Basic Sensor Operation

AN001e-0 (11/2025)

Scope

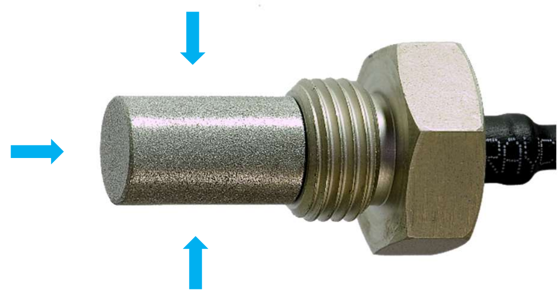
Outlines how to interface and operate a 25% oxygen (O_2) sensor using lab equipment. It covers basic characteristics, how to connect and calibrate our sensor to ensure accurate measurements.

1 Gas Interface

The oxygen sensitive element is a small, heated disc inside the sensor housing. The gas interface is where the ambient gas can enter the sensor housing.

Gas exchange via mesh on top
(TO-8 sensor housing)

Gas exchange via sinter cap or disc
(Threaded sensor housing)

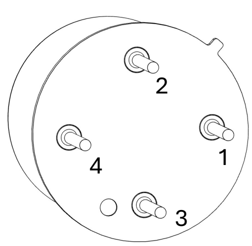


2 Electrical Interface

The sensor heater (H+ and H-) will heat up the sensor element to 550-600°C. The heater voltage should always be measured at the pins of the heater. Therefore, all sensor cables provide sense lines (HS+ and HS-), which are connected to the heater lines (H+ and H-) at the heater pin, see picture below of a 6-pole cable to 4 pins.

After application of a bias voltage (between S+ and S-) the sensor element (also S+ and S-) will act as an oxygen-controlled current source.

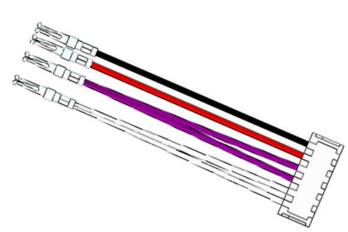
Housing (Pin Side View)



Pin layout /cable color

Pin No	function	color
1	Heater H+ Sense HS+	violet violet
2	Heater H+ Sense HS-	white white
3	Sensor S+	red
4	Sensor S-	black

6 pole cable to 4 pins



3 Basic Sensor Operation

It is recommended to use an O2-sensor with 25% range for initial sensor tests in air. Sensors with 96% range are a possible alternative. Sensors with lower ranges (5%, 2%, 1%, 1000ppm) should not be operated in air, and would therefore require additional means to provide a proper O2-concentration.

3.1 Identify nominal heater voltage and bias voltage from sensor datasheet

The datasheets state a nominal heater voltage under standard conditions (25°C, 1 bara, no heat sink/source):

- For TO-8 housing it is typically between 3.6V and 3.8V
- For threaded housings it is typically between 3.8V and 4.1V
- Recommended stability of the heater voltage: within ± 0.05V
- The heater current typically lies between 350mA and 450mA

Please refer to the sensor data sheet to identify the nominal heater voltage. The nominal bias voltages depend on the measurement range of the sensor, e.g.

- For 96% sensor U_{bias}= 1.0V
- For 25% sensor U_{bias}= 0.85V
- Recommended stability of the bias voltage: within ± 0.05V

3.2 Apply heater voltage

Preparation before connecting the sensor:

- Turn voltage supply output to 0V
- Set current limit to 0.5A

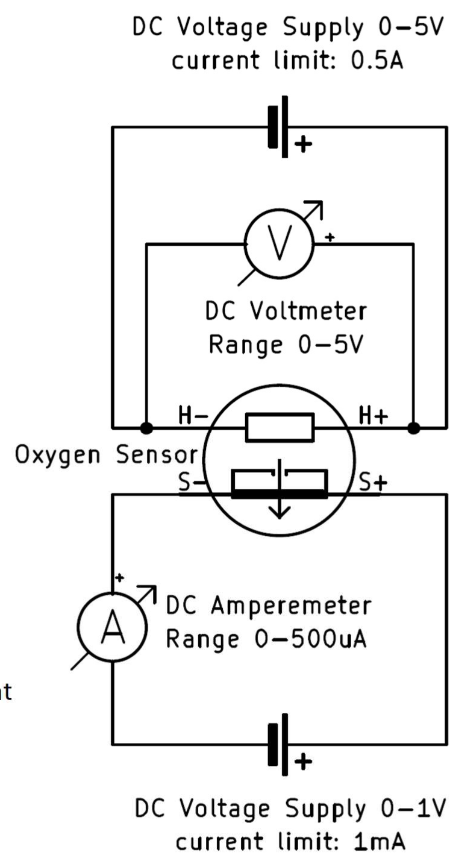
Connect sensor heater via 4-wire connection:

- Power supply with sense lines, or
- use a DC Voltmeter (see picture)

Ramp up heater voltage slowly:

- (linear) voltage ramp for 30s
- up to the nominal heater voltage

The sensor housing will be a hot surface!
Do not touch a heated sensor!



3.3 Apply bias voltage measure sensor current

The bias voltage can be applied before heating up the sensor, an amperemeter is necessary to monitor the sensor current. While the sensor is cold the current is supposed to be 0. During the heat-up ramp, there might be a temporary current peak, after that the sensor current should settle. Typical sensor currents in air:

- 25% sensor between 100 and 200uA
- 96% sensor between 15 and 30uA

4 Further Steps

4.1 Response Test / Bump Test

For a simple response test, it is necessary to reduce (or increase) the O2 concentration in the proximity of the sensor's gas interface, the sensor current should go down (or up) accordingly. Recommended gas supplies:

- high nitrogen concentration from a nitrogen generator or N2 cylinder
- for 96% sensor also high O2 concentration from an oxygen generator or O2 cylinder 100% O2 will saturate and stress the sensor cell, apply it only for a short time

If no artificial gas mixtures are available, you can simulate reduced oxygen levels by slowly exhaling onto the sensor's gas inlet. Beware of hot sensor housing.

4.2 Calibration in air / sensor characteristics

The sensor current *Is* at a given volumetric oxygen concentration $[O_2]$ is given by:

$$Is(O_2) = -k \cdot \ln\left(1 - \frac{[O_2]}{100\,\%}\right) \qquad [1]$$

k is a sensor specific constant. **Each sensor must be calibrated individually!**

The following conversions of equation [1] will be helpful:

$$k = -\frac{Is\,(O_2)}{\ln\left(1 - \frac{[O_2]}{100\,\%}\right)} \qquad [2]$$

$$[O_2] = \left(1 - e^{-\frac{Is(O_2)}{k}}\right) \cdot 100\,\% \qquad [3]$$

Remarks / Examples:

- Dry air has ~20.9 % O2
- At average humidity (50%.r.h @ 25°C) air has ~20.7 % O2, due to O2 displacement.
- For 20.7 % O2 the logarithmic term is: $\ln\left(1 - \frac{20.7}{100}\right) = -0.232$
- This explains the negative signs in the equations
- So, calibration of a 25% sensor is done by exposing the sensor in air and reading out the sensor current, assuming a sensor current of 150uA at 20.7 % O2: $k = \frac{150uA}{0.232}$
- Calibration based on a reference O2/N2-mixture from a gas cylinder, can be done in a similar way by inserting the nominal O2 concentration in equation [2], and performing a sensor current readout during exposure to the reference mixture.
- The oxygen sensor is sensitive to the volumetric oxygen concentration(vol.% O2)