

## Application Notes for the Maxell Oxygen Sensor KE / KE-LF Series

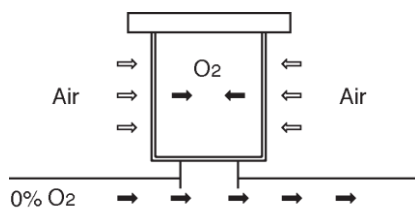
# Application Notes on Offset Voltage and Low Concentration Measurement

*This technical information explains some of the basic matters concerning offset voltage of the Maxell Oxygen Sensor KE/KE-LF Series and notes for using these sensors for performing low concentration measurement.*

### 1. Basic Information

The KE/KE-LF series oxygen sensors have a background current at 0% oxygen concentration which creates an **offset voltage**. This characteristic is not relevant at concentrations higher than 1%, but it is of significance at less than 1% concentrations, and especially for those lower than 0.5%. As a result, it is necessary to develop a suitable methodology to compensate for offset voltage when measuring very low concentrations of oxygen.

The reason that offset voltage exists can be traced to the design of the sensor and the materials used in the sensor's body. The KE/KE-LF series sensors use an acid electrolyte, so in order to avoid corrosion of the sensor's body, a plastic material (ABS) is used for the body. This plastic material allows a small amount of oxygen to diffuse from the atmosphere, and this diffused oxygen dissolves into the electrolyte. The dissolved oxygen in the electrolyte reacts with the electrodes and produces a small current, even when subsequently placed in a 0% oxygen atmosphere.



**Figure 1:** Standard Measuring Method

When the sensor body is exposed to ambient air, the amount of dissolved oxygen reaches an equilibrium level and offset voltage is stabilized.

### 2. Offset Voltage

The offset voltage of each sensor varies within a

certain range, stabilizing at approximately  $0.25\text{mV} \pm 0.10\text{mV}$  for KE-25/KE-25LF, and  $2.50\text{mV} \pm 1.0\text{mV}$  for KE-50 (for standard models).

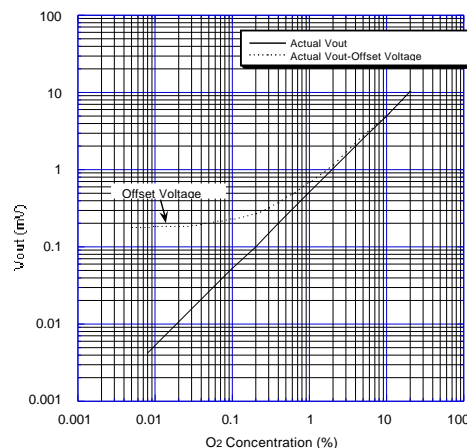
In the electric circuit of an appliance, it is recommended that the output voltage of the zero point is set at  $0.25\text{mV}$  for KE-25/KE-25LF and at  $2.50\text{mV}$  for KE-50 (the center value of the distribution range for offset voltage).

Offset voltage may drift when the equilibrium value of the dissolved oxygen in the electrolyte changes, such as when the sensor is exposed to extremely low oxygen concentrations continuously. When the oxygen concentration is at the zero level, stabilization takes a long time to occur (several hours).

A sampling system for low oxygen concentration measurement is recommended in order to reduce the influence of offset voltage drift as caused by the change in oxygen diffusion through the sensor's body.

### 3. Notes for Low Concentration Detection

For accurate low concentration measurement, it is recommended that offset voltage be subtracted from actual output voltage as shown in the attached **Figure 2**. By using this method, detection to several hundred ppm is possible.



**Figure 2:** KE-25 compensation for offset voltage

## APPLICATION NOTES FOR KE/KE-LF

The recommended procedure to calibrate for low concentration detection (100 ppm level) requires the following steps:

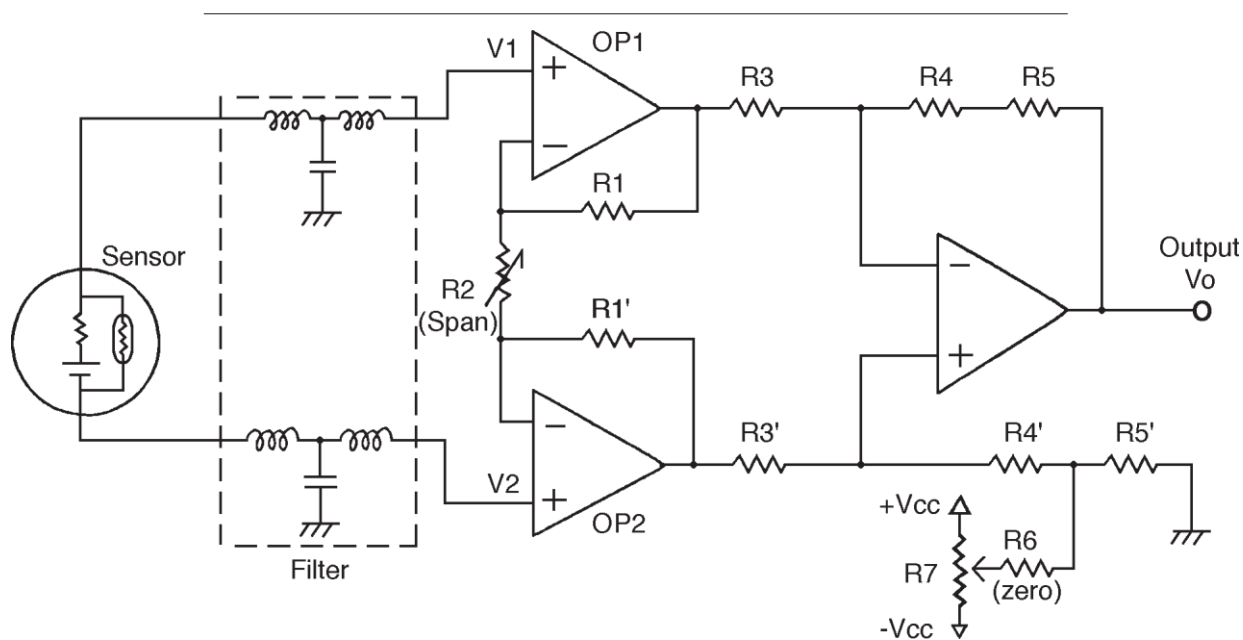
- 1) Positioning the sensor and measurement (see *Figure 1*)
  - Sensor body should be exposed to air.
  - Apply any suitable sampling system for detection. The flow rate should be greater than 1 liter/min.
- 2) Span adjustment
  - 0.5 to 1.0% O<sub>2</sub> is suitable for span adjustment.
- 3) Zero adjustment
  - Perform zero adjustment using a test gas of 0% oxygen, after a suitable sampling time depending on the type of application.

**NOTE:** The offset voltage decreases gradually while 0% oxygen flows and becomes stabilized at approximately 0.1mV ± 0.05mV after eight hours.

### 4. Application Notes

The most commonly recommended electric circuit for low concentration measurement is a precision DC voltage amplifier as shown in the diagram in **Figure 3**. For applications which do not require high precision, an example circuit design is shown in **Figure 4**.

Note that any circuit which may apply bias voltage to the sensor must not be applied to the KE/KE-LF series, e.g. a circuit design for a polarograph type of electrochemical sensors. This type of circuit may cause irreparable damage or destroy KE/KE-LF series sensors.



**Figure 3** - Sample Circuit for Meters (Accuracy-Oriented Circuit)

### REMARKS:

$$V_o = (R_4/R_3) * (V_2 - V_1) * [(2R_1 + R_2) / R_2];$$

$$\text{Sensor output} = V_1 - V_2$$

$$(\text{where: } R_1 = R_1', R_3 = R_3', R_4 = R_4', R_5 = R_5')$$

**NOTE 1:** OP1, OP2 are operational amplifiers for which small offset voltage and small input bias current (< several ten nA) is recommended.

**NOTE 2:** The temperature dependency characteristics of the operational amplifiers and resistors should be precisely matched.

**NOTE 3:** It is recommended that a *low pass filter* (e.g.  $f_c = 1 \text{ Hz}$ ) be used.

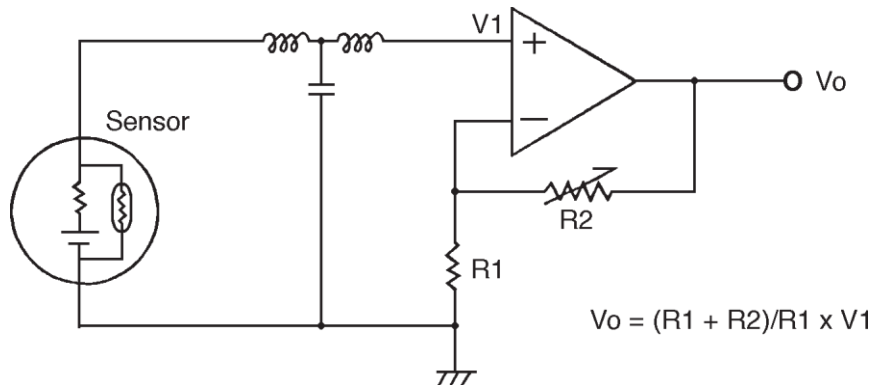


Figure 4 - Non-Invertible Amplifier (Cost-Oriented Circuit)

**Notes on Circuit Diagrams:**

- 1.) An impedance as high as 1MΩ or greater is required for receiving the output voltage from the sensor because of the high impedance of the sensor's output.
- 2.) The sensor is extremely fragile against a reverse voltage input. The sensor would be irreparably harmed by just a few millivolts of reverse voltage.
- 3.) Both offset and output voltages drift slightly with time and, as a result, periodic recalibration is recommended to achieve the best results.
- 4.) Other components such as CMRR, resistors, operational amps, etc. also drift with temperature, etc.
- 5.) In case you need to use an extension wire, please keep the length of the extension at 1.5 meters or shorter, using a shielded twist wire with a ground.

**Calibration Technique:**

If your application does not require a high degree of precision (for example, to alarm for oxygen deficiency in room air), calibration can be carried out in normal room air, interpreting the sensor's output to represent an oxygen concentration at 21%. This process is referred to as Span calibration.

If your application requires a high degree of accuracy, such as an oxygen meter which covers a range from 0 to 100% oxygen, both span calibration as well as Zero calibration (calibrating in a 0% oxygen test atmosphere) are recommended.

The frequency of calibration and method(s) selected should be decided by the user's demands for accuracy.

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