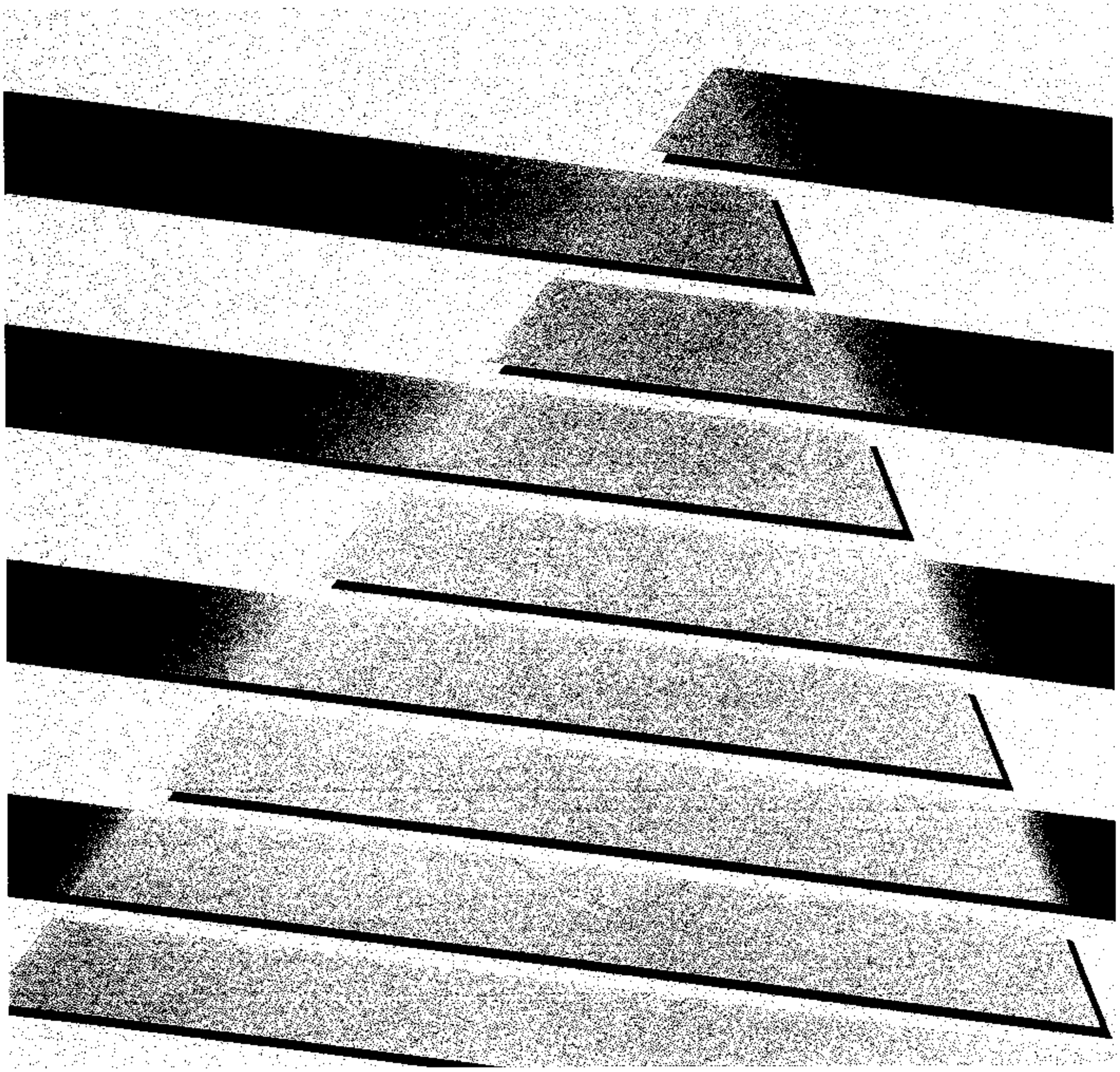
ALLEN-BRADLEY

Fiber-Optic Converter Modules

(Cat. Nos. 1771-AF and 1771-AF1)

User's Manual



Important User Information

Because of the variety of uses for the products described in this publication, those responsible for the application and use of this control equipment must satisfy themselves that all necessary steps have been taken to assure that each application and use meets all performance and safety requirements, including any applicable laws, regulations, codes and standards.

The illustrations, charts, sample programs and layout examples shown in this guide are intended solely for purposes of example. Since there are many variables and requirements associated with any particular installation, Allen-Bradley does not assume responsibility or liability (to include intellectual property liability) for actual use based upon the examples shown in this publication.

Allen-Bradley publication SGI – 1.1, *Safety Guidelines for the Application, Installation, and Maintenance of Solid State Control* (available from your local Allen-Bradley office), describes some important differences between solid-state equipment and electromechanical devices which should be taken into consideration when applying products such as those described in this publication.

Throughout this manual we make notes to alert you to possible injury to people or damage to equipment under specific circumstances.

WARNING: Tells readers where people may be hurt if procedures are not followed properly.

CAUTION: Tells readers where machinery may be damaged or economic loss can occur if procedures are not followed properly.

Warnings and Cautions:

- identify a possible trouble spot
- tell what causes the trouble
- give the result of improper action
- tell the reader how to avoid trouble

Important: We recommend that you frequently backup your application programs on an appropriate storage medium to avoid possible data loss.

Chapter 1

Using This Manual

Chapter Objectives

This chapter shows you:

- what the manual contains
- its purpose
- how the manual is organized

Manual's Purpose

This manual describes how to install, operate, and troubleshoot these fiber–optic converter modules:

- 1771–AF chassis–mounted module
- 1771–AF1 I/O stand–alone module

Audience

We assume that you are familiar with the installation and operation of Allen–Bradley programmable controllers and remote I/O.

If you are not, refer to the appropriate manuals listed under "Related Publications".

Manual Organization

The manual is organized into the following chapters:

Chapter	Title	Tasks Covered
2	Fiber–Optic Overview	Description of fiber optics Computing the excess power budget
3	Introduction and required cables	Comparing AF and AF1 modules Cable characteristics
4	Module Installation	Setting module switches Installing the module Installing twinaxial cable
5	Installing Fiber–optic Cables	Guidelines for installing, routing and pulling fiber–optic cables
6	Remote I/O Connections	Examples to help you design series, parallel, trunkline, and redundant–cable configurations
7	Data Highway Networks	Examples to help you design Data Highway and Data Highway Plus networks

Chapter	Title	Tasks Covered
8	Troubleshooting	Led indicators Troubleshooting procedures
Appendix A	Specifications	
Index	Index	Finding key words and concepts

Related Publications

If you require additional information, refer to the following publications:

Title	Publication
Programmable Controller Wiring and Grounding	1770–4.1
Data Highway Cable Installation Manual	1770–6.2.1
Universal I/O Chassis	1771–2.49
I/O Rack Use with PLC–2/20, PLC–2/30 Controllers	1771–4.3
PLC–2/30 Controller Programming and Operations Manual	1772–6.8.3
PLC–3 Controller Installation and Operations Manual	1775–6.7.1
PLC–5 Programming Manual	1785–6.8.2
PLC–5/250 Manual	5000–6.2.1 and – 6.4.1
DH/DH Plus Manual	6001–6.5.4

Chapter 2

Fiber–Optic Overview

Chapter Objectives

This chapter presents an overview of fiber–optics:

- typical applications
- terms
- power and power loss computations

What is Fiber Optics

The basis of fiber–optic communication is optical fiber: a thin, flexible glass or plastic wave guide through which light is transmitted. Optical fiber is the transmission link connecting two electronic components: a transmitter and a receiver.

The central part of the transmitter is its source, either an LED or a laser diode, which changes electrical signals into light signals. The receiver contains a photodiode or phototransistor that converts light signals back into electrical signals. An output circuit then amplifies the signals.

Typical Fiber–optic Applications

Some typical applications for fiber optic links are:

- electrostatic paint booths
- arc welders
- induction furnaces
- ore and coal mines
- oil wells and offshore oil platforms
- air compressor or electrical generating rooms
- chemical refineries
- subways and tunnels
- drawbridges
- airports

Why Use Fiber Optics?

Fiber–optic transmission represents a significant development in industrial electronic communications, and helps you overcome limitations of traditional copper cable. Some of the advantages of fiber–optic transmission over copper cable are:

Large Bandwidth

The information capacity of a carrier wave increases as its frequency increases. An optical carrier wave has frequencies several orders of magnitude greater than the highest radio frequencies. Optical cables have bandwidths approaching 2 GHz which allow high–speed data transfer.

The low signal attenuation of optical cable allows long cable runs without the use of repeaters. Optical–fiber attenuation is essentially independent of modulation frequency, whereas copper–cable attenuation increases as modulation frequency increases.

Noise Immunity

Electrical noise does not affect fiber–optic transmissions. Transmitted signals are not distorted by electromagnetic energy or radio frequency interference because the cable is a dielectric, and the propagated signal is light which is not affected by induced fields.

Size

Optical cables of a given data capacity are much smaller than conventional cables. This size reduction helps reduce overcrowding in conduits and wireways. Optical cables also weigh less than comparable copper cables. This weight savings eases cable installation.

Transmission Security

Fiber–optic transmissions are secure because they do not emit electromagnetic signals. If a fiber–optic cable is tapped, transmitted data is usually altered enough to indicate an irregularity in the line.

Safety and Electrical Isolation

Optical cables are intrinsically safe because they carry light pulses only – no electrical signals are present. This is an advantage in explosive or hazardous environments. Additionally, optical cables help eliminate ground loop problems.

Fiber-Optic Components

A basic fiber–optic system consists of a light source/transmitter, an optical fiber cable, and a light detector/receiver.

Light Source

Semiconductor light sources are either light–emitting diodes (LEDs) or injection laser diodes. LEDs provide less power and operate at slower speeds than laser diodes but are more cost effective. LEDs are suited to most applications that require data transmissions up to several kilometers in length at speeds up to several hundred megabits per second.

A light source must:

- have an operating speed compatible with the system bandwidth
- provide enough optical power to trigger the detector
- produce a wavelength that takes advantage of the optical characteristics of the cable

Optical Fibers

One way to classify fibers is by material. Glass and silica make efficient fibers. Plastic fibers are larger and less efficient but usually more rugged and economical.

Fibers can also be classified by their refractive index profiles and the number of modes they support. Two main index profiles are step fibers and graded fibers. A step index fiber has a core with a uniform refractive index and a distinct change or step between the indexes of the core and the cladding. A graded index fiber's core does not have a uniform refractive index; it is highest at the center and gradually decreases until it matches the cladding's index.

Multimode Step Index Fibers
Multimode step index fibers have core diameters between 50 μm and 1000μm. Such large core diameters allow many modes of light propagation. Light reflects differently for different modes which means that some rays follow longer paths than others.

In the lowest order mode, the axial ray travels down the center of the fiber without reflecting. It reaches the other end of the fiber before higher order rays do. The higher order rays strike the core–cladding interface close to the critical angle, which causes them to follow longer paths down the fiber. Therefore, a narrow pulse of light spreads out as it travels through the fiber. This spreading of light is called modal dispersion.

Single–Mode Step Index Fibers
Single–mode step index fibers limit modal dispersion by using a small diameter core that only propagates one mode efficiently. A single–mode fiber, with a core diameter of 2 to 10 µm, is very efficient. It is suitable for high–speed and long–distance applications.

Graded Index Fibers
Graded index fibers also limit modal dispersion. These fibers propagate light by using a core made up of a series of concentric rings. Each ring has a lower refractive index than the one preceding it. Since light travels faster in a lower index medium, light farthest from the fiber center travels faster. Since high–order modes have a faster average velocity than low–order modes, all modes tend to arrive at a point at nearly the same time.

The fiber's core–cladding interface does not sharply reflect the rays of light. Instead, the differing layers of the core successively refract the light producing a nearly sinusoidal path.

Attenuation
Attenuation in optical cables is caused by two factors: absorption and scattering.

Absorption is the conversion of photons to heat as light propagates and encounters impurities in the fiber–optic cable. Scattering results from imperfections in the basic structure of the fiber. Small variations in the core diameter, microbends, and small incongruities in the core–cladding interface reduce power.

Dispersion
Dispersion is the spreading of a light pulse as it travels along the fiber. A pulse seen at the output is wider than the input pulse. Dispersion limits a fiber's bandwidth and can be one of two types.

Modal dispersion is due to the different paths that light follows in the various modes. Material dispersion is due to the different velocities of light wavelengths.

Bend Radius
Microbends increase radiation loss by changing the geometry encountered by reflecting rays. Light loss increases as a fiber bends. The minimum bend radius approximates the breaking point of the fiber.

Numerical Aperture

Numerical aperture is the light–gathering capability of the fiber. It establishes the angles of incidence at which the cable will accept and transmit light. The higher the numerical aperture, the more light the cable can gather.

Fiber Strength

The strength of a fiber is related to chemical or physical defects. Defects may occur during manufacturing, handling, or from exposure to the atmosphere. A flawed fiber can be further damaged by stress corrosion. Any defect is a potential point of failure.

The condition of the cladding's surface also affects a fiber's strength. Therefore, abrasion can harm a fiber both mechanically and optically. A buffer coating applied to a fiber protects it from moisture, chemicals, and mechanical damage.

Light Detectors

A fiber–optic light detector converts optical energy into electrical energy. Various devices may serve as detectors:

- semiconductor photodiodes (pin and avalanche types)
- phototransistors
- integrated devices with preamplifiers and receivers

The performance of a fiber–optic link is limited by both dispersion and attenuation. When attenuation is the limiting factor, the detector must be able to respond to weak incoming light signals. The detector's sensitivity rating is one of the factors determining the level of link performance.

Optical Power

Fiber–optic power is defined in watts but is commonly expressed in decibels.

$$\text{Power}_{(dB)} = 10 \log \frac{(\text{Psig})}{(\text{Pref})}$$

Where:
Power = power in dB
Psig = signal power to be measured
Pref = reference power (milliwatts (1mW) or microwatts (1µW))

For example:

$$\text{Power}_{(dBm)} = 10 \log \frac{(\text{Psig})}{(1\text{mW})}$$

$$\text{Power}_{(dB\mu)} = 10 \log \frac{(\text{Psig})}{(1\mu\text{W})}$$

The optical power loss in the fiber–optic circuit can also be expressed in decibels.

$$\text{Power Loss}_{(dB)} = 10 \log \frac{(\text{Pout})}{(\text{Pin})}$$

Where:
Power Loss = power in dB
Pout = optical power leaving the fiber cable
Pin = optical power entering the fiber cable

For example:

$$\text{Power Loss}_{(dBm)} = \text{Pout}_{(dBm)} - \text{Pin}_{(dBm)}$$
$$\text{Power Loss}_{(dB\mu)} = \text{Pout}_{(dB\mu)} - \text{Pin}_{(dB\mu)}$$

Signal Losses

Optical signal losses should be kept to a minimum. The following can cause signal loss:

- connectors
- splices
- splicing cables of different diameters
- splicing cables of different numerical aperture
- fiber attenuation
- core diameter mismatch
- sharp bends in the cable
- age of the light source/detector

Next we show you to to compute the "Fiber–Optic Excess Power Budget".

Computing the Fiber–optic Excess Power Budget

The operation of an optical link depends on the amount of optical power available and the degree of losses in the system.

We show you how to compute the excess power budget (Table 2.A) for a typical fiber–optic transmission link (Figure 2.1), based on:

- 100/140 μm fiber–optic cable
- 5 dBm/km cable attenuation
- 2 km distance
- epoxy/polish connectors with 1.0 dBm loss per connector

Important: The excess power budget should be greater than or equal to zero for the system to operate reliably at the maximum specified distance.

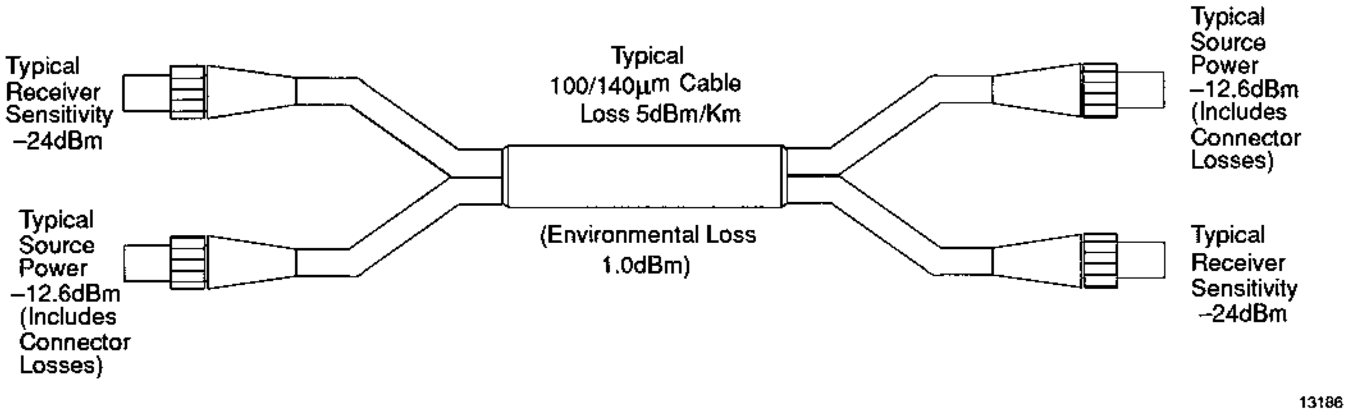
Instructions: Enter your own system–loss values in the blank spaces to compute your Excess Power Budget (Table 2.A). Example values are in parentheses.

Table 2.A
System Loss Computations

a) Min Xmttr Source-Coupled Power[1] =	______	(–12.6dBm)
b) Receiver Sensitivity (fixed) =	______	(–24.0dBm)
c) Maximum Allowable Loss = [a–b]	______	(11.4dBm)
d) Fiber Loss at Maximum Distance =	______	(10.0dBm)/2km
e) Environmental Losses (fixed) =	______	(1.0dBm)
f) Maximum System Loss = [d + e]	______	(11.0dBm)
c) Maximum Allowable Loss =	______	(11.4dBm)
f) Maximum System Loss =	______	(11.0dBm)
g) Excess Power Budget = [c – f]	______	(0.4dBm)

[1] Appendix A lists the transmitter power for specific cable diameters.

Figure 2.1
System Loss Parameters



Chapter 3

Introducing AF and AF1 Modules and Required Fiber–optic Cables

Chapter Objectives

This chapter helps you choose the correct fiber–optic modules and cables for your application.

Module Description

Fiber–optic modules:

- convert electrical signals into light signals and transmit them through a fiber–optic cable
- convert light signals to electrical signals and transmit them through electrical cables.

These modules introduce no appreciable system delay, and are completely transparent to devices connected to them.

Fiber–optic modules also receive, amplify, and re–transmit electrical signals, so you can use the modules as repeaters in an electrical cable (twinaxial) link for cable distances up to 30,000 feet.

Choosing Between Fiber–optic Modules

Allen–Bradley fiber–optic modules (1771–AF and –AF1) are electrically and functionally identical. The only differences are:

- mounting requirements
- source of power
- method of connecting wires

Mounting	Specific Differences	Catalog Number
I/O Chassis	Draws power from I/O chassis backplane Uses wiringarm for wire connections	1771–AF
Stand–alone	Needs separate 5Vdc power supply Uses terminal block for wire connections	1771–AF1

Module Compatibility

Fiber–optic modules are compatible with the following modules and components via twinaxial cable:

Catalog Number	Product
1770–KF2	DH/DH Plus RS–232–C Interface Module
1770–M11	Mass Storage System
1771–AS, –ASB	I/O Adapter Module
1771–DCM	Direct Communication Module
1771–KA	Communication Adapter Module
1771–KE, –KF	Communication Controller Module
1772–SD, –SD2	Remote I/O Scanner/Distribution Panel
1773–KA	Communication Interface Module
1775–GA	Peripheral Communication Module
1775–KA	Communication Adapter Module
1775–RM	Peripheral Interface Adapter Module
1775–S4A,–S4B, –S5, –SR5	I/O Scanner Module
1785–KA	DH/DH Plus Communication Adapter Module
1785–KE	DH Plus RS–232–C Interface Module

Choosing the Correct Fiber–Optic Cable

Use duplex fiber–optic cables with your fiber–optic modules. The cable must meet these criteria:

- Cable size (provided they accept an SMA–905 connector):

  50/125 µm   100/140 µm
  62.5/125 µm   200/230 µm
  85/125 µm

- 17 Mhz or greater bandwidth
- Either epoxy/polish or crimp/cleave SMA–905 connectors
- 1.0 dBm loss or less per connector
- Support 820 nm wavelength

Choose the cable diameter according to cable length and signal attenuation acceptable for your application:

Length Guidelines (km)	(feet)	Cable Diameter	Attenuation (dB loss/km)	Numerical Aperture (NA)
0.50	1625	50/125 μ m	4 dBm/Km	0.20 NA
1.75	5688	62.5/125 μ m	4 dBm/Km	0.28 NA
2	6500	85/125 μ m	4 dBm/Km	0.26 NA
2	6500	100/140 μ m	5 dBm/Km	0.30 NA
2	6500	200/230 μ m	6 dBm/Km	0.37 NA

Choosing Pre–terminated Fiber–Optic Cables

Duplex fiber–optic cables are available from Allen–Bradley in four lengths. The following table lists cable assemblies and catalog numbers:

Cable Length	Catalog Number
30 Meters (98 Feet)	1771–PT1
75 Meters (246 Feet)	1771–PT2
150 Meters (492 Feet)	1771–PT3
300 Meters (984 Feet)	1771–PT4
Splice Connector	1771–CPR

The maximum recommended combination of Allen–Bradley pre–terminated cables in a fiber–optic link is two (2) cables spliced together, i.e. two 300–meter cables for a combined length of 600 meters (1900 feet). Note that two splice connectors are needed to connect the duplex fiber cable.

Choosing Cable Connectors

Epoxy/polish SMA connectors provide a reliable, low cost, low loss fiber–optic cable termination. These connectors use epoxy to securely hold the cable's fiber. You then polish the end of the fiber for a low insertion–loss connection. As an alternative, you may use crimp–type SMA connectors in place of epoxy/polish connectors.

Chapter 4

Module Installation

Chapter Objectives

In this chapter we show you how to:

- choose the operating mode for your application
- set internal switches
- mount the AF1 stand–alone module
- power the AF1 stand–alone module
- install keying bands for the AF chassis–mounted module
- connect twinaxial cables, and correctly ground their shields

Choosing the Operating Mode

Before installing the module, you must select the module's operating mode for your application. These modes are:

- star
- point–to–point

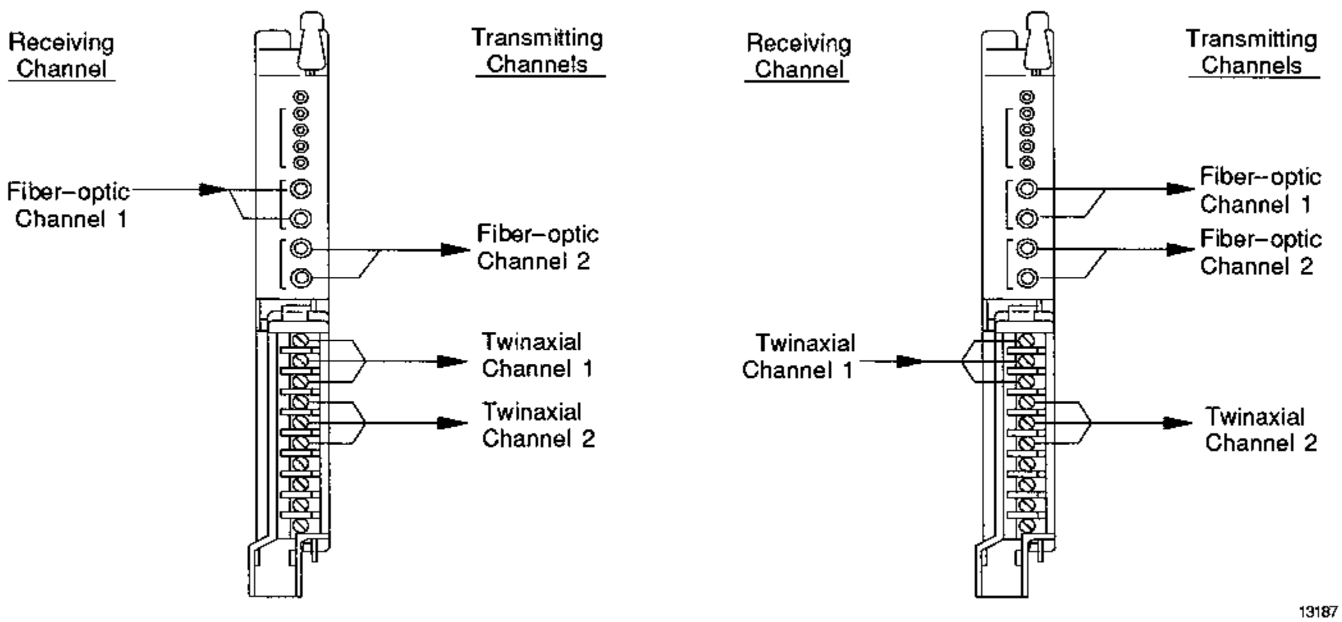
Star Mode

Use star mode for most applications (except for redundant cabling). It is the factory–set mode. Fiber–optic modules act as active directional repeaters or converters. They receive signals on one channel, amplify and re–transmit them on the remaining channels. You can use these 4–channel modules in 2–channel or 3–channel applications by disabling or ignoring the unused channels.

Important: When using star mode, you must disable all unused twinaxial channels as described in Setting Module Switches below.

When you select any one receiving channel	You can use any or all of these transmitting channels
Fiber–optic 1	Fiber–optic 2 Twinaxial 1 & 2
Fiber–optic 2	Fiber–optic 1 Twinaxial 1 & 2
Twinaxial 1	Twinaxial 2 Fiber–optic 1 & 2
Twinaxial 2	Twinaxial 1 Fiber–optic 1 & 2

Figure 4.1
Example Connections for Star Mode



Point-to-Point Mode for Redundant Cabling

Use point–to–point mode with redundant cables when the loss of a channel would be crucial to the application. Two cables of the same type are connected in parallel to paired channels. If one cable breaks or one channel fails, the module switches to the other automatically. You must apply redundancy to both the twinaxial and fiber–optic cables.

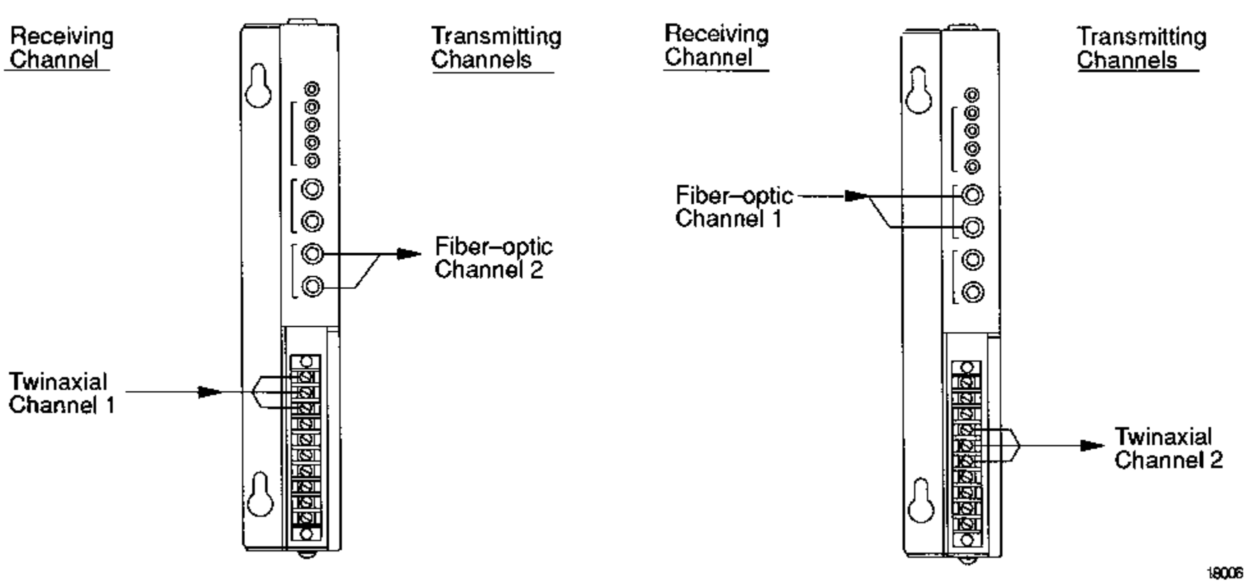
Important: Parallel cables provide a measure of safety, but do not provide complete redundancy. If a module loses power, it stops transmitting data. All devices following it in the serial link likewise stop functioning because the module is an active–signal repeater.

If a channel should fail, the module automatically switches transmission to the other channel, and turns off the failed channel's ACTIVE indicator.

You enable both twinaxial channels for redundant cabling by setting internal switches, described in the next section.

If your receiving channel is	Then you must use this transmitting channel
Twinaxial 1	Fiber–optic 2
Twinaxial 2	Fiber–optic 1
Fiber–optic 1	Twinaxial 2
Fiber–optic 2	Twinaxial 1

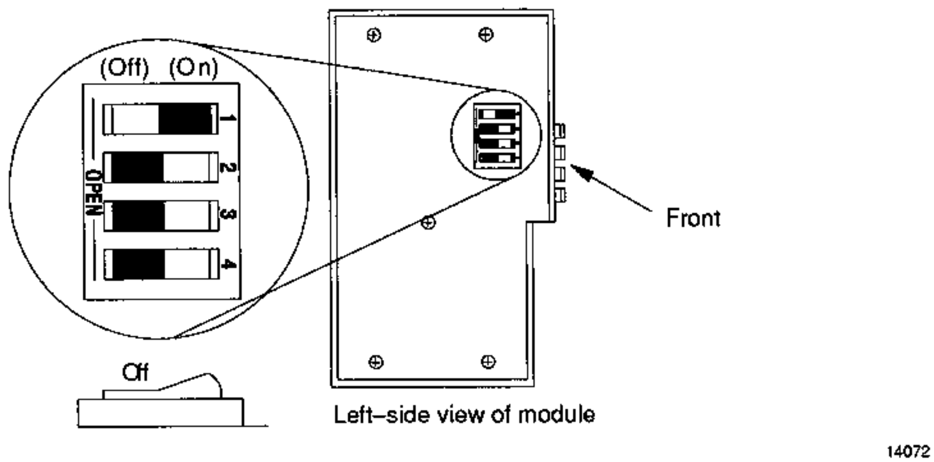
Figure 4.2
Example Connections for Point–to–point Mode



Setting Module Switches

Use the 4–switch assembly inside the module to select operating parameters for your specific application as follows (Figure 4.3):

Figure 4.3
Location of Switch Assembly Inside the Module



1. Remove the module's left cover to access the switches.
2. Use a ball–point pen or a straightened paper clip to set switches. Do not use a pencil because a piece of lead could break and jam the switch.
3. Set switches as follows:

Switch	For this condition	Use	By Setting the Switch
1	Faster transmission under 5000 feet	115.2k bit/sec	OFF (Open)
	Distances over 5000 feet	57.6k bits/sec	ON*
	Important: Set identical bit rates for modules at each end of the cable.		
2	Most applications	Star mode	OFF*(Open
	Redundant cabling	Point–to–Point	ON
3	Enable twinaxial channel 1		OFF*(Open
	Disable twinaxial channel 2		ON
4	Enable twinaxial channel 2		OFF*(Open
	Disable twinaxial channel 2		ON
	Important: For redundant cabling, enable both twinaxial channels. Otherwise, always disable all unused twinaxial channels.		

Important: * = factory setting

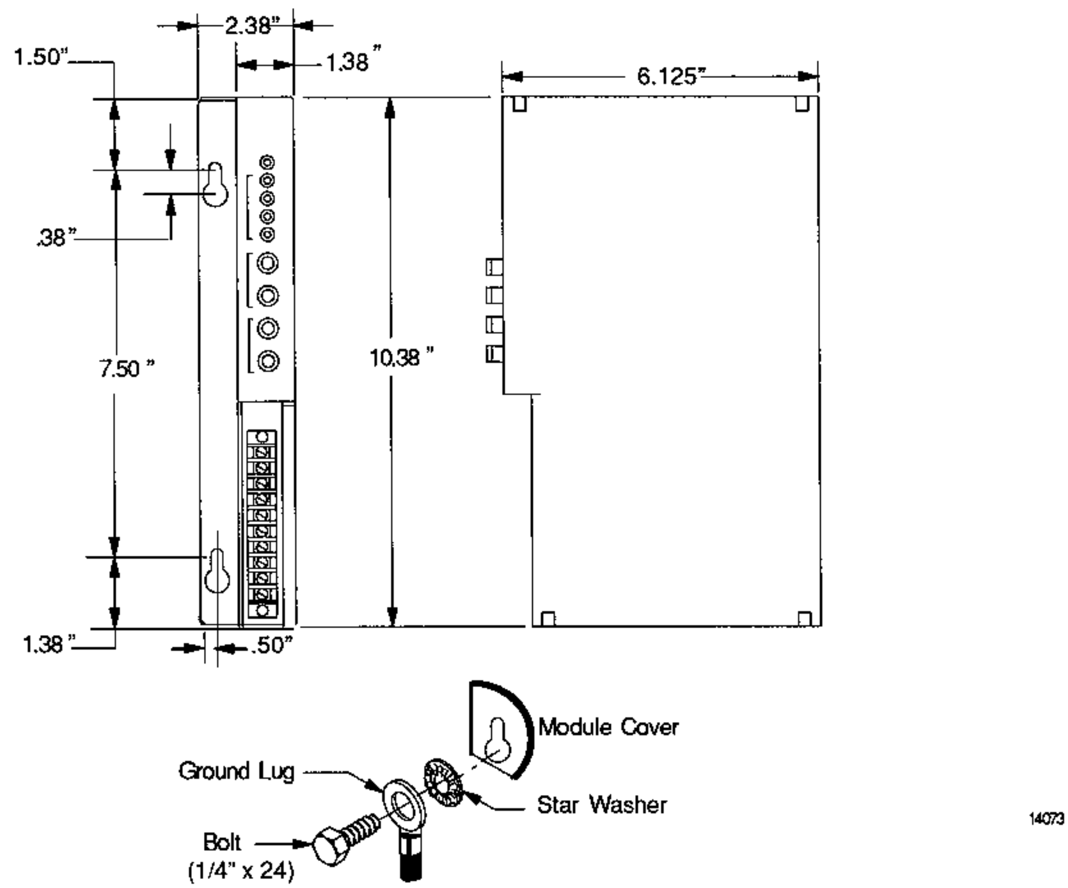
4. Re–assemble the module after setting the switches.

Mounting the AF1 Stand–alone Module

The stand–alone module's rear cover contains a mounting bracket. Mount the module with two 1/4" diameter bolts according to mounting dimensions (Figure 4.4). Enclose the module in a standard industrial enclosure (NEMA type 12 or equivalent) to protect it.

You must connect the module electrically to earth ground. Attach a ground lug to one of the module's mounting bolts (Figure 4.4). To ensure a good electrical connection between the ground lug and the module, remove paint from the cover where the lug makes contact. Connect the ground lug to earth ground with an adequate grounding electrode.

Figure 4.4
Mounting Dimensions



Providing Power to the AF1 Stand–alone Module

The stand–alone module (1771–AF1) requires an external power supply that conforms to NEC Class 2 and the following specifications:

Output Voltage
- +5V dc at 1 A

Ripple and Noise
- 7mV rms (max)

Regulation (Load and Line)
- 0.15% (min)

Operating Temperature
- –25 to +70 °C (–13 to +158 °F)

Storage Temperature

- –25 to +85°C (–13 to +185°F)

Connect power to the stand–alone module with 16–gauge wire:

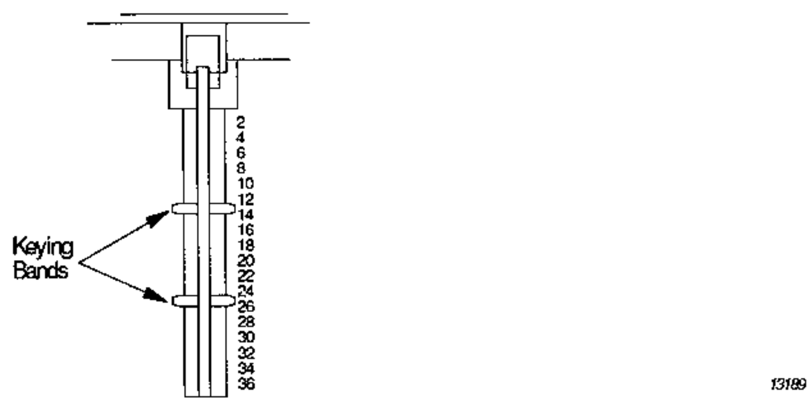
Important: The input power limit of your power supply for the 1771–AF1 must conform to NEC class 2 specifications.

Keying Bands for the AF Module

You can locate the AF module in any I/O chassis slot except for the left–most slot reserved for the adapter module or processor. Use the keying bands supplied with the I/O chassis to key the backplane to accept only this module. Insert the keying bands in the upper backplane connector positions so they mate with matching slots on the back of the module (Figure 4.5). Locate the keying bands between:

12 and 14
24 and 26

Figure 4.5
Locations of Keying Bands



WARNING: Always turn off power to the I/O chassis back–plane and wiring arm before you install or remove an I/O module. Failure to remove power from the backplane could cause injury or equipment damage due to possible unexpected machine operation. Failure to remove power from either could damage the module or degrade performance.

Installing Twinaxial Cables

Connect twinaxial cables between fiber–optic modules at the:

- terminal block
  (Figure 4.6 for 1771–AF1 stand–alone module)
- wiringarm
  (Figure 4.7 for 1771–AF I/O chassis–mounted module)

Figure 4.6
Terminal Block for 1771–AF1

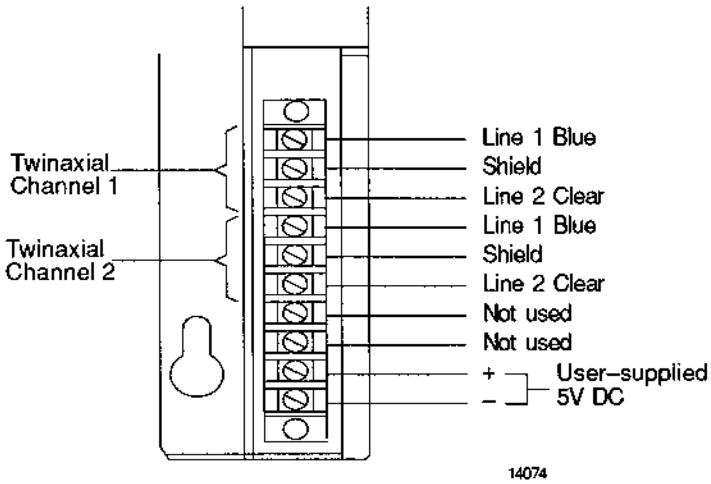
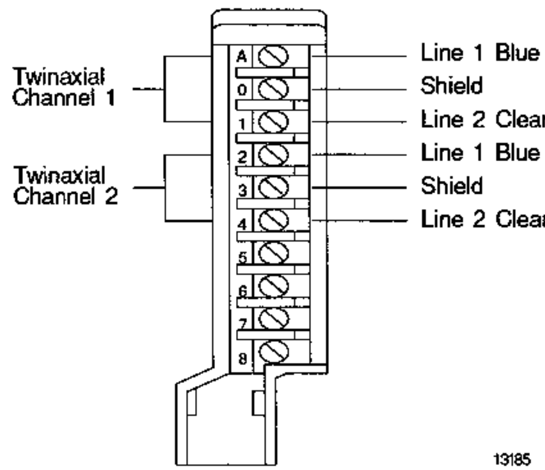


Figure 4.7
Wiringarm for 1771–AF



When wiring twinaxial cables, always properly:

- terminate the cable with termination resistors
- ground the cable shield
  (for non–DH or non–DH + applications)

Terminating Twinaxial Cables with Termination Resistors

Always install a termination resistor (150 ohm, 1/4 watt) at each end of a twinaxial cable, no matter:

- how short or long the cable
- what the application (remote I/O, DH, DH +, etc)

The only exception is when cables are spliced in series: do NOT connect a termination resistor at a splice.

Some PLC–5 family processors have an internal termination resistor that you switch in or out of the circuit for remote I/O and DH+. If available, use the 4–switch assembly, SW3, on the bottom of the processor.

Switch 1 ON = termination resistor for Remote I/O
Switch 2 ON = termination resistor for DH +

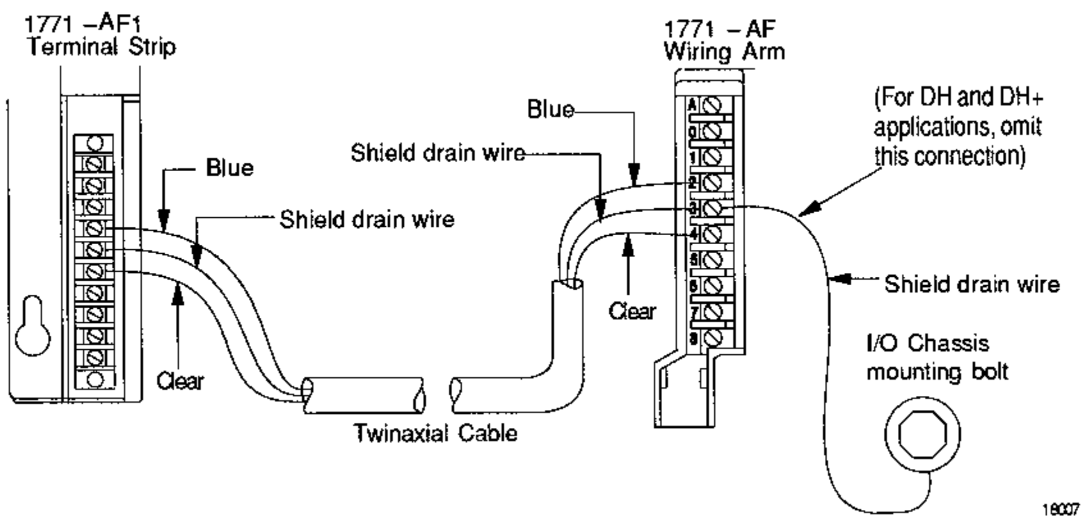
Grounding the Twinaxial Cable Shield

We recommend the following grounding guidelines;

For this Application	Use these Guidelines
Between fiber–optic modules Between a fiber–optic module and a 1771–ASB Adapter	Besides connecting the drain wire to the "shield" terminal at each end, also connect the drain wire to earth ground at only one end of the cable.
Data Highway Data Highway Plus	Do NOT connect the shield to earth ground at either end of the cable. Follow instructions in Data Highway Cable Installation Manual (publication 1770–6.2.1)

When connecting twinaxial cable between two fiber–optic modules or between a fiber–optic module and 1771–ASB Adapter module (non–Data Highway application), connect the shield drain wire to its terminal and to ground. Connect the other end of the shield drain wire only to its terminal. Since each I/O chassis must be connected to earth ground, a connection to a properly mounted I/O chassis is also a connection to earth ground (Figure 4.8).

Figure 4.8
Example Twinaxial Connections with Grounded Shield (non–DH and non–DH + applications)



Important: When grounding twinaxial cables at the processor end of the link, remember that PLC–2, PLC–3, and PLC–5 family processors connect the "shield" terminal directly to chassis ground internally. Conversely, the 1771–ASB Adapter connects the "shield" terminal to ground internally through a capacitor (ac ground) which is NOT an earth ground connection.

Prepare the twinaxial cable for connection between modules as follows (non–DH, and non–DH + applications):

A. At the grounded end:

1. Strip 3 feet of insulation.

2. Without severing the drain wire, remove the drain wire from its shield and clip the shield.

3. Trim insulated wires to approximately 2–inch lengths, and strip about 1/2–inch of insulation from the end of each.

4. Connect insulated wires to terminals (Figure 4.6 or Figure 4.7)

5. Connect the drain wire in two places:

   - loop it around the screw at a "shield" terminal
   - connect the end to an I/O chassis mounting bolt

   Important: Route the drain wire away from terminals to avoid a short circuit. Lash it in place.

B. At the other end:

6. Trim all wires to approximately 2–inch lengths. Strip about 1/2–inch of insulation from the insulated wires.

7. Connect insulated wires and drain wire to terminals.

8. Connect a termination resistor (150 ohm, 1/2 watt) between the terminals of the blue and clear wires at the channel's source and termination point. Also connect a termination resistor at each end of a cable segment as mentioned in Terminating Twinaxial Cables, above.

To wire twinaxial cable in DH and DH+ applications:

1. Connect shield drain wires to "shield" terminals, but NOT to earth ground.

2. Follow instructions in Data Highway Cable Installation manual (publication 1770–6.2.1)

We cover the installation of fiber–optic cable in the next chapter.

Chapter 5

Installing Fiber–optic Cables

Chapter Objectives

In this chapter we show you how to:

- route fiber–optic cables
- connect fiber–optic cables to the AF/AF1 modules
- pull fiber–optic cables

Guidelines for Installing Fiber–optic Cable

Installation of fiber–optic cable is similar to that of twinaxial cable but the fiber cable cannot withstand as great a pulling force as wire cable nor can it bend as sharply. Some general installation guidelines are:

- Do not pull cable over sharp edges.
- Do not install cable where objects may drop and crush it.
- Secure the cable properly to prevent repeated flexing.
- Support the cable in vertical runs at regular intervals.
- Place the cable in polyethylene or PVC conduit if the installation is underground. Be sure the inside diameter of the pipe is at least four times larger than the outside diameter of the cable.
- Be sure suspended cable can support its own weight when stressed by wind, ice, or snow. Use a messenger cable if necessary.
- Secure the cable every six feet (minimum) during long vertical runs. Use clamp bushings constructed of plastic or rubber.

WARNING: Never look into the ends of an active fiber–optic cable or the transmitter ports of the fiber–optic module transmitters. Permanent eye damage could result. Use a fiber–optic power meter to determine if a signal is present.

Cable Parameters

Before you install a fiber–optic cable, follow the manufacturer's recommendations concerning:

- maximum tensile load
- maximum static tensile
- minimum bend radius
- maximum crushing force
- maximum impact
- harmful liquids and/or gasses
- temperature and humidity limitations.

Routing the Cables

You can route fiber cables in the same conduits and wireways that contain conventional wiring. Consult the current edition of the National Electrical Code. Article 770 covers the installation of fiber–optic cables with electrical conductors.

In Ducts

Observe the following guidelines when you install fiber cable in ventilation ducts:

- Do not place fiber cables in ventilation ducts unless the cables are plenum–rated.
- Be sure there are no sharp edges in the duct that could cut the cable.
- Be sure that other heavy wire cables in the ducts do not exceed the maximum crush resistance of the fiber.

In Conduit

The following guidelines apply when you install fiber cables in conduit:

- Be sure bends in the conduit are not sharper than the minimum bend radius for fiber cable.
- Use corner elbow fittings for right–angle bends, such as Crouse–Hinds elbows (type BUB) of the Mogul series or equivalent. These fittings reduce the amount of stress applied to the fiber when pulling cable. Be sure the cable does not kink as you pull it.

CAUTION: Do not pull a fiber cable that contains a splice connector through conduit. The splice connector can separate during installation. Cables that contain a splice connector are intended solely for "lay–in" wire tray installation and repairs.

- Place pull boxes every 200–300 feet to reduce the amount of cable that needs to be pulled at any one time.
- Use pull boxes if the conduit makes bends which exceeds 180°.
- Pull box openings should be at least four times the minimum bend radius of the cable.
- Refer to the current edition of the National Electrical Code for the appropriate article covering cable installation in conduit.

Connecting the Cables

The fiber–optic module requires duplex fiber–optic cable. You can differentiate between the transmitting and receiving cables by the insulation's color coding or ribbing.

To install the cable use the following procedure:

1. Remove the dust cover caps from the module's fiber ports. (Do not discard.) They are required for module storage and shipment.

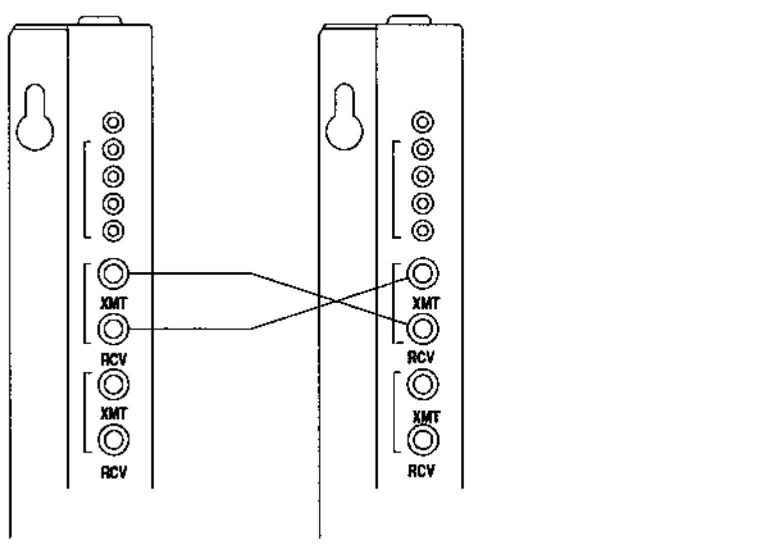
2. Remove the dust covers from the ends of the cable. (Do not discard.)

Important: Do not scratch the ends of the cable by touching them or dropping them on hard surfaces. Also, do not use factory compressed air to clean the transmitter/receiver ports. Contaminants in the air can cloud the ports.

3. Attach the cable to the modules by screwing the cable connectors onto the appropriate fiber ports. Hold the cable body while tightening the connector. Be sure you do not kink the cable and crack the fiber core.

4. When connecting the duplex fiber–optic cable to the next AF/AF1 module, always reverse the terminations (Figure 5.1)

Figure 5.1
Fiber–Optic Cable Terminations



Cable Pulling Guidelines

Pulling fiber cable is similar to pulling conventional copper wire cable. There are two factors, however, which you must consider: fiber– optic tensile strength and minimum bend radius.

Fiber cable has a lower tensile strength than copper wire cable of the same outer diameter (i.e. you cannot exert the same pulling force on a fiber cable as you can on a copper wire cable). Too much fiber cable stretching can cause increased attenuation. You can also cause the fiber–optic connectors to separate from the cable.

CAUTION: A fiber–optic splice connector is designed to optically connect two fiber–optic cables. The connector cannot withstand the tensile load of a cable "pull in" installation. Do not install a fiber– optic cable that contains a splice the way you would a one–piece cable. Spliced cables are intended solely for "lay–in" installation.

The fiber cable's minimum bend radius is the smallest radius the cable can accommodate without being damaged. Straining a cable through a smaller bend radius may permanently damage the cable.

To reliably pull a pre–terminated fiber cable, you must attach the cable to a pulling device that protects the fiber–optic connectors. Refer to Figure 5.1. Use the following procedure:

1. Place the cable in the braided portion of the pulling device, either a Kellems Fiber–Optic Pull Grip or equivalent. Leave the cable connectors and approximately four to six inches of cable extending beyond the braid.

2. Using the attached needle and cord, enclose the cable with the braid by lacing it.

3. Wrap the cable connectors with foam packing material or equivalent. (Leave the dust cover caps on the cable connectors.)

4. Position a piece of heat–shrink tubing over the connectors. Heat the tubing with a hot–air gun. (Be sure you do not use an excessive amount of heat.)

5. Using electrical tape and beginning at the base, spirally overwrap the pull grip where the fiber cable connectors protrude. Be sure you cover the fiber–optic connectors completely.

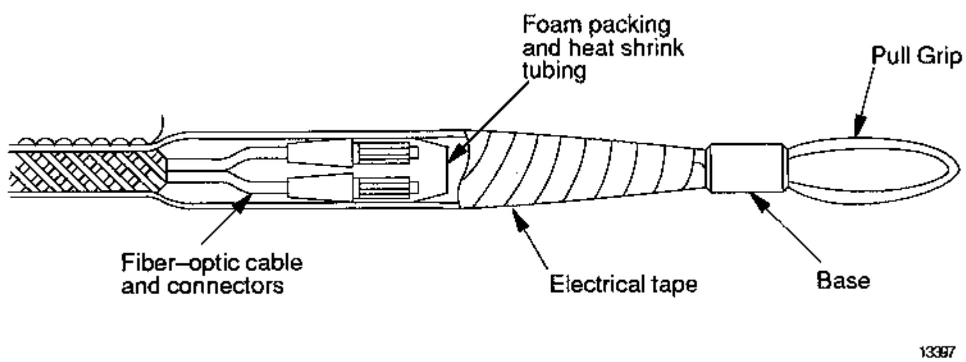
6. Lubricate the cable with conventional cable lubricant.

7. Monitor the cable tensile force while pulling the cable.

8. When the cable enters a pull box at an angle, use at least a 12–inch pulley if the cable is under tension. If the cable is not under tension, use at least a four–inch pulley.

9. As you pull cable from a pull box, coil it in a figure–eight with one–foot loops. This helps prevent the cable from twisting as you continue pulling.

Figure 5.2
Typical Pre–terminated Fiber–Optic Cable Pulling Grip



Kellems Fiber–Optic Pulling Grip

Hubbel Inc.
Kellems Division
P O Box 901
Route 1, Lords Hill
Stonington, CT 06278–0901
203–535–1250

Chapter 6

Fiber–optic/Twinaxial Connections for Remote I/O

Chapter Objectives

Use the examples in this chapter as a guide when connecting remote I/O to the processor with fiber–optic and/or twinaxial cables for the following remote I/O configurations:

Configuration Guidelines

Follow these guidelines when designing your remote I/O configurations:

- The maximum twinaxial cable distance between any two modules or devices is 10,000 feet. A system's total twinaxial cable distance cannot exceed 30,000 feet.

- The maximum fiber–optic cable distance between two fiber–optic modules depends on the cable diameter. Refer to the cable characteristics given in Appendix A.

  Important: We used 100/140μm duplex fiber–optic cable at 6,500 feet max in all our configuration examples.

- A system's combined twinaxial/fiber–optic cable distance cannot exceed 43,000 feet. A fiber–optic trunkline can be installed with as many fiber–optic converter modules as desired, as long as the total distance of twinaxial and fiber–optic cable does not exceed 43,000 feet.

- Use 57.6k bits/sec for twinaxial cable distances over 5,000 feet.

Configuration examples shown in this chapter are typical. Other configurations are possible.

Serial Configuration

This remote I/O configuration illustrates a serial communication link.

Module switch settings are:

- star configuration
- 57.6k bits/sec
- twinaxial port 1 ON
- twinaxial port 2 OFF

This serial configuration (Figure 6.1) requires:

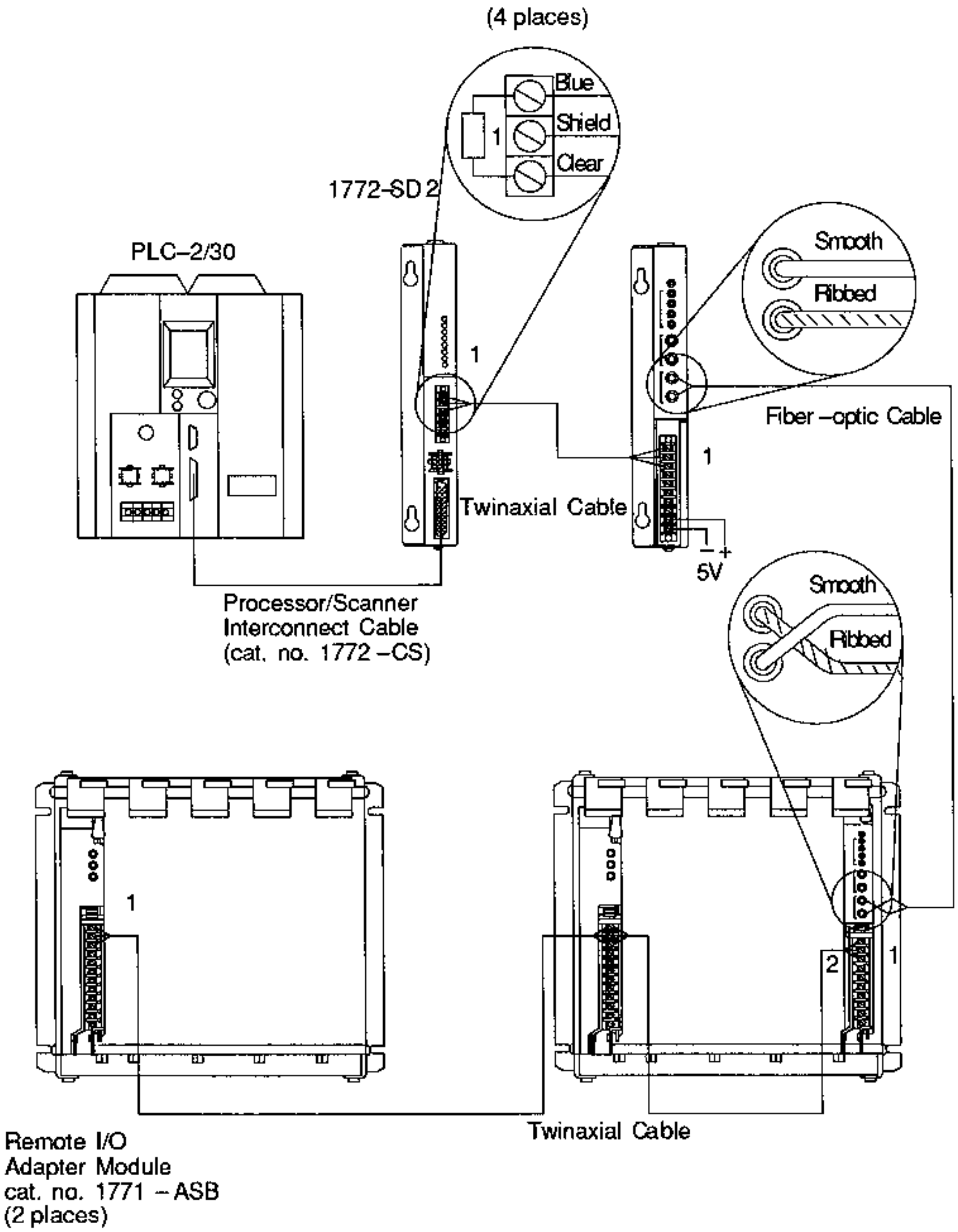
1	A–B processor with remote I/O capability (PLC–2/30 in this example)
2	1771–AF1 modules
1	1771–AF module
2	1771–ASB Adapter modules
1	segment of 100/140µm fiber–optic cable
2	segments of twinaxial cable (Cat. no. 1770–CD, Belden 9463, or equivalent)

Important:

For this type of cable	Under these conditions	The maximum length cannot exceed
twinaxial	between any two devices	10,000 feet
	system total length	30,000 feet
fiber–optic*	between any two fiber–optic modules	6500 feet
combined twinaxial and fiber–optic*	system total length	43,000 feet

* for 100/140µm glass fiber–optic cable
See Appendix A for characteristics of other cables.

Figure 6.1
Serial Configuration



Important:

1. Connect the Termination Resistor – 150 ohm, 1/4 watt, (cat. no. 1770–XT) between Blue and Clear.
2. Ground the drain wire per Figure 4.8.

Maximum Serial Configuration

This remote I/O configuration shows a serial communication link extending to the maximum twinaxial/fiber–optic cable distance of 43,000 feet.

Switch settings for the two 1771–AF module are:

- star configuration
- 57.6k bits/second
- twinaxial port 1 and 2 ON

Switch settings for the two 1771–AF1 modules are:

- star configuration
- 57.6k bits/second
- twinaxial port 1 ON
- twinaxial port 2 OFF

This serial configuration (NO TAG) requires:

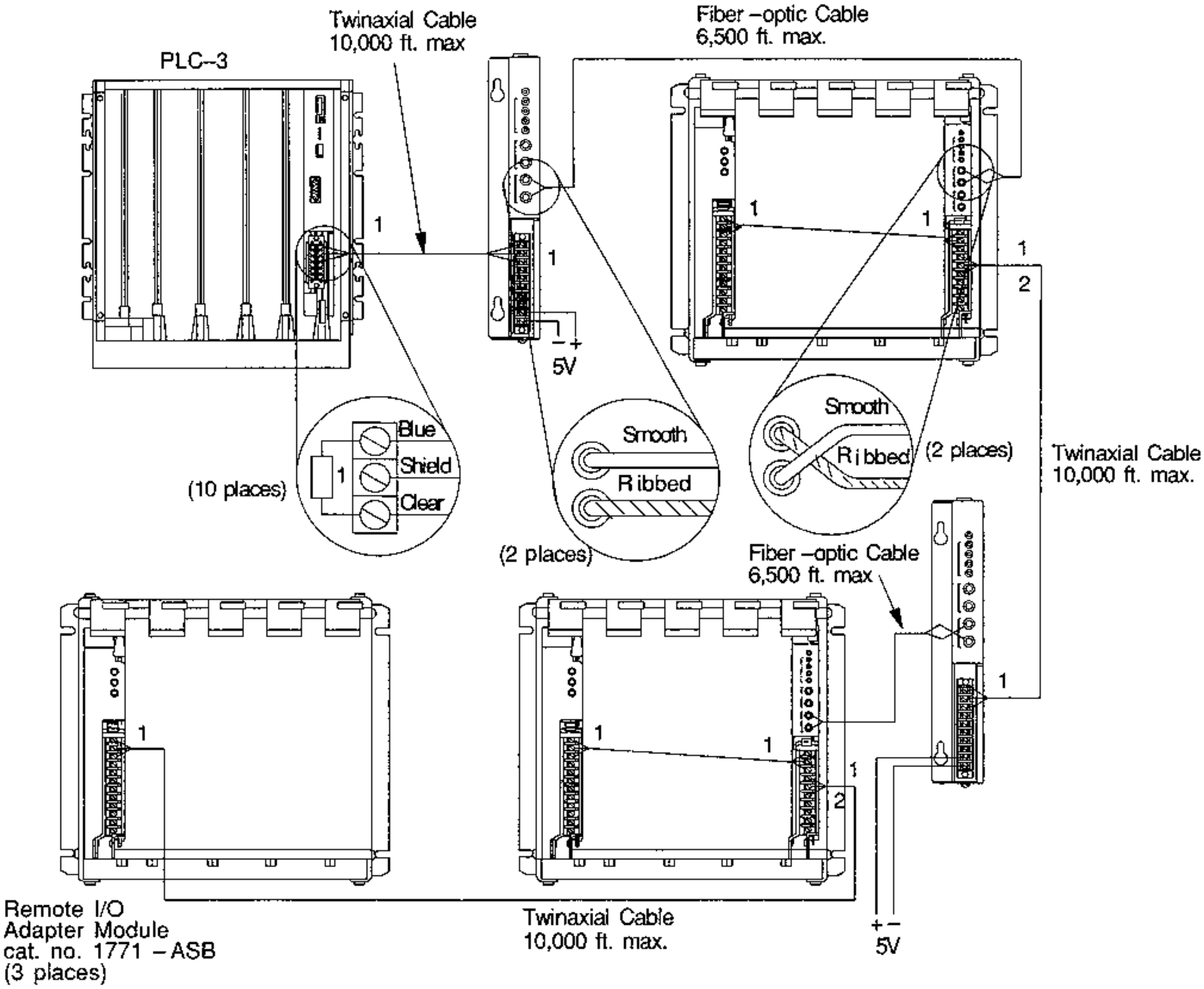
1 A–B processor with remote I/O capability (PLC–3 in this example)
2 1771–AF1 modules
2 1771–AF modules
3 1771–ASB Adapter modules
2 segments of 100/140μm fiber–optic cable
3 segments of twinaxial cable (Cat. no. 1770–CD, Belden 9463, or equivalent)

Important:

For this type of cable	Under these conditions	The maximum length cannot exceed
twinaxial	between any two devices	10,000 feet
	system total length	30,000 feet
fiber–optic*	between any two fiber–optic modules	6500 feet
combined twinaxial and fiber–optic*	system total length	43,000 feet

* for 100/140μm glass fiber–optic cable
See Appendix A for characteristics of other cables.

Figure 6.2
Serial Configuration (Maximum)



Important:

1. Connect the Termination Resistor – 150 ohm, 1/4 watt, (cat. no. 1770–XT) between Blue and Clear.
2. Ground the drain wire per Figure 4.8.

14078

Parallel Configuration

This communication link shows fiber–optic modules in a centrally located I/O chassis connected to several remotely located I/O chassis.

Module switch settings are:

- star configuration
- 57.6k bit/second
- twinaxial port 1 ON
- twinaxial port 2 OFF

This parallel configuration (NO TAG) requires:

1 A–B processor with remote I/O capability (PLC–3 in this example)

1 1771–AF1 module

6 1771–AF modules

5 1771–ASB Adapter modules

4 segment of 100/140μm fiber–optic cable

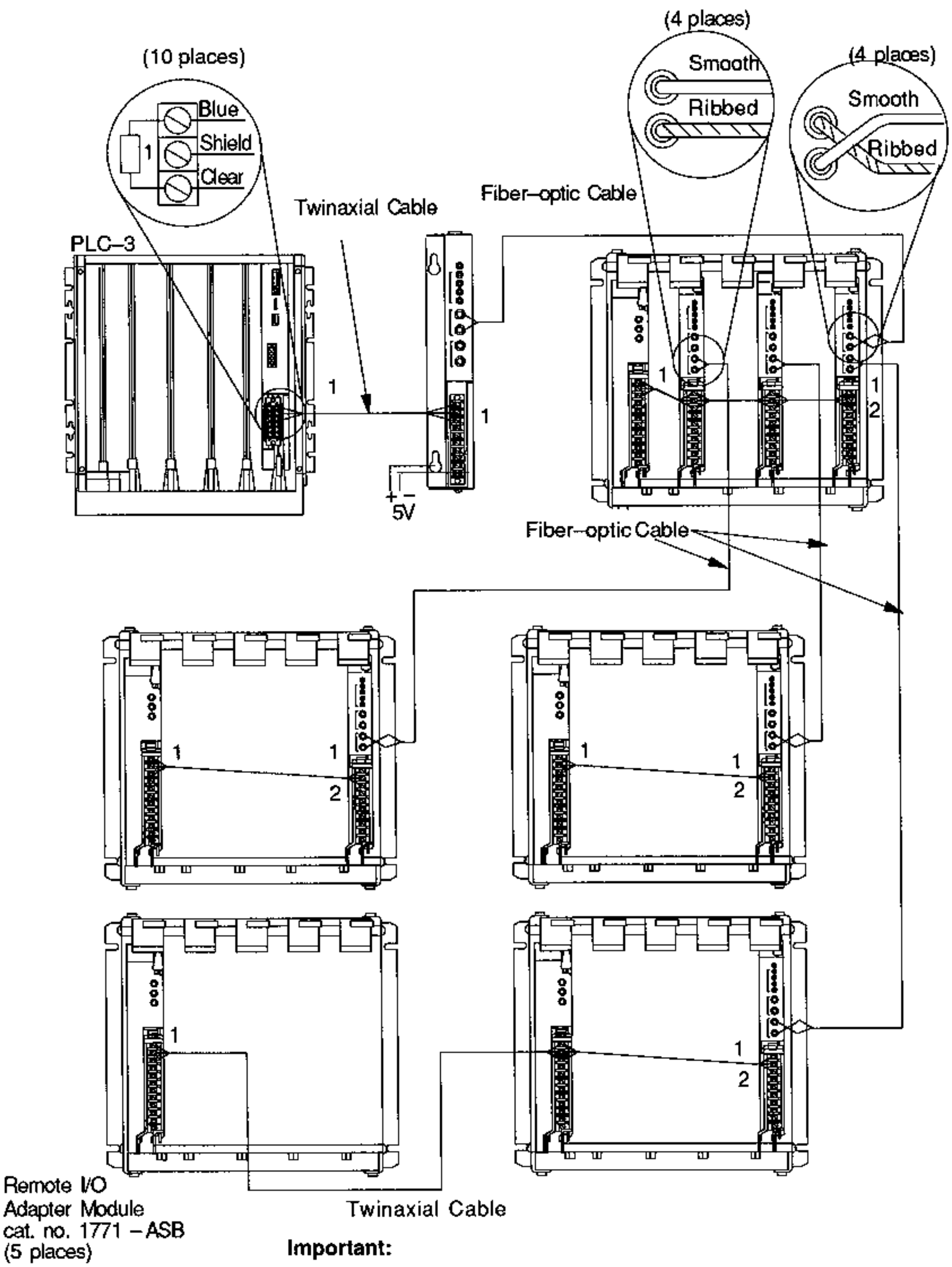
2 segments of twinaxial cable (Cat. no. 1770–CD, Belden 9463, or equivalent)

Important:

For this type of cable	Under these conditions	The maximum length cannot exceed
twinaxial	between any two devices	10,000 feet
	system total length	30,000 feet
fiber–optic*	between any two fiber–optic modules	6500 feet
combined twinaxial and fiber–optic*	system total length	43,000 feet

* for 100/140μm glass fiber–optic cable
See Appendix A for characteristics of other cables.

Figure 6.3
Parallel Configuration



Important:

1. Connect the Termination Resistor – 150 ohm, 1/4 watt, (cat. no. 1770-XT) between Blue and Clear.
2. Ground the drain wire per Figure 4.8.

14079

Serial/Parallel Configuration

This configuration uses stand–alone and fiber–optic modules to communicate with remote I/O locations.

Module switch settings are:

- star configuration
- 57.6k bits/second
- twinaxial port 1 ON
- twinaxial port 2 OFF

This serial/parallel configuration (Figure 6.4) uses:

1 A–B processor with remote I/O capability (PLC–3 in this example)

2 1771–AF1 modules

4 1771–AF modules

3 1771–ASB Adapter modules

3 segments of 100/140µm fiber–optic cable

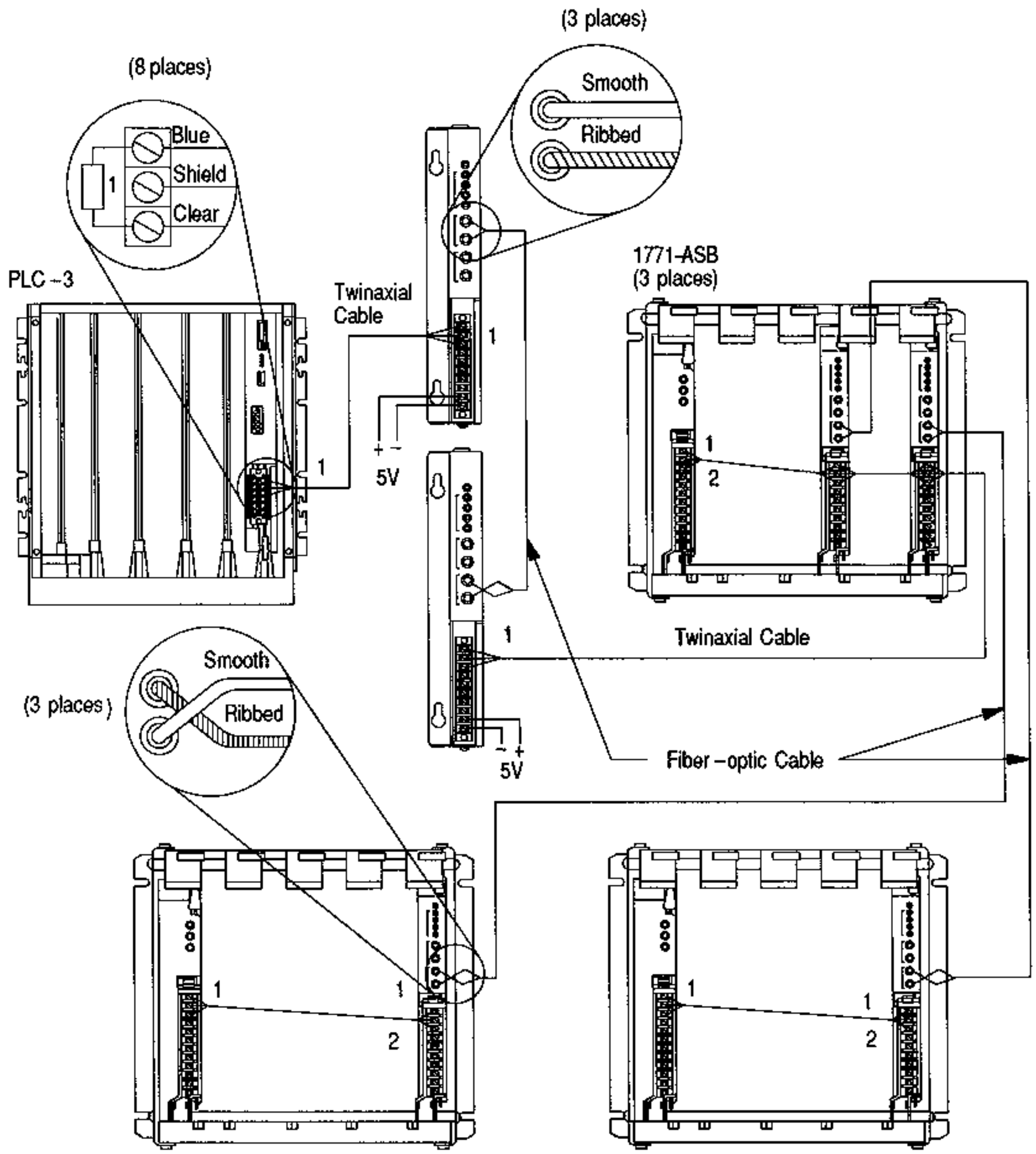
2 segments of twinaxial cable (Cat. no. 1770–CD, Belden 9463, or equivalent)

Important:

For this type of cable	Under these conditions	The maximum length cannot exceed
twinaxial	between any two devices	10,000 feet
	system total length	30,000 feet
fiber–optic*	between any two fiber–optic modules	6500 feet
combined twinaxial and fiber–optic*	system total length	43,000 feet

* for 100/140µm glass fiber–optic cable
See Appendix A for characteristics of other cables.

Figure 6.4
Serial/Parallel Configuration



Important:

1. Connect the Termination Resistor – 150 ohm, 1/4 watt, (cat. no. 1770–XT) between Blue and Clear.
2. Ground the drain wire per Figure 4.8.

14080

Trunkline Configuration

This communication link shows a fiber–optic cable trunkline with twinaxial cable drops to remote I/O chassis. The fiber–optic link can contain any number of fiber–optic modules as long as the overall cable length does not exceed 43,000 feet.

Module switch settings are:

- star configuration
- 57.6k bits/second
- twinaxial port 1 ON
- twinaxial port 2 OFF

This remote I/O trunkline (Figure 6.5) requires:

1 A–B processor with remote I/O capability (PLC–3 in this example)

1 1771–AF1 module

3 1771–AF modules

6 1771–ASB Adapter modules

3 segments of 100/140μm fiber–optic cable

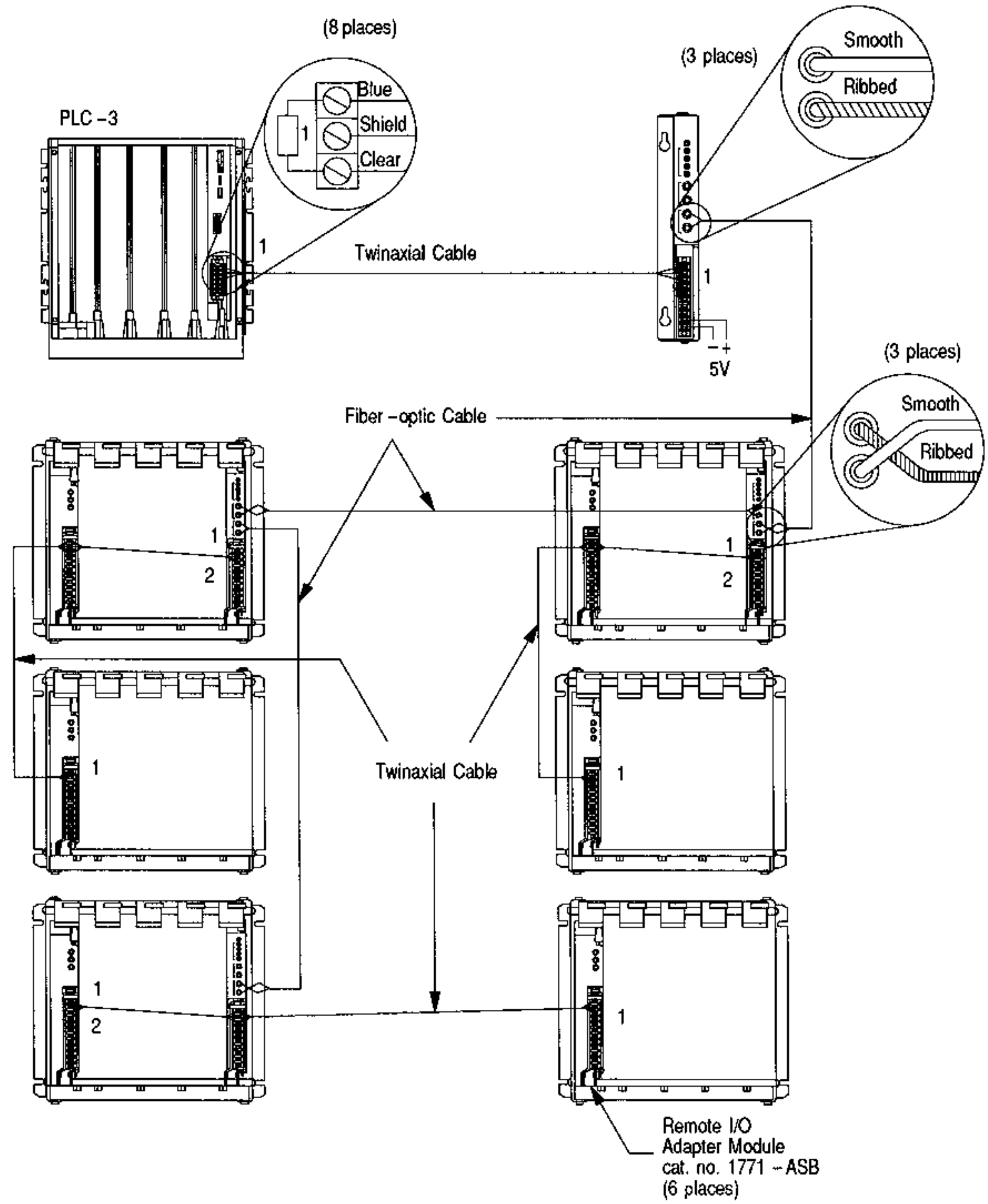
4 segments of twinaxial cable (Cat. no. 1770–CD, Belden 9463, or equivalent)

Important:

For this type of cable	Under these conditions	The maximum length cannot exceed
twinaxial	between any two devices	10,000 feet
	system total length	30,000 feet
fiber–optic*	between any two fiber–optic modules	6500 feet
combined twinaxial and fiber–optic*	system total length	43,000 feet

* for 100/140μm glass fiber–optic cable
See Appendix A for characteristics of other cables.

Figure 6.5
Trunkline Configuration



Important:

1. Connect the Termination Resistor – 150 ohm, 1/4 watt, (cat. no. 1770–XT) between Blue and Clear.
2. Ground the drain wire per Figure 4.8.

14081

Twinaxial to Twinaxial Repeater Configuration

This communication link shows fiber–optic modules wired for twinaxial cable repeater operation.

Module switch settings are:

- star configuration
- 57.6k bits/second
- twinaxial port 1 ON
- twinaxial port 2 ON

This repeater configuration (Figure 6.6) requires:

1 A–B processor with remote I/O capability (PLC–3 in this example)

2 1771–AF1 modules

1 1771–ASB Adapter module

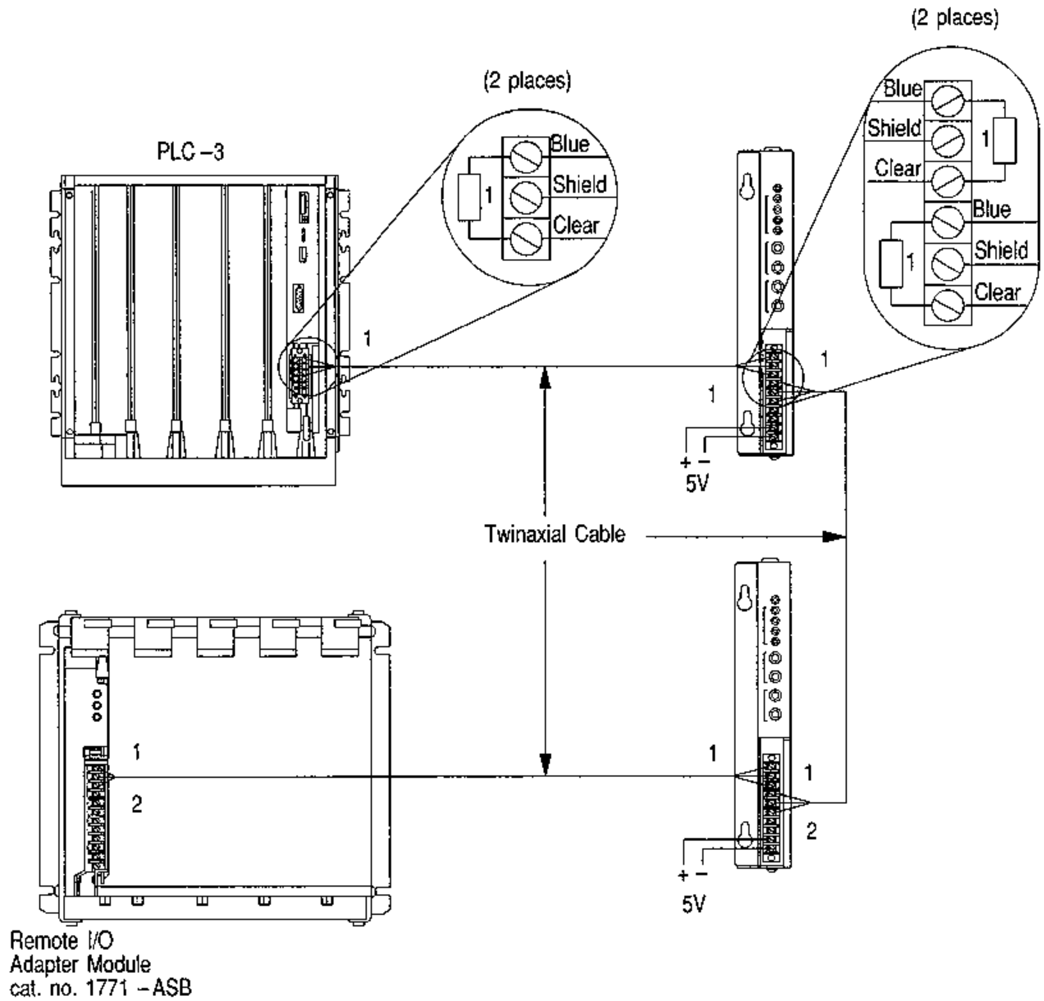
3 segments of twinaxial cable (Cat. no. 1770–CD, Belden 9463, or equivalent)

Important:

For this type of cable	Under these conditions	The maximum length cannot exceed
twinaxial	between any two devices	10,000 feet
	system total length	30,000 feet
fiber–optic*	between any two fiber–optic modules	6500 feet
combined twinaxial and fiber–optic*	system total length	43,000 feet

* for 100/140μm glass fiber–optic cable
See Appendix A for characteristics of other cables.

Figure 6.6
Twinaxial to Twinaxial Repeater Configuration



Important:

1. Connect the Termination Resistor – 150 ohm, 1/4 watt, (cat. no. 1770–XT) between Blue and Clear.
2. Ground the drain wire per Figure 4.8.

Redundant Cabling Configuration

This configuration illustrates fiber–optic/twinaxial cable redundancy.

Important: Parallel cables provide a measure of safety but do not provide complete redundancy since the fiber–optic module is powered by a single power source. If the module loses power, data transfer stops.

The fiber–optic module is an active signal repeater. This means that if one repeater on the link stops transferring data, all other repeaters on the link stop functioning. However, in this configuration, if one channel fails, the module automatically begins transferring data on the other channel. The module indicates that a channel fails by turning OFF the LED for that channel.

Module switch settings are:

- point–to–point configuration
- 57.6k bits/second
- twinaxial ports 1 and 2 are ON

This redundant cabling configuration (Figure 6.7) uses:

1 A–B processor with remote I/O capability (PLC–3 in this example)

2 1771–AF1 modules

1 1771–ASB Adapter module

2 segments of 100/140μm fiber–optic cable

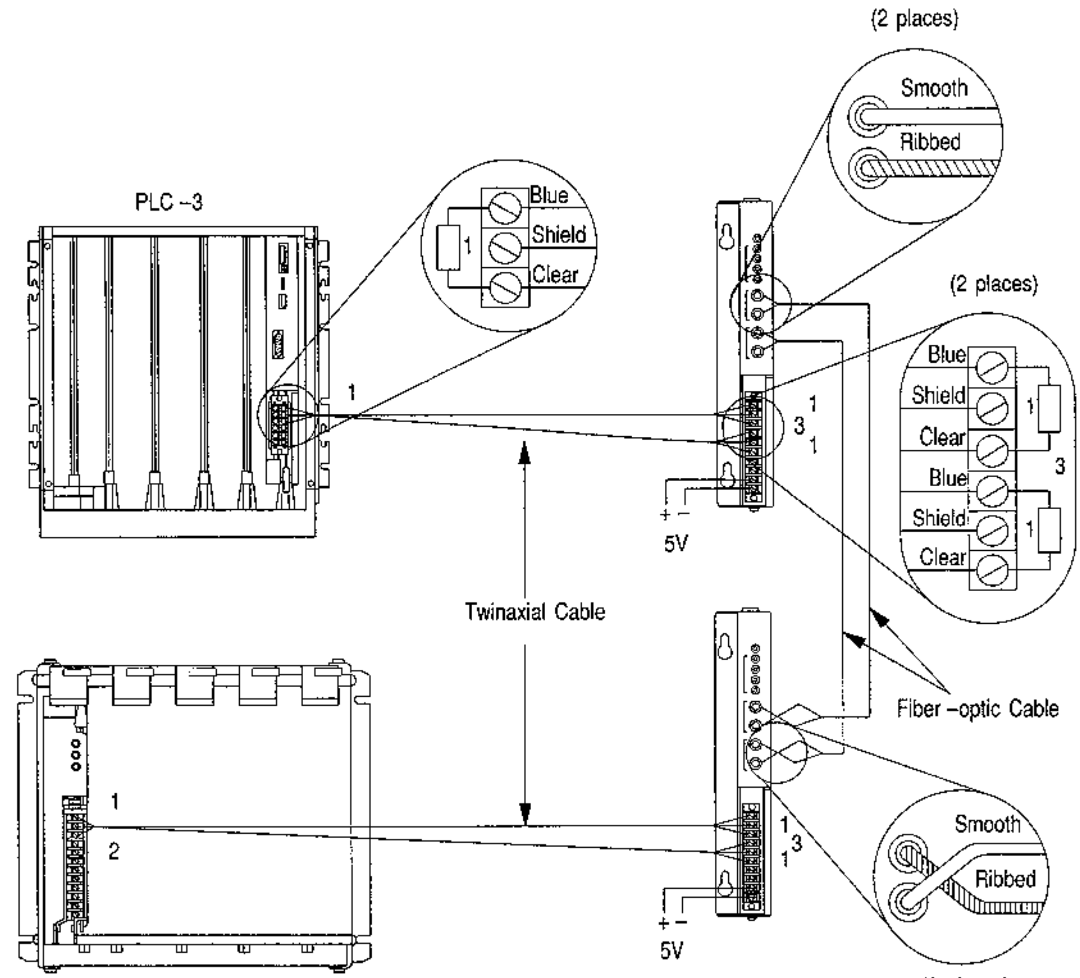
4 segments of twinaxial cable (Cat. no. 1770–CD, Belden 9463, or equivalent)

Important:

For this type of cable	Under these conditions	The maximum length cannot exceed
twinaxial	between any two devices	10,000 feet
	system total length	30,000 feet
fiber–optic*	between any two fiber–optic modules	6500 feet
combined twinaxial and fiber–optic*	system total length	43,000 feet

* for 100/140μm glass fiber–optic cable
See Appendix A for characteristics of other cables.

**Figure 6.7
Redundant Cabling Configuration**



Important:

1. Connect the Termination Resistor – 150 ohm, 1/4 watt, (cat. no. 1770–XT) between Blue and Clear.
2. Ground the drain wire per Figure 4.8.
3. If redundant twinaxial cables are less than 1000 feet long, remove one of the redundant termination resistors.

14084

Chapter 7

Data Highway Networks

Objectives

This chapter shows cable networks for:

- Data Highway (DH)
- Data Highway Plus (DH+)

Data Highway

Data Highway is an industrialized local area network designed specifically for industrial control applications. It is cost effective, highly reliable, and proven in many communications applications. It lets you communicate among Allen–Bradley PLC–2, PLC–3, PLC–5, PLC–5/250 family processors and RS–232–C devices.

Data Highway is a baseband voltage–driven network using twinaxial cable with data signaling levels less than 10 volts. All stations on the network are connected to a common bus and impose no restrictions on the order in which you assign station numbers. Transmissions on the network are received at all stations. Each station looks at the transmission, determines if it is for itself, and either responds to or ignores it.

There is no permanent master on the network. Mastership is determined by the need to send a transmission. Mastership is passed only on a demand basis.

The floating–master algorithm and distributed–bus technology guard against network failure even if several stations on the network should fail. If a station fails, the network continues to work but generates an error message to notify other stations of the failure. If a station should fail while it is the master, another station assumes mastership and normal communications continue.

Maximum Cable Lengths

With fiber–optic modules, you can install a Data Highway network with the same maximum cable lengths as for remote I/O networks described in chapter 6. Also remember that twinaxial droplines from station connectors must not exceed 100 feet.

Linking Two Data Highways With A Repeater

This configuration illustrates using a fiber–optic repeater link to logically connect two Data Highways for a total network length far in excess of the 10,000 ft maximum for an all–twinaxial network.

Module switch settings are:

- Star configuration
- 57.6K bits/second
- Twinaxial ports 1 and 2 are ON

This configuration (Figure 7.1) uses;

2 1771–AF1 modules

1 segment of 100/140µm fiber–optic cable

– twinaxial cable segments as needed
(Cat. no. 1770–CD, Belden 9463, or equivalent)

– twinaxial cable droplines, as needed
(Cat. no. 1770–CD, Belden 9463, or equivalent)

– 1770–SC Station Connectors, as needed

– 1775–KA Communication Adapter modules, as needed

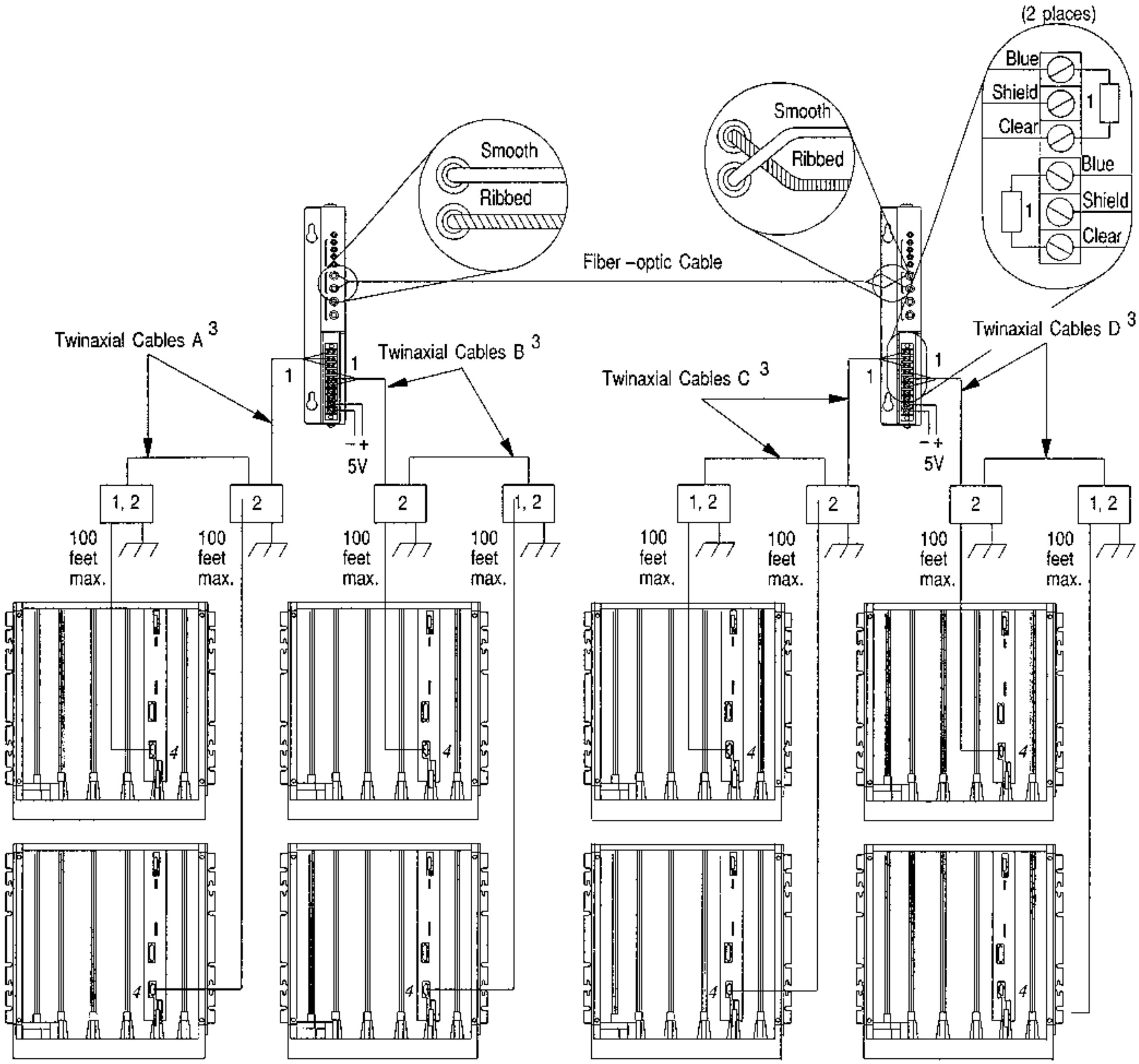
– PLC–3 Processors, as needed

Important:

For this type of cable	Under these conditions	The maximum length cannot exceed
twinaxial	dropline	100 feet
	between any two devices	10,000 feet
	system total length	30,000 feet
fiber–optic*	between any two fiber–optic modules	6500 feet
combined twinaxial and fiber–optic*	system total length	43,000 feet

* for 100/140µm fiber–optic cable
See Appendix A for characteristics of other cables.

Figure 7.1
Linking Two Data Highways



Important:

1. Connect the Termination Resistor – 150 ohm, 1/4 watt, (cat. no. 1770-XT) between Blue and Clear.
2. Splice dropline into trunkline with Station Connector (Cat. no. 1770-SC)
3. Combined lengths of twinaxial cables A + B + C + D cannot exceed 30,000 feet.
4. Pinout for 1775-KA D-shell 15-pin connector: (pin 6 = blue, pin 7 = shield, pin 8 = clear)

14082

Data Highway Trunkline with Droplines

This configuration illustrates using a fiber–optic cable for the trunkline with twinaxial droplines connecting PLC–2 family processors. The 1771–KA2 Communication Adapter provides the interface between processors and the Data Highway. Fiber–optic modules serve as:

- repeaters between trunkline segments
- drop points (station connectors) to A–B processors

Module switch settings are:

- Star configuration
- 57.6K bits/second
- Twinaxial port 1 is ON
- Twinaxial port 2 is OFF

This Data Highway configuration (Figure 7.2) uses:

3 1771–AF1 modules

2 1771–AF modules

4 segments of 100/140μm fiber–optic cable

2 segments of twinaxial dropline cable
(Cat. no. 1770–CD, Belden 0463, or equivalent)

2 1771–KA2 Communication Adapters

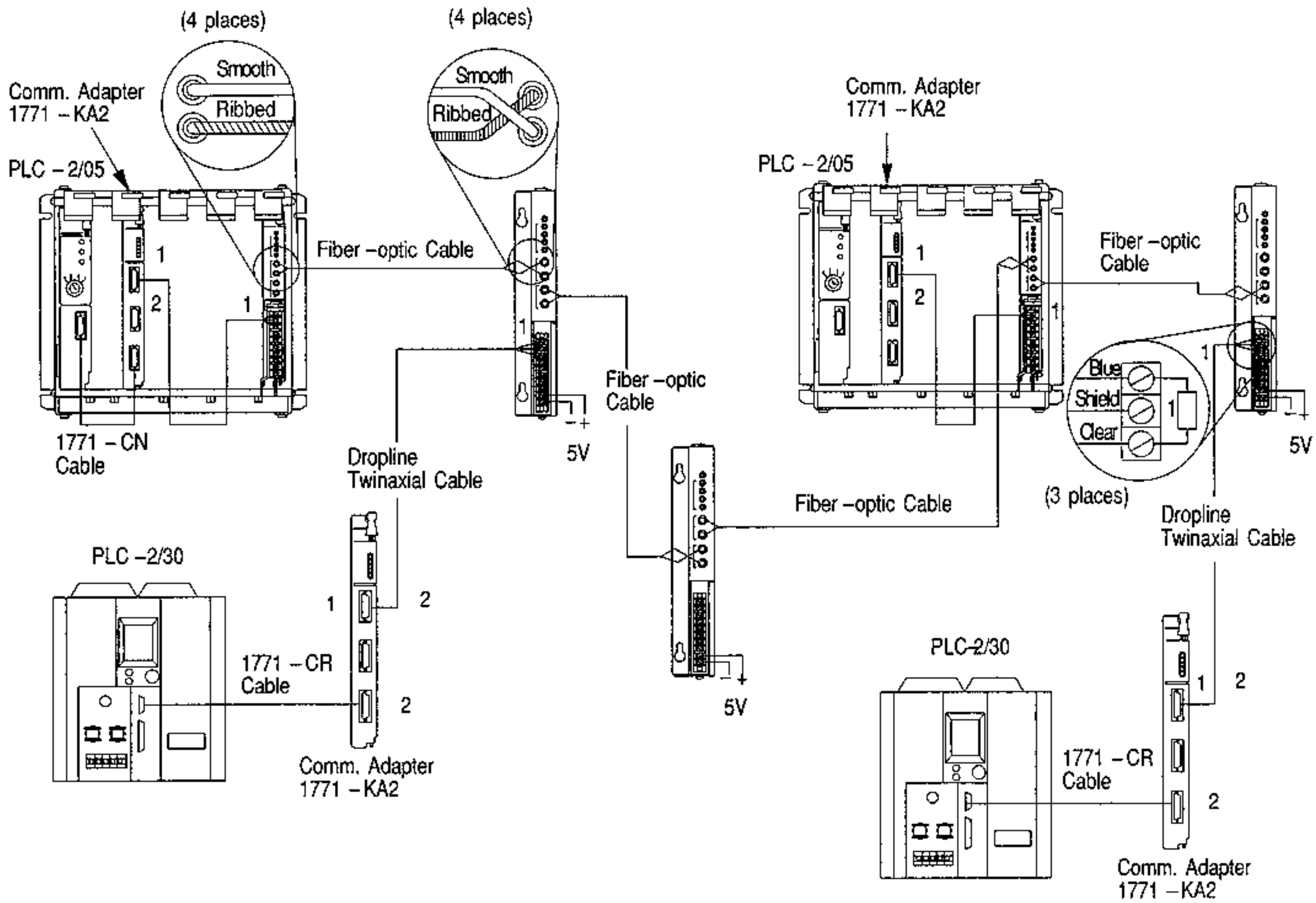
– PLC–2 family processors, as needed

Important:

For this type of cable	Under these conditions	The maximum length cannot exceed
twinaxial	dropline	100 feet
	between any two devices	10,000 feet
	system total length	30,000 feet
fiber–optic*	between any two fiber–optic modules	6500 feet
combined twinaxial and fiber–optic*	system total length	43,000 feet

* for 100/140μm fiber–optic cable
See Appendix A for characteristics of other cables.

Figure 7.2
Fiber–optic Data Highway Trunkline with Twinaxial Drops



Important:

1. Connect the Termination Resistor – 150 ohm, 1/4 watt, (cat. no. 1770–XT) between Blue and Clear.
2. Pinout for 1771–KA2 D–shell 15–pin connector: (pin 6 = blue, pin 7 = shield, pin 8 = clear)

Data Highway Plus

Data Highway Plus is a baseband voltage–driver token–passing network that lets each station send a message. A token is passed from station to station even if no station has a message to send. Data Highway Plus was originally called the Peer Communication Link (PCL), so you may occasionally see the term PCL on some Allen–Bradley equipment.

With DH+ you communicate serially with up to 64 stations such as:

- PLC–3 family processors
- PLC–5 family processors
- PLC–5/250 processors
- computers
- 1784–T45 or –T50 programming terminals
- 1785–KA or 1770–KF2 communication interface modules

Because DH+ protocol is optimized for small station clusters (cells), we recommend that you limit the number of stations on a network to 10 or less if one of them is a programming terminal, or otherwise to 15 stations.

DH+ lets you use up to 10,000 ft of twinaxial cable between the first and last station on the network. You can connect stations with a trunkline/dropline and/or daisy–chain configuration.

2–Station Data Highway Plus Fiber–optic Link (PLC–5)

This configuration illustrates using a fiber–optic cable between two PLC–5 family processors communicating in DH+ mode.

Module switch settings are:

- Star configuration
- 57.6K or 115.2K bits/second
- Twinaxial port 1 is ON
- Twinaxial port 2 is OFF

This configuration (Figure 7.3) uses:

2 A–B processors with DH+ capability (PLC–5 in this example)

2 1771–AF modules

1 segment of 100/140μm fiber–optic cable

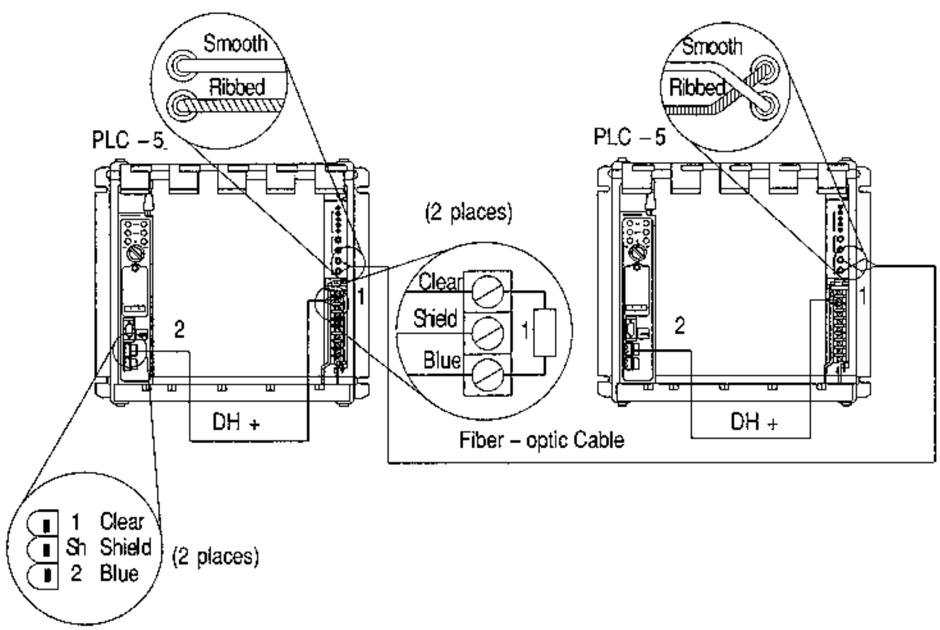
2 short segments of twinaxial cable (Cat. no. 1770–CD, Belden 9463, or equivalent)

Important:

For this type of cable	Under these conditions	The maximum length cannot exceed
twinaxial	between any two devices system total length	10,000 feet 30,000 feet
fiber–optic*	between any two fiber–optic modules	6500 feet
combined twinaxial and fiber–optic*	system total length	43,000 feet

* for 100/140μm fiber–optic cable
See Appendix A for characteristics of other cables.

Figure 7.3
2–Station DH+ Link



Important:

1. Connect the Termination Resistor – 150 ohm, 1/4 watt, (cat. no. 1770–XT) between Blue and Clear.
2. Switch the PLC–5 Termination Resistor into the circuit with SW3 (4–switch assembly) switch 2 = ON.

18010

2–Station Data Highway Plus Fiber–optic Link (PLC–3)

This configuration illustrates using fiber–optic cable between two PLC–3 family processors communicating in DH+ mode.

Module switch settings are:

- Star configuration
- 57.6K or 115.2Kbits/second
- Twinaxial port 1 is ON
- Twinaxial port 2 is ON

This DH+ network (Figure 7.4) requires:

2 A–B processors with DH+ capability (PLC–3 in this example)

2 1771–AF modules

1 segment of 100/140μm fiber–optic cable

2 short segments of twinaxial cable (Cat. no. 1770–CD, Belden 9463, or equivalent)

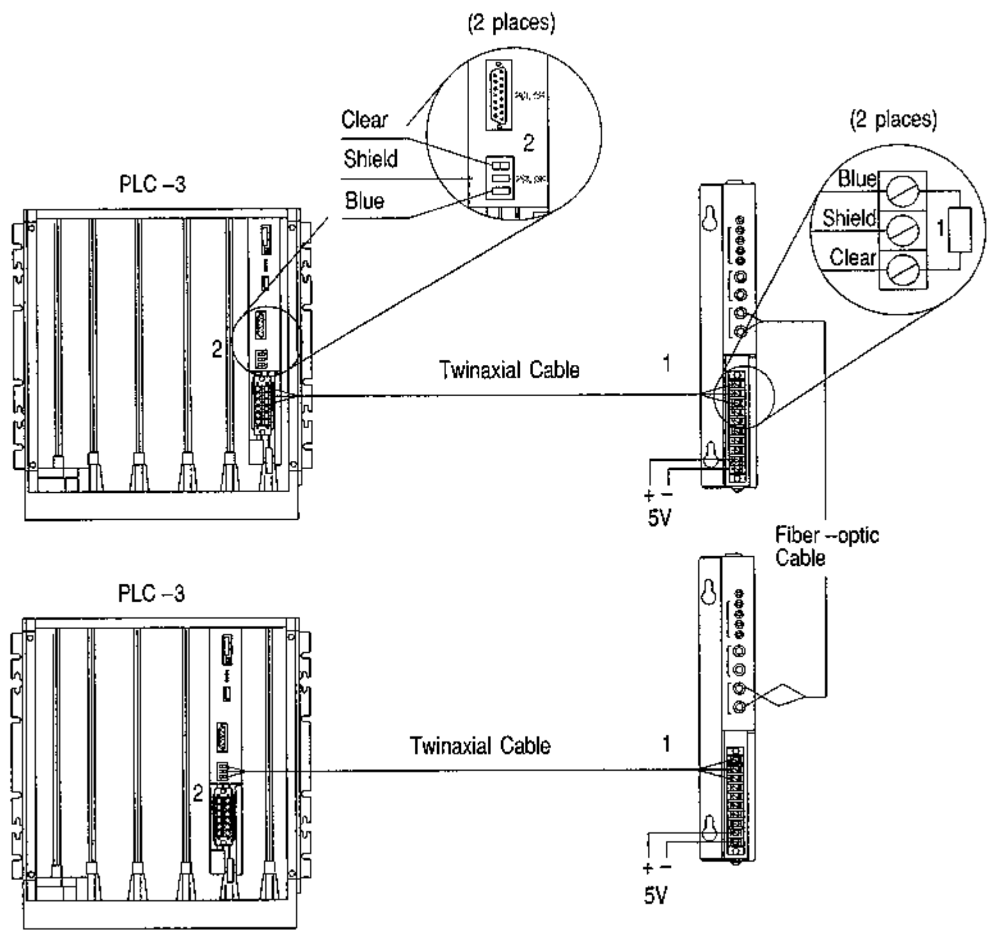
Important:

For this type of cable	Under these conditions	The maximum length cannot exceed
twinaxial	between any two devices system total length	10,000 feet 30,000 feet
fiber–optic*	between any two fiber–optic modules	6500 feet
combined twinaxial and fiber–optic*	system total length	43,000 feet

* for 100/140μm fiber–optic cable
See Appendix A for characteristics of other cables.

Important: If linking the PLC–3 scanner to a computer over a DH+ network via the 1770–KF2 (series B) DH/DH+ Interface Module, use these pins on the adapter's 15–pin D–shell connector:
pin 6= Clear, pin 7 = Shield, pine 8 = Blue.

Figure 7.4
2-Station DH+ Link (PLC-3)



Important:

1. Connect the Termination Resistor – 150 ohm, 1/4 watt, (cat. no. 1770–XT) between Blue and Clear.
2. At the 1775–S5, –SR5 scanner, switch the Termination Resistor for channel 4 into the circuit with the 4–switch assembly, (bottom front) switch 4 = ON.

18488

Data Highway Plus Network

This configuration illustrates using fiber–optic and twinaxial cables to connect PLC–5 processors in a DH+ network.

Module switch settings are:

- Star configuration
- 57.6K bits/second
- Twinaxial port 1 is ON
- Twinaxial port 2 is ON

This DH+ configuration (Figure 7.5) uses:

4 A–B processors with DH+ capability (PLC–5 in this example)

3 1771–AF modules

2 segments of 100/140µm fiber–optic cable

1 segment of twinaxial cable (Cat. no. 1770–CD, Belden 9463, or equivalent)

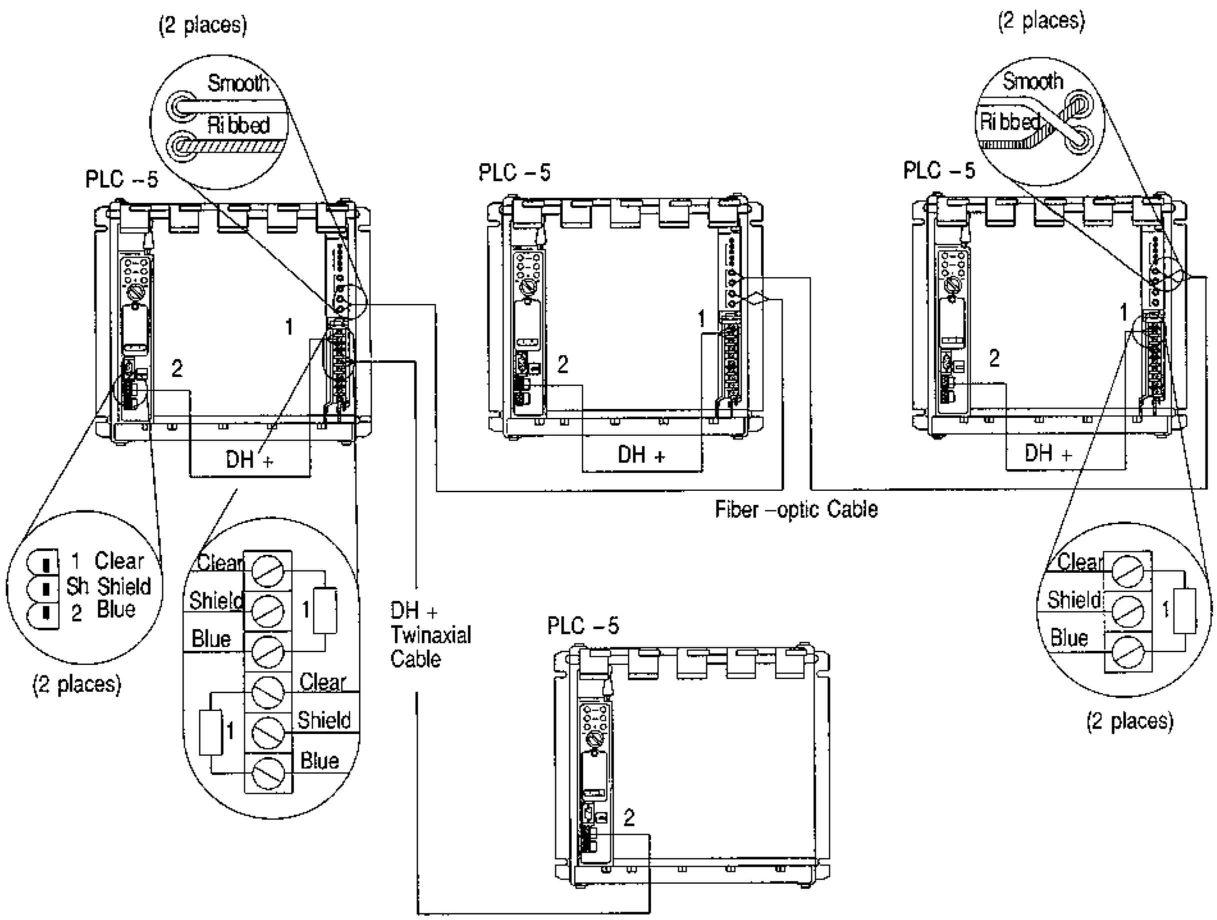
3 short segments of twinaxial cable (Cat. no. 1770–CD, Belden 9463, or equivalent)

Important:

For this type of cable	Under these conditions	The maximum length cannot exceed
twinaxial	dropline	100
	between any two devices	10,000 feet
	system total length	30,000 feet
fiber–optic*	between any two fiber–optic modules	6500 feet
combined twinaxial and fiber–optic*	system total length	43,000 feet

* for 100/140µm fiber–optic cable
See Appendix A for characteristics of other cables.

Figure 7.5
DH+ Network



Important:

1. Connect the Termination Resistor – 150 ohm, 1/4 watt, (cat. no. 1770–XT) between Blue and Clear.
2. Switch the PLC–5 Termination Resistor into the circuit with SW3 (4–switch assembly) switch 2 = ON.

18011

Troubleshooting

Chapter Objectives

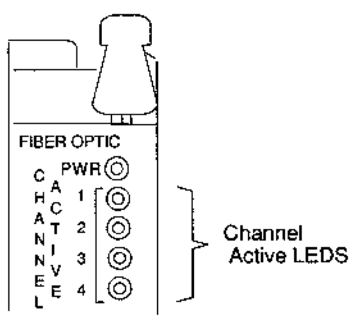
In this chapter we describe:

- LED indicators
- troubledshooting procedures

LED Indicators

To determine the current operating status of the fiber–optic link, examine the module's LED indicators (Figure 8.1). These LEDs show which fiber–optic/twinaxial channels are active and whether 5 VDC power is applied to the module.

Figure 8.1
LED Indicators



Indicators	Active State
PWR (green)	This LED lights when +5 Vdc is supplied to the module
CHANNEL ACTIVE 1 (green)	This LED lights when data is being received on fiber–optic channel 1
CHANNEL ACTIVE 2 (green)	This LED lights when data is being received on fiber–optic channel 2
CHANNEL ACTIVE 3 (green)	This LED lights when data is being received on twinaxial channel 1
CHANNEL ACTIVE 4 (green)	This LED lights when data is being received on twinaxial channel 2

We show LED indicator status for correct operation of a pair of fiber–optic modules (each end of the link) for these conditions:

- channels 1 & 4 ACTIVE – Figure 8.2
- channels 2 & 3 ACTIVE – Figure 8.3

Figure 8.2
Channels 1 & 4 ACTIVE

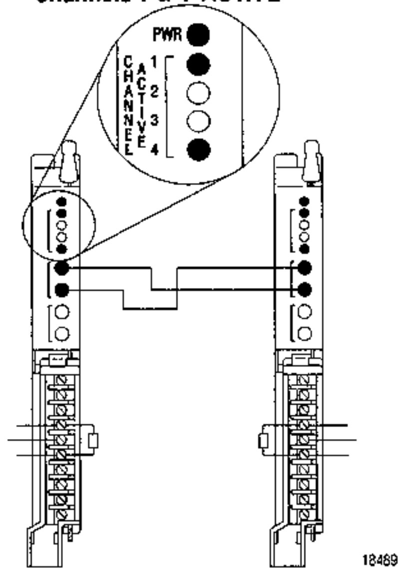
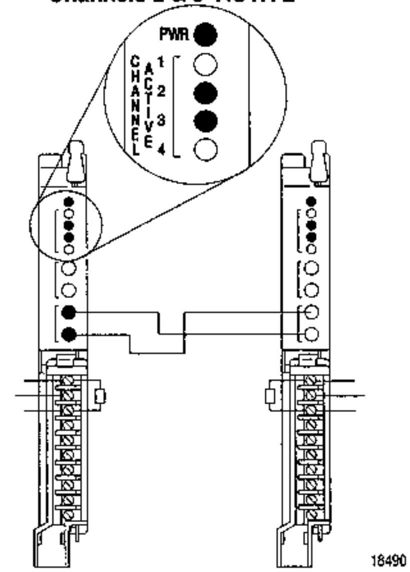


Figure 8.3
Channels 2 & 3 ACTIVE



Troubleshooting

The fiber–optic module is an active repeater which boosts the strength of an attenuated signal. Since the module re–transmits a signal to points farther down the network, a problem with the fiber–optic module will affect system operation from that point on.

Use the following chart to troubleshoot a fiber–optic module:

If:	Then check:
A PWR LED is off	Power supply and power cable (AF1) I/O chassis power (AF)
An active Channel 3 or 4 LED is off	Twinaxial cable and connections Module switch settings for bit rate and active channel
An active Channel 1 or 2 LED is off	Fiber–optic cable and connectors Fiber–optic module

Specifications

Module Location
1771–AF1 Stand alone
1771–AF Single slot, I/O chassis

Operating Temperature
0°C to 60°C
32°F to 140°F

Storage Temperature
–40°C to 85°C
–40°F to 185°F

Humidity – Non–condensing
5 – 95%

Power Supply – User Supplied for 1771–AF1
+5Vdc @ 1A

7mvrms ripple and noise (max)

±0.15% load and line regulation (min)

National electrical code class 2

Backplane Current (1771–AF)
600mA @ 5 Vdc (4 ports ON)

Power Dissipation
3.0 watts
10.3 BTU

Configurations
Point–to–point or star

Maximum Fiber–Optic Cable Distance Between Module Pairs
6500 ft (2KM) of continuous
100/140 μm fiber–optic cable

Maximum Network Cable Distance
43,000 ft. combination twinaxial and
100/140 μm fiber–optic cable, or
30,000 ft twinaxial cable

Maximum Twinaxial Distance Between Module Pairs (Twinaxial Repeater)
10,000 ft twinaxial cable per module pair

Receiver Sensitivity (Optical)
–24dBm @ 1 meter
with 100/140 μm glass fiber–optic cable

Optical Wavelength
820 nm

Fiber–Optic Cable Connector
SMA–905 connector or equivalent

Transmitter Power (Optical)
–21.0 dBm @ 1 meter
with 50/125 μm fiber–optic cable

–16.1 dBm @ 1 meter
with 62.5/125 μm fiber–optic cable

–14.1 dBm @ 1 meter
with 85/125 μm fiber–optic cable

–12.6 dBm @ 1 meter
with 100/140 μm fiber–optic cable.

–5.6 dBm @ 1 meter
with 200/230 μm fiber–optic cable

Connector Loss Guidelines
1dBm or less per connector.
This value has been included
in the transmitter power
(optical) specification.

Minimum Fiber–Optic Cable Bandwidth
17 MHz

Typical Cable Characteristics

Cable Diameter	Attenutation	Numerical Aperture	Length Guidelines
50/125 µm	4 dB/km	0.20 NA	1525ft 0.50 km
62.5/125 µm	4 dB/km	0.28 NA	5280 ft 1.75 km
85/125 µm	4 dB/km	0.26 NA	6500 ft 2 km
100/140 µm	5 dB/km	0.30 NA	6500 ft 2 km
200/230 µm	6 dB/km	0.37 NA	6500 ft 2 km

Glossary

Attenuation
Optical signal reduction inherent in the cable over a given distance. The amount of loss is usually stated in decibels per kilometer at a specific wavelength.

Cladding
The material that surrounds the cable's core. The cladding has a lower refractive index than the core which optically insulates the core during data transmissions.

Core
The center of a fiber–optic cable which carries optical signals. A core has a higher refractive index value than the cladding.

Fiber
A single optical element which is defined as a core and a cladding.

Link
Two fiber–optic modules which are connected via a fiber–optic cable.

LED
A semiconductor device that produces diffused light. The LED's light intensity is proportional to the amount of current flowing through it.

Microbend Loss
Attenuation caused by excessive cable bending or manufacturing flaws.

Micron (um)
One millionth of a meter (10^{-6})

Mode
An electromagnetic propagation pattern within an optical fiber.

Power
The rate at which optical energy is transmitted and received over a given period of time. Defined in watts but is commonly expressed in decibels (dB).

Receiver

A converter that changes an optical signal into an electrical signal (receptor).

Refractive index

The ratio of the velocity of light in free space to the velocity of light in the medium.

Repeater

A receiver/transmitter which boosts the strength of an attenuated signal. A repeater can be either active or passive. The 1771–AF1 module is an active repeater.

Transmitter

A device that changes an electrical signal into an optical signal (sender).

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