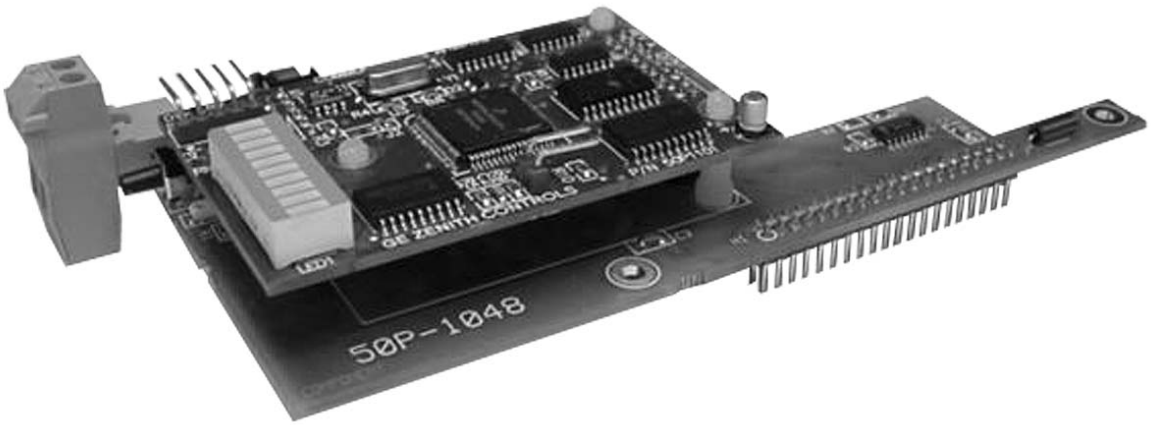
CATERPILLAR®

MX150 / MX250 *(MX Version 6.0+ Only)*
Modbus Network Card *50P-2035*



Operation and Maintenance Manual

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Disclaimer

CATERPILLAR disclaims any and all liability for use of third-party application software that will be used to control the Automatic Transfer Switches.

⚠ WARNING ⚠

Automatic Transfer Switches are often used in critical applications. Failure of an ATS to operate properly could cause serious personal injury (including death) and property damage. Therefore, extreme caution must be used when designing or using programming software that will communicate with the ATS. Improper use of the Modbus network variables will cause the Automatic Transfer Switch to malfunction. Always conduct a full test and debug of the programming software prior to installing and using it in the system.

Overview

The Modbus network card is designed for the MX150 and MX250 controllers, version 6.0 program and above. If the controller is ordered with the Modbus option, the Modbus card will reside on the back of the controller board and it will be part of the controller assembly. The purpose of this card is to allow the controller to be available on a Modbus network as a slave device. This allows a master device, such as a programmable logic controller (PLC), to obtain information from the controller and have that information available for control, data acquisition and monitoring.

Every Modbus network consists of one master device and at least one slave device. All devices on the network are daisy-chained using a twisted pair cable (see Appendix E). Each slave device is assigned a unique address from 1-247. Factory default for each Modbus card is Slave Address 1. This address enables the master to distinguish between the various slaves on the network. It also allows the master device to send a query command to the addressed slave. When the addressed slave receives this command it will send back an appropriate response to the master. *Table 1* shows a list of Modbus commands which the Modbus network card supports. Reference Appendix G for a more detailed description of the Modbus commands.

Modbus Command	Modbus Command Description
01	Read Coil Status
03	Read Holding Register
05	Write Single Coil
06	Write Single Holding Register
15	Write Multiple Coils
16	Write Multiple Holding Registers

Table 1 – Supported Modbus Commands

The Modbus commands allow the master device to read data from, and write data to, specific memory locations in the controller. These memory locations, which are listed in Appendix A and B, make up the Modbus network variables. These variables allow the reading of controller status, configuration, etc. The variables which can be written to (reference Appendix B), include timer values, Fail/Restore settings, and control variables.

Both lists contain a parameter name column that displays the name of the memory locations. The non-indented names in that column are 16-bit registers while the indented ones are individual bits, which make up the 16-bit registers. For example, Status 0, a non-indented name, is a 16-bit register that consists of the following bits:

- S1 Available
- S2 Available
- Load, No Load, Fast Load Test Status
- Load Test Running
- Alarm
- ATS Not in Auto Mode
- Automatic Transfer Relay

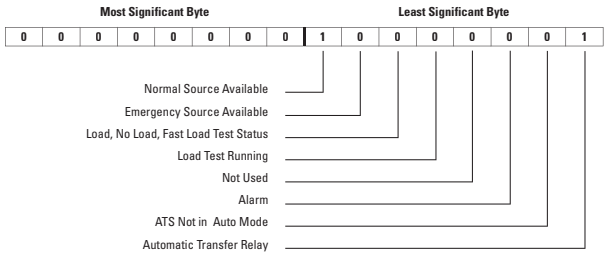


Figure 1 – Status 0 Register

These bits make up the least significant byte of the Status 0 register, while the most significant byte of the Status 0 register contains zeros. *Figure 1* shows an example of what the Master device would see if it read back the entire Status 0 register. In this example, the Master device would read back the decimal value of 129 from the Status 0 register. When this value is decoded, the Master finds out that the S1 source is available and the Automatic Transfer Relay input is active. The Master also has the option of reading the individual bits, indented under Status 0. This allows the Master to know the status of each parameter without doing any decoding. The second column contains the actual addresses for the network variables. These addresses are used when the Master is reading a Holding Register (16-bit reg). The third column contains addresses that are used when the Master is reading a Coil (individual bit). The remaining columns show the values and ranges (only in Appendix B) for the network variables.

LED Indicator

The Modbus card has a 10-segment LED module (Refer to Appendix E for location). These LED's display the slave address of the card as well as transmit and receive status. The first LED from the bottom indicates the receive status, the second LED indicates the transmit status. When a Modbus packet has been successfully transmitted or received, the associated LED will light for 100ms. If another packet is sent or received before the 100ms elapses, the LED on-time will be extended by another 100ms. LED's 3-10 display the slave address of the controller as a binary number with each LED corresponding to a bit. *Figure 2* shows the 10-segment LED module along with LED's 3, 5, and 6 being lit. The lit LED's correspond to slave address 13.

LED 10 - 2^7
LED 9 - 2^6
LED 8 - 2^5
LED 7 - 2^4
LED 6 - 2^3
LED 5 - 2^2
LED 4 - 2^1
LED 3 - 2^0
LED 2 - Transmit
LED 1 - Receive

Figure 2 – LED Module

Installation

Installation on the Controller

If the Modbus network card is not installed on the controller, do the following to install it:

1. Open the ATS cabinet. If the ATS has power going to it, be EXTREMELY cautious not to touch any energized parts.
2. Remove the two Engine Start wires from the P-Relay(s) if applicable (not applicable in Utility-Utility applications). Use electrical tape to tape over the exposed ends of both wires.
3. Obtain a grounding wrist strap and put the elastic end of the strap on your wrist. Attach the alligator clip end to the controller chassis or an equivalent earth ground.
4. Remove the J5 plug from the controller (located on bottom of board), this will remove power. If controller is equipped for external battery, also remove the J4 connector from the side of the controller. When power is removed from the controller, the ATS will not transfer.
5. Unscrew the black metal cover from the back of the controller. Be sure not to lose any screws.
6. Remove the three screws from the metal standoffs on the controller. Plug the Modbus network card into socket J3 and fasten it to the controller with the three screws (previously removed).
7. Screw the black metal cover back on.
8. Reconnect the J5 plug back into the controller. (If controller is equipped for external battery, also reconnect the J4 connector on the side of the controller.)
9. Connect the two Engine Start wires to the P-Relay(s) if applicable.
10. Once the controller has power, the network option must be enabled by going into the CFG menu for the network option (Reference Appendix H).
11. When the network option is enabled, exit the CFG menu.

Termination Resistor

Located on the bottom of the Modbus card is jumper J6 (See Appendix C), which enables or disables a termination resistor on the board *(Figure 3)*. Jumper J6 is disabled when it comes from the factory.

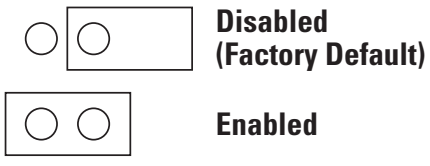


Figure 3 – Jumper J6

The only time that Jumper J6 should be enabled is when its corresponding Modbus card is the last device at the end of the chain.

Configuring a Modbus Network Card

The Modbus card can be configured in a variety of ways. The configuration of the card includes configuring the slave address, RTU or ASCII mode, baud rate, parity, and stop bits **(the default settings are Slave Address 1, RTU mode, 9600 Baud, No Parity and 2 Stop Bits).** These slave settings will be setup by the user and must match the master device settings for proper communications. The user configures these settings using the Modbus Configuration application (Caterpillar Part # 50P-1111). This application can also read the configuration of the card. The following is a procedure for configuring the Modbus Network card (See Appendix D for wiring connections).

To change configuration settings:

1. Disconnect the two Engine Start wires from the P-Relay(s), if applicable. Use electrical tape to tape over the exposed ends of both wires.
2. Obtain a grounding wrist strap and put the elastic end of the strap on your wrist. Attach the alligator clip end to the controller chassis, or an equivalent earth ground.
3. Remove the J5 plug from the controller (located on bottom of board). This will remove power. (If controller is equipped for external battery, also remove the J4 connector from the side of the controller.)
4. Unscrew the black metal cover from the back of the controller.
5. Install the J4 jumper on the back of the Modbus Card (Refer to Appendix C for location).
6. Connect the RS232/485 converter (Caterpillar Part # 50W-1208) to the PC that has the Configuration Application Software Installed.
7. Connect a twisted pair cable between the RS485 connector of the Modbus Card and the RS485 connector of the RS232/485 converter. Verify correct polarity (Refer to Appendix D for connection).
8. Reconnect the J5 plug. This will restore power to the controller.
9. Start up the Configuration Application on the PC.
10. Click on the “READ” button to read the device's current configuration.
11. Click on the “MODIFY” button to enable parameter changing.
12. Make necessary changes to the communication settings.
13. Click on the “WRITE” button to send the new configuration to the Modbus Card.
14. Verify that the configuration was written by clicking the “READ” button, and verify the settings.
15. Remove the J5 plug from the controller.
16. Remove the J4 jumper from the Modbus Card.
17. Screw the black metal cover back on the controller.
18. Reconnect the J5 plug to the controller. (If controller is equipped for external battery, also reconnect the J4 connector on the side of the controller.)
19. Reconnect the two Engine Start wires to the P-Relay(s), if applicable.

Testing a Modbus Network

The Modbus network can be tested using the components in the Modbus Configuration package (Cat Part # 50P-1124). Reference Appendix D for connections.

1. If testing a network consisting of more than one card, make sure that all of the cards are daisy chained as shown in Appendix E. Verify that all Modbus cards are in the run mode (jumper J4 on the Modbus card must not be installed). Termination jumper (J6) is only installed on the last card on the network daisy chain.
2. Connect the RS232/485 converter (CAT Part # 50W-1208) to the PC that contains the Configuration software (CAT Part # 50P-1111). A cable needs to be connected to the RS485 connector of the Modbus card and the RS485 connector of the RS232/485 connector. Check to make sure that the polarity connections are correct. (See Appendix D)
3. Run the Configuration software on the PC.
4. Press the TEST button and then verify that the settings in the Communication Settings section match the settings of the Modbus network. If necessary, make changes to the settings and click the NEXT button.
5. The software will now scan the network and display the serial number of all controllers, which have the Modbus card attached. The user can select any of the listed serial numbers and execute a load test on a controller associated with the selected serial number, but only one controller can be tested at a time.

CDP Programmable Exercisers

CDP Programmable Exercisers are an option on the MX150 and MX250. They allow the controller to be programmed to automatically test the generator and Automatic Transfer Switch. Up to seven exercisers can be programmed to run on a daily, 7 day, 14 day, or 28 day basis; or up to 24 exercisers can be programmed to run on a yearly basis.

Configuration information regarding CDP Programmable Exercisers is available in the Exerciser Configuration Register (Holding Register 40063):

Bit 0 of the Exerciser Configuration Register (Coil 81) indicates whether the controller is configured for CDT or CDP Programmable Exercisers. A one means the controller is configured for CDP Programmable Exercisers.

Bit 2 of the Exerciser Configuration Register (Coil 82) indicates whether or not the CDP Programmable Exercisers can be configured to run under load (transfer the ATS to the generator). A zero indicates that exercisers can only run No-Load. A one indicates that exercisers can be programmed to run Load or No-Load.

Holding Registers 40101 through 40110 are provided to control and report the status of the CDP Exercisers. These registers contain valid data only if the controller is configured for CDP Exercisers. If the controller is configured for CDP Exercisers, then Holding Register 40063, Bit 0 (Coil 81) will be set to 1.

Reading the CDP Exerciser Holding Registers

The controller may be programmed for multiple exercisers, depending on the status of the Exerciser Schedule Selection. All data relevant to every exerciser is read out through Holding Registers 40101 through 40110. These registers will contain data describing one exerciser at a time. The value of Holding Register 40101, "Exerciser Record Pointer", determines which exerciser is presently being displayed in Holding Registers 40102 through 40109.

To read the contents of a different exerciser, the Exerciser Record Pointer must be written. For example, in order to read data about CDP Exerciser #3, the Exerciser Record Pointer must be set to 3.

The controller will automatically place all exercisers in chronological order.

CDT Exercisers

CDT Exercisers are a standard feature of the MX150 and MX250 (unless replaced by CDP Programmable Exercisers). They allow the controller to be programmed to automatically test the generator and Automatic Transfer Switch. The exerciser will run at the same time of day on a daily, 7 day, 14 day, or 28 day basis. Programming of the CDT Exerciser can be done only at the HMI on the front panel of the MX150 or MX250.

Configuration information regarding CDT Exercisers is available in the Exerciser Configuration Register (Holding Register 40063):

Bit 0 of the Exerciser Configuration Register (Coil 81) indicates whether the controller is configured for CDT or CDP Programmable Exercisers. A zero means the controller is configured for CDT Exercisers. Conversely, bit 1 implies the controller is configured for the CDP Exerciser.

Bit 1 of the Exerciser Configuration Register (Coil 82) indicates whether or not the CDT is configured for Load Exercises. A one indicates the CDT will run a Load Exercise. A zero indicates the CDT will run a No-Load Exercise.

The upper byte of the Exerciser Configuration Register (bits 15 through 8) indicates the CDT Exerciser Run Duration, in minutes.

Operation

Setting System Time

Holding Registers 40094 through 40099 are provided to control and report the status of the controller's System Time. Reading Holding Register 40094 through 40099 will report the current Hour, Minute, Day, Month, Year, and Day of Week to which controller's internal clock is currently set.

Writing the System Time Holding Registers

Holding Registers 40094 through 40098 must be written using a Write Multiple Holding Register Command (Function Code 16). This is to ensure that the data contained in these registers is a complete ordered set. Any attempt to write Holding Registers 40094, 40095, 40096, 40097, or 40098 with a Write Single Holding Register Command (Function Code 6), or a Write Multiple Holding Register Command (Function Code 16) that does not include the entire range of 40094 - 40098, will result in an Illegal Data Address exception response from the Modbus Card.

Note: Holding Register 40099, "System Time-Day of Week" is Read Only. The value of this register is automatically computed and updated by the controller, based on the calendar date.

Operation with In-Phase Monitor

Special consideration is required if the controller is configured with the In-Phase Monitor. Most Modbus network data and control are unavailable while the In-Phase Monitor is waiting for phase synchronization. The Modbus Network Card will return a "Slave Device Busy" exception code (06h) to all Modbus queries, except for queries to the System Busy Status Register (Holding Register 40112) or the System Busy Control Register (Holding Register 40113).

If the Modbus Network Card returns a Slave Device Busy exception code, information about the source of the busy condition may be available in the System Busy Status Register (Holding Register 40112). If Bit 0 of the System Busy Status Register (Coil 105) is set to one, the controller is busy waiting for phase synchronization.

If the controller is busy waiting for phase synchronization, the In-Phase Monitor may be bypassed over the Modbus network by performing the following sequence:

Warning: EXTREME CAUTION must be used when bypassing the In-Phase Monitor! Transferring between sources that are not in phase synchronization may cause unexpected operation, resulting in damage to plant equipment and personnel.

1. Set Bit 0 of the System Busy Control Register (Coil 113) to one. This is a request by the Modbus user to bypass the In-Phase Monitor.

2. Once an In-Phase Monitor bypass has been requested, and the controller has been waiting for phase synchronization for more than one minute, the controller will request confirmation of the In-Phase Monitor bypass. This request is indicated by a one in Bit 1 of the System Busy Status Register (Coil 106).

3. To confirm the request to bypass, set Bit 1 of the System Busy Control Register (Coil 114) to one. The controller will bypass the In-Phase Monitor.

Note: The In-Phase Monitor bypass feature is an interlocked command-and-confirm mechanism. The Modbus Card will not allow the Confirm Bypass control bit (Coil 114) to be set before the controller has set Ready to Confirm Bypass status bit (Coil 106). If a write request is received to set Coil 114 before the controller has set Coil 106, an Illegal Data Value error code will be returned.

Bypass Pending Exerciser

Bit 0 (Coil 121) is the Bypass Pending Exerciser bit. The MX Platform performs a logic-OR with this bit and the BPASS EXER key on the HMI. A 1 in Bit 0 bypasses the pending exerciser; a 0 does nothing.

Cancel Bypass

Bit 1 (Coil 122) is the Cancel Bypass bit. The MX Platform performs a logic-OR this bit with the CANCL BPASS key on the HMI. A 1 in Bit 1 cancels the Bypass Pending Exerciser. A 0 in this bit position does nothing.

The Bypass Pending Exerciser Bit works different, between a Timer Exerciser and Clock Exerciser, depending on the state of Exerciser Type (Holding Register 40063, Bit 0, Coil 81). When Coil 81 = 0 (Timer Exerciser), if Coil 121 is set to 1, the Timer Exerciser will be bypassed until the Cancel Bypass Bit (Coil 122) is set to 1. When Coil 81 = 1 (Clock Exerciser), if Coil 121 is set to 1, only the exerciser that is pending at the time gets bypassed, and the exerciser only gets bypassed once. The Controller waits for Coil 121 to reset to a 0 before a subsequent bypass can be performed.

Operation Under Battery Backup

The controller can be powered from an external 12-volt battery in the event that neither S1 nor S2 are available. While the controller is on external battery backup, data will still be available over the Modbus Network as noted below.

While the controller is running on external battery backup, data regarding ATS position and limit switch inputs may be invalid if both S1 and S2 sources are lost. Therefore, if Bits 6 and 7 of Holding Register 40001, or Coils 7 and 8, are both zero, the following Modbus network data may not be reliable:

- Automatic Transfer Relay –
  Holding Register 40001, Bit 0 or Coil 1
- SN Limit Switch –
  Holding Register 40002, Bit 0 or Coil 9
- SE Limit Switch –
  Holding Register 40002, Bit 1 or Coil 10
- SNO Limit Switch –
  Holding Register 40002, Bit 2 or Coil 11
- SEO Limit Switch –
  Holding Register 40002, Bit 3 or Coil 12
- S1 Position Status –
  Holding Register 40004, Bit 9 or Coil 34
- S2 Position Status –
  Holding Register 40004, Bit 10 or Coil 35

Appendix A – Read Only Register List

Holding Reg.	Bit	Coil	Description	Value
40001			MX Status 0	
	0	1	Automatic Transfer Relay	1 = On, 0 = Off
	1	2	ATS Not in Auto Mode	1 = Not in Auto
	2	3	General Purpose Alarm	1 = Alarm Active
	3	4	Unused	
	4	5	Load Test or Fast Load Test Running	1 = Running
	5	6	Load, No Load, Fast Load Test Status	1 = Running
	6	7	S2 Available	1 = Available
	7	8	S1 Available	1 = Available
40002			MX Status 1	
	0	9	SN Limit Switch	1 = On, 0 = Off
	1	10	SE Limit Switch	1 = On, 0 = Off
	2	11	SNO Limit Switch	1 = On, 0 = Off
	3	12	SEO Limit Switch	1 = On, 0 = Off
	4	13	S2 Phase Rotation - Valid only if 3ph and S2 Avail	1 = CW, 0 = CCW
	5	14	S1 Phase Rotation - Valid only if 3ph and S1 Avail	1 = CW, 0 = CCW
	6	15	Number of Phases on S2	1 = Three, 0 = One
	7	16	Number of Phases on S1	1 = Three, 0 = One
40003			MX Status 2	
	0	17	Unused	
	1	18	S5 Active	1 = On, 0 = Off
	2	19	S12 Active	1 = On, 0 = Off
	3	20	Load Shed (LS) Active	1 = On, 0 = Off
	4	21	Q7 Active	1 = On, 0 = Off
	5	22	Q3 Active	1 = On, 0 = Off
	6	23	Closed Transfer Relay (CTR) Active	1 = On, 0 = Off
	7	24	Transfer Mode Select (TMS) Active	1 = On, 0 = Off
40004			Timer ID 0	
	0	25	Timer Bit 0	See Table 1
	1	26	Timer Bit 1	See Table 1
	2	27	Timer Bit 2	See Table 1
	3	28	Unused	
	4	29	Unused	
	5	30	Unused	
	6	31	Unused	
	7	32	Unused	
	8	33	Timer Active	1 = Timer Running
	9	34	S1 Position Status	1 = S1 Position
	10	35	S2 Position Status	1 = S2 Position
	11	36	Unused	
	12	37	Unused	
	13	38	Unused	
	14	39	Unused	
	15	40	Unused	

Appendix A *(cont'd)* Read Only Register List

Holding Reg.	Bit	Coil	Description	Value
40005			Timer Countdown Value	Seconds
40006			S1 Voltage (Phase A-B)	Volts
40007			S1 Voltage (Phase B-C)	Volts
40008			S1 Voltage (Phase C-A)	Volts
40009			S2 Voltage (Phase A-B)	Volts
40010			S2 Voltage (Phase B-C)	Volts
40011			S2 Voltage (Phase C-A)	Volts
40012			Unused	
40013			S1 Frequency	Freq Value = scaled value/10
40014			Unused	
40015			S2 Frequency	Freq Value = scaled value/10
40016			Unused	
40017			Total Transfers to S1	
40018			Unused	
40019			Serial Number (MSR)	
40020			Serial Number (LSR)	
40021			Nominal Full-Scale Voltage	
40022			MX Network Configuration 0	
	0	41	Unused	
	1	42	Unused	
	2	43	Unused	
	3	44	Unused	
	4	45	Unused	
	5	46	Closed Transition Configured	1 = Configured
	6	47	In-Phase Monitor Configured	1 = Configured
	7	48	ATS Type	1 = Delay, 0 = Standard
40023			MX Network Configuration 1	
	0	49	S12 Auto/Manual Option	1 = Configured
	1	50	S5 Auto/Manual Bypass Option	1 = Configured
	2	51	Phase Sequence Check Option	1 = Configured
	3	52	S2 Overfrequency Option	1 = Configured
	4	53	S2 Overvoltage Option	1 = Configured
	5	54	S1 Overfrequency Option	1 = Configured
	6	55	S1 Underfrequency Option	1 = Configured
	7	56	S1 Overvoltage Option	1 = Configured
40024			MX Network Configuration 2	
	0	57	Phase Imbalance Configured	1 = Configured
	1	58	Unused	
	2	59	Closed Transition Configured	1 = Configured
	3	60	Pre-Load Disconnect	1 = Configured
	4	61	Post-Load Disconnect	1 = Configured
	5	62	Open Loop Transfer Option	1 = Configured
	6	63	Unused	
	7	64	Controller Type	1 = MX150/250, 0 = MX200

Appendix A *(cont'd)* Read Only Register List

Holding Reg.	Bit	Coil	Description	Value
40025			S1 Voltage (Phase A-B), Raw A/D	Raw A/D Value - See Note 1
40026			S1 Voltage (Phase B-C), Raw A/D	Raw A/D Value - See Note 1
40027			S1 Voltage (Phase C-A), Raw A/D	Raw A/D Value - See Note 1
40028			S2 Voltage (Phase A-B), Raw A/D	Raw A/D Value - See Note 1
40029			S2 Voltage (Phase B-C), Raw A/D	Raw A/D Value - See Note 1
40030			S2 Voltage (Phase C-A), Raw A/D	Raw A/D Value - See Note 1
40031			S1 Period Count	Raw Value - See Note 2
40032			S2 Period Count	Raw Value - See Note 2
40049			Total S1 Fails	
40050			Total Transfers to S2	
40051			Days Powered Up	
40052			Time S1 Available (MSR)	Hours
40053			Time S1 Available (LSR)	Hours
40054			Time S2 Available (MSR)	Hours
40055			Time S2 Available (LSR)	Hours
40056			Unused	
40057			Unused	
40058			Unused	
40059			Unused	
40060			Unused	
40061			Unused	
40062			Unused	
40063			Exerciser Schedule Status	
	0	81	Exerciser Type	1 = Clock, 0 = Timer
	1	82	Load/No Load Exerciser (Timer Exerciser Only)	1 = Load
	2	83	User can set load exercises (Clock Exerciser Only)	1 = Yes
	3	84	Unused	
	4	85	Unused	
	5	86	Unused	
	6	87	Unused	
	7	88	Unused	
	[15:8]		Timer Exerciser Run Duration	Minutes
40064			MX Status 3	
	0	89	Exerciser Pending	1 = Exerciser Pending
	1	90	Exerciser Bypassed	1 = Exerciser Bypassed
	2	91	Unused	
	3	92	Unused	
	4	93	Unused	
	5	94	Unused	
	6	95	Unused	
	7	96	Unused	
40065			Unused	
40066			Unused	
40067			Unused	

Appendix A *(cont'd)* Read Only Register List

Holding Reg.	Bit	Coil	Description	Value
40068			Timer ID 1	
	0	97	Unused	
	1	98	Unused	
	2	99	A6/A62 Timer Running	1 = Running
	3	100	T Timer Running	1 = Running
	4	101	DT Timer Running	1 = Running
	5	102	T3/W3 Timer Running	1 = Running
	6	103	W Timer Running	1 = Running
	7	104	DW Timer Running	1 = Running
40069			T or W Timer Countdown Value	Seconds
40070			T3/W3 Timer Countdown Value	Seconds
40071			A6/A62 Timer Countdown Value	Seconds
40072			MX Firmware Revision	Ver = Value/10
40073			Modbus Card Firmware Revision	Ver = Value/100
40074			Unused	
40075			Unused	
40076			Unused	
40077			Most Recent Event Pointer	
40082			Unused	
40083			Unused	
40099			System Time – Day of Week	

Holding Reg.	Bit	Coil	Description	Range	Notes
40102			Exerciser Record – Hour	0 - 23	
40103			Exerciser Record – Minute	0 - 59	
40104			Exerciser Record – Month	1 - 12	Not writeable for Daily or Weekly Exercisers
40105			Exerciser Record – Day of Month	1 - 31	Max val. depends on month, year Not writeable for Daily or Weekly Exercisers
40106			Exerciser Record – Day of Week	1 = Sun., 7 = Sat.	Writeable for Weekly Exercisers Only
40107			Exerciser Record – Ex. Duration	0 - 600 minutes	
40108			Exerciser Record – Load/No Load	1 = Load, 0 = No Load	Writeable ONLY if Factory Configured for Load Exercisers
40109			Unused		
40110			Exerciser Schedule Selection	0 = Off	
				1 = Daily (1 Day)	
				2 = Weekly (7 Day)	
				3 = Bi-Weekly (14 Day)	
				4 = 4 Week (28 Day)	
				5 = Calendar (365 Day)	

Appendix A *(cont'd)* Read Only Register List

Holding Reg.	Bit	Coil	Description	Value
40111			System Busy Status	
	0	105	System Busy due to R50	1 = System Busy
	1	106	Ready to Confirm Bypass R50	1 = Ready to Confirm Bypass
	2	107	Unused	
	3	108	Unused	
	4	109	Unused	
	5	110	Unused	
	6	111	Unused	
	7	112	Unused	
40113			Unused	
40114			Unused	
40115			Unused	
40116			Unused	
40117			Unused	
40118			Unused	
40119			Unused	
40120			Unused	
40121			Reason for Event 0	See Table 2
40122			Event 0	Second
40123			Event 0	Hour
40124			Event 0	Minute
40125			Event 0	Month
40126			Event 0	Day of Month
40127			Event 0	Year
40128			Reason for Event 1	See Table 2
40129			Event 1	Second
40130			Event 1	Hour
40131			Event 1	Minute
40132			Event 1	Month
40133			Event 1	Day of Month
40134			Event 1	Year
40135			Reason for Event 2	See Table 2
40136			Event 2	Second
40137			Event 2	Hour
40138			Event 2	Minute
40139			Event 2	Month
40140			Event 2	Day of Month
40141			Event 2	Year
40142			Reason for Event 3	See Table 2
40143			Event 3	Second
40144			Event 3	Hour
40145			Event 3	Minute
40146			Event 3	Month
40147			Event 3	Day of Month
40148			Event 3	Year

Appendix A *(cont'd)* Read Only Register List

Holding Reg.	Bit Coil	Description	Value
40149		Reason for Event 4	See Table 2
40150		Event 4	Second
40151		Event 4	Hour
40152		Event 4	Minute
40153		Event 4	Month
40154		Event 4	Day of Month
40155		Event 4	Year
40156		Reason for Event 5	See Table 2
40157		Event 5	Second
40158		Event 5	Hour
40159		Event 5	Minute
40160		Event 5	Month
40161		Event 5	Day of Month
40162		Event 5	Year
40163		Reason for Event 6	See Table 2
40164		Event 6	Second
40165		Event 6	Hour
40166		Event 6	Minute
40167		Event 6	Month
40168		Event 6	Day of Month
40169		Event 6	Year
40170		Reason for Event 7	See Table 2
40171		Event 7	Second
40172		Event 7	Hour
40173		Event 7	Minute
40174		Event 7	Month
40175		Event 7	Day of Month
40176		Event 7	Year
40177		Reason for Event 8	See Table 2
40178		Event 8	Second
40179		Event 8	Hour
40180		Event 8	Minute
40181		Event 8	Month
40182		Event 8	Day of Month
40183		Event 8	Year
40184		Reason for Event 9	See Table 2
40185		Event 9	Second
40186		Event 9	Hour
40187		Event 9	Minute
40188		Event 9	Month
40189		Event 9	Day of Month
40190		Event 9	Year
40191		Reason for Event 10	See Table 2
40192		Event 10	Second
40193		Event 10	Hour
40194		Event 10	Minute
40195		Event 10	Month
40196		Event 10	Day of Month
40197		Event 10	Year

Appendix A *(cont'd)* Read Only Register List

Holding Reg.	Bit Coil	Description	Value
40198		Reason for Event 11	See Table 2
40199		Event 11	Second
40200		Event 11	Hour
40201		Event 11	Minute
40202		Event 11	Month
40203		Event 11	Day of Month
40204		Event 11	Year
40205		Reason for Event 12	See Table 2
40206		Event 12	Second
40207		Event 12	Hour
40208		Event 12	Minute
40209		Event 12	Month
40210		Event 12	Day of Month
40211		Event 12	Year
40212		Reason for Event 13	See Table 2
40213		Event 13	Second
40214		Event 13	Hour
40215		Event 13	Minute
40216		Event 13	Month
40217		Event 13	Day of Month
40218		Event 13	Year
40219		Reason for Event 14	See Table 2
40210		Event 14	Second
40221		Event 14	Hour
40222		Event 14	Minute
40223		Event 14	Month
40224		Event 14	Day of Month
40225		Event 14	Year
40226		Reason for Event 15	See Table 2
40227		Event 15	Second
40228		Event 15	Hour
40229		Event 15	Minute
40230		Event 15	Month
40231		Event 15	Day of Month
40232		Event 15	Year

Appendix A *(cont'd)* Read Only Register List

Notes:

1. Registers 40025 - 40030 contain unscaled voltage values In order to obtain a full-scale voltage value, use the following formula:
   Voltage = (A/D Raw Value / 192) x
   Full Scale Voltage (Register 40021)

2. Registers 40031 and 40032 contain unscaled frequency values. In order to obtain a full-scale frequency value, use the following formula:
   Scales Frequency + (20,000,000 / Period Count)

Timer	Value
P	111b
W-W3, Unbypassed	110b
W-W3, YE bypassed	101b
T-T3, Unbypassed	011b
Y-T3, YN bypassed	010b
U	000b

Reason Code	Description
0	S1 Fail
1	S2 Fail
2	S1 Phase Imbalance
3	S2 Phase Imbalance
4	S2 Start
5	S2 Stop
6	Sync Fail
7	Load Shed
8	ATS Inhibit
9	Phase Rotation
10	Remove Test
11	Local Test
12	S1-S2 Volt. Imbalance
13	S1-S2 Freq. Imbalance
14	CT Xfr S1>S2
15	CT Xfr S2>S1
16	Xfr S1>S2
17	Xfr S2>S1
18	
19	
20	No Xfr
21	OLC
22	STE
23	S1 UV Fail
24	S1 OV Fail
25	S1 UF Fail
26	S1 OF Fail
27	S2 UV Fail
28	S2 OV Fail
29	S2 UF Fail
30	S2 OF Fail
31	S1 Restore
32	S2 to Open
33	Exerciser
34	Remote Test Network
35	Remote Inhibit
36	Local Inhibit
37	S2 Avail
38	S2 Off

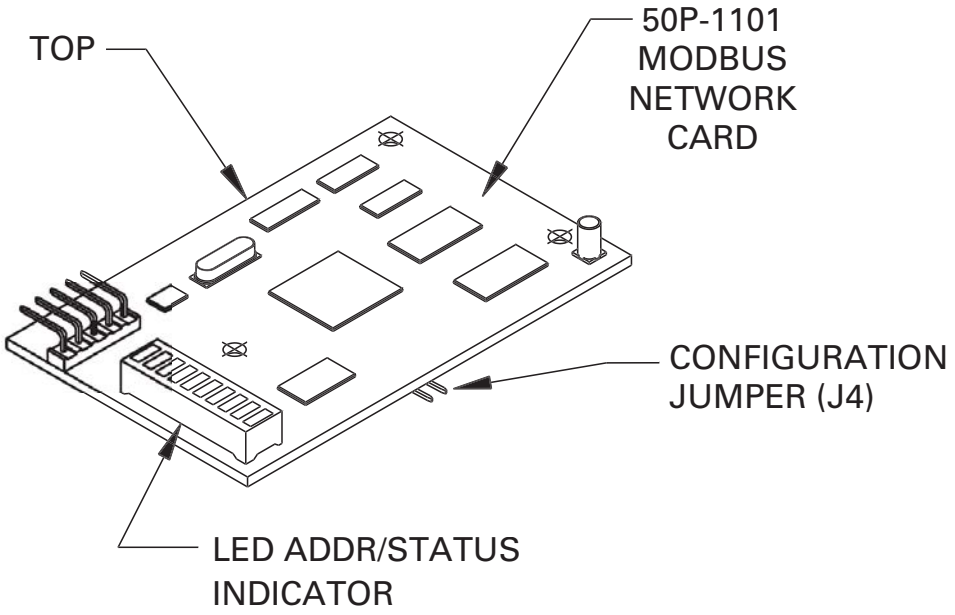
Appendix B - Read/Write Register List

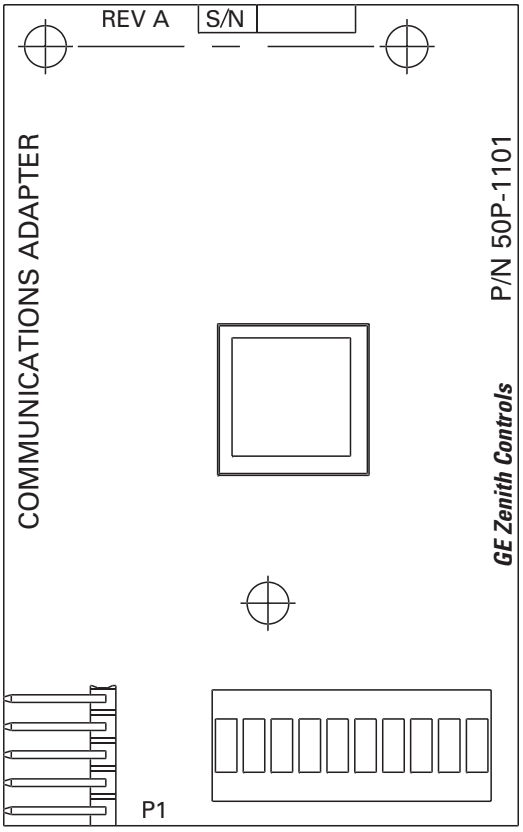
Holding Reg.	Bit	Coil	Description	Range	Notes
40033			P Timer Setting	0 - 1000 1/100 of a second	
40034			W Timer Setting	0 - 300 seconds	
40035			T3/W3 Timer Setting (Mirror of 40038)	0 - 60 seconds	
40036			DW Timer Setting	0 - 600 seconds	
40037			T Timer Setting	0 - 3600 seconds	
40038			T3/W3 Timer Setting (Mirror of 40035)	0 - 60 seconds	
40039			DT Timer Setting	0 - 600 seconds	
40040			U Timer Setting	0 - 3600 seconds	
40041			S1 Undervolt Restore	85 - 100 percent	Must be at least 2 > S1 UV Fail
40042			S1 Undervolt Fail	75 - 98 percent	Must be at least 2 < S1 UV Restore
40043			S2 Undervolt Restore	85 - 100 percent	Must be at least 2 > S2 UV Fail
40044			S2 Undervolt Fail	75 - 98 percent	Must be at least 2 < S2 UV Restore
40045			S1 Underfreq Restore	90 - 100 percent	Must be at least 2 > S1 UF Fail
40046			S2 Underfreq Restore	90 - 100 percent	Must be at least 2 > S2 UF Fail
40047			Net Control 0		
	0	65	Reset Time S2 Available	1 = Reset	
	1	66	Alarm Silence	1 = Silence Alarm	
	2	67	Unused		
	3	68	YE Control	1 = Bypass to S2	
	4	69	YN Control	1 = Bypass to S1	
	5	70	No Load Test Control	1 = Start Test	
	6	71	Load Test Control	1 = Start Test	
	7	72	Fast Load Test Control	1 = Start Test	
40048			Net Control 1		
	0	73	Unused		
	1	74	S5 Control	1 = On, 0 = Off	
	2	75	S12 Control	1 = On, 0 = Off	
	3	76	LS Control	1 = On, 0 = Off	
	4	77	Q7 Control	1 = On, 0 = Off	
	5	78	Q3 Control	1 = On, 0 = Off	
	6	79	Aux 2 Control	1 = On, 0 = Off	
	7	80	TMS Control	1 = On, 0 = Off	
40078			UMD Timer Setting	0 - 300 seconds	
40079			Phase Imbalance Timer Setting	10 - 30 seconds	
40080			Phase Imbalance Fail Setting	5 - 20 percent	
40081			Phase Imbalance Restore Setting	3 - 18 percent	
40084			S1 Overvolt Fail	105 - 110 percent	Must be at least 2 > S1 OV Restore
40085			S1 Overvolt Restore	103 - 108 percent	Must be at least 2 < S1 OV Fail
40086			S2 Overvolt Fail	105 - 110 percent	Must be at least 2 > S2 OV Restore
40087			S2 Overvolt Restore	103 - 108 percent	Must be at least 2 < S2 OV Fail
40088			S1 Underfreq Fail	88 - 98 percent	Must be at least 2 < S1 UF Restore
40089			S1 Overfreq Fail	103 - 105 percent	Must be at least 1 > S1 OF Restore
40090			S1 Overfreq Restore	102 - 104 percent	Must be at least 1 < S1 OF Fail
40091			S2 Underfreq Fail	88 - 98 percent	Must be at least 2 < S2 UF Restore
40092			S2 Overfreq Fail	103 - 105 percent	Must be at least 1 > S2 OF Restore
40093			S2 Overfreq Restore	102 - 104 percent	Must be at least 1 < S2 OF Fail

Appendix B *(cont'd)* Read/Write Register List

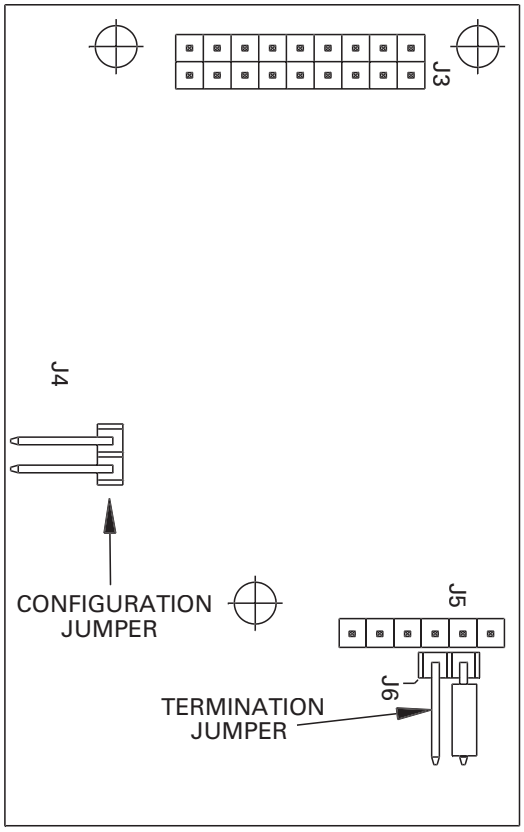
Holding Reg.	Bit	Coil	Description	Range	Notes
HR 40094 - 40098 MUST ALL be written with a Write Multiple Holding Register Command					
40094			System Time – Hour	0 - 23	
40095			System Time – Minute	0 - 59	
40096			System Time – Day	1 - 31	Max val. depends on month, year
40097			System Time – Month	1 - 12	
40098			System Time – Year	0 - 255, 0 = Year 2000	
40100			Daylight Savings Time	1 = ATS follows DST	
HR 40101 - 40109 MUST ALL be written with a Write Multiple Holding Register Command					
HR's listed as "Not Writeable" under certain conditions must be written as zeros					
HR40101-40110 are for CDP Programmable Exercisers Only					
40112			System Busy Control		
	0	113	Command to Bypass In-Phase Monitor	1 = Bypass In-Phase Monitor	
	1	114	Confirm Bypass In-Phase Monitor	1 = Confirm	
	2	115	Unused		
	3	116	Unused		
	4	117	Unused		
	5	118	Unused		
	6	119	Unused		
	7	120	Unused		
40113			Net Control 2		
	0	121	Bypass Pending Exerciser	1 = Bypass	
	1	122	Cancel Exerciser Bypass	1 = Cancel Bypass	
	2	123	Unused		
	3	124	Unused		
	4	125	Unused		
	6	127	Unused		
	7	128	Unused		

Appendix C – Modbus Network Card





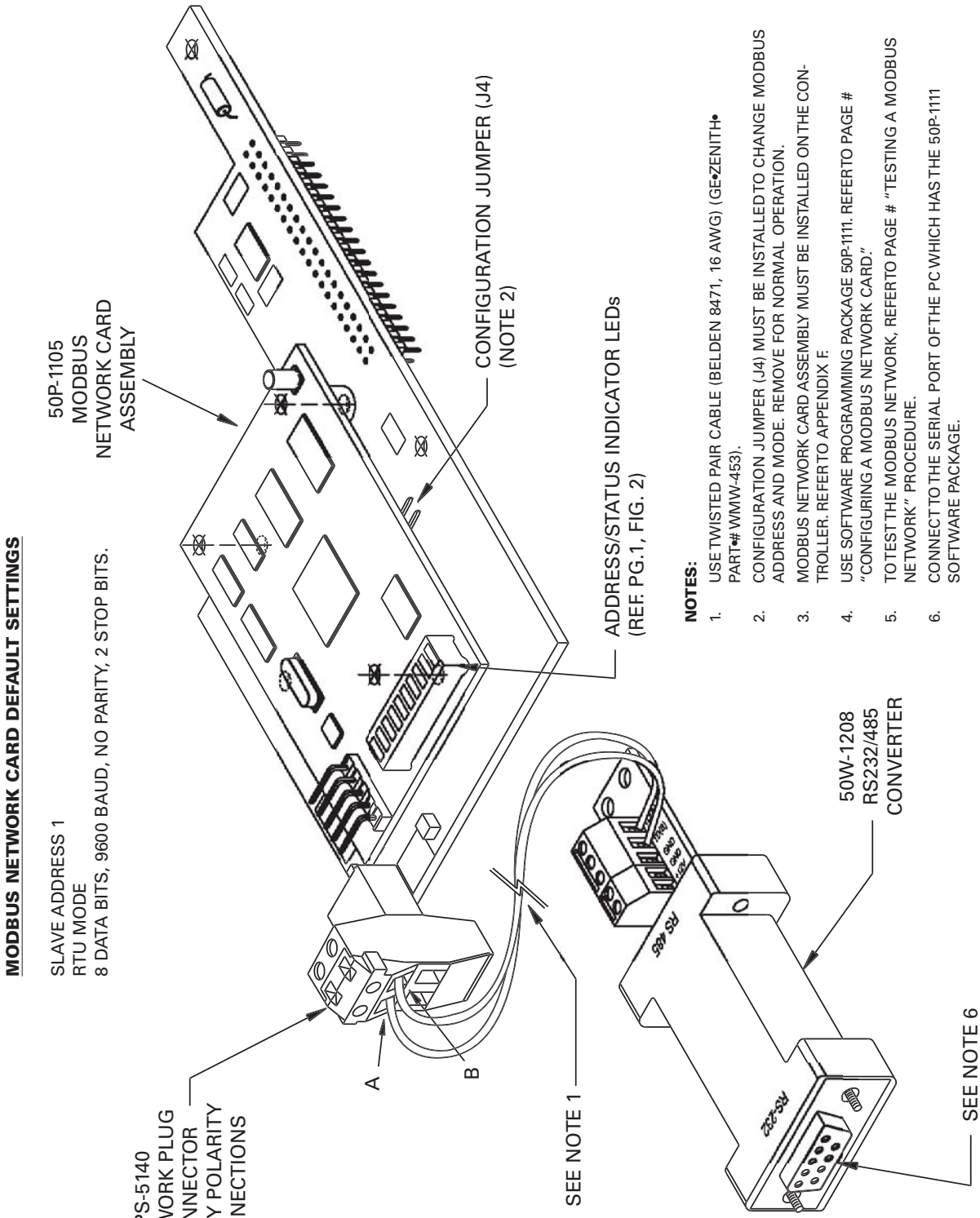
TOP OF MODBUS CARD



BOTTOM OF MODBUS CARD

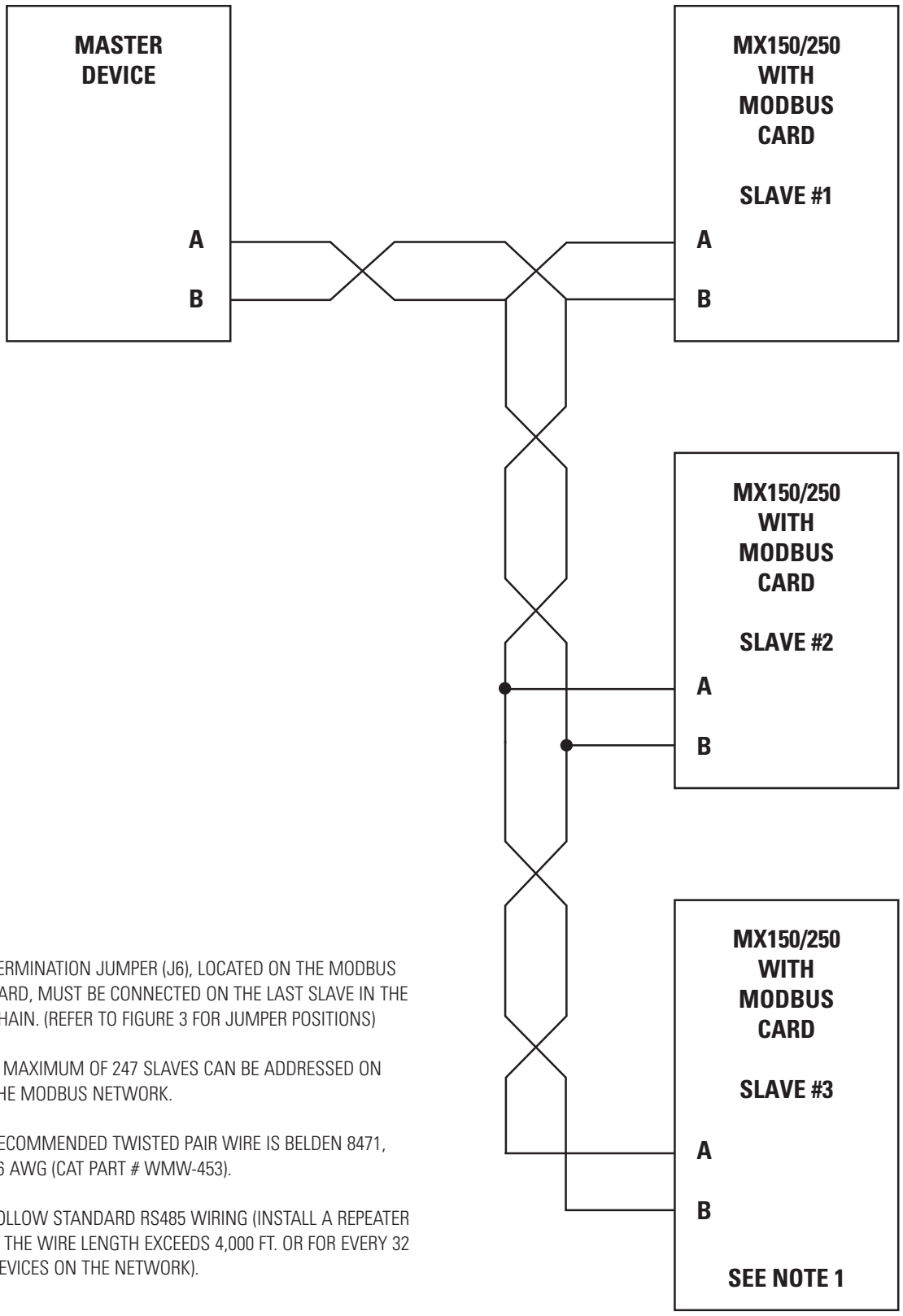
Appendix D

Connections for Configuring and Testing the Modbus Card



Appendix E

RS485 Multi-Drop Connection

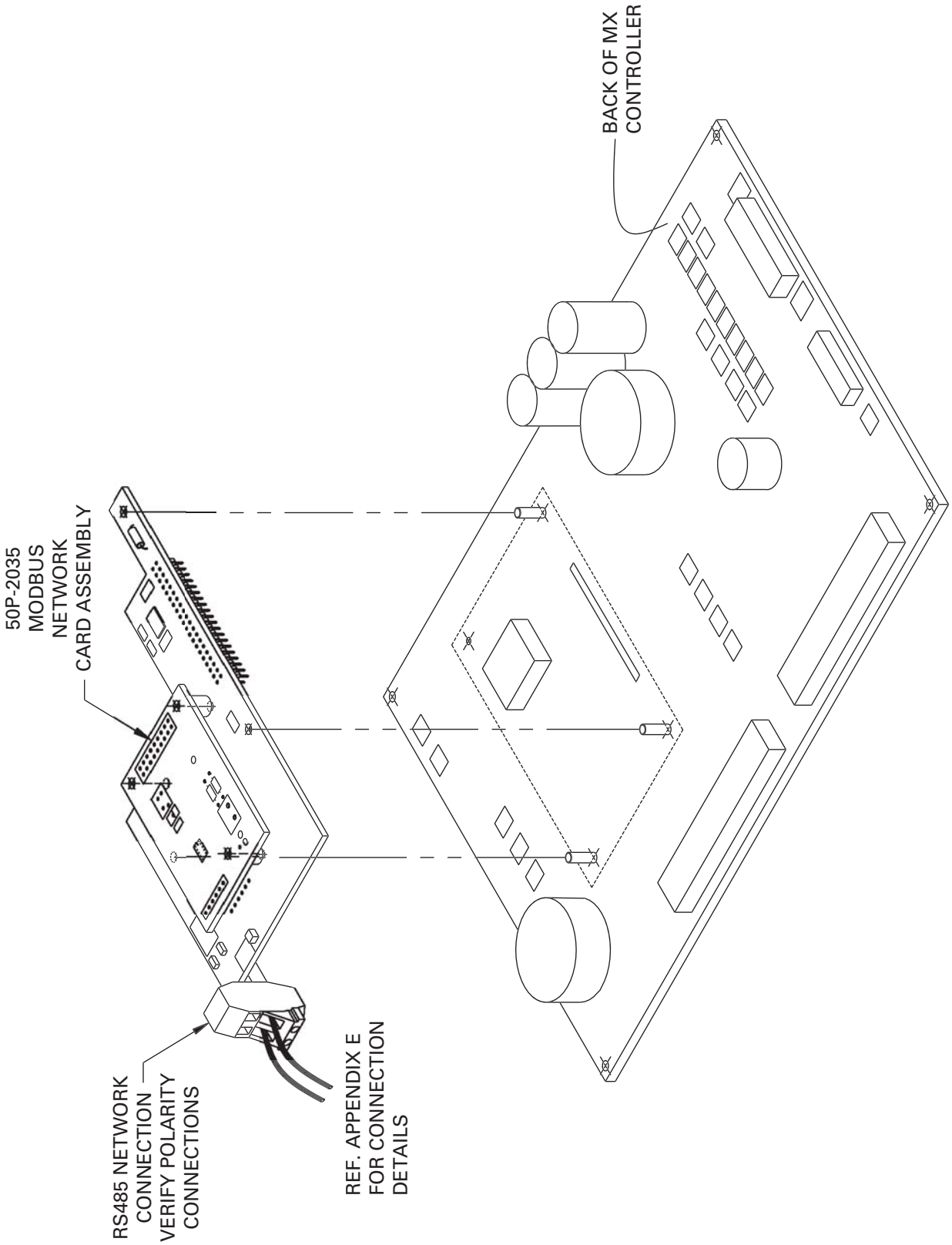


NOTE:

1. TERMINATION JUMPER (J6), LOCATED ON THE MODBUS CARD, MUST BE CONNECTED ON THE LAST SLAVE IN THE CHAIN. (REFER TO FIGURE 3 FOR JUMPER POSITIONS)
2. A MAXIMUM OF 247 SLAVES CAN BE ADDRESSED ON THE MODBUS NETWORK.
3. RECOMMENDED TWISTED PAIR WIRE IS BELDEN 8471, 16 AWG (CAT PART # WMW-453).
4. FOLLOW STANDARD RS485 WIRING (INSTALL A REPEATER IF THE WIRE LENGTH EXCEEDS 4,000 FT. OR FOR EVERY 32 DEVICES ON THE NETWORK).

Appendix F

Installation of Modbus Card on MX Controller



Appendix G

Modbus Protocol Illustration

For a detailed specification of the Modbus protocol, reference the Modicon website address **www.modbus.org**.

The Modbus protocol provides the internal standard for parsing messages. During communications on a Modbus network, the protocol determines how each slave will know its device address, recognize a message addressed to it, determine the kind of action to be taken, and extract any data or other information contained in the message. If a reply is required, the slave will construct the reply message and send it using Modbus protocol.

The following is a brief description of the Modbus commands supported by the Modbus Network Card. Each command consists of the following:

- a sample query message that is sent out by the master device to the designated slave
- the slave's reply message to the master device

The query and reply messages show how the information is packeted and sent out using the Modbus Protocol.

Each query message consists of the following:

- *Slave Address* – address of the slave you wish to establish communications with.
- *Function Code* – code that lets the slave know what command is being requested, e.g. read coil, write single coil.
- *Starting Address High/Low Order* – high and low byte of the address the master reads from or writes to. Coils and Registers are addressed starting at 0. For instance Coil 1 is address 0 and Register 40001 is address 0.
- *Error Check Field* – contains either a CRC (RTU mode) or LRC (ASCII mode) error check value.

The query message for specific functions requires some of the following information:

- *Number of Data Points High/Low Order* – high and low byte of the number of addresses the master wants to read.
- *Data High/Low Order* – high and low byte of the data that will be written to the slave device.
- *Number of Coils High/Low Order* – high and low byte for the number of coils to force ON or OFF.
- *Number of Regs High/Low Order* – high and low byte for the number of registers to preset.
- *Byte Count* – is the number of data bytes which are sent to the slave.

These query and reply messages are for both RTU and ASCII modes depending on whether the Error Check Field contains a CRC or LRC respectively. Each value in the query message is a hexadecimal value.

Read Coil Status (Function Code 01)

Query

This function allows the master device to obtain the ON/OFF bit status of various coils from the addressed slave.

Figure G1 is a sample read coil status request to read coils 9-24 (MX150/250 status bits) from slave device 5.

Slave Address	Function Code	Starting Address *High* Order	Starting Address *Low* Order	No. of Data Points *High* Order	No. of Data Points *Low* Order	Error Check Field (LRC or CRC)
05h	01h	00h	08h	00h	10h	—

Figure G1 – Read Coil Status Query Message

Response

An example response to the Read Coil Status is shown in *Figure G2*. The response includes the slave address, function code, number of data bytes sent, the data, and error checking.

Slave Address	Function Code	Byte Count	Data Coil Status 9-16	Data Coil Status 17-24	Error Check Field (LRC or CRC)
05h	01h	02h	C1h	A2h	—

Figure G2 – Read Coil Status Response Message

The data consists of one bit per coil (1=ON, 0=OFF). The status of coils 9-16 is C1 (hex) or 1100 0001 (binary). Reading left to right, coils 16, 15, and 9 are ON and the remainder is OFF. The other data byte is decoded similarly.

Read Holding Register (Function Code 03)

Read holding registers allows the master device to obtain the binary contents of holding registers 4xxxx in the addressed slave.

Query

Figure G3 is an example that reads registers 40006-40007 from slave 8.

Slave Address	Function Code	Starting Address *High* Order	Starting Address *Low* Order	No. of Data Points *High* Order	No. of Data Points *Low* Order	Error Check Field (LRC or CRC)
08h	03h	00h	05h	00h	02h	—

Figure G3 – Read Holding Register Query Message

Modbus Protocol Illustration *(cont'd)*

Response

The slave responds with its address, function code, number of data bytes, and the data. The contents of the registers requested (data) are two bytes each. The first byte includes the high order bits and the second, the low order bits.

Slave Address	Function Code	Byte Count	High Order Data	Low Order Data	High Order Data	Low Order Data	Error Check Field (LRC or CRC)
08h	03h	04h	00h	76h	00h	78h	—

Figure G4 – Read Holding Register Response Message

Register 40006 , Normal Voltage Ph1-Ph2, has a value of 118 (76 hex) and register 40007, Normal Voltage Ph2-Ph3 has a value of 120 (78 hex).

Write Single Coil (Function Code 05)

This function forces a single coil either ON or OFF. A value of 65,280 (FF00 Hex) will set the coil ON and the value zero will turn it OFF; all other values are illegal and will not affect that coil.

Query

Figure G5 is an example of a request to slave number 3 to turn ON coil 71.

Slave Address	Function Code	Starting Address *High* Order	Starting Address *Low* Order	Data *High* Order	Data *Low* Order	Error Check Field (LRC or CRC)
03h	05h	00h	46h	FFh	00h	—

Figure G5 – Write Single Coil Query Message

Response

The slave's normal response to the Write Single Coil query is to return the original message after the coil state has been altered.

Slave Address	Function Code	Starting Address *High* Order	Starting Address *Low* Order	Data *High* Order	Data *Low* Order	Error Check Field (LRC or CRC)
03h	05h	00h	46h	FFh	00h	—

Figure G6 – Write Single Coil Response Message

Write Single Holding Register (Function Code 06)

This function allows the master to modify the contents of one holding register.

Query

Figure G7 is an example of a request to preset register 40041 (Normal Pickup Voltage) to 92 (00 5C hex) in slave device 17.

Slave Address	Function Code	Starting Address *High* Order	Starting Address *Low* Order	Data *High* Order	Data *Low* Order	Error Check Field (LRC or CRC)
11h	06h	00h	28h	00h	5Ch	—

Figure G7 – Write Single Holding Register Query Message

Response

The slave's response to the Write Single Holding Register query is to return the original message after the registers have been altered.

Slave Address	Function Code	Starting Address *High* Order	Starting Address *Low* Order	Data *High* Order	Data *Low* Order	Error Check Field (LRC or CRC)
11h	06h	00h	28h	00h	5Ch	—

Figure G8 – Write Single Holding Register Response Message

Write Multiple Coils (Function Code 15)

Forces each coil in a sequence of coils to either ON or OFF. The requested ON/OFF states are specified by contents of the query data field. A logical '1' in a bit position of the field requests the corresponding coil to be ON and a logical '0' requests it to be OFF. Coils are addressed starting at 0. For examples coil 1 is addressed as 0.

Query

The following example is a request to force a series of sixteen coils starting at coil 41 (addressed as 40, or 28 hex) in slave device 9.

The query data contents consist of two bytes: 3C 9B hex (0011 1100 1001 1011 binary). The binary bits correspond to the coils in the following way:

Bit:	0	0	1	1	1	1	0	0	1	0	0	1	1	0	1	1
Coil:	48	47	46	45	44	43	42	41	56	55	54	53	52	51	50	49

The first byte sent (3C hex) addresses coils 41-48, with the least significant bit addressing coil 41. The second byte sent (9B hex) addresses coils 49-56, with the least significant bit addressing coil 49.

Slave Address	Function Code	Starting Address *High* Order	Starting Address *Low* Order	Number of Coils *High* Order	Number of Coils *Low* Order	Byte Count	Data *High* Order	Data *Low* Order	Error Check Field (LRC or RC)
09h	0Fh	00h	28h	00h	10h	02h	3Ch	9Bh	–

Figure G9 – Write Multiple Coils Query Message

Modbus Protocol Illustration *(cont'd)*

Response

The response from the slave is an echo of the slave address, function code, starting address and number of coils forced.

Slave Address	Function Code	Starting Address *High* Order	Starting Address *Low* Order	Number of Coils *High* Order	Number of Coils *Low* Order	Error Check Field (LRC or CRC)
09h	0Fh	00h	28h	00h	10h	—

Figure G10 – Write Multiple Coils Response Message

Write Multiple Holding Registers (Function Code 16)

Presets values into a sequence of holding registers.

Query

The following is an example to preset two registers starting at 40034 (W-Time) to 9 hex (9 seconds) and 40035 (W3-time) to 32 hex (50 seconds), in slave device 17.

Slave Address	Function Code	Starting Address *High* Order	Starting Address *Low* Order	Number of Regs *High* Order	Number of Regs *Low* Order	Byte Count	Data *High* Order	Data *Low* Order	Data *High* Order	Data *Low* Order	Error Check Field (LRC or CRC)
11h	10h	00h	21h	00h	02h	04h	00h	09h	00h	32h	–

Figure G11 – Write Multiple Registers Query Message

Response

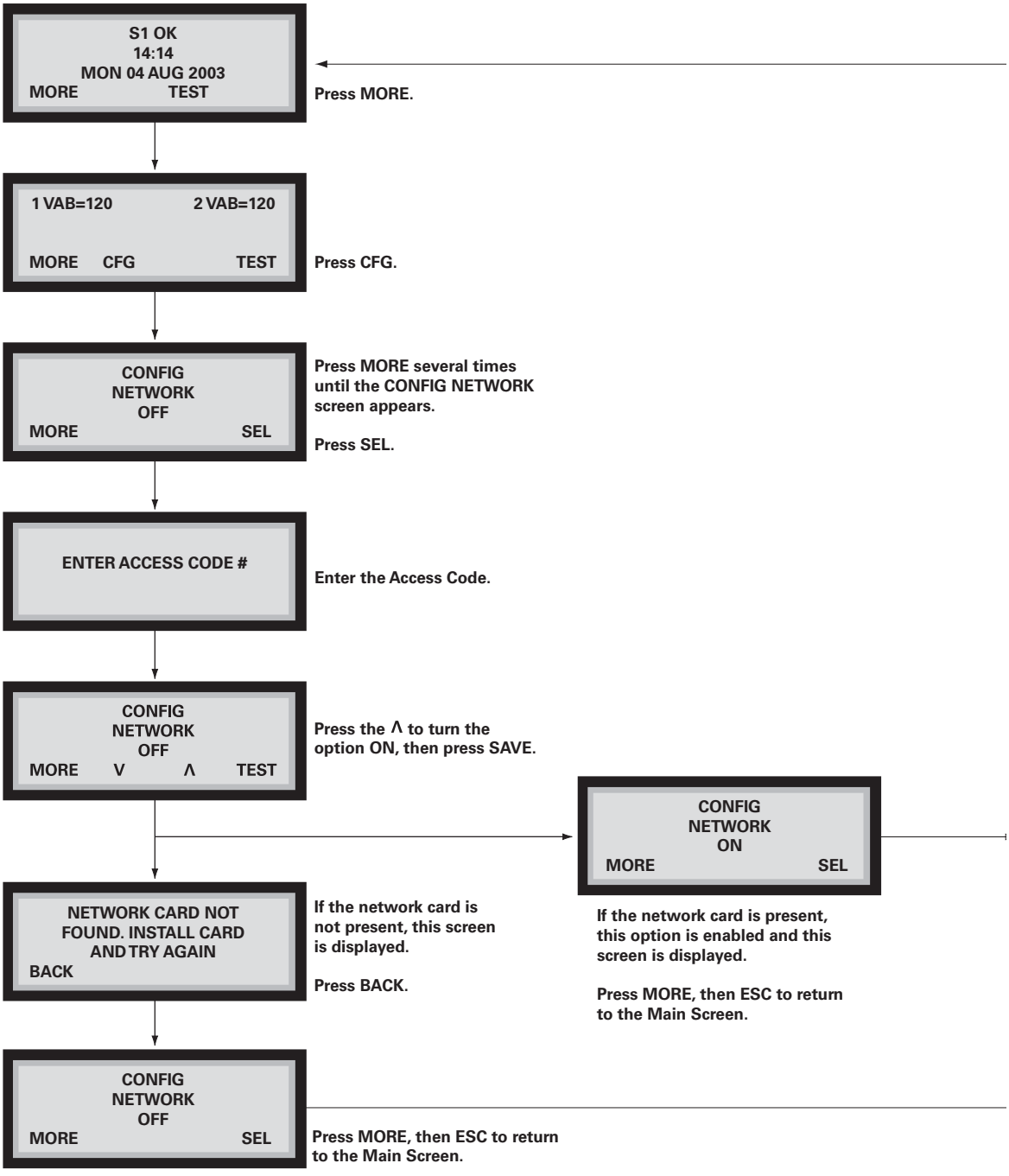
The response from the slave is an echo of the slave address, function code, starting address and number of registers to be loaded.

Slave Address	Function Code	Starting Address *High* Order	Starting Address *Low* Order	Number of Regs *High* Order	Number of Regs *Low* Order	Error Check Field (LRC or CRC)
11h	10h	00h	21h	00h	02h	—

Figure G12 – Write Multiple Registers Response Message

Appendix H

Configuring Controller for Modbus MX150/250



Bill of Materials

Components for the Modbus Option (MX150/250 V 6.0+)

	Part Description	CAT Part Number	Quantity
Assembly	Modbus Network Card Assembly	50P-2035	1
Individual Replacement Components	Modbus Network Card	50P-2025	1
	MX150/250 Network Adapter Card	50P-1048	1
	Network Plug Connector	PS-5140	1
	Miniature Support Post	PS-7363	3
	Operations and Maintenance Manual	CI-AZOM-00036-01-E (71R-2200)	1

Components for the Modbus Card Configuration

	Part Description	CAT Part Number	Quantity
Assembly	Modbus Card Configuration Assembly	50P-1124	1
Individual Replacement Components	RS232/485 Converter	50W-1208	1
	Belden 8471 Twisted Pair Cable	WMW-453	6 Feet
	Network Plug Connector	PS-5140	1
	Configuration Software for Modbus Communications Card	50P-1111	1
	Operations and Maintenance Manual	CI-AZOM-00036-01-E (71R-2200)	1

Troubleshooting

Problem	Possible Cause	Corrective Action
Trouble configuring the Modbus card	Modbus card is not installed on the controller.	Install the Modbus card on the controller.
	Controller does not have power.	Apply power to controller.
	Configuration jumper, J4, is not installed.	Install the configuration jumper J4.
	Wire between the RS232/485 converter and Modbus card is not connected.	See **Appendix D** for the proper connections. Connect the twisted pair wire between the converter and the Modbus card.
	Polarity connections are incorrect.	Make sure that A & B on the Modbus card are connected to A & B on the converter, respectively.
	Wrong com port or baud rate.	Select the correct com port and baud rate. (Refer to Appendix D)
	RS232/485 converter is not connected to the PC.	Connect the RS232/485 converter to the PC's serial port.
	Attempting to configure the Modbus Card to ASCII Mode, No Parity, and 1 Stop Bit.	The combination of ASCII Mode, No Parity, and 1 Stop Bit is not supported. Select another communication setting.
No communications between the Modbus card and the Master device	Controller does not have power.	Power up the controller.
	Communicating with the wrong addressed slave.	Verify that the address on the Modbus card matches the address you are communicating with. See Figure 2 for reference.
	Network wire connection from the Master to the Modbus card is broken or the wire is not connected to the Modbus card.	Check the wire connection from the Master to the Modbus card. Connect the wire to the Network card if necessary.
	Not using twisted pair wire to make the network connection.	Make sure interconnect cable is a twisted pair wire (Belden 8471, 16 AWG) (Caterpillar Part # WMW-453).
	Configuration jumper, J4, is still installed.	Remove the J4 configuration jumper.
	Proper polarity markings are not being followed.	Make sure that A & B on the Modbus card are connected to A & B on the converter, respectively.
	Termination jumper, J6, is not installed on the last slave in the chain.	Install termination jumper, J6, on the last slave in the chain. Make sure no other devices have jumper J6 installed.
	Modbus card communication configuration does not match the Master's.	Verify that the Master and Modbus card have the same baud rate, data bits, parity, stop bits with ASCII or RTU protocol selected.
	Twisted pair wire length exceeds 4,000 ft.	Install repeater if wire length exceeds 4,000 ft.
	RS485 multi-drop has more than 32 devices.	Install one repeater for every 32 devices on the network.
	Controller network option not enabled.	Refer to **Appendix H.**
All LED's on the LED module are off.	Modbus card is not installed on controller.	Install the Modbus card on controller.
	Controller does not have power.	Power up the controller.
	The Modbus card is damaged.	Call **CATERPILLAR** Technical•Support.
Illegal Data Address exception response to a write query	Holding Register or Coil address is beyond the legal range. There are no Holding Registers above address 40232 and no Coils above address 128.	Make sure the correct address is being sent
	Holding Register or Coil is Read Only.	Select a Holding Register or Coil that can be written.
	Write Multiple Holding Register or Coil range includes Read-Only registers.	Break up the write request into sections that contain only Read/Write registers.
	The feature associated with the register being programmed is not enabled.	Enable the feature in the User Configuration Menu on the controller HMI (if applicable), or call Caterpillar Technical Support.
	Writing non-zero data to nonprogrammable date registers for CDP Exercisers.	Refer to the "Exerciser Time and Date Format" section of "Clock Exercisers" for more information.
	Writing CDP Exerciser registers with Write Single Holding Register command, or Write Multiple Holding Register command with invalid range.	Refer to the "Writing the Clock Exerciser Holding Registers" section for more operation information.
	Writing System Time registers with Write Single Holding Register command, or Write Multiple Holding Register command with invalid range.	Refer to the "Writing the System Time Holding Registers" section of "System Time" for more information.
Illegal Data Value exception response to a write query	Data value being written is too high or too low.	Refer to **Appendix B** for maximum/minimum data ranges.
	Data value would violate a minimum offset with respect to another register.	Refer to **Appendix B** for minimum data offsets.
Slave Device Busy exception response to Modbus query	Controller has recently restarted after a power failure and has not initialized the Modbus Card with new data yet.	Wait a few seconds for the controller to initialize the Modbus Card with new data.
	Controller is waiting for the In-Phase Monitor to detect phase synchronization.	Refer to the "Operation with In-Phase Monitor" section of this manual for more information.

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