Control488/16 Power Control Interface

For the Control488/16 and Control/16

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Control488/16
User's Manual

p/n 186-0920 Rev. **1.3**

Warranty

Your IOtech warranty is as stated on the *product warranty card*. You may contact IOtech by phone, fax machine, or e-mail in regard to warranty-related issues.
Phone: (440) 439-4091, fax: (440) 439-4093, email: sales@iotech.com

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CE Notice

Many IOtech products carry the CE marker indicating they comply with the safety and emissions standards of the European Community. As applicable, we ship these products with a Declaration of Conformity stating which specifications and operating conditions apply.

Warnings and Cautions

Refer all service to qualified personnel. This caution symbol warns of possible personal injury or equipment damage under noted conditions. Follow all safety standards of professional practice and the recommendations in this manual. Using this equipment in ways other than described in this manual can present serious safety hazards or cause equipment damage.

This warning symbol is used in this manual or on the equipment to warn of possible injury or death from electrical shock under noted conditions.

This ESD caution symbol urges proper handling of equipment or components sensitive to damage from electrostatic discharge. Proper handling guidelines include the use of grounded anti-static mats and wrist straps, ESD-protective bags and cartons, and related procedures.

Specifications and Calibration

Specifications are subject to change without notice. Significant changes will be addressed in an addendum or revision to the manual. As applicable, IOtech calibrates its hardware products to published specifications. Periodic hardware calibration is not covered under the warranty and must be performed by qualified personnel as specified in this manual. Improper calibration procedures may void the warranty.

Quality Notice

IOtech has maintained ISO 9001 certification since 1996. Prior to shipment, we thoroughly test our products and review our documentation to assure the highest quality in all aspects. In a spirit of continuous improvement, IOtech welcomes your suggestions.

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Introduction

1.1 General Description

The Control488/16 and Control/16 switch and/or sense ac and dc power to devices such as motors, relays, and lamps that operate at up to 120/240 V ac/dc and that may draw several amps of current. Controls accept NEMA ICS2-230-.02 (Opto-22 style) plug-in modules for each of their sixteen channels, allowing each I/O channel to be configured to fit its particular application.

A Control can be set up in one of several configurations: master/slave with RS-232C or IEEE 488 interfacing, LPT port peripheral, or digital I/O port peripheral. A Control488/16 can be set for master, slave, LPT port or digital I/O port peripheral operation. It is a master unit that can be operated independently or as the control unit for up to fifteen slave Control/16s. A Control/16 can only be set for slave, LPT port or digital I/O port peripheral operation. Control/16 is not capable of master operation. Control488/16 programs slave units through its digital control port. Control/16 is programmed with an 8-bit digital control word: 7 bits of data plus one strobe. Digital control can be driven by a Control488/16 acting as a master, any parallel Centronics port, or a digital I/O interface such as the IOtech Power488, the MetraByte PIO-12 or DAS-16 or the digital I/O port of the Data Translation DT2801.

Control488/16 and Control/16 are packaged in a standard 2U (3.5") high, 19-inch rack enclosure. An IEEE 488 standard connector is provided for bus communication and an RS-232C interface is available through a DB-9 connector. Control signal connections are accomplished via screw/compression terminals.

A selection of eleven Opto-22 style modules is available from IOtech. Five control ac and dc loads, and six sense ac or dc voltages. These modules provide ranges of voltage capabilities comprising 12-240 V ac and 5-200 V dc. Output switch modules are solid state relays that provide 4000 Vrms of optical isolation, protecting the controlling computer from power surges or over-voltage transients on the field device circuits.

Switch modules control up to 3 A at 240 V ac or 60 V dc or 1 A at 200 V dc. Sense modules sense 12-280 V ac or 2.4-280 V dc. The modules provide voltage range capabilities of 12-240 V ac and 5-200 V dc.

Output switch modules are solid state relays that provide 4000 Vrms of optical isolation, protecting the controlling computer from power surges or over-voltage transients on the field device circuits. Their high surge current tolerance, isolation and rugged construction make them excellent system components. When installed in the Control488/16, each channel has 350 V ac, 1000 V peak isolation.

Each switch module (with the exception of the PCAC3) is the equivalent of a single pole, single throw, normally open contact (FORM A,SPST-NO, Make). The PCAC3 is equivalent to a single pole, single throw, normally closed contact (FORM B, SPST-NC, Break).

1.2 Available Accessories

Additional accessories that can be ordered for the Control488/16 and Control/16 include:

CA-7-3	6 foot shielded IEEE 488 cable
CA-81	Master to slave interface cable
CA-82	Slave to slave interface cable
CA-83	PC LPT port to slave interface cable
CA-84	Power488 digital output to slave interface cable
CA-85	PC serial port to master interface cable
CA-86	PC/AT serial to master interface cable
FKP1	Optional fuse kit for Opto-22-compatible G1 unfused modules.
STP3	Optional signal termination panel
FU-3-4	Replacement 4 A 250 V ac fuse for Opto-22-compatible G4-style switch modules
FU-1-4	Replacement 4 A 250 V ac fuse for Opto-22-compatible G1-style switch modules
Control488-901	Additional user's manual
PCDC1	Opto-22 G4ODC5 equivalent switch module. 5-60 V dc, NO, FORM A, Make.
PCDC2	Opto-22 G4ODC5A equivalent switch module. 5-200 V dc, NO, FORM A, Make.
PCAC1	Opto-22 G4OAC5 equivalent switch module. 12-240 V dc, NO, FORM A, Make.
PCAC2	Opto-22 G4OAC5A equivalent switch module. 24-280 V dc, NO, FORM A, Make.
PCAC3	Opto-22 G4OAC5A5 equivalent switch module. 24-280 V dc, NC, FORM B, Break.
PSDC1	Opto-22 G4IDC5D equivalent sense module. 2.5-28 V dc.
PSDC2	Opto-22 G4IDC5B equivalent sense module. 4-15 V dc.
PSAC1	Opto-22 G4IDC5 equivalent sense module. 12-32 V ac or 10-32 V dc.
PSAC2	Opto-22 G4IDC5G equivalent sense module. 35-60 V ac or 35-60 V dc.
PSAC3	Opto-22 G4IAC5 equivalent sense module. 90-140 V ac or 90-140 V dc.
PSAC4	Opto-22 G4IAC5 equivalent sense module. 180-280 V ac or V dc.

1.3 Specifications

Power: 90-125/210-240 V ac 50/60 Hz 60 VA

Dimensions: 425 mm wide x 90 mm high x 305 mm deep (16.75" x 3.5" x 12")

Control488/16 Interfaces:

IEEE 488 Interface: SH1, AH1, T6, TE0, L4, LE0, SR1, RL0, PP0, DC1, DT1, C0, E1

RS-232C Interface (EIA RS-232C): AB, BE, BB, CA, CB

Baud Rates: 300, 600, 1200, 2400, 4800, 9600, 19200, 38400

Data Bits: 8

Stop Bits: 1

Parity: Even, Odd, None

Terminator: CR or LF

Control/16 Interface: 7 data, 6 control/status lines, TTL levels.

Slave Control Output: Proprietary 15-pin TTL.

Isolation: 500 V

Temperature Rating: 0-50°C, 0-95% RH, non-condensing.

Weight: 5 kg, (11 lbs)

Sense (Input) Module Specifications							
IOtech Part #		**PSDC1**	**PSDC2**	**PSAC1**	**PSAC2**	**PSAC3**	**PSAC4**
Opto-22 Equivalent Part #		G4IDC5D	G4IDC5B	G4IDC5	G4IDC5G	G4IAC5	G4IAC5A
	Units						
Input Voltage Range	V dc	2.5-28	4-16	10-32	35-60	90-140	180-280
Input Current @ Max Line	mA	30	45	25	6	11	6.5
Input Allowed for no output	mA V	0.2 1	0.7 1	1 3	0.8 9	3 45	1.7 80
Turn-on Time	msec	1	0.05	5	10	20	20
Turn-off Time	msec	1.5	0.1	5	10	20	20

dc Switch (Output) Module Specifications			
IOtech Part #		**PCDC1**	**PCDC2**
Opto-22 Equivalent Part #		**G4ODC5**	**G4ODC5A**
	Units		
Current Rating: **@45°C Ambient** **@70°C Ambient**	Amps Amps	3 2	1 0.55
Off-State Leakage @ Maximum Voltage	mA	1	2
One Cycle Surge	Amps	80 peak	80 peak
One Second Surge	Amps	5	5
Output Voltage Drop Maximum	V	1.6	1.6
Line Voltage - Maximum	V dc	60	200
Operating Voltage Range	V dc	5-60	5-200
Turn-on Time	µseconds	100	100
Turn-off Time	µseconds	750	750

ac Switch (Output) Module Specifications				
IOtech Part #		**PCAC1**	**PCAC2**	**PCAC3**
Opto-22 Equivalent Part #		**G4OAC5**	**G4OAC5A**	**G4OAC5A5**
	Units			
Current Rating: **@45°C Ambient** **@70°C Ambient**	Amps Amps	3 2	3 2	3 2
One Cycle Surge	Amps	80 peak	80 peak	80 peak
Peak Repetitive Voltage	Volts	500	500	500
Operating Frequency	Hz	25-65	25-65	25-65
Turn-on Time		½ cycle maximum - zero voltage		
Turn-off Time		½ cycle maximum - zero current		
DV/DT - Off-State	V/µsec	200	200	200
DV/DT - Commutating		Snubbed for 0.5 power factor load		
Output Voltage Drop Maximum Peak	Volts	1.6	1.6	1.6
Off-State Leakage	mA	5, rms	5, rms	5, rms
Operating Voltage Range	Volts	12-140	24-280	24-280
Line Voltage (Nominal)		120	240	120/240
Contact Mode		NO	NO	NC

Getting Started

The Control488/16 manual includes information about both the Control488/16 and the Control/16. "Control" refers to either the Control488/16 or the Control/16. Where information is specific to the Control488/16 or the Control/16, the full name is used.

2.1 Inspection

The Control was carefully inspected mechanically and electrically prior to shipment. When you receive the interface, carefully unpack all items from the shipping carton and check for any obvious signs of physical damage that may have occurred during shipment. Report any such damage found to the shipping agent immediately. Retain all shipping materials in the event that shipment back to the factory is necessary.

Every Control is shipped with the following items:

Control488/16	RS-232C and IEEE 488 Programmable Power Control Interface	
or		
Control/16	Digital Programmable Power Control Interface	
Control488-901	User's Manual	
000-0720	Sample program disk in IBM Format	
000-0802	Accessory kit, including:	
	CA-1	Power cable
	FE-1	Rubber Feet (4)
	HA-70	Rack Ears (2)
	HA-41-6	Screws (4)
	FU-1-.5	1/2 Amp Replacement Fuse
	FU-1-.25	1/4 Amp Replacement Fuse

WARNING

The interface is intended for INDOOR USE ONLY. Failure to observe this warning could result in equipment failure or personal injury.

2.2 Internal Configuration

The internal configuration of a Control consists of setting the line voltage, replacing fuses and installing the Opto-22 modules. Line voltage must be set for 110 or 220 V ac to match the power being supplied to the Control. If the line voltage is changed, the fuse must also be changed. See Figure 2.1 for line voltage switch and fuse locations.

WARNING

Disconnect the power cord from the power line and from the Control prior to disassembly.

Never open the Control case while it is connected to the power line. Internal voltage potentials exist which could cause personal injury.

The Control is designed to control and sense circuits which may carry dangerous voltages and/or currents. De-energize the circuits to which the Control is connected before changing the configuration of the Control or its wiring.

To avoid injury, de-energize attached circuits, then disconnect the Control from other equipment and the power line before changing the internal configuration of the Control.

To open the unit, place the Control on a flat surface. Remove the two screws on the top rear of the case. Remove the top cover by sliding it out toward the back of the unit. It might be necessary to lift the cover slightly to clear the safety shield over the signal termination panel. Reverse this procedure to reassemble the unit.

2.2.1 Line Voltage Selection

The Control can be operated from 90-125 or 210-250 V ac, 50-60 Hz. The interface was shipped from the factory set for the operating voltage marked on the label placed over the rear panel line cord jack. If this setting is not appropriate for the power that will be supplied to the unit, the setting of the internal voltage switch (S2) and the power fuse must be changed to avoid damage to the unit. The locations of S2 and the fuse are shown in Figure 2.1.

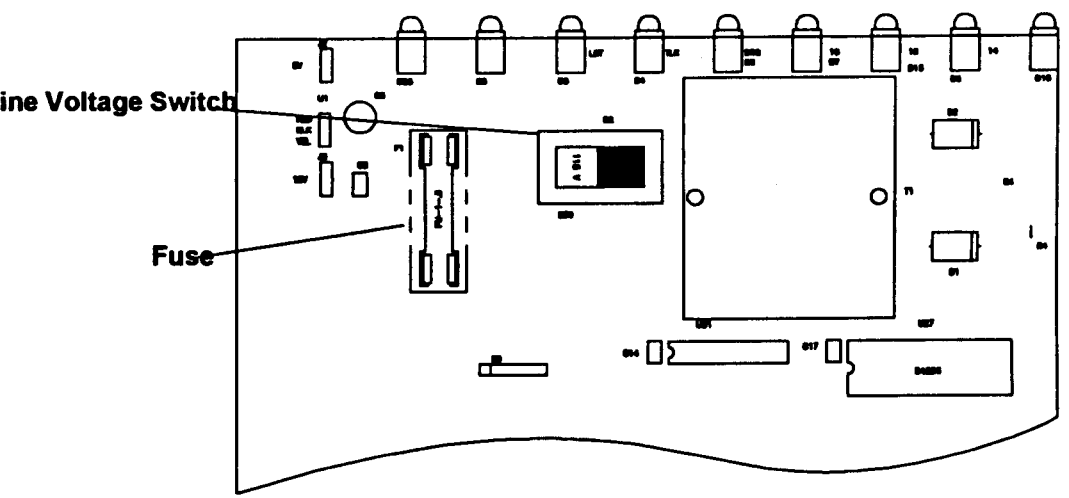

Figure 2.1: Line Voltage Switch and Fuse Location

CAUTION

A fuse with a rating higher than that specified may cause damage to the instrument and may pose a fire hazard. If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before replacing the fuse.

1. The line voltage selection switch (S2) is located next to the power supply transformer. Insert the tip of a small screwdriver into the slot of the switch and slide the switch until it clicks into place with the desired line voltage visible.
2. Install a power line fuse appropriate for the line voltage. The fuse is located next to the internal line voltage switch (S2). Pull upward on the plastic fuse housing to remove the entire housing with the fuse inside. Select a fuse with the proper rating from the table below.

Line Voltage	Fuse Type
90-125V	1/2A 250V, Slo Blo, 3AG
210-250V	1/4A 250V, Slo Blo, 3AG

3. Open the fuse housing by pushing up on the tab on the bottom of the housing.
4. Replace the fuse and close the housing. Replace the fuse housing into the fuse holder. Make sure the fuse snaps into place.
5. Make note of the new voltage setting for later reference and carefully re-assemble the unit.

2.2.2 Opto-22 Module installation

The Opto-22-compatible modules set the functions of each channel: either ac or dc sensing (input) or ac or dc switching (control).

The Control accommodates G1 and G4 Opto-22-compatible control and sensing modules. The G1 modules also require fuses and fuse holders (available as IOtech fuse kit #FKP1). The G4 modules have integral fuses and do not require additional fusing. To install the modules:

1. Match the footprint of the module with the footprint on the circuit board (see Figure 2.2 for module footprint and location).
2. Gently place the module into the footprint and screw it down.
3. Record the channel in which the module was placed.

See Section 2.10 for module wiring.

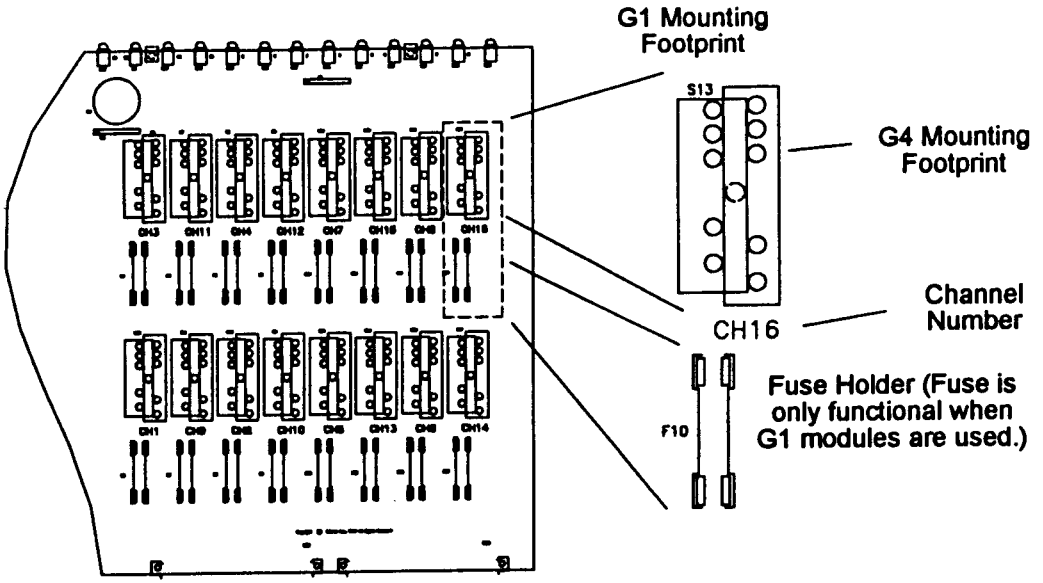

Figure 2.2: Opto-22 Module Installation

2.3 Mounting

The Control includes accessories for rack or bench use.

2.3.1 Rack Mount

If rack mount installation is required, remove the two plastic screws from the predrilled holes on each side of the unit. Only remove the screws from the set of holes that will be toward the front of the rack (the unit can be mounted with the front or rear panel facing the front of the rack fixture).

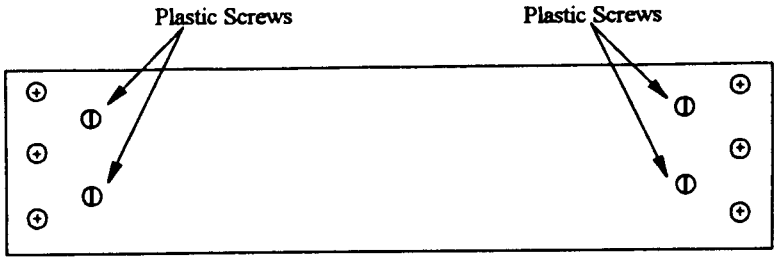

Figure 2.3: Rack Installation (Side View)

Install the two rack ears using the enclosed screws as shown in Figure 2.4.

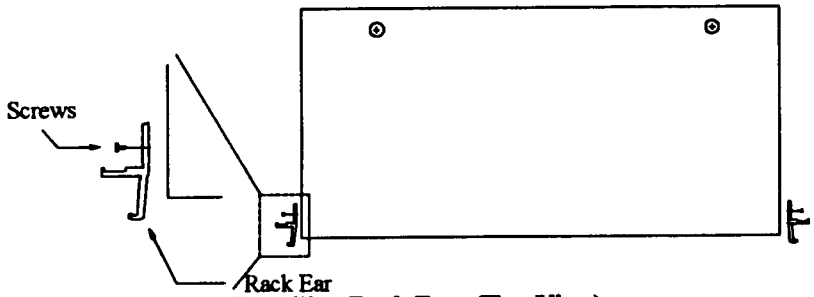

Figure 2.4: Installing Rack Ears (Top View)

2.3.2 Bench Top

If bench top installation is required, install the self-adhesive rubber feet on the bottom of the unit approximately one inch from each corner.

2.4 System Configurations

A Control can be set up in one of several configurations: master/slave with RS-232C or IEEE 488 interfacing, LPT port peripheral, or digital I/O port peripheral. A Control488/16 can be set for master, slave, LPT port or digital I/O port peripheral operation. A Control/16 can only be set for slave, LPT port or digital I/O port peripheral operation. Control/16 is not capable of master operation. The following sections describe the system configurations.

2.4.1 Master/Slave Configuration

In master/slave configuration, a Control488/16 is configured as a master and is connected to a host computer. The master Control488/16 can be connected to as many as fifteen slave Control/16s or Control488/16s through their Master/Slave ports. Master/slave configuration expands a single IEEE 488 bus address or RS-232C port to control a total of sixteen devices

with as many as 256 channels. To set up a system for IEEE 488 master/slave operation, see Section 2.6. To set up a system for RS-232C master/slave operation, see Section 2.7. See Section 3 for operation.

2.4.2 LPT Port Peripheral Configuration

The LPT port peripheral mode allows any IBM-PC compatible printer port to control a single Control/16 or Control488/16. To set up a system for LPT Port Peripheral operation, see Section 2.8. See Section 4 for operation.

2.4.3 Digital I/O Port Peripheral Configuration

Digital I/O port peripheral mode is almost identical to LPT port peripheral mode except that it is designed to allow the individual control of up to fifteen slave units (depending on electronic drive capability) from a single host computer. To set up a system for Digital I/O Port Peripheral operation, see Section 2.9. See Section 5 for operation.

2.5 Default External Switch Settings

The Control system configuration is set by switches accessible from its rear panel. The Control488/16 has two eight position switches that determine the command set used, the configuration mode and the settings for each configuration. The switches labeled W, X, Y and Z are not used on the Control488/16 and should be set down (0) for future compatibility. The Control/16 has one eight position switch that sets the configuration mode and the settings for that configuration.

The rear panel switches are read only during power on or reset and should be set before applying power. Figures 2.5 and 2.6 show the factory default settings for the rear panel switches. The tables following the diagrams show the options for the switches. Switch settings are shown graphically in later sections describing specific setups for IEEE 488, RS-232C, LPT Port and Digital I/O Port operation.

To modify any of these defaults, change the switch settings using a small screwdriver. The enclosure does not need to be opened to change the switches.

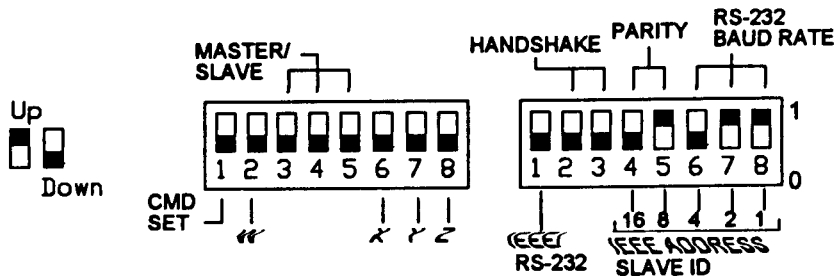

Figure 2.5: Control488/16 Default Switch Settings

Left Control488/16 Rear Panel Switches		
Switch #	**Label**	**Settings**
1	CMD SET	1 (up): Reserved for future enhancements 0 (down): Register-based Command Set (default)
2	W	Not Used; Set to 0 (default).
3, 4, 5	MASTER/SLAVE	000: Master (default)101: LPT Port 100: Slave111: Digital I/O Port
6	X	Not Used; Set to 0 (default).
7	Y	Not Used; Set to 0 (default).
8	Z	Not Used; Set to 0 (default).

Right Control488/16 Rear Panel Switches		
Switch #	**Label**	**Settings**
1	(IEEE) RS-232	0: IEEE 488 Operation (default) 1: RS-232C Operation
4, 5, 6, 7, 8 IEEE 488 Operation	IEEE ADDRESS	IEEE 488 bus address. Default is 11.
2, 3 RS-232C Operation	HANDSHAKE	00: No handshaking 01: XON/XOFF handshaking 10: DTR/CTS handshaking 11: XON/XOFF and DTR/CTS handshaking
4, 5 RS-232C Operation	PARITY	00: No parity 01: Odd parity 10: Even parity
6, 7, 8 RS-232C Operation	RS-232 BAUD RATE	000: 300 baud100: 4800 baud 001: 600 baud101: 9600 baud 010: 1200 baud110: 19200 baud 011: 2400 baud111: 38400 baud
4, 5, 6, 7, 8 Digital I/O Port or Slave Operation	SLAVE ID	Slave identification number.

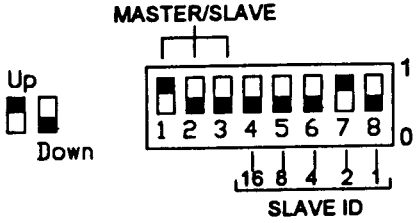

Figure 2.6: Control/16 Default Switch Settings

Control/16 Rear Panel Switches		
Switch #	**Label**	**Settings**
1, 2, 3	MASTER/SLAVE	100 Slave (default) 101 LPT Port 111 Digital I/O Operation
4, 5, 6, 7, 8	SLAVE ID	Slave identification number. Default is 2.

2.6 Master/Slave IEEE 488 Configuration

This section describes the configuration for Controls to be used in master/slave operation commanded through the IEEE 488 bus. When switch setup is completed, refer to page 2.22 for wiring instructions.

The system setup with IOtech cable options is shown in Figure 2.7.

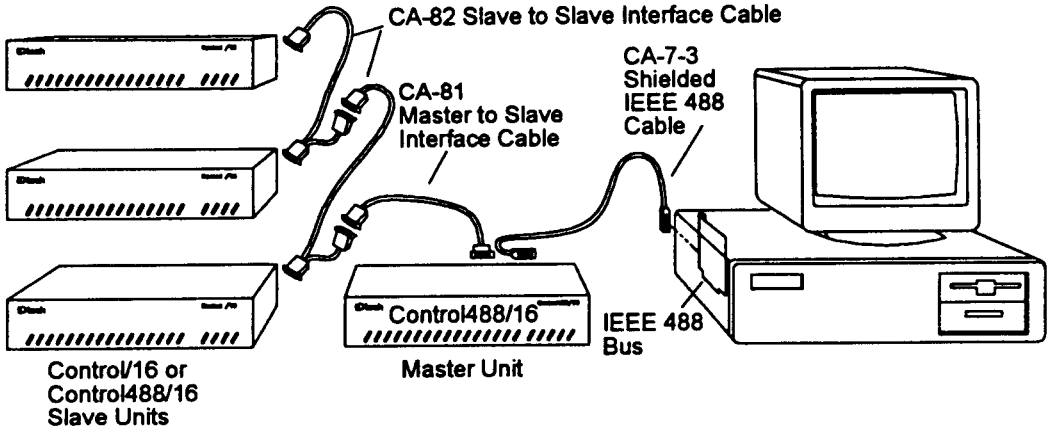

Figure 2.7: IEEE 488 Master/Slave System Configuration

2.6.1 Control488/16 Master Unit Switch Settings

The master unit in a master/slave system configuration must be a Control488/16 (it cannot be a Control/16). The switch settings required for IEEE 488 operation are as follows.

The switch labeled CMD SET must be down (0). The up (1) position is reserved for future enhancements. This sets the unit for the register-based command set.

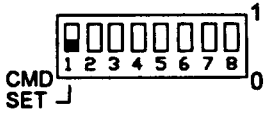

Figure 2.8: Set for Register-Based Command Set

To operate the Control488/16 through its IEEE 488 interface, the unit must be configured as a Master unit. This is done by setting the switches labeled MASTER/SLAVE as shown in Figure 2.9.

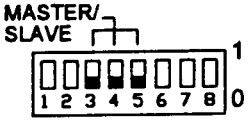

Figure 2.9: Control488/16 Set as Master

The switch labeled IEEE/RS-232 must be set for the IEEE 488 bus, as shown in Figure 2.10.

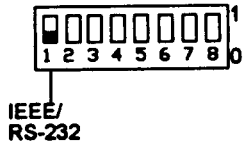

Figure 2.10: Control488/16 Set for IEEE 488 Operation

All IEEE 488 bus devices, including the Control488/16, must have an IEEE 488 bus address. The switches labeled IEEE ADDRESS are used for this purpose. The bus address can be set from 0 through 30 and is read only at power on or reset. The address is selected by simple binary weighting. The switch labeled 1 is the least significant bit; 16 is the most significant bit. The factory default is address 11, as shown in Figure 2.11. If the Control's bus address switches are set to 31, a bus address of 30 is used.

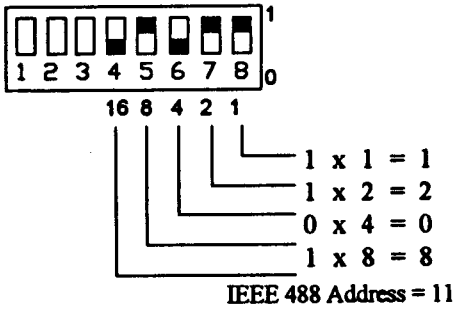

Figure 2.11: IEEE 488 Bus Address Setting (default)

2.6.2 Control/16 Slave Unit Switch Settings

Both the Control488/16 and the Control/16 can be slaved to a Control488/16. When a Control/16 is used, set the switches labeled MASTER/SLAVE as shown in Figure 2.12.

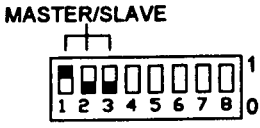

Figure 2.12: Control/16 Set as Slave

Each slave unit must be assigned a unique slave identification number. The slave identification number can be set from 2 through 16 and is read only at power on or reset. The address is selected by simple binary weighting. The switch labeled 1 is the least significant bit; 16 is the most significant bit. The factory default is identification number 2, as shown in Figure 2.13.

Caution

If two or more slave units with the same slave identification settings are connected together, their operation, and the operation of other attached units, is unspecified and may cause errors during operation. Slave identification number 1 is not allowed because it is reserved for the master unit. Identification numbers 17 through 31 are interpreted as 1 through 16 by the Control. 0 is interpreted as 16.

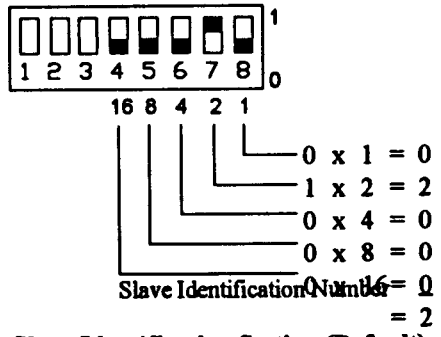

Figure 2.13: Slave Identification Setting (Default)

2.6.3 Control488/16 Slave Unit Switch Settings

Both the Control488/16 and the Control/16 can be slaved to a Control488/16. When a Control488/16 is used, set the switches labeled MASTER/SLAVE as shown in Figure 2.14.

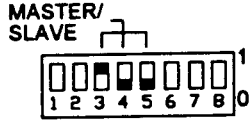

Figure 2.14: Control488/16 Set as Slave

Each slave unit must be assigned a unique slave identification number. The slave identification can be set from 2 through 16 and is read only at power on or reset. The address is selected by simple binary weighting. The switch labeled 1 is the least significant bit; 16 is the most significant bit. The factory default is identification number 11, as shown Figure 2.15.

Caution

If two or more slave units with the same slave identification settings are connected together, their operation, and the operation of other attached units, is unspecified and may cause errors during operation. Slave identification number 1 is not allowed because it is reserved for the master unit. Identification numbers 17 through 31 are interpreted as 1 through 16 by the Control. 0 is interpreted as 16.

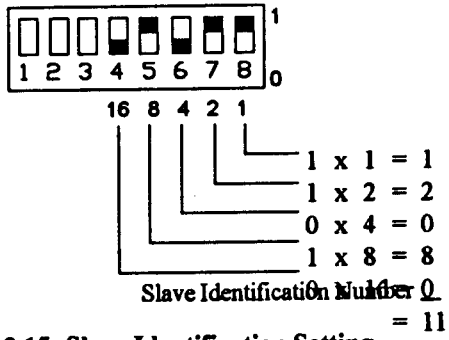

Figure 2.15: Slave Identification Setting

When switch setup is completed, refer to page 2.22 for wiring instructions.

2.7 Master/Slave RS-232C Configuration

This section describes the configuration for Controls to be used in master/slave operation using RS-232C communication. When setup is completed, refer to page 2.22 for wiring instructions.

The system setup with IOtech cable options is shown in Figure 2.7.

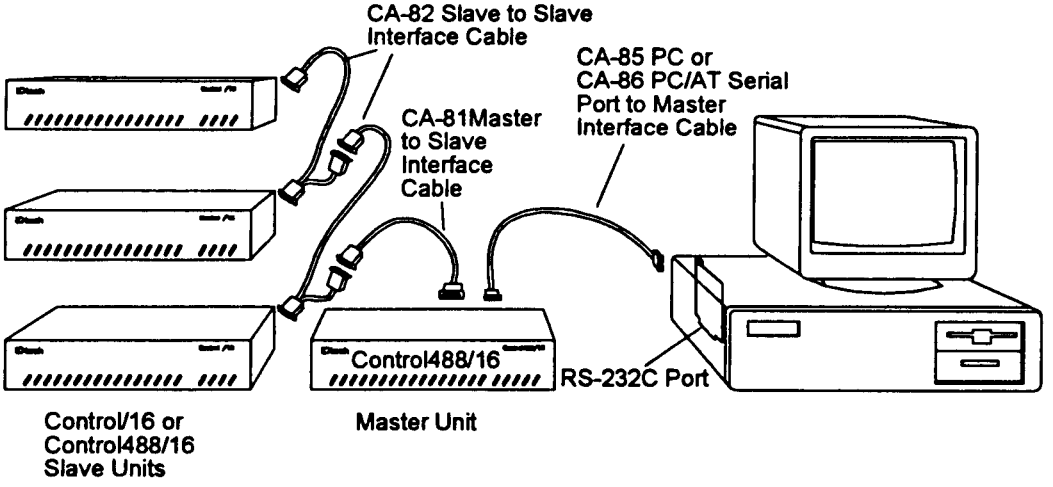

Figure 2.16: RS-232C Master/Slave System Configuration

2.7.1 Control488/16 Master Unit Switch Settings

The master unit in a master/slave system configuration must be a Control488/16 (it cannot be a Control/16). The switch settings required for RS-232C operation are as follows.

The switch labeled CMD SET must be down (0). The up (1) position is reserved for future enhancements. This sets the unit for the register-based command set.

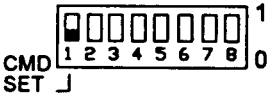

Figure 2.17: Set for Register-Based Command Set

To operate the Control488/16 through its RS-232C interface, the unit must be configured as a master unit. This is done by setting the switches labeled MASTER/SLAVE as shown in Figure 2.18.

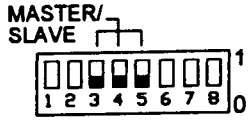

Figure 2.18: Control488/16 Set as Master

The switch labeled IEEE/RS-232 must be set for RS-232, as shown in Figure 2.19.

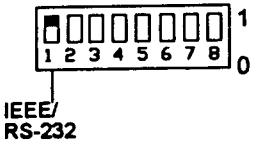

Figure 2.19: Control488/16 Set for RS-232C Operation

When the RS-232C port is used, the type of handshaking must be selected by the switches labeled HANDSHAKE. Control488/16 offers the options of no handshaking, XON/XOFF, DTR/CTS or both XON/XOFF and DTR/CTS handshaking. Figure 2.20 shows the switch settings for each option.

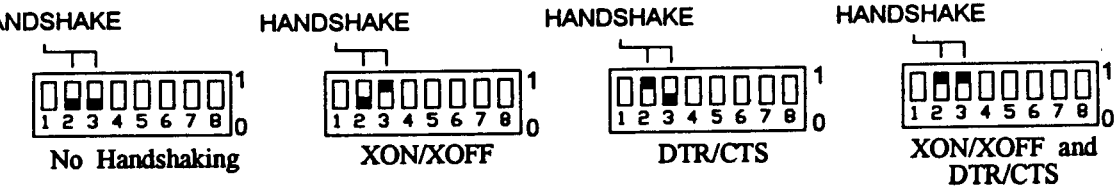

Figure 2.20: RS-232C Handshake Settings

The parity must be selected using the switches labeled PARITY. Control488/16 provides for no parity, odd or even parity. Figure 2.21 shows the switch settings for each option.

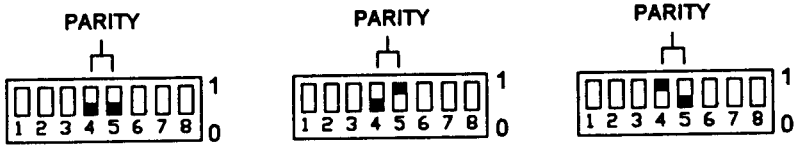

Figure 2.21: RS-232C Parity Settings

The baud rate is selected using the switches labeled RS-232 BAUD RATE. The available baud rates are 300, 600, 1200, 2400, 4800 and 9600. The settings for each are shown in Figure 2.22.

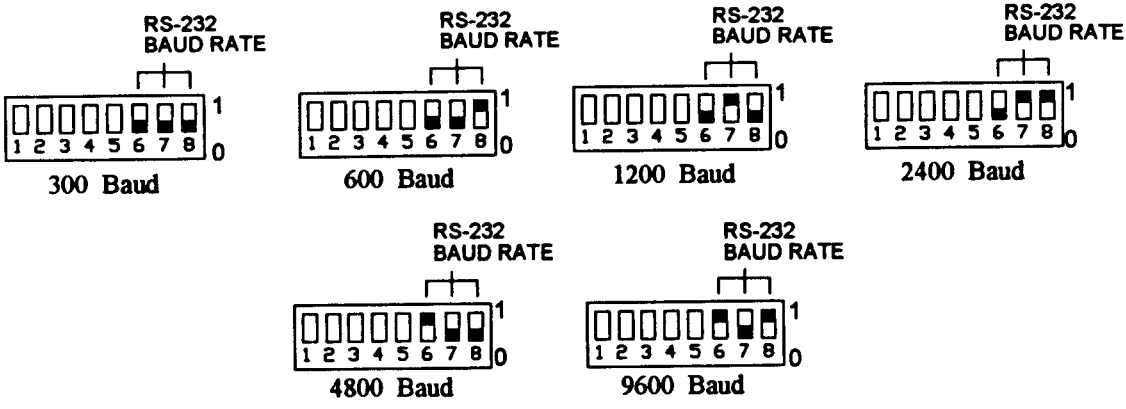

Figure 2.22: RS-232C Baud Rate Settings

2.7.2 Control/16 Slave Unit Switch Settings

Both the Control488/16 and the Control/16 can be slaved to a Control488/16. When a Control/16 is used, set the switches labeled MASTER/SLAVE as shown in Figure 2.23.

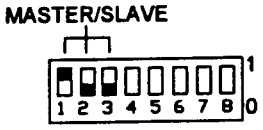

Figure 2.23: Control/16 Set as Slave

Each slave unit must be assigned a unique slave identification number. The slave identification number can be set from 2 through 16 and is read only at power on or reset. The address is selected by simple binary weighting. The switch labeled 1 is the least significant bit; 16 is the most significant bit. The factory default is identification number 2, as shown in Figure 2.24.

Caution

If two or more slave units with the same slave identification settings are connected together, their operation, and the operation of other attached units, is unspecified and may cause errors during operation. Slave identification number 1 is not allowed because it is reserved for the master unit. Identification numbers 17 through 31 are interpreted as 1 through 16 by the Control. 0 is interpreted as 16.

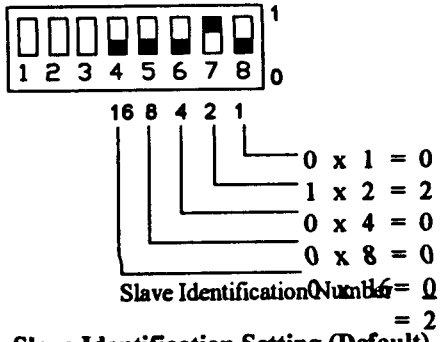

Figure 2.24: Slave Identification Setting (Default)

2.7.3 Control488/16 Slave Unit Switch Settings

Both the Control488/16 and the Control/16 can be slaved to a Control488/16.

When a Control488/16 is used, set the switches labeled MASTER/SLAVE as shown in Figure 2.25.

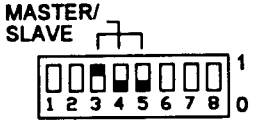

Figure 2.25: Control488/16 Set as Slave

Each slave unit must be assigned a unique slave identification number. The slave identification can be set from 2 through 16 and is read only at power on or reset. The address is selected by simple binary weighting. The switch labeled 1 is the least significant bit; 16 is the most significant bit. The factory default is identification number 11, as shown in Figure 2.26.

Caution

If two or more slave units with the same slave identification settings are connected together, their operation, and the operation of other attached units, is unspecified and may cause errors during operation. Slave identification number 1 is not allowed because it is reserved for the master unit. Identification numbers of 17 through 31 are interpreted as 1 through 16 by the Control. 0 is interpreted as 16.

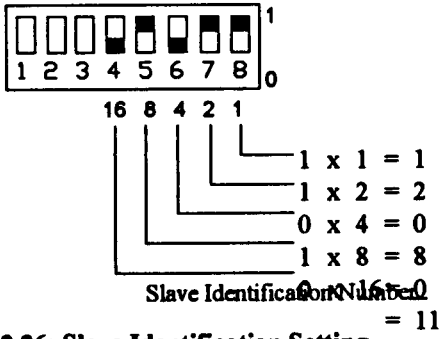

Figure 2.26: Slave Identification Setting

When switch setup is completed, refer to page 2.22 for wiring instructions.

2.8 LPT Port Peripheral Configuration - Switch Settings

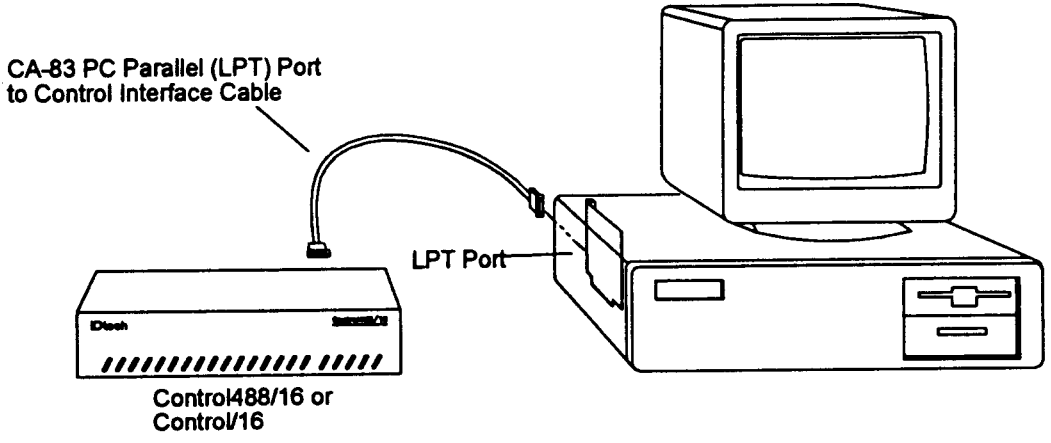

Figure 2.27: LPT Port System Configuration

The only switches that need to be set for LPT Port Peripheral operation are the ones labeled MASTER/SLAVE. All other switches should be set down (0). When setup is completed, refer to page 2.22 for wiring instructions.

For use with an LPT printer port, the Control488/16 must have the switches labeled MASTER/SLAVE set as shown in Figure 2.28.

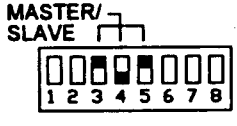

Figure 2.28: Control488/16 Set for LPT Port Mode

If the Control/16 is to be connected to an LPT printer port, the switches labeled MASTER/SLAVE must be set as shown in Figure 2.29.

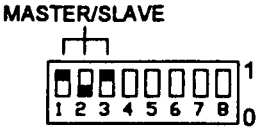

Figure 2.29: Control/16 Set for LPT Port Mode

When switch setup is completed, refer to page 2.22 for wiring instructions.

2.9 Digital I/O Port Peripheral Configuration Settings

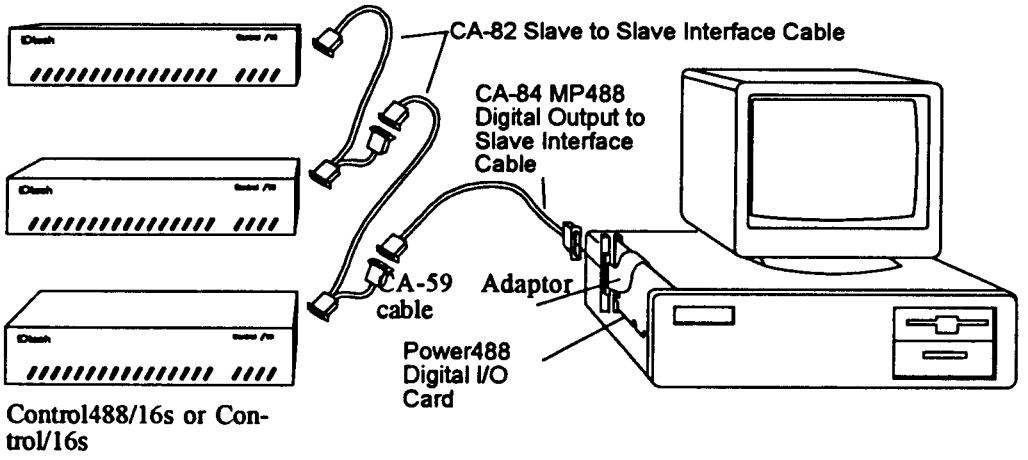

Figure 2.30: Digital I/O Port System Configuration

This section describes the configuration for Controls to be used in digital I/O port peripheral operation. The only switches that need to be set for this mode of operation are the ones labeled MASTER/SLAVE and SLAVE ID.

The number of units allowed in digital I/O port mode may be limited by the output current capabilities of the digital I/O port. Digital I/O must be able to sink at least 1.6 mA at 0.4V for each attached unit. For example, when using a digital output port such as IOtech's Power488, which uses an 8255 output port that can sink 2.5 mA, only one unit can be attached. When driven by a 74LS244 bus buffer, which can sink 12 mA, a maximum of eight Controls can be attached.

When setup is completed, refer to page 2.22 for wiring instructions.

2.9.1 Control488/16 Switch Settings

If the Control488/16 is to be connected to a digital output port, the switches labeled MASTER/SLAVE must be set as shown in Figure 2.31.

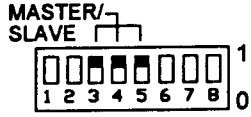

Figure 2.31: Control488/16 Set to Digital I/O Port Mode

Each unit in a digital I/O port system must be assigned a unique slave identification number. The slave identification can be set from 2 through 16 and is read only at power on or reset. The address is selected by simple binary weighting. The switch labeled 1 is the least significant bit; 16 is the most significant bit. Identification number 11 is shown in Figure 2.32.

Caution

If two or more units with the same slave identifications are connected together, their operation, and the operation of other attached units, is unspecified and may cause an error during operation. Identification numbers 17 through 31 are interpreted as 1 through 16 by the Control. 0 is interpreted as 16. 1 is not allowed.

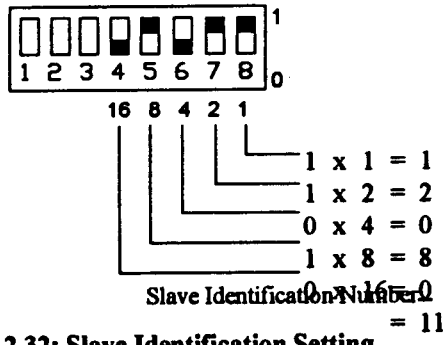

Figure 2.32: Slave Identification Setting

2.9.2 Control/16 Switch Settings

If the Control/16 is to be connected to a digital I/O port, the switches labeled MASTER/SLAVE must be set as shown in Figure 2.33.

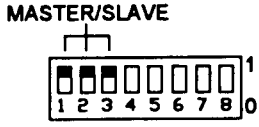

Figure 2.33: Control/16 Set for Digital I/O Port Mode

Each unit must be assigned a unique slave identification number. The slave identification number can be set from 2 through 16 and is read only at power on or reset. The address is selected by simple binary weighting. The switch labeled 1 is the least significant bit; 16 is the most significant bit. The factory default is identification number 2, as shown in Figure 2.34.

Caution

If two or more units with the same slave identifications are connected together, their operation, and the operation of other attached units, is unspecified and may cause errors during operation. Identification numbers 17 through 31 are interpreted as 1 through 16 by the Control. 0 is interpreted as 16. 1 is not allowed.

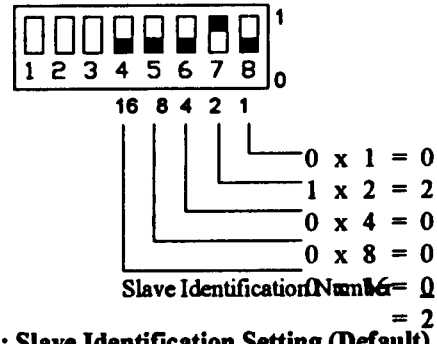

Figure 2.34: Slave Identification Setting (Default)

When switch setup is completed, refer to page 2.22 for wiring instructions.

2.10 Wiring

Wiring of the Control consists of wiring the removable signal termination panel, which holds one two-terminal terminal block for each of the sixteen channels. The terminal blocks are connected internally to their corresponding Opto-22-compatible modules. The terminal blocks accept up to 14 gauge wire into quick-connect screw terminals.

WARNING

The Control is designed to control and sense circuits which may carry dangerous voltages and/or currents. De-energize the circuits to which the Control is connected before changing the configuration of the Control or its wiring.

Each terminal block is marked for polarity. One terminal is marked (+) for positive and the other is marked (–) for negative. When ac sensing or switching modules are used, the polarity does not matter; either wire can be attached to either terminal. However, dc modules are sensitive to polarity and may be damaged if connected incorrectly.

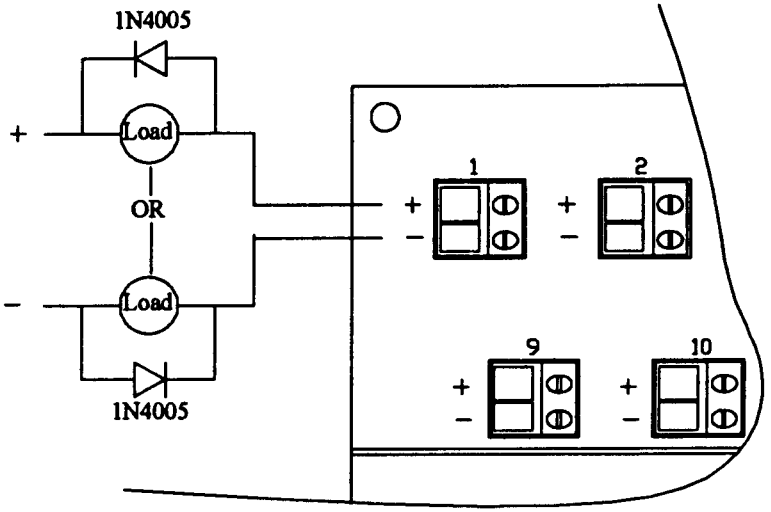

Figure 2.35: Wiring Panel Connections

Figure 2.35 shows the correct connections to a dc switch channel. The positive lead from the power supply is attached to the through the load to the positive wiring terminal. The negative power lead is attached through its load to the negative terminal. As shown in this figure, the load may be on either the positive or negative side of the circuit. Also, commutating diodes (typically 1N4005) must be used as shown on inductive loads to prevent damage to the channel.

DC sense channels must also be connected correctly: with the positive signal lead connected to the positive terminal and the negative lead to the negative terminal.

To add or change the wiring:

WARNING

Do not operate Control with the protective cover removed.

1. Remove the screw in the bottom center of the protective plastic cover. Loosen the screws in the top corners of the cover. Remove the cover by lifting it up and out.
2. Release the strain relief hold-down by pressing down and in on the end tabs. Pull up to remove it.
3. Wire each channel for the appropriate type of module. Place the wires into the screw terminals and tighten the screws to hold them securely in place.
4. Place wires into strain relief; replace hold-down so it holds the wires securely.
5. Replace protective plastic cover by reversing the instructions in step 1.

2.11 Front Panel Indicators

Twenty-one indicator lights on the Control front panel display the status of the interface. The function of each indicator is described below.

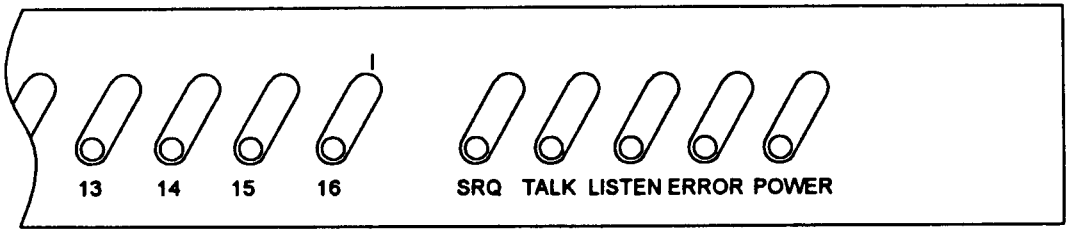

Figure 2.36: Control488/16 Front Panel Indicator Lights

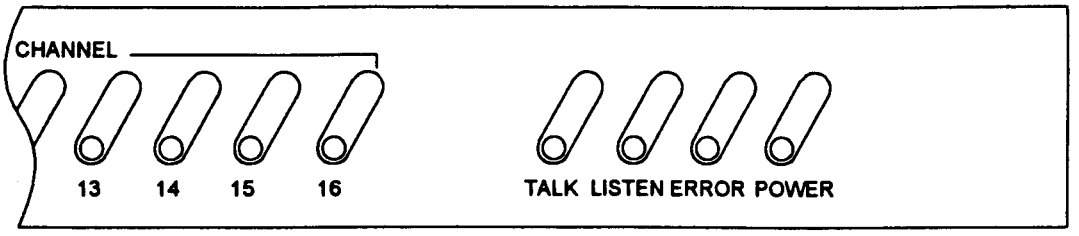

Figure 2.37: Control/16 Front Panel Indicator Lights

CHANNEL 1 - 16 Indicate the status of each channel. A channel indicator is lit if the corresponding Opto-22 module is activated as an output or is sensing an active signal as an input. The Control products continually scan the Opto-22 status and update the channel indicators accordingly.

SRQ (Control488/16 only) SRQ (Service Request) is lit when the Control is set as a master and requires the attention of the RS-232C or IEEE 488 controller. The SRQ light follows the internal Master Summary Status (MSS), which is maintained by the status reporting functions of the interface firmware (see Section 6.7.4 for more discussion).

TALK If the unit is an IEEE 488 master, TALK is lit when Control488/16 has been addressed to talk, and is not lit when it is not. It does not reflect actual data transmission.
If the unit is an RS-232C master, TALK is lit briefly when characters are transmitted out through the RS-232C port.
On a slave device, TALK is lit briefly when a character is transmitted out through the master/slave port.
TALK is not used in LPT or digital I/O configurations.

LISTEN If the system configuration is IEEE 488 master, LISTEN is lit when Control has been addressed to listen, and is not lit when it is not. It does not reflect actual data transmission.
If the system configuration is RS-232C master, LISTEN is lit briefly when a character is received from the RS-232C port.
When LPT port or digital I/O port configuration is used, and on slave devices, LISTEN is lit briefly when characters or commands are received from the master/slave port.

ERROR On when an error has occurred, off when no error condition exists.
ERROR is also used, in combination with other indicators, to display various self test results as described in Section 2.12.

POWER On when power is applied to the Control and the power switch on the rear panel is in the on position (depressed). Off if power is not present. POWER indicates that the digital 5 volt supply is operating.

2.12 Power-Up

At initial power-up or on Reset (*R), the Control performs several automatic self-tests to ensure that it is fully functional. The indicator lights on the Control front panel show any errors if they occur. Possible error conditions and their corresponding indicator light patterns are shown in the following table. Any pattern not shown is an internal error that is not field-serviceable - contact the factory. If ERROR is on by itself, there is a master/slave communication error or non-volatile memory (NVRAM) error. Check the error using the Error Query (E?) command.

Failure	SRQ	Talk	Listen	Error	Power
General Hardware Failure	○	○	○	○	○
Communication or NVRAM Error	●	●	●	○	○
RAM Error	●	○	●	☼	○
ROM Checksum Error	●	●	○	☼	○
Invalid Switch Setting	●	○	○	☼	○

● Indicator light off ○ Indicator light on ☼ Indicator light flashing

To ensure initialization of the slave interfaces, the first command sent to the master unit should be a *R. This causes a reset and establishes communication with the slave units. This is not necessary if the master unit was powered on after the slaves were.

Master/Slave Operation

This section describes Control master/slave operation. In master/slave operation, a master unit and any attached slave units are controlled using an IEEE 488 interface or an RS-232C port. The master unit in the system must be a Control488/16. The optional slave units can be either Control/16s or Control488/16s configured as slave units. See Section 2.6 for IEEE 488 operation setup or Section 2.7 for RS-232C operation setup to configure the units properly for master/slave operation.

By providing communication between a single master unit and up to fifteen slave units, the master/slave configuration expands a single IEEE 488 bus address or RS-232C port to control a total of sixteen units with up to 256 channels.

Each Control in a master/slave system is identified by a unique identification number. Master units are always referred to as unit 1. Slave units' identification numbers can be any number from 2 to 16, as set by the rear panel switches (see Section 2 for switch settings).

3.1 System Reset

Before using the Controls, it is important to reset the system to ensure that the master unit and any attached slave units are reset and functioning. To reset the system send the reset command:

```
PRINT#1,"OUTPUT 11;*RX"
```

and then wait five seconds for the reset to take effect.

Once reset, the slave units' ERROR indicator lights should be off and their TALK and LISTEN indicators should flicker as they communicate with the master.

The master unit's ERROR indicator should be off. However, it is on if the slaves it recognizes are not those that were present when the non-volatile memory was last updated (with the S1 command). The Error Query (E?) and Query Attached Units (U4) commands are used to diagnose the source of the error. For example:

```
OPEN "IEEEIN" FOR INPUT AS #1
                                  Attach and reset the IEEE 488 interface.
IOCTL#1,"BREAK"
PRINT#1,"RESET"
OPEN "IEEEOUT" FOR OUTPUT AS #2
PRINT#1,"TERM LF EOI"      Use line-feed and EOI for terminator.
PRINT#1,"OUTPUT 11;E? X"   Query error source.
PRINT#1,"ENTER 11"         Retrieve response.
```

```
INPUT#2,E
PRINT E                          Displays 64 if communication error occurred, possibly
                                 due to slave inventory mismatch.
PRINT#1,"OUTPUT 11;U4X"          Query attached units.
PRINT#1,"ENTER 11"               Retrieve response.
LINE INPUT#2,A$
PRINT A$                         Displays 01,nn,nn,nn... showing which units are
                                 and are not recognized.
```

The above example assumes the Control is attached to an IOtech IEEE 488 interface and is programmed in BASIC. It is also possible to use an RS-232C interface to communicate with the Control. The RS-232C equivalent of the above example in BASIC is:

```
OPEN "COM1:9600,N,8,1,CS,DS" FOR RANDOM AS #1
                                 Attach the RS-232C interface.
PRINT#1,"E?X"                    Query attached units.
INPUT#1,E                        Retrieve response.
PRINT E                          Displays 64 if communication error occurred, possibly
                                 due to slave inventory mismatch.
PRINT#1,"U4X"                    Query attached units.
LINE INPUT #2,A$                 Retrieve response.
PRINT A$                         Displays 01,nn,nn,nn... showing which units are
                                 and are not recognized.
```

3.2 Control of Channel Settings

Once the Controls have been reset, their channels can be set and sensed.

Each channel of a Control unit senses or switches its attached circuit depending on the Opto-22-compatible module installed. Switching channels can be activated or deactivated with the Output Active (An), Output Inactive (Bn), and Set Outputs (Cn) commands. Sensing channels can be interrogated with the Read Channels commands (Rn and R?). The Select Unit (Pn) command chooses which unit (master or a specific slave) will be programmed.

The Output Active (An) command activates an output channel. If the Opto-22-compatible module installed in that channel is a normally open switch, An closes that switch. If the module is normally closed, An opens its switch. If an input module is installed, An should not be used, as it prevents correct readback of the sense value. It does not interfere with normal operation in any other way.

The n in the An command is the channel number (1-16) to be activated. If the Select Unit (Pn) command has not been specified since power-on or Reset (*R), the master unit's channel is activated. If a slave unit has been specified (with Pn where n is the slave identification number), that slave's channel is activated.

Typical commands:

```
PRINT#1,"OUTPUT 11;P1 X"        Specify master unit.
PRINT#1,"OUTPUT 11;A3 X"        Activate master channel 3.
PRINT#1,"OUTPUT 11;P5 A1 X"     Activate slave 5 channel 1.
PRINT#1,"OUTPUT 11;P1 A4 P2 A5 X"
                                Activate master channel 4 and slave 2 channel 5.
```

An commands do not take effect until the Execute (X) command is interpreted and so An is called a deferred command. If a syntax error is detected before the X is reached, An commands have no effect. In contrast, Select Unit (Pn) is an immediate command that immediately affects all subsequent commands, including subsequent deferred commands such as An. This allows several units to be referred to in a single command string (as in P1 A4 P2 A5 X). See Section 6.3 of the Command Description section for more information on immediate and deferred commands.

The Output Inactive (Bn) command deactivates an output channel. If the Opto-22-compatible module installed in that channel is a normally open switch, Bn opens that switch. If the module is normally closed, Bn closes its switch. If an input module is installed, the Bn command can be used, as it does not affect correct readback of the sense value.

The n in the Bn command is the channel number (1-16) to be deactivated on the unit specified by the Pn command.

Typical commands:

```
PRINT#1,"OUTPUT 11;P1 X"        Specify master unit.
PRINT#1,"OUTPUT 11;B3 X"        Deactivate master channel 3.
PRINT#1,"OUTPUT 11;P5 B1 X"
                                Deactivate slave 5 channel 1.
PRINT#1,"OUTPUT 11;P1 B4 P2 B5 X"
                                Deactivate master channel 4 and slave 2 channel 5.
```

The Bn command, like the An command, is a deferred command that does not take effect until the X.

If multiple An and Bn commands in the same command string refer to the same channel, only the last of those commands takes effect. For example:

```
PRINT#1,"OUTPUT 11;P1 A1 B1 P2 B1 A1 X"
                                Deactivates master channel 1 and activates slave 2 channel 1.
```

The Set Outputs (Cn) command simultaneously activates or deactivates all 16 channels of the current unit (as specified by Pn). The n in the Cn command is a number that specifies the new state (active or inactive) of all sixteen channels. This number is interpreted by the Control as a 16-bit binary integer with the least significant bit of this integer specifying the setting of channel 1, the next most significant bit setting channel 2 and so on up through the most significant bit which sets channel 16. For each channel, if its corresponding bit is a 0, the channel is deactivated; if it is a 1, the channel is activated.

Control can accept the n parameter in any of several different formats, as specified by the Format (Fn) command. In the default format (F0), n is a decimal number, which is then converted by Control into a binary integer. In the binary format (F4), n is a binary pattern of zeros and ones. For example:

```
PRINT#1,"OUTPUT 11;F4 X"
```
Sets binary format.

```
PRINT#1,"OUTPUT 11;C1 X"
```
Activates channel 1 and deactivates all other channels.

```
PRINT#1,"OUTPUT 11;C10 X"
```
Activates channel 2 and deactivates all other channels.

```
PRINT#1,"OUTPUT 11;C11 X"
```
Activates channels 1 and 2 and deactivates all other channels.

```
PRINT#1,"OUTPUT 11;C1000000000000000 X"
```
Activates channel 16 and deactivates all other channels.

```
PRINT#1,"OUTPUT 11;C1111111111111111 X"
```
Activates all 16 channels.

```
PRINT#1,"OUTPUT 11;P1 C0 A1 X"
```
Activates channel 1 and deactivates all other channels.

```
PRINT#1,"OUTPUT 11;P1 A1 C0 X"
```
Deactivates all channels, because the Cn command overrides all preceding An, Bn and Cn settings for the selected unit.

```
PRINT#1,"OUTPUT 11;P1 A1 P2 C0 X"
```
Activates master channel 1 and deactivates all channels of slave 2.

The Format (Fn) command specifies the numeric representation for commands and queries that refer to all sixteen channels, such as the Cn command. The default (F0) format accepts decimal numbers from –32768 to 65535 and replies with a six character decimal number from –32768 to 032767. F1 and F2 formats accept the same inputs and reply with slightly different decimal formats. F3 specifies hexadecimal format and F4 binary. Thus, the following commands all indicate channels 1, 4 and 7 are activated:

```
PRINT#1,"OUTPUT 11;F0 C73 X  "
PRINT#1,"OUTPUT 11;F3 C49 X  "
PRINT#1,"OUTPUT 11;F4 C1001001  X"
```

The Set Outputs query (C?) command interrogates the output setting of the current unit. The reply is in the format selected by the Format command.

```
PRINT#1,"OUTPUT 11;F0 C0 X C? X"
```
Set decimal format.

```
PRINT#1,"ENTER 11"
```
Read the response.

```
INPUT#2,A$
PRINT A$
```
Display response of C000000.

```
PRINT#1,"OUTPUT 11;C73 C? X"
```
Response is still C000000 because the Set Outputs command is not executed until the X is interpreted, while the C?, like all other queries, is executed immediately upon interpretation.

```
PRINT#1,"OUTPUT 11;C? X"
```
Response is now C000073.

```
PRINT#1,"OUTPUT 11;F3 C? X"
```
Set hexadecimal format. Response is C0049.

```
PRINT#1,"OUTPUT 11;F4 C? X"
```
Set binary format. Response is C0000000001001001.

```
PRINT#1,"OUTPUT 11;B1 X C? X"
```
Deactivate channel 1. Response is C0000000001001000.

```
PRINT#1,"OUTPUT 11;A2 X C? X"
```
Activate channel 2. Response is C0000000001001010.

The Control accepts both sensing and switching OPTO-22 modules. The An, Bn, Cn, and C? commands discussed so far control and interrogate the activity of switching modules only. In particular, C? replies with the present output settings, and does not reflect the state of any sense channels. To interrogate a sense channel, the Read Channels (Rn and R?) commands must be used.

The Rn command replies with the state of the specified input channel. If the input is active, the reply is Ann, where nn is the two-digit channel number. If the input is inactive, the response is Bnn. The output setting of a sense channel can interfere with the correct sensing of its input. If the output setting of a sense channel is active, that channel is always sensed as active regardless of the actual input. To correctly sense an input channel, its output setting must be inactive.

The R? command replies with the state of all of the channels of the current unit in the present numeric format. Each channel is sensed the same way it is for the Rn command: outputs replying with their present setting and inputs reflecting their state only if their output settings are inactive.

For a Control that has input modules installed in all channels:

```
PRINT#1,"OUTPUT11;F0 P1 C0 X C? X"
```

Format set to decimal. Master unit channels set inactive. Response is C000000, showing all output settings are deactivated.

```
PRINT#1,"OUTPUT 11;R? X"
```

Response is C000001, showing the input on channel 1 is active and the remaining inputs are inactive.

```
PRINT#1,"OUTPUT11;C2 X R? X"
```

Response is C000003, showing that the output setting overrides the input state on channel 2.

```
PRINT#1,"OUTPUT11;C0 X R? X"
```

Response is C000001, showing the input on channel 1 is active and the input on channel 2 actually was inactive.

3.3 Sequenced Operation

In addition to the ability to set and interrogate the channels with the previously discussed commands, Control can automatically step through a list of channel settings. This is called sequenced operation. During sequenced operation, the master unit senses trigger events, then steps itself and the slaves through their sequence settings tables. Each unit's sequence settings table consists of 1101 elements numbered from 0 to 1100. Each element contains the output settings for all sixteen channels of that unit for that point in sequenced operation. Elements 1 through 1100 of the sequence settings table are used for normal sequenced operation. Element 0 is reserved for the power-on setting and can be specified as the setting to be used at the conclusion of sequenced operation.

In addition to its sequence settings table, the master unit has a sequence duration table. This table contains the duration (the number of triggers) that each corresponding element in the units' sequence settings tables is held. The sequence duration table consists of 1100 elements, numbered 1 to 1100. The power-on setting has no duration element, so there is no element 0 in the sequence duration table.

To illustrate the use of sequenced operation, assume that the master unit and slave unit 2 are both configured with sixteen output channels. The first four channels of each are to be activated in turn, repeated, and then all of the channels are to be deactivated, stepping to the next setting every ¼ second (250 ms). The following table illustrates the sequence:

Time (sec)	Active Channel
0.000	Master 1
0.250	Master 2
0.500	Master 3
0.750	Master 4
1.000	Slave 1
1.250	Slave 2
1.500	Slave 3
1.750	Slave 4
2.000	Master 1
2.250	Master 2
2.500	Master 3
2.750	Master 4
3.000	Slave 1
3.250	Slave 2
3.500	Slave 3
3.750	Slave 4
4.000	All Inactive

The Controls accomplish this sequence by stepping through their sequence settings table at intervals generated by their internal timebase generator. The first step in preparing for this sequence is setting up the sequence tables.

3.3.1 Setting the Sequence Tables

Elements in the sequence settings tables can be activated or deactivated with the Sequence Output Active (Gn), Sequence Output Inactive (Hn), and Set Sequence Outputs (In) commands. Elements in the master unit's sequence duration table can be set with the Sequence Duration (Jn) command. The Sequence Table Location (Wn) command is used to specify which sequence table element is to be affected or interrogated. The Select Unit (Pn) command chooses which unit's (master or a specific slave) sequence settings table is to be affected or interrogated. The Sequence Duration (Jn) command and table is shared among all units, and is independent of the sequence settings table and Select Unit (Pn) commands.

To set or interrogate an element in the sequence setting or duration tables, the Sequence Table Location (Wn) command must be used to set which element is to be interrogated or set. Once the sequence table location is defined, W$ can be used to increment the sequence table location by one location. If the location is incremented past the maximum value of 1100, an execution error occurs. If this occurs, reset the location to a lower value with Wn.

The Sequence Output Active (Gn) command activates an output channel in the sequence settings table. If the Opto-22-compatible module installed in that channel is a normally open switch, Gn closes that switch during sequencing. If the module is normally closed, Gn opens

its switch. If an input module is installed, the Gn command should not be used, as it prevents correct readback of the sense value. It does not otherwise interfere with normal operation.

The n in the Gn command is the channel number (1-16) to be activated. Gn is an immediate command.

The Set Sequence Outputs (In) command simultaneously activates or deactivates all sixteen channels of the current unit (as specified by Pn) at a location in the sequence settings table determined by Wn. The n in the In command is a number interpreted by the Control as a 16-bit binary integer. The least significant bit of this integer specifies the setting of channel 1. If the bit is 0, the channel is deactivated; if it is 1, the channel is activated. The next more significant bit controls channel 2 and so on up through the most significant bit, which controls channel 16.

The Control can accept the n parameter in any of several different formats, as specified by the Format (Fn) command. In the default format (F0), n is a decimal number, which is converted by the Control into a binary integer.

To set the sequence settings table for the example, use the following commands:

```
PRINT#1,"OUTPUT 11;W1 X"
```
Specify the first element in the sequence settings and duration tables.

```
PRINT#1,"OUTPUT 11;P1 I0 G1 X"
```
Activate master channel 1; all others inactive.

```
PRINT#1,"OUTPUT 11;P2 I0 X"
```
Deactivate all slave 2 channels in this sequence settings table element.

```
PRINT#1,"OUTPUT 11;W$ X"
```
Increment the sequence table location.

```
PRINT#1,"OUTPUT 11;P1 I0 G2 P2 I0 X"
```
Activate Master channel 2; all others inactive.

```
PRINT#1,"OUTPUT 11;W$ P1 I0 G3 P2 I0 X"
```
Master channel 3 active.

```
PRINT#1,"OUTPUT 11;W$ P1 I0 G4 P2 I0 X"
```
Master channel 4 active.

```
PRINT#1,"OUTPUT 11;W$ P1 I0 P2 I0 G1 X"
```
Slave 2 channel 1 active; all others inactive.

```
PRINT#1,"OUTPUT 11;W$ P1 I0 P2 I0 G2 X"
```
Slave 2 channel 2 active.

```
PRINT#1,"OUTPUT 11;W$ P1 I0 P2 I0 G3 X"
```
Slave 2 channel 3 active.

```
PRINT#1,"OUTPUT 11;W$ P1 I0 P2 I0 G4 X"
```

Slave 2 channel 4 active.

```
PRINT#1,"OUTPUT 11;W0 X"
```

Select power-on element.

```
PRINT#1,"OUTPUT 11;P1 I0 P2 I0 X"
```

All channels deactivated on both units.

Now sequence settings table elements 1 through 8 contain the desired output settings. Element 0 (the power-on setting, see 3.6 for more information) is set to the final setting, all channels deactivated. This is shown in Figure 3.1.

Element (location) selected in common by Wn.

Sequence Settings Table			Sequence Duration Table
Element	**Master Unit Channels**	**Slave Unit Channels**	**Common to Both Units**
0	All Inactive	All Inactive	n/a
1	1 Active	All Inactive	1
2	2 Active	All Inactive	1
3	3 Active	All Inactive	1
4	4 Active	All Inactive	1
5	All Inactive	1 Active	1
6	All Inactive	2 Active	1
7	All Inactive	3 Active	1
8	All Inactive	4 Active	1
...	...	...	...
1100	Not Set	Not Set	Not Set

f

s

Qs,e,f Sequence Range

e

Figure 3.1: Sequence Settings & Duration Tables

The Sequence Output Inactive (Hn) command deactivates an output channel. If the Opto-22-compatible module installed in that channel is a normally open switch, Hn opens that switch during sequencing. If the module is normally closed, Hn closes its switch. If an input module is installed, the Hn command can be used, as it does not affect correct readback of the sense value.

The n in the Hn command is the channel number (1 through 16) to be deactivated on the unit specified by the Pn command. Hn is an immediate command.

If multiple Gn and Hn commands refer to the same channel, only the last Gn or Hn commands takes effect. Also, the In command overrides any previous Gn, Hn, or In commands that refer to the same channels. For example:

```
W30 G1 I0 G2    H2 H3 G3 X
```

deactivates channels 1 and 2 and activates channel 3 at location 30 in the sequence settings table.

The Set Sequence Outputs query (I?) command interrogates the output setting of the current unit. The reply is in the format selected by the Format (Fn) command.

```
PRINT#1,"OUTPUT 11;W1 F0 P1 I? P2 I? X"
```

Interrogate master and slave sequence settings table element 1.

```
PRINT#1,"ENTER 11"
INPUT#2,A$
PRINT A$
```

Response is I000001I000000, showing that master channel 1 is active and all others are inactive.

```
PRINT#1,"OUTPUT 11;W20 F0 I0 X I? X"
```

Set decimal format, outputs inactive. Response is I000000.

```
PRINT#1,"OUTPUT11;W20 I73 I? X"
```

Response is still I000073 because the Set Sequence Outputs command is executed immediately, before the I?.

```
PRINT#1,"OUTPUT11;W20 I? X"
```

Response is now I000073 in decimal.

```
PRINT#1,"OUTPUT11;W20 F3 I? X"
```

Response is I0049 in hexadecimal.

```
PRINT#1,"OUTPUT11;W20 F4 I? X"
```

Response is I0000000001001001 in binary.

After setting the channels for a sequence table location, set the number of triggers that must be received before moving to the next sequence table location. The Sequence Duration (Jn) command sets this, where n is the number of triggers from 1 to 65,535. The Control continues to output from that location until n numbers of triggers are received. In our case, each step takes the same time and so, assuming that the trigger source happens at the desired rate of four per second, all of the durations can be set to one trigger interval.

```
PRINT#1,"OUTPUT 11;W1 J1  W$ J1 W$ J1 W$ J1 X"
PRINT#1,"OUTPUT 11;W$ J1  W$ J1 W$ J1 W$ J1 X"
```

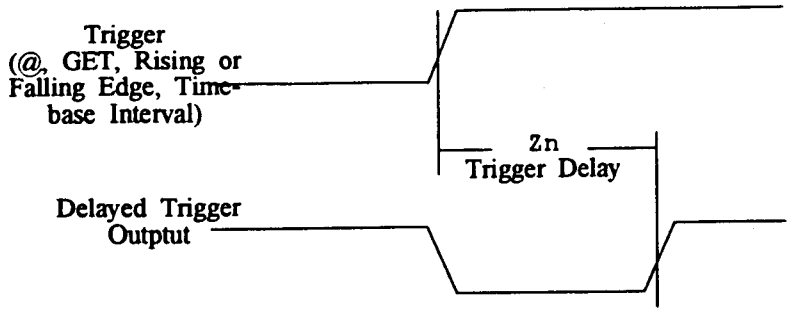

Figure 3.2: Delayed Trigger Output Timing Diagram

No duration is specified for the final output (which is all outputs inactive at sequence table position 0). This is because the final output does not use its duration: it lasts forever (or until the output settings are explicitly changed). Also, sequence table position 0 is special. As mentioned above, it is the power-on setting and its duration cannot be set. It can never be any part of a sequence except the final setting.

Once the sequence settings and durations are set, they can be examined. Several commands can be used to look at the sequence table settings.

The Sequence Table Location query (`W?`) command responds with `Wnnnnn`, where `nnnnn` is the present sequence table location.

The sequence duration settings of a unit in the system are queried with `U3`. The response is in the form:

```
W00001Jnnnnn XW$Jnnnnn X . . . W$Jnnnnn X
```

This response is the entire sequence table for a unit, in one long string of thousands of characters.

To query the sequence duration settings for a section of the sequence duration table, use `U7`. This responds with the same response as `U3`, except the start and end of the response are defined by the start and end parameters of the Sequence Range (`Qs,e,f`) command.

To query the duration at a single location in the sequence duration table, use `J?`. The response is in the form `Jnnnnn`.

The sequence settings table of a unit in the system are queried with `U6`. The response is in the form:

```
Pn Fn X   W00000Innnnn XW$Innnnn X . . . W$Innnnn X
```

This response is the entire sequence table for a unit, in one long string of thousands of characters. The format and number of characters in the response depends on the format selected by the `Fn` command.

To query a section of the sequence settings table of a unit in the system, use U8. This responds with the same response as U6, except the start and end of the response are defined by the Qs,e,f command.

3.3.2 Setting Up Sequenced Operation

Once the sequence table has been initialized, the sequence range must be set. The sequence range is the portion of the sequence table used for sequenced operation. It consists of two parts, a range of settings, and a final setting. The range is the portion of the sequence table to be repeated, one or more times, during sequenced operation. The final setting is the sequence table element that takes effect after the range is completed. In the example, the range, which consists of sequence table elements 1 through 8, is to be repeated twice, and the final setting is element 0. This sequence range is specified with the Sequence Range (Qs,e,f) command:

```
PRINT#1,"OUTPUT 11;Q1,8,0 X"
```

The Sequence Range (Qs,e,f) command defines which part of the sequence settings tables is used for sequenced operation. s is the start of the sequence range (element 1 in the example). e is the end of the range (8 in the example) and must be greater than or equal to s. f is the final element (0 in the example), the one which takes effect when sequenced operation is complete.

The ranges for s and e are 1 to 1100. The range for f is 0 to 1100. If f is 0, the final setting is the power-up state.

If the final element is the same as the end of the range (f is the same as e), sequenced operation stops at the end of the range and does not proceed to the final element and repeat the ending setting. For example, Q1,3,5 produces the sequence 1,2,3,5. But Q1,3,3 does not produce the sequence 1,2,3,3. It stops at the ending element and produces 1,2,3.

If a sequence range has not been specified with the Qs,e,f command, a default range is used for sequenced operation. The default range is based on the sequence table location, which is set or incremented with the Wn command. Control keeps track of the greatest sequence table location that has been referenced and uses that location as the sequence range end and final elements. For example, at power-on or Reset (*R), the default range is Q1,1,1. If W50 X has been specified (elements up through element 50 referenced), the default range would be Q1,50,50.

For the example, the sequence range is:

```
PRINT#1,"OUTPUT 11;Q1,8,0
```

The Sequence Mode (Ln) command specifies how and if the sequence range is to be repeated. L0 disables any sequenced operation. L1 specifies that the sequence range is stepped through exactly once. L2 specifies that the sequence range will be repeated the number of times specified by the Sequence Repetition (Kn) command. L3 specifies that the sequence range is repeated indefinitely until it is stopped by switching to another Ln command mode or until triggering is disabled.

The Sequence Repetition (Kn) command specifies the repetition count (from 1 to 65535) for the L2 mode.

In the example, the sequence range (from 1 to 8) is to be repeated twice:

```
PRINT#1,"OUTPUT 11;K2 L2 X"
```

Now that the sequence settings, durations, range, mode and repetition count have been specified, sequenced operation begins as soon as triggers are detected. In this example, the sequence is to be stepped through every ¼ second, so the internal timebase is set for a rate of 250 milliseconds using the Interval Timer (Yn) command:

```
PRINT#1,"OUTPUT 11;Y250 X"
```

Now set the trigger source to accept triggers from the internal timebase and sequenced operation commences:

```
PRINT#1,"OUTPUT 11; T6 X"
```

Other possible trigger sources include IEEE 488 bus Group Execute Trigger (GET) commands, rising or falling edges on the trigger input connector, or the Command Trigger (@).

When sequenced operation completes, the trigger source is reset to no triggering (T0). The trigger source can be interrogated with the Trigger Query (T?) command:

```
PRINT#1,"OUTPUT 11;T? X"    Query trigger source.
PRINT#1,"ENTER 11"          Retrieve response.
INPUT#2,A$
PRINT A$                    Response is T00 if sequenced operation is complete.
```

The rear-panel BNC TRIGGER OUT connector carries an active low TTL signal which goes active (low) when a new sequence setting element takes effect. This signal goes inactive (high) after the amount of time specified by the Trigger Delay (Zn) command. The Trigger Out signal can be used to indicate to other equipment that a new sequence setting has taken effect. In the example, each of the trigger out pulses last the default 100 microseconds and there are a total of seventeen pulses. Sixteen of the pulses are for the two repetitions of eight settings in the sequence, plus one more pulse for the final setting.

3.4 Sequenced Operation Example Recap

```
PRINT#1,"OUTPUT 11;W1 X"    Specify the first element in sequence settings and
                            duration tables.
PRINT#1,"OUTPUT 11;P1 I0 G1 X"
                            Activate master channel 1, all other channels deactivated.
PRINT#1,"OUTPUT 11;P2 I0 X"
                            Deactivate all slave channels in this sequence settings
                            table element.
PRINT#1,"OUTPUT 11;W$ X"    Increment the sequence table location.
PRINT#1,"OUTPUT 11;P1 I0 G2 P2 I0 X"
                            Activate Master channel 2; all other channels deactivated.
```

```
PRINT#1,"OUTPUT 11;W$ P1 I0 G3 P2 I0 X"
```
Increment sequence table location; activate Master channel 3; all other channels deactivated.

```
PRINT#1,"OUTPUT 11;W$ P1 I0 G4 P2 I0 X"
```
Activate Master channel 4; all other channels deactivated.

```
PRINT#1,"OUTPUT 11;W$ P1 I0 P2 I0 G1 X"
```
Activate slave channel 1; all other channels deactivated.

```
PRINT#1,"OUTPUT 11;W$ P1 I0 P2 I0 G2 X"
```
Activate slave channel 2; all other channels deactivated.

```
PRINT#1,"OUTPUT 11;W$ P1 I0 P2 I0 G3 X"
```
Activate slave channel 3; all other channels deactivated.

```
PRINT#1,"OUTPUT 11;W$ P1 I0 P2 I0 G4 X"
```
Activate slave channel 4; all other channels deactivated.

```
PRINT#1,"OUTPUT 11;W0 X"
```
Select power-on element.

```
PRINT#1,"OUTPUT 11;P1 I0 P2 I0 X"
```
All channels deactivated.

```
PRINT#1,"OUTPUT 11;W1 J1 W$ J1 W$ J1 W$ J1 X"
```
Elements 1 through 4 set to duration of 1.

```
PRINT#1,"OUTPUT 11;W$ J1 W$ J1 W$ J1 W$ J1 X"
```
Elements 5 through 8 set to duration of 1.

```
PRINT#1,"OUTPUT 11;Q1,8,0 X"
```
Sequence range set to start at element 1, end at element 8 and final at element 0.

```
PRINT#1,"OUTPUT 11;K2 L2 X"
```
Sequence repetition set to 2, sequence mode set to counted.

```
PRINT#1,"OUTPUT 11;Y250 X"
```
Internal timebase set to 250 ms.

```
PRINT#1,"OUTPUT 11; T6 X"
```
Trigger source set to internal timebase. Sequenced Operation begins.

3.5 Error Handling

When the Control detects an error, it lights the ERROR indicator, sets the appropriate error code in the error status register, discards any deferred commands that were to be executed, and skips all further commands until it has interpreted an X command.

The Error Query (E?) command responds with the present error condition and clears it. The possible error conditions are:

E000	No error has occurred.
E001	Invalid device dependent command (IDDC).
E002	Invalid device dependent command option (IDDCO).
E004	No such unit.
E008	Self-test failure.
E016	Trigger overrun.
E032	Non-volatile RAM failure.
E064	Master/slave communication error.
E128	Conflict error.
Ennn	If two or more errors occurred, nnn is the sum of those errors.

These errors also set bits in the Standard Event Status Register. The IDDC error sets the Command Error bit, the Conflict error sets the Device Dependent Error bit, and the other errors all set the Execution Error bit. The Standard Event and Status Byte Registers can be used to generate service requests (SRQs) and are described in detail in Section 6.7.

3.6 Power-on and Reset

The Reset (*R) command restores the master unit and any attached slave units to their initial power-up states.

This command has the same effect as removing and re-applying power and is not processed until an Execute (X) command is received. Resetting includes restoring information from the non-volatile RAM (NVRAM) present in each Control. The NVRAM stores, among other *things, the sequence settings and durations up through element 100, including sequence setting* element 0, the power-on setting. Initially upon reset, the Controls de-activate all of their channels. They then restore the sequence settings and duration table elements that were stored in NVRAM. The master unit then interrogates the slave units and, if it finds that the correct slave units (those that were attached when NVRAM was set) are attached, it instructs all units, master and slaves, to set their channel settings to the power-on setting.

If more, fewer or different slave units are found, or any unit detects an error in its NVRAM, all channels are left inactive and an appropriate error code (master/slave communication or NVRAM failure) is set.

When the master unit is reset, either as a result of a power cycle or a reset command, all attached slave units are also reset. This keeps the master and slaves in a consistent state.

The IEEE 488 bus Device Clear commands (DCL and SDC) do not perform a reset. These commands clear any pending commands and responses and prepare the master to receive new commands.

The sequence settings and duration tables (up through element 100) are saved in the NVRAM by the Save (S1) command. The Restore (S0) command restores those portions of the tables from NRAM but does not change any other settings.

```
PRINT#1,"OUTPUT 11;S1 X"
```
Save existing settings as the power-on default.

```
PRINT#1,"OUTPUT 11;S0 X"
```
Restore saved settings.

```
PRINT#1,"OUTPUT 11;Q25,50,50"
```
Use elements 25-50 for sequenced operation.

3.7 IEEE 488 Interface

The IEEE 488 interface provides IEEE 488 peripheral-only functions. It cannot act as a bus controller and cannot accept control.

3.7.1 IEEE 488 Addressing

Control488/16 uses a single IEEE 488 bus primary address in the range from 0 through 30. Secondary addressing is not used. If the rear-panel switches are set for IEEE 488 bus address of 31, address 30 is used.

3.7.2 IEEE 488 Bus Implementation

The Control488/16 implements many of the capabilities defined by the IEEE 488 1978 specification. These are discussed in the following sections. The Control488/16 does not support or respond to the bus uniline and multiline commands:

Remote Enable (REN)	Parallel Poll (PP)
Go to Local (GTL)	Parallel Poll Configure (PPC)
Local Lockout (LLO)	Parallel Poll Unconfigure (PPU)

Take Control (TCT) Parallel Poll Disable (PPD)

3.7.3 My Talk Address (MTA)

When the Control488/16 is addressed to talk, it replies with whatever response strings have been requested by previous commands. If no requests for response strings have been issued, no data are returned. This may cause a time out error on the IEEE 488 bus controller.

If a serial poll enable (SPE) has been received, it responds with the serial poll status byte, rather than the response strings.

3.7.4 My Listen Address (MLA)

When the Control488/16 is addressed to listen, it accepts characters from the active talker and interprets these characters as commands and command parameters. These commands are explained in Section 6.

3.7.5 Device Clear (DCL and SDC)

Device clear clears the command input buffer, the command response queue and any pending commands.

3.7.6 Group Execute Trigger (GET)

When the Control488/16 recognizes a GET, and the Trigger Source command is set for GET (T1 or T7), it performs the specified sequenced operation, if any.

3.7.7 Interface Clear (IFC)

IFC places the Control488/16 in the Talker/Listener Idle state.

3.7.8 Serial Poll Enable (SPE)

When serial poll is enabled, the Control488/16 sets itself to respond to a serial poll with its serial poll status byte if addressed to talk. When the serial poll status byte is accepted by the controller, any pending Service Requests (SRQs) are cleared. The Control488/16 continues to try to output its serial poll response until it is serial poll disabled by the controller.

3.7.9 Serial Poll Disable (SPD)

Disables the Control488/16 from responding to serial polls by the controller.

Take Control (TCT) Parallel Poll Disable (PPD)

3.7.3 My Talk Address (MTA)

When the Control488/16 is addressed to talk, it replies with whatever response strings have been requested by previous commands. If no requests for response strings have been issued, no data are returned. This may cause a time out error on the IEEE 488 bus controller.

If a serial poll enable (SPE) has been received, it responds with the serial poll status byte, rather than the response strings.

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Device clear clears the command input buffer, the command response queue and any pending commands.

3.7.6 Group Execute Trigger (GET)

When the Control488/16 recognizes a GET, and the Trigger Source command is set for GET (T1 or T7), it performs the specified sequenced operation, if any.

3.7.7 Interface Clear (IFC)

IFC places the Control488/16 in the Talker/Listener Idle state.

3.7.8 Serial Poll Enable (SPE)

When serial poll is enabled, the Control488/16 sets itself to respond to a serial poll with its serial poll status byte if addressed to talk. When the serial poll status byte is accepted by the controller, any pending Service Requests (SRQs) are cleared. The Control488/16 continues to try to output its serial poll response until it is serial poll disabled by the controller.

3.7.9 Serial Poll Disable (SPD)

Disables the Control488/16 from responding to serial polls by the controller.

3.7.10 Unlisten (UNL)

UNL places the Control488/16 in the Listener Idle state.

3.7.11 Untalk (UNT)

UNT places the Control488/16 in the Talker Idle state.

3.7.12 Serial Poll Response

Whenever the Control488/16 generates a service request (SRQ), a serial poll responds with a serial poll status byte of at least 64 (decimal), showing that the SRQ was generated by the Control488/16. For complete details on SRQ generation, see Section 6.7, the Serial Poll model.

Note: Service Requests are only generated for those conditions for which their corresponding enable mask bits have been set. See Section 6.7 for details.

3.7.13 IEEE 488 Bus Terminators

Responses from a Control488/16's IEEE 488 port are terminated with a line-feed with EOI (End-Or-Identify) asserted. Line-feed is ASCII 10, also referred to as new-line. The Response Terminator (Dn) command can be used to change the terminator.

Commands to a Control488/16's IEEE 488 port must be terminated with the X command. Control488/16 generally treats control characters, such as carriage-return and line-feed as white space and ignores them unless they are within a command or command option.

3.8 RS-232C Implementation

3.8.1 RS-232C Pinout

The RS-232C interface is connected through a DB-9 plug connector with the following pin-out. Refer to Appendix B for PC-compatible cable pin-outs.

Pin	Description
1	NC
2	Receive Data
3	Transmit Data
4	Ready To Receive Output (DTR)
5	Ground
6	NC
7	Request To Send (RTS) (Held High)
8	Clear To Send Input (CTS)
9	NC

3.8.2 RS-232C Data Format

The RS-232C interface supports the following data formats:

300, 600, 1200, 2400, 4800, 9600, 19200, or 38400 baud.
Odd, Even, or None Parity

Sequenced operation reduces the maximum recommended baud rate to 9600. 19200 and 38400 baud are not recommended if sequenced operation is used.

3.8.3 RS-232C Handshaking

Control supports both hardware (DTR/CTS) and/or software (XON/XOFF) handshaking.

Hardware handshaking uses the DTR and CTS lines. The DTR output is true when the serial interface is ready to receive data and is false when the serial interface cannot accept more data. The Control will not send data unless the CTS input is asserted.

Software handshaking uses the XON and XOFF characters to control data flow. The Control sends an XOFF (ASCII 19) when its input buffer has space for fewer than 1100 characters

and sends XON (ASCII 17) when space for more than 2500 characters becomes available. The Control stops sending data when it receives an XOFF and does not resume until it receives an XON.

3.8.4 RS-232C Terminators

Responses from a Control488/16's RS-232C port are terminated with a carriage-return followed by a line-feed. Carriage-return is ASCII 13, and line-feed is ASCII 10, also referred to as new-line. The Response Terminator (Dn) command can be used to change the terminator.

Commands to a Control488/16's RS-232C port must be terminated with the X command. Control488/16 generally treats control characters, such as carriage-return and line-feed as white space and ignores them unless they are within a command or command option.

LPT Port Peripheral Mode Operation

The LPT port peripheral mode allows any IBM-PC compatible LPT (printer) port to control the output channels of a single Control unit. See Section 2.8 for information on configuring a Control for this mode.

In this mode the Control appears to the computer as a standard printer with Centronics-style parallel interface. It uses the standard DATA, STROBE, BUSY, and ACK signals to transfer data from the computer to the Control. See Appendix B for the IBM PC LPT port to Control Master/Slave port (CA-83) wiring information.

The only functions supported in LPT mode are setting and clearing channels.

Each output setting consists of a decimal number from –32768 to 65535 followed by white space. White space is all ASCII values of 32 and below, including the space, tab, new-line (line-feed) and carriage-return characters. The Control interprets the decimal value as a 16-bit integer and then sets each channel according to the corresponding bit; the least significant bit sets channel 1 and the most significant bit sets channel 16.

For example, to deactivate a Control/16 channel, and then activate channels 1 and 4, use the BASIC statements:

`LPRINT 0`	Deactivate all channels.
`LPRINT 1+8`	Activate channels 1 and 4

4.1 Programming Example

This BASIC program shows the Control attached to the LPT1 port of a PC-compatible computer. In this configuration, the Control receives data as a printer would.

```
10 'Turn off all channels
20 LPRINT 0
30 '
40 'Turn on all channels
50 LPRINT 65535
60 '
70 'Also turn on all channels
80 LPRINT -1
90 '
100 'Turn on each channel in succession, leaving the others off
110 FOR I=1 TO 16
120 LPRINT 2^(I-1)
130 NEXT I□
140 '
```

```
150 'Turn on just channels 1, 3, 5
160 LPRINT 1 + 4 + 16
```

Digital I/O Control Operation

The Digital I/O peripheral mode allows any digital I/O port with eight outputs (seven data plus one strobe) and one input to control up to fifteen Control units. See Section 2.4.3 for information on configuring Control units for this mode.

In this mode, each Control's master/slave port has nine active lines: seven data inputs, one strobe input, and one ready output. The data lines are active high and carry 7-bit ASCII characters to the units. The strobe line is active low. It should be asserted (low) for at least one microsecond after the data lines have been set with the ASCII character, and then unasserted (high) to latch the character into the units. The ready line is active high. It goes inactive (low) when a character has been latched into the units and will not go active (high) until all of the units have processed that character.

This type of interface is very similar to a Centronics-style printer interface with two major exceptions: an active-high ready line is used instead of an active-high busy line, and the ACK line is not used. This similarity allows an IBM PC LPT port to command multiple Control units in this mode, though special software is required (see the example below).

The Digital I/O peripheral mode can also be driven by digital I/O interfaces such as those on the IOtech Power488, the MetraByte PIO-12 or DAS-16, or the Data Translation DT2801.

The number of Controls that can be connected simultaneously to a single digital I/O interface is limited by the current drive capability of the interface. Each Control has an input current of 1.6 mA at 0.4 V. A standard LPT port, using 74LS374 drivers, or their equivalent, can sink 12 mA and so can drive about eight Control units. An IOtech Power488 uses an 8255 I/O driver which can only sink 2.5 mA and so can drive one or at most two Control units.

The digital I/O peripheral mode sets and clears the units' channels by directing commands to individual Control units, referred to by their slave identification numbers (numbers from 2 to 16).

Each output setting consists of a decimal number from –32768 to 65535 followed by white space. White space is all ASCII values of 32 and below, including the space, tab, new-line (line-feed) and carriage-return characters. The Control interprets the decimal value as a 16-bit integer and then sets each channel according to the corresponding bit; the least significant bit sets channel 1 and the most significant bit sets channel 16.

The following protocol is used to send output settings to one or more digital I/O peripheral mode units:

1. Send the addresses of the units that are to receive the command. An address is a single character with an ASCII value equal to the slave ID plus 64. In BASIC, this would be `CHR$(64+slaveID)`.
2. Send the new output setting as a string of ASCII characters. In BASIC, this would be `STR$(setting)`.
3. Send carriage-return (`CHR$(13)`), line-feed (`CHR$(10)`) or white space.

5.1 Digital I/O Control Programming Examples

The following BASIC program sends commands to Control units in Digital I/O peripheral mode connected to the LPT1 port of a PC-compatible computer. As mentioned above, the similarity of the Digital I/O peripheral mode to a standard Centronics-style interface allows the standard PC LPT port hardware to be used to drive the Digital I/O mode. However, the differences do require that different software be used. In this example program, the subroutine starting at line 1000 directly manipulates the LPT port control registers to communicate with the Control units. See Appendix B for the IBM PC LPT port to Control Master/Slave port cable (CA-83) wiring diagram.

```
100 'Find the base port address of LPT1
110 '
115 DEF SEG = 0
120 DATAPORT = (PEEK(&H409) * 256) + PEEK(&H408)
130 STATUSPORT = DATAPORT + 1
140 CONTROLPORT = DATAPORT + 2
145 DEF SEG
150 '
160 'The unit's address plus the address command
170 '
180 UNITADDR = 5 + 64
185 '
200 'Turn off all channels
210 C$ = CHR$(UNITADDR) + "0 " : GOSUB 1000
230 '
240 'Turn on all channels
250 C$ = CHR$(UNITADDR) + "65535 " : GOSUB 1000
260 '
270 'Also turn on all channels
280 C$ = CHR$(UNITADDR) + STR$(-1) + " " : GOSUB 1000
290 '
300 'Turn on each channel in succession, leaving the others off
310 FOR I=1 TO 16
320 C$ = CHR$(UNITADDR) + STR$(2^I-1) + " " : GOSUB 1000
330 NEXT I
340 '
350 'Turn on just channels 1, 3, 5 of slave unit 2
360 C$ = CHR$(64 + 2) + STR$(1 + 4 + 16) + " " : GOSUB 1000
370 '
999 END
```

```
1000 'Send the character string in C$ to the Control unit
1001 'specified by the UNITADDR variable
1002 '
1005 FOR C = 1 TO LEN(C$)
1010 IF (INP(STATUSPORT) AND &H80) <> 0 THEN PRINT "Busy";: GOTO 1010
1020 OUT DATAPORT,ASC(MID$(C$,C))
1030 OUT CONTROLPORT,&HD 'pulse strobe
1040 OUT CONTROLPORT,&HC
1050 NEXT C
1060 RETURN
```

The following BASIC program sends commands to Control units in Digital I/O peripheral mode connected to the digital I/O port of an IOtech Power488 or Power488/CT interface. In this example program, the set-up code at line 100 and the subroutine starting at line 1000 directly manipulate the Power488 8255 I/O chip to communicate with the control units. See Appendix B for the Power488 Digital I/O Port Adapter (CA-59) to Control Master/Slave port cable (CA-84) wiring diagram.

```
100 ' Set the 8255 base address to 02F0
110 '
112 OUT &H8EE1, &HBC
113 '
114 ' Make 8255 port A output, ports B and C input
115 OUT &H2F3, &H8B
117 '
120 DATAPORT = &H2F0
130 STATUSPORT = &H2F2
150 '
160 'The unit's address plus the address command
170 '
180 UNITADDR = 5 + 64
185 '
200 'Turn off all channels
210 C$ = CHR$(UNITADDR) + "0 " : GOSUB 1000
230 '
240 'Turn on all channels
250 C$ = CHR$(UNITADDR) + "65535 " : GOSUB 1000
260 '
270 'Also turn on all channels
280 C$ = CHR$(UNITADDR) + STR$(-1) + " " : GOSUB 1000
290 '
300 'Turn on each channel in succession, leaving the others off
```

```
310 FOR I=1 TO 16
320 C$ = CHR$(UNITADDR) + STR$(2^I-1) + " " : GOSUB 1000
330 NEXT I
340 '
350 'Turn on just channels 1, 3, 5 of slave unit 2
360 C$ = CHR$(2 + 64) + STR$(1 + 4 + 16) + " " : GOSUB 1000
370 '
999 END
1000 'Send the character string in C$ to the Control unit
1001 'specified by the UNITADDR variable
1002 '
1005 FOR C = 1 TO LEN(C$)
1010 IF (INP(STATUSPORT) AND &H80) = 1 THEN PRINT "Busy";: GOTO 1010
1020 OUT DATAPORT,ASC(MID$(C$,C))
1030 OUT DATAPORT,ASC(MID$(C$,C)) + 128
1050 NEXT C
1060 RETURN
```

Command Descriptions

6.1 Overview

The Control488/16 is controlled by modifying the contents of its internal registers through commands. The relationship between the contents of the registers and the actions taken by Control488/16 are described in the command descriptions that follow in this section.

There are two types of register-based commands. System commands affect the entire Control system (including any slave units). Unit commands affect only the unit specified by the Select Unit (Pn) command (the current unit).

The System commands are:

Command Trigger (@)
Reset (*R)
Response Terminator (Dn)
Error Query (E?)
Format (Fn)
Sequence Duration (Jn)
Sequence Repetition (Kn)
Sequence Mode (Ln)
SRQ Mask (Mn)
Event Mask (Nn)
Select Unit (Pn)
Sequence Range (Qs,e,f)
Save/Restore (Sn)
Trigger Source (Tn)
Query Event Status (U0)
Query Status Byte (U1)
Query System Settings (U2)
Query System Buffers (U3)
Query Connected Units (U4)
Query System Buffer Range (U7)
Sequence Table Location (Wn)
Execute (X)
Timebase Interval (Yn)
Trigger Delay (Zn)

The unit is selected using the Pn command. The Unit commands are:

Output Active (An)
Output Inactive (Bn)
Set Outputs (Cn)
Sequence Output Active (Gn)
Sequence Output Inactive (Hn)
Set Sequence Outputs (In)
Read Channels (Rn & R?)
Query Unit Settings (U5)
Query Unit Buffers (U6)
Query Unit Buffer Range (U8)
Query Product Name (U9)
Set Channel Change Mask (Vn)

Most commands consist of one alphabetic character followed by one or more numbers. The alphabetic character is the command and the number(s) are the command parameters.

The examples in this section use a personal computer functioning as an IEEE 488 bus controller, using the IOtech Personal488 PC/IEEE 488 board and associated driver software. All examples are given using BASIC. The Control488/16 bus address is set to 11 for all examples.

In order to establish communication with DRVR488 from BASIC, the following sequence must be used:

```
OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1
IOCTL#1,"BREAK"
PRINT#1,"RESET"
OPEN "\DEV\IEEEIN" FOR INPUT AS #2
PRINT#1,"TERM IN LF EOI"
```

All of the command examples assume the driver has been properly opened and reset by the above sequence.

6.2 Terminators

Responses from a Control488/16's IEEE 488 port are terminated by default with a line-feed with EOI (End Or Identify) asserted. Responses from a Control488/16's RS-232C port are, by default, terminated with a carriage-return followed by a line-feed. The Response Terminator (Dn) command is used to change the terminator(s). Commands to a Control488/16's IEEE 488 port must be terminated with the X command. Control488/16 generally treats control characters, such as carriage-return and line-feed, as white space and ignores them unless they are within a command or command option.

6.3 Command Interpretation

As commands are received by Control488/16, they are interpreted in the order in which they are received. Some commands are immediate, which means they immediately take effect. Other commands are deferred, and have no effect on device operation until the execute command (X) is interpreted.

An example of an immediate command is Select Unit (Pn), which immediately chooses which unit is being referred to. The immediate commands are Dn, Fn, Gn, Hn, In, Jn, Pn, Wn and all queries including Rn and Un.

An example of a deferred command is Output Active (An), which causes the specified channel to be set active when X is interpreted. As deferred commands are interpreted, their desired effects are recorded in internal temporary registers. As additional deferred command are interpreted, their effects are added to these registers, possibly overwriting earlier command's effects. Finally, when X is interpreted, the temporary registers are examined in the execution order described below. If two deferred commands that do not affect the same function are received before the execute command, they take effect in the execution order described below. If two deferred commands are sent that affect the same function, the earlier command is overridden. For example, if A1 B1 X is sent, output 1 is deactivated.

If an error is detected during command processing, commands are ignored up through and including the next execute command. Thus any immediate commands after the error, as well as all deferred commands, are ignored. For example, the command line A1 W2 AA B3 P4 X containing the error AA only executes the W2 because it is an immediate command that occurred before the error. The deferred commands A1 and B3, and the immediate command P4 after the error have no effect.

Deferred commands help reduce the effects of errors. Because the output setting commands (An, Bn and Cn) are deferred, all outputs are simultaneously updated by the execute command. If an error occurs during the specification of the new state, none of the outputs are modified, keeping the outputs consistent. This is the primary advantage of deferred commands: they are executed as a group, either all or none. If any errors occur, deferred commands have no effect and the device is left in a consistent state instead of a partially modified, inconsistent state.

The deferred commands are An, Bn, Cn, Kn, Ln, Mn, Nn, Qs,e,f, Sn, Tn, Yn, Zn, *R and @.

6.4 Command Execution Order

The immediate commands (Dn, Fn, Gn, Hn, In, Jn, Pn, Wn and all queries including Rn and Un) take effect immediately when they are interpreted. Even so, they must be followed by an X command to terminate the command string for correct operation. For example: P1 W0 I5 X.

The deferred commands do not take effect until after the X is interpreted. At that time, they are executed in the following order, regardless of the order they are in in the command string: Mn, Nn, then An, Bn, and Cn simultaneously, Kn, Qs,e,f, Yn, Zn, Sn, Ln, Tn, @, *R.

6.5 Syntax Rules

Most commands are identified by a single letter (A through Z) or an asterisk (*) followed by an single letter. The command trigger is the at-sign (@).

6.5.1 Case Sensitivity

Commands can be entered in upper or lower case. For example, the command A2 X acts the same as a2 x.

6.5.2 Spaces

White space, which consists of all ASCII values of 32 and below and includes the space, tab, new-line (line-feed) and carriage-return characters, is generally allowed anywhere between commands and command arguments. White space is not allowed in the middle of command options (for instance, 1 2 3 is not the same as 123).

Care must be taken when specifying options in hexadecimal. Because hexadecimal numbers may contain valid command letters, the user must be sure that hexadecimal values are separated properly from commands immediately following them. In this case, white space characters are significant. Thus both C0FF F2 X and C0FFF2 X are valid, but they do not result in the same actions. In the first case the format is set to decimal after setting an output of hexadecimal FF, while in the second case the output is set to FFF2.

6.5.3 Multiple parameters

If more than one parameter is used for a command, they must be separated by a comma and can be separated by white space.

Examples:

```
PRINT#1,"OUTPUT 11;Q100,400, 10"
```

is a command with three parameters: 100, 400, and 10.

6.5.4 Command Strings

Commands can be sent individually or in a string with other commands.

For example, these three commands:

```
PRINT#1,"OUTPUT 11;P1"
PRINT#1,"OUTPUT 11;C0 X"
PRINT#1,"OUTPUT 11;A2 X"
```

have the same effect as the single command:

```
PRINT#1,"OUTPUT 11;P1 C0 X A2 X"
```

6.5.5 Query Option

Most commands have a corresponding query command formed by appending a question mark (?) to the command letter. Query commands respond with the present configuration or mode of a previously executed command. When appropriate, the response from a query command is in the form of a command string which, if it were executed, would put the unit into the configuration it was in when the query was executed. For example, the response to a `C? X` is a command of the form `Cnnnnn`, where `nnnnn` is the current output setting. Query responses are always fixed-length strings in a pre-defined format.

Any number of query commands can be combined into one string to create a specialized status command that responds with only the information of interest for a given application. For example, `P? C? X` responds with the current unit number followed immediately by its current setting, such as `P3C012345`. No spaces separate the responses from consecutive queries.

Query commands are immediate. Their responses are generated as soon as they are interpreted, before any other commands, including X. For example:

```
PRINT#1,"OUTPUT 11;C0 X C? X"
                              Response is C000000.
PRINT#1,"OUTPUT 11;C1 X C? X"
                              Response is C000001.
PRINT#1,"OUTPUT 11;C4 C? X"
                              Response is still C000001, because the C? is an
                              immediate command. The C4 is a deferred command that
                              takes effect at the X.
PRINT#1,"OUTPUT 11;C? X       Response is now C000004.
```

Even though query commands generate their response as soon as they are interpreted, they must still be followed by the Execute (X) command for proper termination.

6.6 Default Configuration

The factory default configuration, which is restored at power-on or by the execution of the restore defaults (*R) command, is equivalent to executing the following commands:

Step	Command	Effect
1	F0	Set signed integer numeric format.
2	D2 (RS-232) D4 (IEEE 488)	Set default response terminator to CR-LF (RS-232) or LF EOI (IEEE 488).
3	Pn	Select a unit. n starts at 1 (the master unit) and then steps through the identifications of all attached slave units.
4	C0	Deactivate all outputs.
5	W0I0W1I0J1	Set power-on sequence settings inactive. Set sequence settings table element 1 inactive. Set sequence duration table element 1 to one trigger event.
6	W$I0J1	Repeated 1099 times. Fills sequence tables. All settings are inactive and all durations are one trigger event.
7	--	Repeat steps 3 through 6 for each attached slave device.
8	W1	Reset sequence table location to 1

9	`L0`	Disable sequenced operation.
10	`M0`	Clear service request enable.
11	`N0`	Clear event enable.
12	`K1`	Set sequence repetition to 1.
13	`Q1,1,1`	Set default sequence range to location 1.
14	`T0`	Disable triggering.
15	`Y1`	Set the default timebase interval to 1 millisecond.
16	`Z0.1`	Set the default trigger delay to 100 microseconds.
17	`S1`	Retrieve the first 100 sequence output and duration elements from NVRAM.
18	`X`	Execute the above commands.
19	`--`	Verify that the slave units and external switch settings match the NVRAM values. If they do not, set `No Such Unit` error and stop. If they do, continue with the next step.
20	`--`	Set the output for each unit (master or slave) to the value restored into sequence settings register 0, the power-on setting.

6.7 Status Reporting

The Control488/16 includes several registers whose bits indicate various status conditions within the unit. These registers include:

ESC Error Source Register
ESR Event Status Register
ESE Event Status Enable Register
STB Status Byte Register
SRE Service Request Enable Register

and are shown in Figures 6.1A and 6.1B.

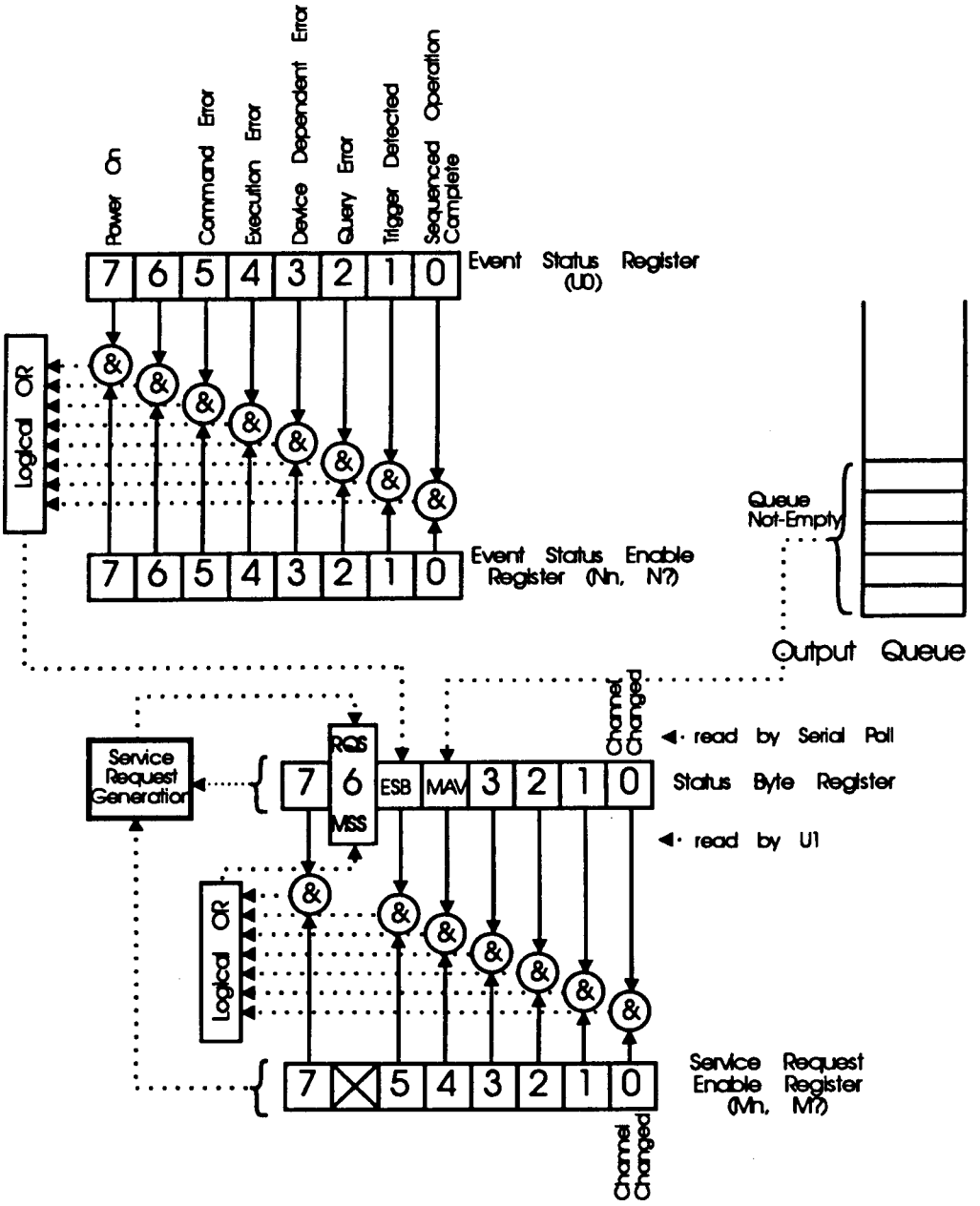


Figure 6.1A: Control488/16 Status Reporting Registers

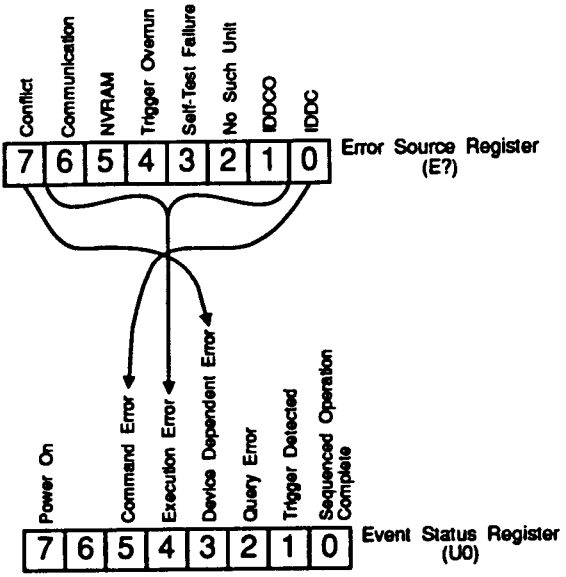


Figure 6.1B: Control488/16 Error Source Registers

6.7.1 Error Source Register

The error source register indicates which errors, if any have occurred. The individual errors are described in the E? command.

When an error occurs, it sets the appropriate bit in the error source register. This in turn sets a bit in the event status register as shown in Figure 6.1B.

6.7.2 Event Status Register

The event status register indicates which events, if any, have occurred. Its bits, and the event that set them, are as follows:

Bit 0	Sequenced Operation Complete	Set when sequenced operation has been stopped for any reason, including completion of the sequence, execution of an appropriate command (such as L0), or an error such as a trigger overrun.
Bit 1	Trigger Detected	Set when the Control488/16 has been configured to accept triggers and the specified trigger has occurred.
Bit 2	Query Error	Set when the controller has attempted to read from the Control488/16 when no response is present or pending, or when a response has been lost because the controller has sent a new query before reading the response to a prior query.
Bit 3	Device Dependent Error	Set when a conflict error has occurred. A conflict error is generated when a command cannot execute correctly because it would interfere with other commands or settings.
Bit 4	Execution Error	Set when one of several errors have occurred during the execution of a command.
Bit 5	Command Error	Set when a command syntax error is detected.
Bit 6	Unused	Reserved for future expansion. Always 0.
Bit 7	Power On	Set on power-on or system reset (*R).

The event status register is read with the U0 command, which clears the register after responding with its contents.

6.7.3 Event Status Enable Register

The event status enable register control which events, if any, are to be reflected in the status byte register. As shown in Figure 6.1A, the bits of the event status register are logically ANDed with the corresponding bits of the event status enable register, and the resulting bits are logically ORed together to form the event status bit (ESB) in the status byte register. The event status enable register does not affect the event status register; it only affects the ESB bit of the status byte register. The event status enable register is set and interrogated with the Nn command.

6.7.4 Status Byte Register

The Control488/16 status byte register has only four active bits:

Bit 0	Channel Changed	Set when the Control488 has sensed that any of masked I/O channel(s) (See V command) has changed. The bit is cleared when the user has read the Status Byte Register via the U1 command.
Bit 4	Message Available (MAV)	Set when a response is waiting to be read by the controller. Unread responses are stored in an output queue which sets the message available bit when it is not empty.
Bit 5	Event Status	Set when the corresponding bits is both the event status register and the event status enable register are set.
Bit 6	Request For Service (RQS)	Request for service is returned with the status byte when it is read by the controller using a serial poll. If it is set, then it indicates that the Control488/16 is requesting service and asserting the IEEE 488 bus Service Request (SRQ) signal. Master summary status is returned with the status byte when it is read with the Read Status Byte U1 command. If it is set, then it indicates that corresponding bits of the status byte and service request enable registers are set. RQS is cleared when the Control488/16 is serial polled.
	Master Summary Status (MSS)	

All other bits of the status byte register are unused and are always 0.

6.7.5 Service Request Enable Register

The service request enable register controls which bits of the status byte register are to be reflected in the request for service and master summary status bits of the status byte register. As shown in Figure 6.1A, the bits of the status byte register are logically ANDed with the corresponding bits of the service request enable register, and the resulting bits are logically ORed together to form the master summary event status bit (MSS) in the status byte register and to control the request for service (RQS) bit in that register. The service request enable register does not affect the status byte register; it only affects the MSS and RQS bits of the status byte register. The event status enable register is set and interrogated with the Mn command.

6.8 Sequenced Operation

The Control488/16 products include the ability to step through a sequence of output settings. Each step includes two items: the outputs which are to be active and inactive, and the number of triggers for which the setting is to persist. The output activities are stored in the 1101-element sequence settings table elements numbered 0 through 1100 and the number of triggers are stored in the 1100-element sequence duration table elements numbered 1 through 1100. As each unit has separate outputs, the sequence settings registers are present in each individual unit and the select unit command is used to choose among them. Commands are provided to set and clear individual outputs within the sequence output registers, as well as to set entire sequence output registers. Commands are also provided to set the sequence duration register. All of these commands are immediate. They directly modify the sequence tables registers and are not deferred.

Sequence settings table element 0 is a special register used to hold the power-up setting. It does not have an associated sequence duration register and cannot be used within a sequence of settings, though it can be used as the final sequence setting.

Command Trigger @

Type: System command, Deferred

`@` Enables generation of a command trigger.

The command trigger enables generation of a command trigger. The trigger occurs when an Execute (X) is interpreted. The system responds to command triggers when Trigger Source is set for a command trigger (T5 or T11) and sequenced operation is enabled (Sequence Mode set to L1, L2 or L3). Command trigger has no affect if trigger source is not set to command trigger.

Command trigger is a deferred command; no trigger is generated if an error occurs before the X.

A conflict error occurs if triggering is not enabled (Trigger Source is T0) when the command trigger is interpreted.

When the trigger source is the @ command (T5 or T11), a trigger is enabled when the next Execute command (X) following the @ is encountered in the command line. A trigger is not generated until the entire command line is processed.

```
PRINT#1,"OUTPUT 11;Q1,10,10X"
```
Set the sequence range to include the first ten sequence elements.

```
PRINT#1,"OUTPUT 11;L1 T5X"
```
Execute the sequence once on command triggers.

```
PRINT#1,"OUTPUT 11;@ X"
```
Generate trigger to step through sequence.

```
PRINT#1,"OUTPUT 11;@X@X@X@X@X@X@X@X@X@X
```
General nine more triggers.

Reset *R

Type: System Command, Deferred

*R Restores the master unit and any attached slave units to their initial power-up state.

This command has the same effect as removing and re-applying power. Control488/16 is returned to its default settings as described in Section 6.6, which includes resetting many of the unit's settings as well as recalling the beginning of the sequence tables from the non-volatile memory.

The reset process takes several seconds, during which the Control488/16 is unable to receive or process commands. No commands should be addressed to the unit for at least five seconds after issuing the reset command.

When the master unit is reset, either as a result of a power cycle or a reset command, all attached slave units are also reset. This keeps the master and slaves in a consistent state. To ensure initialization of the slave interfaces, the first command sent to the master unit should be a *R to establish communication with the slave units. This is not necessary if the master unit was powered on after the slaves were.

The default setting of the Select Unit (Pn) command is unit 1, the master unit. All unit commands will refer to the master unit until a different unit is selected.

The IEEE 488 bus Device Clear commands (DCL and SDC) do not have the same effect as *R. They do not perform a reset. They do clear any pending commands and responses and prepare the master to receive new commands.

```
PRINT#1,"OUTPUT 11;*RX"    Reset master and attached slaves.
SLEEP(5)                   Wait for reset to finish.
```

Output Active An

Type: Unit Command, Deferred

An Activates the output specified by n (1 through 16) in the unit specified by the Pn command.

Output Active activates a single output channel of the Control unit selected by the Pn command. It modifies individual output settings of the Set Outputs (Cn) command. If the Opto-22 module installed in that channel is a normally open switch, An closes that switch. If the module is normally closed, An opens its switch. If an input module is installed, An should not be used, as it prevents correct readback of the sense value. It does not interfere with normal operation in any other way.

An is a deferred command, as are the other commands that affect the outputs, Bn and Cn. As commands are interpreted, the new output setting is generated by the An, Bn, and Cn commands. When the X is interpreted, the complete output setting, including the net effect of all An, Bn and Cn commands is simultaneously output on the master units and all slave units. If an error occurs during the specification of the new state, none of the outputs are modified, keeping the outputs consistent.

A conflict error occurs if triggering is enabled (Trigger Source is not T0) when then output active command is interpreted.

Examples:

```
PRINT#1,"OUTPUT 11;P1 X"
```
Specify master unit.

```
PRINT#1,"OUTPUT 11;A3 X"
```
Activate master channel 3.

```
PRINT#1,"OUTPUT 11;P5 A1 X"
```
Activate slave 5 channel 1.

```
PRINT#1,"OUTPUT 11;P1 A4 P2 B4 X"
```
Activate master channel 4 and deactivate slave 2 channel 4.

```
PRINT#1,"OUTPUT 11;P1 A1 B1 X"
```
Deactivate master channel 1. The B1 overwrites the effect of the A1.

Output Inactive Bn

Type: Unit Command, Deferred

`Bn` Deactivates the output specified by `n` (1 through 16) in the unit specified by the `Pn` command.

Output Inactive deactivates a single output channel of the Control unit specified by the Select Unit (`Pn`) command. It modifies individual output settings of the Set Outputs (`Cn`) command. If the Opto-22 module installed in that channel is a normally open switch, `Bn` opens that switch. If the module is normally closed, `Bn` closes that switch. If an input module is installed, the `Bn` command can be used, as it does not affect correct readback of the sense value.

`Bn` is a deferred command, as are the other commands that affect the outputs: `An` and `Cn`. As commands are interpreted, the new output setting is generated by the `An`, `Bn`, and `Cn` commands. When the `X` is interpreted, the complete output setting, including the net effect of all `An`, `Bn` and `Cn` commands, is simultaneously output on the master units and all slave units. If an error occurs during the specification of the new state, none of the outputs are modified, keeping the outputs consistent.

A conflict error occurs if triggering is enabled (Trigger Source is not `T0`) when the output inactive command is interpreted.

Examples:

```
PRINT#1,"OUTPUT 11;P1 X"        Specify master unit.
PRINT#1,"OUTPUT 11;B3 X"        Deactivate master channel 3.
PRINT#1,"OUTPUT 11;P5 B1 X"
                                Deactivate slave 5 channel 1.
PRINT#1,"OUTPUT 11;P1 B4 P2 A4 X"
                                Deactivate master channel 4 and activate slave 2
                                channel 4.
PRINT#1,"OUTPUT 11;P1 B1 A1 X"
                                Activate master channel 1. The A1 overwrites the effect
                                of the B1.
```

Set Outputs Cn

Type: Unit Command, Deferred (Query is immediate)

Cn	Set all sixteen outputs of the unit selected by Pn.
C?	Responds with Cn where n is the present output setting of the unit specified by the Pn command in the format specified by Fn.

Set Outputs sets all of the output channels on the unit specified by the Select Unit (Pn) command.

The n in the Cn command is a number in the format specified by Fn. It is interpreted by the Control as a 16-bit binary integer. The least significant bit of this integer specifies the setting of channel 1. If the bit is 0, the output channel is deactivated; if it is 1, the output channel is activated. The next more significant bit controls channel 2 and so on up through the most significant bit, which controls channel 16. Control can accept the n parameter in several different formats, as specified by the Format (Fn) command. In the default format (F0), n is a decimal number, which is then converted by the Control into a binary integer.

For example, to activate outputs 1, 4 and 7, with all other outputs deactivated in binary format (F4), the command would be specified as C0000000001001001 (or just C1001001 as the most significant digits of n can be omitted when they are all zero). C0 deactivates all outputs.

To specify Cn in integer format (Fn set to F0, F1 or F2), convert the binary setup to decimal. In the example above, the integer equivalent would be C73.

To specify Cn in hexadecimal format (Fn set to F3), convert the binary setup to hexadecimal. In the example above, the hexadecimal equivalent would be C49.

The Cn command sets all sixteen channels of the currently selected unit. To set or clear individual channels, use the Output Active (An) or Output Inactive (Bn) commands.

Cn is a deferred command, as are the other commands that affect the outputs, An and Bn. As commands are interpreted, the new output setting is generated by the An, Bn, and Cn commands. When the X is interpreted, the complete output setting, including the net effect of all An, Bn and Cn commands, is simultaneously output on the master units and all slave units. If an error occurs during the specification of the new state, none of the outputs are modified, keeping the outputs consistent.

A conflict error occurs if triggering is enabled (Trigger Source is not T0) when the Set Outputs command is interpreted.

Examples:

`PRINT#1,"OUTPUT 11;F0 C1 X"`	Select decimal format. Activate channel 1 and deactivate all other channels.
`PRINT#1,"OUTPUT 11;C2 X"`	Activate channel 2 and deactivate all other channels.
`PRINT#1,"OUTPUT 11;C3 X"`	Activate channels 1 and 2 and deactivate all other channels.

```
PRINT#1,"OUTPUT 11;C32768 X"
```
Activate channel 16 and deactivate all other channels.

```
PRINT#1,"OUTPUT 11;C65535 X"
```
Activate all sixteen channels.

```
PRINT#1,"OUTPUT 11;C-1 X"
```
Also activate all sixteen channels. The binary representation of –1 as a two's complement binary integer is the same as the representation of 65535, which is all 1's.

```
PRINT#1,"OUTPUT 11;P1 C0 A1 X"
```
Activate channel 1 and deactivate all other channels.

```
PRINT#1,"OUTPUT 11;P1 A1 C0 X"
```
Deactivate all channels, because the Cn command overrides all preceding An, Bn and Cn settings for the selected unit.

```
PRINT#1,"OUTPUT 11;P1 A1 P2 C0 X"
```
Activate master channel 1 and deactivate all of slave 2's channels.

The Set Outputs query (C?) command interrogates the output setting of the current unit. The reply is in the format selected by the Format (Fn) command. C? replies with the present output settings, which does not reflect the state of any sense channels. To interrogate a sense channel, the Read Channels (Rn and R?) commands must be used.

Example:

```
PRINT#1,"OUTPUT 11;F0 C0 X C? X"
```
Select decimal format. Response is C000000.

```
PRINT#1,"OUTPUT 11;C73 C? X"
```
Response is still C000000, because the Set Outputs command is not executed until the X is interpreted, while the C?, like all other queries, is executed immediately upon interpretation.

```
PRINT#1,"OUTPUT 11;C? X"
```
Response is now C000073.

```
PRINT#1,"OUTPUT 11;F3 C? X"
```
Select hexadecimal format. Response is C0049.

```
PRINT#1,"OUTPUT 11;F4 C? X"
```
Select binary format. Response is C0000000001001001.

Response Terminator Dn

Type: System Command, Immediate

Dn	Set output terminator used by RS-232C and IEEE 488.
D0	LF
D1	CR
D2	CR-LF
D3	LF-CR
D4	IEEE 488: LF with EOI; RS-232C: LF
D5	IEEE 488: CR with EOI; RS-232C: CR
D6	IEEE 488: CR-LF with EOI; RS-232C: CR-LF
D7	IEEE 488: LF-CR with EOI; RS-232C: LF-CR
D?	Response is Dn, where n is the present termination setting, a one digit number from 0 to 7.

The Response Terminator command sets the character(s) that will be appended to the end of responses from the Control488/16. The power-on default terminator is LF with EOI (D4) for the IEEE 488 interface and CR-LF (D2) for the RS-232C interface. The choice of the correct response terminator can make responses easier to receive and interpret. For example, if CR-LF with EOI was preferred for an IEEE 488 system, the following command could be used:

```
PRINT#1,"OUTPUT 11;D6 X"   Set response terminator to CR-LF with EOI.
```

Error Query E?

Type: System Command, Immediate

E?	Reports and clears the current contents of the error source register After execution of the Error Query command, Control488/16 responds with one of the following error codes:
E000	No error has occurred.
E001	Invalid device dependent command (IDDC). Due to a command syntax error.
E002	Invalid device dependent command option (IDDCO). A command parameter was out of range or missing.
E004	No such unit. The Select Unit (Pn) command specified a slave unit that was not attached.
E008	Self-test failure. Reserved for non-critical internal errors.
E016	Trigger overrun. Triggers occurred faster than they could be processed.
E032	Non-volatile RAM failure. Access to the non-volatile RAM was impossible, or the data retrieved were corrupt.
E064	Master/slave communication error. Different slave units are attached than were expected, or a slave was disconnected or reset during operation, or corrupt data were transferred during master/slave communications.
E128	Conflict error. A command could not be executed because of the setting of another command.
Ennn	If two or more errors occurred, nnn is the sum of the corresponding error codes.

The Error Query command responds with the contents of the error source register and then clears that register. When an error occurs, the appropriate bits are set in the error source and standard event registers, and possibly in the status byte register. The ERROR indicator light on the front panel of the Control488/16 illuminates.

The error query clears the error source register, the corresponding bits in the standard event register, and possibly bits in the status byte register. Clearing the error source register allows the ERROR indicator light to turn off.

Error query responds with Ennn, where nnn is a three-digit decimal number equal to the sum of the error codes.

The following examples show the use of E? in a situation where a master unit was reset and the slaves it recognizes are not those that were present when the non-volatile memory was last updated (with the S1 command). The Error Query (E?) and Query Attached Units (U4) commands are used to diagnose the source of the error.

Response Terminator Dn

Type: System Command, Immediate

Dn	Set output terminator used by RS-232C and IEEE 488.
D0	LF
D1	CR
D2	CR-LF
D3	LF-CR
D4	IEEE 488: LF with EOI; RS-232C: LF
D5	IEEE 488: CR with EOI; RS-232C: CR
D6	IEEE 488: CR-LF with EOI; RS-232C: CR-LF
D7	IEEE 488: LF-CR with EOI; RS-232C: LF-CR
D?	Response is Dn, where n is the present termination setting, a one digit number from 0 to 7.

The Response Terminator command sets the character(s) that will be appended to the end of responses from the Control488/16. The power-on default terminator is LF with EOI (D4) for the IEEE 488 interface and CR-LF (D2) for the RS-232C interface. The choice of the correct response terminator can make responses easier to receive and interpret. For example, if CR-LF with EOI was preferred for an IEEE 488 system, the following command could be used:

```
PRINT#1,"OUTPUT 11;D6 X"   Set response terminator to CR-LF with EOI.
```

Error Query E?

Type: System Command, Immediate

E? Reports and clears the current contents of the error source register
After execution of the Error Query command, Control488/16 responds with one of the following error codes:

E000 No error has occurred.

E001 Invalid device dependent command (IDDC). Due to a command syntax error.

E002 Invalid device dependent command option (IDDCO). A command parameter was out of range or missing.

E004 No such unit. The Select Unit (Pn) command specified a slave unit that was not attached.

E008 Self-test failure. Reserved for non-critical internal errors.

E016 Trigger overrun. Triggers occurred faster than they could be processed.

E032 Non-volatile RAM failure. Access to the non-volatile RAM was impossible, or the data retrieved were corrupt.

E064 Master/slave communication error. Different slave units are attached than were expected, or a slave was disconnected or reset during operation, or corrupt data were transferred during master/slave communications.

E128 Conflict error. A command could not be executed because of the setting of another command.

Ennn If two or more errors occurred, nnn is the sum of the corresponding error codes.

The Error Query command responds with the contents of the error source register and then clears that register. When an error occurs, the appropriate bits are set in the error source and standard event registers, and possibly in the status byte register. The ERROR indicator light on the front panel of the Control488/16 illuminates.

The error query clears the error source register, the corresponding bits in the standard event register, and possibly bits in the status byte register. Clearing the error source register allows the ERROR indicator light to turn off.

Error query responds with Ennn, where nnn is a three-digit decimal number equal to the sum of the error codes.

The following examples show the use of E? in a situation where a master unit was reset and the slaves it recognizes are not those that were present when the non-volatile memory was last updated (with the S1 command). The Error Query (E?) and Query Attached Units (U4) commands are used to diagnose the source of the error.

Example:

```
OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1
                                  Attach and reset the IEEE 488 interface.
IOCTL#1,"BREAK"
PRINT#1,"RESET"
OPEN "\DEV\IEEEIN" FOR INPUT AS #2
PRINT#1,"TERM LF EOI"             Use line-feed and EOI for terminator.
PRINT#1,"OUTPUT 11;E?X"           Query error source.
PRINT#1,"ENTER 11"                Retrieve response.
INPUT#2,E
PRINT E                           Displays 64 (communication error).
PRINT#1,"OUTPUT 11;U4 X"          Query attached units.
PRINT#1,"ENTER 11"                Retrieve response.
LINE INPUT#2,A$
PRINT A$                          Displays 01,nn,nn,nn... showing which units are
                                  and are not recognized.
```

If more than one type of error has occurred, the response is the sum of the corresponding error codes:

```
PRINT#1,"OUTPUT 11;A99 X"         Oops, 99 is too big, causing IDDCO error.
PRINT#1,"OUTPUT 11;P3 X"          Oops, slave unit 3 does not exist, causing EOO4 (No
                                  Such Unit) error.
PRINT#1,"@ X"                     Oops, triggering is not enabled. Command trigger causes
                                  conflict error.
PRINT#1,"OUTPUT 11;E? X"          Retrieve error code.
PRINT#1,"ENTER 11"
INPUT#2,E
PRINT E                           Displays 134 (128 + 4 + 2)
```

Format Fn

Type: System Command, Immediate

- `F0` Signed decimal format.
- `F1` Signed decimal format with leading + sign.
- `F2` Unsigned decimal format.
- `F3` Hexadecimal format.
- `F4` Binary format.
- `F?` Responds with the present format selection in the format `Fn`, where `n` is one digit in the range from 0 to 4.

Format Command	Inputs		Outputs	
	Type	Range	Type (all fixed format)	Range
F0	Signed Integer	–32768 to 65535	6-digit signed integer	–32768 to 032767 (+ implied)
F1	Integer	–32768 to +65535	6-digit signed integer	–32768 to +32767
F2	Integer	–32768 to 65535	5-digit unsigned integer	00000 to 65535
F3	Hexadecimal	0 to FFFF	4-digit hexadecimal	0000 to FFFF
F4	Binary	0 to 1111111111111111	16-digit binary	0000000000000000 to 1111111111111111

Format sets the numeric format used to represent the activity of all sixteen outputs of a unit. This command affects the `Cn`, `C?`, `In`, `I?`, `R?`, `U6` and `U8` commands. All of these commands refer to all sixteen channels at once with a single number that holds all sixteen channel settings. The channel settings are manipulated by the Control as 16-bit binary numbers with channel 1 as the least significant bit. If a channel is active, its corresponding bit is 1. If a channel is inactive, its corresponding bit is 0. For example, if channels 1, 4 and 7 are active, with all other outputs set inactive, the `C?` command responds with `C0000000001001001` in binary format (`F4`). Note that the right-most bit is the least significant bit and represents channel 1; the left most bit represents output 16. The format command determines how the 16-bit value is communicated as a signed or unsigned integer, or as a hexadecimal or binary number. For example, the following commands are equivalent:

```
PRINT#1,"OUTPUT 11;F0 C73 X"
PRINT#1,"OUTPUT 11;F3 C49 X"
PRINT#1,"OUTPUT 11;F4 C1001001 X"
```

The following table shows various decimal and hexadecimal numbers in the various output formats:

Setting (decimal)	Setting (hexadecimal)	F0	F1	F2	F3	F4
–32768 or 32768	8000	–32768	–32768	32768	8000	1000000000000000
–10 or 65526	FFF6	–00010	–00010	65526	FFF6	1111111111110110
–1 or 65535	FFFF	–00001	–00001	65535	FFFF	1111111111111111
0	0000	000000	+00000	00000	0000	0000000000000000
1	0001	000001	+00001	00001	0001	0000000000000001
10	000A	000010	+00010	00010	000A	0000000000001010
32767	7FFF	032767	+32767	32767	7FFF	0111111111111111

Examples:

```
PRINT#1,"OUTPUT11;F0 C-1 X"
```
Format set to signed integer, all channels active.
```
PRINT#1,"OUTPUT11;C? X"
```
Response is `C-00001`.
```
PRINT#1,"OUTPUT11;F2 C? X"
```
Unsigned integer format. Response is `C65535`.
```
PRINT#1,"OUTPUT11;F3 C? X"
```
Format changed to hexadecimal. Response is `CFFFF`.
```
PRINT#1,"OUTPUT11;F4 C? X"
```
Format changed to binary. Response is `C1111111111111111`.
```
PRINT#1,"OUTPUT 11;F0 C0 X C? X"
```
Response is `C000000`.
```
PRINT#1,"OUTPUT 11;C73 X C? X"
```
Response is now `C000073`.
```
PRINT#1,"OUTPUT 11;F3 C? X"
```
Response is `C0049`.
```
PRINT#1,"OUTPUT 11;F4 C? X"
```
Response is `C0000000001001001`.
```
PRINT#1,"OUTPUT 11;F4 C0 X"
```
Binary format selected. All outputs inactive.
```
PRINT#1,"OUTPUT 11;C? X"
```
Response is `C0000000000000000` for slave 2.
```
PRINT#1,"OUTPUT 11;A1 B2 X"
```
Channel 1 active; channel 2 inactive.
```
PRINT#1,"OUTPUT 11;C?"
```
Response is `C0000000000000001`.
```
PRINT#1,"OUTPUT 11;F0 C5 X"
```
Format set to signed integer, channels 1 and 3 active.

Sequence Output Active Gn

Type: Unit Command, Immediate

`Gn` Activates the output specified by `n` (1-16) in the sequence settings table element specified by the current sequence table location (`Wn`).

Sequence Output Active activates an output channel in the sequence settings table at the location specified by the Sequence Table Location (`Wn`) command in the unit specified by the `Pn` command. It modifies individual output settings of the Set Sequence Outputs (`In`) command. The `n` in the `Gn` command is the channel number (1 through 16) to be activated.

If the Opto-22-compatible module installed in that channel is a normally open switch, `Gn` closes that switch during sequencing. If the module is normally closed, `Gn` opens its switch. If an input module is installed, the `Gn` command should not be used, as it prevents correct readback of the sense value. It does not otherwise interfere with normal operation.

If multiple `Gn` and `Hn` commands refer to the same channel, only the last `Gn` or `Hn` command has a lasting effect. For example:

```
PRINT#1,"OUTPUT 11;P1 W30 G1 H1 P2 H1 G1 X"
```

Deactivates master channel 1 and activates slave 2 channel 1 when at location 30 in the sequence settings table.

Example:

`PRINT#1,"OUTPUT 11;P1 X"` Specify master unit.

`PRINT#1,"OUTPUT 11;W50 G3 X"`

Activate master channel 3 in sequence settings table location 50.

`PRINT#1,"OUTPUT 11;P2 W50 G1 X"`

Activate channel 1 in slave 2, sequence settings table location 40.

`PRINT#1,"OUTPUT 11;W50 P1 G4 P2 G5 X"`

Activate master channel 4 and slave 2 channel 5 in sequence settings table location 50.

Sequence Output Inactive Hn

Type: Unit Command, Immediate

Hn Deactivates the output specified by n (1 through 16) in the sequence settings table element specified by the current sequence table location Wn.

Sequence Output Inactive deactivates a single output channel in the sequence settings table at the location specified by the Sequence Table Location (Wn) command for the unit specified by the Pn command. It modifies individual output settings of the Set Sequence Outputs (In) command.

If the Opto-22-compatible module installed in the output channel specified by n is a normally open switch, Hn opens that switch during sequencing. If the module is normally closed, Hn closes its switch. If an input module is installed, the Hn command can be used, as it does not affect correct readback of the sense value.

The n in the Hn command is the channel number (1 through 16) to be deactivated on the unit specified by the Pn command.

If multiple Gn and Hn commands in the same command line refer to the same channel, only the last Gn or Hn commands takes effect. For example:

```
PRINT#1,"OUTPUT 11;P1 W30 G1 H1 P2 H1 G1 X"
```

Deactivates master channel 1 and activates slave 2 channel 1 when at location 30 in the sequence settings table.

Example:

```
PRINT#1,"OUTPUT 11;P1 X"
```
Specify master unit.

```
PRINT#1,"OUTPUT 11;W50 X H3 X"
```
Deactivate master channel 3 when at location 50 in the sequence settings table.

```
PRINT#1,"OUTPUT 11;P2 W40 X H1 X"
```
Deactivate slave 2 channel 1 when at location 40 in the sequence settings table.

```
PRINT#1,"OUTPUT 11;P1 W30 X H4 P2 H5 X"
```
Deactivate master channel 4 and slave 2 channel 5 when at location 30 in the sequence settings table.

```
PRINT#1,"OUTPUT 11;P1 W30 X G1 H1 P2 H1 G1 X"
```
Deactivate master channel 1, activate slave 2 channel 1 when at location 30 in the sequence settings table.

Set Sequence Outputs In

Type: Unit Command, Immediate

`In`	Modifies the output settings in the sequence settings table at the location specified by the `Wn` command for the unit selected by the `Pn` command.
`I?`	Responds with the present setting of `In` in the current format (`Fn`).

Set Sequence Outputs simultaneously activates or deactivates all sixteen channels of the unit selected by `Pn`) at a location in the sequence settings table determined by `Wn`. The `n` in the `In` command is a number in the format specified by `Fn`, which the Control interprets as a 16-bit binary integer. The least significant bit of this integer specifies the setting of channel 1. If the bit is 0, the channel is deactivated; if it is 1, the channel is activated. The next more significant bit controls channel 2 and so on up through the most significant bit, which controls channel 16. The `In` command is similar to the `Cn` command, except that it sets the output settings at a point in the sequence settings table instead of setting the outputs directly.

The Control can accept the `n` parameter in any of several different formats, as specified by the Format (`Fn`) command. In the default format, `n` is a decimal number, which is converted by the Control into a binary integer.

The output settings are manipulated as a 16-bit binary integer with output 1 as the least significant bit. The simplest method of specifying `In` is in binary format (`F4`). To activate an output, its corresponding bit must be 1. To deactivate an output, its corresponding bit must be 0. For example, to activate outputs 1, 4 and 7, with all other outputs inactive, the command is specified as `I0000000001001001`. Note that the right-most bit is the least significant bit and represents output 1; the left most bit represents output 16. When interpreting the `In` command, it starts with the least significant bit and assumes any missing bits are 0. Thus, `I1001001` would have the same effect as the above example.

To specify `In` in integer format (`Fn` set to `F0`, `F1` or `F2`), convert the binary setup to decimal. In the example above, the integer equivalent would be `I73`.

To specify `In` in hexadecimal format (`Fn` set to `F3`), convert the binary setting to hexadecimal. In the example above, the hexadecimal equivalent would be `I49`.

Individual output settings in the `In` specification can be changed using the Sequence Output Active (`Gn`) or Sequence Output Inactive (`Hn`) commands.

Example:

```
PRINT#1,"OUTPUT 11;F0 W10 I1 X"
```
Decimal format. Set sequence settings table location 10 to activate just channel 1 and deactivate the others.

```
PRINT#1,"OUTPUT 11;W$ I2 X"
```
Increment the sequence location and set the sequence settings table location 11 to activate just channel 2.

```
PRINT#1,"OUTPUT 11;W$ I4 X"
```
Set the sequence settings table location 12 to activate just channel 3.

```
PRINT#1,"OUTPUT 11;W$ I8 X"
```
Set the sequence settings table location 12 to activate just channel 4.

The Set Sequence Outputs query (`I?`) command interrogates the output setting of the unit selected by `Pn`. The reply is in the format selected by the Format (`Fn`) command.

Example:

```
PRINT#1,"OUTPUT 11;W20 F0 I0 X I? X"
```
Response is `I000000`.

```
PRINT#1,"OUTPUT 11;W20 I73 X I? X"
```
Response is `I000073`.

```
PRINT#1,"OUTPUT 11;W20 F3 I? X"
```
Response is `I0049`.

```
PRINT#1,"OUTPUT 11;W20 F4 I? X"
```
Response is `I0000000001001001`.

Sequence Duration Jn

Type: System Command, Immediate

Jn	Sets up how many triggers occur for a location in the sequence settings table to n (1 to 65,535).
J?	Responds with the present sequence duration in the format Jnnnnn.

This command sets an element in the sequence duration table. This element specifies the number of triggers received before Control488/16 goes to the next location in the sequence settings table. n is the number of triggers from 1 to 65,535. The Control continues to output from that location until n numbers of triggers are received.

The element to be set in the sequence duration table is determined by the Sequence Table Location (Wn) command. If Wn is W0 (the power-on setting), a conflict error occurs (E002), because it is the power-on setting and does not have a duration.

If sequencing is active and Jn is changed, Jn temporarily suspends sequenced operation to assure synchronization of master and slave units. Trigger events that occur during this suspension, if any, are ignored.

The Select Unit (Pn) command has no effect on the Sequence Duration (Jn) command or table, because a single sequence duration table is used for the entire system.

To query the duration at a single location in the sequence duration table, use J?. The response is in the form Jnnnnn.

Example:

To make the first sequence element last for one trigger event, the next for two trigger events, the third for three, and the fourth for four, execute:

```
PRINT#1,"OUTPUT 11;W1 J1 W$ J2 W$ J3 W$ J4 X"
```

When using a one millisecond trigger source, make sequence element 250 last for three seconds:

```
PRINT#1,"OUTPUT 11;W250 J3000X"
```

Sequence Repetition Kn

Type: System Command, Deferred (Query is immediate)

`Kn`	Sets the number of times the sequence range defined by the start and end parameters of `Qs,e,f` is repeated when sequence mode `L2` is selected. The range for `n` is 1 - 65,535. Default is 1.
`K?`	Responds with the number of repetitions specified in the format `Knnnnn`.

The Sequence Repetition command specifies how many times the sequence range is executed before completion when sequenced operation is performed in sequence mode `L2`. The sequence range is that portion of the sequence table specified by the `s` and `e` parameters of the sequence range `Qs,e,f` command.

Sequence repetition is only used if Sequence Mode is set to counted sequenced operation (`L2`). It is ignored if any other sequence mode is used. If `Kn` is set to `K0` (no repetition), an IDDCO error occurs.

Example:

```
PRINT#1,"OUTPUT 11;K2 L2 X"
```

Sequence repetition set to 2, sequence mode set to counted.

```
PRINT#1,"OUTPUT 11;Y250 X"
```

Internal timebase set to 250 ms.

```
PRINT#1,"OUTPUT 11;Q1,10,0X"
```

Sequence range set from 1 through 10, finishing with 0.

```
PRINT#1,"OUTPUT 11; T6 X"
```

Trigger source set to internal timebase. Sequencing begins, stepping through elements 1 through 10 twice, finishing with 20.

Sequence Mode Ln

Type: System Command, Deferred (Query is immediate)

L0	Disables sequenced operation
L1	Enables once-through operation
L2	Enables counted sequenced operation.
L3	Enables continuous sequenced operation.
L?	Responds with Ln where n is the current sequence mode setting.

The Sequence Mode command specifies how and if the sequence range specified by Qs,e,f is repeated.

L0 immediately disables any sequencing when it is executed, even if a sequence is currently running.

L1 specifies that the sequence range defined by Qs,e,f is stepped through exactly once. L1 is stopped immediately by L0.

L2 specifies that the sequence range defined by Qs,e,f is stepped through the number of times specified by the Sequence Repetition (Kn) command. L2 is stopped immediately by L0 or after the end of the current repetition by L1.

L3 specifies that the sequence range defined by Qs,e,f is stepped through indefinitely. L3 is stopped immediately by L0, after the end of the current repetition by L1 or at the end of Kn cycles by L2. Otherwise, L3 operation will not finish.

Changing the Sequence Mode in any other way (such as from L1 to L3) causes sequenced operation to stop immediately.

If sequenced operation is active and Ln is decreased (from L3 to L2 or L1; L2 to L1), sequenced operation is temporarily stopped to assure synchronization of the master and slave units. Any triggers received during suspension are ignored.

Example:

```
PRINT#1,"OUTPUT 11;Q1,8,0 X"
```
Sequence range set to start at element 1, end at element 8 and final at element 0.

```
PRINT#1,"OUTPUT 11;K2 L2 X"
```
Sequence repetition set to 2, sequence mode set to counted.

```
PRINT#1,"OUTPUT 11;Y250 X"
```
Internal timebase set to 250 ms.

```
PRINT#1,"OUTPUT 11; T6 X"
```
Trigger source set to internal timebase. Sequenced operation begins.

SRQ Mask Mn

Type: System Command, Deferred (Query is immediate)

M0	Clear Service Request Enable Register (default)
M1	SRQ on sensing of I/O channel change
M16	SRQ on Message Available
M32	SRQ on event detected
Mn	Enable SRQ on specified conditions where n is the sum of the corresponding condition codes.
M?	Response is M0Mnnn where nnn is the service request enable mask.

The SRQ Mask command sets or clears the service request enable register, which controls the generation of Master Summary Status, Request for Service, and the IEEE 488 bus SRQ signal.

The SRQ Mask command enables SRQs on one or more of the conditions listed above. Multiple SRQ Mask conditions can be enabled simultaneously by issuing them separately or by combining them in one command string. The programmed SRQ modes remain enabled until the M0 (clear SRQ mask) command is sent, or the controller sends a Reset (*R) command. This command acts directly on the Service Request Enable Register (see Status Reporting, Section 6.7).

When SRQ on I/O change (M1) is specified, the master unit will generate an SRQ when any of its own I/O channels or attached slaves I/O channels have changed as defined by the Channel Change Mask register(s). See the Channel Change Mask (Vn command) in the Command Refernce section for more details on how to set or modify the channel change mask registers.

Example:

`PRINT#1,"OUTPUT 11;M16 M32 X"`	Enable SRQ on Message Available or Event Detected.
`PRINT#1,"OUTPUT 11;M48 X"`	Same effect as previous command.
`PRINT#1,"OUTPUT 11;M? X"`	Read present Mn setting. Response is M048 (32+16).

Event Mask Nn

Type: System Command, Deferred (Query is immediate)

N0	Clear event mask (default)
N1	Sequence Operation Complete
N2	Trigger Detected
N4	Query error
N16	Execution error
N32	Command error
N128	Power-on
Nn	Detect the specified conditions, where n is the sum of the corresponding condition codes.
N?	Read event status enable register. Response is in the form N0Nnnn, where nnn is the event enable register setting.

This command sets the event status enable register (ESE). ESE determines which conditions in the event status register (ESR) are reported in the Event Status register Bit (ESB) in the status byte register. See the section on the Status Reporting (Section 6.7) for more details.

Multiple ESR bits can be enabled simultaneously by issuing them separately or by combining them in one command string or one command. This enables reporting of multiple events. The programmed event enable masks remain set until a Clear Event Mask (N0) command is sent or the controller sends a Reset (*R) command.

Example:

`PRINT#1,"OUTPUT 11;N0 X"`	Clear ESE
`PRINT#1,"OUTPUT 11;N? X"`	Read ESE back. Response is N0N000
`PRINT#1,"OUTPUT 11;N4 N16 X"`	Enable detection of query error and execution error.
`PRINT#1,"OUTPUT 11;N20 X"`	Also enable detection of query error and execution error.
`PRINT#1,"OUTPUT 11;N? X"`	Query event mask setting. Response is N0N020, the logical OR of these two conditions.

Select Unit Pn

Type: System Command, Immediate

`Pn`	Select the unit (master or specified slave) used in subsequent operations.
`P?`	Responds with `Pnn`, where `nn` is a two-digit decimal number specifying the presently selected unit.

Select Unit chooses the unit that subsequent commands affect. The `n` specifies the unit, where 1 is the master and 2 through 16 are the slaves. The default unit number is 1, referring to the master unit, so when no unit has been selected, commands affect the master unit. If the system consists only of a master unit, the unit number does not need to be specified.

The slave unit numbers are the slave identification numbers set by the rear panel SLAVE ID switches (see Section 2 for setting instructions).

Select Unit (`Pn`) immediately affects all subsequent commands, including subsequent deferred commands such as `An`. This allows several units to be referred to in a single command string (as in `P1 A4 P2 A5 X`). If the specified slave is not attached, then a `No Such Unit` error occurs.

Example:

```
PRINT#1,"OUTPUT 11;P1 X"    Specify master unit
PRINT#1,"OUTPUT 11;A3 X"    Activate master channel 3
PRINT#1,"OUTPUT 11;P5 A1 X"
                            Activate slave 5 channel 1
PRINT#1,"OUTPUT 11;P1 A4 P2 A5 X"
                            Activate master channel 4 and slave 2 channel 5
```

Sequence Range Qs,e,f

Type: System Command, Deferred (Query is immediate)

`Qs,e,f` Sets the sequence range. `s` is the starting location of the sequence. `e` is the end location. `f` is the location the unit is left at after sequenced operation is complete.

`Q?` Responds with the sequence range in the format `Qnnnnn,nnnnn,nnnnn`.

Sequence Range chooses a range from the sequence settings and duration tables that is used for sequenced operation and some of the status commands.

The sequence range consists of a range of settings and a final setting. The range (defined by `s` and `e`) is the portion of the sequence table to be repeated during sequenced operation. The final setting (defined by `f`) is the sequence table element that takes effect after sequencing is complete. `s` is the starting sequence settings table location. `e` is the end location and must be greater than or equal to `s`. `f` is the location the unit is left at when sequenced operation is complete.

The range for `s` and `e` is 1 to 1100. The range for `f` is 0 to 1100. If `f` is 0, the final setting is the power-up state.

If the final element is the same as the end of the range (`f` is the same as `e`), sequenced operation stops at the end of the range and does not proceed to the final element and repeat the ending setting. For example, `Q1,3,5` produces the sequence 1,2,3,5. But `Q1,3,3` does not produce the sequence 1,2,3,3. It stops at the ending element and produces 1,2,3.

If a sequence range has not been specified with the `Qs,e,f` command, a default range is used for sequenced operation. The default range is based on the sequence table location, which is set or incremented with the `Wn` command. Control keeps track of the greatest sequence table location that has been referenced and uses that location as the sequence range end and final elements. For example, at power-on or Reset (`*R`), the default range is `Q1,1,1`. If `W50 X` is the largest sequence location that has been specified (elements up through element 50 have been referenced), the default range would be `Q1,50,50`.

`Qs,e,f` is a deferred command and is not acted on until an Execute (`X`) is received.

The start and end locations of the sequence range are also used by the `U7` and `U8` commands to specify the portion of the sequence tables that they will query.

```
PRINT#1,"OUTPUT 11;Q1,8,0 X"
```

Set the sequence range to begin at location 1 and end at location 8, with location 0 as the final setting.

Read Channels Rn & R?

Type: Unit Command, Immediate

Rn	Reads the electrical activity of the channel specified by n of the unit specified by Pn. Responds with Ann if the channel is active and Bnn if it is inactive, where nn is the two-digit decimal channel number.
R?	Responds with Cn where n represents the electrical activity of all of the channels of the unit specified by the Pn command, in the current format Fn.

Read Channels looks at the electrical activity of the channels of the unit specified by the Pn command. This is the same information that is displayed on the front-panel channel indicator lights. A channel is active if either the output register specifies that that channel is to be active, or if an Opto-22-compatible input module is installed and the input is active. To correctly read for an input module, the output for that channel must be set off.

Rn responds with the state of the specified input channel. n can be 1 through 16. If the input is active, the reply is Ann, where nn is the two-digit channel number. If the input is inactive, the response is Bnn. The input channel is always active if its output setting is active. To correctly sense an input channel, its output setting must be set off.

The R? command replies with the state of all of the channels of the current unit in the format set by Fn. Each channel is sensed the same way it is for the Rn command: outputs replying with their present setting and inputs reflecting their state only if their output settings are off. The response for R? is in the same format as Cn. The response may be different than the response for C? if input modules are active.

The output setting of a sense channel can interfere with the correct sensing of its input. If the output setting of a sense channel is active, that channel is always sensed as active regardless of the actual input. To correctly sense an input channel, its output setting must be inactive.

For a Control that has input modules installed in all channels:

```
PRINT#1,"OUTPUT11;F0 P1 C0 X C? X"
```
Response is C000000, showing that all output settings are deactivated.

```
PRINT#1,"OUTPUT11;R? X"
```
Response is C000001, showing that the input on channel 1 is active and the remaining inputs are deactivated.

```
PRINT#1,"OUTPUT11;C2 X R? X"
```
Response is C000003, showing that the output setting overrides the input state on channel 2.

```
PRINT#1,"OUTPUT11;C0 X R? X"
```
Response is C000001, showing that the input on channel 1 is active and the input on channel 2 actually was inactive.

Save/Restore Sn

Type: System Command, Deferred (Query is immediate)

S0	Restore setup stored in NVRAM.
S1	Save the existing command settings as the power-on default setup in NVRAM.
S?	Responds with the previous Sn command.

Save/Restore allows the user to specify the initial configuration of all the units (master and slave) in a system upon power-up or Reset (*R). It saves or restores elements 0 through 100 of the sequence settings table, and 1 through 100 of the sequence duration table, as well as a list of all the attached units as would be reported by the U4 command. Each slave unit also stores the internal identifying number of the master to which it was attached at the time of storage. This allows the master to determine at power-on or Reset (*R) that the correct slaves are present with the correct slave identification numbers before initializing the channel settings.

This information is stored in non-volatile RAM (NVRAM). The NVRAM contents are preserved even if power is off.

At power-on, all of the outputs are initially set inactive. Each unit then restores the elements up through number 100 of its sequence settings and duration tables from NVRAM. The master unit verifies that the same slaves are present as when the non-volatile RAM was saved. If they are, it commands those slaves to change their outputs to the output that was saved from sequence output register 0.

If the slaves are different than those present when the last save was done, all of the outputs are left in their inactive state and a communications error is reported. The master unit may consider a slave to be different if a slave device is added, removed, or changed; or if there is a hardware cabling failure. These failures cause a communication error (E064). Failure of the NVRAM, such as a checksum error would cause an NVRAM error (E032).

Example:

```
PRINT#1,"OUTPUT 11;S1 X"
```
Save existing settings as the power-on default.

```
PRINT#1,"OUTPUT 11;S0 X"
```
Restore saved settings.

```
PRINT#1,"OUTPUT 11;Q25,50,50"
```
Use elements 25-50 for sequenced operation.

Trigger Source Tn

Type: System Command, Deferred (Query is immediate)

T0	Disable triggering (default)
T1	Trigger on IEEE 488 bus (GET) trigger
T2	Trigger on BNC input TTL rising edge
T3	Trigger on BNC input TTL falling edge
T4	Trigger on BNC input TTL rising edge and on falling edge
T5	Trigger on enabled command (@) trigger
T6	Trigger every timebase interval starting after the execute (X) command.
T7	Trigger every timebase interval starting after an IEEE 488 bus (GET) trigger.
T8	Trigger every timebase interval starting after a BNC input TTL rising edge.
T9	Trigger every timebase interval starting after a BNC input TTL falling edge.
T10	Trigger every timebase interval starting after a BNC input TTL rising or falling edge.
T11	Trigger every timebase interval starting after a command trigger.
T?	Responds with the present trigger setting in the format Tnn where nn is a two-digit decimal number.

The Trigger Source command chooses which trigger source is used for sequenced operation. The power-up default is T0, trigger disabled.

Modifying the trigger source is a deferred operation.

When Trigger Source is set to GET (T1 or T7), a Group Execute Trigger on the IEEE 488 bus constitutes a trigger. When trigger source is set to timebase interval, the Timebase Interval (Yn) command controls the time between triggers.

When the trigger source is the @ command (T5 or T11), a trigger is enabled by the @ command, which causes a trigger to occur when the next execute command (X) following the @ is encountered in the command line. A trigger is not generated until the entire command string is processed.

T2, T4, T8, T9, and T10 set the trigger source to the rising and/or falling edges of the BNC trigger input. The trigger input signal must be a TTL compatible signal with a minimum width of 200 ns, high or low.

Regardless of the trigger source, the Control488/16 cannot process more than 4000 triggers per second. At least 250 microseconds must separate consecutive triggers or a trigger overrun error will occur and sequenced operation will immediately stop.

T6 triggers every timebase interval starting after the execute (X) command.

The T7 through T11 modes are used to start timebase triggering after a specified trigger event. In these modes, the unit waits for the specified trigger. When it detects it, the unit initializes the timebase and starts sequenced operation. Note that the initial trigger event is not part of sequenced operation; it does not affect the output settings nor does it generate a trigger delay output pulse.

The timebase interval triggering does not start immediately after the specified trigger events. Instead, there is a variable delay of 100 to 200 microseconds before the timebase is active. After a further delay specified by the Timebase Interval (Yn), a timebase trigger occurs, affecting the output setting and causing a delayed trigger output pulse. The output settings are not affected and no delay output pulse is generated by the initial trigger source.

The timebase interval for the T6 through T11 commands is specified by the Timebase Interval (Yn) command.

When triggering is completed, Tn returns to its power-up default setting, T0.

Note that the Jn and Ln commands may temporarily suspend triggering while they execute to ensure synchronization of the master and slaves. Triggers are ignored during this suspension.

Example:

```
PRINT#1,"OUTPUT 11;Q1,1100,0 K10 L2 T6 X"
```
Execute the entire sequence table 10 times at timebase interval.

```
PRINT#1,"OUTPUT 11;T? X"
```
Query trigger source.

```
PRINT#1,"ENTER 11"
```
Retrieve response.

```
INPUT#2,A$
PRINT A$
```
Response is T00 if sequenced operation is complete.

Status Un

Type: Immediate

U0	Query and clear Event Status Register (ESR)
U1	Query the status byte register (STB)
U2	Query system settings.
U3	Query system buffers.
U4	Query connected units
U5	Query unit settings.
U6	Query unit buffers.
U7	Query system buffer range.
U8	Query unit buffer range.
U9	Query product name and revision.
U?	Responds with the last Un command executed.

U0 reads and clears the Event Status Register (ESR) (see Section 6.7 for details on status reporting). The event status register is a read-only register whose bits correspond to those of the event enable register and indicates which events have occurred since the event status register has last been read. It is reset immediately after being read.

It responds with:

001	Sequenced Operation Complete.
002	Trigger Detected
004	Query error
016	Execution error
032	Command error
128	Power-on
nnn	A three-digit number equalling the sum of some or all of the above responses.

U1 responds with the Status Byte Register. This is a copy of the same byte returned in response to a serial poll from the IEEE 488 bus except that bit 6 carries the Master Summary Status rather than the Request for Service. The status byte register is a read-only register whose bits correspond to those of the service request enable register with the addition of bit value 64, which responds with the Master Summary Status (MSS). The MSS indicates whether or not this device needs service.

U1 responds with:

001	Channel Change Event occurred
016	Message available
032	Event detected.

064	Master Summary Status
nnn	A three-digit number equalling the sum of some or all of the above responses.

U2 responds with the system settings. This is all the information necessary to reconfigure the Control system commands to the same state as the existing state when this command was executed, except for the sequence tables and the NVRAM. Its response is equivalent to the response to the following commands:

```
D?F?L?M?N?K?Q?T?Y?Z?.
```

U3 responds with the contents of the sequence duration table in the form:

```
W00001Jnnnnn X
W$Jnnnnn X . . . W$Jnnnnn X
```

This response is the entire sequence duration table, in one long executable string of 9904 characters (plus one or two terminators). The string consists of the commands that would be necessary to reload the entire sequence duration table.

U4 responds with a list of the connected units in the form:

```
01,02,03,04,00,00,00,00,09,10,11,12,00,00,00,16
```

showing which units are connected and which are not. If a unit is not attached, it is shown as 00. 01, the master unit, is always attached.

U5 responds with the unit-specific settings of the currently selected unit. The response is equivalent to the response of the following commands: P?C?.

The U6 response is the contents of the sequence settings table of the currently specified unit, in the form:

```
Pn Fn X . . . W00000Innnnn X
W$Innnnn X . . . W$Innnnn X
```

This response is the entire sequence settings table of the specified unit, in one long executable string of thousands of characters (plus one or two terminators). The format and number of characters in the response depends on the format selected by the Fn command, as shown in the following table.

Format Command	# of characters in response (without terminators)
F0	11,019
F1	11,019
F2	9918
F3	8817
F4	22,029

U7 responds with the duration settings for a section of the sequence duration table. This response is the same as U3, except the start and end of the response are defined by the Sequence Range (Qs,e,f) command. For example:

```
PRINT#1,"OUTPUT 11;Q10,12,50 X U7 X"
```

responds with W00010JnnnnnXW$JnnnnnXW$JnnnnnX, showing the durations for locations 10, 11, and 12.

The U8 responds with a section of the sequence settings table of a unit in the system. This response is the same as U6, except the start and end of the response are defined by the Qs,e,f command. For example:

```
PRINT#1,"OUTPUT 11;Q10,12,50 X U8 X"
```

responds with P1F0XW00010InnnnnXW$InnnnnXW$InnnnnX, showing the durations for locations 10, 11, and 12.

The U9 response is an ASCII string identifying the product and the revision and version of the firmware installed in the unit specified by Pn. The response is "IOtech,Control488/16,0,v.r" or "IOtech,Control/16,0,v.r" where v is the version and r is the revision of the firmware.

U? responds with the last Un command executed. The response is Unn where nn is the number of the most recent query command from 00 to 09.

Set Channel Change Mask Vn

Type: Unit Command, Immediate

Vn Modifies the Channel Change mask register for the unit currently selected by the Pn command.

V? Responds with the present setting of the Channle Change register for the unit currently selected by the Pn command in the current format (Fn).

Set Channel Change Mask will simultaneously set the Channel Change register of the unit currently specified by the user. The value given should follow the same format as currently defined by the Format (f) command.

Upon receipt of this command the Control488 will update the specified units Channel Change Mask register. This register is a 16-bit value representing the mapping of the 16 channels local to the current unit (as specified by the P command) for which the user wishes the Channel Change event to be enabled. The least significant bit in this register corresponds with channel 1. The next more significant bit corresponds with channel 2 and so on. If a specified bit in the Channel Change Mask register is 1 then the corresponding channel will be enabled for channel change sensing. Likewise, if a specified bit in the Channel Change Mask register is 0 then the corresponding channel will be disabled for channel change sensing.

The sensing of change can be performed by both Input and Output channels. Therefore, if a particular channel is enabled for change sensing then the channel change event will occur regardless of the type of channel.

The default value for the Channel Change Mask is 0 for all units. In other words, no channel change sensing for any channels.

Example:

`PRINT#1, "OUTPUT11;M1X"`	Enables SRQ on channel change.
`PRINT#1, "OUTPUT11;P1 F0 V1 X"`	Set channel 1 of the master unit to sense change.
`PRINT#1, "OUTPUT11;P2 F3 VFFFF"`	Set all channels on unit #2 to sense change.
`PRINT#1, "OUTPUT11;P1V?P2V?X"`	Query the Channel Change Mask registers on master and unit #2.
`PRINT#1, "ENTER11"`	Get response. Screen shows V0001 V00FF

Sequence Table Location Wn

Type: System Command, Immediate

`Wn`	Sets the sequence table to location `n`. The range for `n` is 0 to 1100.
`W$`	Increments the sequence table location.
`W?`	Responds with the present sequence settings table location in the format `Wnnnnn`.

The Sequence Table Location specifies which of the 1101 elements within the sequence settings table is to be referenced by the `Gn`, `Hn`, `In`, `I?`, `Jn` and `J?` commands.

`W$` provides a simple method for incrementing the sequence table location. If the location is incremented past the maximum value of 1100, an IDDCO error occurs. If this occurs, reset the location to a lower value with the `Wn` command.

The Sequence Table Location query (`W?`) command responds with `Wnnnnn`, where `nnnnn` is the present sequence table location.

`W0` is the location of the power-on setting, consisting of an output without a sequence duration. The Sequence Duration (`Jn`) command generates a conflict error if `Wn` is `W0`.

Example:

`PRINT#1,"OUTPUT 11;W10 X"`	Refer to sequence table location 10.
`PRINT#1,"OUTPUT 11;W$ X"`	Increment location to 11.
`PRINT#1,"OUTPUT 11;W? X"`	Response is `W00011`.

Execute X

Type: System Command

X Execute preceding command string.

The Execute command executes all deferred commands in a command string in the order described below, takes care of enabled actions such as command trigger and non-volatile RAM storage, and adds output terminators to any query responses. Deferred commands are interpreted and processed when they are received, but are not executed until an X is received.

Deferred commands are executed in the following order: Mn, Nn, An, Bn, Cn, Kn, Qs,e,f, Yn, Zn, Sn, Ln, Tn, @, *R.

An, Bn and Cn have a combined net effect which occurs all at once.

Immediate commands do not require an Execute command to be processed. For more detail, see the full description for each command.

If multiple deferred commands that refer to the same setting are used in the same string, each use of the command must be followed by an X. Any number of Execute commands can be inserted into the same command string. If a deferred command is repeated without the X between them, only the second command takes effect. For example, C1 C2 X is the equivalent of C2 X. However, P1 C1 P2 C2 X both take effect, because they are setting channel settings for different units.

If errors occur while processing the command string, X has no effect. For example:

If C1 X C0 GGGGGGG X C? X is sent, C1 is the only command that takes effect.

Examples:

`PRINT#1,"OUTPUT 11;A1 B1 X"`	Deactivate channel 1.
`PRINT#1,"OUTPUT 11;A1 X B1 X"`	Activate and then deactivate channel 1.

Timebase Interval Yn

Type: System Command, Deferred (Query is immediate)

`Yn`	Set interval time to `n` (0.250 to 60000.000 milliseconds).
`Y?`	Responds with the present timebase interval setting in milliseconds in the form `Ynnnnn.nnn`.

The timebase interval specifies the time between the start of consecutive pulses generated by the timebase generator. The interval is specified in milliseconds ranging from 0.250 milliseconds (250 microseconds) to 60000 milliseconds (60 seconds). The timebase interval is used as a trigger source when Trigger Source is set to `T6` through `T11`.

Example:

`PRINT#1,"OUTPUT#11;Y1.25 X"`	Set timebase for 1.25 ms (800 Hz).
`PRINT#1,"OUTPUT 11;Y250 X"`	Sets internal timebase to 250 milliseconds (¼ second).

Trigger Delay Zn

Type: System Command, Deferred (Query is immediate)

`Zn`	Set the trigger delay to a specified number of milliseconds from 0.010 to 60000.000.
`Z?`	Responds with the present trigger delay setting.

The delayed trigger output is used with applications that require some delay or setup time after the Control's outputs have been commanded to switch before meaningful action can be taken. The time delay is specified in milliseconds from 0.010 to 60000.000 (10 microseconds to 60 seconds).

When a trigger is detected, the normally-high delayed trigger output immediately goes low. It remains low for the length of time specified by the trigger delay and then returns to a high level. Thus the trigger delay output provides a rising edge signal that is delayed from the trigger event by the trigger delay.

For meaningful operation, the trigger delay must be less than the trigger interval. If the internal timebase interval is used for triggering, the Control488/16 adjusts the trigger delay, if necessary, until it is at least 10 microseconds less than the trigger interval. When other trigger sources are used, the programmer must set the trigger delay to an appropriately small value.

The response of `Z?` is `Znnnnn.nnn`, where `n` is the trigger delay in milliseconds. This might be different from the commanded value if the timebase interval (set by `Yn`) is the trigger source and has caused the trigger delay to be adjusted.

Modifying the trigger out register is a deferred operation.

Example:

`PRINT#1,"OUTPUT 11;Y10 Z5 X"`	Set trigger interval to 10 msec and the trigger delay to 5 msec.

Appendix A: Control Command Summary

Command	Code	Type	Description	Page #
Command Trigger	@	System	Enables generation of a command trigger.	6.13
Reset	*R	System	Restores the master unit and any attached slave units to their initial power-up state.	6.14
Output Active	An	Unit	Activates a single output channel of the Control unit selected by the Pn command.	6.15
Output Inactive	Bn	Unit	Deactivates a single output channel of the Control unit specified by the Select Unit (Pn) command.	6.16
Set Outputs	Cn	Unit	Sets all outputs of the unit selected by Pn.	6.17
	C?	Unit	Response is Cn where n is the present output setting of the unit specified by the Pn command.	
Output Terminator	Dn	System	Set output terminator used by RS-232C and IEEE 488.	6.19
	D0		LF	
	D1		CR	
	D2		CR-LF	
	D3		LF-CR	
	D4		IEEE 488: LF plus EOI; RS-232C: LF	
	D5		IEEE 488: CR plus EOI; RS-232C: CR	
	D6		IEEE 488: CR-LF plus EOI; RS-232C: CR-LF	
	D7		IEEE 488: LF-CR plus EOI; RS-232C: LF-CR	

Command	Code	Type	Description	Page #
Error Query	E?	System	Responds with and clears present error condition.	6.20
			Responds with one of the following error codes:	
	E000		No error has occurred.	
	E001		Invalid device dependent command (IDDC).	
	E002		Invalid device dependent command option (IDDCO).	
	E004		No such unit.	
	E008		Self-test failure.	
	E016		Trigger overrun.	
	E032		Non-volatile RAM failure.	
	E064		Communication error.	
	Ennn		The sum of above if two or more errors occurred.	
Format	Fn	System	Format sets the type of format used to represent the activity of all sixteen outputs of a unit.	6.22
	F0		Inputs: signed integer, range –32768 to 65535. Outputs: fixed format signed integer, range –32768 to 032767 (+ implied).	
	F1		Inputs: integer, range –32768 to +65535. Outputs: fixed format signed integer, range –32768 to +32767.	
	F2		Inputs: integer, range –32768 to 65535. Outputs: fixed format unsigned integer, range 00000 to 65535.	
	F3		Inputs: hexadecimal, range 0 to FFFF. Outputs: fixed format hexadecimal, range 0000 to FFFF.	
	F4		Inputs: binary, range 0 to 1111111111111111. Outputs: fixed format binary, range 0000000000000000 to 1111111111111111.	
	F?		Responds with the present format selection.	

Command	Code	Type	Description	Page #
Sequence Output Active	Gn	Unit	Activates an output channel in the sequence settings table at the location specified by the Sequence Table Location (Wn) command for the unit specified by the Pn command.	6.24
Sequence Output Inactive	Hn	Unit	Deactivates a single output channel in the sequence settings table at the location specified by the Sequence Table Location (Wn) command for the unit specified by the Pn command.	6.25
Set Sequence Outputs	In	Unit	Activates or deactivates all sixteen channels of the unit selected by Pn) at a location in the sequence settings table determined by Wn.	6.26
	I?		Responds with the present setting of In.	
Sequence Duration	Jn	System	Sets the number of triggers that must be received before Control goes to the next location in the sequence settings table.	6.28
	J?		Responds with the present sequence duration.	
Sequence Repetition	Kn	System	Determines how many times the sequence defined by Qs,e,f is repeated when L2 is selected.	6.29
	K?		Responds with the number of sequence repetitions specified.	
Sequence Mode	Ln	System	Specifies how the control table is repeated.	6.30
	L0		Disables sequenced operation.	
	L1		Enables once-through operation.	
	L2		Enables counted sequenced operation.	
	L3		Enables continuous sequenced operation.	
	L?		Responds with Ln where n is the current sequence mode setting.	

Command	Code	Type	Description	Page #
SRQ Mask	Mn	System	Specifies which conditions generate a service request.	6.31
	M0		Clear SRE (default)	
	M1		SRQ on sensing of I/O channel change	
	M16		SRQ on Message Available	
	M32		SRQ on event detected	
	M?		Responds with M0Mnnn where nnn is the service request enable mask.	
Event Mask	Nn	System	Determines the conditions in the Event Status Register (ESR) that are reported in the Event Status register Bit (ESB) in the Serial Poll Status Register.	6.32
	N0		Clear event mask (default).	
	N1		End of trigger sequence.	
	N2		Trigger event.	
	N4		Enable query error.	
	N16		Detect execution error.	
	N32		Detect command error.	
	N128		Power-on.	
	N?		Responds with the event mask in the form N0Nn.	
Select Unit	Pn	System	Select the unit (master or specified slave) used in subsequent operations.	6.33
	P?		Responds with Pnn, where nn is a two-digit decimal number specifying the presently selected unit.	
Sequence Range	Qs,e,f	System	Chooses the range from the sequence duration and settings tables used for triggered operation. s is the starting location of the range. e is the end location. f is the final location.	6.34
	Q?		Responds with the sequence range.	
Read Channels	Rn	Unit	Reads the electrical activity of the channel specified by n of the unit specified by Pn.	6.35

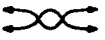
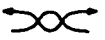
Command	Code	Type	Description	Page #
	R?		Responds with Cn, representing the electrical activity of all channels of the unit specified by Pn.	
Save/Restore	Sn	System	Specifies the initial configuration of all system units upon power-up or Reset (*R).	6.36
	S0		Restore setup stored in NVRAM.	
	S1		Save the present command settings as the power-on default setup in NVRAM.	
	S?		Responds with the previous Sn command.	
Trigger Source	Tn	System	Chooses trigger source for sequenced operation.	6.37
	T0		Disable triggering (default).	
	T1		Trigger on IEEE 488 bus (GET) trigger	
	T2		Trigger on BNC input TTL rising edge	
	T3		Trigger on BNC input TTL falling edge	
	T4		Trigger on BNC input TTL either edge	
	T5		Trigger on enabled command (@) trigger	
	T6		Trigger every timebase interval after the X.	
	T7		Trigger every timebase interval after a GET.	
	T8		Trigger every timebase interval after a BNC input TTL rising edge.	
	T9		Trigger every timebase interval after a BNC input TTL falling edge.	
	T10		Trigger every timebase interval after a BNC input TTL rising or falling edge.	
	T11		Trigger every timebase interval after an @.	
	T?		Responds with the present trigger setting.	

Command	Code	Type	Description	Page #
Status	U0	System	Read and clear Event Status Register (ESR)	6.39
	U1	System	Read the status byte register (STB).	
	U2	System	Query system settings.	
	U3	System	Query system buffers.	
	U4	System	Query connected units.	
	U5	Unit	Query unit settings.	
	U6	Unit	Query unit buffers.	
	U7	System	Query system buffer range.	
	U8	Unit	Query unit buffer range.	
	U9	Unit	Query product name and revision.	
	U?	System	Responds with the last Un command executed.	
Set Channel Change Mask	Vn	Unit	Modifies the Channel Change mask register for the unit currently selected by the Pn command.	6.45
	V?		Responds with the present setting of the Channel Change register for the unit currently selected by the Pn command in the current format (Fn).	
Sequence Table Location	Wn	System	Specifies which of the 1101 elements in the sequence settings table is referenced by the Gn, Hn, In and Jn commands.	6.42
	W$		Increments the sequence table location.	
	W?		Responds with the present sequence settings table location.	
Execute	X	System	Execute preceding command string.	6.44
Timebase Interval	Yn	System	Set interval time to n (0.250 to 60000.000 milliseconds).	6.45
	Y?		Responds with the present timebase interval setting in milliseconds in the form Ynnnnn.nnn.	

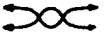
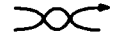
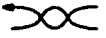
Trigger Delay	`Zn`	System	Set the trigger delay to the specified number of 6.46 milliseconds from 0.010 to 60000.000.
	`Z?`		Responds with the present trigger delay setting.

Appendix B: Cable Pinouts

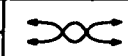
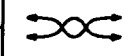
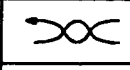
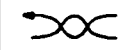
B.1 CA-81: Master to Slave Interface Cable

Master Connector 15-pin Male D-Shell		Signal Direction	Slave Connector 15-pin Male D-Shell	
Master	Pin		Pin	Slave
/STB	1		1	/STB
GND	14		14	GND
D0	2		2	D0
D1	3		3	D1
D2	4		4	D2
D3	5		5	D3
D4	6		6	D4
D5	7		7	D5
D6	8		8	D6
GND	14		14	GND
/ACK	9	NC	9	/ACK
READY	10		10	READY
GND	15		15	GND
/INIT	11		11	/INIT
GND	14		14	GND
SELECT	12	NC	12	SELECT
/TRIGIO	13		13	/TRIGIO
GND	15		15	GND

B.2 CA-82: Slave to Slave Interface Cable

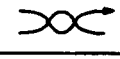
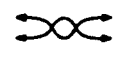
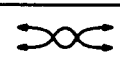
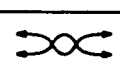
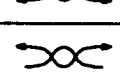
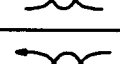
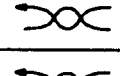
Slave Connector 15-pin Male D-Shell		Signal Direction	Slave Connector 15-pin Male D-Shell		Signal Direction	Daisy-Chain Connector 15-pin Female D-Shell	
Master	Pin		Slave	Pin			
/STB	1		1	/STB		1	/STB
GND	14		14	GND		14	GND
D0	2		2	D0		2	D0
D1	3		3	D1		3	D1
D2	4		4	D2		4	D2
D3	5		5	D3		5	D3
D4	6		6	D4		6	D4
D5	7		7	D5		7	D5
D6	8		8	D6		8	D6
GND	14		14	GND		14	GND
/ACK	9	NC	9	/ACK	NC	9	/ACK
READY	10		10	READY		10	READY
GND	15		15	GND		15	GND
/INIT	11		11	/INIT		11	/INIT
GND	14		14	GND		14	GND
SELECT	12	NC	12	SELECT	NC	12	SELECT
/TRIGIO	13		13	/TRIGIO		13	/TRIGIO
GND	15		15	GND		15	GND

B.3 CA-83: PC Parallel Port to Master Interface Cable

PC LPT Connector 25-pin Male D-Shell		Signal Direction	Slave Connector 15-pin Male D-Shell	
Master	Pin		Pin	Slave
/STB	1		1	/STB
GND	18-21		14	GND
D0	2		2	D0
D1	3		3	D1
D2	4		4	D2
D3	5		5	D3
D4	6		6	D4
D5	7		7	D5
D6	8		8	D6
GND	18-21		14	GND
D7	9	NC		
/ACK	10		9	/ACK
GND	22-25		15	GND
BUSY	11		10	READY
GND	22-25		15	GND
PAPER OUT	12		14	GND
SELECT	13		12	High
/AUTO LF	14	NC		
/ERROR	15		12	High
GND	18-21		14	GND
/INIT	16		11	/INIT
GND			14	GND
SELECT IN	17	NC		
		NC	13	/TRIGIO

B.4 CA-84: MP488 Digital Output Port (CA-59) to Master Interface Cable

Also compatible with Metrabyte PIO-12

CA-59 Connector 37-pin Male D-Shell		Signal Direction	Slave Connector 15-pin Male D-Shell	
Master	Pin		Pin	Slave
PA7	30		1	/STB
GND	11, 13		14	GND
PA0	37		2	D0
PA1	36		3	D1
PA2	35		4	D2
PA3	34		5	D3
PA4	33		6	D4
PA5	32		7	D5
PA6	31		8	D6
GND	11, 13		14	GND
PC6	23		9	/ACK
GND	11, 13		14	GND
PC7	22		10	READY
GND	11, 13		14	GND
		NC	11	/INIT
		NC	12	SELECT=V_{cc}
		NC	13	/TRIGIO
GND	11, 13	——	14	GND
GND	15, 17, 19	——	15	GND
	1-10	NC		
	12	NC		
	14	NC		
	16	NC		
	18	NC		
	20-29	NC		

B.5 CA-85: PC Serial Port to Master Interface Cable

PC/XT Serial Connector 25-pin Female D-Shell		Signal Direction	Master Connector 9-pin Female D-Shell	
Master	Pin		Pin	Slave
TxD	2	→	2	RxD
RxD	3	←	3	TxD
RTS	4	NC		
DSR, CTS	5, 6	←	7	RTS
GND	7	—	5	GND
CD	8	←	7	RTS
DTR	20	→	8	CTS
RI	22	NC		
	1	NC		
	9-19	NC		
	21	NC		
	23-25	NC		
		NC	1	
		NC	6	
		NC	9	

B.6 CA-86: PC/AT Serial Port to Master Interface Cable

PC/AT Serial Connector 9-pin Female D-Shell		Signal Direction	Master Connector 9-pin Female D-Shell	
Master	Pin		Pin	Slave
CD	1	←	7	RTS
RxD	2	←	3	TxD
TxD	3	→	2	RxD
DTR	4	→	8	CTS
GND	5	—	5	GND
DSR, CTS	6	←	4	DTR
RTS	7	→	1	
CTS	8	←	7	RTS
RI	9	NC		

Character Codes and IEEE Multiline Messages

$00 NUL 0	$10 DLE 16	$20 SP 32	$30 0 48	$40 @ 64	$50 P 80	$60 ` 96	$70 p 112
		00	16	00	16	SCG	SCG
$01 SOH 1	$11 DC1 17	$21 ! 33	$31 1 49	$41 A 65	$51 Q 81	$61 a 97	$71 q 113
GTL	LLO	01	17	01	17	SCG	SCG
$02 STX 2	$12 DC2 18	$22 " 34	$32 2 50	$42 B 66	$52 R 82	$62 b 98	$72 r 114
		02	18	02	18	SCG	SCG
$03 ETX 3	$13 DC3 19	$23 # 35	$33 3 51	$43 C 67	$53 S 83	$63 c 99	$73 s 115
		03	19	03	19	SCG	SCG
$04 EOT 4	$14 DC4 20	$24 $ 36	$34 4 52	$44 D 68	$54 T 84	$64 d 100	$74 t 116
SDC	DCL	04	20	04	20	SCG	SCG
$05 ENQ 5	$15 NAK 21	$25 % 37	$35 5 53	$45 E 69	$55 U 85	$65 e 101	$75 u 117
PPC	PPU	05	21	05	21	SCG	SCG
$06 ACK 6	$16 SYN 22	$26 & 38	$36 6 54	$46 F 70	$56 V 86	$66 f 102	$76 v 118
		06	22	06	22	SCG	SCG
$07 BEL 7	$17 ETB 23	$27 ' 39	$37 7 55	$47 G 71	$57 W 87	$67 g 103	$77 w 119
		07	23	07	23	SCG	SCG
$08 BS 8	$18 CAN 24	$28 (40	$38 8 56	$48 H 72	$58 X 88	$68 h 104	$78 x 120
GET	SPE	08	24	08	24	SCG	SCG
$09 HT 9	$19 EM 25	$29) 41	$39 9 57	$49 I 73	$59 Y 89	$69 i 105	$79 y 121
TCT	SPD	09	25	09	25	SCG	SCG
$0A LF 10	$1A SUB 26	$2A * 42	$3A : 58	$4A J 74	$5A Z 90	$6A j 106	$7A z 122
		10	26	10	26	SCG	SCG
$0B VT 11	$1B ESC 27	$2B + 43	$3B ; 59	$4B K 75	$5B [91	$6B k 107	$7B { 123
		11	27	11	27	SCG	SCG
$0C FF 12	$1C FS 28	$2C , 44	$3C < 60	$4C L 76	$5C \ 92	$6C l 108	$7C | 124
		12	28	12	28	SCG	SCG
$0D CR 13	$1D GS 29	$2D - 45	$3D = 61	$4D M 77	$5D] 93	$6D m 109	$7D } 125
		13	29	13	29	SCG	SCG
$0E SO 14	$1E RS 30	$2E . 46	$3E > 62	$4E N 78	$5E ^ 94	$6E n 110	$7E ~ 126
		14	30	14	30	SCG	SCG
$0F SI 15	$1F US 31	$2F / 47	$3F ? 63	$4F O 79	$5F 95	$6F o 111	$7F DEL 127
		15	UNL	15	UNT _	SCG	SCG
ACG	**UCG**	**LAG**		**TAG**		**SCG**	

ACG = Addressed Command Group
UCG = Universal Command Group
LAG = Listen Address Group

TAG = Talk Address Group
SCG = Secondary Command Group