WOODWARD

Application Note 51204
(Revision NEW)
Original Instructions

Grounding and Shield Termination

General Precautions	**Read this entire manual and all other publications pertaining to the work to be performed before installing, operating, or servicing this equipment.** **Practice all plant and safety instructions and precautions.** **Failure to follow instructions can cause personal injury and/or property damage.**

Revisions	**This publication may have been revised or updated since this copy was produced. To verify that you have the latest revision, check manual *26311* , *Revision Status & Distribution Restrictions of Woodward Technical Publications*, on the *publications page* of the Woodward website:** **www.woodward.com/publications** **The latest version of most publications is available on the *publications page*. If your publication is not there, please contact your customer service representative to get the latest copy.**

Proper Use	**Any unauthorized modifications to or use of this equipment outside its specified mechanical, electrical, or other operating limits may cause personal injury and/or property damage, including damage to the equipment. Any such unauthorized modifications: (i) constitute "misuse" and/or "negligence" within the meaning of the product warranty thereby excluding warranty coverage for any resulting damage, and (ii) invalidate product certifications or listings.**

Translated Publications	**If the cover of this publication states "Translation of the Original Instructions" please note:** **The original source of this publication may have been updated since this translation was made. Be sure to check manual *26311* , *Revision Status & Distribution Restrictions of Woodward Technical Publications*, to verify whether this translation is up to date. Out-of-date translations are marked with ⚠. Always compare with the original for technical specifications and for proper and safe installation and operation procedures.**

Revisions—Changes in this publication since the last revision are indicated by a black line alongside the text.

Warnings and Notices

Important Definitions

This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

- **DANGER**—Indicates a hazardous situation which, if not avoided, will result in death or serious injury.
- **WARNING**—Indicates a hazardous situation which, if not avoided, could result in death or serious injury.
- **CAUTION**—Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.
- **NOTICE**—Indicates a hazard that could result in property damage only (including damage to the control).
- **IMPORTANT**—Designates an operating tip or maintenance suggestion.

WARNING Overspeed / Overtemperature / Overpressure	**The engine, turbine, or other type of prime mover should be equipped with an overspeed shutdown device to protect against runaway or damage to the prime mover with possible personal injury, loss of life, or property damage.** **The overspeed shutdown device must be totally independent of the prime mover control system. An overtemperature or overpressure shutdown device may also be needed for safety, as appropriate.**

WARNING Personal Protective Equipment	**The products described in this publication may present risks that could lead to personal injury, loss of life, or property damage. Always wear the appropriate personal protective equipment (PPE) for the job at hand. Equipment that should be considered includes but is not limited to:** • **Eye Protection** • **Hearing Protection** • **Hard Hat** • **Gloves** • **Safety Boots** • **Respirator** **Always read the proper Material Safety Data Sheet (MSDS) for any working fluid(s) and comply with recommended safety equipment.**

WARNING Start-up	**Be prepared to make an emergency shutdown when starting the engine, turbine, or other type of prime mover, to protect against runaway or overspeed with possible personal injury, loss of life, or property damage.**

WARNING Automotive Applications	**On- and off-highway Mobile Applications: Unless Woodward's control functions as the supervisory control, customer should install a system totally independent of the prime mover control system that monitors for supervisory control of engine (and takes appropriate action if supervisory control is lost) to protect against loss of engine control with possible personal injury, loss of life, or property damage.**

NOTICE **Battery Charging Device**	**To prevent damage to a control system that uses an alternator or battery-charging device, make sure the charging device is turned off before disconnecting the battery from the system.**

Electrostatic Discharge Awareness

NOTICE **Electrostatic Precautions**	**Electronic controls contain static-sensitive parts. Observe the following precautions to prevent damage to these parts:** • **Discharge body static before handling the control (with power to the control turned off, contact a grounded surface and maintain contact while handling the control).** • **Avoid all plastic, vinyl, and Styrofoam (except antistatic versions) around printed circuit boards.** • **Do not touch the components or conductors on a printed circuit board with your hands or with conductive devices.** **To prevent damage to electronic components caused by improper handling, read and observe the precautions in Woodward manual *82715*, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.**

Follow these precautions when working with or near the control.

1. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.
2. Do not remove the printed circuit board (PCB) from the control cabinet unless absolutely necessary. If you must remove the PCB from the control cabinet, follow these precautions:
   - Do not touch any part of the PCB except the edges.
   - Do not touch the electrical conductors, the connectors, or the components with conductive devices or with your hands.
   - When replacing a PCB, keep the new PCB in the plastic antistatic protective bag it comes in until you are ready to install it. Immediately after removing the old PCB from the control cabinet, place it in the antistatic protective bag.

Grounding and Shield Termination

Introduction

There are two reasons why grounding and shield termination information seem to keep changing:

- **Technology Change**—Grounding and shield termination schemes have not changed greatly in the past 10 to 15 years. But the technologies being implemented in the field have changed. Today's faster IC (integrated circuit) technologies are more sensitive to interference, reducing the number of grounding and shielding schemes that are effective.
- **Knowledge**—Too often, people have tried to use a single approach to address all grounding and shield termination problems. When problems occurred, a new scheme had to be developed. Then as further problems occurred, more new schemes had to be tried, with the result that schemes were constantly changing.

Grounding and shield terminations must be based on the knowledge that no one scheme solves all problems, requiring trade-offs to define the best scheme for each individual cable.

Grounding Philosophy

Single Point Ground Scheme

The first grounding philosophy is single point grounding. This assumes there is a single place referred to as an equipotential point or plane. Figure 1 shows a schematic of a couple variations of a single point ground.

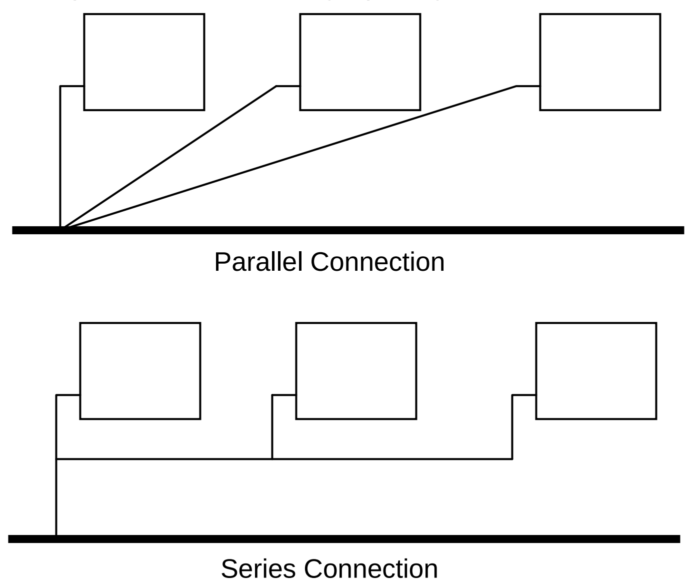

Figure 1. Single Point Ground

This grounding scheme is very effective for low frequency noise reduction (such as 60 Hz noise from power plants). This type of grounding is used for stereo equipment with low signal sources (turn-tables). Figure 2 shows shield terminations and grounding based on this scheme. Figure 3 shows what happens as noise signal increase in frequencies. As frequencies approach 10 MHz, the parasitic capacitance (that is already present in systems) forces the single point ground scheme to start to look like a multipoint grounding scheme (Figure 4).

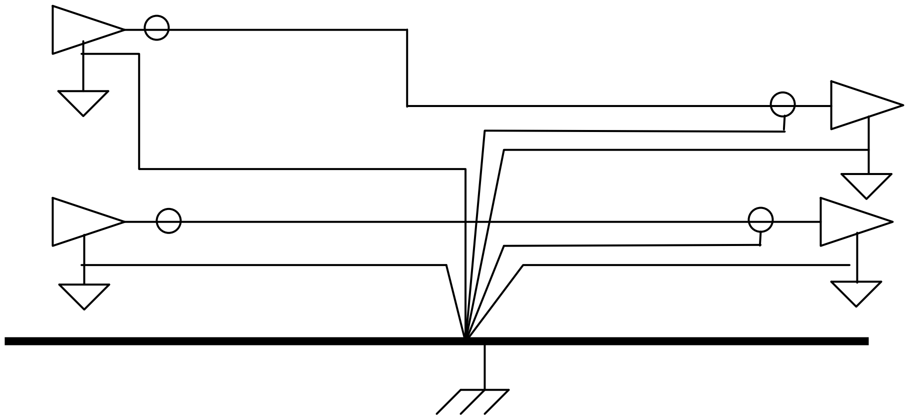

Figure 2. Single Point Ground for Stereo System

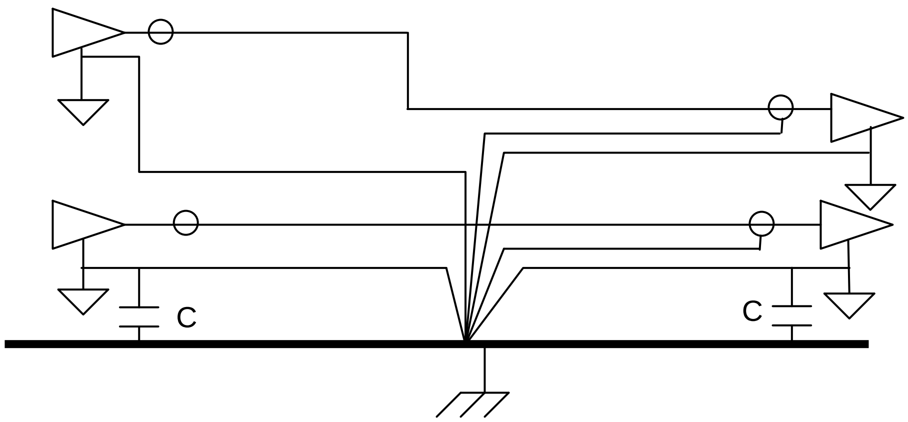

Figure 3. Single Point Ground for Stereo System with Parasitic Capacitance

Multipoint Ground Scheme

The second grounding philosophy is multipoint grounding. This assumes there is an equipotential plane. Figure 4 shows a schematic of a multipoint ground. This grounding scheme is very effective for high frequency noise reduction. This type of grounding is used for digital circuit design and RF designs. Figure 5 shows shield terminations and grounding based on this scheme. The drawback of this system is when there are large current levels in the ground plane (as there are in power station applications), there will be a significant low-frequency noise current in the cable shield, which will affect signals like RTDs.

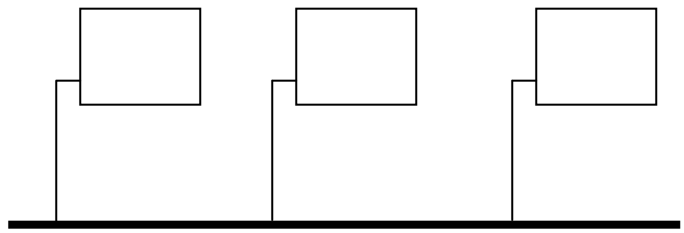

Figure 4. Multipoint Ground Scheme

Figure 5. Multipoint Ground Scheme for Two Remote Chassis

Hybrid Grounding Scheme

The hybrid grounding system attempts to provide the best of a single point grounding scheme along with the best of a multipoint grounding scheme (Figure 6). At low frequencies (below 1 MHz), the capacitors are not low enough in impedance (in most cases) to allow significant current to flow. As the noise frequency rises, the impedance of the capacitor decreases, thereby effectively shorting the point (the capacitor is bypassing) to ground. For this scheme to work, the capacitor must be a very good, high-frequency capacitor (like radial lead ceramics), and the loop area (defined by the mounting of the capacitor) and shield termination must be small. If these loop areas or shield terminations are large in area/length, the inductance becomes to high, thereby decoupling the capacitor and thus removing the short at high frequencies.

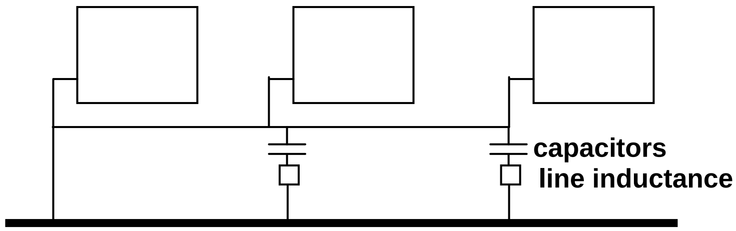

Figure 6. Simple Hybrid Grounding Scheme

Figure 7 shows shield terminations and grounding based on the hybrid-grounding scheme.

Figure 7. Hybrid Grounding Scheme

Grounding Techniques

Intent of a Grounding System

Woodward has done considerable design work to ensure that the cabinet or panel can operate in a variety of industrial environments, and can protect against noise, EMI (electromagnetic interference), and RFI (radio frequency interference) conditions. The primary purposes of equipment grounding are personnel safety and to improve equipment operation and continuity of service. The four main reasons for having grounded systems are: safety, lightning protection, reduction of noise emissions, and signal integrity.

Grounding the Cabinet

The cabinet should have a solid connection to an earth ground. Woodward cabinets provide an earth ground connection, unless the specification clearly calls out for it not to be included. Connections to earth ground can be made by using a metal rod, buried water pipes, buried plates, or buried wire/cable. A ground connection should be durable, have low dc resistance and low ac impedance, and have adequate current-carrying capability.

Cable Isolation and Routing

Field signals should be grouped into high- and low-voltage signals as well as analog and discrete signals. Whenever possible, these signals should be isolated inside the cabinet as well as outside the cabinet. High-voltage signals are classified as greater than 75 V, and low-voltage signals are less than 75 V. Analog signals are classified as signals that vary from one value to another, such as a thermocouple input or a current (4–20 mA) input. Analog signals should always be carried via twisted pair, insulated and shielded cable. Discrete signals are signals that have an 'ON' and an 'OFF' value, but do not vary between the two readings. These types of signals usually do not require shielded cables.

Wire Connections to the Cabinet

Modern electronic systems usually have more than one ground network to satisfy grounding requirements to prevent induction or conduction of undesirable currents and voltage in the signal reference system. Shielding is accomplished by 'overbraiding' and 'inner shielding' of cables. An outside conduit, braid, or cable shield is referred to as the 'overbraid', and any internal signal shielding to the cable is referred to as the 'twisted-wire shield'. When signals are grouped together in a cable, hard ground or capacitively couple the cable overbraid close to the penetration point of the cabinet. Ground bars or some other means of grounding should be provided for this purpose. After the field wiring has been connected to the cabinet, be sure to install any floor plates or panels, and wire duct covers, to 'close' up the cabinet.

For shielded cable to be effective, it should be shielded over the entire length of the cable. It is important that the shield be maintained over the cable as close as possible to the final termination on either end. As an example, if the cable is left unshielded for 10% of its length, the maximum shielding effectiveness of the cable is 20log(100/10) or 20 dB.

Shield Connections in the Field

Cable and component shielding keeps out unwanted radio frequency noise from equipment, and prevents ‘cross-talk’ of signals from one cable or system to another. Shielding a cable can be accomplished by simply grounding the cable shield at one end, and/or by using a capacitor to ground on the other end. Connecting a shield directly to a ground is referred to as a ‘hard’, or dc, ground. Using a capacitor to tie the shield to ground is referred to an ac ground. Single point grounding is effective for low frequency (60 Hz) noise reduction.

Each signal in a system can have a different method used for grounding its shield. Here are some general rules that should be considered first when determining the correct grounding method.

- **Thermocouple Signal Grounding**

These signals are very sensitive to noise. For thermocouples, the twisted-wire shield should be tied to earth ground at the receiving end of the cable (for example, at the control or unit that is first reading the signal). If the thermocouple is included in a cable with other signals, the cable overbraid should be terminated at the control, at the point of penetration into the cabinet. See Figures 8 through 16.

- **RTD Signal Grounding**

These signals are extremely sensitive to noise. For RTDs, the twisted-wire shield should be tied to earth ground at the receiving end of the cable (for example, at the control or unit that is first reading the signal). If the RTD is included in a cable with other signals, the cable overbraid should be terminated at the control, at the point of penetration into the cabinet. See Figures 8 through 16.

- **Current Input Signal Grounding**

For current input signals, the twisted-wire shield should be tied to earth ground at the receiving end of the cable. If the signal is connected in another cabinet before it is connected into the Woodward cabinet, the shield should be grounded at the first point where the signal is first connected and left floating in the Woodward cabinet. If the current input signal is included in a cable with other signals, the cable overbraid should be terminated at the control, at the point of penetration into the cabinet. See Figures 8 through 16 first, or 17 through 25 if the customer requires shields hard grounded at their end.

- **MPU Signal Grounding**

For MPU signals, the twisted-wire shield should be tied to earth ground at the receiving end of the cable. If the MPU signal is included in a cable with other signals, the cable overbraid should be terminated at the control, at the point of penetration into the cabinet. See Figures 8 through 16.

- **Proximity Signal Grounding**

For proximity signals, better noise reduction will occur when the twisted-wire shield is tied to earth ground at the sensor end. At the control end, the shield should be ac coupled to ground through the use of a capacitor. The capacitor can be located at the point of penetration into the cabinet or installed on the field termination module (FTM) if there is an overbraid. See Figures 17 through 25.

- **Current Output Signal Grounding**

For current output signals, the twisted-wire shield should be tied to earth ground at the receiving end of the cable, and not at the control end. At the control end, the shield should be ac coupled to ground through the use of a capacitor. The capacitor can be located at the point of penetration into the cabinet or located on the field termination module (FTM). If the current output signal is included in a cable with other signals, the cable overbraid should be terminated at the control, at the point of penetration into the cabinet. See Figures 17 through 25.

- **Actuator Driver and Feedback Device Signal Grounding**

If the actuator is a passive device, such as a coil or torque motor, the twisted-wire shield should be tied to earth ground at the transmit end (control system). When the actuator drive signal connects to an active device, such as a final driver, TM or EM driver, or a GS10 driver, the twisted-wire shield should be tied to ground at the driver and ac coupled at the control system end. The ac coupling to earth ground can be done by use of a capacitor located at the entry point into the cabinet or at the FTM (if there is an overbraid). If the actuator drive signal is included in a cable with other signals, the cable overbraid should be terminated at the control, at the point of penetration into the cabinet. See Figures 8 through 16 for passive devices. See Figures 17 through 25 for active devices/drivers.

- **Feedback Device (LVDT, RVDT, MLDT, Resolver) Signal Grounding**

For feedback signals, the twisted-wire shield should be tied to earth ground at the receive end (control system). If the feedback signal is included in a cable with other signals, the cable overbraid should be terminated at the control, at the point of penetration into the cabinet. See Figures 8 through 16.

- **Discrete Input Signal Grounding**

Typically these signals are not shielded. If these signals are routed through shielded cables, the shield may be tied to ground at either end. Usually it is easier to tie this shield to the earth ground of the control system because this is a common point for all of the signals on the cable. The cable overbraid should be terminated at the point of penetration into the cabinet. See Figures 8 through 16, or 17 through 25.

- **Discrete Output (Relay) Signal Grounding**

Relay output signals can be used to energize solenoids, turn on indicator lights, or communicate 'on' or 'off' status to other pieces of equipment. If the discrete output signal is included in a cable with other signals, the cable overbraid should be terminated at the control, at the point of penetration into the cabinet. See Figures 8 through 16, or 17 through 25.

- **Communications (Ethernet, RS-422, RS-232, Profibus) Signal Grounding**

Communication cables should ground the twisted-wire shield to the backshell of one of the connectors. Depending on what the cable is connected to outside the cabinet, the first preference for grounding the twisted-wire shield is to the backshell located inside the control cabinet. If the communication signal is included in a cable with other signals, the cable overbraid should be terminated at the control, at the point of penetration into the cabinet. See Figures 8 through 16.

Field Terminal Modules

Woodward field terminal modules (FTMs) are designed to allow a signal to be ac coupled to ground through a capacitor. The capacitor is located on the FTM. Terminating shields on the FTM will tie the shield to ground, through the capacitor. When grounding any shield, it is always important to have only one ‘hard’ ground connection.

LinkNet® Terminal Modules

Woodward LinkNet terminal modules (LTMs) are designed to be installed in the field near the sensor. For this reason, when a signal shield is connected to the LTM, the shield is tied directly to the earth or ground connection. When using LTMs, it is important to have only one ‘hard’ ground connection.

Shield Types

There are many types of shielded cables. The best types employ a braid-type covering for the shield. The lowest-cost cabling usually employs a foil-type shield.

MicroNet FTM, Not Grounded in Field

(Figures 8 through 16)

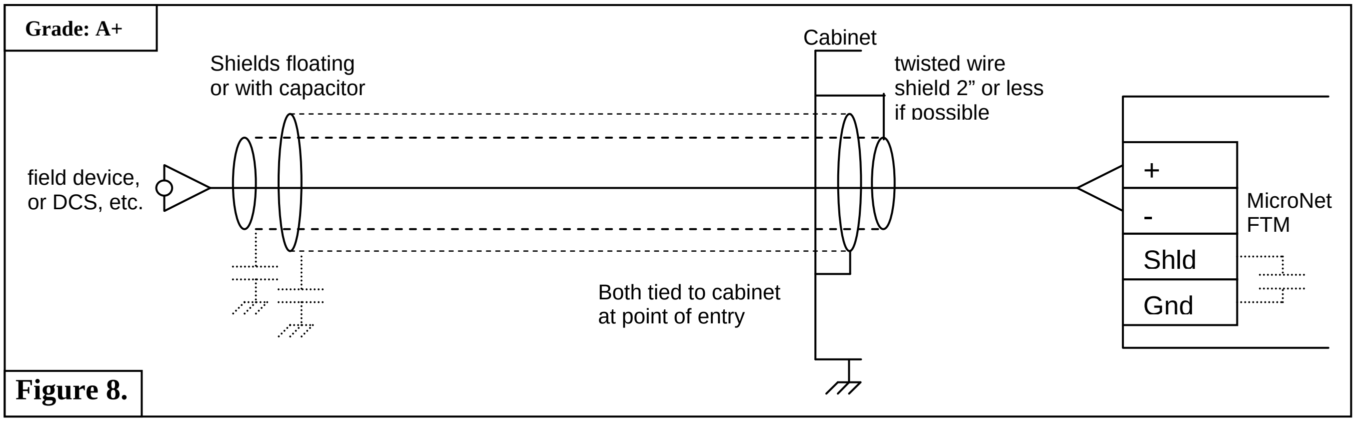

Figure 8.

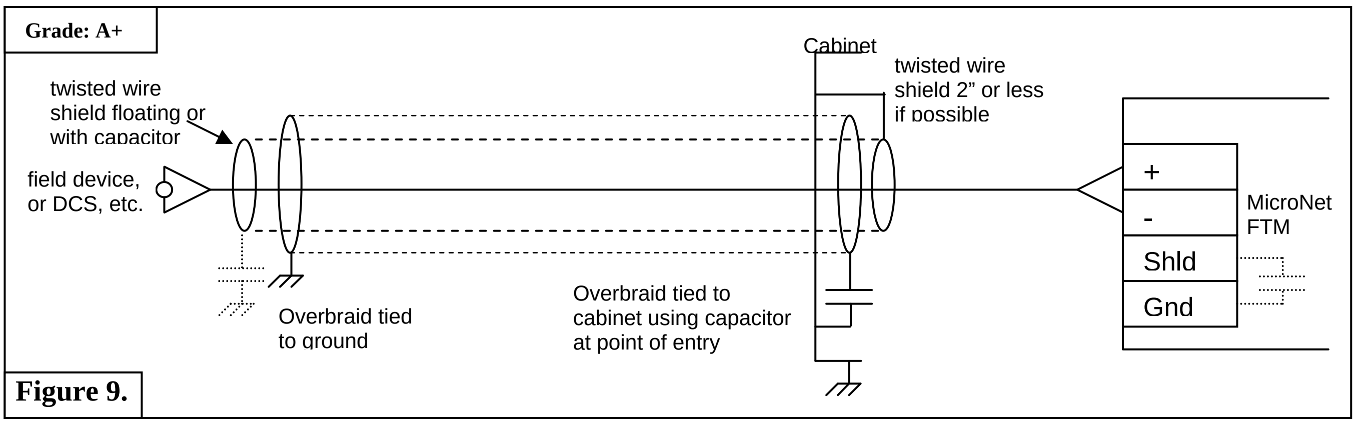

Figure 9.

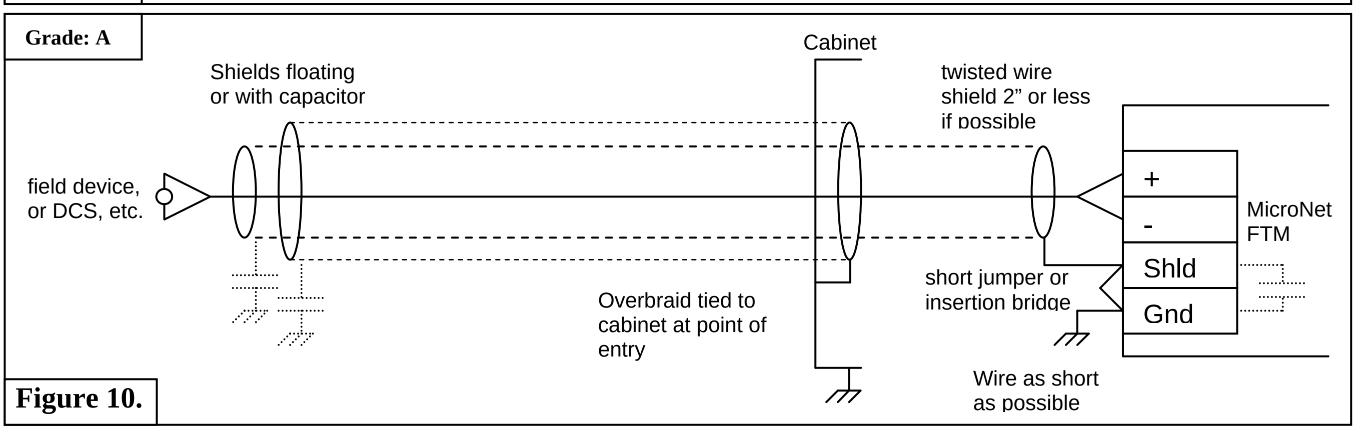

Figure 10.

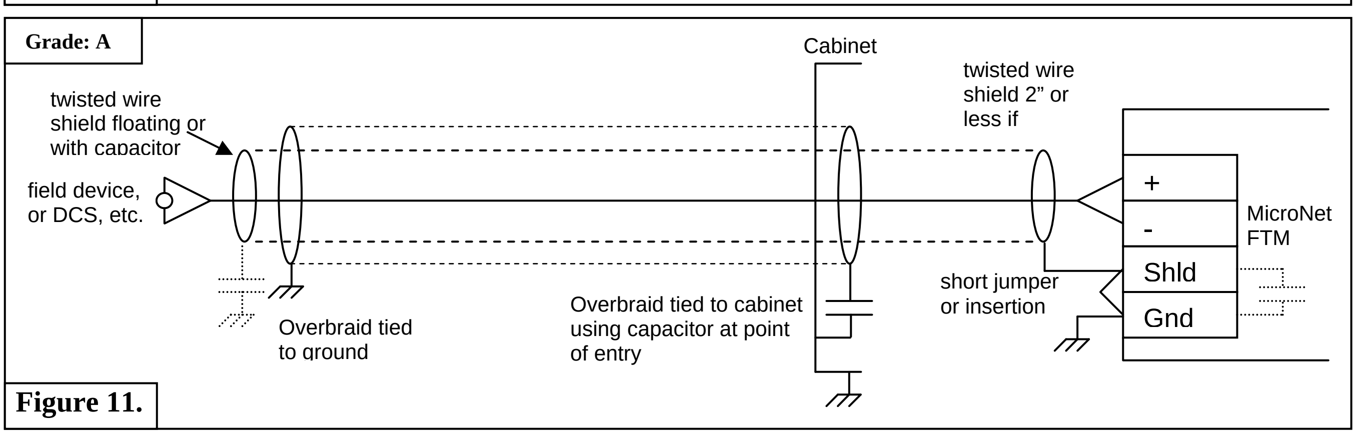

Figure 11.

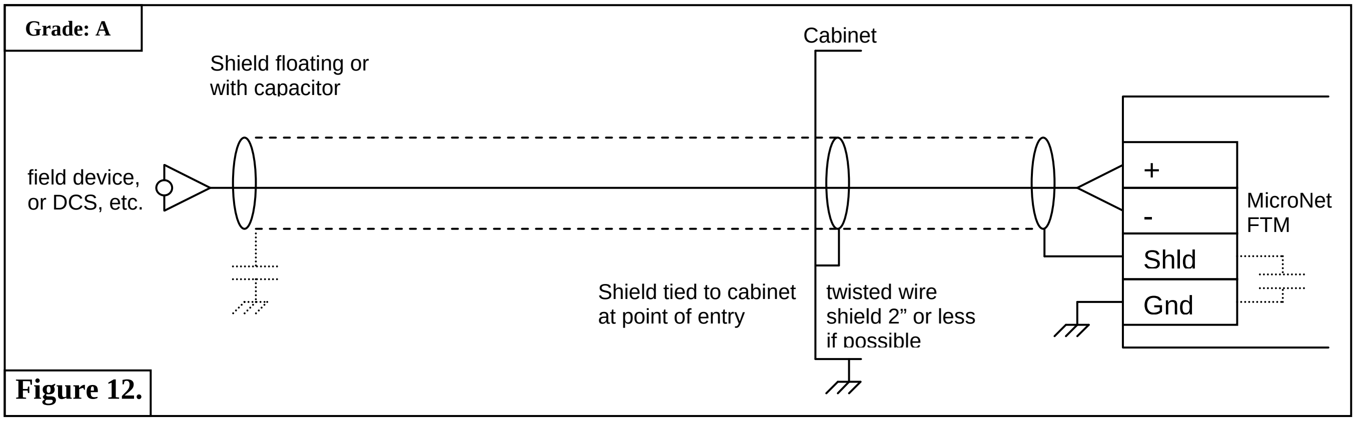

Figure 12.

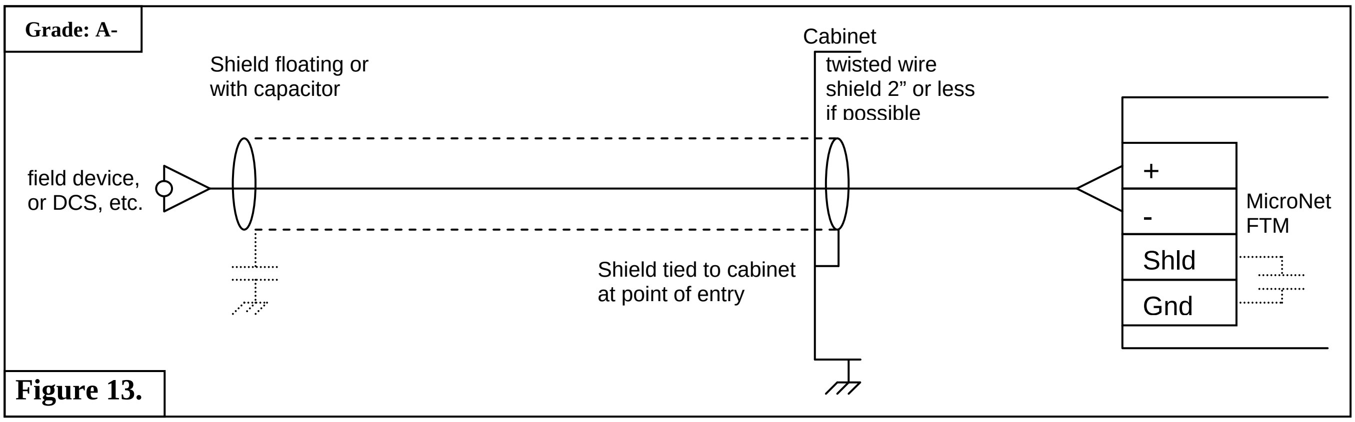

Figure 13.

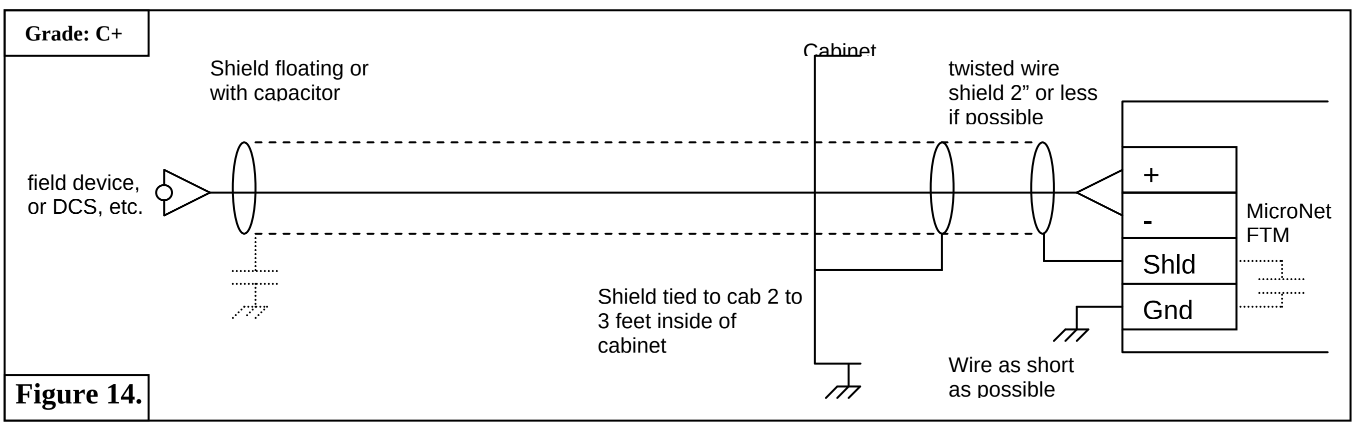

Figure 14.

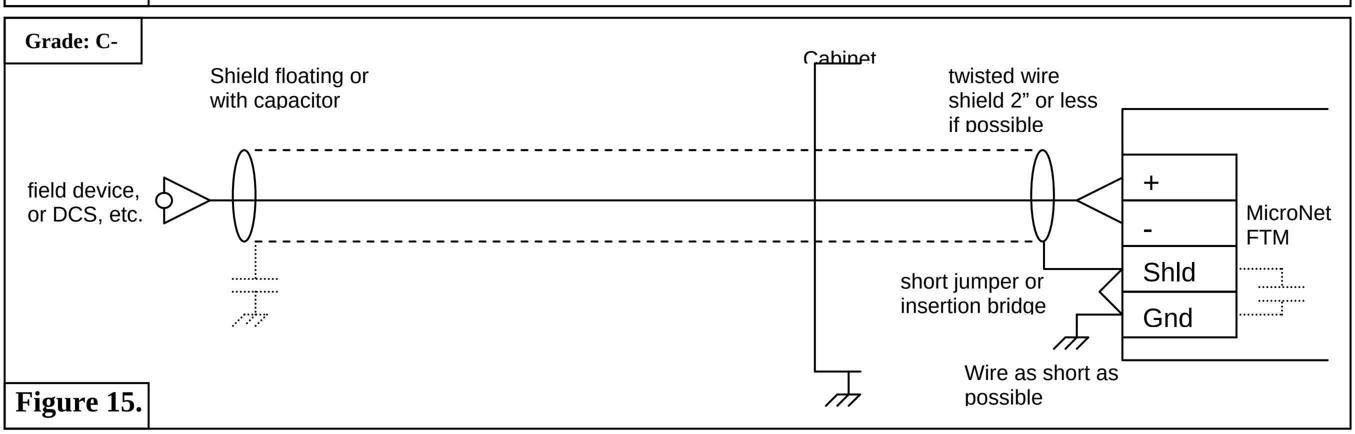

Figure 15.

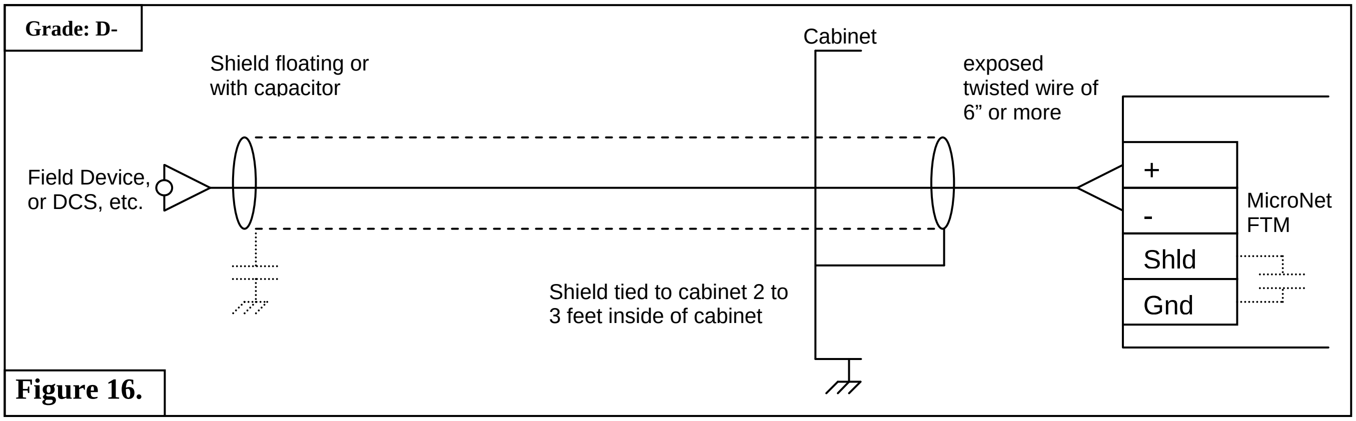

Figure 16.

MicroNet FTM, Grounded in Field

(Figures 17 through 25)

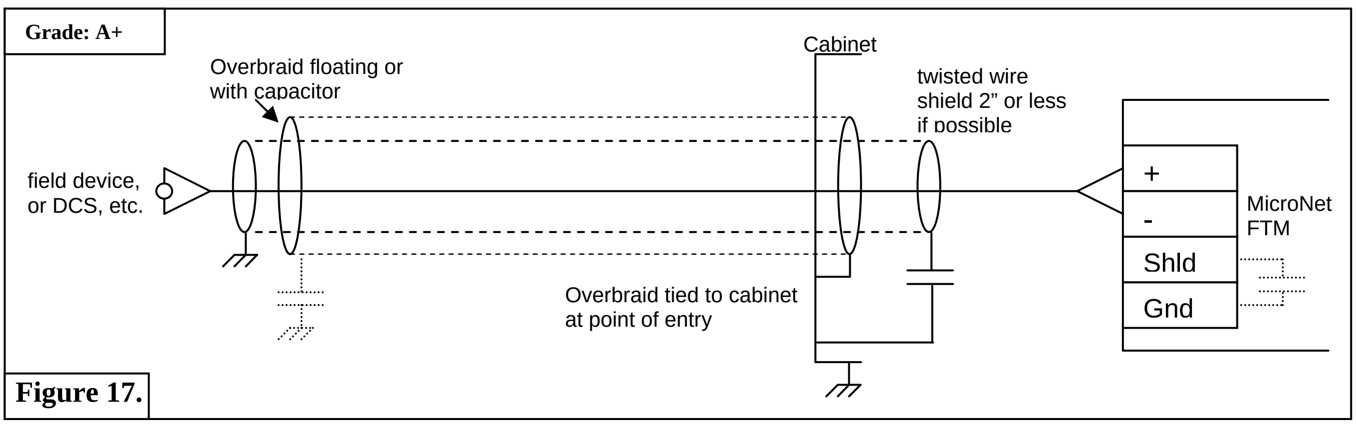

Figure 17.

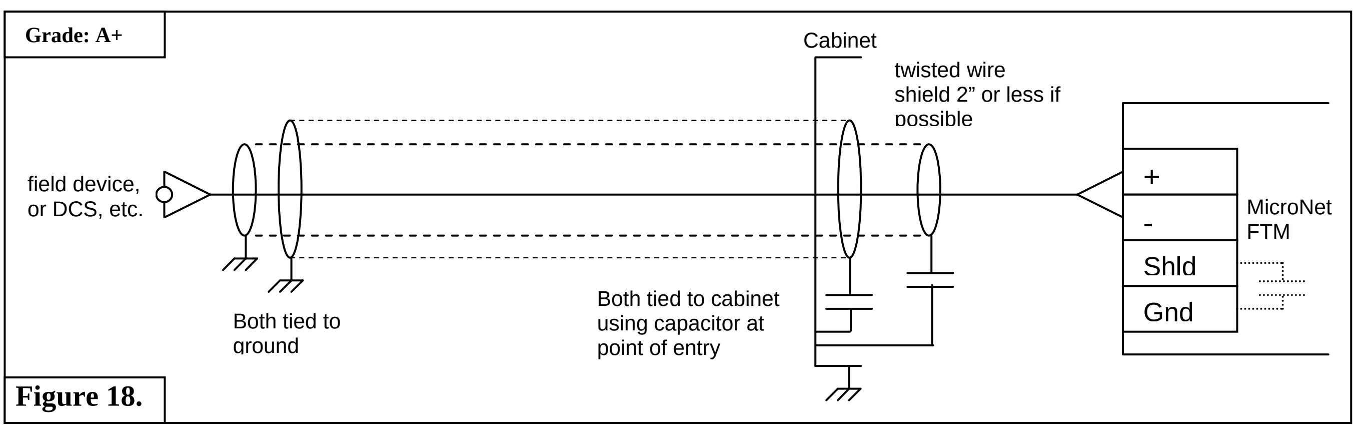

Figure 18.

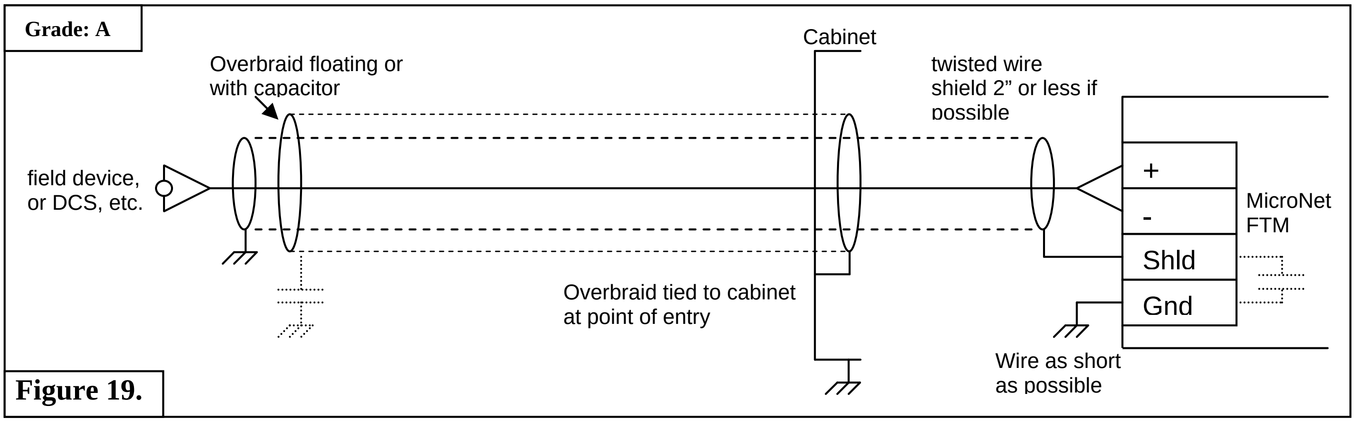

Figure 19.

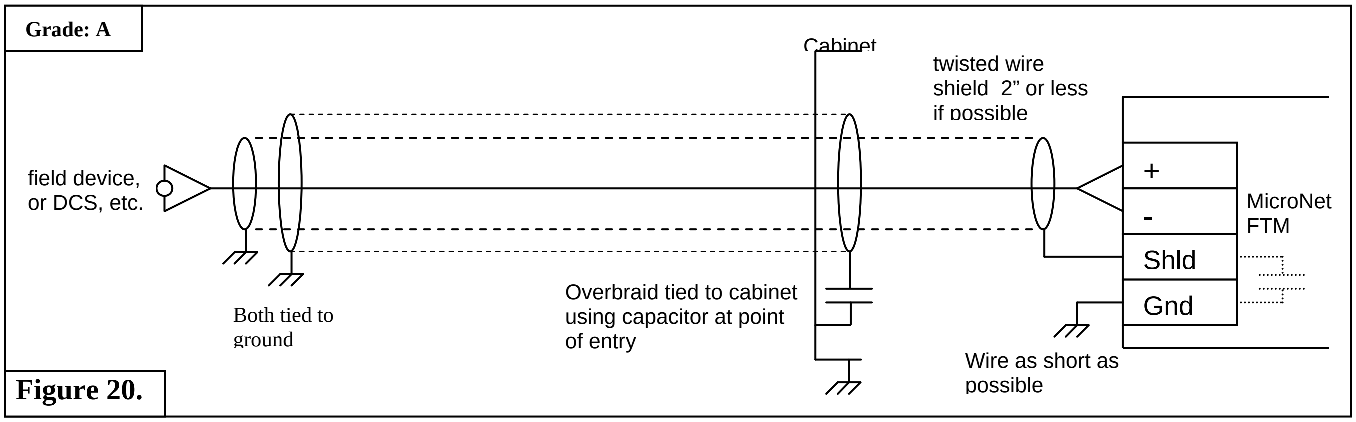

Figure 20.

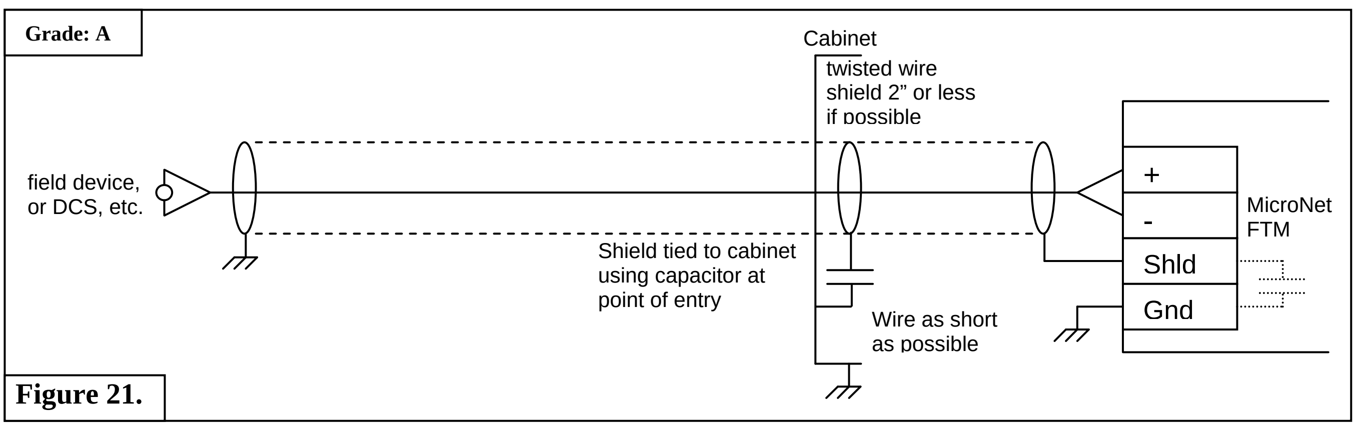

Figure 21.

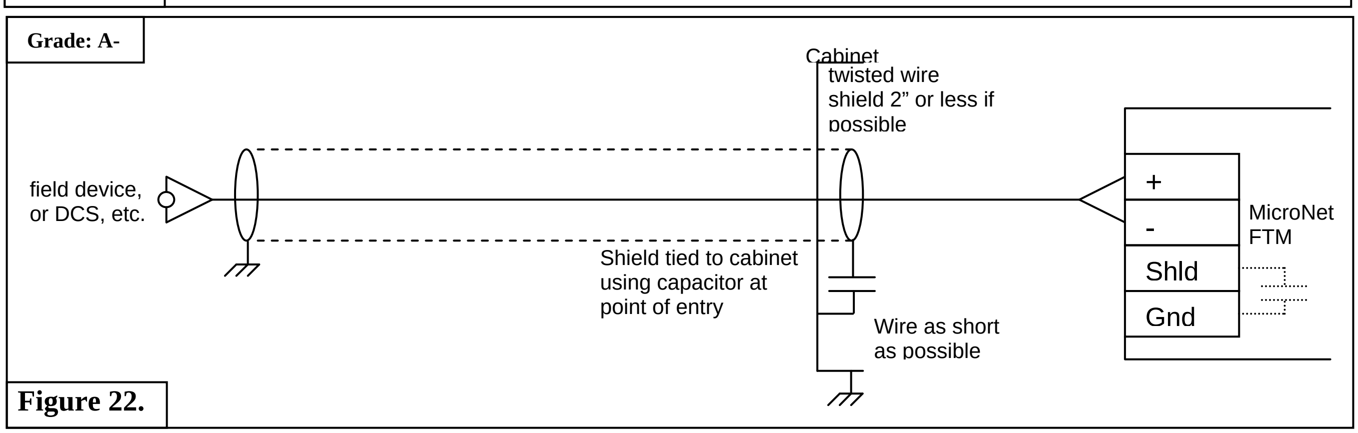

Figure 22.

Grade: C+

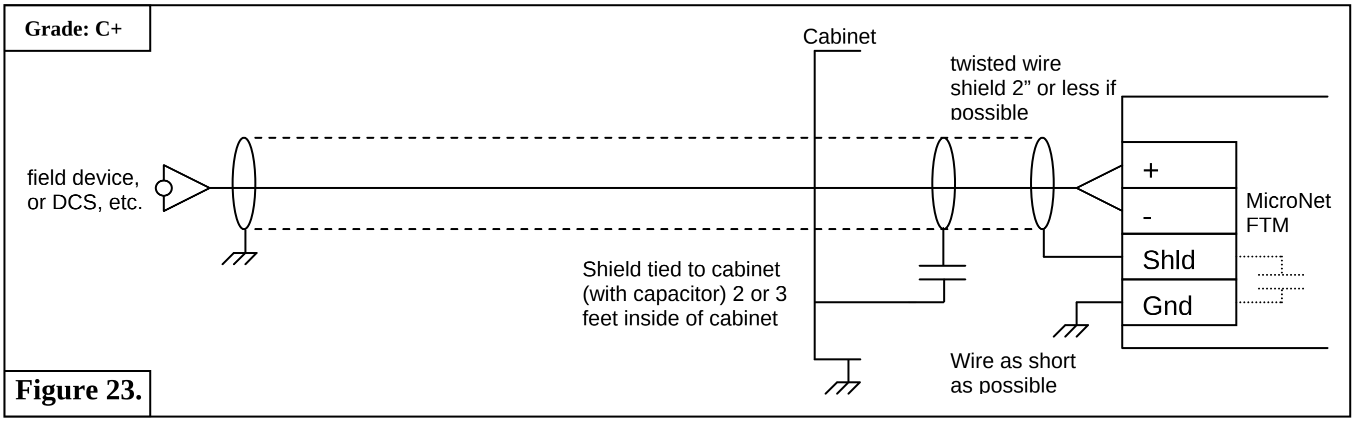

Figure 23.

Grade: C-

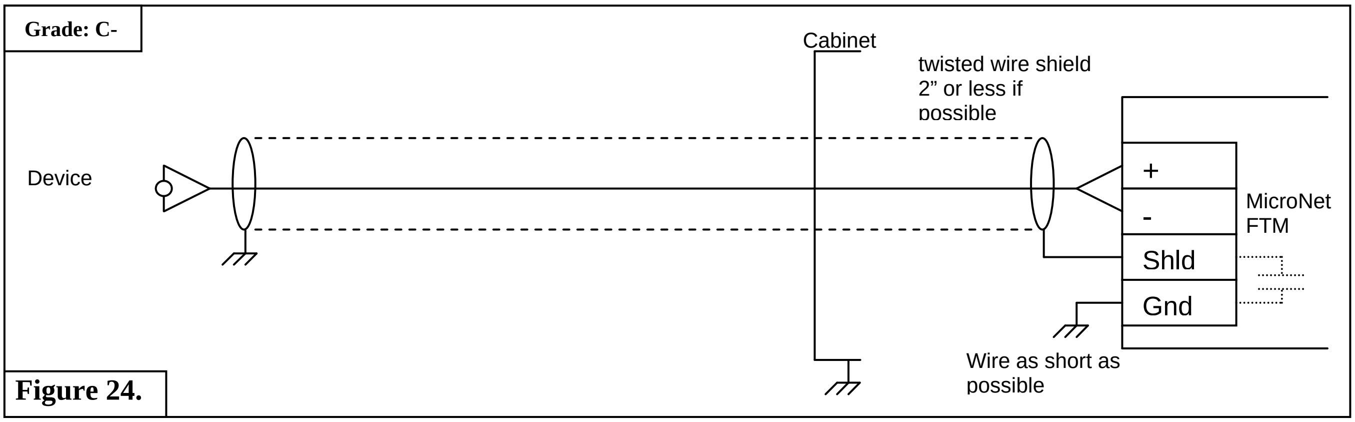

Figure 24.

Grade: D-

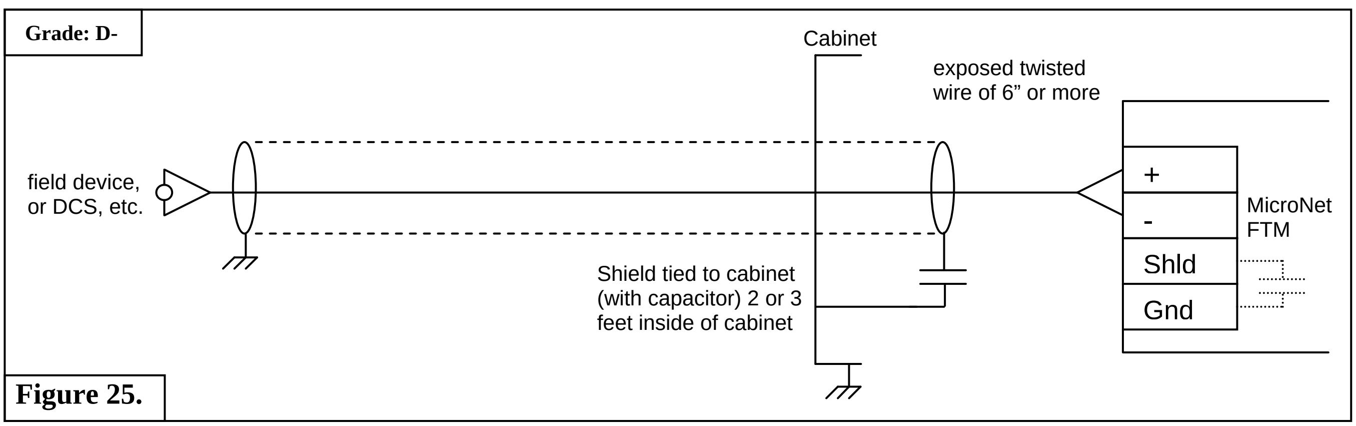

Figure 25.

We appreciate your comments about the content of our publications.

Send comments to: icinfo@woodward.com

Please reference publication 51204.

WOODWARD

PO Box 1519, Fort Collins CO 80522-1519, USA
1000 East Drake Road, Fort Collins CO 80525, USA
Phone +1 (970) 482-5811 • Fax +1 (970) 498-3058

Email and Website—www.woodward.com

Woodward has company-owned plants, subsidiaries, and branches, as well as authorized distributors and other authorized service and sales facilities throughout the world.

Complete address / phone / fax / email information for all locations is available on our website.

2012/11/Colorado