http://www.analog.com/zh/circuits-from-the-lab/CN0234/vc.html

Single Supply, Micropower Toxic Gas Detector Using an Electrochemical Sensor (CN0234)

使用电化学传感器的单电源、微功耗有毒气体探测器(CN0234)

Devices Connected/Referenced

连接/参考器件

ADA4505-2 Micropower Rail-to-Rail I/O Dual Op Amp

ADA4505-2：微功耗、轨到轨 I/O、双通道运算放大器

ADR291 Micropower 2.5 V Voltage Reference

ADR291：微功耗、2.5 V 基准电压源

ADP2503 2.5 MHz Buck-Boost DC-to-DC Converter

ADP2503：2.5 MHz、降压/升压 DC-DC 转换器

AD7798 16-Bit Low Power Sigma-Delta ADC

AD7798：16 位低功耗 Σ-Δ 型 ADC

EVALUATION AND DESIGN SUPPORT

评估和设计支持

Circuit Evaluation Boards

电路评估板

CN-0234 Circuit Evaluation Board (EVAL-CN234-SDPZ)

CN-0234电路评估板(EVAL-CN234-SDPZ)

System Demonstration Platform (EVAL-SDP-CB1Z)

系统演示平台(EVAL-SDP-CB1Z)

Design and Integration Files

设计和集成文件

Schematics, Layout Files, and Bill of Materials

原理图、布局文件、物料清单

CIRCUIT FUNCTION AND BENEFITS

电路功能与优势

The circuit shown in Figure 1 is a single-supply, low power battery operated, portable gas detector using an electrochemical sensor. The Alphasense CO-AX Carbon Monoxide sensor is used in the example.

图 1 所示电路是使用电化学传感器的单电源、低功耗、电池供电、便携式气体探测器。本示例中使用 Alphasense CO-AX 一氧化碳传感器。

Electrochemical sensors offer several advantages for instruments that detect or measure the concentration of many toxic gases. Most sensors are gas specific and have usable resolutions under one part per million (ppm) of gas concentration. They operate with very small amounts of current, making them well-suited for portable, battery powered instruments.

对于检测或测量多种有毒气体浓度的仪器，电化学传感器能够提供多项优势。大多数传感器都是针对特定气体而设计，可用分辨率小于气体浓度的百万分之一(ppm)，所需工作电流极小，非常适合便携式电池供电的仪器。

The circuit shown in Figure 1 uses the ADA4505-2, dual micro-power amplifier, which has a maximum input bias current of 2 pA at room temperature and consumes only 10 µA per amplifier. In addition, the ADR291 precision, low noise, micropower reference consumes only 12 µA and establishes the 2.5 V common-mode pseudo-ground reference voltage.

图 1 所示电路使用双通道微功耗放大器 ADA4505-2，该器件在室温下的最大输入偏置电流为 2 pA，每个放大器的功耗仅为 10 µA。此外，ADR291 精密、低噪声、微功耗基准电压源的功耗仅为 12 µA，可建立 2.5 V 共模伪地基准电压。

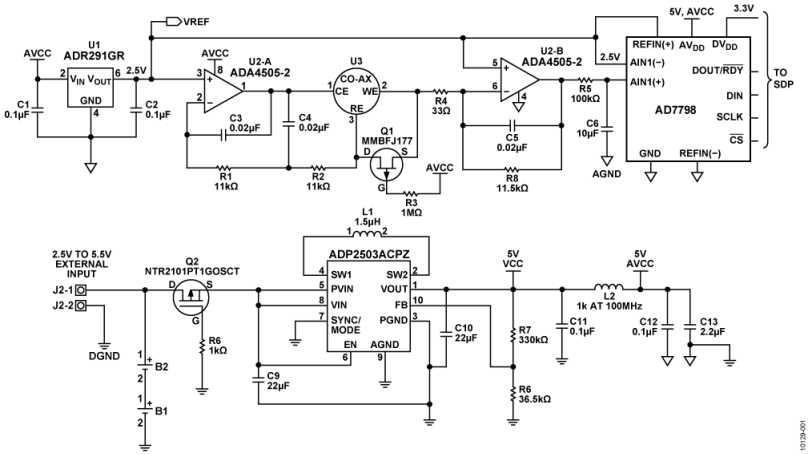

Figure 1. Low Power Gas Detector Circuit

图 1. 低功耗气体探测器电路

Enlarge
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The ADP2503 high efficiency, buck-boost regulator allows single- supply operation from two AAA batteries and consumes only 38 µA when operating in power-save mode.

ADP2503 高效率、降压/升压调节器支持两节 AAA 电池的单电源供电，在节能模式下的功耗仅为 38 µA。

Total power consumption for the circuit shown in Figure 1 (excluding the AD7798 ADC) is approximately 110 µA under normal conditions (no gas detected) and 460 µA under worst- case conditions (2000 ppm CO detected). The AD7798 consumes approximately 180 µA when operational (G = 1, buffered mode) and only 1 µA in the power-save mode.

图 1 所示电路（不包括 AD7798 ADC）的总功耗在正常条件下（未探测到气体）约为 110 µA，在最差条件下（探测到 2000 ppm CO）约为 460 µA。AD7798 工作时的功耗约为 180 µA（G = 1，缓冲模式），节能模式下仅为 1 µA。

Because of the circuit's extremely low power consumption, two AAA batteries can be a suitable power source. When connected to an ADC and a microcontroller, or a microcontroller with a built-in ADC, battery life can be from over six months to over one year.

由于电路功耗极低，两节 AAA 电池便可提供合适的电源。当连接到 ADC 和微控制器或者内置 ADC 的微控制器时，电池寿命可从 6 个月以上到一年以上不等。

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CIRCUIT DESCRIPTION

电路描述

Figure 2 shows a simplified schematic of an electrochemical sensor measurement circuit. Electrochemical sensors work by allowing gas to diffuse into the sensor through a membrane and interacting with the working electrode (WE). The sensor reference electrode (RE) provides feedback to maintain a constant potential with the WE terminal by varying the voltage at the counter electrode (CE). The direction of the current at the WE terminal depends on whether the reaction occurring is oxidation or reduction. In the case of carbon monoxide, oxidation takes place; therefore, the current flows into the working electrode, which requires the counter electrode to be at a negative voltage (typically 300 mV to 400 mV) with respect to the working electrode. The op amp driving the CE terminal should have an output voltage range of approximately ±1 V with respect to V_{REF} to provide sufficient headroom for operation with different types of sensors (Alphasense Application Note AAN-105-03, *Designing a Potentiostatic Circuit, Alphasense*, Ltd.).

图 2 显示电化学传感器测量电路的原理示意图。电化学传感器的工作原理是允许气体通过薄膜扩散到传感器内，并与工作电极(WE)相互作用。传感器参考电极(RE)提供反馈，以便通过改变反电极(CE)上的电压保持 WE 引脚的恒定电位。WE 引脚上的电流方向取决于发生的反应是氧化还是还原。在一氧化碳情况下发生的是氧化；因此，电流会流入工作电极，这要求反电极相对于工作电极处于负电压（通常为 300 mV 至 400 mV）。驱动 CE 引脚的运算放大器相对于 V_{REF} 应具有±1 V 的输出电压范围，以便为不同类型的传感器（Alphasense 应用笔记 AAN-105-03，*设计恒电位电路，Alphasense* 公司）提供充足裕量。

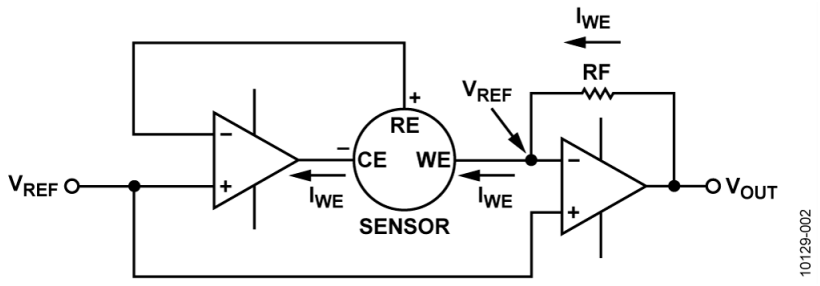

Figure 2. Simplified Electrochemical Sensor Circuit

图 2. 简化电化学传感器电路

Enlarge

放大

The current into the WE terminal is less than 100 nA per ppm of gas concentration; therefore, converting this current into an output voltage requires a transimpedance amplifier with a very low input bias current.

The ADA4505-2 op amp has CMOS inputs with maximum input bias current of 2 pA at room temperature, making this op amp a very good fit for the application.

流入 WE 引脚的电流对于每 ppm 气体浓度低于 100 nA；因此将此电流转换为输出电压需要具有极低输入偏置电流的跨阻放大器。ADA4505-2 运算放大器在室温下具有最大输入偏置电流为 2 pA 的 CMOS 输入，因此很适合这种应用。

The 2.5 V ADR291 establishes the pseudo-ground reference for the circuit, which allows for single-supply operation while consuming very little quiescent current.

2.5 V ADR291 为电路建立伪地基准电压，因此支持单电源供电同时消耗极低的静态电流。

Amplifier U2-A sinks enough current from the CE terminal to maintain a 0 V potential between the WE and RE terminals on the sensor. The RE terminal is connected to the inverting input of U2-A; therefore, no current flows in or out of it. This means that the current comes from the WE terminal, and it changes linearly with gas concentration. Transimpedance Amplifier U2-B converts the sensor current into a voltage proportional to gas concentration.

放大器 U2-A 从 CE 引脚吸取足够的电流，以便在传感器的 WE 和 RE 引脚间保持 0 V 电位。RE 引脚连接到 U2-A 的反相输入；因此其中无电流流动。这意味着电流从 WE 引脚流出，随气体浓度呈现线性变化。跨阻放大器 U2-B 将传感器电流转换为与气体浓度成正比的电压。

The sensor selected for this circuit note is an Alphasense CO-AX Carbon Monoxide sensor. Table 1 shows typical specifications associated with carbon monoxide sensors of this general type.

此电路笔记选择的传感器是 Alphasense CO-AX 一氧化碳传感器。表 1 显示与此常见类型的一氧化碳传感器相关的典型规格。

Warning: Carbon monoxide is a toxic gas, and concentrations higher than 250 ppm can be dangerous; therefore, exercise extreme care when testing this circuit.

警告：一氧化碳是有毒气体，一旦浓度高于 250 ppm 便有危险；测试本电路时应格外小心。

Table 1. Typical Carbon Monoxide Sensor Specifications

Parameter	Value
Sensitivity	55 nA/ppm to 100 nA/ppm (65 nA/ppm typ)
Response Time (t_{90} from 0 ppm to 400 ppm CO)	<30 sec
Range (ppm CO, Guaranteed Performance)	0 ppm to 2,000 ppm
Overrange Limit (Specifications Not Guaranteed)	4,000 ppm

Table 1. Typical Carbon Monoxide Sensor Specifications

表 1. 典型一氧化碳传感器规格

Parameter **参数**	**Value** **值**
Sensitivity 灵敏度	55 nA/ppm to 100nA/ppm (65nA/ppm typ) 5 nA/ppm 至 100nA/ppm（典型值，65nA/ppm）
Response Time(t_{90} From 0 ppm to 400 ppm CO) 响应时间（t_{90}，0 ppm 至 400 ppm CO）	< 30 sec < 30 秒
Range(ppm CO, Guaranteed Performance) 范围（ppm CO，保证性能）	0 ppm to 0 ppm 至
Overrange Limit (Specifications Not Guaranteed) 超量程限制（不保证规格）	2,000 ppm 2,000 ppm 4,000 ppm 4,000 ppm

The output voltage of the transimpedance amplifier is

跨阻放大器的输出电压为：

$$V_O = 2.5\ \text{V} + I_{WE} \times R_F \qquad (1)$$

where I_{WE} is the current into the WE terminal, and R_F is the transimpedance feedback resistor (shown as R8 in Figure 1).

其中 I_{WE} 是流入 WE 引脚的电流，R_F 是跨阻反馈电阻（图 1 中显示为 R8）。

The maximum response of the CO-AX sensor is 100 nA/ppm, and its maximum input range is 2000 ppm of carbon monoxide. This results in a maximum output current of 200 µA and a maximum output voltage determined by the transimpedance resistor, as shown in Equation 2.

CO-AX 传感器的最大响应是 100 nA/ppm，其最大输入范围为 2000 ppm 的一氧化碳。因此，最大输出电流为 200 µA，最大输出电压由跨阻电阻决定，如公式 2 所示。

$$V_O = 2.5\ V + 2000\ ppm \times 100\frac{nA}{ppm} \times R_F$$

$$V_O = 2.5\ \text{V} + 200\ \mu\text{A} \times R_F \qquad (2)$$

Operating the circuit with a 5 V supply results in a usable range of 2.5 V at the output of the transimpedance amplifier, U2-B. Selecting a 11.5 kΩ resistor for the transimpedance feedback resistor gives a maximum output voltage of 4.8 V, which allows for approximately 8% overrange capability.

使用 5 V 电源为电路供电可在跨阻放大器 U2-B 的输出端产生 2.5 V 的可用范围。为跨阻反馈电阻选择 11.5 kΩ 电阻可提供 4.8 V 的最大输出电压，从而提供大约 8%的超量程能力。

Using the sensor's typical response of 65 nA/ppm, Equation 3 shows the circuit output voltage as a function of ppm of carbon monoxide.

传感器使用 65 nA/ppm 的典型响应时，公式 3 显示与一氧化碳的 ppm 有函数关系的电路输出电压。

$$V_O = 2.5\ V + 748\frac{\mu V}{ppm} \qquad (3)$$

Resistor R4 keeps the noise gain at a reasonable level. Selecting the value of this resistor is a compromise between the magnitude of the noise gain and the sensor settling time errors when exposed to high concentrations of gas. For this example, R4 = 33 Ω, which results in a noise gain of 349, as shown in Equation 4.

电阻 R4 将噪声增益保持在合理水平。选择此电阻的值需权衡两个因素决定：噪声增益的幅度和暴露于高浓度气体时传感器的建立时间误差。对于本例，R4 = 33 Ω，由此可计算噪声增益等于 349，如公式 4 所示。

$$NG = 1 + \frac{11.5\ k\Omega}{33\ \Omega} = 349 \qquad (4)$$

The input noise of the transimpedance amplifier appears at the output amplified by the noise gain. For this circuit, we are only interested in low frequency noise because the frequency of operation of the sensor is very low. The ADA4505-2 has a 0.1 Hz to 10 Hz input voltage noise of 2.95 μV p-p; therefore, the noise at the output is 1.03 mV p-p, as shown in Equation 5.

跨阻放大器的输入噪声在输出端表现为由噪声增益放大。对于本电路，我们仅关注低频噪声，因为传感器工作频率极低。ADA4505-2 的 0.1 Hz 至 10 Hz 输入电压噪声为 2.95 μV p-p；因此，输出端噪声为 1.03 mV p-p，如公式 5 所示。

$$V_{OUTPUTNOISE} = 2.95\ \mu\text{V} \times NG = 1.03\ \text{mV p-p} \qquad (5)$$

Because this is very low frequency 1/f noise, it is very hard to filter out. However, the sensor response is also very slow; therefore, we can take advantage of this by using a very low frequency low-pass filter (R5 and C6) with a cutoff frequency of 0.16 Hz. Even with such a low frequency filter, its effect on the sensor response time is negligible when compared to the 30 second response time of the sensor.

由于这是极低频 1/f 噪声，所以很难滤除。然而，传感器响应也极低；因此可以利用这一点，使用截止频率为 0.16 Hz 的极低频率低通滤波器（R5 和 C6）。即使是这样的低频滤波器，与 30 秒的传感器响应时间相比，它对传感器响应时间的影响也可忽略。

One important characteristic of electrochemical sensors is their very long time constant. When first powered up, it can take several minutes for the output to settle to its final value. When exposed to a midscale step in concentration of the target gas, the time required for the sensor output to reach 90% of its final value can be in the order of 25 seconds to 40 seconds. If the voltage between the RE and WE terminals has a sudden change in magnitude, it can take several minutes for the sensor's output current to settle. This also applies when cycling power to the sensor. To avoid very long startup times, P-channel JFET Q1 shorts the RE terminal to the WE terminal when the supply voltage drops below the JFET's gate-to-source threshold voltage (~2.5 V).

电化学传感器的一个重要特性是极长的时间常数。首次上电时，输出建立最终值可能需要几分钟。当暴露于目标气体浓度的中量程阶跃时，传感器输出达到最终值的 90%所需的时间可在 25 秒至 40 秒之间。如果 RE 与 WE 引脚间的电压产生剧烈幅度变化，传感器输出电流建立最终值可能需要几分钟。这也同样适用于传感器周期供电的情况。为避免启动时间过长，当电源电压降至 JFET 的栅极-源极阈值电压（约 2.5 V）以下时，P 沟道 JFET Q1 将 RE 引脚与 WE 引脚短接。

Two AAA batteries or a 2.3 V to 5.5 V power supply powers the circuit. Q2 provides reverse voltage protection, and the ADP2503 regulates the input supply to the 5 V required to power the sensor.

两节 AAA 电池或 2.3 V 至 5.5 V 电源为此电路供电。Q2 提供反向电压保护，ADP2503 将输入电源调节至传感器供电所需的 5 V 电压。

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COMMON VARIATIONS

常见变化

If a programmable rheostat, such as the AD5271, is used instead of a fixed transimpedance resistor (R8), the circuit can be used with different gas sensors without changing the bill of materials. The AD5271 is available with nominal resistance values of 20 kΩ, 50 kΩ, or 100 kΩ. There are 256 positions, resulting in steps of 390.6 Ω for the 100 kΩ option. The 5 ppm/°C resistance temperature coefficient of the AD5271 is better than most discrete resistors, and its 1 µA supply current is a very small contributor to the system's power consumption.

如果使用可编程变阻器（如 AD5271），而不是固定跨阻电阻(R8)，本电路就可以用于不同的气体传感器，而无需改变材料清单。AD5271 提供 20 kΩ、50 kΩ 或 100 kΩ 的标称电阻值。由于有 256 个跳变位置，因

此 100 kΩ 选项的阶跃为 390.6 Ω。AD5271 的电阻温度系数为 5 ppm/°C，优于大多数分立电阻；其电源电流为 1 μA，对系统功耗的影响极小。

While two AAA batteries can power the circuit shown in Figure 1 for several months, some applications may be able to run from an external power source. The most efficient way to implement a dual power configuration is to use a power jack with a built-in switch and a mechanical disconnect feature that automatically removes battery power when the external power plug is inserted into the jack.

虽然两节 AAA 电池就能为图 1 所示电路供电数月之久，一些应用可能需要使用外部电源运行。实施双电源配置的最有效方式是使用内置开关且具有机械断开特性的电源插座，在将外部电源插头插入插座时可自动移除电池电源。

The circuit discussed here operates with very low power consumption. Using two ADA4528-1 op amps instead of the ADA4505-2 results in much lower noise and better accuracy, but higher power consumption. The ADA4528-1 provides practically zero offset drift with industry-leading low input voltage noise.

本文所述电路具有极低的功耗。使用两个 ADA4528-1 运算放大器代替 ADA4505-2 可大幅降低噪声，提高精度，但功耗也会增加。ADA4528-1 具有实际为零的失调漂移和业界先进的低输入电压噪声。

Similarly, the ADR3425 can replace the ADR291 for very low drift with temperature; however, at the expense of higher current consumption.

同样，ADR3425 可取代 ADR291，从而获得极低温漂；但代价是功耗增加。

Finally, the circuit as shown in Figure 1 is suitable for interfacing with a 12-bit ADC, such as the built-in converter in most mixed signal microcontrollers.

最后，图 1 所示电路适用于与 12 位 ADC 接口，例如大多数混合信号微控制器中的内置转换器。

For applications where measuring fractions of ppm of gas concentration is important, using the ADA4528-1 and the ADR3425 makes the circuit performance suitable for interfacing with a 16-bit ADC, such as the AD7798 or the AD7171.

对于必须测量气体浓度 ppm 比例的应用，使用 ADA4528-1 和 ADR3425 使得电路性能适合与 16 位 ADC 接口，例如 AD7798 或 AD7171。

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CIRCUIT EVALUATION AND TEST

电路评估与测试

This circuit uses the EVAL-CN0234-SDPZ circuit evaluation board and the EVAL-SDP-CB1Z system demonstration platform (SDP) evaluation board. In addition, a small adapter board included with the

EVAL-CN0234-SDPZ is required to connect the two circuit boards together. The EVAL-CN0234-SDPZ includes an AD7798 16-bit Σ-Δ ADC to digitize the output voltage of the circuit.

本电路使用 EVAL-CN0234-SDPZ 电路评估板和 EVAL-SDP-CB1Z 系统演示平台(SDP)评估板。此外，连接两个电路板需要 EVAL-CN0234-SDPZ 附带的小适配板。EVAL-CN0234-SDPZ 包括 AD7798 16 位 Σ-Δ 型 ADC，用于对电路的输出电压进行数字化处理。

The CN-0234 evaluation software communicates with the SDP board to capture data from the EVAL-CN0234-SDPZ circuit evaluation board.

CN-0234 评估软件与 SDP 板通信，以从 EVAL-CN0234-SDPZ 电路评估板捕捉数据。

Equipment Needed

设备要求

The following equipment is needed:

需要以下设备：

- PC with USB port and Windows® XP or Windows Vista (32-bit), or Windows 7 (32-bit)
- 带 USB 端口的 Windows® XP、Windows Vista（32 位）或 Windows 7（32 位）PC
- EVAL-CN0234-SDPZ circuit evaluation board and adapter board.
- EVAL-CN0234-SDPZ 电路评估板和适配板
- EVAL-SDP-CB1Z SDP evaluation board
- EVAL-SDP-CB1Z SDP 评估板
- CN0234 evaluation software
- CN0234 评估软件
- Two AAA batteries
- 两节 AAA 电池
- Calibration gas (less than 250 ppm CO recommended)
- 校准气体（建议使用低于 250 ppm 的 CO）

Getting Started

开始使用

Load the evaluation software by placing the CN0234 Evaluation Software CD into the CD drive of the PC. Using **My Computer**, locate the drive that contains the evaluation software CD and open the **Readme** file. Follow the instructions contained in the **Readme** file for installing and using the evaluation software.

将 CN0234 评估软件光盘放入 PC 的光盘驱动器，加载评估软件。打开**我的电脑**，找到包含评估软件光盘的驱动器，打开 **Readme** 文件。按照 **Readme** 文件中的说明安装和使用评估软件。

Functional Block Diagram

功能框图

A functional block diagram of the test setup is shown in Figure 3. The EVAL-CN0234-SDPZ-SCH PDF file gives the complete circuit schematic. This file is contained in the CN0234 Design Support Package.

图 3 显示测试设置的功能框图。EVAL-CN0234-SDPZ-SCH PDF 文件提供了完整电路原理图。此文件位于 CN0234 设计支持包中。

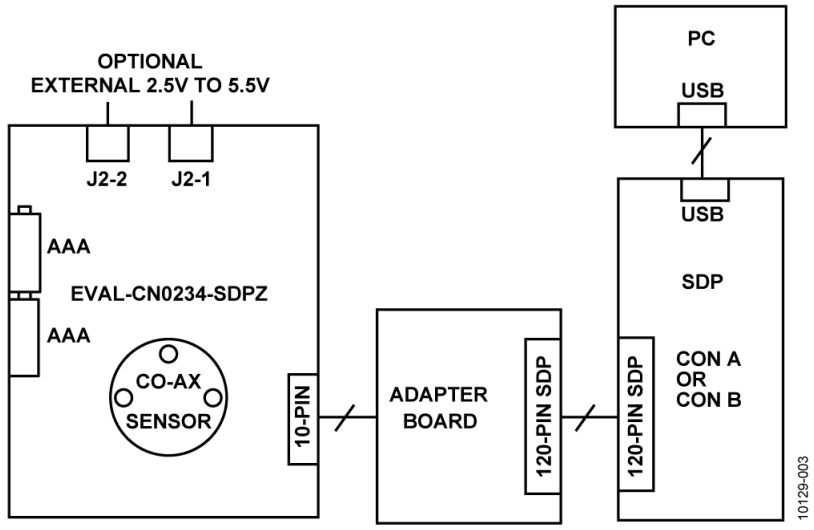

Figure 3. Test Setup Functional Block Diagram

图 3. 测试设置功能框图

Enlarge
放大

Setup

设置

Connect the 10-pin connector on the EVAL-CN0234-SDPZ to the adapter board, and the 120-pin connector of the adapter board to the CON A connector on the EVAL-SDP-CB1Z SDP evaluation board. Use Nylon hardware to firmly secure the adapter board to the SDP board, using the holes provided at the ends of the 120-pin connectors. Connect the electrochemical sensor to the socket on the EVAL-CN0234-SDPZ circuit evaluation board.

将 EVAL-CN0234-SDPZ 上的 10 引脚连接器连接到适配板，将适配板的 120 引脚连接器连接到 EVAL-SDP-CB1Z SDP 评估板上的 CON A 连接器。使用尼龙五金配件，通过 120 引脚连接器两端的孔将适配板牢牢固定至 SDP 板。将电化学传感器连接到 EVAL-CN0234-SDPZ 电路评估板上的插口。

With the power switch in the off position, insert two AAA batteries in the battery holders.

将电源开关滑动到关闭位置，将两节 AAA 电池插入电池座。

Connect the USB cable supplied with the SDP board to the USB port on the PC and to the SDP board. The SDP board derives its power from the USB port of the PC.

将 SDP 板附带的 USB 电缆连接到 PC 上的 USB 端口和 SDP 板。SDP 板从 PC 的 USB 端口取电。

Test

测试

Move the power switch on the EVAL-CN0234-SDPZ circuit board to the on position and launch the evaluation software. The software can communicate with the SDP board if the **Analog Devices System Development Platform** driver appears in the **Device Manager**. When USB communications are established, the SDP board can now send, receive, and capture serial data from the EVAL-CN0234-SDPZ circuit evaluation board.

将 EVAL-CN0234-SDPZ 电路板上的电源开关移动到打开位置，启动评估软件。如果“**Device Manager（设备管理器）**”中出现“**Analog Devices System Development Platform（ADI 系统开发平台）**”驱动器，软件便能与 SDP 板通信。一旦 USB 通信建立，就可以使用 SDP 板来发送、接收、采集来自 EVAL-CN0234-SDPZ 电路评估板的串行数据。

The CN0234 evaluation software readme file contains information and details regarding how to use the evaluation software for data capture. The SDP user guide contains information regarding the SDP board.

CN0234 评估软件 readme 文件包含有关如何使用评估软件采集数据的详细信息。SDP 用户指南包含有关 SDP 板的信息。

The input signal for this board is gas concentration; therefore, a calibration gas source is required. When testing with carbon monoxide consider that 250 ppm is the maximum short-term exposure limit.

该电路板的输入信号是气体浓度；因此需要校准气体源。使用一氧化碳进行测试时，最大短时间接触限值为 250 ppm。

To perform a system calibration, first ensure no carbon monoxide is present. To start acquiring data, click **Start Acquisition**. Select **Set Zero** from the **Calibrate** menu. If you are satisfied with the ADC reading, click **OK**, and the current ADC reading will be stored as the zero point. Apply the calibration gas, and when the sensor output is fully settled, select **Set Span** from the **Calibrate** menu. Enter the concentration of the calibration gas used and click **OK**. This will store the span of the system.

要执行系统校准，首先请确认不存在一氧化碳。要开始采集数据，请单击“**Start Acquisition（开始采集）**”。从“**Calibrate（校准）**”菜单选择“**Set Zero（设置 0）**”。如果满意 ADC 读数，请单击“**OK（确定）**”，当前 ADC 读数会被存储为 0 点。应用校准气体，当传感器输出完全建立后，从“**Calibrate（校准）**”菜单中选择“**Set Span（设置范围）**”。输入所用校准气体的浓度，单击“**OK（确定）**”。如此会存储系统范围。

To apply the system calibration data, select the **Display Calibrated Data** checkbox on the front panel.

要应用系统校准数据，请选中前面板上的“**Display Calibrated Data（显示校准数据）**”复选框。

When the **Display Calibrated Data** checkbox is not checked, the program operates with default scaling values, assuming a nominal sensor response of 65 nA/ppm and no offset errors.

如果未选中“**Display Calibrated Data（显示校准数据）**”复选框，程序采用默认比例值运行，即假定标称传感器响应为 65 nA/ppm，无失调误差。

To save the calibration data to file, choose **Save Calibration Constants to File** from the **File** menu. Similarly, choose **Load Calibration Constants from File** to use previously saved calibration data.

要将校准数据保存到文件，请从“**File（文件）**”菜单中选择“**Save Calibration Constants to File（将校准常数保存到文件）**”。同样，选择“**Load Calibration Constants from File（从文件加载校准常数）**”可使用先前保存的校准数据。

Figure 4 shows the circuit response to a step of 50 ppm of carbon monoxide. The faster initial rise time is due to the sensor response, while the long tail is a function of the test chamber.

图 4 显示电路对 50 ppm 一氧化碳阶跃的响应。传感器响应缩短了初始上升时间，而长尾现象与测试室成函数关系。

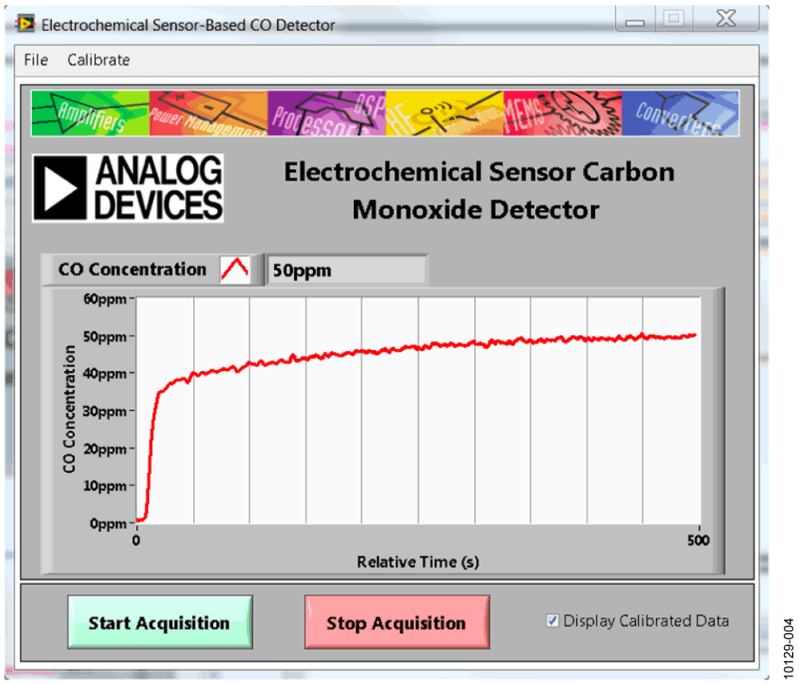

Figure 4. Response to 0 ppm to 50 ppm Step of Carbon Monoxide

图 4. 对 0 ppm 至 50 ppm 一氧化碳阶跃的响应

Enlarge

放大

Figure 5 shows the circuit response after rapidly removing the sensor from the 50 ppm CO atmosphere and is a better representation of circuit performan

图 5 显示从 50 ppm CO 环境迅速移除传感器后的电路响应，它可以更好地衡量电路性能。

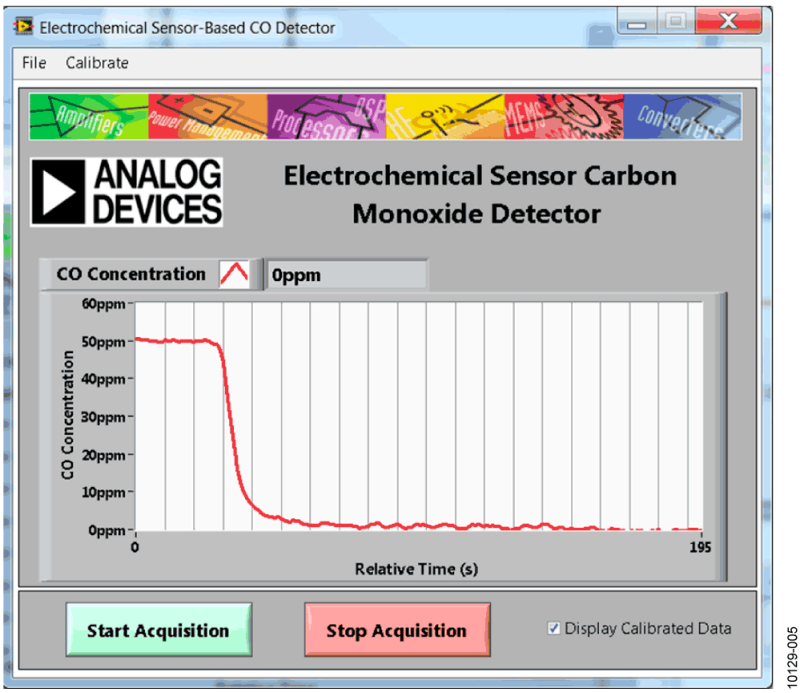

Figure 5. Response to 50 ppm to 0 ppm Step of Carbon Monoxide

图 5. 对 50 ppm 至 0 ppm 一氧化碳阶跃的响应

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