This section recommends certain procedures and provides information about coupling, noise, and interference that apply to RTD and thermocouple measurements.

## Field Wiring Practice Recommendations

The following wiring practices are strongly recommended for installing field wiring. Wiring recommendations regards AC and DC power distribution are discussed in other FRS publications.

1. Ground all shields at one point only, normally at the signal source. When a multi-pair cable is split into shielded single-pair leads at a junction box, connect all shields at the junction box, and ground the multi-pair cable shield at the system.
2. Cable shields should extend to within one inch of the terminations. Shields must be insulated except at the ground point.
3. Ground all unused signal leads in a multi-pair cable at one point only, typically at the same point that the cable shield is grounded.
4. Each multi-pair cable should contain at least one pair of spare leads. Good design practices suggest that at least 10 percent of the leads be spares.
5. High-level analog signals are generally safe to route in multi-pair cable. However, in areas that are extremely noisy electrically, shielded twisted-pair wiring is recommended.
6. Use individually shielded twisted-pair cables to protect millivolt signals that are extremely susceptible to electrically induced noise. Devices such as thermocouples, strain gauges, resistance- temperature detectors (RTD), oxidation-reduction potential electrodes, and pH electrodes generate millivolt signals. Each signal has characteristics that must be taken into consideration when selecting the signal wire. Refer to the manufacturer's recommendations for the wire types to be used with a particular device.
7. Pulse count signals contain fast rise-time components that make them both noisy and susceptible to external noise. Pulse count signals should be routed in individually shielded, twisted-pair cables.
8. Discrete signals in the 5-volt or 20-milliamp range can be safely cabled with high-level analog signals. Higher-level dc signals and 120-volt ac signals, however, should be cabled separately to avoid coupling the signal noise.
9. Route motor control outputs and other high-energy device signals (typically any signals derived from relay contact closures) separately from all other lower-level signals.
10. Field wiring connects to the field termination assembly for each input unit at the screw terminals. Each screw terminal uses a captive wire clamp or collar to securely attach the wires from the external devices. Route the incoming field wires into the horizontal and vertical cable trays of a system cabinet, using lacing as required by local electrical codes or standards. Neat wiring runs, brought directly from the horizontal cable trays, simplifies any modifications and additions or changes that may be required at a later date.
11. The use of twisted-pair leads results in less looparea for inductive pickup because the inductance per foot is lower.
12. Cable used for the transmission of digital data should consist of twisted conductors.
13. Multiple conductor cables should have an overall electrostatic shield.
14. Unused conductors and shields should be terminated. If multiple conductor cables are involved, half of the unused conductors and shields should be terminated at one end and the remainder at the other end.
15. Signals transmitted through multiple conductor cables should have similar characteristics.
16. For transmission of signals that must be noise free, use cable specifically designed for that purpose. Three-conductor, twisted, shielded cable is available for three-wire signals such as potentiometer signals and dc power to amplifiers.
17. Power leads should be kept close together to maximize cancellation of conductor magnetic fields.
18. Conductors carrying alternating currents should be twisted with their returns.
19. Shields should be insulated from ground and each other along their lengths.
20. Where twisted, shielded leads must be broken, keep the unshielded length to a minimum.
21. Low level signal lines should be run unbroken from signal source to receiver.
22. Low level signal lines should not be run parallel to high-current or high-voltage wires.
23. Signal lines that are run in close proximity to switch gear may require special precautions (that is, use of localized magnetic barriers).
24. Conduit should not be buried beneath high-voltage power transmission lines or near known ground currents.
25. Solid-state switches require the same noise considerations as digital logic devices.
26. Difference signals such as those used in error correction require special attention.
27. Cable routing requires special attention. Route cables around rather than through high-noise areas. Cables carrying signals of different classifications should cross at right angles rather than run parallel for a distance before crossing.
28. Cables carrying signals of different classifications should be kept physically separated.
29. Cables carrying signals of like classification can be run adjacent to each other if twisted wiring is used to minimize crosstalk.
30. Documentation for system wiring should be complete and up-to-date to support maintenance and expansion of the system.

## Electrical Noise sources

Electrical noise can be induced on signal wiring by power lines, Radio Frequency transmissions, power-switching circuits, transformers, dc motors, arc welders, lightning, and other sources. These noise-producing sources can have an adverse effect on the signals used by both analog and digital equipment. In the case of the analog equipment, the effect is generally transitory; however, in the case of digital equipment, the noise can be interpreted as data and erroneously stored in memory, thus producing a long-term effect. The most common types of electrically-induced noise are Electromagnetic Interference (EMI) and directly-coupled noise. Electric and magnetic fields outside the signal circuits cause electromagnetic Interference. Directly-coupled noise is caused when two or more signals share a common path such as a ground return. The following paragraphs provide general methods used to avoid problems produced by these noise sources.

### Radio Frequency Interference

With Radio Frequency interference (RFI), a circuit acts as an antenna, picking up signals from nearby radio transmitters, other signal sources, and even nearby radar systems. Although the Delta V system is relatively immune to this form of interference, other external equipment and outside signal leads may be affected. Therefore, do not operate hand-held radio transceivers near the sensors, field-device transmitters, or unshielded signal wires. If a transceiver must be used and noise interference does develop, it may be necessary to shield the signal leads, the sensor, or the field transmitter.

### Inductive Coupling

Inductive coupling induces interference on signal wires chiefly from continuously changing magnetic fields. This type of interference usually occurs when signal leads are routed close to power lines or other high-current ac cabling or equipment. The best way to reduce inductive coupling between power and signal cables is to keep them physically separated.

Table 1 indicates the recommended minimum separation distances between twisted-pair signal cables and ac power lines for up to parallel runs of approximately 20 feet (6 meters). For longer parallel runs, increase the separation by 12 inches for each additional 30-foot length (33 cm for each additional 10 meters of length).

|  |
| --- |
| ***Table 1. Minimum Separation Between signal Cables and******AC Power Lines*** |
| **Voltage** | **Current** | **Minimum Distance to****Signal Cables** |
| **0 - 125** | **0 - 10** | **12 inches (30 cm)** |
| **125 - 250** | **0 - 50** | **15 inches (38 cm)** |
| **250 - 440** | **0 - 200** | **18 inches (46 cm)** |
| **Note** **These distances are applicable to twisted pair, shielded, signal cables.** |

Route signal leads to avoid the strong fields surrounding large transformers, motors, generators, electric furnaces, and other high-current devices. The absolute minimum distance between the signal wires and these devices is 5 feet (1.5 meters), with the recommended minimum separation is 10 to 15 feet (3 to 4.5 meters).

In addition to keeping the signal leads away from interference sources, route the signals through twisted-pair wires. Twisted pairs are effective in reducing noise caused by magnetic fields because the voltages induced in the two wires are approximately of equal magnitude, but of opposite polarity, and thus tend to cancel out. Twisted pairs with about eight crossovers per foot (26 crossovers per meter) are five to six times more effective in reducing noise coupling than only shielding the cable.

When power lines are known to be a source of interference, they can also be twisted to reduce their own field. When signal and power leads must cross, they should do so at 90-degree angles, and both signal and power leads should have their wires twisted on both sides of the crossover for at least the distances given in Table 2-1.

### Electrostatic Coupling

Electrostatic coupling (also known as capacitive coupling) is the main cause of noise on signal wiring. Electrostatic coupling usually occurs when long runs of signal leads are very close together. The leads act as capacitors and couple their signals to each other. The effect is especially severe when wires carrying signals of different types, high frequencies (such as used for digital communications), and high energy levels run close together.

Electrostatic coupling can be controlled. An effective way is to keep wires, which carry signals that are susceptible to this kind of coupling, shielded from each other. The wiring recommendations of this section generally indicate which types of signal wires may and may not be grouped together. The shield used can be a metal conduit, a covered tray or metal trough, or, more commonly, a shielded cable. An overlapping, multiple-folded, foil-shielded cable with a continuous drain wire in contact with the shield is the type recommended.

### Direct Coupling of Noise

There are three basic causes of direct coupling of electrical noise onto signal leads:

1. Common signal return (common mode) lines
2. Leakage and loading (or shunting-effect) currents
3. Common-impedance coupling (ground loops)

Common signal return paths carry currents from all circuits on the path. Each current causes a voltage drop that appears as an unwanted voltage on all other circuits using the path. Providing separate return paths for each signal usually eliminates this type of problem. Common-mode signals are signals that simultaneously appear at both input terminals of a device. These signals must be rejected without disturbing the wanted signal. The Delta V system accomplishes this rejection through circuit design.

Leakage currents are generally caused by poor insulation on cables and between terminals, inadequate separation of exposed signal leads, and buildup of corrosion on terminal strips or circuit wiring components. Excessive moisture compounds these problems. Clean, dry, and well-insulated cables and terminal strips avoid most current-leakage problems. Loading or shunting-effect current noises occur when a signal source is connected to a device with low input impedance, which attenuates the signal voltage because of the shunting effect of the device on the signal source. Circuit design in the Delta V system provides proper matching of source and load impedances that generally eliminates a shunting-effect noise.

Common-impedance coupling (ground loops) occurs when a wire is connected to grounds at more than one point. If the grounds are at different voltages, a current flows in the grounded wire. If the wire is part of a signal return path, any voltage drop caused by the current flow adds or subtracts from the signal on the wire. If the wire is a shield, the spurious signal in the shield may couple to the signal leads by any of the EMI effects discussed above. Ground loop problems must be eliminated through both the grounding system design and the system installation method and techniques chosen.