

Grounding and Shielding

This article was written for CALEX by Mr. Ralph Morrison, President of INSTRUM and the author of "Grounding and Shielding Techniques in Instrumentation" published by Wiley.

Grounding and Shielding of Amplifier, Bridgesensor and Voltsensor Input Leads

Noise can couple into low-level signals in a variety of ways. The coupling mechanisms involve not only the cable type but its shield and ground connections. The coupling is a system problem involving the amplifier, its bandwidth, the transducer type, the distances involved and the nature of the interfering signals. There are many ways to randomly connect shields and grounds but this rarely leads to an optimum set of connections. It is preferable to design a system based on an understanding of the coupling mechanisms and how to avoid their affects.

Noise Sources

1. Conducted Interference

Currents flowing in the ground system are a fact of life. These currents arise from the power system, from reactive coupling and from radiation. The resulting ground potential difference can couple into the signal paths. It is usually futile to attempt to "short out" these potential differences. The two ground points of interest are the instrumentation power supply/output termination and the input lead termination. This ground potential difference is usually referred to as common-mode.

2. Electromagnetic Field Coupling

Fields from nearby transmitters are often a source of contamination. These fields couple voltages into the input cable in the form of a common-mode signal. The signal is proportional to loop area and to frequency. The loop area in question is between the cable and the earth plane. Normally these signals are out of band and do not appear as noise. They are troublesome because they can be rectified in the instrument and appear as a DC offset.

3. Magnetic Field Coupling

Magnetic fields from fans, transformers or motors can induce voltages into input cables. The leads carrying a signal must be very close to the field source and they must open up to provide a loop area for coupling. If reasonable care is taken to limit coupling this noise source can usually be neglected.

4. Capacitive Coupling

Electric fields from nearby conductors can couple capacitively to signal leads. If the leads are shielded, the electric fields terminate on the shield and not on the input leads, and this form

of coupling can be greatly attenuated. Braid does not always provide full coverage and thus allows some electric field coupling to occur.

The shield itself is closely coupled to the input leads of a signal cable. If the shield is connected improperly it can couple significant noise into the signal path.

5. Transfer Impedance

Current flowing in the shield can couple voltage to the conductor pair in a cable. This is generally a high frequency phenomena. For long lines some differential filtering may be needed to attenuate this type of coupling.

Input Cable Treatment

Two wire twisted and shielded cable is preferred for input cable. The shield can serve as a guard, keeping external fields from coupling to the signal leads. The signal is properly guarded when the shield is connected to the zero reference potential for the signal. The only correct point for grounding the shield is where the signal is grounded. If the signal is floating then the shield must connect to one side of the signal. Differential amplifiers work best from grounded signal sources. The fact that the source ground and output ground differ in potential is simply a common-mode rejection problem for the instrument. This signal ground point should be where the transducer is located. If not then the parasitic capacitances between this ground and the transducer can couple noise into the signal path.

The input cable shield cannot be grounded more than once. Two grounds create a shield gradient of potential. If one termination is correct then all other points on the shield are incorrect. The shield should be continuous along the entire path. Openings in connectors or in distribution panels should be kept to a minimum. A correctly configured input cable is shown in Figure 1. Note that the shield is not grounded at the instrument.

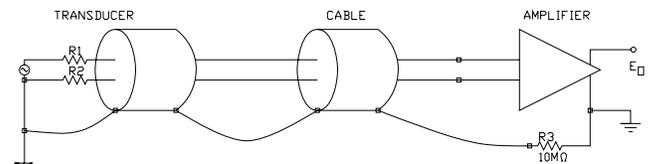


FIGURE 1. A properly grounded input circuit.

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Floating Sources

Ungrounded sources occur in instrumentation as a requirement for safety or performance. The input circuitry of an instrument has a finite input current requirement. This current must return to output ground. If this path is not provided, the instrument may appear to work but in reality it is functioning near a point of saturation to create a return path for input current. The proper way to provide for this current path is via a shield-to-ground resistor at the input. A resistor between the input leads and the ground at the output invites noise current to flow in the input leads and it also reduces the common-mode rejection capability of the instrument. A proper circuit is shown in Figure 2.

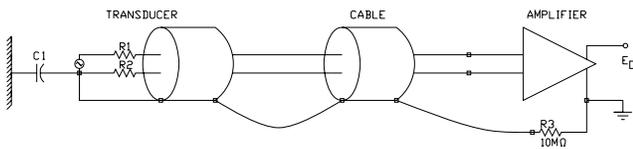


FIGURE 2. A proper connection for floating signal source

Note that parasitic current still flows between the two grounds in capacitor C_1 and resistor R_3 . Current flowing in R_1 , and R_2 is limited by the input impedance of the instrument. This also limits the common-mode rejection ratio. Figure 3 indicates what happens when the input shield is incorrectly connected. The potential difference between G_1 and G_2 drives current in the loop C_1 , R_2 , and C_2 . Note that C_2 is the capacitance in the cable between a signal conductor and the shield. This arrangement will be very noisy. Noise current flows in resistor R_2 and the amplifier sees this as normal signal.

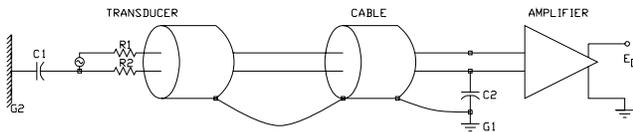


FIGURE 3. An improper shield connection for a floating source

Input Filters

High frequency noise entering the amplifier can cause signal rectification. This rectification causes DC offsets which are amplified as normal signal. The noise can enter both as normal or common-mode components. Normal-mode or differential-mode signals can be filtered by a simple RC filter located at the input. Care must be taken to limit the series resistor to perhaps 500 ohms. Common-mode signals are best attenuated by bypassing the shield to the local ground at the signal interface. If the bypass path is too long it may be too inductive to be effective. A filter arrangement is shown in Figure 4.

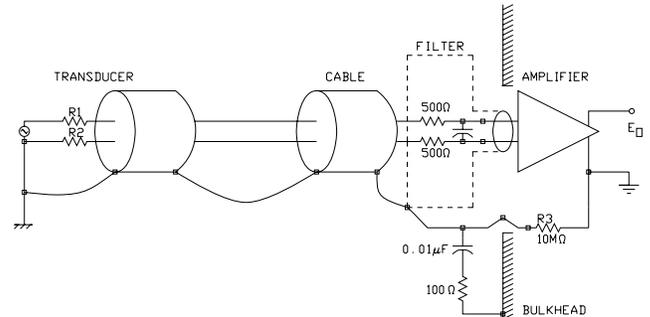


FIGURE 4. Adding a differential and common-mode filter to an input connection.