Technical Article

Gas Chromatography Sensors Address Environmental Monitoring Needs

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Abstract

This article outlines the working principles and components of a gas chromatography sensor system for applications in environmental quality monitoring. It describes how gas chromatography can precisely analyze compounds related to water and soil contamination. The article discusses the key components of a gas chromatography system, including the air inlet, temperature control, detector, and power supply subsystems. It will also provide recommendations for low noise amplifiers, analog-to-digital converters (ADCs), voltage references, and power management ICs that can enable high accuracy measurements.

Introduction

Exhaust gas monitoring plays an important role in environmental protection. As a result of industrial waste, some volatile organic compounds will be dispersed into the air, which will have an impact on the natural environment and human health.

There is a strong focus on environmental monitoring to reduce these emissions. However, traditional sensor systems are unable to meet the speed and accuracy requirements needed today. To compound the challenge, environmental monitoring systems also need to be enhanced to address high precision demands.

This article provides an overview of emerging gas chromatography technology as well as available solutions.

Basic Gas Chromatography Theory

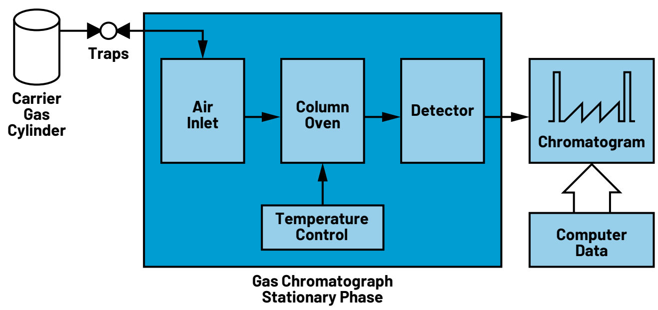

Figure 1. A diagram of a gas chromatograph system.

A gas chromatography system mainly consists of a gas inlet system, autosampler system, separation system, control system, detector system, and data processing. The block diagram of gas chromatography is depicted in Figure 1.

The carrier gas of gas chromatography is the mobile phase, and the sample under test is named stationary phase including solid and liquid mixture. The stationary phase is separated with gas flowing movement to leave the chromatographic column in sequence. Afterward, it enters the detector and generates the ion flow signal. These small signals are reflected to different components of the chromatogram by amplifying to a suitable amplitude on a recorder. The separation process from the mixture to two individual samples is shown in Figure 2. Green and purple colors stand for two different samples, and blue color stands for mixture.

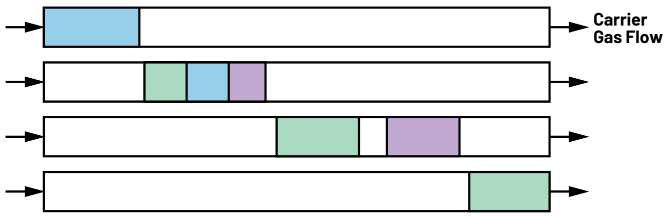

Figure 2. The process of separation.

Gas Chromatography System Solution

Based on Figure 1, Analog Devices has various components that can be applicable to the signal and power supply chain of gas chromatography. These components are well-suited to meet system requirements and are optimized for low power and noise performance.

Air Inlet System

Great precision is required to control the flow of the carrier gas accurately passing through the detector system to separate the mixture, which is realized by the use of a gas sensor. A gas sensor has diverse outputs such as a current signal, 4-20mA loop signal, voltage signal, etc. A signal chain of an air inlet system is depicted in Figure 3.

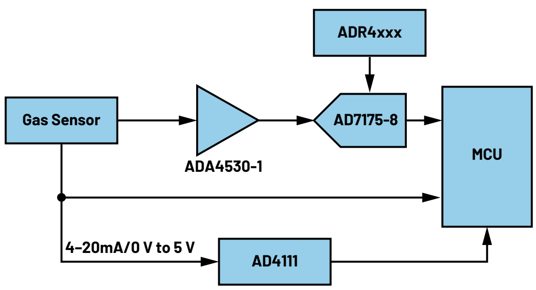

Figure 3. The signal chain of an air inlet system.

- Current signal: The ADA4530-1 is a femtoampere level input bias current operational amplifier used as the I/V (current to voltage) conversion, and it provides ultralow input bias currents (femtoampere) that ensure the device meets accurate performance goals in the system. It also offers low offset voltage, low offset drift, and low voltage and current noise needed for the types of applications that require such low leakages.

Parameter[1]	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
INPUT CHARACTERISTICS						
Input Bias Current[2, 3]	I_B	RH < 50%		<1	±20	fA
		$-40°C < T_A < +85°C$, RH < 50%			±20	fA
		$-40°C < T_A < +125°C$, RH < 50%			±250	fA
Input Offset Current[3]	I_{OS}	RH < 50%		<1	±20	fA
		$-40°C < T_A < +125°C$, RH < 50%			±150	fA

Figure 4. An ADA4530-1 data sheet.

  After converting the current signal into a voltage signal, the AD7175 (24-bit, 8-/16-channel, 250 kSPS, sigma-delta ADC) is used to get accurate results. The AD7175 is a low noise, fast settling, multiplexed, 8-/16-channel (fully/pseudo differential) sigma-delta ADC for low bandwidth inputs.

- 4-20mA signal sampling: the AD4111 ADC is a good choice for sampling the air sensor outputs transmitted by 4-20mA signal, as it has extremely good channel matching due to the integrated sense resistors for the current and voltage sampling. The device is a low power, low noise, 24-bit, sigma-delta ADC that integrates an analog front end (AFE) for fully differential or single-ended, high impedance (≥1 MΩ) bipolar, ±10 V voltage inputs, and 0 mA to 20 mA current inputs. This ADC also integrates key analog and digital signal conditioning blocks to configure eight individual setups for each analog input channel in use. It features a maximum channel scan rate of 6.21 kSPS (161 µs) for fully settled data and it also has the unique feature of open wire detection on the voltage inputs for system—level diagnostics using a single 5 V or 3.3 V power supply.
- Voltage signal: If an external ADC with high resolution is selected, the ADR4xxx series (that is, ADR4525/ADR4530) can provide a high accuracy reference voltage for the ADC. Alternatively, a low cost way is to use the internal ADC of the microcontroller unit (MCU) to perform the sampling, but this may sacrifice the measurement accuracy.

Temperature Control System

The temperature is controlled by a closed-loop system: The LT1241 is used to drive a MOSFET bridge with pulse width modulation (PWM) as thermoelectric cooler (TEC) circuitry to control the thermal cooler, and a resistance temperature detector (RTD) reads back the temperature and connects to the AD7124, an ultralow noise and power sigma-delta ADC. The AD7124 is intended for temperature measurement applications. To improve temperature acquisition accuracy, it can support a 2-wire thermocouple and is optimized for a 3-wire RTD configuration catering to different customers' expectations.

The ADN8835 that integrates the TEC controller is also avaiable. The temperature control system diagram is shown in Figure 5.

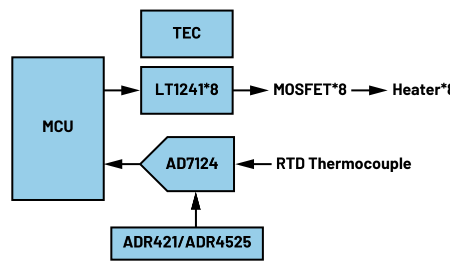

Figure 5. A signal chain of a temperature control system.

Detector System

The detector system is the final stage, which is used for describing the chromatogram. The flow and pressure sensors are used for monitoring the carrier gas flowing movement with different sampling requests, so the AD7124 and LTC2498 with multichannels are selected.

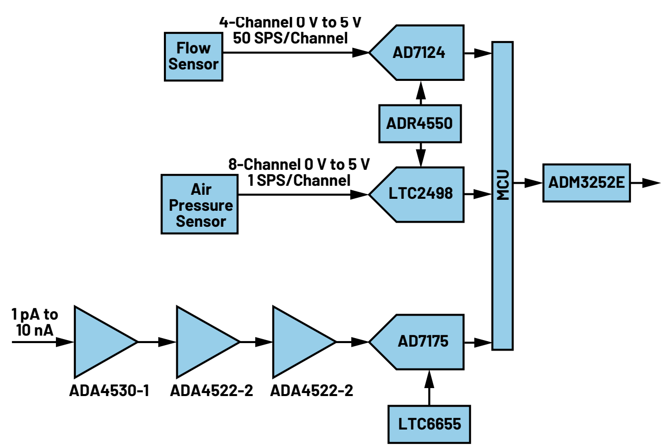

Figure 6. A signal chain of a detector system.

The ion current signal is normally picoampere level entering the detector and the ADA4530-1 works as an electrometer amplifier, which benefits from not only the low input bias current, but also the low noise and offset. The ADA4530-1 is also an operational amplifier with a 2 MHz gain bandwidth product, so the feedback resistor of gain can be very high as the signal bandwidth is normally less than several kHz. Cascaded ADA4522-2 devices with ultralow noise and drift amplifier as the second stage amplifier achieve sufficient gain for ADC input range. The ADA4522-2 offers zero drift op amps with low noise and power, ground sensing inputs, and rail-to-rail output, optimized for total accuracy over time, temperature, and voltage conditions.

Power Supply

The system power supply is derived from 24 VDC, and it is connected to step-down converters (buck) to provide the power supply for circuitry including amplifier, ADC, processor, and so forth.

Both the LT8471 and the LTM4655 are dual outputs with positive and negative voltages. The LTM4655 with included controllers, power MOSFETs, inductors, and filters in the signal chain is designed to reduce design complexity while having a good EMI immunity.

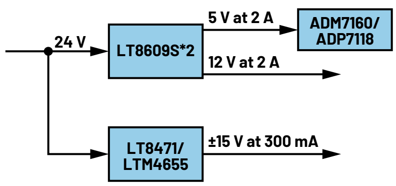

Figure 7. A power supply chain for the system.

Conclusion

Gas chromatography plays an important role in monitoring pollutants for the protection of our environment. It also has the potential and capability to be integrated into other techniques such as liquid chromatography in order to measure and monitor more substances. To address the needs of today and those that may emerge tomorrow, ADI has a wide variety of low noise and high accuracy solutions to meet customer requirements and simplify system design.

Water Quality Monitoring

- The surface water and groundwater are mainly contaminated by nitrobenzene compounds and heavy metal ions. Dissolved contamination will remain due to incomplete transformation during industrial production, and it poses a serious threat to public health. Gas chromatography can monitor contamination with high accuracy.

Soil Residual Pesticide Monitoring

- In agricultural activities, the pesticides that farmers spray on their crops kill pests, but they can also damage people's health. Gas chromatography can analyze the ingredients of pesticides accurately.

In general, gas chromatography is also convenient to be integrated into other techniques including liquid chromatography for the measurement of more substances. Therefore, it has become a widely used technique across most industries and testing facilities. Meanwhile, ADI can offer low noise and high accuracy signal chain solutions to reduce the complexity of system design and achieve excellent performance with high resolution, robustness, etc.

About the Author

Linlong Zhang earned his master's degree in integrated circuit design in 2019 from Nanyang Technological University of Singapore. He joined Analog Devices in 2019 and worked as a field applications engineer with exposure to consumer and healthcare markets. Since 2022, he has been focusing on multimarkets.

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