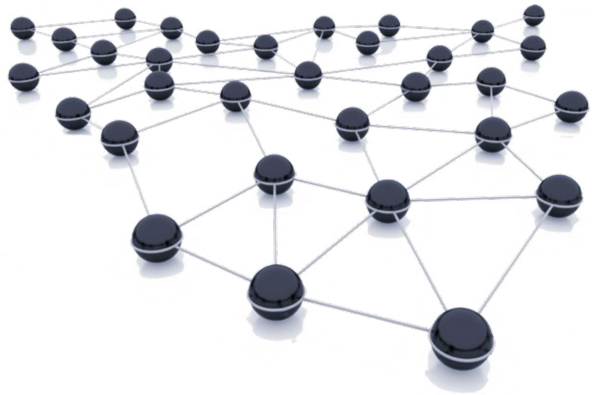
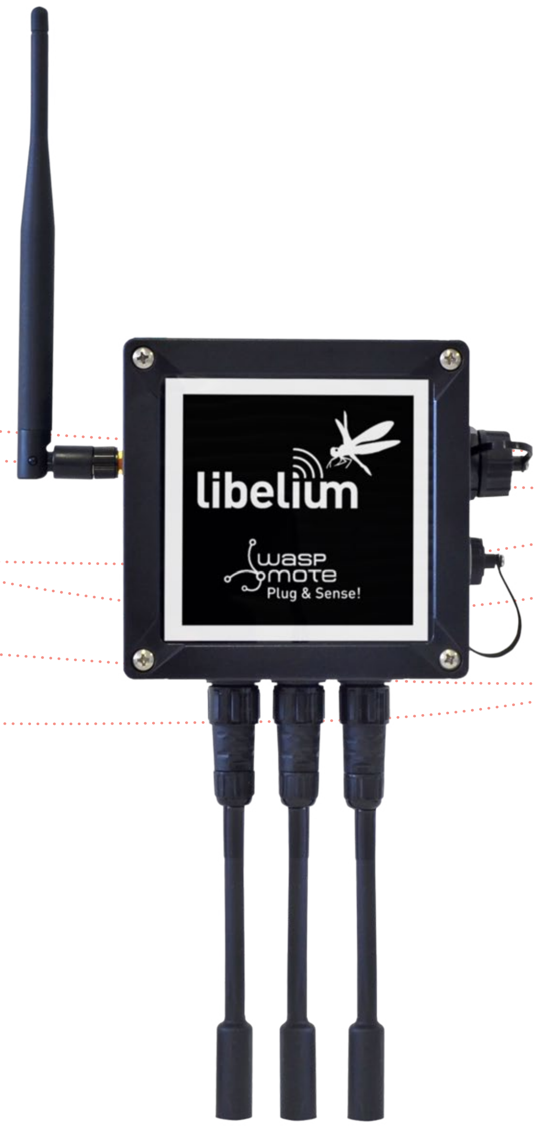
Waspmote Plug & Sense!

Sensor Guide





Document version: v4.1 - 03/2013

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1. General

1.1. General and safety information

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

1.2. Conditions of use

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

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

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

Figure 1: Waspmote Plug & Sense! Line

3. Internal sensors

Figure 2: 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 ±2g/±4g/±8g and it is capable of measuring accelerations with output data rates from 0.5 Hz to 1 kHz.

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

The accelerometer has 7 power modes, the output data rate (ODR) will depend on the power mode selected. The power modes and output data rates are shown in this table:

Power Mode	Output Data Rate (Hz)
Power Down	--
Normal Mode	1000
Low-power 1	0.5
Low-power 2	1
Low-power 3	2
Low-power 4	5
Low-power 5	10

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

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

The accelerometer has 4 types of event which can generate an interrupt: free fall, inertial wake up, 6D movement and 6D position. These thresholds and times are set in the WaspACC.h file.

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

3.2. RTC temperature sensor

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

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

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

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

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 3: 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
A	Carbon monoxide - CO	9229
A	Methane - CH_4	9232
A	Ammonia – NH_3	9233
A	Liquefied Petroleum Gases: H_2, CH_4, ethanol, isobutene.	9234
A	Air pollutants 1: C_4H_{10}, CH_3CH_2OH, H_2, CO, CH_4	9235
A	Air pollutants 2: $C_6H_5CH_3$, H_2S, CH_3CH_2OH, NH_3, H_2	9236
A	Alcohol derivates: CH_3CH_2OH, H_2, C_4H_{10}, CO, CH_4	9237
B	Humidity	9204
B	Atmospheric pressure	9250
C	Carbon dioxide - CO_2	9230
D	Nitrogen dioxide - NO_2	9238
E	Ozone - O_3	9258
E	Hydrocarbons - VOC	9201
E	Oxygen - O_2	9231
F	Carbon monoxide - CO	9229
F	Methane - CH_4	9232
F	Ammonia – NH_3	9233
F	Liquefied Petroleum Gases: H_2, CH_4, ethanol, isobutene.	9234
F	Air pollutants 1: C_4H_{10}, CH_3CH_2OH, H_2, CO, CH_4	9235
F	Air pollutants 2: $C_6H_5CH_3$, H_2S, CH_3CH_2OH, NH_3, H_2	9236
F	Alcohol derivates: CH_3CH_2OH, H_2, C_4H_{10}, CO, CH_4	9237

Figure 4: Sensor sockets configuration for Smart Environment model

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

4.2. Temperature sensor probe

Sensor specifications (MCP9700A)

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

Figure 5: Image of the Temperature sensor probe (MCP9700A)

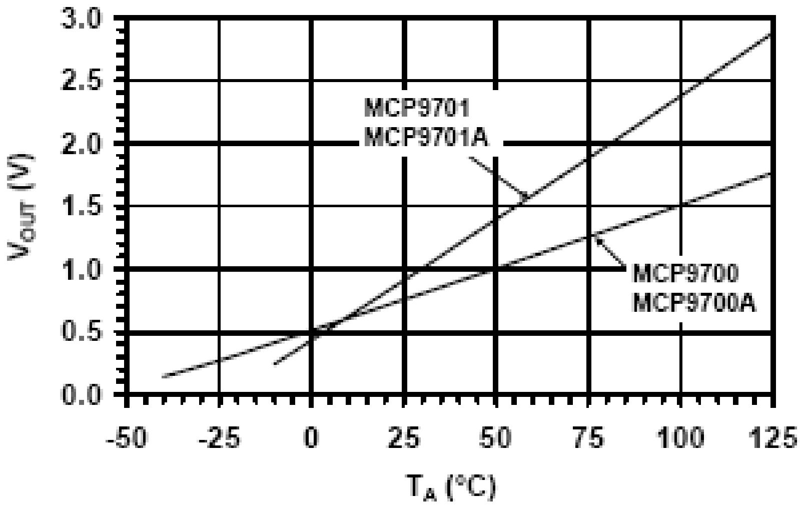


Figure 6: Graph of the MCP9700A sensor output voltage with respect to temperature, taken from the Microchip sensor's data sheet

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

Figure 7: Image of the Humidity sensor probe (808H5V5)

Sensor specifications (808H5V5)

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

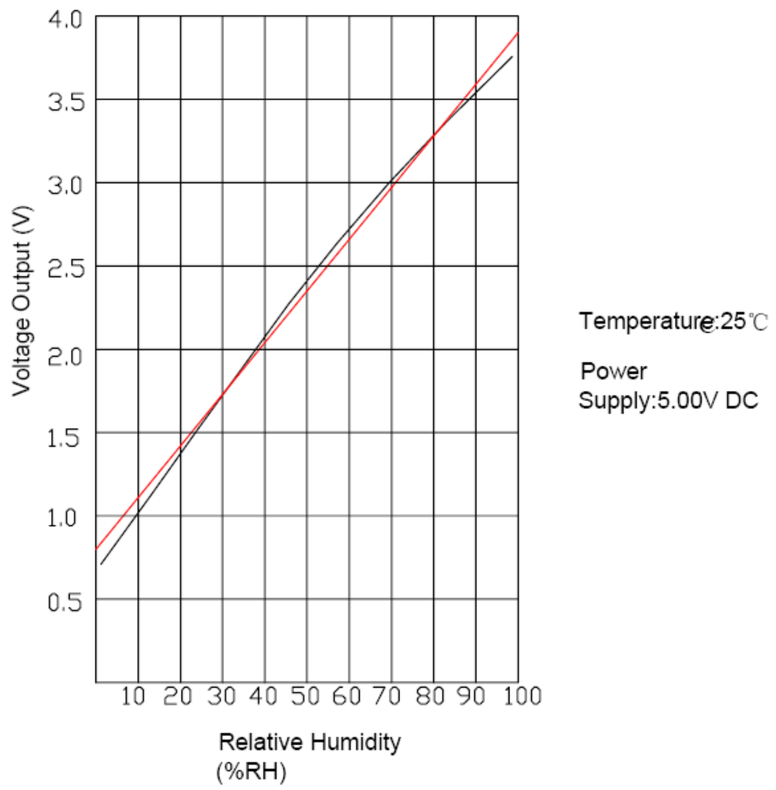


Figure 8: 808H5V5 humidity sensor output taken from the Sencera Co. Ltd sensor data sheet

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

4.4. Atmospheric Pressure sensor probe

Sensor specifications (MPX4115A)

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

Figure 9: Image of the Atmospheric Pressure sensor probe (MPX4115A)

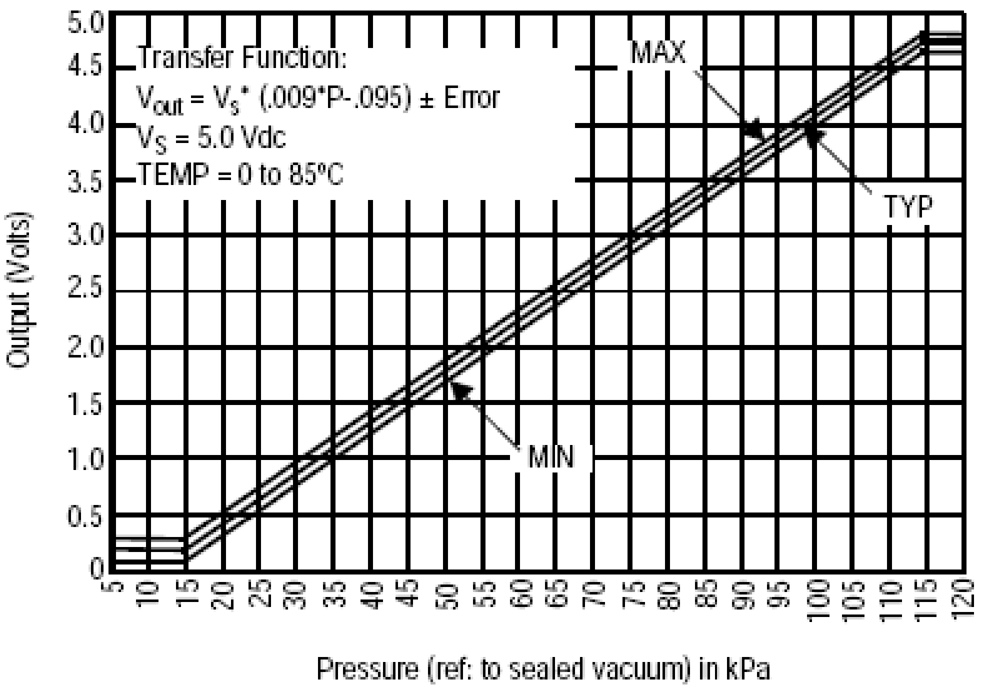


Figure 10: Graph of the MPX4115A sensor's output voltage with regard to pressure taken from the Freescale sensor's data sheet

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

4.5. Carbon Monoxide (CO) sensor probe

Sensor specifications (TGS2442)

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

Figure 11: Image of the CO sensor probe (TGS2442)

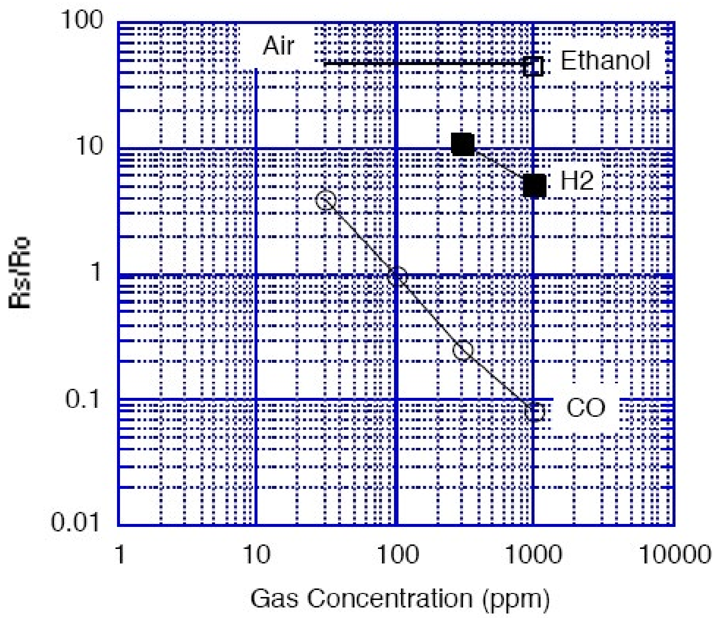


Figure 12: Graph of the sensitivity of the TGS2442 taken from the Figaro sensor's data sheet

The TGS2442 is a resistive sensor sensitive to the changes in concentration of Carbon Monoxide (CO) and, very slightly, Hydrogen (H_2). The sensor's resistance varies according to the graph in figure 12, which may present significant variations between two different sensors, so it is recommended to consult the sensor's documentation to choose the load resistance and amplification gain and calibrate it before finally inserting it into the application.

4.6. Methane (CH_4) sensor probe

Figure 13: Image of the CH_4 sensor probe (TGS2611)

Sensor specifications (TGS2611)

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

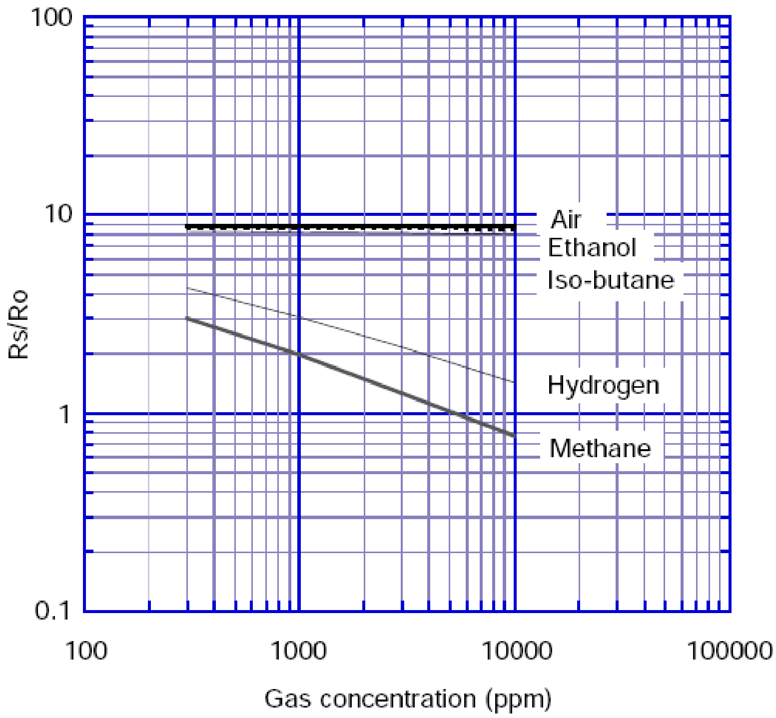


Figure 14: Graph of sensitivity of the TGS2611 taken from the Figaro sensor's data sheet

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

4.7. Ammonia (NH_3) sensor probe

Sensor specifications (TGS2444)

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

Figure 15: Image of the NH_3 sensor probe (TGS2444)

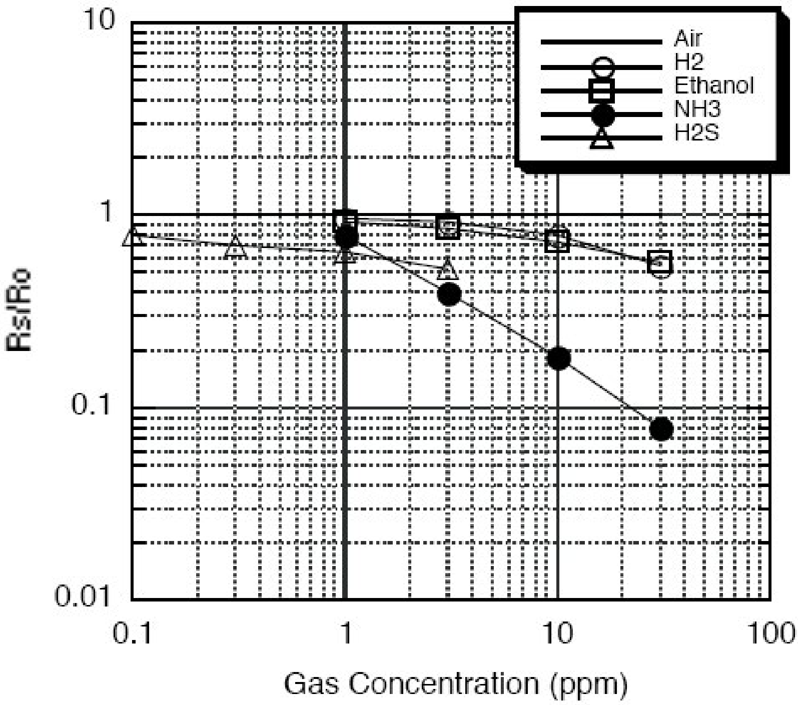


Figure 16: Graph of the sensitivity of the TGS2444 taken from the Figaro sensor data sheet

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

4.8. LPG sensor probe

Sensor specifications (TGS2610)

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

Figure 17: Image of the LPG sensor probe (TGS2610)

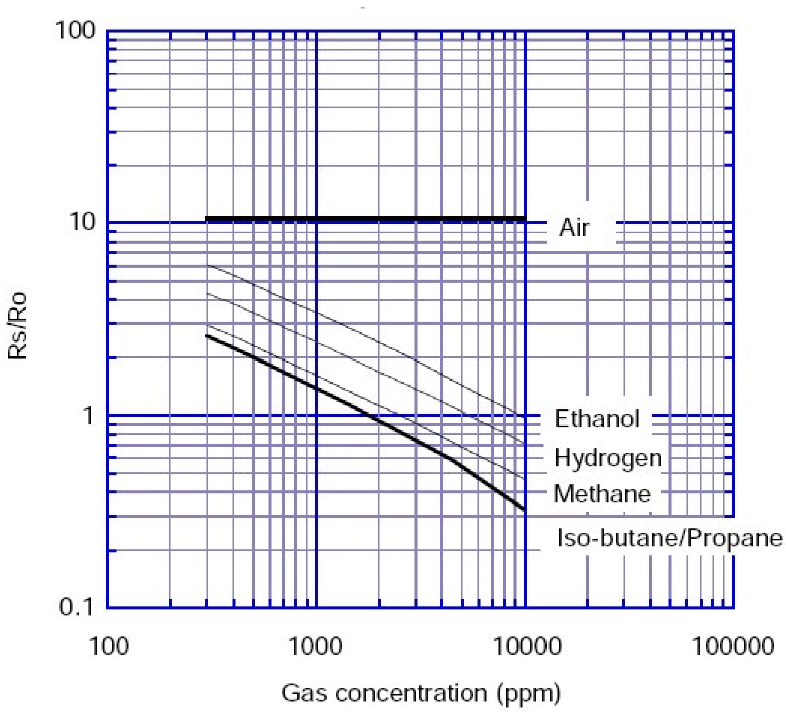


Figure 18: Graph of the sensitivity of the TGS2610 taken from the Figaro sensor's data sheet

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

4.9. Air pollutants 1 sensor probe

Sensor specifications (TGS2600)

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

Figure 19: Image of the Air Pollutants 1 sensor probe (TGS2600)

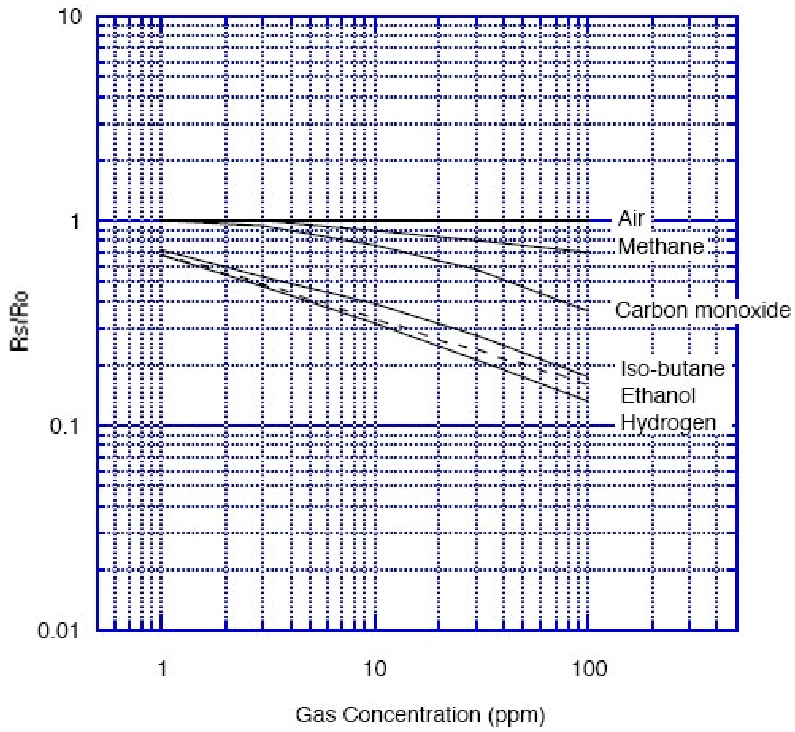


Figure 20: Graph of the sensitivity of the TGS2600 taken from the Figaro sensor's data sheet

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

4.10. Air Pollutants 2 sensor probe

Figure 21: Image of the Air Pollutants 2 sensor probe (TGS2602)

Sensor specifications (TGS2602)

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

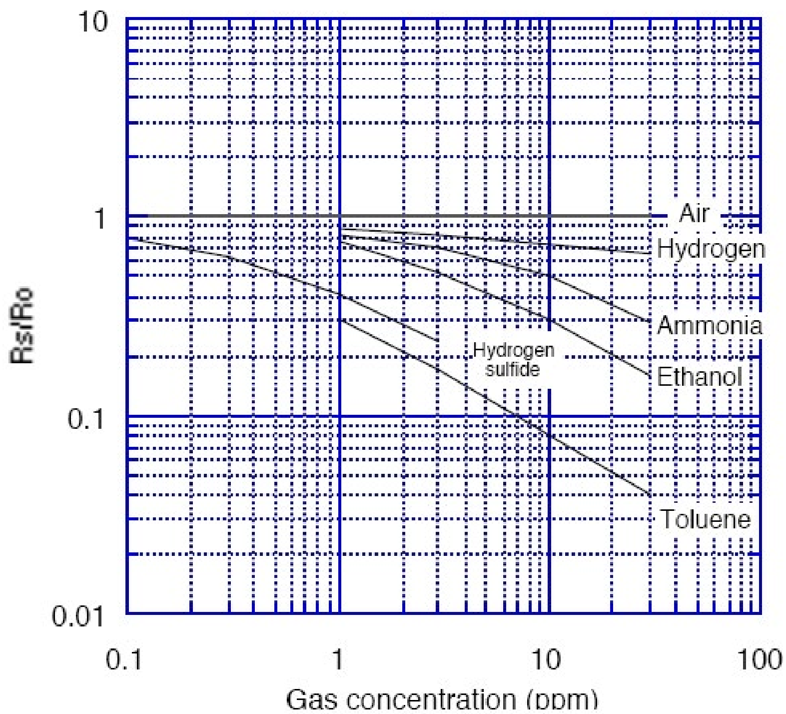


Figure 22: Graph of the sensitivity of the TGS2602 taken from the Figaro sensor's data sheet

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

4.11. Solvent Vapors sensor probe

Sensor specifications (TGS2620)

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

Figure 23: Image of the Solvent Vapors sensor probe (TGS2620)

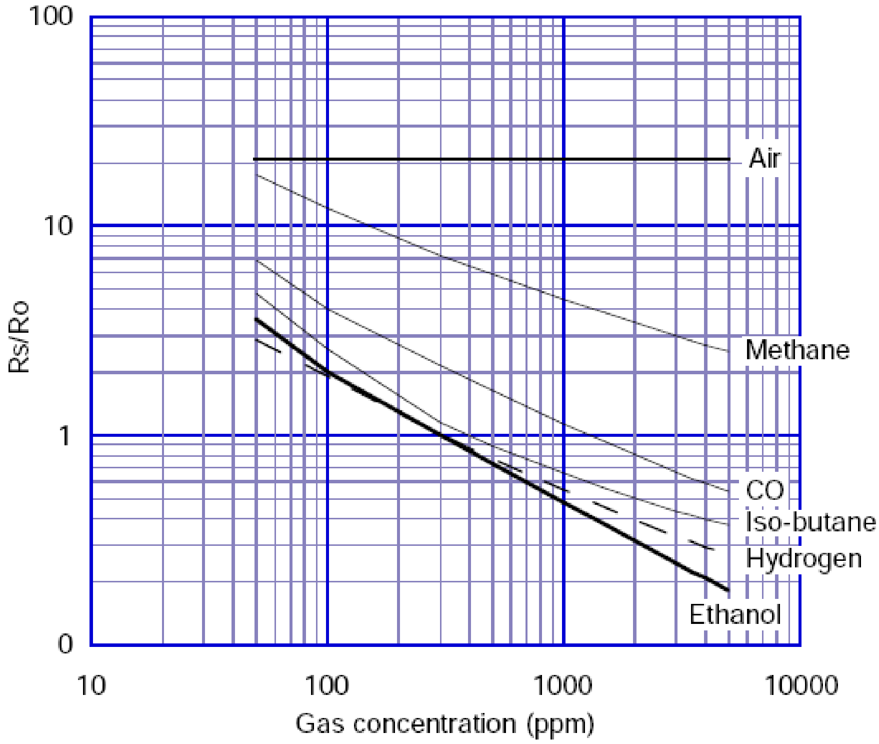


Figure 24: Graph of the sensitivity of the TGS2620 taken from the Figaro sensor's data sheet

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

4.12. Carbon Dioxide (CO_2) sensor probe

Figure 25: Image of the CO_2 sensor probe (TGS4161)

Sensor specifications (TGS4161)

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

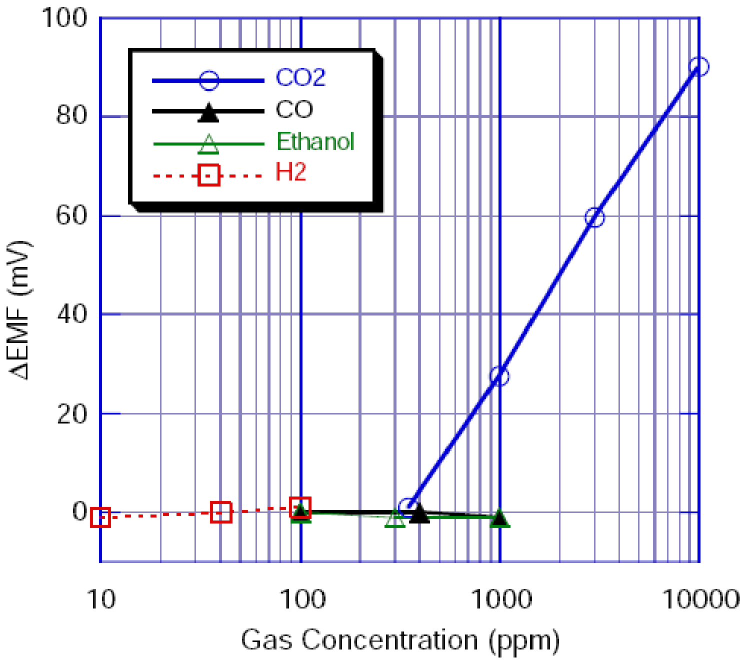


Figure 26: Graph of the sensitivity of the TGS4161 sensor taken from the Figaro sensor's data sheet

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

4.13. Nitrogen Dioxide (NO_2) sensor probe

Sensor specifications (MiCS-2710)

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

Figure 27: Image of the NO_2 sensor probe (MiCS-2710)

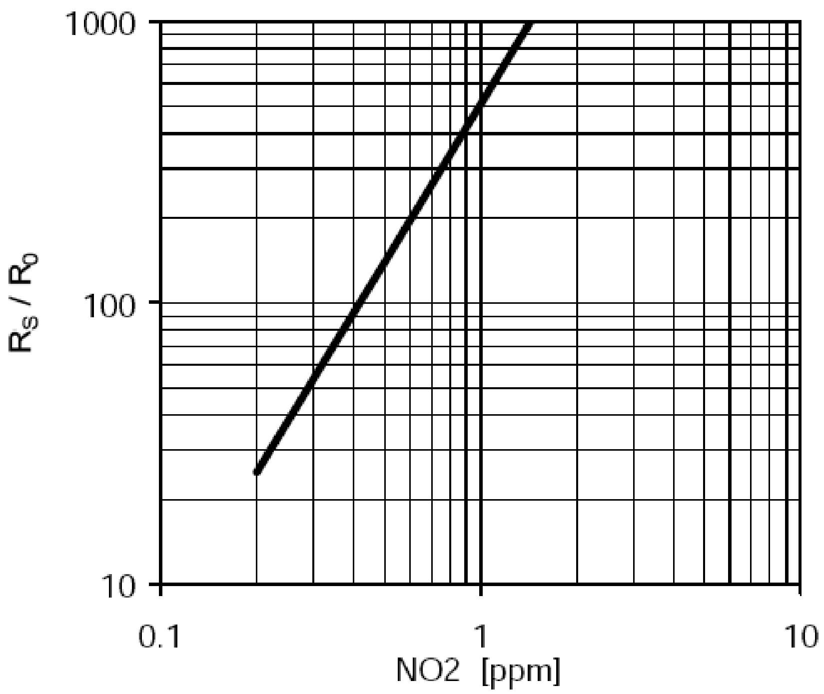


Figure 28: Graph of the sensitivity of the MiCS-2710 taken from the e2v's sensor data

The MiCS-2710 is a sensor whose resistance varies in the presence of small concentrations of NO_2. This value varies between 2kΩ and 2MΩ approximately, providing high accuracy throughout the output range. Unlike the rest of the board's gas sensors, which operate at a voltage of 5V, this sensor is powered through a 1.8V voltage regulator, with consumption of approximately 26mA. The sensor's resistance in air, as well as its sensitivity, can vary between different units, so it is recommended to calibrate each one of them before finally inserting them in the application.

4.14. Ozone (O_3) sensor probe

Sensor specifications (MiCS-2610)

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

Figure 29: Image of the O_3 sensor probe (MiCS-2610)

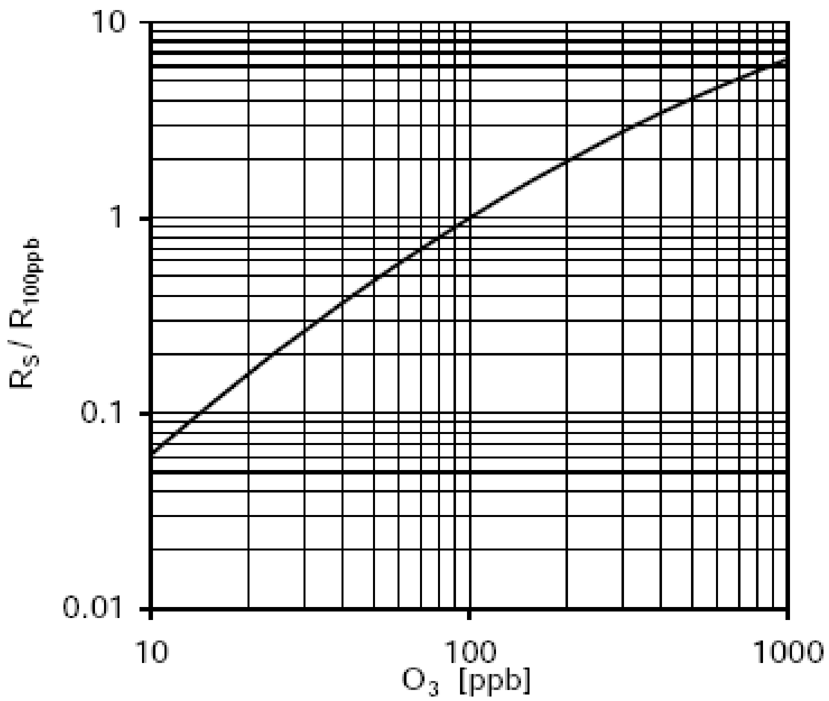


Figure 30: Graph of the sensitivity of the MiCS-2610 taken from the e2v's sensor data

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

4.15. VOC sensor probe

Sensor specifications (MiCS-5521)

Gases: CO, Hydrocarbons, Volatile Organic Compounds *
Measurement range: 30 ~ 400ppm
Air resistance: 100 ~ 1000kΩ
Sensitivity: 1.8 ~ 6 (typically 3, ratio between the resistance at 60ppm and at 200ppm of CO)
Supply voltage: 2.1 ~ 5V DC
Operating temperature: -30 ~ +85ºC
Response time: 30 seconds
Average consumption: 32mA

Figure 31: 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**

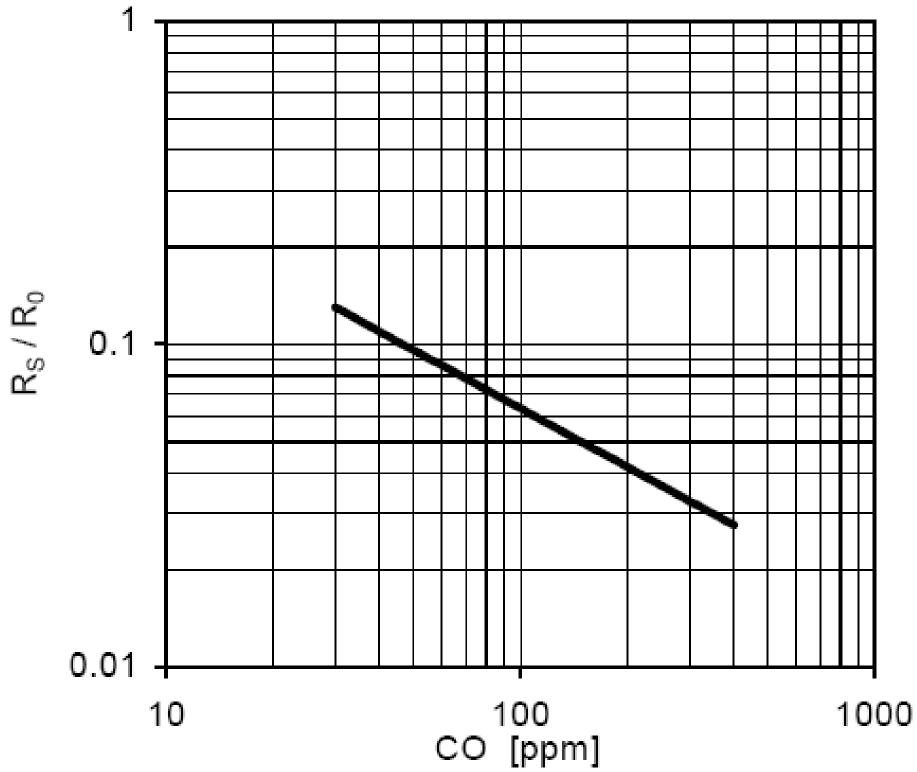


Figure 32: Graph of the sensitivity of the MiCS-5521 taken from the e2v's sensor data

The MiCS-5521 is a resistive sensor that responds to a great variety of gases, such as Carbon Monoxide (CO), Hydrocarbons and Volatile Organic Compounds. It's resistance varies between 1000kΩ and 2kΩ approximately. Like the MiCS-2610, the MiCS-5521 is powered through a 2.5V voltage regulator, with consumption of approximately 32mA. The sensor's resistance in air, as well as its sensitivity, can vary between different units, so it is recommended to calibrate each one of them before finally inserting them in the application.

4.16. Oxygen (O_2) sensor probe

Sensor specifications (SK-25)

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

Figure 33: Image of the O_2 sensor probe (SK-25)

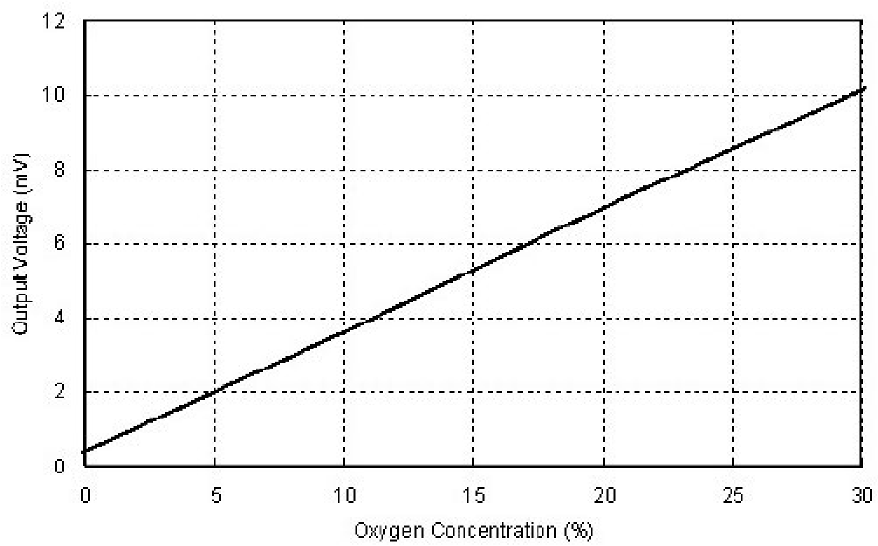


Figure 34: Graph of the sensitivity of the SK-25 extracted from the Figaro sensor's data sheet

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 Security

5.1. General description

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

Figure 35: 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	9205
	Liquid level	9239, 9240, 9242
	Liquid presence	9243
	Hall effect	9207
E	Luminosity	9205
	Liquid level	9239, 9240, 9242
	Liquid presence	9243
	Hall effect	9207
F	Luminosity	9205
	Liquid level	9239, 9240, 9242
	Liquid presence	9243
	Hall effect	9207

Figure 36: 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 37: Configurations of the Presence sensor probe (PIR)

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

5.2. Temperature and Humidity sensor probe

Figure 38: Image of the Temperature and Humidity sensor probe (SHT75)

Sensor specifications (SHT75)

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

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

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

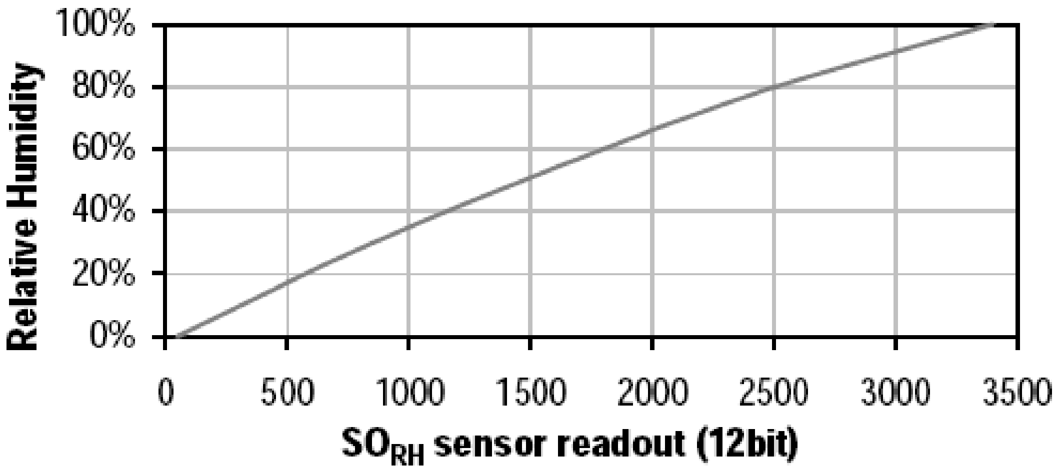


Figure 39: Graph of the sensor output with respect to relative humidity, taken from the Sensirion sensor's data sheet

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

5.3. Liquid Flow sensor probe

Figure 40: Image of the Liquid Flow sensor probe (FS200A)

Sensor specifications

FS100:

Flow rate: 0.15 ~ 2.5L/Min
Working voltage: +3.3V ~ +24V
Working temperature: -10ºC ~ 120ºC
Pulse number: 3900 pulses/liter
Inlet pipe size: 2mm
Outlet pipe size: 4mm
Accuracy: ±0.5%
Max rated current: 8mA

FS200A:

Flow rate: 0.5 ~ 25L/Min
Working voltage: +3.3V ~ +24V
Working temperature: -10ºC ~ 120ºC
Pulse number: 450 pulses/liter
Pipe connection: ½"
Accuracy: ±1%
Max rated current: 8mA

Figure 41: Image of the Liquid Flow sensor probe (FS200A)

FS400:

Flow rate: 1 ~ 60L/Min
Working voltage: +3.3V ~ +24V
Working temperature: -10ºC ~ 120ºC
Pulse number: 390 pulses/liter
Pipe connection: 1"
Accuracy: ±2%
Max rated current: 8mA

Figure 42: Image of the Liquid Flow sensor probe (FS400A)

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.

5.4. Presence sensor (PIR) probe

Sensor specifications (PIR)

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

Figure 43: 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 44: 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.

5.5. Luminosity sensor probe

Figure 45: Image of the Luminosity sensor probe (LDR)

Sensor specifications (LDR)

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

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.

5.6. Liquid Level sensor probe

Figure 46: Image of the Liquid Level sensor probe (PTFA1103)

Sensor specifications

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

Figure 47: Image of the PTFA3415 sensor

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

Figure 48: Image of the PTFA0100 sensor

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

Figure 49: 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).

5.7. Liquid Presence sensor probe

Sensor specifications

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

Figure 50: Image of the Liquid Presence sensor probe

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).

5.8. Hall Effect sensor probe

Sensor specifications (PLA41201)

Length: 32mm
Width: 15mm
Thickness: 7mm
Maximum contact resistance (closed): 150mΩ
Minimum contact resistance (open): 100GΩ

Figure 51: 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. Smart Metering

6.1. 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 52: Smart Metering Waspmote Plug & Sense! model

Sensor sockets are configured as shown in the figure below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A	Temperature	9203
	Soil temperature	86949*
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, 9297, 9298
F	Luminosity	9205

* Ask Libelium **Sales Department** for more information.

Figure 53: 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 54: Configurations of the ultrasound sensor probe

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

6.2. Temperature sensor probe

Sensor specifications (MCP9700A)

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

Figure 55: Image of the Temperature sensor probe (MCP9700A)

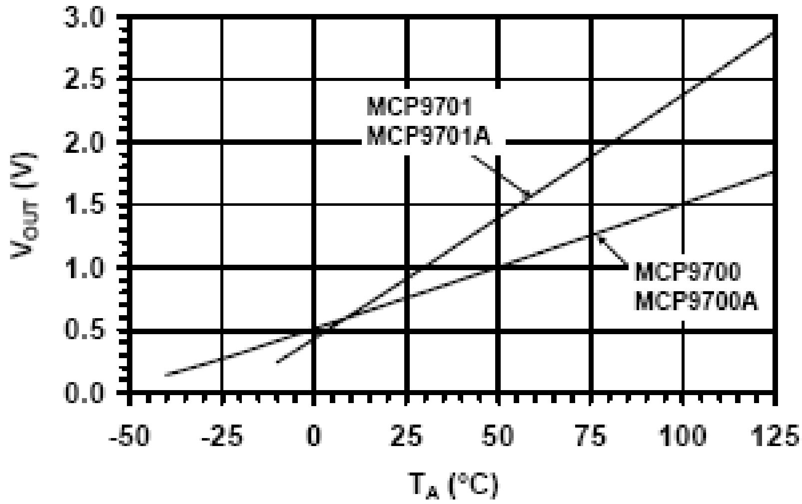


Figure 56: Graph of the MCP9700A sensor output voltage with respect to temperature, taken from the Microchip sensor's data sheet

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.

6.3. Soil Temperature sensor (DS18B20) probe

Sensor specifications (DS18B20)

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

Figure 57: Image of the Soil Temperature sensor probe (DS18B20)

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

6.4. Humidity sensor probe

Sensor specifications (808H5V5)

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

Figure 58: Image of the Humidity sensor probe (808H5V5)

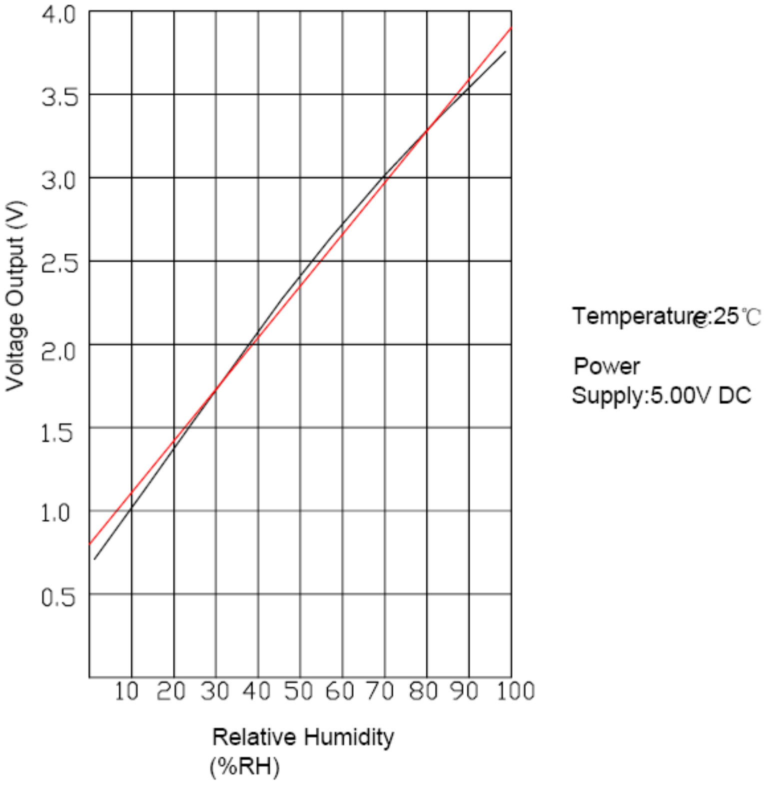


Figure 59: 808H5V5 humidity sensor output taken from the Sencera Co. Ltd sensor data sheet

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.

6.5. Liquid Flow sensor probe

Figure 60: Image of the Liquid Flow sensor probe (FS200A)

Sensor specifications

FS100:
Flow rate: 0.15 ~ 2.5L/Min
Working voltage: +3.3V ~ +24V
Working temperature: -10ºC ~ 120ºC
Pulse number: 3900 pulses/liter
Inlet pipe size: 2mm
Outlet pipe size: 4mm
Accuracy: ±0.5%
Max rated current: 8mA

FS200A:
Flow rate: 0.5 ~ 25L/Min
Working voltage: +3.3V ~ +24V
Working temperature: -10ºC ~ 120ºC
Pulse number: 450 pulses/liter
Pipe connection: ½"
Accuracy: ±1%
Max rated current: 8mA

Figure 61: Image of the Liquid Flow sensor probe (FS200A)

FS400:
Flow rate: 1 ~ 60L/Min
Working voltage: +3.3V ~ +24V
Working temperature: -10ºC ~ 120ºC
Pulse number: 390 pulses/liter
Pipe connection: 1"
Accuracy: ±2%
Max rated current: 8mA

Figure 62: Image of the Liquid Flow sensor probe (FS400A)

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.

6.6. Current sensor probe

Figure 63: Image of the Current sensor probe

Sensor specifications

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

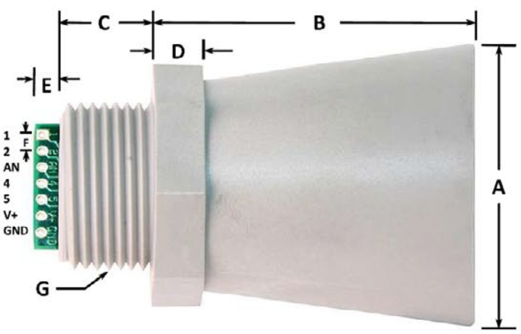
The current clamp is a low cost sensor that outputs a current proportional to the current in the primary circuit. That current (related with the primary current through a 1:2000 ratio) is converted into voltage through a load resistor obtaining a signal readable by the mote's analog-to-digital converter.

6.7. 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 64: 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 mm dia.
I	1.37"	34.8 mm
weight, 1.76 oz., 50 grams		

values are nominal

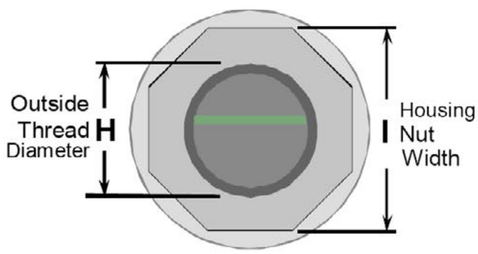


Figure 65: Ultrasonic XL-MaxSonar®-WRA1 sensor dimensions

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):

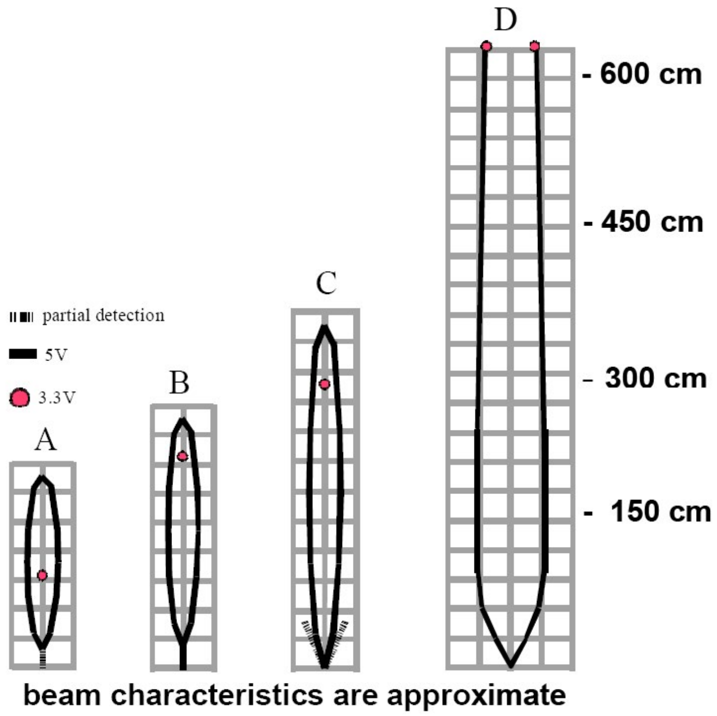


Figure 66: Diagram of the sensor beam extracted from the data sheet of the XL-MaxSonar®-WRA1™ sensor from MaxBotix

Figure 67: Image of configurations of the ultrasound sensor probe

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

6.8. Luminosity sensor probe

Figure 68: Image of the Luminosity sensor probe (LDR)

Sensor specifications (LDR)

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

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.

7. Smart Cities

7.1. 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 69: Smart Cities Waspmote Plug & Sense! Model

Sensor sockets are configured as shown in the figure below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A	Temperature	9203
	Soil temperature	86949*
	Ultrasound (distance measurement)	9246
B	Humidity	9204
	Ultrasound (distance measurement)	9246
C	Luminosity	9205
D	Noise sensor	9259
E	Dust sensor	9320
F	Linear displacement	9319

* Ask Libelium **Sales Department** for more information.

Figure 70: 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 71: Configurations of the ultrasound sensor probe

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

7.2. Temperature sensor probe

Sensor specifications (MCP9700A)

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

Figure 72: Image of the Temperature sensor probe (MCP9700A)

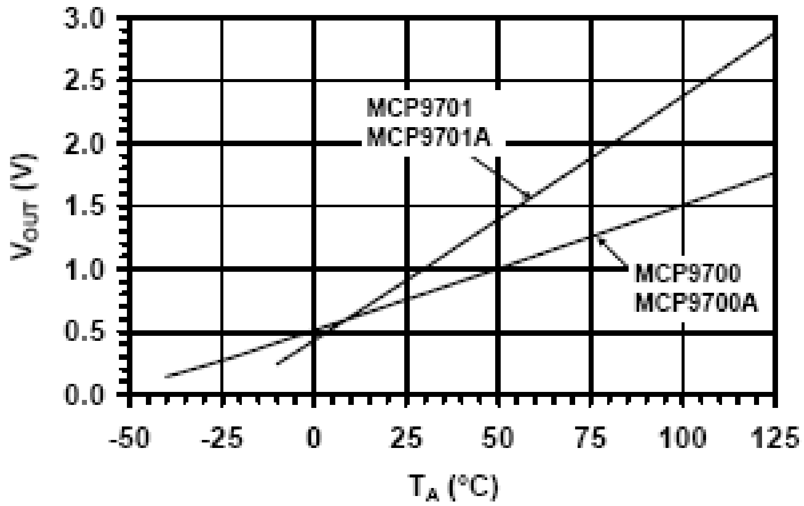


Figure 73: Graph of the MCP9700A sensor output voltage with respect to temperature, taken from the Microchip sensor's data sheet

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.

7.3. Soil Temperature sensor (DS18B20) probe

Sensor specifications (DS18B20)

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

Figure 74: Image of the Soil Temperature sensor probe (DS18B20)

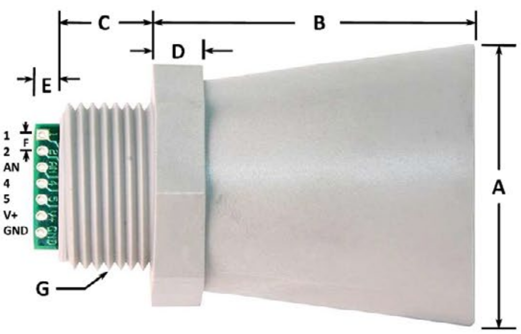
The DS18B20 is a temperature digital sensor which provides an accurate measurement and a high resolution (of up to 0.065ºC) which communicates with the Waspmote's microcontroller through the 1-Wire bus. It has been encapsulated in a plastic seal that isolates it from humidity, thus allowing to use it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

7.4. 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 75: 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 mm dia.
I	1.37"	34.8 mm
weight, 1.76 oz., 50 grams		

values are nominal

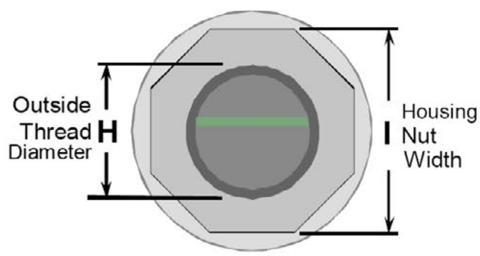


Figure 76: Ultrasonic XL-MaxSonar®-WRA1 sensor dimensions

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):

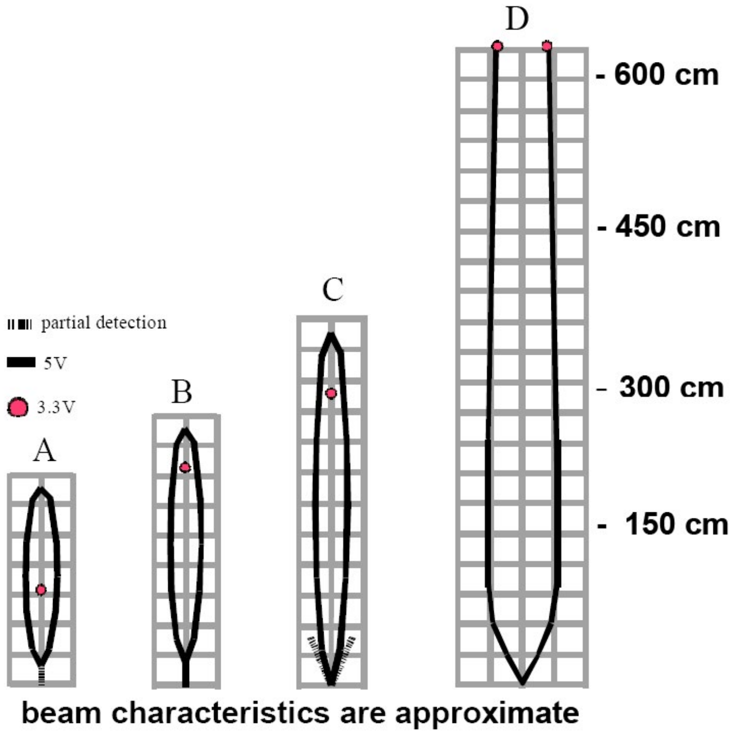


Figure 77: Diagram of the sensor beam extracted from the data sheet of the XL-MaxSonar®-WRA1™ sensor from MaxBotix

Figure 78: 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.

7.5. Humidity sensor probe

Sensor specifications (808H5V5)

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

Figure 79: Image of the Humidity sensor probe (808H5V5)

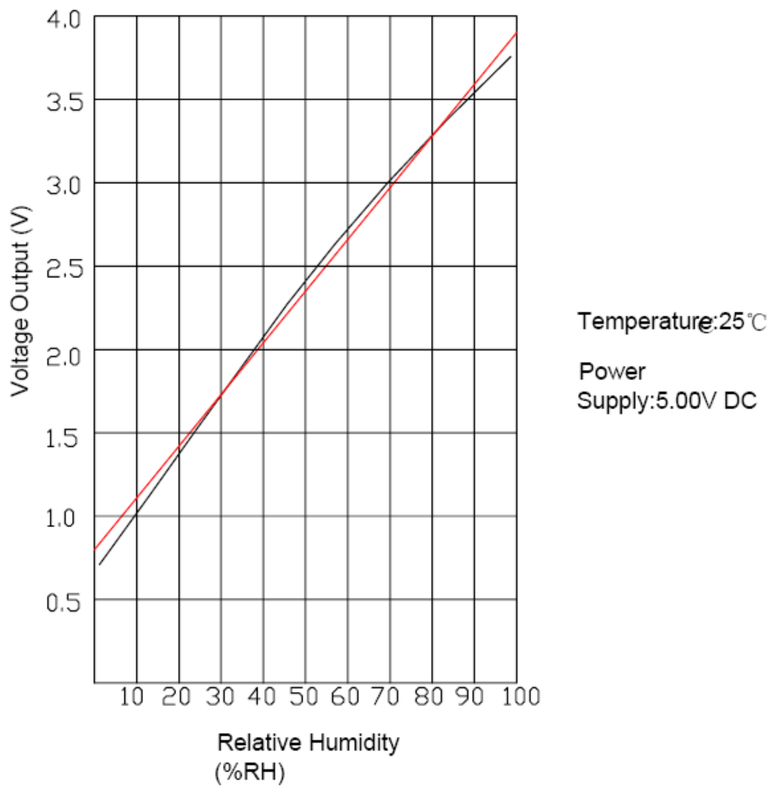


Figure 80: 808H5V5 humidity sensor output taken from the Sencera Co. Ltd sensor data sheet

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.

7.6. Luminosity sensor probe

Figure 81: Image of the Luminosity sensor probe (LDR)

Sensor specifications (LDR)

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

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.

7.7. Noise sensor probe

<u>**Sensor specifications (WM-61A)**</u>

Sensitivity: -35±4dB
Impedance: <2.2kΩ
Directivity: Omnidirectional
Frequency: 20Hz~20kHz
Supply voltage: +2V (Standard), +10V (Maximum)
Maximum current consumption: 0.5mA
Sensitivity reduction: -3dB a 1.5V
Maximum sound pressure level: 114.5±10dBSPL approximately
S/N ratio: 62dB
Noise Level: 26 +/-1 dBSPLA
Stage Measurement range: 50dBSPLA~100dbSPLA

Figure 82: Image of the Noise sensor probe (WM-61A microphone)

The WM-61A, introduced in the Smart Cities board to monitor the environmental noise, is an omnidirectional microphone with an almost flat response in the whole frequency range of human hearing, between 20Hz and 20kHz. A circuit to filter the signal to adapt it to the A decibel scale and output a continuous voltage readable from the mote's processor has been introduced. When sold along with a microphone, the Smart Cities board is supplied calibrated by Libelium to return an output in the range between 50dBSPLA and 100dBSPLA with an accuracy of ±2.5dBSPLA. 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. 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. In figure 77 we can see a table of noise pressure generated by different sources in dBSPLA.

Sound	**dBSPLA**
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 83: Noise in dBSPLA produced by different sources

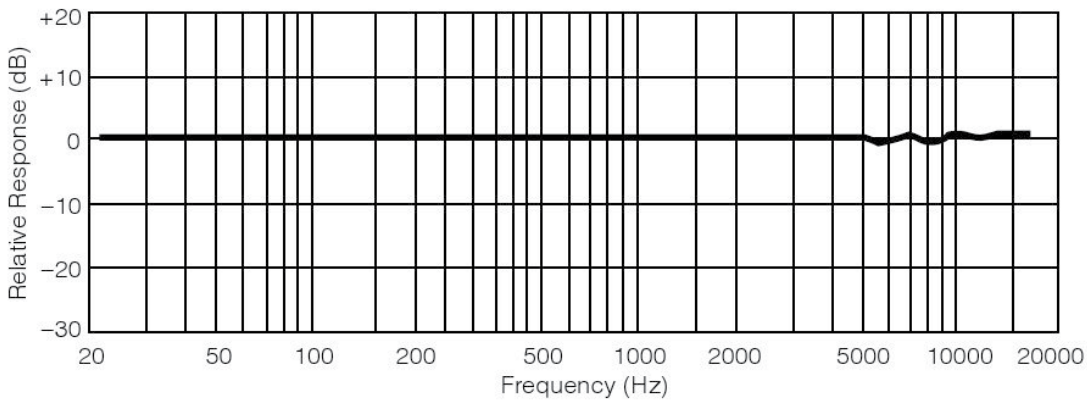


Figure 84: Graph of the frequency response of the WM-61A extracted from the sensor's data sheet from Panasonic

7.8. Dust (PM-10 particles) sensor probe

Figure 85: Image of the Dust sensor probe (GP2Y1010AU0F)

Sensor specifications (GP2Y1010AU0F)

Supply voltage: -0.3V ~ 7V
Sensitivity: Typical: 0.5V/(0.1mg/m^3), Minimum: 0.35V/(0.1mg/m^3), Maximum: 0.65V/(0.1mg/m^3)
Output voltage at no dust: Typical: 0.9V, Minimum: 0V, Maximum: 1.5V
Output voltage range: 3.4V
Operation temperature: -10ºC ~ +65ºC
Current consumption: Typical: 11mA, Maximum: 20mA
LED Pulse Cycle: 10±1ms
LED Pulse width: 0.32±0.02ms
LED Operating supply voltage: 5±0.5V

The GPY21010AU0F is an optical sensor whose principle of operation is based on the detection of the infrared light emitted by an ILED diode, reflected by the dust particles and captured by means of a phototransistor. The ILED diode needs to be supplied with a signal of pulses of 0.32ms width and a period of 10ms, generated automatically by the hardware of the board when the sensor is turned on, being the output a signal of pulses of the same time characteristics whose amplitude is proportional to the environmental dust density (see the graph in figure 80). To read this signal has been added a demodulation circuit that extracts the envelope of the train of pulses at whose output results an analog voltage in a range between 0V and 3V approximately.

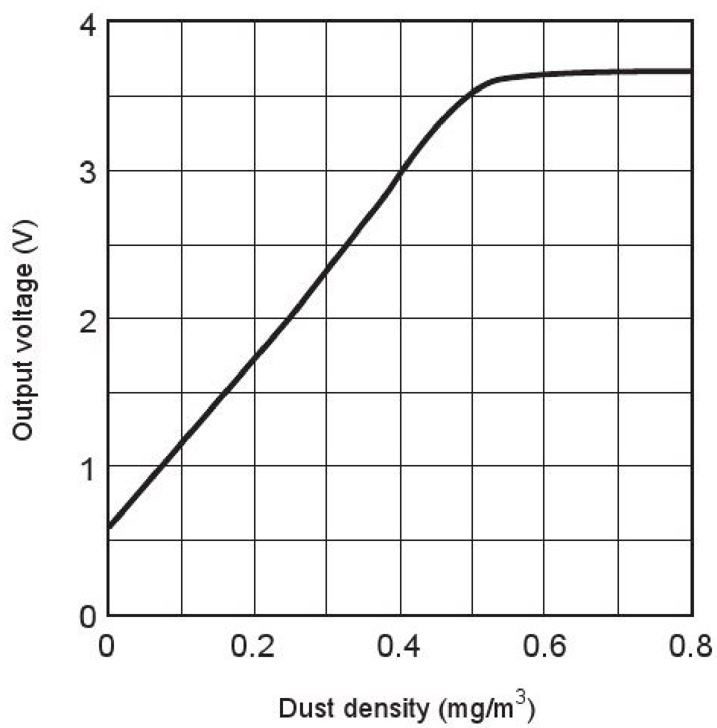


Figure 86: Graph of the output voltage vs dust density extracted from the Sharp's sensor data sheet

7.9. Linear Displacement sensor probe

Figure 87: Image of the Linear Displacement sensor probe (SLS095)

Sensor specifications (SLS095)

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

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.

8. Smart Parking

8.1. General description

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

Sensor specifications

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

Figure 88: 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.

9. Smart Agriculture

9.1. 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 89: Smart Agriculture Waspmote Plug & Sense! Model

9.1.1. 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	Weathermeters + pluviometer	9256
E	Soil moisture	9248
F	Leaf wetness	9249
	Soil moisture	9248

* Ask Libelium **Sales Department** for more information.

Figure 90: Sensor sockets configuration for Smart Agriculture model

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

9.1.2. PRO

Sensor sockets are configured as shown in the figure below.

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

* Ask Libelium **Sales Department** for more information.

Figure 91: 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**.*

9.2. Temperature and Humidity sensor probe

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

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

Figure 92: Image of the Temperature and Humidity sensor probe (SHT75)

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

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

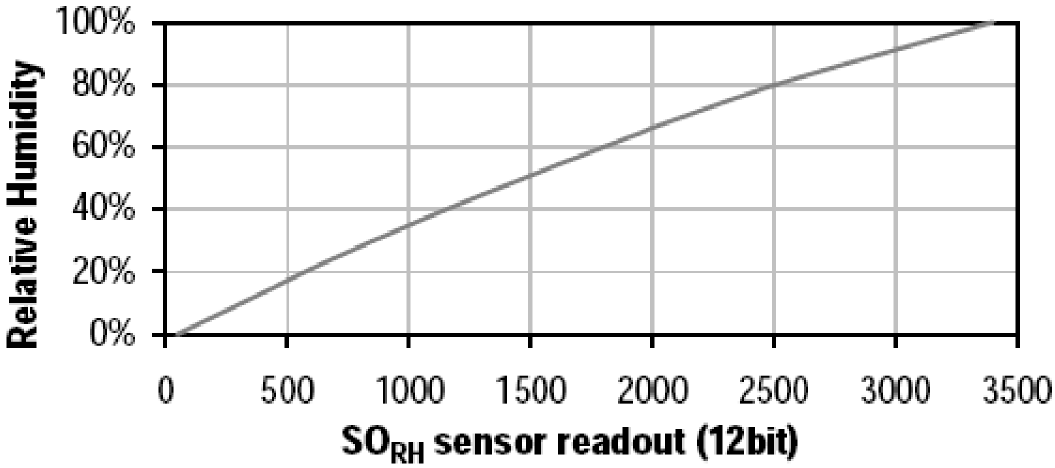


Figure 93: Graph of the sensor output with respect to relative humidity, taken from the Sensirion sensor's data sheet

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

9.3. Atmospheric Pressure sensor probe

Sensor specifications (MPX4115A)

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

Figure 94: Image of the Atmospheric Pressure sensor probe (MPX4115A)

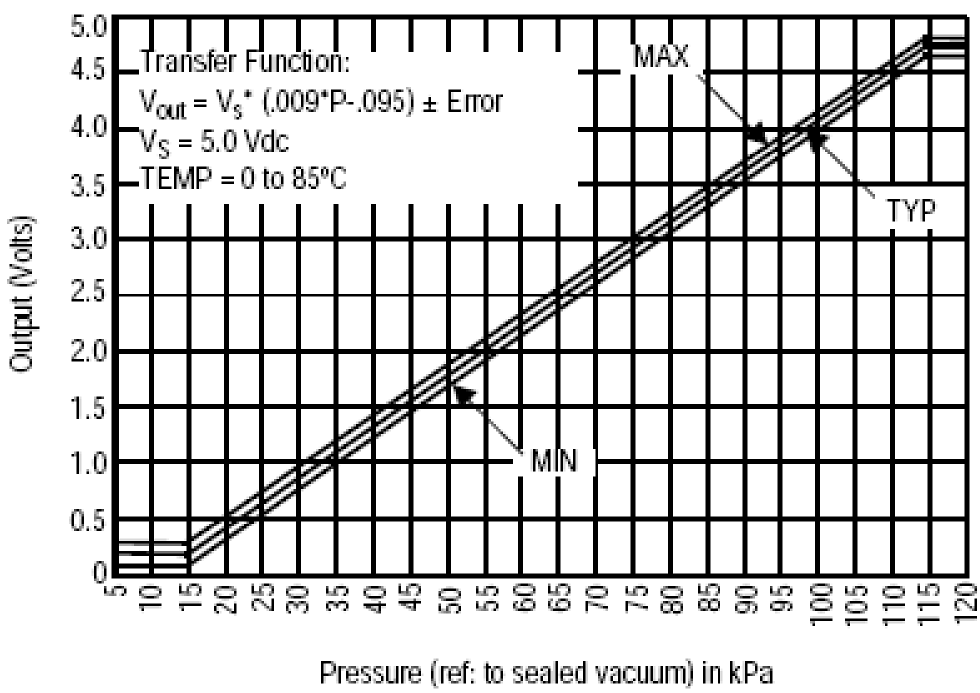


Figure 95: Graph of the MPX4115A sensor's output voltage with regard to pressure taken from the Freescale sensor's data sheet

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.

9.4. Soil Temperature sensor (DS18B20) probe

Sensor specifications (DS18B20)

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

Figure 96: Image of the Soil Temperature sensor probe (DS18B20)

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

9.5. Soil moisture sensor probe

Sensor specifications (Watermark)

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

Figure 97: Image of the Soil Moisture sensor probe (Watermark)

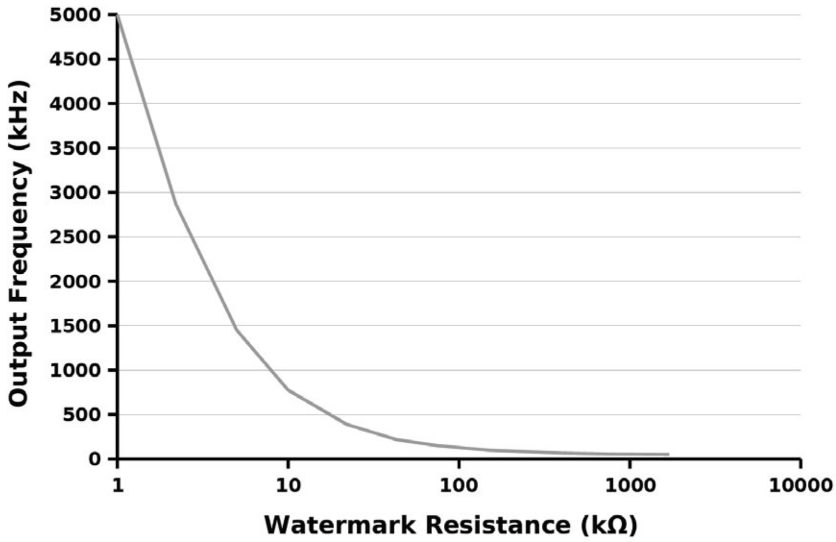


Figure 98: Output frequency of the Watermark sensor circuit with respect to the resistance of the sensor

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

9.6. Weather station 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

Figure 99: Image of the Weather Station probe

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

Sensor specifications (Vane)

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

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

Direction (Degrees)	Resistance (kΩ)	Voltage (V)	Identifier
0	33	2.53	SENS_AGR_VANE_N (0)
22.5	6.57	1.31	SENS_AGR_VANE_NNE (1)
45	8.2	1.49	SENS_AGR_VANE_NE (2)
67.5	0.891	0.27	SENS_AGR_VANE_ENE (3)
90	1	0.3	SENS_AGR_VANE_E (4)
112.5	0.688	0.21	SENS_AGR_VANE_ESE (5)
135	2.2	0.59	SENS_AGR_VANE_SE (6)
157.5	1.41	0.41	SENS_AGR_VANE_SSE (7)
180	3.9	0.92	SENS_AGR_VANE_S (8)
202.5	3.14	0.79	SENS_AGR_VANE_SSW (9)
225	16	2.03	SENS_AGR_VANE_SW (10)
247.5	14.12	1.93	SENS_AGR_VANE_WSW (11)
270	120	3.05	SENS_AGR_VANE_W (12)
292.5	42.12	2.67	SENS_AGR_VANE_WNW (13)
315	64.9	2.86	SENS_AGR_VANE_NW (14)
337.5	21.88	2.26	SENS_AGR_VANE_NNW (15)

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.

9.7. Leaf Wetness sensor probe

<u>**Sensor specifications (Leaf Wetness)**</u>

Resistance Range: 5kΩ ~ >2MΩ
Output Voltage Range: 1V ~ 3.3V
Length: 3.95cm
Width: 1.95 cm

Figure 100: Image of the Leaf Wetness sensor probe

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

9.8. Soil Temperature sensor (PT1000) probe

<u>**Sensor specifications (PT1000)**</u>

Measurement range: -50 ~ 300ºC
Accuracy: DIN EN 60751
Resistance (0ºC): 1000Ω
Diameter: 6mm
Length: 40mm
Cable: 2m

Figure 101: Image of the Soil Temperature sensor sensor probe

The resistance of the PT1000 sensor varies between approximately 920Ω and 1200Ω in the range considered useful in agriculture applications (-20 ~ 50ºC approximately), which results in too low variations of voltage at significant changes of temperature for the resolution of the Waspmote's analog-to-digital converter. The temperature value is returned in Celsius degree (ºC).

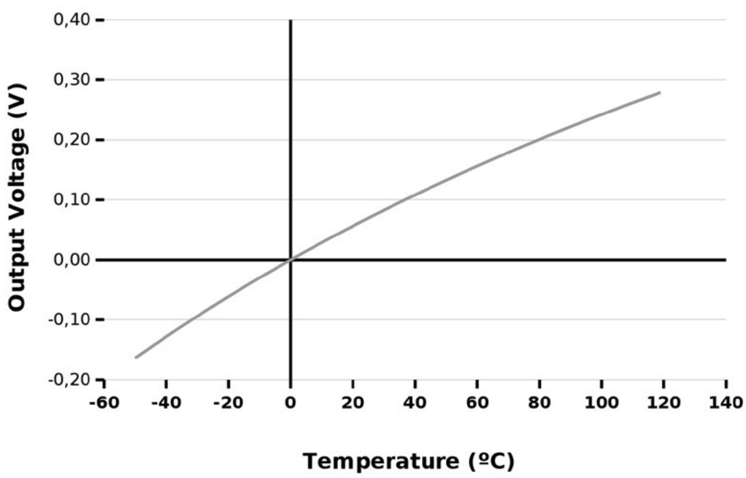


Figure 102: Output voltage of the PT1000 sensor with respect to temperature

9.9. Solar Radiation sensor probe

Sensor specifications (SQ-110)

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

Figure 103: Image of the Solar Radiation sensor probe

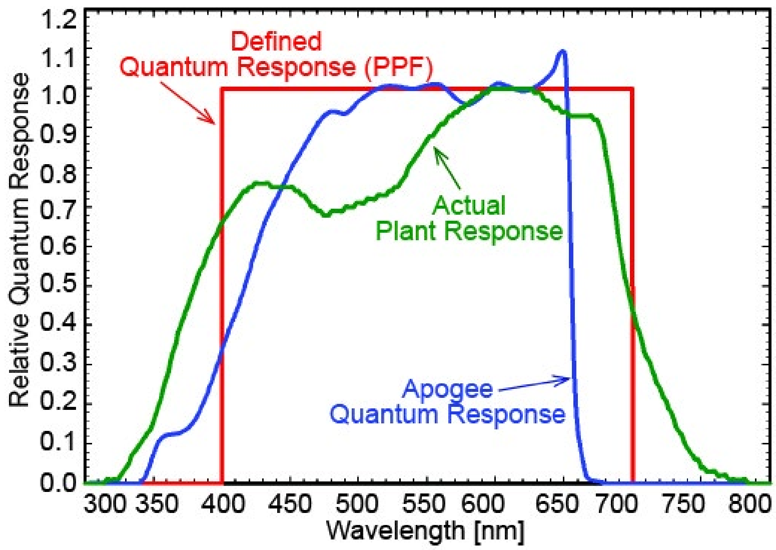


Figure 104: Graph of the spectral response of the SQ-110 sensor compared to the photosynthetic response of a plant

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

Sensor specifications (SU-100)

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

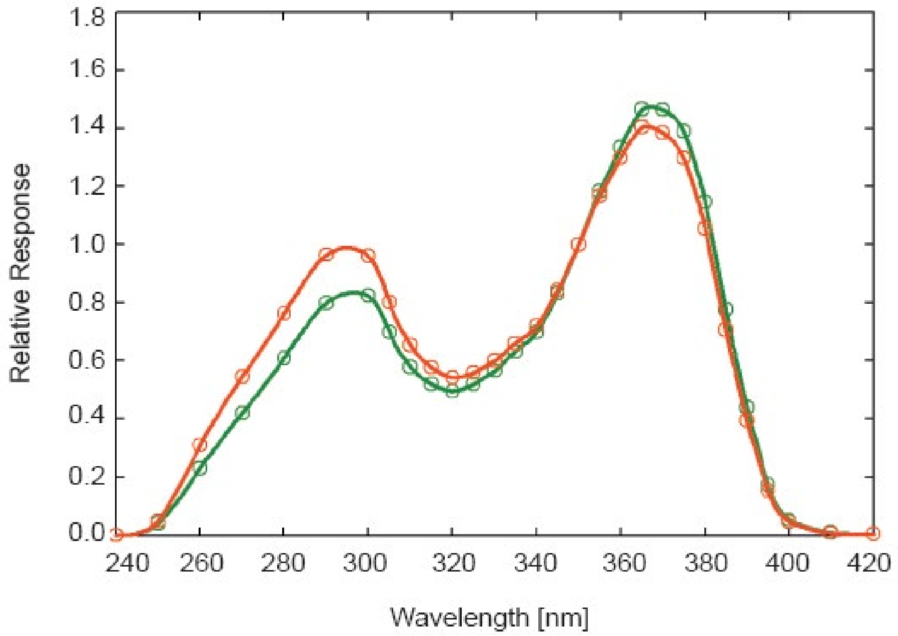


Figure 105: Graph of the spectral response of the SU-100 sensor compared to the photosynthetic response of a plant

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

9.10. Dendrometer sensor probe

Figure 106: Image of the Dendrometer sensor probe

Sensor specifications (Trunk diameter)

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

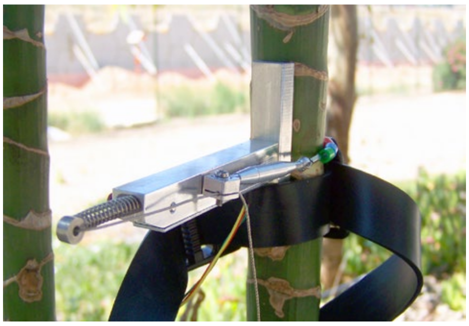


Figure 107: Ecomatik DC2 sensor

Tree Diameter (cm)	Measuring Range in Circumference(mm)	Measuring Range in Diameter (mm)
10	31.25	9.94
40	22.99	7.31
100	16.58	5.27

Sensor specifications (Stem diameter)

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

Figure 108: Ecomatik DD sensor

Sensor specifications (Fruit diameter)

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

Figure 109: 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.

10. Ambient Control

10.1. 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 110: Ambient Control Waspmote Plug & Sense! model

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

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

Figure 111: 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 112: 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**.*

10.2. Temperature and Humidity sensor probe

Figure 113: Image of the Temperature and Humidity sensor probe (SHT75)

Sensor specifications (SHT75)

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

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

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

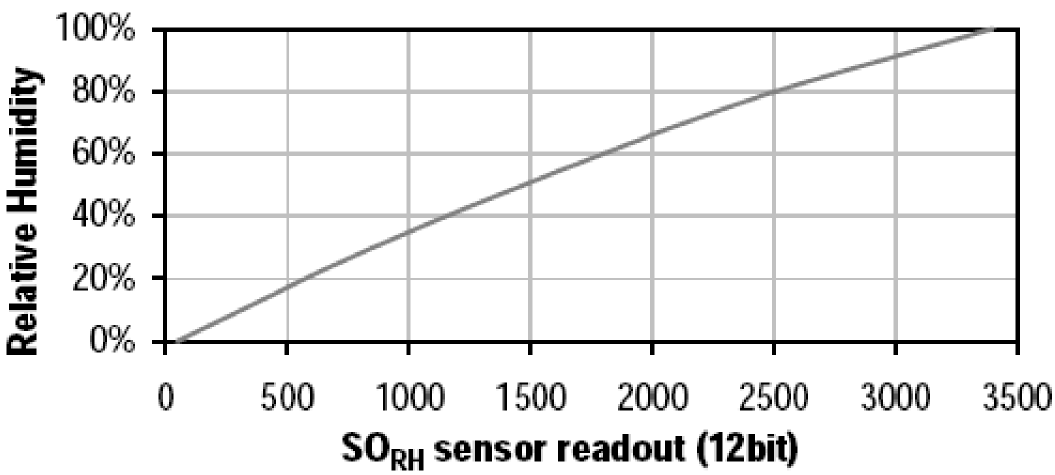


Figure 114: Graph of the sensor output with respect to relative humidity, taken from the Sensirion sensor's data sheet

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

10.3. Luminosity sensor probe (LDR)

Sensor specifications (LDR)

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

Figure 115: 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.*

10.4. Luminosity sensor probe (Luxes accuracy)

Sensor specifications (Luxes accuracy)

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

Figure 116: 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.

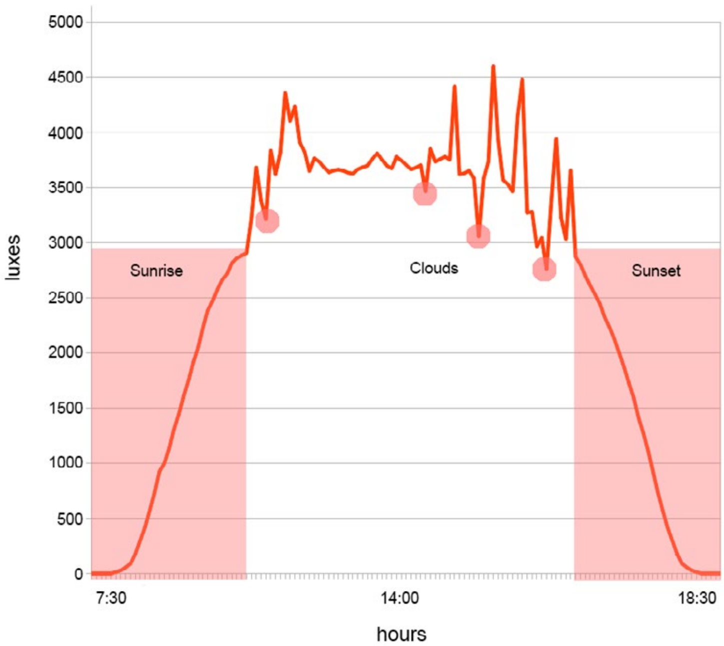


Figure 117: Image of the Luminosity sensor probe (Luxes accuracy)

Figure 118: 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.

10.5. 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.

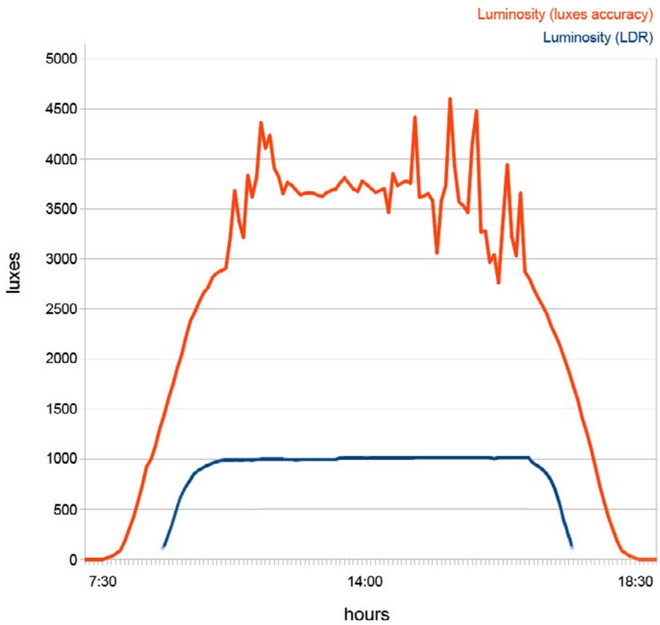


Figure 119: Comparison of the responses of the Luminosity sensor probe (Luxes accuracy) and the Luminosity sensor probe (LDR)

11. Radiation Control

11.1. 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 120: Radiation Control Waspmote Plug & Sense! model

Sensor sockets are no used for this model.

Sensor specifications (Geiger tube)

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

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