



Controlinc Network Master Operations Manual Model NM320A Version 1.2

Table of Contents

<u>Paragraph</u>	<u>Subject</u>	<u>Page</u>
1.0	Introduction	1
1.1	Reference Documents	1
1.2	System Configuration	2
1.3	Parts List	3
2.0	Installation	4
2.1	Mounting	4
2.2	Power Input	4
2.3	Field Network Wiring	5
2.3.1	Network Grounding	5
2.3.2	Network Termination	6
2.4	Modbus Host Cables	6
3.0	Configuring the System	6
3.1	System Protection	7
3.1.1	DirectSOFT Password Protection	7
3.1.2	CoProcessor Software Protection	7
3.1.3	Key Lock Protection	7
3.2	Configuring System Mode Word	7
3.2.1	Selecting Modbus Ports	8
3.2.2	Selecting Diagnostic/Programming Mode	8
3.3	Configuring Modbus Baud Rate	8
3.4	Configuring the Number of Slaves	8
3.5	Configuring Number of Modulating/Positioning Slaves	8
3.6	Configuring Field Network Baud Rate	8
3.7	Configuring Network Master Receiver Time-Out	9
4.0	Modbus Register Maps	9
4.1	Valve Status and Command Registers per Function Code	9
4.2	Valve Status Bit Data for Each Valve	11
4.2.1	Multiple Valve Status Locations Using Function 02	12
4.2.2	Multiple Valve Status Data Using Function Code 03	13
4.2.3	Multiple Valve Status Data Using Function Code 04	14

Table of Contents (continued)

<u>Paragraph</u>	<u>Subject</u>	<u>Page</u>
4.3	Reading Valve Position and Setpoint	15
4.4	Writing Discrete Commands to Valve Actuators	15
4.5	Writing Analog Valve Position Setpoint	17
4.6	Reading Auxiliary Analog Inputs Using Function Code 03	17
4.7	Reading and Writing Auxiliary Analog Outputs	17
4.8	Reading User Discrete Inputs	18
4.9	Writing User Relay Outputs	20
4.10	System Status Word	20
4.11	Network Fault Location	21
4.12	PLC V-Memory Map	21
5.0	Theory of Operation	23
5.1	Valve Actuator Network Connections	23
5.2	Power-up Initialization	23
5.3	Hot Stand-By Fail-Over	24
5.3.1	Modbus Host Fail-over	25
5.4	Network Fault Detection	25
5.5	Polling Process	26
5.6	Report-by-Exception	26
5.7	Priority Scan	26
5.8	Writing Commands to Valve Actuators	27
5.9	Writing Position Setpoint	27
5.10	Writing Analog Outputs	27
5.11	Writing Actuator Configuration	27
5.12	Writing ESD Command	28
6.0	Software Source Code	28

1.0 Introduction

EIM Controlinc Network Masters are the master of EIM Controlinc valve actuator networks. The system provides network management, data concentration, and protocol conversion, off-loading the host system of these tasks. This enhances overall system performance and minimizes software development and system configuration tasks by the system integrator. The Network Master serves as the master of a master/slave network. It manages the network by keeping an orderly cycle of data transfers to and from the slave devices (valve actuators). It handles error detection, alarming, and network recovery. The Network Master serves as a data concentrator for the host by providing a common database for all slave devices. The host is required to communicate with only one slave device (network master) for all data transfers to and from the field. Data can be transferred between the network master and host in large blocks at a much higher communications rate than would be possible if the host communicated with each slave device (valve actuator) on the field network. The Network Master acquires data from the valve actuators by polling or scanning each device in a sequence from slave address #1 to the last slave address on the network. Polling is a process of the Network Master sending to each slave address, in sequence, a command to return its status information, including alarms, discrete and analog inputs and outputs. When control commands (valve open, stop, close, position setpoint, etc.) are generated by a host system up-line of the Network Master, it then sends the appropriate commands over the network to the addressed slave device. A more detailed functional description of operation is provided in the Theory of Operation section of this manual.

1.1 Reference Documents

In addition to this Controlinc Network Master Operations Manual, the following references are required for proper installation, configuration, and operation of the Network Master. All referenced documents are supplied with the system. Paragraph number as listed below makes references to these documents in this manual.

1.1.1 EIM Controlinc 320A Quick Startup Guide

1.1.2 FACTS Engineering Modbus Slave User's Guide F4-SLV-MB-M

1.1.3 FACTS Engineering 405 Basic CoProcessor User's Manual

1.1.4 FACTS Extended BASIC Reference Manual

1.1.5 Direct Logic DL405 User Manual - Provided in separate binder

1.1.6 Direct Logic DirectSOFT User Manual - Provided in separate binder

1.2 System Configuration

Controlinc Network Master Model NM320A consists of a single chassis with modules and software installed to support a single E>Net ring network using standard RS-485 and Modbus protocol. Figure 1-1 shows the specific system configuration of Model NM320A. Version 1.0 and later communicate with Controlinc Model 320A valve actuators with Version 1.0 or later firmware which controls both block valves (Open, Stop, Close) and modulating or positioner type valves. The system consists of a four slot chassis with a central processor, which provides a global database for the CoProcessors installed the chassis. The central processor also performs such functions as watchdog timers and system alarm generation for the CoProcessors. It also provides interrupt control for fast data transfers between processor modules. Each chassis consists of a Modbus Slave module located in Slot 0. This module communicates with a Modbus host system up line. A second optional Modbus Slave module may be added to the system in slot 3 for redundant Modbus host links. The CoProcessor installed in Slot 1 is the Controlinc Network Master to a ring field network. Two ports of the Network Master module are connected to independent Network Interface Units (NIU) ports. Either port may acquire data from and control all actuators in the field in either direction around the network. A more detailed description of operation is provided in the Theory of Operation section of this manual.

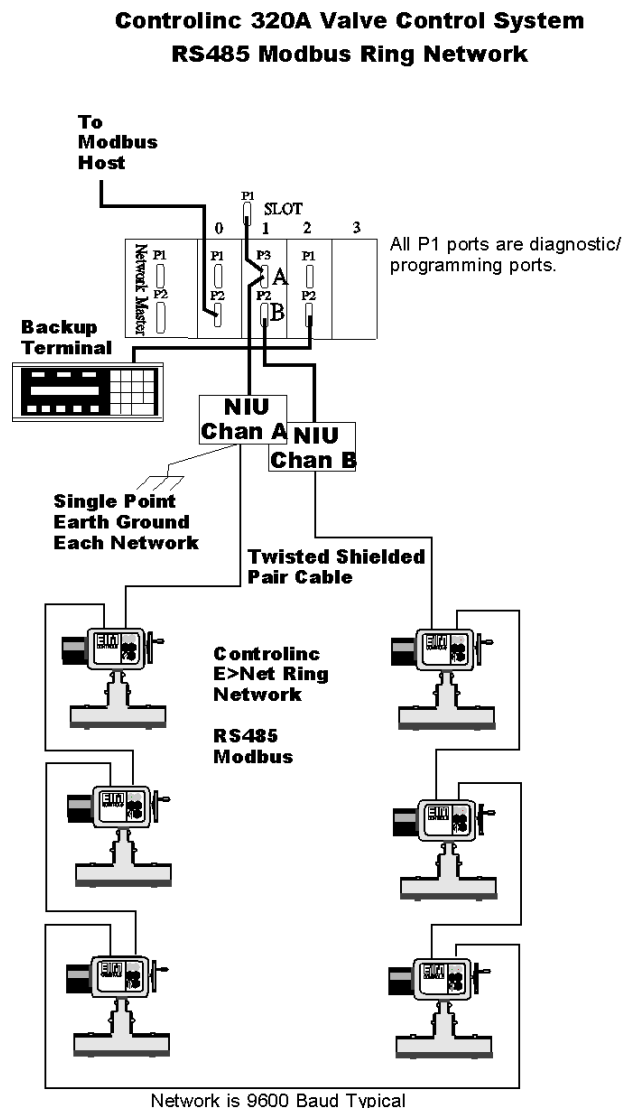


Figure 1-1

NM320A10:GED

1.3 Parts List

The following is a list of materials supplied within each Network Master enclosure. This may be used as a spare parts list.

Qty	Part Number	OEM**	Description
1	D4-04-B	DL	Four slot base (chassis)
1	D4-440	DL	DL405-440 PLC CPU/Power Supply (120VAC)
1	D4-EE-2	DL	EEPROM cartridge (32KB, 15.5K word) installed CPU
1	F4-SLV-MB	FE	Modbus Network Slave module
1	F4-CP128-1	FE	Overdrive CoProcessor with 128K RAM, 26MHz clock
2	NIU-PM	EIM	Network Interface Unit, Panel Mount

Support Equipment, Software and Documentation

F4-CABKIT	FE	Universal cable kit (for programming and test only)
PC-D4OEM-X V2.0	DL	DirectSOFT Windows programming pkg. with manual
ABM-Com-V6.01	FE	Software utilities for CoProcessor modules
NM320A11-V1.1	EIM	Application software back-up disk
D4-USER-M	DL	DL405 PLC User Manual
F4-SLVB-M	FE	Modbus slave module User Manual
F4-CP-M	FE	CoProcessor User Manual with Programming Manual
NM320A_L-M	EIM	Controlinc Network Master Operations Manual

OEM** means Original Equipment Manufacture

DL = Direct Logic
FE = FACTS Engineering
EIM = EIM Company Inc.
OM = OptiMate

2.0 Installation

If the system is supplied from the factory in an EIA 19" rack mount enclosure, no internal wiring is required. The next two paragraphs (2.1 and 2.2) discuss mounting and field network wire connections to the NIU.

2.1 Mounting

The enclosure is designed for standard EIA 19" DIN rail rack mounting. Dimensions of the enclosure are shown in Figure 2-1. The enclosure conforms to EIA RS-310, IEC 297-1, and DIN 41 494, Part 1 standards. The rack in which the enclosure(s) are mounted must allow a minimum of 20" (508mm) depth, allowing space for cable connections.

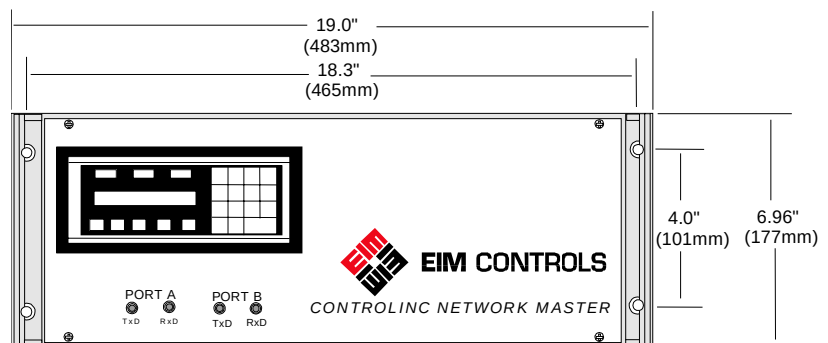


Figure 2-1

2.2 Power Input

The system operates from 120VAC single-phase power with a three-wire power cord and three-prong plug. (Ensure that a good safety ground is provided to the electrical outlet to which the power cord is connected.) The system contains a main fuse (3AG 3Amp) in the fuse block below the power cord socket (see Figure 2-2). Each NIU has an independent 3AG 1Amp slow-blow in-line fuse inside the enclosure. All other modules within the unit are powered over the base back plane from the main processor power supply.

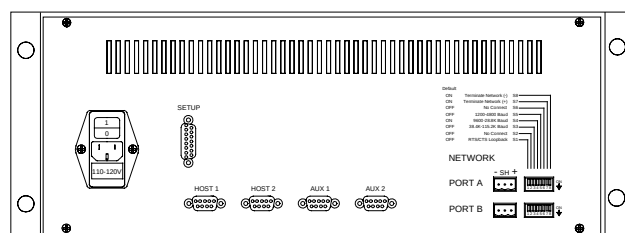
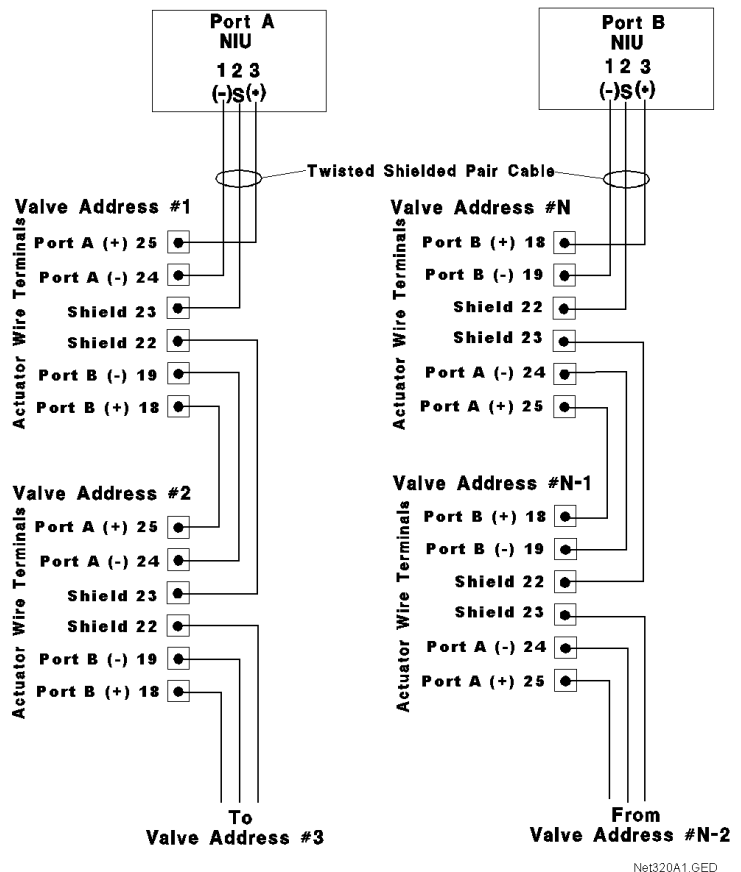


Figure 2-2

2.3 Field Network Wiring

The field network is wired in a ring configuration from Port A around a loop to Port B of the network master. Beginning at Port A, the network is wired to Port A of the first actuator and then from Port B of the first actuator to Port A of the second actuator and so on until the network returns from Port B of the last actuator to Port B of the network master. Networks are polarized with (+) and (-) symbols on all drawings. Proper operation requires that polarity be observed at all connections. Connect the field networks to the Port A and B connectors on the back panel of the network master as shown in Figure 2-2. The networks must be connected to Port A and Port B of the valve actuators as shown in the wiring diagram of the Controlinc 320A manual. Controlinc 320A supports many different network topologies. This manual supports only a single ring E>Net network topology.

**Figure 2-3
Controlinc Ring Network Wiring (typical)**



2.3.1 Network Grounding

The shield or drain wire of the network must be earth grounded at only one point. This single ground point may be at any location in the system where a good earth ground can be obtained. This is normally the building equipment ground grid. Do not connect the network cable shields to a power line ground cable. Power lines can conduct lightning and other transients into the network. Do not connect both ends of the network shield to earth ground at the network master. This can cause a ground loop, make the transient protection system ineffective.

2.3.2 Network Termination

The network requires termination and bias to be asserted at every network connection in the E>Net ring. Setting DIP switches S7 and S8 on the back panel to the ON position terminates the Network Master (NIU). Each valve actuator is terminated by turning ON S5 and S6 of SW4 of the Controlinc 320A module. See Figure 4 of the Controlinc 320A Quick Startup Guide for location of DIP switches.

2.4 Modbus Host Cables

It is necessary for the user to connect cables between the Modbus Host computer and the Modbus slave module (F4-SLV-MB) at HOST 1 port on the back panel of the enclosure. If RS232 is used, components of the cable kit (F4-CBLKIT) may be used during system integration and test but should be replaced by a quality shielded cable when the system is put in service. Two cables are required if redundant Modbus slave modules are installed (HOST 1 and HOST 2 ports). If only one host port is used, the other may be used as a diagnostic port. The system can be configured for communications via either Port 1 or Port 2 of the Modbus slave module (See Configuring the System Section 3.0). The system is configured at the factory for communications on Port 2 of the F4-SLV-MB module at 19.2K baud, 8-bit data, no parity and one stop bit. If baud rates above 38400 are used then Port 1 must be used. This requires the HOST 1 port cable to be moved from Port 1 to Port 2 of the Modbus slave module inside the enclosure. Port 1 is also the Diagnostic/Programming port. It is advisable to integrate and test the system with Port 2 and then configure the system for Port 1 with the higher baud rate and move the host cable connection to Port 1. The Modbus communications link may be configured for RS-232, RS-422 (4-wire), or RS-485 (2-wire). The system is normally configured at the factory to the customer-specified settings. Refer to Appendix B, Page 25 of Reference 1.1.2 for pinout and cable connection requirements of the Modbus slave module.

3.0 Configuring the System

The user should read this entire section before attempting to configure the system. It may also be helpful to read Theory of Operation Section 5.0 of this manual for a better understanding of the system before attempting system configuration. The system is configured from the PLC Relay Ladder Logic (RLL). The system is configured at the factory per the customer specifications. If the user changes the total number of actuators on the field network or the number of modulating/positioner actuators, then the system configuration must be changed. Other parameters such as Modbus port baud rate, network master receiver time-out, and enabling/disabling diagnostic mode may be required during system integration and start-up. DirectSOFT Windows programming software is required to edit configuration parameters in RLL. Refer to Reference 1.1.6 for instructions on loading and using the software package. Refer to the paragraphs of this section for location and value of configuration parameters to be edited.

3.1 System Protection

3.1.1 DirectSOFT Password Protection

The DirectSOFT programming package is supplied with the system under a sub-license agreement of an OEM software license purchased from PLC Direct by EIM Company Inc. The software is PASSWORD protected. Which means the user may not edit the RLL program without the password. To obtain the password you are required to call EIM Company Inc. at (281) 499-1561 and ask for Control Systems Group. EIM can provide additional protection of the system software at the time of system start-up. The password can be changed or editing can be disabled all together by EIM if desired. Users are encouraged to register their copy of DirectSOFT with PLC Direct using the registration form with the software package.

3.1.2 CoProcessor Software Protection

Access to all application software in the CoProcessor modules is disabled unless the system is put into diagnostic mode. The user must be able to edit RLL using DirectSOFT to put the system into diagnostic mode. Thus all application software is protected by the DirectSOFT password described in Paragraph 3.1.

3.1.3 Key Lock Protection

When the system is put into service the key lock should be set to the RUN position and the key removed. This prevents editing of the RLL software and thus the CoProcessor application software, even if the DirectSOFT software package and password is available to an unauthorized person. Additional protection can be added to the system by adding another password in the DL405-440 CPU. See reference 1.1.5 for CPU password protection.

3.2 Configuring System Mode Word

Majority of the system functions is configured by one mode word (SYS-MODE-WRD) in Rung 1 of the RLL. This word is configured by editing the constant loaded to V-Memory location V7351. See Chapter 2, Page 6 of Reference 1.1.2 for meaning of each bit in the mode word. Each bit of the mode word is set or reset by adding or subtracting the binary weighted value of the bit position. Normal mode word values are provided in the comments of Rung 1 of the RLL in Section 6.0 of this manual. Changes in configuration do not take effect until power to the system is cycled off and on.

3.2.1 Selecting Modbus Ports

If Port 2 is active, select Modbus Port 1 by adding 1 to the mode word. If Port 1 is active, select Modbus Port 2 by subtracting 1 from the mode word. Don't forget to cycle power after changing the mode word.

3.2.2 Selecting Diagnostic/Programming Mode

All modules may be configured for Diagnostic/Programming mode by Bit 1 of the Mode Word. Turn on diagnostic mode by adding 2 to the mode word. Turn off diagnostic mode by subtracting 2 from the mode word. Port 1 of the Network Master modules are disabled when not in Diagnostic mode.

3.3 Configuring Modbus Baud Rate

Baud rate of the Modbus (DCS/SCADA) host link is configured by changing the constant (default K7) loaded to the MODBUS-BAUD word in V-Memory V5010. See "Communication Rate Code Table" on Page 6 of Reference 1.1.2 for selection of baud rates. Edit the constant loaded to V5010 with the code corresponding to the baud rate from the table.

3.4 Configuring the Number of Slaves

The number of slaves (valve actuators) on the field network is configured by editing the constant loaded to NUM-SLAVES V-Memory location V6660 in Rung 2 of the RLL. Remember to cycle power after editing RLL.

3.5 Configuring Number of Modulating/Positioning Slaves

The number of valve actuators which are used for modulating or positioned by the host to an analog position setpoint must be entered as NUM-MODULATING V-Memory location V6661 in Rung 2 of RLL.

3.6 Configuring Field Network Baud Rate

Baud rate of the Network Master may be changed by editing the constant loaded to NETWORK-BAUD of V-Memory location V6662 in Rung 2 of RLL. The baud rate must match the baud rate of the valve actuators connected to the network. See Reference 1.1.1 for instructions on setting baud rate of the valve actuators. The default baud of all devices and all ports of the Network Master is 9600. Baud rate is entered as baud/100.

3.7 Configuring Network Master Receiver Time-Out

Receiver time-out of the network masters may be changed by editing the constant loaded to RECEIVER-TIMEOUT of V-Memory location V6663 in Rung 2 of RLL. Receiver time-out is the amount of time the network master will wait for a response from a slave device before moving on to the next device. If this time is too short (less than 10mS) it could cause collisions on the network, degrading communications throughput. If this time is too long, it will cause time to be wasted while the master is trying to put unconnected devices on the network. The default setting is 50 mS.

4.0 Modbus Register Maps

4.1 Valve Status and Command Registers per Modbus Function Code

Controlinc Network Masters communicate with host computer equipment using Modbus RTU protocol. Valve actuator status data may be acquired from the Network Master using any one of four Modbus Function Codes (01 thru 04). Data is returned as either discrete (bit) type using Function Code 01 and 02 or as 16-bit integers using Function Code 03 and 04. Command outputs to the valves may be written to the Network Master using four Function Codes (05, 15, 06, and 16). Table 4-1 is the address map for valve actuators up to a maximum of 250. Status of each valve is stored as 16 discrete inputs and as 16 coils. Discrete commands to each valve consists of four bits (coils) per valve and is stored as coils with four valves per 16-bit register. Position setpoint is a word analog (0-4095) value written to the valve actuator using the 06 or 16 function codes. All registers are unsigned 16-bit integers.

TABLE 4-1
Memory Map of Valve Data and Commands by Function Code

Function Code and Valve data/Command	Command Data Type	Begin Reg	Ending Reg	Max Number
01 Discrete valve status	Read Coils (discrete)	01025	05024	4000
01 Discrete Outputs (0-15)	Read Coils (discrete)	05089	09088	4000
02 Discrete valve status	Read Inputs (discrete)	10001	14000	4000
02 Discrete Inputs (raw 0-15)	Read Inputs (discrete)	14065	18064	4000
03 Valve status word	Read Holding Register	40001	40250	250
03 Valve position feedback	Read Holding Register	40256	40505	250
03 Valve position setpoint	Read Holding Register	40576	40825	250
03 Aux. analog input #1	Read Holding Register	40826	41075	250
03 Aux. Analog input #2	Read Holding Register	41076	41325	250
03 Aux. Analog output	Read Holding Register	41326	41575	250
03 Discrete Inputs (raw 0-15)	Read Holding Register	41576	41825	250
03 Discrete Outputs (0-15)	Read Holding Register	41826	42075	250
04 Valve status word	Read Input Register	30001	30250	250
04 Discrete Inputs (raw 0-15)	Read Input Register	30255	30504	250
05 Discrete valve commands	Write Coils (discrete)	00001	01024	1024
05 Discrete Outputs (0-15)	Write Coils (user relays)	05089	09088	4000
15 Discrete valve commands	Write Multiple Coils	00001	01024	1024
15 Discrete Outputs (0-15)	Write Multiple Coils	05089	09088	4000
06 Discrete valve commands	Write Holding Register	40512	40575	64
06 Valve position setpoint	Write Holding Register	40576	40825	250
06 Aux. analog output	Write Holding Register	41326	41575	250
06 Discrete Outputs (0-15)	Write Holding Register	41826	42075	250
16 Discrete valve commands	Write Multiple Registers	40512	40575	250
16 Valve position setpoint	Write Multiple Registers	40576	40825	250
16 Aux. Analog output	Write Multiple Registers	41326	41575	250
16 Discrete Outputs (0-15)	Write Multiple Registers	41826	42075	250

4.2 Valve Status Bit Data for Each Valve

Valve status information is stored in contiguous registers in sequence with the valve actuator network address. Table 4-2 shows the valve status for valve address #1 when using Modbus Function Code 02.

TABLE 4-2
Valve Status Information for Valve at Network Address #1
For
Controlinc Model 320A

Modbus Address	Valve Status	Description
10001	Open Limit Switch	Valve Fully Open
10002	Close Limit Switch	Valve Fully Closed
10003	Transition Opening	Valve is Moving Open
10004	Transition Closing	Valve is Moving Close
10005	Manual Mode	Selector Swt in Local
10006	Auto Mode	Selector Swt in Remote
10007	Open Torque Alarm	Open Torque Swt Tripped
10008	Close Torque Alarm	Close Torque Swt Tripped
10009	Valve Stall Alarm	Valve is Not Moving
10010	Power Monitor Alarm	Loss of Control Voltage
10011	Motor Overload Alarm	Overload Relay Tripped
10012	Phase Monitor Alarm	3-Phase power reversed
10013	Local ESD Alarm	Local ESD input activated
10014	Actuator Fail Alarm	Failed self-diagnostics
10015	Com No-Response Alarm	Com Failure on both lines
10016	Unit Alarm	Set when any alarm bit set

Note: Unit alarm bit (10016) is set if any one or more alarm bits 7 through 13 are set.

4.2.1 Multiple Valve Status Locations Using Function Code 02

Valve status information shown in Table 4-2 is repeated for each actuator on the network in sequence of network address. Data for valve at network address number 2 is located at Modbus addresses 10017 through 10032. Data for valve at network address 3 is located at 10033 through 10048 and so on for up to 250 valves on the network as shown in Table 4-3.

TABLE 4-3

Using Modbus Function Code 02

Valve Actuator Network Address		Modbus Addresses for Valve Status	
001		10001 thru	10016
002		10017 thru	10032
003		10033 thru	10048
004		10049 thru	10064
005		10065 thru	10080
:	:	:	:
:	thru	:	thru
:	:	:	:
248		13951 thru	13968
249		13969 thru	13984
250		13985 thru	14000

IMPORTANT NOTE:

Modbus addressing shown in the tables of this section is the normal configuration addressing method used by most SCADA and DCS systems. If you are building Modbus messages at the communication driver level, keep in mind that HEX-starting addresses in the Modbus message are offset by one. You must subtract one from the address in the tables when building a Modbus message. For example, to read the first valve status bits as coils using Function Code 01, the starting address of 1025 shown in Table 4-1 would be 400 Hex (1024 decimal) in the Modbus message. If valve status of the first valve is read using Function Code 02, the starting address of 10001 shown in Table 4-1 would be 00 Hex in the Modbus message. If valve status of the first valve is read using Function Code 03, the starting address of 40001 shown in Table 4-1 would be 00 Hex in the Modbus message.

4.2.2 Multiple Valve Status Data Using Modbus Function Code 03

The same valve status data can be accessed by the Host using Function Code 03 by reading unsigned 16-bit integers from holding registers beginning at Modbus Address 40001 as shown in Table 4-4. The 16 bits of valve status for each valve actuator is the same as that shown in Table 4-2.

TABLE 4-4
Using Modbus Function Code 03

Valve Actuator Network Address		Modbus Address	
001		40001	
002		40002	
003		40003	
004		40004	
005		40005	
:		:	
:	thru	:	thru
:		:	
248		40248	
249		40249	
250		40250	

4.2.3 Multiple Valve Status Data Using Modbus Function Code 04

The same valve status data can be accessed by the Host using Function Code 04 by reading unsigned 16-bit integers from input registers beginning at Modbus Address 30001 as shown in Table 4-5. The 16 bits of valve status for each valve actuator is the same as that shown in Table 4-2.

TABLE 4-5
Using Modbus Function Code 04

Valve Actuator Network Address		Modbus Address	
001		30001	
002		30002	
003		30003	
004		30004	
005		30005	
⋮		⋮	
⋮	thru	⋮	thru
⋮		⋮	
248		30248	
249		30249	
250		30250	

4.3 Reading Valve Position and Setpoint

Valve position feedback is accessed by the Host using Modbus Function Code 03 to read holding registers beginning at Modbus address 40256. Position setpoint of each valve may be read in sequence with valve address starting at Modbus address 40576. Analog data representing analog position and setpoint of each valve is unsigned 16-bit integer with a 12-bit value of 0 to 4095. Each valve's analog position and setpoint are located in holding registers in sequence of network address as shown in Table 4-6.

TABLE 4-6

Valve Position Feedback and Setpoint using Modbus Function Code 03

Valve Actuator Network Address	Modbus Address	
	Position	Setpoint
001	40256	40576
002	40257	40577
003	40258	40578
004	40259	40579
005	40260	40580
⋮	⋮	⋮
⋮	thru	thru
⋮	⋮	⋮
248	40503	40823
249	40504	40824
250	40505	40825

4.4 Writing Discrete Commands to Valve Actuators

Discrete commands are written to a single valve actuator as coils (bit) data using Modbus Function Code 05 or to multiple valve actuators using Function Code 15. Commands may also be written to multiple valve actuators by writing a single holding register using Function Code 06 or to multiple holding registers using Function Code 16. Emergency Shut Down to all valve actuators (ESD) is accomplished by writing any non-zero value to the valve corresponding to network address 255 (FF Hex), i.e. the broadcast address. Each valve actuator will respond to four commands as shown in Table 4-7. The four bits associated with each valve is in sequence with the valve

actuator network address. When writing to holding registers, data is written to four valve actuators. Writing zeros to any location has no affect on operation. Each command is a positive one (set coil) and the coil is automatically reset when the command is executed. Only one coil per valve may be written at any one time. Writing multiple coils to a single valve will cause no action, i.e. it is treated as a no-op.

TABLE 4-7**Writing Commands to Valves using Function Code 05 or 15**

Modbus Address	Command and Valve Network Address
00001	Open - Valve at address 001
00002	Stop - Valve at address 001
00003	Close - Valve at address 001
00004	ESD - Valve at address 001
00005	Open - Valve at address 002
00006	Stop - Valve at address 002
00007	Close - Valve at address 002
00008	ESD - Valve at address 002
00009	Open - Valve at address 003
00010	Stop - Valve at address 003
00011	Close - Valve at address 003
00012	ESD - Valve at address 003
00013	Open - Valve at address 004
00014	Stop - Valve at address 004
00015	Close - Valve at address 004
00016	ESD - Valve at address 004

Discrete command holding registers contain four commands per valve for four valves per 16-bit register. A single register may be written to command four valves by using the Modbus Function Code 06. Multiple registers may be written using Function Code 16. Command holding registers begin at Modbus address 40512. A total of 64 registers are used for the command coils. The last valve network address in register 40575 is valve address 255. Writing a non-zero value to this location will cause an ESD command to be sent to all actuators on the network. Each actuator is configured to respond to the

ESD command in either of three ways; go closed, go open, or stay put. Each actuator can also control an ESD relay, which may be wired to control the actuator, external equipment or to override some internal function. See Reference 1.1.1 for instructions on setting ESD functions of the valve actuator.

4.5 Writing Analog Valve Position Setpoint (Function Codes 06 and 16)

If the valve is a modulating or positioning unit, the position setpoint may be written to the valve as an unsigned 16-bit integer from 0 to 4095 using Modbus Function Codes 06 or 16. Setpoint of each valve is in sequence with network address. Any Controlinc 320A actuator may be a positioner or modulating unit. The operating mode is selected at the actuator DIPswitches or via the CCU. Configuration may also be changed by writing to the configuration registers from the host.

IMPORTANT NOTE: The user must set valve actuator network address DIP switches for all modulating/positioner type valves to the first, lower addresses, and then set discrete block valves to the last, higher addresses to obtain maximum performance from the system.

4.6 Reading Auxiliary Analog Inputs Using Function Code 03

Controlinc 320A valve actuators have two auxiliary analog inputs for data acquisition of other equipment such as pressure or temperature transducers. The two inputs for each actuator are identified as AIN2 and AIN3. The analog data is returned as unscaled 12-bit unsigned integers with a value between 0 and 4095. The host is required to scale the values to engineering units for display to the Man Machine Interface (MMI). The values are scaled by $(\text{real time value}/4095 * \text{full scale engineering units})$. Data for auxiliary analog inputs AIN2 is in sequence with network address starting at Modbus register 40826. Up to 250 values may be acquired. The last register for the 250th unit is 41075. Data for auxiliary analog inputs AIN3 is in sequence with network address starting at address 41076. Up to 250 values may be acquired. The last register for the 250th unit is 41325.

4.7 Reading and Writing Auxiliary Analog Outputs

Each Controlinc 320A valve actuator has an option to add one 4-20mA analog output. The host may write to the output by writing to a Modbus register in sequence with network address starting at register 41326. Up to 250 analog outputs may be written. The last register for the 250th unit is 41575. Data must be written to the actuators as 12-bit analog data with a range of 0 to 4095 corresponding to 4-20mA. The data is written to the actuators using Modbus Function Code 06 or 16. The analog output may be read back from the actuator using Function Code 03.

4.8 Reading User Discrete Inputs

Each Controlinc 320A has two isolated discrete inputs available to the User. These are Inputs 13 (User Input #1) and 14 (User Input #2) in the Controlinc 320A discrete input memory map. Inputs 0-15 of the Controlinc 320A are the raw hardware discrete inputs and are de-bounced by software. None of the inputs are software generated. The Network Master reads all discrete inputs (0-15) of each valve actuator and places these into contiguous data base locations corresponding to network address of the actuator. Inputs of each actuator are shown in Table 4-8. The host, using Function Codes 02, 03, and 04, may access these inputs. When using Function Code 02, the inputs are addressed from 14065 to 18064 with 16 inputs per actuator as shown in Table 4-8 for up to 250 actuators. When using Function Code 03, the discrete inputs are addressed from register 41576 (valve #1) to 41825 (valve #250). When using Function Code 04, the discrete inputs are addressed from register 30255 (valve #1) to 30504 (valve #250). Inputs (bits) of each valve actuator within the 40000 and 30000 registers are in the same sequence as shown in Table 4-8.

TABLE 4-8

**Discrete Inputs for Valve at Network Address #1 Using Function Code 02
for
Controlinc Model 320A**

Modbus Address	Valve Status	Description
14001	Open Limit Switch	Valve Fully Open
14002	Close Limit Switch	Valve Fully Closed
14003	Auxiliary Open Contact	Aux. contact of starter
14004	Auxiliary Close Contact	Aux. contact of starter
14005	Manual Mode	Selector Swt in Local
14006	Auto Mode	Selector Swt in Remote
14007	Open Torque Alarm	Open Torque Swt Tripped
14008	Close Torque Alarm	Close Torque Swt Tripped
14009	Power Monitor Alarm	Loss of Control Voltage
14010	Motor Overload Alarm	Overload Relay Tripped
14011	Phase Monitor Alarm	3-Phase power reversed
14012	Local ESD Alarm	Local ESD input activated
14013	VFC Fault Alarm	VFC alarm input activated
14014	User Discrete Input #1	Isolated user wired input
14015	User Discrete Input #2	Isolated user wired input
14016	On-board execute button	Used by 320A only

4.9 Writing User Relay Outputs

Each Controlinc 320A has two User Relay Outputs, which may be controlled by the host. The outputs are Coils 04 (User Relay #1) and 05 (User Relay #2) in the Controlinc 320A Coil Map (0-15). The Network Master may read and write all 16 coils but masks all coils except 04 and 05. If the user attempts to write to any other coils, the command will be ignored. The database of the Network Master is configured for 16 coils per actuator for 250 actuator in sequence with valve address. The User Relays may be controlled using Function Codes 05, 15, 06, or 16. If Function Codes 05 or 15 are used the coils are addressed from coil 05089 to 09088 with 16 coils per actuator. For example, to write to relays of valve number one, write to coil 05093 for Relay #1 and 05094 for Relay #2. Relays of each consecutive valve are offset by 16. For example, Relay #1 of valve number two would be coil 05109 (5093+16).

4.10 System Status Word

The system status word is the status of the Network Master. This word is located in the Modbus register maps as if it were valve number 254. The system status word may be read using Modbus Function Code 03 in the same manor as reading valve status. Only the first least significant eight bits are defined. The eight most significant bits are reserved for future functions and are set to zeros. Bit assignments are shown in Table 4-9.

Table 4-9

System Status Word Bit Map

Bit	Status Definition
0	Watchdog Timer Alarm - Slot 1, Network 1 Network Master module
1	Watchdog Timer Alarm - Slot 2, Network 2 Network Master module
2	Failed Write Command to Slot 1, Network 1 Network Master module
3	Failed Write Command to Slot 2, Network 2 Network Master module
4	Another Master on Line - Slot 1, Chan A Network Master (Hot Stand-By)
5	Another Master on Line - Slot 2, Chan B Network Master (Hot Stand-By)
6	Network Fault Alarm - Slot 1, Network 1 Network Master
7	Network Fault Alarm - Slot 2, Network 2 Network Master
8 - 15	Reserved for future enhancements

4.11 Network Fault Location

If the field network is connected in a ring configuration, the Network Master automatically detects and locates a single line fault. The location of the fault may be displayed by the MMI as two network addresses. The two network addresses between which the fault is located is available in Modbus register 40252 (Network Fault Low Address) and register 40253 (Network Fault High Address). By reading these two locations, the SCADA host may display to the MMI the location of the fault when a Network Fault system alarm bit is set.

4.12 PLC V-Memory Map

Table 4-10 is supplied for the benefit of the software engineer and is not required for system configuration. The system automatically allocates memory as shown.

Table 4-10
PLC V-Memory Allocation

Parameter		Octal	Decimal	Hex	Modbus
Valve Status and Alarms	Begin	1400	0768	300	40001
(251 words)	End	1772	1018	3FA	40251
Network Fault Low Address		1773	1019	3FB	40252
Network Fault High Address		1774	1020	3FC	40253
System Status Word (1 word)		1775	1021	3FD	40254
Reserved system registers	Begin	2000	1024	400	N/A
(7 words)	End	2007	1031	407	N/A
Discrete Valve Commands	Begin	2010	1032	408	40512
(64 words)	End	2501	1095	447	40575
Valve Position Setpoint	Begin	2110	1096	448	40576
(250 words)	End	2501	1345	541	40825
User Analog Input #1	Begin	2502	1346	542	40826
(250 words)	End	3073	1595	63B	41075
User Analog Input #2	Begin	3074	1596	63C	41076
(250 words)	End	3465	1845	735	41325
Valve Position Feedback	Begin	4000	2048	800	40256
(254 words)	End	4375	2301	8FD	40509
System Com & Unit Alarm	Begin	4400	2304	900	N/A
Database (250 words)	End	4771	2553	9F9	N/A
Primary Master Watchdog		5000	2560	A00	N/A
Secondary Master Watchdog		5001	2561	A01	N/A
Pri. Modbus Slave Config.	Begin	5010	2568	A08	N/A
(7 words)	End	5017	2575	A0F	N/A
Sec. Modbus Slave Config.	Begin	5020	2576	A10	N/A
(7 words)	End	5027	2583	A17	N/A
Analog Output	Begin	5050	2600	A28	41326
(250 words)	End	5441	2849	B21	41575
User Discrete Inputs	Begin	5442	2850	B22	41576
(valve inputs 0-15) (250 words)	End	6033	3099	C1B	41825
User Discrete Outputs (coils)	Begin	6034	3100	C1C	coil 5089
(valve coils 0-15) (250 words)	End	6425	3349	D15	coil 9088
Network Master Configuration	Begin	6660	3504	DB0	N/A
(4 words)	End	6663	3507	DB3	N/A

5.0 Theory of Operation

This section describes systems with redundant network masters. If your system does not have redundant masters, references to redundant chassis or modules do not apply. The system normally has two Network Master modules running identical software. System configuration and the Network Master's ability to access the field network determine mode of operation of each module. Either of the network masters may take control of the field network. The following paragraphs explain how the system functions from an application software point of view. This will provide a better understanding of how the system functions. In the following discussions, the Network Masters may be referred to as modules.

5.1 Valve Actuator Network Connections

In order to better understand how the Network Masters operate, the user needs to understand what goes on at the network and actuator level. Each Controlinc 320A valve actuator has a network Port A and Port B connection. When a message is received on either channel, it is repeated by hardware to the other channel. If a message is received on Port A, it is transmitted at Port B. If a message is received at Port B, it is transmitted at Port A. Messages on the network are repeated in both directions without intervention of microprocessor software. As the message passes through the actuator, it is received by the microprocessor of the valve actuator. If the message address matches the actuator address, the command is processed and the valve actuator responds to the host command. When the actuator responds, it transmits on both Ports A and B. Thus, both communication channels of the module receive messages returned from the field. Both Network Masters receive all messages from the network from both ends of the ring.

5.2 Power-up Initialization

The system normally has only one Network Master module per chassis but may support up to four master modules per chassis. The following description is for two master modules per chassis. At power up, each Network Master module configures itself based on information read from the PLC. It first determines which slot it is installed in. If its slot number is odd, e.g. slot 1, then it configures itself as the Network 1 Network Master. If its slot number is even, e.g. slot 2, then it configures itself as the Network 2 Network Master. This determines which registers are used to report system status information to the host. Each module reads the number of slaves configured for the network from V-Memory location 6660. It will use the number of slaves to allocate memory and build a scan list. The module reads the number of modulating/positioner type valves on the network by reading V-Memory location 6661. The module allocates memory for position setpoint for the number of modulating units. The module reads its network baud rate from V-Memory location 6662. This is the baud rate for Port 2 and 3, the network ports. The module reads its receiver time out from V-Memory location 6663. This is the amount of time in milliseconds it will wait for a response from a slave before flagging the slave response as bad and going on to the next slave address. The module reads the

system mode word from V-Memory location 7351. It decodes two bits of the mode word. One is the diagnostic mode bit (bit 1). If the diagnostic mode is turned on, the module will enable Port 1, disable LOCKOUT, and enable entry of Control C at Port 1. The module will transmit to Port 1 messages sent to and received from the network port. It will also transmit other useful messages to Port 1, such as error messages. The second mode bit (bit 9) decoded is the Hot Stand-By mode. If the Hot Stand-By mode is enabled, the module will delay one second after power-up to allow another chassis to take control of the network. If the system is installed with a Hot Stand-By system, this forces the Hot Stand-By unit to remain in the Hot Stand-By mode so long as the primary master is communicating on the same network to which it is connected.

5.3 Hot Stand-By Fail-Over

After power up, all modules listen to the network to which they are connected for 800mS. If no activity is detected (quiet line), the module checks the status of the other module in the same chassis if present. If the other module has also detected a quiet line or is not present, then the first module will proceed to take control of its network. If the other module does not have a quiet line, it will listen to the network for 200mS and again check the status of the other module. This process will continue until network activity is detected or the other module detects a quiet line. If network activity is detected during this process, the timer is reset to 800mS and the whole process begins again. If a host transmission is detected while listening to the line, the message is discarded and the listening process is restarted. If at any time during the listening process, both modules in the same chassis detect quiet lines, they both begin the polling process and thus take over their networks. During the polling process, if another master's message is received, the module will go into Hot Stand-By mode and begin listening to the network again. This process requires only 200mS, where the normal listening process takes up to two seconds to fail over. Each module resets its own watch dog timer only when valid data is received from the network. On every poll cycle, each module checks the status of its own watchdog timer. If the watchdog timer times out, the module goes to the listen mode and turns the network over to the Hot Stand-By chassis. Each module counts the number of no responses from the slave units. If the number of no responses exceeds the number of connected devices, plus ten, without receiving good data, then the module goes into listen mode and releases the network to the Hot Stand-By chassis. If a second master module in the same chassis has detected another module on its network, the first module will also fail over to Hot Stand-By. This insures that both networks are released to the Hot Stand-By chassis.

5.3.1 Modbus Host Fail-over

The system monitors status of both modules. If either of the two modules go into Hot Stand-By mode, Modbus communications with the host system is inhibited. This insures that the host is acquiring data from the system that has control of the network. The same status bits are also available in the system status word available to the host. The host can make the decision which communication channel to select, based on this and other status information such as watchdog timer and network fault status bits.

5.4 Network Fault Detection

If the module gains access to the network, it then performs a network test. It transmits a message from Port A and verifies that the message is received through the network at Port B. If the message is not received at Port B after three attempts, it then sets the network fault alarm. It then polls around the ring from slave address one to the last address from port 3. The module records the last address that responded as the fault location low address. The module polls the network from port 2 by polling from the last address and decrements to address one. The module records the last address to respond as the location of the network fault high address. The network fault is located between the low address and high address. These addresses are available to the host in Modbus registers 40252 and 40253. If a module gains access to the network but does not receive valid data from the connected slaves, it also sets a network fault alarm bit in the system status word. Each time the module finishes a complete poll cycle of all network addresses, it repeats the network fault test described above. If at any time during the normal polling process the module detects that three addresses in sequence do not respond, it goes into the network fault detection routine described above and locates the fault. Network fault conditions reported in the system status word and the location of the fault should be alarmed to the system operator so that the fault can be corrected. If a network fault is detected, the module poll the accessible addresses around the ring in one direction from port 3 and then poll around the ring in the opposite direction from port 2. This allows the master to access all actuators on both sides of the network fault. Under network fault conditions, the module polls one address greater than the last address to respond, i.e. it polls one address past the fault location. If the address beyond the fault responds, the network fault alarm is reset and the normal polling process resumes.

5.5 Polling Process

The module gets slave addresses from a scan list for the next slave to poll. The scan list is initialized at power up with all addresses. If a valid address is the next address in the poll sequence, the slave is polled and received data stored in the global database. If a slave does not return data for three poll cycles, the module sets the COM alarm bit for that slave address. If a slave does not respond for five poll cycles it is taken out of the scan list by inserting a zero in the scan list. If a zero is detected in the scan list, the module checks the number of scan cycles the slave has been off scan. After 200 poll cycles, the module will attempt to bring on-line any slave that was removed from the scan list by polling the slave for five more poll cycles. Valve actuator status includes one COM alarm bit (14th bit). This com alarm bit is set only when both network paths have failed, meaning both port 3 and port 2 of the module loose access to an actuator. The COM alarm bit is reset when either port gains access to the actuator.

5.6 Report-by-Exception

The system uses Modbus Function Code 07 for report-by-exception (RBE). The module normally polls all devices with Function Code 07. If the valve actuator did not have any status, alarms, or analog valve changes since the last master's request it returns zero in the function 7-processor status field. If data changed since the last poll, the valve actuator responses with a hex FF in the processor status field. If zero is returned, the module has no data to process into the database. It simply goes on to the next slave address in the poll list. If hex FF is returned, indication of an exception, the module polls the actuator using Function Code 03. All data is requested in one block and processed into the database when received. This RBE process speeds up the system throughput by a factor of four to six times due to the small amount of data being transferred over the network. Also, due to the fact that no data processing into the database (the most time consuming event) is required until data has changed. To ensure the system always has an accurate database, the valve actuator forces an exception every 200 poll cycles.

5.7 Priority Scan

When a module receives a command from the host and commands an actuator to move, the actuator's address is put into a priority scan list. If a valve transition opening or closing status is received from an actuator, its address is put in the priority scan list. The module polls the valves in the priority scan list first and then polls the next slave in the normal scan list. It continues in this pattern. This interlace scanning process insures fast update of moving valves to the host system. Up to eight slaves addresses may be in the priority scan list at any one time. Slave addresses are removed from the priority scan list as soon as their opening or closing transition bit is cleared.

5.8 Writing Discrete Commands to Valve Actuators

The host system writes discrete valve commands to the Modbus slave module which in turn stores the commands in the global database and sets an interrupt to the central CPU. The CPU writes the commands to the Network Master modules, which generates an interrupt to the module(s). The interrupt causes immediate processing of the commands. If a module does not accept the data written by the CPU within two seconds, a Write Command Alarm bit is set in the system status word for the faulty module. Each module decodes the commands and determines which slave address is to receive the command. If the slave address is not in the scan list, the module ignores the command. If the slave is in the scan list the command is transmitted to the slave and the module waits for an acknowledgment. If an acknowledgment is not received within the receiver time-out period the command is retransmitted. If the slave does not return an acknowledgment after three transmission attempts, its COM alarm bit is set. The host may write commands for multiple valves at the same time. The module will decode each command in the order of the slave address and transmit each in turn. After all commands are transmitted to the actuators, the module zeros the discrete command registers in the global database. The database for analog setpoint, analog output, and user discrete outputs is not zeroed. The host may read back these types of output data at any time.

5.9 Writing Position Setpoint

When the host writes a valve position setpoint to the master, the module compares the new setpoint with the setpoint returned by the valve actuator. If a difference is detected, the new setpoint is transmitted to the valve actuator. The module requires an acknowledgment from the actuator. If an acknowledgment is not received after three attempts, the COM alarm bit for the actuator is set.

5.10 Writing Analog Outputs

When the host writes an analog output to an actuator, the module compares the command output to the received analog output from the actuator. If a difference is detected, it writes the new analog value to the actuator. Like all writes, the module will attempt three times if an acknowledgment is not received.

5.11 Writing User Relay Outputs

When the host writes to a coil corresponding to either User Relay #1 or User Relay #2 or both, the module compares the status of the coils received from the actuator. If a difference is detected, the module writes the new coil output (on or off) to the actuator. The module will make three attempts to write a coil to the actuator if an acknowledgment is not received.



5.12 Writing ESD Command

When the host writes an Emergency Shut Down (ESD) command to the system by writing to valve address 255, an ESD command is immediately transmitted to all valve actuators which are currently active on the network. A broadcast address is not used because the module requires confirmation that each actuator received the ESD command. It will retransmit the ESD command to any one device up to three times. This insures that all actuators receive the ESD command; if not received, an alarm bit is set for the actuators, which do not acknowledge the command.

6.0 Software Source Code

Source code for RLL and software on the Modbus slave module and the Network Master modules is supplied with the system on 3.5" floppy disks. The software is supplied as a back-up copy and should not be copied. Copyright laws protect the software. Thus it must not be printed or copied. The software files under the "projects" directory may be copied to DirectSOFT for the purpose of configuring the system. Modifications to the RLL program may be made only for the purpose of configuring the system.