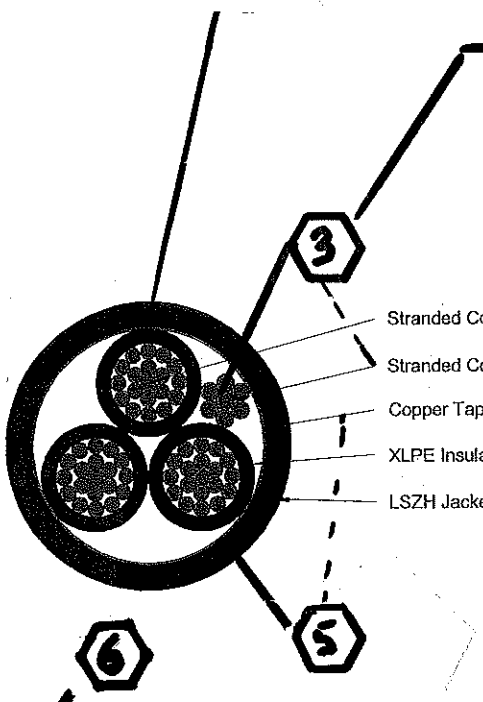
Wire/Cable Types



AC drive installations have specific wire and cable requirements. This section includes information about the major issues for proper selection of cable, and provides recommendations to address these issues. Consider these conditions and requirements when choosing cable material and construction for your installation:

- Environment – such as moisture, temperature, and harsh or corrosive chemicals.
- Mechanical needs – such as geometry, shielding, flexibility, and crush resistance.
- Electrical characteristics – such as cable capacitance/charging current, resistance/voltage drop, current rating, and insulation. Insulation can be the most significant of these. Because drives can create voltages in excess of line voltage, the industry standard cables that were used in the past are not the best choice for variable speed drives. Drive installations benefit from cable that is significantly different than cable used to wire contactors and push buttons.
- Safety issues – such as electrical code requirements, grounding needs, and others.

Choosing incorrect cabling can be costly and can adversely affect the performance of your installation.

General

Material

1

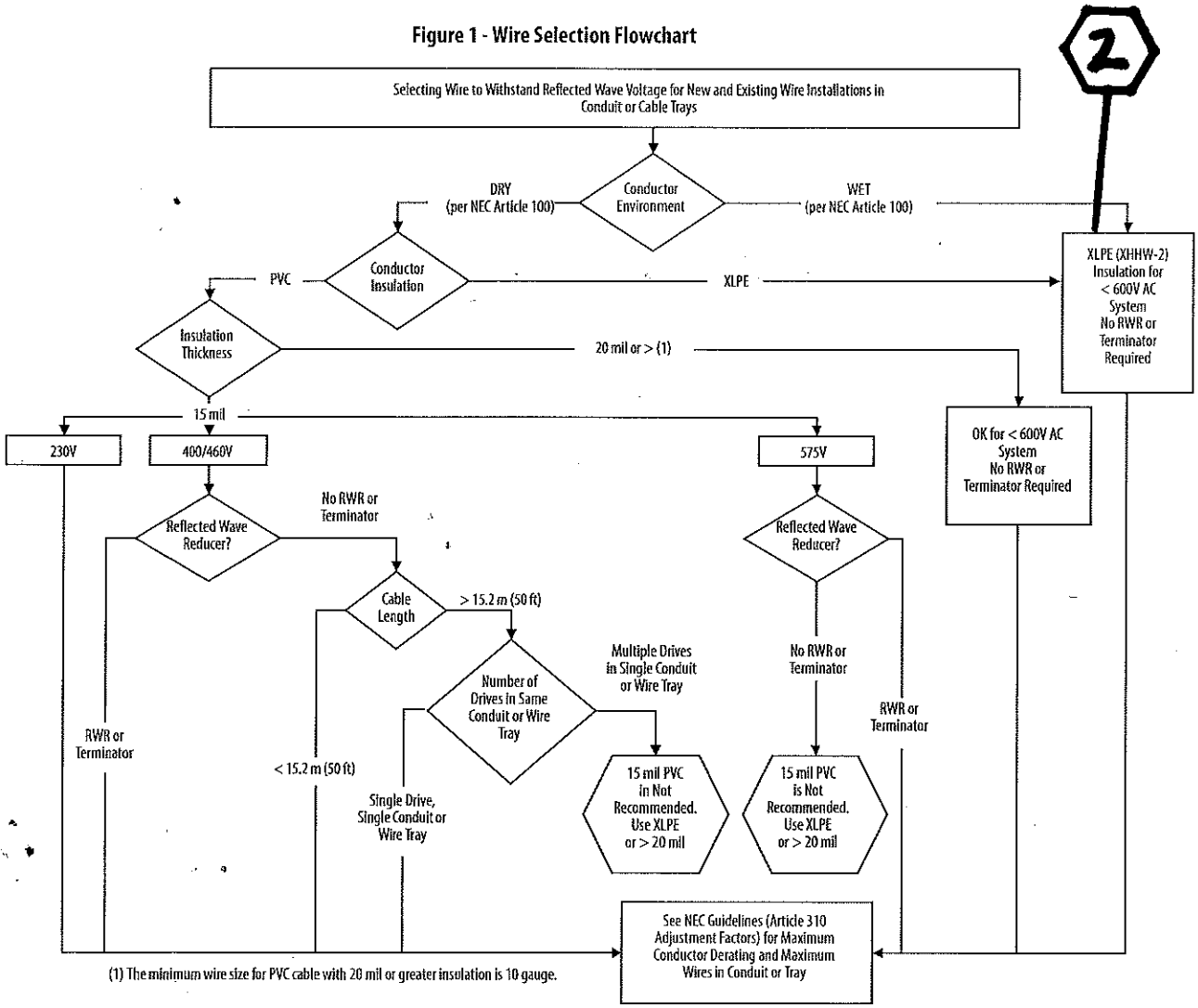
Use only copper wire. The wire clamp-type terminals in Allen-Bradley drives are made for use with copper wire. If you use aluminum wire, the connections can loosen and cause premature equipment failure.

Wire gauge requirements and recommendations are based on 75 °C (167 °F) rating. Do not reduce wire gauge when you use higher temperature wire.

Exterior Cover

Whether shielded or unshielded, the cable must meet all of the application requirements. Consider insulation value and resistance to moisture, contaminants, corrosive agents, and other invasive elements. Consult the cable manufacturer and Figure 1 on page 12 for cable selection criteria.

Figure 1 - Wire Selection Flowchart



Temperature Rating

In general, follow these temperature ratings for installations:

- In surrounding air temperature of 50 °C (122 °F), use 90 °C (194 °F) wire (required for UL)
- In surrounding air temperature of 40 °C (104 °F), use 75 °C (167 °F) wire (required for UL)

Refer to the user manual of the drive for other restrictions.

IMPORTANT The temperature rating of the wire affects the required gauge. Verify that your installation meets all applicable national, state, and local codes.

Gauge

The correct wire size is determined by a number of factors. The user manual for each drive 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 full load current (FLA). Follow both of these requirements.

Number of Conductors

Local or national electrical codes can determine the required number of conductors. Generally, these configurations are recommended:

- Figure 2 shows cable with a single ground conductor that is recommended for drives up to and including 200 Hp (150 kW).
- Figure 3 shows cable with three ground conductors that is recommended for drives larger than 200 Hp (150 kW).

Space the ground conductors symmetrically around the power conductors. Verify that the ground conductors are rated for full drive ampacity.

Figure 2 - Cable with One Ground Conductor

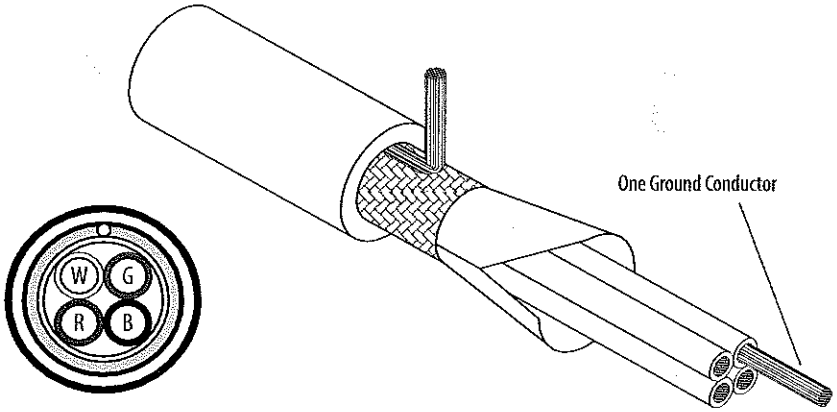
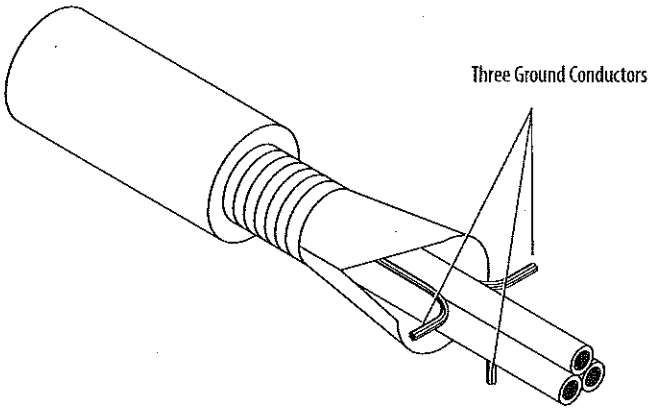


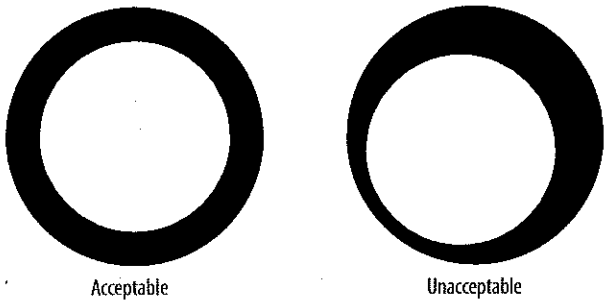
Figure 3 - Cable with Three Ground Conductors



Insulation Thickness and Concentricity

Wire must have an insulation thickness of ≥ 15 mil (0.4 mm/0.015 in.). The wire insulation must not have significant variations of concentricity around the wire.

Figure 4 - Insulation Concentricity



Geometry

The physical relationship between individual conductors is important in drive installations.

Individual conductors in conduit or cable trays have no fixed relationship and are subject to cross coupling of noise, induced voltages, excess insulation stress, and other possible interference.

Fixed geometry cable (cable that keeps the spacing and orientation of the individual conductors constant) offers significant advantages over individual loose conductors, including reduced cross-coupling noise and insulation stress. Three types of fixed geometry, multi-conductor cables are discussed in this section. See Unshielded Cable on page 15, Shielded Cable on page 16, and Armored Cable on page 17.

Table 1 - Recommended Cable Design

Type	Max Wire Size	Where Used	Rating/Type	Description
Type 1	2 AWG	Standard installations 100 Hp or less	600V, 90 °C (194 °F) XHHW2/RHW-2	Four tinned copper conductors with cross-linked polyethylene (XLPE) insulation
Type 2	2 AWG	Standard installations 100 Hp or less with brake conductors	600V, 90 °C (194 °F) RHH/RHW-2	Four tinned copper conductors with XLPE insulation plus one shielded pair of brake conductors.
Type 3	500 MCM AWG	Standard installations 150 Hp or more	Tray-rated 600V, 90 °C (194 °F) RHH/RHW-2	Three tinned copper conductors with XLPE insulation and three bare copper grounds and polyvinyl chloride (PVC) jacket.
Type 4	500 MCM AWG	Water, caustic chemical, crush resistance	Tray-rated 600V, 90 °C (194 °F) RHH/RHW-2	Three bare copper conductors with XLPE insulation and three copper grounds on 10 AWG and smaller. Acceptable in Class I and II, Division I and II locations.
Type 5	500 MCM AWG	690V applications	Tray-rated 2000V, 90 °C (194 °F)	Three tinned copper conductors with XLPE insulation. Three bare copper grounds and PVC jacket. **IMPORTANT:** If terminator network or output filter is used, connector insulation must be XLPE, not PVC.

Unshielded Cable

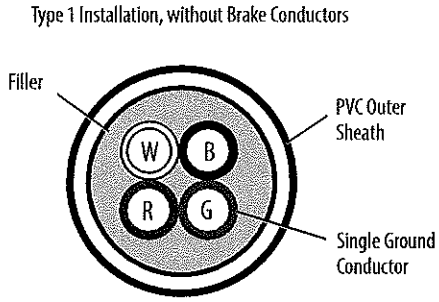
Properly designed multi-conductor cable can provide superior performance in wet applications, significantly reduce voltage stress on wire insulation, and reduce cross coupling between drives.

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 communication cards, photoelectric switches, weigh scales, and others. Verify that the installation does not require shielded cable to meet specific electromagnetic compatibility (EMC) standards for CE, C-Tick, or FCC requirements. Cable specifications depend on the installation type.

Type 1 and Type 2 Installation

Type 1 or Type 2 installations require 3-phase conductors and a fully rated individual ground conductor with or without brake leads. Refer to Table 1 on page 14 for detailed information and specifications on these installations.

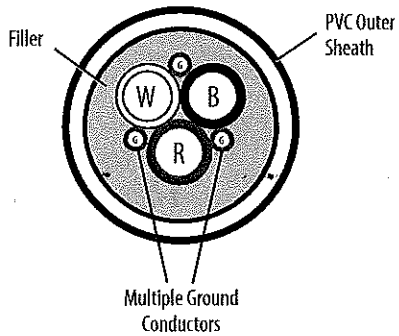
Figure 5 - Type 1 Unshielded Multi-conductor Cable without Brake Leads



Type 3 Installation

Type 3 installation requires three symmetrical ground conductors whose ampacity equals the phase conductor. Refer to Table 1 on page 14 for detailed information and specifications on this installation.

Figure 6 - Type 3 Unshielded Multi-Conductor Cable



Chose the outer sheathing and other mechanical characteristics to suit the installation environment. Consider the surrounding air temperature, chemical environment, flexibility, and other factors in all installation types.

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. Use shielded cable for installations with sensitive equipment, such as weigh scales, capacitive proximity switches, and other devices that can be affected by electrical noise in the distribution system. Applications with large numbers of drives in a single location, imposed EMC regulations, or a high degree of communication/networking, are also good candidates for shielded cable.

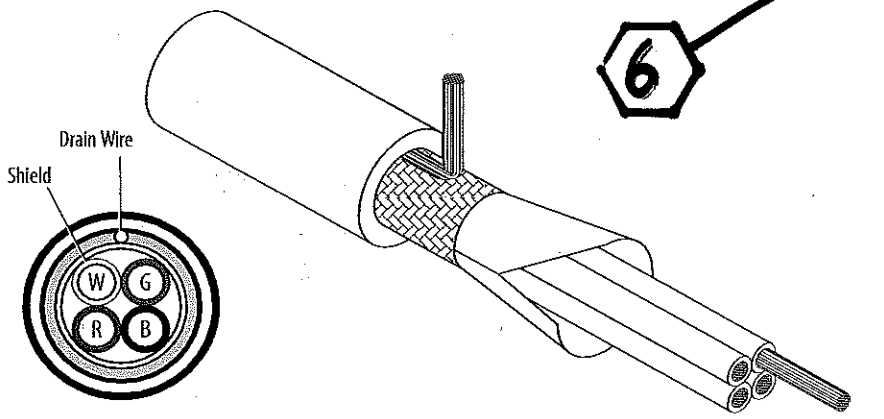
Shielded cable can also help reduce shaft voltage and induced bearing currents for some applications. In addition, the increased size of shielded cable can help extend the distance that the motor can be from the drive without the addition of motor protective devices, such as terminator networks. Refer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

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

Type 1 Installation

An acceptable shielded cable for Type 1 installations has four XLPE insulated conductors with a 100% coverage foil and an 85% coverage copper braided shield (with drain wire) surrounded by a PVC jacket. For detailed specifications and information on Type 1 installations, refer to Table 1 on page 14.

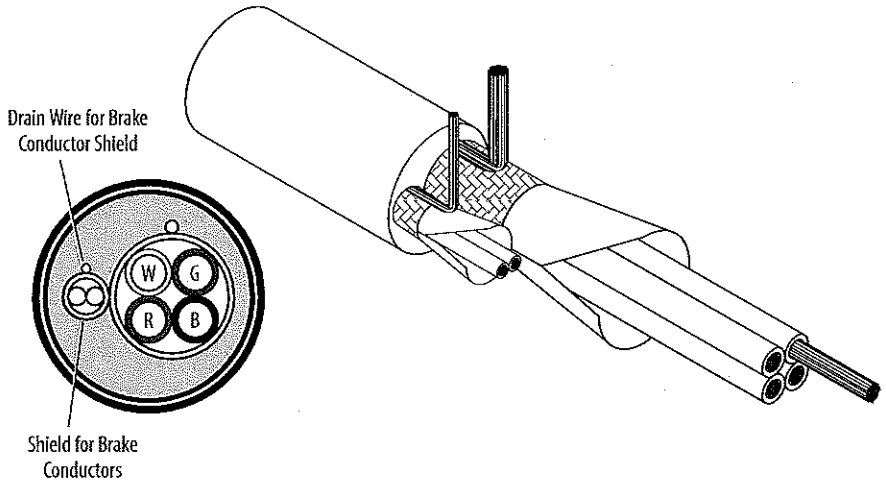
Figure 7 - Type 1 Installation — Shielded Cable with Four Conductors



Type 2 Installation

An acceptable shielded cable for Type 2 installations is essentially the same cable as Type 1, plus one shielded pair of brake conductors. For more information on Type 2 installations, refer to Table 1 on page 14.

Figure 8 - Type 2 Installation — Shielded Cable with Brake Conductors



Type 3 Installation

These cables have 3 XLPE insulated copper conductors, 25% minimal overlap with helical copper tape, and three bare copper grounds in PVC jacket.

TIP Other types of shielded cable are available, but the selection of these types can limit the allowable cable length. Particularly, some of the newer cables twist four 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, these 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 to, Conduit on page 67, Moisture on page 72, Effects On Wire Types on page 73, and Appendix A.

Armored Cable

Cable with continuous aluminum armor is often recommended in drive system applications or specific industries. Armored cable 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 (electrical metallic tubing [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 when the cable is mounted, we recommend that the armored cable has an overall PVC jacket (see Chapter 2).

Interlocked armor is acceptable for shorter cable runs, but continuous welded armor is preferred. General recommendations for ground conductors are listed here:

- Cable with a single ground conductor is sufficient for drive sizes up to and including 200 Hp (150 kW).
- Cable with three ground conductors is recommended for drive sizes larger than 200 Hp (150 kW).

Space the ground conductors symmetrically around the power conductors. Verify that the ground conductors are rated for full drive ampacity.

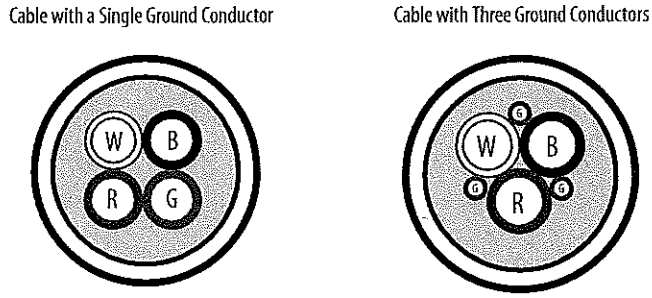
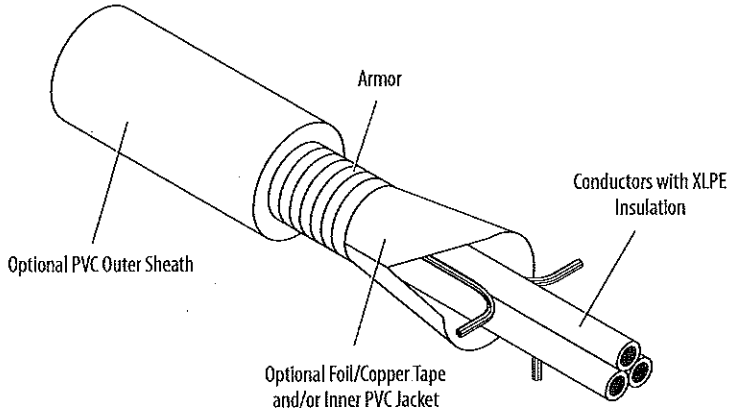


Figure 9 - Armored Cable with Three Ground Conductors



A good example of cable for Type 5 installation is Anixter 7V-5003-3G. This cable has three XLPE insulated copper conductors, 25% minimal overlap with the helical copper tape, and three bare copper grounds in PVC jacket.

IMPORTANT If a terminator network or output filter is used, the connector insulation must be XLPE, and not PVC.

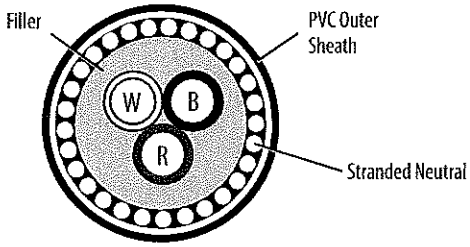
European Style Cable

Cable used in many installations in Europe must conform to Low Voltage Directive (LVD) 2006/95/EC. Generally recommended are flexible cables with a bend radius of 20 times the cable diameter for movable cable, and 6 times the cable diameter for fixed installations, with a screen (shield) of 70...85% coverage. Insulation for both conductors and the outer sheath is PVC.

The number and color of individual conductors can vary, but the recommendation is for three phase conductors (customer-preferred colors) and one ground conductor (green/yellow).

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

Figure 10 - 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 suggest shielded cable to prevent coupling of noise onto the cable (see Chapter 2), and in some cases shielded cable can be required to meet noise standards, such as CE for Europe, C-Tick for Australia/ New Zealand, and others. This can be especially true if an input filter is required to meet a standard. The user manual for the drive has the requirements for meeting these types of standards. Additionally, individual industries can have required standards due to environment or experience.

For AC variable frequency drive applications that must satisfy EMC standards for CE, C-Tick, FCC, or others, we recommend the same type of shielded cable that is specified for the AC motors be used between the drive and transformer. Check the individual user manuals or system schematics for specific additional requirements to meet EMC standards.

Motor Cables

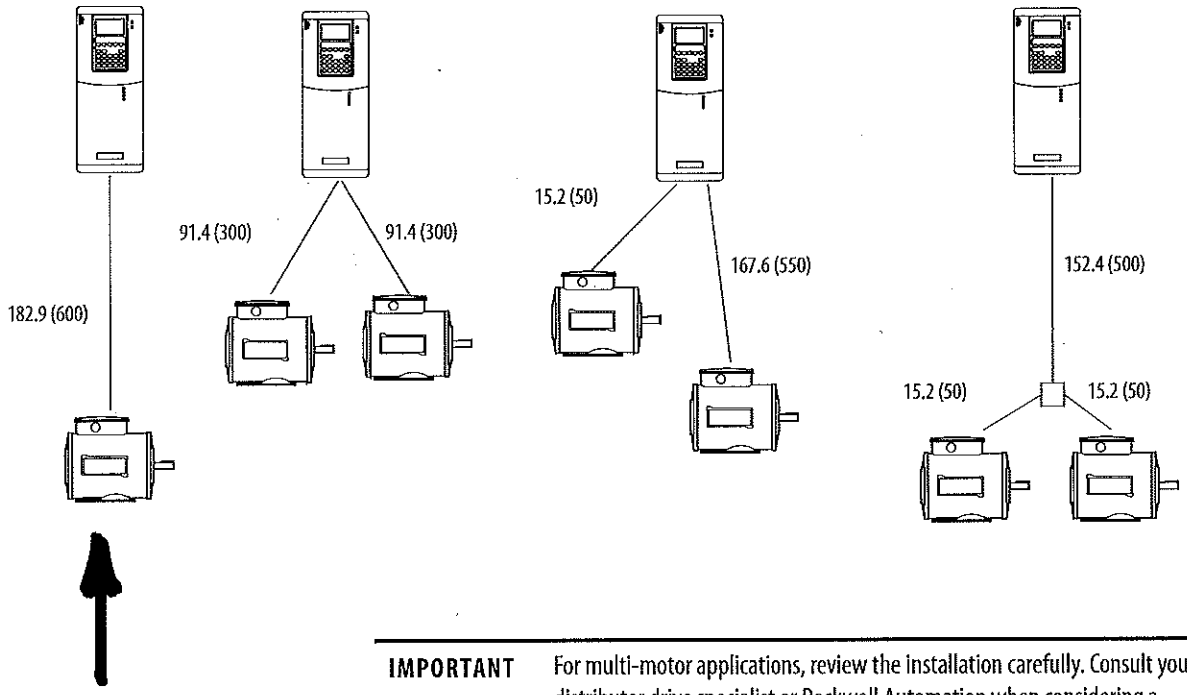
The majority of recommendations regarding drive cables are for issues caused by the nature of the drive output. A PWM drive creates AC motor current by sending DC voltage pulses to the motor in a specific pattern. These pulses affect the wire insulation and can be a source of electrical noise. Consider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

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

Keep the motor cable lengths within the limits set in the user manual for the drive. Various issues, including cable charging current and reflected wave voltage stress, can exist. If the cable restriction is listed because of excessive coupling current, apply the methods to calculate total cable length, as shown in Figure 11. If the restriction is due to voltage reflection and motor protection, refer to Appendix A for exact distances allowed.

Figure 11 - Motor Cable Length for Capacitive Coupling

All examples represent motor cable length of 182.9 m (600 ft)



IMPORTANT For multi-motor applications, review the installation carefully. Consult your distributor drive specialist or Rockwell Automation when considering a multi-motor application with greater than two motors. In general, most installations have no issues. However, high peak cable charging currents can cause drive over-currents or ground faults.