

## INTRODUCTION

This application is to provide information on how to use SGX metal oxide sensors and to interpret the sensor responses. The information should be read in conjunction with the individual sensor datasheet and the other application notes found on the website. The areas covered are as follows:

- Basic sensor principle and performance parameters – at the basic level providing qualitative response.
- How to connect the sensors.
- How to run the sensors, details of the type of test circuit and how to measure the output.
- Warm up time.
- Sensor Responses to gas need for calibration of individual sensors with target gas.
- The effect of environmental factors, temperature, drift, flow rates etc.
- Other performance parameters, cross-sensitivity, response time, sensor poisons, etc.

## BASIC SENSOR PARAMETERS

The basic principle behind the SGX and other metal oxide sensors is that the resistance of the detecting layer in sensor changes in the presence of the target gases.

For oxidising gases such as ozone or nitrogen di oxide the resistance will increase; for reducing gases such as carbon monoxide or VOC's the resistance will go down.

In very simple terms reducing gases remove some of the 'insulative' oxygen species at the grain boundaries thus causing the overall resistance to go down. Alternatively oxidising gases add to the insulative oxygen species causing the resistance to increase.

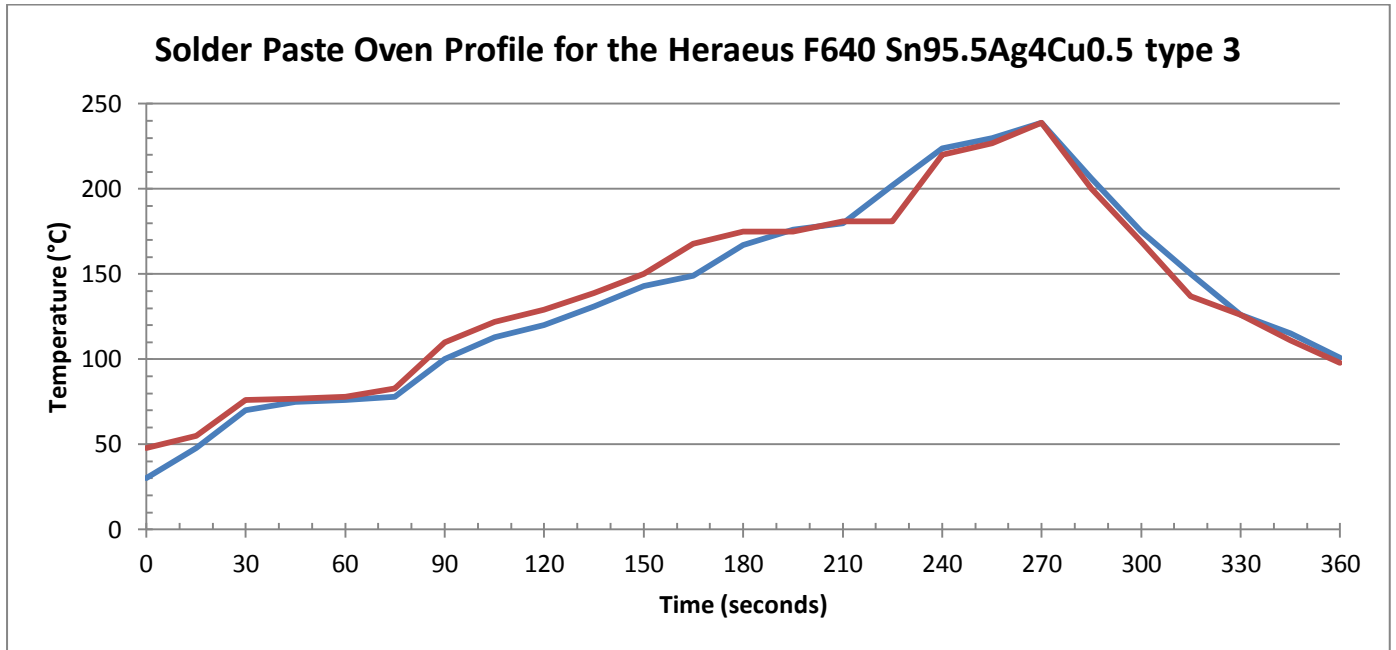
These reactions occur at elevated temperatures and hence the sensing layer needs to be heated with the integrated heater. It is one of the main advantages of the SGX sensor that the power required to heat and run the sensor are less than other types on the market.

The change in resistance with the change in gas concentration is not a linear response. The response can be measured and fitted to a polynomial relationship. Because of this and other factors the sensors are best employed where the end user is looking to detect instances or trends of gas presence rather than seeking to obtain high accuracy such as that achieved by more sophisticated analytical type systems. For these 'event sensing' applications the level of accuracy required is not great and there are unlikely to be safety related issues.

## HOW TO CONNECT THE SENSORS

The sensors are best connected to a PCB using a reflow oven. The solder paste should contain enough flux, (typically 11%) to produce a suitable joint. It is not desirable to expose the sensor to excessive flux. The process should be carried out in a neutral environment i.e. one requiring no

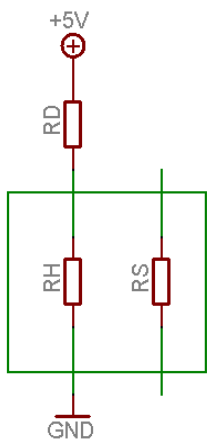
special atmosphere apart from having good filtration and air extraction. A typical solder paste used is the Heraeus F640 Sn95.5Ag4Cu0.5 type 3. A typical solder profile is shown below. The internal connections are shown on the datasheet.



## SENSOR OPERATION

(Details of the type of test circuit and how to measure the output)

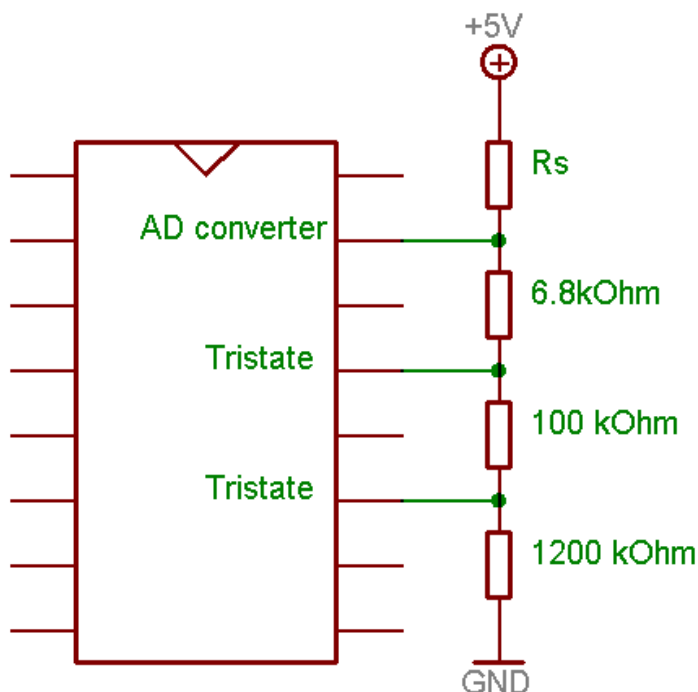
The test circuits are shown in the individual datasheets on the website. A 5 volt supply is required but the circuit requires the presence of a series resistor in the heater circuit to prevent over heating of the sensor. A series resistor is also required in the measuring circuit to limit the voltage across the detecting layer. One of the simplest circuits used for powering SGX Sensortech sensors is shown below-



A resistor  $R_d$  is used to build a voltage divider with the heater resistance ( $R_h$ ). The two resistors in series are powered with 5 V. The sensing resistor ( $R_s$ ) is then measured with an AD converter or a microcontroller, see below for an example.

## HOW TO INTERPRET THE SENSOR SIGNAL

The resistance  $R_s$  can be read with an A/D converter. To adapt the scale to the resistance range, the microcontroller can switch two or three resistors in series. The number of resistors to be switched varies with the precision of the ADC. With a 10-bit ADC, two switching resistors may be sufficient to cover a range of sensing resistance extending for example from 2k $\Omega$  to 1M $\Omega$ .



## WARM-UP TIME

The sensor needs a period of time in order for its chemical equilibrium to be set up. This is due to chemical compounds being desorbed or absorbed on the sensing surface after which point the resistance will stabilise. The rate of stabilisation is faster when the sensor is operated at higher temperatures; consequently pre-heating at a higher voltage than normal operating voltage is initially used to achieve stability before the voltage is subsequently reduced. For example, the NO<sub>2</sub> sensor is preheated (normally operated at 40 mW) at 80 mW for 30 seconds before use. Generally speaking, the longer the warm up phase, the better the precision will be.

## **SENSOR RESPONSES TO GAS**

### **(The need for calibration of individual sensors with target gas)**

Each sensor will have a different resistance in air and how much this resistance changes with concentrations of the target gas will also differ. Therefore to convert from resistance readings to concentration it is necessary to derive a calibration curve for each sensor. This will require measuring the resistances in air and at a number of gas concentrations over the desired range.

It is important that the concentrations are in a background of air as Oxygen is needed for the sensor to work correctly. The more points the better the accuracy. The response will be fitted to a polynomial.

## **THE EFFECT OF ENVIRONMENTAL FACTORS, TEMPERATURE, DRIFTS ETC.**

As the sensor is heated the resistance of the sensing layer will be affected by changes in the ambient temperature. As the resistance is used to calculate the apparent gas concentration changes in ambient temperature will cause an apparent change in the displayed gas concentration.

We observe a change of 50% (reduced to half value) for a temperature increase of 25°C for MiCS-5521 CO/VOC sensor for example.

This will affect the sensor response in air and in concentrations of the target gas. It is possible to compensate for this effect in software if the ambient temperature is measured. Changes in pressure will also affect the resistance but these are likely to be smaller than those caused by temperature changes.

Humidity may also affect the sensor resistance by thermal or chemical processes. Again it is possible to compensate if the humidity is measured. As in the case of pressure the effect will be relatively small.

Another factor which can affect the sensor temperature and hence the resistance is the flow rate of the gas past the sensor. SGX recommends placing the sensor at right angles to the flow possibly protected by a fine mesh or porous PTFE filter (Donaldson part no. EN.07.01.586). In this case the gas tends to diffuse to the sensor. Calibration must be done at the flow conditions used in the application and the flow should be kept as consistent as possible.

Another property of metal oxide sensors is that the detecting layer resistance can change with time due to changes in the internal structure. This change generally takes place over weeks and months but it does mean that sensors need to be calibrated if an optimum accuracy is required. Auto-zeroing before use is commonly used to compensate for the effects of drift.

## OTHER PERFORMANCE PARAMETERS

**Cross-sensitivity:** Metal oxide sensors are non-specific sensors and discrimination between reducing or oxidising chemical species is not possible. As well as positive cross-sensitivity gases with the opposite oxidising properties will produce apparent negative changes in displayed gas concentration. Fitting of filters, the addition of dopants and optimisation of the operating temperature can help to reduce the effects but for the most part the degree of cross-sensitivity will always be present. In many applications however it is desirable that the sensor is non-specific.

**Response Time:** The SGX sensors show a rapid response to changes in gas concentration. T90 response times are generally less than 10 seconds.

**Poisoning:** The response of the sensor can be adversely affected by the presence of compounds which can react with the chemically with the detecting layer or which can decompose to affect the rate of gas reaching the layer. Typical chemicals which can cause problems are organic silicones, high concentrations of organic vapours and fumes from soldering.