"LabVIEW 6i", Student Ed, R-H. Bishop, 2001, Prentice Hall Inc, New Jersey.

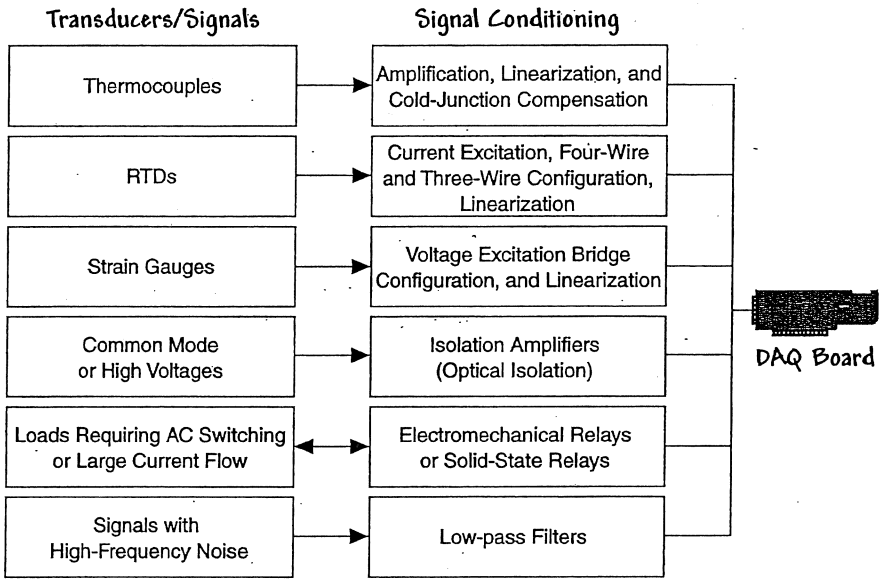


FIGURE 8.14
Common types of transducers/signals and the required signal conditioning.

Some common types of signal conditioning follow:

- Transducer excitation: Certain transducers (such as strain gauges) require external voltages or currents to excite their own circuitry in a process known as transducer excitation. The process is similar to a television needing power to receive and decode video and audio signals. The necessary excitation in a DAQ system can be provided by the plug-in DAQ boards and the signal-conditioning peripherals, and sometimes by external instruments.
- Linearization: Common transducers (such as strain gauges, thermistors, RTDs, and thermocouples) generate voltages that are nonlinear with respect to the phenomena they represent. The LabVIEW DAQ Utility VIs can perform software **linearization** to scale a transducer voltage to the correct units of strain or temperature.
- Isolation: Another common use for signal conditioning is to isolate the transducer signals from the computer. For example, when the signal being monitored contains large voltage spikes that could damage a computer or harm a person, you should not connect the signal directly to a DAQ board without some type of isolation. Figure 8.15 shows two common methods for isolating signals.
- Filtering: Another form of signal conditioning is the filtering of unwanted signals from the desired signal. A common filter reduces 60 Hz AC power-line noise present in many signals. Other well-known types of filters

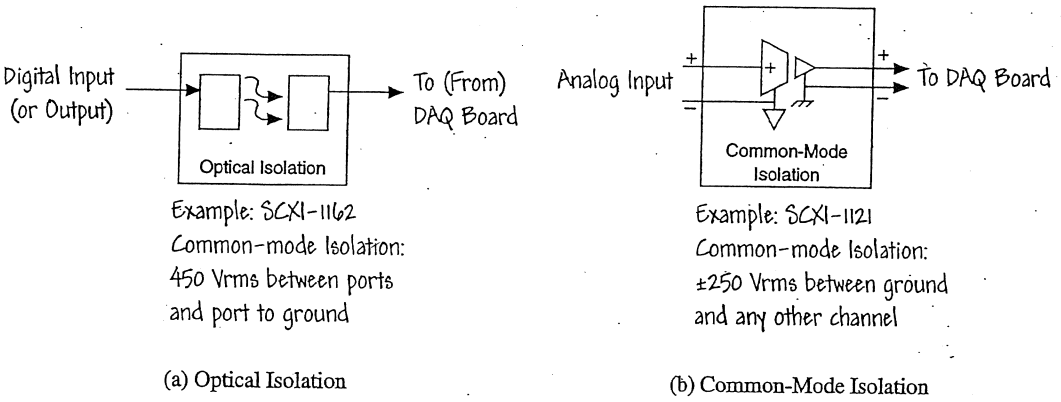


FIGURE 8.15
Two common methods for isolating signals.

include low-pass, high-pass, and notch filters. Some DAQ boards and signal-conditioning devices have built-in filters.

- Amplification: This is the most common type of signal conditioning. Amplification maximizes the use of the available voltage range to increase the accuracy of the digitized signal and to increase the signal-to-noise ratio (SNR). Low-level signals should be amplified at the DAQ board or at an external signal-conditioning peripheral positioned near the source of the signal, as shown in Figure 8.16. One reason to amplify low-level signals close to the signal source, instead of at the DAQ board, is to increase the signal-to-noise ratio. Consider the case where you amplify the signal only on the DAQ board. Then the DAQ board will also measure and digitize any noise that enters the lead wires along the path as the signal travels from the source to the DAQ board. On the other hand, the ratio of signal voltage to noise voltage that enters the lead wires is larger if you amplify the signal close to the signal source. Table 8.2 shows how the SNR changes with the location of amplification.

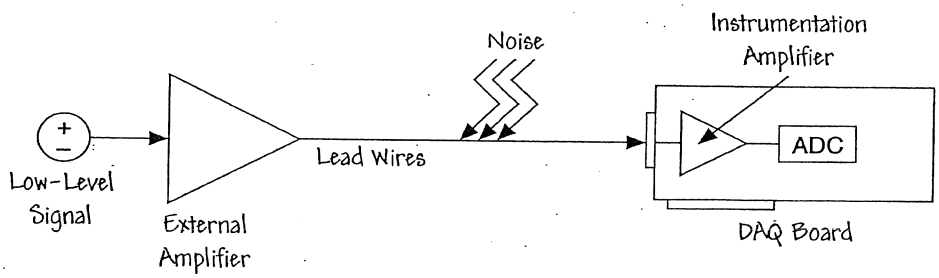


FIGURE 8.16
Low-level signals should be amplified at the DAQ board or at an external signal-conditioning peripheral positioned near the source of the signal.

TABLE 8.2 Effects of Amplification on Signal-to-Noise Ratio (S.C. → Signal-Conditioning Peripheral)

	Signal Voltage	S.C. Amplification	Noise in Lead Wires	DAQ Board Amplification	Digitized Voltage	SNR
Amplify only at DAQ board	0.01 V	None	0.001 V	×100	1.1 V	10
Amplify at S.C. and DAQ board	0.01 V	×10	0.001 V	×10	1.01 V	100
Amplify only at S.C.	0.01V	×100	0.001 V	None	1.001 V	1000

You can minimize the effects of external noise on the measured signal by using shielded or twisted-pair cables and by minimizing the cable length. Keeping cables away from AC power cables and computer monitors will also help minimize 50/60 Hz noise.

8.4 SIGNAL GROUNDING AND MEASUREMENTS

Up to this point, we have discussed three components of the DAQ system: signals, transducers, and signal conditioning. Now you might be tempted to think that all that remains is to wire the signal source to the DAQ board and begin acquiring data. However, a few important items must be considered:

- The nature of the signal source (grounded or floating)
- The grounding configuration of the amplifier on the signal conditioning hardware or DAQ board
- The cabling scheme to connect all the components together

A DAQ system is depicted in Figure 8.17 highlighting the signals and the cabling.

8.4.1 Signal Source Reference Configuration

Signal sources come in two forms: referenced and nonreferenced. Referenced sources are usually called **grounded signals**, and nonreferenced sources are called **floating signals**. A schematic of a grounded signal source is shown in Figure 8.18a.

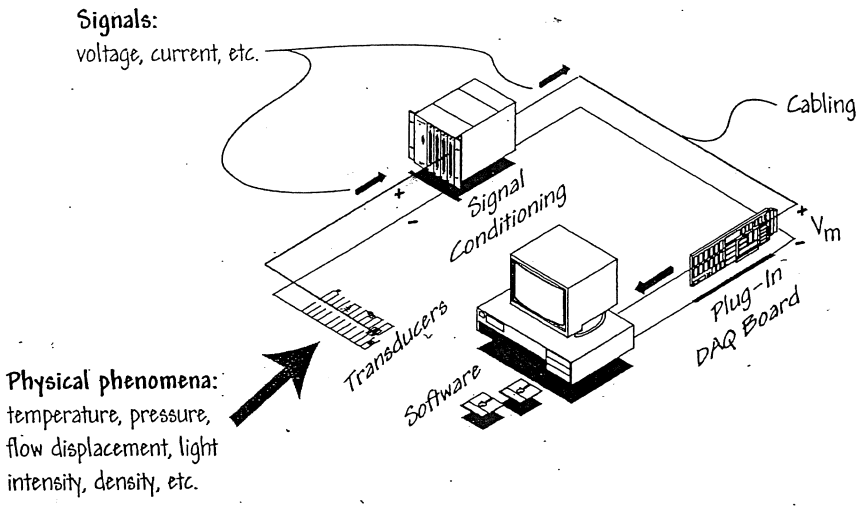
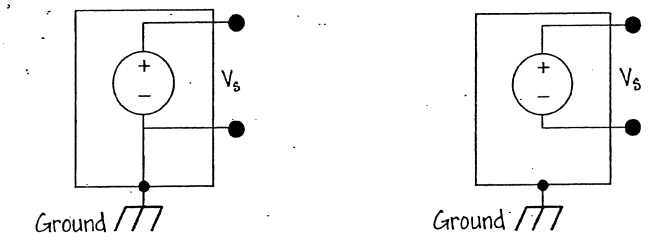


FIGURE 8.17
A DAQ system highlighting the signals and the cabling.



(a) Grounded signal source (b) Floating signal source

FIGURE 8.18
Grounded signal sources have voltage signals that are referenced to a system ground. Floating signal sources contain a signal that is not connected to an absolute reference.

Grounded signal sources have voltage signals that are referenced to a system ground, such as earth or a building ground. Devices that plug into a building ground through wall outlets, such as signal generators and power supplies, are the most common examples of grounded signal sources. Grounded signal sources share a common ground with the DAQ board.

Floating signal sources contain a signal (e.g., a voltage) that is not connected to an absolute reference, such as earth or a building ground. Some common examples of floating signals are batteries, battery-powered sources, thermocouples, transformers, isolation amplifiers, and any instrument that explicitly floats its output signal. As illustrated in Figure 8.18b, neither terminal of the floating source is connected to the electrical outlet ground.

8.4.2 Measurement System

A schematic of a measurement system is depicted in Figure 8.19. A measurement system can be placed in one of three categories:

- Differential
- Referenced single-ended (RSE)
- Nonreferenced single-ended (NRSE)

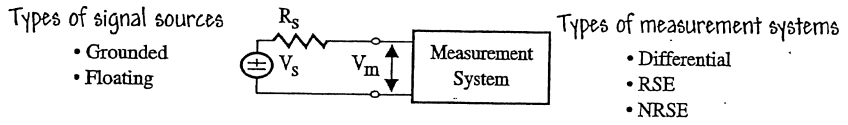


FIGURE 8.19
Types of signal sources and measurement systems.

In a **differential** measurement system, you do not need to connect either input to a fixed reference, such as earth or a building ground. DAQ devices with instrumentation amplifiers can be configured as differential measurement systems. Figure 8.20 depicts the 8-channel differential measurement system used in the MIO series devices. A **channel** is a pin or wire lead where analog or digital signals enter or leave a DAQ device. For this device, the analog input ground pin labeled AIGND is the measurement system ground. The analog multiplexers (labeled MUX in the figure) increase the number of available measurement channels while still using a single instrumentation amplifier.

An ideal differential measurement system, shown in Figure 8.21, reads only the potential difference between its two terminals—the (+) and (−) inputs. It completely rejects any voltage present at the instrumentation amplifier inputs with respect to the amplifier ground. In other words, an ideal differential measurement system completely rejects the common-mode voltage.

A **referenced single-ended** (RSE) measurement system measures a signal with respect to building ground and is sometimes called a grounded measurement system. Figure 8.22 depicts a 16-channel version of an RSE measurement system.

DAQ devices often use a **nonreferenced single-ended** (NRSE) measurement system, which is a variation of the RSE measurement system. In an NRSE measurement system, all measurements are made with respect to a common reference, because all of the input signals are already grounded. Figure 8.23 depicts an NRSE measurement system. AISENSE is the common reference for taking measurements and all signals in the system share this common reference. AIGND is the system ground.

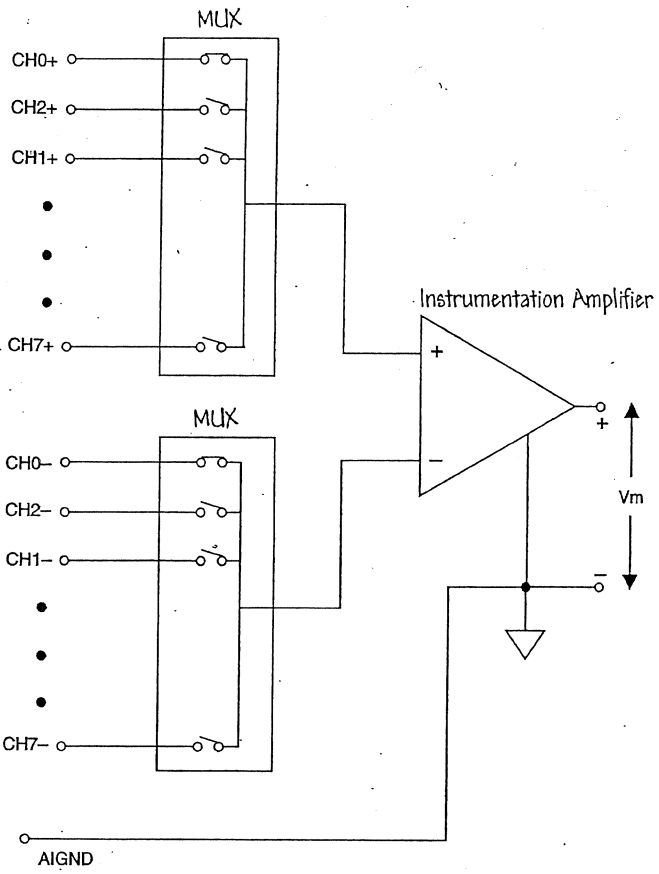


FIGURE 8.20
An 8-channel differential measurement system.

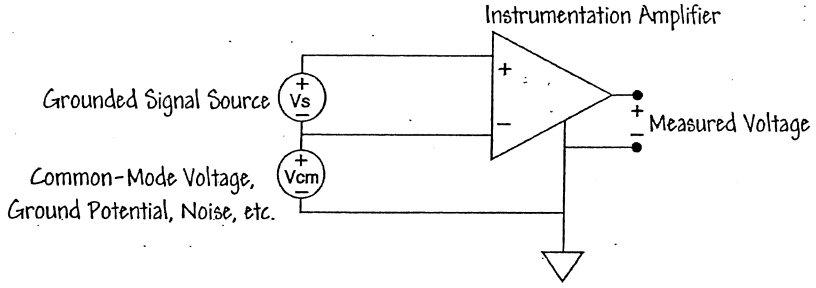


FIGURE 8.21
An ideal differential measurement system completely rejects common-mode voltage.

other hand, the single-ended configuration allows for twice as many measurement channels and is acceptable when the magnitude of the induced errors is smaller than the required accuracy of the data. You can use single-ended measurement systems when all input signals meet the following criteria:

1. High-level signals (normally, greater than 1 V).
2. Short or properly shielded cabling traveling through a noise-free environment (normally less than 15 ft).
3. All signals can share a common reference signal at the source.

A summary of analog input connections is given in Figure 8.24.

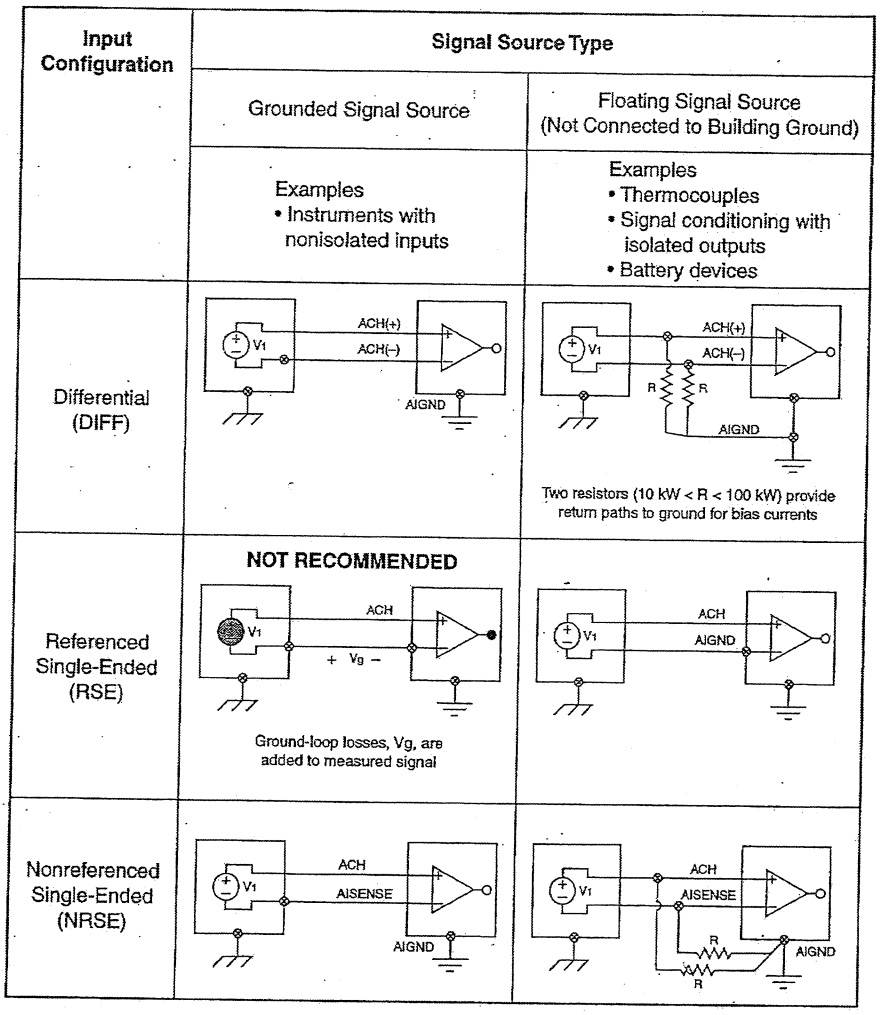


FIGURE 8.24
Summary of analog input connections.

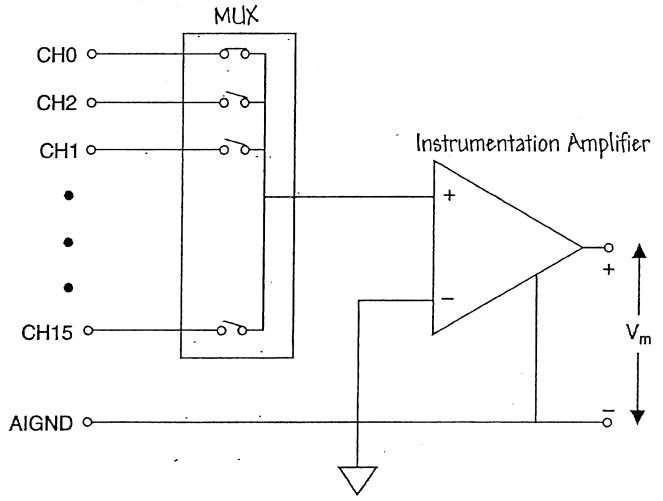


FIGURE 8.22
A 16-channel RSE measurement system.

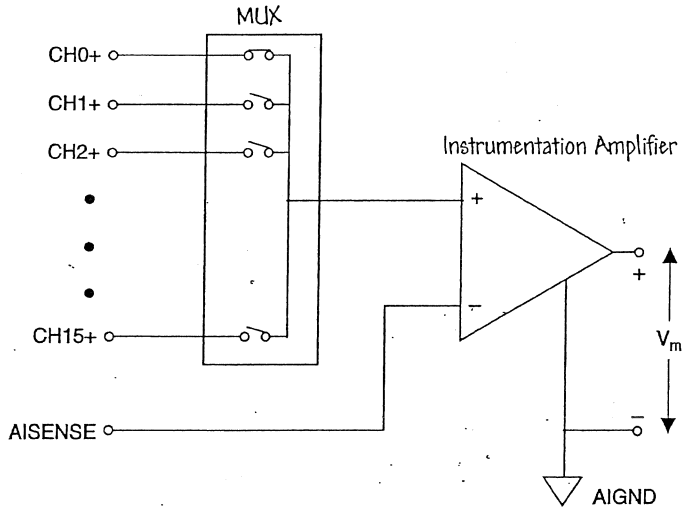


FIGURE 8.23
An NRSE measurement system.

A grounded signal source is best when using a differential or NRSE measurement system. An RSE measurement system can be used with a grounded signal source if the signal levels are high and the cabling has a low impedance. The measured signal voltage will be degraded with the RSE system, but the degradation is usually small relative to the signal voltage. Floating signal sources can be measured with differential, RSE, and NRSE measurement systems. In general, a differential measurement system is preferable because it rejects the ground loop-induced errors and reduces the noise picked up in the environment. On the