Nanopower Circuit Design in Low-Frequency Sensor Applications

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Oxygen sensors (O2 sensors) are used in life safety and industrial applications and can be found inside a low power portable, handheld device or integrated into a larger system. Life safety applications use these sensors to monitor adequate oxygen levels in a confined space such as inside an aircraft or in a lab. Industrial applications use these sensors to measure the absence of atmospheric oxygen to make sure bacterial growth is inhibited in the vacuum packaging of food products. Although this design is specific to an O2 sensor, the application circuit development here applies equally to other types of dc or low-frequency sensors.

The right combination of dc specifications and low power operation is essential in selecting the right operational amplifier for low-voltage, low-current sensor signal conditioning applications where signal frequencies are often below 100Hz.

A 1.5-V powered, O2 sensor signal conditioning circuit that can detect and amplify an O2 sensor's signal voltage is shown in Figure 1.

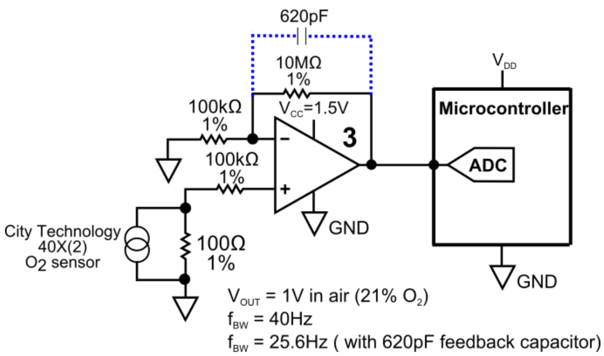

Figure 1. Op amp O2 sensor circuit

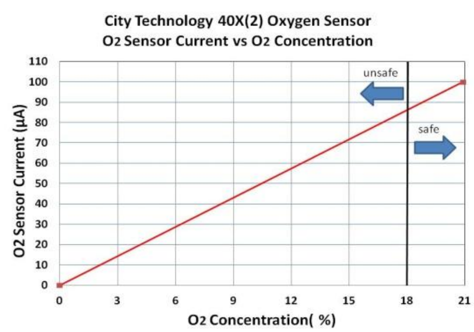

Figure 2. 4OX(2) O2 sensor transfer curve

Circuit Implementation

The City Technology O2 sensor used in this circuit is a 4OX (2) O2 sensor and its accompanying transfer curve shown in Figure 2. This sensor generates an output current proportional to oxygen gas concentration. Some important specifications and attributes of this O2 sensor are:

- Output signal: 100µA(typ) in air (21% O2 - safe)
- Output signal: 85µA(typ) in air (18% O2 - unsafe)
- Response time: ≤ 15s
- Recommended resistive load: 100Ω, ±1% (for specified accuracy)
- Lifetime: 2 years
- Self-powered and self-contained

With a 10mV signal voltage (~21% O2 concentration) applied to the op amp's non-inverting input and a circuit gain of 101, a 1V-full scale voltage is generated. This output voltage can be applied to the input of an ADC to process digitally the signal voltage. With an op amp exhibiting a 4-kHz gain-bandwidth product, the circuit's closed-loop bandwidth is ~40Hz as shown in Figure 3.

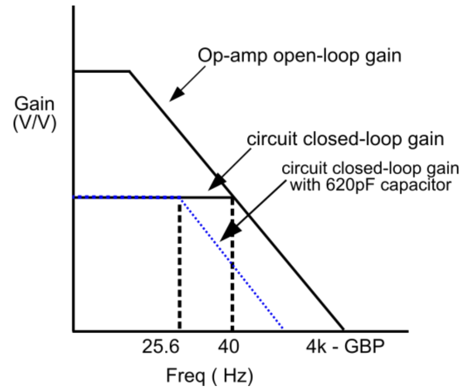

Figure 3. Op amp and O2 circuit transfer curve

Considerations and Results

With the components shown in Figure 1, the Touchstone Semiconductor TS1001 op-amp specifications are:

- Low supply current : ~1µA
- Low Input V_{OS}: ~0.5mV
- Low Input $I_{IN+/-}$: ~0.025nA
- High A_{VOL}: ~90dB
- Rail-to-rail Inputs/Output (maximizes dynamic range and signal-to-noise ratio)

The circuit performance is:

- Total circuit error: <3%
- Total circuit power consumption: ~1µW
- 1.5V AA battery lifetime: >285 years
- O2 sensor replacement: >142 times before battery replacement

To minimize external gain error, ±1% tolerance resistor values are recommended. To reduce circuit bandwidth, an external capacitor can be added across 10MΩ feedback resistor. For example, a 620pF capacitor reduces the circuit bandwidth to 25.6Hz as shown in Figure 3.

Conclusion

An operational amplifier that combines precision dc specifications and low power consumption, such as Touchstone Semiconductor's TS1001 0.8V/0.6µA op amp, produces an ultra low power signal conditioning circuit with low overall error for an O2 sensor or other non-O2/low-frequency sensor applications.

For additional information, please follow the links to the corresponding product pages:

- TS1001 Op Amp

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