Introduction:

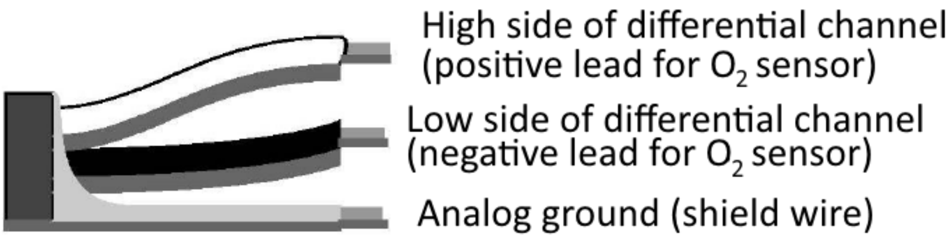
The ICTO2 Soil Oxygen Sensor performs measurements based on a Galvanic cell principle. It is a passive sensor and does not require voltage input. The sensor has an automatic temperature compensation via an in-built thermocouple compensation circuit. The sensors are Teflon coated and made from long lasting plastics. Life expectancy in the field is five years.

Specifications:

Theory	Galvanic battery + porous membrane sheet
Shape	Diameter 35 mm, length 65mm (cable connector length 50mm)
Output	45~65 mV at 20.9% O_2 (users must check the output of the air before set-up)
Accuracy	±0.5%
Weight	220 grams (includes 5m cable)
Cable Length	5 m (+ white, – black, shield cable)
Temperature effect	At R.H. 100% and O_2 20.9%. Sensor output is 20.8% at 5°C, 19.4% at 40°C. At R.H. 0% and O_2 20.9%. Sensor output is not Influenced by temperature.
Temperature	0~40°C when in use

ICTO2 Sensor Wiring Diagram

Connect the sensor to a measurement device capable of measuring a millivolt signal with range of approximately 0-60mV to cover a range from 0-20.95 %.



Absolute and Relative Gas Concentration:

Gas phase oxygen concentration can be described as both absolute and relative. Assuming dry air, relative oxygen concentration is 20.95% and is the same at any elevation and temperature around the world. Absolute gas concentration in air changes with temperature and pressure as described by the ideal gas Law. The ICTO2 responds to absolute oxygen concentration but is internally compensated for temperature to give relative oxygen uncompensated for pressure. The ICTO2 is usually used to measure relative oxygen. The mV measurements from ICTO2 are converted to %O_2 by a linear conversion. If pressure is logged, corrections for pressure can be applied to the measured oxygen concentration. The variation of pressure over altitude will have a significant effect on the ICTO2 relative oxygen concentration measurements. The ICTO2 must be calibrated by the user in a controlled environment which is at the same altitude as the final installation site (see ICTO2 Sensor Calibration Procedure).

Sensor Calibration:

The ICTO2 outputs a voltage that can be converted to relative oxygen concentration. The measured relative oxygen concentration is internally compensated for temperature. The output of the ICTO2 is a linear relationship to relative oxygen concentration assuming no change in barometric pressure.

To convert the sensor output voltage to relative oxygen (in %O2) the measured voltage output of the sensor in millivolts (mV_m) is multiplied by a calibration factor (CF).

$$O_2 = CF \cdot mV_m \qquad (1)$$

The calibration factor is derived by dividing the ambient relative oxygen concentration of air (20.95 %O2) by the measured voltage output from the sensor millivolts under calibration conditions.

$$CF = \frac{20.95\ \%\ O_2}{mV_c} \qquad (2)$$

Where mV_c is the sensor output in mV. See the section titled 'ICTO2 Calibration Procedure' for determining mV_C. The calibration factor is variable from sensor to sensor and a sensor specific calibration must be derived for individual sensors.

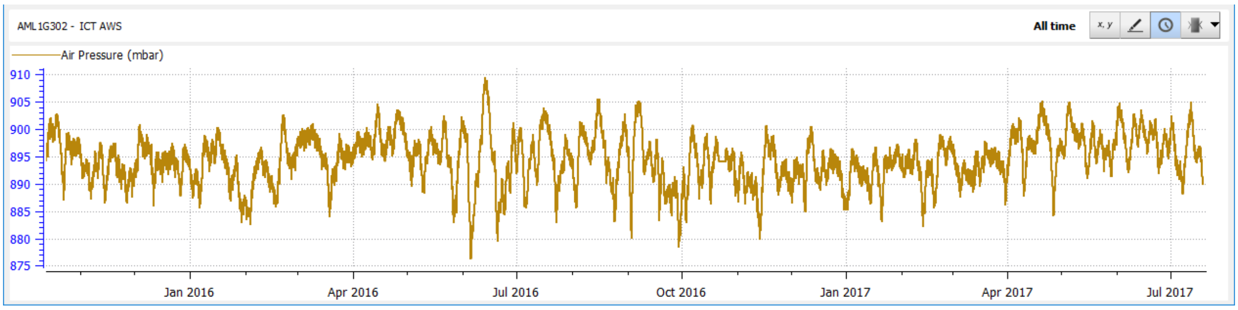
Effect of Barometric Pressure on Oxygen Concentration:

A barometric pressure correction can be applied to the relative oxygen measurement from equation 1. The equation to correct relative oxygen measurements for barometric pressure is:

$$\%O_2 = \text{measured } \%O_2 \left(\frac{P_C}{P_M}\right) \qquad (3)$$

Where, P_C is the barometric pressure at the time of calibration, and P_M is barometric pressure at the time of the measurement.

The plot below shows 1.5 years of pressure data in Armidale where a deviation in pressure of 34mbar is measured.

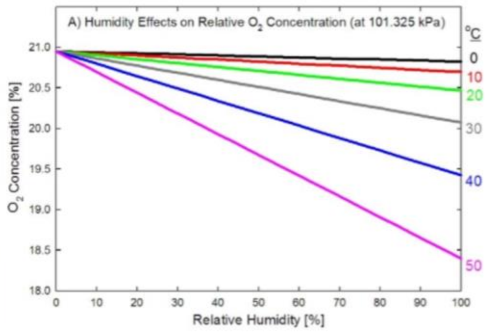


The maximum error in $\%O_2$ measurements that would result if barometric pressure corrections were not applied to relative O_2 measurements in this example, assuming a 20.9 % relative oxygen concentration and assuming the sensor was calibrated when Barometric pressure was 893mbar, for the above example would be ±0.4% O_2.

Unless pressure corrections are applied the user must calibrate at an altitude that is close to that where it is installed.

Effect of Humidity on Oxygen Concentration:

When the absolute humidity of the environment increases the percentage concentration of the gas, including oxygen, decreases. That is, water molecules displace the oxygen and thus cause an actual decrease in relative oxygen concentration. The effect of water vapour on relative oxygen concentration shown as a function of relative humidity and temperature is shown in the figure below.



The air in soil is typically saturated with water vapour.

Deployment and Installation:

To facilitate the most stable readings, sensors should be mounted vertically, with opening pointed down. Sensors are resistant up to about 2.0 G of shock. Vibration and mechanical shock may influence sensor sensitivity and should be minimised in actual usage. Temporary changes/instability in the sensor's output signal may result due to these factors, but the signal may recover to its original state after the sensor is kept motionless in natural air/room temperature for between several hours to several days. If the mechanical shock or vibration is great, an irreversible change in the output signal may occur due to structural damage within the sensor. Shock absorbing measures should be used to protect the sensor during transportation or when used for applications in which shock/vibration is likely to occur.

Maintenance and Recalibration

The life expectancy of the ICTO2 sensor is approximately five years when placed in standard atmosphere pressure exposed to 20.95% relative oxygen concentration at a temperature of 25ºC. Higher temperatures will result in a shorter life expectancy and lower temperature a longer life expectancy.

Recalibration of the sensor can be done periodically. The sensor signal decreases by approximately 1 mV per year (or approximately 2% of signal output) at 25% oxygen. This signal decrease yields an increase in calibration factor of approximately 2% per year.

ICTO2 Sensor Calibration Procedure

1) The ICTO2 sensor has a four-digit serial number engraved on top of the sensor body. The sensor wire should be labelled with this serial number or other identification. The individual ICTO2 sensor calibrations should be related the sensors serial number.
2) Place the ICTO2 sensor/s in air and out of direct sunlight inside a normal room with airflow and orientate with the sensor opening pointed downward, but not blocked at the bottom. The sensor output can be effected if it is subjected to abrupt forces for example dropping or shaking the sensor.
3) Verify the sensor output is between 35-60mV using a multimeter. A new sensor should be between 35 and 60mV. Verify the sensor is not oversensitive by measuring the sensor output while lightly tapping it (you should not see changes greater than 3 mV). If the voltage is not between 35 and 60 mV and or is over sensitive, the sensor may be defective.
4) Connect the ICTO2 sensor/s being calibrated to a logger.
5) Setup logger so that it measures the mV output of the sensor connected, logging at 5 minute intervals for a minimum of 48 hours (longer is recommended) and do not move for the duration of the calibration.
6) If barometric pressure corrections will be applied to the relative oxygen measurements, you will need to know the barometric pressure for the calibration period.
7) Download the data after a test period (a minimum of 48 hours - **3 nights recommend**).
8) Plot the "mV" data set for the sensor/s being calibrated and check that the difference between the maximum and minimum mV value is no more than 2mV. If the data has large variation or there are spikes in the data set, the sensor might be defective.
9) Determine the maximum mV value. The maximum value is the mV_c value needed in equation 2 used to derive the calibration factor (for example mV_c = 48.5 mV). Find the corresponding barometric pressure at this time, which will be the value of P_C in equation 3.
10) Create a conversion script or lookup table for the sensor.
11) You may now test the calibration script or lookup table.