

This application note is a complement to most SGX Sensortech MiCS sensor datasheets. It contains answers to the most frequently asked questions (FAQ) asked by SGX Sensortech MiCS sensor users.

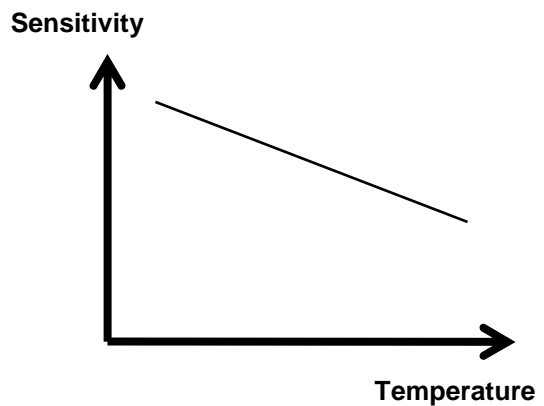
**HOW DOES A SEMICONDUCTOR SENSOR WORK?**

A sensing layer, composed of a metal oxide, generally SnO<sub>2</sub>, is heated by a heater structure. When chemicals are absorbed on its surface, its electrical conductivity changes locally; this leads to a change of its electrical resistance. Analysing the modifications of the resistance over time, compared with reference values, can give some information about variable gas concentrations. Semiconductor gas sensors are more complex than other sensors because they combine thermal, chemical and electrical effects.

The baseline resistance can vary a lot from sensor to sensor, and according to the measuring conditions, which is why SGX Sensortech recommend monitoring the sensitivity, i.e. the relative change of the sensing resistance R<sub>s</sub> against the baseline resistance R<sub>0</sub>;  $S = (R_s - R_0)/R_0$ . This allows the realisation of applications with detection of gas concentration changes rather than absolute measurements (see also calibration topic).

**HOW DO GAS SENSORS REACT TO TEMPERATURE?**

The ambient temperature has an influence on the baseline resistance, the sensitivity and reactivity of the sensors. These effects need to be characterised and compensated in order to provide an absolute measurement (see topic on calibration).



**HOW DO GAS SENSORS REACT TO HUMIDITY AND INTERFERING GASES?**

The ambient humidity has an influence on the baseline resistance, the sensitivity and reactivity of the sensors. The water is absorbed by the sensitive layer and reacts as a reducing gas. However, this effect is not strong and can be neglected in some applications. It is possible to use pulsed modes to discriminate humidity from other target gases (see also pulsed modes topic).

These effects need to be characterised and compensated in order to provide an absolute measurement (see topic on calibration).

As an example, 15 ppm ozone at 40% RH corresponds to 20 ppm ozone at 80% RH.

The influence of interfering gases such as VOCs or ozone can be suppressed by the addition of a filter such as activated carbon.

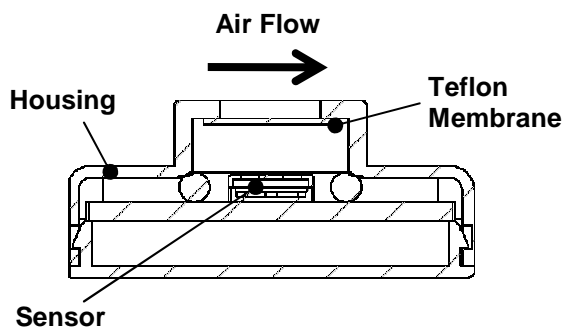
## IS A WARM-UP TIME NEEDED BEFORE USING THE GAS SENSOR?

Yes. The sensor needs some time in order to reach its chemical equilibrium. As the sensor changes temperature, some chemicals will be released and some will be absorbed the sensitive surface and the conductivity will stabilise.

The stabilisation is faster when operated at high temperature. That is why pre-heating at a higher than nominal temperature is sometimes used. As an 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.

## DOES AIRFLOW HAVE AN INFLUENCE ON THE MEASUREMENT?

Yes. Direct airflow on the sensor surface will change the conductivity of the sensor by altering the heated layer temperature. That is why SGX Sensortech recommends placing the sensor behind a Teflon membrane in most applications. The Teflon membrane allows diffusion of the gases, while reducing the influence of the air speed.



## IS CALIBRATION NEEDED, AND HOW OFTEN?

It depends on the application, and on the required precision. Several factors tend to reduce the measurement accuracy e.g. production dispersion on base resistance (R<sub>0</sub>) and sensitivity (S), temperature, humidity, the presence of interfering gases, ageing of the sensor, and on-time.

Calibration is needed when the required accuracy cannot be obtained due to one or more of the factors listed above. This is the case for most applications where an absolute gas measurement is needed.

As the characteristic curves of the sensors are non-linear, SGX Sensortech recommends the use of multi-point calibrations, covering the whole range of the application in terms of temperature, humidity and gas concentration. Once the set of calibration parameters is obtained, the data can be interpreted using polynomials or curve fitting techniques.

For some applications where accurate absolute measurement is required, a periodic recalibration is recommended. Other applications where less precision is required can manage with a single calibration.

Example: A monthly calibration is recommended for the OMC2 to measure ozone pollution in the air in the range 20 ppb to 200 ppb with  $\pm 20\%$  accuracy over a typical range of temperature of 15 °C to 35 °C.

Applications such as automotive AQS, using only relative sensor signals, do not typically require calibration.

## HOW STABLE IS A SEMICONDUCTOR GAS SENSOR WITH TIME?

Above a certain operating temperature, the heater resistance will slowly increase with time. This is a known phenomenon that can be easily compensated with an appropriate circuitry.

Long-term tests have shown that at 40 mW, no drift is measurable over 6000 hours. At 80 mW, the heater resistance can rise up to 30%. By powering the sensor with an appropriate series resistance on the heater, this resistance does not impact the sensor power by more than 2% over the same period, which is sufficient for most applications. More sophisticated "constant power" circuitry can be used to fully eliminate this effect.

A second source of sensor characteristics drift is the ageing of the sensitive layer itself, for example due to poisoning from ambient pollutants. This behaviour is strongly dependent on the application and should be tested in the appropriate configuration.

## HOW LARGE IS THE R<sub>0</sub> AND S PRODUCTION SPREAD?

On the baseline resistance, a factor of 5 in production spread is typical. The sensitivity is typically spread over a factor of 2 to 8 depending on the target gas. This data comes from laboratory measurements. In the real application conditions, these figures are typically lower.

For example, in automotive applications, the gas sensors are set up to react to a broad range of gases (such as VOCs). In this case, the tolerance on sensitivity is reduced by a factor of 2 or 3 instead of 8.

## HOW CAN I AVOID PERMANENTLY DAMAGING THE SENSORS?

Any over-voltage leading to powers greater than 120 mW will permanently damage the sensor. The sensors are also ESD sensitive and should be properly handled to avoid any adverse effects.

Generally, SGX recommendations are as follows:

- The sensor must not be wave soldered without protection.
- The sensor must not be exposed to high concentrations of organic solvents, ammonia, silicone vapours, e.g. HMDS or cigarette smoke, in order to avoid poisoning the sensitive layer. Silicon vapours can permanently damage the sensitive layer of the sensor, due to a coating effect.
- Heater voltages above the specified maximum rating will destroy the sensor due to overheating. Heating by PWM between 0 and 5 V has been tested until 100,000 Hz and destroys the sensor. The heating voltage must be pure DC voltage.
- This sensor should be placed in a filtered package that protects it against liquid, water or dust projections.
- Degassing of plastic material can adversely influence the product performance, mainly due to the presence of Volatile Organic Compounds. The components of the plastic housings, O-rings, foams etc. must be degassed before assembly.
- To protect the sensor, a convenient solution is to place it in a sealed plastic housing. The sensor element is placed near a hole that is closed with a breather membrane (polyester coated with PTFE) such as those used to avoid contamination of microelectronic devices.

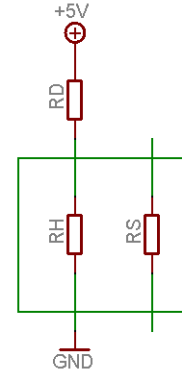
## CAN GAS SENSORS BE POISONED?

Yes, some gases can modify the behaviour of the sensing resistance (see also sensor damage topic).

## HOW TO POWER THE SENSOR

**Warning:** The sensor should be powered with a DC voltage. It could be thought that powering the heating circuit with 5 V and a PWM rate of 65% is equivalent to powering it with 3.25 V constant voltage. This is not the case. As the sensor structure consists of a precisely micro machined silicon diaphragm with an embedded heating resistor  $R_h$ , the resulting over-voltage would permanently damage the sensor. This configuration has been tested with up to 100.000 Hz.

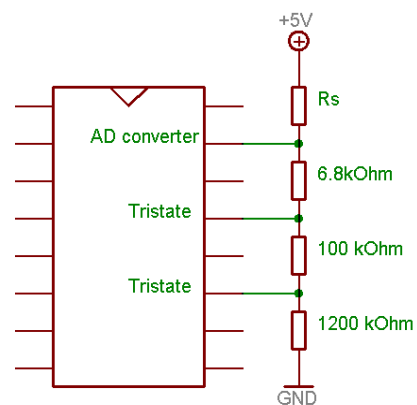
One of the simplest circuits used for powering SGX Sensortech sensors is the following:



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, for example (see also signal interpretation topic).

## 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 $\Omega$ .



## WHAT ARE PULSED MODES, AND HOW CAN THEY HELP?

“Pulsed Modes” consist of powering the sensor heater with pulses instead of DC voltages, and then exploiting the dynamic behaviour of the sensing resistance instead of reading a stabilised or quasi-stabilised output.

These application modes are very powerful and very complex. In order to clarify the possibilities of such methods, an example for the detection of CO is provided.

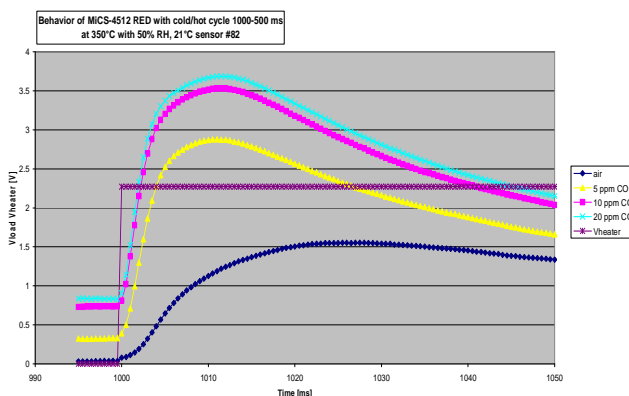
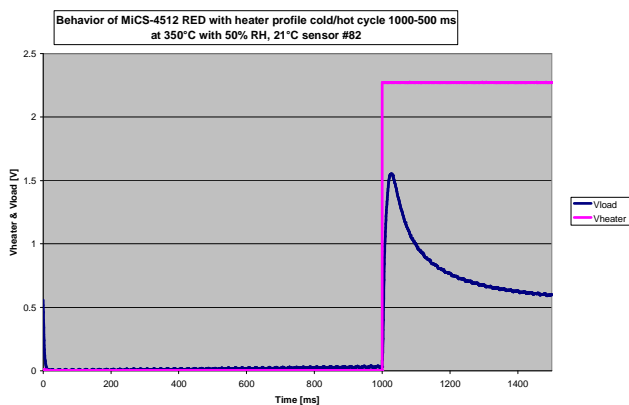
Carbon monoxide reacts at lower temperatures than volatile organic compounds (VOC) or combustible hydrocarbons (CHC) because the CO molecules do not need to dissociate to react with the SnO<sub>2</sub> layer. Therefore, the selectivity to CO is higher at lower temperatures. Unfortunately, at low temperatures, the response time is high and the sensing surface can easily accumulate interfering gas species such as water vapour or VOCs. A high temperature “step” ensures that the sensing layer is cleaned and sensitised before each new measurement. Since the average operating temperature is lower in the cycled mode than in the constant-voltage mode, the average power consumption is reduced as well, which can be a decisive advantage in many applications.

During the high temperature step (around 100 mW for example), absorbed interfering species are removed from the sensing layer). When the temperature abruptly changes\* from the high level to the low level, a new chemical balance tries to establish itself. This leads to dynamic effects on the sensing resistance that carry information on the presence of gases. In the case of CO, after the change from hot to cold, the resistance rises sharply and then falls gradually towards a new stable value. The observed decay in resistance reflects the reaction kinetics involved in the oxidation of the CO molecules and the ion sorption of oxygen. The resistance of the sensing layer can for example be measured at the end of this cold step. Another way to extract valuable information is to measure the sensor resistance on several points immediately following the temperature transitions.

These methods have significant potential but require specific development for each application. Power consumptions as low as 1 mW can be achieved while still extracting appropriate information on the gas(es) to be detected.

The optimum duration of the pulses can vary from 20 ms to several minutes, depending on the application and the response time and accuracy required.

\* The typical heater temperature rise time and fall time is approximately 20 ms.



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