ADI Micropower Toxic Gas Detector Solutions Based on Electrochemical Sensors

Application Introduction

Toxic gases exist in many industrial environments, like oil wells, mining, plastics manufacturing, paper making, and so on. With the increasing concerns of personal safety, the demand for low power portable toxic gas detectors is rapidly increasing so that workers can carry them in the field or they can be installed in the field. Most portable low power toxic gas detectors are based on electrochemical sensors covering most common toxic gases in industrial environments, like carbon monoxide (CO), sulfur dioxide (SO_2), hydrogen sulfide (H_2S), and nitrogen dioxide (NO_2). Compared with other methods of toxic gas detection, electrochemical sensors offer the advantage of low power consumption, low cross sensitivity, and good long-term stability, which is very suitable for battery-powered portable applications.

System Design Considerations

Low Power Consumption

Toxic gas detection requires continuous monitoring of the environment with no maintenance, if possible. Thus, achieving as long battery life as possible is important for this application. Since the electrochemical gas sensors can operate with very small amounts of current, the remaining signal conditioning and data transmission circuitry play a key role in achieving the low power consumption goal for the system.

High Reliability

In some industrial environments, human life depends on toxic gas detectors, which must be highly reliable. High accuracy, interference immunity, and good long-term stability are important factors that should be taken into consideration. An accurate, robust, and low drift signal chain is needed for a reliable gas detector.

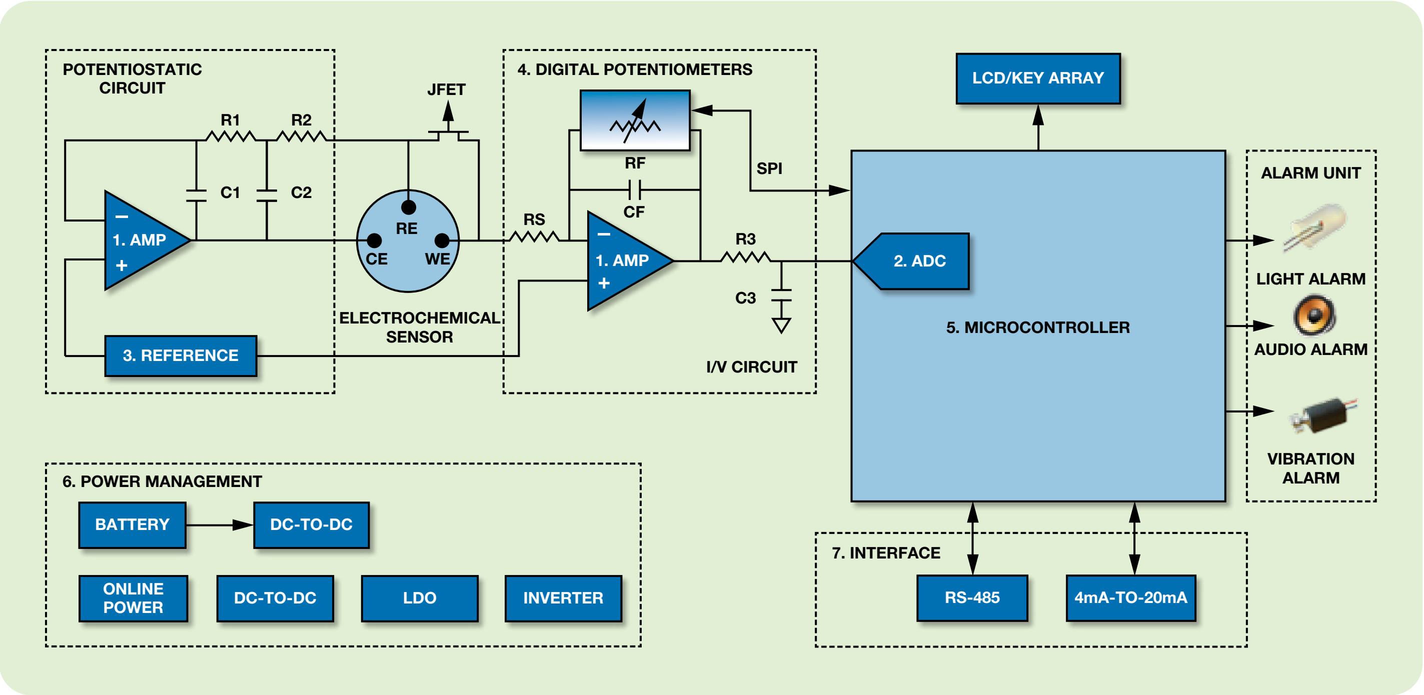
Noise Reduction

To take full advantage of electrochemical sensor dynamic range, the noise reduction should be taken into consideration during signal chain design.

Solutions from ADI

System Block Diagram

Below is the system block diagram of a toxic gas detector including gas sensor, potentiostatic circuit, I/V circuit (current-to-voltage conversion), microcontroller, power supply, interface, and alarm unit.



Note: The signal chains above are representative of the system block diagram of a toxic gas detector design. The technical requirements of the blocks vary, but the products listed in the table below are representative of ADI's solutions that meet some of those requirements.

1. Amplifier	2. ADC	3. Reference	4. Digital Potentiometers	5. Microcontroller	6. Power Management	7. Interface
ADA4505-2/AD8502/ ADA4051-2/ADA4528-1	AD7788/AD7790/ AD7798	ADR291/ADR280/ ADR3425	AD5271	ADuC7023	ADP2503/ADM8828/ ADP2301/ADP160	AD5420/ADM2483/ AD5749

For the electrochemical sensor shown in the diagram above, the working electrode (WE) senses toxic gas and produces current proportional to the gas concentration; the reference electrode (RE) anchors the voltage of the working electrode so that the sensor can work in the linear range; the counter electrode (CE) can balance the current produced on the WE node. The potentiostatic circuit holds the RE node and provides the current generated at the CE node. The I/V circuit transfers the current signal to a voltage signal, that ADC can figure out. Human interfaces, including LCD and key array, are used for system setting and display. LED, beeper, and vibration motor help the alarm to be reliable and efficient.

Low Power Consumption: The power consumption of ADI amplifiers, dc-to-dc converter, and reference in Circuits from the Lab™ circuitry costs about 100 µA at normal condition.[1] Single-supply operation avoids the wasted power of a bipolar supply.[2]

High Reliability: ADI is committed to providing accurate and low drift signal chain products like amplifiers, references, and ADCs which help designers to build an accurate and stable system. The corresponding products are listed in the main products table below. The RC (R1, R2, C1, C2) filter on the feedback of the op amp and series resistor Rs and Cf will make the system stable considering the huge capacitance (mF level) of the gas sensor.

Noise Reduction: Due to the slow response limited by the sensor (about 30 seconds), the cutoff frequency of the RC (R3, C3) filter before the ADC is allowed to be set very low.[1] Not only Johnson noise but also 1/f noise of the system can be reduced so that the system resolution is optimized. Regarding the ADC resolution, ADI provides several choices, such as discrete ADC (16-bit) and integrated MCU (12-bit).

Main Products

Part Number	Description	Benefits
Amplifier		
ADA4505-2	10 µA quiescent current, 2 pA bias current, rail-to-rail input/output, zero input crossover distortion amplifiers; PSRR: 100 dB minimum; CMRR: 105 dB typical	Low power consumption, suitable for portable instrumentation; higher PSRR brings little effect to accuracy even without regulator
AD8502	1 µA quiescent current, 10 pA bias current rail-to-rail input/output	Ultralow power consumption, low bias current contributes to accurate conversion
ADA4051-2	17 µA quiescent current, zero drift 0.1 µV/°C @ max, 50 pA bias current, rail-to-rail input/output	Low power consumption, low bias current; zero drift keeps the output stable in long term
ADA4528-1[2]	Zero drift 15 nV/°C @ max, ultralow noise 97 nV p-p @ 0.1 Hz to 10 Hz	Zero drift and low noise contribute to a very accurate system
ADC		
AD7788	80 µA @ max quiescent current, fixed 16.6 Hz output update rate, 16-bit peak-to-peak resolution	Ultralow power sigma-delta ADC, high resolution and high accuracy, low cost
AD7790	80 µA @ max quiescent current, up to 120 Hz output update rate, 16-bit @ 33 Hz and 14-bit @ 120 Hz peak-to-peak resolution	Ultralow power sigma-delta ADC, high resolution and high accuracy
AD7798	140 µA @ max quiescent current, up to 470 Hz output update rate, 16-bit peak-to-peak resolution @ any sample rate	Low power signma-delta ADC, high resolution and high accuracy
Reference		
ADR291	2.5 V output, 12 µA quiescent current, low noise 8 µV p-p (0.1 Hz to 10 Hz)	Low power, low noise
ADR280	1.2 V output, 16 µA quiescent current	Low power consumption, nice cost performance
ADR3425	2.5 V output, 85 µA quiescent current, 8 ppm/°C, 30 ppm/1000 hr	Low cost, low power, low drift both for temperature and long time stability
Digital Potentiometers		
AD5271	256-position resolution, 20 kΩ and 100 kΩ resistance, ±1% tolerance error, 5 ppm/°C drift, 1 µA supply current	Single assembly and bill of materials for different gas sensors
Microcontroller		
ADuC7023[2]	Precision analog microcontrollers, 10-channel 12-bit SAR ADC, 62K Flash, 8K SRAM, ARM7TDMI MCU; up to 20 GPIO	SoC, higher integration benefits small size applications; larger memory for data storage

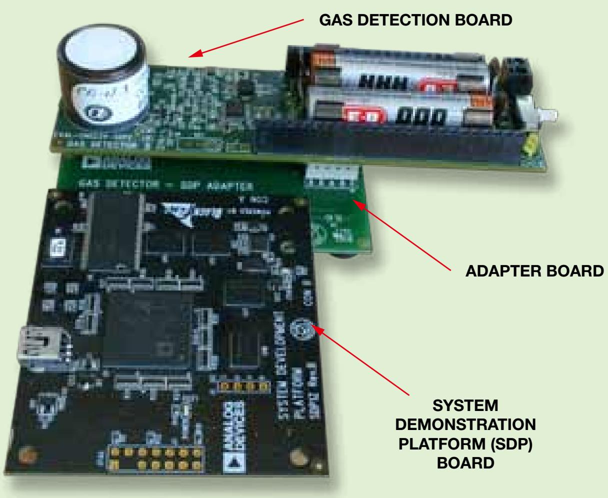
[1] For detailed parts and description, please refer to Circuits from the Lab and App Note listed in the end of this document.

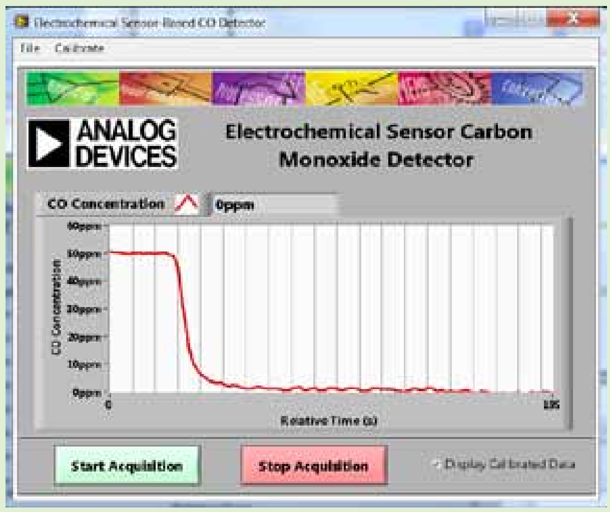
[2] In some cases, like transmitter applications in the industrial environment, low power is not the critical factor due to line power, like 12 V. In this case, the dual supply and higher consumption parts can be applied for better performance and design flexibility. Some parts for this case are also listed in the main products table below.

Main Products (Continued)

Part Number	Description	Benefits
Power Management		
ADP2503	38 µA quiescent current; 2.5 MHz buck-boost dc-to-dc converters, has ability to operate at input voltages greater than, less than, or equal to the regulated output voltage	Low power consumption to achieve long battery life, small package and few external parts for small PCB space
ADM8828[2]	Voltage inverter without inductor, two 1 µF external capacitor	Small package and few external parts around cost small PCB space
ADP2301[2]	3.0 V to 20 V input , 1.2 A, 1.4 MHz frequency, high efficiency up to 91%, current-mode control architecture	Small SOT-23-6 package, few peripheral components, and small solution size
ADP160	2.2 V to 5.5 V input, 150 mA maximum output current, 1% initial accuracy, up to 15 fixed-output voltage options available from 1.2 V to 4.2 V; low quiescent current: 42 µA	Low power consumption, integrated output discharge resistor, small package with only two 1 µF external capacitors
Interface		
AD5420[2]	16-bit resolution; current output ranges: 0 mA to 24 mA, 0.01% FSR typical total unadjusted error; 3 ppm/°C typical output drift; on-chip reference (10 ppm/°C maximum)	16-bit resolution and monotonicity, supports HART communication
ADM2483[2]	Half-duplex, 500 kbps data rate, 5 V or 3 V operations, low power operation: 2.5 mA max, 2.5 kV isolation	Low power operation and competitive price
AD5749[2]	4 mA to 20 mA driver, current output ranges: 0 mA to 24 mA or 4 mA to 20 mA, 0.03% FSR typical total unadjusted error (TUE), 5 ppm/°C typical output drift	Low cost, precision 4 mA to 20 mA driver

Gas Detection Demo System





THE DEMO SYSTEM SHOWN IN THE LEFT PICTURE CAN DETECT CO CONCENTRATION WITH DEFAULT CO ELECTROCHEMICAL SENSOR. THE SYSTEM INCLUDES THE GAS DETECTION BOARD WHICH IS FOR FUNCTION IMPLEMENTATION, ADAPTER BOARD, AND SDP BOARD WHICH SUPPORTS FOR DEMO SYSTEM BY CONNECTING TO PC. ONE DEMO RESULT IS SHOWN IN THE RIGHT GRAPH BY SPECIFIC PC PROGRAM BASED ON NI LABVIEW.

[1] For detailed parts and description, please refer to Circuits from the Lab and App Note listed in the end of this document.

[2] In some cases, like transmitter applications in the industrial environment, low power is not the critical factor due to line power, like 12 V. In this case, the dual supply and higher consumption parts can be applied for better performance and design flexibility. Some parts for this case are also listed in the main products table below.

Design Resources

Circuits from the Lab™

- *Single Supply, Micropower Toxic Gas Detector Using an Electrochemical Sensor* (CN0234)—*www.analog.com/CN0234*

Application Notes/Articles

- "Designing a Low-Power Toxic Gas Detector" *Analog Dialogue*, Volume 46, February 2012, *www.analog.com/library/analogDialogue/archives/46-02/gas_detector.html*

Design Tools/Forums

- ADIsimPower™: ADI Voltage Regulator Design Tool—*www.analog.com/adisimpower*
- ADIsimOpAmp™: ADI Opamp Design Tool—*www.analog.com/adisimopamp*
- EngineerZone™: Online Technical Support Community—*ez.analog.com*

To View Additional Gas Detector Resources, Tools, and Product Information,
Please Visit *instrumentation.analog.com*

Customer Interaction Center

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Free Sample	***www.analog.com/sample***

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