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Quantum Modbus Plus Network Option Modules (140 NOM 21X 00)

11

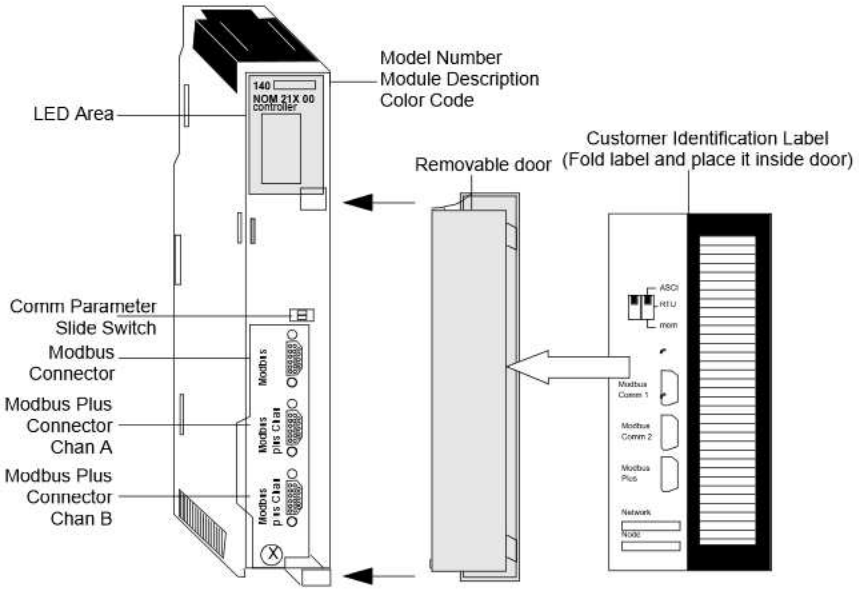
Quantum Modbus Plus Network Option Modules (140 NOM 21X 00)

Overview

This chapter describes the single and dual channel twisted-pair cable NOM 21X 00 modules.

Modbus Plus Module Figure

The following figure shows the parts of the Modbus Plus 140 NOM 21X 00 modules.



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Specifications Table

The Modbus Plus Head Single and Dual Channel modules provide extended communication capabilities for the Quantum system within a Modbus Plus configuration.

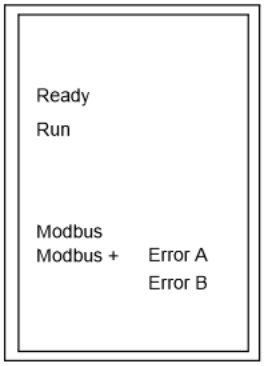
The following specifications show the Modbus Plus communication ports.

Communication Ports		
NOM 211 00	1 Modbus Plus network (RS-485) port (9-pin connector)	
NOM 212 00	2 Modbus Plus network (RS-485) ports (9-pin connectors) for dual connectivity on a single Modbus Plus network. These ports handle identical versions of all inbound and outbound transactions and keep track of the data paths used for these transactions.	
Both Modules	1 Modbus (RS-232) serial port (9-pin connector) A bridge mode capability in the module permits a panel device connected to this port to access nodes on the Modbus Plus network or to access the local PLC directly without having to go out onto the network.	
Diagnostics	Power Up	Runtime
	RAM	RAM
	RAM Address	RAM Address
	Executive Checksum	Executive Checksum
	Processor	
Power Dissipation (Typical)	4 W	
Bus Current Required		
NOM 211 00	780 mA	
NOM 212 00	780 mA	

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LED Indicators Figure

The following figure shows the Modbus Plus NOM LED indicators.



LED Descriptions Table

The following table shows the Modbus Plus NOM LED Descriptions.

LEDs	Color	Indication when On
Ready	Green	The module has passed powerup diagnostics.
Run	Green	Indicates that the unit is in kernel mode–should always be OFF during normal operations.
Modbus	Green	Indicates communication is active on the single RS-232 serial port.
Modbus+	Green	Indicates communication is active on the Modbus Plus port.
Error A	Red	There is an error condition on Cable A of a dual cable Modbus Plus network (140 NOM 212 00 only).
Error B	Red	There is an error condition on Cable B of a dual cable Modbus Plus network (140 NOM 212 00 only).

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Error Codes Table

The blinking run LED error codes for the NOM module shows the number of times the Run LED on the NOM module blinks for each type of error and the crash codes for each (all codes are in hex).

The following table shows the blinking run LED error codes for the NOM module.

Number of Blinks	Code	Error
Steady	014H	normal power down event
2	815	ram sequence error
3	49H	illegal data command received by bypass code
	4BH	diagnostics test pattern invalid in the icb block
	4CH	diagnostics test pattern invalid in the page 0
	4DH	icb address not the same as found in hcb
	4EH	bad code selected for mstrout_sel proc
	52H	config table exec_id is different than the sys table exec_id
	53H	got a pupinit hook for neither S985 nor S975 addr
	56H	did not get bus ack form 984 interface within 400 ms
	59H	unexpected modbus port state in send command to 680 proc
	5AH	system table missing
	5BH	bad DPM critical byte write
4	616h	bad or unexpected interrupt
	617h	loopback error on modbus port 1
	618h	parity error
	619h	set port greater than 21
	61AH	controller ram size is less than 8k
	621H	modbus cmd-buffer overflow
	622H	modbus cmd-length is zero
	623H	modbus abort command error
	624H	bad modbus state trn-int
	625H	bad modbus state rcv-int
	626H	bad comm state trn_asc
	627H	transmit underflow error
	628H	bad comm state trn_tru
	629H	bad comm state rcv_asc
	62aH	bad comm state rcv_rtu
	62bH	bad transmit comm state
	62cH	bad receive comm state

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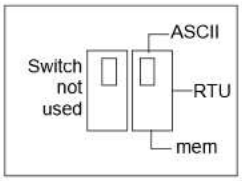
	62dH	bad modbus state tmr0_evt
	62eH	bad uart interrupt
	631H	UPI timeout error
	632H	bad UPI response opcode
	633H	UPI bus diagnostic error
	634H	mbp bus interference error
	635H	bad mbp response opcode
	636H	timeout waiting for mbp
	637H	mbp out of synchronization
	638H	mbp invalid path
	639H	peer did not respond with complement of the opcode
	63AH	peer unable to come out of transitions at powerup
	681h	bad master state
	682h	bad slave state
	683h	unknown routing failure to send
	684h	bad port number in set () proc
	685h	bad port number in reset () proc
	686h	bad port number in getport () proc
	687h	bad port number in bitpos () proc
	688h	bad port number in enable_transmit_interrupt () proc
	689h	bad port number in enable_receive_interrupt () proc
	68ah	bad port number in disable_transmit_interrupt () proc
	68bh	bad port number in
	691h	privilege flag is not reset in the session timeout proc
	692h	bad port number in chkmst_hdw () proc
	6Alh	unknown controller type in reset busy flag
	6A2h	unknown function code in generate_poll_cmd () proc
	6A3h	unknown function code in generate_logout_msg () proc
	6A4h	slave link timeout on port other than port #9
	6A5h	illegal bypass command received by bypass code
5	513h	ram address test error
6	412h	ram data test error
7	311h	prom checksum error

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Front Panel Switches

Two, three-position slide switches are located on the front of the unit. The switch on the left is not used. The three-position slide switch on the right is used to select the comm parameter settings for the Modbus (RS-232) port provided with the Modbus Plus option module. Three options are available, as shown below.

The following figure shows the front panel switches.



Rear Panel Switches

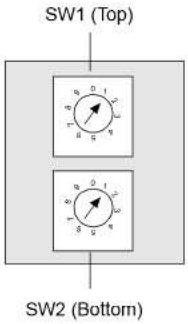
Two rotary switches are located on the rear panel of the modules. They are used together to set the Modbus Plus node and Modbus port address for the unit.

Note: The highest address that may be set with these switches is 64.

Rotary SW1 (top switch) sets the upper digit (tens), and rotary SW2 (bottom switch) sets the lower digit (ones) of the Modbus Plus node address. The illustration below shows the setting for an example address of 11.

SW1 and SW2 Switches Figure

The following figure shows the SW1 and SW2 switches.



Note: If "0," or an address greater than 64 is selected, the Modbus + LED will be "on" steady, to indicate the selection of an invalid address.

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SW1 and SW2 Address Settings

The following table shows the address settings for the SW1 and SW2 switches.

Node Address	SW1	SW2
1 ... 9	0	1 ... 9
10 ... 19	1	0 ... 9
20 ... 29	2	0 ... 9
30 ... 39	3	0 ... 9
40 ... 49	4	0 ... 9
50 ... 59	5	0 ... 9
60 ... 64	6	1 ... 4

Note: If "0," or an address greater than 64 is selected, the Modbus + LED will be "on" steady, to indicate the selection of an invalid address.

ASCII Comm Port Parameters

The following table shows the ASCII comm port parameters.

Baud	2,400
Parity	Even
Data Bits	7
Stop Bits	1
Device Address	Rear panel rotary switch setting

Setting the slide switch to the middle position assigns remote terminal unit (RTU) functionality to the port; the following comm parameters are set and cannot be changed:

RTU Comm Port Parameters

The following table shows the RTU comm port parameters.

Baud	9,600
Parity	Even
Data Bits	8
Stop Bits	1
Device Address	Rear panel rotary switch setting

Setting the slide switch to the bottom position gives you the ability to assign comm parameters to the port in software; the following parameters are valid.

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Valid Comm Port Parameters

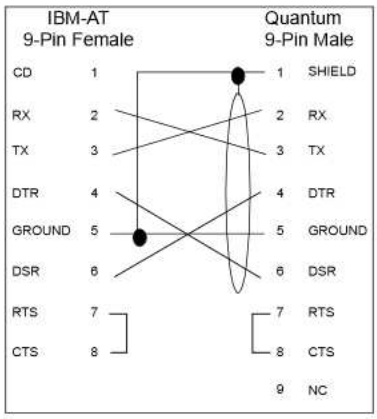
The following table shows the valid comm port parameters.

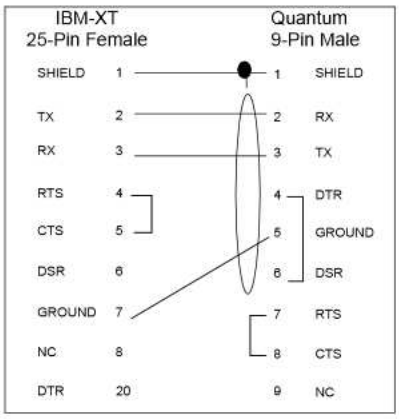
Baud	19,200	1,200
	9,600	600
	7,200	300
	4,800	150
	3,600	134.5
	2,400	110
	2,000	75
	1,800	50
Data Bits	7 / 8	
Stop Bits	1 / 2	
Parity	Enable/Disable Odd/Even	
Device Address	Rear panel rotary switch setting	

Modbus Connector Pinouts

The NOM modules are equipped with a nine-pin RS-232C connector that supports Modicon's proprietary Modbus communication protocol. The following is the Modbus port pinout connections for 9-pin and 25-pin connections.

The following figures show the Modbus port pinout connections for 9-pin (left) and 25-pin (right).





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Quantum Modbus Plus Networking Module (140 NOM 252 00)

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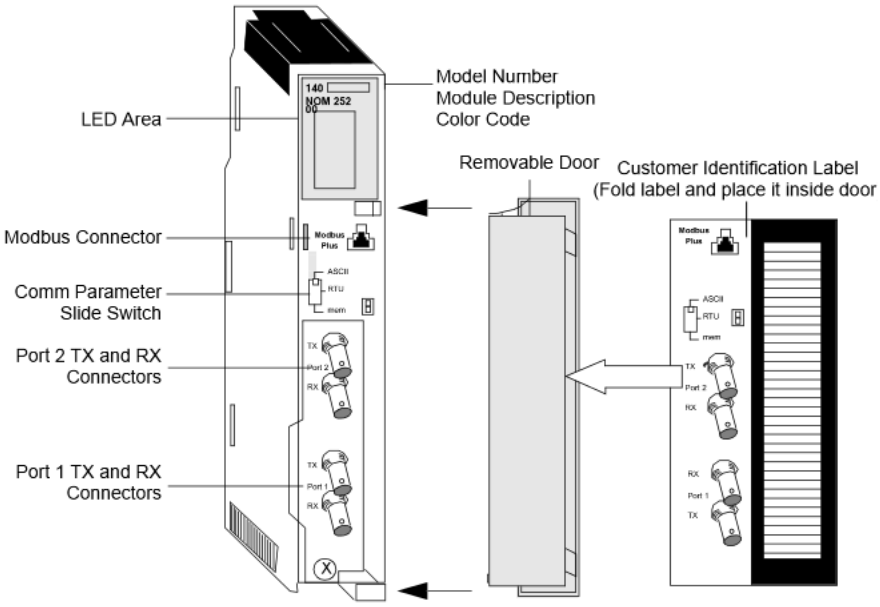
Quantum Networking Modbus Plus on Fiber Module (140 NOM 252 00)

Overview

The following information pertains to the Modbus Plus on Fiber module (140 NOM 252 00).

Modbus Plus on Fiber Module Figure

The following figure shows the parts of the Modbus Plus 140 NOM 252 00 module.



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Specifications Table

The Modbus Plus on Fiber module provides connectivity to Modbus Plus nodes by fiber cable.

The following table shows the specifications for the NOM 252 00 module.

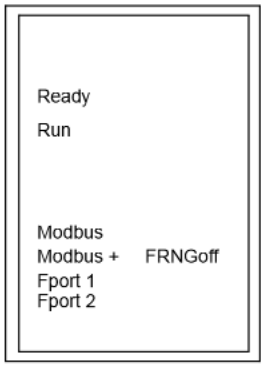
General Communication Ports	
Optical Ports	2 (consisting of an optical receiver and transmitter)
Modbus Port	1 RJ45 (phone jack-type) connector
Transmission/Data Rate	1 Mbit/second for Modbus Plus with Bi-Phase S encoded data
Optical Interface	ST-Type connectors
Pulse Width Distortions and Jitter	5 ns or better
Wavelength	820 micrometer
Power Loss Budget (includes 3 dB of system margins).	50/125 micrometer fiber - 6.5 dB
	62.5/125 micrometer fiber - 11 dB
	100/140 micrometer fiber - 16.5 dB
Maximum Distance for point-to-point connection	2 km over 50 micrometer fiber
	3 km over 62.5 micrometer fiber
	3 km over 100 micrometer fiber
Maximum System Length in Self Healing Ring Configuration	10 km over 62.5 micrometer fiber
Optical Transmitter Specifications	
Optical Power (Measured with 1 m test fiber)	-12.8 ... -19.8 dBm average power in 50/125 micrometer fiber cable
	-9.0 ... -16 dBm average power in 62.5/125 micrometer fiber cable
	-3,5 ... -10.5 dBm average power in 100/140 micrometer fiber cable
Rise/Fall Time	20 ns or better
Silence (OFF leakage)	-43 dBm
Optical Receiver Specifications	
Receiver Sensitivity	-30 dBm average power
Dynamic Range	-20 dB
Detected Silence	-36 dBm
Miscellaneous Specifications	

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Diagnostics	Power Up	Runtime
	RAM	RAM
	RAM Address	RAM Address
	Executive Checksum	Executive Checksum
	Processor	
Power Dissipation	4 W	
Bus Current Required	750 mA max	
External Power	Not required for this module	

LED Indicators Figure

The following figure shows the Modbus Plus on Fiber LED indicators.



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LED Descriptions Table

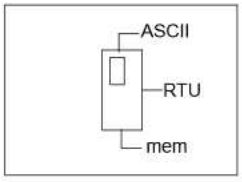
The following table shows the Modbus Plus on fiber LED descriptions.

LEDs	Color	Indication when On
Ready	Green	The module has passed powerup diagnostics.
Run	Green	Indicates that the unit is in kernel mode – should always be OFF during normal operations. Note: The table for the NOM 21X 00 shows the number of times the RUN LED on the Modbus Plus on Fiber Module blinks for each type of error and the crash codes for each (all codes are in hex).
Modbus	Green	Indicates communication is active on the single RS-232 serial port.
Modbus+	Green	Indicates communication is active on the Modbus Plus port.
Fport1	Green	Indicates an optical signal has been received on fiber optic Port 1.
Fport2	Green	Indicates an optical signal has been received on fiber optic Port 2.
FRNGoff	Red	Indicates the first break in a self healing ring.

Front Panel Switch

A three-position slide switch is located on the front of the unit. This switch is used to select the comm parameter settings for the Modbus (RS-232) port. Three options are available, as shown below.

The following figure shows the front panel switch.



Setting the slide switch to the top position assigns ASCII functionality to the port; the following comm parameters are set and cannot be changed.

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ASCII Comm Port Parameters

The following table shows the ASCII comm port parameters.

Baud	2,400
Parity	Even
Data Bits	7
Stop Bits	1
Device Address	Rear panel rotary switch setting

Setting the slide switch to the middle position assigns remote terminal unit (RTU) functionality to the port; the following comm parameters are set and cannot be changed:

RTU Comm Port Parameters

The following table shows the RTU comm port parameters.

Baud	9,600
Parity	Even
Data Bits	8
Stop Bits	1
Device Address	Rear panel rotary switch setting

Setting the slide switch to the bottom position gives you the ability to assign comm parameters to the port in software; the following parameters are valid.

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Valid Comm Port Parameters

The following table shows the valid comm port parameters.

Baud	19,200	1,200
	9,600	600
	7,200	300
	4,800	150
	3,600	134.5
	2,400	110
	2,000	75
	1,800	50
Data Bits	7 / 8	
Stop Bits	1 / 2	
Parity	Enable/Disable Odd/Even	
Device Address	Rear panel rotary switch setting	

Rear Panel Switches

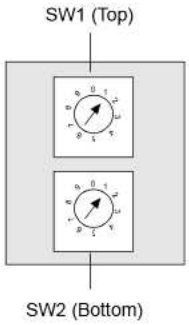
Two rotary switches are located on the rear panel of the modules. They are used together to set the Modbus Plus node and Modbus port address for the unit.

Note: The highest address that may be set with these switches is 64.

Rotary SW1 (top switch) sets the upper digit (tens), and rotary SW2 (bottom switch) sets the lower digit (ones) of the Modbus Plus node address. The illustration below shows the setting for an example address of 11.

SW1 and SW2 Switches Figure

The following figure shows the SW1 (top) and SW2 (bottom) switches.



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SW1 and SW2 Address Settings

The following figure shows the node address settings for the SW1 and SW2 switches.

Node Address	SW1	SW2
1 ... 9	0	1 ... 9
10 ... 19	1	0 ... 9
20 ... 29	2	0 ... 9
30 ... 39	3	0 ... 9
40 ... 49	4	0 ... 9
50 ... 59	5	0 ... 9
60 ... 64	6	1 ... 4

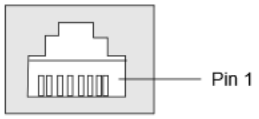
Note: If "0" or an address greater than 64 is selected, the Modbus + LED will be "on" steady, to indicate the selection of an invalid address.

Modbus Connector

The NOM 252 00 module is equipped with an RS-232 port (see below) located on the front of the module. This port uses an eight-position RJ45 (phone jack-type) connector.

Modbus pin 1 Figure

The following figure shows the NOM 252 00 Pin 1 connector.

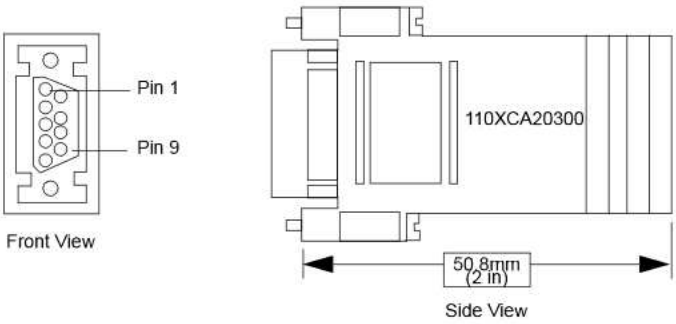


Note: A D-shell adapter is available from Modicon for NOM 252 00-to-computer connections: a (110 XCA 20 300) 9-pin adapter for PC-AT type computers (see the illustration pinout table below).

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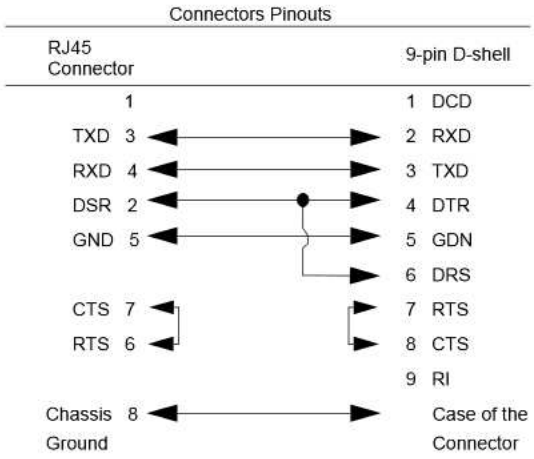
Pinouts Figures

The following figures show the 9-pin adapter front view (left) and side view (right).



Connector Pinouts Figure

The following figure shows the 9-pin RJ45 connector schematic.



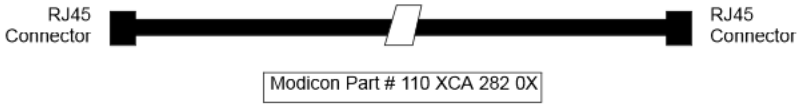
BJ45 Cable Types

This following shows an example of the 110 XCA 282 0X cable. A table is also provided which includes part numbers and cable lengths.

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RJ45 Connector Figure

The following figure shows the RJ45 connector (Modicon Part # 110 XCA 282 OX).



Modicon Part # 110 XCA 282 0X

BJ45 Cable Part Numbers Table

Cable Part Numbers	Cable Lengths
110 XCA 282 01	3 ft. (0.91 m)
110 XCA 282 02	10 ft. (3 m)
110 XCA 282 03	20 ft. (6 m)

Fiber Optic Cable Connections

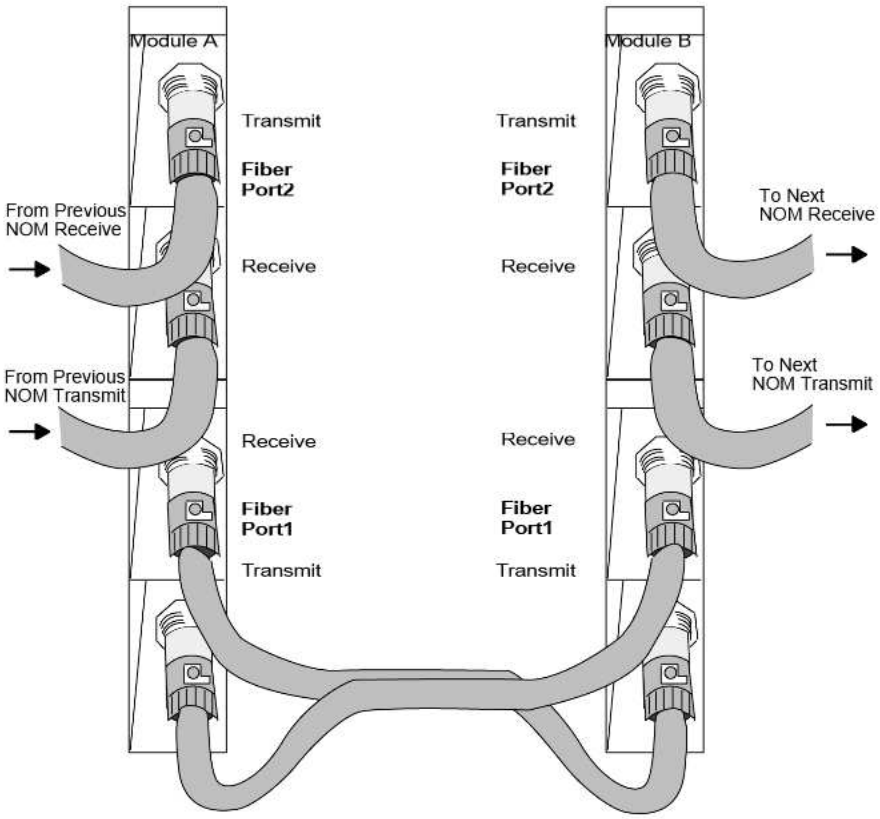
The NOM 252 00 module is connected in the Quantum system by a fiber optic cable (see below). The cable has two strands. Each module transmits a signal in one direction. For this reason, each strand must be connected to the transmit port on one module and the receive port on the other.

One strand of the fiber optic cable is labelled every 10 inches with the manufacturer's name and the cable specifications. This is the only way to distinguish the two strands.

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Fiber Optic Cable Connections Figure

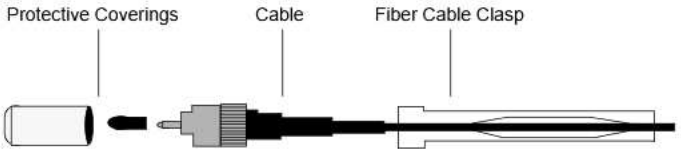
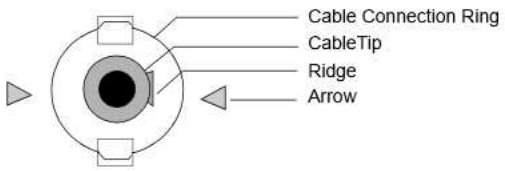
The following figure shows the fiber optic cable connections.



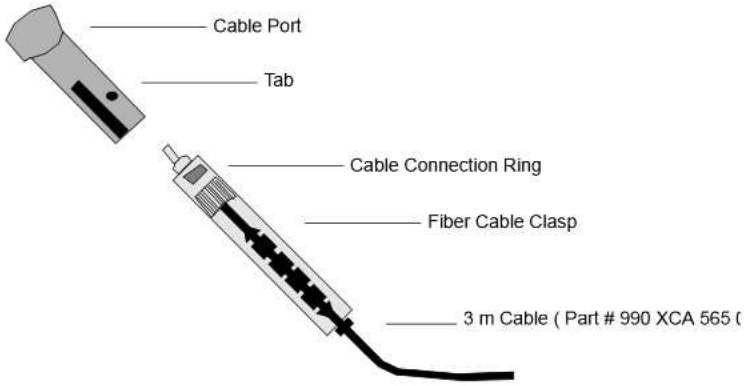
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Connecting the Fiber Optic Cable

The following steps show how to connect the fiber optic cable.

Step	Action
1	Remove the protective plastic coverings from the cable ports and the tips of the cable. Snap one of the fiber cable clasps (shipped with the module) over the cable so that the wider end of the tool is closest to the cable end. 
2	Turn the connection ring so that one of the arrows on the side of the ring lines up with the ridge inside. 

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Step	Action
3	a. Slide the tool up to the connection ring. b. Gripping the cable with the plastic cable clasp, slide the cable end onto the lower cable port. The arrow and the ridge on the connection ring should lineup with the slot on the left of the cable port. c. Use the clasp to push the cable over the tab on top of the port. d. Turn the cable to the right, so that the tab locks securely e. Remove the clasp. f. Repeat this process with the remaining strand of cable. 

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Fiber Optic Overview and Configurations

There are many benefits that result from the use of fiber optics. Some of the benefits are:

- Longer distances between nodes (up to 3 km), thereby, increasing the total length of the network.
- Fiber optic medium is not susceptible to the effects of electromagnetic interference, RF interference, and lightning.
- Intrinsically safe links that are required in many hazardous industrial environments.
- Total electrical isolation between terminal points on the link.

Here are four typical configurations that show the wide range of the network architecture:

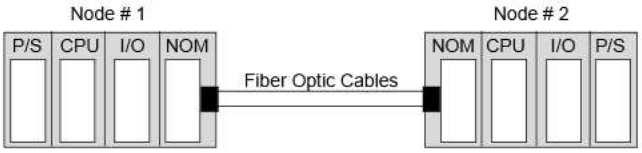
- Point-to-Point connection
- Bus configuration
- Tree and Star configurations
- Self Healing Ring configuration

Point-to-Point Configuration

This type of configuration (see below) allows communication over the distance of up to 3 km through harsh industrial environments.

Point-to-Point Configuration Example Figure

The following figure shows the point-to-point configuration.



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Bus Configuration

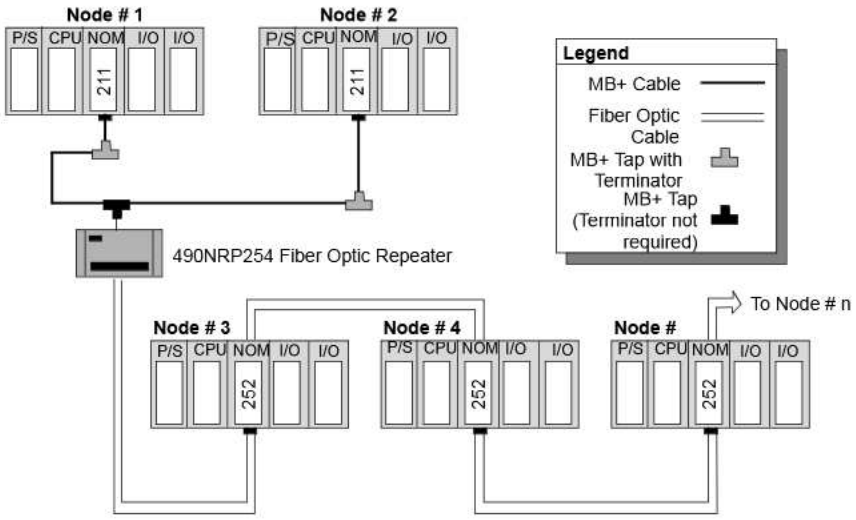
This type of configuration is used when it is required to connect a number of fiber nodes and can be used to increase the distance of a standard Modbus Plus network by changing to a fiber medium. This kind of network allows the connection of up to 32 Quantum NOM 252 nodes over the distance of 5 km.

The following illustrations show the NOM 252 00 module in a mixed fiber optic/ twisted pairs bus configuration network and a pure fiber optic bus configuration network.

	**CAUTION** **Equipment Failure** The loss of a single node in this configuration disables the rest of the network. It is suggested that the Self Healing Ring configuration be used to avoid this problem. **Failure to observe this precaution can result in injury or equipment damage.**

Bus Configuration Example 1

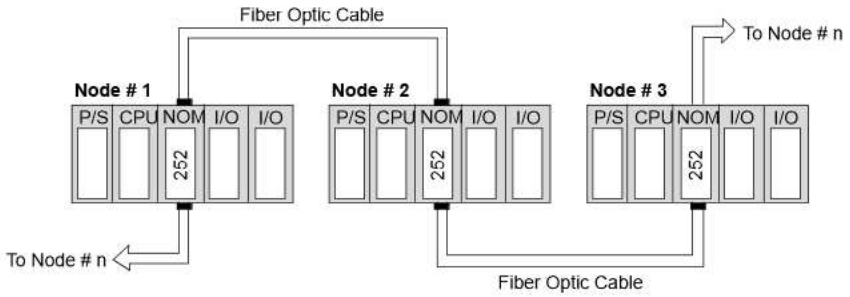
The following figure shows the mixed fiber optic/copper network.



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Bus Configuration Example 2

The following figure shows the pure fiber optic network.



Note: The distance between nodes on fiber is limited by the maximum allowable power loss from end-to-end (3 km over 62.5 mm fiber). Power loss includes the fiber optic cable attenuation, connector losses at the Fiber Optic Receiver and Transmitter ports, and the system margin of 3 dB.

The end NOM 252 00 in this configuration will have the FRNGoff LED active and will display the Cable B Framing error in the MBPSTAT (in ladder logic).

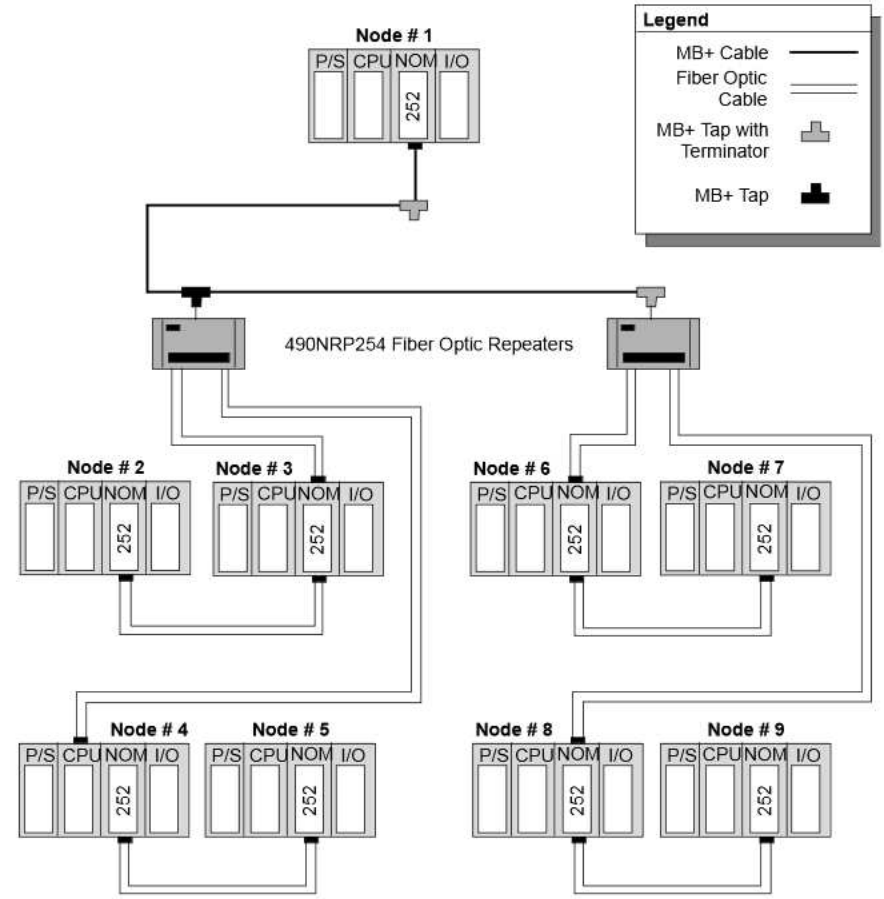
Tree and Star Configurations

The use of tree and star configurations can provide flexibility in the layout of Modbus Plus and NOM 252 00 networks. The following illustrations show examples of tree and star configurations. Additional repeaters can be connected in order to extend communication between electrical links.

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Tree Configuration Example

The following figure shows the tree configuration.

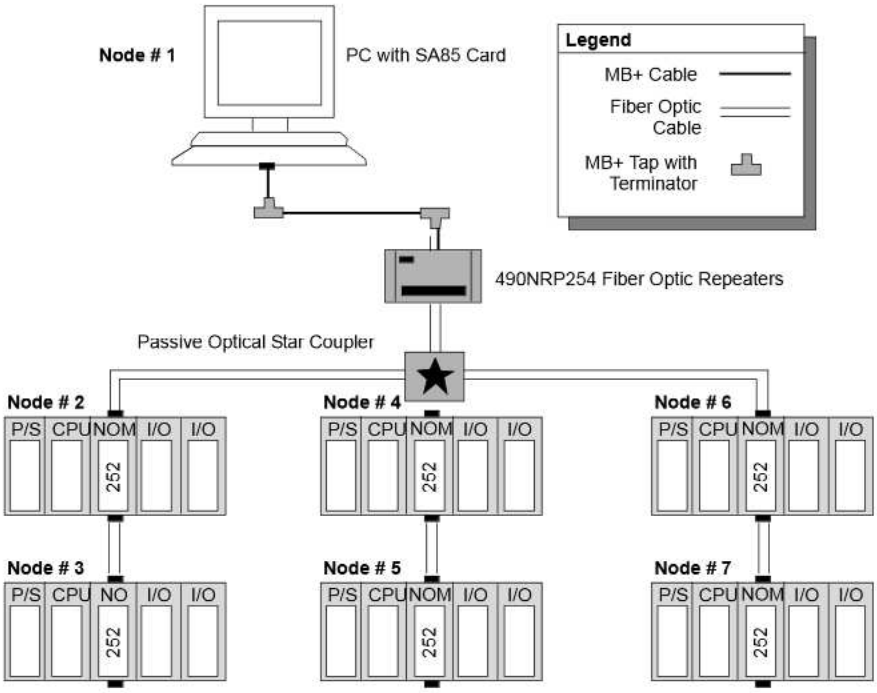


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Star Coupler Configuration Example

Commercially available passive optical star coupler devices can also be introduced to the optical link to provide added flexibility to the NOM 252 00 network. A typical four-port star coupler could be used as follows on a NOM 252 00 optic link.

The following figure shows the star coupler configuration.



Note: If a passive optical star coupler is used:

- The number of repeaters and the length of each segment of fiber cable must be calculated separately and cannot exceed a maximum pulse width, distortions of 200 ns, between any nodes at the end of the branches.
- 100/140 mm fiber cable is recommended because of its higher available optical power.
- The use of a maximum of four ports of the passive optical star coupler is recommended.

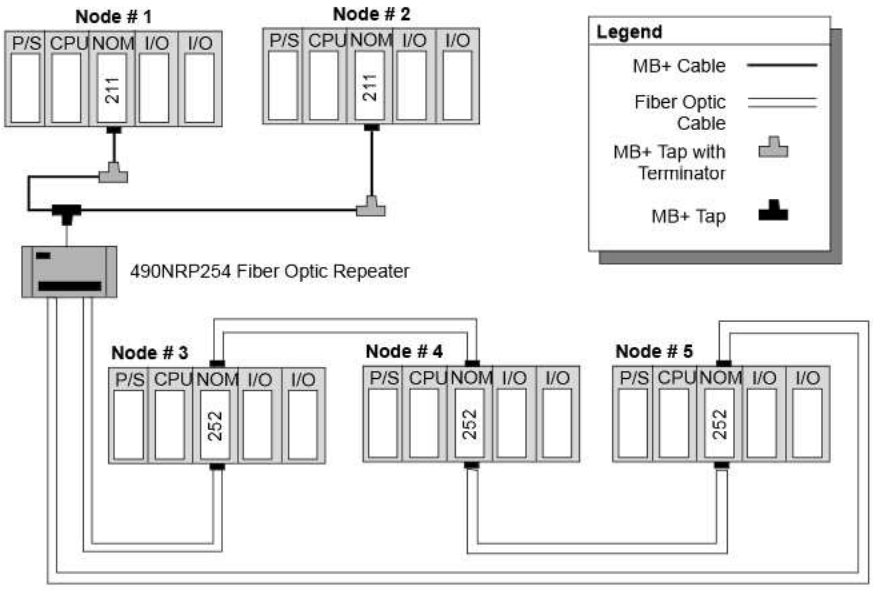
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Self Healing Ring Configuration

This configuration can be achieved by connecting the unused fiber optic ports of the first and last NOM 252 00 directly or through the fiber optic repeater, if a mixed fiber optic/twisted pairs network is used. This type of connection has all the advantages of the previously described configurations, along with built-in redundancy. A broken connection between any two Quantum modules in the ring will automatically reconfigure the network to the Bus Configuration and continue the communication.

Self-Healing Ring Configuration Example

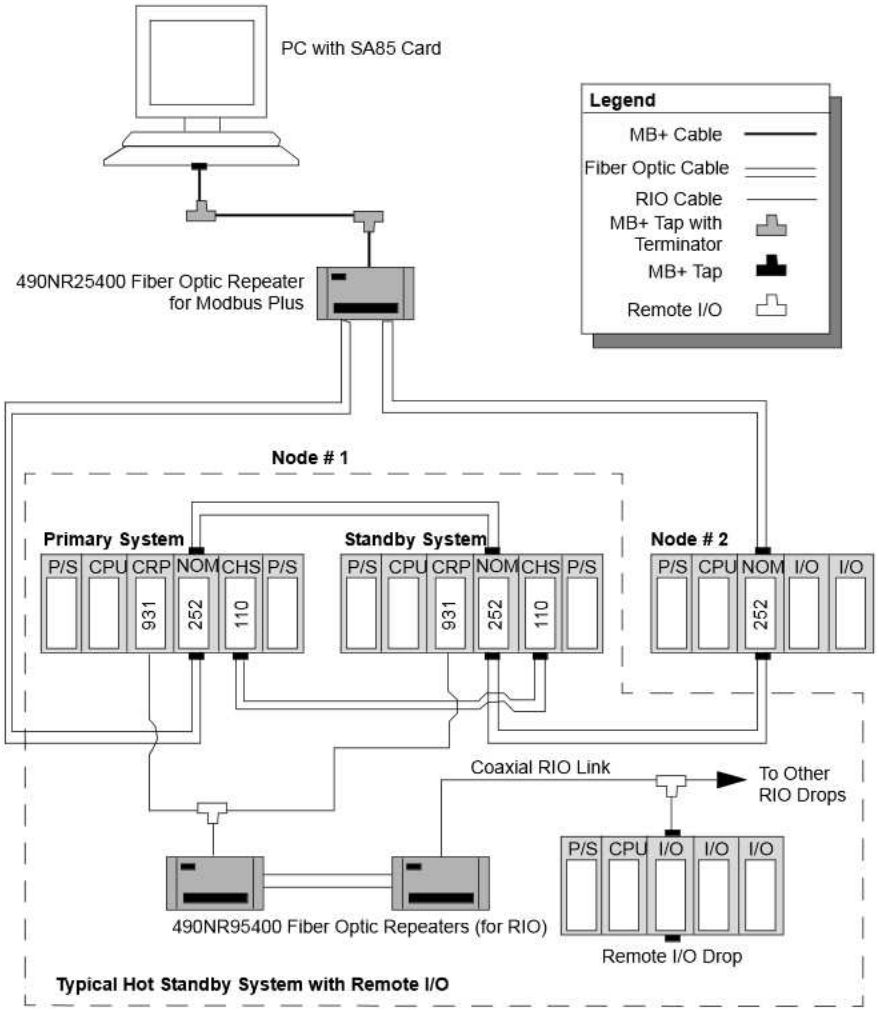
The following figure shows a self healing ring configuration example.



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Hot Standby Systems Figure

The following figure shows the self healing ring configuration for hot standby systems example.



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Network Status

The information about the condition of the network is presented in the form of Network Status. This information indicates the loss of connection (the first break in the self healing ring) and is similar to the way existing 140 NOM 212 00 reports the loss of redundant cable.

The break of the fiber cable will be detected by the module not receiving the signal from the side where the cable is broken and will be reported as a Cable B Framing error by MBPSTAT. This condition will also activate the FRNGoff LED on the front of the module.

Recommended Materials for Fiber Optic Links

Modicon does not manufacture fiber optic products such as cables, connectors, or special tools. However, we have experience with third party suppliers of materials and can give some guidelines on what will work with our products.

Connectors

The following table shows the connector types

Connector Type	Part Number	Operating Temperature
ST Bayonet (Epoxy)	3M 6105	-40 ... +805 C
ST Bayonet (Hot Melt)	3M 6100	-40 ... +605 C
ST Bayonet (Epoxy)	AMP 501380-5 Series	-30 ... +705 C
ST Bayonet (Epoxy)	AMP 503415-1 Series	-20 ... +755 C
Light_Crimp ST Style	AMP 503453-1 Series	-20 ... + 605 C
Mechanical Line Splice (one size fits all)	3M 2529 Fiberlok1 II	-40 ... +805C

Note: All connectors must have a short boot for strain relief.

Termination Kits

The following table shows the termination kits.

Kit Type	Part Number	Description
Bayonet ST (Epoxy)	AMP 503746-1	For all epoxy type ST style
Light_Crimp XTC	AMP 50330-2	For all Light_Crimp
Mechanical Line Splice	3M 2530	Fiber Splice Prep Kit, complete with cleaving tool
3M Hot Melt	3M 05-00185	110 V Termination Kit
	3M 05-00187	220 V Termination Kit

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Optical Star Passive Couplers

The AMP Model 95010-4 is a pig-tail option and must be used with an enclosure (use AMP Model 502402-4, a 19 in rack-mount enclosure, 1.7 in high).

Other Tools Table

The following table shows other tools that may be needed for fiber optic links.

Product	Part Number	Description/Use
3M (Photodyne) Optical Source Driver	9XT	Hand-held optical source driver (requires a light source)
3M (Photodyne) Optical Light Source	1700-0850-T	850 nm Light Source, ST Connectors for 9XT
3M (Photodyne) Power Meter	17XTA-2041	Hand-held Fiber Optic Power Meter
3M Optical Light Source, 660 nm, visible	7XE-0660-J	Use with 9XT to troubleshoot raw fiber, requires FC/ST patch cord
3M FC/ST Patch Cord	BANAV-FS-0001	Connects FC connector on 7XE to ST
3M Bare Fiber Adapter, ST-compatible	8194	Permits use of above source and meter to test raw fiber (two required)

Cables

It is recommended that you use 62.5/125 mm cable (such as AMP 503016-1, AMP 502986-1, or equivalent) with a maximum attenuation of 3.5 dB/km in most of the configurations.

Note: Modicon recommends using the 990 XCA 656 09 cable.

When passive star couplers are used, 100/140 mm cable (such as AMP 503016-3, AMP 502986-3, or equivalent) with a maximum attenuation of 5.0 dB/km is recommended because higher optical power can be pumped in 100 mm cable and as a result, greater distance (up to 1 km) between units can be achieved.

Note: All cables must have a maximum cable diameter of not more than 3 mm at the terminal side.

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Connections

The following information discusses connecting the NOM 252 00 on fiber cable, adding a new mode to the network, and repairing the break in the cable.

Note: When a new network is assembled, it is recommended that you connect all cables before powering up the system. Connect fiber optic cables as described previously in this section.

Adding a New Node to the Network

If a new node is added to an existing network in order to extend the network (at the end of any configuration), then a new node may be connected first by fiber cable and then hot-swapped to the backplane to avoid errors to the existing network.

If a new mode is added to the middle of the network, the fiber optic cables need to be disconnected from one side of the existing NOM 252 module and connected to port 1 or 2 of a new node. Additional fiber optic cable then needs to be connected to the second port of the new NOM 252 and to the next NOM 252 in the network, the new NOM 252 then has to be hot-swapped to the backplane.

Repairing the Break in the Cable

Because the NOM 252 00 will stop transmitting in the direction from which it is not receiving the signal, the replacement of a broken fiber optic cable and the reconnection of it will not re-establish communication over that segment. The hot swap of only one NOM 252 at the repaired connections is required to complete the connection.

Note: The break of any fiber connectors or fiber optic cables is the equivalent to the break of the trunk cable in a Modbus Plus network on copper.

For the self healing ring configuration, the repair of the first break in the fiber optic network has to be scheduled to the time when one of the units on either side of the repaired break can be hot-swapped without creating the problem by disconnecting the node.

Note: Self healing configurations are not considered redundant networks. High system availability can be achieved with redundant networks.

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Calculations

Calculate the number of NOM 252 00 modules in a fiber network using the following formula:

Step	Action
1	The total allowable pulse width distortions and jitter are limited to 20% of the bit period and is 200 nsec for the full fiber optic network.
2	The jitter contributed by the NOM 252 is 5 nsec max.
3	Jitter contributed by fiber optic repeaters (if used) is 40 nsec.
4	The formula to determine the number (N) of chained repeaters is: $N = \frac{200 \text{ nsec} - X(L) \text{ nsec} - 40 \text{ nsec}}{5 \text{ nsec}} + 1$ where "L" is the total cable length (km), and "X" is the jitter (added by the fiber optic cable) in nsec/km: X = 3 ns/km for 50/125 micron meters 5 ns/km for 62.5/125 micron meters 7.5 ns/km for 100/140 micron meters

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