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## Guide to Shielding, Grounding, and Design Techniques for Motion Control Servo Systems used in Factory Automation

Multi-axis motion control servo systems contain digital and micro-processor circuitry that can be affected by Electro-Magnetic Interference (EMI). They also contain high energy switching amplifiers which can generate significant EMI at frequencies from 10MHz to 300MHz. Clearly the potential exists for this switching noise to interfere with correct operation of both the motion controller and any other electronic equipment in the vicinity. While most manufacturers, including ORMEC, are very careful to minimize susceptibility of their products to EMI, complete immunity is not possible. Some responsibility for avoiding EMI problems will inevitably fall to the control system integrator. This guide describes panel layout, wiring, grounding, and shielding techniques that we have found effective in designing and building motion control systems. As in all engineering designs, compromise between the perfect design and what is practical is unavoidable. You may not be able to employ all the suggestions we make. However, careful attention to EMI reduction will minimize startup costs and future operating problems in any system. If you are interested in a more complete understanding of EMI design considerations and techniques, the [bibliography](#) at the end of this guide will direct you to authoritative texts on the subject.

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### Design Goals and Techniques

One of the primary design goals is to keep all signal common return points at the same potential. With the high frequency (up to 300MHz) harmonics generated by switching amplifiers, this is not always easy. At these frequencies, the typical 12 gauge ground wire looks more like a series of inductors and capacitors instead of a low resistance path to ground. Use of silver tinned flat braid and the steel sub-panel itself provide a much better return path than conventional wire. A second, equally important, goal is to minimize the magnetic coupling between circuits. This is generally achieved by minimum separations and wire routing. Radio Frequency coupling is a problem primarily tackled with appropriate shielding and grounding techniques. Protection from and elimination of transient spikes, is achieved with power line filters and appropriate suppressors on relay coils and other inductive loads.

### Organization of Guide

The topics in this guide are grouped into related system components and circuitry. Each group requires the designer to employ grounding and shielding techniques appropriate to the type of energy it emits and the type of emissions to which it might be susceptible. This guide includes techniques for the follow topics:

- [Motor Cable Installation](#)
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- [Encoder/Resolver Cables](#)
- [DC Power Wiring](#)
- [DC I/O Wiring](#)
- [AC Power Wiring](#)
- [AC I/O Wiring](#)
- [Communications Cables](#)
- [General Placement, Mounting, and Routing Practices](#)
- [Cabinet to Machine Grounding](#)

## Motor Cable Installation

Both the shield drain wire and the safety ground wire should be terminated at the servo drive ground terminal located next to the motor power terminals.

The unshielded pigtails at the servo drive end of the motor cable, and the shield drain wire should be less than 8 inches (200 mm) long.

Motor cables should be routed in a separate wire-way or secured with tie-downs to ensure proper placement.

If at all possible, do not add terminal blocks between the servo drive and the motor. Doing this will reduce the effectiveness of the high energy noise path back to the servo drive and should be avoided

## Encoder/Resolver Cables

Try to keep a minimum of 12 inches (300 mm) separation between encoder or resolver feedback cables and the motor cables or any AC power cables. This is usually more critical with resolver cables than encoder cables due to the analog nature of the signals. We highly recommend placing resolver and encoder feedback cables in separate conduit or wire-ways.

The voltage drop in encoder cables longer than 150 feet (50 meters) reduces the voltage at the encoder below the minimum value. If you must use cables longer than 150 feet (50 meters) you will need to provide a 5VDC power supply located close to the motor/encoder to power the encoder.

If encoder or resolver cables must cross motor or AC power cables, try to arrange for them to cross at right angles to each other.

If at all possible do not add terminal blocks between the encoder/resolver and the servo drive or controller. Doing this reduces the effectiveness of the high energy noise path back to the servo drive or controller and should be avoided.

## DC Power Supply Wiring

All power supply returns (reference common) should be tied to the panel using low impedance ground straps. Silver tinned flat copper braid at least 0.25 inches (6 mm) wide is ideal for this purpose. Use of braid rather than conventional wire is more important on switching power supplies than linear supplies. Such grounding straps should be less than 4 inches (100 mm) long. The ground strap should be used in addition to any safety ground wires required by applicable electrical codes.

In systems with more than one controller tied to a PLC, each controller should have its own 24V DC power supply for DC I/O circuits.

On low voltage DC power supplies used to power semiconductor logic boards containing analog or digital circuits, keep the lead wires lengths to a minimum, preferably 8 inches (200mm) or less.

Where feasible use more than one power supply rather than sharing one power supply between circuits that are far apart.

High voltage DC power supplies used for some servo drives should be placed close to the servo drive according to the directions in the installation manual.

If the servo drive has an external regeneration resistor, the regen wiring should be treated the same as the motor cables. It should have a low impedance braided shield which should be terminated to the panel at the drive end only.

## DC Input and Output Wiring

Any connection to an inductive load, including DC electromagnetic relay coils, should be terminated with a high speed flyback-diode to absorb the high energy spikes caused when the load or coil is switched off and its magnetic field collapses. Such diodes should be connected across the coil with the reverse polarity to the voltage that powers the coil. The amount of energy which needs to be absorbed can be considerable and it is important the diode be rated accordingly.

Solid state inputs driven from solid state outputs should have a bleeder resistor across the input to provide a path for the output's

leakage current when the output is off. This will help prevent false tripping on the input when the output is off. The size of the resistor depends on the output device's leakage current and the input device's OFF voltage. ORMEC Customer Support Engineering Tech Note #11 and the ORION Model 30/50/70 Manual provide very detailed information on the selection, configuration and wiring of sensors for use with the high speed sensor inputs on the DSP axis cards. Contact ORMEC and ask for a copies of these if you are planning to use high speed sensor inputs.

## AC Input and Output Wiring

AC circuits used for relays (solid state or electromechanical), should be powered from a separate control transformer. This is especially true if the associated wiring runs outside of the control cabinet.

Any inductive loads, including all electromagnetic relay coils, should have a "snubber" (typically a 4.7k ohm resistor in series with a 0.1 uF capacitor) wired across the load or coil. These devices absorb the high energy returned to the wiring caused when the load or coil is turned off and its magnetic field collapses. The amount of energy which needs to be absorbed can be considerable and it is important the devices be rated accordingly.

Metal Oxide Varistors (MOVs) are often used in place of R-C "snubbers" however MOVs are designed primarily as safety devices to protect equipment from damage due to transients and are less effective than "snubbers" for noise suppression. Also MOVs tend to degrade with time.

## AC Power Wiring

Incoming power brought onto the panel can bring many "dirty" components along with it. This is especially true in facilities that have a large number of SCR controlled devices such as variable speed drives and heating furnaces. Line filters (three phase or single phase as appropriate) should be placed in the incoming power lines immediately after the safety circuits and before any critical control units. ORMEC's controllers do have built-in line filters and transient suppressors to protect them from line induced noise and transients. However, these internal devices cannot prevent such noise from affecting other parts of the system such as high speed sensor inputs and the analog circuits.

Mount filters as close to the incoming power feed as is practical.

High voltage wiring should be as short and direct as possible

Avoid having clean wiring from filtered sources run parallel with dirty unfiltered wiring. If clean and dirty wiring must cross, keep the two sets of wires at right angles to each other.

Constant voltage transformers can be installed if the AC power tends to drop below the specified minimum voltages needed to keep the controllers from resetting.

Where loss of power is critical or an orderly shutdown in the event of a loss of power is required, consider using an uninterruptable power supply (UPS).

Some industrial equipment can "punch holes" in the line causing missed cycles lasting hundreds of milliseconds. Problems caused by this can only be resolved by an active line conditioner such as a UPS or a separate clean feed.

Ground the neutral of any transformer secondary to the panel with a low impedance ground strap made from silver tinned flat copper braid of appropriate width based on the current and voltage in the circuit. The ground strap should be used in addition to any safety ground wires required by applicable electrical codes.

Twisting hot and neutral wires together will help minimize any EMI effects that may be present.

## Communications Cables

Cables used for communications are designed to transmit and receive high frequency signals. When placed in the same electrical enclosure with high energy noise sources such as servo drives, any noise coupled to the communications cabling can be similar in frequency to the actual communications signals. It is important to use cable, termination devices, splitters, etc. that conform exactly to the detailed recommendations contained in the applicable communications standard. Inexpensive hardware store or consumer electronics store substitutes can result in problems. Most communications standards define recommended network

topography, minimum drop lengths and terminator locations. These recommendations should be followed exactly. Communication cables should be placed in the low voltage DC wire-ways. Keep communication separated from AC power and motor cables. If they must cross such wiring, keep them at right angles to each other.

## General Placement, Mounting and Routing Practices

How the parts are placed on the panel and on the enclosure door can play an important role in reducing or worsening the effects of high energy interference. It is good practice to group parts into families of similar components then place these groups according to a pattern of power flow and/or conversion in an effort to minimize wire lengths while maximizing separation.

Avoid running wires from different circuit types (AC/DC, High voltage/Low voltage, Digital/Analog) parallel to each other without at least 12 inches (300 mm) of separation.

When wires from different circuit types must cross, keep the two sets of wires at right angles to each other.

Provide separate wire-ways for high power AC, low power AC, high power DC and low power DC.

When placing components on a cabinet door, make sure that closing the door does not bring the component close to a part of the panel that will cause problems. For example, placing a video terminal too close to a transformer or servo drive.

When mounting any unit, be sure to scrape away any paint on both the unit and the mounting surface to obtain a bare metal-to-metal contact. Use of external toothed washers will improve the connection. If in doubt, use a ground strap made of silver tinned flat copper braid to ensure a good connection between the chassis and the mounting surface.

Use ground straps made from 1 inch (25 mm) silver tinned flat copper braid to connect the cabinet door(s) to the enclosure, the first sub-panel to the enclosure, and from each sub-panel to the next.

Where electrical codes call for the typical green safety ground wires, use them *in addition* to any ground strap suggested in this guide.

## Cabinet to Machine Grounding

Do not rely on the ground wires included in the motor cables to provide cabinet to machine grounding. Make sure that the cabinet and machine grounds are always at the same potential.

Provide a ground connection between all major machine sections and the cabinet using #6 or larger ground wire.

Welding cable is ideal for this purpose since a cable made up of many very small cross section conductors is much more effective at high frequencies than conventional wire.

## Brief Bibliography

Morrison, Ralph. *Grounding and Shielding Techniques in Instrumentation*, 2nd ed., (Wiley-Interscience 1977).

Ott, Henry W. *Noise Reduction Technique in Electronic Systems*. 2nd ed., (New York: John Wiley & Sons, 1976).

## For more information

Contact the motion control experts at ORMEC for further information. Please call us at (585) 385-3520 or email [sales@ormec.com](mailto:sales@ormec.com)  
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