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OPERATING INSTRUCTIONS

SGX-VOX

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This document serves to provide the user with detailed information about the function of the SGX-VOX partial pressure sensor and includes;

- An overview of the design of the SGX-VOX and an insight into how the sensor operates.
- A summary of implementation recommendations which should be considered when designing equipment to use the sensor.
- An overview of the technical performance of the sensor including key characteristics.

It is hoped that the included information is a comprehensive guide to using the sensor but if you require further information, our technical support team is on hand to assist. Please do not hesitate to contact us at sales.is@sgxsensortech.com

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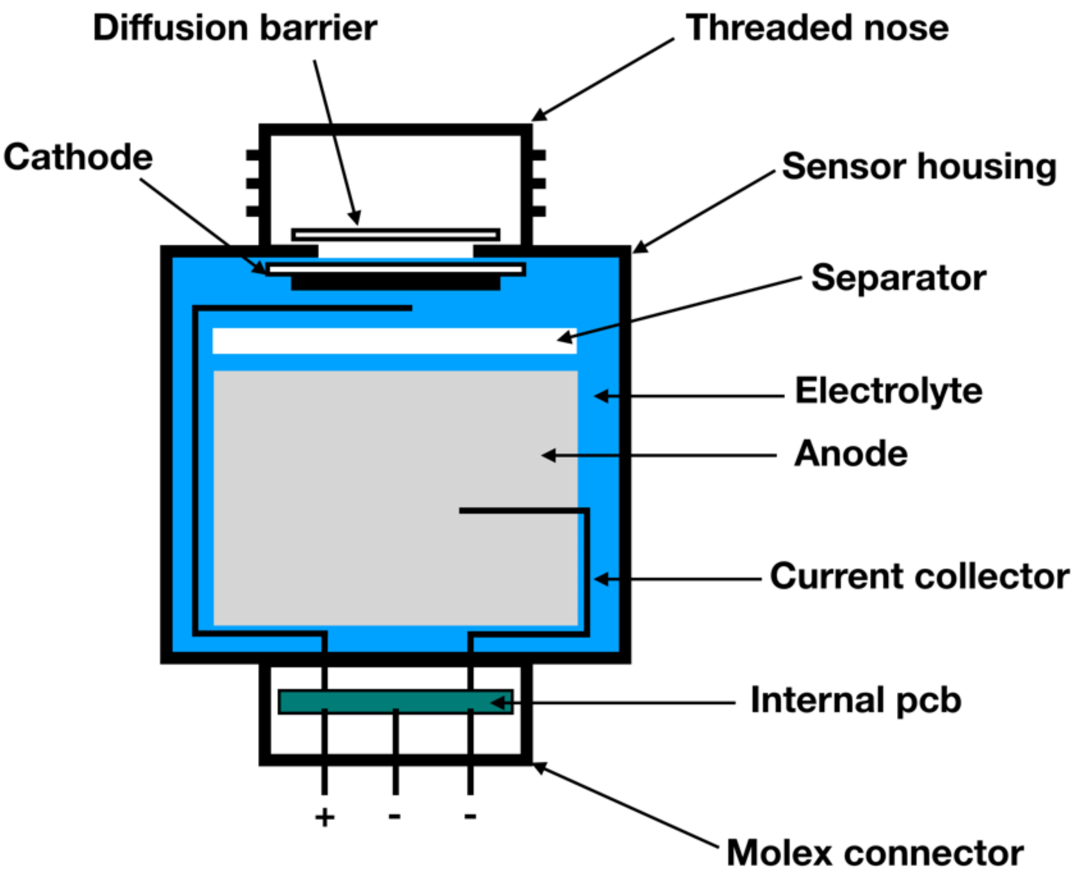
Introduction

The SGX-VOX sensor is an electrochemical oxygen sensor optimized for use in emergency ventilator use and applications where a fast, reliable measurement of oxygen is required in the range of 0-100%. It is provided with an easy Molex- type connection interface and features on-board temperature compensation to flatten the change in response of the sensor between 0°C and 40°C.

An overview of the construction of the sensor is provided below;



The sensor is constructed from ABS (acrylonitrile butadiene styrene) which provides excellent mechanical strength as well as chemical resistance. At the front of the sensor is a threaded nose which allows easy fitment into equipment manifolds. At the rear of the sensor is a Molex socket with three connections; two of the three pins are connected to the negative terminal of the sensor (the anode) and one pin is connected to the positive terminal of the sensor (the cathode).

Inside the sensor, the key components are the electrodes;

- A sensing electrode (or cathode) which catalyzes the reduction of oxygen gas when it enters the sensor according to the following chemical reaction;

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$$

- A counter electrode (or anode), made from metallic lead which reacts with the hydroxyl ions produces at the sensing electrodes to form lead oxide;

$$2Pb + 4OH^- \rightarrow 2PbO + 2H_2O + 4e^-$$

When the two electrodes are connected (via the current collectors and the internal PCB), the electrons (e^-) are able to move freely through the circuit and thus, there is a current generated. This current is proportional to the concentration of oxygen as the amount of O_2 molecules entering the sensor is limited by the diffusion barrier at the top of the sensor. The electrodes are internally insulated inside the sensor by use of a separator.

The net chemical reaction that is taking place inside the sensor is;

$$2Pb + O_2 \rightarrow 2PbO$$

Since the anode is oxidized during this process, the SGX-VOX has a finite life which is directly affected by the amount of oxygen sensor sees. When used in high oxygen sensor concentrations, the sensor will work for less time and vice versa. As a result, the SGX-VOX life is specified as a %hours figure.

An important point to note is that the SGX-VOX provides a signal which is proportional to the **partial pressure** of oxygen present and not the percentage by volume (%) concentration. This is explained in greater detail in the next section.

The rate at which the electrochemical reactions take place varies with temperature and so the output of the sensor also varies as a function of temperature. The SGX-VOX is however fitted with an internal thermistor-resistor network to flatten this effect.

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Partial Pressure versus Percentage Oxygen Concentration

When we talk about oxygen concentrations, it is conventional to denote them in percentage by volume terms. Thus, the ambient concentration of oxygen is air is typically written as 20.9% (with 78% being nitrogen and the remaining 1% a range of other gases). However, the SGX-VOX does not respond to the $\%O_2$ concentration – it responds to the partial pressure of oxygen.

To understand this fully, here is an example. At sea level, the average atmospheric pressure is 1013mbar, at the top of Mount Everest, it is roughly 300mbar. The percentage concentration of oxygen in both places is approximately 21% but it is much harder to breathe at the top of the mountain, because the partial pressure of oxygen is much lower. At sea level, the partial pressure of oxygen is 20.9/100 * 1013 = 212mbar, at the top of Mount Everest, the partial pressure of oxygen is 20.9/100 * 300 = 62.7mbar. If you calibrated the SGX-VOX sensor to 20.9% oxygen at sea level and then measured at the top of Mount Everest (without pressure compensation), you would get an equivalent reading of 6.2%.

Therefore, the output of the SGX-VOX sensor must be compensated for ambient pressure by use of a pressure sensor which is in the gas stream. The relationship of output to pressure of the SGX-VOX is directly proportional to the atmospheric pressure, thus for a sensor with a known output (S0) at a particular pressure (P0), the signal (S1) at a different pressure (P1) can be calculated as follows;

$$S_1 = \frac{S_0 \, x \, P_1}{P_0}$$

Linearity

The output of the sensor is linear with the concentration of oxygen which is to say that the output of the sensor doubles if the oxygen concentration doubles. The tables below show some typical data for the SGX-VOX sensor when subjected to three different oxygen concentrations; 0%, 20.9% and 100%.

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	Output (mV)			%O2		
Sensor / **O_2 Conc.**	**0%**	**20.90%**	**100%**	**0.0%**	**20.9%**	**100.0%**
1	0.03	11.37	54.04	0.06%	20.9%	99.3%
2	0.03	11.73	55.99	0.05%	20.9%	99.8%
3	0.03	11.64	55.55	0.05%	20.9%	99.7%
4	0.03	11.71	55.91	0.05%	20.9%	99.8%
5	0.03	11.77	56.23	0.05%	20.9%	99.9%
6	0.03	11.47	54.79	0.06%	20.9%	99.8%
7	0.03	11.34	54.13	0.06%	20.9%	99.8%
8	0.03	11.25	53.76	0.06%	20.9%	99.9%
9	0.03	11.63	55.56	0.05%	20.9%	99.9%
10	0.02	12.07	57.65	0.04%	20.9%	99.8%
11	0.03	11.56	55.33	0.05%	20.9%	100.0%
12	0.03	11.6	55.39	0.05%	20.9%	99.8%
13	0.03	11.46	54.85	0.06%	20.9%	100.0%
14	0.02	11.26	53.86	0.04%	20.9%	100.0%
15	0.03	11.14	53.31	0.06%	20.9%	100.0%
Mean	**0.03**	**11.53**	**55.09**	**0.05%**	**20.90%**	**99.83%**

The data demonstrates the highly linear behavior of the SGX-VOX sensor. It also highlights the fact than in zero gas (0% oxygen), the sensor has a small but measurable baseline or offset. In most cases, the offset value can be ignored, but for optimum accuracy, we recommend determining the offset of the sensor during calibration by exposure to zero gas.

Please also note that if the sensor is exposed to partial pressure of oxygen of greater than 3.0bar, the sensor will become non-linear. In addition, if the millivolt output of the sensor exceeds 150mV as a result of use at high temperature, the sensor may also demonstrate non-linearity.

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Response Time

The response time of the SGX-VOX is characterized as either a T90 or T99.5 value. This is defined as the time taken for a sensor to change from its initial value to 90% or 99.5% of its final value. The SGX-VOX is a very fast responding sensor as a result of careful selection of diffusion membrane and catalyst material. The response time will vary as a function of temperature – it is typically faster at higher temperatures and slower at lower temperatures. Response times can be enhanced by ensuring that the gas delivery system provides a turbulent flow to the sensor.

Response to Humidity

The SGX-VOX sensor does not respond directly to relative humidity nor is its accuracy affected. However, if the sensor is subjected to high moisture levels where there is a possibility of condensation, water can form on the sensing surfaces and reduce the sensor output. If equipment fitted with the SGX-VOX sensor is moved from a warm environment to a cold environment, we would recommend allowing it to settle at the new temperature for at least two hours before use for measurement.

Sensor Start Up Time and Storage

Unlike many oxygen sensors which are supplied open circuit, the internal PCB of the SGX-VOX effects a connection between the two terminals. This connection ensures that the SGX-VOX has no start-up time when it is removed from its packaging and as soon as it is connected to external electronics, it will provide a to-specification performance. However, the permanent connection does mean that the sensor life is being consumed as soon as the protective cap (pictured right) is removed from the sensor. We would therefore recommend that the protective cap is removed only at the point that the sensor is intended to be used and prolonged storage of the sensor without the cap is avoided.

If the sensor is kept in its original packaging and is stored in a cool (0-20°C) environment away from solvents and cleaning products

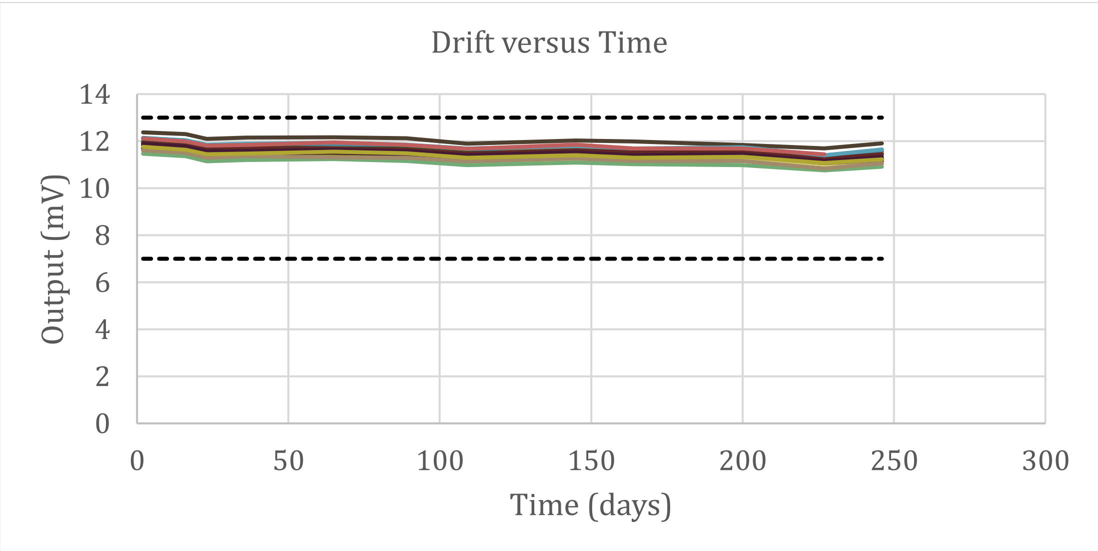
Intrinsic Safety Considerations

The SGX-VOX sensor does actively produce a current but under typical conditions, the current is limited by the diffusion membrane, and typically the oxygen concentration. For intrinsic safety purposes, the maximum short circuit current and open circuit voltages are provided below;

Intrinsic Safety Data	
Maximum current in normal operation (pure O2)	0.01 A
Maximum o/c Voltage (10 to 100% O2)	0.9 V
Maximum s/c Current (10 to 100% O2)	0.5 A

Sensor Life

The SGX-VOX is designed to provide highly stable and accurate measurements throughout its working lifetime. It is specified as having less than 5% drift per annum, as our ambient storage data (shown below) demonstrates.



The sensor will continue to provide a very stable output over time until it nears the end of its life. At this point, the output will collapse quickly over a 2-4 week period; this is the point at which the sensor should be replaced.

Anesthesia Gases and Carbon Dioxide

The SGX-VOX is **not** designed for use in the presence of anesthetic gases. Halogenated anesthetics such as Halothane or Isoflurane will dramatically interfere with the measured signal and lead to highly inaccurate measurements.

The sensor may be used in atmospheres of N_2O (nitrous oxide) for short periods of time. We have characterized the sensor with Entonox and the sensor shows excellent stability for up to 5 hours exposure.

The SGX-VOX sensor can be used in atmospheres where carbon dioxide is present as it has little to no influence from this gas.

Electrical connection

The sensor provides a millivolt output between the positive and negative terminals and requires no additional power to function. If the sensor is used in series with an external load resistor, we recommend using a resistance of greater than 10kOhms. For connecting to the sensor, we recommend the following parts.

Molex Black, 0.2 mm² Equipment Wire KK Series , 300mm
Mfr. Part No. 88941-0700

Molex KK 254 Female Connector Housing, 2.54mm Pitch,
3 Way, 1 Row
Mfr. Part No. 22-01-3037