Noise Reduction and Isolation

CONTROLLING NOISE

Controlling noise in measurement systems is vital because it can become a serious problem even in the best instruments and data acquisition hardware. Most laboratories and industrial environments contain abundant electrical-noise sources, including AC power lines, heavy machinery, radio and TV stations, and a variety of electronic equipment. Radio stations generate high-frequency noise, while computers and other electronic equipment generate noise in all frequency ranges. Building a completely noise-free environment just for running tests and measurements is seldom a practical solution. Fortunately, simple devices and techniques such as using proper grounding methods, shielded and twisted wires, signal averaging methods, filters, and differential input voltage amplifiers can control the noise in most measurements. Some techniques prevent noise from entering the system, while others remove extraneous noise from the signal.

THE GROUNDING CONFLICT

A non-technical dictionary defines the term ground as a place in contact with the earth, a common return in an electrical circuit, and an arbitrary point of zero voltage potential. Grounding, or connecting some part of an electrical circuit to ground ensures safety for personnel and it usually improves circuit operation. Unfortunately, a safe environment and a robust ground system often do not happen simultaneously. It takes planning based on systematically understanding how electricity behaves in various types of circuits. For example, high redundancy is one key feature that makes most of the electrical distribution systems around the world safe and operate properly.

Grounding for Safety

Isolated secondaries of step-down power distribution transformers are generally grounded near the transformer and within the first switching panel in the wired path to the eventual load. (See Figure 10.01.) The ground is a point within the panel connected to a nearby earth ground rod. Typically, a large or significant structure (building frame) or metallic system (plumbing) is also connected to the same point. This minimizes voltage differences that may develop between a water pipe and an appliance with a three-wire grounded cord, for example. An electrical fault such as a non-grounded conductor contacting a metal object is designed to open a fuse or trip a breaker rather than leave an electrically energized appliance at a higher potential than a nearby water pipe or a sink faucet. If the ground connection in the panel disconnects for any reason, the redundant ground near the transformer will provide the path for fault currents to open fuses or trip breakers. Preventing electrical shocks and electrical fires is the highest priority for ground circuits, but the redundancies built into many electrical grounding systems occasionally limit certain kinds of connections for input to data acquisition systems.

Control Panel Grounding

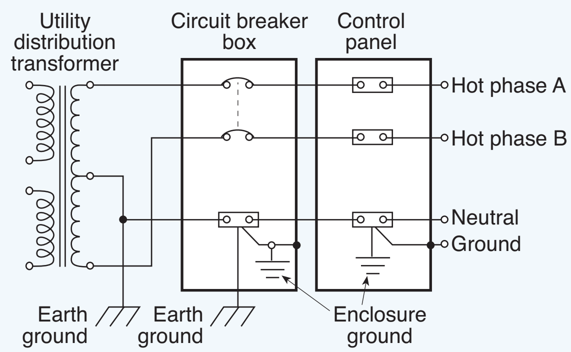

Fig. 10.01. *Utility power transformers are typically grounded to earth ground near the transformer, and again at the input to the electrical junction box or first switching panel. The switching panel, in turn, may be connected to a rod driven into the earth to ensure that it too is at true ground potential.*

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Common Grounds

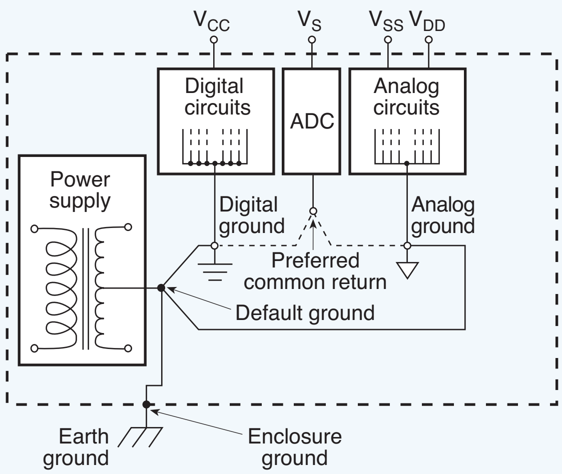


Fig. 10.02. *Significant current fed to multiple circuits should have individual return paths to a common ground or negative terminal. This reduces the risk of voltage drops developing over long ground runs or lead wires that could become input (error) signals to other circuits.*

Interfering Ground loop

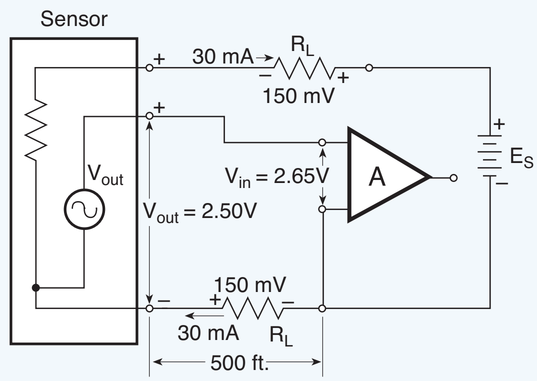


Fig. 10.03. *The 150 mV dropped across R_L in the bottom ground return line arises from the 30 mA of current flowing in 5.2 Ω of lead wire resistance. The voltage adds to the sensor's 2.50V signal to yield 2.65V at the input to the signal-conditioning amplifier and produces a 6.6% error.*

Grounding for Robust Instrumentation

Several internal, common busses in a data control instrument are arranged to regulate current flows and terminate all paths at one common point. This approach ensures that the current flowing in any path will not force a voltage drop in a return path for another circuit and appear as an (erroneous) input signal. (See Figure 10.02.) Usually, this one common point connects through low impedances to the safety ground connection on the instrument's AC power cord. This connection prevents the internal system from floating at an AC potential between earth ground and the input AC supply potential.

GROUND LOOPS

Measuring instruments that contain an earth ground as described above usually generate a ground loop. A ground loop can become a serious problem even when the ground voltage on the measured point equals the ground voltage entering the instrument through the line cord. A voltage that develops between the two grounds can be either an AC or a DC voltage of any value and frequency, and as the voltage and frequency increase, the effects of the ground loop become more troublesome.

Dangerous and Destructive Ground Loops

A transient current can generate a substantial voltage on grounded conductors. During an electrical fault when an energized conductor contacts a safety ground, for example, a fraction of the supply voltage can end up on the safety ground before the fuse or circuit breaker supplying the fault opens and removes the voltage. This happens in a few milliseconds and is usually not a safety hazard. But the problem can be much more serious if lightning strikes a safety ground structure and thousands of amperes flow through the ground system. Potential differences across even a fraction of an ohm can easily exceed 1,000 VAC and damage equipment and endanger lives.

Symptoms of Ground Loops

Sometimes, a measurement error is mistakenly attributed to a ground loop problem, especially where a ground is not strictly involved. The phenomenon relates to two types of situations; shared current flow in a circuit path, which produces unintended voltages, and inadvertent circuits that interfere with the proper operation of intended circuits.

How Ground Loops are Created

A ground loop problem can be illustrated by the following example. An integrated sensor with internal signal conditioning contains three wires; a positive power supply lead, a signal output lead, and a negative lead that serves as both the power return and signal common. (See Figure 10.03.) The sensor's internal circuitry draws about 30 mA and the output signal ranges from 0 to 5 VDC.

The sensor is stimulated and a digital voltmeter reads the correct output of 2.50 VDC on the test bench. But when the three leads are extended by 500 feet with 20 AWG wire (10.4 Ω/1,000 ft. at 20˚C), the common lead wire carrying the 30 mA of power supply current drops about 150 mV. This lead resistance voltage drop adds to the sensors output voltage and delivers 2.65 VDC to the digital voltmeter. The error amounts to about 6.6% and

Bypassed Ground Loop

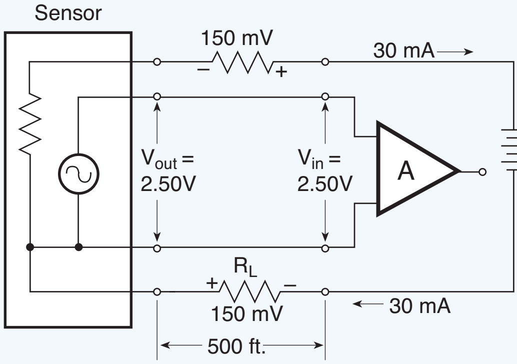


Fig. 10.04. *A separate wire run from the sensor ground (or common terminal) bypasses the power supply ground wire voltage drop. The true output signal of the sensor (Vout) reaches the amplifier input terminals because the input draws negligible current.*

Single-ended Measurement: Unprotected Wires

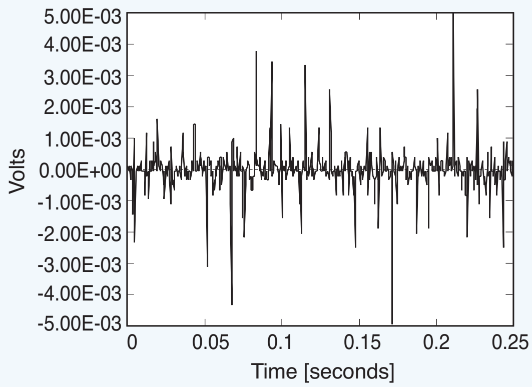


Fig. 10.05. *Radiated noise spikes are easily picked up on non-twisted, non-parallel, unshielded lead wires connected to the single-ended amplifier input terminals, even when the inputs are shorted together.*

what's worse, it varies widely with the temperature of the wire. The specific application determines whether the error can be tolerated or not.

When the current drawn by the sensor circuit is not a steady state value, that is, it consists of an ambient level combined with a dynamic component, the error introduced will be time varying. It might be a relatively high frequency, which acts as noise in the measured output, or it may be in perfect synch with the physical phenomenon being sensed. It then affects the magnitude of the time-varying output signal. Both types of errors often appear in data acquisition systems.

How to Eliminate Ground Loops

A reliable trouble-shooting method analyzes current flow and predicts its results. The wires from the intended point of measurement must carry only current associated with the bias requirements of the analog input channel. (See Figure 10.04.) These currents are typically measured in microamperes. At lower voltage levels, they can be altered substantially if forced to share extremely long wires carrying merely mA. A detailed wiring diagram and a circuit schematic can provide insight and understanding to help prevent this type of problem before hundreds of feet of wire are installed.

Frequently, multiple wires running between two locations cannot be shared. When a common wire is shared, the current in one channel affects the voltage reading in another channel. In the previous numerical example, a fourth wire connected to the lower end of a differential measurement channel provides an output voltage that can be measured accurately with a high degree of confidence. This approach is most effective when the system supports three wires, and they share a common power supply. Differential input connections used with the analog common, which is referenced to the power supply return terminal, eliminates the effect of the ground loops inherent in this multiple-sensor arrangement.

CROSSTALK IN DATA ACQUISITION SYSTEMS

Another type of ground-loop error is crosstalk between channels. This may be defined as an interaction between readings on two or more channels, which may be static or dynamic. When multiple channels are used and ground loops exist, the simplified errors described previously most likely will be compounded by contributions from other channels. The crosstalk may or may not be obvious.

Static Crosstalk

Consider a group of static channels with steady voltages, that when measured individually, yield accurate readings. However, when each channel is connected to an input of the data acquisition system and the readings change, the change indicates that crosstalk is generated by a steady-state ground loop. Likewise, when the reading of a channel changes by connecting another channel, crosstalk exists and the problem is a ground loop.

Dynamic Crosstalk

Dynamic crosstalk is the name given to the situation where a known dynamic signal on a particular channel appears in a physically unrelated channel. The steady-state currents drawn by the transducers discussed in the previous example are idealized for simplicity. These currents commonly vary with the measured physical variables along with the errors.

Sequentially reading signals of widely varying magnitudes produce sequential crosstalk in multiplexed data acquisition systems. Capacitive or inductive coupling

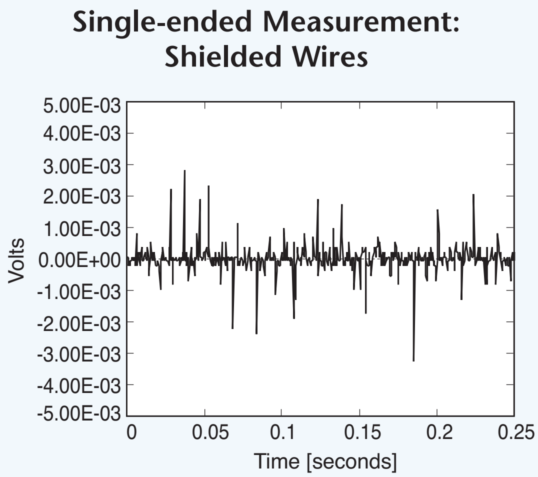


Fig. 10.06. *Shielded wires reduce electrical noise pick up at the input of single-ended amplifier input terminals, but other techniques often are more effective.*

between channels generates crosstalk in systems with improperly or carelessly dressed wires. Generally, however, these are not attributed to ground loops and are less common.

SHIELDED WIRING

Benefits

Metallic shields placed around equipment and test leads effectively prevent noise from either entering or leaving the system. For example, loose or exposed wires become antennas for radio frequency signal pickup, and can form loops that radiate noise.

To emphasize the need for controlling noise, Figure 10.05 shows a single-ended voltage measurement on a shorted channel. Approximately 6 feet of wire, not twisted or shielded, was attached to the data acquisition system. Figure 10.06 shows the noise in a single-ended, shorted channel using shielded cable with obvious improvement.

The best instrumentation wiring schemes consist of carefully grouped lines, twisted in pairs, occasionally covered with a second shield, and routed through a dedicated conduit or raceway. A shielded, twisted pair is quite commonly used in a channel to connect a signal from a source to an input terminal. Shields minimize capacitive coupling and twisted wires minimize inductive coupling.

Proximity to other wires, especially power wires carrying high voltages and high currents can couple noise into low-level signal conductors. Capacitive coupling can exist between any two pieces of metal in close proximity, including two conductors in totally separate circuits. Likewise, air-core transformer coupling can crop up between two closed wiring loops in totally separate circuits.

Proper Installation and Use of Shields

Typically, a shield terminates at one end only, unless it extends to the shield in another span of the same channel wiring. The shield can terminate at either the transducer end or the input channel end, but not both. When the sensor or transducer is in a shielded metallic enclosure, which is also connected to earth ground, the shield may be connected at the sensor end and remain open at the input channel terminals. When the sensor is well insulated, the shield may float and connect to the analog common of the data acquisition system input terminals. Occasionally, multiple-conductor cables composed of a bundle of wires and an overall shield are acceptable for a group of high-level, DC or low-frequency signals, but would not be recommended for the general data acquisition case. Compromising a well planned wiring system with low quality wire, shared conductors or shields, and parallel, untwisted wires will produce less than optimum results.

ISOLATION AND FLOATING DATA ACQUISITION SYSTEMS

Isolation

Isolation is defined as the separation of one signal from another to prevent unintentional interaction between them. All multiplexed data acquisition systems contain a certain degree of channel-to-channel isolation; relay-based systems have galvanic isolation while solid-state systems do not. Galvanic isolation is the absence of any DC path. Most isolation methods eliminate all DC paths below 100 MΩ. Three major benefits of galvanic isolation are circuit protection, noise reduction, and high common-mode voltage rejection, especially those developed by ground loops.

Computer-based data acquisition equipment makes possible an array of multiple channel measurements previously beyond the economic reach of many applications. This has been accomplished by user acceptance of two major compromises, multiplexing and non-isolated inputs. Multiplexing is successful when the sampling rate is adequately high and the source impedances are sufficiently low. Lack of isolation places an entirely different kind of limitation on the type of input signals that can be connected.

Circuit Protection

Isolation separates the signal source from the measurement circuitry that could be damaged by the signal. Voltages higher than about 10V can distort data or damage components used in the system. High-voltage input signals or signals containing high-voltage spikes should therefore be isolated. The protection also works in the opposite direction to safeguard a sensitive signal conditioner from a device failing elsewhere in the system.

Common-Mode Input Voltage

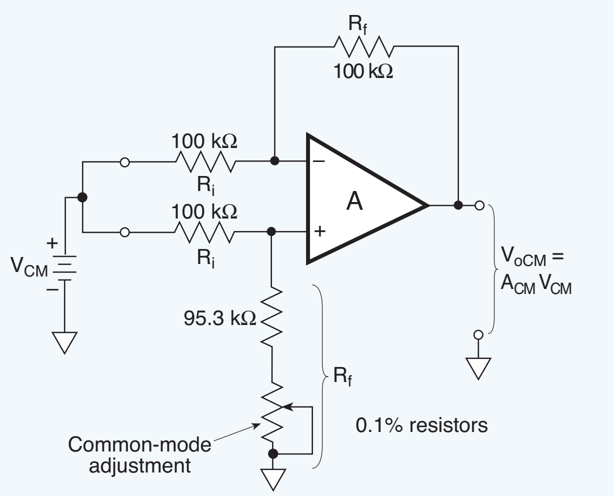


Fig. 10.07. *Common-mode voltage is measured between the two input terminals and the common terminal. Because the two inputs must have identical voltages, they may be tied together and connected to one voltage source.*

Computer-based data acquisition equipment is most often connected to a host computer, which is connected to earth ground. The analog inputs of plug-in cards and most economical external systems are not electrically isolated from earth ground or each other. Many applications are compatible with this situation, but some applications face a problem with high common-mode voltage.

Rejection of High Common-Mode Voltage

Common-mode input voltage is defined as the voltage applied between the common terminal and the two input terminals with the condition that the two input voltages be identical. In other words, the two input terminals may be connected together and the common-mode voltage applied between the shorted inputs and the common terminal as shown in Figure 10.07. In a practical test and measurement situation, the common-mode voltage may exceed the instrument amplifier's input rating, which is typically less than 10V. For safe and accurate measurements, common-mode voltages higher than 10V must be isolated from the instrumentation amplifier while allowing the measured signal to pass. Common types of isolation amplifiers use magnetic, optical, or capacitive means to couple the signal.

Magnetic Isolation

Special instrument amplifiers use transformers that magnetically couple analog-type AC signals from the input section to the output section while effectively sustaining high common-mode voltages. Transformer coupling also lets them provide isolated power to the input stage without using a separate DC/DC converter. A particular instrument amplifier contains an input op amp with a CMRR of about 130 dB at a gain of 100, and 2000V peak common mode voltage isolation. Similar instrumentation amplifiers are available for powering isolated bridges, cold junction compensation, linearization, and other special signal-conditioning requirements. (See Figure 10.08.)

Optical Isolation

Optical isolation is now the most commonly used method to couple digital signals. The measured input voltage signal is converted to a current, which activates a light-emitting diode within an optical coupler. A light-sensitive transistor located adjacent to the diode, but on the opposite side of a voltage barrier, converts the light signal back to a current that the instrumentation amplifier can handle. The voltage

Transformer Isolation Technique

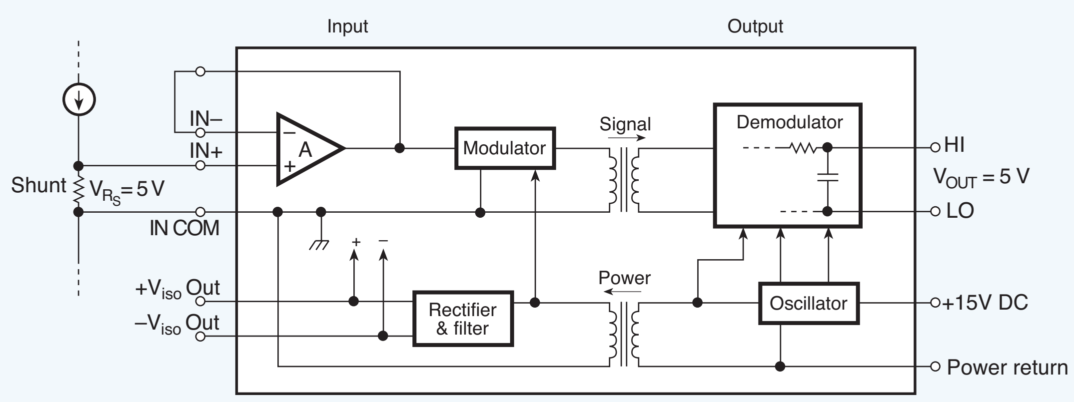


Fig. 10.08. *This instrumentation amplifier with transformer coupling is typically used in an industrial process control loop and provides galvanic isolation in both input and output circuits. It can measure a ±5 VDC signal riding on a common-mode voltage as high as 2000V.*

Optical Isolation Technique

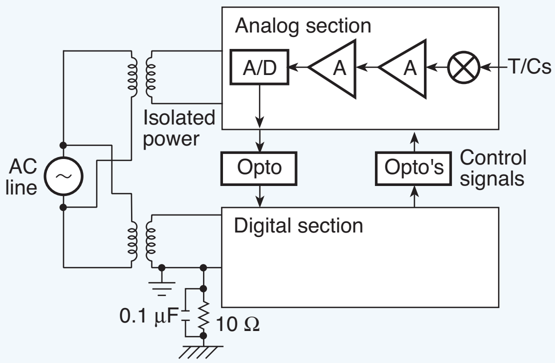


Fig. 10.09. *Optical devices are the most widely used component for coupling signals across high-potential barriers and for low-level signals that are prone to the electrical noise typically coupled through different ground potentials.*

barrier typically provides as much as several thousand volts of isolation between input and output.

Optical devices also are commonly used to isolate the output of an ADC, which is usually a serial string of data pulses passing through a single optical coupler. (See Figure 10.09.) The serial string is often converted from several parallel signals (ranging from 8 to 24 output ports, for example) to minimize the number of optical devices required in a system. Parallel to serial conversion circuits are less expensive than the 8 to 24 optical devices (one for each bit of output from the parallel ADC). In these instances, the power supply for the ADC and associated input circuitry are also isolated, usually with a transformer.

Capacitive Isolation

A capacitor is a passive device that couples AC voltage from one stage to another while blocking the DC component. By this definition, it's a simple but inexpensive isolator. The measured signal to be isolated is modulated and coupled through the capacitor to the receiving side. On the receiving side, the AC signal is demodulated to restore the original signal. This technique is often applied to low-cost isolation amplifiers where the coupling capacitor is composed of a common layer between two isolated IC substrate sections. Signal isolation using these specialized ICs is rated as high as 1500V. The main benefits of this approach are simplicity, low cost, and bandwidths as high as 50 kHz. Figure 10.10 illustrates a DC/DC converter often used as the modulator/demodulator in an isolation amplifier.

Figure 10.11 illustrates a typical multiple-channel, programmable isolation amplifier in a data acquisition system that uses all three types of isolation: transformers, optical devices, and capacitors. A transformer-based DC/DC converter supplies power to the isolated side. A

Modulator/Demodulator Coupling

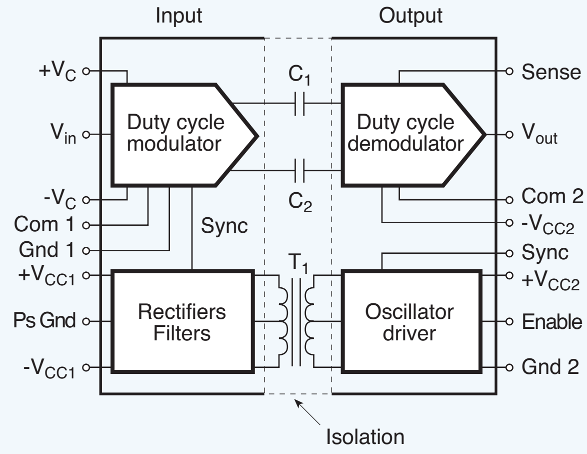


Fig. 10.10. *Low-cost isolation amplifiers couple DC signals by modulating the signal, coupling its ac equivalent through a substrate capacitor connecting the stages, and then demodulating the signal to restore it to its original DC value.*

Programmable Amplifier

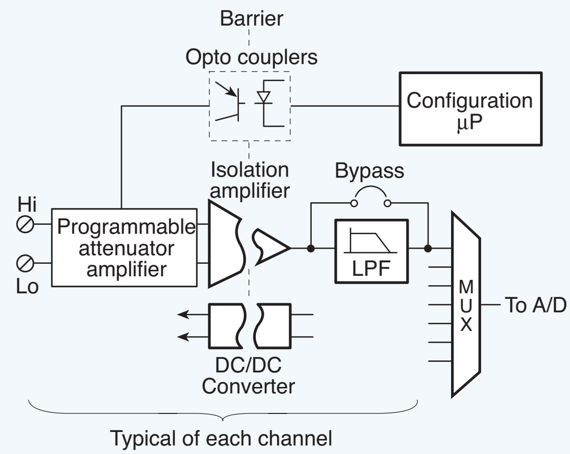


Fig. 10.11 *All three techniques of isolation are used in a multi-channel, programmable amplifier. Optical devices couple digital signals, capacitors couple analog signals, and the DC/DC converter supplies power to the isolated side.*

capacitively coupled device isolates the analog signal while two optical couplers transmit the digital control signals to the floating circuitry.

Fundamental Application Mistakes

Dangers in measurement can easily surface when a non-isolated analog input to a data acquisition system is erroneously connected to a device operating at high common-mode voltage with respect to earth ground. The mistake, which often precedes this problem, is determining the voltage range of the desired signal with a handheld digital

Isolation in Motor Drives

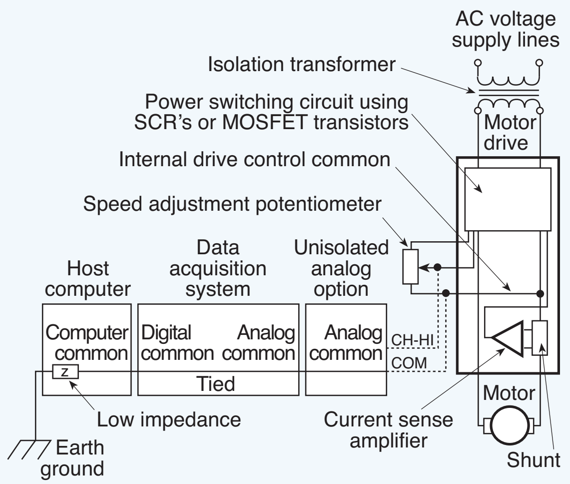


Fig. 10.12. *Common-mode voltage is defined as the voltage between a signal and the localized common, which is usually earth ground. Common-mode voltages can be quite high, depending on the signal source. For example, a current sensing shunt in a DC motor drive might be expected to be at line-voltage potential, although the actual signal level is less than 50 mV across the shunt terminals. Measurement techniques for small signals at high common mode potentials call for isolation.*

or analog multimeter, and neglecting the relationship of the signal with respect to earth ground. If connected with the dotted lines, as shown in Figure 10.12, the motor drive can be damaged as soon as power is applied. This is because the control circuitry in many AC and DC motor drives is necessarily referenced to high voltage with respect to earth ground. When motor current is sensed with a shunt or low-value resistor, the control common bus is generally at high common-mode potential with respect to earth ground.

Some drives use non-contacting current sensors, transformers, and optical couplers to achieve galvanic isolation of the control circuitry. However, unless the drive is specifically known to have an isolated analog interface, assume it does not.

Isolation Transformers

Not all AC line-powered devices contain the internal isolation transformers that step the voltage down to lower operating levels needed for electronic circuits and simultaneously protect users from external ground faults. The power supply common bus in transformerless devices often connects to one side of the AC line cord. If the system is not protected from reversing the line cord connector in the socket, the device common line (and hence the enclosure) can be raised to a voltage level which is higher than the common terminal of other devices in the vicinity or other instruments connected to the data acquisition system. The ground fault resulting from this arrangement effectively shorts out the supply line and can be a hazard to operators and destroy the equipment.

An isolation transformer lets a user safely connect a data acquisition system input channel, grounded through the host computer, to a low voltage signal in an ac-powered device. The preferred isolation transformer for such use has a grounded electrostatic shield between the primary and secondary windings to minimize capacitive coupling and potentials with respect to earth ground. This approach works only when the AC neutral in the electrical system is grounded to earth. Isolation transformers cannot interrupt the path for the safety ground carried by the ground prong of a standard 3-wire cord.

A laptop computer running on an internal battery and not connected to other peripherals that are tied to earth ground (such as printers) can be a floating host safely connected to a data acquisition system. But a better overall approach is to isolate the input signal source.

An isolation transformer usually doesn't supply all the isolation intended for a data acquisition system, because the digital common in most computers provides a low impedance path to earth ground as part of its ESD (electrostatic discharge) protection scheme. But some data acquisition devices that communicate with the host computer through serial data links such as RS232 and RS485 use communication isolators specifically designed for that protocol. By comparison, most Ethernet interfaces are transformer isolated and have ESD protection networks on both sides of the isolation barrier referenced to chassis, plus earth ground through the host computer.

Analog Isolators

The ideal solution for measuring high common-mode signals is the analog isolator. The isolator safely measures low-level analog input signals containing as much as 1500V common mode, through magnetic, optical, or capacitive devices. The amplifiers provide both channel-to-system isolation and channel-to-channel isolation. By contrast, most solid-state multiplexers have no channel-to-channel isolation beyond the standard ±10V signal range.

The most common analog isolators are plug-in modules. These 3-port devices require a DC power supply and provide operating voltages for signal conditioning and modulation circuitry on the input side. They also provide voltage for demodulation and signal reconstruction circuits on the output side. Most devices also provide inherent low-pass filtering and scaling to 0 to 5V output levels. The wide array of available options in these modules can simplify many complex measurement requirements and still provide data to the overall data acquisition system of choice, as all data acquisition manufacturers have products that accept these modules.

Noise Reduction: Signal Averaging

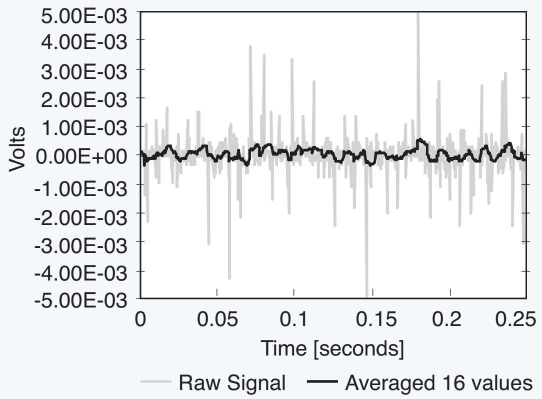


Fig. 10.13. *Signal-averaging using software techniques virtually reduce the effective electrical noise pick up before the data acquisition system processes the measured signal.*

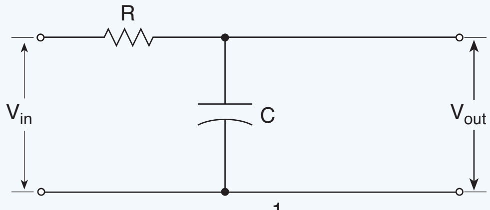
The isolation modules are relatively expensive and are not likely to be used in low-cost data acquisition systems. Low-cost systems typically don't contain analog isolators, but many applications require isolators in at least a few channels. System-wise, the best place to address a high common-mode signal channel is at the source for safety and signal integrity.

Wireless Techniques

Not all data acquisition systems can connect to sensors on the test specimen with wires. They require a form of radio communication called telemetry. Radio transmitters and sensors are located on the device under test and receivers are located at the data acquisition system. For example, the rotating member of a large motor or generator can be monitored remotely and safely. The system can monitor temperature, vibration, deflection, and speed in rpm without the type of slip rings used in the past.

A relatively new protocol called Bluetooth is increasingly being used for remote measurement and control. It is a short-range wireless system that lets devices recognize, connect, and transfer data among them. The devices are equipped with special Bluetooth chips and transmit over a short range, typically 10 m. They can transfer data at a rate of 720 KB/sec over a frequency band of 2.40 to 2.48 GHz. Another system is the 802.11 Ethernet-based wireless system. It often provides physical and electrical isolation on the factory floor and for high voltage utility lines and demolition test sites. It operates in the same frequency range as Bluetooth and can handle higher data transfer rates of 1 to 11 MB/sec.

Single-Pole RC Filter



$$F_{-3dB} = \frac{1}{2\pi RC}$$

Fig. 10.14. *Passive single pole filters are moderately effective in passing a band of frequencies that contain the measured signal, while attenuating other frequencies containing noise.*

NOISE REDUCTION

Signal Averaging

Some noise reduction techniques prevent the noise from entering the system initially, and others remove extraneous noise from the signal. Another technique averages several signal samples through software. Depending on the nature of the noise and the specific averaging method, noise can be reduced by the square root of the number of averaged samples (RMS). But this may require abundant samples to obtain an acceptable measurement. Figure 10.13 shows the voltage across the shorted channel when only 16 samples of data are averaged.

Although averaging is an effective technique, it has several drawbacks. The noise present in a measurement sequence decreases as the square root of the number of measurements. Therefore, in the above example, reducing the RMS noise to a single count by averaging alone would require 3,500 samples. As such, averaging suits only low-speed applications, and it eliminates only random noise. It does not necessarily eliminate many other types of annoying system noise, such as periodic noise from switching power supplies.

Analog Filtering

A filter is an analog circuit element that selectively attenuates a particular band of frequencies in an incoming signal. Filter circuits can be passive or active. Depending on whether the filter is low or high-pass, it determines the frequencies that are attenuated above or below the cutoff frequency. For example, as a signal frequency increases beyond the cutoff point of a single-pole, low-pass filter, its attenuation increases slowly. Multiple-pole filter attenuation also increases slowly. Multiple-pole filters provide greater attenuation beyond the cutoff frequency, but they may introduce phase shifts that could affect some applications. The frequency where the signal is 3 dB down is given by the equation shown in Figure 10.14.

Comparing Single-Pole and Three-Pole Filters

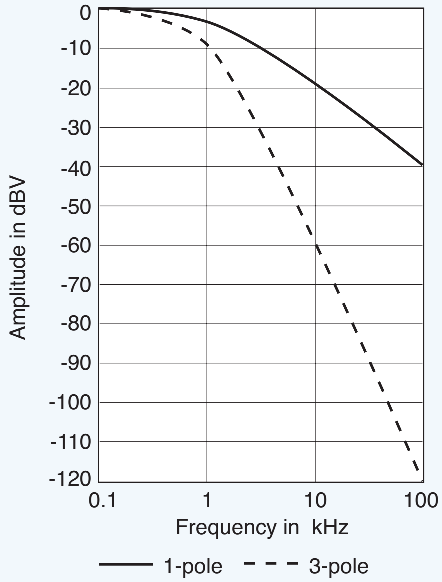


Fig. 10.15. *The three-pole filter attenuates the frequencies after the cutoff point more effectively than does the single-pole filter.*

Noise Reduction: Low-Pass Filter

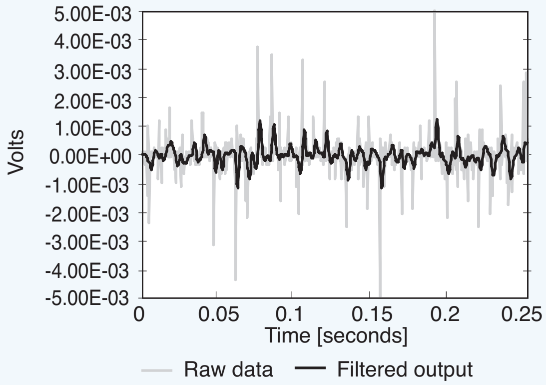


Fig. 10.16. *An active, three-pole low-pass filter, configured as a Butterworth, Bessel, or Chebyshev filter, reduces the noise signal more effectively without significant attenuation than does a passive circuit.*

Passive vs. Active Filters

A passive filter is a circuit or device consisting entirely of non-amplifying components, typically inductors and capacitors, which pass one frequency band while rejecting others. An active filter, on the other hand, is a circuit or device composed of amplifying components such as operational amplifiers, and suitable tuning elements, typically resistors and capacitors, which pass one frequency band while rejecting others. Figure 10.15 compares the amplitude of a single-pole, low-pass filter with a three-pole filter. Both types are set for a 1 kHz cutoff frequency.

Differential-Input Amplifiers

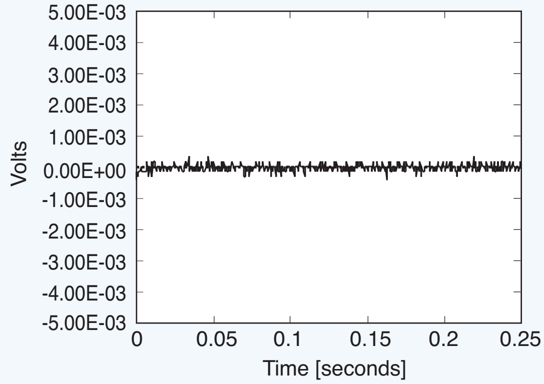


Fig. 10.17. *The biggest improvement in reducing unwanted noise signals from the measured variable comes from differential-input amplifiers. It works so well because most of the noise on the high side duplicates the noise on the low side of the input and the algebraic sum of the two equal parts.*

The three-pole filter has a much greater attenuation for frequencies exceeding the cutoff. The improvement in signal quality provided by low-pass filtering is demonstrated in Figure 10.16 in which a signal containing wideband noise passes through a three-pole filter with a 1 kHz cutoff frequency. The deviation from the average signal is plotted in volts. The maximum deviation is 6 counts, and the RMS noise is 2.1 counts.

The three-pole filter shown in the example has an active input with changeable configurations. The active, three-pole filter can be a Butterworth, Bessel, or Chebyshev with corner frequencies up to 50 Hz. Filter properties depend on the values of the resistors and capacitors, which the user can change. Filters also use switched-capacitors. This type requires a clock signal to set the cutoff frequency. The primary advantage of this filter is the ease of programming the cutoff frequency.

Differential Voltage Measurement

Differential input amplifiers are most often used in data acquisition systems because they provide a high gain for the algebraic difference between their two input signals or voltages, but a low gain for the voltages common to both inputs. Making differential voltage measurements is another means of reducing noise in analog input signals. This technique is effective because often, most noise on the high-side input lead closely approximates the noise on the low lead. This is called common-mode noise. Measuring the voltage difference between the two leads eliminates this common-mode noise.

The improvement gained with differential voltage measurements is illustrated in Figure 10.17. It shows the same signal as Figure 10.05, but using a differential input rather than a single-ended input.

Data Acquisition Solutions

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