BETA version – non official

1 Gases sensors calibration process considerations

Before trying to calibrate the gases sensors, the next points must be taken in account:

- Due to the low accuracy and repeatability of the gases sensor, each sensor must calibrated and it will have his own calibration parameters
- The calibration of the gases sensors improves the behavior of the sensor but it does not ensures high-precision response
- The calibration process must be done in a laboratory by specialized personal and instrumentation
- The life expectancy of the gases sensors is about some month. After this period the gases sensors must be replaced and calibrated
- The stabilization time of the sensors is around 10-20 minutes, and the use of software filtering is highly recommended

2 First step. Understanding the parameters

All sensors must be configured with some parameters before starting the measurements process.

2.1 The GAIN of the sensors stage

The gain of the sensor stage can be configured by software. This parameter can be configured from 1 to 100. As a general rule, gain will be fixed at 1 in almost every application, only in very specific situations, such as operation in the limits of the sensor range, it will be necessary a different value.

2.2 The load resistance R_L and the sensor resistance R_s

2.2.1 Sensors with RL resistance

The CO, NO_2, NH_3, CH_4, Liquefied Petroleum Gas, Air Contaminants (TGS2600, TGS2602), Solvent Vapors, O_3, VOC, uses similar circuit stages, based in voltage divider. This voltage divider consists in two resistors. One of this resistors, is the sensor resistance (R_S), and the other is the load resistance (R_L). The R_S, changes depending on the concentration of the gas, and the R_L resistance can be configured by a digital potentiometer, by the function `configureSensor()`. The value of the RL sensor changes depending on the sensor. In the technical guide you can see the recommended value of the RL resistance for each sensor.

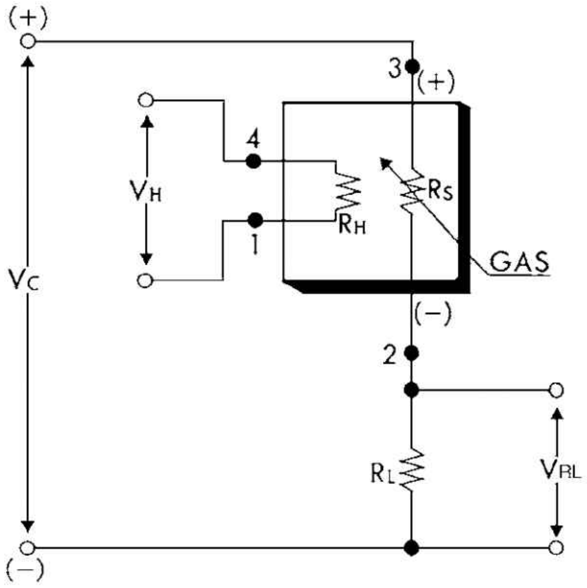

Figure: R_S and R_L resistances

Once the voltage is measured by the analog-digital converter, the R_S can be calculated using the next simple formula.

$$R_S = \frac{V_C \times R_L}{V_{out}} - R_L$$

Figure: R_S calculation

- V_C its power (5V for any sensor except socket 3B for the NO_2 , which is powered at 1.8V, and socket 2B for VOC and O_3 sensors, which is powered at 2.5V)
- V_{OUT} is the output voltage measurement
- RL the load resistance resistance which has been defined

Recommended values of load resistor:

Sensor	R_L
CO	Minimum 10KOhm to 100K
NO2	20 KOhm typical to 100K
NH3	Minimum 8 KOhm to 100K
CH4	Minimum 0.45kΩ to 100K
Liquefied Petroleum Gas	Minimum 0.45kΩ to 100K
TGS2600	Minimum 0.45kΩ to 100K
TGS2602	Minimum 0.45kΩ to 100K
Solvent Vapors	Minimum 0.45kΩ to 100K
O3	20 KOhm typical typical to 100K
VOC	20 KOhm typical to 100K

2.2.2 Sensors with no load resistance

The CO_2 sensor and the O_2 sensor don't need a load resistance and the measurement and calibration process is different.

In the case of the CO_2 sensor the sensor returns a voltage value, and this value is used to calculate the concentration, so only is necessary to configure the GAIN. The value of the GAIN in the majority of the cases is fixed at 1.

The O_2 sensor provides a voltage output proportional to the O_2 concentration in the atmosphere. This value of voltage can be used directly to calculate the concentration of oxygen.

2.3 The R_0 resistance

The R_O is the value of the sensor resistance at a know concentration without the presence of other gases or in fresh air. This value must be measured and stored to calculate the concentration of the gas. This table shows the recommended concentration to measure Ro value extracted from data sheets of the manufacturers:

Sensor	R_O
CO	R_O = Sensor resistance (R_S) in 100 ppm of CO
NO2	R_O = Sensor resistance (R_S) in fresh air
NH3	--
CH4	R_O = Sensor resistance (R_S) in 5000ppm of methane

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Liquefied Petroleum Gas	R_O = Sensor resistance (R_S) in 1800ppm of iso-butane
TGS2600 (Air Contaminants)	R_O = Sensor resistance (R_S) in fresh air
TGS2602 (Air Contaminants)	R_O = Sensor resistance (R_S) in fresh air
Solvent Vapors	R_O = Sensor resistance (R_S) in 300ppm of ethanol
O3	
VOC	R_O = Sensor resistance (R_S) in synthetic air

3 Calibration steps

This process can be applied to all sensor except CO2 and O2 sensors. The O2 sensor have a linear response and is not necessary its calibration. The CO2 sensor uses voltages instead of resistances for calibration.

1. Configure the sensor with the function configureSensor(). The value of the GAIN is normally 1, and the load resistor R_L, can change depending on the sensor. A recommended value of load resistor is described in the data sheet of the sensor. In the corresponding examples included in the API, the typical values of load resistor are used, but his values can be reconfigured.

Example:

```
{
	#define GAIN  1	//GAIN of the sensor stage
	#define RL 20  //LOAD RESISTOR IN KOHM

	// Configure the 4A sensor socket
	SensorGasv20.configureSensor(SENS_SOCKET4A, GAIN, RL);
}
```

2. Measure the R_O resistance at a know concentration, (depending on each sensor) and a controlled temperature and humidity conditions and annotate this value for next calculations

Example:

```
{
	// Read the sensor voltage response
	socket4AVal = SensorGasv20.readValue(SENS_SOCKET4A);
	// Calculate the Ro value from the voltage value
	Ro = SensorGasv20.calculateResistance(SENS_SOCKET4A, socket4AVal, GAIN, RL);
}
```

3. Once the Ro resistance is obtained, is necessary to obtain some values to generate an approximation of the response of the sensors. At least is necessary 2 points, but for a correct calibration we suggest 3 or 4 points of calibration, separated by a decade, but not necessary. For example 30, 300 and 3000 ppm's.

IMPORTANT: the concentration values used in the calibration process are different for each sensor. The values used in this example are only for showing the general calibration process.

The Rs resistance can be read with the function `calculateResistance()`

Example:

```
{
	// We are going to measure the resistance with 30 ppm of gas concentration
	// After the stabilizacion of the signal, annotate this value.
	Rs = SensorGasv20.calculateResistance(SENS_SOCKET4A, socket4AVal, GAIN, RL);
}
```

Repeat the process for 300 and 3000 ppm's and annotate the corresponding values.

IMPORTANT: The stabilization time of the sensors is around 10-20 minutes, and the use of software filtering is highly recommended.

4. Once the Rs is calculated for the three points, we are going to calculate the relation between Rs and Ro (Rs/Ro) of each point.

   Point1 = Rs(30ppm) / Ro; Point2 = Rs(300ppm) / Ro; Point3 = Rs(3000ppm) / Ro

5. These points are the values to introduce in the calibration code to obtain the logarithmic approximation. Introduce this values and the concentration values used for calibration an array and use the function `calculateConcentration()`. This function returns directly the conversion from sensor resistance in kilo ohms in ppm.

Example:

```
{
	// INTRODUCE IN THE NEXT ARRAY THE CONCENTRATION VALUES USED IN CALIBRATION
	int calConcentrations[3] = {30,300,3000};

	// INTRODUCE IN THE ARRAY Rs/Ro VALUES OBTAINED
	float calibrationPoints[3] = {114.3312 , 40.2036 , 11.7751};

	//Read the voltage value
	val = SensorGasv20.readValue(SENS_SOCKET4CO);

	// Conversion from voltage into kiloohms
	RL = SensorGasv20.calculateResistance(SENS_SOCKET4CO, val, GAIN, RESISTOR);

	// Conversion from sensor resistance in kiloohms in parts per million
	ppmVal = 
SensorGasv20.calculateConcentration(coCalibrationConcentration,calibrationPoints,coVal);

}
```