Allen-Bradley

Wiring and Grounding Guidelines for Pulse Width Modulated (PWM) AC Drives

Installation Instructions

Rockwell Automation

Important User Information

Solid state equipment has operational characteristics differing from those of electromechanical equipment. "*Safety Guidelines for the Application, Installation and Maintenance of Solid State Controls*" (Publication SGI-1.1 available from your local Allen-Bradley Sales Office or online at **http://www.ab.com/manuals/gi**) describes some important differences between solid state equipment and hard-wired electromechanical devices. Because of this difference, and also because of the wide variety of uses for solid state equipment, all persons responsible for applying this equipment must satisfy themselves that each intended application of this equipment is acceptable.

In no event will the Allen-Bradley Company be responsible or liable for indirect or consequential damages resulting from the use or application of this equipment.

The examples and diagrams in this manual are included solely for illustrative purposes. Because of the many variables and requirements associated with any particular installation, the Allen-Bradley Company cannot assume responsibility or liability for actual use based on the examples and diagrams.

No patent liability is assumed by Allen-Bradley Company with respect to use of information, circuits, equipment, or software described in this manual.

Throughout this manual we use notes to make you aware of safety considerations.

ATTENTION: Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss.

Attentions help you:

- identify a hazard
- avoid the hazard
- recognize the consequences

Important: Identifies information that is especially important for successful application and understanding of the product.

Shock Hazard labels may be located on or inside the drive to alert people that dangerous voltage may be present.

Chapter 3 Grounding

Chapter 4 Practices

Chapter 5 Reflected Wave

Chapter 6 Common Mode Noise

Overview

The purpose of this manual is to provide you with the basic information needed to properly wire and ground Pulse Width Modulated (PWM) AC drives.

Who Should Use This Manual

This manual is intended for qualified personnel who plan and design installations of Pulse Width Modulated (PWM) AC drives.

Recommended Documentation

The following publications provide general drive information.

Title	Publication	Available…
Wiring and Grounding Practices for AC PWM Drives	Drives IN001A-EN-P	
Installing, Operating and Maintaining Engineered Drive Systems (Reliance Electric)	D2-3115-2	
Safety Guidelines for the Application, Installation and Maintenance of Solid State Control	SGI-1.1	www.ab.com/manuals/dr/index3.html#Safety
IEEE Guide for the Installation of Electrical Equipment to Minimize Electrical Noise Inputs to Controllers from External Sources	IEEE 518	
Recommended Practice for Powering and Grounding Electronic Equipment - IEEE Emerald Book	IEEE STD 1100	
Electromagnetic Interference and Compatibility, Volume 3	N/A	RJ White - publisher Don White Consultants, Inc., 1981
Grounding, Bonding and Shielding for Electronic Equipment and Facilities	Military Handbook 419	
IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems	IEEE Std 142-1991	
National Electrical Code (ANSI/NFPA 70)	Articles 250, 725-5, 725-15, 725-52 and 800-52	
Noise Reduction Techniques in Electronic Systems	N/A	Henry W. Ott Published by Wiley-Interscience
Grounding for the Control of EMI	N/A	Hugh W. Denny Published by Don White Consultants

Title	Publication	Available…
Cable Alternatives for PWM AC Drive Applications	IEEE Paper No. PCIC-99-23	
EMI Emissions of Modern PWM AC Drives	N/A	IEEE Industry Applications Magazine, Nov./Dec. 1999
EMC for Product Designers	N/A	Tim Williams Published by Newnes

Manual Conventions

The following words are used throughout the manual to describe an action:

Word	Meaning
Can	Possible, able to do something
Cannot	Not possible, not able to do something
May	Permitted, allowed
Must	Unavoidable, you must do this
Shall	Required and necessary
Should	Recommended
Should Not	Not recommended

General Precautions

ATTENTION: To avoid an electric shock hazard, verify that the voltage on the bus capacitors has discharged before performing any work on the drive. Measure the DC bus voltage at the +DC & –DC terminals of the Power Terminal Block. The voltage must be zero.

Wire Types

This chapter provides recommendations for different types of wiring.

AC drive installations, along with drive characteristics, have specific requirements for cables used in installations. Recommendations are made to address specific issues such as noise standards, wire integrity and safety. Most significantly, since drives can create voltages well in excess of line voltage, the industry standard cables that have been used in the past may not represent the best choice for customers using variable speed drives. Drive installations benefit from the use of cable that is significantly different than that used to wire contactors and fuse blocks.

The following section covers the major issues and proper selection of cable. In general, the significant selection criteria are wire gauge, shielding, geometry, type of coating, and resistance to moisture and temperature.

General

Material

Always use copper wire.

Exterior Cover

Whether shielded or unshielded, the cable must be chosen to meet all of the application requirements. Consideration must be given to insulation value and resistance to moisture, contaminants, corrosive agents and other invasive elements. Consult the cable manufacturer for the proper selection.

Temperature Rating

In general, installations in surrounding air temperature of 50º should use 90º wire (required for UL) and installations in 40º surrounding air temperature should use 75º wire (also required for UL). Refer to the drive user manual for other restrictions

The temperature rating of the wire affects the required gauge. Be certain to meet all applicable national, state and local codes.

Gauge

The proper wire size is determined by a number of factors. Each individual drive user manual lists a minimum and maximum wire gauge based on the amperage rating of the drive and the physical limitations of the terminal blocks. Local or national electrical codes also set the required minimum gauge based on motor FLA. Both of these requirements should be followed.

Number of Conductors

While local or national electrical codes may determine the required number of conductors, certain configurations are recommended. Figure 1.1 on page 1-2 shows cable with a single ground conductor, which is recommended for drives up to and including 200 HP (150 kW). Figure 1.2 on page 1-2 shows cable with three ground conductors, which is recommended for drives larger than 200 HP (150 kW). The ground conductors should be spaced symmetrically around the power conductors. The ground conductor(s) should be rated for full drive ampacity.

Figure 1.1 Cable with One Ground Conductor

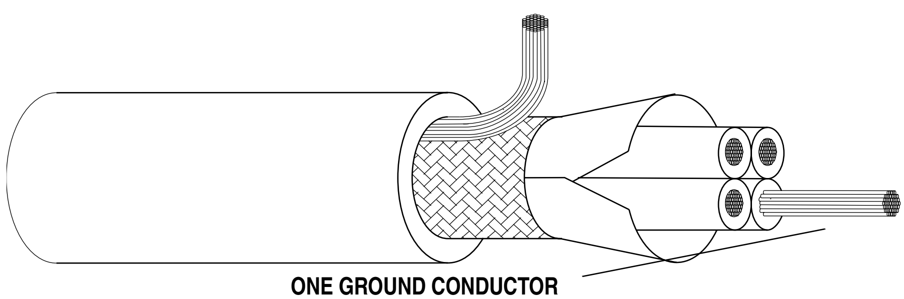
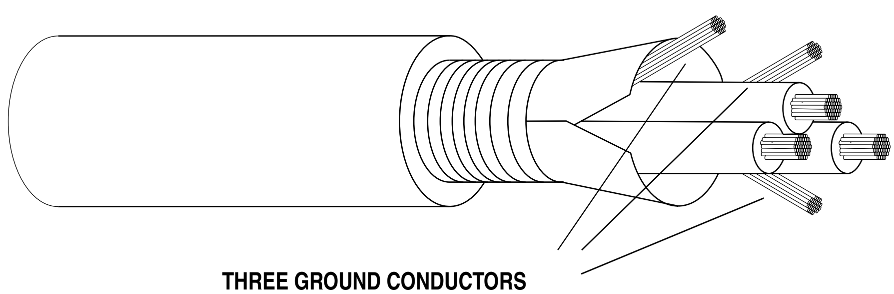


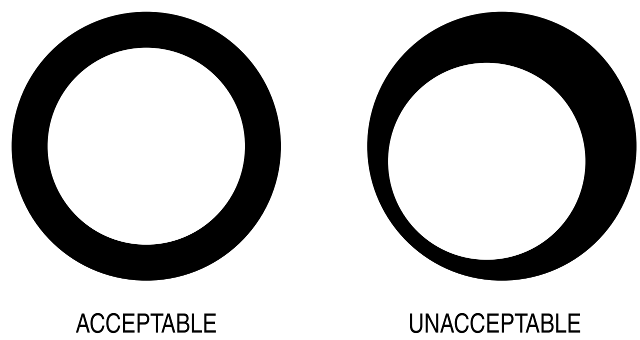
Figure 1.2 Cable with Three Ground Conductors



Insulation Thickness and Concentricity

Selected wire must have an insulation thickness of equal to or more then 15 mils (0.4 mm / 0.015 in.). The quality of wire should not have significant variations on concentricity of wire and insulation.

Figure 1.3 Insulation Concentricity



Geometry

The physical relationship between individual conductors plays a large role in drive installation.

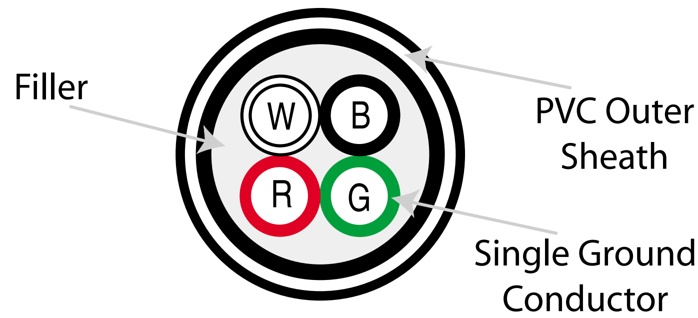
Individual conductors in conduit or cable tray have no fixed relationship and are subject to a variety of issues including: cross coupling of noise, induced voltages, excess insulation stress and others.

Fixed geometry cable (cable that keeps the spacing and orientation of the individual conductors constant) offers significant advantages over individual loose conductors including reducing cross coupling noise and insulation stress. Three types of fixed geometry multi-conductor cables are discussed below: Unshielded, shielded, and armored.

Unshielded Cable

Properly designed multi-conductor cable can provide superior performance in wet applications, significantly reduce voltage stress on wire insulation and reduce cross coupling between drives.

Figure 1.4 Unshielded Multi-Conductor Cable



The use of cables without shielding is generally acceptable for installations where electrical noise created by the drive does not interfere with the operation of other devices such as: communications cards, photoelectric switches, weigh scales and others. Be certain the installation does not require shielded cable to meet specific EMC standards, such as CE or C-Tick. Cable should have 3 phase conductors and a fully rated individual ground conductor or 3 symmetrical ground conductors whose ampacity equals the phase conductor. The outer sheathing and other mechanical characteristics should be chosen to suit the installation environment. Consideration should be given to surrounding air temperature, chemical environment, flexibility and other factors as necessary.

Shielded Cable

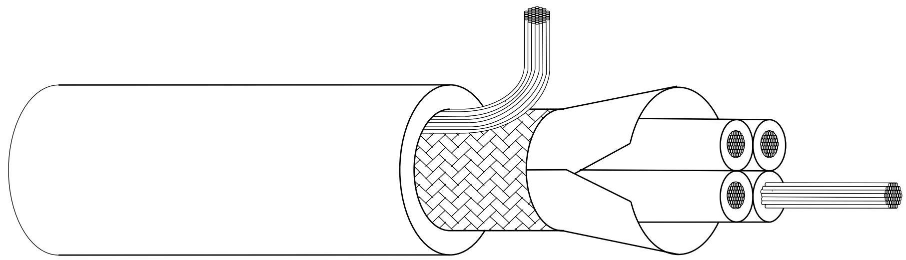
Shielded cable contains all of the general benefits of multi-conductor cable with the added benefit of a copper braided shield that can contain much of the noise generated by a typical AC Drive. Strong consideration for shielded cable should be given for installations with sensitive equipment such as weigh scales, capacitive proximity switches and other devices that may be affected by electrical noise in the distribution system. Applications with large numbers of drives in a similar location, imposed EMC regulations or a high degree of communications / networking are also good candidates for shielded cable.

Shielded cable may also help reduce shaft voltage and induced bearing currents for some applications. In addition, the increased size of shielded cable may help extend the distance that the motor can be located from the drive without the addition of motor protective devices such as terminator networks. Refer to Chapter 5 for information regarding reflected wave phenomena.

Consideration should be given to all of the general specifications dicated by the environment of the installation, including temperature, flexibility, moisture characteristics and chemical resistance. In addition, a braided shield should be included and specified by the cable manufacturer as having coverage of at least 75%. An additional foil shield can greatly improve noise containment.

A good example of recommended cable is Belden® 295xx (xx determines gauge). This cable has 4 XLPE insulated conductors with a 100% coverage foil and an 85% coverage copper braided shield (with drain wire) surrounded by a PVC jacket.

Figure 1.5 Shielded Cable with Four Conductors



TIP: Other types of shielded cable are available, but the selection of these types may limit the allowable cable length. Particularly, some of the newer cables twist 4 conductors of THHN wire and wrap them tightly with a foil shield. This construction can greatly increase the cable charging current required and reduce the overall drive performance. Unless specified in the individual distance tables as tested with the drive, theses cables are not recommended and their performance against the lead length limits supplied is not known. For more information, about motor cable lead restrictions refer Appendix A, Conduit on page 4-10, Moisture on page 4-14 and Wire Types And Effects On Them on page 5-1 on THHN wire.

Armored Cable

Cable with continuous aluminum armor is often recommended in drive system applications or specific industries. It offers most of the advantages of standard shielded cable and also combines considerable mechanical strength and resistance to moisture. It can be installed in concealed and exposed manners and removes the requirement for conduit (EMT) in the installation. It can also be directly buried or embedded in concrete.

Because noise containment can be affected by incidental grounding of the armor to building steel (see Chapter 2) when the cable is mounted, it is recommended the armored cable have an overall PVC jacket.

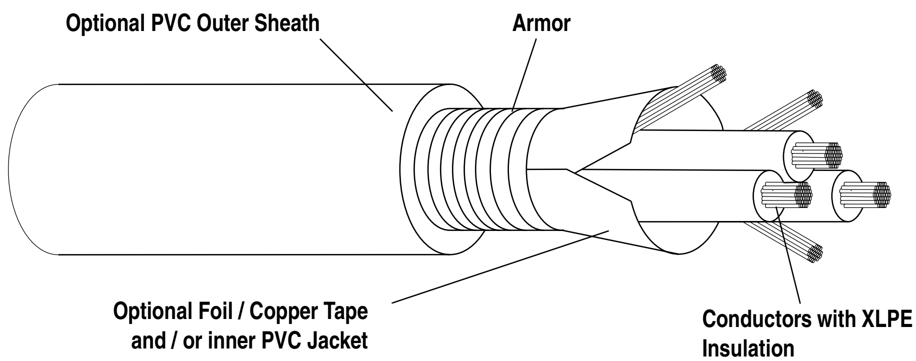
Interlocked armor is acceptable for shorter cable runs, but continuous welded armor is preferred.

Best performance is achieved with 3 spaced ground conductors, but acceptable performance below 200 HP is provided via a single ground conductor.

Table 1.A Recommended Shielded/Armored Cable

Location	Rating/Type	Description
Stand (Option 1)	600 V, 90°C (194°F) XHHW2/RHW-2 Anixter B209500-B209507 Belden® 29501-29507, or equivalent	Four tinned copper conductors with XLPE insulation. Copper braid/aluminum foil combination shield and tinned copper drain wire. PVC jacket
Standard (Option 2)	Tray rated 600V, 90°C (194°F) RHH/RHW-2 Anixter OLF-7xxxxx or equivalent	Three tinned copper conductors with XLPE insulation. 5mil single helical copper tape (25% overlap min.) with three PVC jacket.
Class I & II Division I & II	Tray rated 600V, 90°C (194°F) RHH/RHW-2 Anixter 7V-7xxxx-3G or equivalent	Three bare copper conductors with XLPE insulation and impervious corrugated continuously welded aluminum armor. Black sunlight resistanct PVC jacket overall. Three copper grounds on #10 AWG and smaller.

Figure 1.6 Armored Cable with Three Ground Conductors



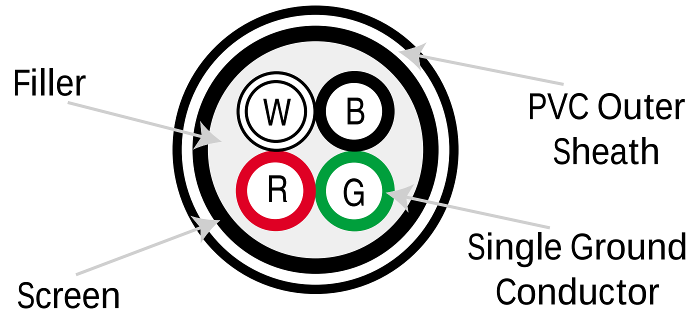
European Style Cable

Cable used in many installations in Europe should conform to the CE Low Voltage Directive 73/23/EEC. Generally recommended are flexible cables with a recommended bend radius of 20 times the cable diameter for movable cable and 6 times the cable diameter for fixed installations. The screen (shield) should be between 70 and 85% coverage. Insulation for both conductors and the outer sheath is PVC.

The number and color of individual conductors may vary, but the recommendation is for 3 phase conductors (customer preferred color) and one ground conductor (Green / Yellow)

Ölflex® Classic 100SY or Ölflex Classic 110CY are examples.

Figure 1.7 European Style Multi-Conductor Cable



Input Power Cables

In general, the selection of cable for AC input power to a drive has no special requirements. Some installations may suggest shielded cable to prevent coupling of noise onto the cable (see Chapter 2) and in some cases, shielded cable may be required to meet noise standards such as CE for Europe, C-Tick for Australia / New Zealand, and others. This may be especially true if an input filter is required to meet a standard. Each individual drive user manual will show the requirements for meeting these types of standards. Additionally, individual industries may have required standards due to environment or experience.

For AC variable frequency drive applications that must meet EMC standards such as CE, Rockwell Automation may recommend that the same type of shielded cable specified for the AC motors be used between the drive and transformer. Check the individual user manuals for specific additional requirements in these situations.

Motor Cables

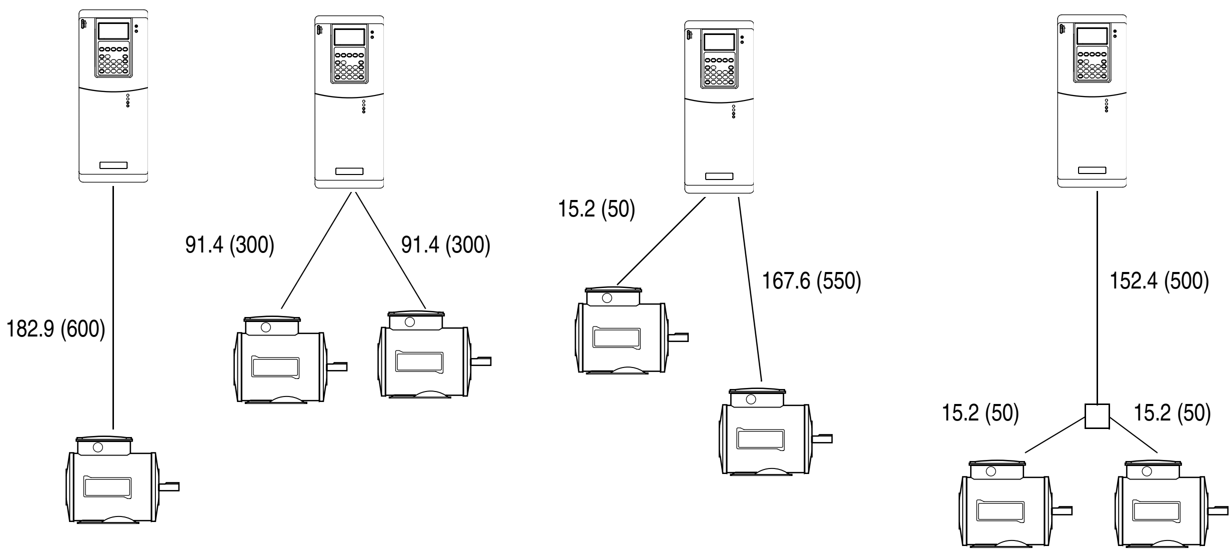
The majority of recommendations regarding drive cable address issues caused by the nature of the drive output. A PWM drive creates AC motor current by sending DC voltage pulses to the motor in a specific pattern. These pulses affect the wire insulation and can be a source of electrical noise. The rise time, amplitude, and frequency of these pulses must be considered when choosing a wire / cable type. The choice of cable must consider:

1. The effects of the drive output once the cable is installed
2. The need for the cable to contain noise caused by the drive output
3. The amount of cable charging current available from the drive
4. Possible voltage drop (and subsequent loss of torque) for long wire runs

Keep the motor cable lengths within the limits set by the drive's user manual. Various issues, including cable charging current and reflected wave voltage stress may exist. If the cable restriction is listed because of excessive coupling current, apply the methods to calculate total cable length, as shown in Figure 1.8 on page 1-8. If the restriction is due to voltage reflection and motor protection, tabular data is available. Refer to Appendix A for exact distances allowed.

Figure 1.8 Motor Cable Length

All examples represent motor cable length of 182.9 meters (600 feet)



Cable for Discrete Drive I/O

Discrete I/O such as Start and Stop commands can be wired to the drive using a variety of cabling. Shielded cable is recommended, as it can help reduce cross-coupled noise from power cables. Standard individual conductors that meet the general requirements for type, temperature, gauge and applicable codes are acceptable if they are routed away from higher voltage cables to minimize noise coupling. Although, multi-conductor cable may be less expensive to install. Control wires should be separated from power wires by at least 0.3 meters (1 foot)

Table 1.B Recommended Control Wire for Digital I/O

Type	Wire Type(s)	Description	Minimum Insulation Rating
Unshielded	Per US NEC or applicable national or local code	–	300V, 60° C (140 ° F)
Shielded	Multi-conductor shielded cable such as Belden 8770 (or equiv.)	0.750 mm^2 (18 AWG), 3 conductor, shielded.	

Analog Signal and Encoder Cable

Always use shielded cable with copper wire. Wire with insulation rating of 300V or greater is recommended. Analog signal wires should be separated from power wires by at least 0.3 meters (1 foot). It is recommended that encoder cables be run in a separate conduit. If signal cables must cross power cables, cross at right angles.

Table 1.C Recommended Signal Wire

Signal Type	Wire Type(s)	Description	Minimum Insulation Rating
Standard Analog I/O	Belden 8760/9460 (or equiv.)	0.750 mm^2 (18 AWG), twisted pair, 100% shield with drain[1].	300V, 75-90 °C (167-194 °F)
	Belden 8770 (or equiv.)	0.750 mm^2 (18 AWG), 3 cond., shielded for remote pot only.	
Encoder/ Pulse I/O	Less than or equal to 30 m (98 ft.) – Belden 9730 (or equiv.)	0.196 mm^2 (24 AWG), individually shielded.	
	Greater than 30 m (98 ft.) – Belden 9773 (or equiv.)	0.750 mm^2 (18 AWG), twisted pair, shielded.	

(1) If the wires are short and contained within a cabinet which has no sensitive circuits, the use of shielded wire may not be necessary, but is always recommended.

Communications

DeviceNet

DeviceNet cable options, topology, distances allowed and techniques used are very specific to the DeviceNet network. Refer to *DeviceNet Cable System Planning and Installation Manual*, publication DN-6.72.

In general, there are 4 acceptable cable types for DeviceNet media. These include:

1. Round (Thick) cable with an outside diameter of 12.2 mm (0.48 in) normally used for trunk lines but can also be used for drop lines
2. Round (Thin) cable with an outside diameter of 6.9 mm (0.27 in) normally used for drop lines but may also be used for trunk lines
3. Flat cable normally used for trunk lines
4. KwikLink drop cable used only in KwikLink systems.

Round cable contains five wires: one twisted pair (red and black) for 24V DC power, one twisted pair (blue and white) for signal and a drain wire (bare).

Flat cable contains four wires: one pair (red and black) for 24V DC power and one pair (blue and white) for signal.

Drop cable for KwikLink is a 4-wire unshielded gray cable.

The distance between points, installation of terminating resistors and chosen baud rate all play a significant part in the installation. Again, refer to the DeviceNet Cable System Planning and Installation Manual for detailed specifics.

ControlNet

ControlNet cable options, topology, distances allowed and techniques used are very specific to the ControlNet network. For more information refer to *ControlNet Coax Cable System Planning and Installation Manual*, publication 1786-6.2.1.

Depending on the environment at the installation site there are several types of RG-6 quad shield cables that may be appropriate. The standard cable recommended is A-B Cat # 1786-RG6, Quad Shield coax (Belden 3092A). Country, state or local codes such as the U.S. NEC govern the installation.

For:	Use this Cable Type
Light Industrial	• Standard PVC • CM-CL2
Heavy Industrial	• Lay-on Armored • Light Interlocking Armor
High / Low Temperature or Corrosive (Harsh Chemicals)	• Plenum-FEP • CMP-CL2P
Festooning or Flexing	• High Flex
Moisture: direct burial, with flooding compound, fungus resistant	• Flood Burial

The allowable length of segments and installation of terminating resistors play a significant part in the installation. Again, refer to the *ControlNet Coax Cable System Planning and Installation Manual* for detailed specifics.

Ethernet

The Ethernet communications interface wiring is very detailed as to the type of cable, connectors and routing. Because of the amount of detail required to bring Ethernet into the industrial environment, planning an installation should be done by following all recommendations in the *Ethernet/IP Media Planning and Installation Guide*, publication ENET-IN001.

In general, Ethernet systems consist of specific cable types (STP shielded Cable or UTP unshielded cable) using RJ45 connectors that meet the IP67 standard and are appropriate for the environment. Cables should also meet TIA/EIA standards at industrial temperatures.

Shielded cable is always recommended when the installation may include welding, electrostatic processes, drives over 10 HP, Motor Control Centers, high power RF radiation or devices carrying current in excess of 100 Amps. Shield handling and single point grounding, also discussed in this document, play an extremely important role in the proper operation of Ethernet installations.

Finally, there are distance and routing limitations published in detail.

Remote I/O and Data Highway Plus (DH+)

Only 1770-CD, Belden #9463 is tested and approved for Remote I/O and DH+ installations.

The maximum cable length depends on the chosen baud rate:

Baud Rate	Maximum Cable Length
57.6 KBPS	3,048 m (10,000 ft.)
115.2 KBPS	1524 m (5000 ft.)
230.4 KBPS	762 m (2500 ft.)

All three connections (blue, shield and clear) must be connected at each node.

Do not connect in star topology. Only two cables may be connected at any wiring point. Use either series or daisy chain topology at all points.

Serial (RS232 / 485)

Standard practices for serial communications wiring should be followed. Belden 3106A or equivalent is recommended for RS232. It contains one twisted pair and 1 signal common. Recommended cable for RS485 is 2 twisted pair with each pair individually shielded.

Notes:

Power Distribution

This chapter discusses different power distribution schemes and factors which affect drive performance.

System Configurations

The type of transformer and the connection configuration feeding a drive plays an important role in its performance and safety. The following is a brief description of some of the more common configurations and a discussion of their virtues and shortcomings.

Figure 2.1 Delta / Wye with Grounded Wye Neutral

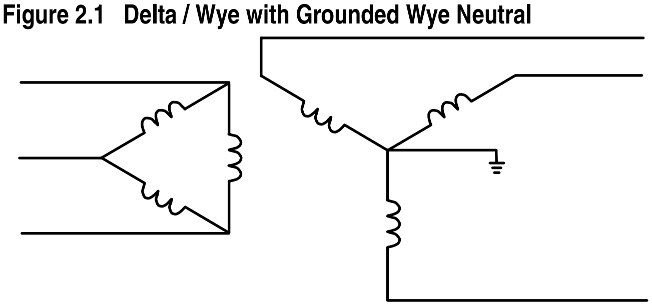


Figure 2.1 on page 2-1 is the most common. It provides re-balancing of unbalanced voltage with a 30 degree phase shift. Depending on the output connections from the drive to motor, the grounded neutral may be a path for common mode current caused by the drive output (see Chapter 3 and Chapter 6).

Figure 2.2 Delta / Delta with Grounded Leg

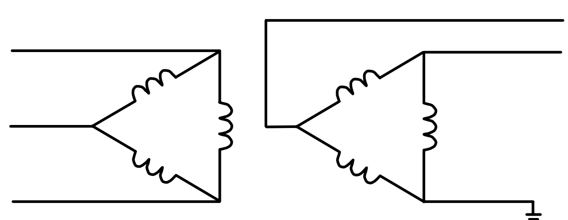
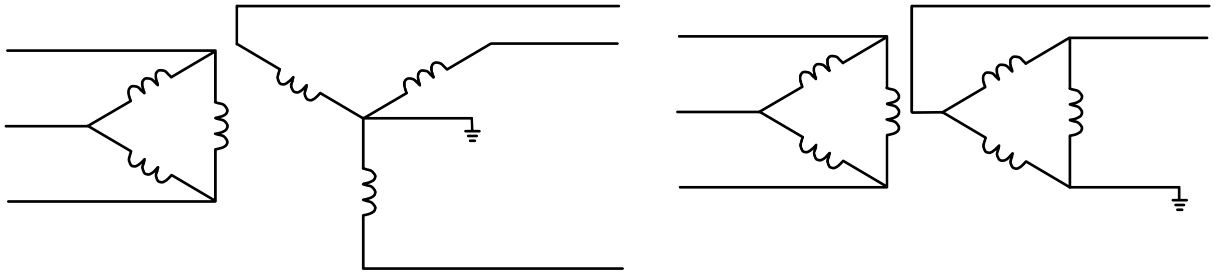


Figure 2.2 on page 2-1 is a common configuration providing voltage re-balancing with no phase shift between input and output. Again, depending on the output connections from the drive to motor, the grounded neutral may be a path for common mode current caused by the drive output.

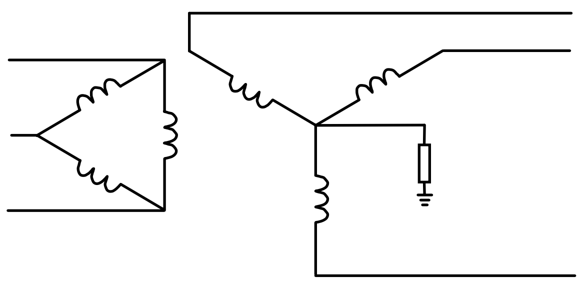
Figure 2.3 Ungrounded Secondary



Grounding the transformer secondary is essential to the safety of personnel and safe operation of the drive. Leaving the secondary floating allows dangerously high voltages between the chassis of the drive and the internal power structure components. Exceeding the voltage rating of the drive's input MOV (Metal Oxide Varistor) protection devices could cause a catastrophic failure. In all cases, the input power to the drive should be referenced to ground.

If the system is ungrounded, other general precautions such as a system level ground fault detector or system level line to ground suppressor may be necessary or an isolation transformer must be considered with the secondary of the transformer grounded. Refer to local codes regarding safety requirements.

Figure 2.4 High Resistance Ground



Grounding the wye secondary neutral through a resistor is an acceptable method of grounding. Under a short circuit secondary condition, any of the output phases to ground will not exceed the normal line to line voltage. This is within the rating of the MOV input protection devices on the drive. The resistor is often used to detect ground current by monitoring the associated voltage drop. Since high frequency ground current can flow through this resistor, care should be taken to properly connect the drive motor leads using the recommended cables and methods. In some cases, multiple drives (that may have one or more internal references to ground) on one transformer can produce a cumulative ground current that can trigger the ground fault interrupt circuit.

AC Line Impedance

To prevent excess current that may damage drives during events such as line disturbances or certain types of ground faults, drives should have a minimum amount of impedance in front of them. In many installations, this impedance comes from the supply transformer and the supply cables. In certain cases, an additional transformer or reactor is recommended. If any of the following conditions exist, serious consideration should be given to adding a line reactor in front of the drive:

A. Line impedance is less than 1%

B. Available short circuit current is greater than 100,000 Amps AND the drive is less then 5 HP

C. Supply transformer exceeds the value in Table 2.A

D. Line has switched Power Factor correction capacitors

E. Line has frequent lightning strikes or voltage spikes in excess of 6000V Peak

F. Line has frequent power interruptions or voltage dips in excess of 200V AC

The recommendations are merely advisory and may not address all situations. User judgement must be exercised to assure a quality installation.

Table 2.A AC Line Impedance Recommendations

	Drive Catalog #	Volts	HP/kW	Max Supply KVA (1) (2)	3% Line Reactor Open Style 1321-
160-	-AA02	240	0.5	15	3R4-B
	-AA03	240	0.75	20	3R4-A
	-AA04	240	1	30	3R4-A
	-AA08	240	2	50	3R8-A
	-AA12	240	3	75	3R12-A
	-AA18	240	5	100	3R18-A
	-BA01	480	0.5	15	3R2-B
	-BA02	480	0.75	20	3R2-A
	-BA03	480	1	30	3R2-A
	-BA04	480	2	50	3R4-B
	-BA06	480	3	75	3R8-B
	-BA10	480	5	100	3R18-B

	Drive Catalog #	Volts	HP/kW	Max Supply KVA (1) (2)	3% Line Reactor Open Style 1321-
1305-	-AA02A	240	0.5	15	3R4-A
	-AA03A	240	0.75	20	3R4-A
	-AA04A	240	1	30	3R8-A
	-AA08A	240	2	50	3R8-A
	-AA12A	240	3	75	3R18-A
	-BA01A	480	0.5	15	3R2-B
	-BA02A	480	0.75	20	3R2-B
	-BA03A	480	1	30	3R4-B
	-BA04A	480	2	50	3R4-B
	-BA06A	480	3	75	3R8-B
	-BA09A	480	5	100	3R18-B
PowerFlex 70	20AB2P2	240	0.5	25	3R2-D
	20AB4P2	240	1	50	3R4-A
	20AB6P8	240	2	100	3R8-A
	20AB9P6	240	3	125	3R12-A
	20AB015	240	5	150	3R18-A
	20AB022	240	7.5	250	3R25-A
	20AB028	240	10	300	3R35-A
	20AC1P3	400	0.37	15	3R2-B
	20AC2P1	400	0.75	20	3R2-B
	20AC3P4	400	1.5	30	3R4-B
	20AC5P0	400	2.2	50	3R4-B
	20AC8P0	400	4	75	3R8-B
	20AC011	400	5.5	100	3R12-B
	20AC015	400	7.5	150	3R18-B
	20AC022	400	11	250	3R25-B
	20AC027	400	15	300	3R35-B
	20AD1P1	480	0.5	15	3R2-B
	20AD2P1	480	1	30	3R2-B
	20AD3P4	480	2	50	3R4-B
	20AD5P0	480	3	75	3R4-B
	20AD8P0	480	5	100	3R8-B
	20AD011	480	7.5	120	3R12-B
	20AD015	480	10	150	3R18-B
	20AD022	480	15	250	3R25-B
	20AD027	480	20	300	3R35-B
	20AE0P9	600	0.5	15	3R1-B
	20AE1P7	600	1	20	3R2-B
	20AE2P7	600	2	30	3R2-B
	20AE3P9	600	3	50	3R4-B
	20AE6P1	600	5	75	3R8-C
	20AE9P0	600	7.5	120	3R8-C
	20AE011	600	10	150	3R12-B
	20AE017	600	15	250	3R18-B
	20AE022	600	20	300	3R25-B

	Drive Catalog #	Volts	HP/kW	Max Supply KVA [1] [2]	3% Line Reactor Open Style 1321-
PowerFlex 700	20BB2P2	240	0.5	25	3R2-D
	20BB4P2	240	1	50	3R4-A
	20BB6P8	240	2	100	3R8-A
	20BB9P6	240	3	125	3R12-A
	20BB015	240	5	150	3R18-A
	20BB022	240	7.5	250	3R25-A
	20BB028	240	10	300	3R35-A
	20BB042	240	15	450	3R45-A
	20BB054	240	20	600	3R80-A
	20BC1P3	400	0.37	15	3R2-B
	20BC2P1	400	0.75	25	3R2-B
	20BC3P5	400	1.5	50	3R4-B
	20BC5P0	400	2.2	50	3R4-B
	20BC8P7	400	4	100	3R8-B
	20BC011	400	5.5	120	3R12-B
	20BC015	400	7.5	150	3R18-B
	20BC022	400	11	200	3R25-B
	20BC030	400	15	3000	3R35-B
	20BC037	400	18.5	350	3R45-B
	20BC043	400	22	450	3R45-B
	20BC056	400	30	600	3R55-B
	20BC072	400	37	700	3R80-B
	20BC105	400	55	1000	3R130-B
	20BC125	400	55	1000	3R130-B
	20BD1P1	480	0.5	25	3R2-B
	20BD2P1	480	1	30	3R2-B
	20BD3P4	480	2	50	3R4-B
	20BD5P0	480	3	75	3R4-B
	20BD8P0	480	5	100	3R8-B
	20BD011	480	7.5	120	3R12-B
	20BD014	480	10	150	3R18-B
	20BD022	480	15	250	3R25-B
	20BD027	480	20	300	3R35-B
	20BD034	480	25	400	3R35-B
	20BD040	480	30	450	3R45-B
	20BD052	480	40	600	3R55-B
	20BD065	480	50	750	3R80-B
	20BD077	480	60	900	3R80-B
	20BD096	480	75	1000	3R100-B
	20BD125	480	100	1000	3R130-B
	20BD156	480	125	1000	3R160-B

	Drive Catalog #	Volts	HP/kW	Max Supply KVA (1) (2)	3% Line Reactor Open Style 1321-
1336 Family- • Plus • Plus II • IMPACT™ • FORCE™	AQF05	240	0.5	25	3R4-A
	AQF07	240	0.75	25	3R4-A
	AQF10	240	1	50	3R8-A
	AQF15	240	1.5	75	3R8-A
	AQF20	240	2	100	3R12-A
	AQF30	240	3	200	3R12-A
	AQF50	240	5	275	3R25-A
	A007	240	7.5	300	3R25-A
	A010	240	10	350	3R35-A
	A015	240	15	600	3R45-A
	A020	240	20	800	3R80-A
	A025	240	25	900	3R80-A
	A030	240	30	950	3R80-A
	A040	240	40	1000	3R130-A
	A050	240	50	1200	3R160-A
	A060	240	60	1400	3R200-A
	A075	240	75	1500	3R250-A
	A100	240	100	2200	3R320-A
	A125	240	125	2500	3R320-A
	BRF05	480	0.5	25	3R2-B
	BRF07	480	0.75	30	3R2-B
	BRF10	480	1	30	3R4-B
	BRF15	480	1.5	50	3R4-B
	BRF20	480	2	50	3R8-B
	BRF30	480	3	75	3R8-B
	BRF50	480	5	100	3R12-B
	BRF75	480	7.5	200	3R18-B
	BRF100	480	10	275	3R25-B
	BRF150	480	15	300	3R25-B
	BRF200	480	20	350	3R25-B
	B015	480	15	350	3R25-B
	B020	480	20	425	3R35-B
	B025	480	25	550	3R35-B
	B030	480	30	600	3R45-B
	BX040	480	40	750	3R55-B
	B040	480	40	800	3R55-B
	B050	480	50	900	3R80-B
	BX060	480	60	950	3R80-B
	B060	480	60	950	3R100-B
	B075	480	75	1000	3R100-B
	B100	480	100	1200	3R130-B
	B125	480	125	1400	3R160-B
	BX150	480	150	1500	3R200-B
	B150	480	150	2000	3R200-B
	B200	480	200	2200	3R250-B
	B250	480	250	2500	3R320-B
	B300	480	300	3000	3R400-B
	B350	480	350	3500	3R500-B
	B400	480	400	4000	3R500-B
	B450	480	450	4500	3R600-B
	B500	480	500	5000	3R600-B
	B600	480	600	5000	3R750-B

	Drive Catalog #	Volts	HP/kW	Max Supply KVA (1) (2)	3% Line Reactor Open Style 1321-
1336 Family- • Plus • Plus II • Impact • Force	B700	480	700	5000	3R850-B
	B800	480	800	5000	3R1000-B
	CWF10	600	1	25	3R4-C
	CWF20	600	2	50	3R4-C
	CWF30	600	3	75	3R8-C
	CWF50	600	5	100	3R8-B
	CWF75	600	7.5	200	3R8-B
	CWF100	600	10	200	3R12-B
	C015	600	15	300	3R18-B
	C020	600	20	350	3R25-B
	C025	600	25	500	3R25-B
	C030	600	30	600	3R35-B
	C040	600	40	700	3R45-B
	C050	600	50	850	3R55-B
	C060	600	60	900	3R80-B
	C075	600	75	950	3R80-B
	C100	600	100	1200	3R100-B
	C125	600	125	1400	3R130-B
	C150	600	150	1500	3R160-B
	C200	600	200	2200	3R200-B
	C250	600	250	2500	3R250-B
	C300	600	300	3000	3R320-B
	C350	600	350	3000	3R400-B
	C400	600	400	4000	3R400-B
	C450	600	450	4500	3R500-B
	C500	600	500	5000	3R500-B
	C600	600	600	5000	3R600-B
	C650	600	650	5000	3R750-B
	C700	600	700	5000	3R850-B FN-1
	C800	600	800	5000	3R850-B FN-1

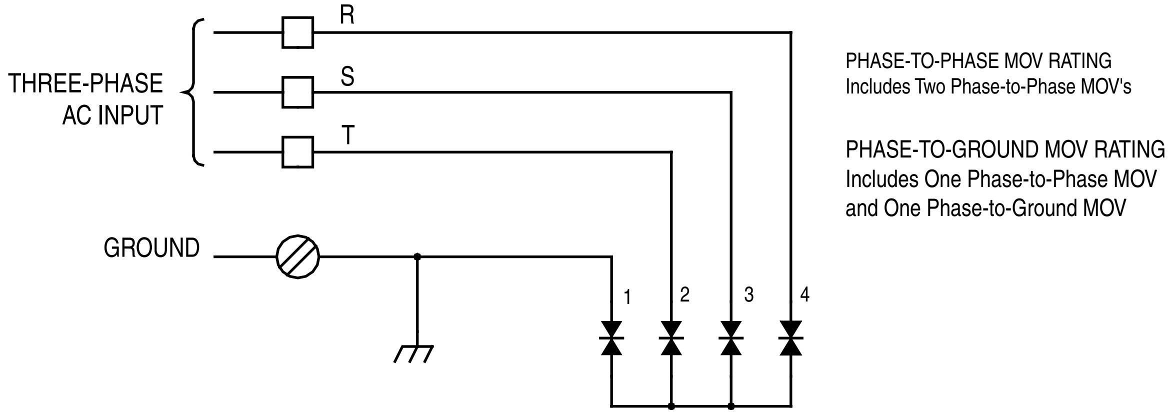
(1) Maximum suggested KVA supply without consideration for additional inductance

(2) 2000 KVA represents 2MVA and Greater

Surge Protection MOVs

Most drives are designed to operate on three-phase supply systems whose line voltages are symmetrical. Most drives are equipped with a MOV that provides voltage surge protection and phase-to-phase plus phase-to-ground protection designed to meet IEEE 587. The MOV circuit is designed for surge suppression (transient line protection) only, not continuous operation.

Figure 2.5 Typical MOV Configuration



Suitable isolation is required for the drive when there is potential for abnormally high phase-to-ground voltages (in excess of 125% for nominal line-to-line voltage), or the supply ground is tied to another system or equipment that could cause the ground potential to vary with operation. An isolation transformer is strongly recommended when this condition exists.

With ungrounded distribution systems, the phase-to-ground MOV connection could become a continuous current path to ground. Energy ratings are listed for each drive (see Figure 2.5 on page 2-8). Exceeding the published phase-to-phase, phase-to-ground voltage or energy ratings may cause physical damage to the MOV. Theses devices should be removed when the drive is used in an ungrounded distribution system.

Common Mode Capacitors

Many drives also contain common mode capacitors that are referenced to ground. To guard against drive damage, these devices should be disconnected if the drive is installed on an ungrounded distribution system where the line-to-ground voltages on any phase could exceed 125% of the nominal line-to-line voltage. Check the appropriate user manual for instructions on removal of these devices. Many drives offer jumpers to remove these devices from the circuitry when used in an ungrounded system.

Grounding

This chapter discusses various grounding schemes for safety and noise reduction.

An effectively grounded system or product is one that is “intentionally connected to earth through a ground connection or connections of sufficiently low impedance and having sufficient current-carrying capacity to prevent the buildup of voltages which may result in undue hazard to connected equipment or to persons” (as defined by the US National Electric Code NFPA70, Article 100B). Grounding of a drive or drive system is done for 2 basic reasons: safety (defined above) and noise containment or reduction. While the safety ground system and the noise current return circuit may sometimes share the same path and components, they should be considered different circuits with different requirements.

Grounding Safety Grounds

The object of safety grounding is to ensure that all metalwork is at the same ground (or Earth) potential at power frequencies. Impedance between the drive and the building system ground must conform to the requirements of national and local industrial safety regulations or electrical codes. These will vary based on country, type of distribution system and other factors. Periodically check the integrity of all ground connections.

General safety dictates that all metal parts are connected to earth with separate copper wire or wires of the appropriate gauge. Most equipment has specific provisions to connect a safety ground or PE (protective earth) directly to it.

Building Steel

If intentionally bonded at the service entrance, the incoming supply neutral or ground will be bonded to the building ground. Building steel is judged to be the best representation of ground or earth. The structural steel of a building is generally bonded together to provide a consistent ground potential. If other means of grounding are used, such as ground rods, the user should understand the voltage potential, between ground rods in different areas of the installation. Type of soil, ground water level and other environmental factors can greatly affect the voltage potential between ground points if they are not bonded to each other.

Grounding PE or Ground

The drive safety ground - PE must be connected to system or earth ground. This is the safety ground for the drive that is required by code. This point must be connected to adjacent building steel (girder, joist), a floor ground rod, bus bar or building ground grid. Grounding points must comply with national and local industrial safety regulations or electrical codes. Some codes may require redundant ground paths and periodic examination of connection integrity.

RFI Filter Grounding

Using an optional RFI filter may result in relatively high ground leakage currents. Therefore, the filter must only be used in installations with grounded AC supply systems and be permanently installed and solidly grounded to the building power distribution ground. Ensure the incoming supply neutral is solidly connected to the same building power distribution ground. Grounding must not rely on flexible cables or any plug or socket that may be accidentally disconnected. Some codes may require redundant ground connections. Periodically check the integrity of all connections. Refer to the instructions supplied with the filter.

Grounding Motors

The motor frame or stator core must be connected directly to the drive PE connection with a separate ground conductor. It is recommended that each motor frame be grounded to building steel at the motor.

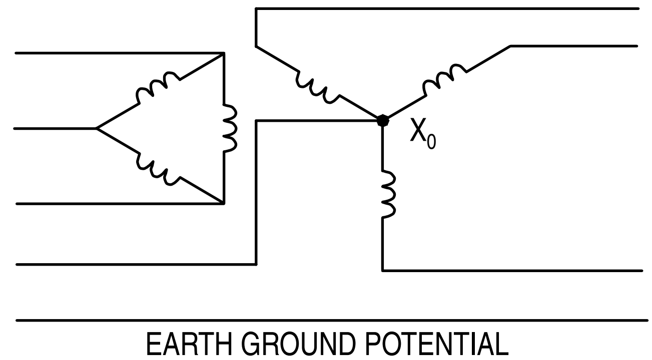
Noise Related Grounds

It is important to take care when installing the PWM AC drive because output can produce high frequency common mode (coupled from output to ground) noise which may cause sensitive equipment to malfunction. The grounding system used can greatly affect the amount of noise and its impact on the system. The power system used is likely to be one of three types:

- Ungrounded System
- System with High Resistance Ground
- Fully Grounded System

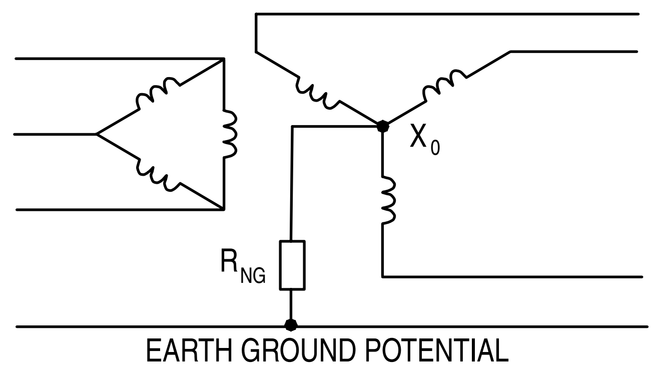
An ungrounded system, as shown in Figure 3.1, breaks the common mode noise path and so does not generally have noise issues.

Figure 3.1 Ungrounded System



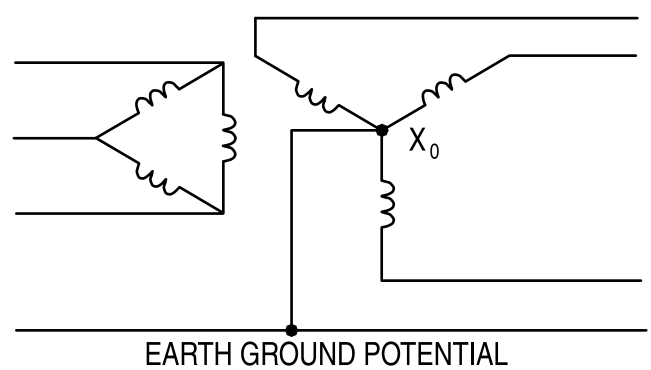
A system with a high resistance ground, shown in Figure 3.2, dampens the common mode noise and reduces its impact.

Figure 3.2 System with High Resistance Ground



A fully grounded system, shown in Figure 3.3, provides a complete noise path and is the most susceptible to common mode noise issues.

Figure 3.3 Fully Grounded System

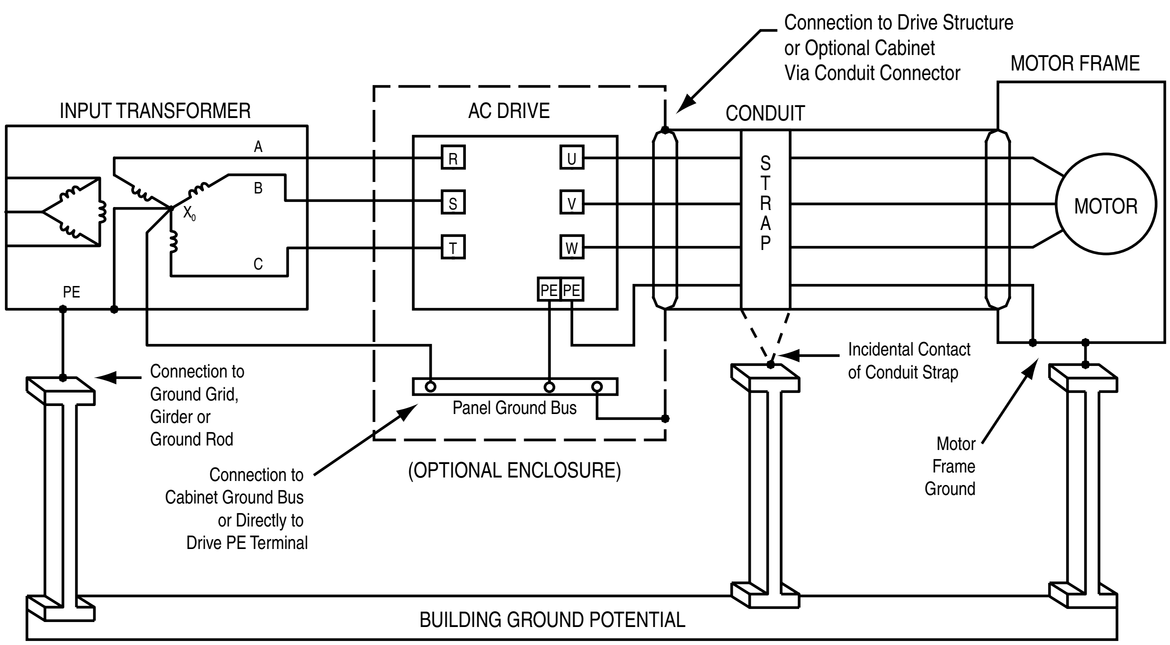


The installation and grounding practices to reduce common mode noise issues can be categorized into three ratings. The system used must weigh additional costs against the operating integrity of all system components. If no sensitive equipment is present and noise is not be an issue, the added cost of shielded cable and other components may not be justified.

Acceptable Grounding Practices

The system shown below is an acceptable ground layout. However, conduit may not offer the lowest impedance path for any high frequency noise. If the conduit is mounted so that it contacts the building steel, it is likely that the building steel will offer a lower impedance path and allow noise to inhabit the ground grid.

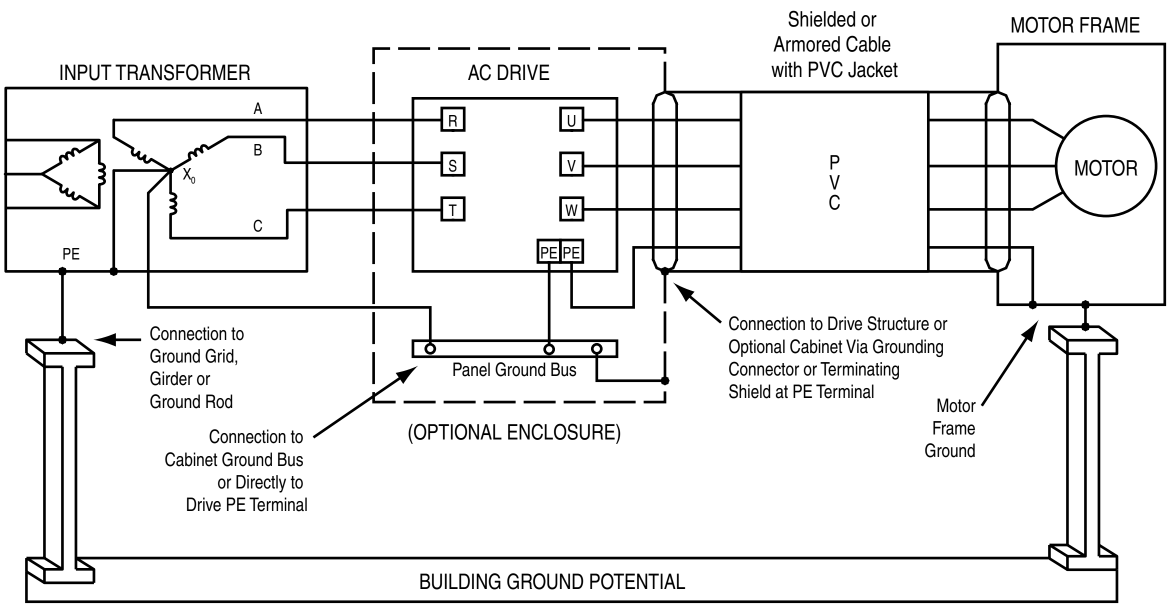
Figure 3.4 Acceptable Grounding



Effective Grounding Practices

This system replaces the conduit with shielded or armored cable that has a PVC exterior jacket. This PVC jacket prevents accidental contact with building steel and reduces the possibility that noise will enter the ground grid.

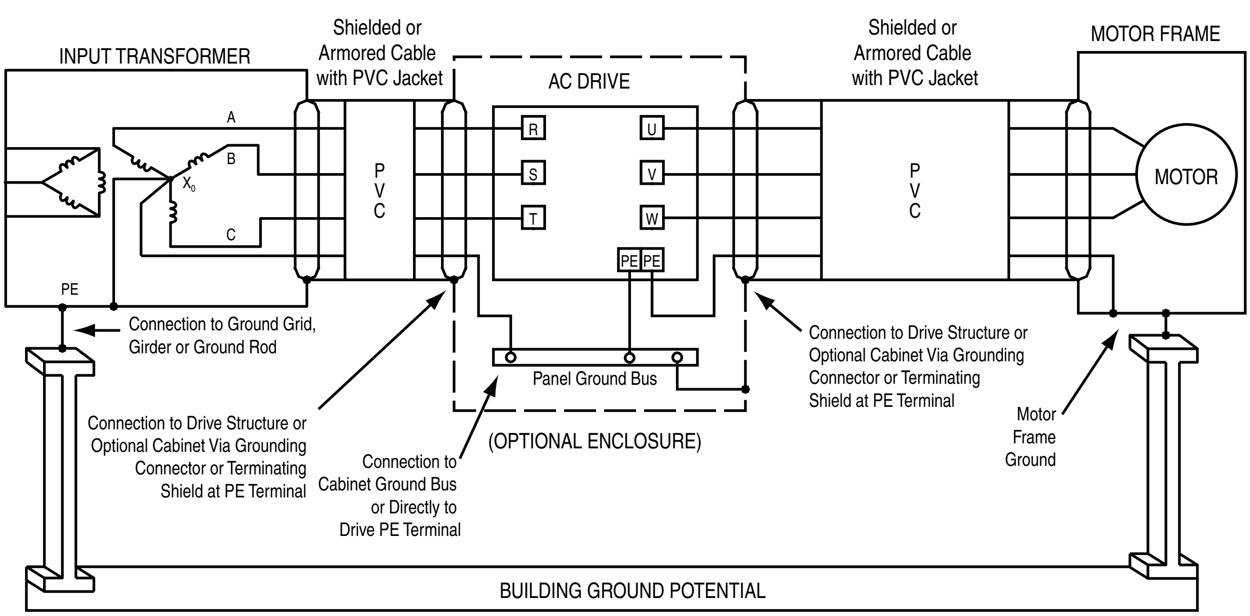
Figure 3.5 Effective Grounding



Optimal - Recommended Grounding Practices

The fully grounded system provides the best containment of common mode noise. It uses PVC jacketed, shielded cable on both the input and the output to the drive. This method also provides a contained noise path to the transformer to keep the ground grid as clean as possible.

Figure 3.6 Optimum Grounding



Cable Shields

Motor and Input Cables

Shields of motor and input cables must be grounded at both ends to provide a continuous noise path.

Control and Signal Cables

Shields of control cables should be connected at one end only. Never connect a shield to the common side of a logic circuit (this will introduce noise into the logic circuit). Connect each shield directly to a chassis ground. Ground each shield at the end specified in the appropriate publication for the product. The other end should be cut back and insulated.

Shields for cables from a cabinet to an external device must be connected at the cabinet end. Shields for cables from one cabinet to another must be connected at the source end cabinet.

Splicing of Shields

If the shielded cable needs to be stripped it should be stripped back as little as possible and ensure that continuity of the shield is not interrupted.

Single Point

A single safety ground point or ground bus bar should be directly connected to the building steel for cabinet installations. All circuits including the AC input ground conductor should be grounded independently and directly to this point/bar.

Isolated Inputs

If the drive's analog inputs are from isolated devices and the output signal is not referenced to the ground, the drive's inputs do not need to be isolated. An isolated input is recommended to reduce the possibility of induced noise if the transducer's signal is referenced to ground and the ground potentials are varied (Refer to Noise Related Grounds on page 3-2). An external isolator can be installed if the drive does not provide input isolation.

Practices

This chapter discusses various installation practices.

Mounting

Standard Installations

A steel enclosure is recommended.

EMC Specific Installations

A steel enclosure is recommended. A steel enclosure can help guard against radiated noise to meet EMC standards. If the enclosure door has a viewing window, it should be a laminated screen or a conductive optical substrate to block EMC.

Do not rely on the hinge for electrical contact between the door and the enclosure - install a bonding wire. For doors 2 m (78 in.) in height, bond two or three (three is preferred) braided straps (top, bottom, and center). EMC seals are not normally required for industrial systems.

Equipment Mounting Plate

To make use of the panel as a part of the grounding system, a zinc plated mild steel mounting plate is preferred. If the mounting plate is painted, remove the paint at each mounting point of every piece of metal-clad equipment (including DIN rails).

Zinc plated steel is strongly recommended due to its inherent ability to bond with the device chassis and resist corrosion. If a painted panel is used and areas of paint are removed, any future corrosion of the unprotected mild steel will compromise noise performance. Plain stainless steel panels are also acceptable but are inferior to zinc plated mild steel due to their higher ohms-per-square resistance.

Layout

Plan the cabinet layout so that drives are separated from sensitive equipment. Choose conduit entry points that allow any common mode noise to remain away from PLCs and other equipment that may be susceptible to noise. Refer to Moisture on page 4-14 for additional information.

Hardware

You can mount the drive and/or mounting panel with either bolts or welded studs.

Figure 4.1 Stud Mounting of Ground Bus or Chassis to Back Panel

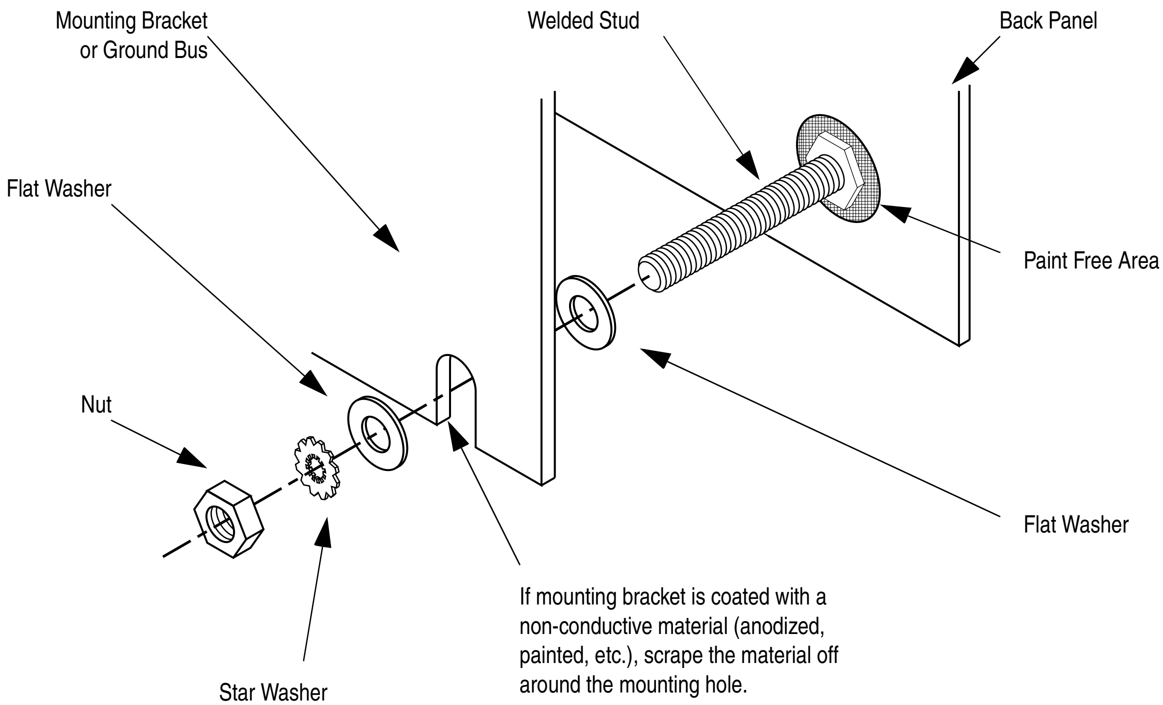
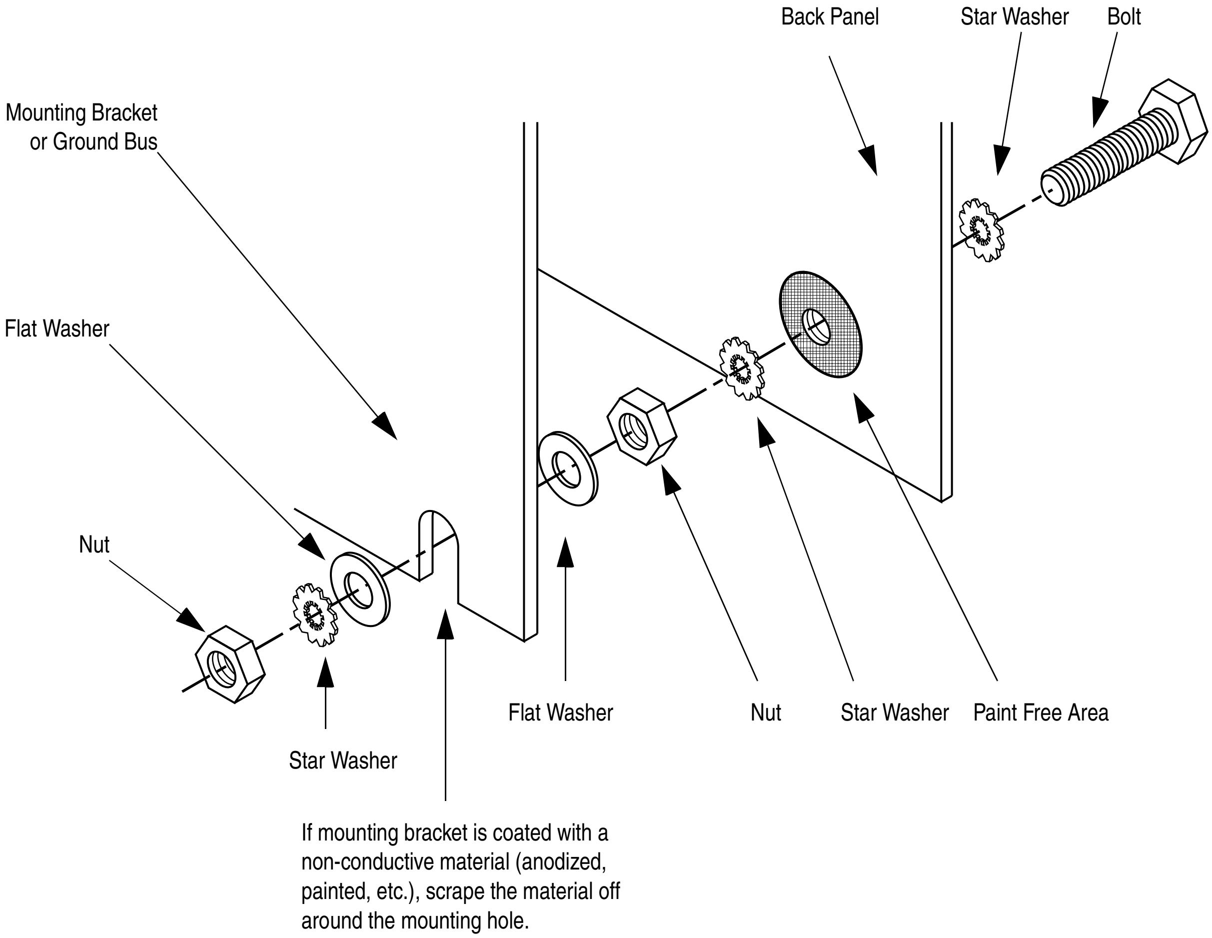


Figure 4.2 Bolt Mounting of Ground Bus or Chassis to Back Panel



If the drive chassis does not lay flat before the nuts / bolts are tightened, use additional washers as shims so that the chassis does not bend when you tighten the nuts.

Conduit Entry

Entry Plates

In most cases, the conduit entry plate will be a paint-free conductive material. The surface of the plate should be clean of oil or contaminants. If the plate is painted, use a connector that cuts through the paint and makes a high quality connection to the plate material

Or

Remove the paint around the holes to the bare metal one inch in from the edge of the plate. Grind down the paint on the top and bottom surfaces. Use a high quality joint compound when reassembling to avoid corrosion.

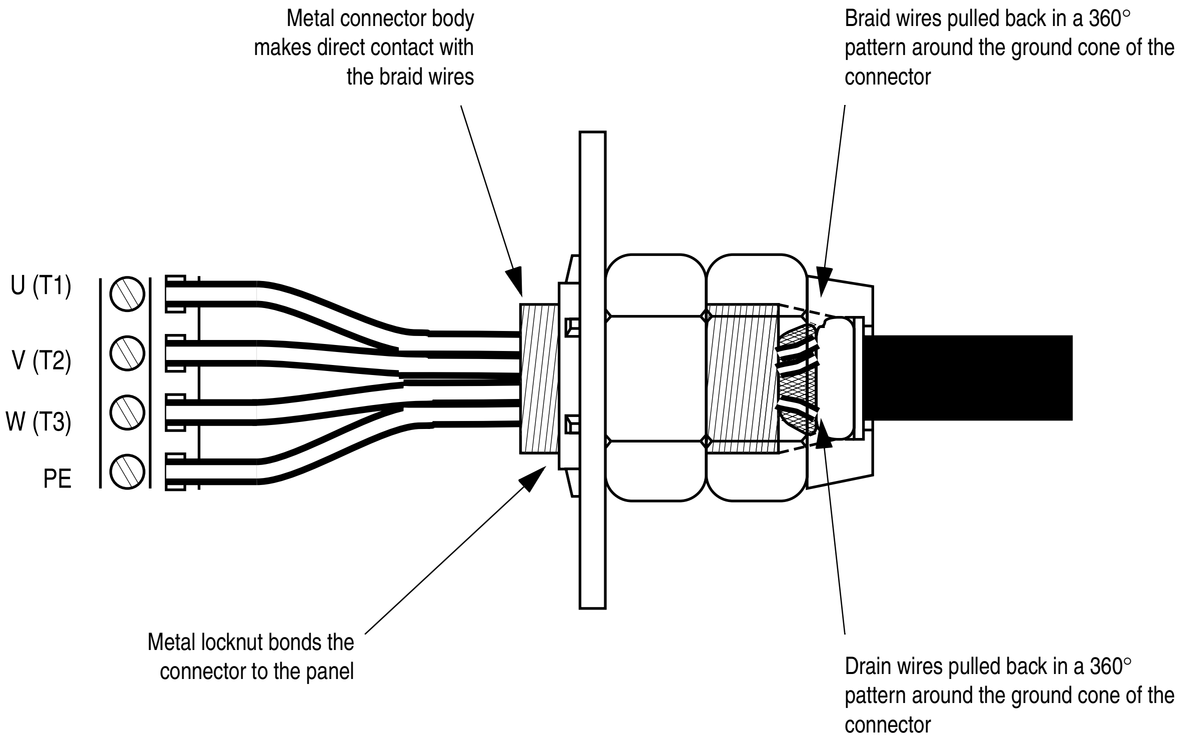
Cable Connectors / Glands

Choose cable connectors or glands that offer the best cable protection, shield termination and ground contact. Refer to Shield Termination on page 4-11 for more information.

Shield terminating connectors

The cable connector selected must provide good 360° contact and low transfer impedance from the shield or armor of the cable to the conduit entry plate at both the motor and the drive or drive cabinet for electrical bonding. Use a connector with 3 ground bushings when using a cable with 3 ground conductors.

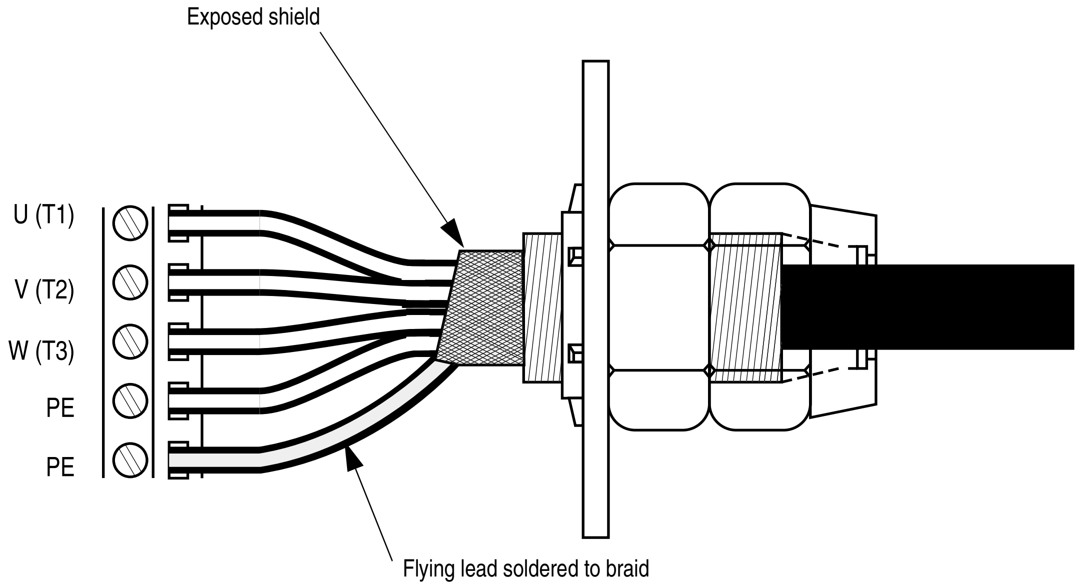
Figure 4.3 Terminating the Shield with a Connector



Shield termination via Pigtail (Lead)

If a shield terminating connector is not available, the ground conductors or shields must be terminated to the appropriate ground terminal. If necessary, use a compression fitting for ground conductor(s) and/or shields together as they leave the cable fitting.

Figure 4.4 Terminating the Shield with a Pigtail Lead



Pigtail termination is the least effective method of noise containment.

It is not recommended if:

- the cable length is greater than 1 m (39 in.) or extends beyond the panel
- in very noisy areas
- the cables are for very noise sensitive signals (for example, registration or encoder cables)
- strain relief is required

If a pigtail is used, pull and twist the exposed shield after separation from the conductors. Solder a flying lead to the braid to extend its length.

Ground Connections

Ground conductors should be connected with care to assure safe and adequate connections.

For individual ground connections, star washers and ring lugs should be used to make connections to mounting plates or other flat surfaces that do not provide proper compression lugs.

If a ground bus system is used in a cabinet, follow the bus bar mounting diagrams.

Figure 4.5 Connections to Ground Bus

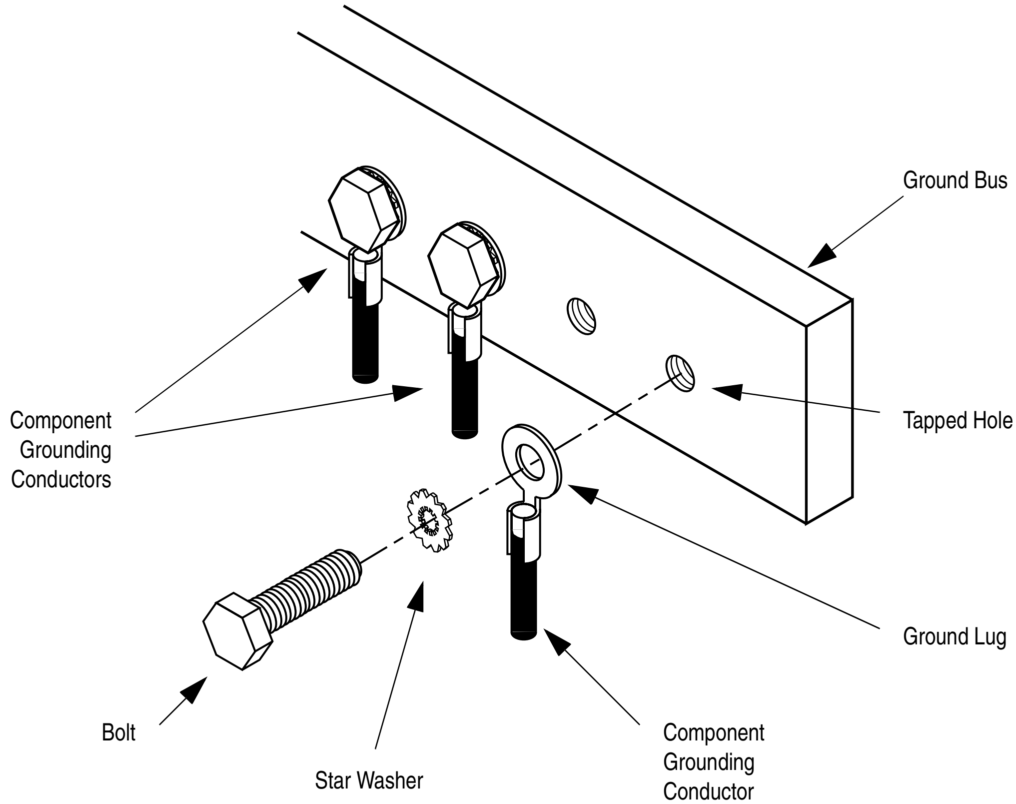
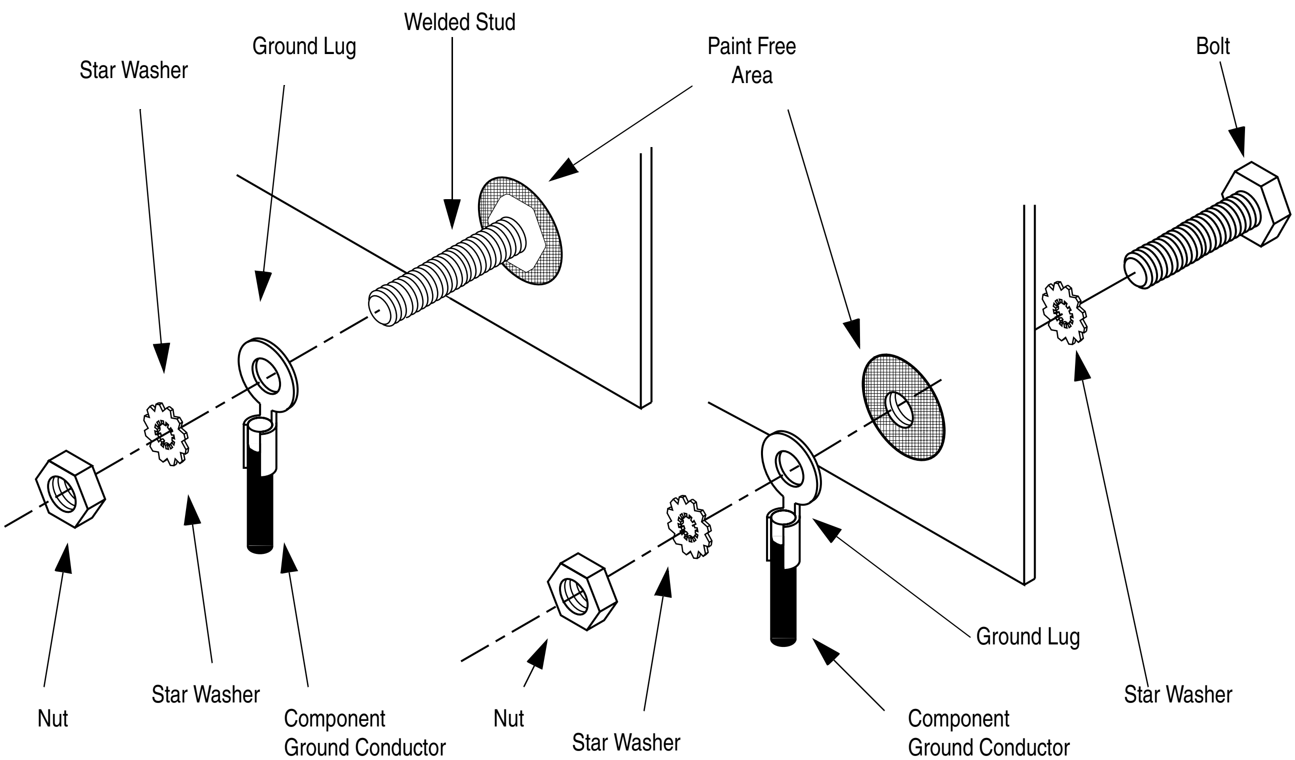
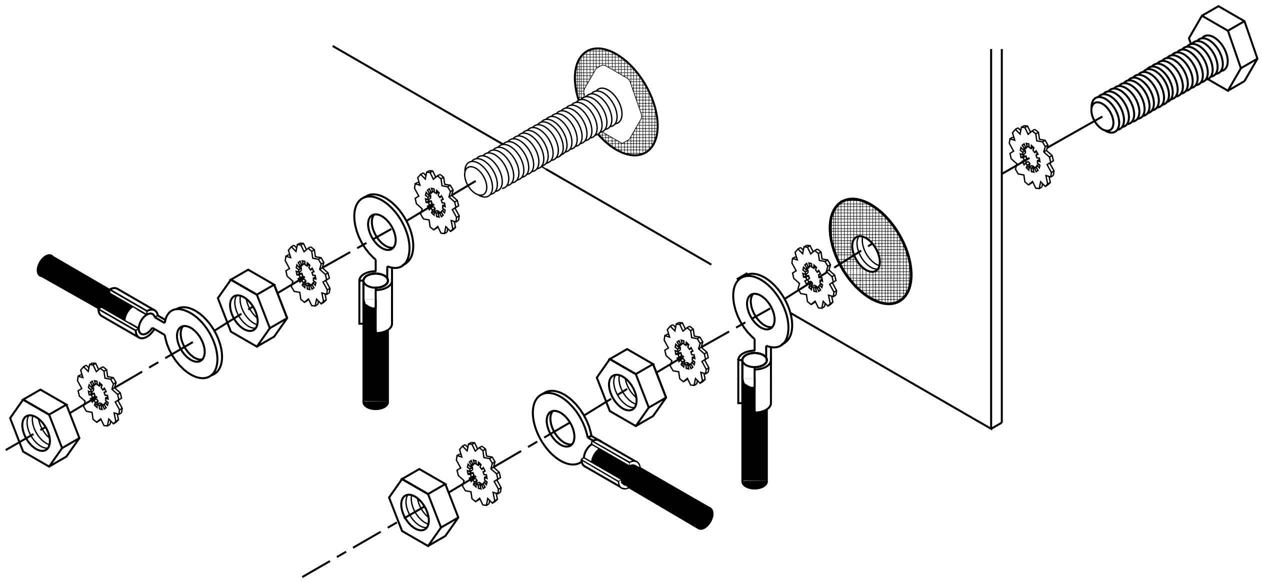


Figure 4.6 Ground Connections to Enclosure Wall



Do not lay one ground lug directly on top of the other. This type of connection can become loose due to compression of the metal lugs. Sandwich the first lug between a star washer and a nut with another star washer following. After tightening the nut, sandwich the second lug between the first nut and a second nut with a captive star washer.

Figure 4.7 Multiple Connections to Ground Stud or Bolts



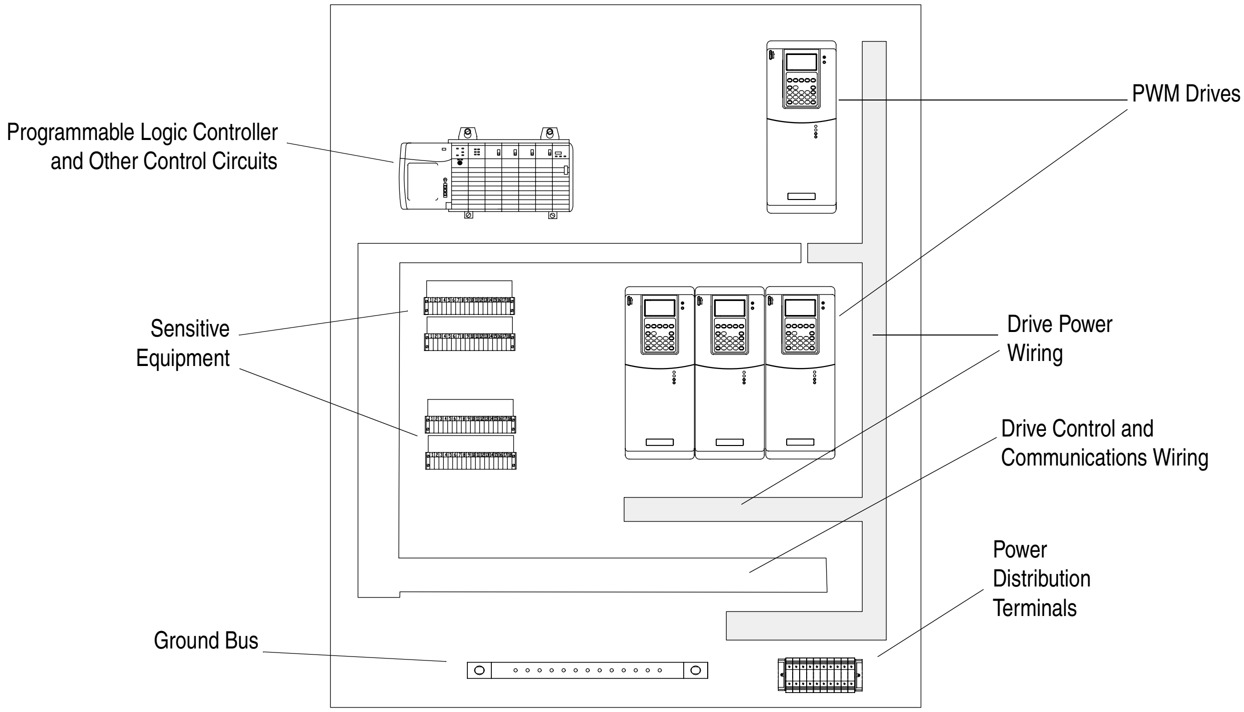
Wire Routing

When routing wiring to a drive, separate high voltage power and motor leads from I/O and signal leads. To maintain separate routes, route these in separate conduit or use tray dividers.

Within A Cabinet

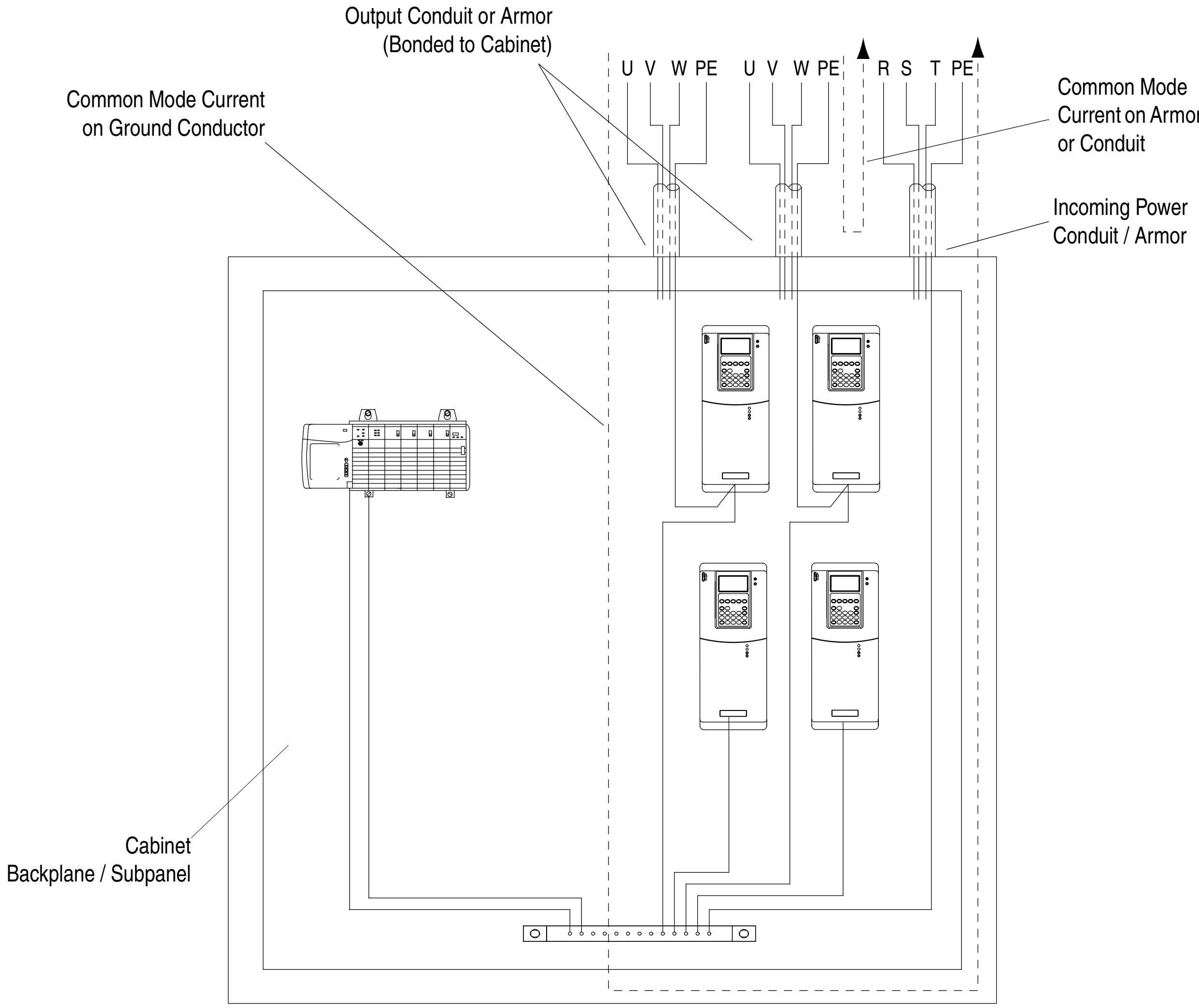
When multiple equipment is mounted in a common enclosure, group the input and output conduit/armor to one side of the cabinet as shown in Separating Susceptible Circuits on page 4-8. Separating any Programmable Logic Controller (PLC) or other susceptible equipment cabling to the opposite side will minimize many effects of drive induced noise currents.

Figure 4.8 Separating Susceptible Circuits



Common mode noise current returning on the output conduit, shielding or armor can flow into the cabinet bond and most likely exit through the adjacent input conduit/armor bond near the cabinet top, well away from sensitive equipment (such as the PLC). Common mode current on the return ground wire from the motor will flow to the copper PE bus and back up the input PE ground wire, also away from sensitive equipment (Refer to Proper Cabinet Ground - Drives & Susceptible Equipment on page 4-9). If a cabinet PE ground wire is run it should be connected from the same side of the cabinet as the conduit/armor connections. This keeps the common mode noise shunted away from the PLC backplane.

Figure 4.9 Proper Cabinet Ground - Drives & Susceptible Equipment



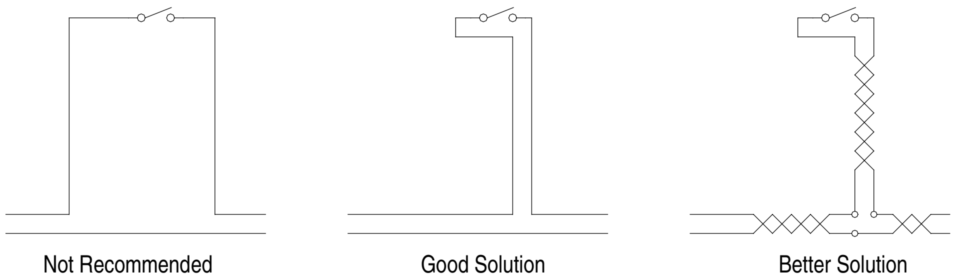
Within Conduit

Do not route more than 3 sets of motor leads (3 drives) in the same conduit. Maintain fill rates per applicable electrical codes. **Do not** run power or motor cables and control or communications cables in the same conduit.

Loops, Antennas and Noise

When routing signal or communications wires, avoid routes that produce loops. Wires that form a loop can form an efficient antenna. Antennas work well in both receive and transmit modes, these loops can be responsible for noise received into the system and noise radiated from the system. Run feed and return wires together rather than allow a loop to form. Twisting the pair together further reduces the antenna effects. Refer to Avoiding Loops in Wiring on page 4-10.

Figure 4.10 Avoiding Loops in Wiring



Conduit

Conduit must be magnetic steel and be installed so as to provide a continuous electrical path through the conduit itself. This path can become important in the containment of high frequency noise.

To avoid nicking, use caution when pulling the wire. Insulation damage can occur when nylon coated wiring such as THHN or THWN is pulled through conduit, particularly 90º bends. Nicking can significantly reduce or remove the insulation. Use great care when pulling nylon coated. Do not use water based lubricants with nylon coated wire such as THHN.

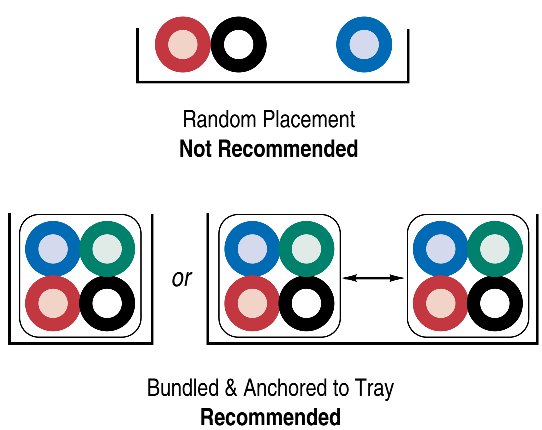
Do not route more than 3 sets of drive cables in one conduit. Maintain the proper fill rates per the applicable electrical codes.

Cable Trays

When laying cable in cable trays, do not randomly distribute them. Power cables for each drive should be bundled together and anchored to the tray. Refer to Figure 4.11 on page 4-10. A minimum separation of one cable width should be maintained between bundles to reduce overheating and cross-coupling. Current flowing in one set of cables can induce a hazardous voltage and / or excessive noise on the cable set of another drive, even when no power is applied to the second drive.
Seperation should also be maintained between power and control cables.

Dividers also provide excellent separation.

Figure 4.11 Cable Tray Practices



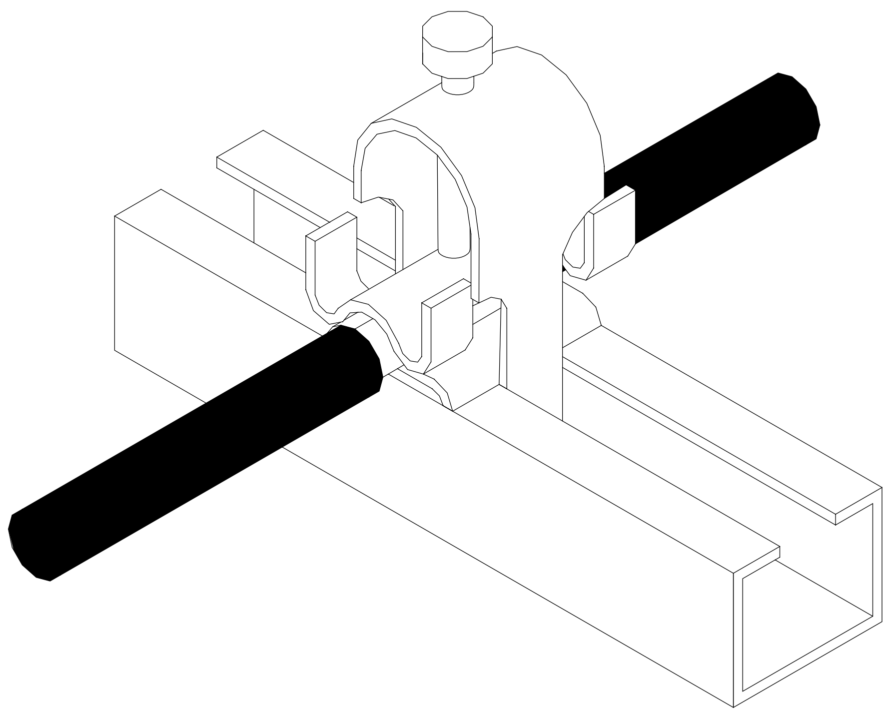
Shield Termination

Refer to Splicing of Shields on page 3-6 to splice shielded cables. The following methods are acceptable if the shield connection to the ground is not accomplished by the gland or connector. Refer to the table associated with each type of clamp for advantages and disadvantages.

Termination via circular clamp

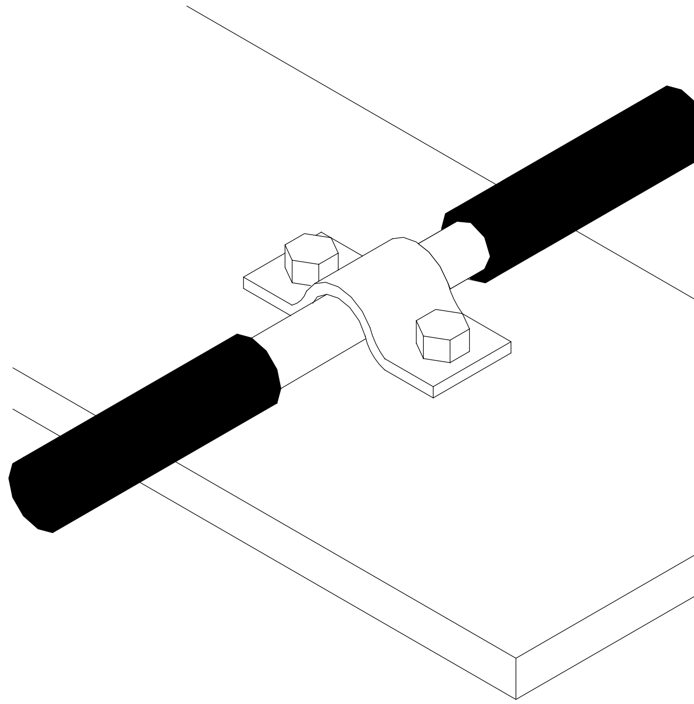
Clamp the cable to the main panel closest to the shield terminal using the circular section clamping method. The preferred method for grounding cable shields is clamping the circular section of 360º bonding, as shown in Commercial Cable Clamp (Heavy Duty) on page 4-11. It has the advantage of covering a wide variety of cable diameters and drilling / mounting is not required. Its disadvantages are cost and availability in all areas.

Figure 4.12 Commercial Cable Clamp (Heavy Duty)



Plain copper saddle clamps, as shown in Figure 4.13 on page 4-12, are sold in many areas for plumbing purposes, but are very effective and available in a range of sizes. They are low cost and offer good strain relief as well. They do require to drill mounting holes.

Figure 4.13 Plain Copper Saddle Clamp



Shield Termination via Pigtail (Lead)

If a shield terminating connector is not available, the ground conductors and/or shields must be terminated to the appropriate ground terminal. If necessary, use a compression fitting on the ground conductor(s) or shield together as they leave the cable fitting.

Pigtail termination is the least effective method of noise containment.

It is not recommended if:

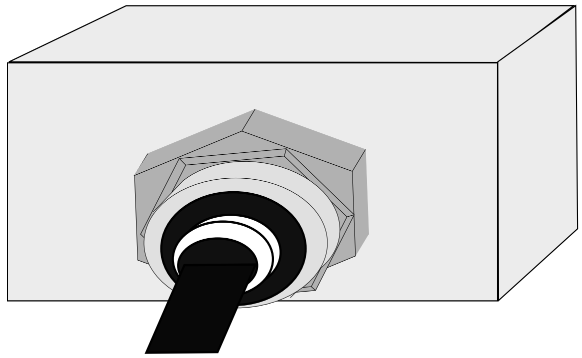
- the cable length is greater than 1 m (39 in.) or extends beyond the panel.
- being used in very noisy areas
- the cables are for very noise sensitive signals (for example, registration or encoder cables)
- strain relief is required

If a pigtail is used, pull and twist the exposed shield after separation from the conductors. To extend the length, solder a flying lead to the braid.

Shield Termination via Gland Clamp

Conductive gland grounding, see Figure 4.14 on page 4-13, is a simple method for terminating shields, but may carry unnecessary cost. It is normally only required for extreme applications, such as radar, aerospace, etc. It is the most effective method and offers excellent strain relief. It is only applicable when entry is through a cabinet surface or bulkhead.

Figure 4.14 Gland Clamp



Conductor Termination

Terminate power, motor and control connections to the drive terminal blocks. User manuals list minimum and maximum wire gauges, tightening torque for terminals and recommended lug types if stud connections are provided. Check for recommended conduit connector / gland locations to help maintain separation of power and control wiring. Bending radii minimums per the applicable electrical code should be followed.

Power TB

Power terminals are normally fixed (non-pull apart) and can be cage clamps, barrier strips or studs for ring type crimp lugs depending on the drive style and rating. Cage clamp styles may require a non-standard screwdriver. Crimp lugs will require a crimping tool. On smaller sizes, a stripping gauge may be provided on the drive to assist in the amount of insulation to remove. Normally the three phase input is not phase sensitive. That is, the sequence of A,B,C phases has no effect on the operation of the drive or the direction of motor rotation.

Control TB

Control terminal blocks are either pull apart or fixed (non pull apart). Terminals will be either spring clamp type or barrier strip. A stripping gauge may be provided on the drive to assist in the amount of insulation to remove. Some control connections, such as analog input and output signals, are polarity sensitive. Consult the applicable user manual for correct connection.

Signal TB

If an encoder or tachometer feedback is used, a separate terminal block or blocks may be provided. Consult the user manual for these phase sensitive connections. Improper wiring could lead to incorrect drive operation.

Cables terminated here are typically shielded and the signals being carried are generally more sensitive to noise. Carefully check the user manual for recommendations on shield termination. Some shields can be terminated at the terminal block and others will be terminated at the entry point.

Moisture

The U.S. NEC defines “dry, damp and wet” locations. It permits the use of heat-resistant thermoplastic wire in both dry and damp applications (Table 310-13). However, PVC insulation material is more susceptible to absorbing moisture than XLPE (Cross Linked polyethylene) insulation material (XHHW-2) identified for use in wet locations. Because the PVC insulating material absorbs moisture, the corona inception voltage (CIV) insulation capability of the “damp” or “wet” THHN was found to be less than ½ of the same wire when “dry.” For this reason, certain industries where water is prevalent in the environment have refrained from using THHN wire with IGBT drives.

Belden 29500 style cable is a PVC jacketed, shielded type TC with XLPE conductor insulation designed to meet NEC code designation XHHW-2 (use in wet locations per the U.S. NEC, Table 310-13). Based on Rockwell Automation research, tests have determined this cable is notably superior to loose wires in dry, damp and wet applications and can significantly reduce capacitive coupling and common mode noise. Other cable types for wet locations include continuous welded armor cables or CLX designation.

Reflected Wave

This chapter discusses the reflected wave phenomenon and its impact on drive systems.

Description

The inverter section of a drive does not produce sinusoidal voltage, but rather a series of voltage pulses created from the DC bus. These pulses travel down the motor cables to the motor. The pulses are then reflected back to the drive. The reflection is dependent on the rise time of the drive output voltage, cable characteristics, cable length and motor impedance. If the voltage reflection is combined with another, subsequent pulse, peak voltages can be at a destructive level. A single IGBT drive output may have reflected wave transient voltage stresses of up to twice (2 pu or per unit) the DC bus voltage between its own output wires. Multiple drive output wires in a single conduit or wire tray further increase output wire voltage stress between multi-drive output wires that are touching. Drive #1 may have a (+) 2 pu stress while drive #2 may simultaneously have a (-) 2 pu stress.

Wire Types And Effects On Them

Wires with dielectric constants greater than 4 cause the voltage stress to shift to the air gap between the wires that are barely touching. This electric field may be high enough to ionize the air surrounding the wire insulation and cause a partial discharge mechanism (corona) to occur. The electric field distribution between wires increases the possibility for corona and greater ozone production. This ozone attacks the PVC insulation and produces carbon tracking, leading to the possibility of insulation breakdown.

Based on field and internal testing, Rockwell Automation/Allen-Bradley has determined conductors manufactured with Poly-Vinyl Chloride (PVC) wire insulation are subject to a variety of manufacturing inconsistencies which can lead to premature insulation degradation when used with IGBT drives. Flame-retardant heat-resistant thermoplastic insulation is the type of insulation listed in the NEC code for the THHN wire designation. This type of insulation is commonly referred to as PVC. In addition to manufacturing inconsistencies, the physical properties of the cable can change due to environment, installation and operation, which can also lead to premature insulation degradation. The following is a summary of our findings:

Due to inconsistencies in manufacturing processes or wire pulling, air voids can also occur in the THHN wire between the nylon jacket and PVC insulation. Because the dielectric constant of air is much lower than the dielectric constant of the insulating material, the transient reflected wave voltage might appear across these voids. If the corona inception voltage (CIV) for the air void is reached, ozone is produced. Ozone attacks the PVC insulation leading to a breakdown in cable insulation.

Asymmetrical construction of the insulation has also been observed for some manufacturers of PVC wire. A wire with a 15 mil specification was observed to have an insulation thickness of 10 mil at some points. The smaller the insulation thickness, the less voltage the wire can withstand.

THHN jacket material has a relatively brittle nylon that lends itself to damage (i.e. nicks and cuts) when pulled through conduit on long wire runs. This issue is of even greater concern when the wire is being pulled through multiple 90º bends in the conduit. These nicks may be a starting point for CIV leading to insulation degradation.

During operation, the conductor heats up and a “coldflow” condition may occur with PVC insulation at points where the unsupported weight of the wire may stretch the insulation. This has been observed at 90º bends where wire is dropped down to equipment from an above wireway. This “coldflow” condition produces thin spots in the insulation which lowers the cable's voltage withstand capability.

The U.S. NEC 1996 code defines “dry, damp and wet” locations (7-31) and permits the use of heat-resistant thermoplastic wire in both dry and damp applications (Table 310-13). However, PVC insulation material is more susceptible to absorbing moisture than XLPE (Cross Linked polyethylene) insulation material (XHHN-2) identified for use in wet locations. Because the PVC insulating material absorbs moisture, the Corona Inception Voltage insulation capability of the “damp” or “wet” THHN was found to be less than ½ of the same wire when “dry.” For this reason, certain industries where water is prevalent in the environment have refrained from using THHN wire with IGBT drives. Rockwell Automation strongly suggests the use of XLPE insulation for wet areas.

Length Restrictions For Motor Protection

To protect the motor from reflected waves, limit the length of the motor cables from the drive to the motor. Each drive's user manual lists the lead length limitations based on drive size and the quality of the insulation system in the chosen motor.

If the distance between drive and motor must exceed these limits, contact the local office or factory for analysis and advice. Refer to Appendix A for complete tables.

Common Mode Noise

This chapter discusses common mode noise and its impact on drive systems.

What Causes Common Mode Noise

Faster output dv/dt transitions of IGBT drives increase the possibility for increased Common Mode (CM) electrical noise. Common Mode Noise is a type of electrical noise induced on signals with respect to ground.

There is a possibility for electrical noise from drive operation to interfere with adjacent sensitive electronic equipment, especially in areas where many drives are concentrated. Generating common mode currents by varying frequency inverters is similar to the common mode currents that occur with DC drives. Although AC drives produce a much higher frequency then DC drives (250 kHz - 6MHz). Inverters have a greater potential for exciting circuit resonance because of very fast turn on switches causing common mode currents to look for the lowest impedance path back to the inverter. The dv/dt and di/dt from the circulating ground currents can couple into the signal and logic circuits, causing improper operation and possible circuit damage. When conventional grounding techniques do not.work you must use high frequency bonding techniques. High Frequency bonding techniques must be employed when the conventional grounding techniques fail. If these techniques are not followed, bearing currents increase, circuit boards have the potential to fail prematurely, and the ground system has higher then normal current problems with computer systems and distributed control systems.

Containing Common Mode Noise With Cabling

Cable type has a great effect on the ability to contain common mode noise in a system that incorporates a drive.

Conduit

Combining the ground conductor and the conduit absorb most capacitive current and returns it to the drive without polluting the ground grid. A conduit may still have unintended contact with grid ground structure due to straps, support, etc. The AC resistance characteristics of earth are generally variable and unpredictable, making it difficult to predict how noise current will divide between wire, conduit or the ground grid.

Shielded or Armored Power Cable

The predominant return path for common mode noise is the shield/armor itself when using shielded or armored power cables. Unlike conduit, the shield/armor is isolated from accidental contact with grounds by a PVC outer coating. Making the majority of noise current flow in the controlled path and very little high frequency noise flows into the ground grid.

Noise current returning on the shield or safety ground wire is routed to the drive PE terminal, down to the cabinet PE ground bus, and then directly to the grounded neutral of the drive source transformer. The cable's radiated emissions are minimal because the armor completely covers the noisy power wires. Also, the armor prevents EMI coupling to other signal cables that might be routed in the same cable tray.

Another effective method of reducing common mode noise is to attenuate it before it can reach the ground grid. Installing a common mode ferrite core on the output cables can reduce the amplitude of the noise to a level that makes it relatively harmless to sensitive equipment or circuits. Common mode cores are most effective when multiple drives are located in a relatively small area.

As a general rule:

IF the distance between the drive and motor or the distance between drive and input transformer is greater than 75 feet.

AND

IF sensitive circuits with leads greater then 75 feet such as: encoders, analog, or capacitive sensors are routed, in or out of the cabinet, near the drive or transformer

THEN

Common mode chokes should be installed.

Motor Cable Length Restrictions Tables

The distances listed in each table are valid only for specific cable constructions and may not be accurate for lesser cable designs, particularly if the length restriction is due to cable charging current (indicated in tables by shading). When choosing the proper cable, note the following definitions:

Unshielded Cable

- Tray cable - fixed geometry without foil or braided shield but including an exterior cover
- Individual wires not routed in metallic conduit

Shielded Cable

- Individual conductors routed in metallic conduit
- Fixed geometry cables with no twist in the conductors and with foil or braided shield of at least 75% coverage
- Continuous weld or interlocked armored cables with no twist in the conductors (may have and optional foil shield)

Important: Certain shielded cable constructions may cause excessive cable charging currents and may interfere with proper application performance, particularly on smaller drive ratings. Shielded cables that do not maintain a fixed geometry, but rather twist the conductors and tightly wrap the bundle with a foil shield may cause unnecessary drive tripping. Unless specifically stated in the table, the distances listed ARE NOT applicable to this type of cable. Actual distances for this cable type may be considerably less.

Type A Motor

- No phase paper or misplaced phase paper
- Lower quality insulation systems
- Corona inception voltages between 850 and 1000 volts

Type B Motor

- Properly placed phase paper
- Medium quality insulation systems
- Corona inception voltages between 1000 and 1200 volts

1488V Motor

- Meets NEMA MG 1-1998 section 31 standard
- Insulation can withstand voltage spikes of 3.1 times rated motor voltage due to inverter operation.

1329 R/L Motor

- AC variable speed motors are “Control-Matched” for use with Allen-Bradley drives.
- Motor designed to meet or exceed the requirements of the Federal Energy Act of 1992.
- Optimized for variable speed operation and include premium inverter grade insulation systems, which meet or exceed NEMA MG1 (Part 31.40.4.2).

TIP: To increase the distance between the drive and the motor, some device (RWR or Terminator) needs to be added to the system

Table A.A 1336 PLUS II/IMPACT Drive, 380-480V in meters (feet)[1]

Drive Frame	Drive kW (HP)	Motor kW (HP)	No External Devices – Motor A – Any Cable	No External Devices – Motor B – Any Cable	No External Devices – Motor 1329 – Any Cable	No External Devices – Motor 1329R/L (1850V) – Any Cable[6]	w/1204-TFB2 Term. – Motor A or B – Cable Type Shld[3]	w/1204-TFB2 Term. – Motor A or B – Cable Type Unshld.	w/1204-TFB2 Term. – Motor 1329 – Any Cable	w/1204-TFA1 Terminator – Motor A – Cable Type Shld.[3]	w/1204-TFA1 Terminator – Motor A – Cable Type Unshld.	w/1204-TFA1 Terminator – Motor B – Cable Type Shld.[3]	w/1204-TFA1 Terminator – Motor B – Cable Type Unshld.	w/1204-TFA1 Terminator – Motor 1329 – Any Cable	Reactor at Drive[2] – Motor A – Any Cable	Reactor at Drive[2] – Motor B or 1329 – Any Cable
A1	0.37 (0.5)	0.37 (0.5)	12.2 (40)	33.5 (110)	91.4 (300)	91.4 (300)				30.5 (100)	61.0 (200)	30.5 (100)	61.0 (200)	91.4 (300)	22.9 (75)	182.9 (600)
	0.75 (1)	0.75 (1)	12.2 (40)	33.5 (110)	91.4 (300)	91.4 (300)				30.5 (100)	30.5 (100)	30.5 (100)	30.5 (100)	91.4 (300)	22.9 (75)	182.9 (600)
		0.37 (0.5)	12.2 (40)	33.5 (110)	91.4 (300)	91.4 (300)	Use 1204-TFA1			30.5 (100)	61.0 (200)	30.5 (100)	61.0 (200)	91.4 (300)	22.9 (75)	182.9 (600)
	1.2 (1.5)	1.2 (1.5)	12.2 (40)	33.5 (110)	91.4 (300)	91.4 (300)				30.5 (100)	30.5 (100)	61.0 (200)	61.0 (200)	91.4 (300)	22.9 (75)	182.9 (600)
		0.75 (1)	12.2 (40)	33.5 (110)	91.4 (300)	91.4 (300)				30.5 (100)	30.5 (100)	61.0 (200)	61.0 (200)	91.4 (300)	22.9 (75)	182.9 (600)
		0.37 (0.5)	12.2 (40)	33.5 (110)	114.3 (375)	121.9 (400)				30.5 (100)	30.5 (100)	61.0 (200)	61.0 (200)	121.9 (400)	22.9 (75)	182.9 (600)
A2	1.5 (2)	1.5 (2)	7.6 (25)	12.2 (40)	91.4 (300)	91.4 (300)	91.4 (300)	91.4 (300)	91.4 (300)	30.5 (100)	30.5 (100)	91.4 (300)	61.0 (200)	91.4 (300)	22.9 (75)	182.9 (600)
		1.2 (1.5)	7.6 (25)	12.2 (40)	114.3 (375)	182.9 (600)	91.4 (300)	182.9 (600)	182.9 (600)	30.5 (100)	30.5 (100)	91.4 (300)	61.0 (200)	182.9 (600)	22.9 (75)	182.9 (600)
		0.75 (1)	7.6 (25)	12.2 (40)	114.3 (375)	182.9 (600)	182.9 (600)	182.9 (600)	182.9 (600)	30.5 (100)	30.5 (100)	91.4 (300)	61.0 (200)	182.9 (600)	22.9 (75)	182.9 (600)
		0.37 (0.5)	7.6 (25)	12.2 (40)	114.3 (375)	182.9 (600)	182.9 (600)	182.9 (600)	182.9 (600)	30.5 (100)	30.5 (100)	91.4 (300)	61.0 (200)	182.9 (600)	22.9 (75)	182.9 (600)
	2.2 (3)	2.2 (3)	7.6 (25)	12.2 (40)	91.4 (300)	91.4 (300)	182.9 (600)	182.9 (600)	182.9 (600)	Use 1204-TFB2					22.9 (75)	182.9 (600)
		1.5 (2)	7.6 (25)	12.2 (40)	114.3 (375)	182.9 (600)	182.9 (600)	182.9 (600)	182.9 (600)						22.9 (75)	182.9 (600)
		0.75 (1)	7.6 (25)	12.2 (40)	114.3 (375)	182.9 (600)	182.9 (600)	182.9 (600)	182.9 (600)						22.9 (75)	182.9 (600)
		0.37 (0.5)	7.6 (25)	12.2 (40)	114.3 (375)	182.9 (600)	182.9 (600)	182.9 (600)	182.9 (600)						22.9 (75)	182.9 (600)
A3	3.7 (5)	3.7 (5)	7.6 (25)	12.2 (40)	114.3 (375)	**Note** For applications/installations using new motors, no restrictions in lead length due to voltage reflection are necessary. You should observe standard practices for voltage drop, cable capacitance, and other issues. For retrofit situations, check with the motor manufacturer for insulation rating.	182.9 (600)	182.9 (600)	182.9 (600)						22.9 (75)	182.9 (600)
		2.2 (3)	7.6 (25)	12.2 (40)	114.3 (375)		182.9 (600)	182.9 (600)	182.9 (600)						22.9 (75)	182.9 (600)
		1.5 (2)	7.6 (25)	12.2 (40)	114.3 (375)		182.9 (600)	182.9 (600)	182.9 (600)						22.9 (75)	182.9 (600)
		0.75 (1)	7.6 (25)	12.2 (40)	114.3 (375)		182.9 (600)	182.9 (600)	182.9 (600)						22.9 (75)	182.9 (600)
		0.37 (0.5)	7.6 (25)	12.2 (40)	114.3 (375)		182.9 (600)	182.9 (600)	182.9 (600)						22.9 (75)	182.9 (600)
A4	5.5-15 (7.5-20)	5.5-15 (7.5-20)	7.6 (25)	12.2 (40)	114.3 (375)		182.9 (600)	182.9 (600)	182.9 (600)						24.4 (80)	182.9 (600)
B	11-22 (15-30)	11-22 (15-30)	7.6 (25)	12.2 (40)	114.3 (375)		182.9 (600)	182.9 (600)	182.9 (600)						24.4 (80)	182.9 (600)
C	30-45 (X40-X60)	30-45 (40-60)	7.6 (25)	12.2 (40)	114.3 (375)		182.9 (600)	182.9 (600)	182.9 (600)						76.2 (250)	182.9 (600)
D	45-112 (60-X150)	45-112 (60-150)	12.2 (40)	30.5 (100)	114.3 (375)		182.9 (600)	182.9 (600)	182.9 (600)						61.0 (200)	91.4 (300)
E	112-187 (150-250)	112-187 (150-250)	12.2 (40)	53.3 (175)	114.3 (375)		182.9 (600)	182.9 (600)	182.9 (600)						182.9 (600)	182.9 (600)
F	187-336 (250-450)	187-336 (250-450)	18.3 (60)	53.3 (175)	114.3 (375)		182.9 (600)	182.9 (600)	182.9 (600)						182.9 (600)	182.9 (600)
G	187-448 (X250-600)	187-448 (250-600)	18.3 (60)	53.3 (175)	114.3 (375)		182.9 (600)	182.9 (600)	182.9 (600)						182.9 (600)	182.9 (600)

Table A.B 1336 PLUS II/IMPACT Drive, 600V in meters (feet)❹

			No External Devices			w/1204-TFB2 Terminator			w/1204-TFA1 Terminator			Reactor at Drive❷		
			Motor			Motor			Motor			Motor		
			A	B	1329R/L ❺	A	B	1329R/L ❺	A	B	1329R/L ❺	A	B	1329R/L ❺
Drive Frame	**Drive kW (HP)**	**Motor kW (HP)**	Any Cable	Any Cable	Any Cable	Any Cable	Any Cable	Any Cable	Any Cable	Any Cable	Any Cable	Any Cable	Any Cable	Any Cable
A4	0.75 (1)	0.75 (1)	NR	NR	NA	NR	182.9 (600)	335.3 (1100)	NR	61.0 (200)	182.9 (600)	Not Recommended		
		0.37 (0.5)	NR	NR	NA	NR	182.9 (600)	335.3 (1100)	NR	61.0 (200)	182.9 (600)			
	1.5 (2)	1.5 (2)	NR	NR	NA	NR	182.9 (600)	335.3 (1100)	NR	61.0 (200)	182.9 (600)			
		1.2 (1.5)	NR	NR	NA	NR	182.9 (600)	335.3 (1100)	NR	61.0 (200)	182.9 (600)			
		0.75 (1)	NR	NR	182.9 (600)	NR	182.9 (600)	335.3 (1100)	NR	61.0 (200)	182.9 (600)			
		0.37 (0.5)	NR	NR	182.9 (600)	NR	182.9 (600)	335.3 (1100)	NR	61.0 (200)	182.9 (600)			
	2.2 (3)	2.2 (3)	NR	NR	NA	NR	182.9 (600)	335.3 (1100)	NR	61.0 (200)	182.9 (600)			
		1.5 (2)	NR	NR	NA	NR	182.9 (600)	335.3 (1100)	NR	61.0 (200)	182.9 (600)			
		0.75 (1)	NR	NR	182.9 (600)	NR	182.9 (600)	335.3 (1100)	NR	61.0 (200)	182.9 (600)			
		0.37 (0.5)	NR	NR	182.9 (600)	NR	182.9 (600)	335.3 (1100)	NR	61.0 (200)	182.9 (600)			
	3.7 (5)	3.7 (5)	NR	NR	NA	NR	182.9 (600)	335.3 (1100)	NR	61.0 (200)	182.9 (600)			
		2.2 (3)	NR	NR	NA	NR	182.9 (600)	335.3 (1100)	NR	61.0 (200)	182.9 (600)			
		1.5 (2)	NR	NR	182.9 (600)	NR	182.9 (600)	335.3 (1100)	NR	61.0 (200)	182.9 (600)			
		0.75 (1)	NR	NR	182.9 (600)	NR	182.9 (600)	335.3 (1100)	NR	61.0 (200)	182.9 (600)			
		0.37 (0.5)	NR	NR	182.9 (600)	NR	182.9 (600)	335.3 (1100)	NR	61.0 (200)	182.9 (600)			
	5.5-15 (7.5-20)	5.5-15 (7.5-20)	NR	9.1 (30)	182.9 (600)	91.4 (300)	182.9 (600)	182.9 (600)	NR	61.0 (200)	182.9 (600)	30.5 (100)	91.4 (300)	182.9 (600)
C	18.5-45 (25-60)	18.5-45 (25-60)	NR	9.1 (30)	182.9 (600)	91.4 (300)	182.9 (600)	182.9 (600)	NR	61.0 (200)	182.9 (600)	30.5 (100)	91.4 (300)	182.9 (600)
D	56-93 (75-125)	56-93 (75-125)	NR	9.1 (30)	182.9 (600)	91.4 (300)	182.9 (600)	182.9 (600)	NR	61.0 (200)	182.9 (600)	61.0 (200)	91.4 (300)	182.9 (600)
E	112-224 (150-X300)	112-224 (150-X300)	NR	9.1 (30)	182.9 (600)	91.4 (300)	182.9 (600)	182.9 (600)	NR	61.0 (200)	182.9 (600)	182.9 (600)	182.9 (600)	182.9 (600)
F	261-298 (350-400)	261-298 (350-400)	NR	9.1 (30)	182.9 (600)	91.4 (300)	182.9 (600)	182.9 (600)	NR	61.0 (200)	182.9 (600)	182.9 (600)	182.9 (600)	182.9 (600)
G	224-448 (300-600)	224-448 (300-600)	NR	9.1 (30)	182.9 (600)	91.4 (300)	182.9 (600)	182.9 (600)	NR	61.0 (200)	182.9 (600)	182.9 (600)	182.9 (600)	182.9 (600)

NR = Not Recommended

NA = Not Available at time of printing

❶ Values shown are for nominal input voltage, drive carrier frequency of 2 kHz or as shown and surrounding air temperature at the motor of 40° C. Consult factory regarding operation at carrier frequencies above 2 kHz. Multiply values by 0.85 for high line conditions. For input voltages of 380, 400 or 415V AC, multiply the table values by 1.25, 1.20 or 1.15, respectively.

❷ A 3% reactor reduces motor and cable stress but may cause a degradation of motor waveform quality. Reactors must have a turn-turn insulation rating of 2100 Volts or higher.

❸ Includes wire in conduit.

❹ Values shown are for nominal input voltage and drive carrier frequency of 2 kHz. Consult factory regarding operation at carrier frequencies above 2 kHz.

❺ When used on 600V systems, 1329R/L motors have a corona inception voltage rating of approximately 1850V.

❻ These distance restrictions are due to charging of cable capacitance and may vary from application to application.

Table A.C 1305 Drive, 480V in meters (feet)

Drive HP (480V)	Motor HP (480V)	No External Devices at the Motor (480V) Using a Motor with Insulation V_{P-P}			
		Type A	Type B	1329R/L	
		Any Cable	Any Cable	Shielded Cable	Unshielded Cable
Maximum Carrier Frequency		4 kHz	4 kHz	2 kHz	2 kHz
High-Line Derate Multiplier		0.85	0.85	0.55	0.55
5	5	9m (30ft)	30m (100ft)	121m (400ft)	121m (400ft)
	3	9m (30ft)	30m (100ft)	121m (400ft)	121m (400ft)
	2	9m (30ft)	30m (100ft)	121m (400ft)	121m (400ft)
	1	9m (30ft)	30m (100ft)	121m (400ft)	121m (400ft)
	0.5	9m (30ft)	30m (100ft)	121m (400ft)	121m (400ft)
3	3	9m (30ft)	30m (100ft)	91m (300ft)	121m (400ft)
	2	9m (30ft)	30m (100ft)	121m (400ft)	121m (400ft)
	1	9m (30ft)	30m (100ft)	121m (400ft)	121m (400ft)
	0.5	9m (30ft)	30m (100ft)	121m (400ft)	121m (400ft)
2	2	9m (30ft)	30m (100ft)	76 m (250ft)	121m (400ft)
	1	9m (30ft)	30m (100ft)	121m (400ft)	121m (400ft)
	0.5	9m (30ft)	30m (100ft)	121m (400ft)	121m (400ft)
1	1	9m (30ft)	30m (100ft)	68 m (225ft)	121m (400ft)
	0.5	9m (30ft)	30m (100ft)	121m (400ft)	121m (400ft)
0.5	0.5	9m (30ft)	30m (100ft)	45m (150ft)	106 m (350ft)

Table A.D 1305 Drive, 480V in meters (feet)

Drive HP (460V)	Motor HP (460V)	Reactor (1) at the Drive Using a Motor with Insulation V_{P-P}			With 1204-TFB2 Terminator Using a Motor with Insulation V_{P-P}		With 1204-TFA1 Terminator Using a Motor with Insulation V_{P-P}			
		Type A	Type B or 1329R/L		Type A or Type B		Type A		Type B	
		Any Cable	Shielded	Unshielded	Shielded	Unshielded	Shielded	Unshielded	Shielded	Unshielded
Maximum Carrier Frequency		2 kHz	2 kHz	2 kHz	2 kHz	2 kHz	2 kHz	2 kHz	2 kHz	2 kHz
High-Line Derating Multiplier		0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
5	5	15m (50ft)	182m (600ft)	182m (600ft)	NR	NR	91m (300ft)	61m (200ft)	91m (300ft)	121m (400ft)
	3	15m (50ft)	182m (600ft)	182m (600ft)	91m (300ft)	121m (400ft)	99m (325ft)	61m (200ft)	152m (500ft)	121m (400ft)
	2	15m (50ft)	182m (600ft)	182m (600ft)	121m (400ft)	182m (600ft)	99m (325ft)	61m (200ft)	182m (600ft)	121m (400ft)
	1	15m (50ft)	182m (600ft)	182m (600ft)	121m (400ft)	182m (600ft)	99m (325ft)	61m (200ft)	182m (600ft)	121m (400ft)
	0.5	15m (50ft)	182m (600ft)	182m (600ft)	182m (600ft)	182m (600ft)	99m (325ft)	61m (200ft)	182m (600ft)	121m (400ft)
3	3	15m (50ft)	91m (300ft)	182m (600ft)	NR	NR	91m (300ft)	61m (200ft)	91m (300ft)	121m (400ft)
	2	15m (50ft)	182m (600ft)	182m (600ft)	91m (300ft)	121m (400ft)	99m (325ft)	61m (200ft)	152m (500ft)	121m (400ft)
	1	15m (50ft)	182m (600ft)	182m (600ft)	91m (300ft)	182m (600ft)	99m (325ft)	61m (200ft)	182m (600ft)	121m (400ft)
	0.5	15m (50ft)	182m (600ft)	182m (600ft)	121m (400ft)	182m (600ft)	99m (325ft)	61m (200ft)	182m (600ft)	121m (400ft)
2	2	15m (50ft)	76m (250ft)	167m (550ft)	NR	NR	91m (300ft)	61m (200ft)	91m (300ft)	121m (400ft)
	1	15m (50ft)	182m (600ft)	182m (600ft)	61m (200ft)	61m (200ft)	99m (325ft)	61m (200ft)	121m (400ft)	121m (400ft)
	0.5	15m (50ft)	182m (600ft)	182m (600ft)	91m (300ft)	121m (400ft)	99m (325ft)	61m (200ft)	152m (500ft)	121m (400ft)
1	1	15m (50ft)	68m (225ft)	152m (500ft)	NR	NR	45m (150ft)	61m (200ft)	45m (150ft)	76m (250ft)
	0.5	15m (50ft)	182m (600ft)	182m (600ft)	NR	NR	76m (250ft)	61m (200ft)	76m (250ft)	121m (400ft)
0.5	0.5	15m (50ft)	45m (150ft)	106m (350ft)	NR	NR	NR	NR	NR	NR

(1) IMPORTANT: A 3% reactor reduces motor stress but may cause a degradation of motor waveform quality. Reactors must have a turn-to-turn insulating rating of 2100 volts or higher. Reactors are not recommended for lightly loaded applications because over voltage trips may result at low output frequencies.

NR = Not Recommended

Table A.E 160 Drive, 480V - Voltage Peak

380-460V Ratings	**Motor Insulation Rating**	**Motor Cable Only**				**RWR at Drive**				**Reactor at Motor**			
		Shielded		Unshielded		Shielded		Unshielded		Shielded		Unshielded	
	Volts $_{P-P}$	*meters*	*feet*	*meters*	*feet*	*meters*	*feet*	*meters*	*feet*	*meters*	*feet*	*meters*	*feet*
4.0 kW (5 HP)	1000	13.7	45	6.1	20	160	525	183	600	99.1	325	91.5	300
	1200	27.4	90	12.2	40	160	525	183	600	160	525	130	425
	1600	160	525	145	475	160	525	183	600	160	525	183	600
2.2 kW (3 HP)	1000	12.2	40	12.2	40	160	525	183	600	68.6	225	76.2	250
	1200	27.4	90	18.3	60	160	525	183	600	99.1	325	130	425
	1600	160	525	152	500	160	525	183	600	160	525	183	600
1.5 kW (2 HP)	1000	12.2	40	12.2	40	130	425	183	600	99.1	325	91.5	300
	1200	27.4	90	18.3	60	130	425	183	600	130	425	137	450
	1600	152	500	152	500	130	425	183	600	165	540	183	600
0.75 kW (1 HP)	1000	16.8	55	12.2	40	99.1	325	183	600	99.1	325	107	350
	1200	38.1	125	18.3	60	99.1	325	183	600	152	500	137	450
	1600	152	500	152	500	99.1	325	183	600	152	500	183	600
0.55 kW (0.75 HP)	1000	13.7	45	12.2	40	91.5	300	183	600	91.5	300	91.5	300
	1200	38.1	125	18.3	60	91.5	300	183	600	152	500	152	500
	1600	152	500	152	500	91.5	300	183	600	152	500	183	600
0.37 kW (0.5 HP)	1000	13.7	45	27.4	90	91.5	300	130	425	91.5	300	130	425
	1200	38.1	125	54.9	180	91.5	300	130	425	152	500	152	500
	1600	152	500	152	500	91.5	300	130	425	152	500	152	500

Table A.F 160 Drive, 240 & 480V - Cable Charging Current

480V Ratings	kHz	Motor Cable Only				RWR at Drive				Reactor at Motor			
		Shielded ❶		Unshielded		Shielded ❶		Unshielded		Shielded ❶		Unshielded	
		meters	*feet*	*meters*	*feet*	*meters*	*feet*	*meters*	*feet*	*meters*	*feet*	*meters*	*feet*
4.0 kW (5 HP)	2	107	350	183	600	91.5	300	183	600	122	400	183	600
	4	130	425	183	600	107	350	183	600	137	450	138	600
	8	145	475	152	500	NR				137	450	152	500
2.2 kW (3 HP)	2	110	360	183	600	85.4	280	183	600	122	400	183	600
	4	114	375	183	600	83.8	275	183	600	122	400	183	600
	8	122	400	152	500	NR				122	400	152	500
1.5 kW (2 HP)	2	91.5	300	168	550	83.8	275	183	600	91.5	300	183	600
	4	91.5	300	168	550	83.8	275	183	600	91.5	300	152	500
	8	99.1	325	152	500	NR				107	350	152	500
0.75 kW (1 HP)	2	61	200	114	375	61	200	130	425	68.6	225	122	400
	4	68.6	225	114	375	61	200	130	425	68.6	225	114	375
	8	76.2	250	114	375	NR				68.6	225	122	400
0.55 kW (0.75 HP)	2	54.9	180	107	350	54.9	180	114	375	54.9	180	107	350
	4	54.9	180	107	350	54.9	180	114	375	54.9	180	107	350
	8	54.9	180	107	350	NR				54.9	180	107	350
0.37 kW (0.5 HP)	2	30.5	100	99.1	325	30.5	100	107	350	30.5	100	91.5	300
	4	30.5	100	99.1	325	30.5	100	107	350	30.5	100	107	350
	8	30.5	100	99.1	325	NR				30.5	100	107	350

240V Ratings	No Reactor				RWR at Drive				Reactor at Motor			
0.37 to 4.0 kW (0.5 to 5 HP) 2 through 8 kHz	Shielded ❶		Unshielded		Shielded ❶		Unshielded		Shielded ❶		Unshielded	
	meters	*feet*	*meters*	*feet*	*meters*	*feet*	*meters*	*feet*	*meters*	*feet*	*meters*	*feet*
	160	525	183	600	NR				160	525	183	600

❶ When using shielded cable at lightly loaded conditions, cable length recommendations for drives rated 0.75 kW (1 HP) and below are 61 meters (200 feet).

PowerFlex 4

Reflected Wave Protection

Install the drive as close to the motor as possible. Installations with long motor cables may require the addition of external devices to limit voltage reflections at the motor (reflected wave phenomena). See Table A.G for recommendations.

The reflected wave data applies to all frequencies of 2 to 16 kHz.

Reflected wave effects do not need to be considered for 240V ratings.

Table A.G PowerFlex 4 Drive, 480V

No external devices					
Type A		Type B		1329R/L	
meters	*feet*	*meters*	*feet*	*meters*	*feet*
15	49	40	131	170	558

Table A.H PowerFlex 70, 480 V - No External Devices

480V drive/ motor HP	Carrier frequency kHz Cable Type	Type A			Type B			1488V Motor			11329 R / L		
		Shielded ❷	Shielded ❶	Un-shielded	Shielded ❷	Shielded ❶	Un-shielded	Shielded ❷	Shielded ❶	Un-shielded	Shielded ❷	Shielded ❶	Un-shielded
0.5	2		60	40		175	60		175	150		175	150
	4		60	40		175	60		175	130		175	150
	6		60	40		175	50		175	130		175	150
	8		60	40		175	50		175	130		175	150
	10		60	40		175	50		175	130		175	150
1	2		70	30		275	55		275	180		275	350
	4		70	30		250	55		250	180		250	300
	6		70	30		250	55		250	170		250	280
	8		70	30		250	55		250	160		250	260
	10		70	30		200	55		250	160		250	240
2	2		70	40		275	75		275	500		275	500
	4		70	40		250	75		250	400		250	400
	6		70	40		250	75		250	360		250	400
	8		70	40		240	75		250	260		250	400
	10		70	40		220	75		250	260		250	400
3	2		70	40		220	75		425	600		425	600
	4		70	40		220	75		400	520		400	600
	6		70	40		220	75		425	520		425	600
	8		70	40		220	75		400	380		400	580
	10		70	40		220	75		400	380		400	550
5	2		80	40		280	80		450	600		450	600
	4		80	40		280	80		400	600		400	600
	6		80	40		280	80		400	560		400	600
	8		80	40		280	80		300	400		300	600
	10		80	40		280	80		300	360		300	580
7.5	2		50	40		300	60		400	600		400	600
	4		50	40		300	60		400	600		400	600
	6		50	40		300	60		400	520		400	600
	8		50	40		300	60		400	400		400	560
	10		50	40		300	60		300	320		300	500
10	2		50	40		300	60		400	600		400	600
	4		50	40		300	60		400	600		400	600
	6		50	40		300	60		400	560		400	600
	8		50	40		300	60		400	440		400	560
	10		50	40		300	60		300	380		300	520
15	2		80	50		600	80		600	600		600	600
	4		80	50		400	80		600	600		600	600
	6		80	50		400	80		600	600		600	600
	8		80	50		400	80		600	500		600	600
	10		80	50		400	80		600	400		600	480
20	2		70	50		600	80		600	600		600	600
	4		70	50		400	80		600	600		600	600
	6		70	50		200	80		600	600		600	600
	8		70	50		160	80		600	600		600	600
	10		70	50		160	80		600	340		600	600

❶ Cable is Alcatel C1202 or equivalent. Shielded cable with twisted conductors and no filler
❷ Cable is Belden 295xx series or equivalent

Table A.I PowerFlex 70 Drive - With Reactor

Contact Technical Support for data not shown.

480V drive/ motor HP	Carrier frequency kHz Cable Type	Type A Motor			Type B Motor			1488 Volt motor			1329 R / L		
		Shielded ❷	Shielded ❶	Un-shielded	Shielded ❷	Shielded ❶	Un-shielded	Shielded ❷	Shielded ❶	Un-shielded	Shielded ❷	Shielded ❶	Un-shielded
0.5	2												
	4												
	6												
	8												
	10												
1	2								425			425	
	4								425			425	
	6												
	8												
	10												
2	2								600			600	
	4								600			600	
	6												
	8												
	10												
3	2												
	4												
	6												
	8												
	10												
5	2												
	4												
	6												
	8												
	10												
7.5	2												
	4												
	6												
	8												
	10												
10	2												
	4												
	6												
	8												
	10												
15	2												
	4												
	6												
	8												
	10												
20	2												
	4												
	6												
	8												
	10												

❶ Cable is Alcatel C1202 or equivalent. Shielded cable with twisted conductors and no filler.
❷ Cable is Belden 295xx series or equivalent

Table A.J PowerFlex 70 Drive with RWR or Eliminator

Contact Technical Support for data not shown.

480V drive/ motor	Carrier frequency kHz Cable Type	Type A Motor			Type B Motor			1488 V Motor			1329 R / L		
		Shielded ❷	Shielded ❶	Un-shielded	Shielded ❷	Shielded ❶	Un-shielded	Shielded ❷	Shielded ❶	Un-shielded	Shielded ❷	Shielded ❶	Un-shielded
0.5	2												
	4			600			600						
	6												
	8												
	10												
1	2												
	4			600			600						
	6												
	8												
	10												
2	2												
	4			600			600						
	6												
	8												
	10												
3	2												
	4			600			600						
	6												
	8												
	10												
5	2												
	4			600			600						
	6												
	8												
	10												
7.5	2												
	4			200			600						
	6												
	8												
	10												
10	2												
	4			200			600						
	6												
	8												
	10												
15	2												
	4												
	6												
	8												
	10												
20	2												
	4												
	6												
	8												
	10												

❶ Cable is Alcatel C1202 Or equivalent. Shielded cable with twisted conductors and no filler
❷ Cable is Belden 295xx series or equivalent

Table A.K PowerFlex 700 Drive, 480V

Contact Technical Support for data not shown.

480V drive/ motor HP	Carrier frequency kHz Cable Type	Type A Motor			Type B Motor			1488 V Motor		
		Shielded	Shielded	Unshielded	Shielded	Shielded	Unshielded	Shielded	Shielded	Unshielded
0.5	4	50	25	75	50	220	320	220	420	
	8	40	20	75	40	220	220	220	420	
1	4									
	8									
2	4									
	8									
3	4									
	8									
5	4	25	25	75	40	420	520	420	620	
	8	25	25	75	40	420	275	420	520	
7.5	4									
	8									
10	4									
	8									
15	4	20	20	40	50	420	620	420	620	
	8	20	20	40	40	420	520	420	520	
25	4	20	20	40	50	620	620	620	620	
	8	20	20	40	40	620	420	620	620	

Notes:

Notes:

Ambient Air

Air around any equipment cabinet.
See surrounding air for more detail.

Armored

A fixed geometry cable that has a protective "sheath" of continuous metal

Capacitive Coupling

Current or voltage that is induced on one circuit by another because of their close physical proximity. For drive installations it is generally seen in two areas:

1. Coupling between motor leads of two drives, such that the operating drive induces voltage onto the motor leads (and thus the motor) of a non-operating drive.

2. Coupling between the conductors /or shields of motor leads that creates a requirement for more current than the motor itself would demand.

CIV (Corona Inception Voltage)

The amplitude of voltage on a motor or other electrical winding that produces corona (ionization of air to ozone). CIV is increased by adding phase paper, placing windings in the proper pattern and reducing or eliminating air bubbles (voids) in the varnish applied.

Common Mode Core

A ferrite bead or core that can be used to pass control, communications or motor leads through to attenuate high frequency noise. Catalog Number/ Part Number 1321-Mxxx

Common Mode Noise

Electrical noise, typically high frequency, that is imposed on the ground grid, carriers in an electrical system

Conduit

Conductive ferrous electrical metal tubing used to contain and protect individual wires

Damp

Wet locations per U.S. NEC or local code

Discrete

Individual, hard-wired inputs or outputs, typically used for control of the drive (Start, Stop, etc.)

Dry

Dry locations per U.S. NEC 7-31 or local code

dv/dt

The rate of change of voltage over time

Fill Rates

The maximum number of conductors allowed in a conduit, as determined by local, state or national electrical code.

Fixed Geometry

Cable whose construction fixes the physical position of each conductor within the overall coating, usually with filler material that prevents individual conductors from moving.

IGBT

Insulated Gate Bi-Polar Transistor. The typical power semi conductor device used in most PWM AC drives today

mil

0.001 inches

MOV

Metal Oxide Varistor

NEC

United States National Electric Code NFPA70

PVC

Polyvinyl Chloride (typically thermoplastic)

RWR

Reflected Waver Reducer, an RL network mounted at or near the drive, used to reduce the amplitude and rise time of the reflected wave pulses. Cat No 1204-RWR2-09-B or 1204-RWR2-09-C

Shielded

Cable containing a foil or braided metal shield surrounding the conductors. Usually found in multi-conductor cable. Shield coverage should be at least 75%.

Signal

Individual hard wired analog inputs or outputs, typically used to issue reference commands or process information to or from the drive.

Surrounding Air Temperature

The temperature of the air around the drive. If the drive is free standing or wall mounted, the surrounding air temperature is room temperature. If the drive is mounted inside another cabinet, the surrounding air temperature is the interior temperature of that cabinet

Terminator

An RC network mounted at or near the motor, used to reduce the amplitude and rise time of the reflected wave pulses. Catalog Number 1204-TFxx

THHN / THWN

U.S. designations for individual conductor wire, typically 75º C or 90ºC rated and with PVC insulation and nylon coating.

Unshielded

Cable containing no braided or foil sheath surrounding the conductors. Can be multi-conductor cable or individual conductors.

Wet

Locations with moisture present - see Damp

XLPE

Cross Linked Polyethylene

UL

Underwriters Laboratories

Numerics

A

C

D

E

G

H

I

L

M

Notes:

Notes:

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