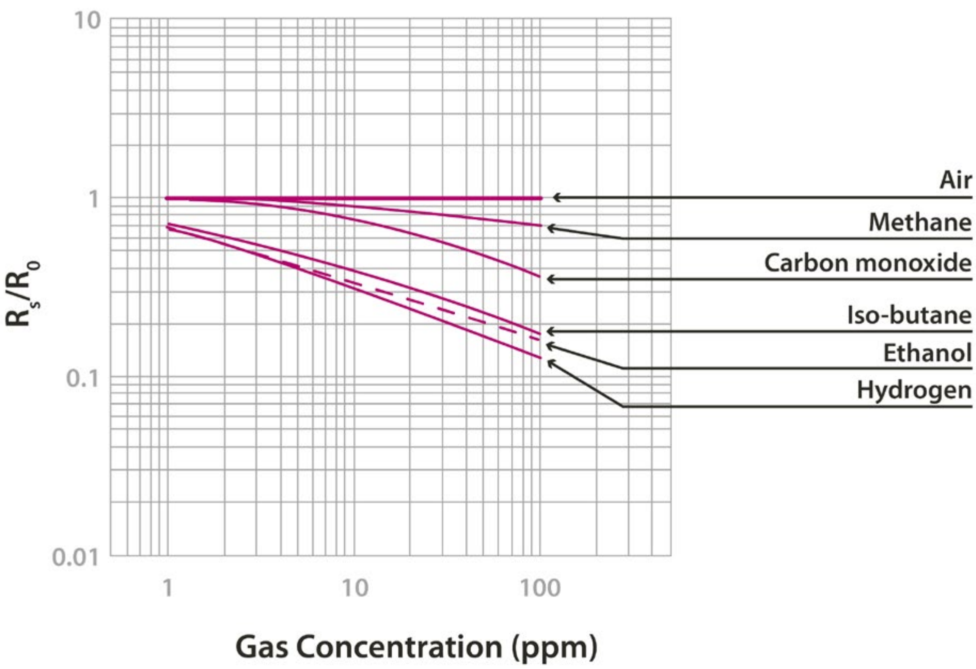


Figure: Graph of the sensitivity of the TGS2600 taken from the Figaro sensor's data sheet

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 90kΩ, with a ratio of sensitivity between 0.3 and 0.6 for an H_2 concentration of 10ppm. 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 ~ 5000ppm
Resistance to 300ppm of Ethanol: 1 ~ 5kΩ
Sensitivity: 0.3 ~ 0.5 (ratio between the resistance at 300ppm and at 50ppm)
Supply voltage: 5V ±0.2V DC
Operating temperature: -10 ~ +40ºC
Response time: 30 seconds
Load minimum resistance: 0.45kΩ
Average consumption: 46mA (throughout the complete power supply cycle in 250ms)

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

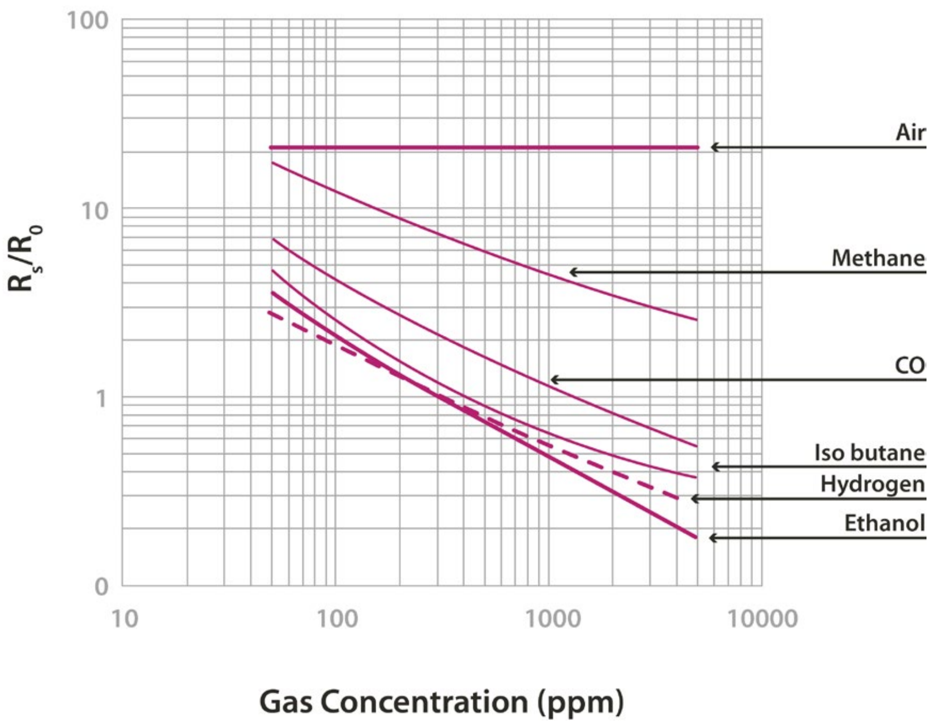


Figure: Graph of the sensitivity of the TGS2620 taken from the Figaro sensor's data sheet

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 300ppm concentration of Ethanol can vary between 1 and 5kΩ, while the sensitivity ratio between this and the resistance in 50ppm 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 ~ 10000ppm
Voltage at 350ppm: 220 ~ 490mV
Sensitivity: 44 ~ 72mV (variation between the voltage at 350ppm and at 3500ppm)
Supply voltage: 5V ±0.2V DC
Operating temperature: -10 ~ +50ºC
Response time: 1.5 minutes
Average consumption: 50mA

Figure: Image of the CO_2 sensor probe (TGS4161)

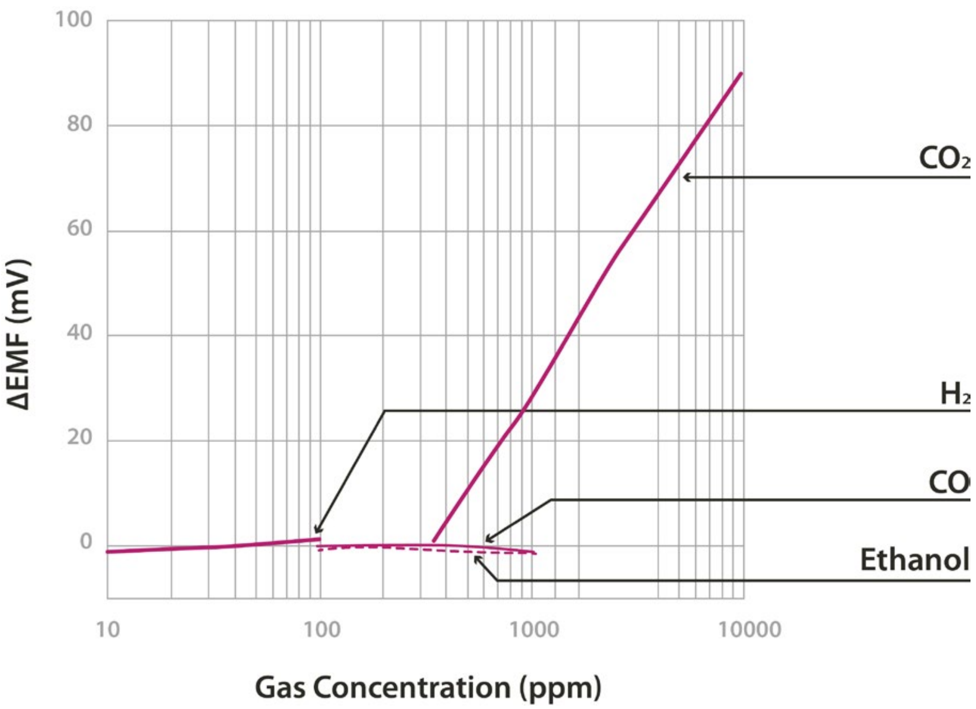


Figure: Graph of the sensitivity of the TGS4161 sensor taken from the Figaro sensor's data sheet

The TGS4161 sensor provides a voltage output proportional to the CO_2 concentration in the atmosphere. It shows a value between 220 and 490mV for a concentration of 350ppm (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 350ppm 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-2710)

Sensor specifications (MiCS-2710)

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

Figure: Image of the NO_2 sensor probe (MiCS-2710)

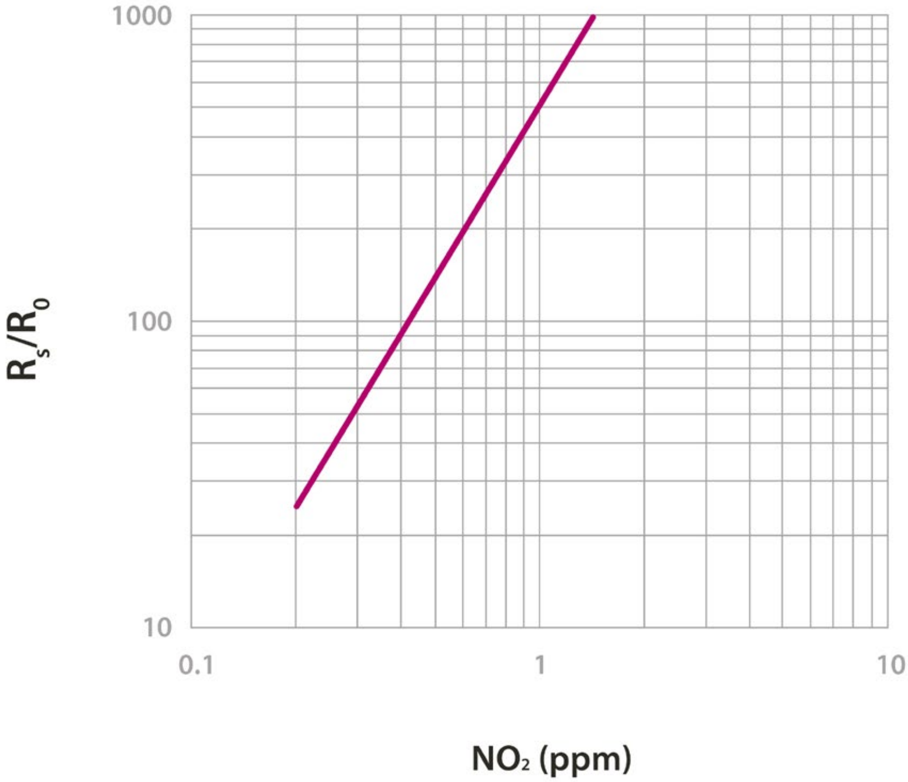


Figure: Graph of the sensitivity of the MiCS-2710 taken from the e2v's sensor data

The MiCS-2710 is a sensor whose resistance varies in the presence of small concentrations of NO_2. This value varies between 2kΩ and 2MΩ approximately, providing high accuracy throughout the output range. Unlike the rest of the board's gas sensors, which operate at a voltage of 5V, this sensor is powered through a 1.8V voltage regulator, with consumption of approximately 26mA. 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. Nitrogen Dioxide (NO_2) Sensor - 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:

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

Figure: Image of the MiCS-2714 sensor

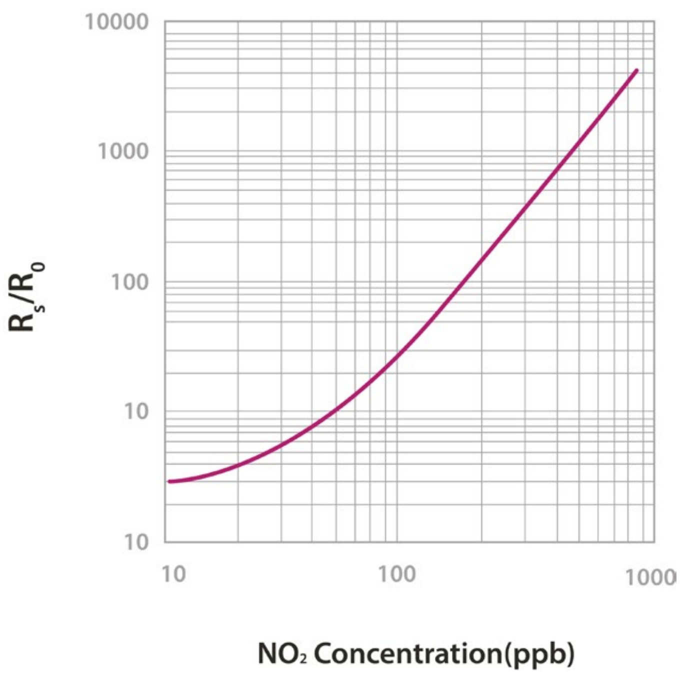


Figure: Graph of the sensitivity of the MiCS-2714 taken from the e2v's sensor data.

The MiCS-2714 is a sensor whose resistance varies in the presence of small concentrations of NO_2. This value varies between 2kΩ and 2MΩ approximately, providing high accuracy throughout the output range. Unlike the rest of the board's gas sensors, which operate at a voltage of 5V, this sensor is powered through a 1.8V voltage regulator, with consumption of approximately 26mA. 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. Ozone (O_3) sensor probe (MiCS-2610)

Sensor specifications (MiCS-2610)

Gases: O_3

Measurement range: 10 ~ 1000ppb

Air resistance: 3 ~ 60kΩ (typically 11kΩ)

Sensitivity: 2 ~ 4 (typically 1.5, ratio between the resistance at 100ppm and at 50ppm)

Supply voltage: 1.95 ~ 5V DC

Operating temperature: -30 ~ +85ºC

Response time: 30 seconds

Average consumption: 34mA

Figure: Image of the O_3 sensor probe (MiCS-2610)

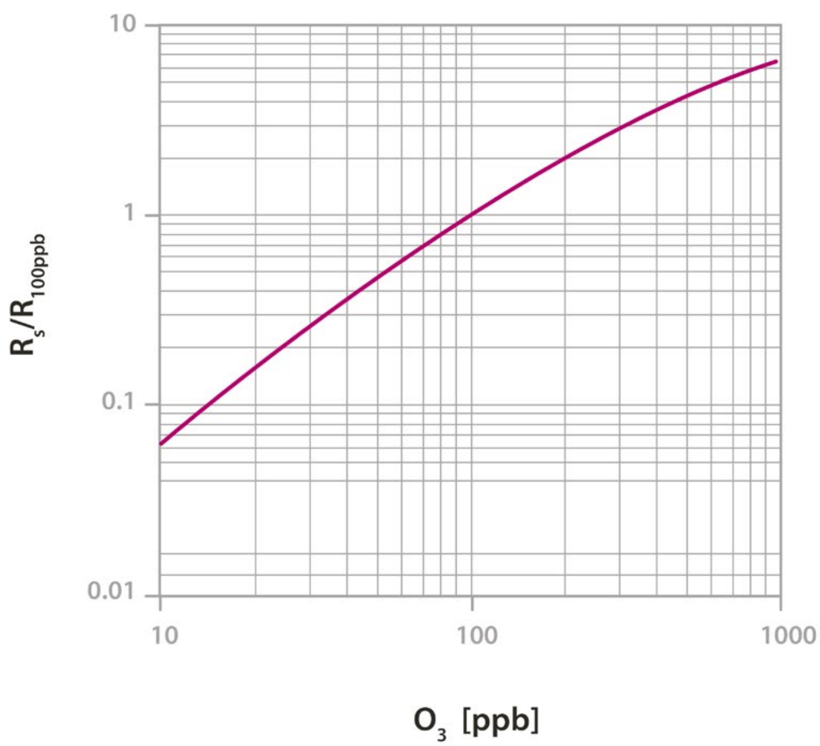


Figure: Graph of the sensitivity of the MiCS-2610 taken from the e2v's sensor data

The MiCS-2610 is a resistive sensor that allows to measure the variation of the O_3 concentration between 10ppb and 1000ppb. It's resistance varies between 11kΩ and 2MΩ approximately. Unlike the MiCS-2710, this sensor is powered through a 2.5V voltage regulator, with consumption of approximately 34mA. 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.

4.16. Ozone (O_3) Sensor - MiCS-2614

Specifications

This sensor is the new version for the MiCS-2610 sensor. The new version is provided since June 2014 and has similar specifications:

Gases: O_3
Measurement range: 10 ~ 1000ppb
Air resistance: 3 ~ 60kΩ (typically 11kΩ)
Sensitivity: 2 ~ 4 (typically 1.5, ratio between the resistance at 100ppb and at 50ppb)
Supply voltage: 1.95 ~ 5V DC
Operating temperature: -30 ~ +85ºC
Response time: 30 seconds
Average consumption: 34mA

Figure: Image of the MiCS-2614 sensor

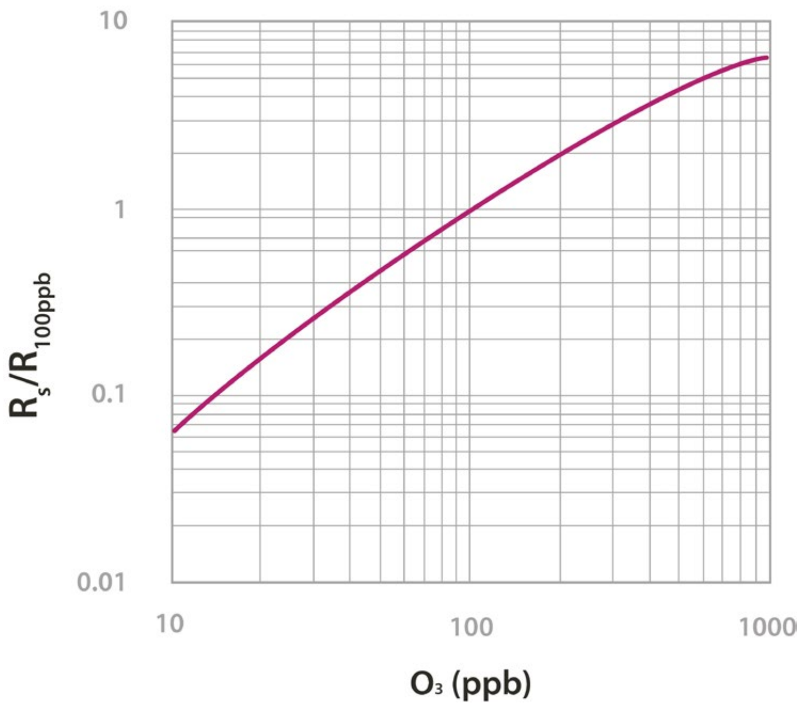


Figure: Graph of the sensitivity of the MiCS-2614 taken from the e2v's sensor data

The MiCS-2614 is a resistive sensor that allows to measure the variation of the O_3 concentration between 10ppb and 1000ppb. It's resistance varies between 11kΩ and 2MΩ approximately. Unlike the MiCS-2710, this sensor is powered through a 2.5V voltage regulator, with consumption of approximately 34mA. 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.

4.17. VOC sensor probe (MiCS-5521)

Sensor specifications (MiCS-5521)

Gases: CO, Hydrocarbons, Volatile Organic Compounds *

Measurement range: 30 ~ 400ppm

Air resistance: 100 ~ 1000kΩ

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

Supply voltage: 2.1 ~ 5V DC

Operating temperature: -30 ~ +85ºC

Response time: 30 seconds

Average consumption: 32mA

Figure: Image of the VOC sensor probe (MiCS-5521)

(*) 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

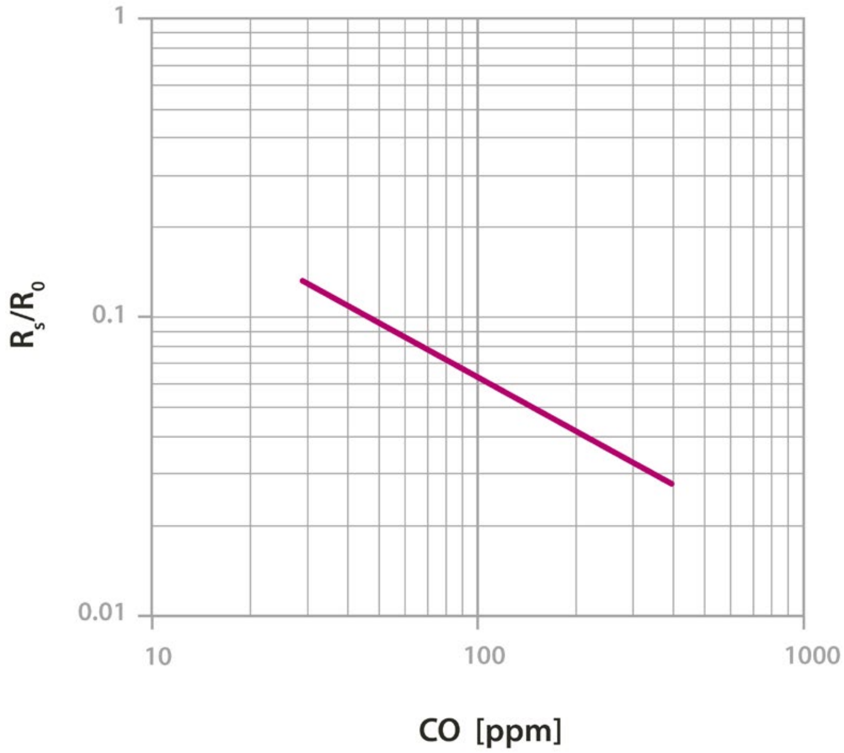


Figure: Graph of the sensitivity of the MiCS-5521 taken from the e2v's sensor data

The MiCS-5521 is a resistive sensor that responds to a great variety of gases, such as Carbon Monoxide (CO), Hydrocarbons and Volatile Organic Compounds. It's resistance varies between 1000kΩ and 2kΩ approximately. Like the MiCS-2610, the MiCS-5521 is powered through a 2.5V voltage regulator, with consumption of approximately 32mA. 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.

4.18. VOC sensor (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 ~ 400ppm
Air resistance: 100 ~ 1500kΩ
Sensitivity: 1.8 ~ 6 (typically 3, ratio between the resistance at 60ppm and at 200ppm of CO)
Supply voltage: 2.1 ~ 5V DC
Operating temperature: -30 ~ +85ºC
Response time: 30 seconds
Average consumption: 32mA

Figure: Image of the MiCS-5524 sensor

(*) 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

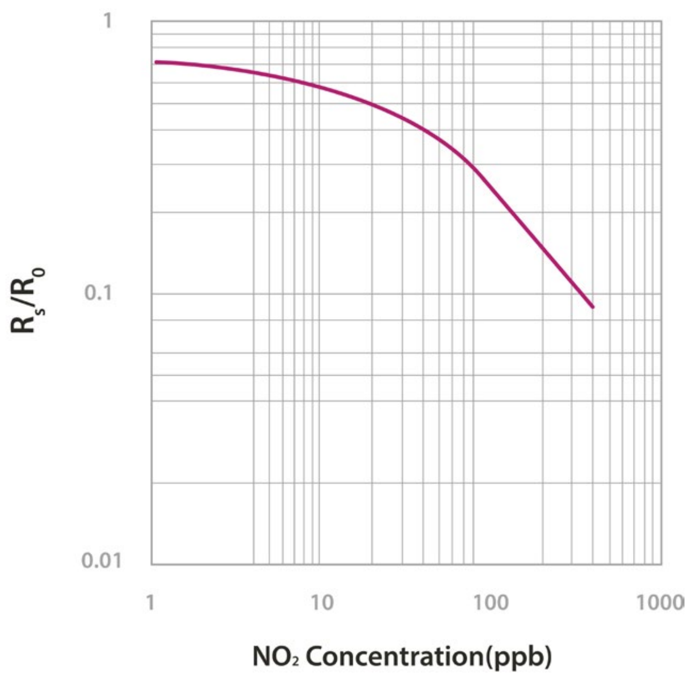


Figure: Graph of the sensitivity of the MiCS-5524 taken from the e2v's sensor data

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. It's resistance varies between 1000kΩ and 2kΩ approximately. Like the MiCS-2614, the MiCS-5524 is powered through a 2.5V voltage regulator, with consumption of approximately 32mA. 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.

4.19. 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 ~ 10mV
Initial Voltage: 5.5 ~ 8.8mV
Operating temperature: 5 ~ +40ºC
Response time: 15 seconds
Consumption: 0µA

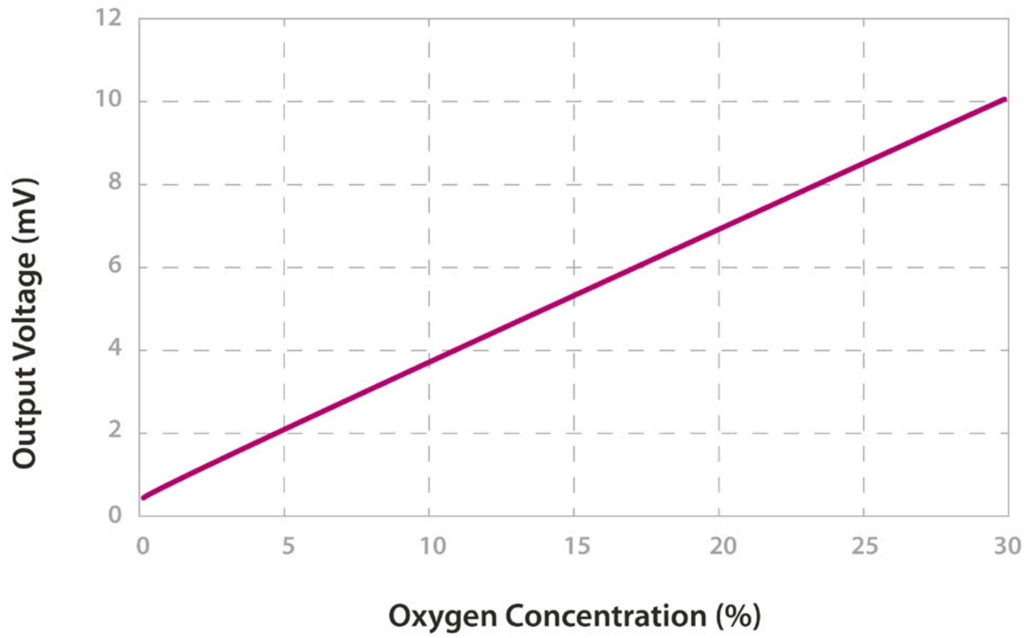


Figure: Graph of the sensitivity of the SK-25 extracted from the Figaro sensor's data sheet

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 10mV, with voltage in standard conditions (approximately 21% O_2 concentration) of between 5.5 and 8.8mV. 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 and 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
	Hydrogen Cyanide (HCN) [Calibrated]	9383-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

Figure: Sensor sockets configuration for Smart Environment PRO model

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

5.2. Temperature, Humidity and Pressure sensor

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

Figure: Image of the Temperature, Humidity and Pressure sensor

Specifications

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

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

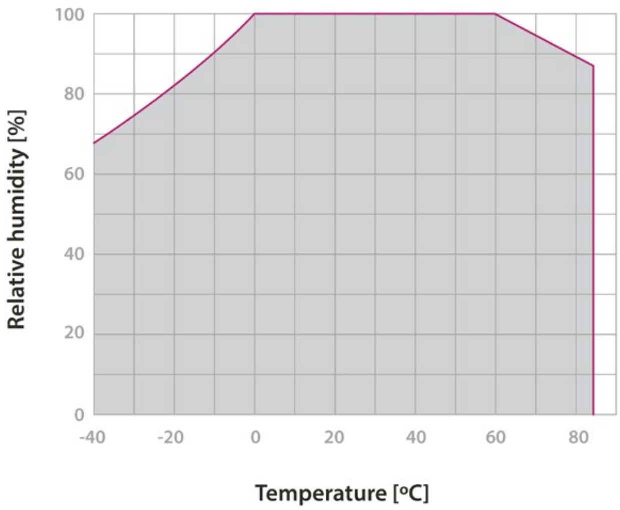


Figure: Humidity sensor operating range

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. Carbon Monoxide (CO) Gas Sensor [Calibrated]

Specifications

Gas: CO
Sensor: 4-CO-500

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

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.*

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

Specifications

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

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.*

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

Specifications

Gas: O_2
Sensor: 4-OL

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

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.*

5.6. Ozone (O_3) Gas Sensor [Calibrated]

Specifications

Gas: O_3
Sensor: O3-A4

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

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.*

5.7. Nitric Oxide (NO) Gas Sensor [Calibrated]

Specifications

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

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.*

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

Specifications

Gas: NO_2
Sensor: 4-NO2-20

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

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.*

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

Specifications

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

Gas: SO_2
Sensor: 4-SO2-20

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.*

5.10. Ammonia (NH_3) Gas Sensor [Calibrated]

Specifications

Gas: NH_3
Sensor: 4-NH3-100

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

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.*

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

Specifications

Main gas: Methane CH_4
Sensor: CH-A3

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

Performance Characteristics

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

Operation Conditions

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

Inhibition/Poisoning

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

Table : Inhibition and poisoning effects

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.*

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

Specifications

Gas: H_2
Sensor: 4-H2-1000

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

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

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.*

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

Specifications

Gas: H_2S
Sensor: 4-H2S-100

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

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

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

Average consumption: less than 1 mA

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

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

Specifications

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

Gas: HCl
Sensor: 4-HCl-50

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

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

Average consumption: less than 1 mA

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

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

Specifications

Gas: HCN
Sensor: 4-HCN-50

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

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

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

Average consumption: less than 1 mA

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

5.16. Phosphine (PH_3) Gas Sensor [Calibrated]

Specifications

Gas: PH_3
Sensor: 4-PH3-20

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

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.*

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

Specifications

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

Gas: ETO
Sensor: 4-ETO-100

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

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

Average consumption: less than 1 mA

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

5.18. Chlorine (Cl_2) Gas Sensor [Calibrated]

Specifications

Gas: Cl_2
Sensor: 4-Cl2-50

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

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.*

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

Specifications

Sensor: OPC-N2

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

Figure: Image of the Particle Matter sensor, encapsulated

Power Characteristics
Measurement mode (laser and fan on): 250 mA @ 5 Volts (typical)
Voltage Range: 4.8 to 5.2 Volts 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.*

5.19.1. Particle matter: the parameter

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

Some examples:

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

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

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

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

5.19.2. 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.

5.19.3. 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 excesive 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 enclouse should be firmly fixed to a wall with the provided screws, or fixed to a lampost 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.

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	Temperature + Humidity (Sensirion)	9247
B	Liquid flow	9296, 9297, 9298
C	Presence - PIR	9212
D	Luminosity (LDR)	9205
	Liquid level	9239, 9240, 9242
	Liquid presence	9243, 9295
	Hall effect	9207
E	Luminosity (LDR)	9205
	Liquid level	9239, 9240, 9242
	Liquid presence	9243
	Hall effect	9207
F	Luminosity (LDR)	9205
	Liquid level	9239, 9240, 9242
	Liquid presence	9243
	Hall effect	9207

Figure: Sensor sockets configuration for Smart Security model

As we see in the figure below, thanks to the directionable 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](#) in [Libelium Website](#).*

6.2. Temperature and Humidity sensor probe

Figure: Image of the Temperature and Humidity sensor probe (SHT75)

Sensor specifications (SHT75)

Power supply: 2.4 ~ 5.5V
Minimum consumption (sleep): 2µW
Consumption (measurement): 3mW
Average consumption: 90µW
Communication: Digital (two wire interface)
Storage temperature: 10 ~ 50ºC (0 ~ 80ºC maximum)
Storage humidity: 20 ~ 60%RH

Temperature:
Measurement range: -40ºC ~ +123.8ºC
Resolution: 0.04ºC (minimum), 0.01ºC (typical)
Accuracy: ±0.4ºC (range 0ºC ~ +70ºC), ±4ºC (range -40 ~ +125ºC)
Repeatability: ±0.1ºC
Response time (minimum): 5 seconds (63% of the response)
Response time (maximum): 30 seconds (63% of the response)

Humidity:
Measurement range: 0 ~ 100%RH
Resolution: 0.4%RH (minimum), 0.05%RH (typical)
Accuracy: ±1.8%RH
Repeatability: ±0.1%RH
Response time: 8 seconds

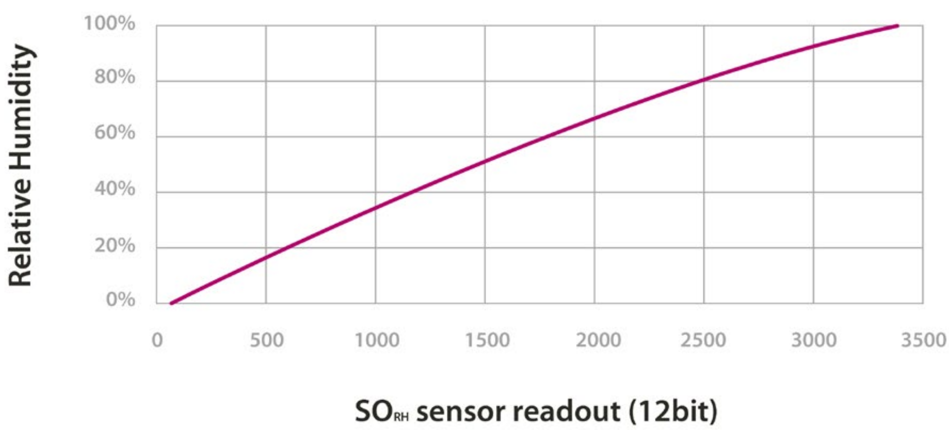


Figure: Graph of the sensor output with respect to relative humidity, taken from the Sensirion sensor's data sheet

The SHT75 sensor by Sensirion incorporates a capacitive sensor for environmental relative humidity and a band gap sensor for environmental temperature in the same package that permit to measure accurately both parameters. The sensor output is read through two wires following a protocol similar to the I2C bus (Inter- Integrated Circuit Bus) implemented in the library of the board, returning the temperature value in Celsius degree (ºC) and the humidity value in relative humidity percentage (%RH).

6.3. 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 ~ 6L/Min
Working voltage: +3.3V ~ +24V
Working temperature: 0ºC ~ 80ºC
Pipe connection: 1/8”
Accuracy: ±3%
Max rated current: 15mA (DC 5V)

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

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

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

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

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 0Hz and 100Hz, is directly read through one of the digital input/output pins of the microcontroller.

6.4. Presence sensor (PIR) probe

<u>**Sensor specifications (PIR)**</u>

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.

6.5. Luminosity sensor probe

<u>**Sensor specifications (LDR)**</u>

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

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 (400nm – 700nm) 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.

6.6. Liquid Level sensor probe

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

<u>**Sensor specifications**</u>

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

Figure: Image of the PTFA3415 sensor

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

Figure: Image of the PTFA0100 sensor

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

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).

6.7. Liquid Presence sensor probe (Point)

Sensor specifications

Maximum Switching Voltage: 100V
Operating temperature: +5ºC ~ +80ºC
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).

6.8. Hall Effect sensor probe

Sensor specifications

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

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.

6.9. Liquid Presence sensor probe (Line)

Sensor specifications

Lenght: 5 meters sensor + 2 meters jumper wire
Material: PE + alloy lend
Weight: 18g/meter
Pull force limit: 60kg
Cable diameter: 5,5mm
Core resistance: 3ohm/100meters
Maximum exposed temperature: 75ºC
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 triggers 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.

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 Calcium (Ca^{2+}), Fluoride (F^-), Fluoroborate (BF_4^-), Nitrate (NO_3^-), Bromide (Br^-), Chloride (Cl^-), Cupric (Cu^{2+}), Iodide (I^-), Lead (Pb^{2+}), Silver (Ag^+) 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 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
B	pH	9328
	Oxidation-Reduction Potential (ORP)	9329
C	pH	9328
	Oxidation-Reduction Potential (ORP)	9329
D	Soil/Water Temperature	9255 (included by default)
E	Dissolved Oxygen (DO)	9327
F	Conductivity	9326
	Turbidity	9353

Figure: Sensor sockets configuration for Smart Water model

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

7.2. Soil/Water Temperature sensor (Pt1000) probe

Sensor specifications

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

Figure: Image of the Soil/Water Temperature sensor probe

The resistance of the Pt1000 sensor varies between approximately 920Ω and 1200Ω in the range considered useful in agriculture applications (-20 ~ 50ºC 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).

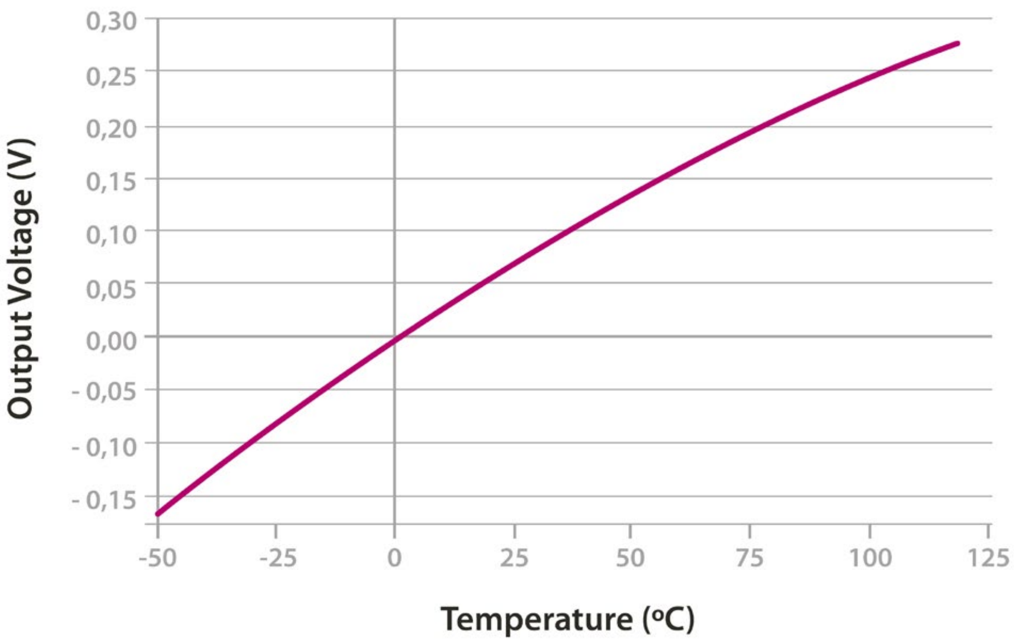


Figure: Output voltage of the PT1000 sensor with respect to temperature

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 1cm^{-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. This current's frequency can be set at four different values (100Hz, 1kHz, 10kHz and 100kHz) to adapt the measurement to the optimal operation point, which will be a function of the conductivity of the liquid and the characteristics of the sensor. For the sensor integrated in the Smart Water board, it is recommended to use a 100Hz frequency of conductivities lower than 50µS/cm, 1kHz between 50µS/cm and 5mS/cm, 10kHz between 5mS/cm and 500mS/cm and 100kHz for conductivities higher than 500mS/cm.

7.4. Dissolved Oxygen sensor probe

Sensor specifications

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

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: 0~14pH
Temperature of operation: 0~80ºC
Zero electric potential: 7±0.25p
Response time: <1min
Internal resistance: ≤250MΩ
Repeatability: 0.017
PTS: >98.5
Noise: <0.5mV
Alkali error: 15mV
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 2.048V of the circuit, with an uncertainty of ±0.25pH. 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: 245~270mV
Reference impedance: 10kΩ
Stability: ±8mV/24h

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 2.048V 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

<u>**Specifications**</u>

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 °C
Material: PVC, Quartz, PMMA, Nickel-plated brass

Figure: Turbidity sensor

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

In the OEM version, the sensor comes as a kit because it needs additional equipment (see list below). The user will connect the sensor to a special RS-485 module.

On the other hand, 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. Be informed that Plug & Sense! nodes capable of measuring turbidity are produced on demand (so standard Smart Water Plug & Sense! nodes cannot integrate the turbidity sensor).

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

7.7.2. Measurement process

The Turbidity sensor, is a digital sensor and must be used with the RS-485 module in combination with the Modbus library. The use of the Smart Water Board is no necessary with this sensor, but is very interesting in water monitoring applications. In fact, the Turbidity sensor can be used in combination with any Sensor Board. The RS-485 standard allows the use of longer wires, and thanks to the use of differential signaling it resists the electromagnetic interferences.

Up now, the measurement of the turbidity was not easy and must be done by qualified personal, collecting samples for laboratory exams. Libelium's sensor permits automatic metering. According to the sensor's manufacturer specifications, the measurement of the turbidity must be done in a light tight pot, the sensor must be in a fixed position and the water container must be clean or the measure may be wrong.

The accuracy of this sensor is about 1 NTU. The WHO (World Health Organization), establishes that the turbidity of drinking water shouldn't be more than 5 NTU, and should ideally be below 1 NTU. This sensor can be used to determine if the turbidity level of the water is under acceptable levels for consumption, but can't be used to determine the exact value of turbidity, because this values is measured in specialized laboratories using special equipment.

The sensor takes some time to get stable values. The correct way to measure the turbidity using this sensor is to take samples for approximately 60-90 seconds and then make the mean between the measured values. Libelium, provides the necessary examples included in the Waspmote IDE.

The Turbidity sensor is calibrated in Libelium. Basically, Libelium performs measurements with a range of normalized chemical solutions, which have a known and exact NTU value. This allows us to generate calibration data which the user will use to improve the accuracy of the sensor.

In the code below a basic example for reading this sensor connected to the RS-485 board:

```
{
  // Start a new measure
  turbiditySensor.readTurbidity();
  // Get the Turbidity Measure
  float turbidity = turbiditySensor.getTurbidity();
}
```

You can find a complete example code for reading the turbidity sensor in the following link:
http://www.libelium.com/development/waspmote/examples/sw-07-turbidity-sensor-reading

In the image below you can see the necessary material for measuring turbidity with Waspmote. This OEM kit includes:

- The Turbidity sensor, with DB9 connector to connect directly to the RS-485 module
- An especial Waspmote, able to drive the SPI bus to SOCKET0
- The RS-485 module, who must be connected in the SOCKET0
- The expansion board, for connecting wireless modules in SOCKET1
- Two stackable headers, for connecting sensor boards to Waspmote
- Document with laboratory calibration data

Note: *in Plug & Sense! version, the user receives items 2, 3, 4 and 5 inside the node. It is just needed to connect the sensor probe to the F socket.*

Note: *The RS-485 module included in this kit is a special version ready to be used with the Turbidity sensor, and includes the necessary hardware for supplying the sensor from the DB9 connector. The standard version of the RS-485 module can't be used with this sensor.*

Figure: The necessary material for connecting the Turbidity sensor (Plug & Sense! version)

The placement of the sensor is important to get a correct turbidity measurement. The sensor must be placed in a fixed position, you must make sure that light cannot interfere with the optical part of the sensor. Otherwise, sun or light can affect the values. It is necessary a minimum distance, about 3-4 centimeters, between the sensor and the bottom of the beaker.

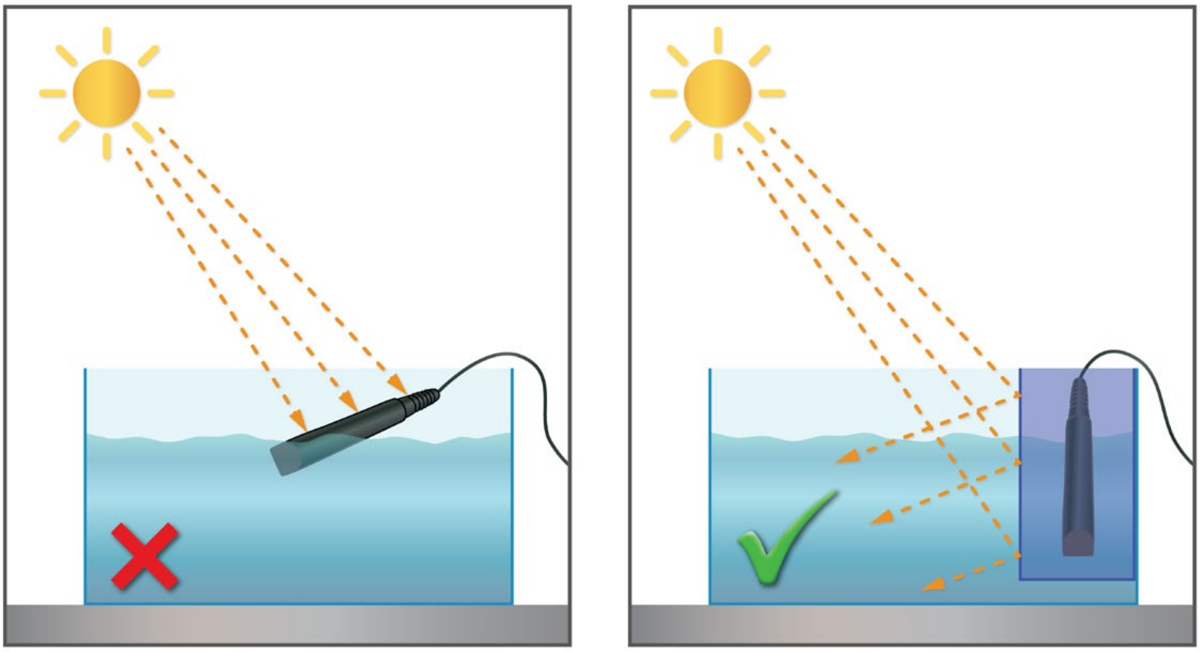


Figure: Turbidity sensor image wrongly and correctly placed

7.7.3. Calibration procedure

Important: Libelium provides this sensor calibrated, but a periodic recalibration of the sensors is highly advisable (every 6 months approximately) in order to maintain an accurate measurement along time. The good recalibration process of the sensor is responsibility of the user. Libelium provides standard calibration solutions for some turbidity values; these solutions are optional but highly recommended.

Libelium can provide 2 different turbidity calibration kits, each one is composed of 2 solutions which will provide 2 reference points:

- Low turbidity: about 0-10 NTU
- High Turbidity: about 10-40 NTU

Figure: Turbidity calibration kit

1. Turn on the Waspmote with the Turbidity sensor connected. Upload the "Turbidity sensor calibration" code to Waspmote. Make sure that the data from the sensor is being received in a PC through the USB.

2. Pour the calibration solution in a beaker. The baker must be clean and according to the manufacturer specifications, the measurement of the turbidity must be done in a light tight pot, the sensor must be in a fixed position and the water container must be clean or the measure may be wrong.

3. Introduce the sensor into the calibration solution, making sure it stays immersed without contact with the beaker walls or bottom, and wait for the code's output value for stabilize. You have to annotate the value of the used solution and the returned values from the sensor (e.g. [25, 24.1]).

4. Remove the sensor, and clean it properly before continuing.

5. Repeat steps 2, 3 and 4, depending on the number of solutions you want to recalibrate with.

6. Introduce the measured values in the Waspmote code or in the data processing in the receiver. These values will be introduced manually in the code by the user. The new calibration values can replace the old ones.

In the Waspmote Development section you can find complete examples about using this board.
Go to: http://www.libelium.com/development/waspmote/examples

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 2 variants for Smart Water Ions: Single and Double. 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

8.1.1. 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	Calcium Ion (Ca^{2+})	9352
	Fluoride Ion (F^{-})	9353
	Fluoroborate Ion ($BF4^{-}$)	9354
	Nitrate Ion (NO_3^{-})	9355
	pH (for Smart Water Ions)	9363
B	Calcium Ion (Ca^{2+})	9352
	Fluoride Ion (F^{-})	9353
	Fluoroborate Ion (BF_4^{-})	9354
	Nitrate Ion (NO_3^{-})	9355
	pH (for Smart Water Ions)	9363
C	Calcium Ion (Ca^{2+})	9352
	Fluoride Ion (F^{-})	9353
	Fluoroborate Ion (BF_4^{-})	9354
	Nitrate Ion (NO_3^{-})	9355
	pH (for Smart Water Ions)	9363
D	Calcium Ion (Ca^{2+})	9352
	Fluoride Ion (F^{-})	9353
	Fluoroborate Ion (BF_4^{-})	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 in Libelium website.*

8.1.2. 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	Bromide Ion (Br^-)	9356
	Chloride Ion (Cl^-)	9357
	Cupric Ion (Cu^{2+})	9358
	Iodide Ion (I^-)	9360
	Lead Ion (Pb^{2+})	9361
	Silver Ion (Ag^+)	9362
	pH (for Smart Water Ions)	9363
B	Bromide Ion (Br^-)	9356
	Chloride Ion (Cl^-)	9357
	Cupric Ion (Cu^{2+})	9358
	Iodide Ion (I^-)	9360
	Lead Ion (Pb^{2+})	9361
	Silver Ion (Ag^+)	9362
	pH (for Smart Water Ions)	9363
C	Bromide Ion (Br^-)	9356
	Chloride Ion (Cl^-)	9357
	Cupric Ion (Cu^{2+})	9358
	Iodide Ion (I^-)	9360
	Lead Ion (Pb^{2+})	9361
	Silver Ion (Ag^+)	9362
	pH (for Smart Water Ions)	9363
D	Bromide Ion (Br^-)	9356
	Chloride Ion (Cl^-)	9357
	Cupric Ion (Cu^{2+})	9358
	Iodide Ion (I^-)	9360
	Lead Ion (Pb^{2+})	9361
	Silver Ions (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 in Libelium website.*

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

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

Figure: Soil/Water Temperature (Pt-1000) Sensor

The resistance of the Pt1000 sensor varies between approximately 920Ω and 1200Ω in the range considered useful in agriculture applications (-20 ~ 50ºC 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).

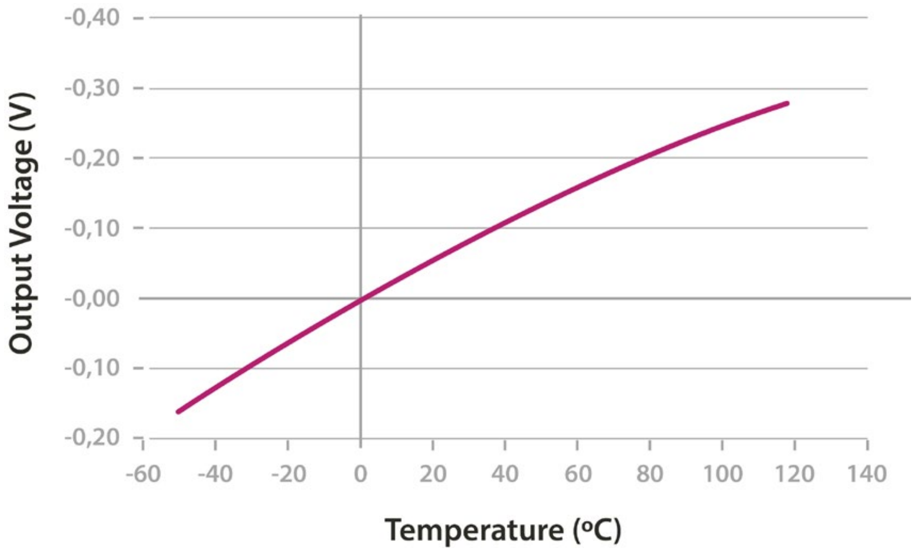


Figure: Output voltage of the PT1000 sensor with respect to temperature

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.

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


Figure: Reference 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

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	Temperature	9203
	Soil temperature	86949*
	Ultrasound (distance measurement)	9246
B	Humidity	9204
	Ultrasound (distance measurement)	9246
C	Luminosity (LDR)	9205
D	Noise sensor	9259
F	Linear displacement	9319

* Ask Libelium Sales Department for more information.

Figure: Sensor sockets configuration for Smart Cities model

As we see in the figure below, thanks to the directionable 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. Temperature sensor probe

Sensor specifications (MCP9700A)

Measurement range: [-40ºC ,+125ºC]
Output voltage: (0ºC): 500mV
Sensitivity: 10mV/ºC
Accuracy: ±2ºC (range 0ºC ~ +70ºC), ±4ºC (range -40 ~ +125ºC)
Supply voltage: 2.3 ~ 5.5V
Response time: 1.65 seconds (63% response from +30 to +125°C).
Typical consumption: 6µA
Maximum consumption: 12µA

Figure: Image of the Temperature sensor probe (MCP9700A)

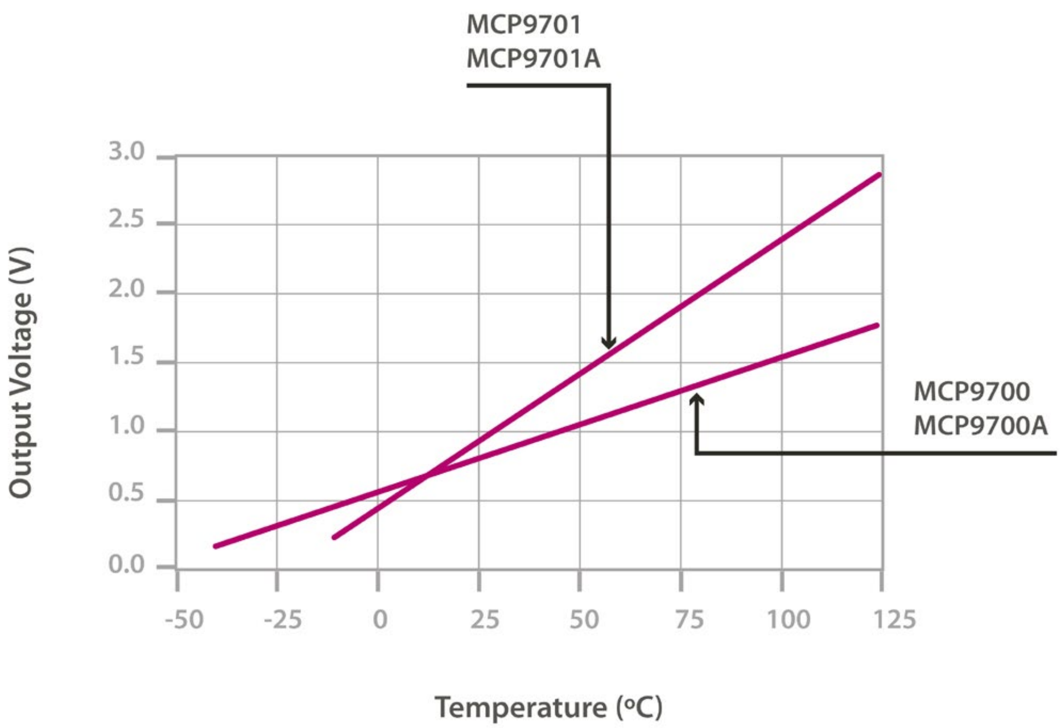


Figure: Graph of the MCP9700A sensor output voltage with respect to temperature, taken from the Microchip sensor's data sheet

The MCP9700A is an analog sensor which converts a temperature value into a proportional analog voltage. The range of output voltages is between 100mV (-40°) and 1.75V (125°C), resulting in a variation of 10mV/°C, with 500mV of output for 0°C.

9.3. Soil Temperature sensor (DS18B20) probe

Sensor specifications (DS18B20)

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

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

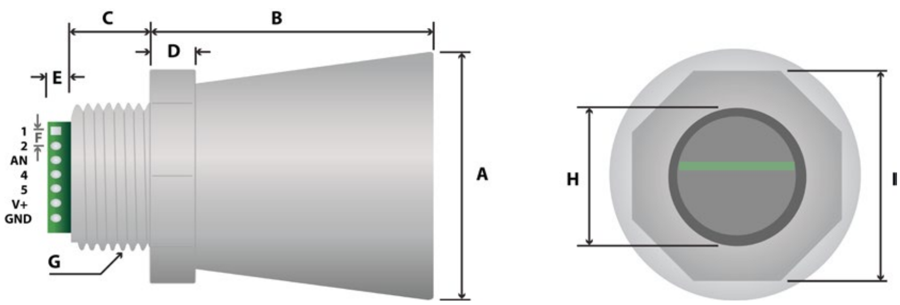
The DS18B20 is a temperature digital sensor which provides an accurate measurement and a high resolution (of up to 0.065ºC) which communicates with the Waspmote's microcontroller through the 1-Wire bus. It has been encapsulated in a plastic seal that isolates it from humidity, thus allowing to use it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

9.4. Ultrasound sensor probe

Sensor specifications (XL-MaxSonar®-WRA1™)

Operation frequency: 42kHz
Maximum detection distance: 765cm
Maximum detection distance (analog output): 600cm (powered at 3.3V) - 700cm (powered at 5V)
Sensitivity (analog output): 3.2mV/cm (powered at 3.3V) – 4.9mV/cm (powered at 5V)
Power supply: 3.3 ~ 5V
Consumption (average): 2.1mA (powered at 3.3V) – 3.2mA (powered at 5V)
Consumption (peak): 50mA (powered at 3.3V) – 100mA (powered at 5V)
Usage: Indoors and outdoors (IP-67)

Figure: Image of the Ultrasound sensor probe (XL-MaxSonar®-WRA1™)



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 XL-MaxSonar®-WRA1 sensor dimensions

The MaxSonar® sensors from MaxBotix output an analog voltage proportional to the distance to the object detected. This sensor can be powered at both 3.3V or 5V, although the detection range will be wider for the last one. The XL-MaxSonar®-WRA1™ sensor is endowed with an IP-67 casing, so it can be used in outdoors applications, such as liquid level monitoring in storage tanks.

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

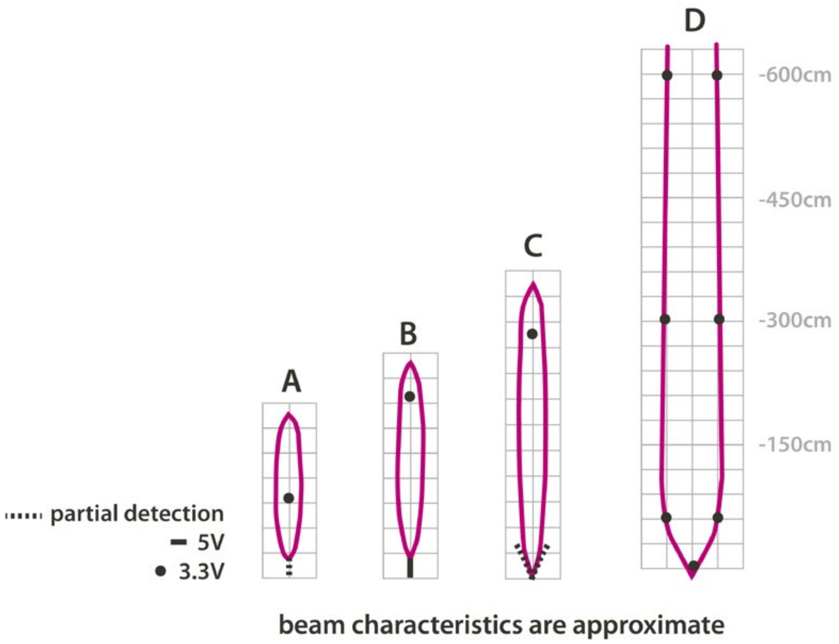


Figure: Diagram of the sensor beam extracted from the data sheet of the XL-MaxSonar®-WRA1™ sensor from MaxBotix

Figure: Image of configurations of the ultrasounds 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.

9.5. Humidity sensor probe

<u>Sensor specifications (808H5V5)</u>

Measurement range: 0 ~ 100%RH
Output signal: 0.8 ~ 3.9V (25ºC)
Accuracy: <±4%RH (at 25ºC, range 30 ~ 80%), <±6%RH (range 0 ~ 100)
Supply voltage: 5VDC ±5%
Operating temperature: -40 ~ +85ºC
Response time: <15 seconds
Typical consumption: 0.38mA
Maximum consumption: 0.5mA

Figure: Image of the Humidity sensor probe (808H5V5)

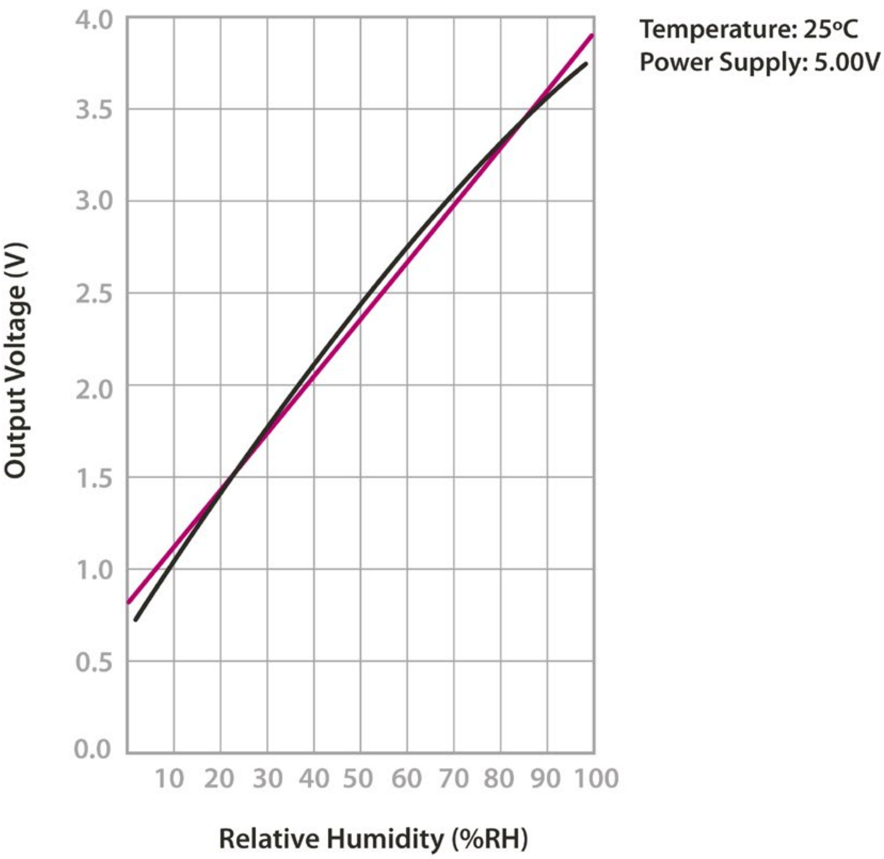


Figure: 808H5V5 humidity sensor output taken from the Sencera Co. Ltd sensor data sheet

This is an analog sensor which provides a voltage output proportional to the relative humidity in the atmosphere. As the sensor's signal range is outside of that permitted to the Waspmote's input, a voltage divider has been installed which converts the output voltage to values between 0.48 ~ 2.34V.

9.6. Luminosity sensor probe

Sensor specifications (LDR)

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

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 (400nm – 700nm) 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.

9.7. Noise sensor probe

Sensor specifications (POM-2735P-R)

Sensitivity: -35±4dB
Impedance: <2.2kΩ
Directivity: Omnidirectional
Frequency: 20Hz~20kHz
Supply voltage: +3V (Standard), +10V (Maximum)
Maximum current consumption: 0.5mA
Sensitivity reduction: -3dB a 1.5V
Maximum sound pressure level: 114.5±10dBSPL approximately
S/N ratio: 60dB
Noise Level: 26 +/-1 dBA
Stage Measurement range: 50dBA~100dbA

Figure: Image of the Noise sensor probe (POM-2735P-R microphone)

The POM-2735P-R, introduced in the Smart Cities board to monitor the environmental noise, is an omnidirectional microphone with an almost flat response in the whole frequency range of human hearing, between 20Hz and 20kHz. A circuit to filter the signal to adapt it to the A decibel scale and output a continuous voltage readable from the mote's processor has been introduced. When sold along with a microphone, the Smart Cities board is supplied calibrated by Libelium to return an output in the range between 50dBA and 100dBA with an accuracy of ±2.5dBA. The calibration data associated to the microphone reading is stored in the microcontroller's EEPROM, between addresses 164 and 185. **Be very careful not to overwrite this memory positions** or it could lead to an irreparable error when reading this sensor.

***Note:** Because of this needed calibration process, the user always must purchase any noise sensor probe with its corresponding Plug & Sense! Smart Cities board.*

The A weighting for the audio measurements is a compensation curve that is used to fit the sound pressure measurement to the ear response in function of the frequency, and is the most common standard for noise measurement. Below, we can see a table of noise pressure generated by different sources in dBA.

Sound	dBA
Audition threshold	0
Quiet Room	30
Normal conversation	60~70
Heavy traffic (hearing loss under continued exposure)	90
Pain threshold	130
Jet engine (permanent damage)	140

Figure: Noise in dBA produced by different sources

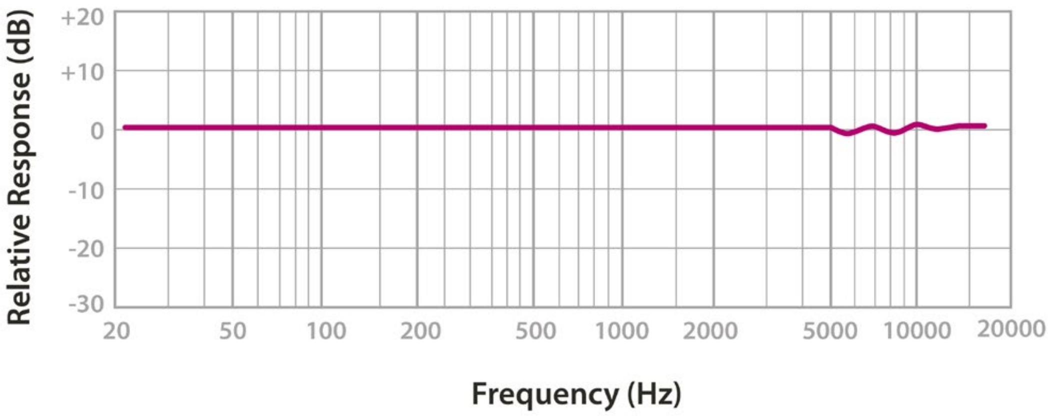


Figure: Graph of the frequency response of the POM-2735P-R extracted from the sensor's data sheet

9.8. Linear Displacement sensor probe

Sensor specifications (SLS095)

Electrical stroke: 10mm
Sensor resistance: 400Ω
Linearity: ±0.5%
Resolution: 10µm (imposed by the analog-to-digital conversion)
Supply Voltage: +8.9V
Power dissipation (20ºC): 0.2W
Temperature Operation: -30ºC ~ 100ªC

Figure: Image of the Linear Displacement sensor probe (SLS095)

The SLS095 linear displacement sensor by Penny+Giles is a potentiometer whose wiper moves along with an axis guided by the sensor's body. Fixing both ends of the potentiometer at the sides of the crack we can measure its width by reading the voltage at the wiper. For this, the sensor has been configured as a voltage divider, with one of the ends sourced from a 3V supply, the other end grounded and the wiper connected to an input of the analog-to-digital converter of the Waspmote, which leads to a resolution of 11µm approximately.

10. Smart Parking

10.1. General description

Smart Parking allows to detect available parking spots by placing the node under the pavement. It works with a magnetic sensor which detects when a vehicle is present or not. Waspmote Plug & Sense! Can act as a repeater for a Smart parking node.

Sensor specifications

Maximum Supply Voltage: 12V
Operation Temperature: -40 ~ 125ºC
Bridge Resistance: 600 ~ 1200Ω
Typical Output Voltage: 3,5mV/V/gauss
Average consumption: 15mA
Maximum consumption (peak): 500mA

Figure: Smart Parking enclosure

Sensor sockets are no used for this model.

There are specific documents for parking applications at Libelium website. Refer to 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 (Sensirion), solar visible radiation, wind speed and direction, rainfall, atmospheric pressure.

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

11.1.1. Normal

Sensor sockets are configured as shown in the figure below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A	Humidity + Temperature (Sensirion)	9247
B	Atmospheric pressure	9250
C	Soil temperature	86949*
	Soil moisture	9248
D	Weather Station WS-3000 (anemometer + wind vane + pluviometer)	9256
E	Soil moisture	9248
F	Leaf wetness	9249
	Soil moisture	9248

* Ask Libelium Sales Department for more information.

Figure: Sensor sockets configuration for Smart Agriculture model

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

11.1.2. PRO

Sensor sockets are configured as shown in the figure below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A	Humidity + Temperature (Sensirion)	9247
B	Soil temperature	9255
C	Solar radiation	9251, 9257
D	Soil temperature	86949*
	Soil moisture	9248
E	Dendrometers	9252, 9253, 9254
	Soil moisture	9248
F	Lear wetness	9249
	Soil moisture	9248

* Ask Libelium Sales Department for more information.

Figure: Sensor sockets configuration for Smart Agriculture PRO model

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

11.2. Temperature and Humidity sensor probe

Figure: Image of the Temperature and Humidity sensor probe (SHT75)

<u>**Sensor specifications (SHT75)**</u>

Power supply: 2.4 ~ 5.5V
Minimum consumption (sleep): 2µW
Consumption (measurement): 3mW
Average consumption: 90µW
Communication: Digital (two wire interface)
Storage temperature: 10 ~ 50ºC (0 ~ 80ºC maximum)
Storage humidity: 20 ~ 60%RH

<u>**Temperature:**</u>
Measurement range: -40ºC ~ +123.8ºC
Resolution: 0.04ºC (minimum), 0.01ºC (typical)
Accuracy: ±0.4ºC (range 0ºC ~ +70ºC), ±4ºC (range -40 ~ +125ºC)
Repeatability: ±0.1ºC
Response time (minimum): 5 seconds (63% of the response)
Response time (maximum): 30 seconds (63% of the response)

<u>**Humidity:**</u>
Measurement range: 0 ~ 100%RH
Resolution: 0.4%RH (minimum), 0.05%RH (typical)
Accuracy: ±1.8%RH
Repeatability: ±0.1%RH
Response time: 8 seconds

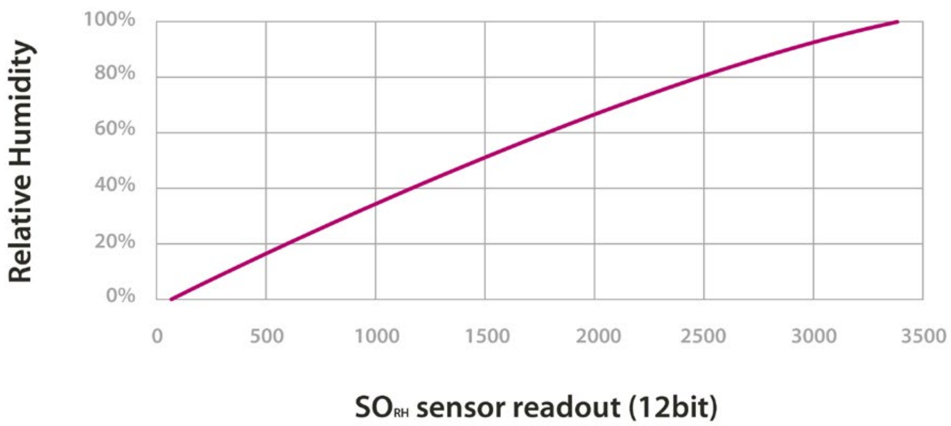


Figure: Graph of the sensor output with respect to relative humidity, taken from the Sensirion sensor's data sheet

The SHT75 sensor by Sensirion incorporates a capacitive sensor for environmental relative humidity and a band gap sensor for environmental temperature in the same package that permit to measure accurately both parameters. The sensor output is read through two wires following a protocol similar to the I2C bus (Inter- Integrated Circuit Bus) implemented in the library of the board, returning the temperature value in Celsius degree (ºC) and the humidity value in relative humidity percentage (%RH).

11.3. Atmospheric Pressure sensor probe

Sensor specifications (MPX4115A)

Measurement range: 15 ~ 115kPa
Output signal: 0,2 ~ 4,8V (0 ~ 85ºC)
Sensitivity: 46mV/kPa
Accuracy: <±1,5%V (0 ~ 85ºC)
Typical consumption: 7mA
Maximum consumption: 10mA
Supply voltage: 4.85 ~ 5.35V
Operation temperature: -40 ~ +125ºC
Storage temperature: -40 ~ +125ºC
Response time: 20ms

Figure: Image of the Atmospheric Pressure sensor probe (MPX4115A)

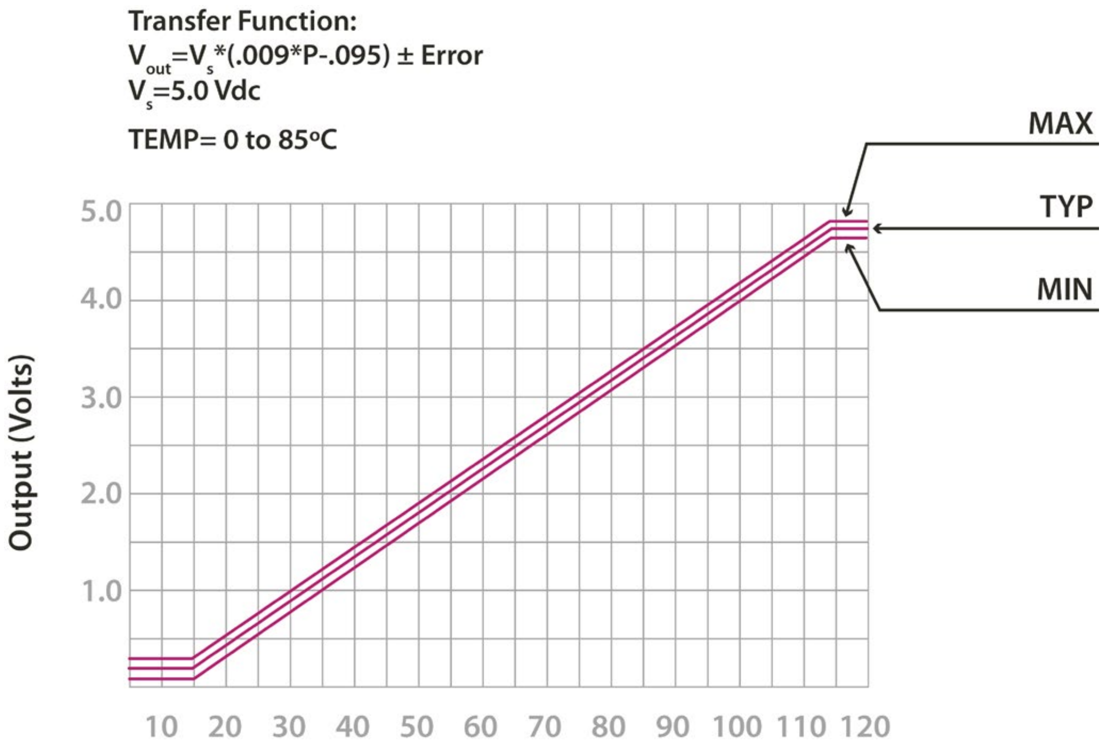


Figure: Graph of the MPX4115A sensor's output voltage with regard to pressure taken from the Freescale sensor's data sheet

The MPX4115A sensor converts atmospheric pressure to an analog voltage value in a range covering between 0.2V and 4.8V. As this is a range which exceeds the maximum value admitted by Waspmote, its output has been adapted to fit in a range between 0.12V and 2.88V.

11.4. Soil Temperature sensor (DS18B20) probe

Sensor specifications (DS18B20)

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

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 0.065ºC) 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.

11.5. Soil moisture sensor probe

Sensor specifications (Watermark)

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

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

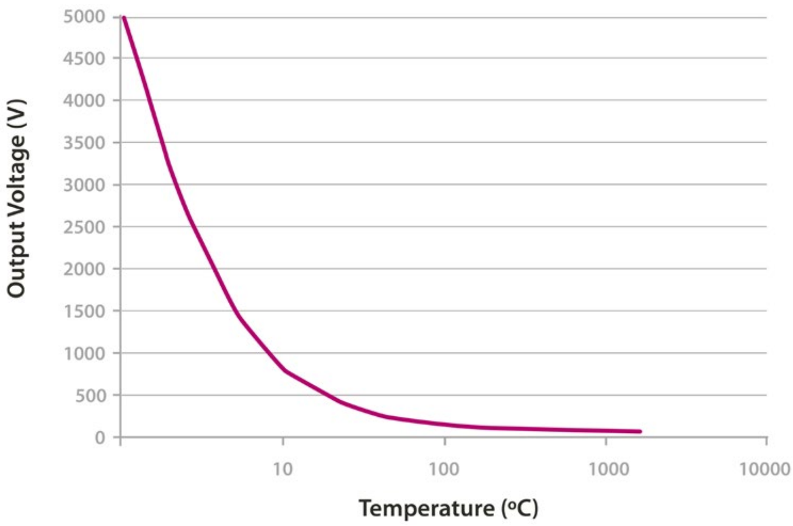


Figure: Output frequency of the Watermark sensor circuit with respect to the resistance of the sensor

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 xin Herzs (Hz), for more information about the conversion into soil water tension look at Appendix 1 of the Agriculture 2.0 Board technical guide.

11.6. Weather station WS-3000 probe

Figure: Image of the Weather Station WS-3000 probe

Sensor specifications (Anemometer)

Sensitivity: 2.4km/h / turn
Wind Speed Range: 0 ~ 240km/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).

Sensor specifications (Vane)

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

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 10kΩ resistance, form a voltage divider, powered at 3.3V, 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 (0.28mm 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.

11.7. Leaf Wetness sensor probe

<u>**Sensor specifications (Leaf Wetness)**</u>
Resistance Range: 5kΩ ~ >2MΩ
Output Voltage Range: 1V ~ 3.3V
Length: 3.95cm
Width: 1.95 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.

11.8. Soil Temperature sensor (PT1000) probe

<u>**Sensor specifications (PT1000)**</u>
Measurement range: -50 ~ 300ºC
Accuracy: DIN EN 60751
Resistance (0ºC): 1000Ω
Diameter: 6mm
Length: 40mm
Cable: 2m

Figure: Image of the Soil Temperature sensor sensor probe

The resistance of the PT1000 sensor varies between approximately 920Ω and 1200Ω in the range considered useful in agriculture applications (-20 ~ 50ºC 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).

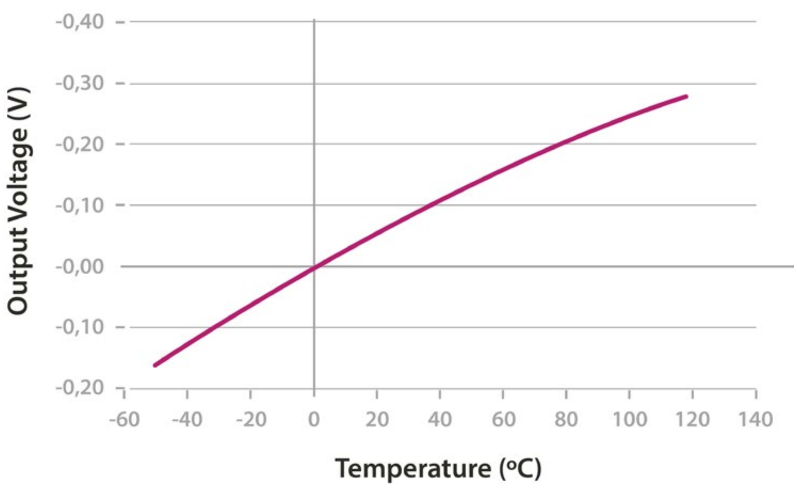


Figure: Output voltage of the PT1000 sensor with respect to temperature

11.9. Solar Radiation sensor probe

Figure: Image of the Solar Radiation sensor probe

Sensor specifications (SQ-110)

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

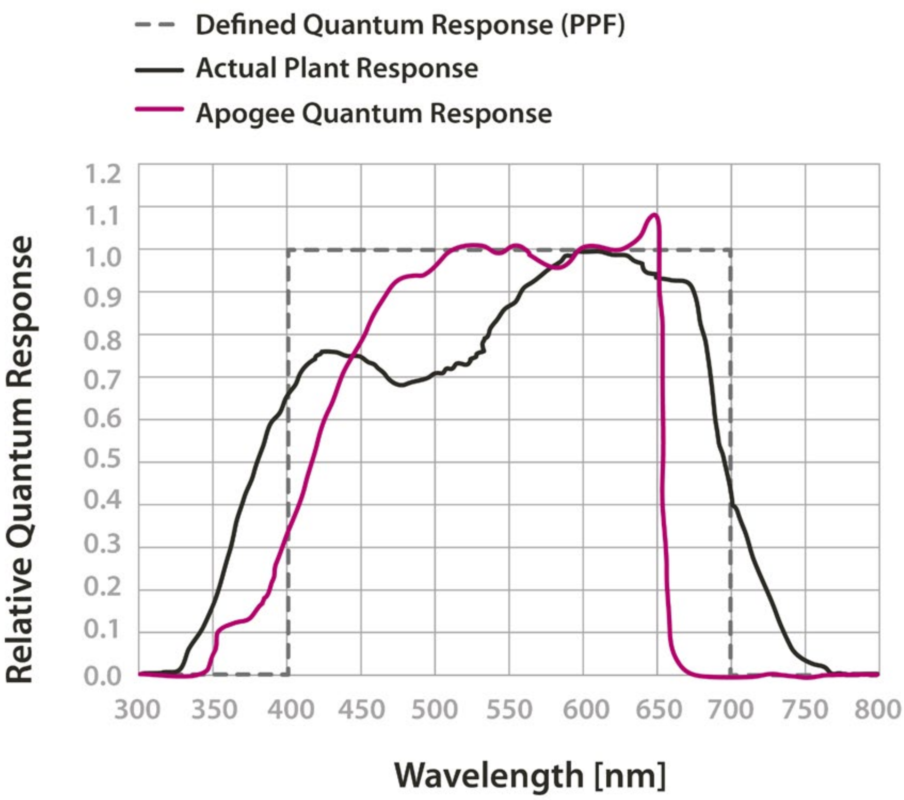


Figure: Graph of the spectral response of the SQ-110 sensor compared to the photosynthetic response of a plant

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 400mV under maximum radiation conditions and a sensitivity of 5.00μmol·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: 0.15mV / µmol·m^{-2}s^{-1}
Maximum radiation output: 26mV (170µmol·m^{-2}s^{-1})
Lineal range: 60mV (400µmol·m^{-2}s^{-1})
Sensibility: 6.5µmol·m^{-2}s^{-1}/mV
Spectral range: 250 ~ 400nm
Accuracy: ±10%
Repeatability: ±1%
Diameter: 2.4cm
Height: 2.75cm
Cable length: 3m
Operation humidity: 0 ~ 100%RH

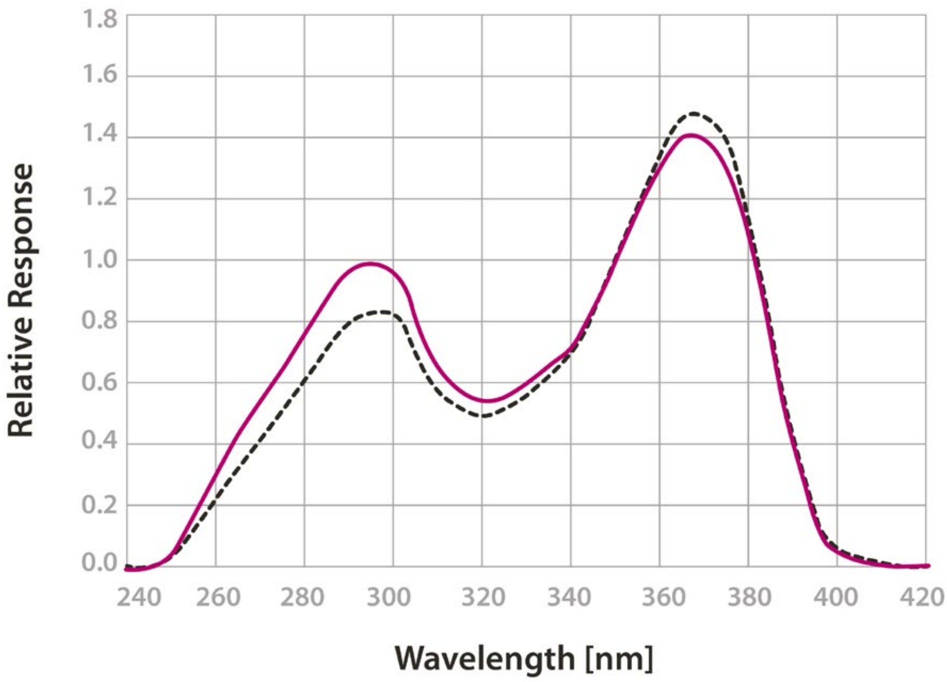


Figure: Graph of the spectral response of the SU-100 sensor compared to the photosynthetic response of a plant

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 26mV under maximum radiation conditions and a sensitivity of 6.5µmol·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.

11.10. Dendrometer sensor probe

Figure: Image of the Dendrometer sensor probe

Sensor specifications (Trunk diameter)

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

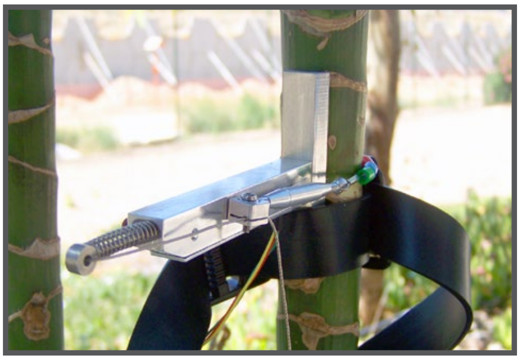


Figure: Ecomatik DC2 sensor

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

Figure: Ecomatik DD sensor

Sensor specifications (Fruit diameter)

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

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 3V 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 main environment parameters in an easy way. 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
B	Luminosity (LDR)	9205
C	Luminosity (Luxes accuracy)	9325
D	Not used	-
E	Not used	-
F	Not used	-

Figure: Sensor sockets configuration for Ambient Control model

As we see in the figure below, thanks to the directionable probe, the luminosity 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] in [Libelium Website]*.

12.2. Temperature and Humidity sensor probe

Figure: Image of the Temperature and Humidity sensor probe (SHT75)

Sensor specifications (SHT75)

Power supply: 2.4 ~ 5.5V
Minimum consumption (sleep): 2µW
Consumption (measurement): 3mW
Average consumption: 90µW
Communication: Digital (two wire interface)
Storage temperature: 10 ~ 50ºC (0 ~ 80ºC maximum)
Storage humidity: 20 ~ 60%RH

Temperature:
Measurement range: -40ºC ~ +123.8ºC
Resolution: 0.04ºC (minimum), 0.01ºC (typical)
Accuracy: ±0.4ºC (range 0ºC ~ +70ºC), ±4ºC (range -40 ~ +125ºC)
Repeatability: ±0.1ºC
Response time (minimum): 5 seconds (63% of the response)
Response time (maximum): 30 seconds (63% of the response)

Humidity:
Measurement range: 0 ~ 100%RH
Resolution: 0.4%RH (minimum), 0.05%RH (typical)
Accuracy: ±1.8%RH
Repeatability: ±0.1%RH
Response time: 8 seconds

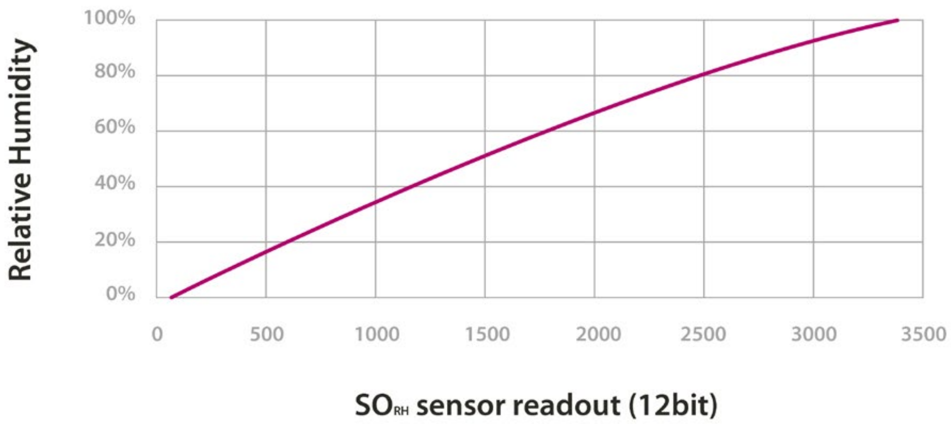


Figure: Graph of the sensor output with respect to relative humidity, taken from the Sensirion sensor's data sheet

The SHT75 sensor by Sensirion incorporates a capacitive sensor for environmental relative humidity and a band gap sensor for environmental temperature in the same package that permit to measure accurately both parameters. The sensor output is read through two wires following a protocol similar to the I2C bus (Inter- Integrated Circuit Bus) implemented in the library of the board, returning the temperature value in Celsius degree (ºC) and the humidity value in relative humidity percentage (%RH).

12.3. Luminosity sensor probe (LDR)

Sensor specifications (LDR)

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

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 (400nm – 700nm) 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.

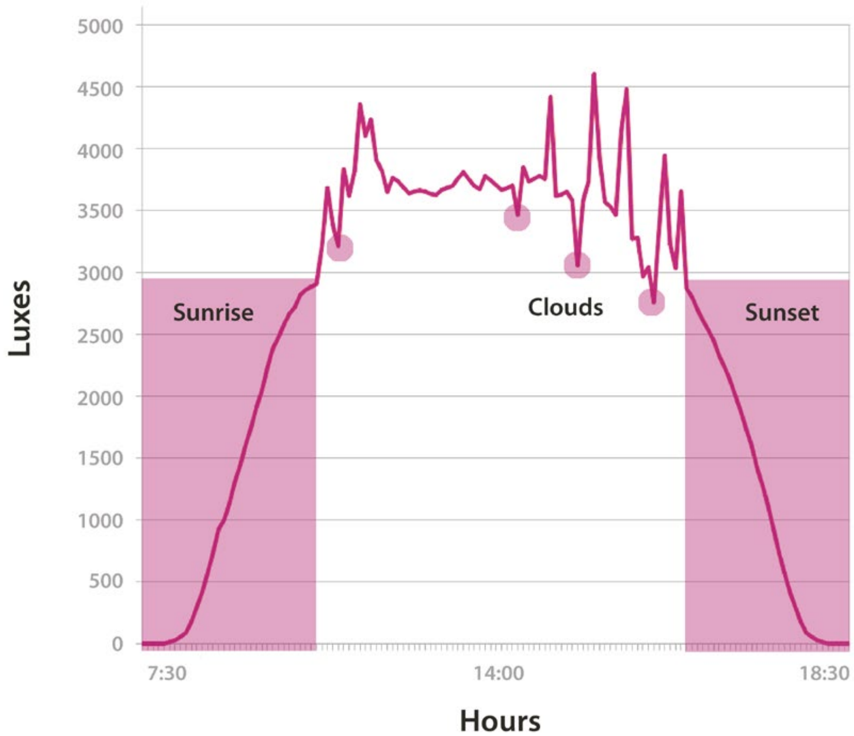


Figure: Image of the Luminosity sensor probe (Luxes accuracy)

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.

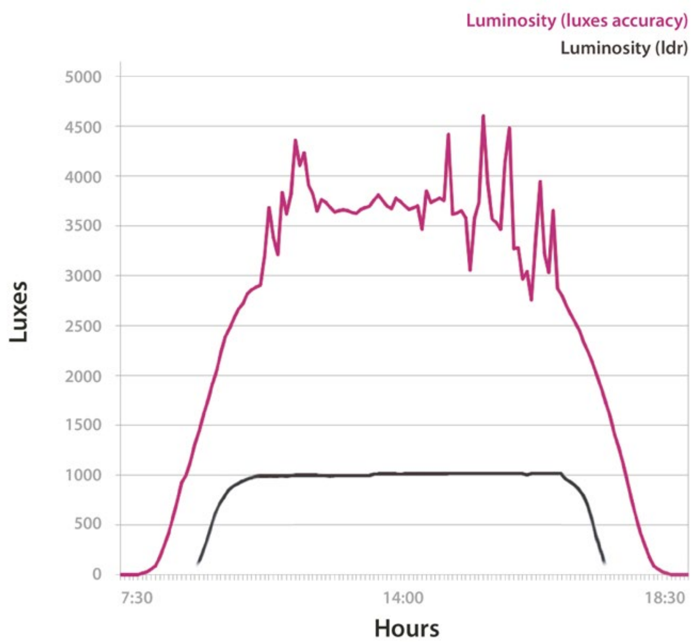


Figure: Comparison of the responses of the Luminosity sensor probe (Luxes accuracy) and the Luminosity sensor probe (LDR)

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 no used for this model.

Sensor specifications (Geiger tube)

Manufacturer: North Optic
Radiation Detection: Beta, Gamma [β, γ]
Length: 111mm
Diameter: 11mm
Recommended Voltage: 350V
Plateau Voltage: 360-440V
Sensitivy γ (60Co): 65cps/(μR/s)
Sensitivy γ (equivalent Sievert): 108cpm / (μSv/h)
Max cpm: 30000
cps/mR/h: 18
cpm/m/h: 1080
cpm/μSv/h: 123.147092360319
Factor: 0.00812037037037

Note: *For more technical information about each sensor probe go to the [Development section](#) in [Libelium Website](#).*

14. Documentation Changelog

From 5.3 to 5.4:
- New section for the new sensor probes format

From 5.2 to 5.3:
- The Smart Metering line was discontinued
- The Hall effect sensor probe changed

From 5.1 to 5.2:
- Socket A was deleted from the Smart Water Plug & Sense! Because it is no longer needed.

From 5.0 to 5.1:
- References to the new Smart Water Ions line
- Dissolved ions sensors were moved from Smart Water to Smart Water Ions
- Updated specifications for the Gases PRO sensors Carbon Monoxide (CO), Molecular Oxygen (O_2), Molecular Hydrogen (H_2) and Hydrogen Sulfide (H_2S)

From 4.9 to 5.0:
- Added chapter for the new Smart Environment PRO / Gases PRO line
- The Dust sensor is discontinued in the Plug & Sense! ecosystem; now, the recommended option is the Particle Matter sensor

From 4.8 to 4.9:
- Removed the discontinued water flow sensors (FS100A, FS200A and FS400) and added the new equivalent ones (YF-S401, FS300A and YF-G1)

From 4.7 to 4.8:
- Added references to the new Turbidity sensor for Smart Water
- Added MiCS-2714 NO_2 sensor, MiCS-2614 O_3 sensor and MiCS-5524 VOC's sensor (new versions)
- The correct noise sensor's output is indicated: dBA
- Introduced the new equivalent noise sensor's name
- Noted that the dust sensor probe must be maintained periodically, and purchased with the big Solar Shield
- Noted that the noise sensor probe and Plug & Sense! Smart Cities must be purchased together

From 4.6 to 4.7:
- Updated list of calibrated gas sensors

From 4.5 to 4.6:
- Added chapter for the new Smart Water line

From 4.4 to 4.5:
- Added references to the new Calibrated Gas Sensor line

From 4.3 to 4.4:
- Changed Weather Meters name to Weather Station WS-3000
- Details about new filtered function for reading the wind vane

From 4.2 to 4.3:
- Added new Liquid Presence sensor.

From 4.1 to 4.2:

- Errata correction in Air Pollutants sensors and one figure.
- Creation of the "Documentation Changelog" chapter.