p-type Metal Oxide Sensor Overview and Interface Circuit

The new range of Alphasense metal-oxide sensors, comprising p-type gas-sensitive materials, can detect a diverse spectrum of gases. The p-type metal oxide sensors are particularly applicable to the detection of CO, H_2S and VOCs (Volatile Organic Compounds), equally suitable for use in benign and harsh environments, from sub-zero temperatures to an excess of 120^{o}C. Unlike n-type materials, these p-type metal oxide sensors can detect over a large concentration range. The sensing principle relies on the interaction between the porous gas-sensitive layer and the target gas: the adsorption of the gas causes a change in the electrical resistance of the porous layer. The gas-sensitive layers are screen printed onto an alumina chip, which comprises an integrated heater and a co-planar interdigitated electrode (IDE) pattern. We also supply a driver/detection PCB for your testing. Discrimination between different gases is optimised through a combination of fine-tuning manufacturing processes, selecting the sensor operating parameters and including embedded bespoke filters.

Generic specifications of Alphasense metal oxide sensors are shown in Table 1 below:

Parameter	**Value at 400**^{0}C	**Value at 525**^{0}C
Sensor resistance in air 50%RH (kΩ)	250 ± 100	30 ± 5
Heater resistance (Ω)	24 ± 4	28 ± 4
Heater Voltage (V)	2.7 ± 0.2	3.7 ± 0.3
Heater Power (mW)	350 ± 40	540 ± 60

Table 1. Typical specifications for Alphasense p-type metal oxide sensors.

A simple multimeter measurement of an unconnected sensor will confirm the pinout: heater resistance at RT is low (10 ± 2 Ω), while the sensing layer will either appear open circuit or have a high (MΩ) resistance. Please refer to the relevant product datasheet for the exact pinout of your MOS sensor.

Two-temperature pulsing

Alphasense recommends the use of two-temperature pulsing when using our p-type metal oxide sensors; this enhances the performance of the sensors, providing increased sensitivity, improved baseline stability, shorter setup time, faster response time and elimination of time-dependent response effects. Two-temperature pulsing raises the temperature from 400^{o}C to 525^{o}C for a short period, then returns to 400^{o}C for measurement. As the sensor will be effectively "blind" to the target gas whilst at 525^{o}C, it is important to consider this in your application. We recommend measuring the sensing layer resistance just before increasing the temperature to 525^{o}C. As a starting point, we recommend a 1:5 time ratio of 525^{o}C and 400^{o}C. If you are measuring low concentrations then you may wish to extend the time at 400^{o}C. Figure 1 gives an example of two-temperature pulsing with 60 seconds at 525^{o}C and 300 seconds of measurement phase at 400^{o}C.

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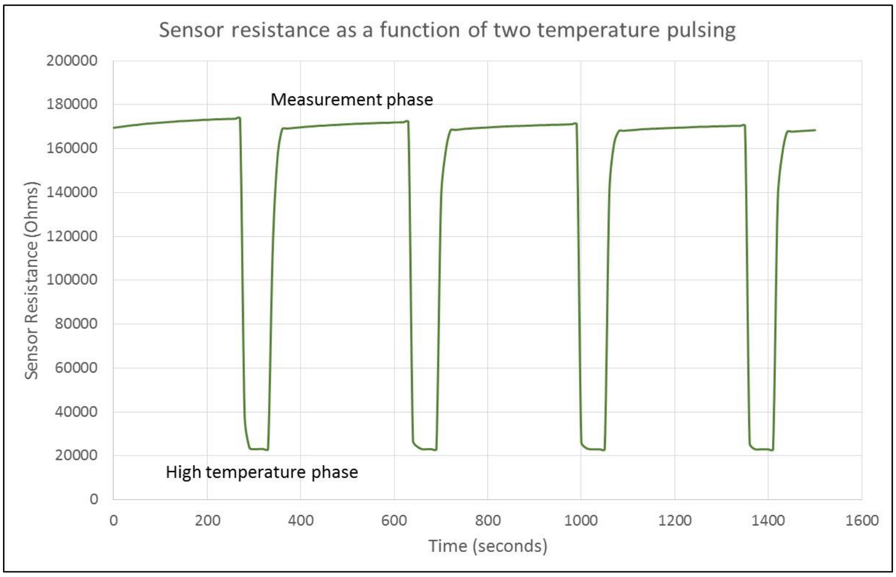

Figure 1. Typical two-temperature pulsing profile for p-type metal oxide sensor

Heater Circuit

The performance of metal oxide sensors is strongly dependent on the operating temperature, especially when using our recommended two-temperature pulsing approach. When the sensor is in use, it will be exposed to variations in flow rate and environmental conditions. Without appropriate temperature control, the sensor can deviate from its optimum operating temperature, resulting in both a shift in the baseline resistance and gas sensitivity. Temperature stability is normally achieved by accurate control of the heater temperature- in this case a thin platinum serpentine track. Platinum has a repeatable and stable TCR (temperature coefficient of resistance) for tight temperature control; if the heater is held at a constant resistance then the operating temperature of the sensor will remain constant.

Temperature control can be achieved by using a simple heater drive bridge circuit, based on a constant resistance principle. This provides a high level of accuracy, stability and repeatability to maximise the performance of the Alphasense metal-oxide based sensors. This heater drive circuit can compensate for environmental temperature ranges from -40^{o}C to +120^{o}C and changes in gas flow rates up to 1,000 sccm (1 L/min). The heater forms one arm of a Wheatstone bridge and is compared with a second 'reference' arm. If the heater resistance moves away from the reference arm setpoint due to changes in the environment or gas flow, the circuit will bring it back into balance by correcting the heater resistance, and hence heater temperature.

This circuit provides good performance, but the supply voltage must be in excess of the sensor voltage (5 V is recommended). This supply voltage must also be stable. The exact voltage applied to the heater will depend on the environment and gas flow, but will be between 2.5 and 2.9 V for 400^{o}C. This circuit also provides the opportunity for two-temperature pulsing. In normal operation, applying 'logic 0' or 0 V to the IN input allows the heater temperature to be set to 400^{o}C. When a high temperature pulse is required the IN signal should be set to 'logic 1' or 5 V; this will elevate the heater temperature to 525^{o}C.

An example circuit is shown in Figure 2, with the heater component of the sensor forming part of the arm of the Wheatstone bridge. The value of the heater resistance (and thus temperature) is set by the potentiometer. As an initial starting point, the potentiometer should be in the centre of its range. We recommend a 10-turn potentiometer.

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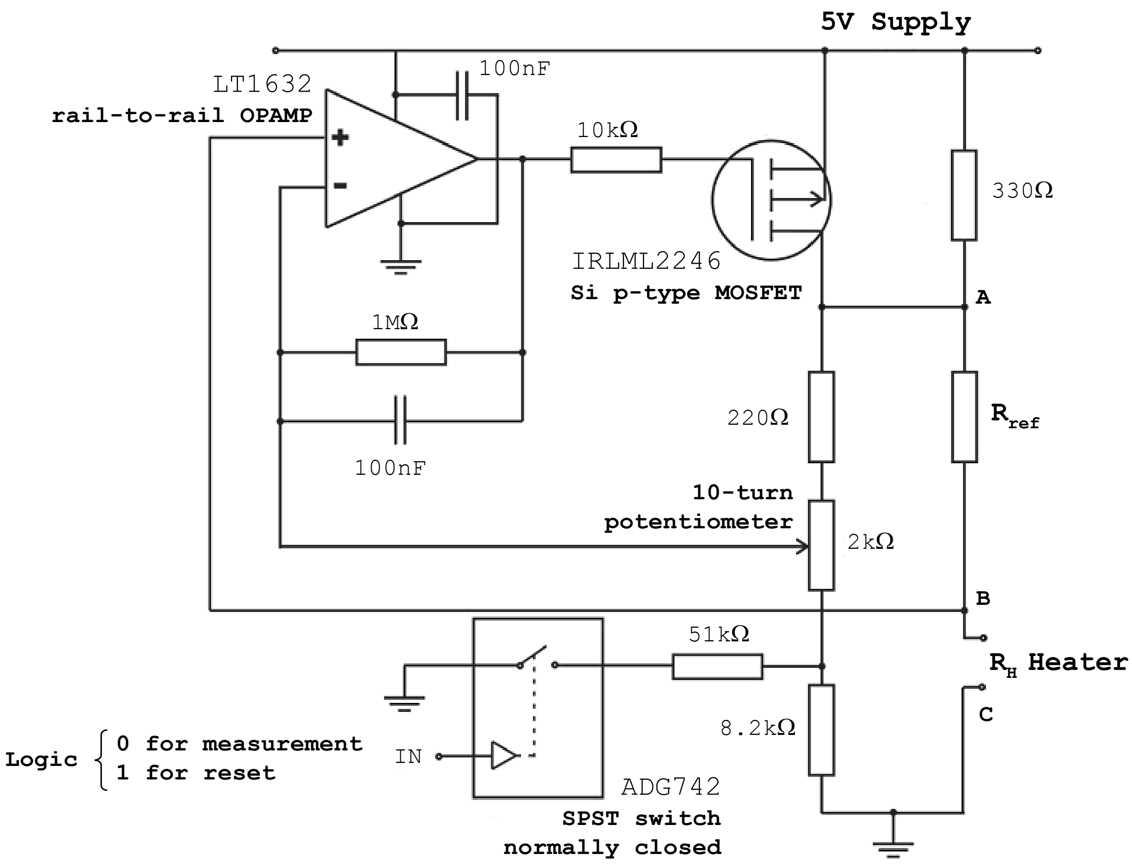

Figure 2. Wheatstone Bridge Heater Circuit

Follow the procedure below to set accurately the sensor operating temperature:

<u>Calculate Heater Resistance</u>

1. With the sensor unconnected to the circuit, measure the heater resistance (R_0). The ambient temperature should be close to 23^{o}C. You should measure a resistance around 10 Ω. We recommend using at least a 4-digit multimeter. Ideally a 4-wire resistance measurement method should be used to cancel the effect of test lead resistances.

2. Calculate the heater resistance (R_H) at 400^{o}C, using the equation:

$$R_H = R_0(1+\alpha(T-T_0))$$

   where T is the target temperature (e.g., 400^{o}C), T_0 is ambient temperature and α is the temperature coefficient of resistance, which is nominally 3255 ppm/k (at reference temperature of 23^{o}C).

3. With the sensor out of the circuit, measure accurately the resistor value between points A and B (R_{ref}, nominally 2.2 Ω, 3W).

4. Fit the sensor and power the circuit with the IN input set to logic 0. Measure the voltages between points A and B (V_{AB}) and B and C (V_{BC}) shown in Figure 2. Adjust the

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potentiometer until you achieve the expected heater resistance (calculated in step 2). You will need to measure V_{AB} and V_{BC} throughout this process. The relationship between the heater resistance (R_H) and these variables is given by:

$$R_H = R_{ref} \left(\frac{V_{BC}}{V_{AB}}\right)$$

The other resistor values are set to give 525°C when IN is set to logic 1.

Sensing Circuit

The resistance of the sensing material varies in the presence of CO, H_2S or VOCs. As the concentration of the target gas increases, so does the resistance of the sensor. For most gases, the gas concentration has a non-linear relationship with sensor resistance, following a power law where the power coefficient is typically 0.5. A linear relationship is observed using the two temperature operational mode for H_2S (< 20ppm) and CO (< 50ppm). The easiest way to measure the change in resistance of the sensor is to use a potential divider as shown in Figure 3.

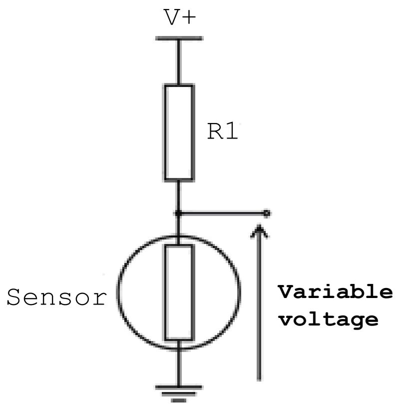

Figure 3. Simple DC sensing circuit.

A value of R1 between 100 and 200 kΩ and an applied voltage V+ less than 1 V would be typical. The output from this circuit can be amplified and filtered before being measured, with necessary tuning for the specific intended application and gas concentration range.

Sensor Usage

Alphasense metal-oxide gas sensors can be supplied in three different housings to suit your application:

1. TO-5 metal can
2. Plastic 6-pin housing
3. Ex housing (stainless steel 316 housing)

(Refer to our MMO Introduction document for further information.)

Do not obstruct the top of the sensor. Some sensors are equipped with a PTFE-based dust/water filter. Although this membrane protects sensors from water and particulates, solvents and certain corrosive gases may still damage the sensor. If your application requires additional protection, then contact Alphasense for extra or special membranes.

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