Dual Beam Spectrophotometer: ADI Solutions Application Brief

Introduction

A spectrophotometer is an instrument that can measure intensity as a function of the light source wavelength. A spectrophotometer is commonly used for the measurement of transmittance or reflectance of solutions and transparent or opaque solids or gases. The use of spectrophotometers spans various scientific fields, such as physics, materials science, chemistry, biochemistry, and molecular biology. Spectrophotometers are widely used in many industries including semiconductors, laser and optical manufacturing, printing, and forensic examination, as well as in laboratories for the study of chemical substances.

The most common spectrophotometers are used in the UV and visible (UV/VIS) region of the spectrum, with some of these instruments operating in the near-infrared region as well.

Here we introduce a general spectrophotometer with a simplified optical system as an example.

System Design Considerations and Major Challenges

Stability, drift with time, and drift with temperature are very important factors during spectrophotometer design. To achieve this objective, low drift and an accurate signal chain are required.

In addition, high dynamic range is important in order to analyze a wide range of compounds. A programmable gain transimpedance amplifier can provide high dynamic range with lower noise than two stages of amplification. For best performance, the system must strongly reject any external electrical and optical noise.

Theory of Operation

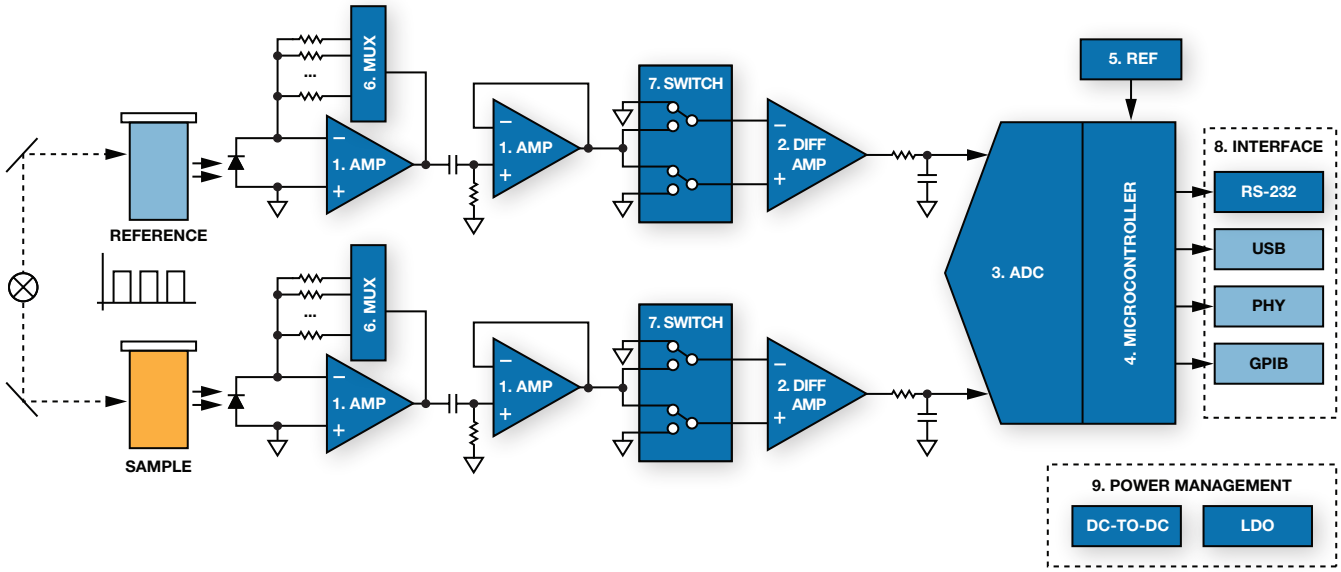
This simplified optical system generates modulated light which passes through both reference and sample cells. The photodiodes generate a current proportional to the light energy hitting their active area, and the transimpedance amplifiers convert this current to a voltage. The signal is then converted and demodulated into a dc voltage for the precision Σ-Δ analog-to-digital converter (ADC), which can be independent or integrated in the microcontroller. The demodulation step will strongly reject any noise or other signals that are not in phase with the modulated signal from the LED. The ADC measures the amplitude of the reference and sample channels. The ratio of the two amplitudes is related to the concentration of the sample solution.

The main advantage of a dual beam system is the ability to generate stable results even with changing external conditions such as amplitude fluctuations in the light source and to compensate for different sample holder materials. The modulated light method helps to eliminate the effect of ambient light and other noise sources that are not in phase with the modulating clock.

Simplifying Design for Your Competitive Edge

System Block Diagram

Below is the system block diagram of a general spectrophotometer including a simplified optical system, sample and reference cells, dual channel signal conditioning circuit, microcontroller (ADC integrated), communication interface, and power management.



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

1. Operational Amplifier	2. Difference Amplifier	3. Analog-to-Digital Converter	4. Analog Microcontroller	5. Reference	6. Multiplexer	7. Switch	8. Interface	9. Power Management
AD8615, AD8605, AD8626	AD8271, AD8278	AD7798, AD7799, AD7190, AD7192	ADUCM361, ADuC7061	ADR4525, ADR3425, ADR291	ADG704, ADG708, ADG1609	ADG733, ADG1636	ADM3251E	ADP2441, ADP2370, ADP160, ADP7102, ADP7182

Main Products

Part Number	Description	Benefit
Operational Amplifier		
AD8615	Precision 20 MHz CMOS single RRIO operational amplifier	Low bias current at room temperature, high speed, low noise, low offset op amp
AD8605	Precision, low noise, CMOS, RRIO op amp (single)	Low bias current at room temperature, high speed, low noise, low offset op amp
AD8626	Precision, low power, single supply, JFET amplifier in MSOP	Wider power supply range, low bias current @ 0°C to 50°C, low offset drift
Difference Amplifier		
AD8271	Programmable gain precision difference amplifier	Low gain drift and high speed, suitable for the drive ADC
AD8278	Low power, wide supply range, low cost difference amplifiers, G = ½, 2	Low power consumption, enough bandwidth
Analog-to-Digital Converter		
AD7798	3-channel, low noise, low power, 16-bit, Σ-Δ ADC with on-chip in-amp	Low power consumption and high integrated Σ-Δ ADC, high resolution and high accuracy
AD7799	3-channel, low noise, low power, 24-bit, Σ-Δ ADC with on-chip in-amp	Low power consumption and high integrated Σ-Δ ADC, high resolution and high accuracy
AD7191/AD7192	4.8 kHz ultralow noise, 24-bit Σ-Δ ADC with PGA	Low power consumption, low noise and high integrated Σ-Δ ADC, high resolution and high accuracy
Analog Microcontroller		
ADuCM361	Low power precision analog microcontroller, ARM Cortex-M3 with single Σ-Δ ADC	Low power consumption, high precision 24-bit Σ-Δ ADC, 4 mA to 20 mA loop applications, small package
ADuC7061	Low power precision analog microcontroller, dual Σ-Δ ADCs, flash/EE, ARM7TDMI	Low power consumption, low cost, 24-bit Σ-Δ ADC, 4m A to 20 mA loop applications, small package

Main Products (Continued)

Part Number	Description	Benefit
Reference		
ADR4525	Ultralow noise, high accuracy 2.5 V voltage reference	Low drift, very good stability and low noise reference, low hysteresis, and many other choices for output voltage in the ADR45xx family
ADR3425	Micropower, high accuracy 2.5 V voltage reference	Low drift, good stability, and many other choices for output voltage in the ADR34xx family
ADR291	Low noise micropower precision voltage reference (2.5 V)	Low power consumption, pretty good drift and stability
Multiplexer		
ADG704	CMOS, low voltage, 2.5 Ω, 4-channel multiplexer	Low leakage and low on resistance help to build a highly accurate system
ADG708	CMOS, low voltage, single 8 to 1 multiplexer	Low leakage and low on resistance help to build a highly accurate system
ADG1609	4.5 Ω R_{ON}, 4-channel, ±5 V,+12 V, +5 V, and +3.3 V multiplexer	Wider power supply range, low leakage, and low on resistance help to build a highly accurate system
Switch		
ADG733	CMOS, 2.5 Ω, low voltage, triple SPDT switch	Low leakage and low on resistance help to build a highly accurate system
ADG1636	1 Ω typical on resistance, ±5 V, +12 V, +5 V, and +3.3 V dual SPDT switches	Wider power supply range, low leakage, and low on resistance help to build a highly accurate system
Interface		
ADM3251E	Isolated single-channel RS-232 line driver/receiver	High integrated isolated RS-232 transceiver
Power Management		
ADP2441	36 V, 1 A, synchronous, step-down dc-to-dc regulator	Small 3 mm × 3 mm LFCSP package, high efficiency
ADP2370	High voltage, 1.2 MHz/600 kHz, 800 mA, low quiescent current buck regulator	Small 3 mm × 3 mm LFCSP package, few peripheral components, and small solution size
ADP160	Ultra low quiescent current, 150 mA, CMOS linear regulator	Low power consumption, integrated output discharge resistor, small package with only two 1 µF external capacitor
ADP7102	20 V, 300 mA, low noise CMOS LDO	High input voltage, low noise LDO
ADP7182	–28 V, 200 mA, low noise linear regulator	High input voltage, low noise negative LDO

System Benefits

More Functionality/ Integrated Solutions

Reduce equipment size with parts that add more functionality per square inch such as the AD7190/AD7192 with integrated PGA or the ADuCM361 analog microcontroller: ARM Cortex®-M3 with on-chip 24-bit Σ-Δ ADC.

Faster Time to Market

Speed time to market by reducing and simplifying development efforts with ADI's tools such as Photodiode Wizard, signal chains, reference designs, and more.

More Accurate and Faster Solutions

Use multichannel, 24-bit Σ-Δ ADCs such as the AD7799 or the 4.8 kHz AD7192/AD7193/AD7194 family and higher speed amplifiers like the AD8615.

Superior Services and User Experience

Broad Product Portfolio

ADI provides the broadest product portfolio for analytical test and measurement instrumentation applications including:

- Sensor interfaces
  - FET input amps—mostly precision—for photodetectors
  - Low noise, low drift amplifiers and references
  - Analog switches and multiplexers
- Signal conditioning and processing
  - ADC drivers—typically lower bandwidth (less than 5 MHz)
  - 24-bit Σ-Δ ADCs, low bandwidth
  - Signal generation
  - Precision DACs—voltage and current sources
  - Direct digital synthesis (DDS)—waveform generators
- Pressure and vacuum measurement
  - Capacitive sensor measurement
  - Strain gauge measurement
- Temperature measurement
- Temperature sensors
  - Digital temperature sensors
  - Multichannel temperature monitors
- Current/voltage measurements and references
  - Current sense amplifiers—high and low side
  - Low drift amps and voltage references
- Power management

Design Resources

Circuits from the Lab® Reference Designs

- Dual-Channel Colorimeter with Programmable Gain Transimpedance Amplifiers and Synchronous Detectors (CN0312)—*www.analog.com/CN0312*

Application Notes/Technical Articles

- Programmable Gain Transimpedance Amplifiers Maximize Dynamic Range in Spectroscopy Systems—*www.analog.com/library/analogdialogue/archives/47-05/pgtia.pdf*

Design Tools/Forums

- Chemical Analysis Signal Chains—*instrumentation.analog.com/en/chemical-analysis/segment/im.html*
- Analog Photodiode Wizard—*www.analog.com/en/content/photodiode_wizard/fca.html*
- ADIsimPower™: ADI Voltage Regulator Design Tool—*designtools.analog.com/dtPowerWeb/dtPowerMain.aspx*
- ADIsimOpAmp™: ADI Op Amp Design Tool—*www.analog.com/en/amplifier-linear-tools/topic.html*
- ADuCM361 Design Tools—*ftp.analog.com/pub/MicroConverter*
- EngineerZone®: Online Technical Support Community—*ez.analog.com*

To view additional resources, tools, and product information, please visit *instrumentation.analog.com*.

Customer Interaction Center

Email	North America: *cic.americas@analog.com* Europe: *cic@analog.com* Asia: *cic.asia@analog.com*
EngineerZone	*ez.analog.com*
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Analog Devices, Inc.
Worldwide Headquarters
Analog Devices, Inc.
One Technology Way
P.O. Box 9106
Norwood, MA 02062-9106
U.S.A.
Tel: 781.329.4700
(800.262.5643,
U.S.A. only)
Fax: 781.461.3113

Analog Devices, Inc.
Europe Headquarters
Analog Devices, Inc.
Wilhelm-Wagenfeld-Str. 6
80807 Munich
Germany
Tel: 49.89.76903.0
Fax: 49.89.76903.157

Analog Devices, Inc.
Japan Headquarters
Analog Devices, KK
New Pier Takeshiba
South Tower Building
1-16-1 Kaigan, Minato-ku,
Tokyo, 105-6891
Japan
Tel: 813.5402.8200
Fax: 813.5402.1064

Analog Devices, Inc.
Asia Pacific Headquarters
Analog Devices
5F, Sandhill Plaza
2290 Zuchongzhi Road
Zhangjiang Hi-Tech Park
Pudong New District
Shanghai, China 201203
Tel: 86.21.2320.8000
Fax: 86.21.2320.8222

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BR11806-0-1/14(A)

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