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E2 Controller Wiring Practices

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FCC COMPLIANCE NOTICE

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

CE COMPLIANCE NOTICE

Class A Product Information for Einstein, E2 Controllers:

The CPC Einstein and E2 controllers are Class A products. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures. This covers:

- All Einstein family product types: RX - Refrigeration Controller (830-xxxx), BX - Building/HVAC Controller (831-xxxx), and all version models: (300, 400, 500).
- All E2 family product types: RX - Refrigeration Controller (834-xxxx), BX - Building/HVAC Controller (835-xxxx), CX- Convenience Store Controller (836-xxxx), and all version models: (300, 400, 500).

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1 Overview

One of the most common causes of communication problems experienced by CPC site controllers is excess electromagnetic interference (EMI), commonly referred to as electrical noise or just "noise." Because refrigeration and HVAC controls are typically installed in motor rooms and utility rooms, they are often in close proximity to other electrical devices that generate EMI, such as power lines or motors.

Noise can be picked up by any length of wire. Just as an antenna helps a radio receive AM and FM radio signals, a long length of wire between a controller and I/O board or sensor can also act as an antenna for noise.

CPC site controllers such as the E2, as well as the peripheral I/O boards and unit controllers to which it communicates, go through rigorous testing to ensure (1) that they are not overly susceptible to noise, and (2) that the devices themselves do not generate excess noise. Regardless, **every long wire used in network, power, and signal wiring can potentially be an antenna for EMI.** Unless proper noise abatement wiring practices are used, even one wiring mistake could result in enough noise to impede or disable an RS485, Echelon, or Ethernet network.

This document is meant to provide a list of guidelines that should always be followed when wiring RS485 (I/O networks, MODBUS), Echelon, and Ethernet networks in an E2 control system.

1.1. "Noise" and its Effects

Noise, in the context of this document, refers to EMI induced on a network wire or connector that result in signals that hinder the controllers' ability to receive and send network messages. Just as loud audio noise in a room makes it harder for people to communicate with each other through speech, a noisy network makes it hard for a control device to read messages sent from other controllers.

You should suspect a noisy network if your E2 control system experiences any of the following problems:

- Periodic outages of communication between the main controller (E2) and its peripheral devices. This is most often indicated by a large number of "Controller Offline" alarms in the E2 Alarm Log, which usually return to normal.
- Inability to commission devices during setup. During commissioning, the E2 attempts to find a device and read its commissioning information - on a noisy network, the E2 may fail to find devices or require several retries before finding them. Noise may also cause commissioning to proceed very slowly.
- Intermittent Ethernet connections to E2 (ping works, but UltraSite or InSite cannot make connection to the E2).
- Communication outages that occur when changes are made to network connections to the E2. Example: the I/O network devices stop communicating when the Ethernet cable is plugged into the E2.
- Reboots of the E2, in situations where excessive noise is present.

1.2. Sources of Noise

The most common causes of noise in an E2 controller installation are:

- Wiring that comes close to an electrical device that generates lots of noise,
- Routing cable that runs parallel and/or in close proximity to wires that carry high AC voltage and current,
- Network cable that does not meet specifications,
- Power wiring from the transformer secondary that is the wrong wire gage,
- Improper network structure or termination resistance, and
- Cable that is not grounded or that is grounded improperly.

2 Avoiding Noise-Generating Devices

There are a number of electrical devices commonly used in supermarkets and buildings that generate noise.

- Motor starters, contactors, or other electrical equipment that switches ON and OFF. Switching heavy electrical loads ON and OFF will generate noise.
- Inverters for variable-speed motors. Inverters generate a constant amount of high levels of noise.
- Fluorescent light ballasts. Light ballasts also generate constant noise.
- Arc welders (excessive intermittent noise).

The best way to eliminate network noise coming from a noise-generating device is to keep all networked devices and cable runs as far away from the device as possible. Cable runs should be routed around noise-generating devices, and the E2 (as well as the devices the E2 is networked with) should be physically located far away from noise-generating devices.

The minimum distance devices and cabling should be kept away from noise generators is **1 ft. (0.3m) with 5 ft. (1.5 m) being the ideal minimum distance.** The minimum distance may be more or less depending on the amount of noise generated by the device - refer to the device's user manual for more information.

2.1. Control Techniques Variable-Speed Drives

E2 controllers whose versions are 2.40F01 and above feature the ability to communicate with certain models of Control Techniques variable-speed drives (VSDs) using a MODBUS network connection.

Control Techniques and CPC both require all VSDs that will network with E2 controllers to be installed with line filters to minimize noise. If installing an E2 network into a site that already has installed VSDs, verify the drives were installed with line filters before networking them to an E2. Contact your Control Techniques representative to obtain line filters and assistance with installation.

In addition, CPC requires that all MODBUS network connections to Control Techniques VSDs use a CT Drive Interface (*P/N 535-2725*). This assembly, which plugs into the RJ45 MODBUS jack on the VSD, provides the noise filtering circuitry recommended by Control Techniques, and it also provides a screw terminal connector for easier daisy chaining to the MODBUS network.

If you are using an analog output to control a CT drive, make sure you are using shielded cable from the analog output to the drive. Connect the shield wire on the CT drive end to an earth ground.

For further information on noise abatement when using Control Techniques VSDs, consult the manufacturer's instructions and follow all recommended guidelines for installing the drive and reducing noise.

3 Avoiding High Voltage Wiring

A common mistake made by wiring technicians is to wire communication cabling in parallel with 120VAC, 240VAC, or 480VAC power wiring (sometimes together in the same conduit). High voltage wiring radiates noise in all directions perpendicular from the direction of the wire. When a communication wire is run parallel and in close proximity to a high voltage wire, the electromagnetic field from the high voltage wire will induce noise on the communication cable. The amount of noise induced depends on the voltage and current of the wire, the distance between the two wires, and the angle between the two wire runs (with parallel being the highest induction).

To avoid noise induced from high-voltage wiring:

1. If possible, wire serial, Echelon, and Ethernet wiring away from high-voltage wire. Communication cabling should be kept **a minimum of 3 in. (7.6 cm) apart at all points, with 12 in. (30 cm) being the ideal minimum distance.**
2. Do not wire communication wire and high-voltage wire in the same conduit. Always separate the power wiring in a separate grounded rigid steel conduit if the two wires must be run close together and in parallel.
3. Avoid running even part of the communication wiring in close parallel with high voltage wiring. A run of parallel wire as short as a few inches could yield enough noise to affect network communication. If the wires must cross each other in close proximity, cross them perpendicular to each other so the amount of noise is minimized (see ***Figure 3-1***).

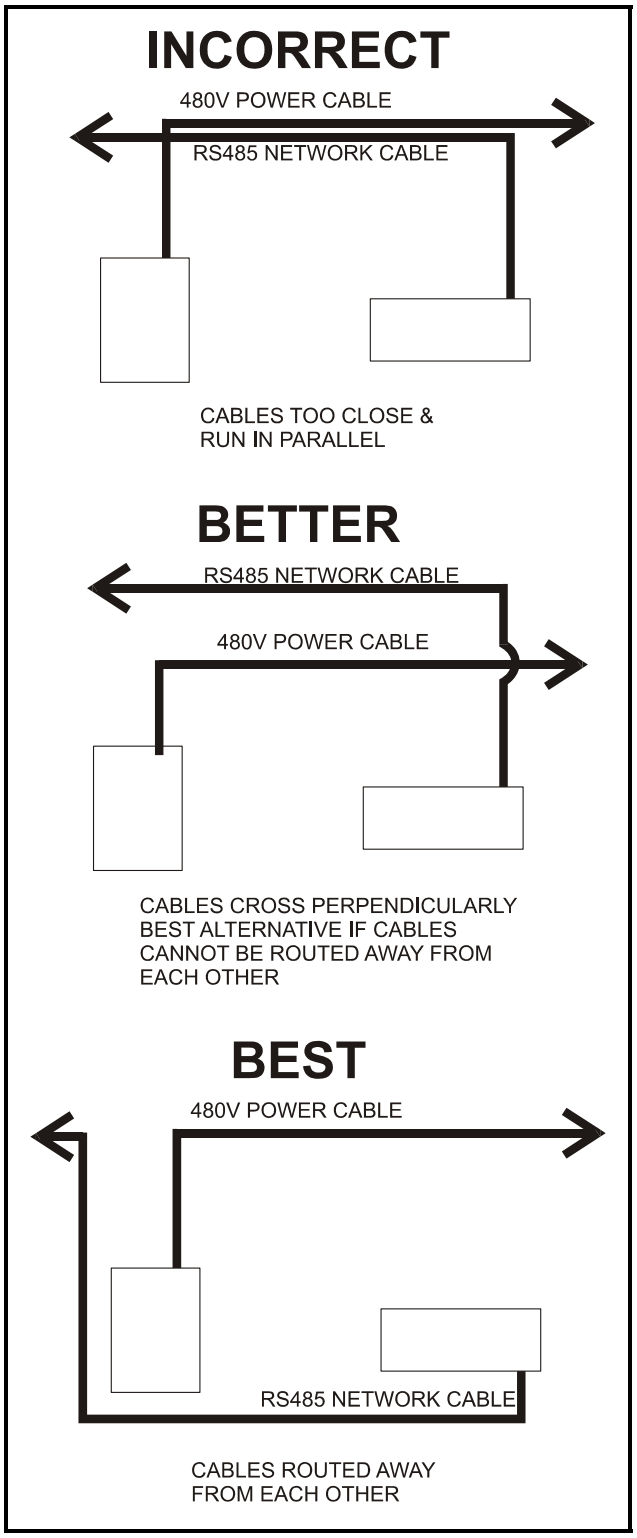

Figure 3-1 *- Examples of Good & Bad Cable Routing*

4 Using The Correct Cable

4.1. RS485 Communication Wiring

CPC specifies all RS485 I/O and MODBUS wiring used by the E2 must be Belden 8641 (24AWG, 300V, CPC P/N 135-8641); Belden 8761 (22 AWG, 300V not stocked by CPC); or a 600V-shielded 22AWG equivalent stocked by CPC (P/N 135-0600). These are two-connector shielded twisted pair cable that support a maximum daisy chain cable distance of 4000 feet (1219 m) between the E2 and the end device on the network.

Provided the cable can be routed away from noise generators and running in parallel with high-voltage wire, any of the three specified cables will provide adequate shielding from external noise.

If it is necessary for the cable to come in contact with noise generating devices or parallel to high-voltage wire, as an alternative you may use Belden 9855— a shielded, two-pair cable — and connect the unused pair of wires to the 0V terminal of each network connector. In this method, the shield must be tied together and connected to a separate earth ground (NOT on the I/O devices' 0V terminals).

This wiring method is **not recommended** and should only be used if proper routing cannot be done. Refer to ***Figure 4-1*** if you choose to use this wiring strategy.

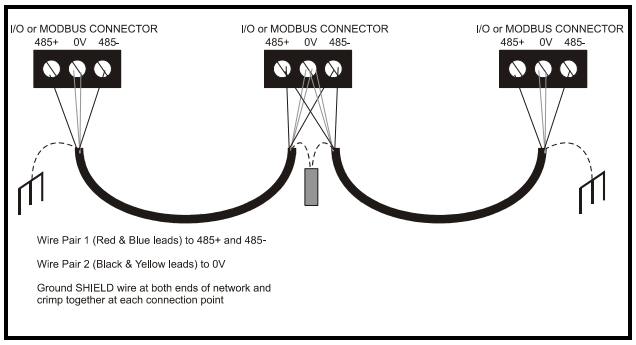

Figure 4-1 *- Alternate Two-Pair Grounded Cable Installation for Noisy Networks*

4.2. Echelon Network Wiring

CPC specifies one type of cable for Echelon Network wiring: a Level 4, twisted pair, stranded, shielded cable that meets all requirements for Echelon LonWorks networks. This cable is available in both plenum and non-plenum varieties from CPC (see part numbers in ***Table 4-1***). This cable is the only cable type supported by CPC.

Cable Type	CPC Part Number
1 pair, non-plenum	135-2300
1 pair, plenum	135-2301

Table 4-1 *- Recommended Wiring*

4.3. Ethernet Network Wiring

4.3.1. Shielding

Standard, unshielded CAT5/5e cable can be used for wiring E2s to an Ethernet network as long as the cable is not run near sources of electrical noise. Otherwise, if the cable will be used in a noisy environment, shielded CAT5e cable (Belden 1533, plenum; 1533R for non-plenum) should be used. For this type of cable, you should use shielded RJ45 connectors meant for **solid conductor wire** (L-Com TDS8PC5 or equivalent). When connecting CAT5e cable to shielded RJ45 connectors:

1. Carefully strip the outer sheath insulation back 1". Roll back the foil shield insulation and wrap the drain wire around the foil ***(Figure 4-2)***. Do not remove any insulation from the conductors.
2. Untwist the wires to within 1/8" of the jacket. Arrange the wires according to TIE/EAI 586A & 586B ***(Figure 4-3)***. For straight patch cables, wire both ends 586A; for crossover cables, wire one end 586A and the other 586B. Insert wires into the loading bar. Trim excess wires.
3. Hold the connector in front of you with the locking tab down. Orient the wires so connector pin 1 aligns with cable pin 1, etc. (Pin 1 is on the far left). Slide the wires into the CAT5e connector. The cable jacket should extend into the connector about 1/4" for strain relief ***(Figure 4-4)***.
4. Insert the plug into a crimp tool. Firmly squeeze the handles to set the contacts and secure the cable.

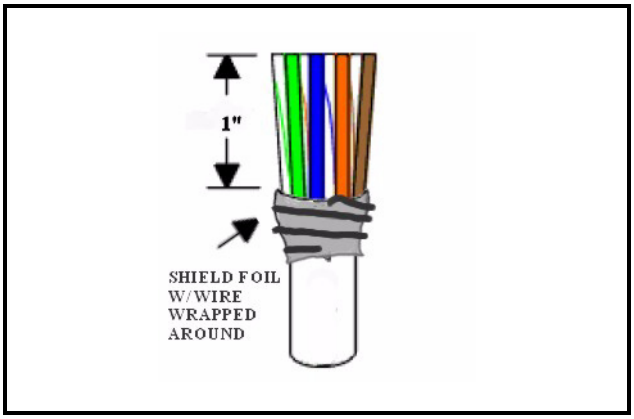

Figure 4-2 *- CAT5e Shielded Cable w/ 1" Stripped Jacket*

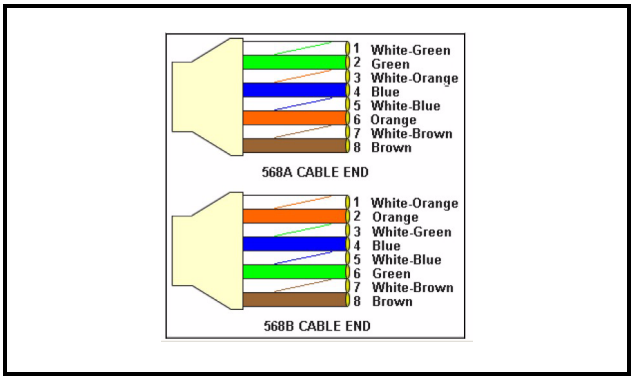

Figure 4-3 *- 586A & 586B Cable End Wire Color Diagram*

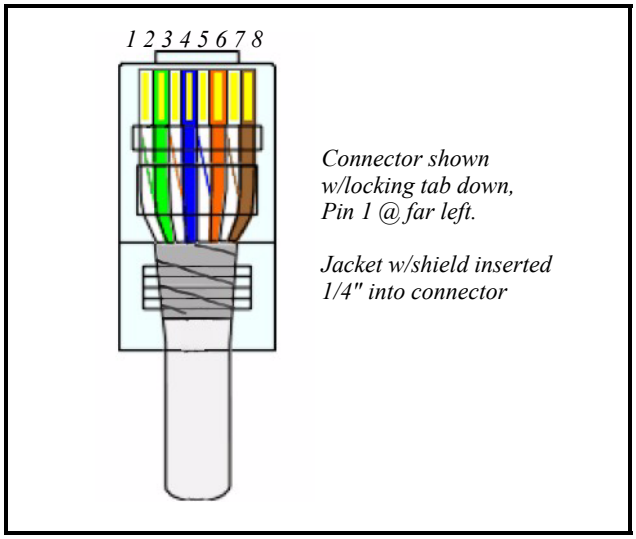

Figure 4-4 *- CAT5e Cable End Loaded Into Connector*

4.3.2. Maximum Cable Length

An Ethernet cable should be no longer than 328 feet (100 meters) from E2 to switch or hub. Exceeding this length will cause communication problems.

5 Power Wire Gage Selection

The gage of wire used to connect networked devices to the transformer secondary also plays a significant part in noise reduction. Most CPC controllers and I/O devices are powered by 24VAC transformers. Power wiring from the transformer secondary should be either 18AWG, 16AWG, or 14AWG, depending upon the total wire length to all devices and the total VA of all devices powered.

To determine the correct wire gage to use:

1. Add together the VA ratings of all devices that will be powered by the transformer. ***Table 5-1*** shows the VA devices for the E2 controller and the most common RS485 I/O and Echelon devices used in an E2 control system.

Controller	VA	VAC	Center Tapped?
E2	40	24	No
16AI	5	24	Yes
8RO	15	24	Yes
4AO	10	24	Yes
8DO	18	24	Yes
8IO/ARTC	18	24	No
MultiFlex 16	6	24	Yes
MultiFlex I/O (except ESR)	15	24	No
ESR8	80	24	No
MultiFlex ESR	80	24	Yes
TD3	4	24	No
Gateway	5	24	Yes

Table 5-1 *- VA Ratings for CPC I/O Devices*

2. Use the total VA calculated in step 1 in the following equations to determine the maximum wire length allowable for each wire gage:

- 14AWG: $1200 \div (VA)$ (feet)
- 16AWG: $750 \div (VA)$ (feet)
- 18AWG: $462 \div (VA)$ (feet)

3. Estimate the total length of wire necessary to power the devices, measured from the transformer secondary to the last device that will be connected. Using the maximum wire lengths calculated in step 2, choose a gage of wire whose maximum wire length is longer than the total length of wire you will be using.

Example: A 24VAC transformer will be used to power three MultiFlex 168AOs. The total length of power wire needed is 15 feet. Since the total VA of the three MultiFlex boards is 45VA, 18AWG wire may not be used, since 462 / 45 = 10.2 feet maximum. 16AWG wire and 14AWG wire may both be used, since with 45VA these wires would have maximum distances of 16.7 ft. and 26.7 ft. respectively.

6 Network Structure, Biasing, and Termination Resistance

6.1. RS485 Networking

The RS485 Input/Output (I/O) Network connects all input and output communication boards together in a single open communications loop. This loop, or "daisy chain," connects the E2 to multiple input and output communication boards, and terminates at the last input or output board on the network. A diagram of this network arrangement is shown in ***Figure 6-1***.

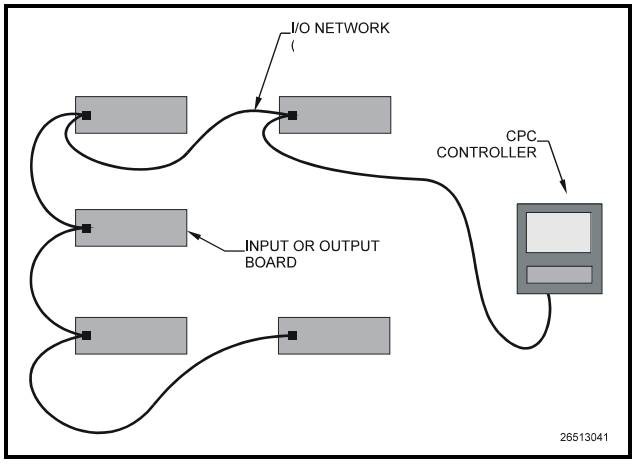

Figure 6-1 *- I/O Network Configurations*

Daisy chains are the only allowable network structure for CPC RS485 I/O networks. Branching and "star configurations" can seriously affect network performance and therefore are not allowed.

6.1.1. Terminating and Biasing an I/O Networks and MODBUS Networks

Proper termination and biasing is an important part of reducing I/O network noise. All CPC-manufactured devices with RS485 ports are equipped with three on-board jumpers that can provide the resistance necessary to terminate and bias the network endpoint. The middle jumper provides the termination resistance, while the two outside jumpers provide biasing.

I/O Network daisy chains must be terminated AND biased at both ends of the daisy chain (***Figure 6-2***).

MODBUS daisy chains must be terminated at both ends of the daisy chain, but must only be biased at ONE end. Biasing the E2 is the preferred method of network biasing. Most third-party MODBUS devices have no termination or network bias capabilities and will require use of a MODBUS termination block (see **Section 6.1.1.1.,** *MODBUS Termination Blocks*). Others, like the Control Link, have three jumpers similar to CPC I/O devices. For these devices, set the termination jumper (middle) to the UP position and leave the biasing jumpers in the DOWN position. (***Figure 6-2***)

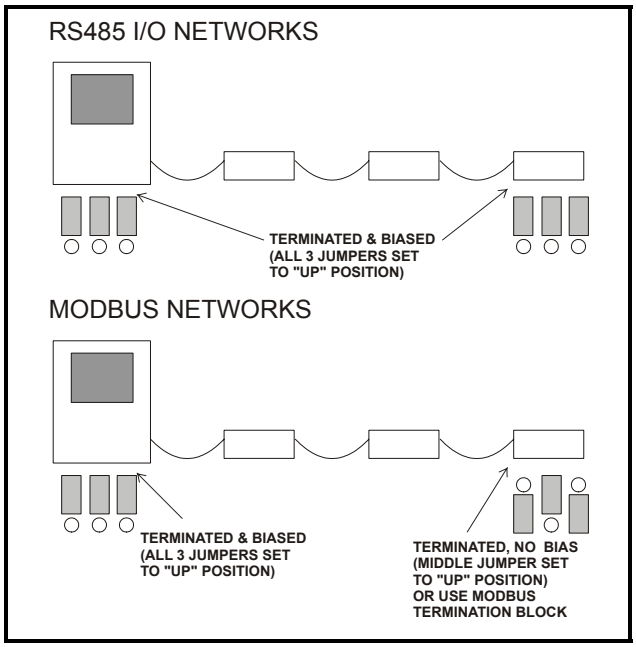

Figure 6-2 *- I/O Network and MODBUS Termination and Biasing*

6.1.1.1. MODBUS Termination Blocks

Third-party devices may or may not have on-board termination jumpers — consult the manufacturer's instructions for termination information.

If an end device does not have termination jumpers, CPC offers a termination block that can be used to terminate MODBUS network endpoints (CPC P/N 535-2711). Connect this block either in series with the MODBUS network just before the end device (***Figure 6-3***) or if necessary, at the very end of the network run (***Figure 6-4***).

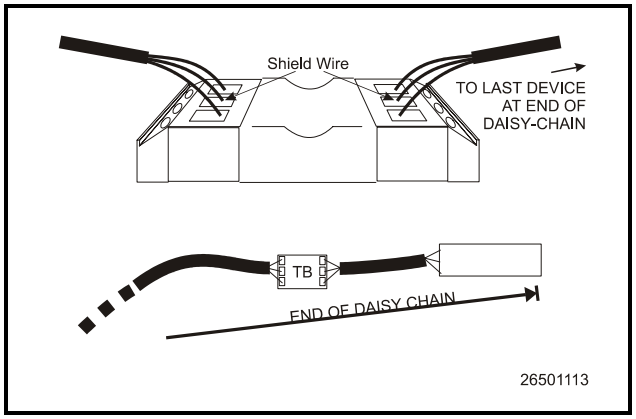

Figure 6-3 *- MODBUS Termination Block (P/N 535-2711)*

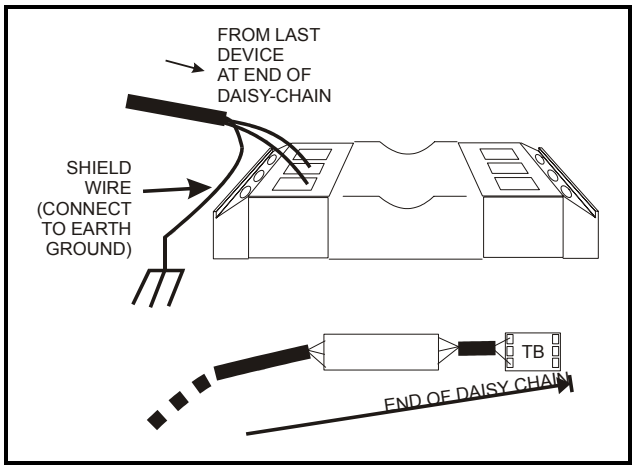

Figure 6-4 *- MODBUS Term Block End-of-Chain Install*

6.2. Echelon Networking

Echelon devices are networks together into configurations called **segments.** A segment is a group of up to 64 Echelon devices that are connected together on an unbroken series of wires.

The recommended way of constructing an Echelon Network is called **daisy-chaining.** In the daisy-chain network configuration, devices are arranged by **subnets**, which consist of one E2 and all Echelon devices associated with the E2.

First, all devices in a subnet are connected in an unbroken chain without branches or "star configurations" (see ***Figure 6-5***). Then, if more than one E2 is present on-site, all chains are connected so that the entire network forms a large unbroken chain, called a daisy chain (see ***Figure 6-6***). This allows for all devices in the Echelon Network to be hard wired together for trouble free communication.

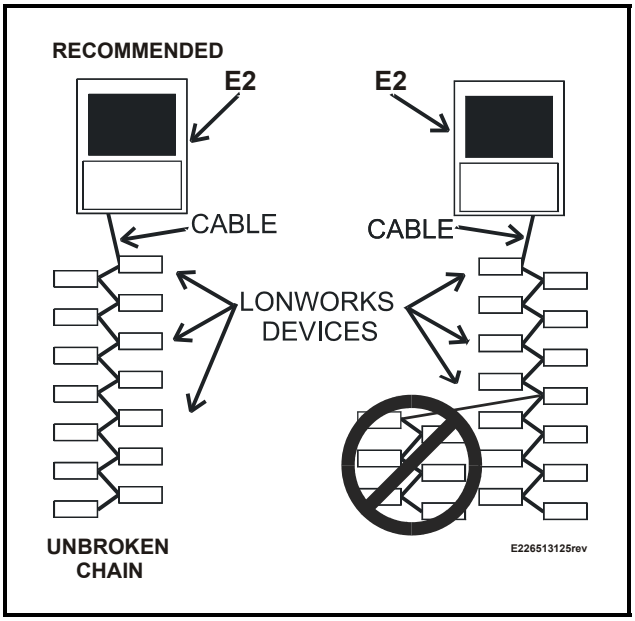

Figure 6-5 *- Echelon Wiring - Subnets*

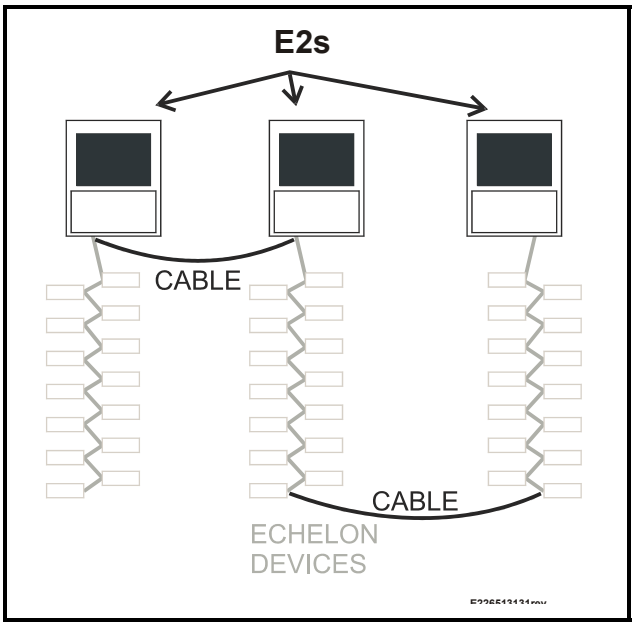

Figure 6-6 *- Echelon Wiring, pt. 2*

6.2.1. Echelon Network Termination

Echelon networks require the devices on each end of the daisy chain to be terminated with a 108-ohm resistor across the signal-carrying leads. Most CPC-manufactured Echelon devices have on-board termination jumpers that, when set to the "terminated" position, provide the required termination resistance (refer to the device's own installation documentation). If the device does not have termination jumpers, CPC offers an Echelon termination block (*P/N 535-2715)* that may be wired in series right before the end device (see ***Figure 6-7***) or at the end of an Echelon network run (necessary for TD3 installations) ***(Figure 6-8)***. The termination block provides the necessary 108-ohm resistance for network termination.

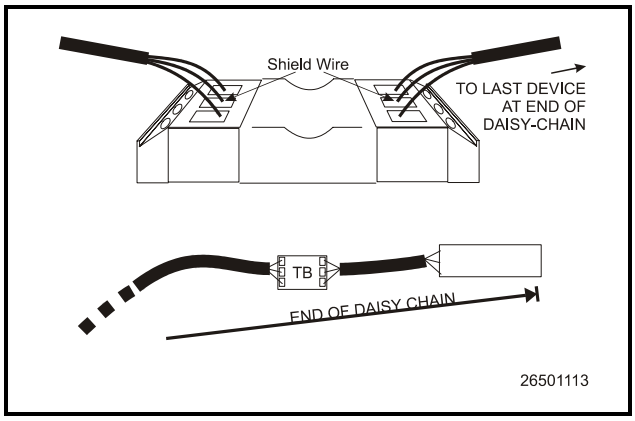

Figure 6-7 *- Echelon Termination Block (P/N 535-2715)*

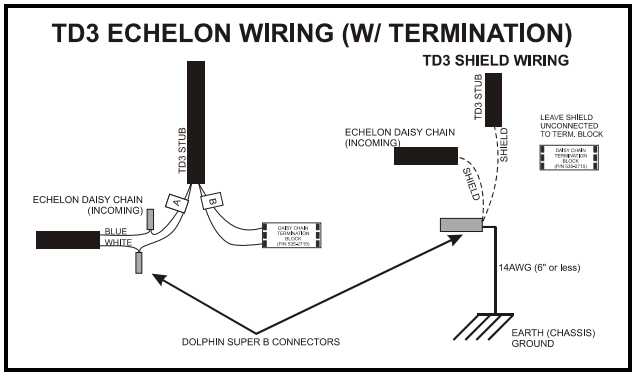

Figure 6-8 *- Termination Block Usage With TD3s*

7 Cable and Device Grounding

Proper grounding is an essential part of reducing network noise. Failure to properly ground power and network wiring is one of the most common causes of critical noise problems. Follow these guidelines when installing RS485/MODBUS and Echelon networks, and refer to them when troubleshooting problematic installations to ensure the grounding is correct.

7.1. General Grounding Guidelines

A good ground wire provides a low-DC-resistance path between the cable's or device's ground connection and the earth ground. However, because of the presence of high frequency AC noise, the ground wire itself must also be limited in length, or else it may become an "antenna" and add noise to the network.

7.1.1. Ground Wire Specifications

The length of all ground wires should be kept to **6 inches (15.3 cm) or less.** Use a 14AWG wire or larger.

7.1.2. Ground Source Specifications

The best earth ground sources to use are listed below, in priority order:

- A large metal panel or plate that is connected to a good electrical ground. A panel or plate that is at least 3 feet by 3 feet (0.9 m by 0.9 m) is desirable.
- Earth grounded steel rack.
- Water pipes (metal, assuming there are no plastic sections).
- Electrical system earth ground.

Note: If grounding against a metal plate or panel that is coated or painted, scrape away the coating to expose the bare metal before making the ground attachment.

7.2. Power Input Grounding

7.2.1. E2

The Power Interface Board (PIB) on the E2 has an earth ground connector (J3) next to the power connector on the lower right corner of the board. Connect this connector to an earth ground source using a ground wire at least 14AWG and no longer than six inches.

7.2.2. MultiFlex and other I/O Devices

For all I/O devices, including both devices that are powered by center-tapped transformers and devices powered by non-center-tapped transformers, the 0V terminal (center pin) of each device must be connected to a separate earth ground ("separate" meaning ground wires from multiple devices should not be tied together - each terminal must have its own ground wire leading to the earth ground source). The ground wire should be at least 14AWG and no longer than six inches.

7.2.3. Control Link Modules

The Control Link Module does not have a ground terminal on its power output. If MODBUS network noise is suspected, and all precautions have been taken to route low-voltage wiring away from high-voltage wiring, it is recommended you connect the "Common" terminal on the top input block to an earth ground (see ***Figure 7-1***). The ground wire

should be at least 14AWG, no longer than six inches, and should be routed away from all high-voltage wiring leading from the power input and the relay outputs.

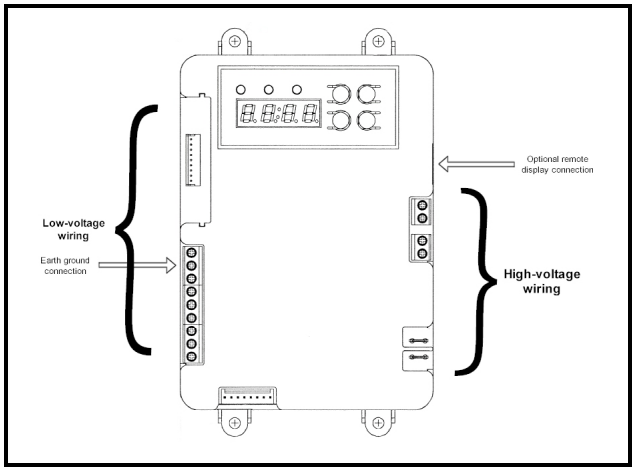

Figure 7-1 *- Earth Ground Connection Location*

7.3. RS485 I/O Network and MODBUS Cable Grounding

The shield wire for RS485 network cable must be connected to the 0V (center pin) terminals of each I/O Network connector. Provided the power inputs are properly grounded, you do not need to connect the 0V terminals to a separate earth ground, since the center pins of both the power and network connectors are common on the board.

If you are experiencing network problems that might be related to noise, it is recommended you ground each I/O device's 0V terminal to a separate solid earth ground. The ground wire should be at least 14AWG and no longer than six inches.

7.3.1. Grounding When Using Belden 9855 (Two Pair) Cable

If close proximity to noise-generating devices or high-voltage lines requires the I/O network be wired with Belden 9855 two-pair cable, connect the unused pair of wires to each 0V terminal on the I/O network, and tie the shield wires together at each connection point. Do NOT connect the shield wires to the 0V terminals on any board or controller. Connect the shield wires at both ends of the RS485 I/O network to a separate solid earth ground. Refer to *Figure 4-1* on **page 4-4** for a diagram of how to wire and ground the Belden 9855 cable.

If an E2 is at one end of the network, do NOT connect the shield wire to the earth ground connection on the E2 Power Interface Board (PIB) — connect the shield wire to a separate earth ground outside of the E2 enclosure.

7.4. Echelon Cable Grounding

The shield wires for Echelon cable should be connected to the 0V (center pin) of each Echelon network connector. At each node and at each break in the shield, connect the 0V terminals to earth ground. Use 16AWG or 18AWG wire for the 3.81mm Echelon connectors and 14AWG or greater for the 5mm Echelon connectors, and limit the ground wire length to six inches or less.

At the E2, it is recommended the shield wire be connected to a separate earth ground outside of the E2 enclosure instead of connected to the 0V terminal on the E2's Echelon connector.