Chapter 6
System Level
Configuration, Planning, and Cabling

This chapter describes the proper methods of configuring 984 Controllers with local and remote I/O. It describes the following topics:

Cabling components and topologies.

Controller selection and installation

Cable fabrication, installation, and testing.

Standard Configurations

Single Cable Remote I/O

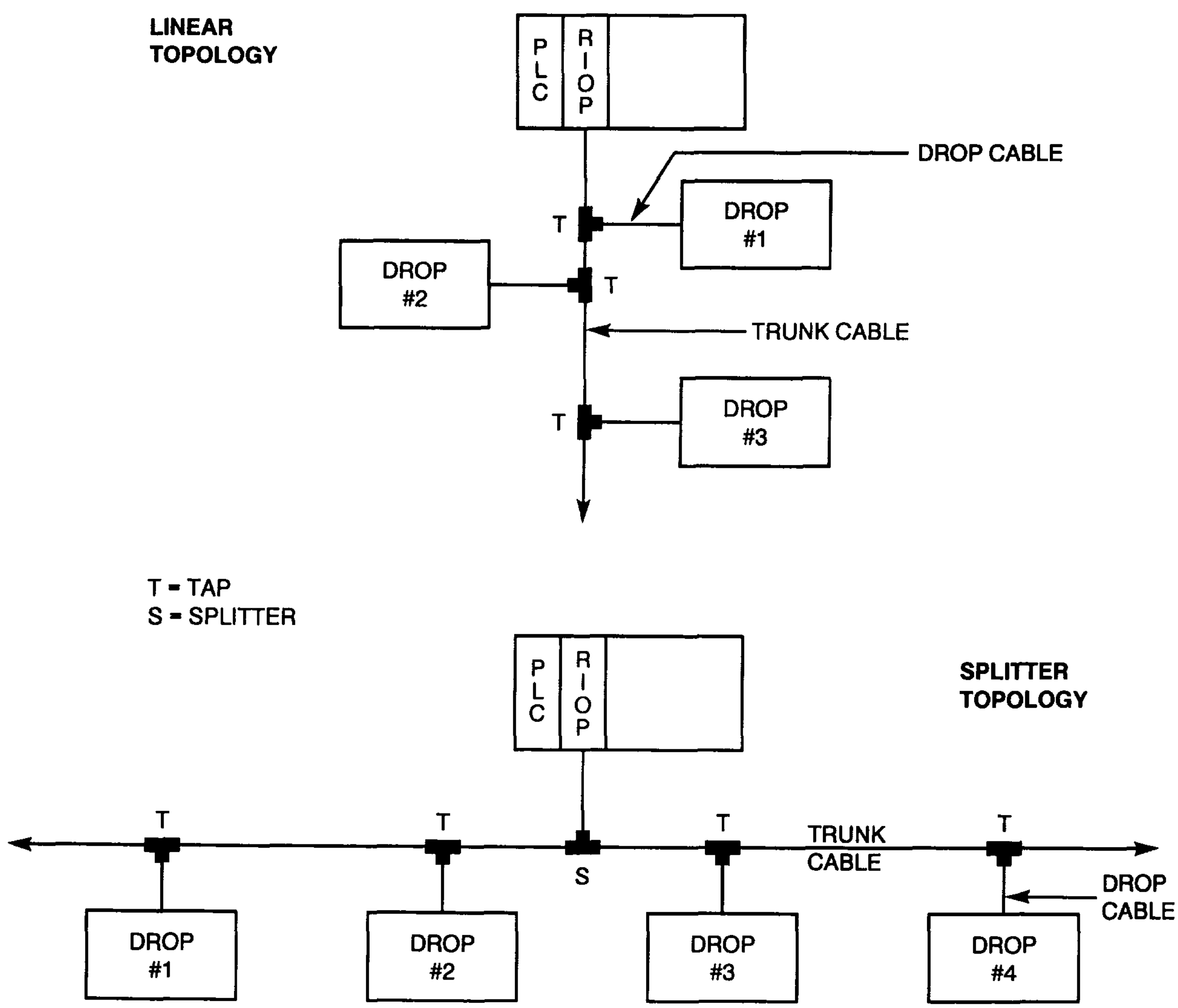
Requires a single cable connector at the RIO Processor.

Requires a single cable connector at each RIO Interface.

Supported by both S901 and S908 RIO Processors.

Supported by the S929 MOP Processor.

Figure 6-1 Single Cable Topology



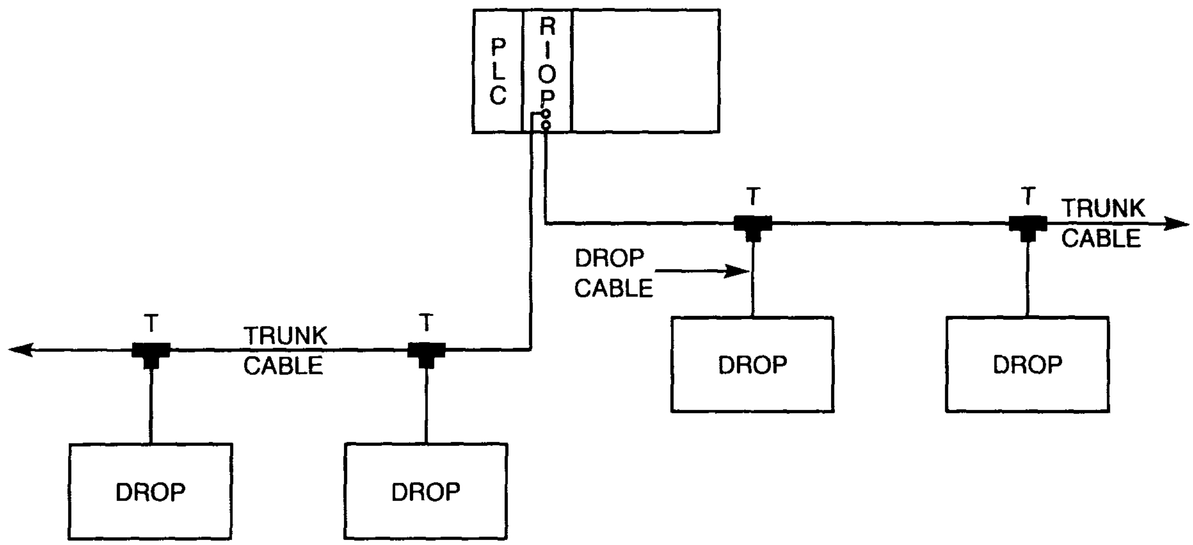
Dual Cable Remote I/O

Requires one cable connector at each RIO Interface.

Requires a dual cable S908 RIO Processor

Allows running two independent trunk cables to a large number of I/O drops without the use of a splitter.

Figure 6-2 Dual Cable Topology



T = TAP

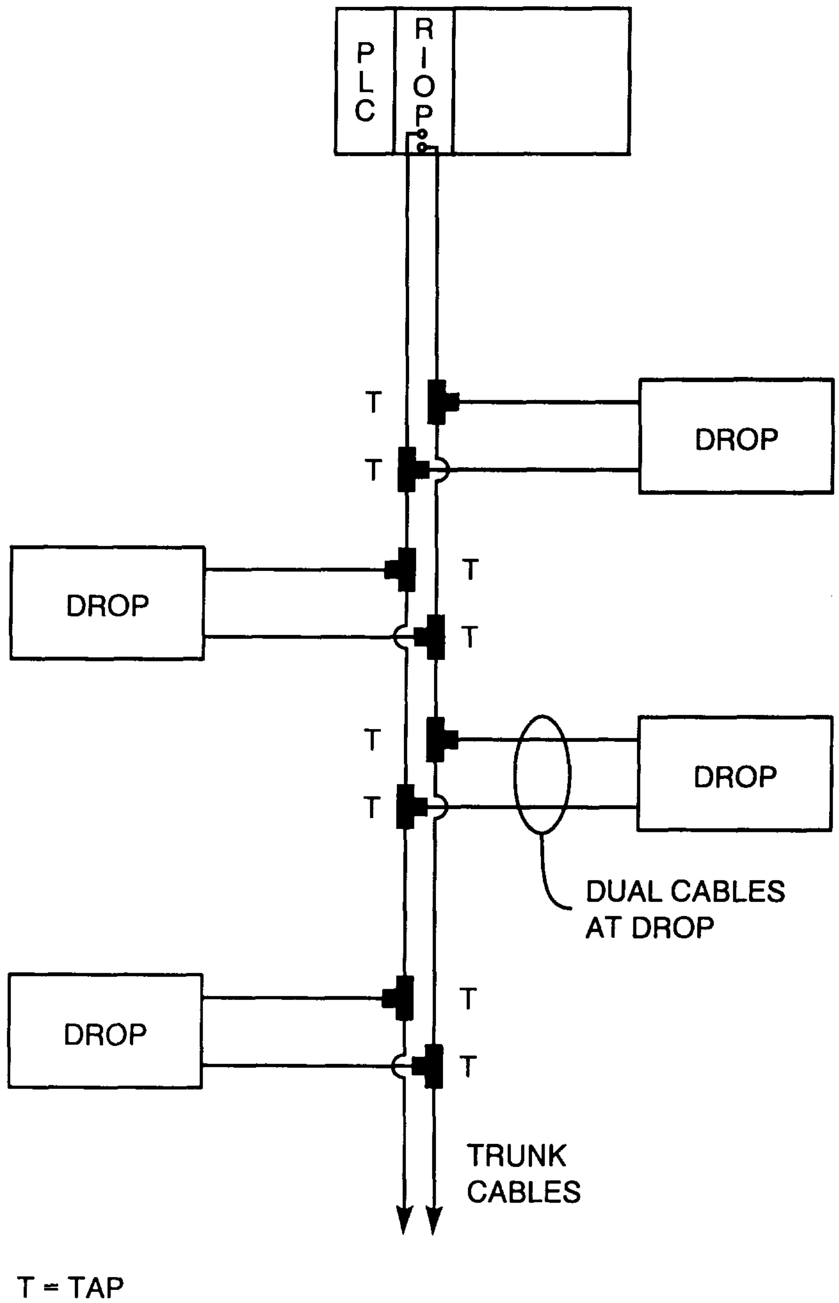
Redundant Cable Remote I/O

Requires two cable connectors at each RIO Interface (J890/J892-002, or P453-591, -691, -592, -692)

Requires a dual cable S908 RIO Processor (P/N AS-S908-021)

Provides added security for maintaining RIO signal integrity.

Figure 6-3 Redundant Cable Topology



Hot Standby Configurations

Hot Standby Single Cable Remote I/O

Requires a single cable connector at each RIO Interface.

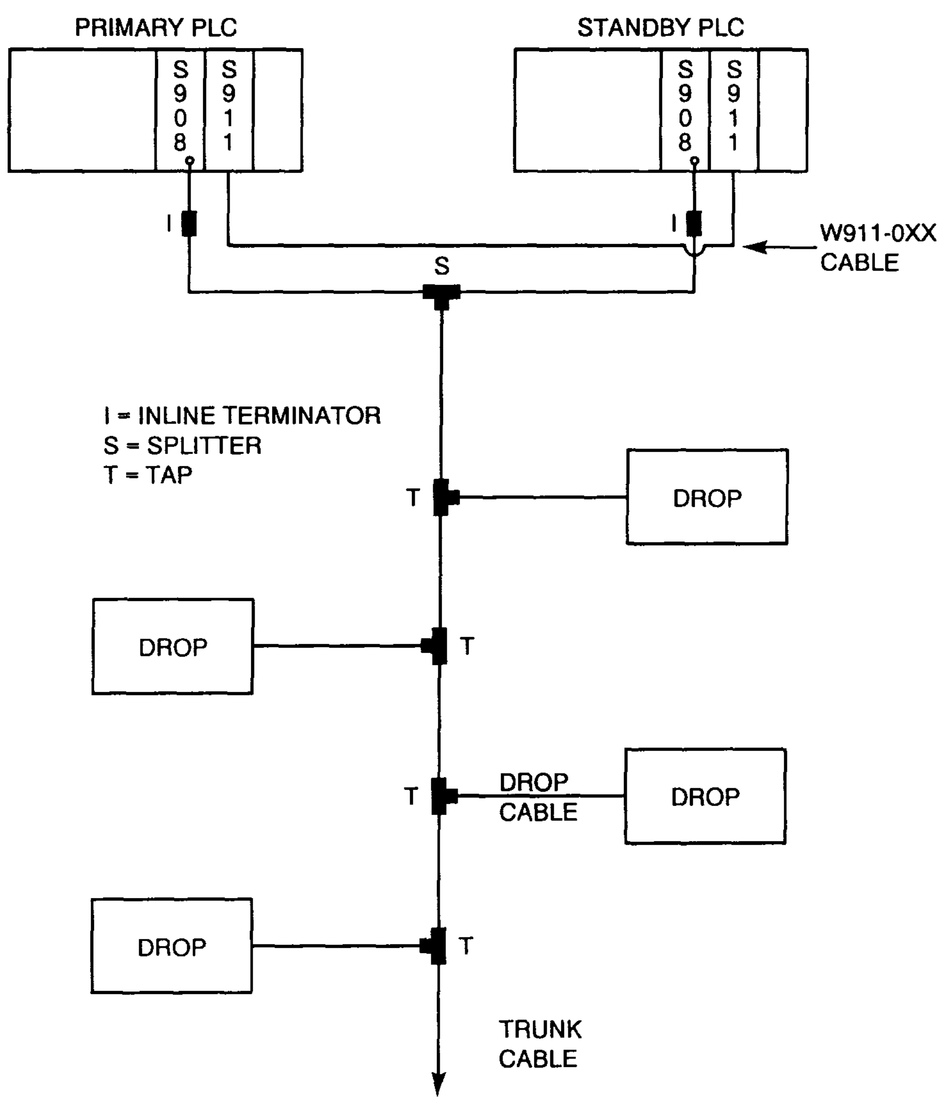
Requires two single cable S908 RIO Processors.

Requires a splitter.

Requires two S911 Hot Standby Modules

The two 984 controllers must be configured identically. The primary controller handles all processing. The standby module is updated with system status on each scan.

Figure 6-4 Hot Standby, Single Cable Topology



Hot Standby, Dual Cable Remote I/O

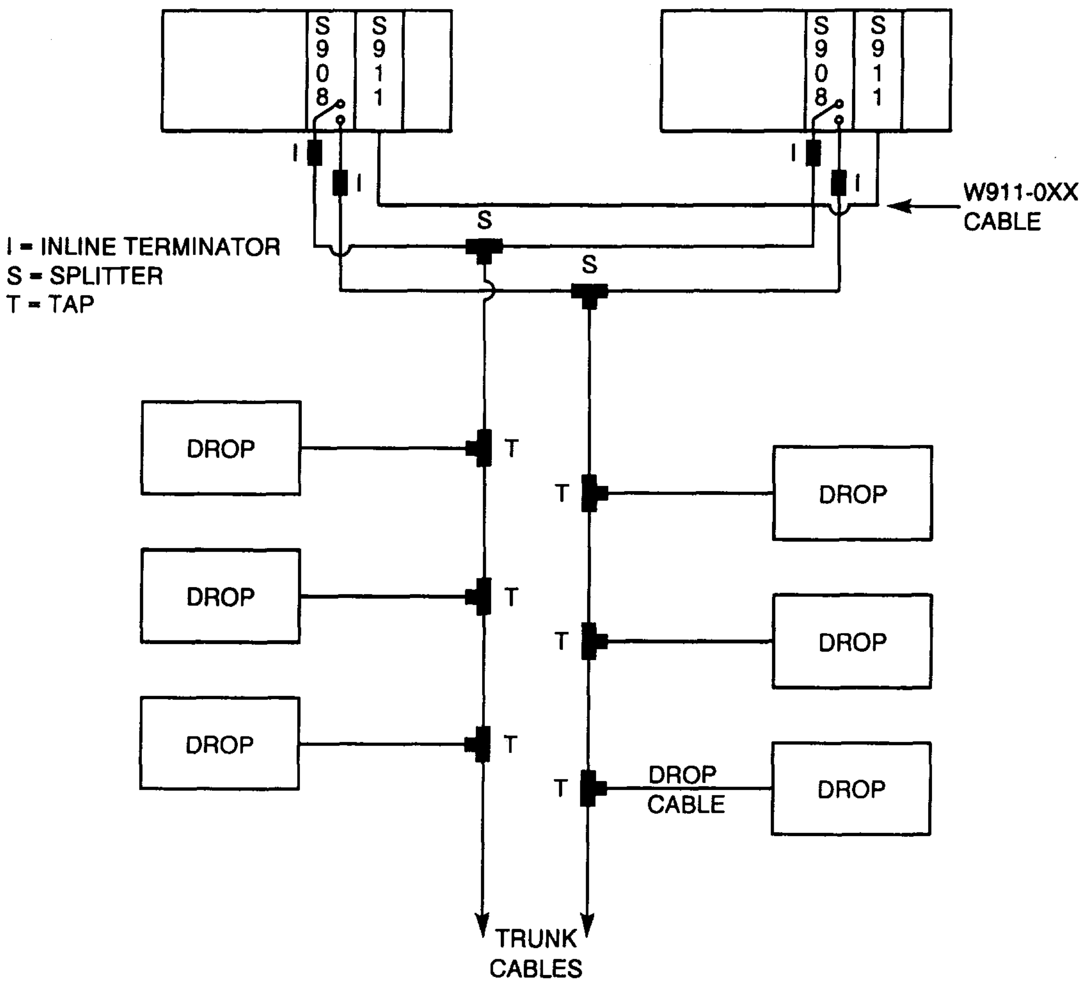
Requires one cable connector at each RIO Interface.

Requires two dual cable S908 RIO Processors

Requires two S911 Hot Standby Modules

The two 984 controllers must be configured identically. The primary controller handles all processing. The standby module is updated with system status on each scan.

Figure 6-5 Hot Standby, Dual Cable Topology



Hot Standby, Redundant Cable Remote I/O

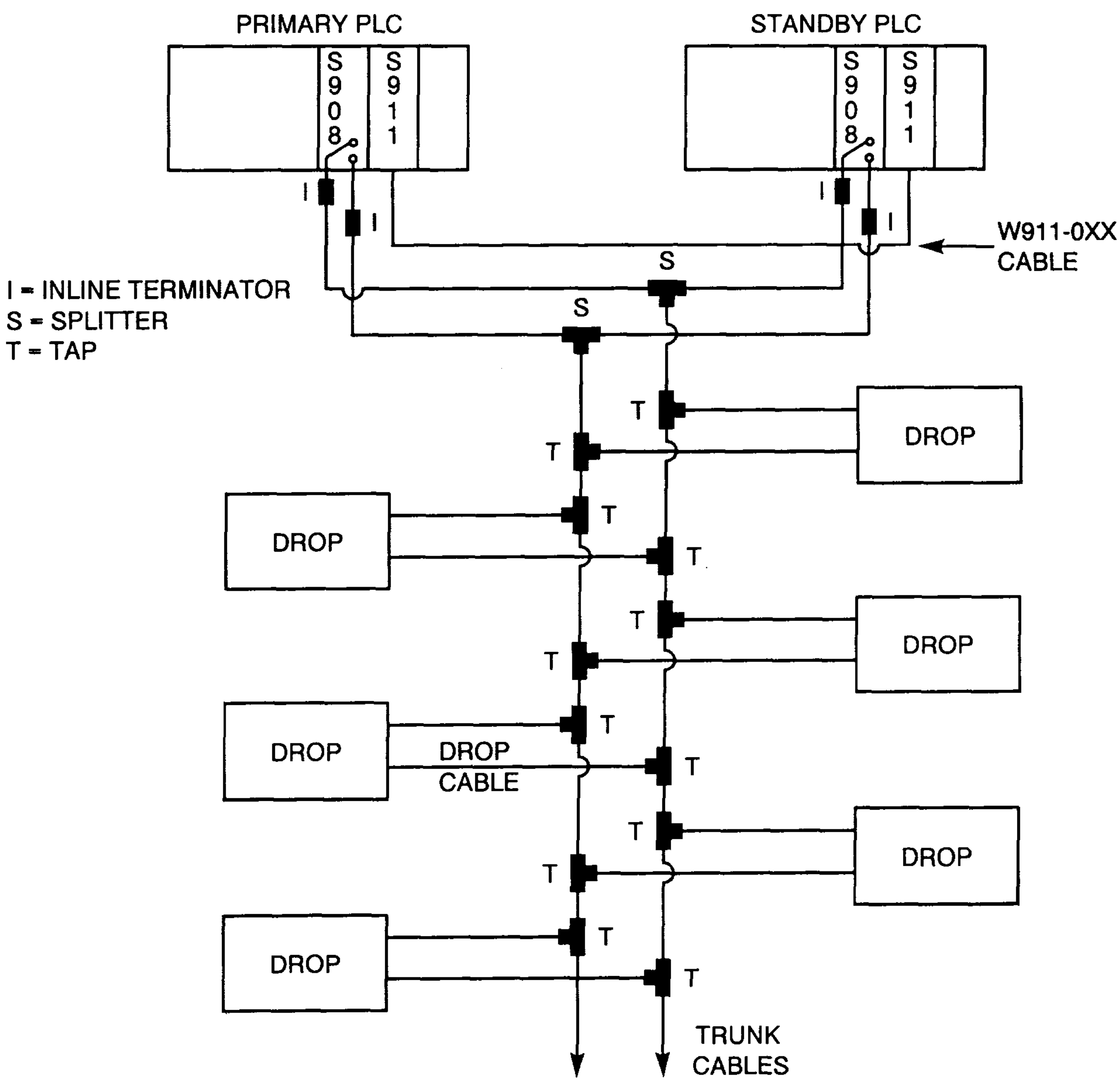
Requires two cable connectors at each RIO Interface.

Requires two dual cable S908 RIO Processors

Requires two S911 Hot Standby Modules

The two 984 controllers must be configured identically. The primary controller handles all processing. The standby module is updated with system status on each scan.

Figure 6-6 Hot Standby, Redundant Cable Topology

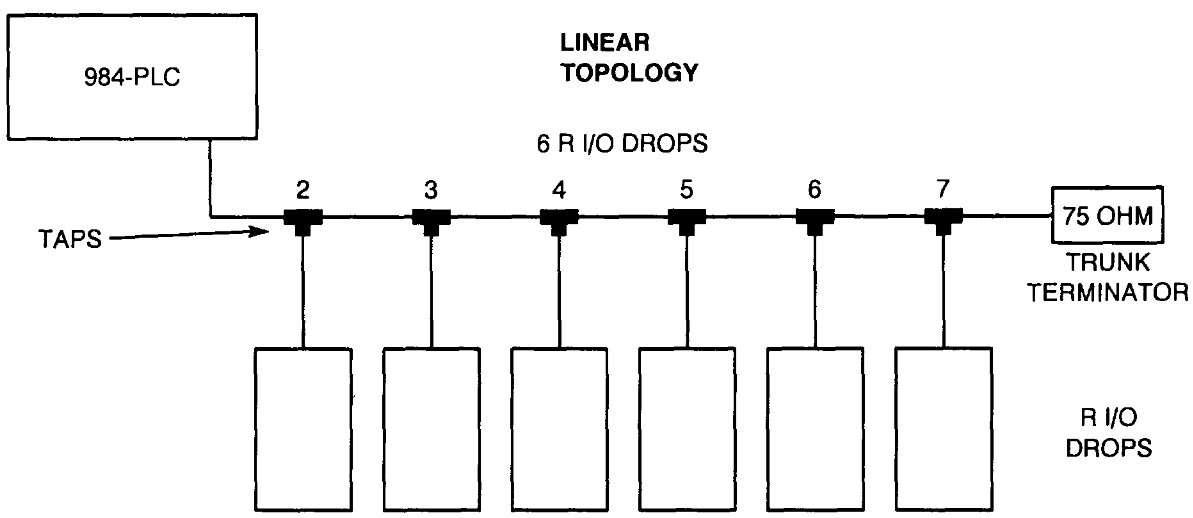


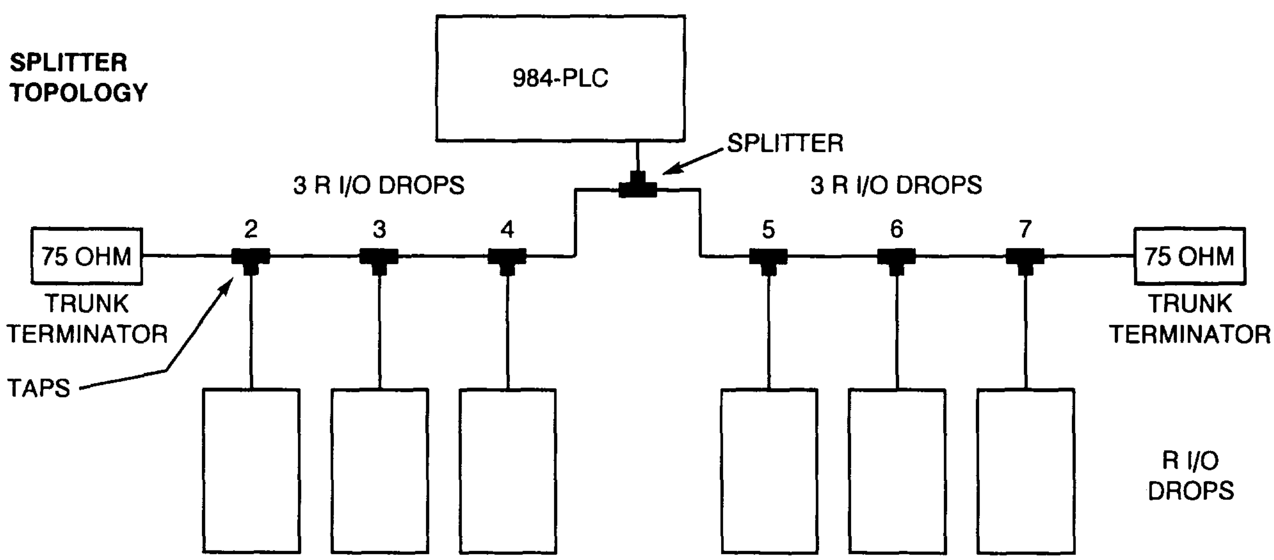
Summary Of Legal Remote I/O Configurations

Linear configuration is preferred. Tap positions can be chosen as needed as long as the insertion loss between the PLC and any remote drop remains less than 35 dB. Maintain 8.5 ft. between taps.

Splitter configuration is allowed but *not* recommended. With a splitter, cable length on both sides of the splitter should be equal and tap positions should be located at equal distances from either side of the splitter to minimize signal degradation caused by reflections. The maximum allowable insertion loss is 35 dB between the PLC and any remote drop. The procedure for determining insertion loss is covered in the cable testing section.

Figure 6-7 Legal Remote I/O Configuration Summary

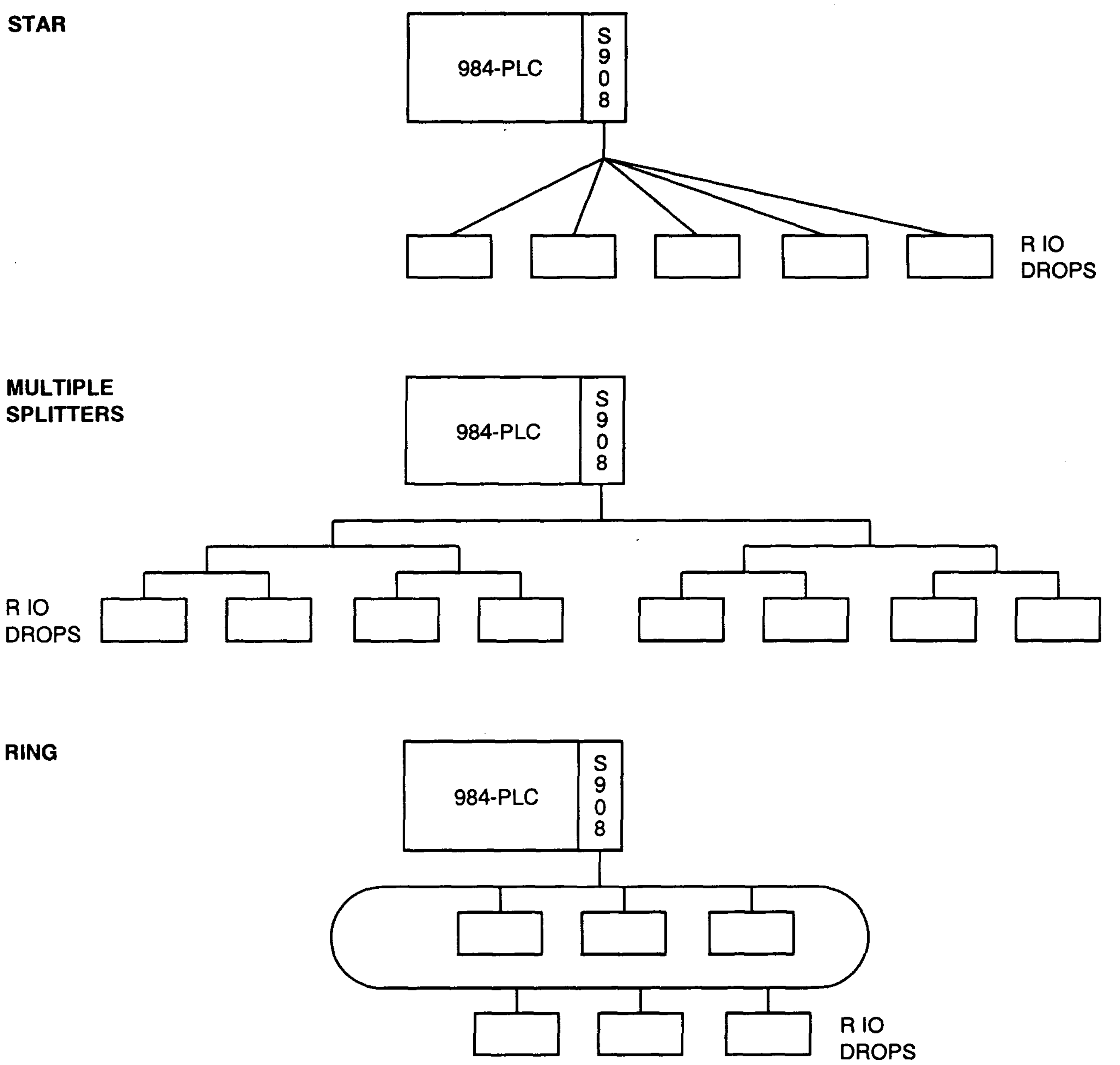




Illegal Remote I/O Configurations

These configurations are not to be used for any type of 984 controller.

Figure 6-8 Illegal Remote I/O Topologies



Standard Distributed Control Configurations

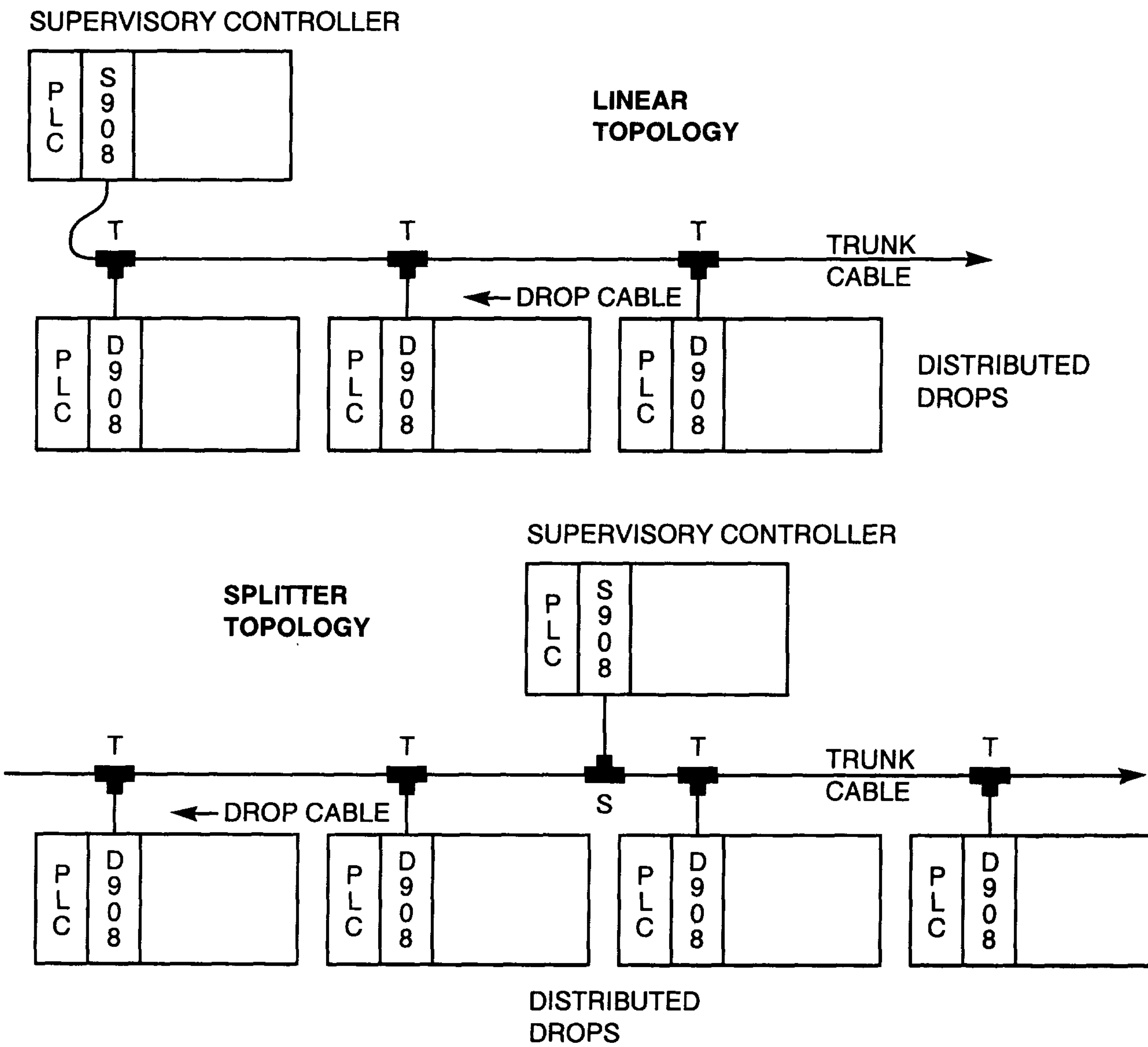
Single Cable Distributed Configurations

Converts remote I/O networks into a distributed control network

Requires a 984 Supervisory Controller with S908 remote I/O processor

Each distributed drop must have a D908 and one of the following controllers; 984-680, -685, -780, or -785

Figure 6-9 Single Cable, Distributed Topologies

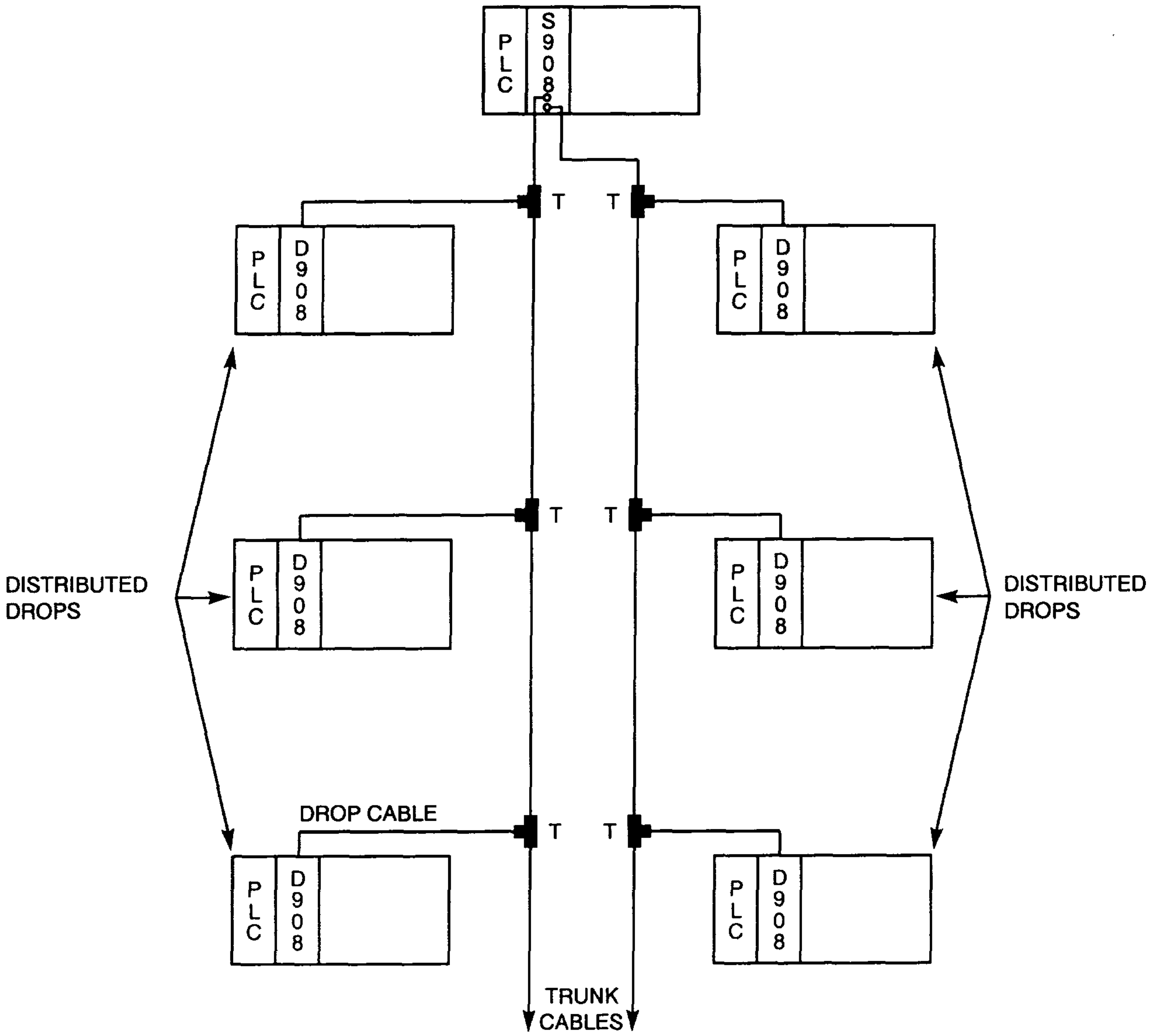


Dual Cable Distributed Configuration

Requires a dual cable S908

Each distributed drop must have a D908 and one of the following controllers; 984-680, -685, -780, or -785

Figure 6-10 Dual Cable, Distributed Topology



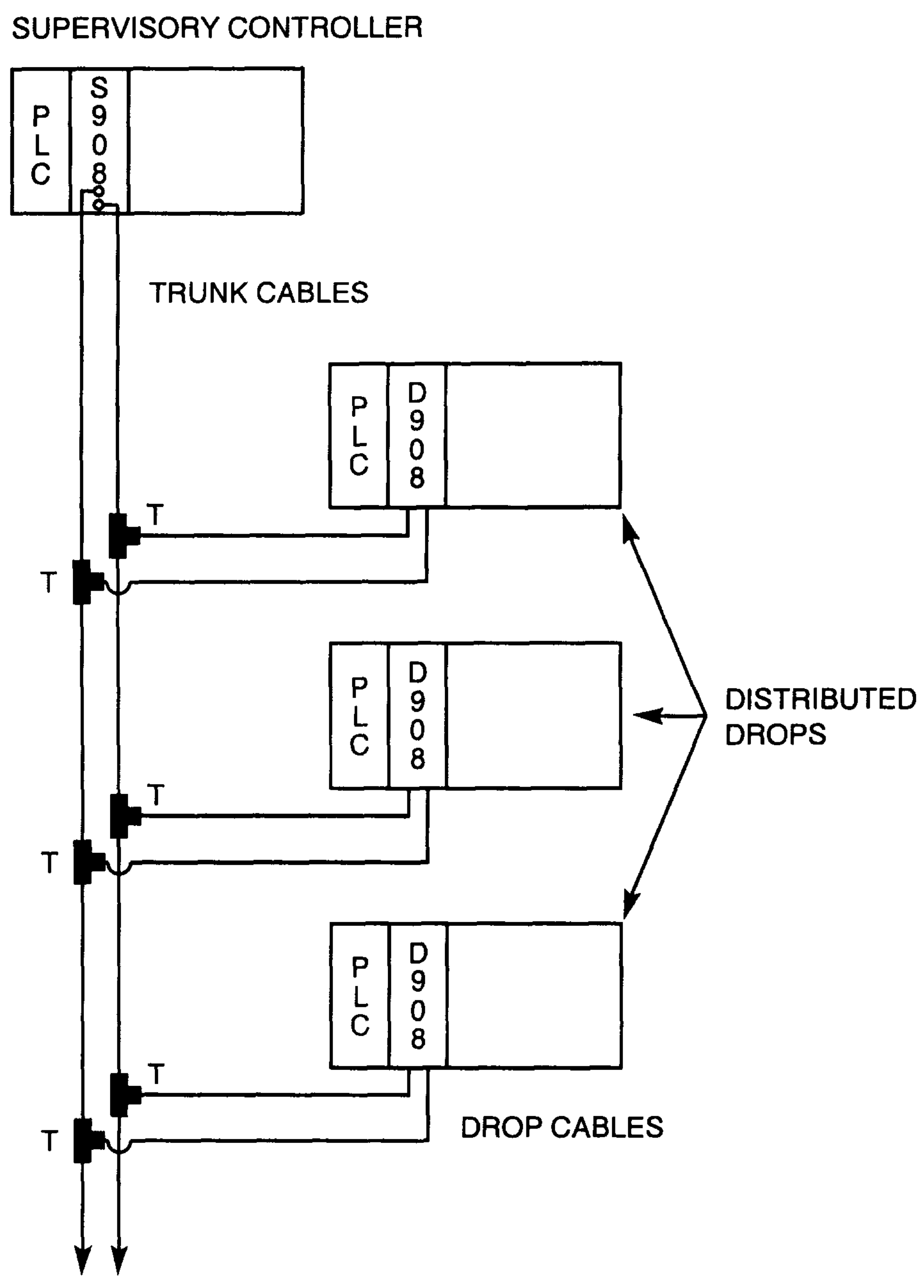
Redundant Cable, Distributed Configuration

Requires a dual cable S908

Requires 984-680, -685, -780, or -785 controller in the distributed drop

Requires a dual cable D908

Figure 6-11 Redundant Cable, Distributed Topology



Hot Standby Distributed Control Configurations

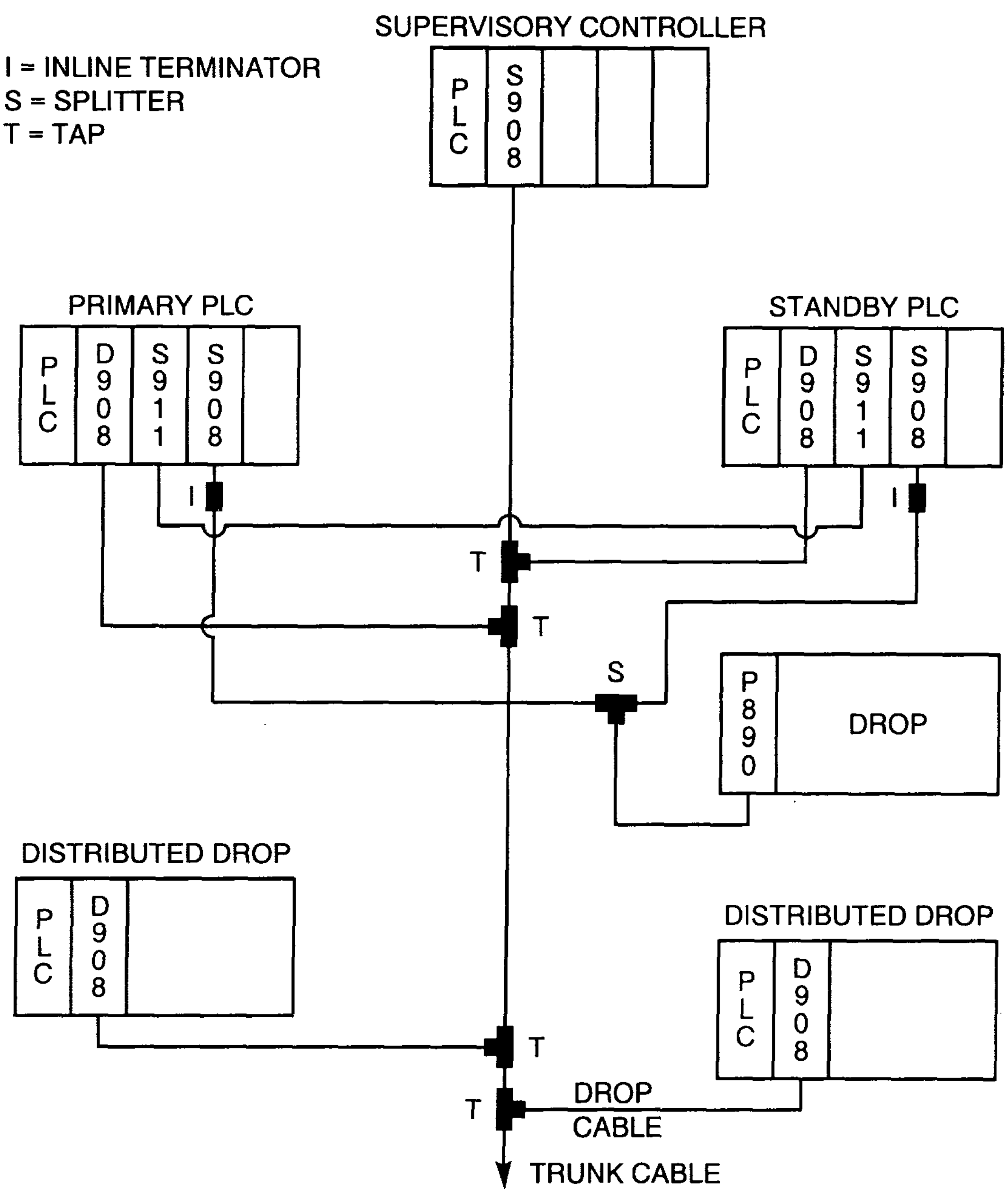
Single Cable, Distributed Hot Standby Configuration

The D908 in the standby PLC is inactive until the standby assumes control

Requires 984-680, -685, -780, or -785 controller in the distributed drop

Figure 6-12 Single Cable, Distributed Hot Standby Topology

The supervisory controller may also be in a Hot Standby Configuration.



Dual Cable, Distributed Hot Standby Configuration

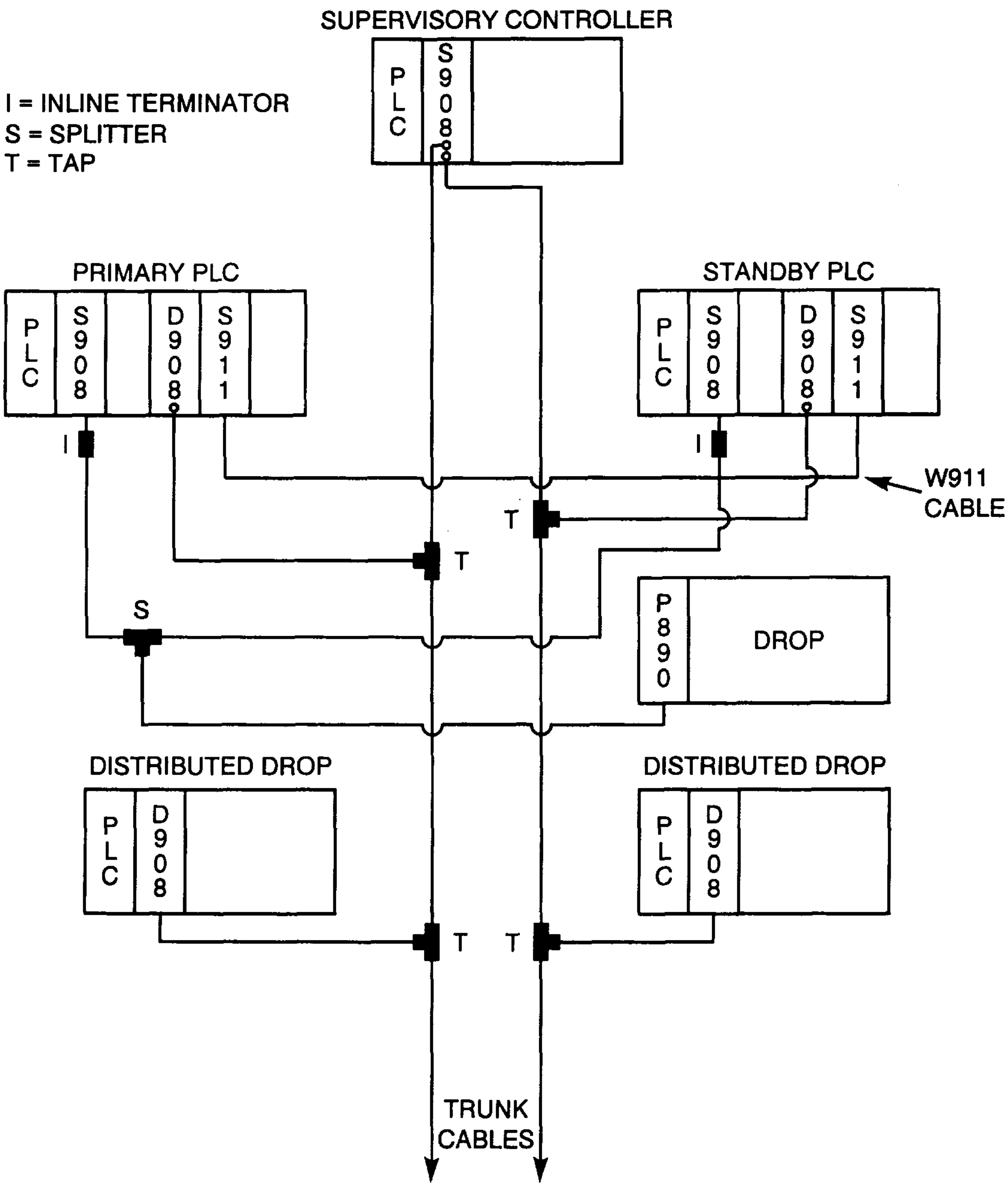
The D908 in the standby PLC is inactive until the standby assumes control

Requires 984-680, -685, -780, or -785 controller in the distributed drop

A dual cable S908 is required

Figure 6-13 Dual Cable, Distributed Hot Standby Topology

The supervisory controller may also be in a Hot Standby Configuration.



Redundant Cable, Distributed Hot Standby Configuration

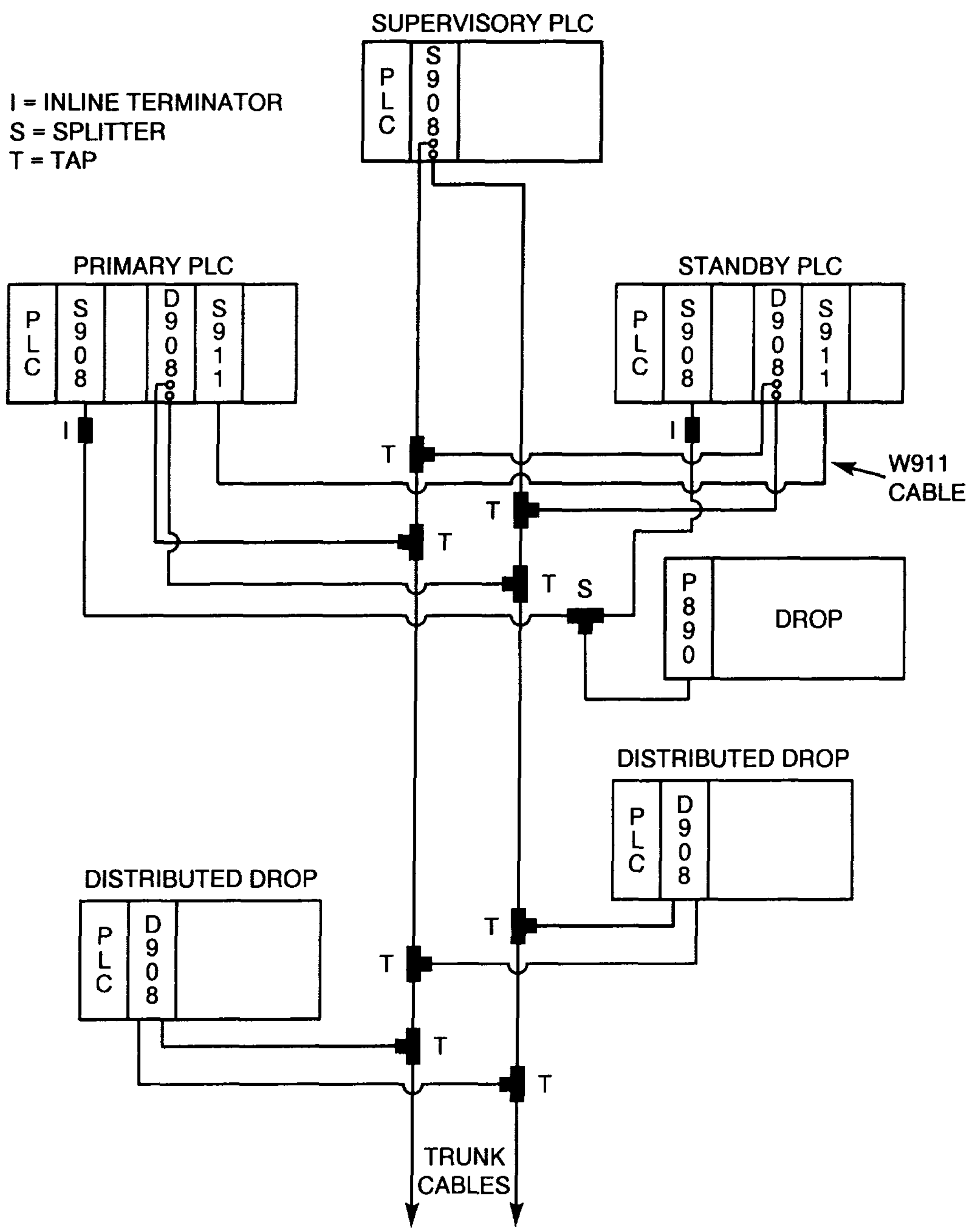
The D908 in the standby PLC is inactive until the standby assumes control

Requires 984-680, -685, -780, or -785 controller in the distributed drop

A dual cable S908 is required

Figure 6-14 Dual Cable, Distributed Hot Standby Topology

The supervisory controller may also be in a Hot Standby Configuration.



Summary of Distributed Configurations

Supervisory PLC must have an S908 remote I/O processor

Distributed drops must have a 985-680, -685, -780, or -785 controller and a D908

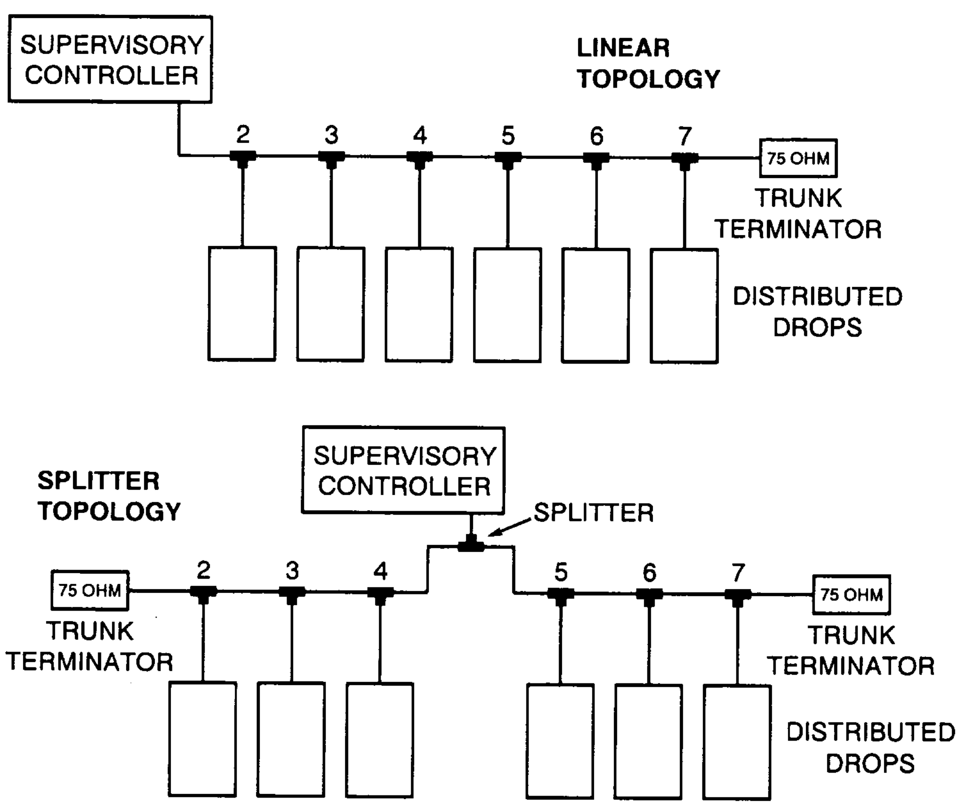
Registers are automatically exchanged between the supervisory controller and the distributed drops

All legal cable topologies are supported

Linear configuration is preferred. Tap positions can be chosen as needed as long as the insertion loss between the PLC and any remote drop remains less than 35 dB.

Splitter configuration is allowed but *not* recommended. With a splitter, cable length on both sides of the splitter should be equal and tap positions should be located at equal distances from either side of the splitter to minimize signal degradation caused by reflections. The maximum allowable insertion loss is 35 dB between the PLC and any remote drop. The procedure for determining insertion loss is covered in the cable testing section.

Figure 6-15 Legal Distributed Configuration Topologies



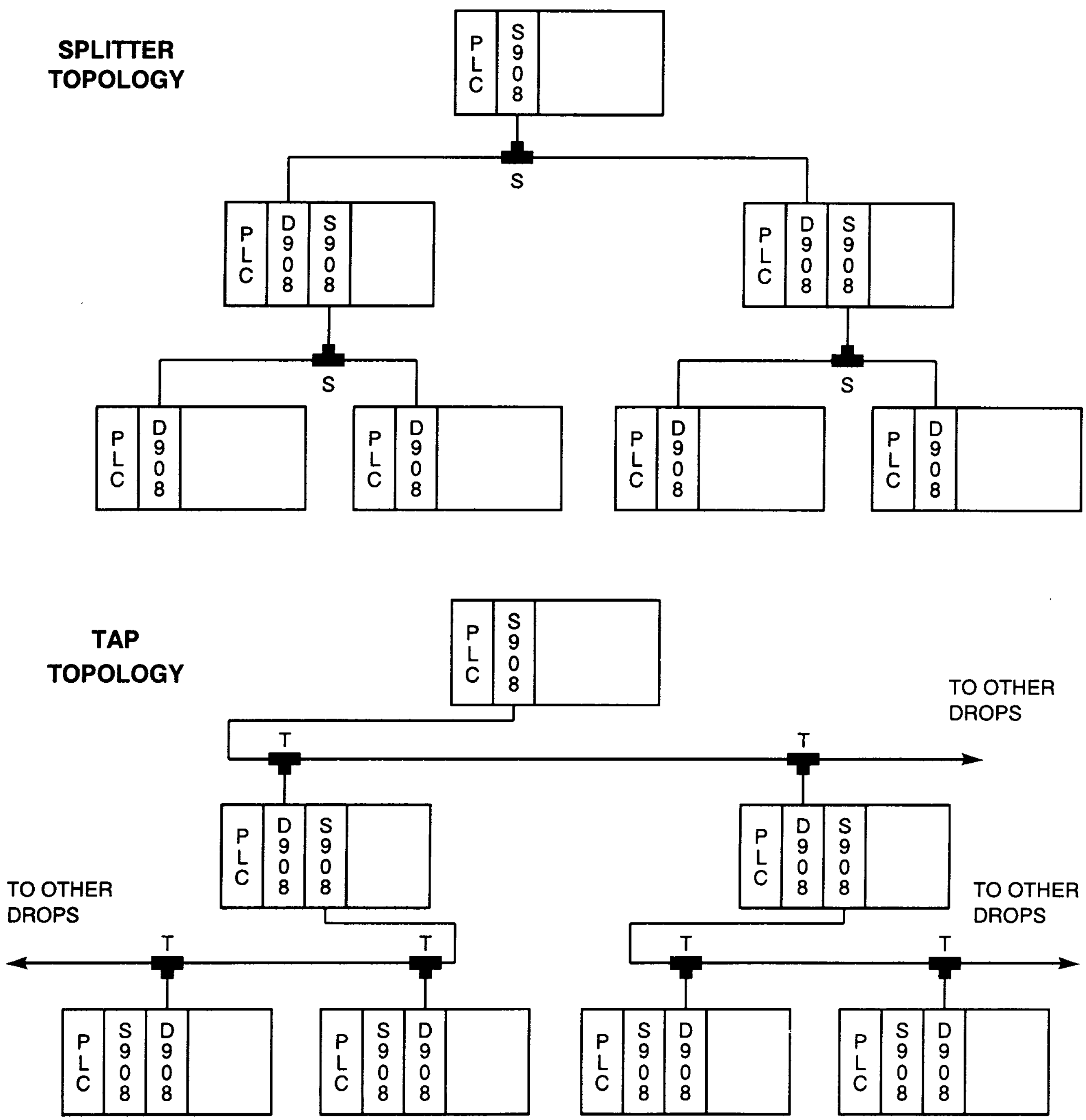
Pyramid Distributed Configurations

Lower level distributed networks are allowed

Linear, splitter, dual, and, redundant cable topologies are allowed on all levels

Each level may have its own local and remote I/O plus Distributed drops

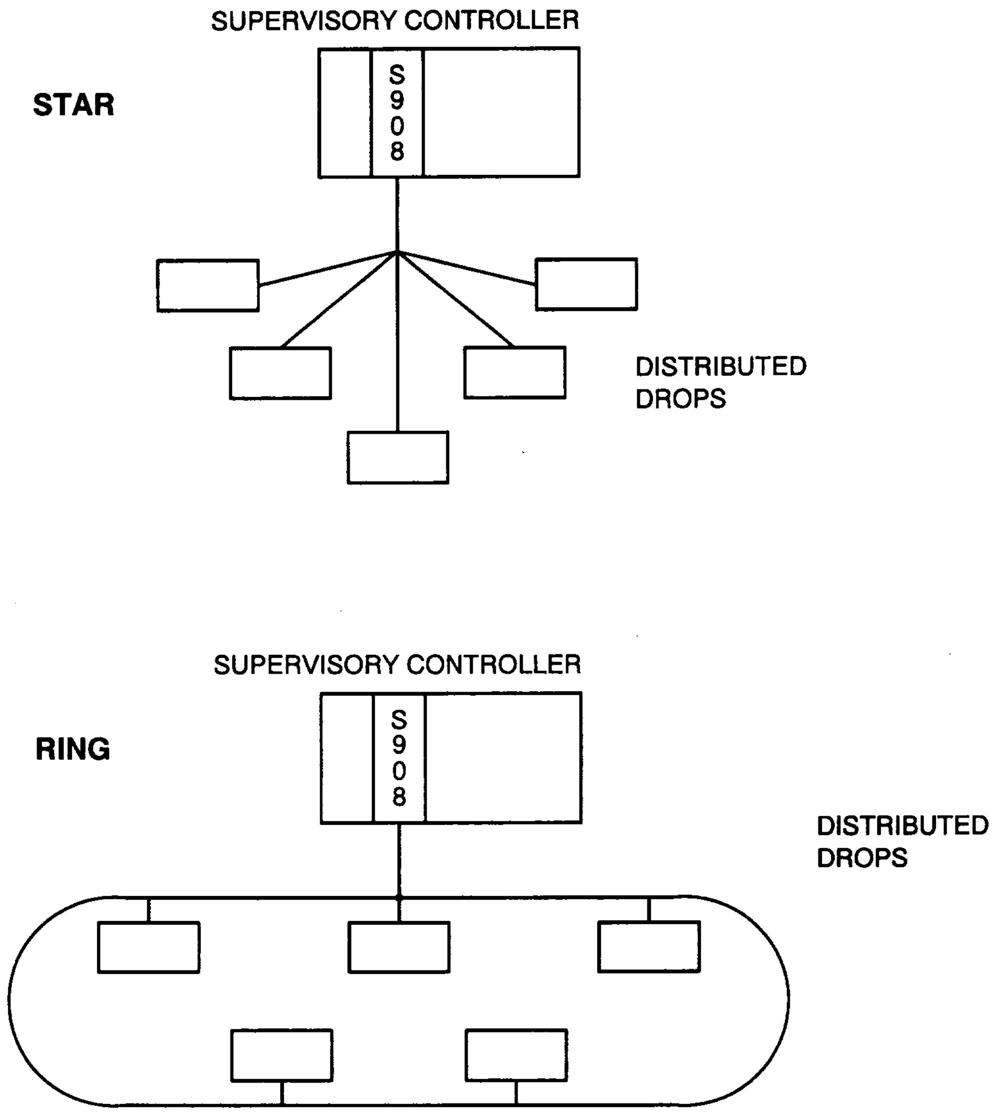
Figure 6-16 Pyramid Distributed Configuration Topology



Illegal Distributed I/O Configurations

These configurations are not to be used in a distributed system

Figure 6-17 Illegal Distributed Configuration Topologies



Controller Memory Usage

System Overhead Memory Requirements How a controller manages its memory is useful information when selecting a controller for an application. Modicon controllers use a portion of User Logic memory to store the configuration table and traffic cop information. This decreases the amount of memory available for your programming. In the smaller PLC's this may be significant. A controller with the smallest possible configuration requires 888 words of logic memory and includes the elements shown in the table below.

Table 6-1 Minimum Configuration Requirement

16 - 0XXXX	Coils
16 - 1XXXX	Discrete Inputs
1 - 3XXXX	Input Registers
1 - 4XXXX	Holding/Output Registers
1 - I/O Drop	
0 - I/O Modules	

Other factors that affect logic memory are :

I/O Modules - When you configure I/O modules, memory is allocated at 6 words per module. Configuring 20 I/O modules requires 120 words of logic memory.

0XXXX references - When configuring coils, memory is allocated at 1 word per 16 coils. Configuring 32 coils uses two words of memory.

1XXXX, 3XXXX and 4XXXX references - Do not affect logic memory.

I/O Drops - When configuring multiple I/O drops, memory is allocated at 5 words per drop (after the first drop).

Software loadables - These will impact user logic memory.

ASCII Messages - These will impact user logic memory

Figure 6-18 Sample Calculation of Available User Memory

A sample estimate of available logic memory in a 984-380 with 1.5 K of user logic, configured for 128 coils, 10 I/O modules, and 100 inputs is determined as shown below.

Memory required for configuration

Min. configuration	888 words
I/O modules	60 words (10 mod. x 6 words/module)
0XXXX references	+ 8 words (sample configured for 128 coils, 128/16=8)
memory required for configuration	956 words

User Memory Available After Configuration

Total user logic available in 984-380 controller	1536 words
Memory used by configuration	- 956 words
User logic available	580 words

Logic Element Memory Requirements Each time you program a new column, a word of memory is used as a "Beginning of Column" marker. This word stores information and indicates; the column is programmed, the location of any vertical shorts within the column, and the location of logic elements, by row, within the column. Each new network you program requires a word of memory to indicate the "Start of Network" marker. Logic elements require the following amounts of memory.

Table 6-2 Logic Element Memory Requirements

No. of Words	Logic Element(s)
0	Vertical shorts
1	Contacts, coils, horizontal shorts, skip
2	Counters, timers
3	Calculations, data transfers (DX)

Controller Selection Considerations

Selecting the correct PLC to control a process is based on many considerations. The information below is designed to help you determine the correct PLC for your application.

Know the Process - A thorough analysis of process and what the controller will be required to do will help in the selection of an appropriate controller.

Determine the amount and type of inputs and outputs - I/O capability varies between 984 models. Allow 25% for future expansion. Any special I/O requirements need to be noted.

Determine the type of control - Individual, centralized or distributed control are possible.

Develop preliminary program - The amount of memory your application requires will be an important factor in determining the size controller needed. Create a preliminary version of your program and calculate the amount of memory it will consume. Refer to the section entitled Controller Memory Use for specific information on memory useage. Add to this figure the system overhead and allow a safety margin of 25% for future expansion.

Evaluate processor scan times - Does your application have any scan sensitive areas that require a faster controller ? Select a faster scanning controller or consider distributed control.

Determine physical and environmental restrictions - Is available space for the controller and its I/O a problem?

Equipment Standardization - Do you presently have any other Modicon controllers installed? Standardization reduces the number of inventory of spare parts that you must stock.

984 System Capabilities Tables

The size and capability of the control system is one of the determining factors when selecting an appropriate controller. The table below summarizes the system capabilities of the 984 controller family.

Figure 6-19 984 System Capabilities by Controller

Controller							Input/Output (I/O)				
	Memory							System Maximum			
Controller Model	Logic[1]	Reg. [2]	Total	Scan Time	MODBUS Ports	MODBUS Plus Ports	I/O Series	Discrete I/O Bits[5]	16 Bit I/O Words[4]	Total Drops	# Local Racks
984-380	1.5K 4K 6K	1920	3.5K 6K 8K	5ms/K	1	N/A	800	256 any mix	32/32	1	2
984-381	1.5K 4K 6K	1920	3.5K 6K 8K	5ms/K	2	N/A	800	512 any mix	32/32	1	2
984-385	4K 6K	1920	6K 8K	3ms/K	1	1	800	512 any mix	32/32	1	2
984-480	4K 8K	1920	6K 10K	5ms/K	2	N/A	800/200 /500	1024 any mix	224/224	7	2
984-485	4K 8K	1920	6K 10K	3ms/K	2	1	800/200 /500	1024 any mix	224/224	7	2
984-680	8K 16K	1920	10K 18K	3ms/K	2	N/A	800/200 /500	2048 any mix	1K/1K	32	5
984-685	8K 16K	1920	10K 18K	2ms/K	1	1	800/200 /500	2048 any mix	1K/1K	32	5
984-780	16K 32K	9999	26K 42K	1.5ms/K	2	N/A	800/200 /500	8192/ 8192	1.5K/1.5K	32	5
984-785	16K 32K	9999	26K 42K	1.5ms/K	1	1	800/200 /500	8192/ 8192	1.5K/1.5K	32	5
984X	8K	1920	10K	.75ms/K	2	N/A	800/200 /500	2048 any mix	224/224	7	5
984A	16K 32K	1920	18K 34K	.75ms/K	3	N/A	800/200 /500				
w/S908								2048 any mix	2K/2K any mix	32	N/A
w/S901								2048 any mix	256/256	16	N/A
984B	32K 64K	9999	42K 74K[3] 106K[3] 138K[3]	.75ms/K	3	N/A	800/200 /500				
w/S908								8192/ 8192	2K/2K	32	N/A
w/S901								8192 any mix	256/256	16	N/A

[1] Deduct approx. 1K words for system overhead
[3] 0-96K Extended Memory available
[2] Includes Analog/Register I/O and internal register space
[4] Each I/O Analog point or Register word requires one 16 bit word
[5] "Any Mix" of discrete I/O must be in groups of 16.

Evironmental

Ambient Temperature	0-60°C 32-140°F
Humidity	0-95% non-condensing
Shock	10G's for 11 mSec
Vibration	.625 @ 50-500Hz
RFI/EMI susceptability	ML-STD-461B CS02-Conducted RS03-Radiated
UL Listing	E54088*
CSA Listing	LR32678*

*Only for 984A, 984B, 984X. The 984-68X, -48X, -38X submittals for agency approval are pending.

Power Requirements

Nominal Voltage	120V RMS input voltage range (98-133 VAC) frequency range (47-63 Hz) 220V RMS input voltage range (195-265 VAC) frequency range (47-63 Hz) 24 VDC input voltage range (20.4-27.6 VDC) (984-380, -480, -680)
Surge Withstand	ANSI C37 .90a/IEEE 472
Normal Load	180 Volt-Amps (P930) 300 Volt-Amps (P933) 40 Volt-Amps (984-38X and -48X) 80 Volt-Amps (984-68X)

The development of an installation plan is a conscientious approach to the planning, placement and interconnection of components in a PLC control system. The installation plan also considers peripheral equipment associated with the PLC such as operator interfaces as well as isolation transformers, power sources, and environmental considerations. Installation planning requires research, measuring, and the drafting of a cable run plan. In a well planned installation, all components of the system are accessible and easily maintained.

Controller Location

The location of a 984 PLC may be as far as 15,000 feet from it's furthest I/O drop. The following items should be considered:

If the I/O system is clustered in a single location, and environmental issues are not a factor, a centralized control configuration may not be the best choice.

Always consider the ultimate location of the 984 PLC in regards to the required distance of the communications cable run. Any reduction in the length of coax cable through careful planning will result in lower installation costs.

In redundant cabling configurations, plan to route the second cable along the same general path as the first cable in order to reduce installation costs. However, the cables should be physically separated by a space sufficient to minimize the chance of damage to both cables from the same accident or the introduction of noise into the cable from the same source.

Power Sources

Primary Power Source In planning for the placement of the 984 controller, it is possible that the decision may be influenced in part by the availability of primary AC or DC power sources in the immediate vicinity of the proposed placement. However, since power cable is far more inexpensive than coaxial cable, you should place the controller in a location where this cost difference can be taken best advantage of. Power lines should be dedicated to avoid problems that can result from sharing power with other electrically noisy equipment.

Auxiliary Power Supplies If a large number of 800 series I/O modules are present in a drop, it may be necessary to add a second auxiliary power supply to power them. To determine if more power is required than the first auxiliary power supply can provide, you must calculate the loading the modules create. A sample calculation is shown below.

Sample Power Requirement Calculation A system has a 984-680 controller. You wish to add three B817-116 and one B805-016 I/O modules to the system. The table below shows a portion of the 800 series I/O module specifications table. Information about I/O module power requirements are included. The figure below shows a sample calculation that would be performed to determine the increased load caused by the additional I/O modules.

Table 6-4 I/O Module Specification Table

Discrete Input Modules

Model	Voltage Range	Number of Inputs	Number Per Common	I/O Power Required (mA) +5.0V	+4.3V	-5.0V	Required Addressing Disc. I/O	Reg. I/O	Required Connector
B807-032	115VAC	32	8	80	2	0	32/0	0/0	AS-8535-000
B805-016	115VAC	16	8	40	1	14	16/0	0/0	AS-8534-000
B817-116	115VAC	16	1	25	25	8	16/0	0/0	AS-8535-000

Calculate the increased load by adding together the milliamperage requirements, in each voltage range, that the new modules require. Since there are three B817-116 modules, the figures are multiplied by three.

Figure 6-20 Sample Calculation of Power Requirements

Added Modules	Quantity	5.0V	5.0V Total	4.3V	4.3V Total	-5.0V	-5.0V Total
B805-016	1	40	40	1	1	14	14
B817-116	3	25	+75	25	+75	8	+ 24
Milliamp Totals			115		76		38

Insure that the increased loading does not exceed the maximum rating of the main power supply of the drop in any of the three supplied voltages. If it does, an auxiliary power supply is required.

984 Environmental Considerations

Consideration should be given to the environment around the controller. Although designed to operate in a harsh industrial environment, problems can be avoided by placing the controller in an area where there is less ambient heat, acidic atmosphere, vibration, dust, or dirt. Controllers should be located away from equipment that generates excessive electromagnetic interference (EMI) or radio frequency interference (RFI). Equipment such as welding machines, induction heaters or large motor starters are sources of this type of interference.

Space Requirements

800 Series housings are designed for either rack or panel mounting. The four or seven card chassis may be either wall or panel mounted, the seven card chassis may be rack mounted. In considering a potential mounting location, insure that adequate space is available. Recommended mounting clearances are described below.

Controller Housing Allow 12 inch clearance on the left for access to power supply connections. Allow 6 inches on top and right side for cooling. Allow 12 inches at the bottom for cable access.

Primary or Secondary Housings Allow 6 inches on the top and sides of each housing for cooling and 12 inches below for cable access. If housings are to be stacked vertically, allow 18 inches between housings for cooling and cable access.

Figure 6-21 Dimensions of 4 and 7 Card Controller Chassis

Basic depth of chassis is 12 inches. If memory protect key is to left in the lock, add an additional 25mm (1 inch) to the depth of 267mm (10.5 inches).

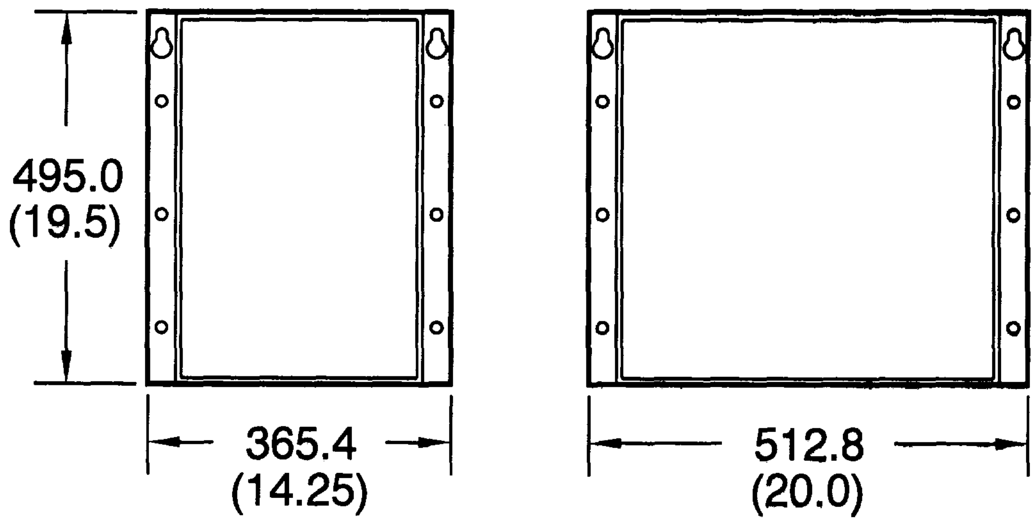
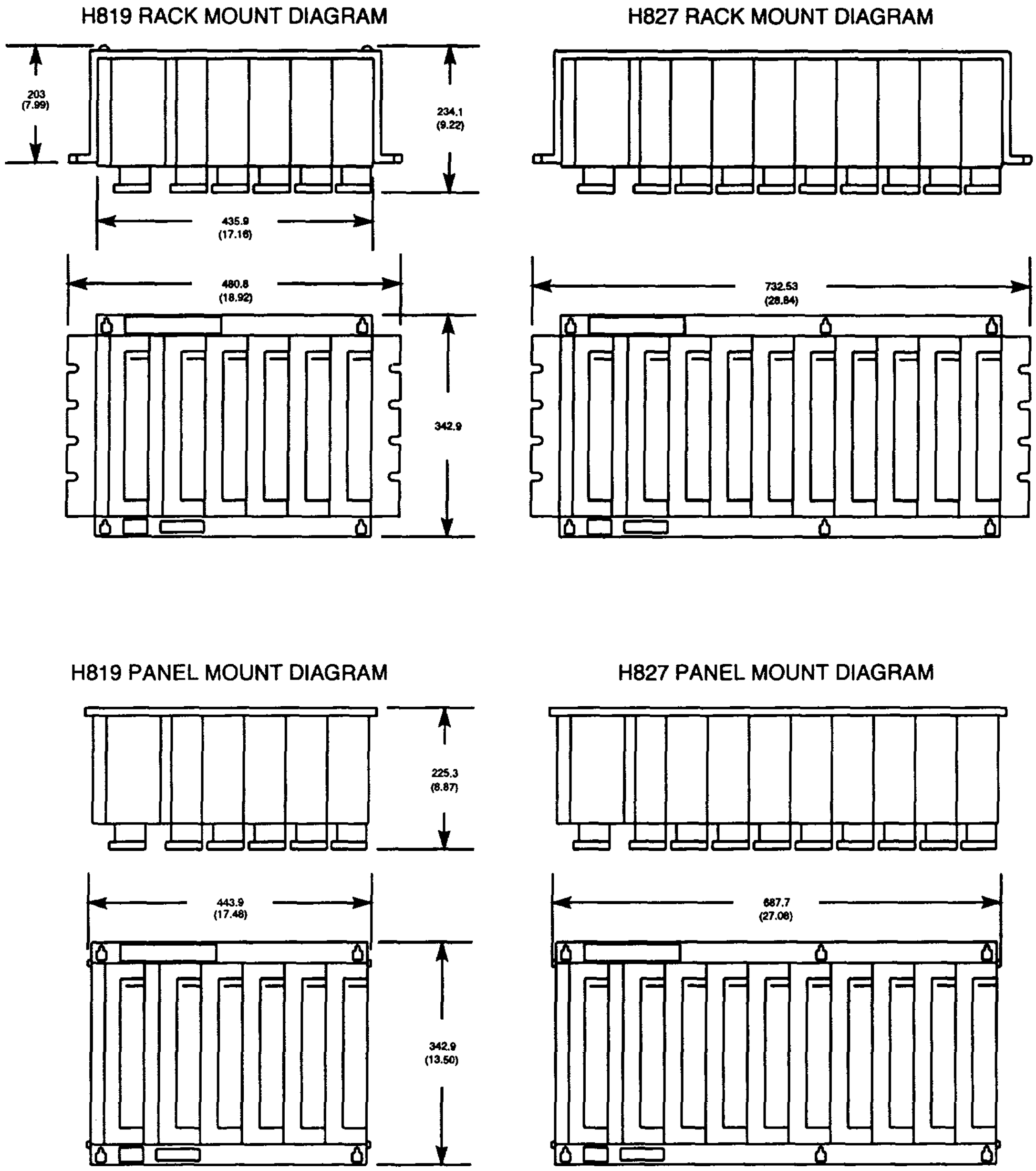


Figure 6-22 Dimensions of H819/H827 Housings

If the memory protect key is to be left in the lock, add an additional 25mm (1 inch) to the depth figures shown.



Panel Enclosures

Mounting a controller in an enclosure is a good way of controlling the environment the controller will be operating in. The enclosure layout should conform to NEMA standards and placement and wiring of the components should consider electrical noise, vibration, heat, maintenance and safety. The following items should be considered when using enclosures.

Place the enclosure in a position that allows the doors to be opened fully. This allows easy access to the equipment inside.

The enclosure should have a removable back panel. This will make mounting and removing of components simple.

The enclosure should be deep enough to allow the doors to fully close without hitting the controller. When measuring the depth of the controller, remember to allow for the memory protect key on the front of the controller.

Always include an emergency disconnect in the enclosure in a readily accessible location.

Consider including AC power outlets, interior lighting, and plexiglass windows for viewing the processor or I/O indicators.

Component Placement Within Enclosures When determining the placement of components inside a panel enclosure, the following items should be considered.

Components that generate excessive heat, such as power supplies, should be mounted near the top of the enclosure with at least 10 inches of clearance between the power supply and the top of the enclosure. Power supplies may be mounted adjacent to other equipment if adequate spacing is available.

Mount all components according to the manufacturers recommendations to allow for maximum convection cooling. Observe spacing requirements for controller housings.

The Controller housing should be mounted at eye level for easy access and maintenance.

Incoming power and line devices such as isolation or constant voltage transformers, local power disconnects, are normally located near the top of the enclosure. Proper placement of these devices will minimize wire runs and help reduce any electrical noise that they might produce.

If heat build up inside the enclosure is a problem, fans may be installed near the heat producing equipment. Outside air should not be introduced into the enclosure unless filters are used.

Any magnetic devices, such as relays, contactors, motor starters, should be placed near the top of the cabinet. Magnetic devices are typically placed adjacent and opposite from the power supply and incoming line devices. A clearance of at least 6 inches between the magnetic devices and the controller area is good practice.

I/O Module Grouping Whenever possible, the grouping of similar type I/O modules is advantageous. The grouping of modules makes wiring simpler and may help reduce any crosstalk problems. Some of the grouping considerations are listed below.

Segregate I/O modules into groups such as AC inputs, AC outputs, DC inputs, DC outputs, analog inputs, and analog outputs if possible.

Segregate AC and DC modules into separate housings if possible or leave an unused slot between modules if not.

Duct and Wiring Layout A duct and wiring layout plan defines:

The physical location of wireways

The routing of field I/O signals, power, and controller interconnections

The following items should be considered when developing a duct and wiring layout plan.

AC power lines should be kept separate from I/O power supply cables, any low voltage DC lines, and any I/O housing interconnecting cables.

TTL and Analog I/O lines should not be routed in the same duct as AC I/O lines.

If low voltage I/O lines must cross AC power lines, it should be done at right angles. This will minimize the possibility of electrical noise being introduced into the signal lines.

Allow at least 2 inches between I/O modules and wiring ducts or terminal strips.

984 PLC Mounting

Panel or Bulkhead Mounting 984 housings and chassis have keyholes at the top and at the bottom of the housings for bulkhead mounting.

The keyholes on the chassis are sized for 5/16-inch bolts. The recommended chassis mounting bolts are 1/4-20 bolts 7/8" long and are not provided.

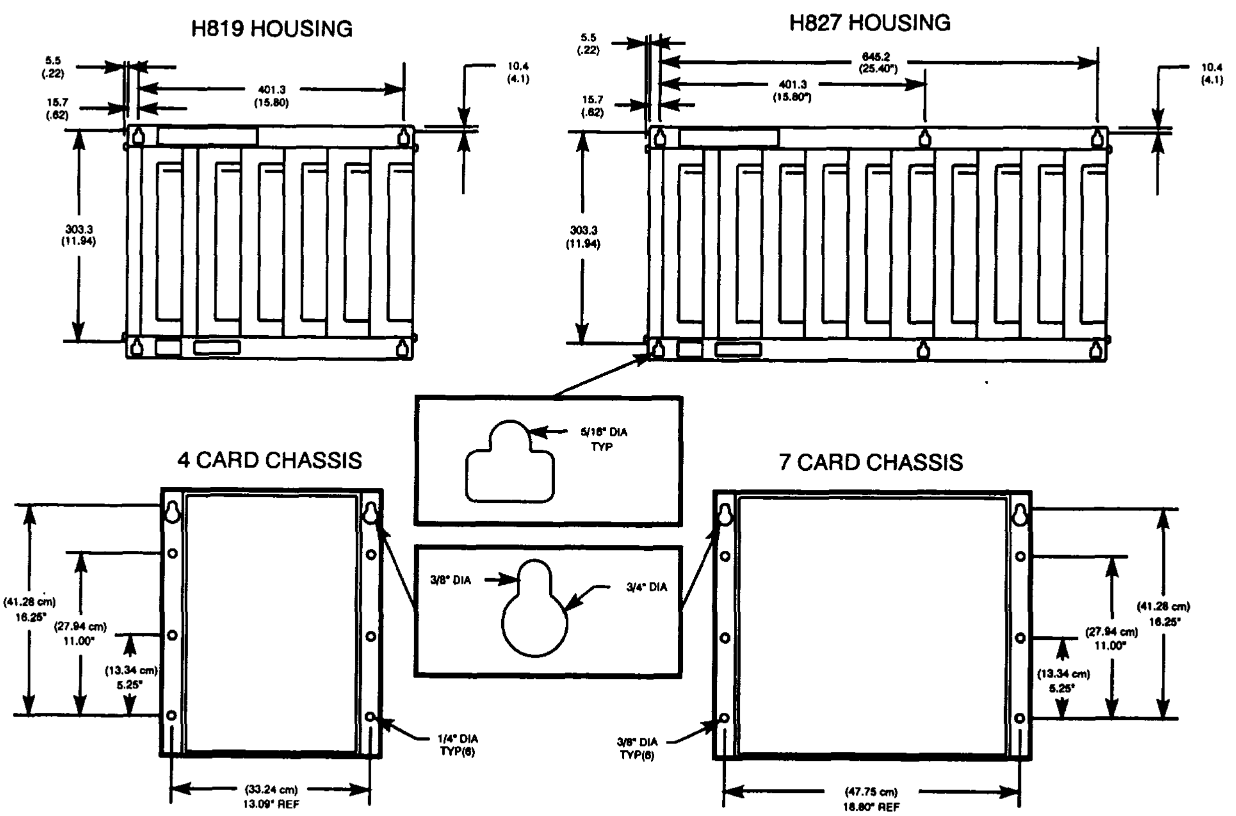
The keyholes on the housings are sized for 1/4-20 bolts. The recommended housing mounting bolts are also 1/4-20 bolts 7/8" long and are not provided.

After the mounting bolts have been attached to the vertical mounting surface, the housing/chassis is hung on them by setting the keyhole slots over the mounting bolts. Lower the housing onto the mounting bolts. Tighten the mounting bolts to secure the housing in place.

➤ **NOTE** See Grounding and Shielding for appropriate mounting pan-..

Figure 6-23 Panel or Bulkhead Mounting Dimensions

Allow 12" beneath primary housings and 6" beneath secondaries. Cables between housings not to exceed 6 feet; total cumulative interconnecting cable length not to exceed 20 feet per drop.

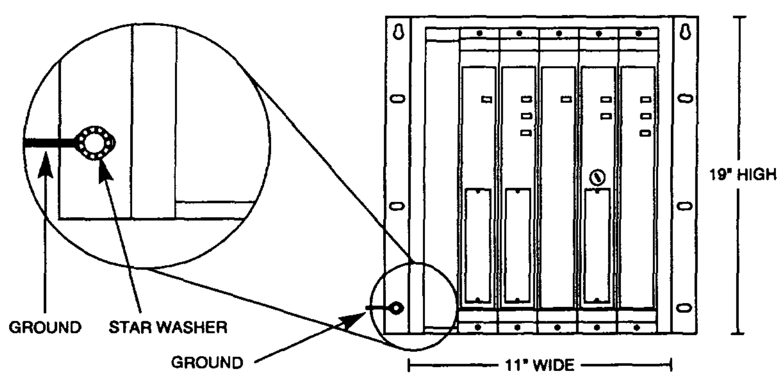


The 984 PC chassis can be mounted on any suitable vertical surface capable of supporting the controller's weight — 43 pounds (94.6 Kg) for a four-card PC and approximately 60 pounds (132 Kg) for the seven-card PC. Mounting flanges with pre-drilled keyholes are attached to the back plane of the chassis. The keyholes are sized for 5/16-inch bolts and appear at the top end of the mounting flange. Mounting bolts are NOT provided. The recommended mounting bolts are 0.312-24 UNF-2B (insert or tapped) stainless steel (#8-13-SS). Once the mounting bolts have been attached to the vertical mounting surface, the PC chassis can be set over the keyholes until the weight of the chassis is resting on the mounting bolts. Then tighten the bolts to hold the chassis firmly in place.

To rack mount a seven-card chassis, remove both rear mounting flanges. Each flange is attached to the chassis by four bolts. The front flanges are welded to the chassis.

A grounding strap (supplied by the user) made of flexible braided wire is attached to the mounting flange as shown in Figure 6-24. Proper attachment of the grounding strap requires the use of a 5/16-inch hex head bolt, flat washer and star washer (to assure good metal-to-metal contact), and nut. The ground cable must be led and attached to the best factory ground available.

Figure 6-24 Ground Strap Details



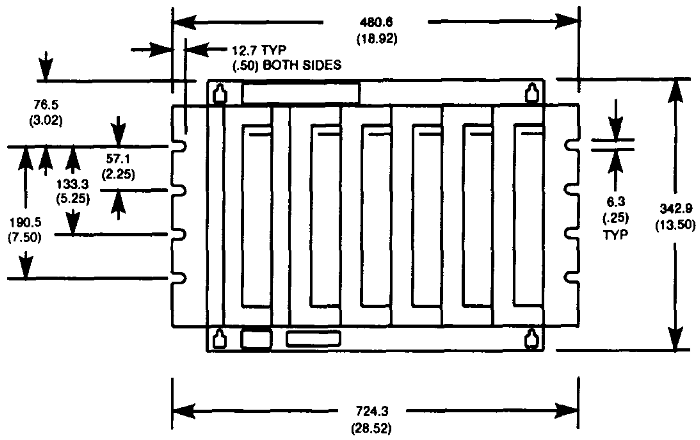
Primary Power Cable

Next, you must obtain a primary power cable of a length sufficient to reach from the nearest primary power source to the power-in terminal strip of the PC power supply. For an AC power cable, there must be three rubber insulated leads terminated with crimp terminal lugs. Color code (standard) for the AC cable is black = 120 VAC, white = neutral, and green = factory or earth ground. For the appropriate wire size within the primary power cable, it is necessary to determine the maximum current drain of the power supply option selected for your 984 PC. This can be found on the model/serial number label on the PC chassis top surface. Carefully check and tighten the screws holding the jumper (4 and 5), if used.

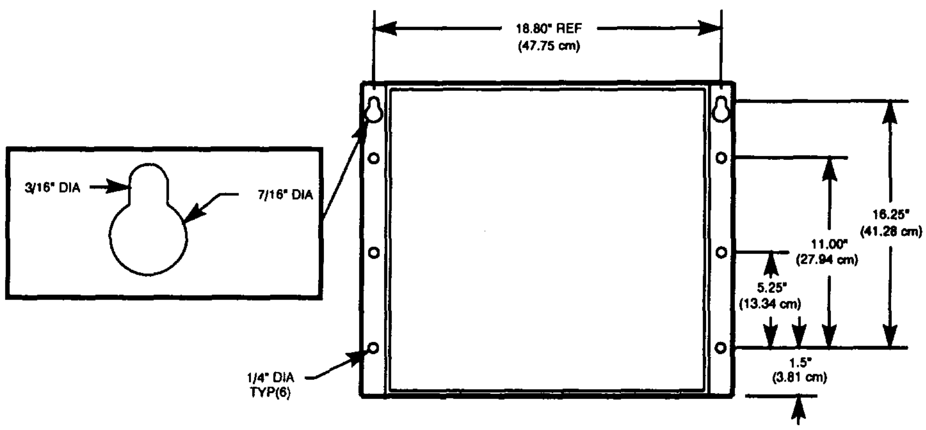
Rack Mounting The H819 housing and the 7-card chassis can be mounted in a standard 19-inch (EIA) rack. Hardware for rack mounting is included. The size of the mounting bolts is usually determined by the manufacturer of the rack you purchase. Many racks come drilled and tapped for a #10-32 bolt. Others use a snap-in nut assembly that mounts in square mounting slots. Insure that the rack you have selected uses bolts of sufficient strength to support the weight of the 984 PLC or secondary housing you are mounting. Mounting bolts are not included with the 984 PLC.

Figure 6-25 Rack Mounting Dimensions

H819 DIMENSIONS



7 CARD CHASSIS



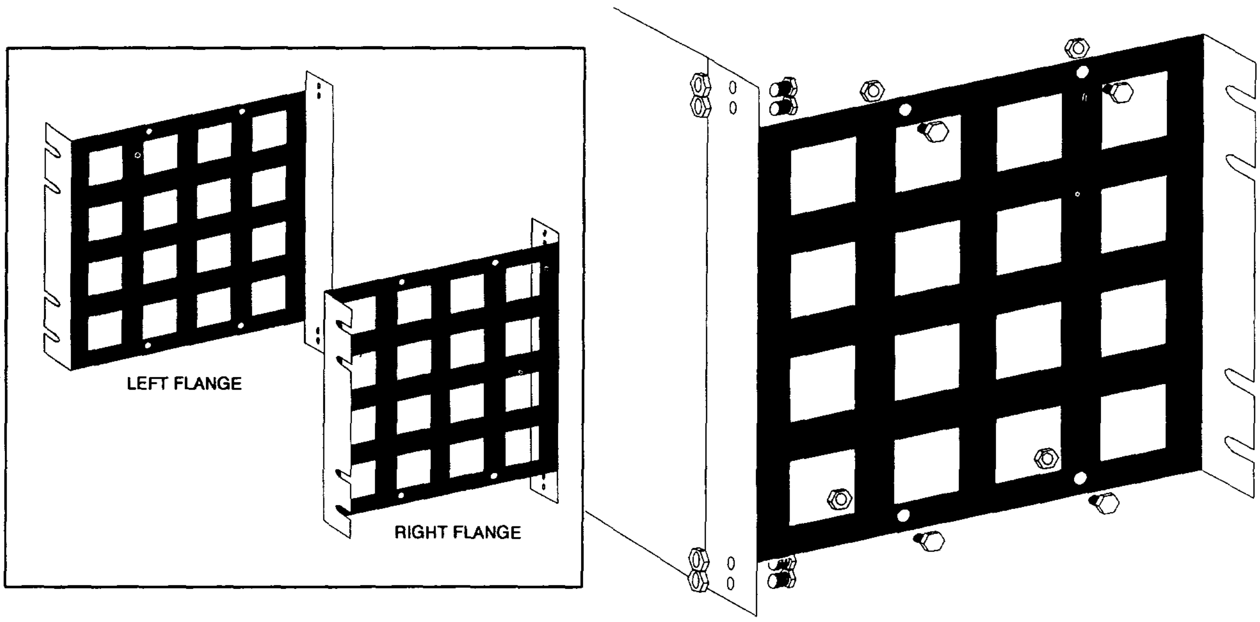
Procedure Rack Mounting Installation

Step 1 Using #8-32 mounting hardware shown in the figure below, replace the primary housing's two end plates with rack mounting flanges.

Step 2 Use 1/4-inch bolts (supplied). Attach each flange to the housing's back panel.

Step 3 When the rack mounting flange is installed, ensure that contact with the back plate of the housing is a good ground.

Figure 6-26 Attaching Rack Mounting Flanges



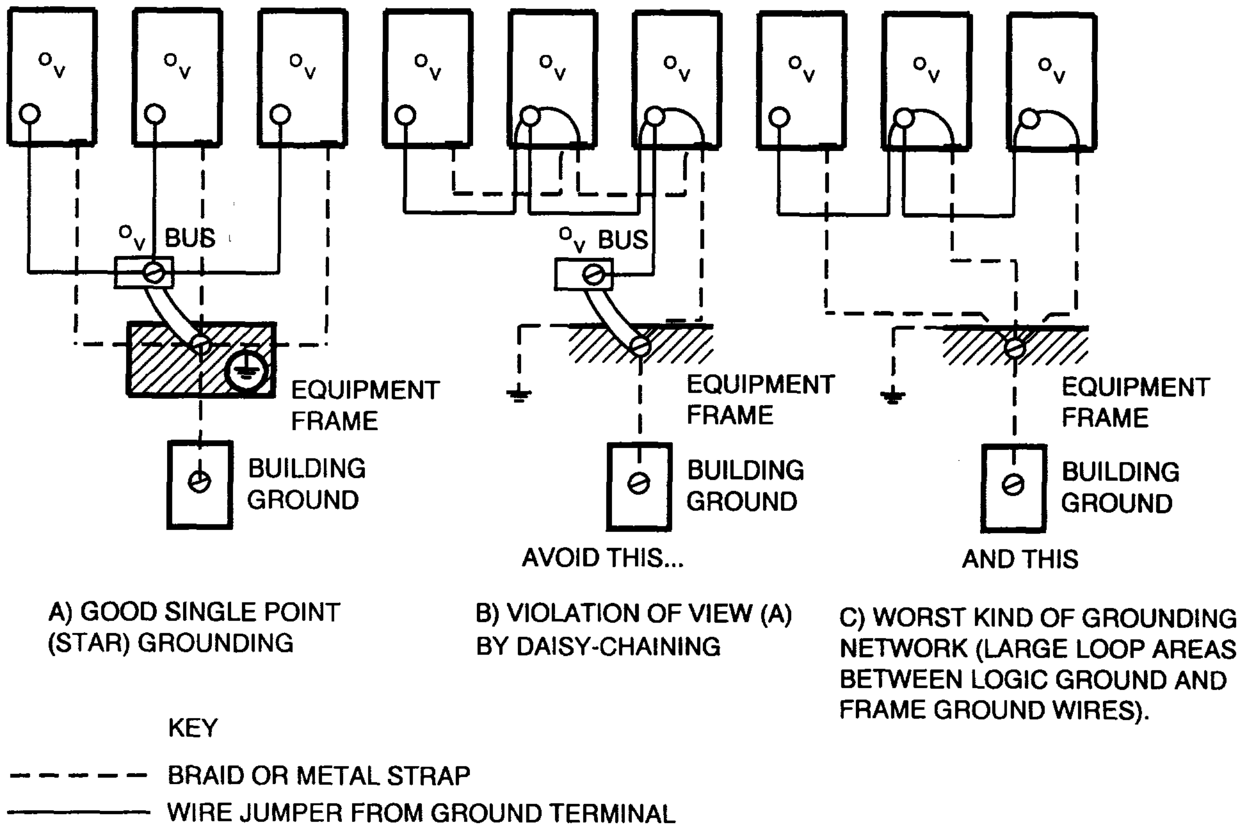
Chassis Grounding For grounding purposes, Modicon recommends that your controller housing(s) be mounted on a suitably finished metallic mounting plate capable of supporting its weight along with the other modules in the installation. An aluminum mounting plate with a chromate finish such as IRIDITE, ALODINE or OAKITE No. 36 would meet the requirement. A plain metal plate with a clean surface, free of grease, oil, etc. would be the second choice. The plate should be connected to building ground either by mounting hardware or through a single heavy-gauge conductor. A metal strap is best, with braid the alternate choice. This type of installation is recommended because it provides both an AC safety ground and a low impedance path to ground for high frequency EMI/RFI interference.

If a metallic mounting plate (the preferred method) is not feasible, Modicon recommends that all controller housings within each drop be grounded by a flat, braided strap with a minimum width of 1 inch. The ground strap should be installed without loops and bends. Although loops and braids may be aesthetically pleasing, they increase impedance at noise frequencies. Braid should be installed as straight and flat as possible. Metal straps, The first choice for grounding and bonding, offer the lowest impedance paths at noise frequencies, but braid is more practical to use. Stranded wire should not be used for plate or chassis grounding due to its higher impedance at noise frequencies. Use stainless steel hardware, including a flat washer to secure straps and braid at connection points.

The figure below shows both recommended and incorrect methods for equipment grounding when strap or braid and wire is used. In some cases, even units that are mounted on metal plates may benefit from chassis, 0-volt, or both connections as shown. Star grounding of the equipment AC ground wire (0v) may not be beneficial in all applications. Grounding examples (B) and (C) attempt to implement star grounding but cause ground loops when jumpers are added in this manner. Remember that star grounding is the preferred method for noise suppression and avoidance of ground current loops. Daisy-chaining should never be used.

Figure 6-27 Chassis Grounding

Examples of recommened and not recommended grounding methods are shown.



Safety Grounding Each chassis or housing must be bonded to a good earth ground. In addition, the green wire in the controller power cable must be electrically connected to the facility system ground. This is done at the entry point of the power line. While this action is considered to be primarily a personnel safety requirement, it has an excellent noise reduction effect as a corollary benefit.

Signal Grounding System installation design requires you to decide upon either a single-point or multi-point ground. The decision should be based upon the severity of the EMI/RFI environment. The multi-point signal ground is used in a moderate to severe environment. A single-point can be used where the control system is located in a single area and has a common power source.

Controller Shielding Various levels of shielding are included in the design of the controller. The level and extent of additional shielding that may be required during the installation is dependant upon the severity of EMI/RFI environment and the application. If it is not practical to place the controller within an effective shield, then the installation design must provide special, direct shielding for sensitive components within the control system. In addition to controllers and peripherals, the designer should consider the shielding requirements of the connecting cables.

Enclosure Shielding A common and effective shielding method in a high EMI/RFI environment is a metal enclosure that completely surrounds the controller. The most important quality of the enclosure is not its thickness but rather its tightness or impermeability to electrical noise in terms of openings and seams. The designer must consider the following guidelines.

Use a minimum number of joints, seams, gasket seals, and openings.

Compress all RFI gaskets.

Keep the number of inspection plates, adjustment holes, and screened ventilation ports to a minimum.

Carefully test for RFI leakage through meters, toggle switches, indicator lamps, fuse holders, handles, access doors, and any openings.

Electrically bond screens and honeycomb material to the enclosures frame.

Close off or terminate open cable connectors.

Shielding of Nonconductive Enclosures These enclosures require that the equipment inside has shielding and that the inside of the enclosure has has a good conductive coating. A conductive enclosure is more effective in reducing the effects of EMI/RFI.

Electrical Bonds and Permanent Seams Proper bonding techniques are critical to the reduction of RFI and EMI. An improperly bonded seam caused by poor welds and poorly spaced fasteners can result in gaps. A continuous weld between two conductive surfaces is more effective. Overlap seams may be used. In either of these techniques the radio frequency impedance of the seam should be equal to that of the enclosure material, i.e., a short circuit to the RF. Rounded seams are preferred to perpendicular seams.

RFI Gaskets When it is not practical to make a permanent bond, an RFI gasket may be considered. This type of gasket is placed between the mating surfaces which are held together by bolts or clamps. In the selection of an RFI gasket, consider its resistance to corrosion, as well as its conductivity and durability.

Nonsolid Shields Shielding can be constructed from woven or perforated materials such as copper screening. Where ventilation is critical in high ambient temperature areas, this is especially useful. Although the overall effectiveness of woven or perforated shields is not as effective as solid shields, nonsolid shields may provide enough protection for the application. The type of shield used must be evaluated in terms of the application and EMI/RFI environment.

Cable Shielding Controllers are assembled with shielded cable products. Shielding must be considered for connectors, taps, splitters and terminators. Follow proper installation practices in cable installation with the avoidance of stress or damage to the cable shield. If conduit is used, it must be metal conduit with metal junction boxes, grounded at each individual piece.

The following are general recommendations for the installation of communication cable sub-systems for a 984 PLC system. Since many facilities have unique requirements that require special considerations, the recommendations should be viewed as *guidelines only.*

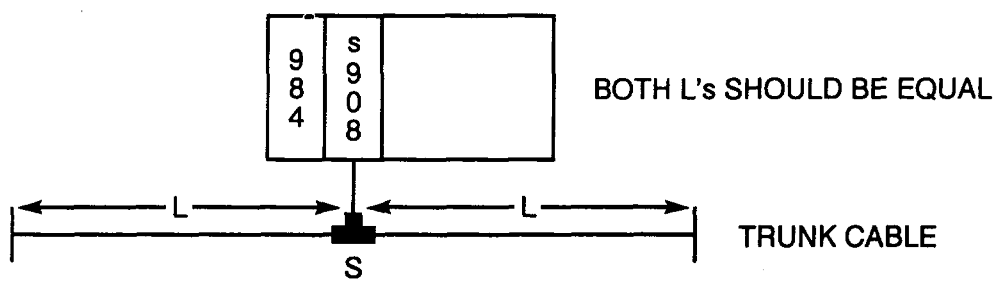
Cabling Requirements

The coax trunk cable originates from the remote I/O processor and is routed so that the remote drops can be connected to it via taps and drop cables. A splitter may be used if the trunk cable must be routed in two different directions. If you are using a dual cable S908 remote I/O processor, one splitter per network may be used. The splitter is installed close to the controller to create a TEE in the system. It is recommended that the lengths of trunk cable on each side of the splitter be as equal as possible. Unbalanced line lengths can cause mismatches and communication errors.

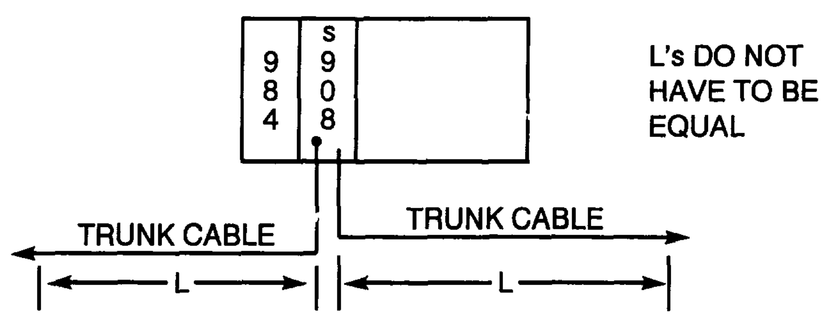
Figure 6-28 Trunk Cable Topologies

The dual cable S908 is preferred. Splitters may be used but are not recommended.

SPLITTER TOPOLOGY



DUAL CABLE S908 TOPOLOGY



The maximum length of any drop cable using quad shield cable is 164 feet (50 meters). The maximum length of any drop cable not using quad shield cable is 100 feet (30 meters). It is recommended to mount taps within a separate enclosure so that the tap and trunk cable are less susceptible to physical damage and will always be spaced away from power cable and systems.

Total cable length should not exceed 5000 feet (1.5 km) for RG-6, 8000 feet (2.4 km) for RG-11, or 15,000 feet (4.5 km) for semi-rigid.

Do not mix types of cable on a trunk or drop (drop may well vary from trunk). Cabling should consist of one type (same vendor). Mixing cable types will increase the VSWR due to reflections occurring as signals move from one type of cable to another.

Figure 6-29 dB Losses (Attenuation) for Cables, Taps, and Splitters

The maximum allowable dB loss between 984 PC and any drop is 35 dB. Actual dB loss varies by cable vendor and model. See Tables 6-5 througe 6-9.

The dB loss for the acceptable cables, taps, and splitters are:

RG-6	= 0.48 dB/100 ft.
RG-11	= 0.24 dB/100 ft.
Semi-rigid	= 0.09 dB/100 ft.
Tap	= 0.8 dB insertion loss; 14 dB down drop
Splitter	= 6 dB from center to either side.

The cable system must be grounded near the headend (suggest within 20 feet). A tap or splitter may be used to ground the cable system. But if a tap or splitter is not located near the headend, a ground block (Modicon P/N 60-0545-000) must be installed. This ground serves as a single point permanent ground used mainly for safety purposes.

If using Modicon (Comm/Scope) RG-11 cable, taps should be installed on a band marker only. Taps or splitters must have at least 8.5 feet of cable between them.

Using a Cable Diagram

After you have determined the type of control (i.e., single cable, dual cable, centralized or distributed), number of I/O drops your system will have and determined where the local or remote I/O is to be located, it is recommended that a cable diagram be created. Indicate approximate cable lengths in the drawing. Calculate maximum attenuation using data provided with the cable, taps, and splitters to verify your system design before proceeding with the actual installation. After the system has been installed, record your actual measured attenuation on the cable diagram for future reference and as a troubleshooting tool.

The maximum allowable attenuation (signal loss) between the remote I/O processor and any drop is 35 dB. The attenuation limit cannot be exceeded or transmission errors will occur.

Attenuation is caused by taps, splitters, splices, cable, connections, and feed through type terminators. The designer's goal is to provide remote I/O services and still keep the attenuation from exceeding 35 dB to any node. Attenuation is the amount of signal loss measured in dB.

On a network with only one trunk leg, the maximum attenuation can be measured between the headend and the last drop on the network. On a network using a splitter to split the trunk into two legs, you will have to calculate attenuation on each trunk leg. The attenuation must be calculated for each trunk leg separately. Each trunk leg of a split network must not exceed 35 dB attenuation.

Some remote I/O interfaces cannot be directly connected to a remote I/O processor on the trunk cable or communications errors may result. To avoid this problem, all interfaces *must* always be connected via a tap, and not directly connected to the trunk cable system. Connecting interfaces directly to the trunk will also cause a severe impedance mismatch. The following interfaces will have communications errors if connected directly to a RIOP: P451, P453, J810, and J812.

Since all remote I/O taps have a tap drop loss of 14 dB and taps have an insertion loss of 0.8 dB, the main concern of signal loss to the designer is the type of cable used in the system. Many designers use semi-rigid cable for the main trunk cable in high noise environments or when maximum distance is necessary. But, the majority of remote I/O networks will use more flexible trunk cable such as RG-11 or RG-6.

RG-59 cable cannot be used on a remote I/O network, as it has poor noise immunity, and high attenuation.

To calculate attenuation (signal loss) you must add all sources of attenuation between the remote I/O processor and a remote I/O interface and ensure that the loss does not exceed 35 dB. Most designers calculate attenuation between the remote I/O processor and the last interface on the network. The last interface on the network usually represents the maximum loss of the entire cable system. But, other interfaces connected to taps near the end of the cable system, with longer drop cable, may have greater attenuation. If there are other taps placed close to the end of the cable system with longer drop cables, also check the attenuation to those interfaces.

To calculate attenuation (dB Loss) for remote I/O at 1.5 MHz, use the Network Attenuation Formula. Rules for using the Network Attenuation Formula are as follows:

1. Find the dB loss of each type of cable (Semi-rigid, RG-11, or RG-6) in use in your system at a frequency of 1.5 MHz.
2. Count the number of taps used on a trunk branch exclusive of the last tap.
3. Count the number of splitters used on the network.

Network Attenuation Formula

$$TCA + DCA + TDA + (NOS \times 6.0) + (NOT \overset{TIL}{\times} 0.8) = \text{dB loss}$$

TCA – Trunk Cable Attenuation between the headend and the end of the trunk exclusive of tap and drop loss.
DCA – Drop Cable Attenuation at drop under calculation.
TDA – Tap Drop Attenuation (14 dB).
NOS – Number Of Splitters, if present, for insertion loss.
NOT – Number Of Taps BETWEEN the node under calculation and the headend .
TIL – Tap Insertion Loss.

Again only the maximum attenuation need be calculated for the network. The attenuation calculation should be performed between the remote I/O processor connection and the end of the last drop cable at each endpoint of the network. If a splitter is used, both endpoints must be calculated.

Figure 6-30 Attenuation Worksheet Calculated Losses for System in Figure 6-31

Enter the channel or drop number after "Endpoint:".

Network Attenuation Formula

Maximum Attenuation (at 1.5 MHz) for Trunk One:
Between Headend and Endpoint: Drop 5

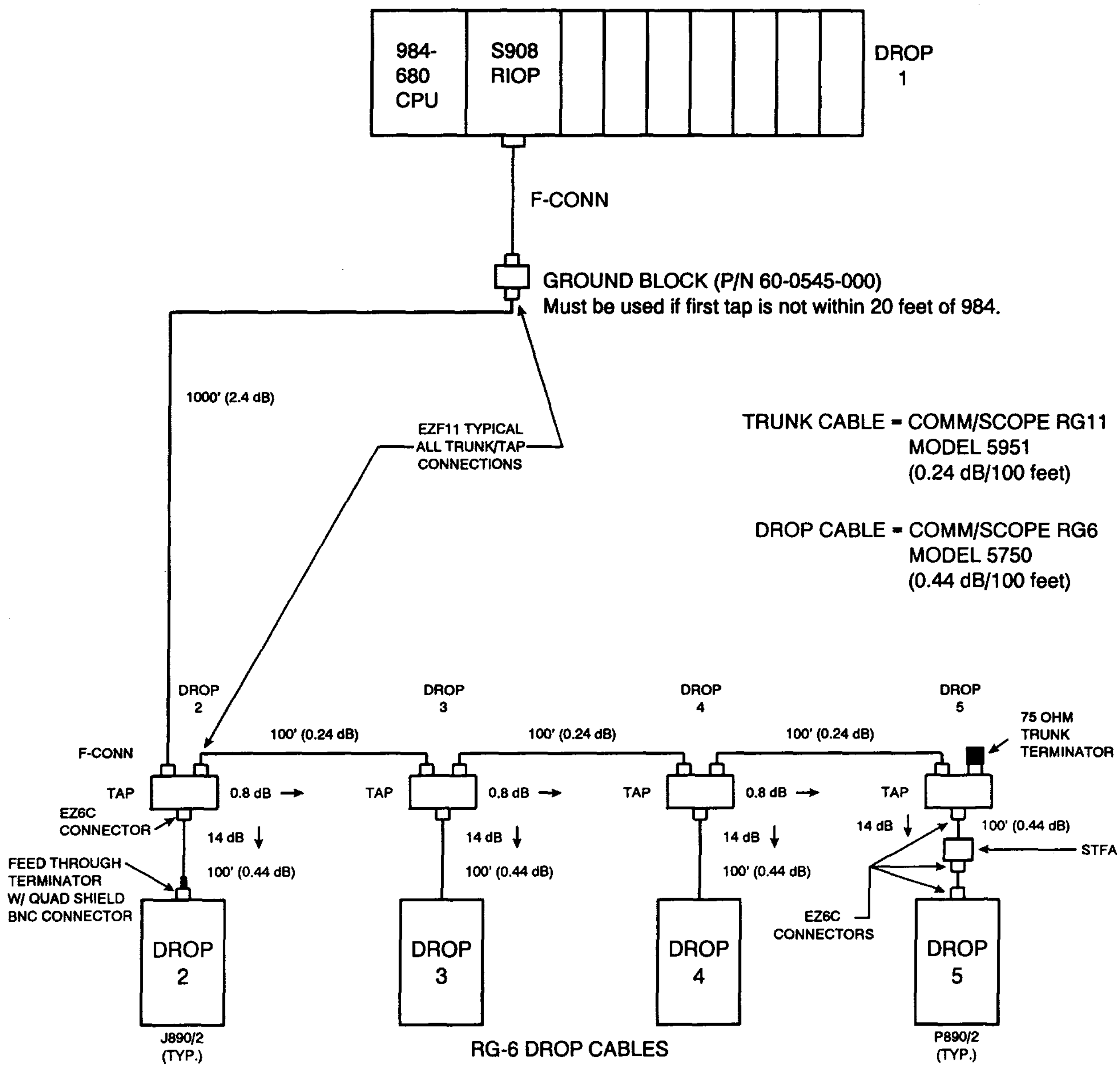
TCA +	DCA +	TDA +	(NOS x 6.0) +	(NOT x 0.8) TIL	= dB loss
3.12 +	0.44 +	14 +	(0 x 6.0) +	(3 x 0.8)	= 19.96

Maximum Attenuation (at 1.5 MHz) for Trunk Two, if present:
Between Headend and Endpoint: ________

TCA +	DCA +	TDA +	(NOS x 6.0) +	(NOT x 0.8) TIL	= dB loss
+	+	+	(x 6.0) +	(x 0.8)	=

Figure 6-31 Typical Cable System Diagram

Refer to the previous figure for a sample loss calculation between the controller and drop 5.



➤ **NOTES**

1. Drops with F connectors require self-terminating F adapters (STFA) and a drop cable warning label.
2. 984A or B controllers using the larger S908 with BNC connectors require an F to BNC adapter, P/N 52-0614-000.
3. Connectors and terminators are listed on page 6-49.

Cables, Taps, Splitters and Termination Components

Remote I/O Cable Selection

The Remote I/O system operates on a band of frequencies centered around 1.544 MHz. For this reason, the system cannot use cables of the type associated with cable TV. Cable types that have not been qualified by Modicon should not be used.

➤ **CAUTION A single type cable should be used throughout the trunk. Mixing cable types significantly increases the Voltage Standing Wave Ratio (VSWR) caused by reflections resulting from the signal moving from one type cable to another.**

There are three types of cable that are qualified. They are semi-rigid, RG-11, and RG-6. The highest rated RG-11 and RG-6 cables are available from Modicon in 1000 ft. reels. The distance from the remote I/O processor to the furthest drop may dictate the type of cable you select. Maximum allowable distances are shown in the table below. All drop cable must be a minimum of 8.5 feet (2.5 meters).

Table 6-5 Recommended Cable Types and Maximum Lengths

Cable Type	Maximum Trunk Length	Modicon P/N
Semi-rigid	15,000 ft. (main runs plus drops)	
RG-11	8,000 ft. (main runs plus drops)	*P/N 97-5951-000
RG-6	5,000 ft. (main runs plus drops)	*P/N 97-5750-000

*This Quad Shield MAP/TOP cable is sold in 1000 foot reels.
This cable is recommended for Modbus II and Remote I/O use.

Semi-rigid Cabling The following are semi-rigid cables that have been qualified by Modicon.

➤ **CAUTION For proper RIO operation, maximum Semi-rigid cable total trunk length MUST NOT exceed 15,000 feet (4572 meters). Cable must not be mechanically pulled during installation. Refer to manufacturer's specifications for correct cable tension.**

Table 6-6 Recommended Semi-rigid Cable (up to 15,000') Manufactured by Comm/Scope.

Model	Description	Minimum Bend Radius	Attenuation Per 100 ft.
P-3-75-500-CA	Bare Cable, Alum. Sheath	8.0 in. (20.32 cm)	0.087
P-3-75-500-JCA	Polyethylene Jacket	8.0 in. (20.32 cm)	0.087
P-3-75-500-JCASSP	Underground/Waterproof	8.0 in. (20.32 cm)	0.087
P-3-75-500-JACASS	Waterproof/Armored	8.0 in. (20.32 cm)	0.087
QR-540-JCA	PVC Jacket	5.0 in. (12.7 cm)	0.087
QR-860-JCA	PVC Jacket	7.0 in. (17.8 cm)	0.045

All cable listed have 15.3 pF per foot capacitance.

Table 6-6 Semi-rigid Cable (up to 15,000') Manufactured by Times Fiber.

Model	Description	Minimum Bend Radius	Attenuation Per 100 ft.
T6500	.500 inch Semi-rigid	5.0 in. (12.7 cm)	0.089
T6625	.625 inch Semi-rigid	7.0 in. (17.8 cm)	0.073
T6750	.750 inch Semi-rigid	7.0 in. (17.8 cm)	0.062
T6875	.875 inch Semi-rigid	7.0 in. (17.8 cm)	0.051
T61000	1.0 inch Semi-rigid	7.0 in. (17.8 cm)	0.046

All cables listed have 15 pF per foot capacitance.

RG-11 Cabling The following cables have been qualified by Modicon. The preferred choice appears in the table below.

➤ **CAUTION For proper RIO operation, maximum RG-11 trunk cable length must not exceed 8000 feet. Cable must not be mechanically pulled during installation and pull strength must not exceed 200 lbs. (91 kg).**

Table 6-8
Recommended Coaxial Cable Type RG-11 (up to 8000 feet) Available from Modicon

Manufacturer Comm/Scope	Model	Description	Modicon Part No.	Min. Bend Radius
	5951	Quad Shield Coax Cable	97-5951-000	2.5 inches 63.5 mm

16.2 pF per foot capacitance and losses, @ 1.544 MHz, of 0.24 dB per 100 feet (30 meters)

RG-6 Cabling The following cables have been qualified by Modicon. The preferred choice appears in the table below.

Table 6-9 RG-6 Coaxial Cable (up to 4500 feet) Available from Modicon

Manufacturer	Model	Description	Modicon Part No.	Min. Bend Radius
Manufacturer: Comm/Scope	5750	Quad Shield Coax Cable	97-5750-000	2.5 inches 63.5 mm

Model 5750 is a quad shielded cable with 16.2 pF per foot. Nominal Losses, at 1.544 MHz, of 0.44 dB per 100 feet (30 meters).

Belden Corp. (Replacement only) Not Recommended

Model 9114 solid conductor with a minimum bend radius 3.3 in (8.25 cm.), capacitance per foot of 17.3 pfd. nom. and losses, @ 1.544 MHz, of 0.48 dB per 100 feet (30 meters).

Belden Corp. (Discontinued) Not Recommended

Model 9587 solid conductor flooded burial cable with a minimum bend radius 3.3 in (8.25 cm.), capacitance per foot of 17.3 pfd. nom. and losses, @ 1.544 MHz, of 7.0 dB per 1000 feet (304.8 meters).

Cable Connectors and Terminators

➤ **CAUTION For optimum system performance, it is recommended that only one brand of connector be used throughout a remote I/O system. Brand mixing is undesirable, and the results of such mixing, in terms of system performance, are unpredictable.**

Taps and Splitters The following recommended tap and splitter is offered by Modicon.

Table 6-10 F Type Line Tap

Modicon Part #	Insertion Loss	Return Loss	Tap Loss	Freq. Range	Impedance
MA-0185-000/Rev. C MA-0185-100/Rev. A	0.8 dB Max.	18 dB Min.	14 dB Nom.	0.1 to 5 MHz.	75 Ohms

Table 6-11 F Type Line Splitter

Modicon Part #	Insertion Loss	Return Loss	Freq. Range	Impedance
MA-0186-000/Rev. B MA-0186-100/Rev. A	6.0 dB Max.	18 dB Min.	0.1 to 5 MHz.	75 Ohms

Connectors The following connectors have been qualified by Modicon for use in communication systems.

Table 6-12 Coaxial Cable Connectors

Item	Type	Modicon Part Number	Connectors Per Order
RG-6 Male F Connector	Quadshield	MA-0329-001*	10
	Non-quad	52-0400-000	12
RG-6 Male BNC Connector	Quadshield	52-0488-000*	1
	Non-quad	52-0487-000*	1
RG-11 Male F Connector		52-0401-000	6
Semi-rigid to F Connector	LRC Electronics	AI-500-FM-K3,W3	

* Use Modicon Crimp Tool #60-0544-000

Terminators A 75 Ohm feed through terminator is required if you are using a J890/892 interface module. Modicon P/N 60-0513-000 is recommended for use on the J890/892.

Table 6-13 Terminators

Modicon Part #	Characteristics
52-0422-000	14 dB Modbus II/RIO Trunk Terminator
52-0399-000	Self Term. F Adapter for Non-quad Cable (Belden)
52-0411-000	Self Term. F Adapter for Quad Cable (Comm/Scope)
52-0370-000	Self Term. BNC Adapter (for R911)
60-0513-000	Feed-Through BNC Terminator
52-0402-000	Tap Port Terminator

Recommended Tools

The following tools are recommended for communications cable fabrication.

Table 6-14 Tools, Adapters, and Miscellaneous

Part Number	Description
Tools	
60-0528-000	RG-6 Installation Tool
60-0530-000	RG-11 Installation Tool
60-0529-000	RG-6 Installation Tool Blade Pack
60-0531-000	RG-11 Installation Tool Blade Pack
60-0544-000	Crimp Tool (Crimp Tool is used for EZ6C, BNC, and STFA)
60-0558-000	Cable Cutters
Adapters	
52-0480-000	Right Angle F Adapter
52-0614-000	F to BNC Adapter
Miscellaneous	
60-0545-000	Ground Block
MD-9100-440	Drop Cable Warning Label
MD-9423-000	R911 Redundancy Warning Label
99-0181-000	Sealing Tape

STFA = Self Terminating F Adapter