Opto 22 Technical Note

TN9603A Grounding and Wiring Practices

One of the best methods to avoid problems with noise and signal interference in electronic control systems is to use proper grounding and shielding practice. Most noise and interference problems can be eliminated through the use of good shielding and the elimination of grounding conflicts. Many industrial environments have a sufficiently low background electronic noise level that secure shielding and "good" wiring are not an issue; there are many environments, however, where good practice in terms of grounding, shielding, and wiring can mean the difference between an excellent and an unacceptable electronic control system.

I. Grounding

Proper grounding in essential to the proper operation of the majority of electrical and electronic equipment, as well as the minimization of equipment generated EMI. Unfortunately, even a ground or grounds that seem secure may not be of sufficient quality to offer optimal performance from a given electronic system.

There are many sources for a ground connection in an industrial environment, ranging from the ground socket on a power receptacle to a cold-water pipe to a panel grounding bus to a copper rod literally buried in the ground. These are all typically secure grounds, meant to reliably source or sink any excess current the grounded device might require. Unfortunately, the quality of a ground can vary greatly, even if it acts ideally as a current source or sink. First, ground potential varies from point to point on the earth's surface. This is especially true when a large amount of current is being sunk or sourced near to or at a grounding point; one example is typical one-phase power, where the neutral and ground conductors are really the same, and may even be connected together at the service panel. I have personally measured differences of several tens of volts on receptacles on different circuits in the same room. The impedance of the wiring between any connected equipment and earth ground, combined with sourced or sunk current, can create a voltage offset between "ground" and the true earth potential of zero. This is not normally a problem for electronic systems linked to a single ground, as the regulators in the power supply float above this ground reference, no matter how imperfect it might be. The problem comes when there is a system with multiple grounds at different potentials.

Multiple grounds at different potentials can cause all sorts of problems with electronic systems. First, power supplies at different grounds will reference these grounds to regulate their voltage. A voltage reference difference can mean that any voltage signal referenced to its source ground sent from one location to another will have a severe offset at the receiving location. This is not a problem for isolated I/O, where the I/O is floated up to a common reference potential. For non-isolated I/O, however, the signal might cease to have any meaning. Worse, if a common line is run between non-isolated I/O at different ground, and hence reference potentials, large currents might begin to flow from one point to another through the common line. At the least, this will alter the power regulation at one or both ends, and possibly cause circuit protection to be tripped or fuses to be blown; more extreme cases could lead to fires or other hazards. Remember that a grounded shield, in this case, is a common line. The moral of this story is that the potential between two different grounding points should be checked before any connection is made between them. Remember that an ideal ground is an ideal current source and sink, hence even a small voltage imbalance could lead to large amounts of current flowing. If at all possible, avoid making connections between non-isolated devices referenced to different grounds. If practical, try to use the same ground reference for all electronic devices in a control system.

II. Wiring

Many noise problems can be addressed by using proper wiring practice when connecting elements of a control system. Control system wiring can carry any number of different types of signals, or even power. The relative difference in signal amplitude between different lines can cause cross talk or other interference problems. Bad wiring layout or practice can accentuate the noises inherent in any wiring.

First, it is important to make sure that low-level signal lines (analog or discrete) are always routed separately from any lines that carry either high voltage, current, or both. Analog and discrete signal lines should also be routed away from each other whenever possible. This is doubly true for discrete lines using 120 VAC for a signal voltage. "Routing separately" in this case means making sure that the conductors are in separate wire bundles, separated by at least a few inches in a panel situation. Different conductor types should be routed in separate conduit for any counduited runs. It's also nice to try to dedicate one side of an installation to high level signals, and the other to low level signals. Where signal or data lines must cross power conductors, they should cross at a right angle to prevent electromagnetic coupling between the lines.

Second, all analog signal and digital data line conductors should be shielded individually. The shield should be connected at one end only, typically on the controller side. It is extremely important that millivolt level signals from devices like load cells and thermocouples be shielded. If a thermocouple is grounded at the sensing end, an isolated input module should be used. Current signals, like 4-20 mA signals, are typically more immune to noise than voltage signals, but conductors carrying these signals should also be shielded. Data lines should also typically be shielded; the exceptions to this are short RS-422/485 runs (less than two meters) using twisted-pair cable, the Pamux parallel bus, and the Mistic Local Bus. In the case of the two buses, adding a shield or ground plane changes the line impedance enough that bus performance over long distances is reduced. Shielded cable is often described in terms of percent shield coverage. Braided shields will offer from 75 to 100% shield coverage, while foil or foil-backed plastic will offer 100% coverage. It is important to note that percent coverage is not an indicator of shielding effectiveness, as this is frequency and radiated-power dependent. A good quality shielded cable should suffice for most industrial purposes, though.

Last, as stated in the previous section, it is best to avoid wiring non-isolated equipment referenced to separate grounds together. It is also important to check the potential difference between two commons before they are wired together. In no case should earth ground beused as a common reference in distributed ground applications. Power supply wiring should be sized appropriately for the largest potential load that the wiring in question will see. Electromechanical equipment and electronics should never share power supplies without adequate line-to-line filtering and regulation installed, as this type of equipment can introduce large amounts of noise into a wiring system. When possible, devices that share a common power supply should be wired in a star configuration. For more information please refer to Opto 22 Application Note 9606, about implementation of power supplies.

Most industrial noise problems can be eliminated by the application of proper practice when it comes to connecting field devices together. For the most part, good wiring practice can be derived from good common sense, though there are some issues that might not necessarily be obvious without some background or experience with the subject. For more information about how to protect an electronic control system from external interference and noise, please see Opto 22 Technical Note 9603B.