APPLICATION NOTE
PASSIVE NETWORK TO COMPENSATE SENSOR OUTPUT VARIATION WITH TEMPERATURE

Teledyne's **Micro-Fuel Cells** are accurate and reliable sensors for oxygen gas concentration measurements.

For the **Micro-Fuel Cell**, a thin **Teflon** membrane is used to control the rate of oxygen diffusion to the sensing electrode. This approach is superior to that of a small capillary in that it minimizes electrolyte leakage, eliminates cell failure due to clogging **and is leaner at high concentrations of oxygen.**

The use of a **Teflon** sensing membrane therefore ensures a linear relationship between the output signal of the micro-fuel cell and the partial pressure of oxygen in the sample gas at all times. **The sensor is also more forgiving in the presence of condensing water, dust and other foreign material that may find its way onto the sensing membrane.**

The variation of gas permeability of the **Teflon** sensing membrane with temperature is predictable and repeatable. Figure 1 is a plot showing the sensor output current as a function of temperature.

Although the output current increases with temperature (approximately 2.5% per degree Centigrade), the output voltage can be "temperature compensated" through the use of a thermistor in a passive network as shown in Figure 2. This temperature compensation network is based on the fact that the resistance of the thermistor, $R_{thermistor}$, decreases in value with increase in temperature.

As the sensor current flows through the components R_2, R_1, $R_{thermistor}$, and R_3, the output voltage (i.e. voltage across R_3) is dependent on the product of sensor current and effective impedance of the circuit. The effective impedance of the circuit can be calculated according the following expression:

$$R_{eq} = (R_1R_2R_3+R_1R_3R_{thermistor}+R_2R_3R_{thermistor})/(R_1R_2+R_1R_3+R_1R_{thermistor}+R_2R_{thermistor}+R_3R_{thermistor}) \quad \text{Eq (1)}$$

R_1 and R_3 control the fraction of sensor current that flows through the thermistor. R_2 produces a voltage component that is essentially proportional to the sensor current.

The sensor output voltage using this circuit is then equal to:

$$V_{out} = I^* (R_1R_2R_3+R_1R_3R_{thermistor}+R_2R_3R_{thermistor})/(R_1R_2+R_1R_3+R_1R_{thermistor}+R_2R_{thermistor}+R_3R_{thermistor}) \quad \text{Eq (2)}$$

By choosing appropriate values for R_1, R_2, and R_3 in conjunction with the thermistor, the circuit can produce a sensor output voltage nearly independent of temperature.

Example:

Consider compensating a sensor with a nominal current output of 130 micro-amperes in air using a curve-X thermistor with a nominal resistance of 72.6 ohms at 25 deg C. The sensor output current at various temperatures can be estimated using Figure 1. The thermistor resistance at various temperatures can be found in catalogs provided by thermistor suppliers. Table 1 lists the sensor current and thermistor resistance values over the temperature range of 0 deg C to 50 deg C at 5-degree increments.

Table 1 Sensor output current and thermistor resistance

Temp (deg C)	Output (micro-amp)	Thermistor R
0	62.4	177.9
5	72.8	146.7
10	83.2	122.0
15	96.2	103.1
20	111.8	85.7
25	130	72.6
30	149.5	62.0
35	170.3	53.1
40	191.1	45.6
45	213.2	39.0
50	236.6	33.7

Using the information contained in Table 1, one can easily calculate the sensor output voltage for various values of R_1, R_2, and R_3.

For a 2000-ohm R_1, a 10-ohm R_2, and a 3000-ohm R_3, the output voltage variation with temperature is shown in Figure 3. Also shown in Figure 3 is the sensor output current as a function of temperature.

Generally, the narrower the range of operating temperature, the better the temperature compensation. It should be noted that the tolerances of production components (e.g. sensor output, resistor, thermistor etc.) will impact the accuracy of compensation. Depending on the application some improvement in temperature compensation can be realized by utilizing high tolerance components or selecting component values, which more closely match the sensor output.

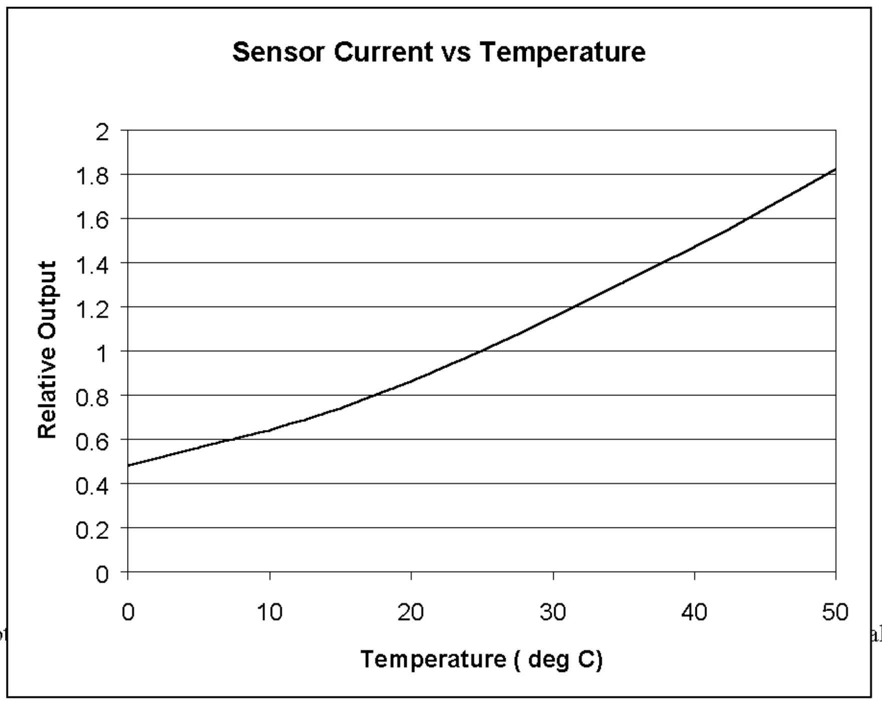

Figure 1 Sensor Output Current as A Function of Temperature

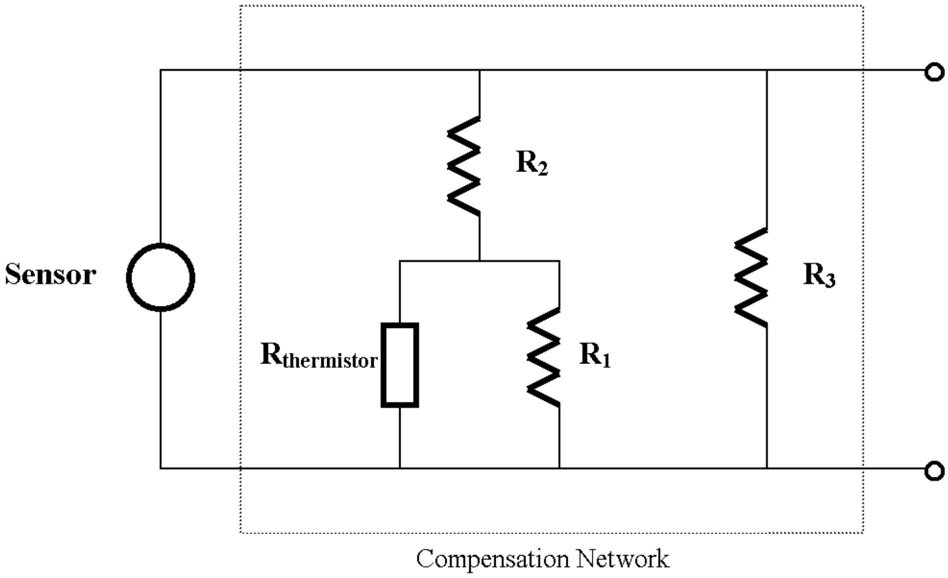

Figure 2 Temperature Compensation Network Consisting of All Passive Components

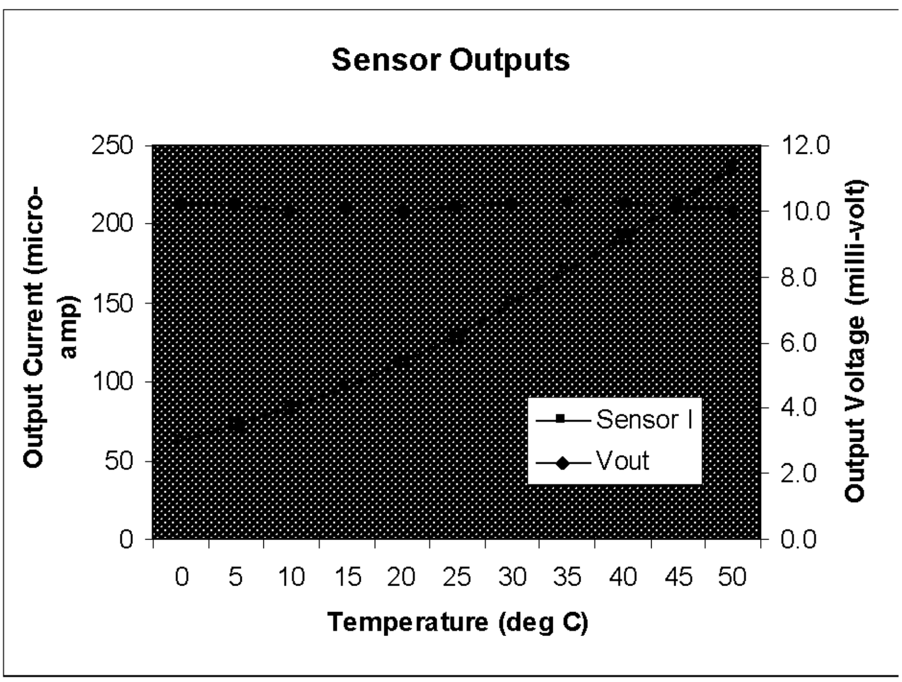

Figure 3 Sensor Outputs as A Function of Temperature