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Digital488/80
Instruction Manual

Part No. Digital488/80-901

Revision 1.0

August 1988

IOtech, Inc. • 25971 Cannon Road • Cleveland, Ohio 44146 • (216) 439-4091

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Appendix A **Digital488/80 Command Summary**

Appendix B **IEEE Command and Address Messages**

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Introduction

1.1 General Description

The Digital488/80 is a digital input and output interface to the IEEE 488 bus. Each unit has 80 TTL level digital I/O lines which are divided into two 40 bit Channels. Each Channel is divided into five eight-bit Ports. Each port is software programmable for input or output. Thus, a configuration can range from 80 input lines to 80 output lines or any combination in between in multiples of 8 bits. As an added feature, Channel 1 lines can be configured as high current high voltage outputs to allow interfacing with solenoids, relays or other high voltage high current devices.

The Digital488/80 has several features which give it versatile interface capability. A trigger output signal is asserted on the Group Execute Trigger (GET) bus command. Edge-triggered inputs can generate a Service Request on the bus. Six data formats are software programmable, including ASCII hexadecimal, ASCII character, ASCII binary, binary, high speed binary and ASCII decimal. There are also individual bit set and bit clear commands. Programmable terminators are provided to facilitate interfacing to various controllers.

A Status command enables the controller to interrogate the programmed status of the Digital488/80 at any time. Additionally, all Digital488/80 commands offer a query (?) option which allows the user to build user-defined status command strings to request only that status information which is needed for a given application. A self-test is initiated at power-on which checks for proper RAM and ROM operation.

When addressed to talk, the Digital 488/80 will output data from all forty bits of the selected Channel or a selected 8 bit Port. When addressed to listen, the unit will accept input data and programming information from the controller and output the data to the appropriate I/O port.

Two addressing modes are available allowing communication with the Digital488/80 using either Dual Primary or Secondary addressing. Using these addressing modes, the two Channels may reside at two consecutive primary bus addresses or at the same primary bus address with two consecutive secondary addresses.

Up to 100 preset configurations for each Channel may be saved in Non-volatile RAM for later use allowing easy configuration of the device for many varied applications. A power-on configuration can also be created and stored thereby automatically configuring the device upon upon power on.

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1.2 Available Accessories

Additional accessories that can be ordered for the Digital488/80 include:

CA-7-1	1.5 foot IEEE 488 Cable
CA-7-2	6 foot IEEE 488 Cable
CA-7-3	6 foot shielded IEEE 488 Cable
CA-7-4	6 foot reverse entry IEEE 488 Cable
CA-8-50	6 foot, 50 conductor ribbon cable with a card edge connector on one end, the other end un-terminated.
CN-6-50	50 Pin solder tab edge connector.
CN-20	Right Angle IEEE 488 adapter, male and female
CN-22	IEEE 488 Multi-tap bus strip, four female connectors in parallel
CN-23	IEEE 488 panel mount feed-through connector, male and female
Digital488/80 -901	Additional Instruction Manual

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Digital488/80

Digital I/O Interface

Configuration:	Dual channels each with five 8-bit ports, programmable as inputs or outputs. Also included per channels are programmable handshake lines, data latching capability, clear and trigger outputs and a service request input.
Logic Levels:	Outputs will drive 2 TTL loads.
Connector:	Two 50 pin card edge. Mating connectors supplied.
High-Current Outputs:	Up to forty lines of channel 1 can be configured as high-current outputs. These are selected in 8 bit groups by positioning jumpers internal to the Digital488/80. Each high-current output is capable of sinking up to 200mA at 50VDC max.
IEEE 488-1978 Implementation:	SH1, AH1, T4, TE8, L4, LE4, SR1, RL0, PP0, DC1, DT1, C0, E1.
Terminators:	Selectable CR, LF, LF-CR and CR-LF with EOI.
Connector:	Standard IEEE 488 connector with metric studs.
Programmable:	IEEE Terminators, EOI, SRQ Mask, Port Data, Active Levels, Handshake lines, Format and configuration.

General

Indicators:	LEDs for Talk, Listen, SRQ, Error, Test and Power.
Power:	105-125V or 210-250V; 50-60 Hz, 20 VA Max.
Dimensions:	425mm wide x 45mm high x 203mm deep (16.75" x 1.75" x 8")
Weight:	2 kg. (4.5 lbs).
Environment:	0° - 50°C; 0 to 70% R.H. to 35°C. Linearly derate 3% R.H./°C from 35° to 50°C.
Controls:	Power Switch ,external dip switch for IEEE addressing mode and IEEE address, and channel 1 configuration jumpers (internal).

Specifications subject to change without notice.

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1.4 Abbreviations

The following IEEE 488 abbreviations are used throughout this manual.

addr n	IEEE bus address "n"
ATN	Attention line
CA	Controller Active
CR	Carriage Return
data	Data String
DCL	Device Clear
GET	Group Execute Trigger
GTL	Go To Local
LA	Listener Active
LAG	Listen Address Group
LF	Line Feed
LLO	Local Lock Out
MLA	My Listen Address
MTA	My Talk Address
PPC	Parallel Poll Configure
PPU	Parallel Poll Unconfigure
SC	System Controller
SDC	Selected Device Clear
SPD	Serial Poll Disable
SPE	Serial Poll Enable
SRQ	Service Request
TA	Talker Active
TAD	Talker Address
TCT	Take Control
term	Terminator
UNL	Unlisten
UNT	Untalk
*	Unasserted

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Getting Started

2.1 Inspection

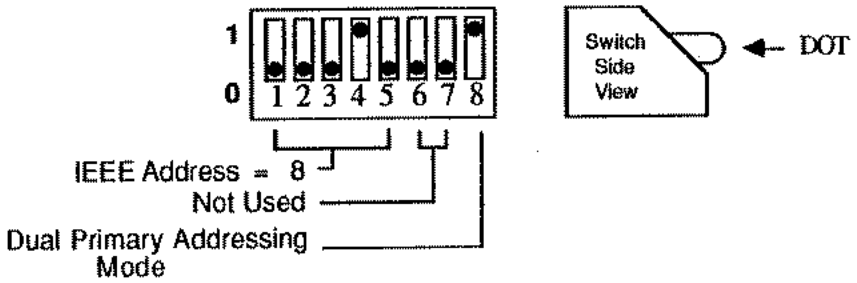
The Digital488/80 was carefully inspected, both mechanically and electrically, prior to shipment. When you receive the interface, carefully unpack all items from the shipping carton and check for any obvious signs of physical damage which may have occurred during shipment. Report any such damage found to the shipping agent immediately. Remember to retain all shipping materials in the event that shipment back to the factory becomes necessary. Every Digital488/80 is shipped with the following items:

• Digital488/80	IEEE Digital I/O Converter
• CN-6-50	50 Pin Card Edge Connectors (2)
• Digital488/80-901	Instruction Manual
• CA-1	Power Cable
• HA-41-6	Screws (4)
• FE-1	Rubber Feet (4)
• HA-31	Rack Ears (2)
• FU-1-.25	1/4 Amp Fuse

2.2 Configuration

The Digital488/80 has one internal 8 position switch (SW1) accessible from the rear panel. This switch determines the unit's IEEE address and its addressing mode. The switch is read only when the unit is powered on, and should be set prior to applying power. The following figure illustrates the factory default setting for SW1.

SW1 Factory Default Settings



2.1

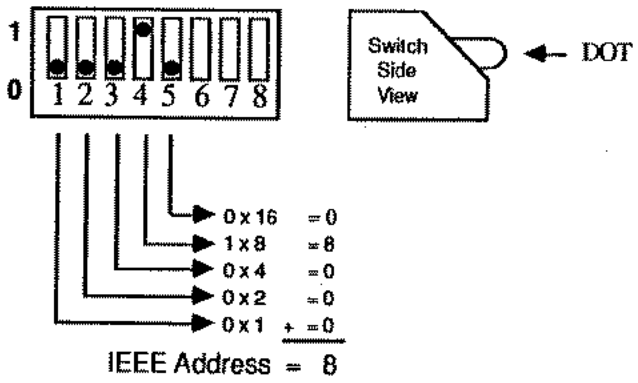
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To modify any of these defaults, disconnect the power cord from the AC line and change the switch settings using a small screwdriver. SW1 is accessible through the rear panel of the device. The enclosure does not need to be opened to change SW1 switch settings.

2.2.1 IEEE 488 Address Selection

The IEEE 488 bus address is set by SW1-1 through SW1-5 (located on rear of unit). The address can be set from 0 through 30 and is read only at power on. The address is selected by simple binary weighting with Switch 1 being the least significant bit and Switch 5 the most significant bit. The factory default is address 8. If address 31 is selected, it defaults to address 30 because the IEEE 488 standard has reserved address 31.

SW1 View for IEEE Bus Address Selection



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2.2.2 Digital488/80 Addressing Modes

The Digital488/80 can be thought of as two identical IEEE 488 to Digital I/O interfaces. Each interface occupies one bus address and has one I/O channel. Therefore the Digital488/80 occupies two bus addresses in an IEEE 488 system. To allow communication with each interface, two addressing modes are available: Dual Primary and Secondary addressing. The addressing mode is selected by SW1-8 located on the rear of the unit. The switch settings for both modes are shown below.

SW1 View for Addressing Mode Selection



Secondary Addressing Mode

Dual Primary Addressing Mode

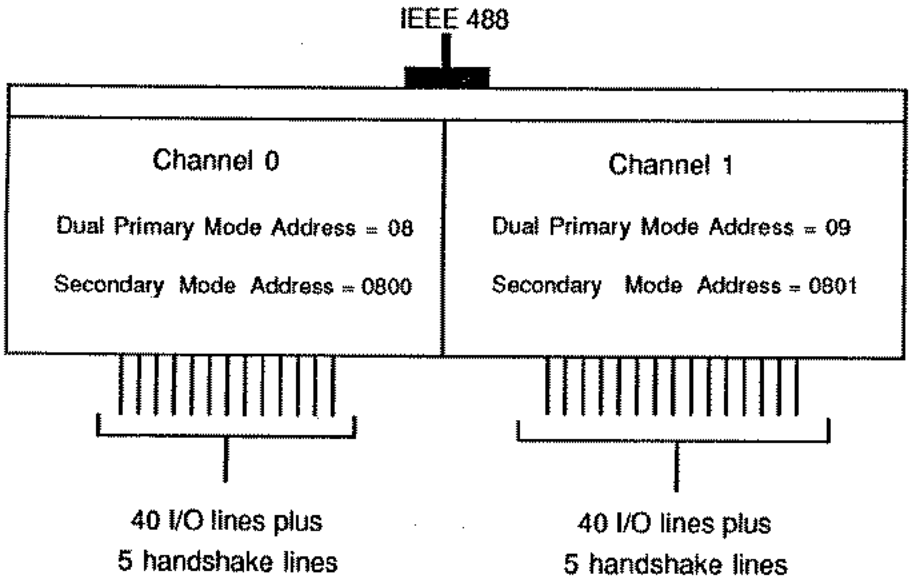
When Dual Primary addressing is selected, SW1-1 (the LSB) of the address is ignored. The Channel 0 interface resides at an even-numbered bus address while the Channel 1 interface resides at the next odd address. For example, if the address switches are set for bus address 6, the Channel 0 interface will reside at bus address 6 and the Channel 1 interface will reside at bus address 7. Note: if address 30 is selected in Dual Primary Addressing mode, the Digital488/80 will default to address 28 for Channel 0 and address 29 for Channel 1.

When Secondary addressing is used, both interfaces reside at the same primary bus address selected by SW1-1 through SW1-5. To communicate with Channel 0, secondary address 00 must be used along with the primary address. To communicate with Channel 1, secondary address 01 must be used. Note: if address 31 is selected in Secondary Addressing mode, The Digital488/80 will default to address 3000 for Channel 0 and address 3001 for Channel 1.

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The picture below shows the relationship between the channels and the two addressing modes. For this example, the address switches are set for bus address 8.

Pictorial View of the Digital488/80



To illustrate the differences between the two Channels and how to communicate with the Digital488/80 using the two addressing modes, several programming examples are given at the end of this section.

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2.2.3 IEEE 488 Bus Output Terminator Selection

The terminating characters sent on output by the Digital488/80 are set by using the Terminator command. Upon power on, the unit's IEEE 488 bus terminators are determined by the Power-On Configuration `O0`. The factory default terminator selection is `Y0` (CR LF). The power on default terminators can be changed to any of the four available options listed under the `Terminator` command in the following Command Description section. The four available terminator options, and the commands associated with them are : `Y0` - CR LF, `Y1` - LF CR, `Y2` - CR only, and `Y3` - LF only. If it is desired to have particular power on default terminator(s), the terminator(s) may be selected using the `Terminator` Command and this selection can be saved as part of Configuration `O0` which is the power on configuration.

The Digital488/80 ignores all terminators received from the bus controller. Only the `Execute` command (`X`) is used to signal the Digital488/80 that a command string has been completed.

2.3 Digital Input/Output Ports

The Digital488/80 has 40 data lines per channel which can be programmed in groups of 8 as either input or output. At power on, the configuration of data lines and ports is determined by the options saved as Configuration `0` (the power on configuration). Therefore, in order to set the unit to a particular configuration upon power on, the `Save Configuration` (`S0`) command must be used once all the desired options have been selected.

2.3.1 Logic Levels

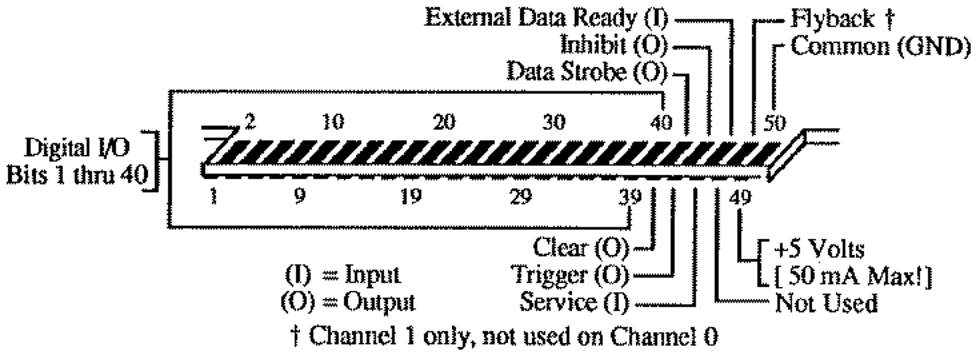
The data and handshake output lines will drive two TTL loads. In addition, ports 1 and 2 on each Channel can function as 5 Volt CMOS compatible outputs. All input lines are less than 1.5 TTL loads. All inputs are protected against damage due to high static voltages. Normal precautions should be taken to limit the input voltages to -0.3 to +7.0 volts. All I/O lines are referenced to COMMON (Pin 50).

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2.3.2 Digital I/O Port Pin Outs

The following diagram illustrates one of the digital I/O edge connectors as view from the rear of the Digital488/80. Both edge connectors are identical with the exception of pin 48 which is used as a FLYBACK connection for Channel 1 but is unused on Channel 0.

Digital488/80 Rear Panel I/O Connector Pin Out



† Channel 1 only, not used on Channel 0

Pin	Description
1 thru 8	DATA PORT1 (Input or Output). Pin 1 is bit 1 (LSB), Pin 8 is bit 8 (MSB). Least Significant Port
9 thru 16	DATA PORT2 (Input or Output). Pin 9 is bit 1 (LSB), Pin 16 is bit 8 (MSB).
17 thru 24	DATA PORT3 (Input or Output). Pin 17 is bit 1 (LSB), Pin 24 is bit 8 (MSB).
25 thru 32	DATA PORT4 (Input or Output). Pin 25 is bit 1 (LSB), Pin 32 is bit 8 (MSB).
33 thru 40	DATA PORT5 (Input or Output). Pin 33 is bit 1 (LSB), Pin 40 is bit 8 (MSB). Most Significant Port

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41	CLEAR (Output).
42	DATA STROBE (Output).
43	TRIGGER (Output).
44	INHIBIT (Output).
45	SERVICE INPUT (Input).
46	EXTERNAL DATA READY [EDR] (Input).
47	Not used.
48	Channel 0 - Not used Channel 1 - FLYBACK
49	+5 Volts (Do not exceed 50 mA load).
50	I/O COMMON (Gnd).

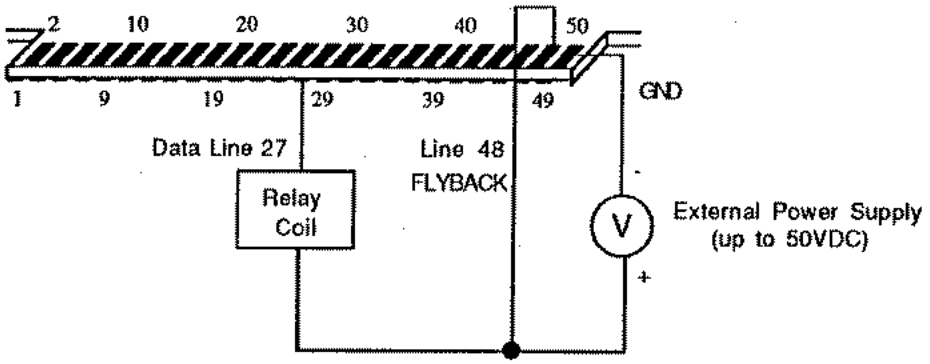
2.3.2.1 High Voltage, High Current Outputs - Channel 1

In addition to interfacing with TTL and CMOS logic levels, the data lines of Channel 1 can be configured as high voltage high current outputs in groups of 8. Lines configured in this manner can only be used as outputs. These outputs can sink up to 200mA at up to 50VDC through the use of open collector drivers with integral diodes for inductive load transient suppression. This allows for interfacing with relays, and solenoids.

When used with relays or solenoids, the FLYBACK pin on the edge card connector should be connected to the positive supply lead of the power supply used with the external devices being driven.

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View of Edge Connector Showing use of FLYBACK Line



To configure the channel 1 data lines for this purpose, it is necessary to open the enclosure and reposition the configuration jumpers according to the following instructions. Disconnect the power cord from the AC line and from the interface. Disconnect any IEEE or digital I/O cables prior to disassembly.

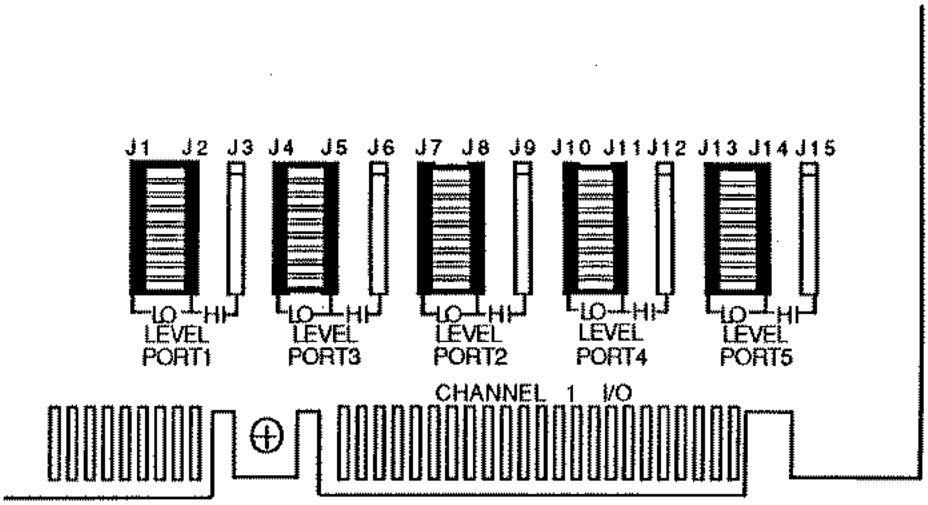
WARNING

Never open the Digital488/80 case while it is connected to the AC line. Internal voltage potentials exist which could cause personal injury or death.

Place the interface on a flat surface. Remove the four screws on top of the case and remove the top cover. Located in front of the card edge connectors, there are five sets of connectors with configuration jumpers. These are factory set to configure the channel 1 data lines for low level TTL logic levels.

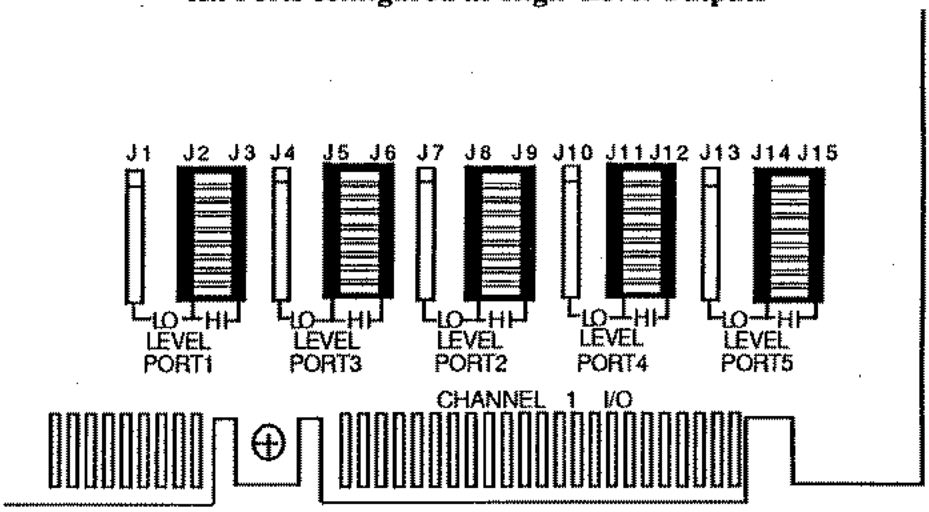
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View of Configuration Jumpers - Factory Setting
All Ports configured as Low Level Inputs or Outputs



To configure data lines as high voltage high current outputs, remove the configuration jumpers for the ports which are to be used for this purpose and reinsert them so that the center socket is now connected to the right socket.

View of Configuration Jumpers
All Ports configured as High Level Outputs



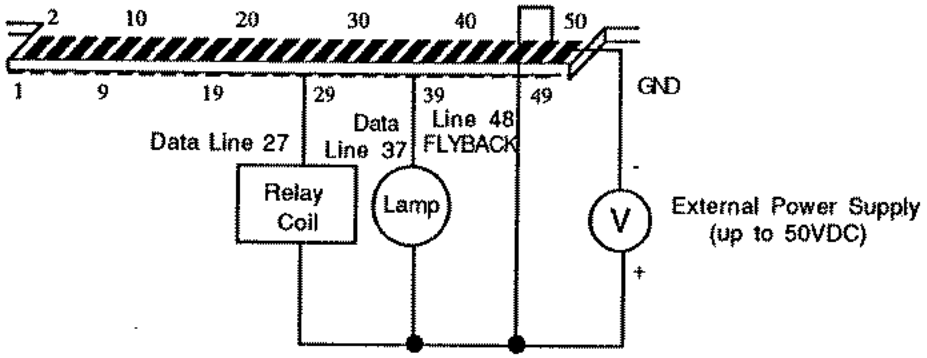
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Once the jumper(s) have been repositioned for your particular application, make note of the new jumper settings for later reference and carefully re-assemble the unit.

2.3.2.2 Using the High Voltage High Current Outputs

Once the Channel 1 port(s) are configured for high level operation, they can be used to drive devices such as relays, solenoids and displays. For example, a typical application may require a lamp and a relay to be driven by the Digital488/80. The relay is connected to data line 28 (port 4) and the lamp is connected to data line 38 (port 5). These two ports must be configured as high level outputs. These devices would be connected as shown below.

View of Channel 1 Edge Card Connector
Using High Level Outputs to Drive a Relay and Lamp



CAUTION

Never connect external high level devices to a Channel 1 port which has not first been configured for this purpose. Failure to do so may result in damage to the Digital488/80.

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CAUTION

Never connect external high level devices to any port on Channel 0. Failure to do so may result in damage to the Digital488/80.

Since a relay is used for this application, the flyback terminal is connected to the positive terminal of the external power supply. Note also that the Ground lead of the power supply should be connected to pin 50 (GND) on the edge card connector. Remember that ports configured as high level outputs can only be used as outputs.

2.3.3 Control Lines

Five control lines on each channel enable handshaking of digital I/O data transfer to the Digital488/80. They are automatically activated with the corresponding I/O activity and can also be independently activated with the `Handshake (Hn)` command. For all descriptions that follow, information on the function and action of a given line is true for both channels except where noted.

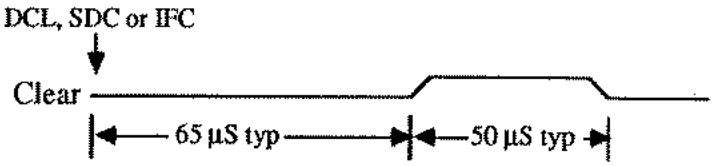
2.3.3.1 Clear (Pin 41)

The Clear output can be pulsed for approximately 50 microseconds after a Device Clear (DCL), Selected Device Clear (SDC), or Interface Clear (IFC) command has been sent on the bus depending on the `Format (Fn)` mode of each channel. Whenever an SDC to either channel or a DCL is executed, both channels are affected. The effect depends on whether either channel is in the High Speed Binary (`F5`) mode. If in the `F5` mode, the channel(s) in the `F5` mode will have their command interpreter re-enabled, and are returned to the ASCII Hexadecimal (`F0`) mode. All other parameters remain unchanged. In addition, the CLEAR lines on both channels are not pulsed. If neither channel is in the `F5` mode, an SDC to either channel or a DCL will return both Channels to their power-up configuration and pulse both CLEAR lines for approximately 50 microseconds.

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The Clear line is normally active high. The Invert command (I8) will program it active low. The `Handshake` command (`H0`) can pulse the Clear line of either channel, independent of any I/O operations.

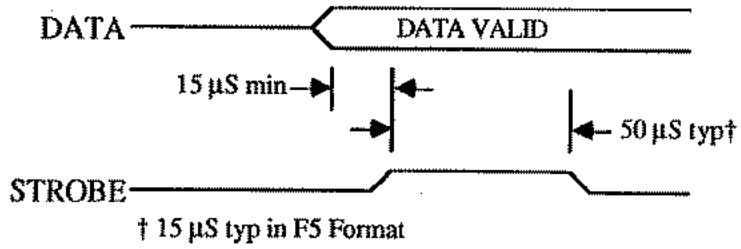
Timing Diagram for Clear Output



2.3.3.2 Data Strobe (Pin 42)

The Data Strobe output is pulsed for approximately 50 microseconds after new data is output on the I/O port. The Data Strobe line is normally active high but may be programmed active low by the `Invert` command (`I4`). The `Handshake` command (`H1`) can pulse the Data Strobe line, independent of any I/O operations. The Data Strobe output is not pulsed when `Bit Set (An)` and `Bit Clear (Bn)` commands are executed.

Timing Diagram for Strobe Output



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2.3.3.3 External Data Ready [EDR] (Pin 46)

The External Data Ready [EDR] line is an edge sensitive input which is used to latch input data. It is used in conjunction with the `Data Ready` command (`R1` or `R2`). The EDR signal must be at least 1 microsecond wide and must have a rise and fall time of less than one microsecond. The EDR line is normally rising-edge sensitive but can be programmed with the `Invert` command (`I32`) to be falling-edge sensitive. Refer to the following diagram for timing relationships.

When using the EDR line with the `R1` command, data is not read when the Digital488/80 is addressed to talk as with `R0`. The Digital488/80 will only output data when the EDR line transitions.

When using the EDR line with the `R2` command, data is read and stored in an internal data buffer each time the EDR line transitions. The Digital488/80 will only output data when there is data in the buffer to output.

EDR is not functional in the high speed binary (`F5`) format.

2.3.3.4 Inhibit (Pin 44)

The Inhibit output is asserted while data on the selected I/O port is being read into the I/O port buffer. This line is normally active high but may be programmed active low by the `Invert` command (`I1`). The Inhibit line can be programmed independent of any I/O operations with the Inhibit command (`Qn`). Refer to the following diagram for timing relationships.

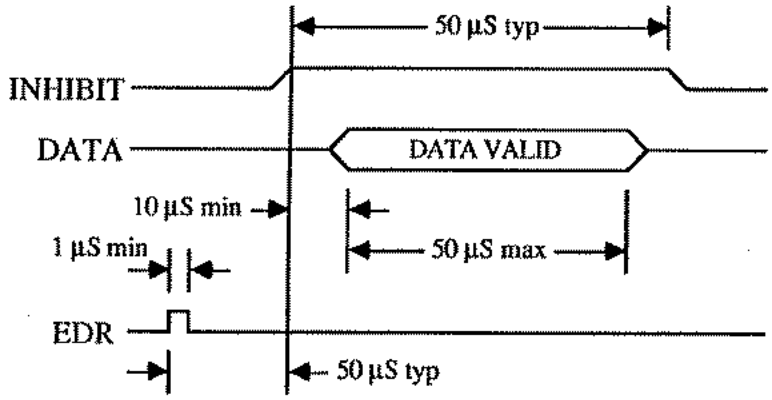
The Inhibit line is asserted once for each data read operation for all `Format` (`Fn`) modes except high speed binary (`F5`). In this mode, it is asserted for the first data read after the Digital488/80 is addressed to talk. On the last data byte transfer, the data is read again with Inhibit asserted in anticipation of another data transfer. If Inhibit is used to sequence external hardware, you should be aware that this line will pulse N+1 times; where N is the number of

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total (5 byte) data transfers.

The Inhibit Line is not pulsed when reading a particular bit status using the `Status` (`Un`) command.

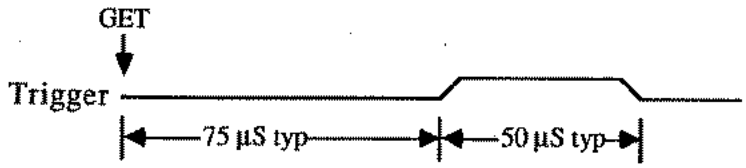
Timing Diagram for EDR Input and Inhibit Output



2.3.3.5 Trigger (Pin 43)

The Trigger output is pulsed for approximately 50 microseconds after a GET (Group Execute Trigger) command is received from the bus controller. The trigger pulse is normally active high, but can be made active low with the `Invert` command (`I2`). The `Handshake` command (`H2`) can independently pulse the Trigger line, independent of any bus activity.

Timing Diagram for Trigger Output



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2.3.3.6 Service (Pin 45)

The Service input is an edge sensitive input capable of generating a bus Service Request (SRQ). It is enabled with the `Service Request Mask (M1)` command and defaults to rising-edge sensitive. The `Invert` command (`I64`) can be used to program it to be falling-edge sensitive.

2.4 IEEE 488 Bus Implementation

The Digital488/80 implements many of the capabilities defined by the IEEE 488 1978 specification. These are discussed in the following sections. Those bus uniline and multiline commands that the Digital488/80 does not support or respond to include:

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)

2.4.1 My Talk Address (MTA)

In `R0` mode, when the Digital488/80 is addressed to talk, it asserts Inhibit, reads the data from all ports, un-asserts Inhibit and outputs the data to the bus in the format as defined by the `Format (Fn), Port (Pn)` and `Bus Input/Output (Gn)` commands. The output bus terminators are appended to the output with the exception of the `F4` and `F5` formats. `F4` does not append terminators. The output format of `F5` will be described separately. After output in the `F0` through `F4` formats, the Digital488/80 must be re-addressed to talk to perform subsequent reads of the port.

In `R1` mode, the Digital488/80 will wait for the selected EDR transition before reading the data and formatting it for output. If the EDR line has changed state prior to being addressed to talk, the data read at the time of EDR will be buffered for output when next addressed to talk. If EDR

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changes again before the previous EDR buffered data has been output, the Digital488/80 will generate an EDR Overrun error and ignore the EDR read request. After output in the F0 through F4 formats, the Digital488/80 must be re-addressed to talk to perform subsequent buffered output of EDR captured data.

In R2 mode, the Digital488/80 will wait for the selected EDR transition before reading the data and storing it in the internal data buffer. Up to 2000 readings may be latched and stored. The EDR and Inhibit lines function in the same manner as in the R1 mode. If an attempt is made to store more than 2000 readings, the Digital488/80 will generate an Overrun error. After output in the F0 through F4 formats, the Digital488/80/80 must be re-addressed to talk to perform subsequent buffered output of EDR captured data.

In any Rn mode, the Digital488/80 can request status using the Status (Un) command without affecting the data ports or the Inhibit line. After the requested status is output, the presently programmed Rn mode returns.

EDR cannot be used to capture data in the high speed binary format (F5). When addressed to talk in this format it asserts Inhibit, reads the data from all ports, un-asserts Inhibit and outputs the binary data to the bus with EOI asserted on the fifth byte. When the last data byte is transferred, the data is read again in anticipation of another data transfer. If Inhibit is used to sequence external hardware, this line will pulse N+1 times; where N is the number of total (5 byte) data transfers. In this format the Digital488/80 does not have to be re-addressed to talk to read the ports multiple times.

With all Fn formats, the data is output in a PORT5, PORT4, PORT3, PORT2, PORT1 sequence.

2.4.2 My Listen Address (MLA)

When the Digital488/80 is addressed to listen in the F0 through F4 format, it accepts characters from the active talker and interprets these characters as commands and command parameters. These commands are explained in Section 3.

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In the high speed binary format (F5), the command interpreter is disabled. The Digital488/80 treats all bytes received as data to be output to the Digital I/O ports. Each time it receives five bytes or detects EOI it pulses the Data Strobe for approximately 15 microseconds. Data is expected in a PORT5, PORT4, PORT3, PORT2, PORT1 sequence.

If only two bytes are received, with EOI asserted on the second byte, the Digital488/80 will update PORT5 with the first byte received, PORT4 with the second and pulse the Data Strobe. Since the interface treats all received characters as data, the Status (Un) command will not be recognized.

2.4.3 Device Clear (DCL and SDC)

In the F0 thru F4 formats, Device Clear resets the Digital488/80 to power on defaults and pulses the Clear output line for approximately 50 microseconds.

If either Channel is in the high speed binary data format (F5), a DCL or SDC to either Channel will enable the command interpreter on the Channel in the F5 mode and then change the format to F0. All other parameters remain unchanged. In addition, the Clear output line is not pulsed by DCL or SDC when the either Channel is in the F5 mode. This is the only programmable method to exit the F5 format.

2.4.4 Group Execute Trigger (GET)

When the Digital488/80 recognizes a GET on either channel, it pulses the Trigger output lines on both channels for approximately 50 microseconds. If it is desired to pulse only one handshake line, the Handshake (H2) command should be issued to the desired channel.

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2.4.5 Interface Clear (IFC)

IFC places the Digital488/80 in the Talker/Listener Idle State and pulses the Clear output line for approximately 50 microseconds.

2.4.6 Serial Poll Enable (SPE)

When Serial Poll Enabled, the Digital488/80 sets itself to respond to a serial poll with its serial poll status byte if addressed to talk. When the serial poll byte is accepted by the controller, any pending SRQs are cleared. The Digital488/80 will continue to try to output its serial poll response until it is serial poll disabled by the controller.

2.4.7 Serial Poll Disable (SPD)

Disables the Digital488/80 from responding to serial polls by the controller.

2.4.8 Unlisten (UNL)

UNL places the Digital488/80 in the Listener Idle State.

2.4.9 Untalk (UNT)

UNT places the Digital488/80 in the Talker Idle State.

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2.4.10 Serial Poll Response

Whenever the Digital488/80 generates an SRQ, a serial poll of either channel will return a serial poll status byte of at least 64 (decimal) showing that an SRQ has been generated by the Digital488/80. In order to determine which channel generated the SRQ, use the `Service Request Mask` command (with the `Query` option `M2`) to recall what SRQ conditions are selected. The Digital488/80 will return `M0` if SRQs are disabled or a response between either `M1` through `M7` or `M16` through `M23` depending on what SRQ conditions are selected. The following BASIC program illustrates one approach for handling service requests:

```
PRINT#1,"SPOLL08"                    Serial poll channel 0
INPUT#2,SRQ08
PRINT#1,"SPOLL09"                    Serial poll channel 1
INPUT#2,SRQ09
PRINT#1,"OUTPUT08;M?"                Get SRQ selection(s) from channel 0
PRINT#1,"ENTER08"
INPUT#2,M08$
PRINT#1,"OUTPUT09;M?"                Get SRQ selection(s) from channel 1
PRINT#1,"ENTER09"
INPUT#2,M09$
IF M08$="M0" THEN GOTO 500           SRQs disabled Channel 0, test Channel 1
IF M08$="M1" AND SRQ08 = 65 THEN GOTO 600
                                     Service input transition routine, Chan 0
IF M08$="M2" AND SRQ08 = 66 THEN GOTO 700
                                     EDR input transition routine, Chan 0
IF M08$="M4" AND SRQ08 = 70 THEN GOTO 800
                                     Bus Error routine, Chan 0
```

Note: To allow the Digital488/80 to detect each of the above conditions, the `Service Request Mask` (`Mn`) command must be executed for each condition. More extensive comparisons of the Serial Poll Status Byte and the `M?` response are needed if multiple SRQ conditions are selected.

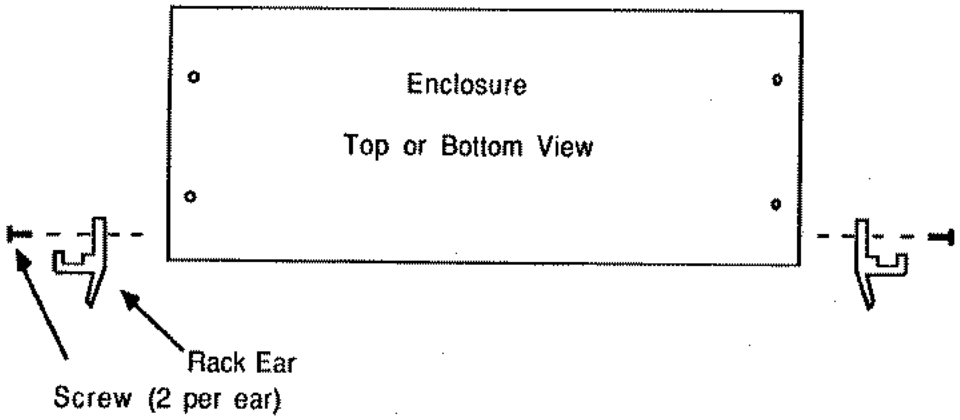
The unit may be programmed to generate an SRQ on power-on by selecting the `M16` option (SRQ on Ready) of the `Service Request Mask` (`Mn`) command and saving this selection as part of the power-on configuration (configuration `0`).

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2.5 Hardware Installation

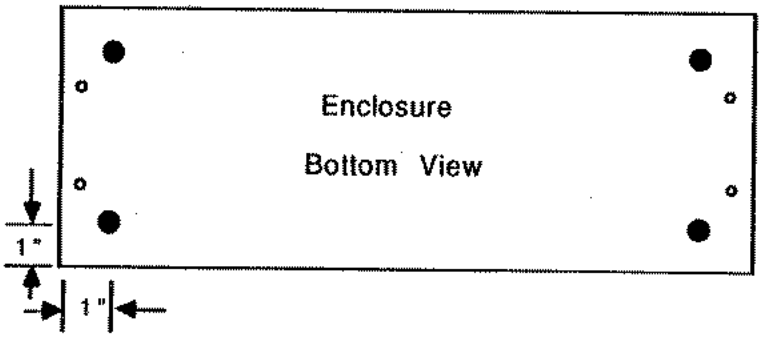
Included with the Digital488/80 are accessories for rack or bench use. If rack mount installation is required, install the two rack ears using the enclosed screws. These ears can be installed so either the front or the rear of the unit faces the front of the rack fixture.

View of Enclosure showing Rack Hardware Installation



If bench installation is required, the rubber feet can be installed on the underside of the unit approximately one inch from each corner.

View of Enclosure Showing Feet Placement



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2.6 Operation

Before operating the Digital488/80, note that the interface may be operated from 110 or 220 volts AC. The operation voltage is set by an internal switch (SW-4) located next to the power supply transformer. The factory setting of SW-4 is for 110 volt operation. To change the operation voltage, it is necessary to open the enclosure and change the setting of SW-4 according to the following instructions. Disconnect the power cord from the AC line and from the interface. Disconnect any IEEE or digital I/O cables prior to disassembly.

WARNING

Never open the Digital488/80 case while it is connected to the AC line. Internal voltage potentials exist which could cause personal injury or death.

Place the interface on a flat surface. Remove the four screws on top of the case and remove the top cover. Located next to the transformer is SW-4. Using a small screwdriver, insert the tip of the screwdriver into the slot of the switch and move the switch to the left or right so that the desired line voltage selection appears on the switch. Make note of the new setting for later reference and carefully re-assemble the unit.

WARNING

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

After plugging in the power cord, turn on the Digital488/80 by depressing the rear panel power switch. All the front panel LEDs should light for approximately one second while the Digital488/80 performs an internal ROM and RAM self check. At the end of this self check all indicators should turn off except POWER.

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If you obtain the above response then your Digital488/80 is alive and well. If all LEDs remain on, then a ROM error has occurred. If all LEDs (except the power LED) flash continuously, then a RAM error has occurred. Try cycling the power to the Digital488/80 to determine that the error is repeatable.

If all LEDs except the Power and Error LEDs go out, there was a checksum error on non-volatile RAM and the saved configurations may be lost. The checksum error condition may be cleared by doing a save of a configuration using the `Save Configuration (Sn)` command.

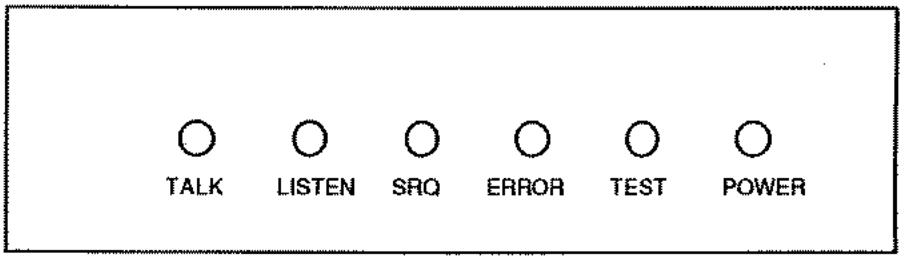
If the LEDs do not flash and the POWER indicator does not light, there may not be any power supplied to the interface. In this event, check to make sure the AC power is supplied to the unit. If the problem persists, refer to the Service Information section of this manual.

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2.6.1 Front Panel Indicators

Six LEDs on the front panel of the Digital488/80 display the status of the interface. The function of each indicator is described below.

View of Digital488/80 Front Panel Indicators



TALK	ON when the Digital488/80 is in the Talker state, OFF when the Digital488/80 is in the Idle or Listener state
LISTEN	ON when the Digital488/80 is in the Listener state, OFF when the Digital488/80 is in the Idle or Talker state
SRQ	ON when the Digital488/80 has generated a service request, OFF when no SRQ is pending. (see `Service Request Mask` Command for more information)
ERROR	ON when an error has occured, OFF when no error condition exists (see `Error` command for more information)
TEST	Used in conjunction with the `TEST` command to verify that communication has been established wtih the Digital488/80
POWER	ON when power is applied to the Digital488/80 and the power switch on the back panel is in the on position (depressed) OFF if power is not present or the internal fuse or power supply is faulty

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2.7 Programming Examples

These examples use the IOtech Personal488 and the BASIC Keyboard Controller program listed in appendix C. The Keyboard Controller program allows direct communication with the Digital488/80 (or any IEEE device on the bus) and is the most convenient method of exercising the Digital488/80 and becoming familiar with the commands and their actions.

First, set SW1 for Dual Primary addressing mode and bus address 8. Connect an IEEE cable from the Digital488/80 to the IEEE connector on the Personal488. Turn on the Digital488/80 by depressing the rear panel power switch. All of the front panel LEDs should light for approximately one second while the Digital488/80 performs an internal ROM and RAM self test. At the end of this self test all indicators should turn off except power. Run the Keyboard Controller program and verify that the CMD> prompt appears on the screen. The following is a listing of commands given to the Digital488/80 and the response received. Responses are separated by extra vertical space for clarity although these spaces will not actually appear when using the program.

```
CMD>                          Command prompt from Keyboard Controller program
CMD>OUTPUT08;T1X              Turn on the Test LED (Test LED should light)
CMD>OUTPUT08;T0X              Turn off the Test LED (Test LED should turn off)
CMD>CLEAR                     Reset the Digital488/80
CMD>OUTPUT08;U0X              Get status of Channel 0
CMD>ENTER08
1.0C0E0F0G0I000K0L0000M000P0R0Y0

                              Status message shows all default options are in use
CMD>OUTPUT09;U0X              Get status of Channel 1
CMD>ENTER09
1.0C0E0F0G0I000K0M000P0R0Y0

                              Status message shows all default options are in use
CMD>OUTPUT08;C?               Request Port Configuration Mode for Channel 0
CMD>ENTER08
C0                            C0 is returned showing default port configuration
CMD>OUTPUT08;C5X              Configure all Channel 0 Ports as outputs
CMD>OUTPUT08;C?               Request Port Configuration Mode for Channel 0
```


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`CMD>ENTER08`	
`C5`	`C5` is returned showing that our `Cn` command was executed
`CMD>OUTPUT09;C?`	Request Port Configuration Mode for Channel 1
`CMD>ENTER09`	
`C0`	`C0` is returned since we didn't change the default configuration of the Ports on Channel 1
`CMD>OUTPUT08;G2R0X`	Send output data when addressed to talk,Channel 0
`CMD>OUTPUT08;D123ZX`	Send '123' to Channel 0
`CMD>ENTER08`	Read data from Channel 0
`0000000123`	
`CMD>OUTPUT08;A37X`	Set bit 37 on Channel 0
`CMD>ENTER08`	Read data from Channel 0
`1000000123`	Display shows bit 37 set and also the previous data

The above examples may also be repeated using Secondary addressing. To do this, turn off the Digital488/80, set SW1 for Secondary addressing mode and repeat the above commands substituting `0800` for `08` and `0801` for `09` in all commands.

2.8 Data Transfer Speed Specifications

The Digital488/80 has been measured to perform at the speeds listed below. The testing was done in such a way that the limiting factor was the Digital488/80 and not the IEEE contrtroller driving it. All explanations discuss only one channel although the specifications given are valid for either channel.

2.8.1 Collection and Storage of Data

The Digital488/80 has an internal data buffer capable of storing 2000 readings of 40 bit data per channel. When operating in the `R2` mode (data is latched and stored on an EDR transition), a transition on the External Data Ready input causes the Digital488/80 to collect the current value of all 40 bits and store the reading in the buffer. This collection and storage of 40 bits of data can occur at a maximum rate of once every 140 microseconds.

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2.8.2 Output of Data to Ports

When sending data to the outputs on a channel of the Digital488/80, the fastest `Format` mode is high-speed binary mode (`F5`). In this mode, five bytes of binary data are accepted from the bus and sent directly to the Digital488/80 outputs (all 40 bits). This constitutes one data transfer. The data transfer rate in this mode is approximately 1400 transfers per second.

2.8.3 IEEE 488 Bus Communication

The fastest data transfer rate across the IEEE bus to the IEEE 488 controller is approximately 1 byte every 140 microseconds whether reading data from the internal data buffer, or accepting commands or data from the bus.

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Command Descriptions

Control of the Digital 488/80 is implemented with 23 bus commands, described here in detail. Examples are given for the commands using a PC functioning as an IEEE 488 controller by using the IOtech Personal488 PC/IEEE 488 board and associated driver software. All examples are given using GWBASIC or BASICA. The Digital488/80 bus address should be set to 8 for all examples.

In order to establish communication with DVR488 from GWBASIC or BASICA, 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
```

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

Most of the instructions offer a query (?) option. This option can be used to determine the present configuration or mode of a command previously executed. Any number of these query commands may be combined into one string to allow the user to construct a specialized status command requesting the Digital488/80 to return only that information which is of interest for a given application.

Attention!

It is necessary that the **EXECUTE** command **(X)** follow all command strings sent to the **Digital488/80.** No commands are executed until an **X** is received by the **Digital488/80.** The only exception to this rule are the query commands. Any query commands do not have to be followed by an **X**.

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Bit Set An

The Bit Set command programs a logic one output to a bit described by the argument 'n'. Setting a bit may represent either a +5 volt or 0 volt output, depending on whether an Invert command (I16) has been sent. If data is active high (default condition), then Bit Set outputs +5 volts. If multiple bits are to be set within the same command string, an Execute command (X) must be included after every Bit Set command.

The bit which is being set must have been configured as an output bit by the Configure command to be valid. The Strobe output line is not pulsed when the Bit Set command is sent.

An	Bit n (1 thru 40) is set to logic one
A?	Return n (1 thru 40) of last bit set

Examples:

Using Dual Primary Addressing Mode
to communicate with channel 0:

```
PRINT#1,"CLEAR08"              reset the Digital488/80
PRINT#1,"OUTPUT08;C5P0X"       configure all ports as output, select all ports
PRINT#1,"OUTPUT08;A22X"        set bit 22 to a logic one
PRINT#1,"OUTPUT08;A23XA24X"    set bits 23 and 24 to a logic one
```

Using Secondary Addressing Mode
to communicate with channel 0:

```
PRINT#1,"CLEAR0800"            reset the Digital488/80
PRINT#1,"OUTPUT0800;C5P0X"     configure all ports as output, select all ports
PRINT#1,"OUTPUT0800;A22X"      set bit 22 to a logic one
PRINT#1,"OUTPUT0800;A23XA24X"  set bits 23 and 24 to a logic one
```


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Bit Clear Bn

The `Bit Clear` command will clear to a logic zero an output bit described by the argument 'n'. Clearing a bit may represent either a 0 volt or +5 volt output, depending on whether an `Invert` command (`I16`) has been sent. If data is active high (default condition), then `Bit Clear` outputs 0 volts. When multiple `Bit Clear` commands are used in the same command string, an `Execute` command (`X`) must follow each command.

The bit which is being cleared must have been defined as an output by the `Configure` (`Cn`) command in order to be valid. The Strobe output line is not pulsed when the `Bit Clear` command is sent.

`Bn`	Bit `n` (1 thru 40) is cleared to a logic 0
`B?`	Return `n` (1 thru 40) of last bit cleared

Example:

`PRINT#1,"CLEAR08"`	reset the Digital488/80
`PRINT#1,"OUTPUT08;C5P0X"`	configure all ports as output, select all ports
`PRINT#1,"OUTPUT08;A7XA8XA9X"`	set bits 7, 8, and 9 to +5 volts
`PRINT#1,"OUTPUT08;B7X"`	clear bit 7 to zero volts
`PRINT#1,"OUTPUT08;B8XB9X"`	clear bits 8 and 9 to zero volts

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Configure Cn

Ports 1 through 5 are configured as inputs or outputs with the `Configure` command. Each port is eight bits wide. At power-on, all ports are initialized as inputs. The `Configure` command is usually the first command to be sent after power on. All ports programmed as outputs will be set to a logic zero after receiving the Configure command. The actual output level is dependent on the `Invert` command (`I16`).

`Cn` Mode `n` (0 thru 5) defines which ports are input and output

		Port				
		5	4	3	2	1
	C0	in	in	in	in	in
	C1	in	in	in	in	out
Command	C2	in	in	in	out	out
	C3	in	in	out	out	out
	C4	in	out	out	out	out
	C5	out	out	out	out	out

in = programmed as an input port
out = programmed as an output port

`C?` Return present port configuration

Examples:

```
PRINT#1,"CLEAR08"                reset the Digital488/80
PRINT#1,"OUTPUT08;C1X"           select port 1 as output, ports 2 thru 5
                                 as inputs
PRINT#1,"OUTPUT08;C?"            request present port configuration
PRINT#1,"ENTER08"
INPUT#2,A$
PRINT A$                         display shows C1
```


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Data Dn....Z

The Data command outputs up to 40 bits of data to the output ports on a selected channel. The number of bits which can be sent with the Data command is limited by the number of bits programmed as outputs. For formats F0 through F3, if the amount of data sent is less than the the number of bits programmed as outputs, the least-significant bits will contain the data sent and the most-significant bits will be cleared to logic zero. If a single port is selected with the Port command, only eight bits may be sent with the Data command. The Data Strobe output of the selected channel is pulsed for approximately 50 microseconds after new data is output on the selected ports of that channel.

For formats F0 through F3, data sent by the controller is contained within a prefix (D) and a suffix (Z). In format F4, the five bytes immediately following the prefix (D) is interpreted as data and the suffix (Z) is not used. For the high speed binary F5 format, all bytes received are treated as data and the prefix and suffix are not used. Refer to the Format (Fn) command for additional details.

Dn...Z n... represents the data to be outputted, terminated by Z.
(note: in the F4 mode, the Z terminator is not allowed)

Examples:

```
PRINT#1,"CLEAR08"                    reset the Digital488/80
PRINT#1,"OUTPUT08;C5P1G2R0X"         all ports are output, select port 1
PRINT#1,"OUTPUT08;D55ZX"             send 55 to port 1
PRINT#1,"ENTER08"
INPUT#2,A$                           read data from port 1
PRINT A$                             display shows 55
PRINT#1,"OUTPUT08;P0X"               select all ports
PRINT#1,"OUTPUT08;D1234567890ZX"     send data to all 40 data lines
PRINT#1,"ENTER08"
INPUT#2,A$                           read data from the Digital488/80
PRINT A$                             display shows 1234567890
```


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```
PRINT#1,"CLEAR08"                reset the Digital488/80
PRINT#1,"OUTPUT08;C5P1G2R0X"     all ports are output, select port 1
PRINT#1,"OUTPUT08;D123ZX"        send 12 bits of data to the least significant bits
PRINT#1,"ENTER08"
INPUT#2,A$                       read data from the Digital488/80
PRINT A$                         display shows 0000000123
PRINT#1,"OUTPUT08;P5D21ZX"       select port 5 only
PRINT#1,"OUTPUT08;P0X"           select all ports
PRINT#1,"ENTER08"
INPUT#2,A$                       read data from the Digital488/80
PRINT A$                         display shows 2100000123
```


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Error E?

The Error command is used to determine the present error condition on the selected channel of the Digital488/80. After execution of the Error command, the present error condition is cleared. The error condition is also cleared by executing the Status (U0) command. When an error has occurred, the Error light on the front panel of the Digital488/80 will turn on. The Error light will stay on until an Error (E?) or Status (U0) command is executed.

If a Non-Volatile RAM Checksum Failure (E5) occurs, this error condition may only be cleared by doing a save of a configuration using the Save Configuration (Sn) command. Executing this command updates the checksum to a known value and clears the E5 error condition.

E? Return and clear present error condition

After execution of the Error command, the Digital488/80 will return one of the following error codes:

E0	No Error has occurred
E1	Unrecognized command (W4X, J5 etc.)
E2	Invalid Command Parameter (A62X, C10X etc.)
E3	Conflict Error (outputting data to an input port, sending excess data)
E4	Not used
E5	Non-Volatile RAM Checksum Failure
E6	Internal Data Buffer Overrun (attempting to store data in a full buffer)

Examples:

```
PRINT#1,"CLEAR08"              reset the Digital488/80
PRINT#1,"OUTPUT08;E?"          request error status
PRINT#1,"ENTER08"
INPUT#2,A$
PRINT A$                       display shows E0, no errors have occurred
```


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```
PRINT#1,"OUTPUT08;W5X"
PRINT#1,"OUTPUT08;E?"
PRINT#1,"ENTER08"
INPUT#2,A$
PRINT A$
```

send an illegal command to the Digital488/80
request error status (Note: error light should be on)

display shows `E1`–Unrecognized Command
(Error light should be off)

```
PRINT#1,"OUTPUT08;E?"
PRINT#1,"ENTER08"
INPUT#2,A$
PRINT A$
```

request error status

display shows `E0` since error condition has been cleared after reading error status

```
PRINT#1,"OUTPUT08;C8X"
PRINT#1,"OUTPUT08;E?"
PRINT#1,"ENTER08"
INPUT#2,A$
PRINT A$
```

send a command with an invalid option
request error status (Note: error light should be on)

display shows `E2`–Invalid Parameter
(Error light should be off)

```
PRINT#1,"OUTPUT08;G0C5P1X"
PRINT#1,"OUTPUT08;D123456ZX"
PRINT#1,"OUTPUT08;E?"
PRINT#1,"ENTER08"
INPUT#2,A$
PRINT A$
```

configure all ports as outputs, select port 1
send too much data for 1 port
request error status (Note: error light should be on)

display shows `E3`–Conflict Error
(Error light should be off)

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Format Fn

The Format command determines the method by which input and output data will be described. Six data formats are available.

F0	ASCII Hexadecimal (4 bits per character)
F1	ASCII Character (4 bits per character)
F2	ASCII Binary (1 bit per character)
F3	ASCII Decimal (8 bits per number)
F4	Binary (each byte represents 8 bits)
F5	High Speed Binary (each byte represents 8 bits)
F?	Return present data format

F0 Format - ASCII Hexadecimal

In the default F0 format, the data is described in ASCII hexadecimal, with each character having a value from 0 thru 9 or A thru F. Each ASCII character describes 4 bits of data.

F0 Character	Decimal Equiv	F0 Character	Decimal Equiv
0	0	8	8
1	1	9	9
2	2	A	10
3	3	B	11
4	4	C	12
5	5	D	13
6	6	E	14
7	7	F	15

Data received for output to the digital ports must be contained within a prefix (D) and a suffix (Z). If the amount of data sent is less than the number of bits programmed as outputs, the least-significant bits will contain the data sent and the most-significant bits will be cleared to logic zero. If the data sent is greater than the number of bits programmed for output or selected by the Port (Pn) command, the Digital488 will generate a conflict error (E3) and ignore the entire command string up to the next X. The Data Strobe output is pulsed for approximately 50 microseconds after new data is output on the selected port(s).

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When the Digital488/80 is addressed to talk (in `Data Ready` mode `R0`) it asserts Inhibit, reads the data from all ports, unasserts Inhibit and outputs the number of characters determined by the `Bus Input/Output (Gn)` and `Port (Pn)` commands. Leading zeros are not suppressed and the bus terminators are appended to the output. After output the Digital488/80 must be re-addressed to talk to perform subsequent reads. EDR (in `R1` or `R2` mode) may also be used to capture data in this format.

Example:

```
PRINT#1,"CLEAR08"                reset the Digital488/80
PRINT#1,"OUTPUT08;R0P0C2G2X"     configure ports 1 & 2 as output
PRINT#1,"OUTPUT08;F0X"           select ASCII Hexadecimal format
PRINT#1,"OUTPUT08;D4E6BZX"       output hexadecimal 4E6B to ports 1 & 2
PRINT#1,"ENTER08"
INPUT#2,A$                       read data from the Digital488/80
PRINT A$                         display shows 4E6B
```

F1 Format - ASCII Character

In the `F1` format, the data is coded and transmitted in ASCII Characters with the four least significant bits of each ASCII character representing four bits of data.

F1 Character	Decimal Equiv	F1 Character	Decimal Equiv
0	0	8	8
1	1	9	9
2	2	:	10
3	3	;	11
4	4	<	12
5	5	=	13
6	6	>	14
7	7	?	15

Data received for output to the digital ports must be contained within a prefix (`D`) and a suffix (`Z`). If the amount of data sent is less than the number of bits programmed as outputs, the least-significant bits will contain the data sent and the most-significant bits will be cleared to logic zero. If the data sent is greater than the number of bits programmed for output or selected by the `Port (Pn)` command, the Digital488/80 will

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generate a conflict error (E3) and ignore the entire command string up to the first X. The Data Strobe output is pulsed for approximately 50 microseconds after new data is output on the selected port(s).

When the Digital488/80 is addressed to talk (in R0 mode) it asserts Inhibit, reads the data from all ports, unasserts Inhibit and outputs the number of characters determined by the Gn and Pn commands. Leading zeros are not suppressed and the bus terminators are appended to the output. After output the Digital488/80 must be re-addressed to talk to perform subsequent reads. EDR (in R1 or R2 mode) may also be used to capture data in this format.

Example:

```
PRINT#1,"CLEAR08"                reset the Digital488/80
PRINT#1,"OUTPUT08;C5G2R0P0X"     all ports are outputs, select all ports
PRINT#1,"OUTPUT08;F1X"           select ASCII Character format
PRINT#1,"OUTPUT08;D4>6ZX"        send 4>6 to the Digital488/80
PRINT#1,"ENTER08"
INPUT#2,A$                       read data from the Digital488/80
PRINT A$                         display shows 00000004>6
PRINT#1,"OUTPUT08;D1??2ZX"       send 1??2 to the Digital488/80
PRINT#1,"ENTER08"
INPUT#2,A$                       read data from the Digital488/80
PRINT A$                         display shows 0000001??2
```


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F2 Format - ASCII Binary

In the F2 format, the each data bit is described with an ASCII 0 or 1. Each byte is formatted in two 4-bit multiples separated by semicolons.

F2 String	Decimal Equiv	F2 String	Decimal Equiv
0000;0000	0	0000;1001	9
0000;0001	1	0000;1010	10
0000;0010	2	0000;1011	11
0000;0011	3	0000;1100	12
0000;0100	4	0000;1101	13
0000;0101	5	0000;1110	14
0000;0110	6	0000;1111	15
0000;0111	7	1000;0001	129
0000;1000	8	1111;1111	255

Data received for output to the digital ports must be contained within a prefix (D) and a suffix (Z) and each 4-bit quantity must be separated by semicolons. Leading zeros are not required. If the amount of data sent is less than the number of bits programmed as outputs, the least-significant bits will contain the data sent and the most-significant bits will be cleared to logic zero. If the data sent is greater than the number of bits programmed for output or selected by the Pn command, the Digital488/80 will generate a conflict error (E3) and ignore the entire command string up to the next X. The Data Strobe output is pulsed for approximately 50 microseconds after new data is output on the selected port(s).

When the Digital488/80 is addressed to talk (in R0 mode) it asserts Inhibit, reads the data from all ports, unasserts Inhibit and outputs the number of characters determined by the Gn and Pn commands. Leading zeros are not suppressed and the bus terminators are appended to the output. After output the Digital488/80 must be re-addressed to talk to perform subsequent reads. EDR (in R1 or R2 mode) may also be used to capture data in this format.

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Example:

```
PRINT#1,"CLEAR08"                    reset the Digital488/80
PRINT#1,"OUTPUT08;C5G2R0P1X"         all ports are outputs, select port 1
PRINT#1,"OUTPUT08;F2X"               select ASCII/binary mode
PRINT#1,"OUTPUT08;D1;1011ZX"

                                     send binary data
PRINT#1,"ENTER08"
INPUT#2,A$                           read data from the Digital488/80
PRINT A$                             display shows 0001;1011
```

F3 Format - ASCII Decimal

In the F3 format, the data is described in decimal 8 bit multiples and transmitted in ASCII. Each decimal number (0 to 255) to be output must be separated by semicolons.

F3 Number	Decimal Equiv	F3 Number	Decimal Equiv
000	0	008	8
001	1	009	9
002	2	010	10
003	3	020	20
004	4	100	100
005	5	200	200
006	6	210	210
007	7	255	255

Data received for output to the digital ports must be contained within a prefix (D) and a suffix (Z). If the amount of data sent is less than the number of bits programmed as outputs, the least-significant bits will contain the data sent and the most-significant bits will be cleared to logic zero. If the data sent is greater than the number of bits programmed for output or selected by the Pn command, the Digital488/80 will generate a conflict error (E3) and ignore the entire command string up to the next X. The Data Strobe output is pulsed for approximately 50 microseconds after new data is output on the selected port(s).

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When the Digital488/80 is addressed to talk (in R0 mode) it asserts Inhibit, reads the data from all ports, unasserts Inhibit and outputs the number of characters determined by the Gn and Pn commands. Leading zeros are not suppressed and the bus terminators are appended to the output. After output the Digital488/80 must be re-addressed to talk to perform subsequent reads. EDR (in R1 or R2 mode) may also be used to capture data in this format.

Examples:

```
PRINT#1,"CLEAR08"                reset the Digital488/80
PRINT#1,"OUTPUT08;F3X"           select decimal mode
PRINT#1,"OUTPUT08;C5G2R0P0X"     all ports are outputs, select all ports
PRINT#1,"OUTPUT08;D240;165ZX"    send data to the Digital488/80
PRINT#1,"ENTER08"                read data from the Digital488/80
INPUT#2,A$
PRINT A$                         display shows 000;000;000;240;165
```

F4 Format - Binary

In the F4 binary format, no error checking is performed and caution must be exercised when using this mode to avoid locking the IEEE bus.

When addressed to listen, the Digital488/80 expects the "D" prefix followed by five bytes of data beginning with PORT5 without the "Z" suffix. If any digital I/O port is configured as an input, the data to that input port will be ignored.

When the Digital488/80 is addressed to talk (in R0 mode) it asserts Inhibit, reads the data from all ports, unasserts Inhibit and outputs 5 bytes beginning with PORT5 with EOI asserted on the last bye. Bus terminators, with the exception of EOI, are not appended to the output. After output the Digital488/80 must be re-addressed to talk to perform subsequent reads. EDR (in R1 or R2 mode) may also be used to capture data in this format.

F5 Format - High Speed Binary

In the F5 high speed binary format, the command interpreter is disabled. When

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addressed to listen, the Digital488/80 treats all bytes received as data to be output to the Digital I/O ports. Each time it receives five bytes or detects EOI asserted, it pulses the Data Strobe for approximately 15 microseconds. Data is expected in a PORT5, PORT4, PORT3, PORT2, PORT1 sequence. If only two bytes are received, with EOI asserted on the second byte, the Digital488/80 will update PORT5 with the first byte received, PORT4 with the second and pulse the Data Strobe. Since the interface treats all received characters as data, no commands will be recognized.

To place the Digital488/80 in the F5 format, the 3 character string "F5X" should be the last command sent to the interface without terminators. Any characters appended to this command, such as carriage return or line feed, will be considered data and the output ports will reflect those character values. (see the following program example)

When addressed to talk in this format it asserts Inhibit, reads the data from all ports, unasserts Inhibit and outputs the binary data to the bus with EOI asserted on the fifth byte. When the last data byte is transferred, the data is read again in anticipation of another data transfer. If Inhibit is used to sequence external hardware, this line will pulse N+1 times; where N is the number of total (5 byte) data transfers. In this format the Digital488/80 does not have to be re-addressed to talk to read the ports multiple times. EDR cannot be used to capture data in the F5 high speed binary format.

The only programmable method to exit the F5 high speed binary format is device clear (DCL) or Selected Device Clear (SDC). When received, it enables the command interpreter and changes the format to F0. All other parameters remain unchanged. In addition, the Clear output line is not pulsed by DCL or SDC when the interface is in F5.

When either channel (or both) is in the F5 mode, a DCL or an SCD to either channel will clear the F5 mode. It will not reset the interface. It will only take the unit out of the F5 mode and place it in the F0 mode.

Example:

```
PRINT#1,"OUTPUT08#3F5X"          put Channel 0 in F5 mode
PRINT#1,CHR$(255),CHR$(125)      send data
```

Note: The #3 tells DRVR488 to send only the 3 bytes F5X without terminators. If this was not done, the first data bytes to appear at the output of the Digital488/80 would be CR LF or whatever terminators were selected.

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Bus Input/Output Gn

The Bus Output command determines whether input port data, output port data, both input and output port data, or buffered data will be transmitted on the bus when the Digital488/80 is addressed to talk. The amount of data sent is dependent on the Pn command.

The G0 default mode causes all input and output port data to be sent to the controller when addressed to talk. The G1 mode causes only data from the ports programmed as inputs to be returned when addressed to talk. The G2 mode causes only data from ports programmed as outputs to be returned when addressed to talk.

The G3 mode causes data in the data buffer to be returned when addressed to talk. Both input and output data (all 40 bits) are returned in this mode. If the count of readings in the buffer is 0, the Digital488/80 will hold off the bus until the next transition of EDR and another reading has been collected and buffered. After the EDR transition, it will then return that newly collected reading.

If all ports are programmed as outputs with G1 selected and the Digital488/80 is addressed to talk, nothing will be transmitted and the bus will hang. The converse will also cause the bus to hang with all ports programmed as inputs and G2 selected.

G0	Input and output port data is sent when addressed to talk
G1	Only input port data is sent when addressed to talk
G2	Only output port data is sent when addressed to talk
G3	Buffered input and output data sent when addressed to talk
G?	Return present Bus Input/Output mode

Examples:

```
PRINT#1,"CLEAR08"                reset the Digital488/80
PRINT#1,"OUTPUT08;P0C1R0X"       port1 as output, ports 2-5 as input
PRINT#1,"OUTPUT08;G1X"           select only input ports for data
PRINT#1,"ENTER08"
INPUT#2,A$                       read data from the input ports
PRINT A$                         display shows FFFFFFFF (data is
                                 dependent on what is connected).
```


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Handshake Hn

The Handshake control command enables software control of the handshake lines, independent of any other I/O operations. When the Digital488/80 receives an Hn command, the respective handshake line is pulsed for approximately 50 microseconds. It returns to its steady-state condition after pulsing. The `Invert (In)` command may be used to change the active state of any of the handshake lines.

`H0`	The Clear line is pulsed
`H1`	The Strobe line is pulsed
`H2`	The Trigger line is pulsed
`H?`	Return last Handshake command executed

Example:

```
PRINT#1,"OUTPUT08;H1X"          pulse the Strobe line on Channel 0
```


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Invert In

The `Invert` command is used to change the polarity of the handshake and data lines. At power up all handshake and control lines are active high (logic one = + 5 volts). The `Invert` command can selectively change the polarity of each of the handshake lines, and of the data lines. If multiple `Invert` commands are contained within the same string, then an `Execute` command (`X`) should be included between each `Invert` command. An alternative is to add the values of each `Invert` command desired, and send one command with the sum of the desired commands. The `Invert` commands are ORed together as received. To delete any one command, it is necessary to program the default mode `I0`, then reprogram the desired commands.

`I0`	All control lines are active high, all data lines are high true
`I1`	Inhibit output is active low
`I2`	Trigger output is active low
`I4`	Data Strobe output is active low
`I8`	Clear output is active low
`I16`	Data is low true
`I32`	EDR input is falling-edge sensitive
`I64`	Service input is falling-edge sensitive
`I?`	Return last `Invert` command executed

Example:

`PRINT#1,"CLEAR08"`	reset the Digital488/80
`PRINT#1,"OUTPUT08;I32XI64X"`	select EDR and Service input as falling-edge sensitive

Note:

`PRINT#1,"OUTPUT08;I96X"`	performs the same function as above

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End or Identify (EOI) Kn

The EOI line is one of five interface management lines on the IEEE 488 Bus. It is used by a talker to indicate the end of a multiple byte transfer sequence. The controller can change the EOI mode by programming the Digital488/80 from the bus. In the K0 mode, the EOI line is asserted by the Digital488/80 on the last byte of every bus output string. In the K1 mode the EOI function is disabled (except when using the binary modes [F4 and F5]).

K0	EOI enabled, assert EOI on last byte transferred
K1	EOI disabled, do not assert EOI on last byte transferred
K?	Return present EOI selection

Examples:

```
PRINT#1,"OUTPUT08;K1X"          disables EOI on last byte

PRINT#1,"OUTPUT08;K?"           request EOI selection from Digital488/80
PRINT#1,"ENTER08"
INPUT#2,A$
PRINT A$                        display shows K1
```


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Buffer Ln

The `Buffer` command is used to clear the internal data buffer or to determine the number of readings in the buffer. It is used primarily with the Buffered `Data Ready` command (`R2`) although it may be used at any time to determine the buffer status.

`L0` Clear the internal data buffer
`L?` Return number of port readings in the internal data buffer

Examples:

```
PRINT#1,"OUTPUT08;C0P0R2G3X"
```
buffer data to be sent when addressed to talk

collect some data

```
PRINT#1,"OUTPUT08;L?X"
PRINT#1,"ENTER08"
INPUT#2,COUNT$
COUNT$ = RIGHT$(COUNT$,4)
COUNT = VAL(COUNT$)
PRINT COUNT
```
request buffer status of Channel 0

display shows 24
(24 port readings in buffer)

```
DIM B(100)
FOR I = 1 TO COUNT
PRINT#1,"ENTER08"
INPUT#2,A$
B(I) = VAL(RIGHT$(A$,4))
NEXT I
```
store readings in an array
readings are stored as integers

```
PRINT#1,"OUTPUT08;L?X"
PRINT#1,"ENTER08"
INPUT#2,COUNT$
PRINT COUNT$
```
request buffer status

display shows L000 since all data has been read

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Service Request Mask (SRQ) Mn

The Service Request (SRQ) Mask command is used by the Digital488/80 to alert the controller to one of several conditions described below. Multiple Service Request conditions can be enabled simultaneously by issuing them separately or by combining them in one command string. If multiple Mn commands are contained within the same command string, each command should be followed by an Execute (X) command. The programmed SRQ modes will remain enabled until the M0 (SRQ disabled) command is sent, or the controller sends a Device Clear (DCL) or Selected Device Clear (SDC).

M0	SRQ is disabled
M1	SRQ on Service input transition
M2	SRQ on EDR input transition
M4	SRQ on bus error
M16	SRQ on Ready

M0 default mode disables the SRQ function, preventing the Digital488/80 from generating a Service Request.

M1 enables the Digital488/80 to generate a Service Request when the Service Input line makes a transition. Refer to the Invert (I64) command description for programming the polarity of the Service input line.

M2 enables the Digital488/80 to generate a Service Request when the EDR input makes a transition. Refer to the Invert (I32) command description for programming the polarity of the EDR input line.

M4 enables the Digital488/80 to generate a Service Request when a bus error occurs. The most common bus error is sending an invalid command to the Digital488/80. For example, selecting an 'F6' format will cause the Digital488/80 to generate a Service Request when the M4 mode is selected.

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M16 enables the Digital488/80 to generate a Service Request when it has completed the execution of a set of commands from the bus controller. This may be used by the controller to assure the completion of a set of commands before sending a subsequent set of commands.

Like the Invert (In) commands, the Service Request Mask commands are also ORed together as received. To delete any one command, it is necessary to program the default mode M0, then reprogram the desired commands.

Example:

```
PRINT#1,"CLEAR08"          reset the Digital488/80
PRINT#1,"OUTPUT08;M4X"     select SRQ on Bus error
PRINT#1,"OUTPUT08;F7X"     send an invalid command.

                           Note: ERROR and SRQ LEDs should illuminate

PRINT#1,"CLEAR08"          reset the Digital488/80
PRINT#1,"OUTPUT08;M1XM4X"  select SRQ on Bus Error and
                           SRQ on Service Input Transition.

PRINT#1,"OUTPUT08;M5X"     This has the same effect as the command above
                           where M1X plus M4X equals M5X.
```


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Recall Configuration On

The `Recall Configuration` command is used to load a previously saved configuration from non-volatile RAM and use it as the present configuration. The argument of the command (`n`) may range from `0` to `100`. As mentioned under the `Save Configuration` command, configuration `0` is the power-on configuration. Any load of a configuration not previously saved with the `Save Configuration` command will configure the channel with the default setting for each command (i.e. `Format F0, Terminator Y0` etc.) Issuing an `O?` command will return the configuration number last recalled.

`On`	Load configuration `n` for use as present channel configuration
`O?`	Return present channel configuration number (`n`)

Example:

```
PRINT#1,"CLEAR08"          reset the Digital488/80
PRINT#1,"OUTPUT08;O5X"     load configuration 5 from non-volatile RAM
                           for use as present configuration
```


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Port Pn

The `Port` command determines which port is selected for data input/output. In the default mode (`P0`), all ports are selected. The `P1` thru `P5` commands select a specific eight bit port.

It is recommended that the `Bus Input/Output (Gn)` command be used with the `P0` mode to select which type of port data (input or output) will be sent when the Digital488/80 is addressed to talk. Data in modes `P1` throuth `P5` will be input or output in groups of eight bits.

`P0`	All five ports are selected
`P1`	Port 1 is selected
`P2`	Port 2 is selected
`P3`	Port 3 is selected
`P4`	Port 4 is selected
`P5`	Port 5 is selected
`P?`	Return present port selection

Example:

```
PRINT#1,"CLEAR08"          reset the Digital488/80
PRINT#1,"OUTPUT08;P4X"     select port 4
```


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Inhibit Q n

The `Inhibit` control command allows software control of the Inhibit line, independent of any other I/O activities. The 'set' and 'clear' levels of the Inhibit line are determined by the `Invert` (`In`) command.

`Q0`	Clear the Inhibit line (return to unasserted state)
`Q1`	Set the Inhibit line (place in the asserted state)
`Q?`	Return the last Inhibit command executed

Example:

```
PRINT#1,"CLEAR08"              reset the Digital488/80
PRINT#1,"OUTPUT08;Q1X"         set the Inhibit line on Channel 0
```


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Data Ready Rn

The Data Ready command enables digital input port data to be latched. When used in conjunction with the Service Request Mask (M2) command, the External Data Ready line can both latch the input data and generate an SRQ to signal the controller that new data is available.

In the default mode (R0) data is read when the Digital488/80 is addressed to talk. In the R1 mode, it will wait for the selected External Data Ready (EDR) transition before reading the data and formatting it for output. If the Digital488/80 is addressed to talk before EDR is asserted, the bus will hang up until the EDR pulse occurs. Once EDR is asserted the data will remain latched until the interface is addressed to talk and the data is read by the controller. If EDR transitions again before the previous EDR buffered data has been read, the Digital488 will generate a Buffer Overrun error (E6) and ignore the EDR read request. The Inhibit line is asserted once for each data read operation for all format (Fn) modes except high speed binary (F5).

In the R2 mode, successive readings (up to 2000) may be latched and stored in the internal data buffer. The number of readings in the buffer may be found using the L? command. The EDR and Inhibit lines function in the same manner as in the R1 mode. If an attempt is made to store more than 2000 readings in the internal buffer, the Digital488/80 will generate a Buffer Overrun error (E6).

After output in the F0 through F4 formats, the Digital488 must be re-addressed to talk to perform subsequent buffered output of EDR captured data. EDR cannot be used to capture data in the F5 high speed binary format

The EDR signal must be at least 1 microsecond wide and should have a rise and fall time of less than 1.0 microsecond. The EDR line defaults to rising-edge sensitive, but can be changed to falling-edge sensitive with the Invert command (I32).

R0	Data is not latched, and is read whenever the Digital488/80 is addressed to talk
R1	Data is latched on an EDR transition
R2	Data is latched and buffered on an EDR transition
R?	Return present programmed Data Ready mode

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Examples:

`PRINT#1,"CLEAR08"`	reset the Digital488/80
`PRINT#1,"OUTPUT08;R1X"`	data is read only after a rising-edge signal is applied to the EDR line (only 1 reading is stored in buffer and must be read before another reading can be taken)
`PRINT#1,"CLEAR08"`	reset the Digital488/80
`DIM B$(100)`	dimension an array to store buffered data
`PRINT#1,"OUTPUT08;C0P0X"`	all ports are inputs, select all ports
`PRINT#1,"OUTPUT08;R2X"`	data is latched and buffered on EDR transition
`PRINT#1,"OUTPUT08;G3X"`	buffered I/O data sent when addressed to talk
	50 readings (1 reading per EDR transition) are taken and stored in the internal buffer
`FOR I = 1 TO 50`	read the internal buffer and store the data in the array
`PRINT#1,"ENTER08"`	
`INPUT#2,B$(I)`	
`NEXT I`	

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Save Configuration Sn

The Save Configuration command is used to save a non-volatile copy of the present channel configuration for later recall with the Recall Configuration (On) command. The argument (n) for this command may range from 0 to 100, allowing 101 different configurations to be saved in battery-backed-up RAM. Upon power on, the default configuration will be the S0 configuration. The present state of all output bits is read before saving. When the configuration is restored using the Recall Configuration (On) command, the outputs will be set to the same values they had at the time the Sn command was executed. If it is desired that the outputs be set to a specific state as part of a configuration, then the Data (Dn...Z) command should be used just prior to the Save Configuration command to insure that the data bits are set to the proper state upon retrieval of the configuration.

Sn	Save present configuration as configuration n (n = 0 to 100)
S?	Return the last configuration number (n) saved. (not the current configuration loaded)

Example:

PRINT#1,"CLEAR08"	reset the Digital488/80
PRINT#1,"OUTPUT08;C5X"	configure all ports as outputs
PRINT#1,"OUTPUT08;F3X"	select ASCII Decimal data format
PRINT#1,"OUTPUT08;P4X"	select port 4
PRINT#1,"OUTPUT08;S57X"	save present channel configuration as configuration 57.

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Test Tn

The Test command is used to verify that communication has been established with the Digital488/80. If the `T1` command is executed, the front panel TEST LED should light. If the `T0` command is then executed, the TEST LED should turn off. This command can be used to test the connection between the IEEE Controller and the Digital488/80.

`T1`	Turn on Test LED
`T0`	Turn off Test LED

Example:

`PRINT#1,"CLEAR08"`	reset the Digital488/80
`PRINT#1,"OUTPUT08;T1X"`	turn on the TEST LED TEST LED should illuminate
`PRINT#1,"OUTPUT08;T0X"`	turn off the TEST LED TEST LED should extinguish

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Status Un

The Status (U0) command will cause the Digital488/80 to send the status message when next addressed to talk. The status of the Digital488/80 may be read at any time without interfering with normal operation. Any error conditions are cleared after the status string is read by the controller. The Status (Un) command enables the controller to read any single bit from the I/O ports (n = 1 through 40).

U0	Send the Digital488/80 status when next addressed to talk
Un	Send the status of bit n (n = 1 through 40) when next addressed to talk
U?	Return last status command executed

The format of the status byte returned by the Digital488/80 after receiving a U0 command is as follows:

```
*.*C#E#F#G#I###K#L####M###P#R#Y#
```

where each # equals the number corresponding to that command. The leading information *.* is the revision level of the Digital488/80 firmware.

Example:

```
PRINT#1,"CLEAR08"              reset the Digital488/80
PRINT#1,"OUTPUT08;U0X"         request the status of the Digital488/80
PRINT#1,"ENTER08"
INPUT#2,A$                     read the status byte
PRINT A$                       display =
                    1.0C0E0F0G0I000K0L0000M000P0R0S00Y0
```

The status returned after receiving a U1 through U40 is an ASCII character '1' or '0', depending on the level of the line, and the state of the Invert (I16) command.

```
PRINT#1,"CLEAR08"              reset the Digital488/80
PRINT#1,"OUTPUT08;U22X"        request the status of bit 22
INPUT#2,A$                     read the status
PRINT A$                       display shows a 0 (dependent on the signal
                               applied to the input)
```


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Below is a summary of the Status (U0) information.

C#	Configuration
C0	All ports are inputs
C1	Port 1 is an output, ports 2 thru 5 are inputs
C2	Ports 1 and 2 are outputs, ports 3 thru 5 are inputs
C3	Ports 1 thru 3 are outputs, ports 4 and 5 are inputs
C4	Ports 1 thru 4 are outputs, port 5 is an input
C5	All ports are outputs

E#	Error Message
0	No error
1	Unrecognized command (ex. W3)
2	Invalid command option (ex. F8)
3	Conflict (ex. attempting to output data to an input port)
4	Not used
5	Non-Volatile RAM checksum error
6	Buffer Overrun error

F#	Data Format
F0	Hexadecimal
F1	ASCII
F2	Binary
F3	Decimal
F4	High Speed Binary

G#	Bus Input/Output mode
G1	Only Input port data sent when addressed to talk
G2	Only Output port data sent when addressed to talk
G3	Buffered port data sent when addressed to talk

I###	Invert Control Lines
I0	All control and data lines are active high
I1	Inhibit output is active low
I2	Trigger output is active low
I4	Data Strobe output is active low
I8	Clear output is active low

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I16	Data is active low
I32	EDR input is fallling edge sensitive
I64	Service input is falling edge sensitive

Note: the status indication reflects the sum of all received Invert commands.

K#	End Or Identify
K0	EOI enabled
K1	EOI disabled

L####	Buffer Status #### = number of readings in the buffer (0 to 2000)

M##	Service Request
M0	SRQ is disabled
M1	SRQ on Service input transition
M2	SRQ on EDR input transition
M4	SRQ on Bus error
M16	SRQ on Ready

Note:the status indication reflects the sum of all received Service Request Mask commands

P#	Selected Port
P0	All ports selected
P1	Port 1 selected
P2	Port 2 selected
P3	Port 3 selected
P4	Port 4 selected
P5	Port 5 selected

R#	Data Ready
R0	Data is not latched, but is read when Digital 488 is addressed to talk
R1	Data is latched on EDR transition
R2	Data is latched and buffered on EDR transition

Y#	Terminator
Y0	CR LF
Y1	LF CR
Y2	CR only
Y3	LF only

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View Configuration Vn

The View Configuration command is used to look at a configuration previously saved without loading it for use as the present configuration. In response to this command, the Digital488/80 will return a string in the following format:

```
S###C#F#G#I###K#M###P#R#Y#D0000000000Z
```

where each # equals the option for that command saved in the requested configuration. Data in between the D and Z is dependent on the state of the I/O lines at the time the configuration was saved.

Example:

```
PRINT#1,"CLEAR08"              reset the Digital488/80
PRINT#1,"OUTPUT08;V12X"        view configuration 12
PRINT#1,"ENTER08"
INPUT#2,A$
PRINT A$                       display shows
                        S018C5F2G2I00K1M016P0R1Y2D0000000000Z
```

This message is interpreted as follows:

S018	Configuration 18
C5	All ports are outputs
F2	ASCII Binary data format
G2	Only output port data sent when addressed to talk
I0	Data lines are active high
K1	EOI disabled
M16	SRQ on Ready
P0	All ports are selected
R1	Data is latched on EDR transition
Y2	Terminator is CR only
D0000000000Z	All I/O lines are low

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View Version V?

The `View Version` command is used to look at the firmware revision level of the ROM. In response to this command, the Digital488/80 will return a number in the following format *.* where each * is a 1 digit number. The `Execute` (`X`) command is not needed since the `View Version` command is a query command.

Examples:

```
PRINT#1,"CLEAR08"          reset the Digital488/80
PRINT#1,"OUTPUT08;V?"      request firmware revision level
PRINT#1,"ENTER08"          read data from the Digital488/80
INPUT#2,A$
PRINT A$                   display shows 1.0 (or higher)
```


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Execute X

Commands sent to the Digital488/80 will result in no action until the unit is instructed to execute these commands. This is done by sending an `X`, usually as the last character of a command string. Commands sent without an `X` are stored in an internal buffer until an `X` is received. Any number of `Execute` commands may be inserted into the same command string. Certain commands, such as `Bit Set (An)` require an `X` after each command in a string if more than one of that command is within the same string.

Examples:

`PRINT#1,"CLEAR08"`	reset the Digital488/80
`PRINT#1,"OUTPUT08;F2"`	send "F2" to the Digital488/80 command input buffer
`PRINT#1,"OUTPUT08;X"`	instruct the Digital488/80 to execute its command input buffer
`PRINT#1,"OUTPUT08;A1XA2X"`	two `Bit Set (An)` commands are within the same string, requiring an `X` after each command.

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Terminator Yn

The IEEE 488 bus terminator defaults at power-on to the `Terminator` setting saved in configuration `0` (the power-on configuration). It also may be programmed for any combination of Carriage Return (CR) and Line Feed (LF). The `Y0` mode is the most commonly accepted terminator, CR-LF. `Y1` reverses the sequence to send LF-CR. `Y2` sends CR only and `Y3` sends LF only.

`Y0` CR LF
`Y1` LF CR
`Y2` CR only
`Y3` LF only
`Y?` Return present `Terminator` selection

Example:

```
PRINT#1,"OUTPUT08;Y3X"
```
select line feed terminator

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Query ?

All Digital488/80 commands offer a Query (?) option which may be used to determine the present configuration or mode of a command previously executed. To use this option, the first letter of the command is used followed by a question mark (?). Any number of these query commands may be combined into one string to allow the user to construct a specialized status command requesting the Digital488/80 to return only that information which is of interest for a given application. The Execute (X) command is not needed when using the Query option.

? Return the present configuration or mode of the command preceding the ?
Examples:

```
PRINT#1,"CLEAR08"          reset the Digital488/80
PRINT#1,"OUTPUT08;M4X"     select SRQ on Bus error
PRINT#1,"OUTPUT08;M?"      determine last M command executed
PRINT#1,"ENTER08"          read data from the Digital488/80
INPUT#2,A$
PRINT A$                   display shows  M4


PRINT#1,"OUTPUT08;U0X"     request the status of  Channel 1
PRINT#1,"ENTER08"          read data from the Digital488/80
INPUT#2,A$
PRINT A$                   display shows  status message
                          *.*C#E#F#G#I###K#L####M###P#R#S##Y#
```

Using the Query command to return the same status message:

```
PRINT#1,"OUTPUT08;V?C?E?F?G?I?K?L?M?P?R?S?Y?X"
                           request the status of  Channel 1
PRINT#1,"ENTER08"          read data from the Digital488/80
INPUT#2,A$
PRINT A$                   display shows  status message
                             *.*C#E#F#G#I###K#L####M###P#R#S##Y#
```


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Serial Poll Status Byte

The Serial Poll Status byte is sent upon receiving the serial poll (SPOLL) command from the controller. Refer to the Service Request Mask (Mn) command description for details on how the Serial Poll byte is affected. To enable each bit to reflect the true status of the device, the appropriate Mn command must be excecuted. Below is a description of the significance of each bit in the Serial Poll Status byte.

Bit Location	Value	(SRQ Bit Value if set to logic 1)
DIO1 (LSB)	1	Service Input transition
DIO2	2	EDR input transition
DIO3	4	Bus error
DIO4	8	Not used,always 0
DIO5	16	Ready for more commands
DIO6	32	Not used, always 0
DIO7	64	Service Request bit
DIO8 (MSB)	128	not assigned, always 0

Serial Poll Bit Description

DIO1 When enabled by the M1 command, DIO1 is set by a transition on the Service Input line (active transition state determined by the Invert (I64)) command. DIO1 is cleared after the controller serial polls the Digital488/80.

DIO2 When enabled by the M2 command, DIO2 is set on an EDR transition (active transition state determined by the Invert (I32) command). DIO2 is cleared after the controller serial polls the Digital488/80.

DIO3 DIO3 is set when an invalid command is sent to the Digital488/80. The M4 command will enable a Service Request to occur when an invalid command is received. The bit is cleared after the controller sends a Status (U0) command and reads the status string from the Digital488/80.

DIO4 DIO4 is not used, and is always a logic zero.

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DIO5 The DIO5 bit is set after an entire command string has been received and processed by the Digital488/80. The bit is cleared while the Digital488/80 is processing commands which have been received from the controller. When used with the M16 command, a Service Request will also be generated when the DIO5 bit is set. An Execute (X) command must be received before the DIO5 bit can be cleared.

DIO6 DIO6 is not used, and is always a logic zero.

DIO7 When the Digital488/80 generates a Service Request, the DIO7 bit will be set . This is used by the controller to determine that the Service Request was generated by the Digital488/80.

DIO8 DIO8 is not used, and is always a logic zero.

Example:

```
PRINT#1,"CLEAR08"          reset the Digital488/80
PRINT#1,"OUTPUT08;M4X"     select SRQ on Bus error
PRINT#1,"OUTPUT08;F7X"     send an invalid bus command.
                           ERROR and SRQ LEDs should illuminate
PRINT#1,"SPOLL08"          display should be 84 (64+16+4)
```

64 denotes the Digital488/80 was the source of the SRQ. 16 denotes the Digital488/80 is READY for more commands. 4 denotes a Bus error.

When serial polled,the SRQ LED will turn off.

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IEEE 488 Primer

4.1 HISTORY

The **IEEE 488** bus is an instrumentation communication bus adopted by the Institute of Electrical and Electronic Engineers in 1975 and revised in 1978. The **Digital488** conforms to this most recent revision designated **IEEE 488-1978.**

Prior to the adoption of this standard, most instrumentation manufacturers offered their own versions of computer interfaces. This placed the burden of system hardware design on the end user. If his application required the products of several different manufacturers, then he might need to design several different hardware and software interfaces. The popularity of the **IEEE 488** interface (sometimes called the **General Purpose Interface Bus** or **GPIB**) is due to the total specification of the electrical and mechanical interface as well as the data transfer and control protocols. The use of the **IEEE 488** standard has moved the responsibility of the user from design of the interface to design of the high level software that is specific to the measurement application.

4.2 GENERAL STRUCTURE

The main purpose of the **GPIB** is to transfer information between two or more devices. A device can either be an instrument or a computer. Before any information transfer can take place, it is first necessary to specify which will do the talking (send data) and which devices will be allowed to listen (receive data). The decision of who will talk and who will listen usually falls on the **System Controller** which is, at power on, the **Active Controller**.

The **System Controller** is similar to a committee chairman. On a well run committee, only one person may speak at a time and the chairman is responsible for recognizing members and allowing them to have their say. On the bus, the device which is recognized to speak is the **Active Talker**. There can only be one Talker at a time if the information transferred is to be clearly understood by all. The act of "giving the floor" to that device is called **Addressing to Talk**. If the committee chairman can not attend the meeting, or if other matters require his attention, he can appoint an acting chairman to take control of the proceedings. For the **GPIB**, this device becomes the **Active Controller**.

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At a committee meeting, everyone present usually listens. This is not the case with the **GPIB**. The **Active Controller** selects which devices will listen and commands all other devices to ignore what is being transmitted. A device is instructed to listen by being **Addressed to Listen**. This device is then referred to as an **Active Listener**. Devices which are to ignore the data message are instructed to **Unlisten**.

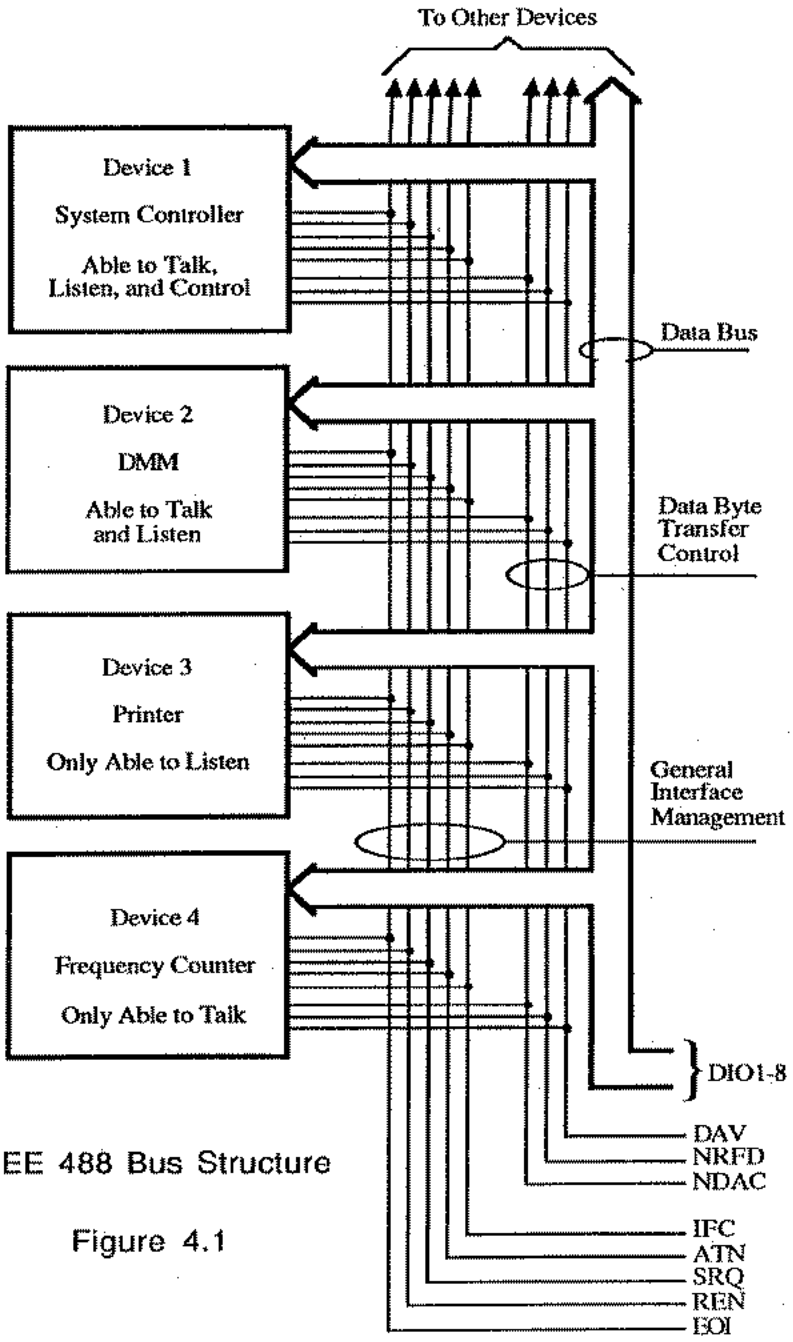
The reason some devices are instructed to **Unlisten** is quite simple. Suppose a college instructor is presenting the day's lesson. Each student is told to raise their hand if the instructor has exceeded their ability to keep up while taking notes. If a hand is raised, the instructor stops his discussion to allow the slower students the time to catch up. In this way, the instructor is certain that each and every student receives all the information he is trying to present. Since there are a lot of students in the classroom, this exchange of information can be very slow. In fact, the rate of information transfer is no faster than the rate at which the slowest note-taker can keep up. The instructor, though, may have a message for one particular student. The instructor tells the rest of the class to ignore this message (**Unlisten**) and tells it to that one student at a rate which he can understand. This information transfer can then happen much quicker, because it need not wait for the slowest student.

The **GPIB** transfers information in a similar way. This method of data transfer is called **handshaking**. More on this later.

For data transfer on the **IEEE 488**, the **Active Controller** must...

a) **Unlisten** all devices to protect against eavesdroppers.
b) Designate who will **talk** by **addressing** a device to **talk**.
c) Designate all the devices who are to **listen** by **addressing** those devices to **listen**.
d) Indicate to all devices that the data transfer can take place.

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IEEE 488 Bus Structure

Figure 4.1

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4.3 SEND IT TO MY ADDRESS

In the previous discussion, the terms **Addressed to Talk** and **Addressed to Listen** were used. These terms require some clarification.

The **IEEE 488** standard permits up to 15 devices to be configured within one system. Each of these devices must have a unique address to avoid confusion. In a similar fashion, every building in town has a unique address to prevent one home from receiving another home's mail. Exactly how each device's address is set is specific to the product's manufacturer. Some are set by DIP switches in hardware, others by software. Consult the manufacturer's instructions to determine how to set the address.

Addresses are sent with **universal (multiline)** commands from the **Active Controller**. These commands include **My Listen Address** (MLA), **My Talk Address** (MTA), **Talk Address Group** (TAG), and **Listen Address Group** (LAG).

4.4 BUS MANAGEMENT LINES

Five hardware lines on the **GPIB** are used for bus management. Signals on these lines are often referred to as **uniline** (single line) commands. The signals are active low, i.e. a low voltage represents a logic "1" (asserted), and a high voltage represents a logic "0" (unasserted).

4.4.1 Attention (ATN)

ATN is one of the most important lines for bus management. If Attention is asserted, then the information contained on the data lines is to be interpreted as a multiline command. If it is not, then that information is to be interpreted as data for the **Active Listeners**. The **Active Controller** is the only bus device that has control of this line.

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4.4.2 Interface Clear (IFC)

The **IFC** line is used only by the **System Controller**. It is used to place all bus devices in a known state. Although device configurations vary, the **IFC** command usually places the devices in the Talk and Listen Idle states (neither **Active Talker** nor **Active Listener**).

4.4.3 Remote Enable (REN)

When the **System Controller** sends the **REN** command, bus devices will respond to remote operation. Generally, the **REN** command should be issued before any bus programming is attempted. Only the **System Controller** has control of the **Remote Enable** line.

4.4.4 End or Identify (EOI)

The **EOI** line is used to signal the last byte of a multibyte data transfer. The device that is sending the data asserts **EOI** during the transfer of the last data byte. The **EOI** signal is not always necessary as the end of the data may be indicated by some special character such as carriage return.

The **Active Controller** also uses **EOI** to perform a **Parallel Poll** by simultaneously asserting **EOI** and **ATN**.

4.4.5 Service Request (SRQ)

When a device desires the immediate attention of the **Active Controller** it asserts **SRQ**. It is then the Controller's responsibility to determine which device requested service. This is accomplished with a **Serial Poll** or a **Parallel Poll**.

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4.5 HANDSHAKE LINES

The **GPIB** uses three handshake lines in an "I'm ready - Here's the data - I've got it" sequence. This handshake protocol assures reliable data transfer, at the rate determined by the slowest Listener. One line is controlled by the Talker, while the other two are shared by all Active Listeners. The handshake lines, like the other **IEEE 488** lines, are active low.

4.5.1 Data Valid (DAV)

The **DAV** line is controlled by the **Talker**. The **Talker** verifies that **NDAC** is asserted (active low) which indicates that all Listeners have accepted the previous data byte transferred. The **Talker** then outputs data on the bus and waits until **NRFD** is unasserted (high) which indicates that all Addressed Listeners are ready to accept the information. When **NRFD** and **NDAC** are in the proper state, the **Talker** asserts **DAV** (active low) to indicate that the data on the bus is valid.

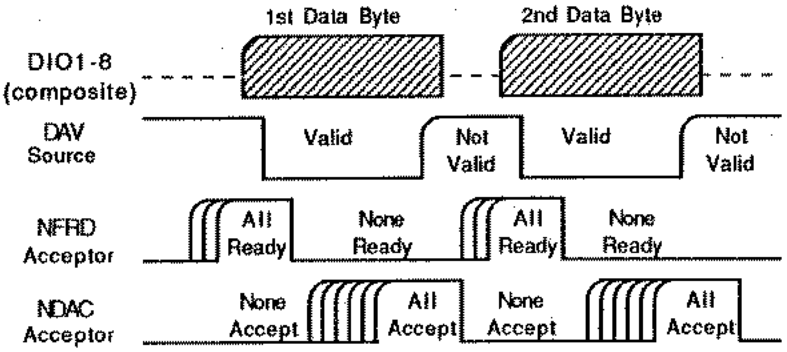
4.5.2 Not Ready for Data (NRFD)

This line is used by the **Listeners** to inform the **Talker** when they are ready to accept new data. The **Talker** must wait for each **Listener** to unassert this line (high) which they will do at their own rate when they are ready for more data. This assures that all devices that are to accept the information are ready to receive it.

4.5.3 Not Data Accepted (NDAC)

The **NDAC** line is also controlled by the **Listeners**. This line indicates to the **Talker** that each device addressed to listen has accepted the information. Each device releases **NDAC** (high) at its own rate, but the **NDAC** will not go high until the slowest Listener has accepted the data byte.

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IEEE Bus Handshaking

4.6 DATA LINES

The **GPIB** provides eight data lines for a bit parallel/byte serial data transfer. These eight data lines use the convention of **DIO1** through **DIO8** instead of the binary designation of **D0** to **D7**. The data lines are bidirectional and are active low.

4.7 MULTILINE COMMANDS

Multiline (bus) commands are sent by the **Active Controller** over the data bus with **ATN** asserted. These commands include addressing commands for talk, listen, Untalk and Unlisten.

4.7.1 Go To Local (GTL)

This command allows the selected devices to be manually controlled. ($01)

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4.7.2 Listen Address Group (LAG)

There are 31 (0 to 30) listen addresses associated with this group. The 3 most significant bits of the data bus are set to 001 while the 5 least significant bits are the address of the device being told to listen.

4.7.3 Unlisten (UNL)

This command tells all bus devices to Unlisten. The same as Unaddressed to Listen. ($3F)

4.7.4 Talk Address Group (TAG)

There are 31 (0 to 30) talk addresses associated with this group. The 3 most significant bits of the data bus are set to 010 while the 5 least significant bits are the address of the device being told to talk.

4.7.5 Untalk (UNT)

This command tells bus devices to Untalk. The same as Unaddressed to Talk. ($5F)

4.7.6 Local Lockout (LLO)

Issuing the **LLO** command prevents manual control of the instrument's functions. ($11)

4.7.7 Device Clear (DCL)

This command causes all bus devices to be initialized to a pre-defined or power up state. ($14)

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4.7.8 Selected Device Clear (SDC)

This causes a single device to be initialized to a pre-defined or power up state. ($04)

4.7.9 Serial Poll Disable (SPD)

The **SPD** command disables all devices from sending their Serial Poll status byte. ($19)

4.7.10 Serial Poll Enable (SPE)

A device which is Addressed to Talk will output its Serial Poll status byte after **SPE** is sent and **ATN** is unasserted. ($18)

4.7.11 Group Execute Trigger (GET)

This command usually signals a group of devices to begin executing a triggered action. This allows actions of different devices to begin simultaneously. ($08)

4.7.12 Take Control (TCT)

This command passes bus control responsibilities from the current **Controller** to another device which has the ability to control. ($09)

4.7.13 Secondary Command Group (SCG)

These are any one of the 32 possible commands (0 to 31) in this group. They must immediately follow a talk or listen address. ($60 to $7F)

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4.7.14 Parallel Poll Configure (PPC)

This configures devices capable of performing a **Parallel Poll** as to which data bit they are to assert in response to a **Parallel Poll**. ($05)

4.7.15 Parallel Poll Unconfigure (PPU)

This disables all devices from responding to a **Parallel Poll**. ($15)

4.8 MORE ON SERVICE REQUESTS

Most of the commands covered, both uniline and multiline, are the responsibility of the **Active Controller** to send and the bus devices to recognize. Most of these happen routinely by the interface and are totally transparent to the system programmer. Other commands are used directly by the user to provide optimum system control. Of the uniline commands, **SRQ** is very important to the test system and the software designer has easy access to this line by most devices. Service Request is the method by which a bus device can signal to the **Controller** that an event has occurred. It is similar to an interrupt in a microprocessor based system.

Most intelligent bus peripherals have the ability to assert **SRQ**. A DMM might assert it when its measurement is complete, if its input is overloaded or for any of an assortment of reasons. A power supply might **SRQ** if its output has current limited. This is a powerful bus feature that removes the burden from the **System Controller** to periodically inquire, "Are you done yet?". Instead, the **Controller** says, "Do what I told you to do and let me know when you're done" or "Tell me when something is wrong."

Since **SRQ** is a single line command, there is no way for the **Controller** to determine which device requested the service without additional information. This information is provided by the multiline commands for **Serial Poll** and **Parallel Poll**.

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4.8.1 Serial Poll

Suppose the **Controller** receives a service request. For this example, let's assume there are several devices which could assert **SRQ**. The **Controller** issues an **SPE** (Serial Poll enable) command to each device sequentially. If any device responds with DIO7 asserted it indicates to the **Controller** that it was the device that asserted **SRQ**. Often times the other bits will indicate why the device wanted service. This **Serial Polling** sequence, and any resulting action, is under control of the software designer.

4.8.2 Parallel Poll

The **Parallel Poll** is another way the **Controller** can determine which device requested service. It provides the who but not necessarily the why. When bus devices are configured for Parallel Poll, they are assigned one bit on the data bus for their response. By using the Status bit, the logic level of the response can be programmed to allow logical OR/AND conditions on one data line by more than one device. When **SRQ** is asserted, the **Controller** (under user's software) conducts a **Parallel Poll**. The **Controller** must then analyze the eight bits of data received to determine the source of the request. Once the source is determined, a **Serial Poll** might be used to determine the why.

Of the two polling types, the **Serial Poll** is the most popular due to its ability to determine the who and why. In addition, most devices support **Serial Poll** only.

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Service Information

5.1 Factory Service

IOtech maintains a factory service center in Cleveland, Ohio. If problems are encountered in using the **Digital488/80** you should first telephone the factory. Many problems can be resolved by discussing the problems with our applications department. If the problem cannot be solved by this method, you will be instructed as to the proper return procedure.

5.2 Theory of Operation

The Heart of the **Digital488/80** is a 6809 microprocessor [U101] supported by 8K bytes of firmware EPROM [U102] and 32K bytes of battery-backed-up RAM [U103]. Interface to the IEEE 488 bus is accomplished by a 9914 interface chip [U105]. A 65C22 [U104] generates real-time interrupts for the firmware operating system and also drives the front panel LEDs.

The digital I/O prts are controlled through 6821 interface chips [U109 - U114]. High-voltage, high-current output capability is optionally provided on Channel 1 through 74HCTLS240s and ULN2803A peripheral drivers [U116 - U125].

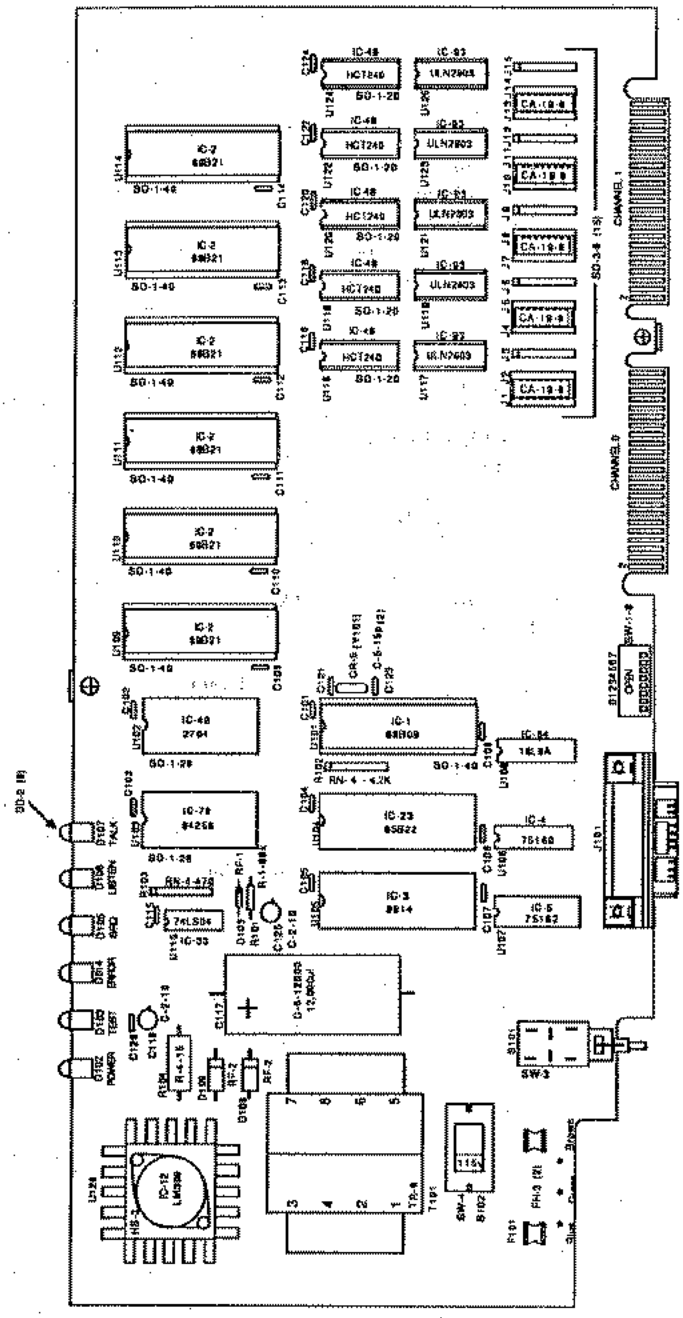
Power is supplied by an on-board transformer and full-wave rectifier. Regulation to the required +5 volts is provided by an LM309K [U126].

The Memory space allocation on the Digital488/80 is...

Address	Device	Part Number	Function
$0000-$7FFF	U103	84256	32K x 8 RAM
$8010-$8014	U109	6821	Digital I/O
$8020-$8024	U110	6821	Digital I/O
$8040-$8044	U111	6821	Digital I/O
$8080-$8084	U112	6821	Digital I/O
$8100-$8104	U113	6821	Digital I/O
$8200-$8204	U114	6821	Digital I/O
$8800-$8810	U104	65C22	Timer, Digital I/O
$9000-$9907	U105	TMS9914A	IEEE488 Interface
$E000-$FFFF	U102	2764	Programmed EPROM

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5.3 Digital488/80 Component Layout



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5.4 Digital488/80 Replaceable Parts List

Schematic	Part Number	Description
C101-C116	C-5-.1	Ceramic, 25v
C118,C124	C-5-.1	Ceramic, 25v
C120-C122	C-5-.1	Ceramic, 25v
C126	C-5-.1	Ceramic, 25v
C121,C123	C-5-15p	Ceramic, 25v
C119,C125	C-2-10	Electrolytic, 25v
C117	C-6-12000	Electrolytic, 25v
Not shown	CN-35	Power Connector
D103	RF-1	Small Signal Diode
D108-D109	RF-2	3A Diode
D102-D107	DD-2	Red PC Mount
F101	FH-3	Fuse Clip
Not shown	FH-4	Fuse Holder
J101	CN-2	IEEE 488 Connector
R101	R-1-68K	68KΩ, 1/4w carbon
R104	R-4-15	15 Ω, 2W
R102	RN-4-4.7K	4.7KΩ x 7 SIP
R103	RN-2-470	470Ω x 5 SIP
S101	SW-3	DPDT Push-Push
S102	SW-4	DPDT Slide 110/220
T101	TR-6	Transformer 10v @1.2A
SW-1-8	SW-1-8	8 Pole Piano Switch
U108	Digital488/80-600	Programmed EPROM
U104	IC-23	65B22 Versitile Interface Adapter
U106	IC-4	SN75160BN IEEE Driver
U107	IC-5	SN75162BN IEEE Driver
U113	IC-33	74LS04 Hex Inverter
U101	IC-1	MC68B09P Microprocessor
U126	IC-12	LM309 Regulator, + 5v
U109-U114	IC-2	68B21 PIA
U105	IC-3	TMS9914ANL IEEE Controller
U115	IC-33	74LS04
U116,U118	IC-48	74LS240 Octal Buffer
U120,U122	IC-48	74LS240 Octal Buffer
U124	IC-48	74LS240 Octal Buffer
U117,U119	IC-93	ULN2803 Relay Drivers
U121,U123	IC-93	ULN2803 Relay Drivers
U125	IC-93	ULN2803 Relay Drivers
Y101	CR-5	8.0000 MHz Crystal

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Command	Code	Description
Bit Set	**An**	Set bit n (n = 1 thru 40) of selected channel (0 or 1)
	A?	Return n (1 thru 40) of last bit set of selected channel
Bit Clear	**Bn**	Clear bit n (1 thru 40) of selected channel (0 or 1)
	B?	Return n (1 thru 40) of last bit cleared of selected channel
Buffer	**L0**	Clear data buffer
	L?	Return number of readings in the data buffer
Bus Input/Output	**G0**	Input and Output port data sent when addressed to talk
	G1	Only Input port data sent when addressed to talk
	G2	Only Output port data sent when addressed to talk
	G3	Buffered data sent when addressed to talk
	G?	Return present Bus Output mode
Configure	**C0**	All ports of selected channel (0 or 1) are inputs
	C1	Port 1 is an output, ports 2 thru 5 are inputs
	C2	Ports 1 and 2 are outputs, ports 3 thru 5 are inputs
	C3	Ports 1 thru 3 are outputs, ports 4 and 5 are inputs
	C4	Ports 1 thru 4 are outputs, port 5 is an input
	C5	All ports of selected channel are outputs
	C?	Return present port configuration of selected channel
Data	**Dn..Z**	Data to be output on selected channel (0 or 1) is entered after "D" and terminated by "Z"
Data Ready	**R0**	Data is read when system is addressed to talk
	R1	Data is latched on EDR transition
	R2	Data is latched and buffered on EDR transition
	R?	Return present Data Ready mode
EOI	**K0**	EOI enabled
	K1	EOI disabled
	K?	Return present EOI selection
Error	**E?**	Return and clear present error condition

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Keyboard Controller Program

The Keyboard Controller Program is a simple BASIC program that accepts commands from the keyboard and sends them to Personal488. It then displays any responses from Personal488 on the screen. The Keyboard Controller Program is a convenient method of exercising the Digital488/80 and becoming familiar with the commands and their actions.

```
10 ' Personal488 Keyboard Controller Program
20 '
30 ' For use with the IOtech Personal488
40 ' IEEE 488 interface
50 '
100 OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1
110 IOCTL#1,"BREAK"
120 PRINT#1,"RESET"
130 OPEN "\DEV\IEEEIN" FOR INPUT AS #2
140 '
150 ON ERROR GOTO 300
160 PRINT#1,"ERROR OFF"
170 '
180 LINE INPUT "CMD> ",CMD$
190 PRINT#1,CMD$
200 '
210 IF IOCTL$(2)<>"1" THEN 180
220 PRINT INPUT$(1,2);
230 GOTO 210
290 '
300 ' Error Handler
310 '
320 IOCTL#1,"BREAK"
330 PRINT#1,"STATUS"
340 INPUT#2,ST$
350   PRINT   CHR$(7);"Error   #";MID$(ST$,15,2);":
";MID$(ST$,27)
360 RESUME NEXT
```


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