

Servo Drive Installation Best Practices

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Introduction

Use this publication as a quick reference guide of installation best practices for Rockwell Automation® single-axis and multi-axis servo drive systems. These practices also apply to most variable frequency (VFD) drives, adjustable speed (ASD) drives, and other control components with solid state power supplies (SSPS). Use these best practice examples to help reduce the number of potential noise or electromagnetic interference (EMI) sources in your system and make sure that the noise sensitive components are not affected by the remaining noise.

EMI mitigation or management is a process that involves reducing and managing the cause and magnitude of EMI, and then combining these reduced levels with proper routing of generating and receiving conductors and components.

While reading this reference guide, keep in mind the following key points that tend to be misunderstood:

- EMI is present in all control systems and can affect expected signal integrity, which can in turn cause circuits to energize or de-energize inputs and loads, stopping production, and causing equipment failure.
- The frequency range of primary concern is 100 kHz to 10 MHz, which in this document is referred to as high frequency or HF.
- The physics property skin-depth or skin-effect refers to the outer circumferential depth of a conductor (from OD towards center) through which AC current can flow. As the frequency increases, the skin depth decreases. In addition, as the diameter of the conductor decreases or the conductor length increases, the reflected impedance increases. Consequently, it is important to avoid the use of long or high gauge (small diameter) conductors for HF bonding purposes.
- Typical control wiring or conductors (green insulated ground wires) reflect much higher impedance (resistance) at HF than is typically expected, due to inductive reactance. The frequency effect is often forgotten and the digital multi-meter resistance measurement of 0.1 or 1 ohm is based on the power frequency (50 and 60 Hz) and not at the HF range (100 kHz to 10 MHz).
- Bonding conductors or components are not the same as ground conductors or wires. The bond conductor's purpose is to create an equipotential level at HF for a control system and the ground conductor's purpose is to route unexpected, dangerous currents/voltages present on the equipment chassis to earth ground. Due to the points mentioned above, ground conductors provide a lower resistance to ground than body parts, however, they do not typically make good low impedance paths to the equipotential plane at HF. Failure to create low impedance paths from component to component can result in an offset or potential difference and voltage.

This document is not intended to replace any existing documentation including, but not limited to, product user manuals, installation instructions, and the System Design for Control of Electrical Noise Reference Manual, publication [GMC-RM001](#).

Installation Checklist

Section	Technique	√
Panel Material	Whenever possible, use galvanized or plated panels. For painted panels, remove paint from mating surfaces	
Establishing Noise Zones	Noise zones established, clean/dirty components and cables segregated	
High Frequency Bonding	Panels, ground buses, control components, and machine structure properly bonded	
Grounding the Drive	Drive chassis and power rail (if applicable) properly grounded	
Installing 24V Power Supplies	24V power supply properly grounded and decoupled at clean loads	
Installing EMC Line Filters	EMC line filter installed as close to drive as possible	
Installing Enclosure Lighting	Fluorescent lamps properly installed so as to suppress EMI	
Installing Cables	Cables shielded where appropriate with 360° termination methods employed and grounded at both ends, cable lengths minimized, and wire loops avoided	
Suppressing Contact Switched Loads	Contact switched loads suppressed	
Isolation Transformers	Isolation transformer used in place of EMC line filter ⁽¹⁾	

(1) Use this technique only if designing to reduce leakage current, rather than to minimize noise. EMC line filter is required to meet CE approval.

Planning the Installation

When planning your servo drive panel installation, consider the panel material and how you plan to lay out the system components.

Panel Material

High-frequency (HF) bonding of the servo drive system components with the panel they are mounted on is essential to minimizing electrical noise:

- Conductive-plated steel panels are strongly recommended due to the inherent ability of the material to resist corrosion and to bond with the drive chassis, bonding components (for example, shield clamps), programmable logic controllers, and solid state power supplies (SSPS). In addition, a steel cabinet provides good magnetic shielding properties and provides equipotential bond (ground) points anywhere on the panel. This eliminates the need for long, high-impedance conductors routing to some distant ground terminal. A plated cabinet frame is also highly desirable because it makes HF bonding between panel and cabinet sections more reliable.
- Painted metal panels must have the mating surfaces scoured free of paint and roughed at each mounting point of every piece of metal-clad equipment and the exposed surfaces protected against corrosion with conductive paint or petroleum jelly.

The disadvantage with painted panels, apart from the labor cost to remove paint and re-coat the areas with a conductive coating, is the difficulty of making quality control checks to verify that paint was properly removed. Without a conductive re-coating, future corrosion of the unprotected mild steel will compromise the already reduced bonding performance.

- Anodized aluminum panels must have the mating surfaces cleaned of anodizing and the exposed surfaces protected against corrosion. This type of back panel material should also be avoided when mounting solid state components, because aluminum does not provide magnetic shielding benefits.
- Stainless steel panels are acceptable, but are inferior to conductive-plated mild steel due to their higher resistance. Most versions or families of stainless steel have poor magnetic properties, thus eliminating some of the shielding benefits that sheet steel offers.

In summary, do not consider painted steel, aluminum, anodized aluminum, and stainless steel panels and enclosures. If these materials are used, additional steps should be taken to minimize EMI.

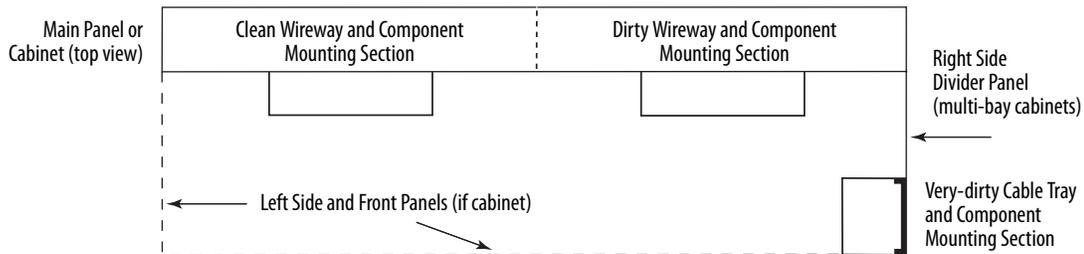
Establishing Noise Zones

You can greatly reduce noise by segregating components and wiring in zones according to their EMI levels and noise susceptibility. A good practice to consider is the application of colored wireways to provide the installer with a constant reminder of where the different classes of conductors can be routed safely. Refer to Component and Wiring Noise Zone Classifications on [page 30](#).

Segregating Components

This figure shows how you can create three zones in a standard panel or cabinet enclosure. The very-dirty items are placed in the right/front section. The dirty items are placed behind them in the right/rear section and the least noisy (clean) items are placed in the left/rear section.

Figure 1 - Relative Position of Noise Zones on the Panel



A side panel is fitted on the right to support the power cable shield clamps and any very-dirty wires, cables, or components. This leaves the main panel free for the clean and dirty zones.

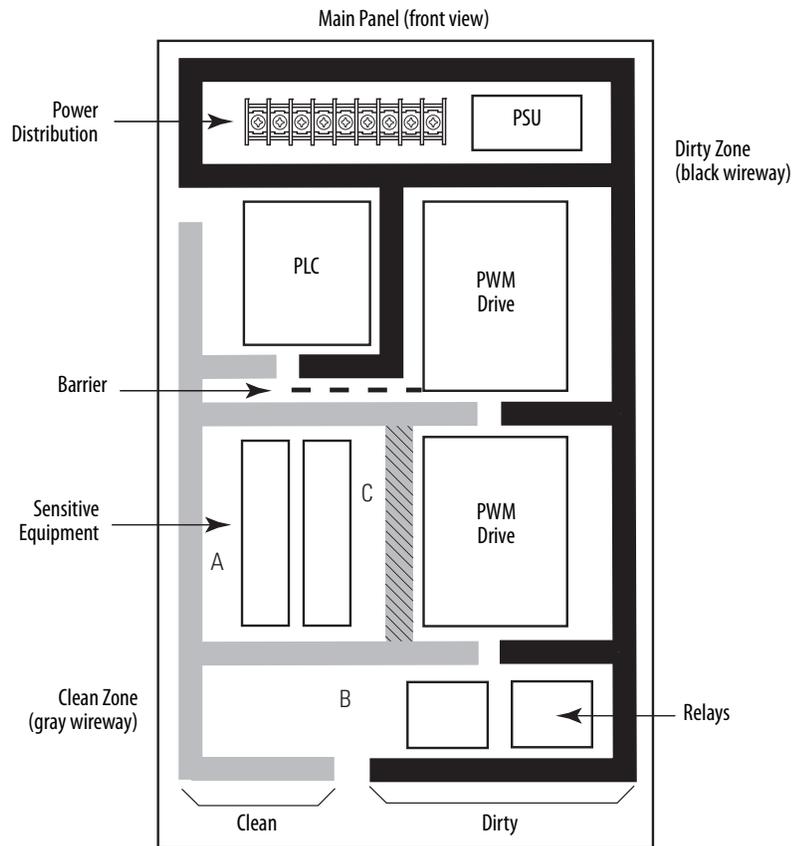
TIP It is preferable to mount the PLC and motion control equipment in a separate cabinet away from the power control equipment (motor starters for example).

Additional isolation can be obtained by employing a simple slotted or perforated sheet metal barrier between wire ducts. Maintain good contact with the plated back panel surface to make sure the 'L' barrier has equipotential with the back panel. Be careful to keep slots and holes to a minimum to avoid radiating EMI through the material voids based on frequency and wave length.

Routing Cables

These figures provide examples of how to route clean, dirty, and very-dirty wireways or cable trays within a panel. Refer to Component and Wiring Noise Zone Classifications on [page 30](#).

Figure 2 - Routing Clean and Dirty Cables

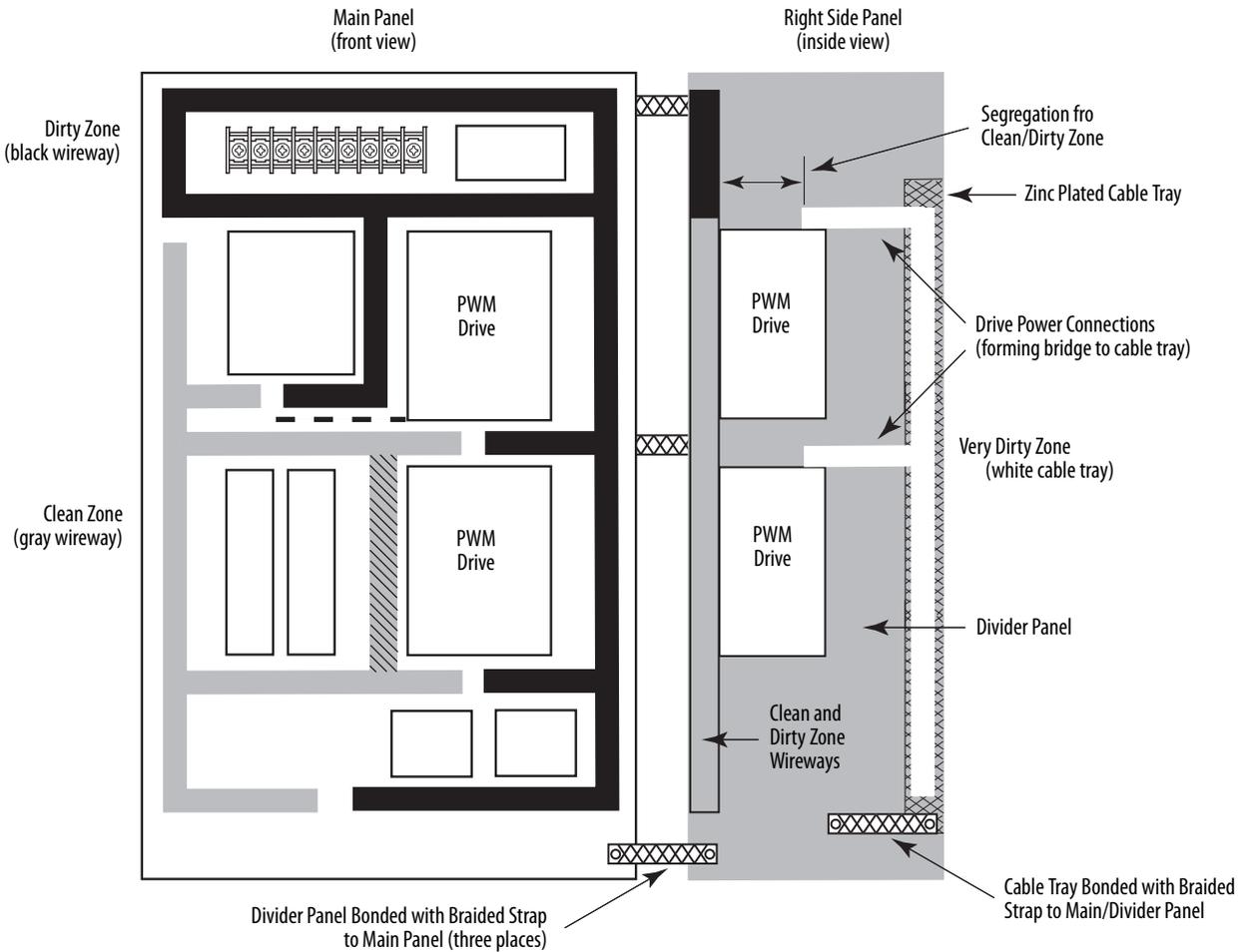


Observe these guidelines when planning your panel layout for clean and dirty cables:

- The plated steel barrier between clean and dirty wireways allows them to run close together.
- If dirty power is required at A, then run it via wireway B using shielded cable.
- The vertical wireway at C is not good practice as it encourages the creation of loops (refer to Minimizing Loops on [page 23](#)).
- The use of different colored wireways (for example, gray for clean and black for dirty) encourages good segregation.

When strict segregation is not practical, make sure that the cables cross at right angles to minimize noise transfer.

Figure 3 - Routing Very Dirty Cables



Observe these guidelines when planning your panel layout for very-dirty cables:

- Power cables bridge across to the drive terminals from the cable tray on the right.
- The cable tray is bonded to the divider panel with braided strap. If no divider panel is used, then bond the cable tray to the main panel.
- A divider panel is used on the right to segregate very-dirty wiring from the clean zone of the next panel to the right.
- The divider panel is bonded with braided straps to the main panel at top, center, and bottom.
- Use 25.4 mm (1.0 in.) wide braided strap for bonding (preferred method). Braided strap 12.7 mm (0.5 in.) wide is acceptable.

You can convert wiring designated dirty or very-dirty to the next lower category by using either shielded cable or conduit where required. These figures show how this technique can be used to mix categories without breaking the segregation rules.

Figure 4 - Very Dirty Cable in Clean Zone

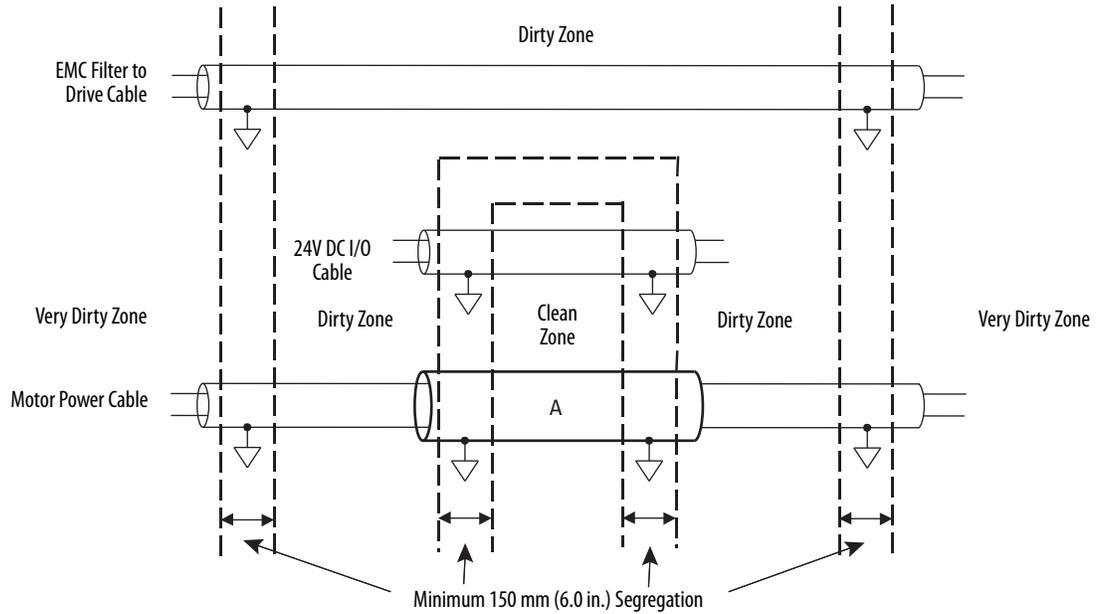
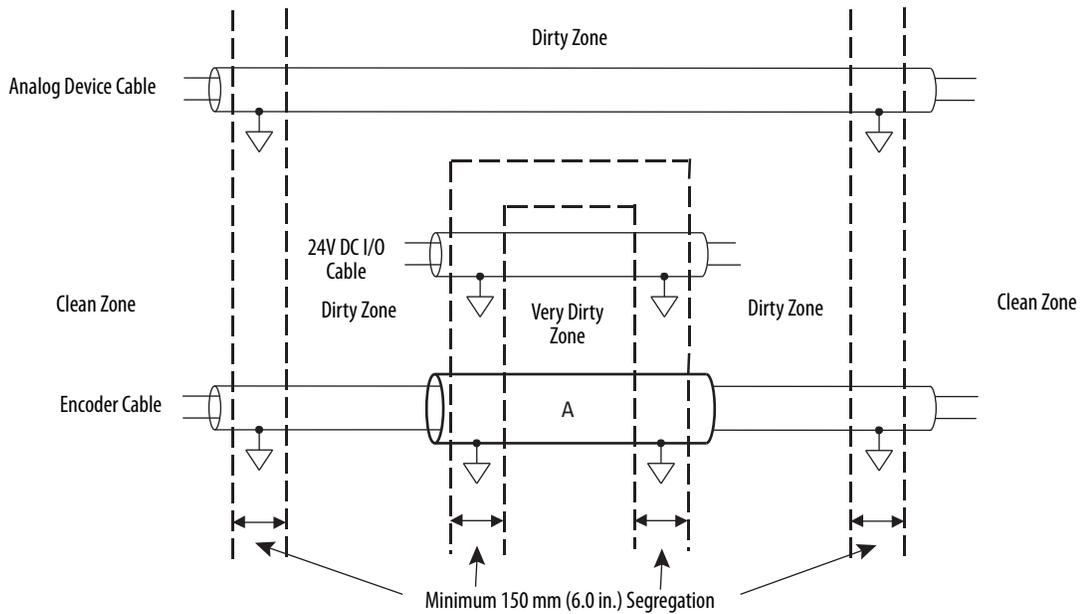


Figure 5 - Clean Cable in Very Dirty Zone



The cable is locally shielded to cross another zone. Each shield is grounded at each boundary and the cable is run close to the panel. The outer shield A is thick-walled steel conduit.

During the Installation

During the installation of your servo drive and motor/actuator system, make sure you observe these noise-reducing techniques for high-frequency bonding, installing system components, installing cables, and suppressing contact switched loads.

High Frequency Bonding

The purpose of high-frequency bonding is to present a defined low-impedance path for HF noise currents returning to their source.

When using a painted panel, mating surfaces must be scoured free of paint at each mounting point of every piece of metal-clad equipment. Exposed surfaces must be protected against corrosion with conductive paint or petroleum jelly. The following figure illustrates the recommended bonding practices for painted panels.

Figure 6 - Recommended Bonding Practices for Painted Panels

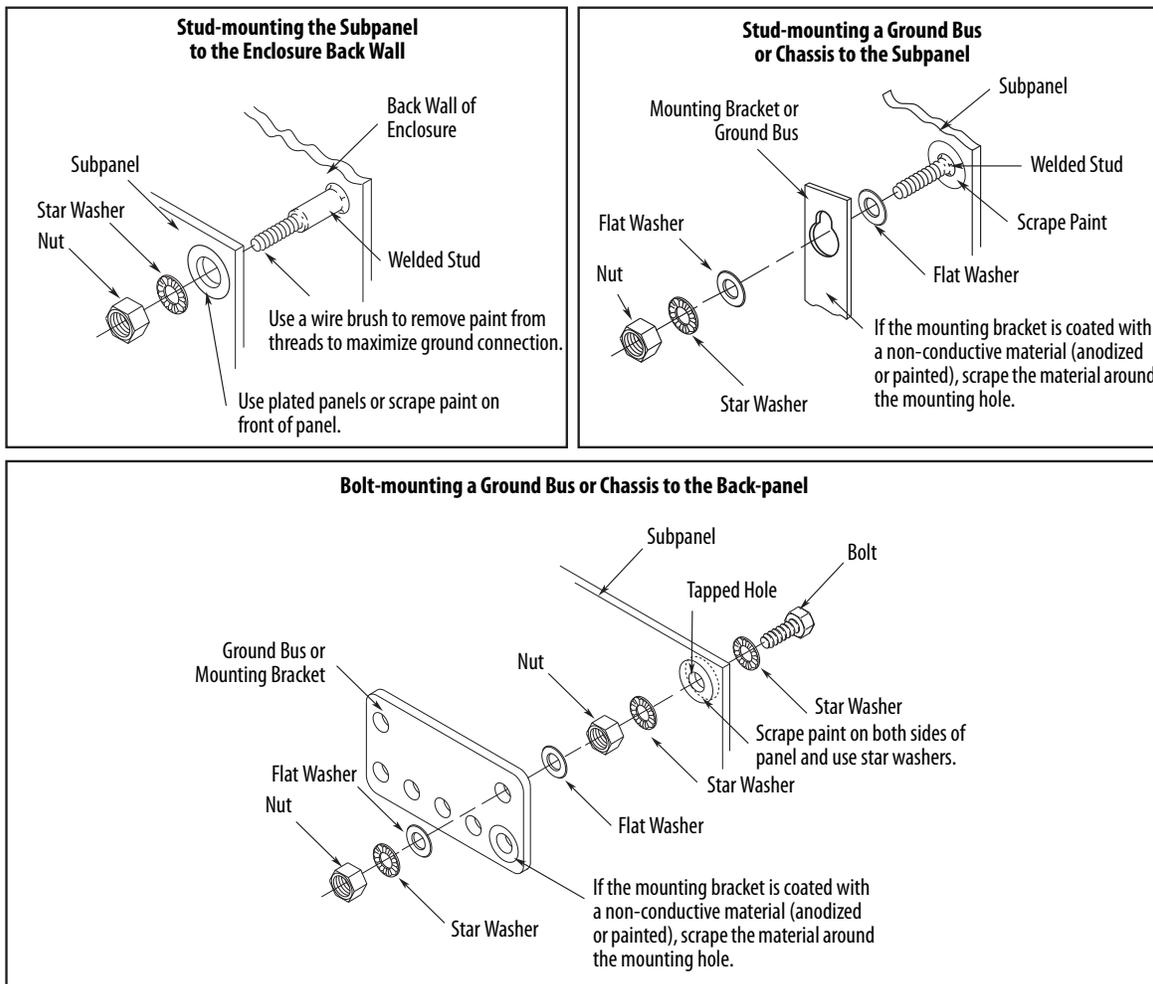
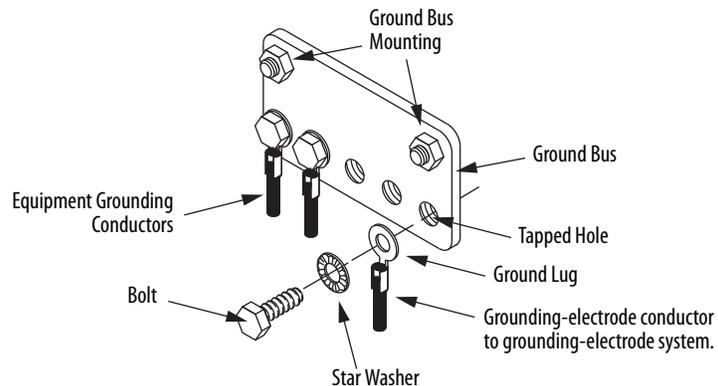


Figure 7 - Ground Bus Example

Bonding multiple subpanels creates a common low impedance exit path for the high frequency energy inside the cabinet. Subpanels that are not bonded together may not share a common low impedance path. This difference in impedance may affect networks and other devices that span multiple panels.

Observe these guidelines when bonding multiple subpanels:

- Bond the top, middle and bottom of each subpanel to the cabinet by using 25.4 mm (1.0 in.) by 6.35 mm (0.25 in.) wire braid. As a rule, the wider and shorter the braid is, the better the bond. Panel bonding is illustrated in the following figure.
- As an alternative, mount a filler plate between the panels using multiple fasteners along the edges of the plate.
- Scrape the paint or anodizing from around each fastener to maximize metal-to-metal contact.
- Though not always applicable, a plated cabinet frame is desirable since it makes a high frequency bond between the panel and cabinet sections more reliable.
- For doors 2 m (78 in.) in height, ground the door to the cabinet with two or three braided straps.

Figure 8 - Panel Ground Plane Extended to Adjacent Panels

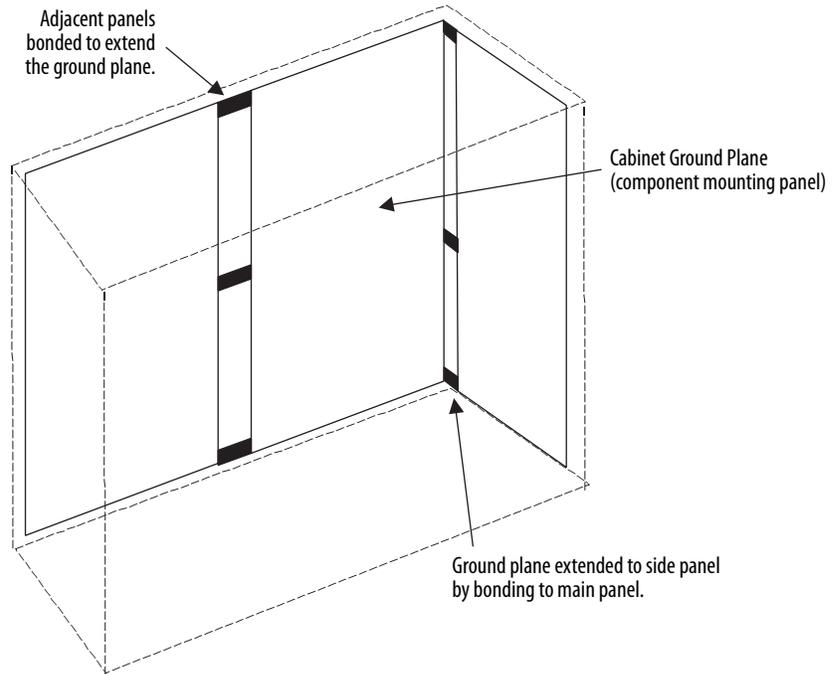
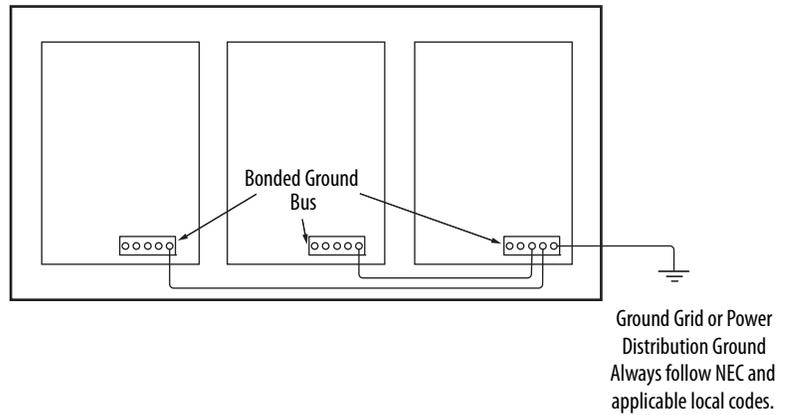


Figure 9 - Bonded Ground Buses Connecting Multiple Subpanels



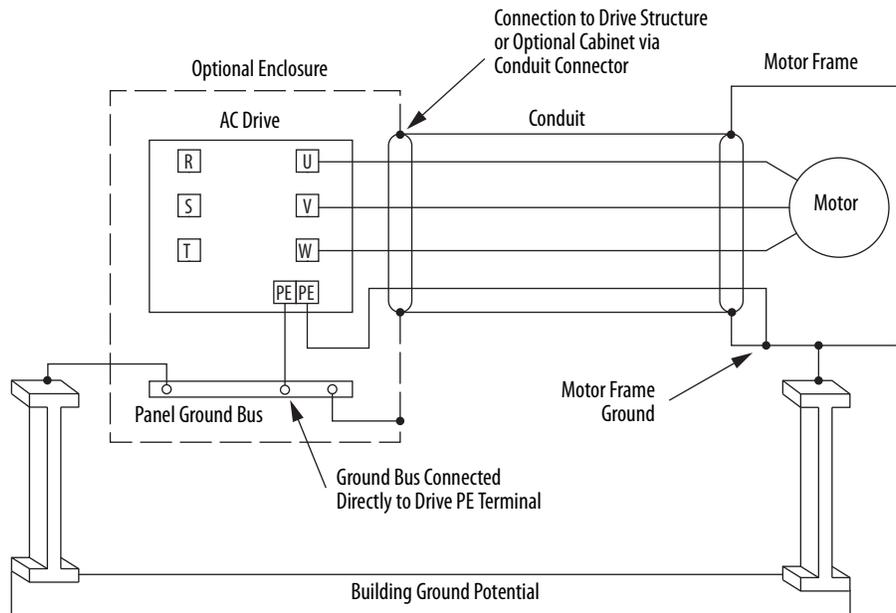
Installing System Components

In addition to making good connections through each bolt or stud, use either copper braid, 25.4 mm (1.0 in.) wide or 8 AWG minimum stranded copper wire, to connect each chassis, enclosure, and central ground bus mounted on the back-panel.

Drive/Motor Installations

Make sure that drive grounding is properly connected as illustrated below. The ground wire return between the motor and the drive must be terminated directly to the drive PE terminal. Shielded cable is recommended, but not always needed. Refer to the product-specific documentation for requirements.

Figure 10 - Grounding the Drive and Motor/Actuator

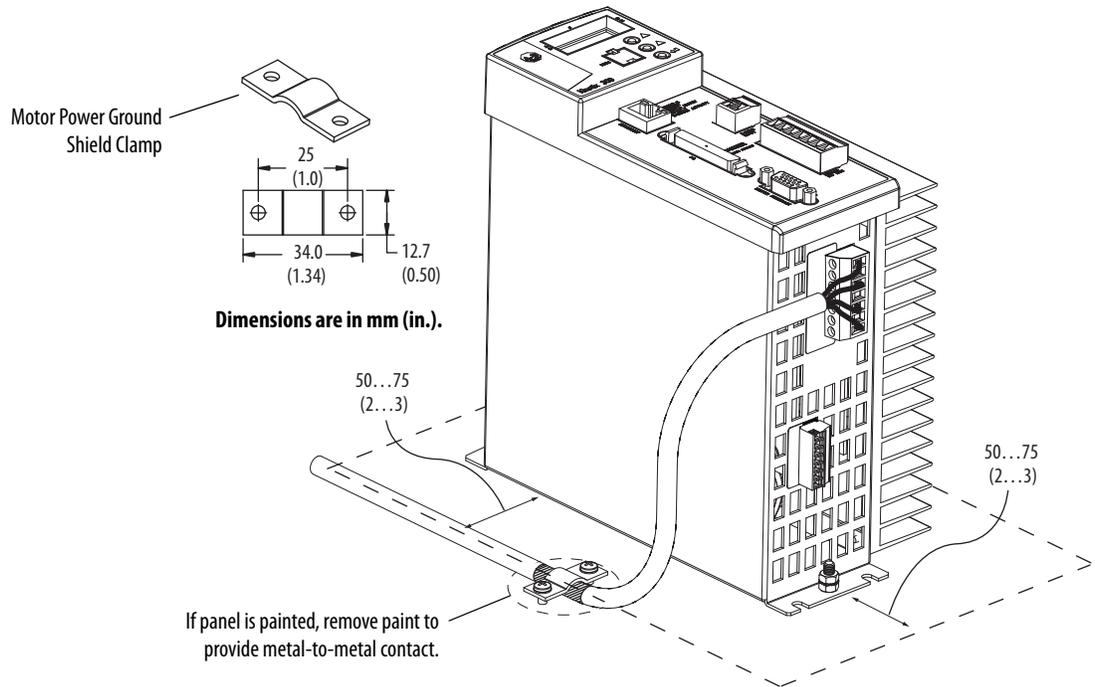


Making an adjustment to the servo drive to bleed off static charges when ungrounded or high-impedance grounded power configurations exist can improve system performance. This usually involves a jumper setting or similar action, depending on the drive family. Refer to your servo drive user manual for drive-specific information.

Kinetix 300/350 Drive Installations

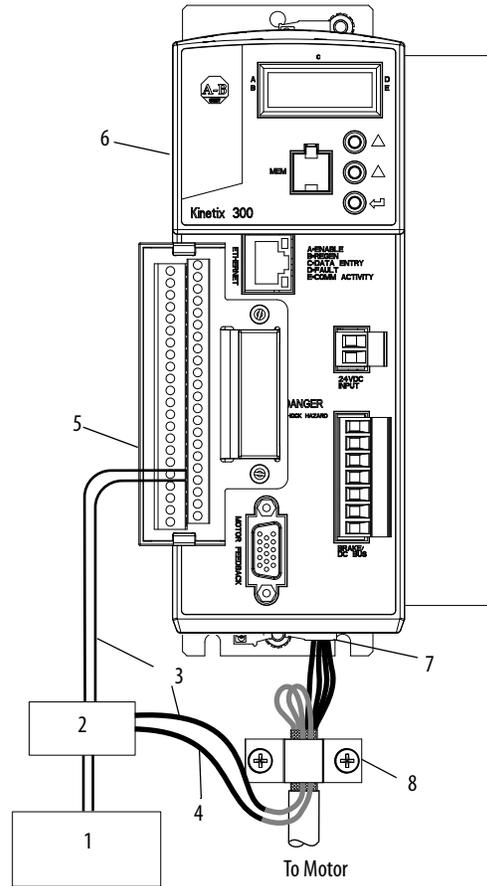
This figure shows an example of three-phase power wires for motors/actuators that do not require brake wires. Thermal switch wires are included in the feedback cable.

Figure 11 - Motor Power Terminations (three-phase wires only)



This figure shows an example of wiring with three-phase power and brake wires. The brake wires have a shield braid (shown as gray) that folds back under the cable clamp before the conductors are attached to the motor brake circuit. Thermal switch wires are included in the feedback cable.

Figure 12 - Motor Power Terminations (three-phase and brake wires)



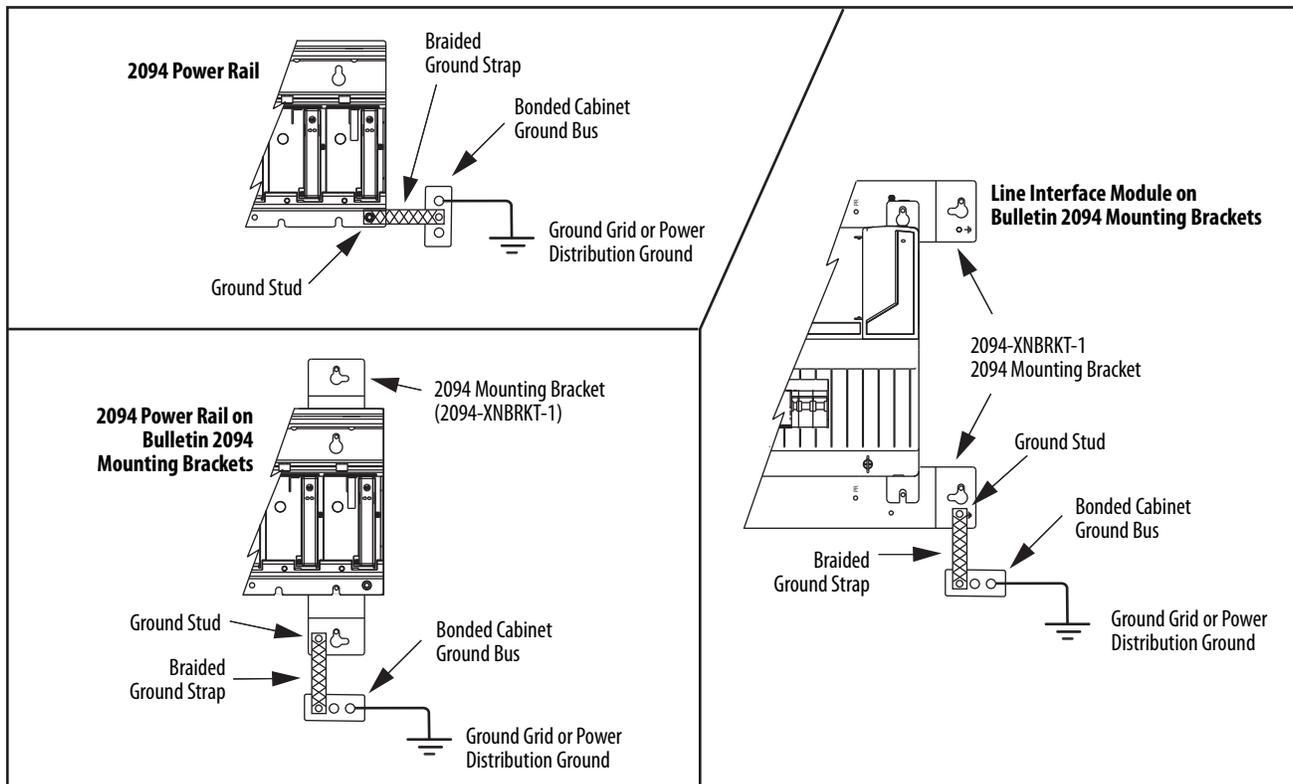
Item	Description
1	24V power supply
2	Relay and diode assembly
3	Minimize unshielded wires in brake circuit
4	MP-Series™ cable brake wires

Item	Description
5	I/O (IOD) connector
6	2097-V3xPRx-xx Kinetix® 300/350 drive
7	Motor power (MP) connector
8	Cable clamp

Kinetix 6000 and Kinetix 6200/6500 Drive Installations

- Attach the braided grounding strap from the grounding stud on the power rail to the bonded cabinet ground.
- When installing mounting brackets with either the Kinetix 6000 power rail (or the LIM module), attach the braided grounding strap as illustrated in the figure below.

Figure 13 - Power Rail Grounding



24V Power Supply Installations

Power supplies are inherently associated with two EMI related issues:

- The use of a common power supply (one power supply for all load types) allows galvanic (conductive) coupling via the conductors.
- If solid state power supplies (SSPS) are used, they can generate EMI on the input and output of the SSPS.

To avoid noise related problems caused by 24V DC power supplies, observe these guidelines:

- Unless a floating supply is required, bond the common output terminal to a ground terminal near the SSPS. Avoid the use of long conductor lengths, > 150mm (5.9 in.) for this bond. This bond provides an equipotential bond at high frequencies for all loads and normal machine wire appears as high impedance at high frequencies. The longer the conductor, the higher the impedance.
- Use a ground terminal installed on the DIN rail fastened to a zinc-plated panel to make the ground connection. The use of clip-on or snap-on grounding terminals should be avoided. Instead, use clamp-on style grounding terminals for a mechanical connection and additional bonding area.
- When a common supply is part of the system design, provide some isolation, where needed, using low-pass DC filters. Refer to Chapter 5 of the System Design for Control of Electrical Noise Reference Manual, publication [GMC-RM001](#), for more information.

An option for suppressing the related noise is to decouple the +24V DC line to the same ground terminal with a 1 μ F, 50V ceramic capacitor to achieve the clean category.

Single-phase Power Supply Installations

To avoid noise related problems caused by single-phase power supplies, observe these guidelines:

- Treat single phase wiring as dirty.
- Include line filters for loads that create noise, such as PWM devices with DC switch-mode power supplies and fluorescent cabinet lights.
- Include line filters for potentially sensitive loads, such as PLC logic power.
- Mount the line filter as close to the load as possible.

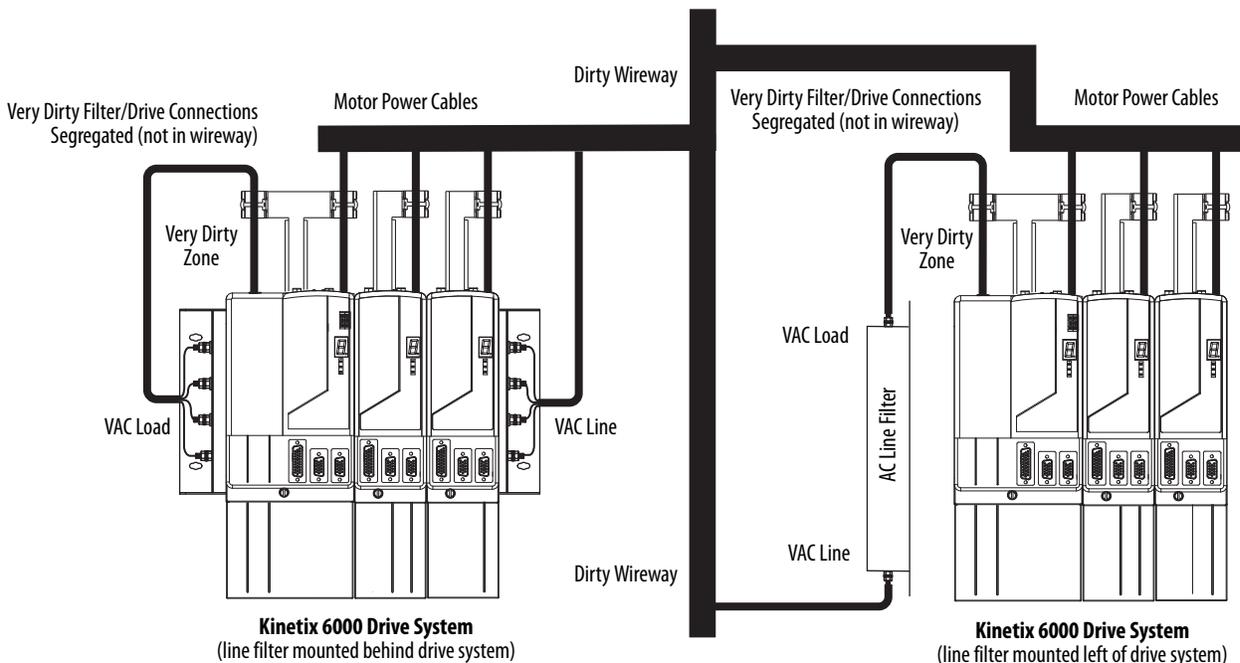
EMC Line Filter Installations

To meet CE requirements, include line filters for loads that create noise, such as drives and other PWM loads with three-phase power supplies.

Observe these guidelines when installing line filters:

- Install the line filter as close to each drive as possible, preferably next to the drive input connector. Position the filter output terminals as close to the drive input terminals as possible (refer to [Figure 14](#) for example).
- Install the filter and drive on the same panel to provide the same equipotential surface to each. The filter chassis has internal high-frequency capacitors that conduct the stray current (which originated in the attached drive) back to the output phase conductors and into the originating drive. This means that the stray currents return back to the source. Therefore, it is important to have the filter chassis at the same potential as the drive, ground terminals, DIN rail terminals, and cable shield clamps.
- Treat wiring between filter and drive as very-dirty (provide shielding as required).
- Segregate input and output wiring as far as possible. Do not route the two sets of conductors parallel to each other in the same wire duct. This allows cross coupling of the dirty (filter output) to the clean (filter input) conductors, thus defeating the purpose of the filter.

Figure 14 - Positioning Line Filter and Servo Drive

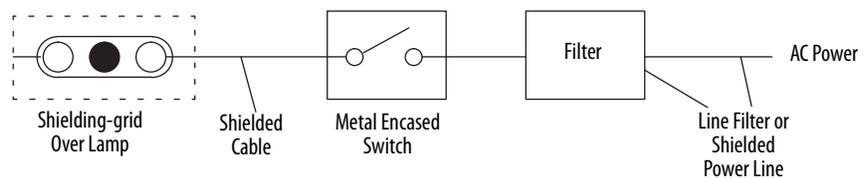


Enclosure Lighting Installations

If you must use fluorescent lamps inside of an enclosure, observe these guidelines, as shown in the figure:

- Install a shielding grid over the lamp.
- Use shielded cable between the lamp and its switch.
- Use a metal-encased switch.
- Install a filter between the switch and the power line, or shield the power line cable.

Figure 15 - Fluorescent Lamps Wired Inside an Enclosure



Installing Cables

Consider these cable shield clamping methods and guidelines for cable length, excess cable, ferrite sleeves, and ferrite beads.

Clamping at the Circular Section

For a modern control system, comprised of a considerable amount of high-frequency currents, the only acceptable method for terminating most cable shields is with a circular or 360° clamping method. This clamping method provides a balanced contact and conductivity for current flow around the circumference of the shield. In addition, a typical circular conductor exhibits higher than expected impedance at high frequencies. Clamping at the circular section or 360° bonding, as illustrated, is the preferred method for grounding cable shields. All of the clamping methods shown are acceptable.

[Table 1](#) through [Table 4](#) provide advantages and disadvantages for each method illustrated beginning on [page 19](#).

Figure 16 - Cable Clamping Methods

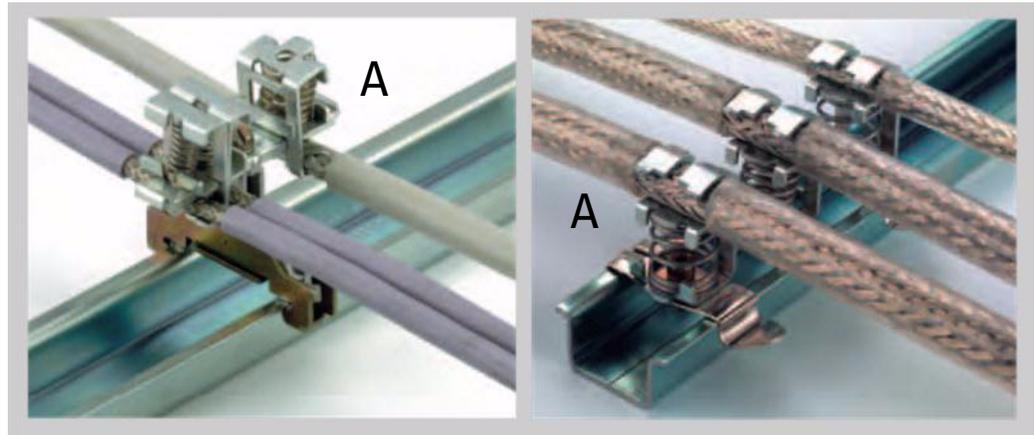


Table 1 - Spring Clamp (method A)

Advantages	Disadvantages
Very effective method	Cost
Easy to install - snap or screw clamp onto DIN rail and insert cable section	
Plated material - conductivity and oxidation benefits from dissimilar metals	Limited strain relief capabilities
Sized to accommodate wide range of cable diameters	
Provides good 360° bonding to exposed braided shield area	

Figure 17 - Cable Clamping Methods (continued)

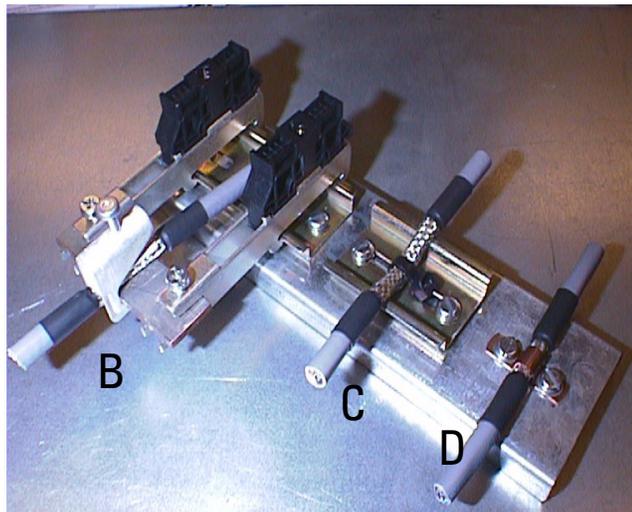


Table 2 - Heavy Duty Commercial Cable Clamp (method B)

Advantages	Disadvantages
Very effective method	Cost
Each size covers a wide range of diameters	Limited strain relief
No additional drilling or tapping required	Poor availability in some areas

Strapping your cable to a DIN rail (the cable labeled C) is crude, but effective. The DIN rail is raised off the panel slightly by using conductive washers to allow metal cable ties to pass underneath.

If spacing is desired, care should be taken to use large outer-diameter plated washers for the gap to maximize contact area. Metal ties should be thin enough to avoid the spacing washers. The use of non-conductive ties will not provide adequate, balanced conductivity around the circumference of the cable shield.

Table 3 - Strapping to DIN Rail (method C)

Advantages	Disadvantages
Very effective method	Appearance
Each size covers a wide range of diameters	
Moderate strain relief	
Low cost	

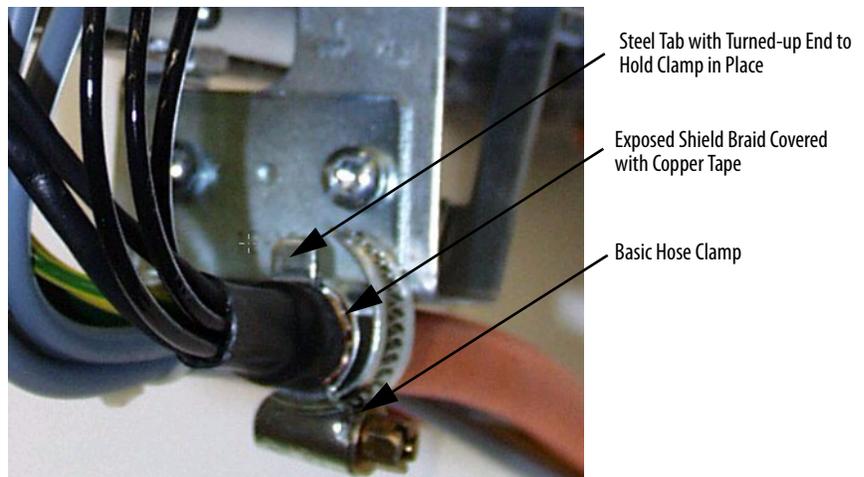
Plain copper saddle clamps (the cable labeled D) are sold for plumbing purposes, but are very effective and available in a range of sizes.

Table 4 - Saddle Clamp (method D)

Advantages	Disadvantages
Very effective method	Requires two drilled and tapped holes per cable
Available in a wide range of sizes	
Excellent strain relief	Each size will accommodate a limited range of diameters
Low cost	

Additionally, you can install and mount flat copper or galvanized plated tabs to the plated back panel. Use these tabs with metal cable ties or small hose clamps to form a simple 360° cable shield termination with good strain relief. This method is easy to install and made from ordinary shop materials.

Figure 18 - Cable Clamping Methods (plated tabs and hose clamp)



You can protect the small strands of a braided cable shield by using adhesive copper tape. Use foil that offers the best coverage and electromagnetic shielding of the cables. Wrap the tape around the exposed braid area. This avoids having to bend and possibly break the individual strands by the clamp or wire tie.

Figure 19 - Cable Clamping Methods (adhesive copper tape and wire tie)



Cable Shield Terminations

Proper cable shield termination is affected by where the shield is terminated. In the past, attempts to bond the cable shield at both ends sometimes caused low frequency currents to flow through the shield causing a hum or disturbance to the inner conductor signal, referred to as a ground loop. As a result, single-end cable shield termination or in some cases, the avoidance of using shielded cable is common practice. Single-ended shield termination causes the cable to act as a high-frequency antenna and consequently is susceptible to high-frequency pickup. For this reason, avoid using the single-ended termination method.

With modern high-frequency control systems, there are noticeable benefits to properly terminating the cable shield at both ends of the cable using 360° termination techniques:

- For a motor power cable, terminating at both ends often provides the lowest impedance path for stray capacitive-coupled currents to return back to the drive chassis (source). Using proper 360° terminations further reduces this impedance.
- The common-mode voltage across the self-inductance of the shield generates a canceling voltage to the EMI in the conductors inside the shield when it is bonded at both ends.

When the cable shield is properly managed, the high-frequency currents usually have little effect on modern digital circuits. However, if the low-frequency currents appear to cause disturbances on a cable using dual-ended 360° terminations, then a hybrid termination can be achieved by replacing the machine-end termination with a conductive band and 1.0 μ F capacitor installed from the band to chassis (there are products manufactured for this purpose). The capacitor blocks low-frequency currents from circulating through the shield and shorts the high-frequency currents to the shield.

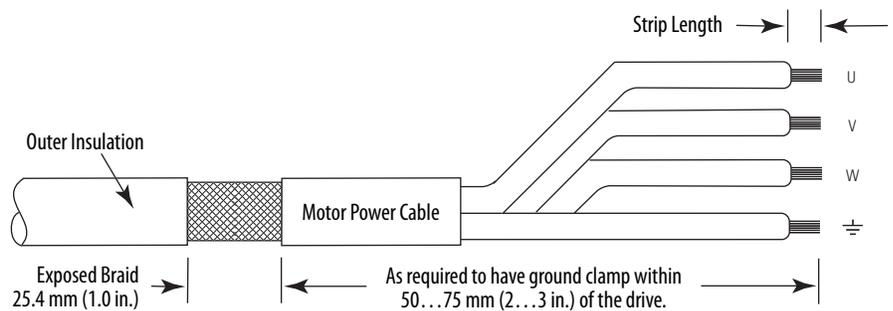
A common mistake when terminating a cable shield is using the drain conductor to create a pigtail by twisting the braid together and inserting a portion of it into a convenient, inexpensive terminal. This technique should not be used, as it generates a large loss through potential attenuation or reduction in EMI on the inner signal conductors of the cable. The benefits of the cable shield are reduced as a result of the following:

- The non-uniform distribution of shield current around the circumference of the shield
- The added impedance at high frequencies created by using a conductor effect and the loss of conductive contact at the bond point

Shielding Cables

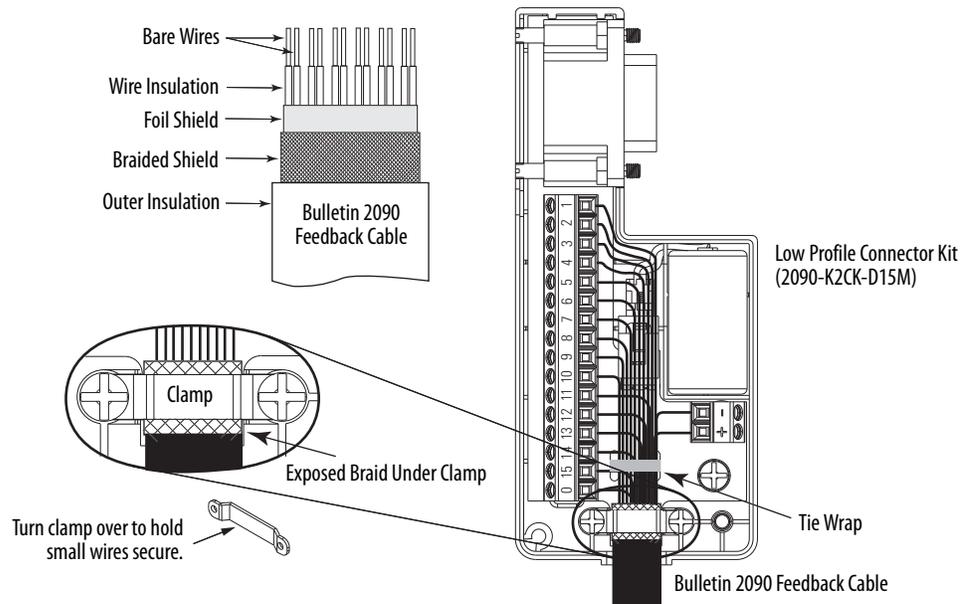
This figure illustrates how to properly prepare the power cable shield braid for a 360° cable clamp.

Figure 20 - Power Cable Shield and Lead Preparation



This figure illustrates how to properly clamp the flying-lead feedback cable shield braid and make wiring connections in a connector kit.

Figure 21 - Feedback Cable Shield and Lead Preparation



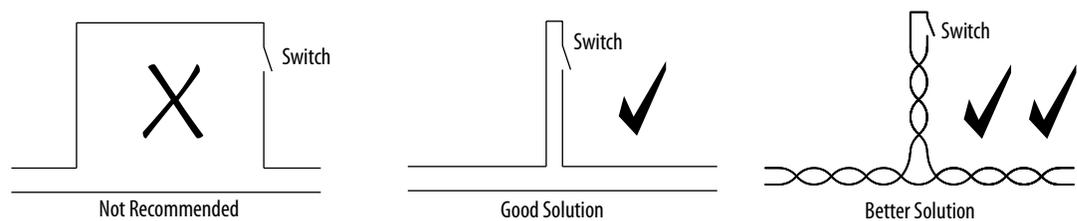
Cable Lengths

Although motor power and feedback cables are available in standard lengths up to 90 m (295.3 ft), the drive/motor/feedback combination may limit the maximum feedback cable length. Combined motor power cable length for all axes on the same DC bus is also subject to drive-specific limitations. Refer to your servo drive user manual for more information.

Minimizing Loops

Wires that form a loop make an efficient antenna. Run feed and return wires together rather than allowing a loop to form. Twisting the pair further reduces the antennae effects and can significantly reduce EMI.

Figure 22 - Avoiding Loops in Wiring Designs



TIP

This applies to victim wiring too. Antennae work equally well in receive and transmit modes.

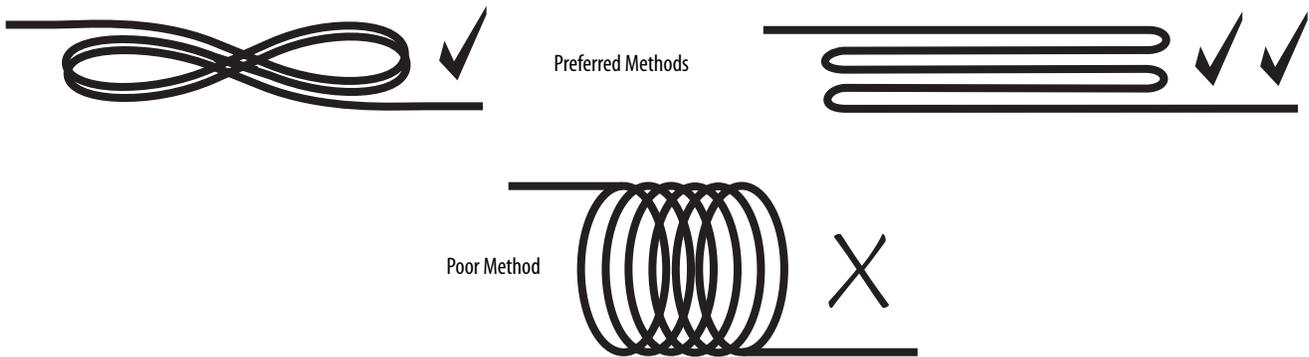
The twisting of the signal pair reduces the magnetic field pickup area and helps to make sure that both conductors in the pair couple have the same level of EMI. As a result, the EMI is rejected by the differential op-amp receiver.

Excess Cable

Observe these guidelines when handling excess cable:

- Do not coil excess cable of different types (for example, motor power and feedback) together. An efficient transformer is formed at HF.
- Cable lengths should ideally be trimmed to fit the application.
- If excess cable cannot be trimmed, it should be laid in an 'S' or figure eight pattern (refer to the figure below).

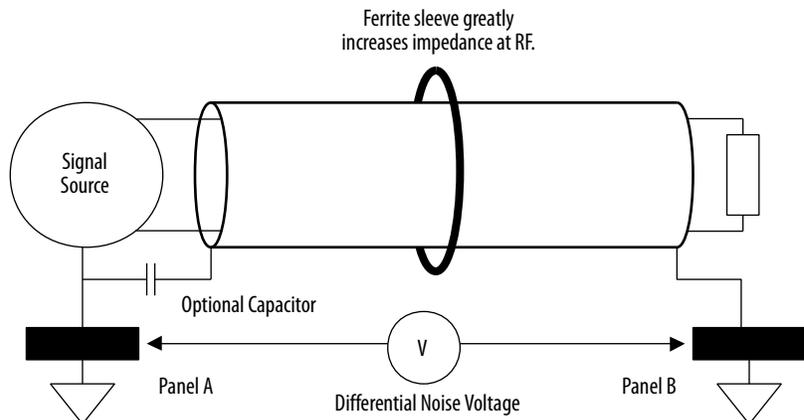
Figure 23 - Excess Cable Treatment



Ferrite Sleeves

Shielded data cables grounded at both ends (important at high frequencies) may carry noise current due to voltage differences between the two ends. Because the shields have a low impedance, currents may be quite high even though voltage is low. By installing ferrite sleeves, the common-mode impedance of the cable is greatly increased at high frequencies, thus blocking the noise currents without affecting the signal currents. In this figure, capacitor grounding is very effective and avoids no-grounding rules, but can be awkward to implement.

Figure 24 - Ferrite Sleeves Increase Common Mode Impedance



Observe these implementation guidelines for ferrite sleeves:

- Always install ferrite sleeves to data cables where specified.
- Always use ferrite sleeves when cable length is greater than 10 m (30 ft).
- If power frequency ground currents are expected, or measured by current clamp, one shield/ground connection could be made via a 1 μ F, 50V capacitor.

Ferrite Beads

Ferrite beads provide additional suppression of transient noise and are available for category-2 and -3 conductors. You can secure them with heat-shrink tubing or tie-wraps. With a ferrite bead located near the end of a cable (or cable segment in the case of a daisy-chain or dropline configuration) transient noise induced onto the cable can be suppressed by the bead before it enters the equipment connected to the end of the cable.

Suppressing Contact Switched Loads

Contact suppressors for solenoids, relays, and various other switches can directly reduce electrical noise.

AC Circuits

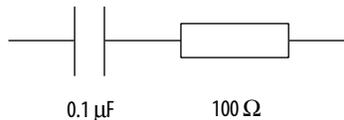
Examples of AC devices requiring contact suppression include the following:

- Line filters (often present an inductive load)
- Contactor controlled motors
- Solenoid coils
- Conductor coils
- Relay coils
- Transformer primaries
- Transformer driven indicator lamps
- Fluorescent cabinet lights (also require line filters close to the lamp)

A commonly overlooked point of suppression are the contacts of the relays or contactors for single and three-phase loads, specifically contacts that can be cycled during machine operation. Contactors that are energized when the machine is powered up may generate EMI which could be missed by signals or circuits which are not yet active. Other contacts should be suppressed with the appropriate single or three-phase RC network.

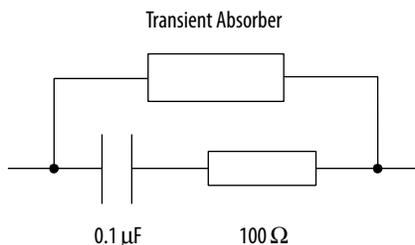
This typical RC suppressor circuit consists of a $0.1 \mu\text{F}$ capacitor in series with a 100Ω resistor.

Figure 25 - RC Suppressor Circuit



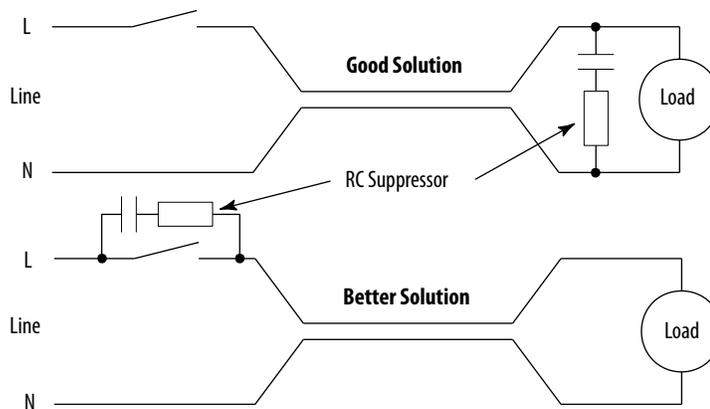
This typical RC plus transient absorber circuit consists of the RC network shown in the figure above in parallel with a transient absorber. These are used in high current, high energy applications such as motor starters. A three-phase contactor requires three suppressors.

Figure 26 - RC Plus Transient Absorber Circuit



This suppressor across the contact reduces the noise from the wiring inductance as well as the coil inductance.

Figure 27 - RC Suppressor in Circuit



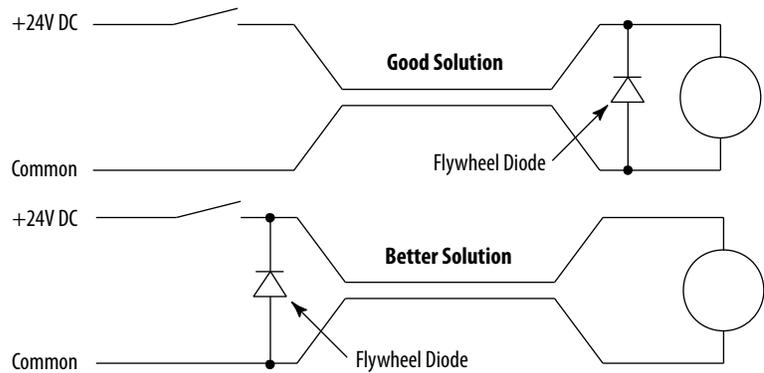
24V DC Circuits

Examples of DC devices requiring contact suppression include the following:

- Solenoid coils
- Contactor coils
- Relay coils

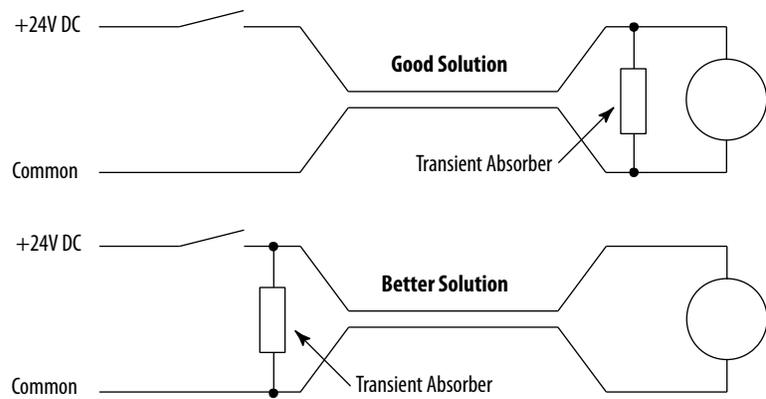
The first choice for DC circuit suppression is a flywheel diode, but this increases the release time that may not be acceptable in all applications.

Figure 28 - Flywheel Diode



The second choice for DC circuit suppression is a transient absorber.

Figure 29 - Transient Absorber



Leakage Current Considerations

Leakage current is inevitable in servo drive systems due to the capacitive components within the drives. Another source for leakage current is the cabling in the system, which induces capacitance in the system. As cable lengths increase so does leakage current. In addition, the leakage current increases with unbalanced loads from the mains phases and when the number of drives increases in a system. Finally, line filters drastically increase the leakage current in the system. This presents a particular challenge in designing a system to reduce noise and leakage current.

If a filter must be used for EMC purposes, but European Conformity (CE) is not required, consider applying a low leakage current filter to reduce overall leakage current.

If using an Earth Leakage Circuit Breaker (ELCB), consider reducing the sensitivity to minimize nuisance trips. In some cases a harmonic filter (to filter noise) in conjunction with a circuit breaker set at 60 Hz (to protect personnel) can replace the ELCB.

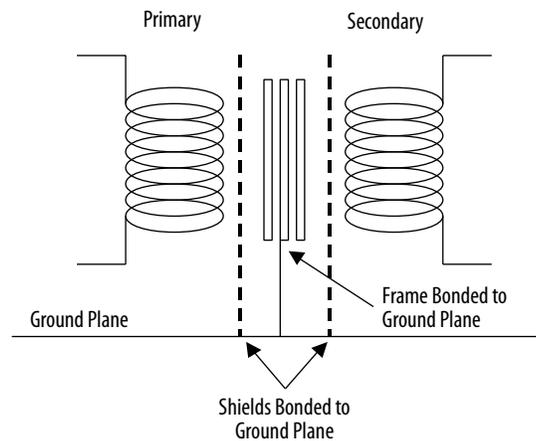
IMPORTANT Reduce cable lengths as much as possible to minimize capacitive loading along cables.

Isolation Transformers

If European Conformity (CE) is not a requirement, consider installing a system isolation transformer rather than an EMC line filter to isolate noise within the system. Transformers must be sized at double the sum of the output power of each axis.

An isolation transformer is frequently assumed to give good noise isolation. In fact, this applies only if the transformer is equipped with one or more electrostatic (ES) shields, as illustrated in the figure below.

Figure 30 - Electrostatically Shielded Transformer



This technique is very effective, though EMC filters are required to meet European regulation standards. Observe these guidelines when installing transformers:

- Install the transformer to the same panel as the rest of your system (or HF bond from panel-to-panel).
- Treat wiring between transformer and drive as very-dirty when no EMC filter is present (provide shielding as required).
- Bond shield, if used, with braid directly to the panel. The transformer mounting bolts are useful for this.
- Segregate input and output wiring as far as possible.

When using an isolation transformer, attach a chassis ground wire to the neutral connection. This grounded neutral connection does the following:

- Prevents the system from floating and thereby avoids any high voltages that might otherwise occur, for example, due to static electricity.
- Provides a solid earth path for fault conditions.



ATTENTION: If the supply transformer is an auto transformer (not recommended), a chassis earth ground should not be added. A chassis earth ground should already be included elsewhere in the system and adding another would create a short.

Component and Wiring Noise Zone Classifications

These tables indicate the zoning requirements of cables connecting to the drive components.

Table 5 - Component Noise Zone Categories

Component Noise Zone Description	Zone ⁽¹⁾			Method		
	Very Dirty	Dirty	Clean	Suppress	Ferrite ⁽²⁾ Sleeve	Shielded ⁽³⁾ Cable
PWM drives/amplifiers ⁽⁴⁾	X	X	X			
Dynamic braking components	X					
External dump resistor (shielded)		X				X
EMC line filter	X	X				
Dump resistor module (metal-clad)		X				
Switch-mode DC power supply		X				
Ultrasonic transducer	X					
Contactors		X		X		
MCB		X				
Switched 24V DC loads ⁽⁵⁾ (for example, E-stop/Piltz circuit, solenoids, relays)		X		X		
Encoder buffer board			X			
PLC			X			
Registration 24V DC power supply filter			X			
Dirty to clean filter		X	X			
Linear DC power supply			X			
Other 24V DC non-switched loads			X			
Data/communication devices			X			
Analog devices			X			

(1) An X in multiple zones indicates that the component straddles the two zones. Under these circumstances it is important to position the component in the correct orientation.

(2) An X in this column indicates a ferrite sleeve fitted to the wire is recommended.

(3) An X in this column indicates a shielded cable is recommended.

(4) The connector/terminal block locations on the drive will normally dictate the zone geometry since it normally has connections in all categories. Design zones around the drives.

(5) All inductive switched loads must be suppressed.

Table 6 - Wiring Noise Zone Categories

Wiring Noise Zone Description	Zone			Method		
	Very Dirty	Dirty	Clean	Suppress	Ferrite ⁽¹⁾ Sleeve	Shielded ⁽²⁾ Cable
Three-phase between sine filter and drive (shielded)		X				X
Extended DC bus (shielded)		X				X
PWM drive/inverter to motor power (shielded)		X				X
PWM drive/inverter to sine wave filter	X					
Sine wave filter to motor		X				
CM choke to motor power (shielded)		X				X
Line terminator to motor power (shielded)		X				X
External dump shunt resistor (shielded)		X				X
Contactors to AC motor (shielded)		X				X
Three-phase power supply		X				
Single-phase power supply		X				
24V hydraulic/pneumatic to solenoids		X				
Motor feedback resolver (shielded)			X			X
PLC digital I/O		X				
Dedicated drive inputs (except registration)		X				
Limit switches		X				
Push buttons		X				
Proximity switches (except registration)		X				
Photoelectric cell		X				
24V DC relay		X				
Transformer indicator lamp		X				
Data/communication (shielded)			X		X	X
Encoder/resolver (shielded)			X			X
Logic circuit power (shielded)			X			X
High-speed registration inputs (shielded)			X			X
PLC analog I/O			X			X
PLC high-speed counter input			X			X

(1) An X in this column indicates a ferrite sleeve fitted to the wire is recommended.

(2) An X in this column indicates a shielded cable is recommended.

Additional Resources

These documents contain additional information concerning related products from Rockwell Automation.

Resource	Description
System Design for Control of Electrical Noise Reference Manual, publication GMC-RM001	Information, examples, and techniques designed to minimize system failures caused by electrical noise.
EMC Noise Management DVD, publication GMC-SP004	
Wiring and Grounding Guidelines for Pulse Width Modulated (PWM) AC Drives, publication DRIVES-INO01	Provides basic information needed to properly wire and ground pulse width modulated (PWM) AC drives.
Industrial Automation Wiring and Grounding Guidelines, publication 1770-4.1	Provides general guidelines for installing an Allen-Bradley® industrial automation system that may include programmable controllers, industrial computers, operator-interface terminals, display devices, and communication networks.

You can view or download publications at <http://www.rockwellautomation.com/literature>. To order paper copies of technical documentation, contact your local Allen-Bradley distributor or Rockwell Automation sales representative.

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www.rockwellautomation.com

Power, Control and Information Solutions Headquarters

Americas: Rockwell Automation, 1201 South Second Street, Milwaukee, WI 53204-2496 USA, Tel: (1) 414.382.2000, Fax: (1) 414.382.4444

Europe/Middle East/Africa: Rockwell Automation NV, Pegasus Park, De Kleetlaan 12a, 1831 Diegem, Belgium, Tel: (32) 2 663 0600, Fax: (32) 2 663 0640

Asia Pacific: Rockwell Automation, Level 14, Core F, Cyberport 3, 100 Cyberport Road, Hong Kong, Tel: (852) 2887 4788, Fax: (852) 2508 1846

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