1. Introduction

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.

2. Overview

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 100 Hz.

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.

![Op Amp O2 Sensor Circuit](image)

Figure 1. Op Amp O2 Sensor Circuit
2.1. 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: 100 µA(typ) in air (21% O2 – safe)
- Output signal: 85 µA(typ) in air (18% O2 – unsafe)
- Response time: ~15s
- Recommended resistive load: 100?, ±1% (for specified accuracy)
- Lifetime: 2 years
- Self-powered and self-contained

With a 10 mV signal voltage (~21% O2 concentration) applied to the op amp’s non-inverting input and a circuit gain of 101, a 1 V-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 ~40 Hz as shown in Figure 3.
2.2. Considerations and Results

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

- Low supply current: ~1 µA
- Low Input VOS: ~0.5 mV
- Low Input IIN±: ~0.025 nA
- High AVOL: ~90 dB
- 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: ~1 µW
- 1.5 V 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 10 MΩ feedback resistor. For example, a 620 pF capacitor reduces the circuit bandwidth to 25.6 Hz as shown in Figure 3.

3. Conclusion

An operational amplifier that combines precision dc specifications and low power consumption, such as the TS1001 0.8V/0.6 µA 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. See the documentation for the TS1001 Op Amp. For additional information, contact Silicon Labs.
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