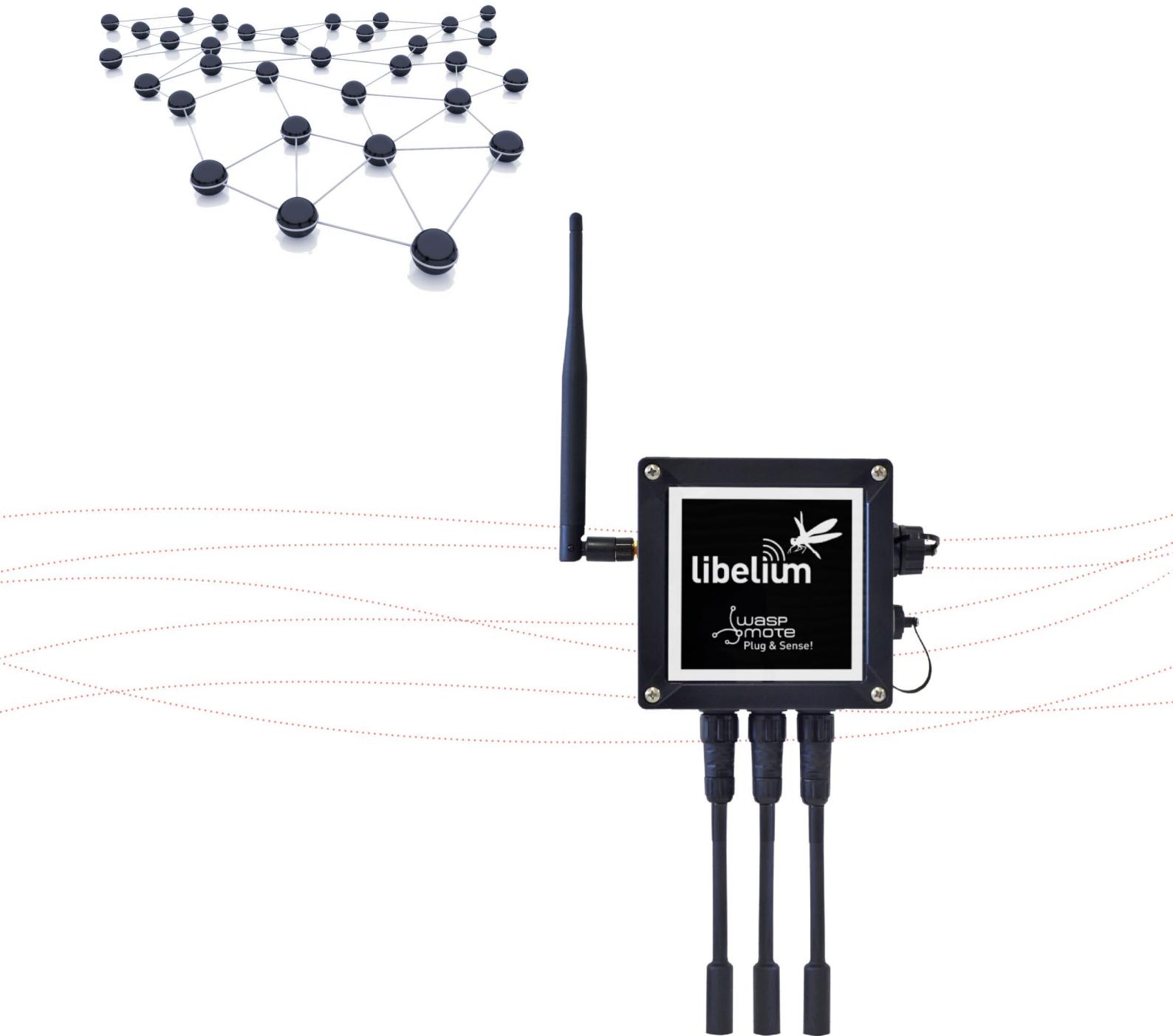


# Waspmote Plug & Sense!

## Sensor Guide



Document version: v5.1 - 06/2015  
© Libelium Comunicaciones Distribuidas S.L.

## INDEX

<b>1. General .....</b>	<b>6</b>
1.1. General and safety information .....	6
1.2. Conditions of use .....	6
<b>2. Introduction .....</b>	<b>7</b>
<b>3. Internal sensors .....</b>	<b>8</b>
3.1. Accelerometer .....	8
3.2. RTC temperature sensor .....	9
<b>4. Smart Environment .....</b>	<b>10</b>
4.1. General description .....	10
4.2. Temperature sensor probe .....	12
4.3. Humidity sensor probe .....	13
4.4. Atmospheric Pressure sensor probe .....	14
4.5. Carbon Monoxide (CO) sensor probe .....	15
4.6. Methane (CH <sub>4</sub> ) sensor probe .....	16
4.7. Ammonia (NH <sub>3</sub> ) sensor probe .....	17
4.8. LPG sensor probe .....	18
4.9. Air Pollutants 1 sensor probe .....	19
4.10. Air pollutants 2 sensor probe .....	20
4.11. Solvent Vapors sensor probe .....	21
4.12. Carbon Dioxide (CO <sub>2</sub> ) sensor probe .....	22
4.13. Nitrogen Dioxide (NO <sub>2</sub> ) sensor probe (MiCS-2710) .....	23
4.14. Nitrogen Dioxide (NO <sub>2</sub> ) Sensor - MiCS-2714 .....	24
4.15. Ozone (O <sub>3</sub> ) sensor probe (MiCS-2610) .....	25
4.16. Ozone (O <sub>3</sub> ) Sensor - MiCS-2614 .....	26
4.17. VOC sensor probe (MiCS-5521) .....	27
4.18. VOC sensor (MiCS-5524) .....	28
4.19. Oxygen (O <sub>2</sub> ) sensor probe .....	29
<b>5. Smart Environment PRO .....</b>	<b>30</b>
5.1. General description .....	30
5.2. Temperature, Humidity and Pressure sensor .....	32
5.3. Carbon Monoxide (CO) Gas Sensor [Calibrated] .....	33
5.4. Carbon Dioxide (CO <sub>2</sub> ) Gas Sensor [Calibrated] .....	34
5.5. Molecular Oxygen (O <sub>2</sub> ) Gas Sensor [Calibrated] .....	35
5.6. Ozone (O <sub>3</sub> ) Gas Sensor [Calibrated] .....	36
5.7. Nitric Oxide (NO) Gas Sensor [Calibrated] .....	37
5.8. Nitric Dioxide (NO <sub>2</sub> ) Gas Sensor [Calibrated] .....	38

5.9. Sulfur Dioxide ( $\text{SO}_2$ ) Gas Sensor [Calibrated].....	39
5.10. Ammonia ( $\text{NH}_3$ ) Gas Sensor [Calibrated] .....	40
5.11. Methane ( $\text{CH}_4$ ) and Combustible Gas Sensor [Calibrated].....	41
5.12. Molecular Hydrogen ( $\text{H}_2$ ) Gas Sensor [Calibrated].....	42
5.13. Hydrogen Sulfide ( $\text{H}_2\text{S}$ ) Gas Sensor [Calibrated].....	43
5.14. Hydrogen Chloride (HCl) Gas Sensor [Calibrated] .....	44
5.15. Hydrogen Cyanide (HCN) Gas Sensor [Calibrated] .....	45
5.16. Phosphine ( $\text{PH}_3$ ) Gas Sensor [Calibrated] .....	46
5.17. Ethylene Oxide (ETO) Gas Sensor [Calibrated] .....	47
5.18. Chlorine ( $\text{Cl}_2$ ) Gas Sensor [Calibrated] .....	48
5.19. Particle Matter (PM1 / PM2.5 / PM10) - Dust Sensor .....	49
5.19.1. Particle matter: the parameter.....	50
5.19.2. Measurement process.....	50
5.19.3. Installing the Sensor Probe .....	51
<b>6. Smart Security .....</b>	<b>53</b>
6.1. General description.....	53
6.2. Temperature and Humidity sensor probe.....	55
6.3. Liquid Flow sensor probes (FS100A, FS200A, FS300A, FS400, YF-S401 and YF-G1).....	56
6.4. Presence sensor (PIR) probe.....	57
6.5. Luminosity sensor probe.....	58
6.6. Liquid Level sensor probe.....	58
6.7. Liquid Presence sensor probe (Point).....	59
6.8. Hall Effect sensor probe.....	60
6.9. Liquid Presence sensor probe (Line) .....	60
<b>7. Smart Water .....</b>	<b>61</b>
7.1. General description.....	61
7.2. Soil/Water Temperature sensor (Pt1000) probe.....	63
7.3. Conductivity sensor probe .....	64
7.4. Dissolved Oxygen sensor probe.....	64
7.5. pH sensor probe .....	65
7.6. Oxidation-reduction potential sensor probe .....	65
7.7. Turbidity sensor probe .....	66
7.7.1. Turbidity: the parameter.....	66
7.7.2. Measurement process .....	66
7.7.3. Calibration procedure.....	69
<b>8. Smart Water Ions .....</b>	<b>70</b>
8.1. General description.....	70
8.1.1. Single .....	71
8.1.2. Double.....	72
8.2. Soil/Water Temperature sensor (Pt-1000) .....	73
8.3. Reference probes .....	74

<b>9. Smart Metering.....</b>	<b>76</b>
9.1. General description.....	76
9.2. Temperature sensor probe .....	78
9.3. Soil Temperature sensor (DS18B20) probe .....	79
9.4. Humidity sensor probe .....	80
9.5. Liquid Flow sensor probes (FS100A, FS200A, FS300A, FS400, YF-S401 and YF-G1).....	81
9.6. Current sensor probe.....	82
9.7. Ultrasound sensor probe.....	82
9.8. Luminosity sensor probe.....	84
<b>10. Smart Cities.....</b>	<b>85</b>
10.1. General description .....	85
10.2. Temperature sensor probe.....	87
10.3. Soil Temperature sensor (DS18B20) probe.....	88
10.4. Ultrasound sensor probe .....	88
10.5. Humidity sensor probe.....	90
10.6. Luminosity sensor probe .....	91
10.7. Noise sensor probe .....	92
10.8. Linear Displacement sensor probe .....	93
<b>11. Smart Parking .....</b>	<b>94</b>
11.1. General description .....	94
<b>12. Smart Agriculture .....</b>	<b>95</b>
12.1. General description .....	95
12.1.1. Normal .....	96
12.1.2. PRO .....	96
12.2. Temperature and Humidity sensor probe .....	97
12.3. Atmospheric Pressure sensor probe.....	98
12.4. Soil Temperature sensor (DS18B20) probe.....	99
12.5. Soil moisture sensor probe .....	99
12.6. Weather station WS-3000 probe .....	100
12.7. Leaf Wetness sensor probe .....	102
12.8. Soil Temperature sensor (PT1000) probe .....	102
12.9. Solar Radiation sensor probe .....	103
12.10. Dendrometer sensor probe .....	105
<b>13. Ambient Control .....</b>	<b>107</b>
13.1. General description .....	107
13.2. Temperature and Humidity sensor probe .....	109
13.3. Luminosity sensor probe (LDR) .....	110
13.4. Luminosity sensor probe (Luxes accuracy) .....	111
13.5. Comparative between Light and Luminosity sensor .....	112

<b>14. Radiation Control .....</b>	<b>113</b>
14.1. General description .....	113
<b>15. Documentation Changelog .....</b>	<b>114</b>

# 1. General

## 1.1. General and safety information

- In this section, the term "Wasp mote" encompasses both the Wasp mote 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.
- Wasp mote 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.
- Wasp mote 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 Wasp mote in accordance with the electrical specifications and the environment described in the "Electrical Data" section of this manual.
- Wasp mote 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 Wasp mote 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/](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](http://www.libelium.com/development/plug-sense/sdk_applications)



Figure: Waspmote Plug & Sense! Line

## 3. Internal sensors



Figure: Image of WaspMote Plug & Sense!

### 3.1. 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  $\pm 2g/\pm 4g/\pm 8g$  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  $-40^{\circ}C$  and  $+85^{\circ}C$ .

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](#).

## 3.2. 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 **0.25°C**. The measurable temperature range is between **-40°C and +85°C**.

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](#).

## 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 <sub>4</sub>	9232
	Ammonia – NH <sub>3</sub>	9233
	Liquefied Petroleum Gases: H <sub>2</sub> , CH <sub>4</sub> , ethanol, isobutene	9234
	Air pollutants 1: C <sub>4</sub> H <sub>10</sub> , CH <sub>3</sub> CH <sub>2</sub> OH, H <sub>2</sub> , CO, CH <sub>4</sub>	9235
	Air pollutants 2: C <sub>6</sub> H <sub>5</sub> CH <sub>3</sub> , H <sub>2</sub> S, CH <sub>3</sub> CH <sub>2</sub> OH, NH <sub>3</sub> , H <sub>2</sub>	9236
	Alcohol derivates: CH <sub>3</sub> CH <sub>2</sub> OH, H <sub>2</sub> , C <sub>4</sub> H <sub>10</sub> , CO, CH <sub>4</sub>	9237
B	Humidity	9204
	Atmospheric pressure	9250
C	Carbon dioxide - CO <sub>2</sub>	9230
D	Nitrogen dioxide - NO <sub>2</sub>	9238 , 9238 -B
E	Ozone - O <sub>3</sub>	9258 , 9258 -B
	Hydrocarbons - VOC	9201 , 9201-B
	Oxygen - O <sub>2</sub>	9231
F	Carbon monoxide - CO	9229
	Methane - CH <sub>4</sub>	9232
	Ammonia – NH <sub>3</sub>	9233
	Liquefied Petroleum Gases: H <sub>2</sub> , CH <sub>4</sub> , ethanol, isobutene	9234
	Air pollutants 1: C <sub>4</sub> H <sub>10</sub> , CH <sub>3</sub> CH <sub>2</sub> OH, H <sub>2</sub> , CO, CH <sub>4</sub>	9235
	Air pollutants 2: C <sub>6</sub> H <sub>5</sub> CH <sub>3</sub> , H <sub>2</sub> S, CH <sub>3</sub> CH <sub>2</sub> OH, NH <sub>3</sub> , H <sub>2</sub>	9236
	Alcohol derivates: CH <sub>3</sub> CH <sub>2</sub> OH, H <sub>2</sub> , C <sub>4</sub> H <sub>10</sub> , CO, CH <sub>4</sub>	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:** [-40°C ,+125°C]

**Output voltage (0°C):** 500mV

**Sensitivity:** 10mV/°C

**Accuracy:**  $\pm 2^\circ\text{C}$  (range 0°C ~ +70°C),  $\pm 4^\circ\text{C}$  (range -40 ~ +125°C)

**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)

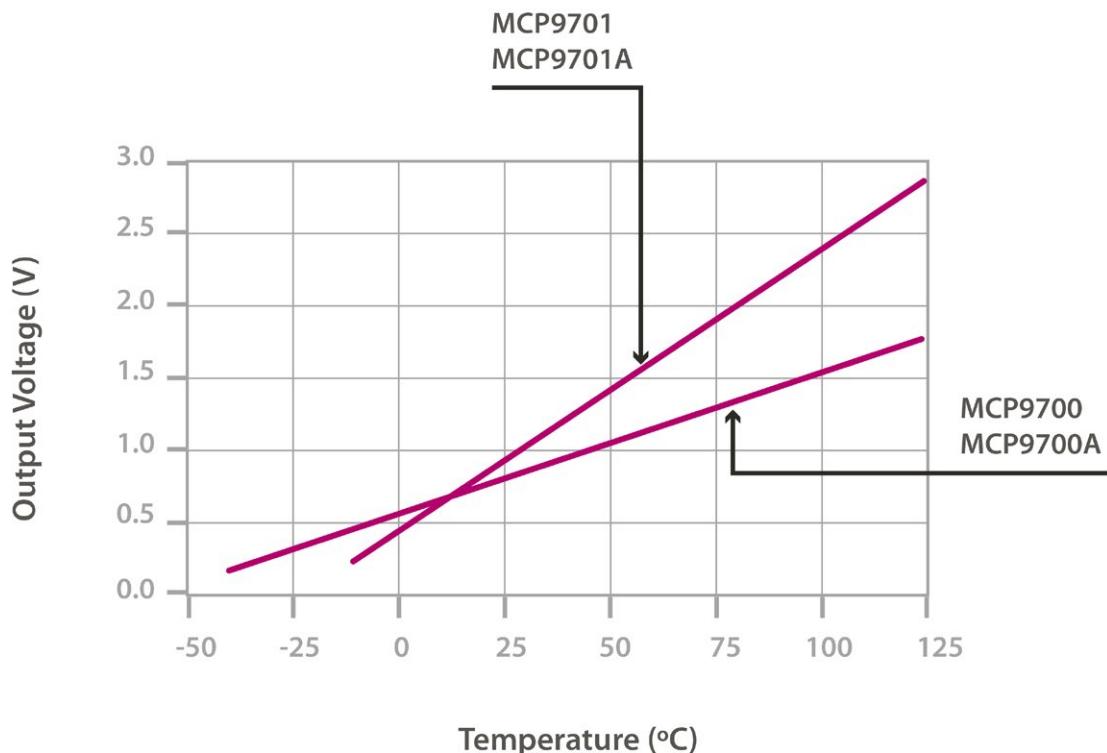


Figure: Graph of the MCP9700A sensor output voltage with respect to temperature, taken from the Microchip sensor's data sheet

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 (25°C)  
**Accuracy:** <±4%RH (at 25°C, range 30 ~ 80%), <±6%RH (range 0 ~ 100)  
**Supply voltage:** 5VDC ±5%  
**Operating temperature:** -40 ~ +85°C  
**Response time:** <15 seconds  
**Typical consumption:** 0.38mA  
**Maximum consumption:** 0.5mA



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

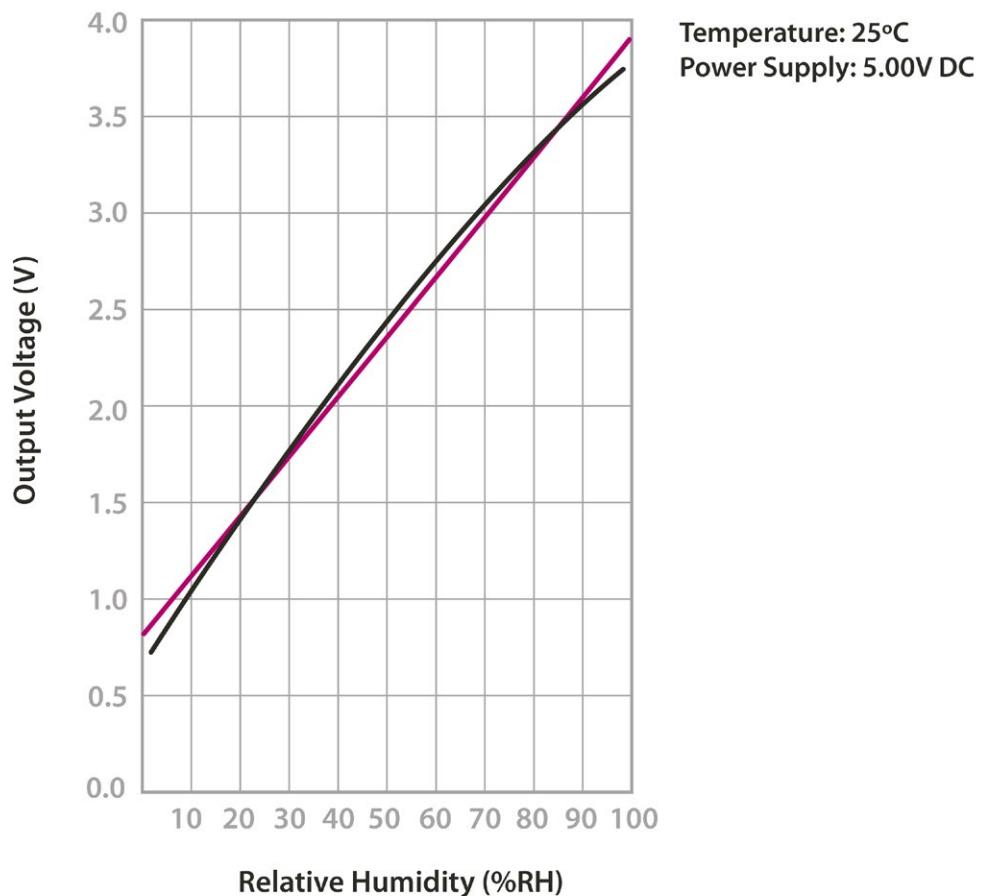


Figure: 808H5V5 humidity sensor output taken from the Sencera Co. Ltd sensor data sheet

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 ~ 85°C)  
**Sensitivity:** 46mV/kPa  
**Accuracy:** <±1,5%V (0 ~ 85°C)  
**Typical consumption:** 7mA  
**Maximum consumption:** 10mA  
**Supply voltage:** 4.85 ~ 5.35V  
**Operation temperature:** -40 ~ +125°C  
**Storage temperature:** -40 ~ +125°C  
**Response time:** 20ms



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

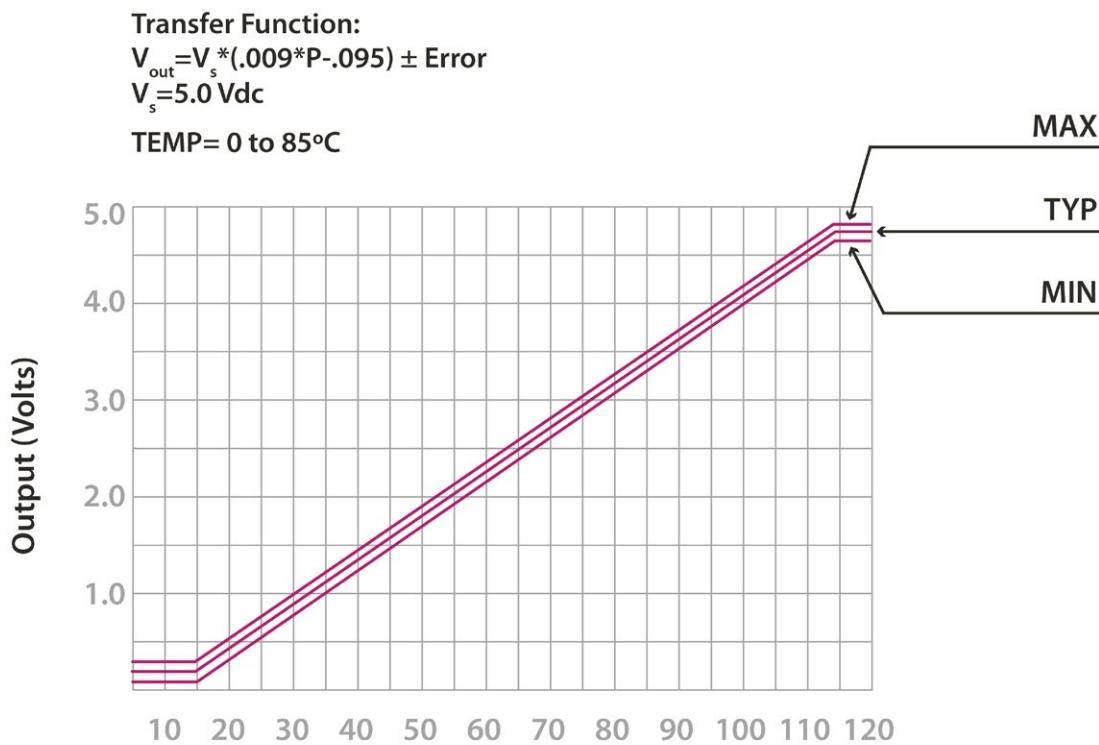


Figure: Graph of the MPX4115A sensor's output voltage with regard to pressure taken from the Freescale sensor's data sheet

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 ~ 133k $\Omega$

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

**Supply voltage:** 5V ±0.2V DC

**Operating temperature:** -10 ~ +50°C

**Response time:** 1second

**Minimum load resistance:** 10k $\Omega$

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



Figure: Image of the CO sensor probe (TGS2442)

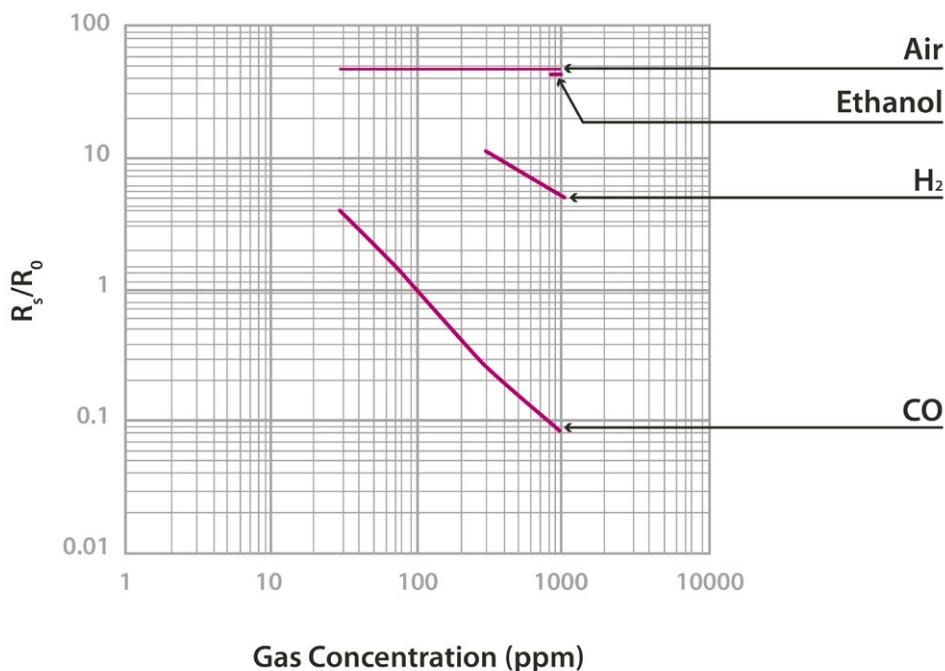


Figure: Graph of the sensitivity of the TGS2442 taken from the Figaro sensor's data sheet

The TGS2442 is a resistive sensor sensitive to the changes in concentration of Carbon Monoxide (CO) and, very slightly, Hydrogen (H<sub>2</sub>). 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 ( $\text{CH}_4$ ) sensor probe

### Sensor specifications (TGS2611)

**Gases:**  $\text{CH}_4, \text{H}_2$

**Measurement range:** 500 ~ 10000ppm

**Resistance at 5000ppm:** 0.68 ~ 6.8k $\Omega$

**Sensitivity:**  $0.6 \pm 0.06$  (ratio between the resistance at 9000 and at 3000ppm)

**Supply voltage:** 5V  $\pm 0.2$ V DC

**Operating temperature:** -10 ~ +40°C

**Response time:** 30 seconds

**Minimum load resistance:** 0.45k $\Omega$

**Average consumption:** 61mA



Figure: Image of the  $\text{CH}_4$  sensor probe (TGS2611)

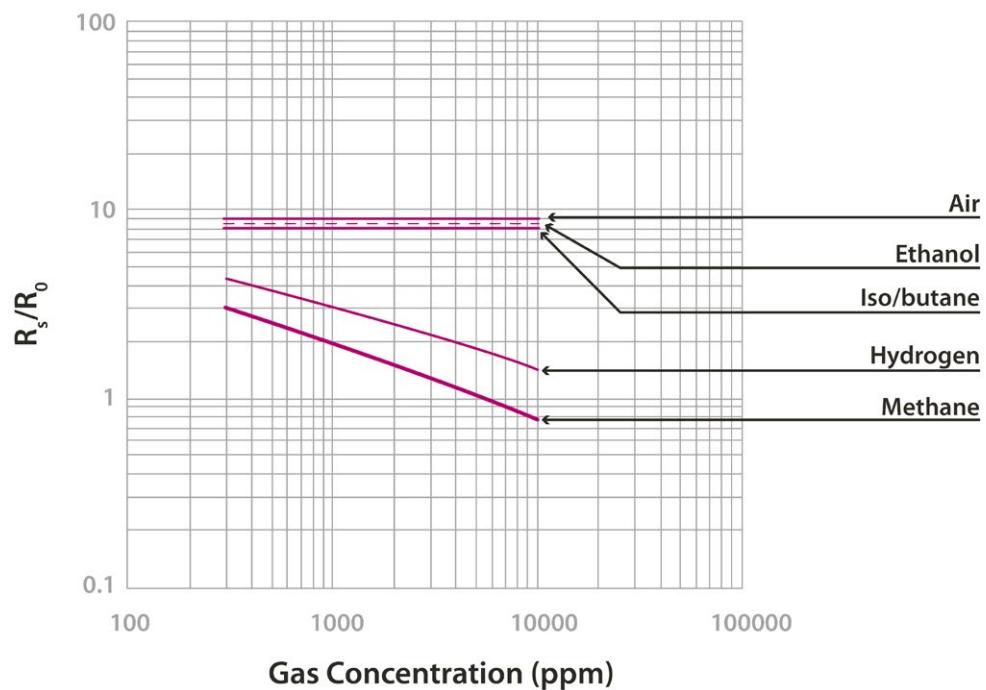


Figure: Graph of sensitivity of the TGS2611 taken from the Figaro sensor's data sheet

The TGS2611 sensor shows a variable resistance with the concentration of  $\text{CH}_4$  and to a lesser extent with the concentration of  $\text{H}_2$ . 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 ( $\text{NH}_3$ ) sensor probe

### Sensor specifications (TGS2444)

**Gases:**  $\text{NH}_3$ ,  $\text{H}_2\text{S}$

**Measurement range:** 10 ~ 100ppm

**Resistance at 10ppm:** 3.63 ~ 36.3k $\Omega$

**Sensitivity:** 0,063 ~ 0.63 (ratio between the resistance at 3000 and at 1000ppm)

**Supply voltage:** 5V  $\pm 0.2$ V DC

**Operating temperature:** -10 ~ +50°C

**Response time:** 250ms

**Minimum load resistance:** 8k $\Omega$

**Average consumption:** 12mA (throughout the complete power supply cycle in 250ms)



Figure: Image of the  $\text{NH}_3$  sensor probe (TGS2444)

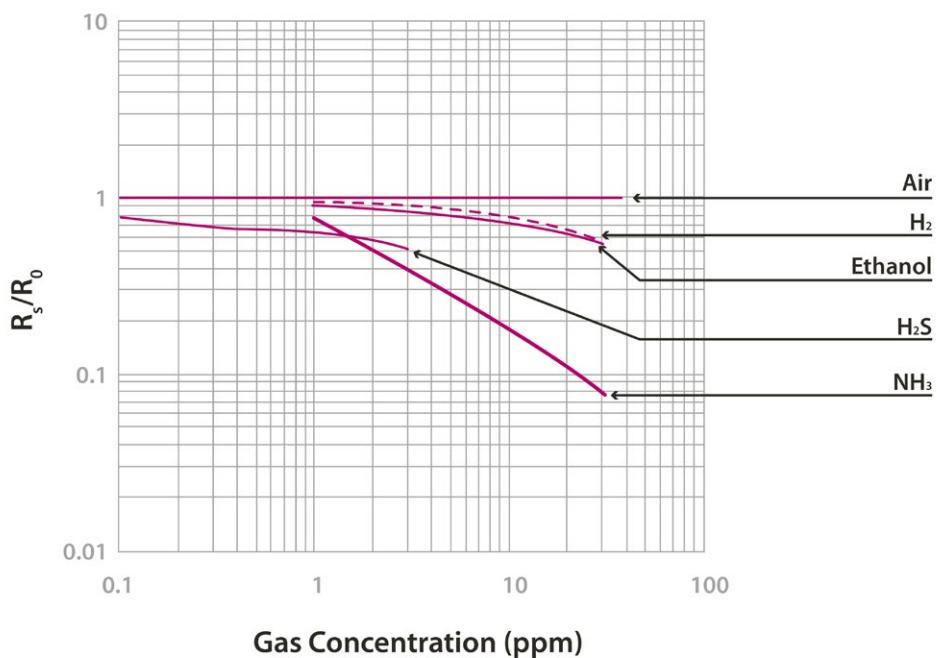


Figure: Graph of the sensitivity of the TGS2444 taken from the Figaro sensor data sheet

The TGS2444 sensor is a resistive sensor which is highly sensitive to variations in the concentration of Ammonia ( $\text{NH}_3$ ) and which shows slight sensitivity to hydrogen sulphide ( $\text{H}_2\text{S}$ ) and to a lesser extent, to Hydrogen ( $\text{H}_2$ ) and Ethanol ( $\text{CH}_3\text{CH}_2\text{OH}$ ). 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:**  $\text{CH}_3\text{CH}_2\text{OH}$ ,  $\text{CH}_4$ ,  $\text{C}_4\text{H}_{10}$ ,  $\text{H}_2$

**Measurement range:** 500 ~ 10000ppm

**Resistance at 1800ppm (isobutane):** 0.68 ~ 6.8k $\Omega$

**Sensitivity:**  $0.56 \pm 0.06$  (ratio between the resistance at 3000 and at 1000ppm)

**Supply voltage:** 5V  $\pm 0.2$ V DC

**Operating temperature:** -10 ~ +40°C

**Response time:** 30 seconds

**Minimum load resistance:** 0.45k $\Omega$

**Average consumption:** 61mA



Figure: Image of the LPG sensor probe (TGS2610)

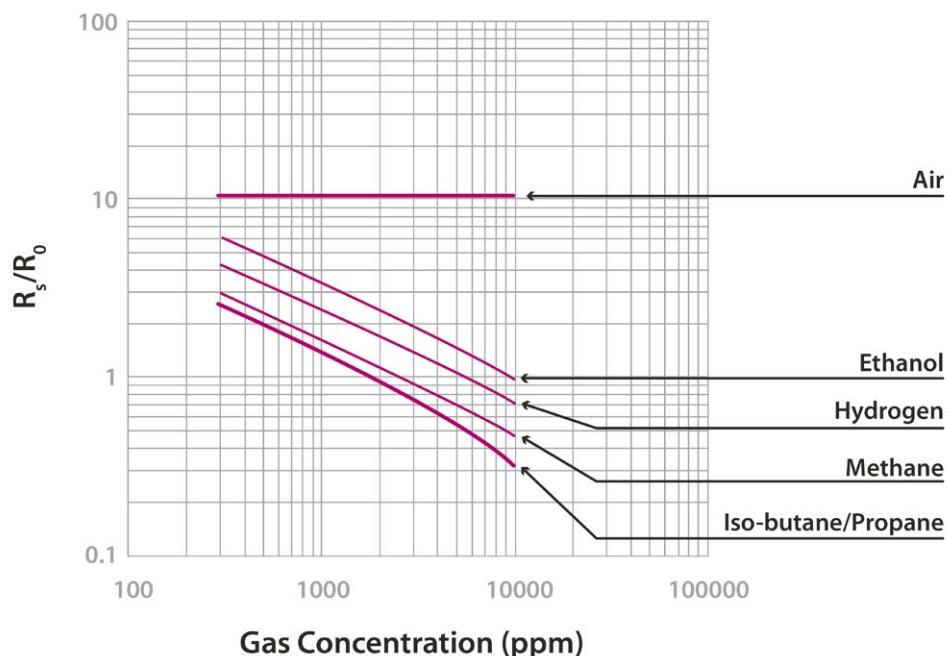


Figure: Graph of the sensitivity of the TGS2610 taken from the Figaro sensor's data sheet

The TGS2610 is a resistive sensor which shows sensitivity to combustible gases and derivatives. Especially reactive to Isobutane ( $\text{C}_4\text{H}_{10}$ ), it is also sensitive to Methane ( $\text{CH}_4$ ), Ethanol ( $\text{CH}_3\text{CH}_2\text{OH}$ ) and Hydrogen ( $\text{H}_2$ ). 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<sub>6</sub>H<sub>5</sub>CH<sub>3</sub>, H<sub>2</sub>S, CH<sub>3</sub>CH<sub>2</sub>OH, NH<sub>3</sub>, H<sub>2</sub>

**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 ~ +50°C

**Storage temperature:** -20 ~ +60°C

**Response time:** 30 seconds

**Minimum load resistance:** 0.45kΩ

**Average consumption:** 61mA



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

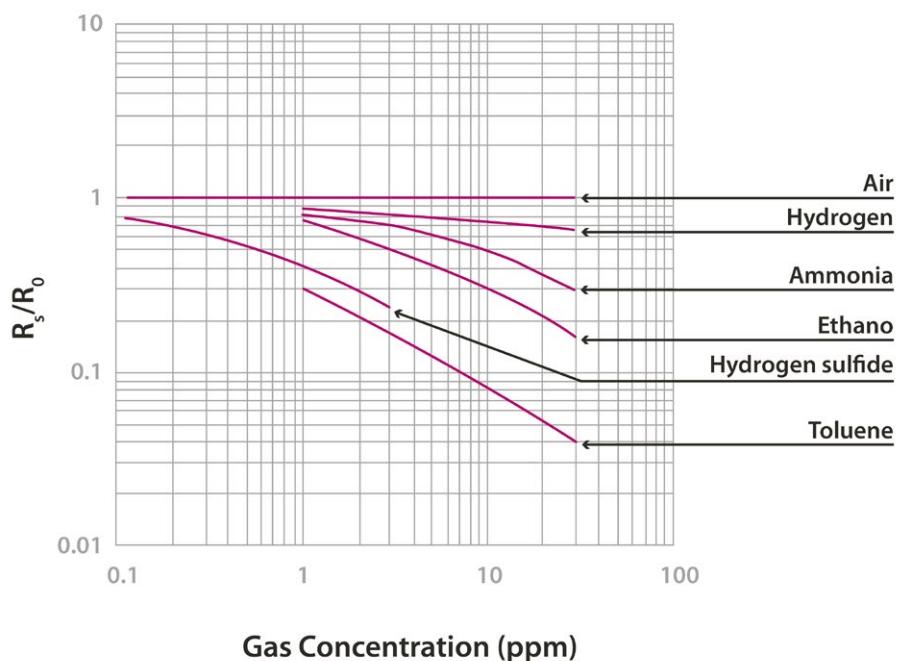


Figure: Graph of the sensitivity of the TGS2602 taken from the Figaro sensor's data sheet

The TGS2602 is a sensor similar to the TGS2600 which reacts varying its resistance in the presence of contaminant gases, mainly Toluene (C<sub>6</sub>H<sub>5</sub>CH<sub>3</sub>), Hydrogen Sulphide (H<sub>2</sub>S), Ethanol (CH<sub>3</sub>CH<sub>2</sub>OH), Ammonia (NH<sub>3</sub>) and to a lesser extent, Hydrogen (H<sub>2</sub>). 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<sub>3</sub>CH<sub>2</sub>OH 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 ~ 90k $\Omega$

**Sensitivity:** 0.3 ~ 0.6 (ratio between the resistance in 10ppm of  $H_2$  and in air)

**Supply voltage:** 5V  $\pm 0.2$ V DC

**Operating temperature:** -10 ~ +40°C

**Response time:** 30 seconds

**Minimum load resistance:** 0.45k $\Omega$

**Average consumption:** 46mA



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

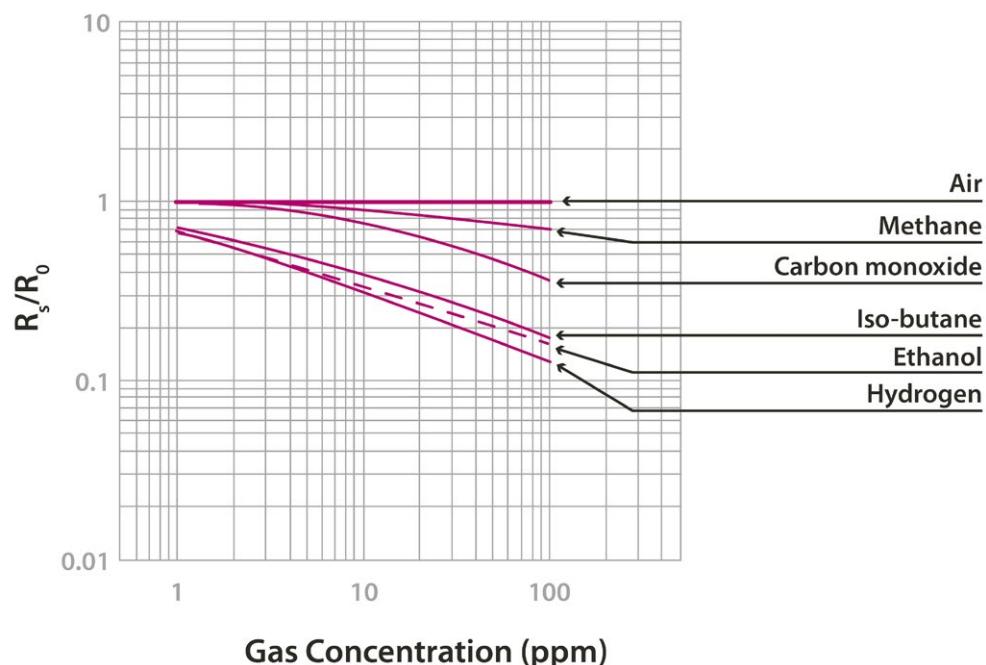


Figure: Graph of the sensitivity of the TGS2600 taken from the Figaro sensor's data sheet

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 90k $\Omega$ , 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:**  $\text{CH}_3\text{CH}_2\text{OH}$ ,  $\text{H}_2$ ,  $\text{C}_4\text{H}_{10}$ ,  $\text{CO}$ ,  $\text{CH}_4$

**Measurement range:** 50 ~ 5000ppm

**Resistance to 300ppm of Ethanol:** 1 ~ 5k $\Omega$

**Sensitivity:** 0.3 ~ 0.5 (ratio between the resistance at 300ppm and at 50ppm)

**Supply voltage:** 5V  $\pm 0.2$ V DC

**Operating temperature:** -10 ~ +40°C

**Response time:** 30 seconds

**Load minimum resistance:** 0.45k $\Omega$

**Average consumption:** 46mA (throughout the complete power supply cycle in 250ms)



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

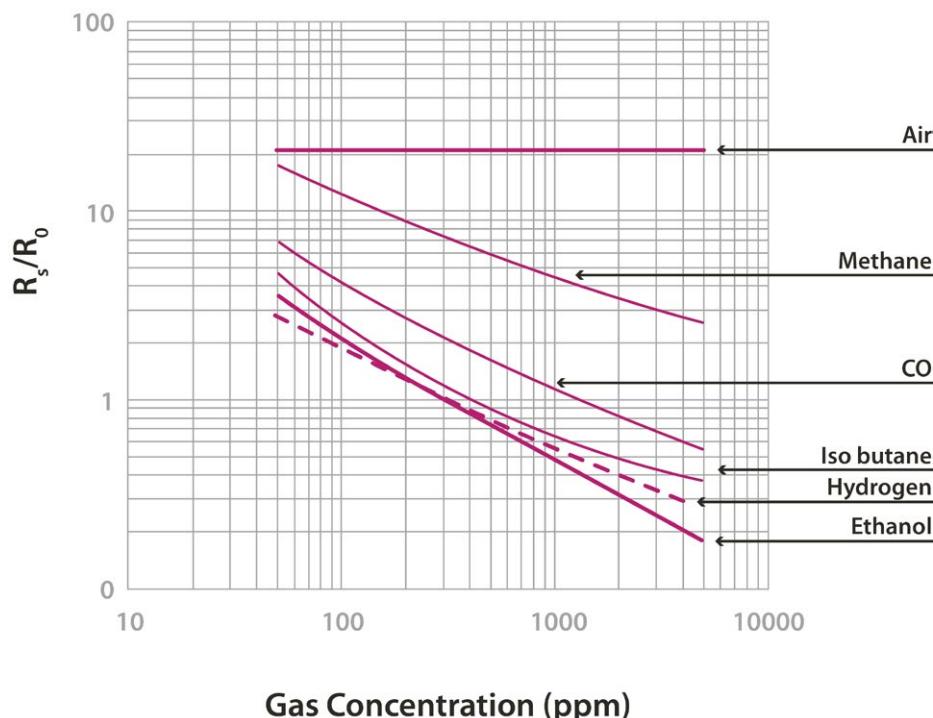


Figure: Graph of the sensitivity of the TGS2620 taken from the Figaro sensor's data sheet

The TGS2620 sensor allows detection of alcohol and organic gases, mainly Ethanol ( $\text{CH}_3\text{CH}_2\text{OH}$ ), Hydrogen ( $\text{H}_2$ ), Isobutane ( $\text{C}_4\text{H}_{10}$ ), Carbon Monoxide ( $\text{CO}$ ) and Methane ( $\text{CH}_4$ ). The resistance the sensor shows in a 300ppm concentration of Ethanol can vary between 1 and 5k $\Omega$ , 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 ( $\text{CO}_2$ ) sensor probe

### Sensor specifications (TGS4161)

**Gases:**  $\text{CO}_2$

**Measurement range:** 350 ~ 10000ppm

**Voltage at 350ppm:** 220 ~ 490mV

**Sensitivity:** 44 ~ 72mV (variation between the voltage at 350ppm and at 3500ppm)

**Supply voltage:** 5V  $\pm 0.2$  V DC

**Operating temperature:** -10 ~ +50°C

**Response time:** 1.5 minutes

**Average consumption:** 50mA



Figure: Image of the  $\text{CO}_2$  sensor probe (TGS4161)

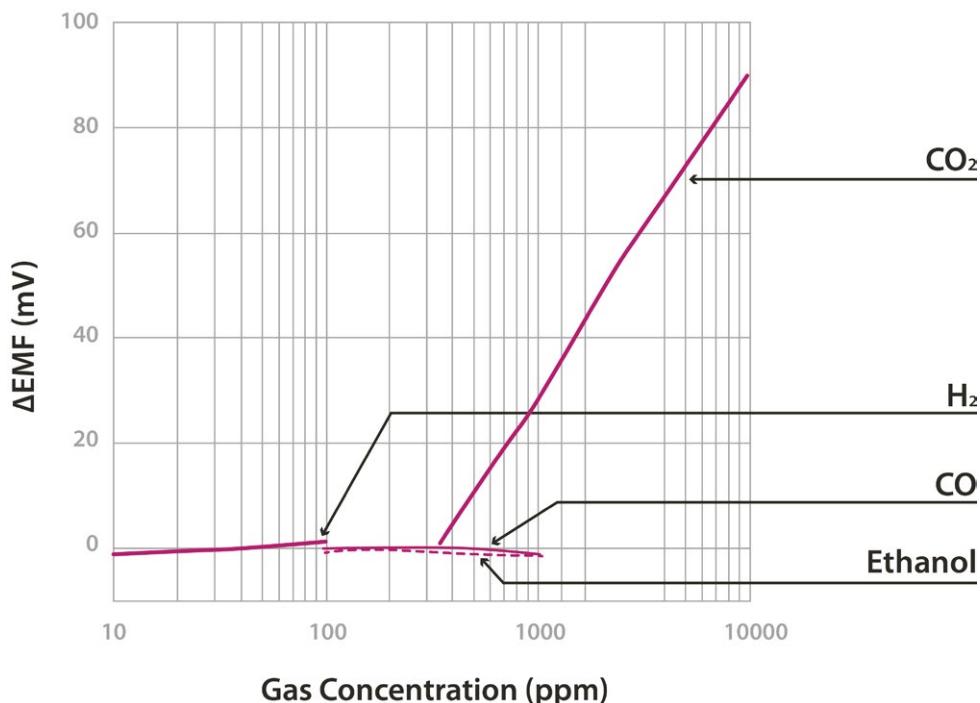


Figure: Graph of the sensitivity of the TGS4161 sensor taken from the Figaro sensor's data sheet

The TGS4161 sensor provides a voltage output proportional to the  $\text{CO}_2$  concentration in the atmosphere. It shows a value between 220 and 490mV for a concentration of 350ppm (approximately the normal  $\text{CO}_2$  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 ( $\text{NO}_2$ ) sensor probe (MiCS-2710)

### Sensor specifications (MiCS-2710)

**Gases:**  $\text{NO}_2$

**Measurement range:** 0.05 ~ 5ppm

**Air resistance:** 0.8 ~ 8k $\Omega$  (typically 2.2k $\Omega$ )

**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 ~ +85°C

**Response time:** 30 seconds

**Average consumption:** 26mA (throughout the complete power supply cycle in one second)



Figure: Image of the  $\text{NO}_2$  sensor probe (MiCS-2710)

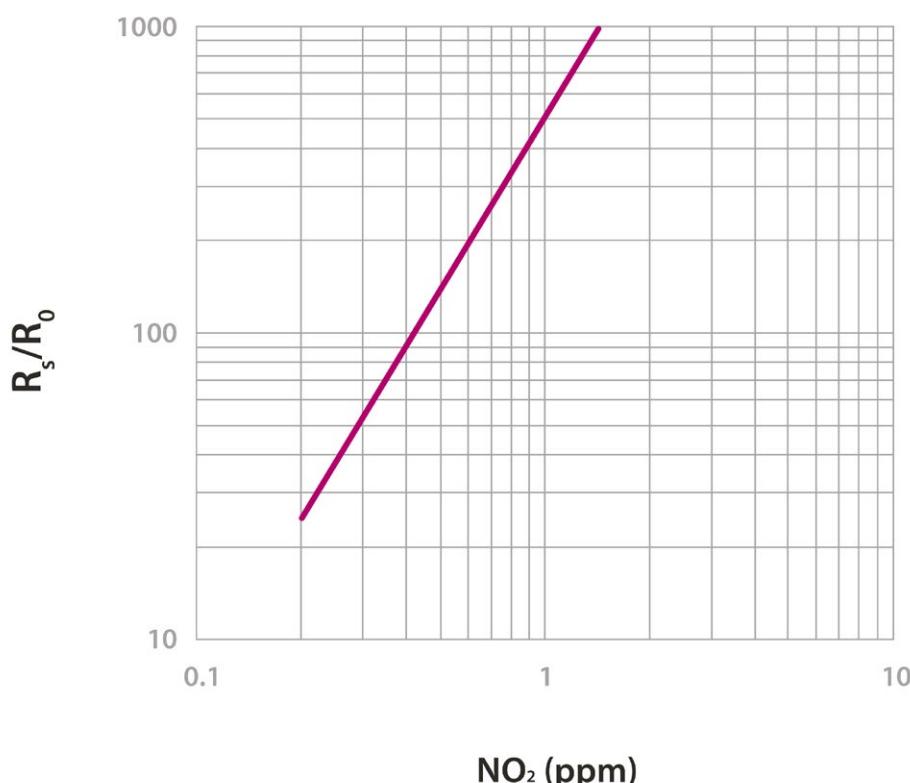


Figure: Graph of the sensitivity of the MiCS-2710 taken from the e2v's sensor data

The MiCS-2710 is a sensor whose resistance varies in the presence of small concentrations of  $\text{NO}_2$ . This value varies between 2k $\Omega$  and 2M $\Omega$  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 ( $\text{NO}_2$ ) 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:**  $\text{NO}_2$

**Measurement range:** 0.05 ~ 5ppm

**Air resistance:** 0.8 ~ 8k $\Omega$  (typically 2.2k $\Omega$ )

**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 ~ +85°C

**Response time:** 30 seconds

**Average consumption:** 26mA (throughout the complete power supply cycle in one second)



Figure: Image of the MiCS-2714 sensor

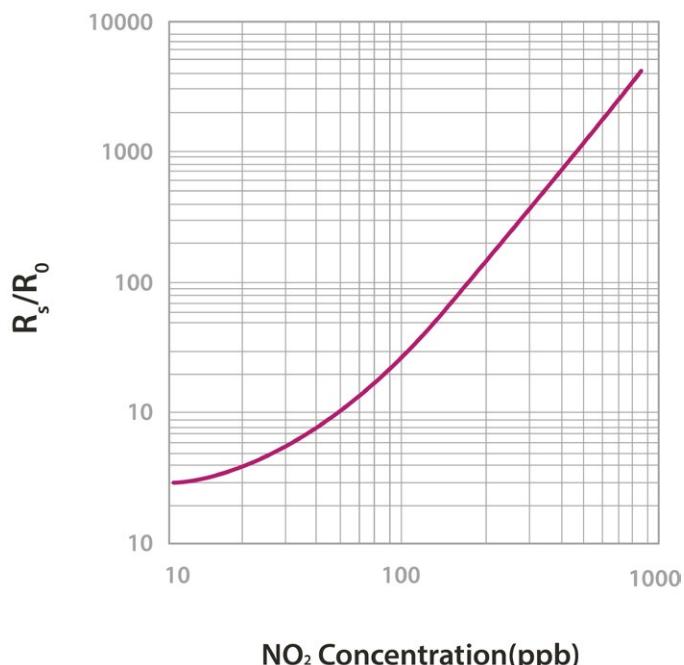


Figure: Graph of the sensitivity of the MiCS-2714 taken from the e2v's sensor data.

The MiCS-2714 is a sensor whose resistance varies in the presence of small concentrations of  $\text{NO}_2$ . This value varies between 2k $\Omega$  and 2M $\Omega$  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 ~ 1000 ppb

**Air resistance:** 3 ~ 60 k $\Omega$  (typically 11 k $\Omega$ )

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

**Supply voltage:** 1.95 ~ 5 V DC

**Operating temperature:** -30 ~ +85 °C

**Response time:** 30 seconds

**Average consumption:** 34 mA



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

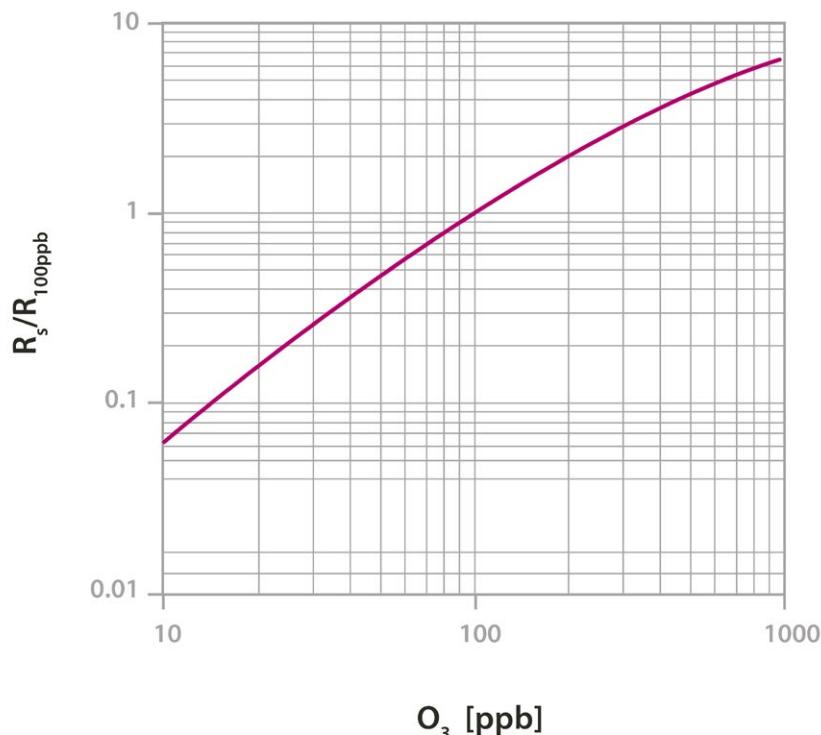


Figure: Graph of the sensitivity of the MiCS-2610 taken from the e2v's sensor data

The MiCS-2610 is a resistive sensor that allows to measure the variation of the  $O_3$  concentration between 10 ppb and 1000 ppb. Its resistance varies between 11 k $\Omega$  and 2 M $\Omega$  approximately. Unlike the MiCS-2710, this sensor is powered through a 2.5 V voltage regulator, with consumption of approximately 34 mA. The sensor's resistance in air, as well as its sensitivity, can vary between different units, so it is recommended to calibrate each one of them before finally inserting them in the application.

## 4.16. 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 ~ 1000 ppb

**Air resistance:** 3 ~ 60 k $\Omega$  (typically 11 k $\Omega$ )

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

**Supply voltage:** 1.95 ~ 5 V DC

**Operating temperature:** -30 ~ +85°C

**Response time:** 30 seconds

**Average consumption:** 34 mA



Figure: Image of the MiCS-2614 sensor

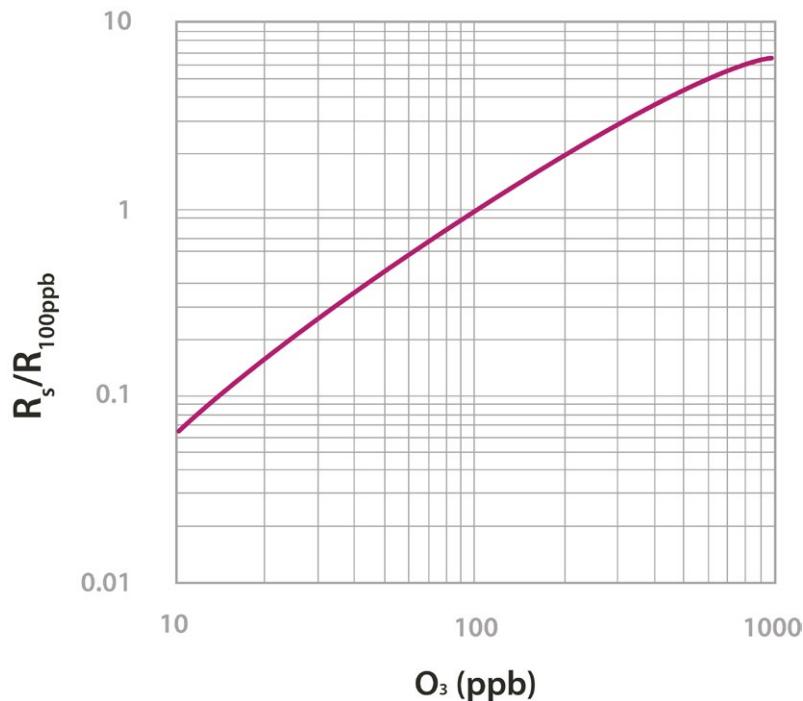


Figure: Graph of the sensitivity of the MiCS-2614 taken from the e2v's sensor data

The MiCS-2614 is a resistive sensor that allows to measure the variation of the  $O_3$  concentration between 10 ppb and 1000 ppb. Its resistance varies between 11 k $\Omega$  and 2 M $\Omega$  approximately. Unlike the MiCS-2710, this sensor is powered through a 2.5V voltage regulator, with consumption of approximately 34 mA. The sensor's resistance in air, as well as its sensitivity, can vary between different units, so it is recommended to calibrate each one of them before finally inserting them in the application.

## 4.17. 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 ~ +85°C

**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>

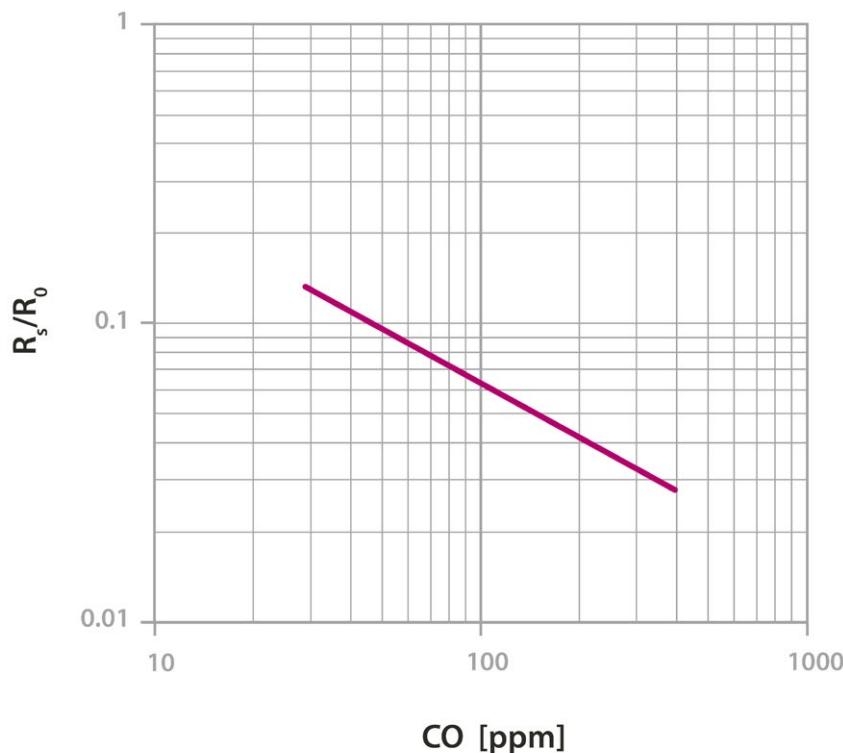


Figure: Graph of the sensitivity of the MiCS-5521 taken from the e2v's sensor data

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. Its 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 ~ +85°C

**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>

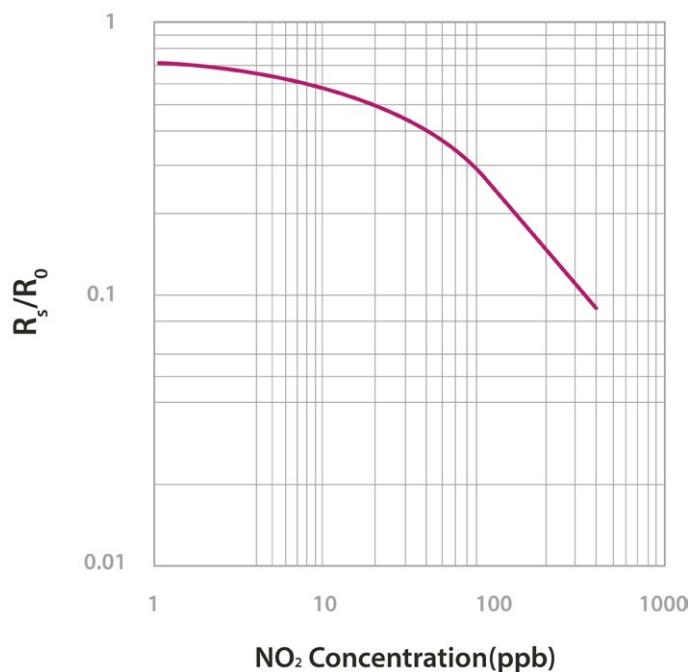


Figure: Graph of the sensitivity of the MiCS-5524 taken from the e2v's sensor data

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 ~ +40°C

**Response time:** 15 seconds

**Consumption:** 0 $\mu$ A

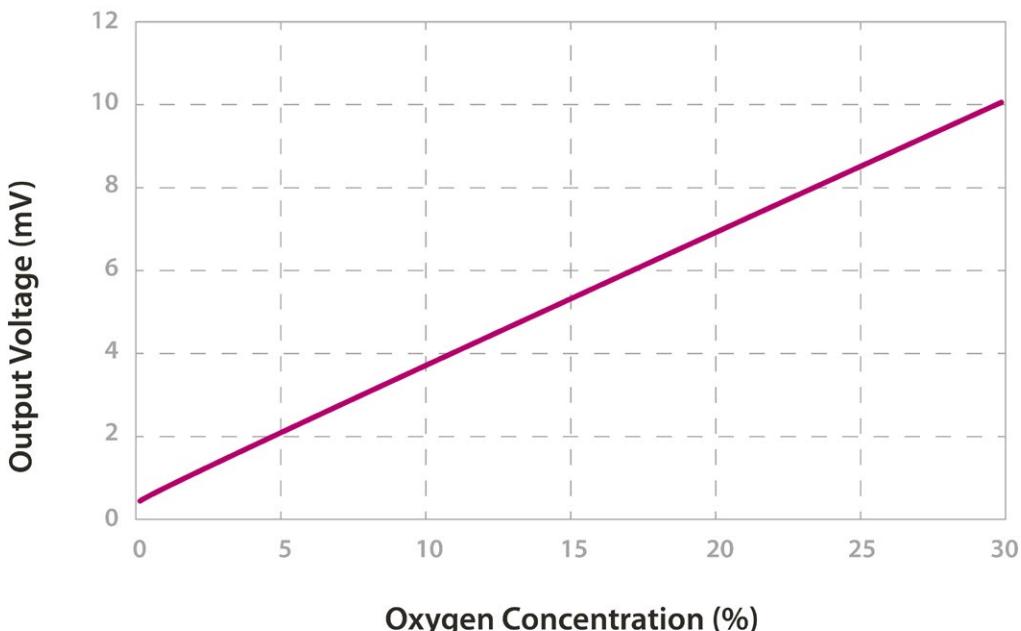


Figure: Graph of the sensitivity of the SK-25 extracted from the Figaro sensor's data sheet

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 Environment PRO

### 5.1. General description

The Smart Environment PRO model has been created as an evolution of Smart Environment. 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.

<b>Sensor Socket</b>	<b>Sensor probes allowed for each sensor socket</b>	
	<b>Parameter</b>	<b>Reference</b>
A, B, C and F	Carbon Monoxide (CO) [Calibrated]	9371-P
	Carbon Dioxide (CO <sub>2</sub> ) [Calibrated]	9372-P
	Oxygen (O <sub>2</sub> ) [Calibrated]	9373-P
	Ozone (O <sub>3</sub> ) [Calibrated]	9374-P
	Nitric Oxide (NO) [Calibrated]	9375-P
	Nitric Dioxide (NO <sub>2</sub> ) [Calibrated]	9376-P
	Sulfur Dioxide (SO <sub>2</sub> ) [Calibrated]	9377-P
	Ammonia (NH <sub>3</sub> ) [Calibrated]	9378-P
	Methane (CH <sub>4</sub> ) and Combustible Gas [Calibrated]	9379-P
	Hydrogen (H <sub>2</sub> ) [Calibrated]	9380-P
	Hydrogen Sulfide (H <sub>2</sub> S) [Calibrated]	9381-P
	Hydrogen Chloride (HCl) [Calibrated]	9382-P
	Hydrogen Cyanide (HCN) [Calibrated]	9383-P
	Phosphine (PH <sub>3</sub> ) [Calibrated]	9384-P
	Ethylene (ETO) [Calibrated]	9385-P
	Chlorine (Cl <sub>2</sub> ) [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.



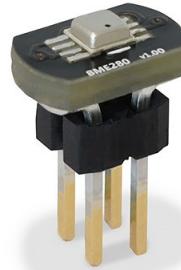
### Specifications

#### 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 °C

*Figure: Image of the Temperature, Humidity and Pressure sensor*

**Full accuracy range:** 0 ~ +65 °C

**Accuracy:** ±1 °C (range 0 °C ~ +65 °C)

**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 °C, range 20 ~ 80%)

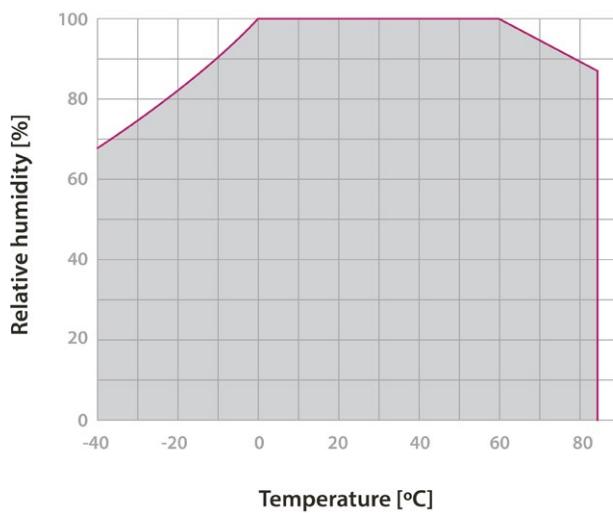
**Hysteresis:** ±1% RH

**Operating temperature:** -40 ~ +85 °C

**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 °C

**Full accuracy temperature range:** 0 ~ +65 °C

**Absolute accuracy:** ±0.1 kPa (0 ~ 65 °C)

**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

#### 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:**  $70 \pm 15 \text{ nA/ppm}$

**Accuracy:** as good as  $\pm 1 \text{ ppm}^*$  (ideal conditions)



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

#### Operation Conditions

**Temperature Range:** -20 °C to 50 °C

**Operating Humidity:** 15 to 90% RH non-condensing

**Pressure Range:** 90 to 110 kPa

**Storage Temperature:** 0 °C to 20 °C

**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<sub>2</sub>) Gas Sensor [Calibrated]

### Specifications

**Gas:** CO<sub>2</sub>

**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 °C

At least 30 min for full specification @ 25 °C

**Response Time (T90):** ≤ 60 seconds

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

**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 °C to 60 °C

**Operating Humidity:** 0 to 95%RH non-condensing

**Storage Temperature:** -40 °C to 85 °C

**MTBF:** ≥ 5 years

**Average consumption:** 80 mA

**Note:** The CO<sub>2</sub> Sensor and the Methane (CH<sub>4</sub>) 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

#### Performance Characteristics

**Nominal Range:** 0 to 30 Vol.%

**Maximum Overload:** 90 Vol.%

**Long Term Output Drift:** < 2% signal/3 months

**Response Time (T90):**  $\leq$  30 seconds

**Sensitivity:**  $1.66 \pm 0.238 \text{ nA/ppm}$

**Accuracy:** as good as  $\pm 0.1\%$  (ideal conditions)



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

#### Operation Conditions

**Temperature Range:** -20 °C to 50 °C

**Operating Humidity:** 5 to 90%RH non-condensing

**Pressure Range:** 90 to 110 kPa

**Storage Temperature:** 0 °C to 20 °C

**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



### Performance Characteristics

**Nominal Range:** 0 to 5 ppm

**Maximum Overload:** 10 ppm

**Long Term sensitivity Drift:** -20 to -35 % change/year

**Response Time (T90):**  $\leq$  15 seconds

**Sensitivity:** -200 to -400 nA/ppm

**Accuracy:** as good as  $\pm 0.005$  ppm\* (ideal conditions)

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

### Operation Conditions

**Temperature Range:** -20 °C to 50 °C

**Operating Humidity:** 15 to 90 %RH non-condensing

**Pressure Range:** 80 to 120 kPa

**Storage Temperature:** 0 °C to 20 °C

**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

**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:**  $400 \pm 80$  nA/ppm

**Accuracy:** as good as  $\pm 0.5$  ppm\* (ideal conditions)



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

#### Operation Conditions

**Temperature Range:** -20 °C to 50 °C

**Operating Humidity:** 15 to 90%RH non-condensing

**Pressure Range:** 90 to 110 kPa

**Storage Temperature:** 0 °C to 20 °C

**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 ( $\text{NO}_2$ ) Gas Sensor [Calibrated]

### Specifications

**Gas:**  $\text{NO}_2$

**Sensor:** 4-NO2-20

#### Performance Characteristics

**Nominal Range:** 0 to 20 ppm

**Maximum Overload:** 250 ppm

**Long Term Output Drift:** < 2% signal/month

**Response Time (T90):**  $\leq$  30 seconds

**Sensitivity:**  $600 \pm 150 \text{ nA/ppm}$

**Accuracy:** as good as  $\pm 0.1 \text{ ppm}^*$  (ideal conditions)



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

#### Operation Conditions

**Temperature Range:** -20 °C to 50 °C

**Operating Humidity:** 15 to 90%RH non-condensing

**Pressure Range:** 90 to 110 kPa

**Storage Temperature:** 0 °C to 20 °C

**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 ( $\text{SO}_2$ ) Gas Sensor [Calibrated]

### Specifications

**Gas:**  $\text{SO}_2$

**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:**  $500 \pm 150 \text{ nA/ppm}$

**Accuracy:** as good as  $\pm 0.1 \text{ ppm}^*$  (ideal conditions)



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

#### Operation Conditions

**Temperature Range:** -20 °C to 50 °C

**Operating Humidity:** 15 to 90%RH non-condensing

**Pressure Range:** 90 to 110 kPa

**Storage Temperature:** 0 °C to 20 °C

**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 ( $\text{NH}_3$ ) Gas Sensor [Calibrated]

### Specifications

**Gas:**  $\text{NH}_3$

**Sensor:** 4-NH3-100



### Performance Characteristics

**Nominal Range:** 0 to 100 ppm

**Long Term Output Drift:** < 2% signal/month

**Response Time (T90):** ≤ 90 seconds

**Sensitivity:**  $135 \pm 35 \text{ nA/ppm}$

**Accuracy:** as good as  $\pm 0.5 \text{ ppm}^*$  (ideal conditions)

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

### Operation Conditions

**Temperature Range:** -20 °C to 50 °C

**Operating Humidity:** 15 to 90%RH non-condensing

**Pressure Range:** 90 to 110 kPa

**Storage Temperature:** 0 °C to 20 °C

**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 ( $\text{CH}_4$ ) and Combustible Gas Sensor [Calibrated]

### Specifications

**Main gas:** Methane  $\text{CH}_4$

**Sensor:** CH-A3



#### Performance Characteristics

**Nominal Range:** 0 to 100% LEL methane

**Long Term Output Drift:** < 2% signal/month

**Response Time (T90):** ≤ 30 seconds

**Accuracy:** as good as ±0.15% LEL\* (ideal conditions)

Figure: Image of the Methane ( $\text{CH}_4$ ) and Combustible Gas Sensor (pellistor) mounted on its AFE module

#### Operation Conditions

**Temperature Range:** -40 °C to 55 °C

**Expected Operating Life:** 2 years in air

#### Inhibition/Poisoning

Gas	Conditions	Effect
Chlorine	12hrs 20ppm $\text{Cl}_2$ , 50 % sensitivity loss, 2 day recovery	< 10% loss
Hydrogen Sulfide	12hrs 40ppm $\text{H}_2\text{S}$ , 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 ( $\text{CH}_4$ ) and Combustible Gas Sensor and the  $\text{CO}_2$  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):**  $\leq$  70 seconds

**Sensitivity:**  $20 \pm 10$  nA/ppm

**Accuracy:** as good as  $\pm 10$  ppm\* (ideal conditions)



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

#### Operation Conditions

**Temperature Range:** -20 °C to 50 °C

**Operating Humidity:** 15 to 90%RH non-condensing

**Pressure Range:** 90 to 110 kPa

**Storage Temperature:** 0 °C to 20 °C

**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<sub>2</sub>S) Gas Sensor [Calibrated]

### Specifications

**Gas:** H<sub>2</sub>S

**Sensor:** 4-H2S-100



#### 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)



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

#### Operation Conditions

**Temperature Range:** -20 °C to 50 °C

**Operating Humidity:** 15 to 90%RH non-condensing

**Pressure Range:** 90 to 110 kPa

**Storage Temperature:** 0 °C to 20 °C

**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

**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:**  $300 \pm 100 \text{ nA/ppm}$

**Accuracy:** as good as  $\pm 1 \text{ ppm}^*$  (ideal conditions)



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

#### Operation Conditions

**Temperature Range:** -20 °C to 50 °C

**Operating Humidity:** 15 to 90%RH non-condensing

**Pressure Range:** 90 to 110 kPa

**Storage Temperature:** 0 °C to 20 °C

**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

#### 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:**  $100 \pm 20 \text{ nA/ppm}$

**Accuracy:** as good as  $\pm 0.2 \text{ ppm}^*$  (ideal conditions)



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

#### Operation Conditions

**Temperature Range:** -20 °C to 50 °C

**Operating Humidity:** 15 to 90%RH non-condensing

**Pressure Range:** 90 to 110 kPa

**Storage Temperature:** 0 °C to 20 °C

**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<sub>3</sub>) Gas Sensor [Calibrated]

### Specifications

**Gas:** PH<sub>3</sub>

**Sensor:** 4-PH3-20

#### Performance Characteristics

**Nominal Range:** 0 to 20 ppm

**Maximum Overload:** 100 ppm

**Long Term Output Drift:** < 2% signal/month

**Response Time (T90):** ≤ 60 seconds

**Sensitivity:** 1400 ± 600 nA/ppm

**Accuracy:** as good as ±0.1 ppm\* (ideal conditions)



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

#### Operation Conditions

**Temperature Range:** -20 °C to 50 °C

**Operating Humidity:** 15 to 90%RH non-condensing

**Pressure Range:** 90 to 110 kPa

**Storage Temperature:** 0 °C to 20 °C

**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

**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:**  $250 \pm 125 \text{ nA/ppm}$

**Accuracy:** as good as  $\pm 1 \text{ ppm}^*$  (ideal conditions)



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

#### Operation Conditions

**Temperature Range:** -20 °C to 50 °C

**Operating Humidity:** 15 to 90%RH non-condensing

**Pressure Range:** 90 to 110 kPa

**Storage Temperature:** 0 °C to 20 °C

**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<sub>2</sub>) Gas Sensor [Calibrated]

### Specifications

**Gas:** Cl<sub>2</sub>

**Sensor:** 4-Cl2-50

#### Performance Characteristics

**Nominal Range:** 0 to 50 ppm

**Maximum Overload:** 100 ppm

**Long Term Output Drift:** < 2% signal/month

**Response Time (T90):** ≤ 30 seconds

**Sensitivity:** 450 ± 200 nA/ppm

**Accuracy:** as good as ±0.1 ppm\* (ideal conditions)



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

#### Operation Conditions

**Temperature Range:** -20 °C to 50 °C

**Operating Humidity:** 15 to 90%RH non-condensing

**Pressure Range:** 90 to 110 kPa

**Storage Temperature:** 0 °C to 20 °C

**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 °C to 50 °C

**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  $\mu\text{m}$
- Pollen: 10-100  $\mu\text{m}$
- Germs: 0.5-10  $\mu\text{m}$
- Oil smoke: 1-10  $\mu\text{m}$
- Cement dust: 5-100  $\mu\text{m}$
- Tobacco smoke: 0.01-1  $\mu\text{m}$

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

- PM1: Mass (in  $\mu\text{g}$ ) of all particles smaller than 1  $\mu\text{m}$ , in 1  $\text{m}^3$ .
- PM2.5: Mass (in  $\mu\text{g}$ ) of all particles smaller than 2.5  $\mu\text{m}$ , in 1  $\text{m}^3$ .
- PM10: Mass (in  $\mu\text{g}$ ) of all particles smaller than 10  $\mu\text{m}$ , in 1  $\text{m}^3$ .

Many countries and health organizations have studied the effect of the particle matter in humans, and they have set maximum thresholds. As a reference, the maximum allowed concentrations are about 20  $\mu\text{m}/\text{m}^3$  for PM2.5 and about 50  $\mu\text{m}/\text{m}^3$  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  $\mu\text{m}$ . 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 excessive dirt outside. Fixing accessories and one connection cord are also provided. All the system is called the Particle Matter – Dust Sensor Probe.



Figure: Input and output accessories in the enclosure

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



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



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

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



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

## 6. Smart Security

### 6.1. General description

The main applications for this WaspMote Plug & Sense! configuration are perimeter access control, liquid presence detection and doors and windows openings.



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

### Sensor specifications (SHT75)

**Power supply:** 2.4 ~ 5.5V

**Minimum consumption (sleep):** 2 $\mu$ W

**Consumption (measurement):** 3mW

**Average consumption:** 90 $\mu$ W

**Communication:** Digital (two wire interface)

**Storage temperature:** 10 ~ 50°C (0 ~ 80°C maximum)

**Storage humidity:** 20 ~ 60%RH



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

### Temperature:

**Measurement range:** -40°C ~ +123.8°C

**Resolution:** 0.04°C (minimum), 0.01°C (typical)

**Accuracy:**  $\pm 0.4^\circ\text{C}$  (range 0°C ~ +70°C),  $\pm 4^\circ\text{C}$  (range -40 ~ +125°C)

**Repeatability:**  $\pm 0.1^\circ\text{C}$

**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:**  $\pm 1.8\%$ RH

**Repeatability:**  $\pm 0.1\%$ RH

**Response time:** 8 seconds

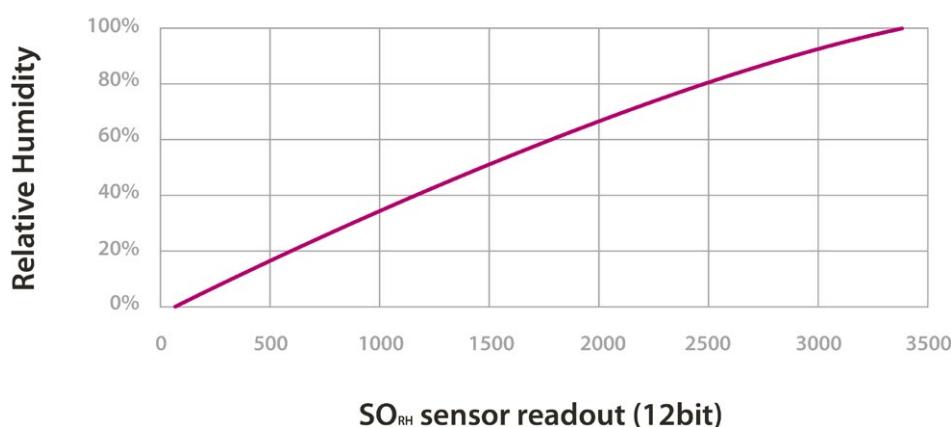


Figure: Graph of the sensor output with respect to relative humidity, taken from the Sensirion sensor's data sheet

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 (°C) 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:** 0°C ~ 80°C

**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:** 0°C ~ 80°C

**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:** 0°C ~ 80°C

**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

### Sensor specifications (PIR)

**Height:** 22mm

**Diameter:** 20.2mm

**Consumption:** 170µA

**Range of detection:** 12m

**Circuit Stability Time:** 30seconds



Figure: Image of the Presence sensor probe (PIR)

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



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

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

## 6.5. Luminosity sensor probe

### Sensor specifications (LDR)

**Resistance in darkness:**  $20\text{M}\Omega$

**Resistance in light (10lux):**  $5 \sim 20\text{k}\Omega$

**Spectral range:**  $400 \sim 700\text{nm}$

**Operating temperature:**  $-30^\circ\text{C} \sim +75^\circ\text{C}$



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)

### Sensor specifications

#### PTFA3415

**Measurement Level:** Horizontal

**Liquids:** Water

**Material (box):** Propylene

**Material (float):** Propylene

**Operating Temperature:**  $-10^\circ\text{C} \sim +80^\circ\text{C}$



Figure: Image of the PTFA3415 sensor

### PTFA0100

**Measurement Level:** Horizontal

**Liquids:** Heavy oils and combustibles

**Material (box):** Polyamide

**Material (float):** Polyamide

**Operating temperature:** -10°C ~ +80°C



Figure: Image of the PTFA0100 sensor

### PTFA1103

**Measurement Level:** Vertical

**Liquids:** Water

**Material (box):** Propylene

**Material (float):** Propylene

**Operating temperature:** -10°C ~ +80°C



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:** +5°C ~ +80°C

**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 (PLA41201)

**Length:** 32mm

**Width:** 15mm

**Thickness:** 7mm

**Maximum contact resistance (closed):** 150mΩ

**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 (P6250000) it can be used in applications of monitoring proximity or opening mechanisms.

## 6.9. Liquid Presence sensor probe (Line)

### Sensor specifications

**Length:** 5 meters sensor + 2 meters jumper wire

**Material:** PE + alloy lead

**Weight:** 18g/meter

**Pull force limit:** 60kg

**Cable diameter:** 5,5mm

**Core resistance:** 3ohm/100meters

**Maximum exposed temperature:** 75°C

**Detectable liquids:** Water



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

This sensor detects conductive liquids anywhere along its length. After it is installed, once the cable senses the leakage of liquids, it will trigger an alarm. The sensor cable can detect 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 ( $\text{Ca}^{2+}$ ), Fluoride (F), Fluoroborate ( $\text{BF}_4^-$ ), Nitrate ( $\text{NO}_3^-$ ), Bromide (Br<sup>-</sup>), Chloride (Cl<sup>-</sup>), Cupric ( $\text{Cu}^{2+}$ ), Iodide (I<sup>-</sup>), Lead ( $\text{Pb}^{2+}$ ), Silver (Ag<sup>+</sup>) 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.

<b>Sensor Socket</b>	<b>Sensor probes allowed for each sensor socket</b>	
	<b>Parameter</b>	<b>Reference</b>
A	pH	9328
	Oxidation-Reduction Potential (ORP)	9329
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 ~ 100°C

**Accuracy:** DIN EN 60751

**Resistance (0°C):** 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 ~ 50°C 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 (°C).

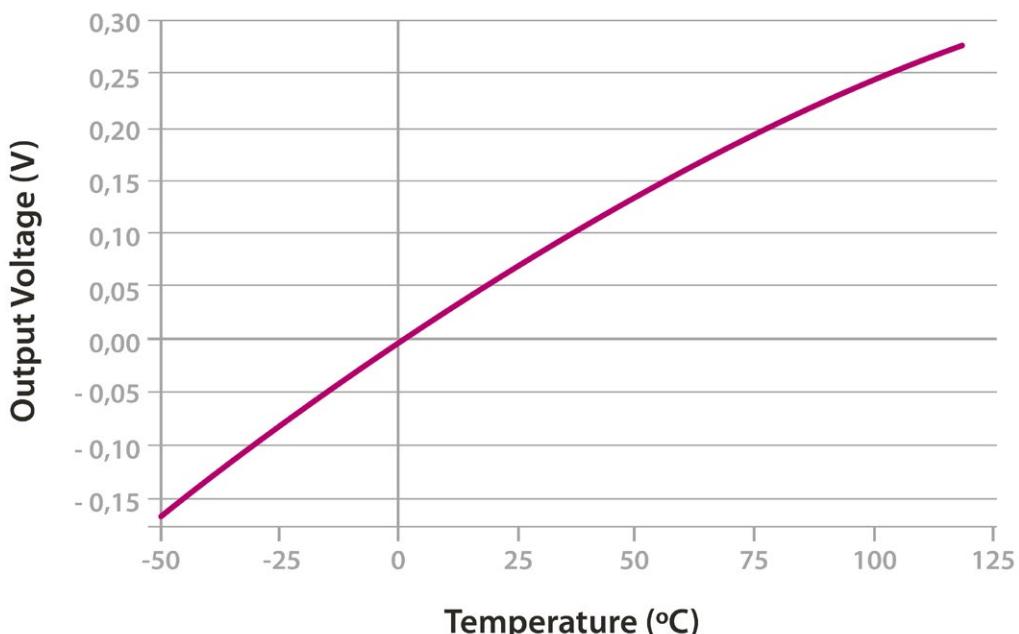


Figure: Output voltage of the PT1000 sensor with respect to temperature

## 7.3. Conductivity sensor probe

### Sensor specifications

**Sensor type:** Two electrodes sensor

**Electrode material:** Platinum

**Conductivity cell constant:**  $1 \pm 0.2 \text{ cm}^{-1}$



*Figure: Image of the Conductivity sensor probe*

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

To power the conductivity sensor an alternating current circuit has been installed in order to avoid the polarization of the platinum electrodes. 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  $50\mu\text{S}/\text{cm}$ , 1kHz between  $50\mu\text{S}/\text{cm}$  and  $5\text{mS}/\text{cm}$ , 10kHz between  $5\text{mS}/\text{cm}$  and  $500\text{mS}/\text{cm}$  and 100kHz for conductivities higher than  $500\text{mS}/\text{cm}$ .

## 7.4. Dissolved Oxygen sensor probe

### Sensor specifications

**Sensor type:** Galvanic cell

**Range:**  $0\text{~}20\text{mg/L}$

**Accuracy:**  $\pm 2\%$

**Maximum operation temperature:**  $50^\circ\text{C}$

**Saturation output:**  $33\text{mV} \pm 9\text{mV}$

**Pressure:**  $0\text{~}100\text{psig}$  (7.5Bar)

**Calibration:** Single point in air

**Response Time:** After equilibration, 2 minutes for  $2\text{mV}$



*Figure: Image of the Dissolved Oxygen sensor probe*

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

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

## 7.5. pH sensor probe

### Sensor specifications

**Sensor type:** Combination electrode

**Measurement range:** 0~14pH

**Temperature of operation:** 0~80°C

**Zero electric potential:**  $7 \pm 0.25\text{p}$

**Response time:** <1min

**Internal resistance:**  $\leq 250\text{M}\Omega$

**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  $\pm 0.25\text{pH}$ . To get an accurate value from these sensors it is necessary both to carry out a calibration and to compensate the output of the sensor for the temperature variation from that of the calibration moment.

## 7.6. Oxidation-reduction potential sensor probe

### Sensor specifications

**Sensor type:** Combination electrode

**Electric Potential:** 245~270mV

**Reference impedance:**  $10\text{k}\Omega$

**Stability:**  $\pm 8\text{mV}/24\text{h}$



Figure: Image of the Oxidation-reduction potential sensor probe

Like the pH sensor, the ORP probe is a combination electrode whose output voltage is equivalent to the potential of the solution, so it will share the connection sockets with that sensor. The output of the circuitry to which it is connected is directly read from the analog-to-digital converter of the Smart Water sensor board, being the 2.048V 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

### Specifications

**Sensor type:** IR optical sensor with optical fibre

**Measurement range:** 0-4000 NTU

**Accuracy:** 5% (around 1 NTU in the lower scale)

**Robust and waterproof:** IP68

**Digital output:** Modbus RS-485

**Power consumption :** 820 µA

**Power supply:** 5 V

**Stocking temperature:** -10 to +60 °C

**Material:** PVC, Quartz, PMMA, Nickel-plated brass



Figure: Turbidity sensor

This sensor is available for Wasp mote "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.

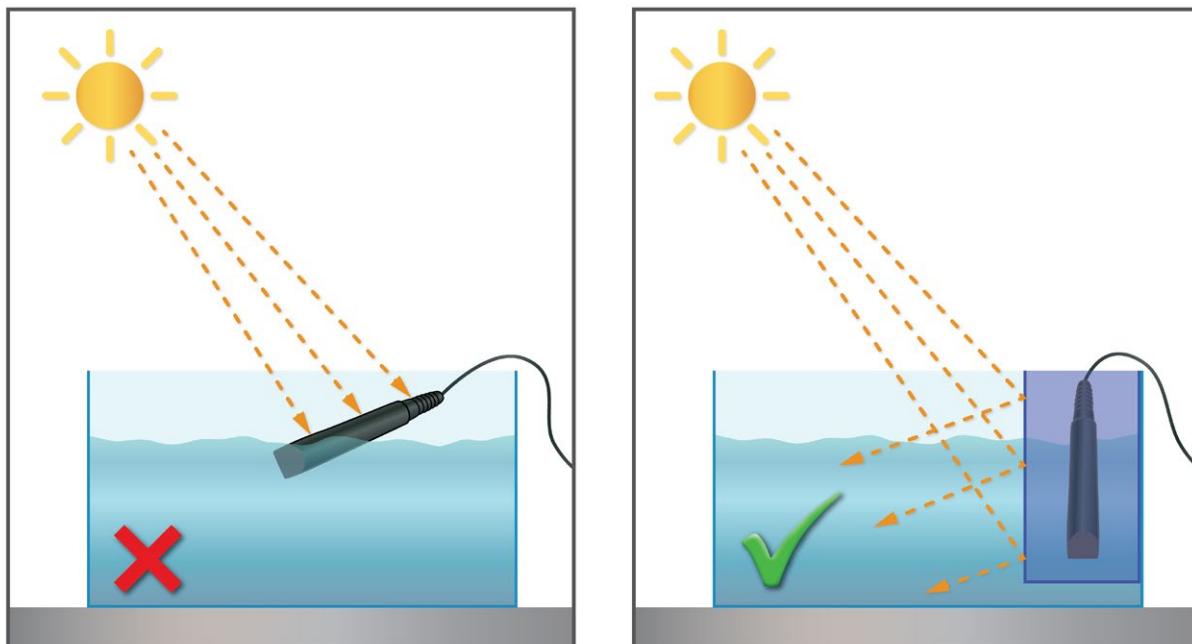


Figure: Turbidity sensor image wrongly and correctly placed

### 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 beaker 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/waspmite/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 ( $\text{Ca}^{2+}$ )	9352
	Fluoride Ion ( $\text{F}^-$ )	9353
	Fluoroborate Ion ( $\text{BF}_4^-$ )	9354
	Nitrate Ion ( $\text{NO}_3^-$ )	9355
	pH (for Smart Water Ions)	9363
B	Calcium Ion ( $\text{Ca}^{2+}$ )	9352
	Fluoride Ion ( $\text{F}^-$ )	9353
	Fluoroborate Ion ( $\text{BF}_4^-$ )	9354
	Nitrate Ion ( $\text{NO}_3^-$ )	9355
	pH (for Smart Water Ions)	9363
C	Calcium Ion ( $\text{Ca}^{2+}$ )	9352
	Fluoride Ion ( $\text{F}^-$ )	9353
	Fluoroborate Ion ( $\text{BF}_4^-$ )	9354
	Nitrate Ion ( $\text{NO}_3^-$ )	9355
	pH (for Smart Water Ions)	9363
D	Calcium Ion ( $\text{Ca}^{2+}$ )	9352
	Fluoride Ion ( $\text{F}^-$ )	9353
	Fluoroborate Ion ( $\text{BF}_4^-$ )	9354
	Nitrate Ion ( $\text{NO}_3^-$ )	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 <sup>-</sup> )	9356
	Chloride Ion (Cl <sup>-</sup> )	9357
	Cupric Ion (Cu <sup>2+</sup> )	9358
	Iodide Ion (I <sup>-</sup> )	9360
	Lead Ion (Pb <sup>2+</sup> )	9361
	Silver Ion (Ag <sup>+</sup> )	9362
	pH (for Smart Water Ions)	9363
B	Bromide Ion (Br <sup>-</sup> )	9356
	Chloride Ion (Cl <sup>-</sup> )	9357
	Cupric Ion (Cu <sup>2+</sup> )	9358
	Iodide Ion (I <sup>-</sup> )	9360
	Lead Ion (Pb <sup>2+</sup> )	9361
	Silver Ion (Ag <sup>+</sup> )	9362
	pH (for Smart Water Ions)	9363
C	Bromide Ion (Br <sup>-</sup> )	9356
	Chloride Ion (Cl <sup>-</sup> )	9357
	Cupric Ion (Cu <sup>2+</sup> )	9358
	Iodide Ion (I <sup>-</sup> )	9360
	Lead Ion (Pb <sup>2+</sup> )	9361
	Silver Ion (Ag <sup>+</sup> )	9362
	pH (for Smart Water Ions)	9363
D	Bromide Ion (Br <sup>-</sup> )	9356
	Chloride Ion (Cl <sup>-</sup> )	9357
	Cupric Ion (Cu <sup>2+</sup> )	9358
	Iodide Ion (I <sup>-</sup> )	9360
	Lead Ion (Pb <sup>2+</sup> )	9361
	Silver Ions (Ag <sup>+</sup> )	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 °C
- **Accuracy:** DIN EN 60751
- **Resistance (0 °C):** 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 ~ 50°C 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 (°C).

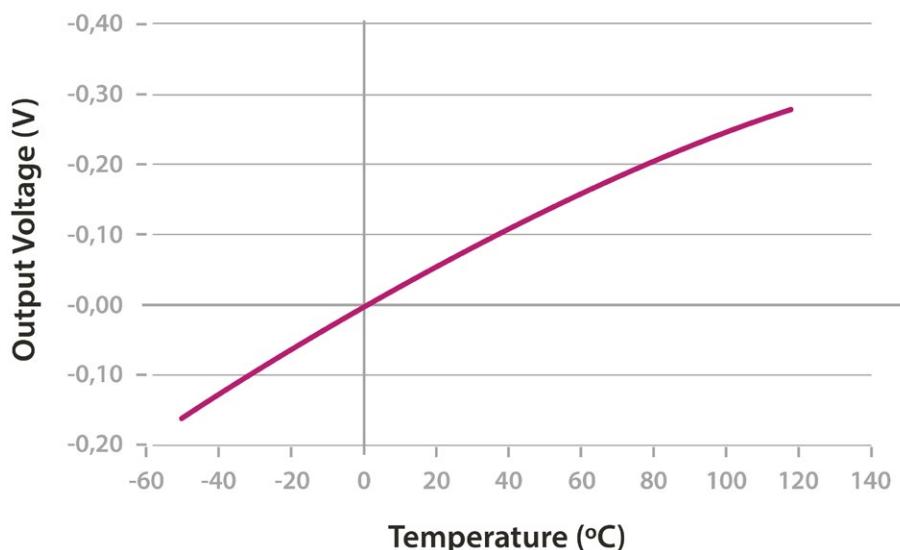


Figure: Output voltage of the PT1000 sensor with respect to temperature

## 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 ( $\text{Ca}^{2+}$ ) Sensor Probe
- Fluoride Ion ( $\text{F}^-$ ) Sensor Probe
- Fluoroborate Ion ( $\text{BF}_4^-$ ) Sensor Probe
- Nitrate Ion ( $\text{NO}_3^-$ ) Sensor Probe

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

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



Figure: Reference 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 (°C)	Dimensions (mm)	Required Reference
Bromide (Br <sup>-</sup> )	Solid State Half-cell	10 <sup>-1</sup> -10 <sup>-6</sup>	2-11	5-60	Ø10x155	Double Junction
Chloride (Cl <sup>-</sup> )	Solid State Half-cell	10 <sup>-1</sup> -5x10 <sup>-5</sup>	2-12	5-60	Ø10x155	Double Junction
Cupric (Cu <sup>2+</sup> )	Solid State Half-cell	10 <sup>-1</sup> -10 <sup>-6</sup>	2-12	5-60	Ø10x155	Double Junction
Iodide (I <sup>-</sup> )	Solid State Half-cell	10 <sup>-1</sup> -5x10 <sup>-7</sup>	2-12	5-60	Ø10x155	Double Junction
Lead (Pb <sup>2+</sup> )	Solid State Half-cell	10 <sup>-1</sup> -10 <sup>-6</sup>	4-7	5-60	Ø10x155	Double Junction
Silver (Ag <sup>+</sup> )*	Solid State Half-cell	10 <sup>-1</sup> -3x10 <sup>-7</sup>	2-8 (Ag <sup>+</sup> )	5-60	Ø10x155	Double Junction
Calcium (Ca <sup>2+</sup> )	Plastic Membrane Half-cell	10 <sup>-1</sup> -10 <sup>-5</sup>	2.5-11	5-60	Ø10x155	Single Junction
Fluoride (F <sup>-</sup> )	Plastic Membrane Half-cell	10 <sup>-1</sup> -10 <sup>-6</sup>	5-7	5-60	Ø10x155	Single Junction
Fluoroborate (BF <sub>4</sub> <sup>-</sup> )	Plastic Membrane Half-cell	10 <sup>-1</sup> -3x10 <sup>-6</sup>	2.5-11	5-60	Ø10x155	Single Junction
Nitrate (NO <sub>3</sub> <sup>-</sup> )	Plastic Membrane Half-cell	10 <sup>-1</sup> -10 <sup>-5</sup>	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 (°C):** 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 Metering

### 9.1. General description

The main applications for this WaspMote Plug & Sense! model are energy measurement, water consumption, pipe leakage detection, liquid storage management, tanks and silos level control, supplies control in manufacturing, industrial automation, agricultural irrigation, etc. Go to the application section in the [Libelium website](#) for a complete list of services.



Figure: Smart Metering WaspMote Plug & Sense! model

Sensor sockets are configured as shown in the figure below.

<b>Sensor Socket</b>	<b>Sensor probes allowed for each sensor socket</b>	
	<b>Parameter</b>	<b>Reference</b>
A	Temperature	9203
	Soil temperature	86949*
B	Humidity	9204
C	Ultrasound (distance measurement)	9246
	Liquid flow	9296, 9297, 9298
D	Current sensor	9266
E	Ultrasound (distance measurement)	9246
	Liquid flow	9296, 9298
F	Luminosity	9205

\* Ask Libelium [Sales Department](#) for more information.

Figure: Sensor sockets configuration for Smart Metering 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:** [-40°C, +125°C]

**Output voltage (0°C):** 500mV

**Sensitivity:** 10mV/°C

**Accuracy:** ±2°C (range 0°C ~ +70°C), ±4°C (range -40 ~ +125°C)

**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)

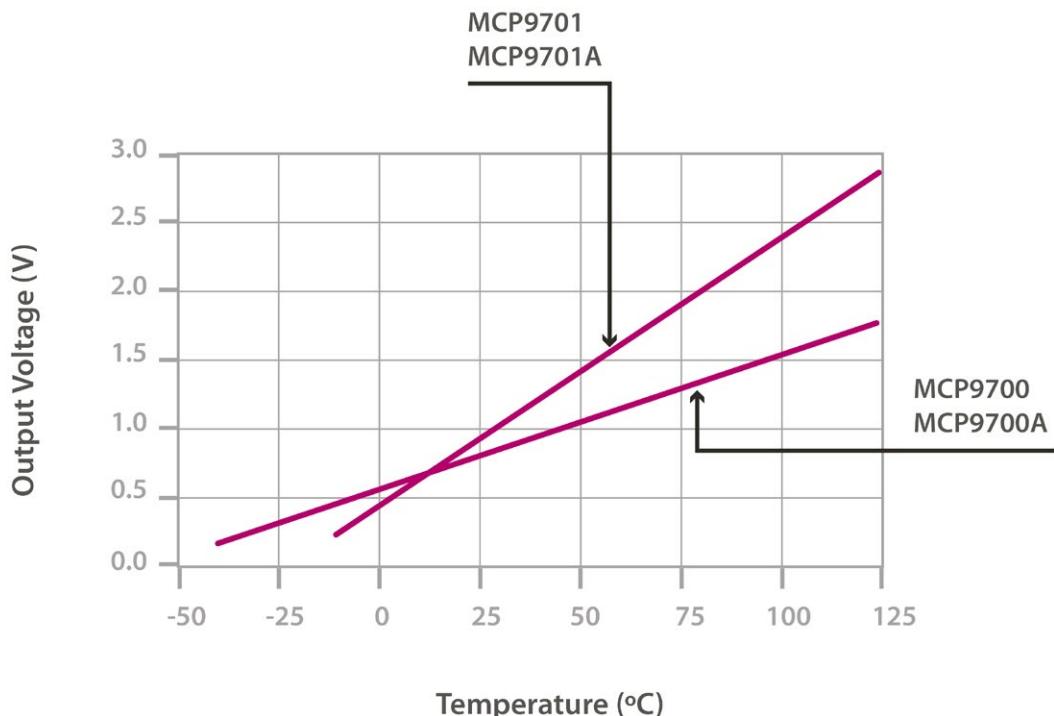


Figure: Graph of the MCP9700A sensor output voltage with respect to temperature, taken from the Microchip sensor's data sheet

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:** [-55°C,+125°C]

**Output voltage (0°C):** 500mV

**Resolution:** 12bits (0.0625°C)

**Accuracy:** ±0.5°C (range -10°C ~ +85°C)

**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 0.065°C) 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. Humidity sensor probe

### Sensor specifications (808H5V5)

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



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

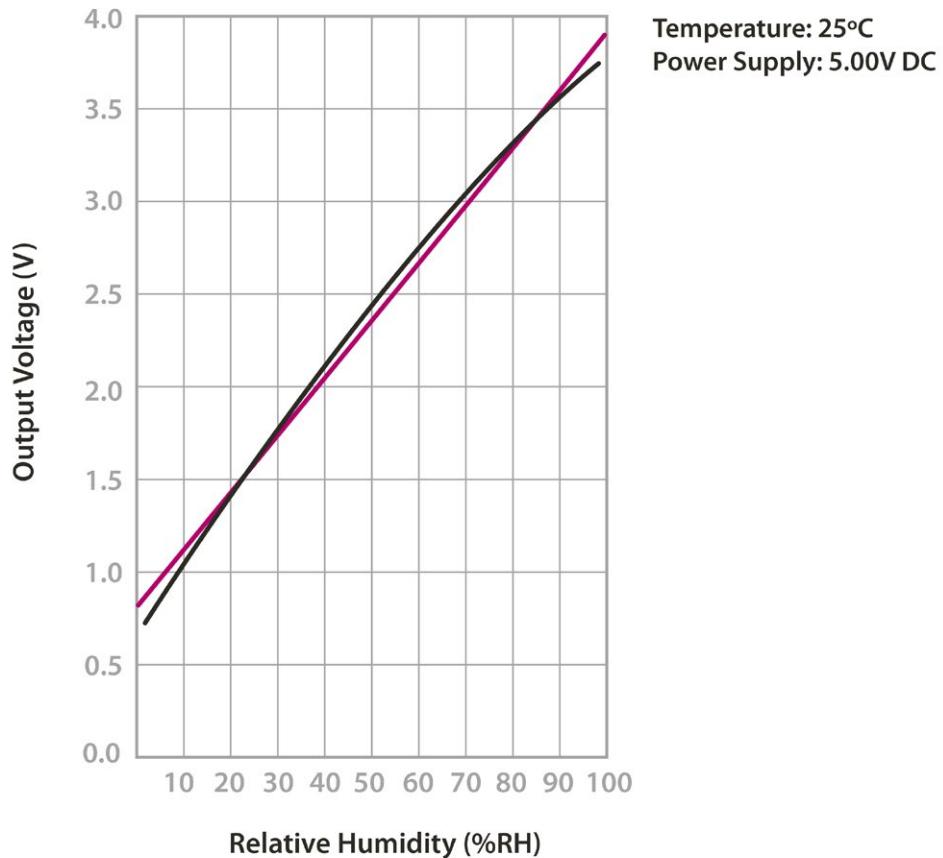


Figure: 808H5V5 humidity sensor output taken from the Sencera Co. Ltd sensor data sheet

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.

## 9.5. 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:** 0°C ~ 80°C

**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:** 0°C ~ 80°C

**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:** 0°C ~ 80°C

**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.

## 9.6. Current sensor probe

### Sensor specifications

**Maximum primary current:** 100A  
**Turns ratio:** 1:2000 approximately  
**Minimum resolution:** 130mA approximately  
**Measurement range:** 500mA ~ 40A



Figure: Image of the Current sensor probe

The current clamp is a low cost sensor that outputs a current proportional to the current in the primary circuit. That current (related with the primary current through a 1:2000 ratio) is converted into voltage through a load resistor obtaining a signal readable by the mote's analog-to-digital converter.

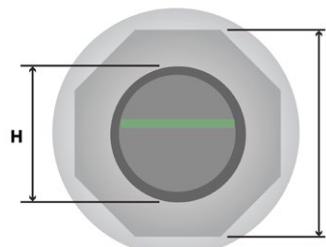
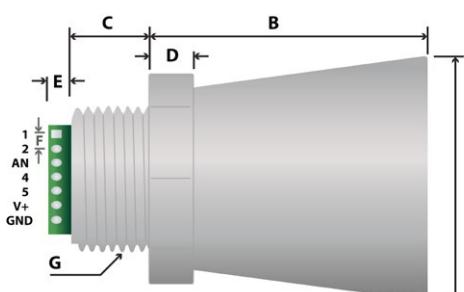
## 9.7. Ultrasound sensor probe

### 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):

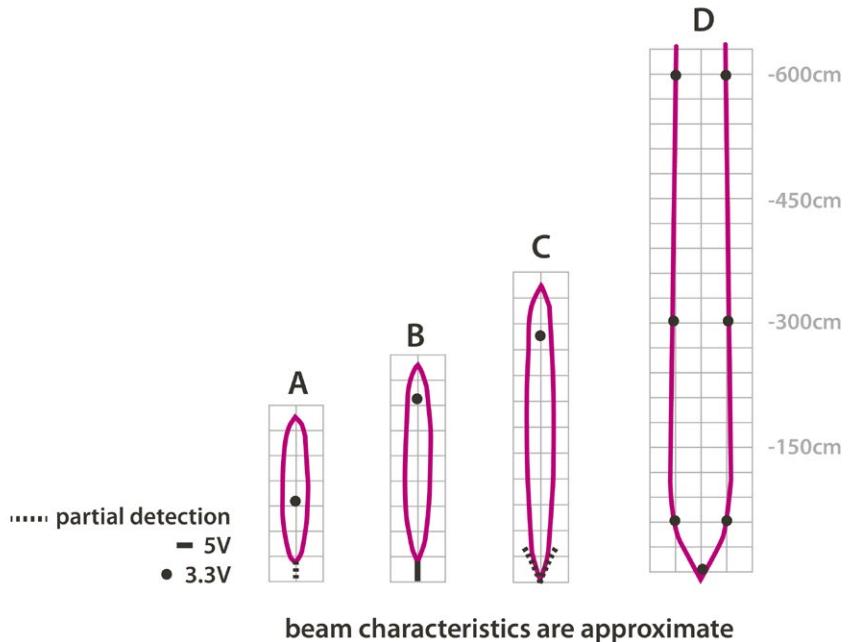


Figure: Diagram of the sensor beam extracted from the data sheet of the XL-MaxSonar®-WRA1™ sensor from MaxBotix



Figure: Image of configurations of the ultrasound sensor probe

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

## 9.8. Luminosity sensor probe

### Sensor specifications (LDR)

**Resistance in darkness:**  $20\text{M}\Omega$

**Resistance in light (10lux):**  $5 \sim 20\text{k}\Omega$

**Spectral range:**  $400 \sim 700\text{nm}$

**Operating temperature:**  $-30^\circ\text{C} \sim +75^\circ\text{C}$



Figure: Image of the Luminosity sensor probe (LDR)

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

## 10. Smart Cities

### 10.1. 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.

<b>Sensor Socket</b>	<b>Sensor probes allowed for each sensor socket</b>	
	<b>Parameter</b>	<b>Reference</b>
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](#).

## 10.2. Temperature sensor probe

### Sensor specifications (MCP9700A)

**Measurement range:** [-40°C ,+125°C]

**Output voltage:** (0°C): 500mV

**Sensitivity:** 10mV/°C

**Accuracy:**  $\pm 2^\circ\text{C}$  (range 0°C ~ +70°C),  $\pm 4^\circ\text{C}$  (range -40 ~ +125°C)

**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)

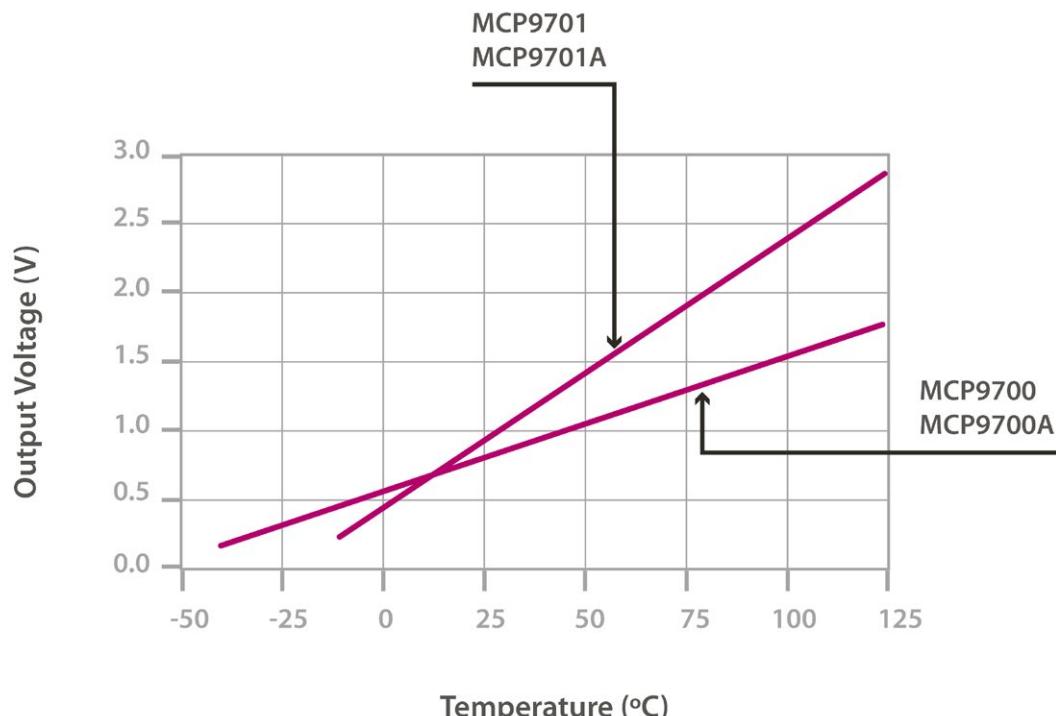


Figure: Graph of the MCP9700A sensor output voltage with respect to temperature, taken from the Microchip sensor's data sheet

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.

## 10.3. Soil Temperature sensor (DS18B20) probe

### Sensor specifications (DS18B20)

**Measurement range:** [-55°C ,+125°C]  
**Output voltage (0°C):** 500mV  
**Resolution:** 12bits (0.0625°C)  
**Accuracy:** ±0.5°C (range -10°C ~ +85°C)  
**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 0.065°C) 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.

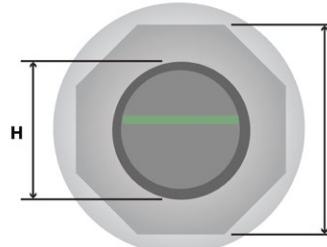
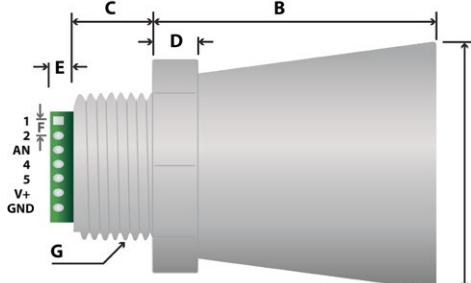
## 10.4. Ultrasound sensor probe

### 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™)



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

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):

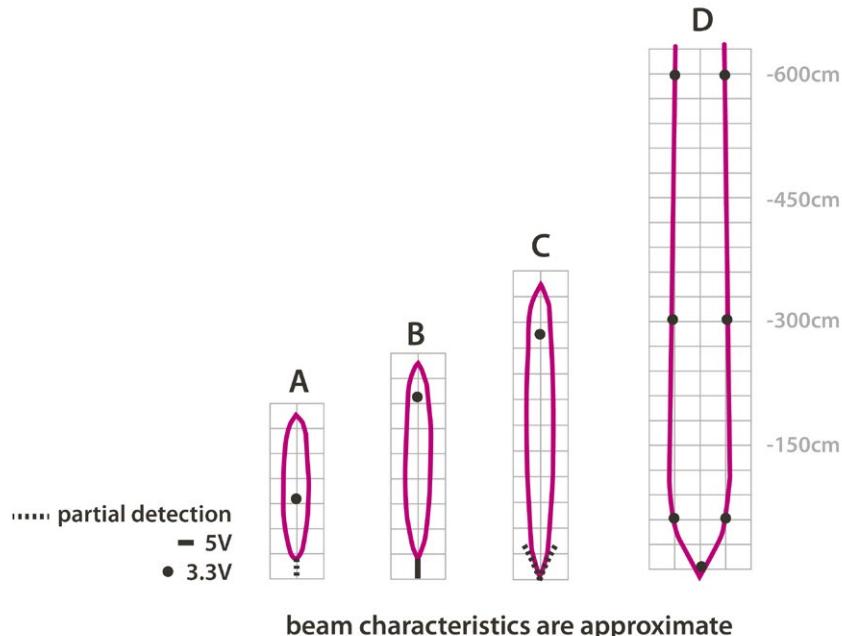


Figure: Diagram of the sensor beam extracted from the data sheet of the XL-MaxSonar®-WRA1™ sensor from MaxBotix



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.

## 10.5. Humidity sensor probe

### Sensor specifications (808H5V5)

**Measurement range:** 0 ~ 100%RH

**Output signal:** 0.8 ~ 3.9V (25°C)

**Accuracy:** <±4%RH (at 25°C, range 30 ~ 80%), <±6%RH (range 0 ~ 100)

**Supply voltage:** 5VDC ±5%

**Operating temperature:** -40 ~ +85°C

**Response time:** <15 seconds

**Typical consumption:** 0.38mA

**Maximum consumption:** 0.5mA



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

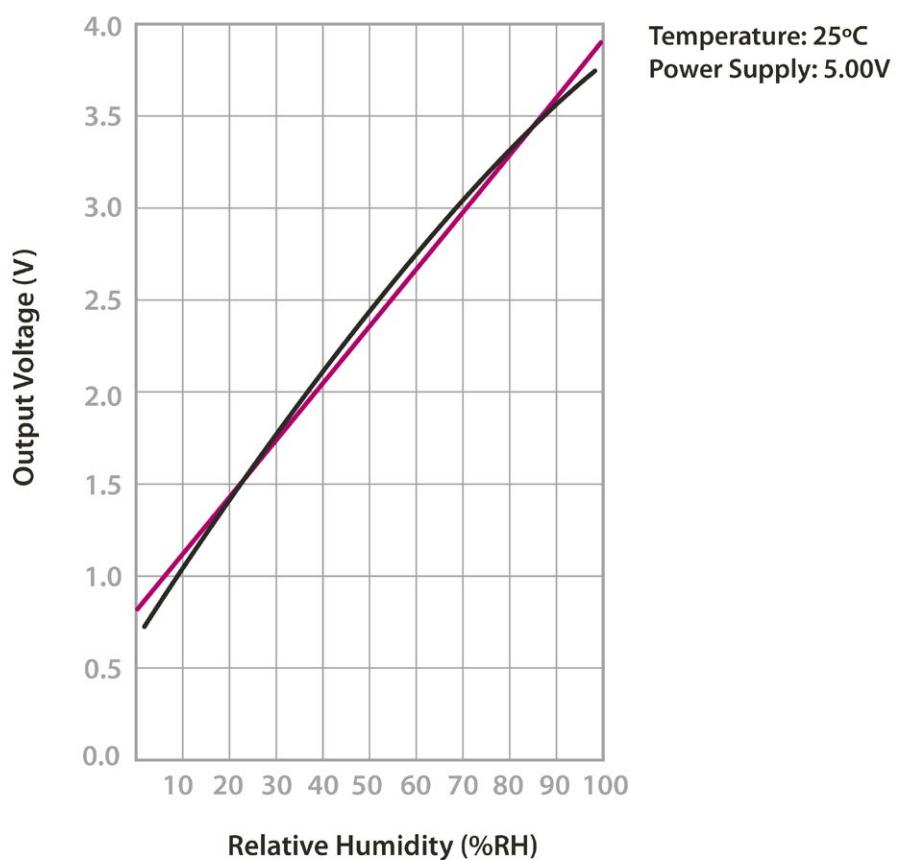


Figure: 808H5V5 humidity sensor output taken from the Sencera Co. Ltd sensor data sheet

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.

## 10.6. Luminosity sensor probe

### Sensor specifications (LDR)

**Resistance in darkness:**  $20\text{M}\Omega$

**Resistance in light (10lux):**  $5 \sim 20\text{k}\Omega$

**Spectral range:**  $400 \sim 700\text{nm}$

**Operating temperature:**  $-30^\circ\text{C} \sim +75^\circ\text{C}$



*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.

## 10.7. Noise sensor probe

### Sensor specifications (POM-2735P-R)

**Sensitivity:**  $-35 \pm 4 \text{ dB}$

**Impedance:**  $<2.2 \text{ k}\Omega$

**Directivity:** Omnidirectional

**Frequency:**  $20 \text{ Hz} \sim 20 \text{ kHz}$

**Supply voltage:**  $+3 \text{ V}$  (Standard),  $+10 \text{ V}$  (Maximum)

**Maximum current consumption:**  $0.5 \text{ mA}$

**Sensitivity reduction:**  $-3 \text{ dB}$  at  $1.5 \text{ V}$

**Maximum sound pressure level:**  $114.5 \pm 10 \text{ dBSPL}$  approximately

**S/N ratio:**  $60 \text{ dB}$

**Noise Level:**  $26 \pm 1 \text{ dBA}$

**Stage Measurement range:**  $50 \text{ dBA} \sim 100 \text{ dBA}$



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  $20 \text{ Hz}$  and  $20 \text{ kHz}$ . 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  $50 \text{ dBA}$  and  $100 \text{ dBA}$  with an accuracy of  $\pm 2.5 \text{ dBA}$ . 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

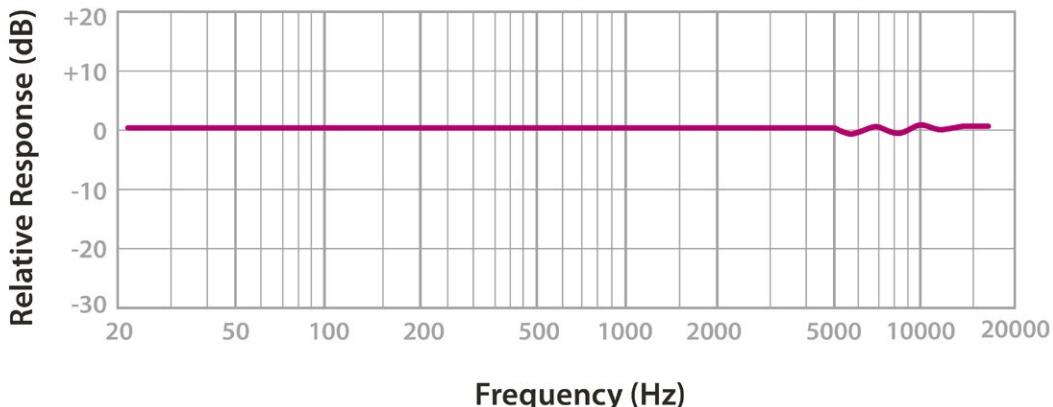


Figure: Graph of the frequency response of the POM-2735P-R extracted from the sensor's data sheet

## 10.8. 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 (20°C):** 0.2W

**Temperature Operation:** -30°C ~ 100°C



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.

## 11. Smart Parking

### 11.1. 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 ~ 125°C

**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.

## 12. Smart Agriculture

### 12.1. 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

### 12.1.1. 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](#).

### 12.1.2. 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	Leaf 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](#).

## 12.2. Temperature and Humidity sensor probe

### Sensor specifications (SHT75)

**Power supply:** 2.4 ~ 5.5V

**Minimum consumption (sleep):** 2 $\mu$ W

**Consumption (measurement):** 3mW

**Average consumption:** 90 $\mu$ W

**Communication:** Digital (two wire interface)

**Storage temperature:** 10 ~ 50°C (0 ~ 80°C maximum)

**Storage humidity:** 20 ~ 60%RH



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

### Temperature:

**Measurement range:** -40°C ~ +123.8°C

**Resolution:** 0.04°C (minimum), 0.01°C (typical)

**Accuracy:**  $\pm 0.4^\circ\text{C}$  (range 0°C ~ +70°C),  $\pm 4^\circ\text{C}$  (range -40 ~ +125°C)

**Repeatability:**  $\pm 0.1^\circ\text{C}$

**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:**  $\pm 1.8\%$ RH

**Repeatability:**  $\pm 0.1\%$ RH

**Response time:** 8 seconds

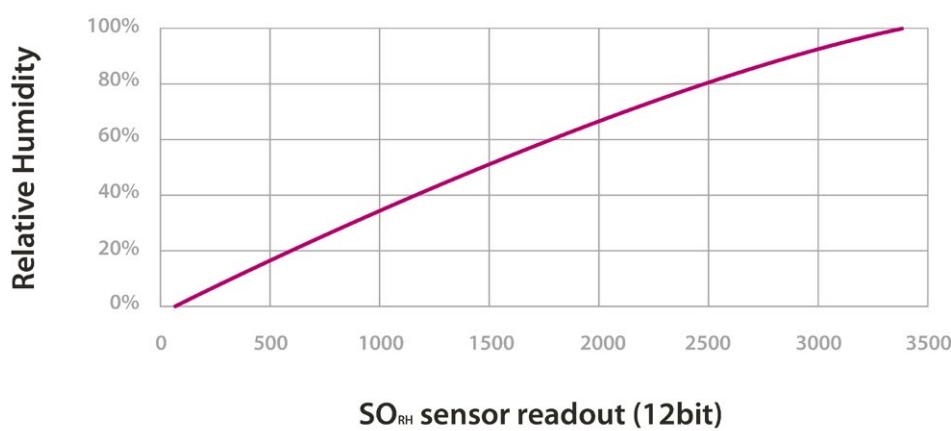


Figure: Graph of the sensor output with respect to relative humidity, taken from the Sensirion sensor's data sheet

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 (°C) and the humidity value in relative humidity percentage (%RH).

## 12.3. Atmospheric Pressure sensor probe

### Sensor specifications (MPX4115A)

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



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

### **Transfer Function:**

$$V_{out} = V_s * (.009 * P - .095) \pm \text{Error}$$

$$V_s = 5.0 \text{ Vdc}$$

TEMP= 0 to 85°C

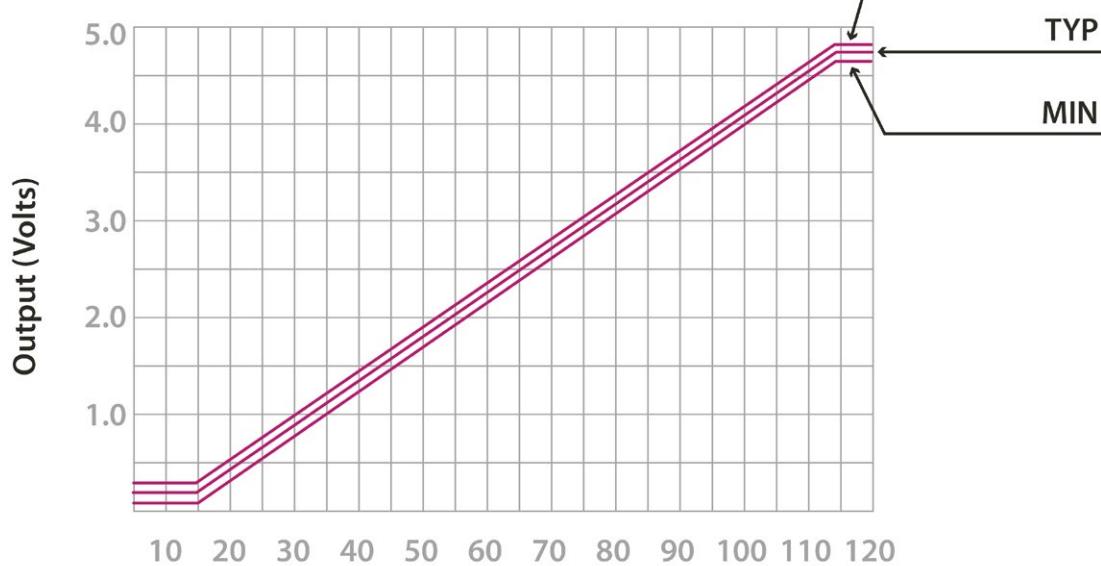


Figure: Graph of the MPX4115A sensor's output voltage with regard to pressure taken from the Freescale sensor's data sheet

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 Wasp mote, its output has been adapted to fit in a range between 0.12V and 2.88V.

## 12.4. Soil Temperature sensor (DS18B20) probe

### Sensor specifications (DS18B20)

**Measurement range:** [-55°C ,+125°C]

**Output voltage (0°C):** 500mV

**Resolution:** 12bits (0.0625°C)

**Accuracy:** ±0.5°C (range -10°C ~ +85°C)

**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 0.065°C) 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.

## 12.5. 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)

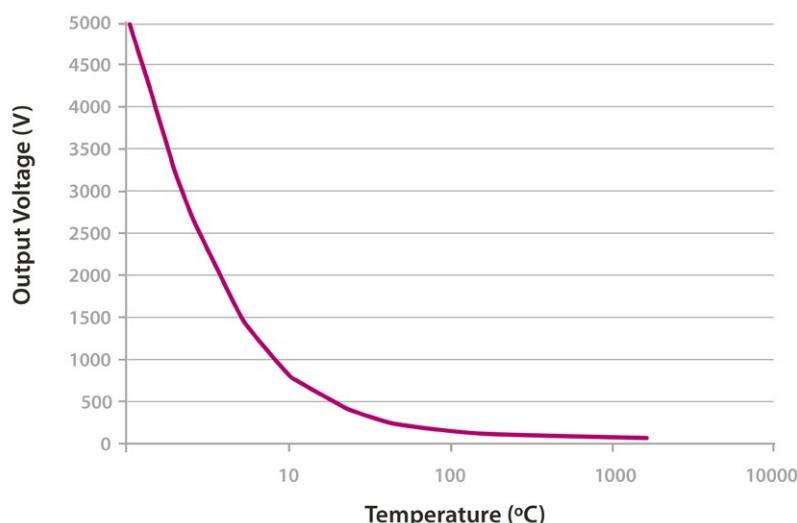


Figure: Output frequency of the Watermark sensor circuit with respect to the resistance of the sensor

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

## 12.6. 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).



Figure: Image of the Weather Station WS-3000 probe

### Sensor specifications (Vane)

**Height:** 8.9 cm

**Length:** 17.8 cm

**Maximum accuracy:** 22.5°

**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 22.5°). 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

Direction (Degrees)	Resistance (kΩ)	Voltage (V)	Identifier
157.5	1.41	0.41	SENS_AGR_VANE_SSE
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.

## 12.7. Leaf Wetness sensor probe

### Sensor specifications (Leaf Wetness)

**Resistance Range:**  $5\text{k}\Omega \sim >2\text{M}\Omega$

**Output Voltage Range:**  $1\text{V} \sim 3.3\text{V}$

**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  $5\text{k}\Omega$  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.

## 12.8. Soil Temperature sensor (PT1000) probe

### Sensor specifications (PT1000)

**Measurement range:**  $-50 \sim 300^\circ\text{C}$

**Accuracy:** DIN EN 60751

**Resistance ( $0^\circ\text{C}$ ):**  $1000\Omega$

**Diameter:** 6mm

**Length:** 40mm

**Cable:** 2m



Figure: Image of the Soil Temperature sensor sensor probe

The resistance of the PT1000 sensor varies between approximately  $920\Omega$  and  $1200\Omega$  in the range considered useful in agriculture applications ( $-20 \sim 50^\circ\text{C}$  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 ( $^\circ\text{C}$ ).

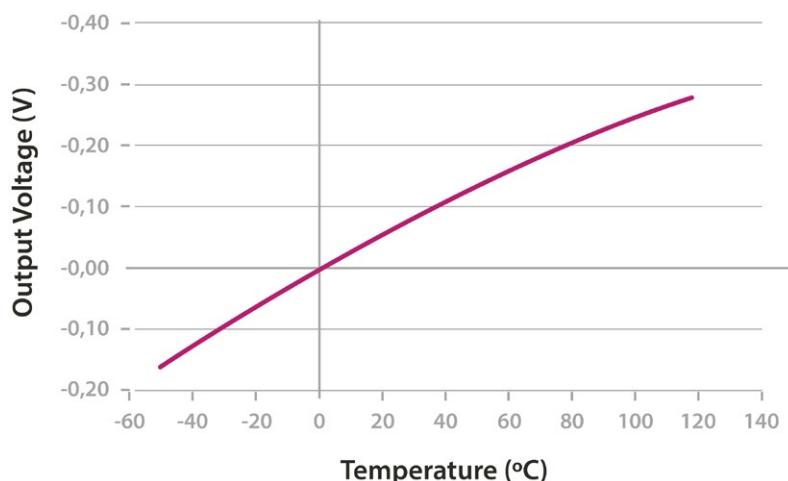


Figure: Output voltage of the PT1000 sensor with respect to temperature

## 12.9. Solar Radiation sensor probe

### Sensor specifications (SQ-110)

**Responsivity:**  $0.200\text{mV} / \mu\text{mol}\cdot\text{m}^{-2}\text{s}^{-1}$

**Maximum radiation output:**  $400\text{mV}$  ( $2000\mu\text{mol}\cdot\text{m}^{-2}\text{s}^{-1}$ )

**Lineal range:**  $1000\text{mV}$  ( $5000\mu\text{mol}\cdot\text{m}^{-2}\text{s}^{-1}$ )

**Sensibility:**  $5.00\mu\text{mol}\cdot\text{m}^{-2}\text{s}^{-1}/\text{mV}$

**Spectral range:**  $400 \sim 700\text{nm}$

**Accuracy:**  $\pm 5\%$

**Repeatability:**  $\pm 1\%$

**Diameter:**  $2.4\text{cm}$

**Height:**  $2.75\text{cm}$

**Cable length:**  $3\text{m}$

**Operation temperature:**  $-40 \sim 55^\circ\text{C}$

**Operation humidity:**  $0 \sim 100\%\text{RH}$



Figure: Image of the Solar Radiation sensor probe

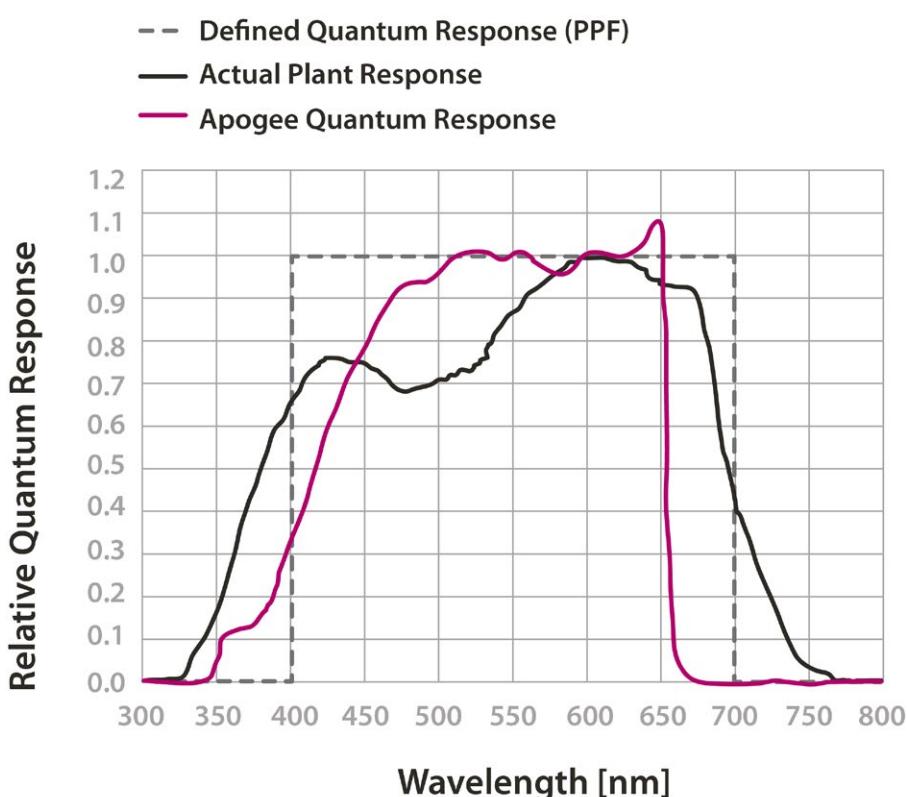


Figure: Graph of the spectral response of the SQ-110 sensor compared to the photosynthetic response of a plant

The SQ-110 sensor, specifically calibrated for the detection of solar radiation, provides at its output a voltage proportional to the intensity of the light in the visible range of the spectrum, a key parameter in photosynthesis processes. It presents a maximum output of  $400\text{mV}$  under maximum radiation conditions and a sensitivity of  $5.00\mu\text{mol}\cdot\text{m}^{-2}\text{s}^{-1}/\text{mV}$ . 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 I<sup>2</sup>C.

### Sensor specifications (SU-100)

**Responsivity:**  $0.15\text{mV} / \mu\text{mol}\cdot\text{m}^{-2}\text{s}^{-1}$

**Maximum radiation output:**  $26\text{mV}$  ( $170\mu\text{mol}\cdot\text{m}^{-2}\text{s}^{-1}$ )

**Lineal range:**  $60\text{mV}$  ( $400\mu\text{mol}\cdot\text{m}^{-2}\text{s}^{-1}$ )

**Sensibility:**  $6.5\mu\text{mol}\cdot\text{m}^{-2}\text{s}^{-1}/\text{mV}$

**Spectral range:**  $250 \sim 400\text{nm}$

**Accuracy:**  $\pm 10\%$

**Repeatability:**  $\pm 1\%$

**Diameter:**  $2.4\text{cm}$

**Height:**  $2.75\text{cm}$

**Cable length:**  $3\text{m}$

**Operation humidity:**  $0 \sim 100\%\text{RH}$

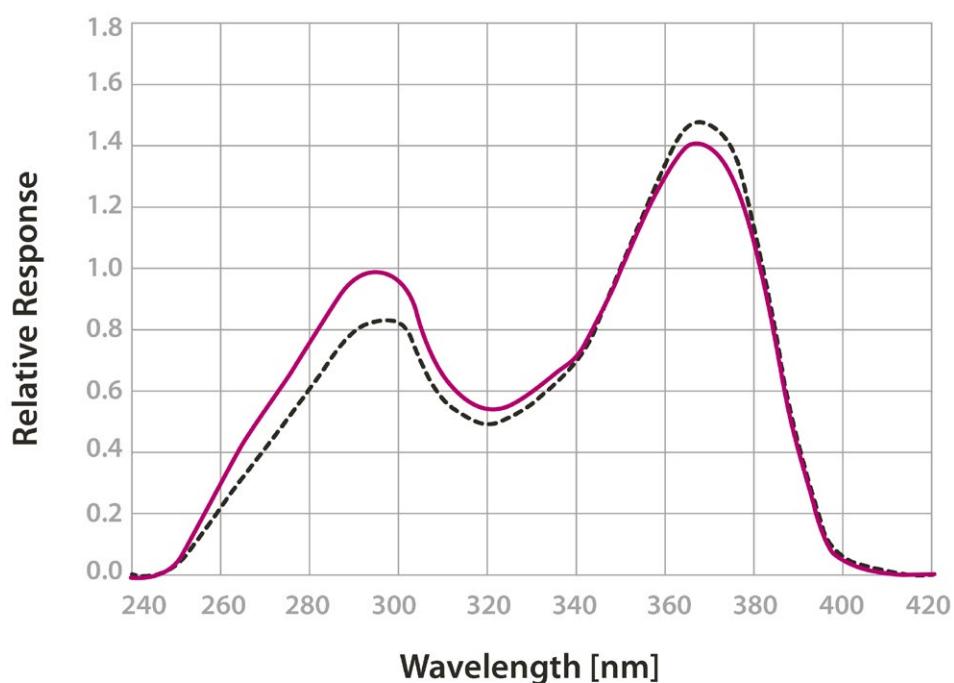


Figure: Graph of the spectral response of the SU-100 sensor compared to the photosynthetic response of a plant

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

## 12.10. Dendrometer sensor probe



Figure: Image of the Dendrometer sensor probe

### Sensor specifications (Trunk diameter)

**Trunk/branch diameter:** From 2 cm

**Accuracy:**  $\pm 2\mu\text{m}$

**Temperature coefficient:**  $<0.1\mu\text{m}/\text{K}$

**Linearity:**  $<2\%$

**Operation temperature:**  $-30 \sim 40^\circ\text{C}$

**Operation humidity:**  $0 \sim 100\%\text{RH}$

**Cable length:** 2m

**Output range:**  $0 \sim 20\text{k}\Omega$

**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:**  $0 \sim 20\text{cm}$

**Range of the sensor:** 11mm

**Output range:**  $0 \sim 20\text{k}\Omega$

**Accuracy:**  $\pm 2\mu\text{m}$

**Temperature coefficient:**  $<0.1\mu\text{m}/\text{K}$

**Operation temperature:**  $-30 \sim 40^\circ\text{C}$

**Operation humidity:**  $0 \sim 100\%\text{RH}$

**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 ~ 40°C

**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.

## 13. Ambient Control

### 13.1. 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 Wasp mote Plug & Sense! model

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

<b>Sensor Socket</b>	<b>Sensor probes allowed for each sensor socket</b>	
	<b>Parameter</b>	<b>Reference</b>
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](#).

## 13.2. Temperature and Humidity sensor probe

### Sensor specifications (SHT75)

**Power supply:** 2.4 ~ 5.5V

**Minimum consumption (sleep):** 2 $\mu$ W

**Consumption (measurement):** 3mW

**Average consumption:** 90 $\mu$ W

**Communication:** Digital (two wire interface)

**Storage temperature:** 10 ~ 50°C (0 ~ 80°C maximum)

**Storage humidity:** 20 ~ 60%RH



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

### Temperature:

**Measurement range:** -40°C ~ +123.8°C

**Resolution:** 0.04°C (minimum), 0.01°C (typical)

**Accuracy:**  $\pm 0.4^\circ\text{C}$  (range 0°C ~ +70°C),  $\pm 4^\circ\text{C}$  (range -40 ~ +125°C)

**Repeatability:**  $\pm 0.1^\circ\text{C}$

**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:**  $\pm 1.8\%$ RH

**Repeatability:**  $\pm 0.1\%$ RH

**Response time:** 8 seconds

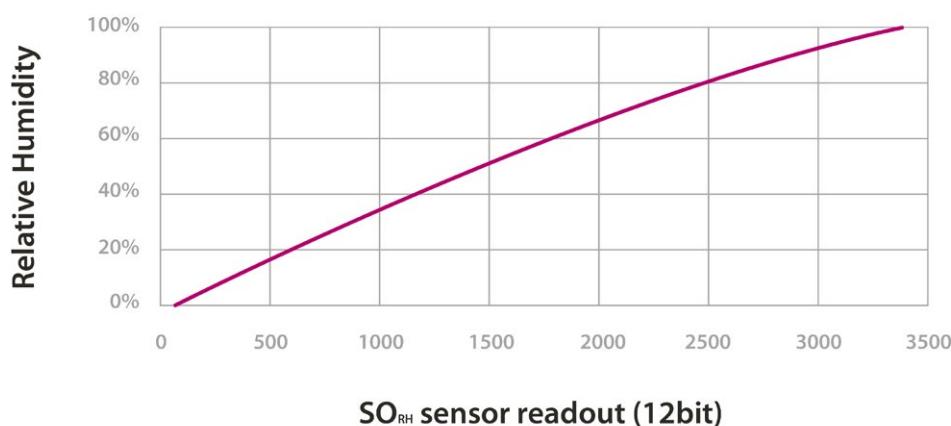


Figure: Graph of the sensor output with respect to relative humidity, taken from the Sensirion sensor's data sheet

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 (°C) and the humidity value in relative humidity percentage (%RH).

## 13.3. Luminosity sensor probe (LDR)

### Sensor specifications (LDR)

**Resistance in darkness:**  $20\text{M}\Omega$

**Resistance in light (10lux):**  $5 \sim 20\text{k}\Omega$

**Spectral range:**  $400 \sim 700\text{nm}$

**Operating temperature:**  $-30^\circ\text{C} \sim +75^\circ\text{C}$



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.

## 13.4. 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:** -30°C to +80°C

**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.

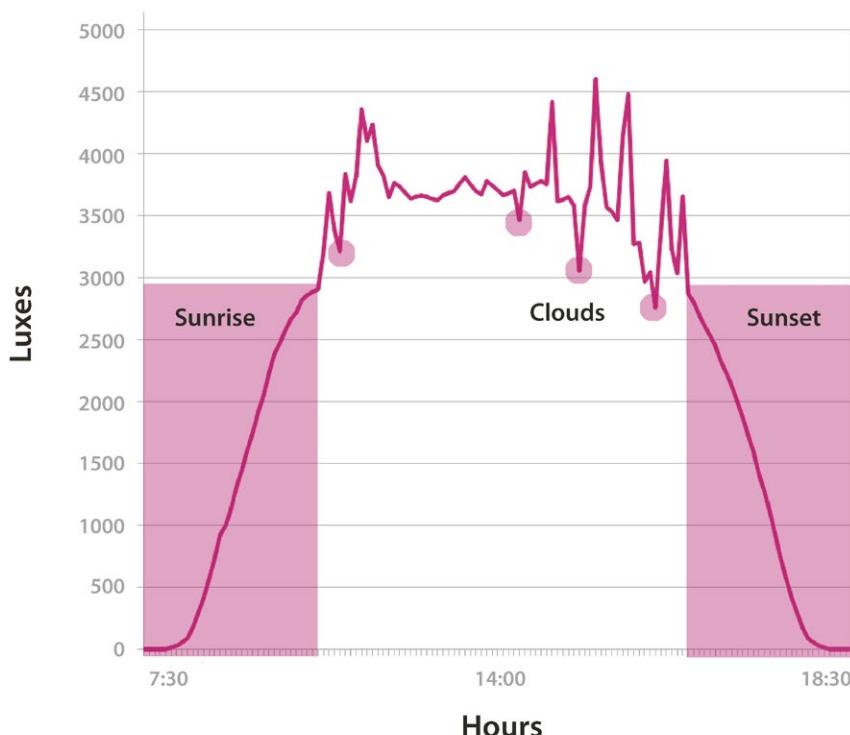


Figure: Image of the Luminosity sensor probe (Luxes accuracy)



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.

## 13.5. 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.

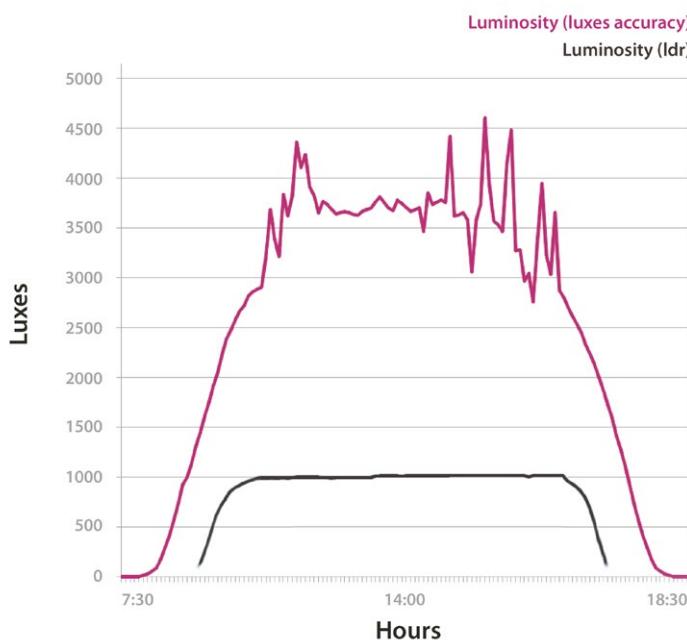


Figure: Comparison of the responses of the Luminosity sensor probe (Luxes accuracy) and the Luminosity sensor probe (LDR)

## 14. Radiation Control

### 14.1. 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 [ $\beta$ ,  $\gamma$ ]

**Length:** 111mm

**Diameter:** 11mm

**Recommended Voltage:** 350V

**Plateau Voltage:** 360-440V

**Sensitivity  $\gamma$  (60Co):** 65cps/( $\mu$ R/s)

**Sensitivity  $\gamma$  (equivalent Sievert):** 108cpm / ( $\mu$ Sv/h)

**Max cpm:** 30000

**cps/mR/h:** 18

**cpm/m/h:** 1080

**cpm/ $\mu$ Sv/h:** 123.147092360319

**Factor:** 0.00812037037037

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

# 15. Documentation Changelog

## 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<sub>2</sub>), Molecular Hydrogen (H<sub>2</sub>) and Hydrogen Sulfide (H<sub>2</sub>S)

## 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<sub>2</sub> sensor, MiCS-2614 O<sub>3</sub> 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.