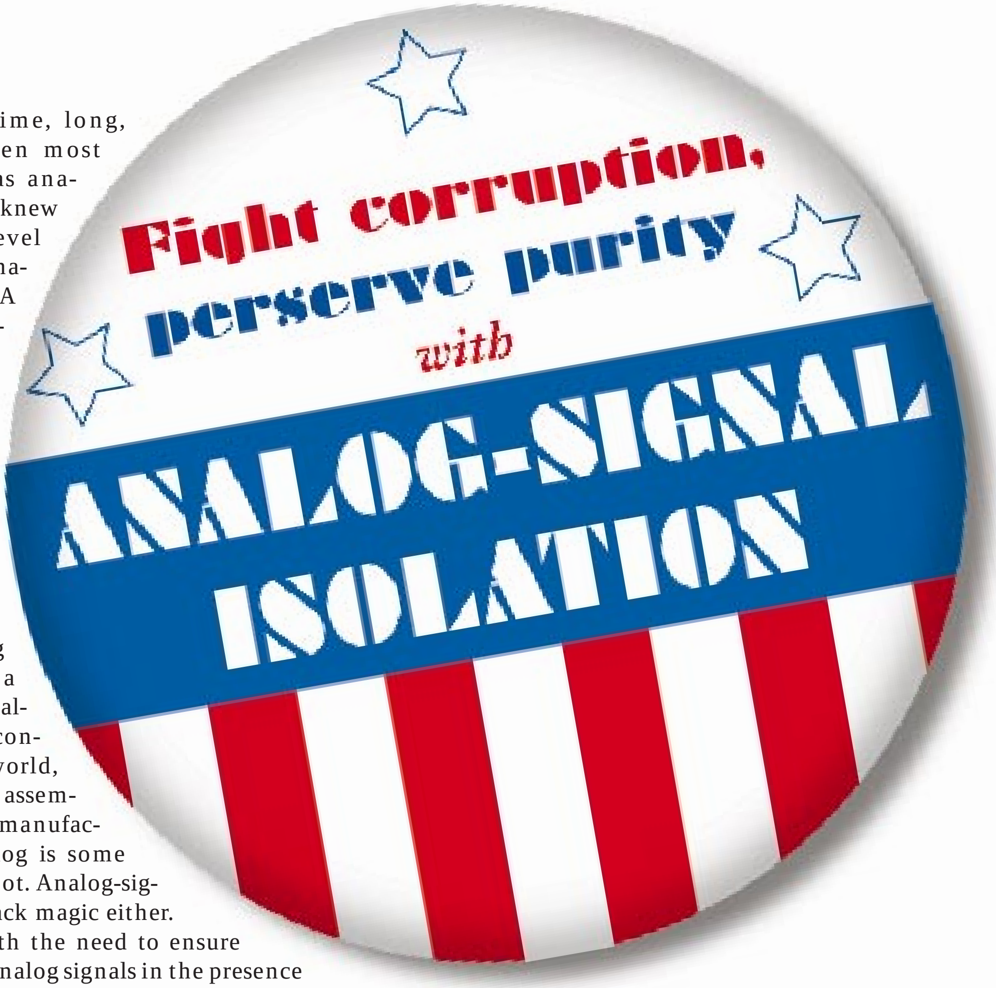


Once upon a time, long, long ago, when most electronics was analog, many EEs knew why measuring low-level signals could require analog-signal isolation. A smaller number of engineers could actually design isolators. Now, however, EEs who thoroughly understand analog isolation are even more uncommon than they were in the 1960s. Yet the need for isolation continues nearly unabated despite analog design's having become the preserve of a shrinking cadre of specialists. Because of limited contact with the analog world, most EEs who work for assembled-electronic-product manufacturers believe that analog is some sort of black magic. It's not. Analog-signal isolation isn't black magic either.

Confronted with the need to ensure the integrity of analog signals in the presence of noise, some engineers turn their backs on isolation. Sometimes cost is an issue; sometimes the problem is fear of poorly understood side effects. On the other hand, some engineers look upon isolation as a panacea. It isn't that either.

Analog-signal isolation (also called "galvanic isolation") inserts an ohmic barrier between the signal source and the circuits that use what is usually an amplified version of the signal. At dc, an ohmic barrier is an open circuit (usually thousands of megohms). In every isolation circuit, a small stray capacitance often no more than a few picofarads shunts the barrier. In nearly all cases, the barrier can continuously withstand hundreds of volts without breaking down. In most isolation devices, the withstanding voltage is more than 1 kV. Devices that withstand several kilovolts are not uncommon, and units that withstand tens of kilovolts often through the use of fiber-optic technology are not unheard of.

Numerous approaches

Engineers have used numerous approaches to provide analog isolation. One technique uses relays in a flying-capacitor multiplexer (**Figure 1**). Some analog isolators use electro-optical techniques. Despite their popularity with digital signals, whose precise waveshapes are usually unimportant, optoisolators play only a minor role in the analog-signal-isolation market.

DAN STRASSBERG, SENIOR TECHNICAL EDITOR

Analog-signal isolation isn't just for preventing injury and damage from high voltages. It can dramatically reduce noise and artifacts that corrupt sensitive measurements.

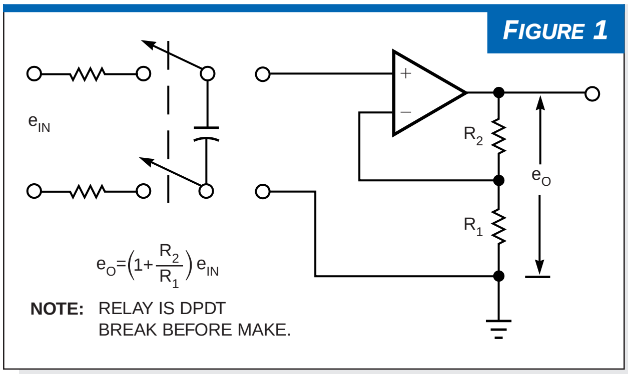
Optical components must overcome several problems in analog isolators. In these isolators, the optical components must provide excellent linearity, low and stable offsets, and stable gain. Optical isolators are more important in isolated ADCs, in which the signals are already in digital form before they cross the isolation barrier.

In some analog isolators, signals traverse the isolation barrier by way of small capacitors. A technique announced at this year's International Solid-State Circuits Conference uses resistors that are sensitive to magnetic fields (**Reference 1**).

So far, however, the largest number of analog-isolation circuits have used transformers. Transformers inherently provide ohmic isolation. Unfortunately, most analog-isolation applications involve sending dc across the isolation barrier, and transformers work only for ac. EEs have devised many ingenious modulation and demodulation schemes to allow transformers to transmit dc signals as ac. Some of these schemes offer errors as low as 0.01% of full-scale and bandwidth of tens of kilohertz. Transformer isolation is probably still the most popular analog-isolation technique, but it is unclear whether it will remain so.

In one area related to isolation, however, transformers are unlikely to relinquish their dominance any time soon: powering floating circuitry. Nearly all isolation amplifiers either incorporate floating power supplies or require the user to supply them. Usually, the supplies are dc/dc converters in which transformers supply the floating output power. No other approach matches these converters cost-effectiveness, compactness, and efficiency.

FIGURE 1



The capacitor in this flying-capacitor multiplexer switch captures a floating input signal and then transfers the signal to the input of a single-ended, ground-referenced amplifier. The circuit relies on the relay's break-before-make switching action and the open contacts acting as near-perfect open circuits.

Isolated VFCs

A circuit technique that is popular in applications that require high accuracy but can tolerate limited bandwidth is V/F conversion. V/F conversion is really a form of modulation that produces a digital output (usually a pulse train but sometimes a square wave) whose frequency is proportional to the input-signal level. Because their outputs are digital (that is, because output-voltage levels and pulse shapes have limited importance), VFCs can use optoisolators, capacitors, or transformers to send signals across an isolation barrier.

VFCs offer another advantage. Today, nearly all data-acquisition systems convert analog signals to digital form near the system input. You can easily convert a VFC output to a numerical representation of the input voltage; just count the pulses for a fixed time interval. VFCs are by no means the only method of isolated A/D conversion, however. You can buy or build higher speed isolated ADCs successive-approximation types, for example.

Often, the motivation for isolating analog signals is the same as the reason for isolating digital signals: safety. In some applications, a fault can place a signal source that is normally within a few millivolts of ground at the ac-line potential. Nonisolated circuits that monitor such sources may withstand only 15V dc. In that case, the line voltage (normally 120V rms in North America and 220 or 240V rms in Europe) will almost surely destroy the circuit. Moreover, failure of the circuit might precipitate a series of failures that could wipe out an entire system.

@a glance

- Analog isolation is not black magic.
- Although isolation is an important tool for preventing death or serious injury and damage to or destruction of equipment, analog isolation also improves signal integrity.
- Engineers have devised and continue to devise myriad schemes to send analog signals across isolation barriers.
- Many vendors supply a variety of analog-isolation products. Whether you need components for mounting on pc boards of your own design, system components for a manufacturing- or process-control system, or higher level products, you have many choices.

Early in a system's design, you may not suspect the possibility of signal sources becoming shorted to the ac line. Moreover, it might take considerable work to determine how such shorts could occur. Nevertheless, determining that you need an isolator for safety rarely requires a complex mathematical analysis.

ECG amplifiers

Electrocardiograph (ECG) amplifiers that are usable with external pacemakers whose electrodes can be implanted within a human heart are excellent examples of devices that require isolation for safety. Research in the 1950s demonstrated that a 60-Hz current greater than 10 µA flowing through the heart could induce ventricular fibrillation. Ventricular fibrillation is a fluttering of the heart muscle that stops the heart's pumping action and is fatal unless quickly terminated.

If you assume that a fault can superimpose 265V rms (240V+~10%) at 60 Hz on the pacemaker output, the 60-Hz impedance to ground from the ECG electrodes must exceed 26.5 MΩ. That impedance requires a capacitance no larger than 100 pF from the ECG-amplifier input to ground. Moreover, if the patient receives an intentional shock from a defibrillator, the amplifier input must not fail and allow higher line-frequency currents to flow. Although defibrillator output voltages depend on the load (that is, the impedance of the patient s body), the worst-case output voltage can be as high as 6.5 kV. Thus, many suppliers of medical isolation amplifiers certify that the devices withstand 6.5 kV.

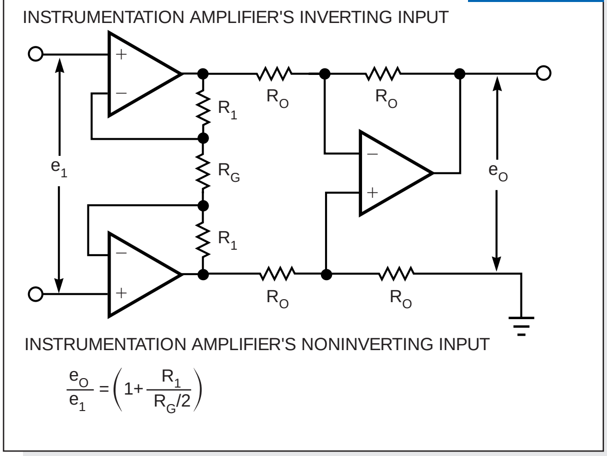
The role of isolators in preserving signal integrity is somewhat less obvious. Imbalances in the signal source s internal resistance combined with the signal lines capacitance to ground convert ac common-mode voltages to differential-mode signals (**Figure 2**). The effect can occur even when the common-mode voltage is at a low frequency. Line frequency (60 Hz in North America; 50 Hz in Europe) is quite high enough.

Once the common-mode voltage becomes a differential-mode signal, the signal becomes inseparable from the signals you are trying to measure. Only by accepting A/D-conversion times that are multiples of the ac-line period can you re-ject line-frequency differential-mode signals added to smaller signals that you want to measure. Thus, at a 60-Hz line frequency, the conversion rate must not exceed 60 samples/second. And, if you extend the conversion time over multiple ac-line cycles, the line-frequency rejection improves. Line-frequency or line-frequency-submultiple conversion rates are too slow for many sensor-based applications, however. For example, to observe subtle artifacts in ECGs, you must sample the signals at least 200 times per second.

Instrumentation, not op amps

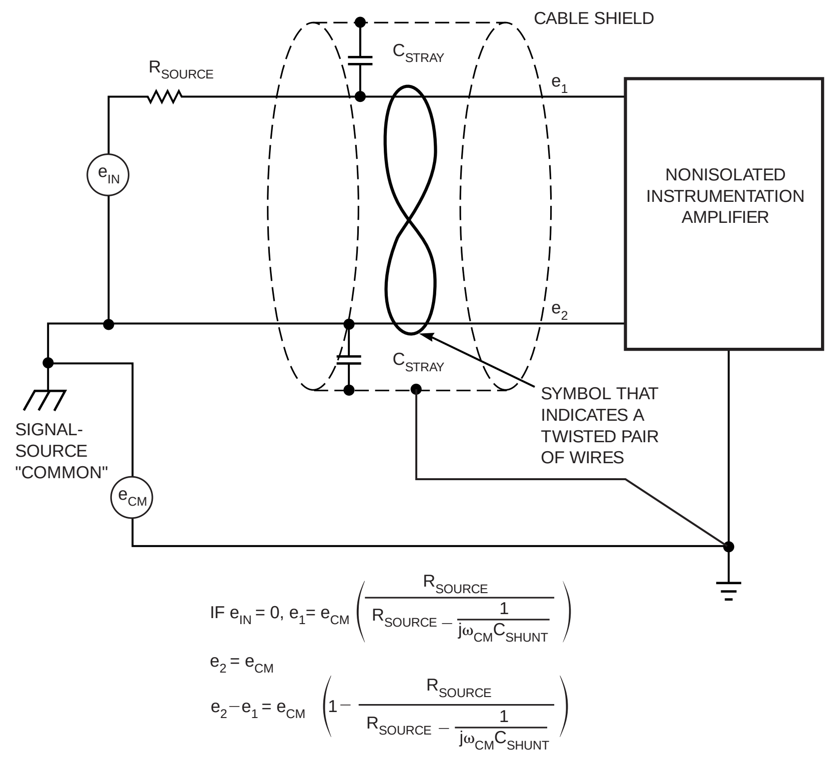
When you don t use isolation, the circuit you use to monitor sensors output signals is usually not an operational amplifier but an instrumentation amplifier. Instrumentation amplifiers differ from op amps in that both of the instrumentation amp s input terminals are unencumbered by feedback and hence have high input impedance. In circuits that use one op amp, you connect the feedback network to one of the amplifier s input terminals (normally the inverting input). This connection lowers the input impedance at the feedback input. The classic instrumentation-amp circuit uses three op amps (**Figure**

FIGURE 3



This classic instrumentation amplifier uses three op amps. Although more instrumentation amps use this configuration than any other, there are dozens of other instrumentation-amp circuits.

FIGURE 2



$$\text{IF } e_{IN}=0,\ e_1=e_{CM}\left(\frac{R_{SOURCE}}{R_{SOURCE}-\frac{1}{j\omega_{CM}C_{SHUNT}}}\right)$$

$$e_2=e_{CM}$$

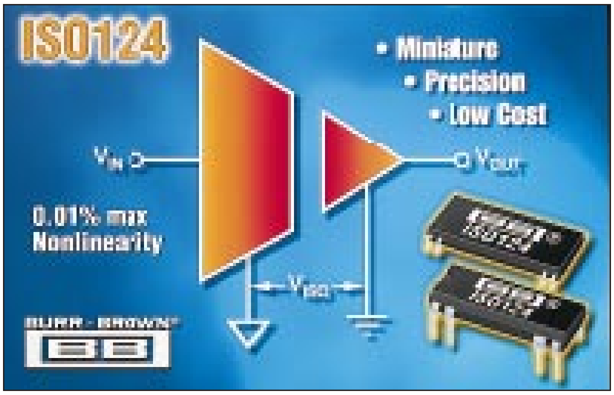
$$e_2-e_1=e_{CM}\left(1-\frac{R_{SOURCE}}{R_{SOURCE}-\frac{1}{j\omega_{CM}C_{SHUNT}}}\right)$$

The input wiring s stray capacitance to ground acts with the signal source s internal resistance to form a voltage divider at the amplifier s noninverting input. The absence of a corresponding divider at the inverting input limits the circuit s CMRR.

3), but instrumentation amps use a host of other circuit configurations.

Often, using isolation lets you choose a less expensive input-amplifier configuration one that is not truly differential. In many applications, an amplifier whose input is single-ended and floating (floating is a synonym for isolated) performs just as well as an amplifier whose input is both differential and floating. A floating single-ended amplifier offers near-infinite resistance to ground from each input terminal. A configuration that can work very well in a floating front end is the follower with gain (**Figure 4**). When properly connected, this circuit exhibits a gain that is independent of the signal source's internal resistance.

Resistance in series with only one signal lead is the normal source configuration. Inserting a compensating resistance in series with the other lead is usually impractical. If the input amplifier is a floating follower with gain, return the closed-loop amplifier's negative input directly to the signal source's common terminal. (Note that the follower's negative input is the floating power supply's ground reference, *not* the op amp's inverting input.) Resistance between the source common and the amplifier's negative input alters the amplifier gain. If the amplifier is both differential and floating, you can place the source resistance in series with either input terminal.



Although several companies continue to offer modular units, more and more isolation amplifiers for pc-board mounting resemble ICs. These units from Burr-Brown use PWM and a pair of 1-pF high-breakdown-voltage capacitors to send signals across the isolation barrier. Prices begin at less than $10 (1000).

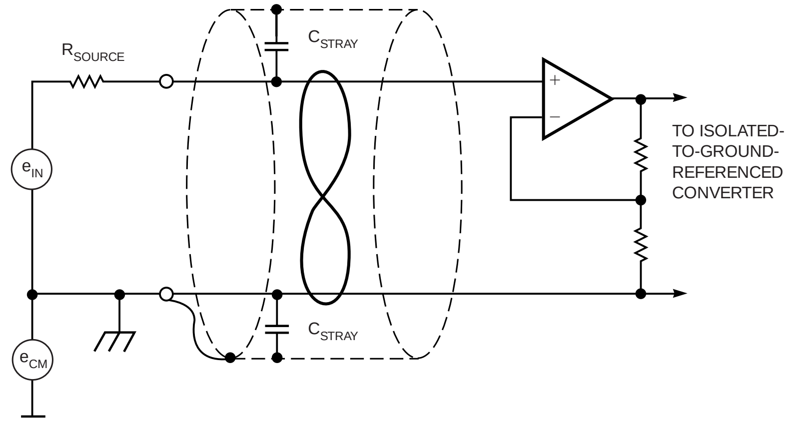
At the heart of the conversion of common-mode voltages to differential-mode signals is the voltage-divider formed by the differential-mode voltage source's series resistance and the amplifier's input impedance. The input impedance consists of a high resistance a property of the amplifier in parallel with the stray capacitance of the wiring between the signal source and the amplifier. With a conventional ground-referenced instrumentation amplifier, source resistance that appears in series with one signal lead slightly attenuates the common-mode voltage on one side, but not the other.

As an extreme (but not uncommon) example, suppose the common-mode voltage is 120V rms (340V p-p) at 60 Hz and the resistive unbalance is 1 kΩ. Also, suppose that the wiring that joins the signal source to the amplifier is a shielded, twisted-pair cable. The cable is 100 ft long and has a capacitance of 30 pF/ft (a total of 3000 pF) from each conductor to the shield.

With a nonisolated instrumentation amplifier, your first impulse might be to return the cable shield to the amplifier's ground reference (**Figure 2**). At 60 Hz, the 3000-pF cable capacitance has a reactance of 884 kΩ. The magnitude of the reactance is 884 times the series resistance. However, the shunt impedance is not resistive; it is purely reactive, so you must use vector math to calculate the attenuation. Only about 1.38 ppm of the common-mode voltage becomes a differential-mode signal. This analysis assumes that the amplifier's input resistance is infinite an ideal case, but usually a workable approximation. Resistance in parallel with the cable capacitance simply makes the problem worse.

Although 1.38 ppm sounds tiny, if the signal you want to measure emanates from a thermocouple or strain gauge, the sensor's output could be only a few tens of microvolts. Meanwhile, 1.38 ppm of the 340V-p-p common-mode voltage is 471 µV p-p. In other words, the resistive unbalance, in concert with the cable's shunt capaci-

FIGURE 4



NOTE: CABLE SHIELD CONNECTS TO e_{CM}.

Because isolation amplifiers exhibit nearly infinite common-mode input resistance and essentially infinite CMRR at dc, they can often use single-ended input circuits, such as this follower with gain. To obtain accurate gain, you must ensure that the source resistance appears in series with the follower's noninverting input.

tance, transforms the common-mode voltage into a differential-mode signal. This signal can be 50 times as large as the signal you want to measure.

Upping shunt impedances

Although guarding, a technique that does not necessarily involve isolation, can drastically reduce the voltage-divider action, you may still want to use isolation. In this example, you are unlikely to have a choice; few nonisolated instrumentation amplifiers can tolerate a common-mode voltage of 340V p-p.

Even if you can find such an amplifier, reducing the 340V p-p common-mode voltage to 10 μV p-p requires a CMRR greater than 150 dB. And this requirement is for 60-Hz CMRR with a 1-kΩ source-resistance unbalance. Few nonisolated instrumentation amplifiers offer *dc* CMRRs that high with *zero* source-resistance unbalance. Moreover, even attenuated by 150 dB, a 340V-p-p signal may still be large enough to obscure the details of a 50-μV waveform.

Suppose, however, that the common-mode voltage was smaller—less than 20V p-p. This value lies within the common-mode-voltage tolerance of nearly all nonisolated instrumentation amps that operate from –15V supplies. If the signal-source ground provides a low-impedance path back to the instrumentation amplifier's ground, you might connect the cable shield to the signal-source ground (**Figure 4**). In many cases, this shield connection avoids common-mode-to-differential-mode conversion without the use of an isolation amplifier.

With this connection, the common-mode voltage causes no current to flow through the capacitance between the conductors and the cable's shield, because no voltage exists across the capacitance. This approach is guarding. Although it works by reducing the voltage across shunt impedances, guarding has the same effect as raising those impedances.

However, even though guarding can reduce the effective cable capacitance, nonisolated instrumentation amps can sometimes still convert common-mode voltages to differential-mode signals. All such amplifiers are direct-coupled. Those amplifiers that offer the best dc performance use superbeta bipolar-transistor input stages. Such stages offer the lowest offset-voltage temperature coefficients and lowest noise with source impedances below about 10 kΩ. These stages require a dc return for their bias currents. Even instrumentation amplifiers that use JFET input stages need such a path.

Watch those bias resistors

If the signal-source ground provides no satisfactory bias-current return path to the instrumentation amplifier's ground, you must provide such a path at the amplifier input. When you provide this path, you create a voltage divider at one amplifier input—the one that receives its input via the source's internal resistance. With a 1-kΩ source-resistance unbalance and shunt resistors of a practical value (say, 20 MΩ or less), the CMRR is about 66 dB (**Figure 5**). Such a low CMRR proves inadequate if the signal levels are low, even with a common-mode voltage of only 20V p-p.

Signal conditioners for DIN-rail mounting take several forms, although all have slim profiles to maximize the number of modules that fit on a rail of a given length. These units from DataForth include isolated resistance-temperature detectors and thermocouple signal conditioners. DataForth also manufactures 5B-style units.

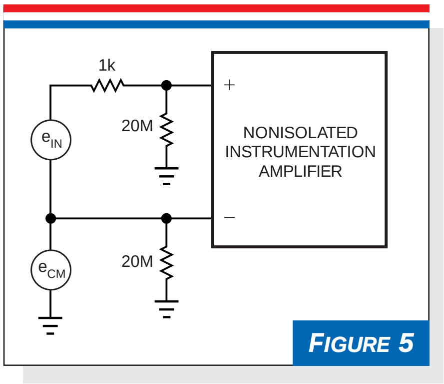


FIGURE 5

Even if the instrumentation amplifier itself has infinite CMRR, the 1-kΩ source resistance, which appears in series only with the noninverting input, limits the circuit's CMRR to 66 dB. The 1-kΩ resistor and the upper 20-MΩ bias resistor form a voltage divider, which has no counterpart at the instrumentation amplifier's inverting input.

To digitize 10-mV full-scale signals to 12-bit resolution with a successive-approximation ADC and an instrumentation amplifier whose CMRR is 66 dB, you must limit the common-mode voltage to 4.88 mV p-p. Larger voltages cause errors greater than 1 LSB. Averaging ADCs (multiple-slope types, for example) accurately digitize signals with more superimposed noise, but such ADCs lack the speed of successive-approximation devices.

Besides working well with larger common-mode voltages than those that nonisolated amplifiers can handle, analog isolators perform well when no reliable low-resistance path exists between the signal-source and amplifier grounds. An isolation amplifier has essentially infinite dc resistance from its input terminals to its output. Thus, nonzero signal-source resistance does not create a voltage divider at dc. To guard out the cable capacitance, you can (and should) connect the floating input circuit's ground reference to the signal-source ground—that is, to the source of the common-mode voltage.

For ac, an isolation amplifier's effectiveness in reducing the conversion of common-mode voltages to differential-mode signals depends on the isolation capacitance—the capacitance between the floating and ground-referenced sections. The smaller this capacitance, the better. In an earlier example, the cable capacitance from each signal-source terminal to ground was 3000 pF. From a common-mode standpoint, the capacitance is 6000 pF. If you return the cable shield to the floating section's ground, you insert the isolation capacitance in series with this 6000 pF. The isolation capacitance can be as small as 2 pF. Because 2 pF in series with 6000 pF=2 pF, the cable capacitance becomes irrelevant.

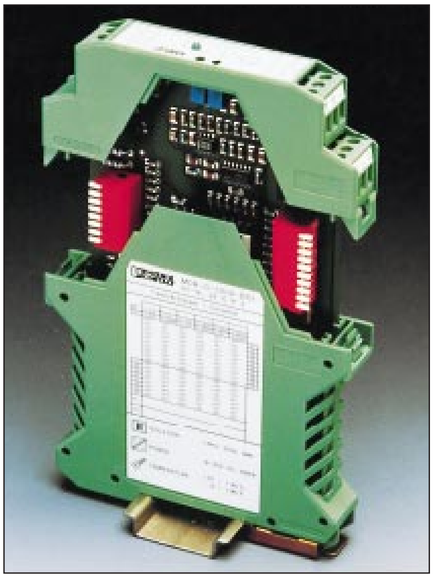
Isolators can introduce noise

Analog-signal isolators exist to improve safety and to reduce noise attributable to common-mode voltages. Some people view as ironic, then, the propensity of analog isolators to add noise to the signals they isolate. A large fraction of all of the analog isolators ever built uses transformer isolation, which is based on modulation and demodulation. Even isolators that transfer signals via capacitors use modulation and demodulation. The noise at the units' outputs is really ripple that modulation introduces and demodulation doesn't entirely remove.

You can, of course, remove ripple by lowpass filtering the demodulator output. The trouble with lowpass filters (analog ones, at any rate) is that the closer the signal frequencies get to half the carrier frequency, the more complicated, expensive, and problematic the filters become. Except in special cases (downconversion, for example) the signal frequency should not exceed half of the carrier frequency.

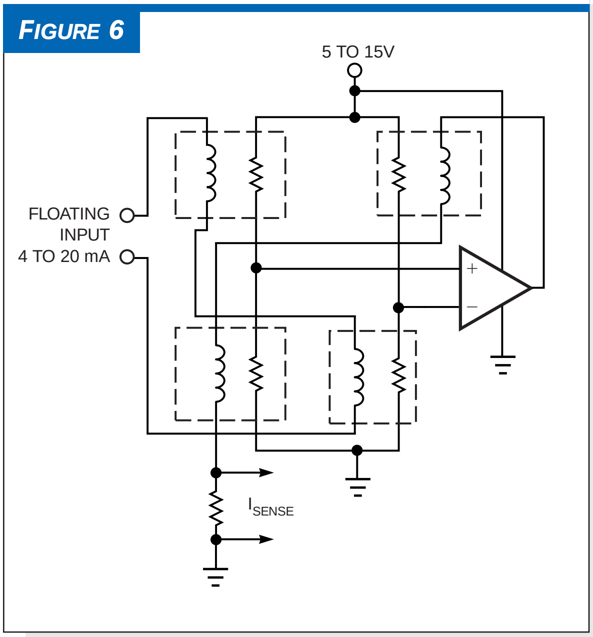
For a given filter bandwidth, one way to mitigate filter problems is to raise the carrier frequency. That's what Burr-Brown has done in some of its isolators. These units use a carrier frequency of 500 kHz. However, Burr-Brown didn't stop there. The company also removed the transformer, opting instead to use a matched pair of 1-pF capacitors to transmit the modulated carrier across the isolation barrier. Some of Burr-Brown's capacitive isolators offer full-scale bandwidths of 60 kHz.

Burr-Brown's data sheets point out an interesting problem, which always exists in systems that use modulation but which you don't often think of in purely analog applications. Isolation amplifiers that use modulation are subject to the limitations of the same sampling theorem that limits the frequencies of signals you digitize with sampling ADCs. If you apply a signal whose frequency is more than half of the modulator's carrier frequency, the output contains aliases low-frequency signals that the original data did not contain. For this reason, you may want to use an antialias filter to limit the signal bandwidth ahead of the modulator. Many isolation amplifiers include such filters.



DIN-rail-mounted signal conditioners are popular in the discrete-manufacturing and continuous-process industries. Several manufacturers of these products include isolation amplifiers in their lines. This Phoenix Contact unit (shown partially disassembled) is representative.

FIGURE 6



By using magnetic-field-sensing GMR resistors, this circuit provides isolation without modulation and demodulation. The bridge configuration provides first-order cancellation of resistor drift and nonlinearity. Moreover, with the 4- to 20-mA input signal for which this circuit was designed, there is no need for a dc/dc converter to power floating amplifiers.

Doing away with the carrier

If there were no modulation, there would be no aliasing or ripple problems, however. For years, analog designers have dreamed of ways to transmit signals across an isolation barrier without modulation. Now, sensors that use the giant magnetoresistive (GMR) effect offer that promise. GMR sensors are resistors whose values depend on the magnetic field surrounding them. The sensors are thin-film devices that the manufacturer can deposit atop silicon chips. Because the technology for depositing coils atop silicon chips now also exists, another dream of analog designers monolithic isolation amplifiers is finally also within reach.

GMR sensors have many potential applications that are unrelated to analog isolation. One such application is in pickup heads for hard-disk drives. Some hard-disk manufacturers are already shipping drives that use GMR heads. The enormous production volumes of such devices presage economies of scale that should benefit analog isolators.

Figure 6 is the schematic of a monolithic GMR isolator developed at Iowa State University (Ames, IA, www.iastate.edu) with cooperation from Nonvolatile Electronics (NVE). NVE makes GMR sensors. (For additional information, e-mail wcblack@iastate.edu.) The concept is very simple. You supply a current through a series pair of input coils. The coils are ohmically isolated from, but close to, two GMR resistors. These resistors are diagonally opposite each other in a bridge circuit.

A ground-referenced amplifier monitors the differential signal at the corners of the bridge. The amplifier drives current through a second pair of coils, which vary the resistance of a pair of GMR resistors that are opposite the first pair in the bridge. The current in the second pair of coils forces the bridge back into balance. The amplifier's output current is thus equal to the current you send through the floating input coils. A sense resistor in series with the second pair of coils presents an output voltage proportional to the input current.

Because all of the GMR resistors are deposited simultaneously, their characteristics tend to match closely and vary in unison. This situation is especially true of the temperature and voltage

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Notes: * Currently, NVE manufactures GMR sensors for constructing your own board-mounted isolation amplifiers.

^{B}=Supplier of board-mounted analog isolators. ^{S}=Supplier of system-component-level analog isolators. ^{O}=Supplier of analog isolators as part of higher level products, such as data loggers.

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coefficients of resistance. Stability and linearity should therefore be outstanding. The results are good, but not as good as you might expect from codeposited circuit elements (**Reference 1**). The tested device was a developmental unit, however, and probably did not benefit from a process-improvement effort.

If the source that supplies the signal to the isolator develops enough power to directly drive the input coils, the isolator needs no floating active circuitry. An isolated-output, 4- to 20-mA signal conditioner could provide such a source. Unfortunately, many sensors need a floating amplifier to produce signals large enough to drive the coils. Such an amplifier requires a floating power supply. In some applications, a battery could act as an acceptable power source. Batteries avoid dc/dc converters with their associated ripple and noise.

Where batteries are unacceptable, solar cells might work. If such cells could acceptably power the floating amplifier, the result might be a truly useful isolation amplifier in which no circuitry uses a carrier frequency. Of course, to achieve this result, you must illuminate the solar cells with a light source that requires no dc/dc converter an incandescent lamp, for example. If you refuse to use a dc/dc converter to power the light source, you can t use highly efficient light sources, such as cold-cathode fluorescent lamps. Those lamps require high voltages that you don t find in most systems.

Key architectural issues

If you re designing a product that requires analog-signal isolation, you must resolve several architectural issues. The first is the isolation-voltage levels that your system must withstand. The second is whether you pass signals across the isolation barrier in analog form or convert them first to digital form.

If you pass analog signals across the isolation barrier, you must decide whether you need an instrumentation amplifier, a programmable-gain amplifier, a buffer, an op amp, or a specialized signal conditioner. Depending on the type of transducer they re designed to work with, signal conditioners perform a variety of functions besides amplification. Examples are supplying transducer excitation, linearizing outputs and converting them to engineering units, compensating for thermocouple cold-junction temperatures, and detecting open thermocouples.

You should also consider whether two-port (input-to-output) isolation is sufficient, or whether you need three-port isolation. In three-port isolators, the power-supply terminals one of which is common with the output ground in most isolators are ohmically isolated from both the input and output. Three-port isolators are popular in industrial applications in which voltage differences can exist between the signal-source and control-system grounds as well as between the control system and the element that the system drives (a motor or actuator, for example).

The ubiquitous 5B series of isolators is now available from several sources. These units from Analog Devices, which pioneered the format, accept inputs from potentiometric sensors, 4- to 20-mA current loops, and platinum resistance-temperature detectors.

The nature of your application determines the physical form of the isolation products you select. Packaging considerations also have a major impact on cost. Isolation components that mount on pc boards of your own design target products produced in reasonably high volumes. System components, many of which incorporate screw terminals, target one-of-a-kind or few-of-a-kind installations. A major concern is ease of setup by personnel who normally don t work with electronics.

Many choices

Regardless of your decisions on these issues, you have several choices (see **sidebar** For more information).

Circuit-board-mounted isolation components divide into two categories. Most are now hybrid circuits, but a few epoxy-encapsulated discrete-component modules are still available. One of these modules comes from Analogic, and several are from Intronics. Intronics has designed and manufactured such modules for years, but the company recently acquired the rights to manufacture and sell a line of isolator products that Analog Devices formerly produced. Board-mounted analog isolators particularly the hybrid units represent excellent values. Prices begin at much less than $10 each (1000).

System-component products take several forms. Some are the widely distributed 5B series that Analog Devices pioneered and continues to supply. DataForth developed and manufactures a similar line. Many companies distribute such products. Most of those companies obtain the products from Analog or DataForth.

Modules that mount on DIN rails comprise another major system-component category. Such modules are popular among system designers and integrators in both the discrete-manufacturing and continuous-process industries. These units often appear in systems built around programmable-logic controllers. A major difference between the 5B style of product and DIN-rail-mounted units is how you connect signals. You connect directly to the DIN-rail units. In the 5B units, the screw terminals and connectors are on manifolds (backplanes) that the units plug into.

Most system-component isolation products cost considerably more than board-mounted devices. You pay for the system components physical ruggedness and the ease with which you can mount and connect to the units. Prices range from about $50 to more than $200.

Instrument-level products

The third category (other in the **sidebar**) includes higher level products that incorporate isolation technology. In this category are data-logging systems and oscillographic and magnetic-tape recorders intended for collecting sensor data. Most such systems offer isolated-input signal conditioners as options.

Because system characteristics vary widely, prices of the isolated signal-conditioning options also vary. Most such options cost more than $500/channel. This sum often purchases a plug-in module that, besides providing transducer excitation, offers a high level of programmability. Often, you can program both gain and offset. With these features, you can expand small variations superimposed on large static signals to span the full dynamic range of the ADC that follows the signal conditioner.

Reference

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