FX MS/TP Communications Bus Technical Bulletin

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Contents

Document Introduction

The BACnet® protocol MS/TP communications bus is a local network that connects supervisory controllers and field controllers to field point interfaces.

This document describes the specifications, device limits, and rules of the MS/TP communications bus, as well as how to wire and terminate devices, and troubleshoot device communication on the MS/TP bus. The remote MS/TP field bus is also described. With the addition of a BACnet IP to BACnet MS/TP Router, the Remote Field Bus allows connection to remote equipment controllers over IP.

This document is intended for the user who needs to know the rules, requirements, limits, specifications, and configuration of the MS/TP bus to design, wire, or troubleshoot an MS/TP application.

Summary of Changes

The following information is new or revised:

- Document updated to include the new I/O expansion modules (F4-XMP) and supervisory controller (F4-SNC)
- Document updated to include the new WRG1830/ZFR183x Pro Wireless Field Bus System

FX Related Documentation

The following table lists the related documentation that describes controllers and systems related to the MS/TP communications bus.

Table 1: Related Documentation

For Information On	See Document	LIT or Part Number
Installation and specifications of the FX Supervisory Controller	*FX Supervisory Controller Installation Instructions*	*Part No. 24-10051-0*
Specifications of the Facility Explorer System Field Controllers	*FX-PC Programmable Controllers and Related Products Product Bulletin*	*LIT-12011657*
Specifications of the F4-CGM General Purpose Application Controllers	*F4-CGM General Purpose Application Controllers Installation Instructions*	*Part No. 24-10143-01787*
Specifications of the F4-CVM VAV Terminal Equipment Controllers	*F4-CVM VAV Terminal Equipment Controllers Installation Instructions*	*Part No. 24-10143-01809*
Specifications of the F4-XPM Expansion Modules	*F4-XPM Expansion Modules Installation Guide*	*Part No. 24-10143-02155*
Installation and specifications of the FX-PCG16 or FX-PCG26	*FX-PCG16 General Purpose Programmable Controller Installation Instructions*	*Part No. 24-10143-152*
	FX-PCG26 General Purpose Programmable Controller Installation Instructions	*Part No. 24-10143-144*
Installation and specifications of the FX-PCV	*FX-PCV Programmable VAV Box Programmable Variable Air Volume Box Controllers Installation Instructions*	*Part No. 24-10143-179*
	PCV1615 and PCV1630 Programmable Variable Air Volume Box Controllers Installation Instructions	*Part No. 24-10143-357*
	FX-PCV1930 VAV Controller Installation Instructions	*Part No. 24-10143-01523*

Table 1: Related Documentation

For Information On	See Document	LIT or Part Number
Installation and specifications of the FX-PCX Expansion Modules	*FX-PCX17 and FX-PCX27 Expansion Input/ Output Module Installation Instructions*	*Part No. 24-10144-106*
	FX-PCX37 Expansion Input/Output Module Installation Instructions	*Part No. 24-10144-114*
	FX-PCX47 Expansion Input/Output Module Installation Instructions	*Part No. 24-10144-122*
	FX-PCX2721 Expansion Input/Output Module Installation Instructions	*Part No. 24-10144-173*
	FX-PCX3731 Expansion Input/Output Module Installation Instructions	*Part No. 24-10144-181*
	FX-PCX3721 Expansion Input/Output Module Installation Instructions	*Part No. 24-10144-203*
Installation and specifications of the FX-PCA Series Controllers	*FX-PCA2611-0 Advanced Application Programmable Controller Installation Instructions*	*Part No. 24-10143-403*
	FX-PCA2612-1 Advanced Application Programmable Controller Installation Instructions	*Part No. 24-10143-268*
	PCA3613 Advanced Application Programmable Controller Installation Instructionss	*Part No. 24-10143-1175*
	FX-PCA4911 Advanced Application Controller Installation Guide	*Part No. 24-10143-01531*
Integrating BACnet MS/TP and BACnet IP devices into the FX Supervisory Controllers	*FX Workbench User's Guide*	*LIT-12011149*
Installation of and specifications for the MS-BACEOL-0 End-of-Line Terminator Module	*MS-BACEOL-0 RS-485 End-of-Line Terminator Installation Instructions*	*Part No. 24-10264-4*
Applications, features, and benefits of the WRG1830/ZFR Series Wireless Field Bus System	*WRG1830/ZFR183x Pro Series Wireless Field Bus System Catalog Page*	*LIT-1901026*
Controller Configuration Tool Software	Controller Tool *Help*	LIT-12011147 **Note:** This LIT number represents a printer-friendly version of the *Help*.
Installing the F4-SNC	*F4-SNC Installtion Guide*	*Part No. 24-10143-02031*
Installing the FX80	*FX80 Supervisory Controller Installation Instructions*	*Part No. 24-10143-861*

MS/TP Bus Overview

The BACnet protocol MS/TP communications bus is a local network that connects supervisory controllers and equipment controllers to field point interfaces. The bus is based on BACnet standard protocol ANSI/ASHRAE Standard 135.

The BACnet MS/TP protocol is a peer-to-peer, multiple master protocol based on token passing. Only master devices can receive the token, and only the device holding the token is allowed to originate a message on the bus. The token is passed from master device to master device using a small message. The token is passed in consecutive order starting with the lowest address. Subordinate devices on the bus only communicate on the bus when responding to a data request from a master device.

An MS/TP bus is used for two types of buses: a Field Controller bus (FC) and a Sensor Actuator (SA) bus (Figure 1).

The FC bus and SA bus are networks of daisy-chained devices. Each bus has only one bus supervisor, depending on which controllers are connected. On a local FC bus, the bus supervisor is the supervisory controller. On the local SA bus, the bus supervisor is a field controller.

The bus supervisor communicates with devices on the supervised bus and with devices on the next (higher level) bus on the network. The bus supervisor typically starts the communication on the FC bus or SA bus. If an SA bus or FC bus does not have a bus supervisor, the master device with the lowest device address value on the bus and a specific baud rate selected starts the communication.

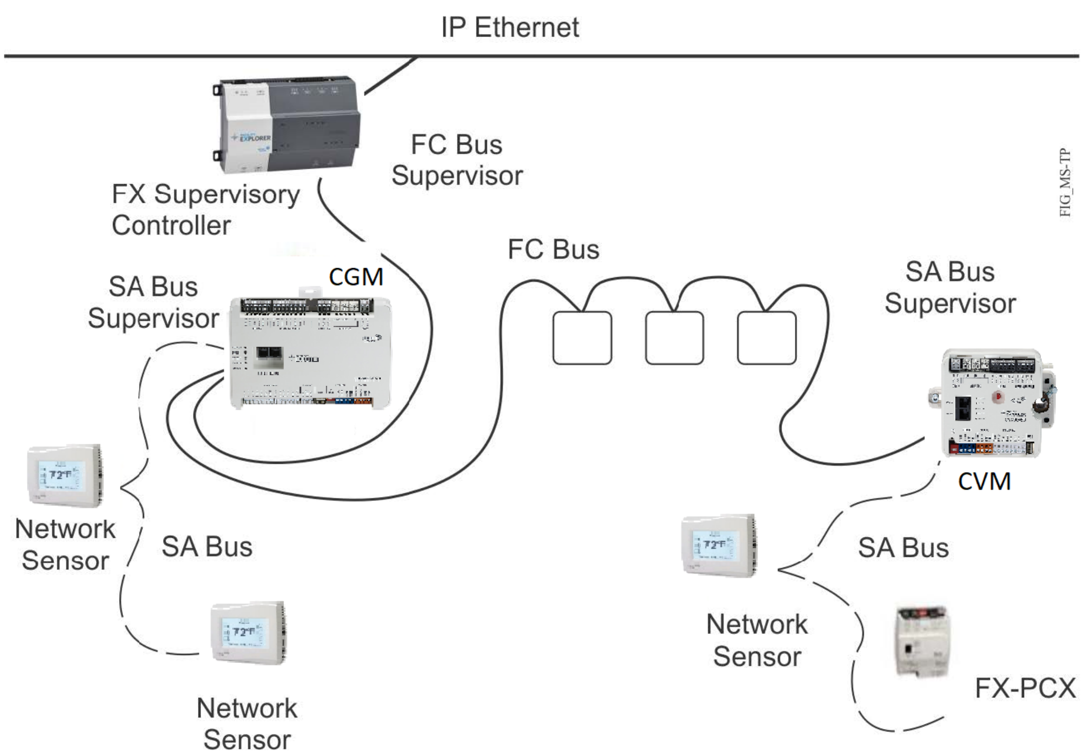
The WRG1830/ZFR183x Series Wireless Field Bus System enables wireless communication on an MS/TP bus, allowing you to create wireless connections between General Purpose Application Controllers (CGMs), VAV Terminal Equipment Controllers (CVMs), Expansion Modules (XPMs), General Purpose Programmable Controllers (PCGs), Input/Output Modules (PCXs), Advanced Application Programmable Controller (PCAs), Programmable Variable Air Volume Box Controller (PCVs), and supervisory devices such as the FX80 and FX-SNC.

See Enabling FX-PC Controllers for Wireless Operation and for detailed information about the WRG1830/ZFR183x Series Wireless Field Bus System.

FC Bus

An FC Bus connects an FX Supervisory Controller to CVM, CGM, XPM, or FX-PC Series Programmable Controllers and TEC26xx or TEC30xx Series Thermostat Controllers. On an FC Bus, the FX Supervisory Controller is the bus supervisor.

Figure 1: Example of an MS/TP Communications Bus



An FC bus supports up to three bus segments that are connected with network repeaters (Figure 6). See Local FC Bus Rules and Specifications for more information.

SA Bus

The SA bus connects CGM, CVM, SNC and FX-PC devices to endpoint devices, such as FX-PCX Expansion I/O Modules, XPM Expansion Modules, network sensors, FX-DIS Local Controller Displays, FX-TAD and Johnson Controls Variable Speed Drives (VSDs).

On an SA bus, a CGM, CVM, SNC, or FX-PC controller is the bus supervisor. The SA bus is a private MS/TP bus that only supports those devices that can be defined using the Controller Configuration Tool (CCT) programming tool. The bus does not support bus segments (Figure 10). See SA Bus Rules and Specifications for more information.

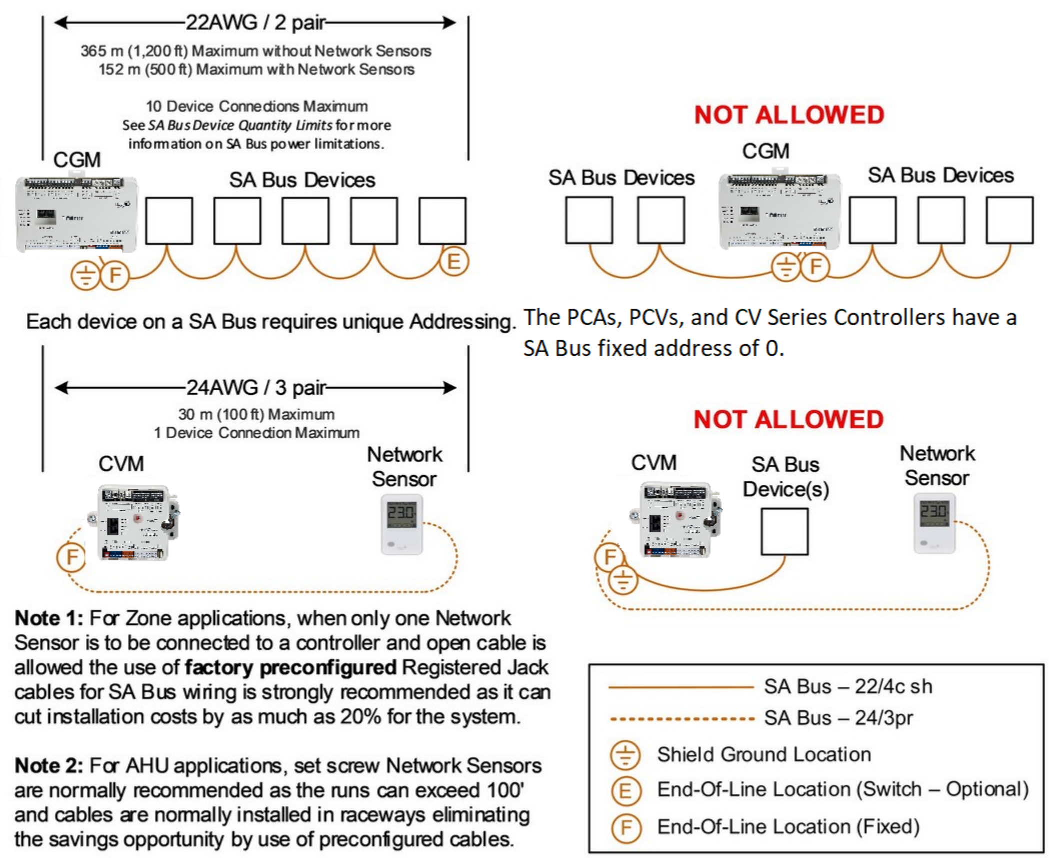
End-of-Line Termination on the MS/TP Bus

Daisy-chained RS485-protocol networks typically require some type of end-of-line (EOL) termination to reduce interference caused by signal reflection that occurs when data transmissions reach the end of a bus segment and bounce back on the segment. The high baud rates on MS/TP bus applications require robust EOL termination and strict adherence to the EOL termination rules. Figure 2 shows an example of the EOL termination settings on an MS/TP bus application.

The EOL termination requirements for the FC bus are different from the SA bus requirements. See End-of-Line Termination on Local FC Bus and End-of-Line Termination on SA Bus for more information.

Also, third-party MS/TP devices and TEC30xx Series thermostats have different EOL termination requirements from Facility Explorer devices on the FC bus. See for more information.

Figure 2: EOL Terminations on an MS/TP Bus



Baud Rates on the MS/TP Bus

An MS/TP bus can be configured to communicate at one of four different baud rates. All of the devices on an MS/TP bus must communicate at the same baud rate.

The baud rate setting determines the rate at which devices communicate data over the bus. The baud rate settings available on Facility Explorer MS/TP devices are 9600 bps, 19.2 kbps, 38.4 kbps, 76.8 kbps, and Auto. The baud rate setting for Facility Explorer devices is set in the software.

ⓘ **Note:** The BACnet Standard only requires support for 9600 and 38400 baud. Some third-party vendor devices might not support all the baud rates supported by the FX system. Reducing the baud rate to accommodate these devices affects overall performance.

We recommend setting all MS/TP bus supervisors FX Supervisory Controllers or BACnet Routers to 38,400.

We recommend setting all CGM and CVM controllers, XPM modules or FX-PC controllers on the FC bus (FX-PCGs, FX-PCAs, FX-PCVs, and FX-PCXs) to Auto. In the Auto setting, the FX devices listen for the bus supervisor to communicate first; the devices then automatically set their baud rate to the bus supervisor's baud rate. CGM and CVM controllers, XPM modules and FX-PC controllers ship with a default baud rate setting of Auto.

If you anticipate critical peer-to-peer communication and therefore do not want equipment controllers to wait for the bus supervisor to establish the baud rate, you can specify the baud rate for each device immediately at startup. Choose the baud rate carefully if you use this method, since changing it requires changing each device separately.

Typically, the baud rate setting on bus repeaters and third-party MS/TP devices is configured manually at the device, and the baud rate setting must match the bus supervisor's baud rate. A third-party device that does not support auto-baud establishes the baud rate for the MS/TP network if the FX80 or F4-SNC is not connected. Refer to the manufacturer's product documentation for information on setting the device's baud rate.

The FX software contains the following two device attributes that relate to the baud rate:

- **Baud Rate Selection** allows you to set the baud rate for the device using the CCT for CGMs, CVMs, XPMs, FX-PCGs, FX-PCAs, FX-PCVs, and FX-PCXs.
- **Active Baud Rate** allows you to view the baud rate at which the device is communicating on the active bus when Auto baud is selected for the device.

The high baud rates capable on MS/TP buses limit the range of wire gauges used on the bus. The baud rate, wire gauge, wire length, and the number of devices are related. Higher baud rates support more devices but require small gauge wire that provides lower capacitance. A lower baud rate may be required to use existing, larger gauge wire that has higher capacitance, but may support fewer devices. We recommend 38,400 baud using 22 AWG stranded wire. This combination provides the best balance between performance and installation sensitivity.

For information on determining wire gauges, wire lengths, and the number of devices supported, see MS/TP Bus Cable Recommendations.

Device Addressing on the MS/TP Bus

Each device connection on an MS/TP bus requires a device address to coordinate communication. Each bus has a set of device addresses that is separate and independent from the device addresses on all other buses. Devices connected to both an MS/TP bus and SA bus have two device addresses, one for each bus connection (Figure 3).

In the MS/TP bus hierarchy, device connections on separate buses can have the same device address. For example, every bus supervisor connection on an MS/TP bus has a device address of

0 (zero), and the device address for the first network sensor on any SA bus is 199. This is possible because separate buses are identified with different network numbers. Figure 3 shows a simple example of an MS/TP bus and the device addresses for connections on the FC bus and SA bus.

An FX Supervisory Controller (FX80 or F4-SNC) is the bus supervisor on an FC bus. The CGM and CVM controllers, XPM modules, or FX-PC controller is the bus supervisor on an SA bus. The supervisory devices have a default address of 0. Bus supervisors have a fixed device address of 0 (zero) that cannot be changed (Figure 3). The current range of network sensors are all addressable with the DIP switch set from 199 to 206 and the factory set at 199. Table 2 provides a list of the valid MS/TP device address values and address value ranges for MS/TP devices.

Each MS/TP master controller passes the token to the controller with the next known address. After 50 token passes, each controller searches for other controllers that might have joined the network by attempting to send the token to the controller with the next consecutive address, starting with one higher than its own, until one is found. While you do not need to address devices on the trunk consecutively, you can improve performance by minimizing address skipping. To help with address value selection, see Table 2.

ⓘ **Note:** The devices on the bus do not need to be physically wired in sequential order.

Setting a Device Address

For most devices on an MS/TP bus, the (non-supervisory) device address is set by positioning the Rotary or DIP switches on the device’s address DIP switch block. The DIP switch blocks are binary switch blocks, with each switch representing a binary numerical value when the switch is in the ON position. The CGM and CVM controllers have three rotary switches for setting the device address.

The device address set on the address DIP switch block or rotary switches applies to the device connection on the bus where the device is not the bus supervisor. For example, the rotary switches on CGMs or CVMs and the DIP switches on FX-PCAs, FX-PCGs, or FX-PCVs (master devices) set the device address for the device connection to the FC bus. If the CGMs, CVMs, FX-PCAs, FX-PCGs, or FX-PCVs also supervise an SA bus, the FX-PCAs, FX-PCGs, or FX-PCVs address on an SA bus is 0 by default (Figure 3).

A FX-PCX or F4-XPM has only one device connection, which can connect to either an FC bus or an SA bus (but not both); therefore, the device address set on a FX-PCX or F4-XPM applies to the bus to which the FX-PCX or F4-XPM is connected. (An FX-PCX or F4-XPM is never a bus supervisor.)

Figure 3: MS/TP Bus Showing FC Bus and SA Bus Addresses

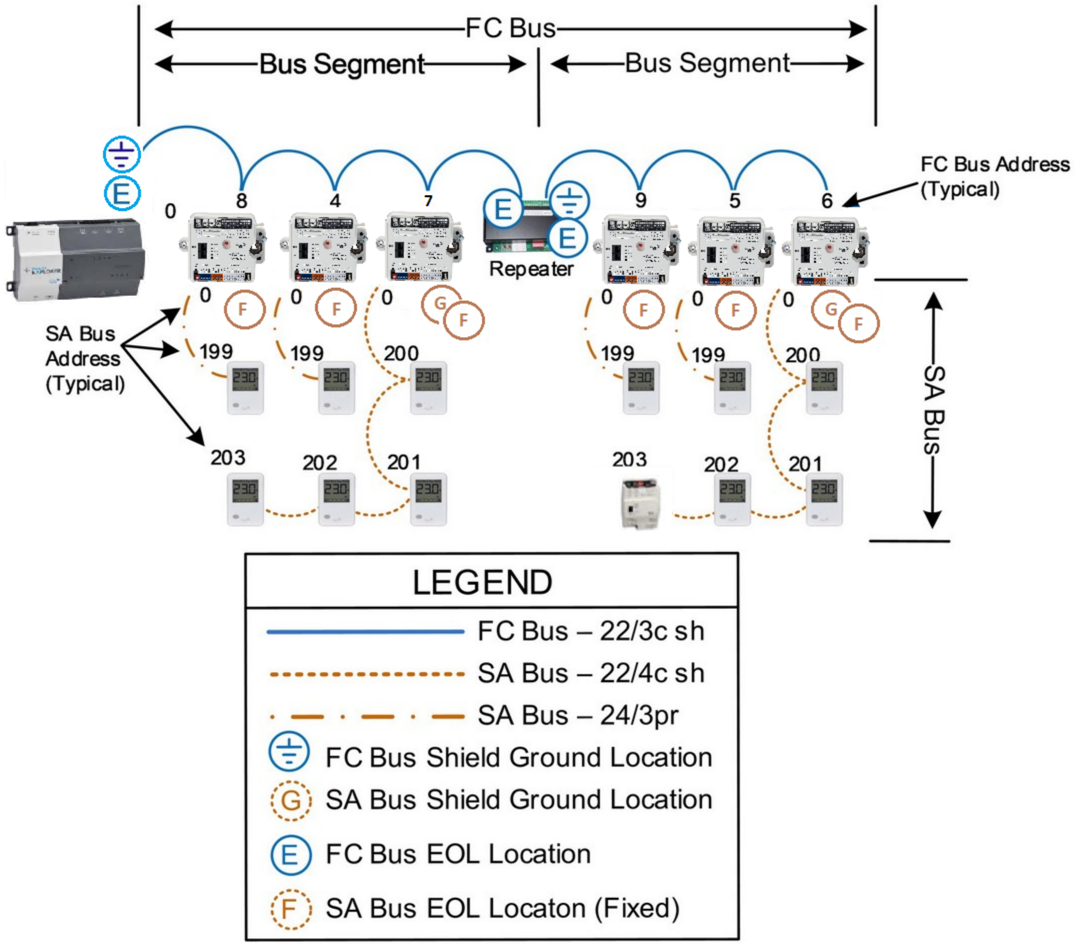


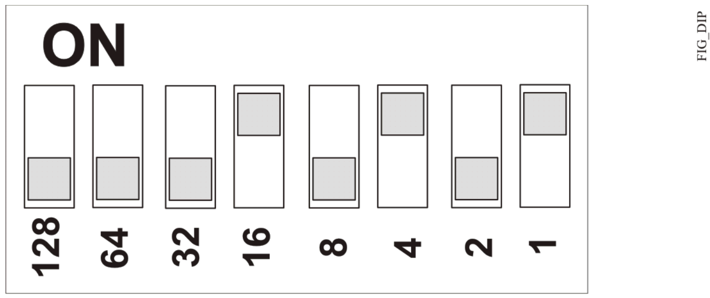
Table 2: Valid MS/TP Bus Address Values and Address Ranges for MS/TP Bus Devices

Address Value/ Address Range	Class	Devices
0	Bus Supervisor	FC Bus: FX Supervisory Controller (FX80 or F4-SNC) SA Bus: CGMs, CVMs, F4-SNCs, FX-PCA, FX-PCG, or FX-PCV
1	Reserved for JCI use	Reserved for the Field Inspection Tool (FIT)
2	Reserved for JCI use	Reserved for Mobile Access Portal (MAP)and ZFR/ZFRPro Wireless Field Bus Converter
3	Reserved for JCI use	FX-DIS1710 Local Controller Display
4–127	Master Range	FC Bus: CGMs, CVMs, XPMs, FX-PCA, FX-PCG, or FX-PCV and FX-PCXs Controllers and TEC26xx or TEC30xx Series Thermostat Controllers SA Bus: FX-PCXs and F4-XPMs
128–254	Subordinate Range	Subordinate devices, VSDs, and NS network sensors on the SA Bus. Not Supported on the FC bus.
198	Reserved	VAV Balancing Sensor (handheld)
199	Reserved	Most NS Series Network Sensor models or VAV Balancing Sensor (wall-mounted)
200–219	Reserved	NS Series Network Sensors
255	Broadcast	Do **not** apply address 255 to any device.

➤ **Important: On any FX-PCA, FX-PCG, FX-PCV, or FX-PCX that is hardwired to an MS/TP Bus, set the 128 DIP switch to the OFF position.** Operating any FX-PCA, FX-PCG, FX-PCV, or FX-PCX that is hardwired to an MS/TP Bus with the controller's 128 DIP switch set to the ON position results in communication failure on the bus.

As you set the device address on controllers with dip switch blocks, the best practice is to set the highest switch value first, then the next highest switch value, and so on, until the total of the switch values equal the intended device address. For example, positioning switches 16, 4, and 1 to ON sets the device address to 21 for a device on the FC bus.

Figure 4: Setting the Device Address and Wireless Operation Mode on the address DIP Switch Block



Notes:

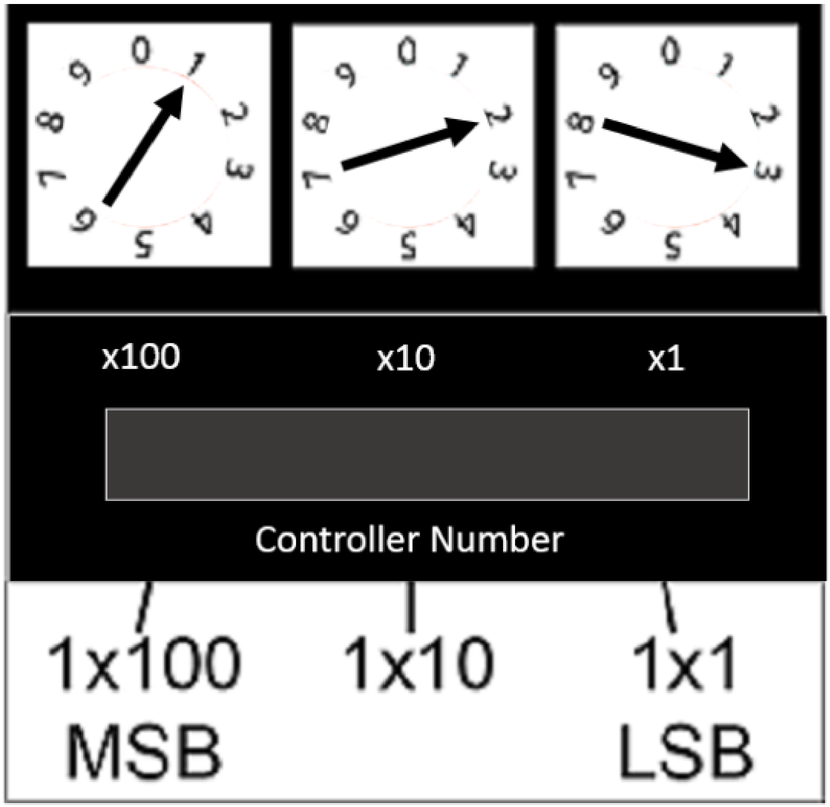
- You must set switch 128 to OFF on all FX controllers that are hardwired to an FC bus.
- Devices may go offline momentarily when a device address is changed on an active bus. A device reset is not required on FX controllers or supervisory controllers after changing the MS/TP address.

Some devices, such as the TEC30xx Series thermostats and third-party MS/TP devices, use their own configuration settings to establish the device address for their connection to the bus. The graphical display model of the NS8000 as well as the TEC300 series have their addresses configured in software via drilling down through menus. Refer to the device manufacturer's product documentation for instructions on setting the device address. The device address values for TEC thermostats and all third-party devices must comply with the rules and ranges described previously.

Rotary switch dials

The SNC has 3 rotary switch dials labeled Controller Number for setting the controller number which can be numbered from 000 to 999. The switches are shipped from the factory set to 000. You can use them to set a decimal number from 000 to 999 as a unique identifier for each SNC. The controller number is set using three rotary switches and may be numbered from 000 to 999. The numbers are ordered from left to right, most significant bit (MSB) to least significant bit (LSB) when the controller is oriented as shown in the following figure where the switches are set to 1 2 3.

Figure 5: Rotary switch device addressing



Enabling FX-PC Controllers for Wireless Operation

The ZFR/ZFRPro Series Wireless Field Bus System enables wireless communication, allowing you to create wireless connections between CVM and CGM controllers, XPM expansion modules, FX-PC devices and FX Supervisory Controllers (FX80 and F4-SNC).

To operate with a ZFR Pro Series field bus, a CVM, CGM, or FX-PC Controller must be connected to a ZFR Pro Wireless Field Bus Router, and the associated FX Supervisory Controllers (FX80 or F4-SNC) must be connected to a ZFR Pro Wireless Field Bus Coordinator.

Local FC Bus Rules and Specifications

Table 3, Table 4, and Figure 6 provide rules and specifications for the local FC bus.

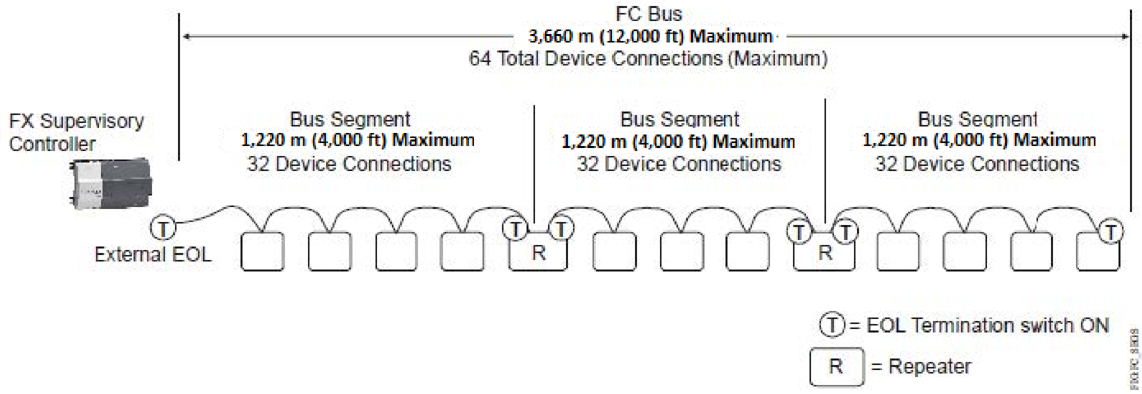
Table 3: Local FC Bus Rules and Limitations

Category	Rules/Limits
General	**SNC2515x-0x** Series models can support one local FC bus. **SNC1612x-0x** Series models can support one local FC bus. FX80 Supervisory Controllers can support one or more FC Buses. Check FX Supervisory Controller product literature to determine the exact number supported by specific model. CVM, CGM, and FX-PC Controllers' EOL termination and bias circuitry are much more robust than FX Supervisory Controllers. We recommend using FX-PC Controllers at both ends of the FC Bus.
Number of Devices and Bus Segments	**SNC2515x-0x** models support the following device limits on an FC bus trunk: 32 **SNC1612x-0x** models support the following device limits on an FC bus trunk: 32 The **FX80** supports 32 bus segments per FC bus, 64 devices in total
	Bus segments on an FC bus are connected with repeaters (only). Up to two cascaded repeaters may be applied to an FC bus (to connect three bus segments).
Cable Length for FC Bus and Bus Segments	When **all** of the devices connected on the FC bus are Facility Explorer devices the cable length limits (using 22 AWG 3-wire twisted, shielded cable) are as follows: • Each bus segment can be up to 1,220 m (4,000 ft) in length. • Each FC bus can be up to 3,660 m (12,000 ft) in length. When one or more third-party MS/TP device is connected on the FC bus, the device and bus segment limits are as follows: • Each bus segment can be up to 1,220 m (4,000 ft) in length. • Each FC bus can be up to 3,660 m (12,000 ft) in length. **Note:** Do not place subordinate devices on the FC bus. Subordinate devices on the FC bus are not supported.
	When using fiber-optic connections: 2,010 m (6,600 ft) between two fiber modems.
Recommended Cable	22 AWG Stranded, 3-Wire Twisted, Shielded Cable
EOL Termination	The EOL switch must be set to **On** (or an EOL terminator installed) on the two devices located at either end of each bus segment on an FC bus. The EOL switches must be set to **Off** (or EOL termination disabled) for all other devices on the bus segment on an FC bus. See End-of-Line Termination on Local FC Bus for more information.

Notes:

- The recommended cable type provides the best bus performance. See MS/TP Bus Cable Recommendations for information on alternative cable types and lengths that may be used in MS/TP applications.
- If third-party devices are connected to the bus, the cable lengths should be reduced (if necessary) to match the third-party vendor recommendations.

Figure 6: FC Bus with Three Bus Segments Connected with Repeaters



The bus segments on an FC bus are connected using repeaters (only). A repeater has two device connections, which are independent of each other. Each device connection on the repeater is connected to a bus segment just like any other device connection on the segment, and a repeater device connection can be connected at the end of a bus segment or anywhere along the segment. When a repeater device connection is at the end of a bus segment, EOL termination must be enabled on that repeater device connection. See Figure 7 for more examples of repeaters on FC buses.

Table 4: FC Bus Specifications

Category	Specification
Error Checking	Message Headers checked using 8-bit Cyclic Redundancy Check (CRC) test. Message data check using 16-bit CRC test.
Device Addressing	0–255 (See Device Addressing on the MS/TP Bus for more information.)
Data Transmission Standard	RS485
Signaling Method	BACnet® MS/TP
Signaling Rate	9600; 19,200; 38,400; or 76,800 baud as selected by bus supervisor. (See Baud Rates on the MS/TP Bus.)
Transient Immunity	Meets EN61000-4-4 and EN6100-4-5 requirements for heavy industrial applications. Protected against misapplication of 24 VAC.
EOL Termination Method	Integral EOL Termination switch or add-on EOL Terminator module (See End-of-Line Termination on Local FC Bus.) **Do not** use third-party EOL termination.

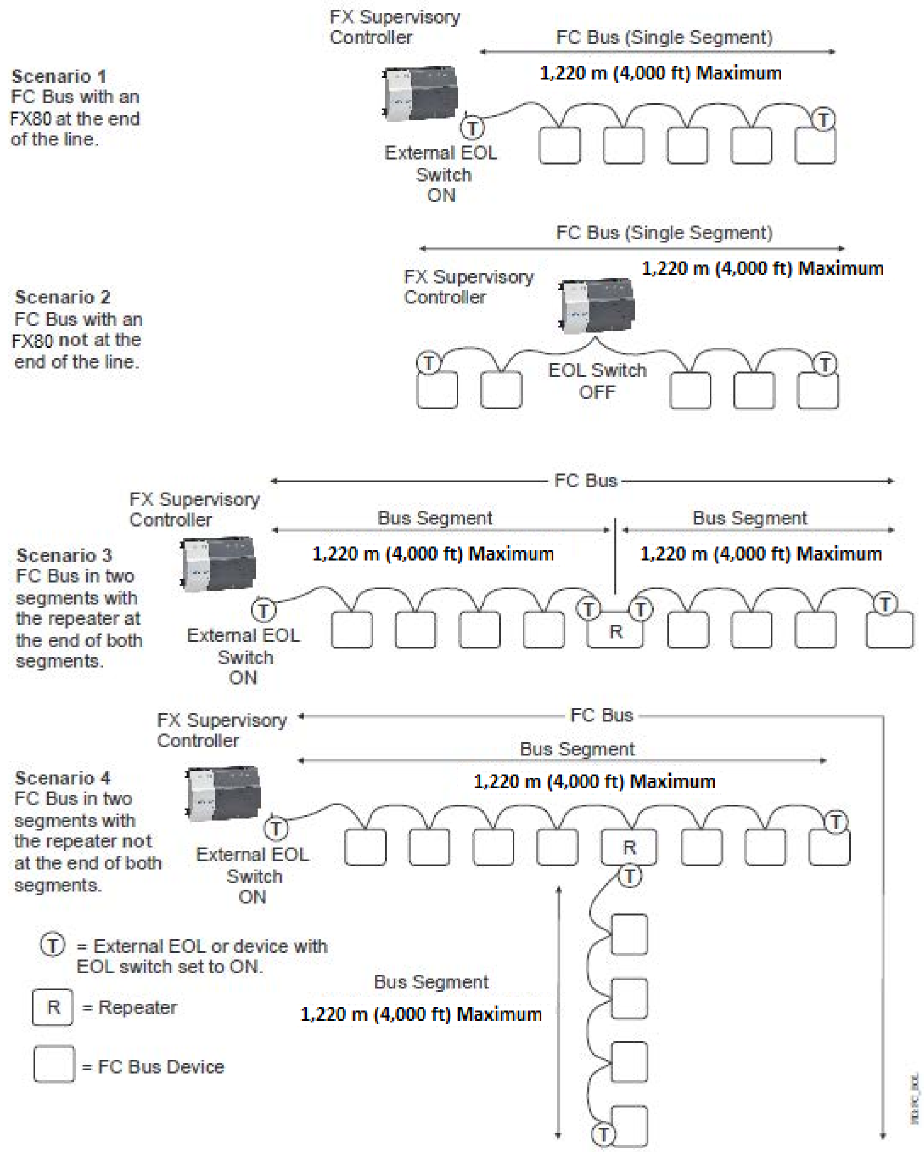
Table 4: FC Bus Specifications

Category	Specification
Shield Grounding	Only one hard ground connection per bus segment when using shielded cable. (See Grounding the MS/TP Bus Cable Shield.)
Physical Configuration	Daisy-chained
Optional Vendor Components	**Repeaters** • Acromag® 4683-TTM-1F (115 VAC) • Acromag 4683-TTM-2F (230 VAC) • Acromag 4683-TTM-3F (24 VAC) **Note:** A repeater is required to support more than 32 devices per trunk segment or trunk cable segment longer than 1,220 m (4,000 ft). Only the repeaters listed here provide EOL termination switching that is compatible with MS/TP. **Transient Eliminator** For further information, see Surge Protectors. **Fiber Modem** • S.I. Tech Model 2110BAC Fiber-Optic Modem and S.I. Tech 2121 Power Supply • 9-pin Male Connector Kit (required by 2110BAC modem) • Does not support 76,800 baud **Note:** A DIN rail mounting version of the Model 2110BAC may be available as Model 2110BAC-DIN. However it does not appear on the S.I. Tech web site at the time of this writing. Contact S.I. Tech using contact information on their web site at http://www.sitech-bitdriver.com/index.htm.

End-of-Line Termination on Local FC Bus

The FC bus requires EOL termination at the end of each bus segment. Figure 7 shows four examples of EOL termination on the FC bus.

Figure 7: FC Bus Segment EOL Termination Scenarios

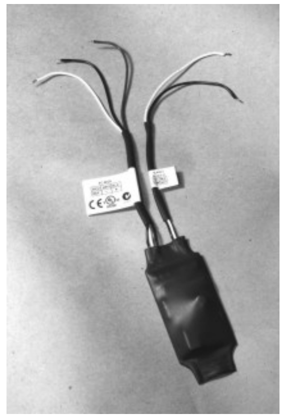


EOL Terminator Module

The FX-BACEOL-0 RS485 EOL Terminator is a **non-smoke control** listed component that provides EOL termination on FC bus segments when the device connected at the end of a bus segment does not have integral EOL termination capability.

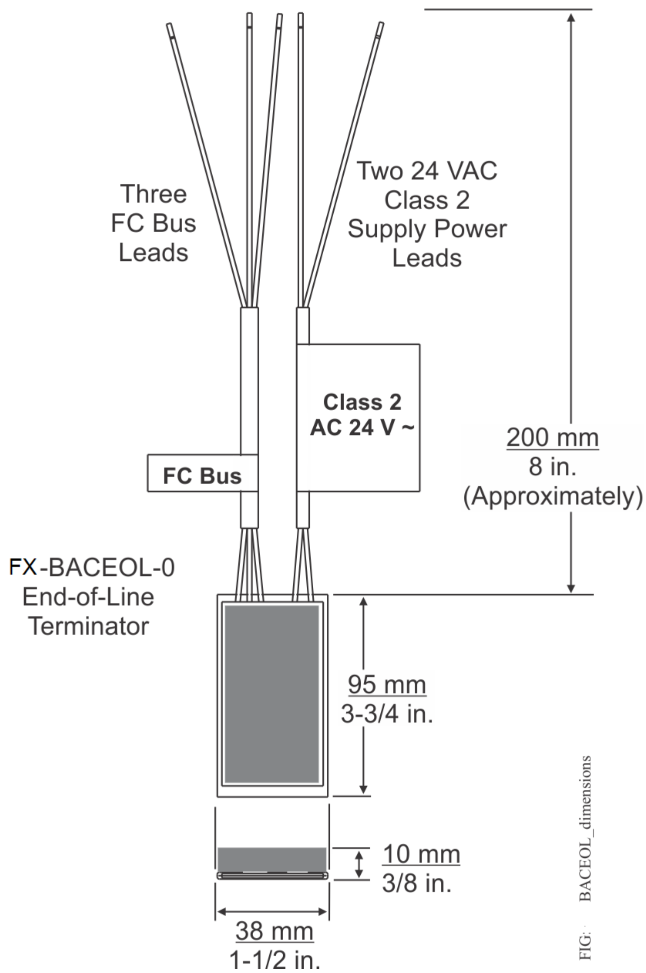
The EOL terminator is a compact, lightweight, module wrapped in a protective cover, as shown in the following figure, which can be quickly installed in a variety of ways. The EOL connects directly to the terminating device on a bus segment with the attached wire leads. The EOL requires 24 VAC, Class 2 power supplied by the field device or other 24 VAC source.

Figure 8: FX-BACEOL-0 RS485 EOL Terminator



The EOL terminator is designed for FC buses and provides better bus performance than the integral EOL termination on third-party devices. An EOL is recommended wherever a third-party device terminates an FC bus segment. If the EOL terminator is connected to a third-party device that has integral EOL termination, the integral EOL termination on the third-party device must be disabled.

Figure 9: FX-BACEOL-0 RS485 End-of-Line Terminator Dimensions



SA Bus Rules and Specifications

The SA bus connects FX-PCXs and F4-XPMs, VSDs, and NS-Series network sensors to FX-PC controllers. Figure 10 shows three SA bus examples. Table 5 provide SA bus rules and specifications.

Table 5: SA Bus Rules

Category	Rules/Limits
General	Each bus supervisor supports one SA Bus (and each SA Bus is a single segment).
Number of Devices Supported on the SA Bus	An SA Bus supports up to **10** devices. **The SA bus supervisor provides power for all subordinate devices connected to the SA bus**, including up to four NS network sensors. FX-PCXs or F4-XPMs connected to the SA bus are not powered by the bus supervisor.
	SA Buses do not support repeaters.
Cable Length	365 m (1,200 ft) maximum bus length
	152 m (500 ft) maximum distance between an NS network sensor and the bus supervisor (CGM, CVM or FX-PC controller supplying power to the sensor) using bus cable connected to the SA Bus screw terminal blocks
	30 m (100 ft) maximum length for network sensors using bus cables connected to the RJ-Style modular jack (6-Pin SA Bus Port)
	366 m (1,200 ft) maximum bus length
Recommended Cable Type	**Screw Terminal Connections:** 22 AWG Stranded 4-wire, 2-Twisted Pairs, Shielded Cable for screw terminals. **Modular Jack Connections:** 6-Pin RJ-Style Modular Connectors with 24 or 26 AWG Solid 6-Wire, 3 Twisted-Pairs
EOL Termination	Each SA bus supervisor has integral (fixed ON) EOL termination, which typically provides sufficient EOL termination on an SA bus. Long SA bus runs or persistent communication problems on an SA bus may require EOL termination at the last device on the SA bus (in addition to the integral EOL termination at the SA bus supervisor).
Mixing Device Types	Do not mix RJ-style modular (phone) jack devices and screw terminal devices on the SA bus.

ⓘ **Note:** The recommended cable types provide the best bus performance. See *MS/TP Bus Cable Recommendations* for information on alternative cable types.

SA Bus Device Limits

The SA Bus is limited to 10 devices total to ensure good communication on the bus and is limited to four NS sensors because only four unique addresses can be set on the sensors. Due to change of value (COV) limitations, it is best to limit the number of FX-PCXs or F4-XPMs on the SA Bus to four. The SA bus is also limited by the total power consumption of the devices connected on the bus. Exceeding the total power consumption limit can cause poor bus communication and cause devices to go offline.

Table 6 provides information on the power consumption of devices commonly connected to the SA bus.

Important: The total power consumption for the SA Bus is limited to 210 mA on the SA Bus modular jack and 240 mA on the SA Bus terminal block. Exceeding the total power consumption limit can cause poor bus communication and cause devices to go offline.

Table 6: Power Consumption by Common SA Bus Devices

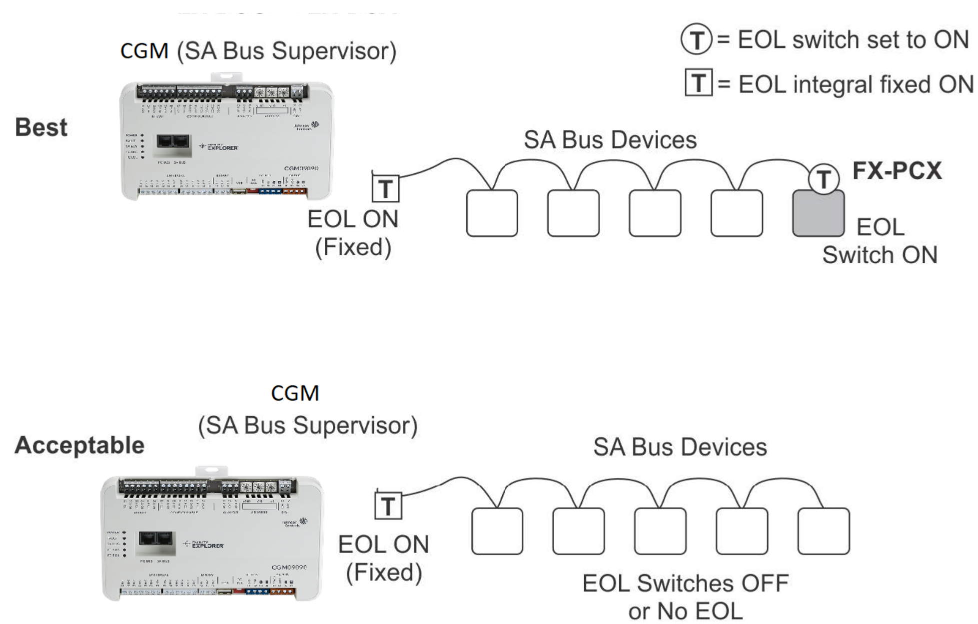
SA Bus Device	Power Consumption on the SA Bus
Discharge Air Sensors (NS-DTN70x3-0)	12 mA
Network Sensors without display	13 mA
Network Sensors with display no RH	21 mA
Network Sensors with display and RH	27 mA
CO2 Network Sensors (NS-BCN7004-0)	28 mA (non-isolated) or 5 mA (isolated)
ZFR Pro Wireless Field Bus Router	90 mA
FX-DIS1710 Local Controller Display	90 mA - may be a temporary load
Variable Speed Drives	NA (self-powered)
FX-PCX Series or XPM Expansion I/O Modules	NA (self-powered)

SA bus applications are limited to a power load of 210 mA (SA Bus modular jack) or 240 mA (SA Bus terminal block).

End-of-Line Termination on SA Bus

On an SA bus, the minimum requirement is that EOL termination **must** be enabled on at least one device. Since an SA bus supervisor always has EOL termination enabled, this requirement is always met; however, for enhanced bus performance, we recommend that you enable EOL termination on the devices at each end of the SA bus. See Figure 10 for SA bus EOL termination scenarios. In this example the configuration that is labelled Best is preferred because the wire is terminated at both ends. The other configuration labelled Acceptable has only one termination, and therefore is more prone to communication errors depending on the amount of loads, wire length, and noise conditions.

Figure 10: SA Bus EOL Termination Scenarios



ⓘ **Note:** The FX-BACEOL-0 RS485 End-of-Line Terminator module is not designed for EOL termination on the SA bus.

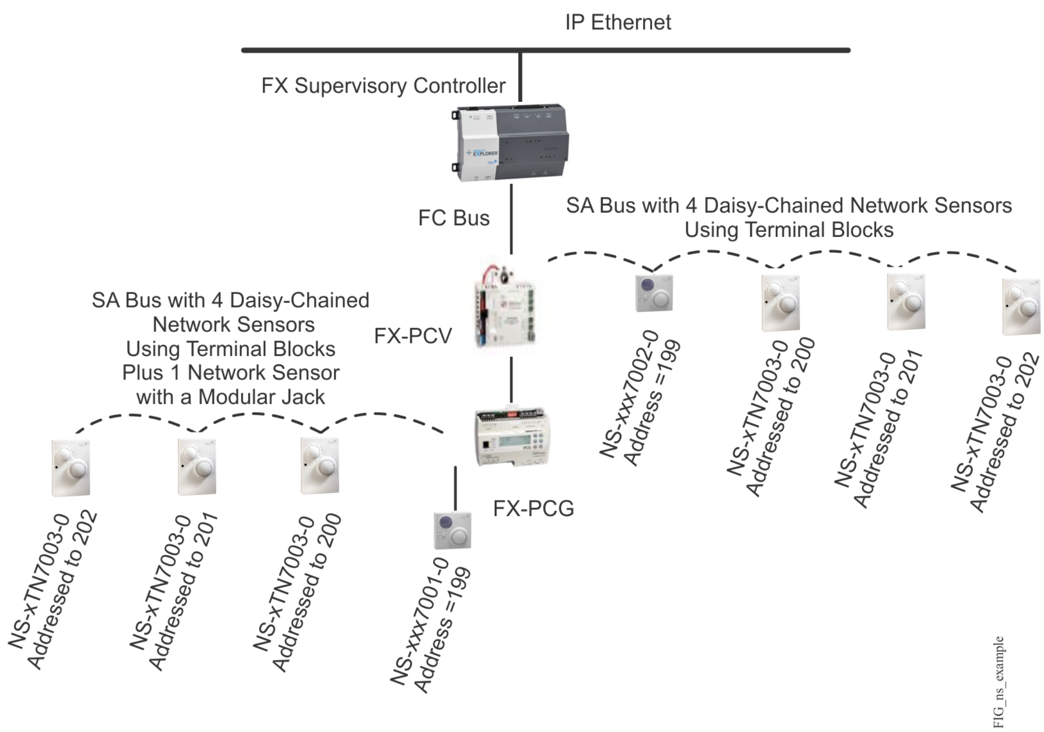
SA Buses with Multiple Network Sensors

An SA bus supports up to four network sensors. Figure 11 shows an example of two SA buses, each with four network sensors.

ⓘ **Note:** Do not mix RJ-style modular (phone) jack and screw terminal devices on the SA bus. Due to the permanent internal SA bus EOL termination contained in CGMs, CVMs, XPMs, FX-PCAs, FX-PCGs, FX-PCVs, and FX-PCXs, using both the phone jack and terminal block effectively puts the EOL termination in the middle of the SA trunk, creating a star network configuration. This configuration violates the RS-485 network wiring guidelines and can cause unpredictable communication problems.

Some NS Series Network Sensors and NS Series Discharge Air Sensors models are DIP switch addressable.

Figure 11: SA Bus Example Showing Multiple Networks Sensors



MS/TP Bus Cable Recommendations

The MS/TP bus supports much higher baud rates than the N2 bus. Higher baud rates make the MS/TP bus less fault tolerant and less immune to interference from inductive noise sources that may be present in the application environment.

For the best performance on MS/TP bus applications, use 22 AWG stranded wire in a shielded cable with proper cable shield grounding. . Other wire gauges and non-shielded cable **may** provide acceptable bus performance in many applications, especially applications that have short cable runs and low ambient inductive noise levels.

Table 7 provides cable recommendations for MS/TP applications. The recommended FC bus and SA bus cables are available from Belden CDT Inc. and Anixter, Inc.

Alternative cables may be used in MS/TP applications. Table 8 provides information regarding the relationship between baud rate, wire gauge, wire length, and supported device numbers. You can also use the information provided in Table 8 to determine if existing cable runs may be used in a retrofit or upgrade MS/TP application.

ⓘ **Note:** In Table 7, the shielded bus and cable types are **recommended**; the non-shielded bus and cable types are **acceptable**.

Table 7: Cable for FC Buses and SA Buses in Order of Preference

Bus and Cable Type	Non-Plenum Applications		Plenum Applications	
	Part Number	O.D.	Part Number	O.D.
FC Bus: 22 AWG Stranded, 3-Wire Twisted Shielded Cable	Anixter: CBL-22/3-FC-PVC Belden®: B5501FE	0.138 in.	Anixter: CBL-22/3-FC-PLN Belden: B6501FE	0.140 in.
SA Bus (Terminal Block): 22 AWG Stranded, 4-Wire, 2 Twisted-Pair Shielded Cable	Anixter: CBL-22/2P-SA-PVC Belden: B5541FE	0.209 in.	Anixter: CBL-22/2P-SA-PLN Belden: B6541FE	0.206 in.
SA Bus (Modular Jack): 26 AWG Solid 6-Wire, 3 Twisted-Pair Cable	—	—	Anixter preassembled: CBL-NETWORK25 CBL-NETWORK50 CBL-NETWORK75 CBL-NETWORK100	0.15 in.
FC Bus: 22 AWG Stranded, 3-Wire Twisted Non-Shielded Cable	Belden: B5501UE	0.135 in.	Belden: B6501UE	0.131 in.
SA Bus (Terminal Block): 22 AWG Stranded, 4-Wire, 2 Twisted-Pair Non-Shielded Cable	Belden: B5541UE	0.206 in.	Belden: B6541UE	0.199 in.

ⓘ **Note:** We strongly recommend 3-wire (for FC bus) and 4-wire, 2 twisted-pair (for SA bus), 22 AWG stranded, shielded cable. A 22 gauge cable offers the best performance for various baud rates, cable distances, and number of trunk devices primarily due to lower conductor-to-conductor capacitance. Shielded cable offers better overall electrical noise immunity than non-shielded cable. Observe the shield grounding requirements.

ⓘ **Note:** We recommend 26 AWG solid, 6-wire (3 twisted pairs) cable as the best fit for fabricating modular cables with the modular jack housing assembly. Be sure the cable you use fits the modular jack housing. The preassembled cables that are available from Anixter (Part No. CBL-NETWORKxxx) use 24 gauge wire.

Table 8: FC Bus Wire Gauge and FC Bus Baud Rate

AWG Wire Gauge	Maximum Cable Length and Device Connections Limit	Baud Rate				
		9600	19,200	38,400	76,800	
18	Maximum Cable Length per Bus Segment (m [ft])	1,524 (5,000) (APR)	1,524 (5,000) (APR)	1,219 (4,000) (NR)	609 (2,000) (NR)	305 (1,000) (NR)
	Maximum Number of devices (per Segment / per FC Bus)	25/25 (APR)	50/50 (APR)	50/100 (NR)	10/30 (NR)	50/100 (NR)
20	Maximum Cable Length per Bus Segment (m [ft])	1,524 (5,000) (APR)	1,524 (5,000) (APR)	1,524 (5,000) (APR)	1,524 (5,000) (NR)	1,219 (4,000) (NR)
	Maximum Number of devices (per Segment / per FC Bus)	25/25 (APR)	50/50 (APR)	50/100 (APR)	40/100 (NR)	50/100 (NR)

Table 8: FC Bus Wire Gauge and FC Bus Baud Rate

22	Maximum Cable Length per Bus Segment (m [ft])	1,524 (5,000) (A)	1,524 (5,000) (A)	1,524 (5,000) (**Best**)	1,524 (5,000) (A)
	Maximum Number of devices (per Segment / per FC Bus)	25/25 (A)	50/50 (A)	50/100 (**Best**)	50/100 (A)
24	Maximum Cable Length per Bus Segment (m [ft])	1,524 (5,000) (APR)	1,524 (5,000) (APR)	1,524 (5,000) (APR)	1,524 (5,000) (APR)
	Maximum Number of devices (per Segment / per FC Bus)	25/25 (APR)	50/50 (APR)	50/100 (APR)	50/100 (APR)
26	Maximum Cable Length per Bus Segment (m [ft])	1,524 (5,000) (APR)	1,524 (5,000) (APR)	1,524 (5,000) (APR)	1,524 (5,000) (APR)
	Maximum Number of devices (per Segment / per FC Bus)	25/25 (APR)	50/50 (APR)	50/100 (APR)	50/100 (APR)
A = Acceptable APR = Acceptable with Possible Restrictions NR = Not Recommended					

ⓘ **Note:** The maximum number of devices is reduced at lower baud rates (9,600, 19,200) due to increased token loop times.

ⓘ **Note:** 3-wire conductor (FC Bus), 22 AWG stranded, shielded cable is recommended. 22 gauge cable offers the best performance for various baud rates, cable distances, and number of trunk devices primarily due to lower conductor-to-conductor capacitance. Shielded cable offers better overall electrical noise immunity than non-shielded cable.

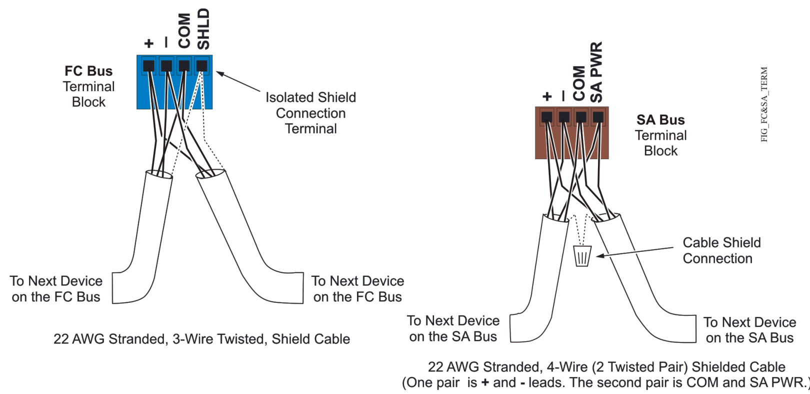
Screw Terminal Blocks for Connecting FC and SA Bus Cables

Both the FC bus and SA bus terminations have pluggable screw terminal blocks that allow you to connect the bus devices in a daisy-chain configuration. Connect the devices to the FC bus segments and SA bus as shown in Figure 12.

ⓘ **Note:**

- The SHLD terminal on the FC bus terminal block is electrically isolated from ground and is provided as a convenient terminal for connecting the cable shield in a daisy-chain on the bus segment.
- Do not mix RJ-style modular (phone) jack and screw terminal devices on the SA bus. Due to the permanent internal SA bus EOL termination contained in CGMs, CVMs, XPMs, FX-PCAs, FX-PCGs, FX-PCVs, and FX-PCXs, using both the phone jack and terminal block effectively puts the EOL termination in the middle of the SA trunk, creating a star network configuration. This configuration violates the RS-485 network wiring guidelines and can cause unpredictable communication problems.

Figure 12: FC Bus and SA Bus Terminal Block Wiring Details



Grounding the MS/TP Bus Cable Shield

Inductive interference and Radio Frequency (RF) interference can adversely affect MS/TP applications, causing poor bus performance and frequent device offline occurrences. Experience has shown that installing a properly grounded shielded bus cable in MS/TP applications greatly reduces the impact of ambient inductive noise and RF interference. Applications installed without shielded cable are much less tolerant to ambient interference.

We recommend installing MS/TP bus applications using shielded cable. In applications using shielded cable, it is very important to ground the cable shield properly. Improper shield grounding can also result in poor bus performance and frequent device offline occurrences.

To properly ground the cable shield on an MS/TP application, the cable shields on each **bus segment** must be connected in a daisy-chain as shown in Figure 12. Each daisy-chained segment must be connected at **one** point (only) to a hard ground connection. We recommend connecting the cable shield to hard ground close to the bus supervisor’s bus terminations. In metal panel or enclosure applications, connect the cable shield to ground where the bus cable enters the panel or enclosure that contains the bus supervisor. On bus segments without a bus supervisor, the best practice is to connect the cable shield to hard ground at a bus device near the middle of the bus segment.

Important: Ensure that the cable shield is **connected to hard ground at only one point on the bus segment** and is completely isolated from hard ground at all other points. Multiple hard ground connections on a bus segment can create ground loop currents in the cable shield, resulting in poor bus performance and frequent device offline occurrences.

In certain environments with high ambient inductive interference or strong radio frequency transmissions, an MS/TP application may require the addition of soft ground connections along the bus segments to enhance bus performance and reduce device offline occurrences, or possible device damage.

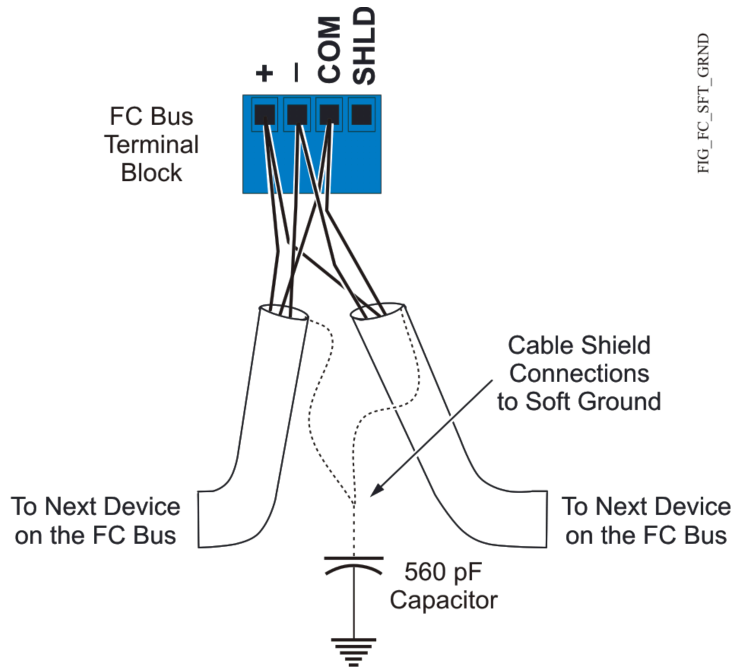
Examples of potential inductive interference include large motors, contactors, relays, welding equipment, high-voltage conductors that are not in metal conduit or raceways, other high wattage devices within 10 m (30 ft) of the bus cable, and areas of frequent lightning.

Examples of potential radio frequency interference include locations near airports, hospitals, radio or television transmission towers, police and fire stations, or factories. Mobile transmitters in police, fire, emergency, and fleet vehicles are also potential sources of radio frequency interference.

Note: The majority of properly grounded MS/TP applications do not require soft ground connections, but you should assess the potential interference that your application may encounter (before you install the bus). It is more efficient to prepare for soft ground connections when making the bus terminations at the initial installation than to return and do it later.

Soft ground connections should be made within 2 inches of the bus terminations of any bus device that experiences frequent offline occurrences resulting from high ambient inductive or RF interference (Figure 13).

Figure 13: Applying a Soft Ground Connection to an FC Bus



RJ-Style Modular Jack and Cables for SA Bus

The 6-pin modular jack SA bus connection (Figure 14) is a straight-through (not a crossover) connection and that uses a 6-wire connector cable (with 6-pin RJ-style modular jacks) to connect SA devices to network sensors, FX- DIS1710 Local Controller Display, and the FX-PCV Balancing Sensor. On the 6-wire cable, two wires are used for network communication, two wires for network sensor power, and two wires supply 15 VDC (200 mA maximum) power to the devices connected to the sensor.

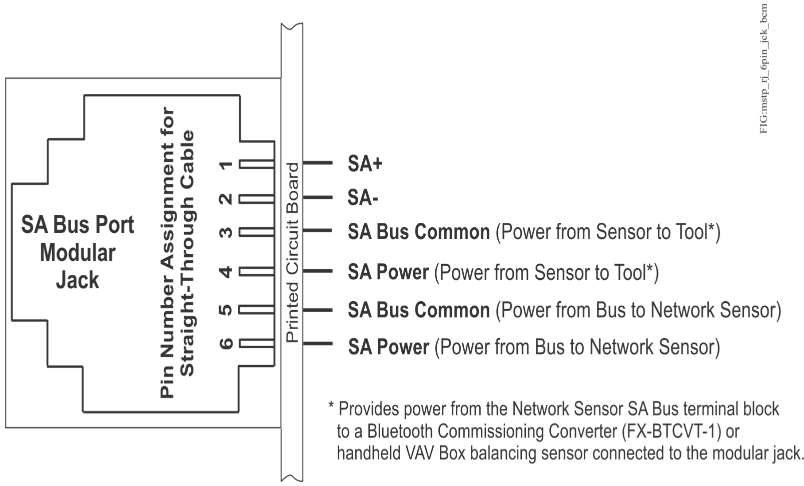
The cable connected to the SA bus 6-pin modular jack is a straight-through cable and cannot exceed 30 m (100 ft). Do not use crossover cables on the SA bus.

The SA bus 6-pin modular jack supports only one device and no other SA device may be daisy-chained to the port.

Important: Failure to adhere to these wiring details may cause your network sensor to function incorrectly. You are not able to connect to the system using the Handheld Variable-Air-Volume (VAV) Balancing Sensor, nor can you expand the system with future offerings.

Note: Do not mix RJ-style modular (phone) jack and screw terminal devices on the SA bus. Due to the permanent internal SA bus EOL termination contained in CGMs, CVMs, XPMs, FX-PCAs, FX-PCGs, FX-PCVs, and FX-PCXs, using both the phone jack and terminal block effectively puts the EOL termination in the middle of the SA trunk, creating a star network configuration. This configuration violates the RS-485 network wiring guidelines and can cause unpredictable communication problems.

Figure 14: 6-Pin Modular Jack Pinout Details



Commissioning Devices on the MS/TP Bus

Commission the devices on the MS/TP bus using the CCT software. Refer to the Controller Tool *Help (LIT-12011147)* for information on commissioning an MS/TP bus application.

Applications and device configurations are downloaded to the hardware from the CCT computer using the MAP Gateway or through the FX Supervisory Controller acting as a BACnet router.

Peer-to-Peer Communication

Peer-to-peer communication allows non-supervisory on a bus to communicate system data with each other directly, bypassing the FX Supervisory Controller on the bus.

Appendix: FC Bus Auxiliary Devices

Repeaters

Repeaters are optional components on the FC bus that increase the maximum allowable length and device counts of the FC bus. One repeater is counted as one device on the FC bus. Repeaters are not allowed on the SA Bus. Table 9 describes how the length and device maximums of the bus change when you add repeaters. The repeater is specified in Local FC Bus Rules and Specifications.

A maximum of two repeaters can be between any two points on the FC bus.

Note:

- The values in this table represent the recommended 3 conductor, 22 AWG stranded, shielded cable.
- Some device models and third-party devices may have reduced capabilities.

Table 9: Repeaters on the FC Bus

Maximums	With No Repeater	With 1 Repeater	With 2 Repeaters
Maximum Segment Length (ft)	4,000	5,000	5,000
Maximum Total Length (ft)	4,000	10,000	15,000
Maximum Device Count Per Segment	50	50	50
Maximum Total Device Count	50	100	100

Configuring Repeaters

The instructions for configuring the repeater for use with the FC bus require that you perform the following:

- Set the baud rate to match the FC bus baud rate.
- Wire the repeater between two segments of the MS/TP bus. If you are using this repeater in a branch, the side with the branch has double the number of wires terminated. See Figure 15.
- Set the EOL jumpers on the repeater according to Table 10.

ⓘ **Note:** The EOL jumpers are located below the cover of the repeater.

ⓘ **Note:** Sides A and B have separate EOL settings. Determine the settings individually.

For repeater installation instructions and important safety information, refer to the repeater manufacturer's literature.

⚠ WARNING

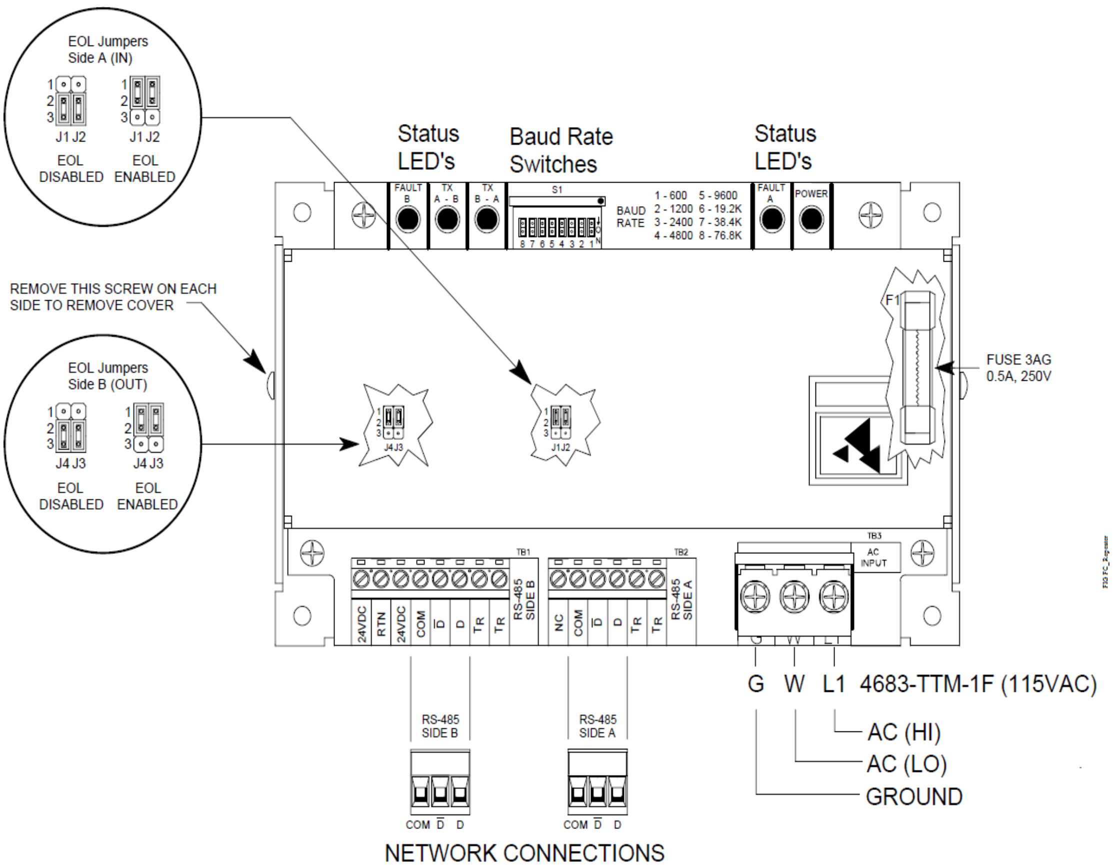
Risk of Electric Shock:

Disconnect or isolate all power supplies before making electrical connections. More than one disconnection or isolation may be required to completely de-energize equipment. Contact with components carrying hazardous voltage can cause electric shock and may result in severe personal injury or death.

Table 10: EOL Settings for Repeater

Side	Jumper	Instructions
Side A	J1 and J2	At end-of-line: Install both jumpers over Pins 1 and 2 (EOL In).
		Not at end-of-line: Install both jumpers over Pins 2 and 3 (EOL Out).
Side B	J3 and J4	At end-of-line: Install both jumpers over Pins 1 and 2 (EOL In).
		Not at end-of-line: Install both jumpers over Pins 2 and 3 (EOL Out).

Figure 15: Configuring the Repeater



Fiber-Optic Modems

You can install the 2110BAC fiber-optic modems in any location on the FC bus. Just as only two repeaters can be cascaded on the FC bus, only two pairs of 2110BAC modems can be cascaded.

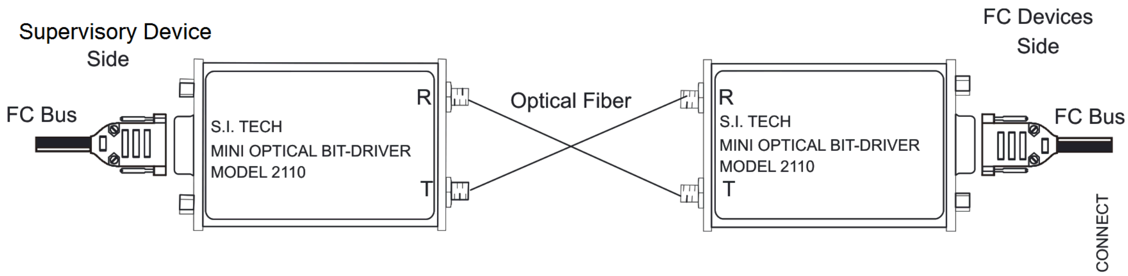
The first installation step is to route the optical fiber and connect each modem to the ends of the fiber. The second step is to connect the FC bus on both sides of the modems.

Routing and Connecting the Fiber Cables

About this task:
To route and connect the fiber cables, follow these steps and see Figure 16:

1. Route the optical fiber in a manner that is required for the application.
2. Connect the fiber cable from the T (Transmit) output of the modem nearest to the Supervisory Controller to the R (Receive) input of the modem near the MS/TP devices.
3. Connect the fiber cable from the T (Transmit) output of the modem near the MS/TP devices to the R (Receive) input on the modem nearest to the Supervisory Controller.
4. Plug in the power supply for each modem.

Figure 16: Connecting the 2110 Modems



Connecting Modems to MS/TP Bus

Connect the MS/TP bus to the 2110BAC modem by soldering the MS/TP wires to pins on the 9-pin connector, which can also configure the modem as an EOL device. To connect the bus, see Setting Termination on Fiber Modems.

ⓘ **Note:** A DIN rail mounting version of the Model 2110BAC may be available as Model 2110BAC-DIN. This model would not require soldering the MS/TP wires. However, Model 2110BAC-DIN does not appear on the S.I. Tech web site at the time of this writing. Contact S.I. Tech using contact information on their web site at http://www.sitech-bitdriver.com/index.htm.

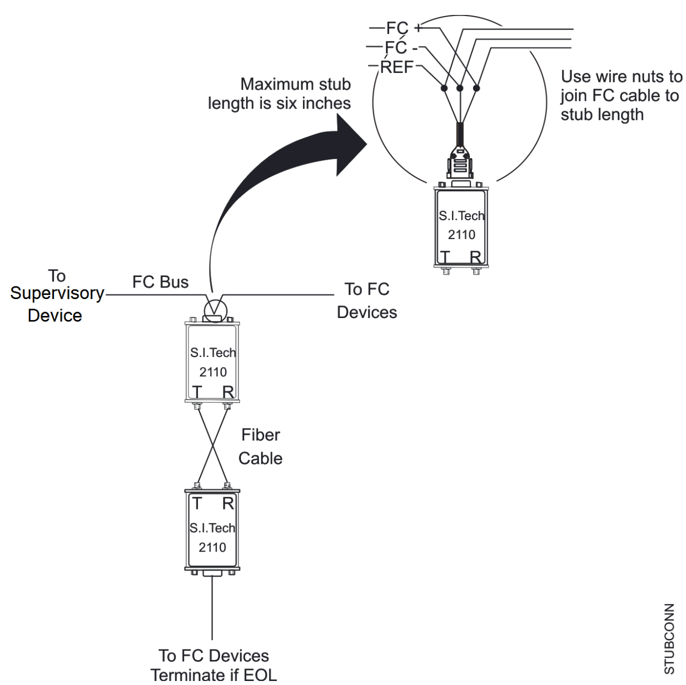
Fiber Modem between Two Segments

If you need to place the 2110BAC modem between two segments of MS/TP bus, wire a stub length of 6 inches or less, as shown in Figure 17, and terminate the two pairs of MS/TP bus cable at the end of the stub length.

If the fiber modem is at the end of a segment, set the EOL to In.

Important: If the fiber modem is at the end of a network segment (one wire connected) then **you must use** the built-in termination. Failure to use the built-in termination will affect the biasing and other electrical characteristics of the trunk.

Figure 17: Connecting 2110BAC Modem in between Two MS/TP Bus Segments



Setting Termination on Fiber Modems

The 2110BAC modem does not have an EOL jumper. Instead, establish EOL termination on a 2110BAC modem by properly terminating the FC bus wires to the 9-pin connector. Soldering the wires to specific pins and soldering two jumper wires configures the modem as an end-of-line device (see Figure 18, Figure 19, and Table 11 for more information).

ⓘ **Note:** A DIN rail mounting version of the Model 2110BAC may be available as Model 2110BAC-DIN. This model would not require soldering the MS/TP wires. However it does not appear on the S.I. Tech web site at the time of this writing. Contact S.I. Tech using contact information on their web site at http://www.sitech-bitdriver.com/index.htm.

Do not set the fiber modem as an EOL device on the SA bus.

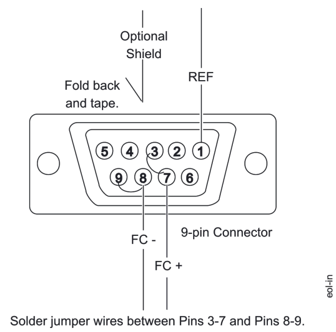
Modem Set EOL to In

To set the modem as an end-of-line device, wire the 9-pin connector using solder connections as shown in Figure 18.

Important: If the fiber modem is at the end of a network segment (one wire connected) then **you must use** the built-in termination. Failure to use the built-in termination will affect the biasing and other electrical characteristics of the trunk.

ⓘ **Note:** The following figure shows the 9-pin female connector. The pin numbers on the 9-pin male connector are reversed.

Figure 18: Female Modem Cable Connector: EOL Set to In



Modem Set EOL to Out

To set the modem with the end-of-line selection set to Out, wire the 9-pin connector using solder connections as in Figure 19.

ⓘ **Note:** The following figure shows the 9-pin female connector. The pin numbers on the 9-pin male connector are reversed.

Figure 19: Female Modem Cable Connector: EOL Set to Out

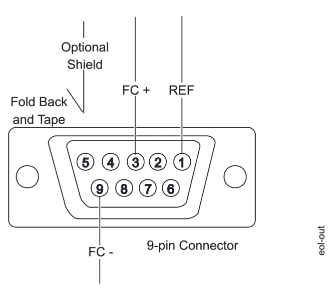


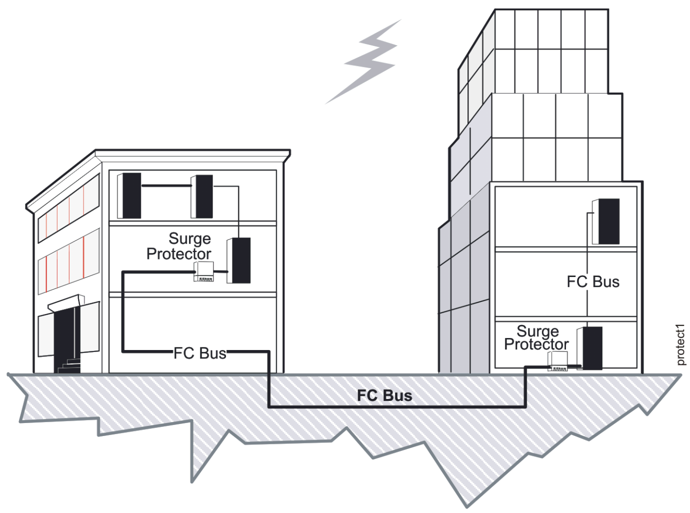
Table 11: EOL Connections Summarized

FC Bus Signal	For EOL Selection	For Non-EOL Selection
FC +	Terminal 7, Jumper 7-3	Terminal 3
FC -	Terminal 8, Jumper 8-9	Terminal 9
REF	Terminal 1 or 5	Terminal 1 or 5
SHIELD	Tape Back	Tape Back

Surge Protectors

Surge protection is strongly recommended if the MS/TP bus is wired between buildings. The protection is provided by a voltage surge suppressor, which is installed on the MS/TP bus near the MS/TP device. Example applications are shown in Figure 20.

Figure 20: Surge Protector Installation on MS/TP Bus



ⓘ **Note:** Fiber-optic bus connections between buildings are immune to transient voltage and other problems associated with hard-wire bus connections. Fiber-optic bus connections do not require surge protection and may be less costly to install. See Fiber-Optic Modems for information.

The surge protector protects the MS/TP bus from indirect lightning, and shunts both common and normal mode voltage surges to ground repeatedly without damage to MS/TP bus components.

Important: The surge protector is capable of protecting the MS/TP bus from indirect lightning strikes, not direct lightning strikes. A direct strike may cause actual damage to the bus cable or surrounding property. An indirect lightning strike may cause induced voltage transients that could cause electronic malfunction without visible damage to equipment if the equipment were not protected.

Use the surge protector with the standard MS/TP bus wiring. Do not use it with any other type wiring such as leased line. If you need surge protection for other wire types, contact a transient noise protection company.

Table 12 lists the specifications of the surge protector.

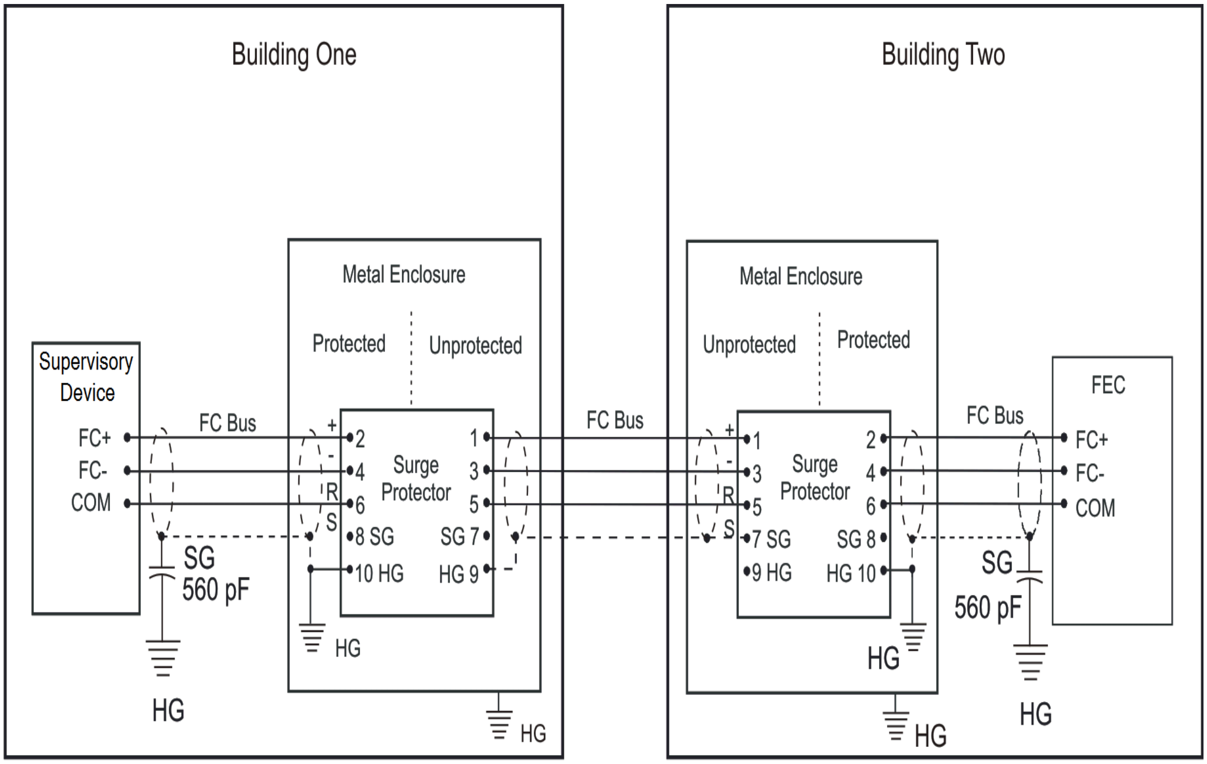
Table 12: Surge Protector Specifications

Category	Specification
Design	Three stage solid-state design using both metal oxide varistors and silicon avalanche diodes for suppression
Response Time	Less than 1 nanosecond
Maximum Impulse Current (8/20 ms current impulse)	10 kA per conductor
Maximum Energy Dissipation	80 Joules per conductor (10/1000 us)
Maximum Operating Voltage	12 VDC
Protection	Common and normal modes
Suppression Voltage Levels (Common mode)	100 kHz ringwave at 200 A: 15.8 volts 100 kHz ringwave at 500 A: 16.8 volts 3 kA combination wave: 20.8 volts
Maximum Number of Protectors Allowed on MS/TP Bus	One pair per bus segment
Maximum Length of MS/TP Bus Between Two Buildings Using Protector	1,524 m (5,000 ft) (standard MS/TP bus specification)

One pair of surge protectors is required whenever the MS/TP bus wire is routed outside between two buildings. Install the protector close to the MS/TP device that first receives the bus wires from the outside. Figure 21 shows an FC bus surge protector wiring example.

The protector does not require that you use any special type of wire for the MS/TP bus, such as double-shielded twisted cable. Use the standard recommended twisted cable types.

Figure 21: FC Bus Surge Protector Wiring Example



Notes:
Hard Ground (HG) bus shielding connections should be at a single location in each bus segment. Introducing multiple hard ground points of bus shielding in a single bus segment may result in large circulating ground currents in the shield.

For the surge protector's hard ground, use 12 AWG stranded wire, 4.57 m (15 ft) maximum length, connected to Pin 9 or 10 (pins 9 and 10 are internally connected on the surge protector).

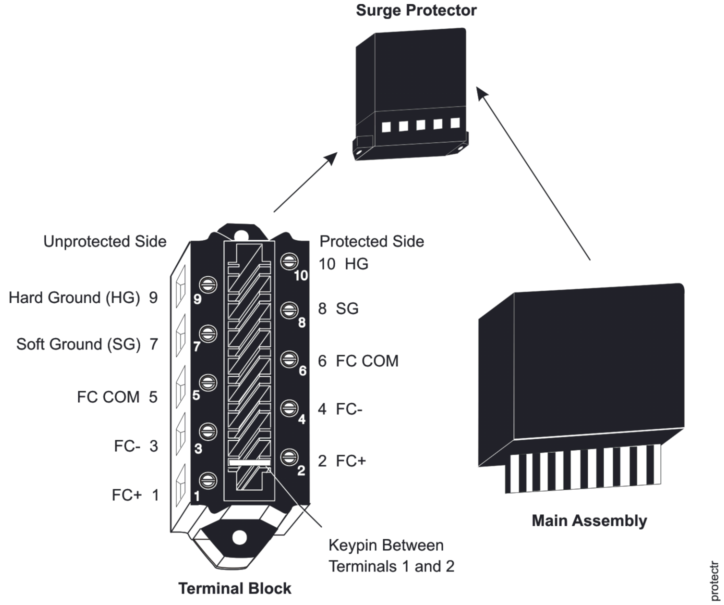
Make sure wires entering the surge protector's enclosure are not close to the wires leaving the enclosure.

Soft Ground (SG) the Bus shield at all other controllers wired to the FC Bus.

FC_Bus_Surge

The surge protector consists of two sections: the terminal block and the main assembly. These sections separate to make the unit easier to install and replace (Figure 22).

Figure 22: Sections of Surge Protector



The surge protector is wired depending on which device requires protection. Follow these general steps:

1. Mount the surge protector device in accordance with local codes. Install in an enclosure, if required, as close as possible to the first MS/TP device connecting the trunk segment entering the building. Any electrical box with a cover is acceptable. Bond the surge protector enclosure to the MS/TP device enclosure by connecting the two with the conduit that carries the MS/TP cable.
2. Connect the MS/TP segment from the outside to the unprotected side of the device. If possible, run the segment inside metallic conduit because the conduit acts like a shield for lightning.
3. Connect the MS/TP segment that goes to the MS/TP device to the protected side of the device. Keep this segment away from the unprotected segment.
4. Connect the protector to earth ground with 12 AWG stranded green wire (Figure 21). The total length of ground wire cannot exceed 4.57 m (15 ft), which means an earth ground must be available within 4.57 m (15 ft) of the MS/TP device. Your installation design must accommodate this requirement.
5. For hard ground installation, connect the shield to Pin 9. For soft ground installation, connect the shield to Pin 7.

For more details on installation, refer to the specific manufacturer’s literature.

Appendix: Maximizing and Troubleshooting the MS/TP Bus

Maximizing Tips

Table 13: Optimization guidelines

Guideline	Description
Use sequential master addresses	Assign the master range of addresses on the FC Bus sequentially, starting at 4, up to 127. Do not skip addresses. Gaps in the master address range cause the bus to wait while devices poll for the next master. The devices on the bus do not have to be physically sequential to follow this guideline. For example, the devices on the bus can be 4, 7, 6, and 5 as long as the range does not skip numbers.
Limit the number of Change of Value (COV) report rates over the MS/TP Bus	COV reports account for the highest amount of traffic on the bus. For best performance, keep the COV rate at 500 COVs per minute or fewer for each network. To reduce the COV traffic: • Set the COV increment to the largest value that still provides acceptable performance. • Do not map more points to the FX Supervisory Controller than are required. For mapped analog points, where the values are changing frequently, consider the following to limit COV reports: • Increase the COV increment on the point. ⓘ **Note:** For some Analog Inputs (AIs), this value cannot be modified. • Set the **Use Cov Min Send Time** flag to true, which causes the COVs to be sent on a timed basis. The time value is specified in the controller device object.
Do not place subordinate devices on the FC bus	Subordinate devices on the FC bus are not supported. The SA bus only supports a specific set of subordinate devices.
Carefully evaluate third-party devices	Third-party devices can seriously degrade both hardware and software performance depending on their quality and configuration. Consider and configure third-party devices carefully according to the manufacturer’s specifications.
Do not add extra traffic	Once the system is configured, commissioned, and running, avoid adding extra traffic to the bus by performing unnecessary auto-discovery operations, or downloads.
Observe the MS/TP wiring guidelines	Follow the wiring rules carefully. The tolerances of the MS/TP bus are tighter than other, slower protocols may be. Improper terminations may result in errors causing serious network degradation.

Parameters that affect MS/TP communication

The following parameters can be adjusted to tune MS/TP communication.

Important: Do not adjust attributes with which you are unfamiliar. If set improperly, the following parameters can adversely affect MS/TP communication.

- The **Baud Rate Selection** attribute specifies the baud rate. If the baud rate is forced to be different from other devices on the bus, communication ceases.
- The **Max Master** attribute specifies the highest address that can be a master on the bus. By adjusting this value, you can prevent some devices from coming online as bus masters. All devices on the bus must have the same Max Master attribute value to prevent the token from going to a device with an address above the Max Master attribute value.
- The **Max APDU Length Accepted** attribute specifies the largest data packet that is allowed on the bus.

  CAUTION: If set improperly, this parameter can cripple the bus.
- The **APDU Timeout** attribute determines how long the FX Supervisory Controller waits for an acknowledgement from a device when the message can be sent in one transmission. If set too low, most messages fail. If set too high, error recovery is delayed. You can change this value in special situations when dealing with third-party devices or overloaded networks.
- The **APDU Retries** attribute determines how many retries are allowed when trying to recover from an error. If changed improperly, the network may slow down or become more sensitive to noise.

Duplicate addresses

Two or more devices on a bus cannot have the same address. If two devices on the same bus have the same address, performance can degrade or serious communication problems can occur, including devices not coming online and the cessation of all communications on the bus.

Check for duplicate addresses in the following ways, depending on the severity of the situation:

- If bus performance is degraded, check the address switch settings at the devices with unreliable communications.
- If the bus communications problems are severe, and there is no communication or you cannot determine where communication is unreliable, partition (disconnect and isolate a portion of the bus for testing purposes) and test the bus portion connected to the FX Supervisory Controller (or Commissioning Converter).

Common problems

Several factors can influence the behavior of the MS/TP bus. In addition, certain problems can affect the bus in multiple ways and have more than one symptom, making the exact diagnosis difficult. For example, duplicate addresses on the bus can degrade performance, make a device go offline, or stop communication completely. Table 10 lists common problems that you should consider when troubleshooting an MS/TP bus. The first row, Multiple Symptoms, lists possible problem causes that can have multiple symptoms.

Table 14: Commpn problems

Symptom	Common cause
Multiple symptons	• Excessive bus errors are occurring. • A device was added or changed with a duplicate address (may not be the same address as some devices having problems, and may have happened some time before the problem was noticed). • Wiring errors or wire problems exist. • The baud rate was changed on some devices on the network, but not all devices. • Max Master was changed incorrectly (this may have happened some time before the problem was noticed). • A download is in progress. • There is a fault at a device. • A repeater is needed or configured incorrectly. • There is a duplicated Device Object name or instance. • The EOL termination is improperly set.
Poor performance	In addition to the causes listed in **Multiple Symptoms**, possible causes include the following: • Excessive bus traffic exists (bus overload). • Baud rate may be set too low. • Too many devices may exist on the network. • Unaccounted devices are on the network (that is, not mapped to the FX Supervisory Controller • Unusually slow devices are on the network or devices that are slow to pass the token.
Devices go offline	In addition to the causes listed in **Multiple Symptoms**, possible causes include the following: • Power or other failure occurred at the device. • Communication is disabled at the device.
Device does not come online	In addition to the causes listed in **Multiple Symptoms**, possible causes include the following: • The device may be connected to the wrong bus. • The baud rate of a new device is incompatible with the baud rate of the running network. • No device on the network is configured to use a specific baud rate (normally the FX Supervisory Controller), but all devices are set to use auto baud. At least one device, typically the bus supervisor (FX Supervisory Controller), must have an assigned baud rate. Set the baud rate in the bus supervisor and set all other devices to Auto baud. • Device failed to download **Main Code**.

Correcting physical bus problems

The MS/TP bus is subject to a number of physical factors that can affect performance. Consider the following common physical attributes:

- Check wires:
  - Verify proper wire gauge, connections, polarity, and lengths.
  - Look for opens and shorts.
- Check terminations:
  - Verify that EOL terminations are only at the ends of daisy chains.
- Check addresses:
  - Check for duplicate addresses.
  - Verify that the address range is sequential.
- Check for and eliminate T-Taps (wire configurations that create a T shape) and star configurations.
- Check for consistent baud rates.
- Check for sources of interference.

Correcting bus overload problems

Excessive data communication on the MS/TP bus can degrade system performance. To reduce the load on the bus, consider the following:

- Unmap points you do not need.
- Minimize the number of COVs on the bus.
  - Check and increase the COV increment for noncritical points.
  - Use a timed COV interval for fast changing points. Set the **Use COV Min Send Time** attribute to **True**.
  - Lengthen the COV timed interval **COV Min Send Time** 10-255 in the device object. The default is 15 seconds.
- Check for and correct unstable sensors.
- Reduce the number of devices on the bus, if possible.
- If running at less than 38.4k baud, increase the baud rate if possible.
- Verify repeaters, if applicable.
  - Verify that repeaters are used where needed.
  - Verify that repeaters are configured and wired correctly.

Appendix: Integrating 2-wire BACnet devices on a common MS/TP bus with JCI 3-wire devices

The following drawing illustrates a suggestion on how to integrate 2-wire BACnet devices on a common MSTP bus with the FX80 and JCI 3-wire devices.

Observe the other RS485 network configuration guidelines outlined in this document, especially those in the following tables:

- Use of cable types recommended in Table 7 and Table 8.
- Use of FC Bus rules recommended in Table 3.

Figure 23: Suggested termination

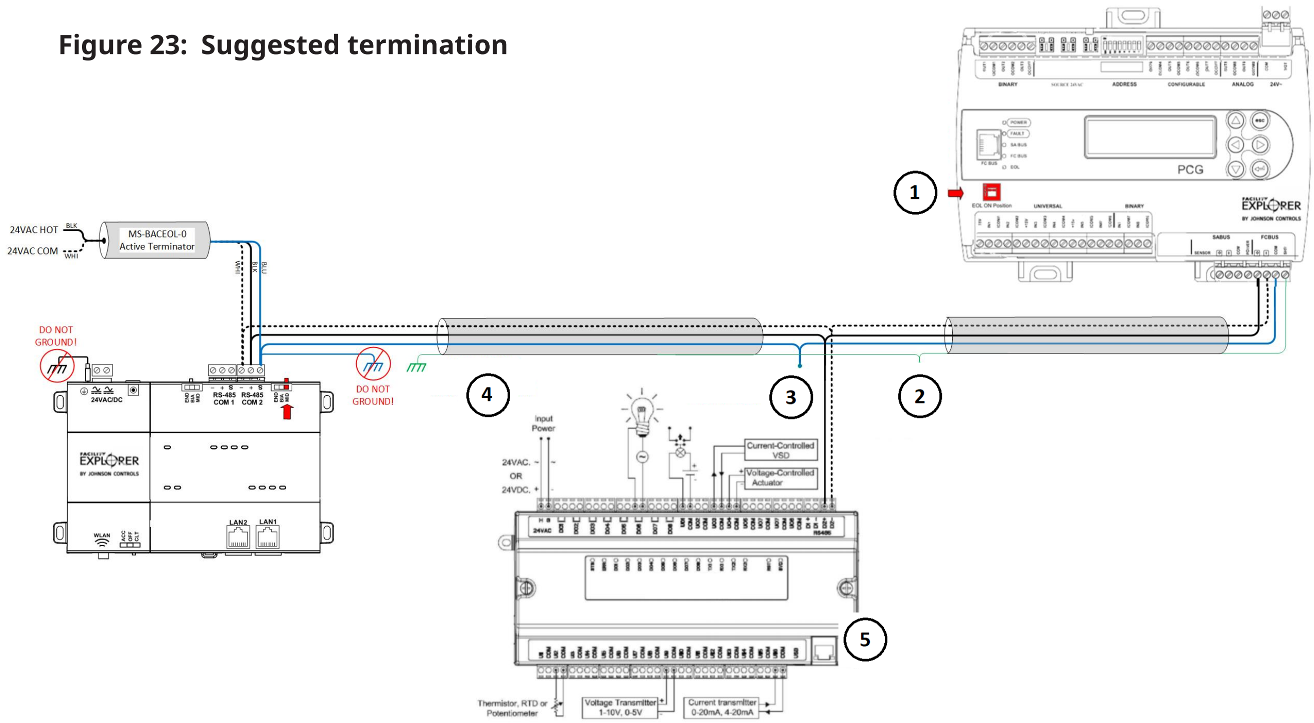


Table 15: Suggested termination

Number	Description
1	Set end-of-line (EOL) switch to the **On** position at the last physical FX controller on the RS-485 segment. All other FX controllers should have their EOL switches in the default **Off** position. Note that this switch may be underneath the cover on some models
2	Wire nut shield drain wire at each device to ensure continuity
3	Wire nut ref wire at each 2-wire device to ensure continuity
4	Hard ground shield drain wire in one location only
5	Standard 2-wire BACnet device

Appendix: Optimizing SA Bus Traffic

This appendix describes how to configure the devices on the Sensor Actuator (SA) bus if excessive traffic on the bus is causing delays in communication.

Apply the solutions if:

- Control applications on your site include multiple Input/Output Modules FX-PCXs or F4-XPMs that use more than 8 analog outputs (AOs) with fast control processes (time constant of less than 100 seconds)

You can also apply these solutions if:

- Analog input (AI) values on the SA bus report offline for a few seconds at a time. The FX-PCX or or F4-XPMs to which the AIs are connected may not show offline at the same time.
- FX-PCX or F4-XPMss on the SA bus report offline for several seconds during startup or shutdown of processes involving multiple AO commands.
- FX-PCX or F4-XPMs experience unusually high CPU usage.

The solution to this problem is to limit the fast, sensitive control processes that occur over the SA bus. Examples of this type of control include airflow, static pressure control, and room pressurization. Instead, leave these control systems on the FX controller or supervisory device, and move slower response or monitor only points on the SA Bus.

The sections in this appendix provide detail on messages and command calculations and strategies that reduce SA Bus traffic.

Excessive Traffic

SA Bus traffic includes change of value (COV) messages that are issued from inputs located on FX-PCXs or F4-XPMs and commands issued to outputs located on the FX-PCXs or F4-XPMs. Excessive traffic is defined as more than 500 COVs per minute or more than 500 commands per minute.

To resolve communication issues associated with excessive SA Bus traffic, reduce the number of COVs to fewer than 500 per minute and the number of commands to fewer than 500 per minute.

ⓘ **Note:** The limit of 500 commands per minute is an approximate maximum that assumes a 1 second token loop time. If your network is configured differently, the actual threshold for this problem may vary. For example, if your token loop time is 2 seconds, the maximum is 240. If you reduce traffic on the SA Bus to 500 and still experience this problem, or you are uncertain of your token loop time, we recommend you reduce command traffic to 240.

To find the number of COVs and commands on your SA Bus, see Inputs and COVs and Outputs and Commands. For strategies on reducing traffic on your SA Bus, see SA Bus Traffic Reduction.

Inputs and COVs

The COVs for all AIs on FX-PCXs or F4-XPMs are fixed at .001. FX controller devicess immediately acknowledge all SA Bus COV reports. The goal is to have the total number of COVs on an SA Bus be fewer than 500 per minute. Use the following table to determine the total potential COVs per minute.

ⓘ **Note:** The Update Interval (refresh rate for the user interface and CCT applications) depends on the Filter Setup, Process ID, and Time Constant attribute values in the Analog Input object. If a fast process (time constant of less than 100 seconds) receives its input from sensors located on SA Bus devices, excessive bus traffic can result.

Table 16: COV Rates: Inputs

Process ID	Time Constant (Seconds)	Update Interval (Hundredths of Seconds)	Approximate COVs Per Minute
Airflow	30	100	60
Airflow %	30	100	60
Airflow Difference	30	100	60
Bldg Static	30	100	60
Duct Static	30	100	60
Pump Diff P	30	100	60
CHWS-T Mixing	60	200 100	30
HWS-T Mixing	60	200	30
MA-T	80	200	30
CHWS-T HEX	90	300	20
HWS-T HW HEX	90	300	20
HWS-T Steam HEX	90	300	20
DA-H	200	600	10
DA-T	200	600	10
CWS-T	600	2,000	3
RA-H	900	3,000	2
ZN-H	900	3,000	2
ZN-T	900	3,000	2
ZN-T LC	900	3,000	2
ZN-H LC	900	3,000	2

For example, assume you have a Mixed Air Single Path, Variable Speed Supply fan with Volume matching system. The list of sensors includes discharge air temperature, mixed air temperature, duct static pressure, supply flow, and return flow. The following table shows how to calculate the COV rate.

Table 17: Change of Value Rate Calculation: Inputs

Sensor	Process ID	Update Interval (Hundredths of Seconds)	Approximate COVs Per Minute
Duct Static	Duct Static	100	60
Supply Flow	Airflow	100	60
Return Flow	Airflow	100	60
MA-T	MA-T	200	30
DA-T	DA-T	600	10
		Total	220

When these sensors are located on SA Bus devices, 220 is the expected COV rate. This number is below the maximum of 500 COV, and no communication issues should result.

Outputs and Commands

Excessive SA Bus traffic can also result when a fast process sends commands to multiple AOs on the SA Bus. AO commands are sent every time the proportional-integral-derivative (PID) loop execution results in a new value. The FX-PC controllers can issue only 10 commands on the SA Bus per pass of the token. If excessive AO commands are generated, the output queue may fill up, and the issuance of commands may be delayed for several token loop times. In addition, the BACnet protocol engine in the controller may become overwhelmed and discard messages when the total pending queue count exceeds 50 messages. This state can result in AOs or the FX-PCX or F4-XPMs appearing offline for short periods of time.

A healthy SA bus should not exceed 20 for the Maximum Output Queue Used value because that value requires 2 token passes to issue the commands. Use the following table to determine the command rate per minute on the SA Bus. The goal is to have the total number of commands under the 500 per minute with a 1 second or less token loop time.

Table 18: Command Rates: Outputs

Process ID	Time Constant (Seconds)	PID Interval (Seconds)	Approximate Command Rate Per Minute
CHWS-T HEX	90	10	6
HWS-T HW HEX	90	10	6
HWS-T Steam HEX	90	10	6
DA-H	200	12	5
DA-T	200	12	5
MA-T	80	12	5
CWS-T	600	60	1
RA-H	900	60	1
ZN-H	900	60	1
ZN-T	900	60	1
ZN-T LC	900	60	1
ZN-H LC	900	60	1

For example, assume you have a Mixed Air Single Path, Variable Speed Supply fan with Volume Matching system. The control loops include discharge control, duct status pressure control, and return fan flow control. Use the following table to calculate the command rate per minute.

Table 19: Command Rate Calculation: Outputs

Control Loop	Process ID	PID Interval (Seconds)	Command Rate Per Minute
Duct Static Pressure Control	Duct Static	1	60
Return Fan Flow Control	Airflow	1	60
Discharge Control	DA-T	12	5
		Total	125

When the outputs are located on SA Bus devices, 125 is the expected command rate per minute. This number is below the maximum of 500 commands per minute, and no communication issues result.

SA Bus Traffic Reduction

If the COV rate exceeds 500 for inputs or the command rate exceeds 500 for outputs, use the following strategies to reduce the traffic on your SA Bus:

- If possible, connect fast process inputs and outputs directly to the FX-PC controller. Fast processes include airflow, static or differential pressure control, central plant temperature control, and mixed air control. Move slower process inputs and outputs on the FX controller or supervisory device to devices on the SA Bus, and move the inputs and outputs for the fast processes to the FX controller or supervisory device in turn. The internal update process does not contribute to SA Bus communication issues.
- Limit the number of processes controlled across the SA Bus to use 8 AOs or fewer.
- If an FX-PCX or F4-XPM is used strictly for monitoring, place the device on the Field Controller (FC) Bus instead of the SA Bus. Alternatively, relocate AIs used for monitoring to a separate FX-PCX or F4-XPM on the FC Bus.
- If the AIs must remain on the SA Bus, configure the Filter Setup attribute to monitor only. If the AI is part of a process, reduce the resulting update interval by modifying the time constant attribute of the analog input object with the following steps:

  a. Set the Filter Setup attribute to the value Process Data.
  b. Set the Time Constant attribute to 0.3 times the desired update interval value. This configuration allows the low pass filter to continue to operate properly.

     ⓘ **Note:** Update interval has units of hundredths of a second. A time constant of 30 results in a 1 second update interval (displayed as 100 hundredths of a second).

- If you must leave inputs on the SA bus, slow down the process unless it will affect Pattern Recognition Adaptive Control (PRAC).

  Important: Use caution. Changing the PID interval or the analog input filtering may affect the PID controller's ability to provide proper control. This change also may affect the adaptive tuner's ability to tune the control process. Make sure that the AI has an update interval less than or equal to the PID interval. We recommend an AI update interval that is half the PID interval or less.

  - Change the inputs of the PID Pre Processor logic block in the CCT to match the current outputs (Table 20). Refer to the PID Pre-Processor section of the *Controller Tool Help (LIT-12011147)* for details on this block.

Table 20: Inputs and Matching Outputs

PID Pre-Processor Inputs	PID Pre-Processor Block Outputs	Notes
Process Range	Eff Process Range	--
Time Constant	Eff Time Constant	--
Process Dead Time	Eff Process Dead Time	--
Interval	Eff Period (Release 5.1 and later)	For the Interval value, add several seconds to the Eff Period value. Interval should be in the range of Time Constant/10 to Time Constant/5.

Table 20: Inputs and Matching Outputs

Proportional Band	Eff Proportional Band (Release 5.1 and later)	--
Integral Time	Eff Integral Time (Release 5.1 or later)	--
Saturation Time	Eff Saturation Time (Release 5.1 or later)	--
Standard Tuning	False	--

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