

**YOU CAN IMPLEMENT ISOLATION USING OPTICAL, DIGITAL, AND MAGNETIC TECHNIQUES.**

# Isolation techniques for high-resolution data-acquisition systems

**I**SOLATION IS AN IMPORTANT requirement in many data-acquisition applications. A key industrial function that requires isolation is intrinsic safety. In intrinsically safe applications, the devices and wiring in the hazardous area must be incapable of releasing enough electrical or thermal energy under normal or fault conditions to cause sparks or ignition of explosive gases in their most flammable concentration. You can achieve intrinsic safety by keeping capacitance in the hazardous area as small as possible and by limiting the amount of power available to the electronics in the hazardous area to a level that will not ignite the gases. Isolation is also a requirement in medical applications, specifically ECG (electrocardiogram) systems, for which both patients and ECG machines need protection from electric shock or high voltages.

In general, isolation is an important feature for any application in which common-mode potentials pose a threat to the integrity of data, equipment, or organisms. To prevent large ground currents and induced noise that stem from differences in ground potential, it is frequently necessary to isolate analog loads from the digital data source. You can achieve isolation by using optical, capacitive, or magnetic coupling of either the digital or the analog signal.

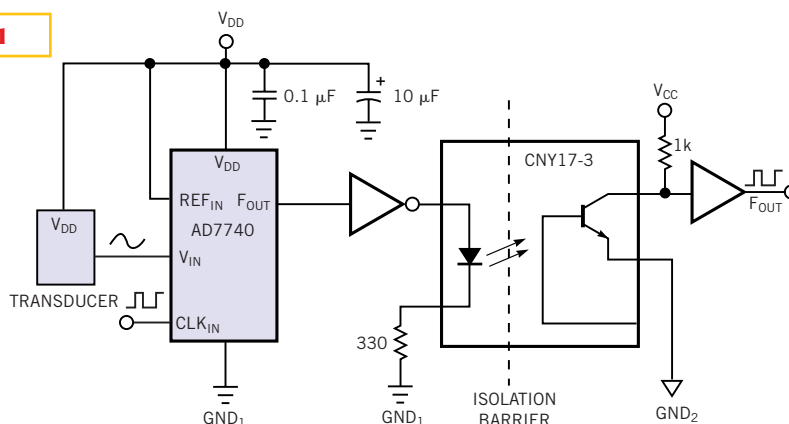
## OPTICAL ISOLATION

Optocouplers are the most common isolation devices for transferring digital signals. They operate by emitting and detecting light. The input voltage drives an internal light-emitting device, and an internal photode-

tor drives the output. Optocouplers generally consist of an LED and a phototransistor that are galvanically isolated from each other and reside in a single light-excluding package. Optocouplers are versatile, small, and easy to use, and they can transmit low-frequency signals, including dc.

A typical optical-isolation circuit uses a VFC (voltage-to-frequency converter) with an optocoupler (Figure 1). Due to noise, safety requirements, or distance, you may need to isolate a transducer from its controlling circuitry. Thus, this circuit consists of a transducer and a VFC on the isolated side. The transducer measures some physical quantity, such as temperature, weight, or acceleration, and the VFC converts the transducer's analog output into a pulse train. The circuit feeds the pulse train to the host computer via an optocoupler, which eliminates any ground-loop noise or common-mode-voltage

**Figure 1**



**A typical isolation circuit uses an optocoupler and a voltage-to-frequency converter. In this case, the maximum  $F_{out}$  is 50 kHz.**

effects. A frequency-to-voltage converter can reconvert the pulse train to an analog voltage. The result is a cheap, compact circuit in which the duty cycle of the pulse train at  $F_{OUT}$  is directly proportional to the measured quantity. Alternatively, you can feed the pulse train into a counter to generate a digital signal. In this case, the gate signal of the counter determines the resolution of the system. For example, the gate interval must be at least equal to  $1024/(0.9 \times CLK_{IN})$  for a resolution of 10 bits.

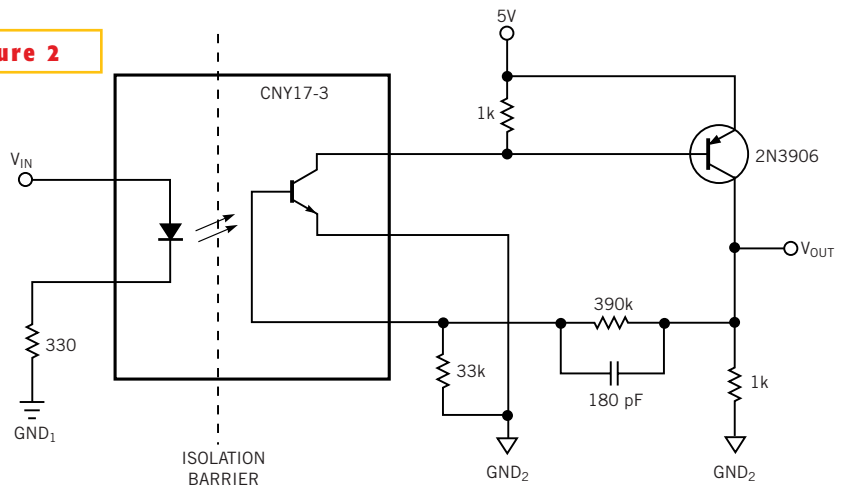
A disadvantage of the circuit in **Figure 1** is that the speed of the optocoupler determines the maximum frequency of  $F_{OUT}$ . Low-cost optocouplers have low switching speeds, and their high-speed counterparts are often expensive. Adding positive feedback to the light-sensitive base of the phototransistor greatly increases its switching speed (**Figure 2**). By adding one transistor, four resistors, and a capacitor, this circuit increases the maximum data-rate capability of the optocoupler by a factor of 10.

Another approach is to use a differential line driver (**Figure 3**). Adding the differential line driver increases the maximum frequency through the PS2502-2 optocoupler from 5 to 32 kHz. This approach ideally suits low-power applications for which the clock rate of the VFC is typically 32 kHz. At  $V_{DD} = 3V$ , the power dissipation of the VFC is typically 2.7 mW, and you can further reduce this number by gating off the  $CLK_{IN}$  input when the circuit is not monitoring  $V_{IN}$ . This action shuts down the VFC, and its power dissipation typically reduces to 0.09 mW. For a range of 0V to  $V_{DD}$  on  $V_{IN}$ , the corresponding output range of  $F_{OUT}$  is 3.2 to 28.8 kHz.

**DIGITAL ISOLATION**

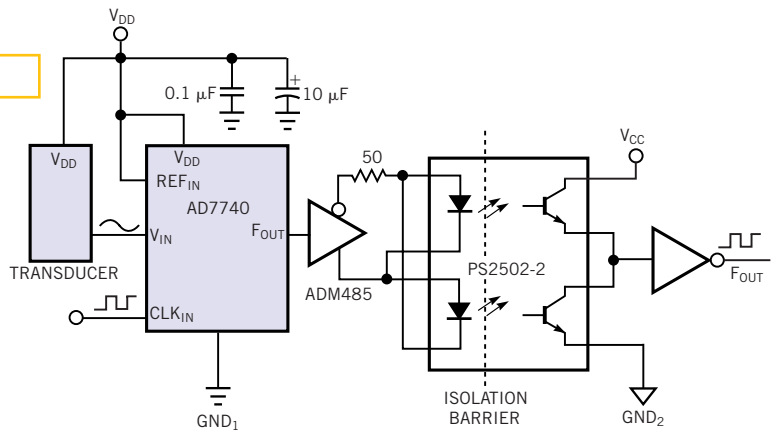
For applications that require high-speed data transmission, you can use digital-isolation techniques. The digital isolator in **Figure 4** combines high-speed CMOS and air-core-transformer technology, supports data rates from dc to 100 Mbps, and operates at low power. The device has a quiescent current of 0.6 mA and a dynamic current of less than 230  $\mu A$ /Mbps. The circuit clocks the VFC at its maximum frequency of 1

**Figure 2**



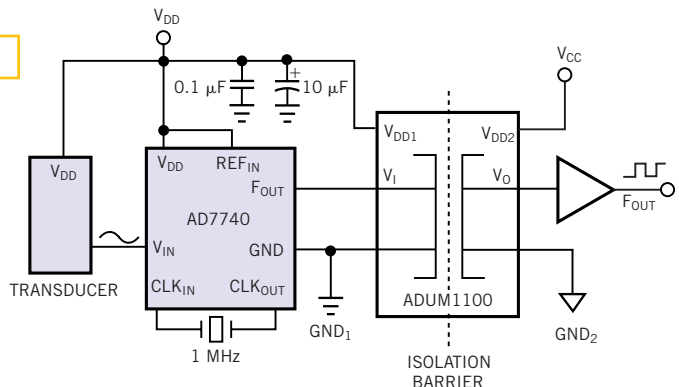
Adding positive feedback to the light-sensitive base of the phototransistor greatly increases its switching speed—in this case, to a maximum speed of 500 kHz.

**Figure 3**



For low-power applications, adding a differential line driver increases the maximum frequency through the optocoupler from 5 to 32 kHz.

**Figure 4**



A digital isolator provides for high-speed data transmission—in this case, from dc to 100 Mbps.

MHz, and the digital isolator isolates the VFC from the host.

You can also use digital isolators in field-bus-communication networks, such as Profibus or DeviceNet. These networks, interconnecting sensors, actuators, controllers, and various other devices, typically recommend the use of galvanic isolation at each interface location (Figure 5). Isolation increases data integrity and provides protection from power faults and ground-loop effects.

An alternative is to use capacitively coupled digital isolators. These also provide high bandwidths and have very low power consumption. Their biggest drawbacks, however, are their large packages, which are necessary to accommodate the large physical separation between the capacitors that provide the isolation.

**MAGNETIC ISOLATION**

For applications that require both power and signal isolation, you can use transformer-coupled isolation amplifiers to provide complete isolation. This approach eliminates the need for an external dc/dc converter, which reduces overall design and component costs. Some isolation amplifiers use internal transformer coupling to provide  $\pm 2$  kV of continuous common-mode isolation. You can use these isolation amplifiers to provide excitation to a strain gauge, to isolate low-level temperature sensors, or to power a range of ancillary circuits.

For example, the circuit in Figure 6 shows how you can use this type of isolation amplifier, IC<sub>1</sub>, to provide local power to a temperature sensor, IC<sub>2</sub>, and to isolate the sensor's analog output from the main control system. IC<sub>2</sub> requires a 5V supply and 0.65-mA operating current. Its output ranges from 0.475 to 3.288V for a temperature range of  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ . A low-power regulator, IC<sub>3</sub>, generates 5V from the 7.5V output of IC<sub>1</sub>. IC<sub>1</sub> can supply as much as 3 mA, which is sufficient to drive the regulator and the temperature sensor.

**DESIGN A FULLY ISOLATED SYSTEM**

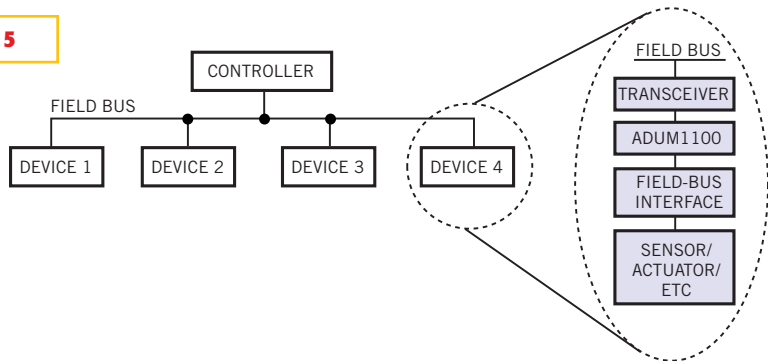
The circuit in Figure 7 is a fully isolated pressure-measurement system. The circuit uses a sigma-delta converter IC, IC<sub>1</sub>, which is a complete analog front end for low-frequency-measurement appli-

cations. Unlike VFCs, which require end users to integrate over a period of time to obtain the desired resolution, sigma-delta converters provide a fully settled digital output with, in this case, 16-bit resolution. IC<sub>1</sub> accepts two low-level input signals directly from a transducer and produces a serial digital output that represents the analog input. No signal conditioning is necessary between the sensor and the ADC. IC<sub>1</sub> applies the selected input signal to a programmable-gain front end based around an analog modulator. An on-chip digital filter processes the modulator output to give an accurate output with high resolution. Some of the key features that make these devices suitable for isolated applications include a serial interface that you can configure for three-wire operation. Using this serial port, you can use software

to configure the gain settings, signal polarity, filter cutoff, and update rate. The part contains self- and system-calibration options to eliminate gain and offset errors on the part itself or in the system. CMOS processing ensures low power dissipation, and the power-down mode typically reduces the standby power consumption to 20  $\mu\text{W}$ . Lower power combines with a minimum number of interface lines to make implementing a fully isolated system simple and inexpensive.

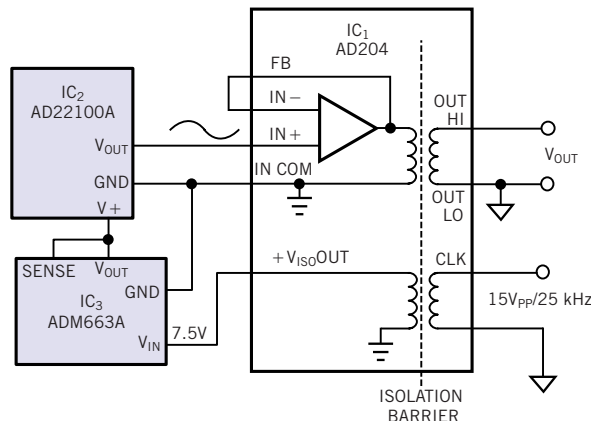
The pressure transducer, the BP01 (www.sensym.com), is part of a bridge network and produces a differential output voltage between its OUT(+) and OUT(-) terminals. With rated full-scale pressure on the transducer, which in this case is 300 mm of mercury, the differential output voltage is 3 mV/V of the input voltage, which is the voltage between the

**Figure 5**



Digital isolators also work well in field-bus-communication networks, such as Profibus or DeviceNet. These networks, interconnecting sensors, actuators, controllers, and various other devices typically need galvanic isolation at each interface location.

**Figure 6**



An isolation amplifier, IC<sub>1</sub>, provides local power to a temperature sensor, IC<sub>2</sub>, and provides magnetic isolation between the sensor's analog output and the main control system.

IN(+) and IN(-) terminals. Assuming a 5V excitation voltage, the full-scale output range from the transducer is 15 mV. The excitation voltage for the bridge also generates the reference voltage for IC<sub>1</sub>. Therefore, variations in the excitation voltage do not introduce errors in the system. Resistor values of 24 and 15 kΩ result in a 1.92V reference voltage for IC<sub>1</sub> when the excitation voltage is 5V. Programming IC<sub>1</sub>'s gain to 128 results in a full-scale input span for IC<sub>1</sub> of 15 mV, which matches the transducer's output span.

You can use the second input channel of IC<sub>1</sub> as an auxiliary channel to measure a secondary variable, such as temperature. For example, you can use the secondary channel to adjust the output of the primary channel, thus removing temperature effects in the system.

IC<sub>2</sub> in Figure 7 provides the isolation. IC<sub>2</sub> actually isolates five digital lines of IC<sub>1</sub> that provide the digital interface along with a reset to the ADC. You can reduce

the number of isolated lines to a minimum of three wires if necessary by tying the CS line permanently low and implementing the reset in software. Each line of IC<sub>2</sub> has a minimum bandwidth of 20 MHz with propagation delays of only 14 nsec, which allows for extremely fast data transmission. The isolation barrier provides a system-to-field barrier of 3.5 kV rms. The barrier design also provides excellent common-mode transient immunity from 10-kV/μsec common-mode voltage excursions of field-side terminals relative to the system side with no false output triggering on either side. A center-tap transformer within IC<sub>2</sub> generates isolated power for the front end of the data-acquisition system and provides for an isolated dc-dc power supply with 3.5 kV of isolation. □

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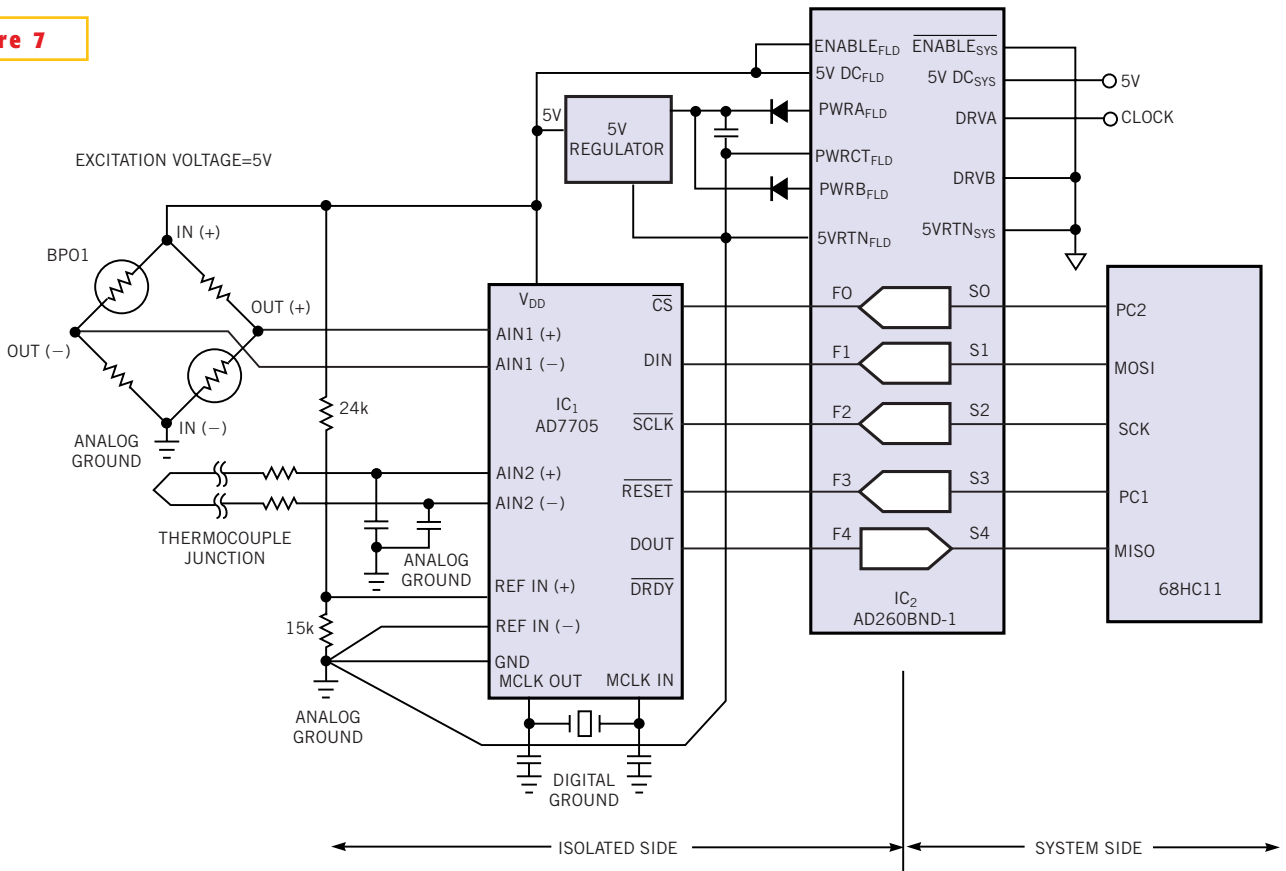


*land), where she has worked for five years. She provides customer service for many of the company's DACs and VFCs (voltage-to-frequency converters) and has worked on the AD5532 and AD53xx DACs and the AD774x VFCs. She has a bachelor's degree in electronics engineering from University College Cork (Ireland).*



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**Figure 7**



**A fully isolated system uses a sigma-delta ADC, IC<sub>1</sub>, and a pressure transducer in a bridge network.**