Circuit Note CN-0213

Circuits from the Lab™ Reference Circuits

Circuits from the Lab™ reference circuits are engineered and tested for quick and easy system integration to help solve today's analog, mixed-signal, and RF design challenges. For more information and/or support, visit www.analog.com/CN0213.

Devices Connected/Referenced	
AD7685	16-Bit , 250 kSPS PulSAR® ADC in MSOP/QFN
AD8226	Wide Supply Range, Rail-to-Rail Output Instrumentation Amplifier
AD8275	G = 0.2, Level Translation, 16-Bit ADC Driver
ADP1720	50 mA, High Voltage, Micropower Linear Regulator
ADR439	Ultralow Noise XFET® Voltage Reference

Complete High Speed, High CMRR Precision Analog Front End for Process Control

EVALUATION AND DESIGN SUPPORT

Design and Integration Files

Schematics, Layout Files, Bill of Materials

CIRCUIT FUNCTION AND BENEFITS

Signal levels in industrial process control systems generally fall into one of the following categories: single-ended current (4 mA-to-20 mA), single-ended, differential voltage (0 V to 5V, 0 V to 10 V, ±5 V, ±10 V), or small signal inputs from sensors such as thermocouples or load cells. Large common-mode voltage swings are also typical, especially for small signal differential inputs; therefore good common-mode rejection is an important specification in the analog signal processing system.

The analog front-end circuit shown in Figure 1 is optimized for high precision and high common-mode rejection ratio (CMRR) when processing these types of industrial-level signals.

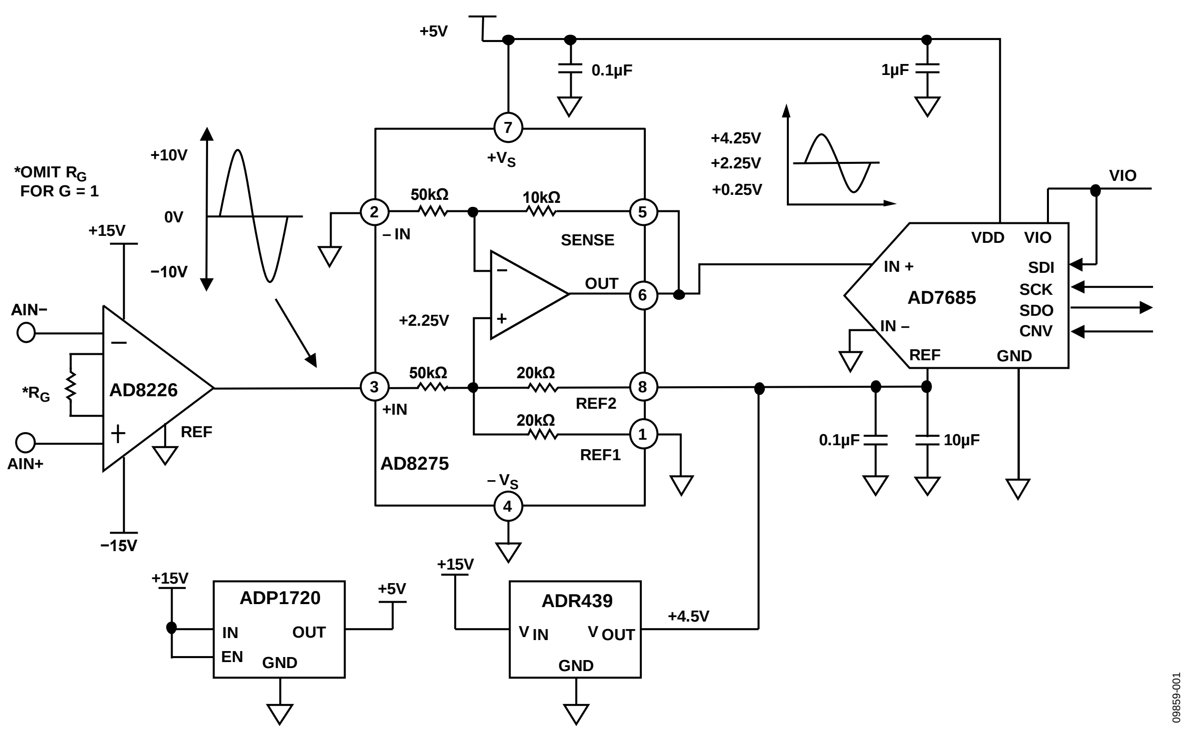

Figure 1. High Performance Analog Front End for Process Control (Simplified Schematic: All Connections and Decoupling Not Shown)

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The circuit level shifts and attenuates the signals so they are compatible with the input range requirements of most modern single-supply SAR ADCs, such as the AD7685 high performance 16-bit 250 kSPS PulSAR® ADC.

With an 18 V p-p input signal, the circuit achieves approximately 105 dB common-mode rejection (CMR) at 100 Hz and 80 dB CMR at 5 kHz.

High precision, high input impedance, and high CMR are provided by the AD8226 instrumentation amplifier. For high precision applications, a high input impedance is required to minimize system gain errors and also to achieve good CMR. The AD8226 gain is resistor-programmable from 1 to 1000.

A resistive level shifter/attenuator stage directly on the input would inevitably degrade CMR performance due to the mismatch between the resistors. The AD8226 provides the excellent CMR required for both small signal and large signal inputs. The AD8275 level shifter/attenuator/driver performs the attenuation and level shifting function in the circuit, without any need for external components.

Traditionally, sigma-delta ADCs have been used in high resolution measurement systems because signal bandwidths are quite low, and the sigma-delta architecture provides excellent noise performance at low update rates. However, there is an increased trend for higher update rates, especially in multichannel systems, to allow faster per-channel update, or for increased channel density. In such cases a high performance SAR ADC is a good alternative. The circuit shown in Figure 1 uses the AD7685 250 kSPS 16 bit ADC, with the AD8226 high performance in-amp, and the AD8275 attenuator/level shifter amplifier implemented as a complete system solution without the need for any external components.

CIRCUIT DESCRIPTION

This circuit is comprised of an AD8226 rail-to-rail output in-amp, connected to the positive input of the AD8275 G = 0.2 difference amplifier, whose output is then connected to the input of the AD7685, a 16-bit, 250 kSPS PulSAR ADC in MSOP/QFN. The AD8226 is set for a gain-of-one mode (high voltage/current inputs), and its output is referenced to ground. Single-ended or differential inputs can be used. The output of the AD8226 is a bipolar signal, which drives the AD8275 input. The AD8275 acts to attenuate and level shift the bipolar input, providing for a gain of 0.2. Hence, differential inputs of 20 V p-p at its inputs will yield a 4 V p-p single-ended range on the output. The ADR439 precision 4.5 V reference is used to provide both the internal common-mode bias voltage for the AD8275 (VREF/2 = 2.25V), as well as the external reference voltage for the AD7685 ADC. Under these conditions, the output of the AD8275 swings from +0.25 V to +4.25 V, which is within the range of the AD7685, 0 V to +4.5 V.

The ADP1720 is used to provide the 5 V supply for the AD8275 and the AD7685. The ADP1720 was chosen because it has a high input voltage range (up to 28 V). In this circuit, the ADP1720 is only required to supply approximately 4 mA to the AD8275 and AD7685, so the worst case power dissipation in the regulator with 28 V input is about 90 mW. This allows the complete system to run from the external ±15 V supplies.

System Level Common-Mode Rejection Performance

Initial testing was to verify the performance of the AD8226 common-mode rejection at a system level through to the ADC. Input test tones of 10 Hz, 100 Hz, 500 Hz, 1 kHz, 2 kHz, 3 kHz, 4 kHz, 5 kHz were used, with an 18 V p-p input signal. The test results are summarized in Table 1. In Test 1 the AIN+ and AIN− signals are shorted together and connected to the ac test tone, and the results measured with an FFT. The AD8226 should reject the ac signal because its inputs are connected together. In Test 2 the signal is applied to AIN+, and AIN− is connected to ground. Under these conditions, the FFT measures the level of the tone. The common-mode rejection can then be calculated as the difference in the FFT results between Test 1 and Test 2. Table 1 summarizes the CMR values obtained at different frequencies. It is important to note that the CMR of the AD8226 is specified at 80 dB at 5 kHz, so no loss in CMR performance is realized at the system level.

System Level AC Performance

The ac accuracy of the system was also tested at a system level with the AD7685 operating at a sampling rate of 250 kSPS. Figure 2 shows an FFT test result for a 5 V p-p input at 10 kHz. The results shown in the plot are given below:

- SNR = 87.13 dBFS
- SINAD = 85.95 dBFS
- SFDR = 81.82 dBc
- THD = −78.02 dBc

Table 1. CMR Performance of Circuit for 18 V p-p Input

Frequency (kHz)	FFT Signal Level (dBFS), 18 V p-p Input		CMR (dB)
	Test 1: AIN+ = AIN−	Test 2: Input = AIN+, AIN− = GND	
0.1	−104.64	−2.86	101.78
0.5	−100.00	−3.28	96.72
1	−94.67	−2.85	91.82
2	−88.58	−2.88	85.70
3	−84.93	−2.93	82.00
4	−82.07	−3.01	79.06
5	−79.43	−3.10	76.33

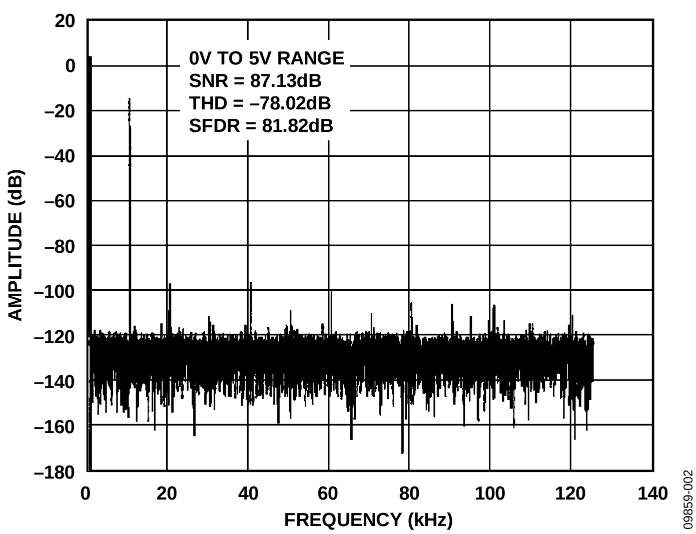

Figure 2. FFT Results for 10 kHz Input Signal 14 dB Below Full-Scale, 250 kSPS Sampling Rate

The performance of this or any high speed circuit is highly dependent on proper PCB layout. This includes, but is not limited to, power supply bypassing, controlled impedance lines (where required), component placement, signal routing, and power and ground planes. (See MT-031 Tutorial, MT-101 Tutorial, and article, *A Practical Guide to High-Speed Printed-Circuit-Board Layout*, for more detailed information regarding PCB layout.)

A complete design support package for this circuit note can be found at http://www.analog.com/CN0213-DesignSupport.

COMMON VARIATIONS

This circuit is proven to work well with good stability and accuracy with component values shown. Other ADI analog-to-digital converters can be used in place of the AD7685 to achieve even higher speed/resolution or higher performance. The AD7688 provides a true differential input to achieve even better CMR. The AD7982 18-bit ADC provides higher resolution at speeds up to 1 MSPS and is also fully differential. The AD8475 funnel amplifier can also accept high voltage bipolar inputs and provide attenuation and level shifting with differential outputs, making it ideal for industrial applications using ADCs with differential inputs (See Circuit Note CN-0180).

CIRCUIT EVALUATION AND TEST

The circuit was tested using the System Demonenstration Platform (SDP). The SDP platform includes the necessary ADC drivers and also the USB connectivity to the PC. Sampled data from the ADC is sent to the PC via USB using the SDP board. The FFT plots were generated using the standard ADC LabVIEW evaluation software tools available from ADI. A fuctional block diagram of the test setup is shown in Figure 3 and a photograph of the boards in Figure 4.

Equipment Used to Collect Test Data

- PC with a USB port and Windows® XP or Windows Vista® (32-bit), or Windows® 7 (32-bit)
- EVAL-A-INPUT-1AZ circuit evaluation board
- EVAL-SDP-CB1Z, SDP-A evaluation board
- Evaluation software
- Power supply: +5 V @ 200 mA.
- Power supply: ±15 V, Agilent E3630A or equivalent
- Signal generator: Agilent 33120A or equivalent

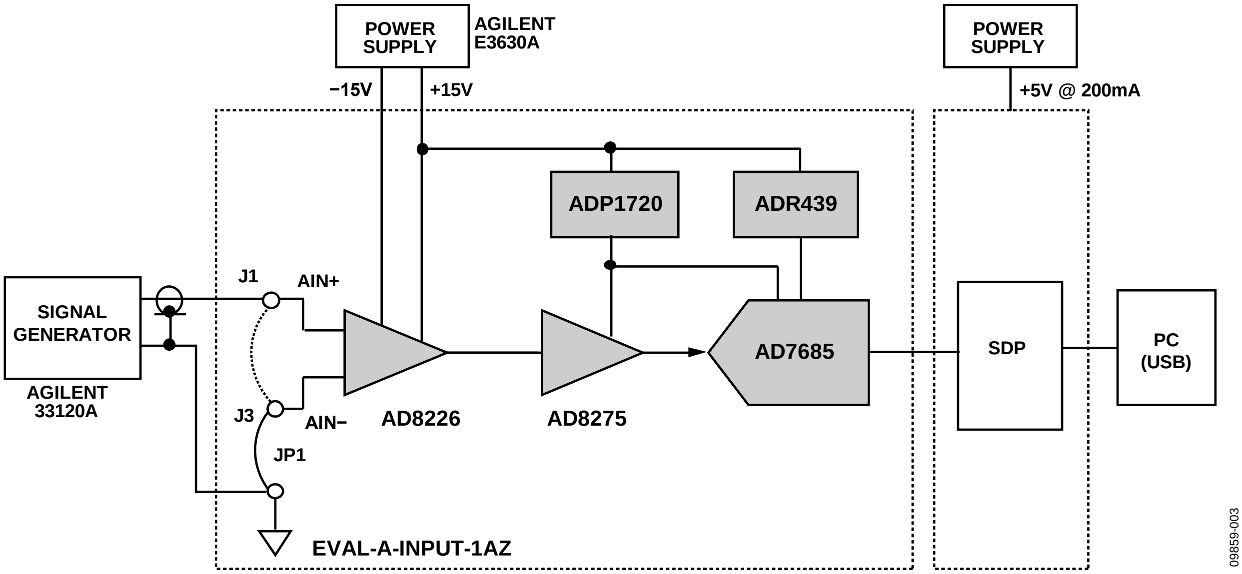

Figure 3. Functional Block Diagram of Test Setup

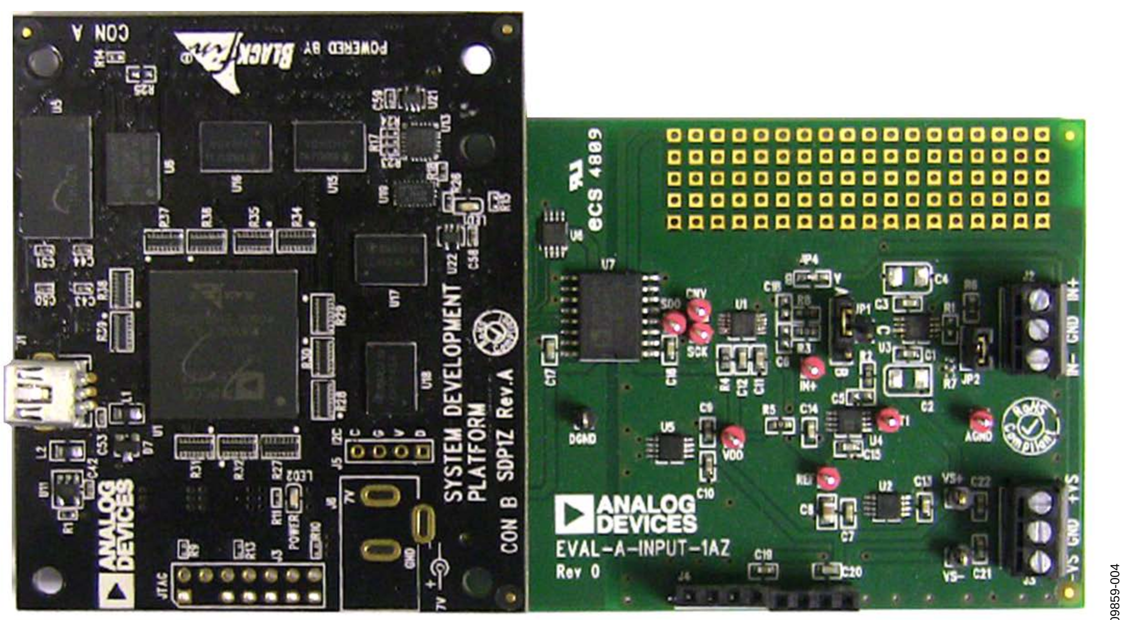

Figure 4. Photo of EVAL-A-INPUT-1AZ Evaluation Board Connected to SDP Board

Setup and Test

Evaluation software was loaded in the CD drive of the PC.

The 120-pin connector on the EVAL-A-INPUT-1AZ circuit board was connected to the connector marked "CON B" on the EVAL-SDP-CB1Z evaluation (SDP) board. Nylon hardware was used to firmly secure the two boards, using the holes provided at the ends of the 120-pin connectors. The signal source was connected to the EVAL-A-INPUT-1AZ board J1 input (AIN+) terminal. When running normal FFT tests, the JP1 jumper was connected between the J3 terminal (IN−) and ground. When running CMR tests, the jumper was connected between J1 (AIN+) and J3 (AIN−).

With power to the supply off, a +5 V power supply was connected to the SDP board. The USB cable was used to connect the SDP board to the USB port on the PC.

The ±15 V supplies were then connected to EVAL-A-INPUT-1AZ circuit board. The evaluation software was launched, and the USB cable was connected from the PC to the USB mini-connector on the SDP board.

Once USB communications are established, the SDP board was used to send, receive, and capture serial data from the EVAL-A-INPUT-1AZ board.

LEARN MORE

CN-0213 Design Support Package: http://www.analog.com/CN0213-DesignSupport

Ardizzoni, John. *A Practical Guide to High-Speed Printed-Circuit-Board Layout*, *Analog Dialogue* 39-09, September 2005.

MT-031 Tutorial, *Grounding Data Converters and Solving the Mystery of "AGND" and "DGND"*, Analog Devices.

MT-101 Tutorial, *Decoupling Techniques*, Analog Devices.

Data Sheets and Evaluation Boards

System Demonstration Platform (EVAL-SDP-CB1Z)

AD7685 Data Sheet

AD7685 Evaluation Board

AD8226 Data Sheet

AD8275 Data Sheet

REVISION HISTORY

7/11—Revision 0: Initial Version