

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

The circuit shown in Figure 1 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** analog-to-digital converter (ADC). The **ADuM5401** provides all the necessary signal isolation and power between the microcontroller and the ADC. The circuit includes standard external protection and is fully compliant with IEC 61000 specifications.

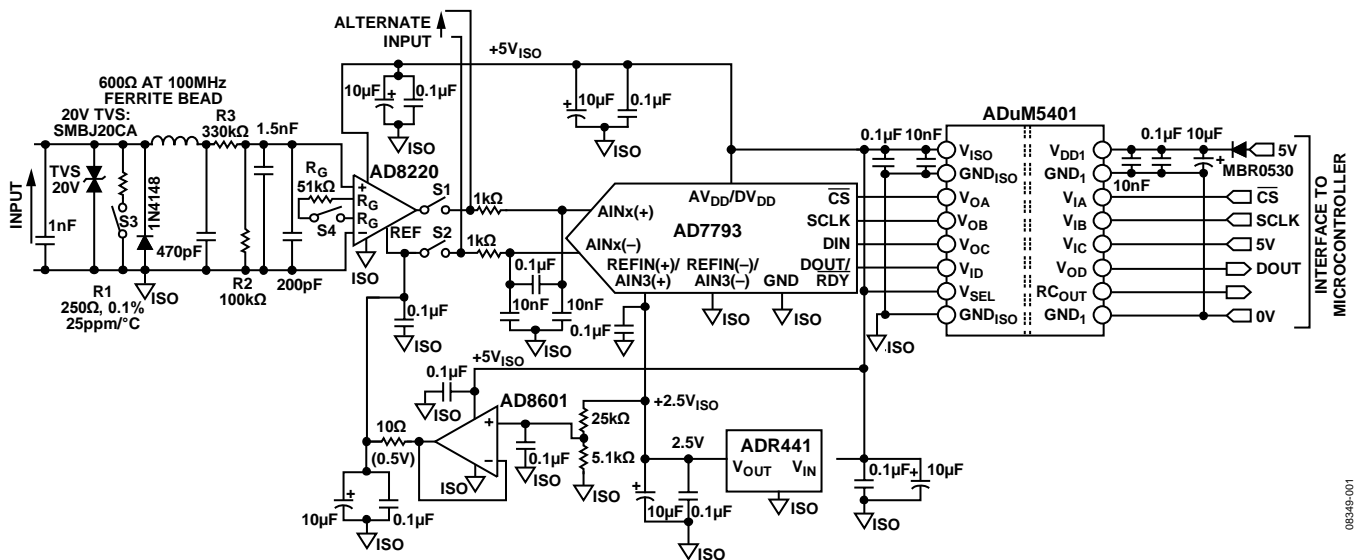


Figure 1. 24-Bit Isolated Industrial Control Voltage Input Module (Simplified Schematic)

08349-001

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REVISION HISTORY

1/2018—Rev. B to Rev. C

Document Title Changed From CN0067 to AN-1522..... Universal	
Changes to Circuit Function and Benefits Section	1
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5/2011—Rev. A to Rev. B

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7/2009—Revision 0: Initial Version

CIRCUIT DESCRIPTION

Ranges for industrial control modules, analog input voltage, and current 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 to R3) on the input attenuates high voltage inputs to match the maximum input range of the AD8220 (−0.1 V to +2.9 V when operating on a single 5 V supply). The AD8226 is a variation of this circuit, which has a wider maximum input range (−0.1 V to +4.1 V). The AD8220 level shifts the input signal and provides gain so that the voltage range matches the input range of the AD7793. Figure 1 is specifically designed for unipolar analog inputs. Other boards have been designed for bipolar operation, which requires bipolar supplies (see the AnalogDialogue article, *iCoupler® Digital Isolators protect RS-232, RS-485, and CAN Buses in Industrial, Instrumentation, and Computer Applications*).

The AD8220 has a common-mode rejection ratio (CMRR) required for these applications. Jumpers (shown in Figure 1 as switches for clarity) switch between current and voltage ranges in the hardware and set the gain of the AD8220. For example, when the input is set to receive a 4 mA to 20 mA current, the switches reconfigure 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 and is divided down to provide a 0.42 V bias voltage. The AD8601 buffers the bias and connects to the REF pin of the AD8220. The REF input to the AD8220 must be driven with a low impedance, heavily decoupled source.

The ADR441 is the chosen reference for this circuit. The ADR441 has 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. The ADuM5401 provides isolation between the field side and the system microcontroller, with an isolation rating of 2.5 kV rms. The ADuM5401 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 the analog circuitry on the input module. Four wires are used on the ADuM5401: three for transmit (CS, SCLK, and DIN) and one for receive (DOUT), which connect to the standard serial peripheral interface (SPI).

The AD7793 is specified for an AV_{DD} of 2.7 V to 5.25 V under normal operation. In lighter load conditions (<10 mA), it is possible for the ADuM5401 setpoint voltage to go from 4.7 V to 5.4 V. Under these conditions, the maximum voltage is too high for the AV_{DD} input of the AD7793. To ensure that the circuit draws enough current during operation, place a diode in series with the AV_{DD} supply of the AD7793.

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 noise free code resolution of the ADC 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 (INL) error of the AD7793 is 0.0015%.

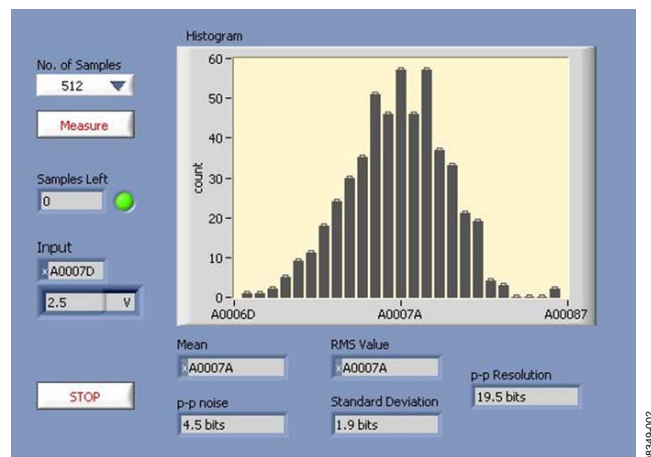


Figure 2. Input Module Histogram, 4.7 Hz Update Rate, Gain = 1, Input = 2.5 V Reference

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 the article, *PLC Evaluation Board Simplifies Design of Industrial Process Control systems* for more discussion of external protection techniques).

A sample was tested during initial release of the PLC Demo System (V07) and met the test compliances listed in Table 1. Review these results as typical data taken at 25°C. For these tests, the digital-to-analog converter (DAC) outputs were connected to the ADC inputs. The DAC outputs were set to 5 V, 6 V, and 10 mA, respectively.

Table 1. Conformance to IEC Specifications

Test Item	Description	Result
EN 55022	Radiated emission Class A, 3 meter anechoic chamber	Passed and met –6 dB margin.
EN 61000-4-2 and IEC 61000-4-2	Electrostatic discharge (ESD) ±8 kV VCD 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 61000-4-3 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 61000-4-4 and IEC 61000-4-4	Electrically fast transient (EFT) ±4 kV power port EFT ±2 kV analog input/output ports	Passed Class B. Passed Class B.
EN 61000-4-5 and IEC 61000-4-5	Power line surge, ±2 kV	No board or part damage occurred, no performance degrade, passed with Class A.
EN 61000-4-6 and IEC 61000-4-6	Immunity test on power cord, 10 V/m for 30 minutes Immunity test on input/output 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 ≤0.05% when interference stopped.

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