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Devices Connected/Referenced	
AD7793	24-Bit Σ - Δ ADC
ADR441	Precision 2.5 V Reference
AD8220	High CMRR Bipolar In-Amp
ADuM5401	Quad-Channel <i>isoPower</i> ® Digital Isolator
AD8601	Single-Supply Op Amp

Fully Isolated Input Module Based on the AD7793 24-Bit Σ - Δ ADC, the ADuM5401 Digital Isolator, and a High Performance In-Amp

CIRCUIT FUNCTION AND BENEFITS

This circuit provides a complete solution for an industrial control input module. This design is suitable for process control programmable logic controllers (PLCs) and distributed control system (DCS) modules that must digitize standard 4 mA to 20 mA current inputs and unipolar input voltage ranges. The AD8220 in-amp is used to level shift the bipolar signals to provide a 0 V to 5 V input signal to the AD7793 ADC. The ADuM5401 provides all the necessary signal isolation and power between the microcontroller and the ADC. The circuit also includes standard external protection and has been tested and verified to be fully compliant with IEC 61000 specifications.

CIRCUIT DESCRIPTION

For industrial control modules, analog input voltage and current ranges include 0 V to 5 V, 0 V to 10 V, 4 mA to 20 mA, and 0 mA to 20 mA. A resistor divider (R2-R3) on the input is used to attenuate high voltage inputs so that they match the maximum input range of the AD8220 (–0.1 V to +2.9 V when operating on a single +5 V supply). A good variation of this circuit is to use the AD8226, which has a wider maximum input range (–0.1 V to +4.1 V). The AD8220 is used to level shift the input signal and provide gain so that it matches the input range of the AD7793. This circuit is specifically designed for unipolar analog inputs. Other boards have been designed for bipolar operation, which requires bipolar supplies (see [Scott Wayne, “iCoupler” Digital Isolators Protect RS-232, RS-485, and CAN Buses in Industrial, Instrumentation, and Computer Applications, Analog Dialogue, October 2005](#)).

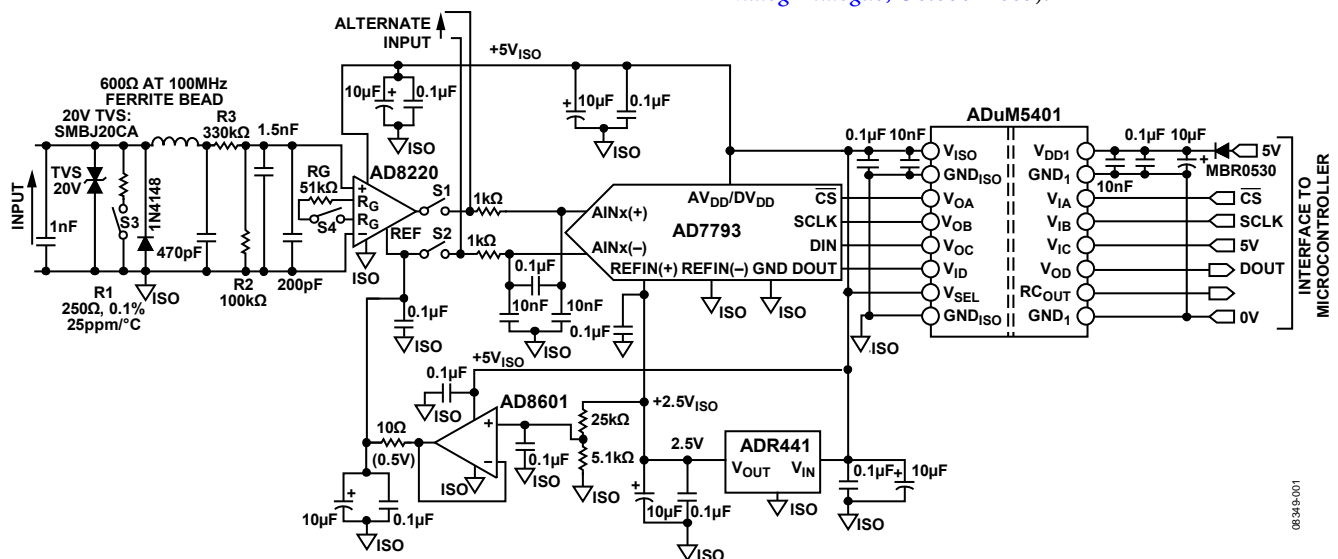


Figure 1. 24-Bit Isolated Industrial Control Voltage Input Module (Simplified Schematic)

Rev. B

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The AD8220 also has the excellent CMRR needed in these applications. Jumpers (shown here as switches for clarity) are used to switch between current and voltage ranges in hardware and to set the gain of the AD8220. For example, when the input is set to receive a 4 mA-to-20 mA current, the switches are configured to provide a 250 Ω load resistor (R1) on the input, providing a full-scale voltage of 5 V.

The AD8220 output is biased with a common-mode signal connected to the REF pin. This reference signal is generated from the same reference as the AD7793, divided down to provide a 0.42 V bias voltage that is buffered using the AD8601 and connected to the REF pin of the AD8220. The REF input to the AD8220 should always be driven with a low impedance, heavily decoupled source.

The ADR441 is the chosen reference for this circuit. The ADR441 has excellent accuracy specifications of 0.04% and drift specifications of 3 ppm/°C maximum.

The ADuM5401 is a quad-channel isolator with integrated *isoPower* technology, based on Analog Devices, Inc., *iCoupler*® technology. It is used to provide isolation between the field side and the system microcontroller, with an isolation rating of 2.5 kV rms. The ADuM5401 also has an integrated dc-to-dc converter that can provide 500 mW of regulated isolated power at either 5 V or 3.3 V. This design uses 5 V provided from the ADuM5401 to supply all the analog circuitry on the input module. Four wires are used: three for transmit (CS, SCLK, and DIN) and one for receive (DOUT), which connect to the standard SPI interface.

The AD7793 is specified for an AV_{DD} of 2.7 V to 5.25 V under normal operation. For loads greater than 10 mA, the output voltage of the ADuM5401 is 4.75 V to 5.25 V, although for lighter loads, it is 4.7 V to 5.4 V. For this reason, the user can either ensure that the isolated circuit draws more than 10 mA during operation or place a diode in series with the AV_{DD} supply of the AD7793 to ensure that the AV_{DD} voltage is within the specification. The circuit shown in Figure 1 draws ~4.8 mA.

Figure 2 shows a noise plot of the input module when a 2.5 V input signal is connected using the 0 V to +10 V input range. The measured noise on the output is in peak-to-peak resolution. The 19.5 bit peak-to-peak noise-free code resolution means there are 4.5 bits of noise flicker on the output of the ADC with respect to the ADC's 24-bit resolution. Therefore, the ADC's noise-free code resolution is 19.5 bits. In terms of contributing to the overall system error, the measured noise of 4.5 bits contributes ~0.00014% error with respect to the full-scale range of the ADC. The integral nonlinearity error of the AD7793 is 0.0015%.

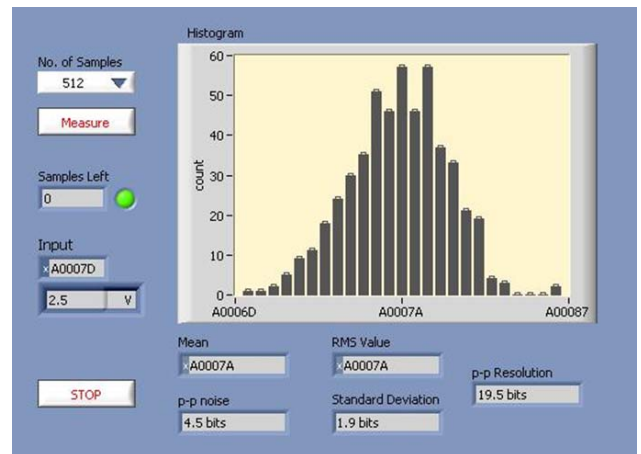


Figure 2. Input Module Histogram, 4.7 Hz Update Rate, Gain =1, Input = 2.5 V Reference

This circuit is from a portion of the PLC demo system. The PLC demo system has been successfully tested to the IEC 61000 standards shown in Table 1 (see Colm Slattery, Derrick Hartmann, and Li Ke, “PLC Evaluation Board Simplifies Design of Industrial Process Control Systems,” *Analog Dialogue* (April 2009) for more discussion of external protection techniques).

Table 1. Conformance to IEC Specifications¹

Test Item	Description	Result
EN55022	Radiated emission Class A, 3 meter anechoic chamber	Passed and met –6 dB margin.
EN and IEC 61000-4-2	Electrostatic discharge (ESD) ±8 kV VCD Electrostatic discharge (ESD) ±8 kV HCD	Maximum deviations in Input Channel 2, Input Channel 3, and Input Channel 4 are respectively –8 ppm, 10 ppm, and 13 ppm when there is interference. Maximum deviations in Input Channel 2, Input Channel 3, and Input Channel 4 are respectively –8 ppm, 10 ppm, and 13 ppm when there is interference.
EN and IEC 61000-4-3	Radiated immunity 80 MHz to 1 GHz 18 V/m, vertical antenna polarization Radiated immunity 80 MHz to 1 GHz 18 V/m, horizontal antenna polarization	Maximum deviations in Input Channel 2, Input Channel 3, and Input Channel 4 are respectively 0.05%, 0.004%, and –0.13%. Performance automatically resorted to ≤0.05% after interference. Class B. Maximum deviations in Input Channel 2, Input Channel 3, and Input Channel 4 are respectively –0.09%, 0.003%, and –0.02%. Performance automatically resorted to ≤0.05% after interference. Class B.
EN and IEC 61000-4-4	Electrically fast transient (EFT) ±4 kV power port Electrically fast transient (EFT) ±2 kV analog I/O ports	Passed Class B. Passed Class B.

Test Item	Description	Result
EN and IEC 61000-4-5	Power line surge, ± 2 kV	No board or part damage occurred, no performance degrade, passed with Class A.
EN and IEC 61000-4-6	Immunity test on power cord, 10 V/m for 30 minutes Immunity test on I/O cable, 10 V/m for 30 minutes	Maximum deviations in Input Channel 2, Input Channel 3, and Input Channel 4 are respectively 9.3%, 11%, and 3.4%. Passed Class B. Maximum deviations in Input Channel 2, Input Channel 3, and Input Channel 4 are respectively 4.5%, 4.7%, and 1.4%. Performance automatically resorted to $\leq 0.05\%$ when interference stopped.

¹ A sample was tested during initial release of the PLC Demo system (V07) and met the test compliances listed in this table. These results should be viewed as typical data taken at 25°C. For these tests, the DAC outputs were connected to the ADC inputs, that is, DAC_CH2 to ADC_CH2, DAC_CH3 to ADC_CH3, and DAC_CH4 to ADC_CH4. The DAC outputs were set to 5 V, 6 V, and 10 mA, respectively.

LEARN MORE

- Cantrell, Mark. AN-0971 Application Note, *Recommendations for Control of Radiated Emissions with isoPower Devices*. Analog Devices.
- Chen, Baoxing. 2006. *iCoupler Products with isoPower Technology: Signal and Power Transfer Across Isolation Barrier Using Microtransformers*. Analog Devices, Inc.
- MT-004 Tutorial, *The Good, the Bad, and the Ugly Aspects of ADC Input Noise—Is No Noise Good Noise?* Analog Devices, Inc.
- MT-022 Tutorial, *ADC Architectures III: Sigma-Delta ADC Basics*. Analog Devices, Inc.
- MT-023 Tutorial, *ADC Architectures IV: Sigma-Delta ADC Advanced Concepts and Applications*. Analog Devices, Inc.
- Slattery, Colm, Derrick Hartmann, and Li Ke. "PLC Evaluation Board Simplifies Design of Industrial Process Control Systems." *Analog Dialogue* (April 2009).
- Wayne, Scott. "iCoupler Digital Isolators Protect RS-232, RS-485, and CAN Buses in Industrial, Instrumentation, and Computer Applications." *Analog Dialogue* (October 2005).

Data Sheets and Evaluation Boards

- [PLC Demo System.](#)
- [ADuM5401 Evaluation Board.](#)
- [ADuM5401 Data Sheet.](#)
- [AD7793 Data Sheet.](#)
- [AD8220 Data Sheet.](#)
- [AD8226 Data Sheet.](#)
- [ADR441 Data Sheet.](#)
- [AD8601 Data Sheet.](#)

REVISION HISTORY

5/11—Rev. A to Rev. B

Changes to Circuit Functions and Benefits Section	1
Changes to Figure 1	1
Changes to Circuit Description Section.....	2
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Changes to Learn More Section	3

2/10—Rev. 0 to Rev. A

Changes to Figure 1	1
Changes to Circuit Description Section.....	1

7/09—Revision 0: Initial Version

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