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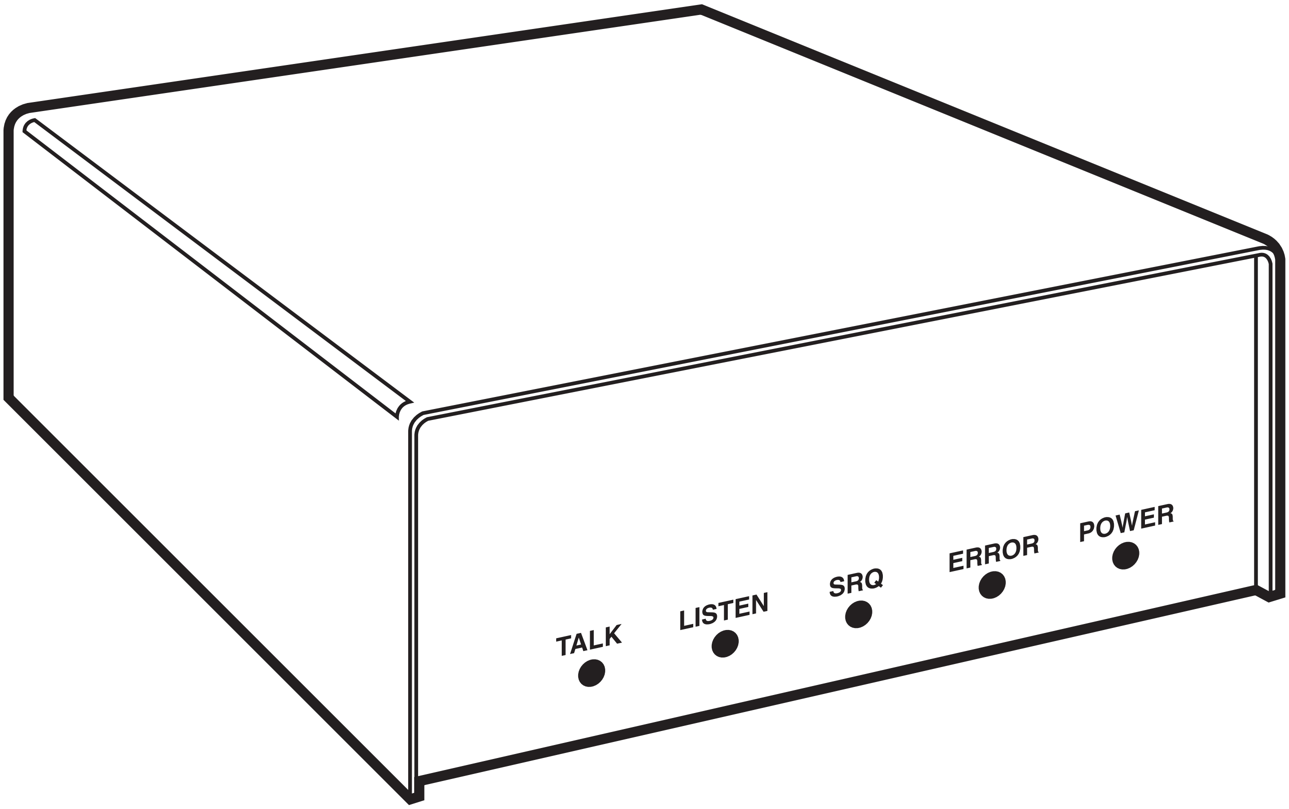
488 Controller



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To maintain safety, emission, and immunity standards of this declaration, the following conditions must be met.

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- All cable screw locks must be tightened at both ends of the cable.
- The host computer must be properly grounded.
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- The operator must observe all safety cautions and operating conditions specified in the documentation for all hardware used.
- The host computer, peripheral equipment, power sources, and expansion hardware must be CE compliant.
- All power must be off to the device and externally connected equipment before internal access to the device is permitted.
- An external power supply is provided with this product. Its input is 105 to 125 VAC or 210 to 250 VAC, 50-60 Hz, 10 VA maximum power draw. Its 9-VDC output connects to the power input of the unit (marked 10VDC MAX @ 500 mA).
- The RS-232/422 terminal is meant to be connected only to devices with serial-communications-level signals. The IEEE 488 terminal is meant to be used only with non-isolated IEEE 488 systems. The common mode voltage (cable shell to earth) must be zero.
- Terminal Installation Category for CE Compliance is Category 1.
- Operating environment for CE compliance is: Indoor use at altitudes below 2000 m, 0 to 40°C, 80% maximum RH up to 31°C decreasing linearly 4%RH/°C to 40°C.
- Regarding DC power input: Please note that the power input is marked 10VDC MAX @ 600 mA. This is just something to check; check your equipment's power input labels for "600 mA" (or even 500 mA).

WARNING!

Noted conditions pertain to potential safety hazards. When you see the WARNING!, IMPORTANT!, or CAUTION! notes, carefully read the information and be alert to the possibility of personal injury.

Failure to follow these directives voids emissions and immunity compliance.

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1. Specifications

488 Controller

IEEE 488-1978 Implementation —	C1, C2, C3, C4, and C28 controller subsets. SH1, AH1, T6, TE0, L4, LE0, SR1, RL0, PP0, DC1, DT1, E1.
Terminators —	Selectable CR, LF, LF-CR, and CR-LF with EOI.
Connector —	Standard IEEE 488 connector with metric studs.

Serial Interface

EIA RS-232C —	AB, BA, BB, CA, CB
EIA RS-422A —	Balanced voltage on TxD and RxD.
Character Set —	Asynchronous bit serial.
Output Voltage —	±5 volts min (RS-232C); 3.5 volts typical (RS-422A)
Input Voltage —	±3 volts min.; ±15v max.
Baud Rate —	Selectable 110, 300, 600, 1200, 1800, 2400, 3600, 4800, 7200, 9600, 19,200 and 57,600.
Data Format —	Selectable 7 or 8 data bits; 1 or 2 stop bits; odd, even, mark, space and no parity on transmit.
Duplex —	Full with Echo/No Echo.
Serial Control —	Selectable CTS/RTS or XON/XOFF.
Terminators —	Selectable CR, LF, LF-CR, and CR-LF.
Connector —	25-pin Sub-D male. RS-232C DCE configured.

General

Data Buffer —	32,000 characters total, dynamically allocated.
Indicators —	LEDs for Talk, Listen, SRQ, Error and Power
Power —	105-125V or 210-250V; 50-60 Hz, 10 VA Max.
Size —	2.7"H x 5.5"W x 7.4"D (6.9 x 14 x 18.8 cm)
Weight —	3.6 lb. (1.6 kg)
Environment —	0 to 50 degrees Centigrade; 0 to 70% R.H. to 35 degrees Centigrade. Linearly derate 3% R.H./degrees Centigrade from 35 to 50 degrees Centigrade.
Controls —	Power Switch (external), IEEE and Serial parameter switches (internal). Jumper selection of RS-232 or RS-422 operation (internal).
Certification —	FCC, CE

WARNING!

Do not use this interface outdoors. The interface is intended for indoor use only. Using this equipment outdoors could result in equipment failure, bodily injury, or death.

CAUTION

Do not connect AC line power directly to the 488 Controller. Direct AC connection will damage equipment.

2. Introduction

2.1 Description

The 488 Controller converts a host RS-232 or RS-422 computer into an IEEE 488 bus talker, listener and controller. The 488 Controller provides full IEEE 488-1978 bus implementation including advance capabilities such as PASS CONTROL, RECEIVE CONTROL, PARALLEL POLL, SERIAL POLL and SECONDARY ADDRESSING. The device may be located several hundred feet from the host and may control as many as fourteen 488 bus instruments. In the noncontroller mode the 488 Controller converts the host into a bus peripheral for data processing and mass storage.

The 488 Controller interprets simple high-level commands sent from the computer's serial port and performs the necessary, and usually complex, bus control and handshaking. The commands and protocol are similar to those used by the Hewlett-Packard® HP-85 computer.

Additional features provide a transparent IEEE to serial converter and a serial to IEEE pass-thru controller.

As a serial-to-IEEE-488 converter, the 488 Controller receives data from a serial host, then automatically performs the bus sequences necessary to send this data to the IEEE 488 device. If desired, data can be requested from the IEEE 488 device and returned to the host.

As an IEEE-488-to-serial converter, the 488 Controller is a peripheral to an IEEE 488 controller. Data received from the controller is sent to the serial device and data received from the serial device is buffered for transmission to the IEEE 488 controller. The 488 Controller can inform the host, by the serial poll-status byte, that it has received data from the serial device.

2.2 Abbreviations

The following IEEE 488 abbreviations are used throughout this manual.

addr n	IEEE bus address “n”
ATN	Attention line
CA	Controller Active
CO	Controller
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
PE	Peripheral
PPC	Parallel Poll Configure
PPU	Parallel Poll Unconfigure
REN	Remote Enable
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

3. Getting Started

3.1 Inspection

The 488 Controller was carefully inspected, both mechanically and electrically, prior to shipment. When you receive it carefully unpack all items from the shipping carton and check for any obvious signs of damage that may have occurred during shipment. Immediately report any damage found to the shipping agent. Remember to retain all shipping materials in the event that shipment back to the factory becomes necessary.

Every 488 Controller is shipped with the following:

- 488 Controller
- This instruction manual
- Power supply

3.2 Configuration

Three DIP switches internal to the 488 Controller set the configuration of the interface.

NOTE

Selectable functions are read *only* at power-on and should only be set prior to applying power to the interface.

The following figures illustrate the factory default conditions, which are:

Serial Port:

9600 Baud

8 Data Bits

2 Stop Bits

No Parity

Serial Terminator = CR-LF

Echo Disabled

RTS/CTS Handshake

IEEE:

Mode = System Controller

Address = 10

Bus Terminator = CR-LF; EOI Disabled

Talk-back Enabled

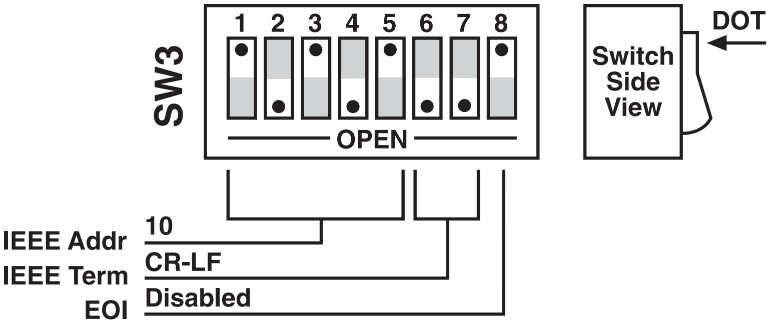


Figure 3-1. SW3 Factory-Default Settings.

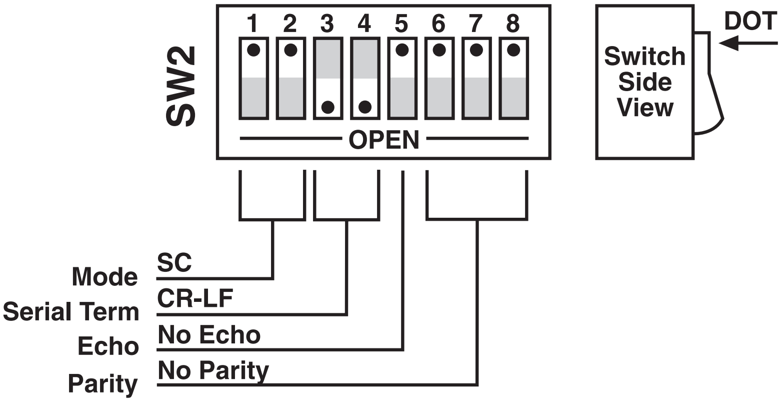


Figure 3-2. SW2 Factory-Default Settings.

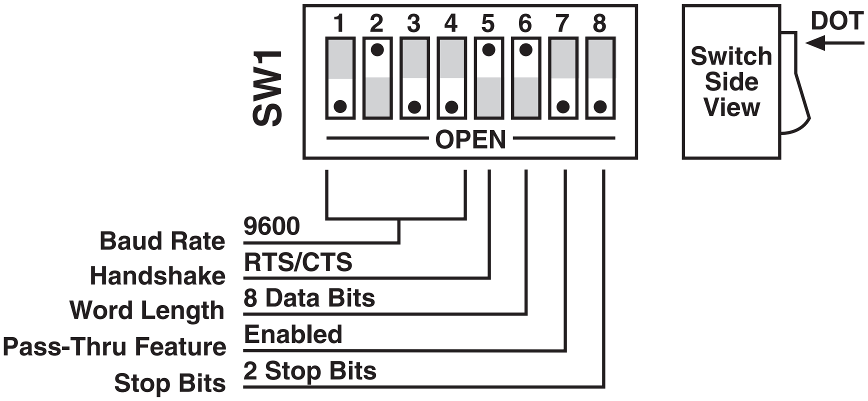


Figure 3-3. SW1 Factory-Default Settings.

Note that the 488 Controller comes configured as an IEEE controller. In this mode the 488 Controller is designed to allow an RS-232 host computer to control up to 14 IEEE 488 devices. This mode of operation is described in detail, along with its command descriptions, in **Chapters 4** and **5**. These sections also cover the peripheral mode of operation.

The 488 Controller can be configured to transparently communicate with a single IEEE peripheral, such as a plotter. This Controller Pass-Thru mode is described in detail in **Chapter 6**.

The 488 Controller may also be configured as a transparent IEEE Pass-Thru Peripheral. As a Pass-Thru Peripheral, it allows an IEEE controller to communicate with an RS-232 device. The Peripheral Pass-Thru mode of operation is described in detail in **Chapter 7**.

To modify any of these defaults, follow this simple procedure:

1) Disconnect the power supply from the AC line and from the 488 Controller. Also disconnect any IEEE or serial cables prior to disassembly.

WARNING

Never open the 488 Controller's case while it is connected to the AC line. Failure to observe this warning may result in equipment failure, personal injury or death.

2) Place the 488 Controller upside down on a flat surface. Remove the four screws located near the rubber feet.

3) Return the interface to the upright position and carefully remove the top cover.

4) Change whichever DIP-switch settings you need to change.

5) When you have made all of your changes, reverse this procedure to reassemble the 488 Controller.

3.3 Serial-Port Settings

The first parameters to configure are those that correspond to the RS-232 port. These include baud rate, word length, number of stop bits, parity selection and type of RS-232 handshake. Each of these is described in the following sections.

3.3.1 Serial Baud Rate

The "baud rate" is the number of serial bits per second transferred into and out of the serial interface. SW1-1 through SW1-4 determine the serial baud rate. The factory-default baud rate is 9600 baud. Baud rates may be selected from 110 to 57,600 baud. Refer to the following diagram for specific baud rates.

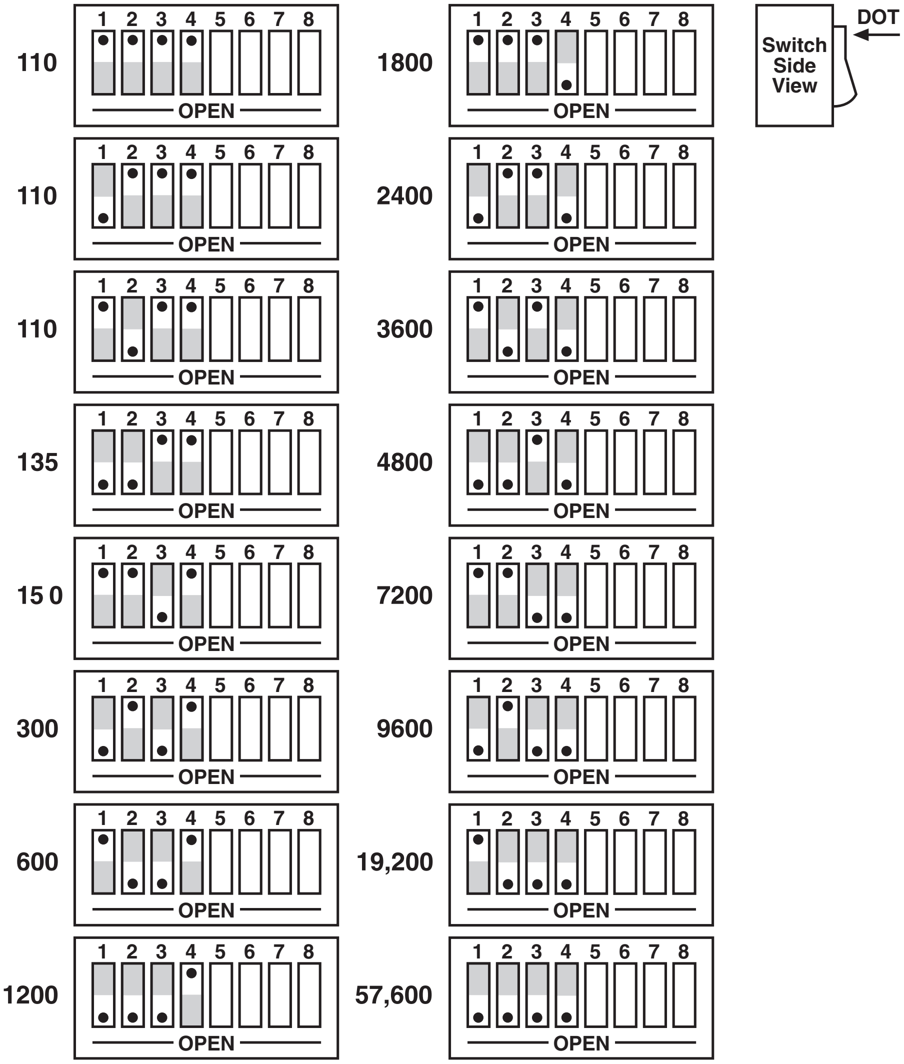


Figure 3-4. Switch SW1: Selecting the Serial Baud Rate.

3.3.2 Serial Word Length (Data Bits)

SW1-6 determines the number of data bits, often referred to as word length, for each serial character transmitted or received. The factory default is 8 data bits.

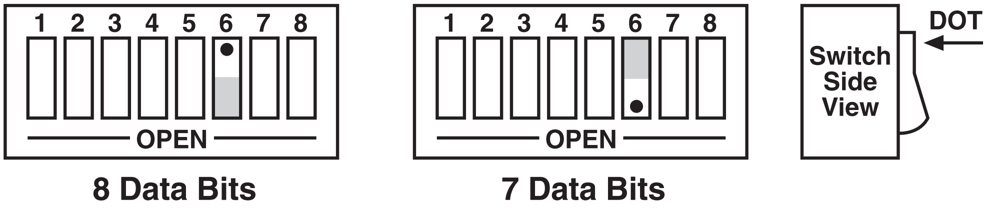
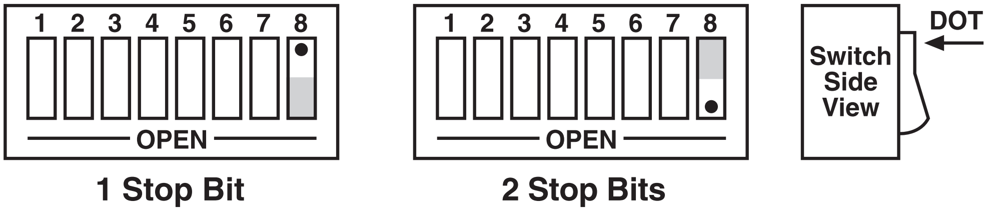


Figure 3-5. Switch SW1: Selecting the Serial Word Length (Data Bits).

3.3.3 Serial Stop Bits

Switch SW1-8 determines the number of stop bits contained in each serial character transmitted and received. The factory default is 2 stop bits.



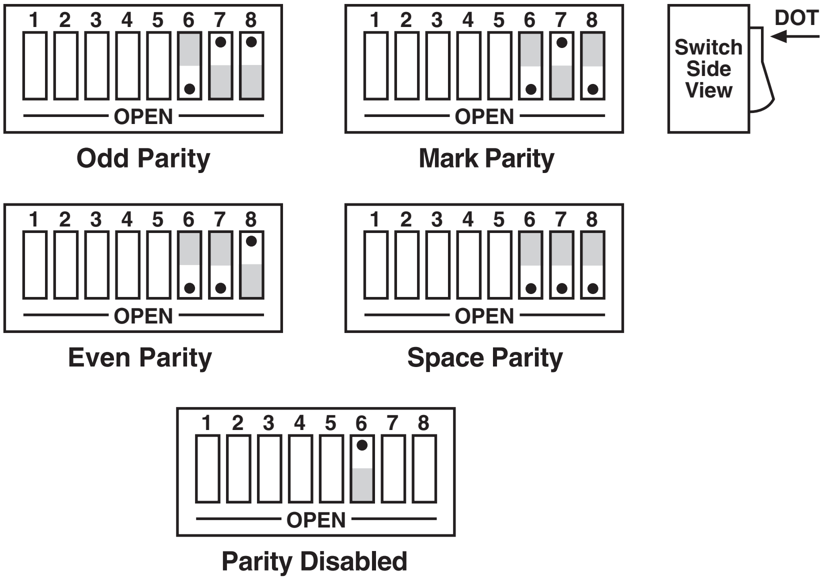
1 Stop Bit

2 Stop Bits

Figure 3-6. Switch SW1: Selecting the Serial Stop Bits.

3.3.4 Serial Parity

Serial Parity is selected with S2-6 through S2-8. The 488 Controller generates the selected parity during serial transmissions but it does not check parity on data that is received. The factory default is parity disabled.



Odd Parity

Mark Parity

Even Parity

Space Parity

Parity Disabled

Figure 3-7. Switch SW2: Selecting the Serial Parity.

3.3.5 Serial Echo

Serial data sent to the 488 Controller will be echoed back to the serial host if SW2-5 is set to the open position. The factory default is Echo Disabled.

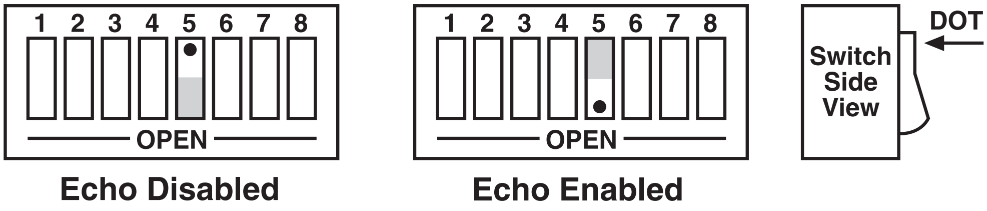


Figure 3-8. Switch SW2: Enabling or Disabling Echo.

3.3.6 Serial Handshake

Switch SW1-5 is used to select hardware [RTS/CTS] or software [X-ON/X-OFF] serial handshake control.

With X-ON/X-OFF, the 488 Controller issues an X-OFF character [ASCII value of &H13] when its buffer memory is near full. When the X-OFF character is sent, there are still more than 1000 character locations remaining to protect against buffer overrun. When it is able to accept more information, the 488 Controller issues an X-ON character [ASCII value of &H11]. The 488 Controller also accepts X-ON/ X-OFF on transmit from the serial host it is communicating with. RTS/CTS serial control becomes inactive when X-ON/X-OFF is enabled. The RTS output is, however, set to an active high state. The CTS input is not used for this handshake and may be left floating (unconnected).

With RTS/CTS, the 488 Controller un-asserts RTS (sets RTS low) when its buffer memory is near full. When RTS is un-asserted, there are still more than 1000 character locations remaining to protect against buffer overrun. When it is able to accept more information, the 488 Controller asserts RTS (sets RTS high). The 488 Controller will not transmit data to the serial host if it detects the CTS input un-asserted (low) when configured for this hardware handshake.

The factory-default serial control is hardware, RTS/CTS.

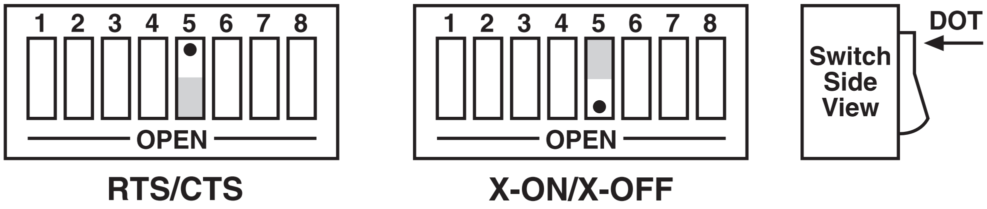


Figure 3-9. Switch SW1: Selecting the Serial Handshake.

3.4 Selecting Terminator Substitution

In the Controller and Peripheral Modes, the 488 Controller is not sensitive as to whether CR or LF is used as a serial input terminator to a command. In general, it requires only one of either to cause command execution. The IEEE input terminator is fixed to LF. The switches that allow terminator selection, shown in the following diagrams, set only the serial output and IEEE output terminators for these modes of operation.

In the transparent Pass-Thru modes, the 488 Controller can be configured to provide RS-232-to-IEEE 488 and IEEE-488-to-RS-232 terminator substitution. This is useful when interfacing an RS-232 device which only issues carriage return [CR] as an output terminator to an IEEE controller which expects a carriage return followed by a line feed [CR-LF].

In the above case, the serial terminator should be selected for CR Only while the IEEE terminator is set to CR-LF. When a serial CR character is received, it is discarded, and an IEEE CR-LF is substituted for it. In the IEEE-to-RS-232 direction, the IEEE CR is unconditionally discarded. Upon receipt of the IEEE LF, a serial CR is substituted.

The 488 Controller can be made totally data transparent in the Pass-Thru modes by setting both the serial and IEEE terminators to be CR Only or LF Only.

3.4.1 Serial Terminator

SW2-3 and SW2-4 select the serial terminators for the serial input (Pass-Thru Modes Only) and output. The factory default is CR-LF.

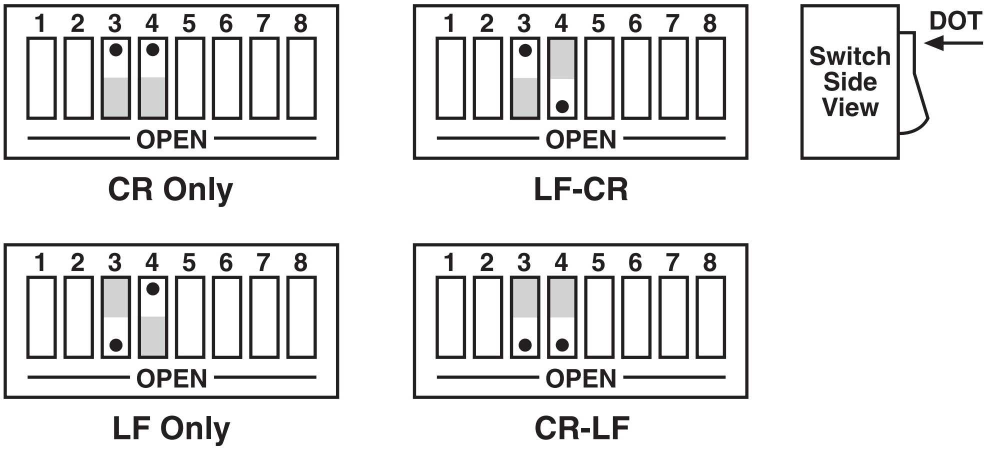


Figure 3-10. Switch SW2: Selecting the Serial Terminator.

3.4.2 IEEE Bus Terminator

SW3-6 through SW3-8 set the IEEE bus terminators used for data sent or received (Pass-Thru modes only) by the 488 Controller. EOI, a line used to signal the end of a multiple character bus transfer, may also be enabled. If enabled, EOI is asserted when the last selected bus terminator is sent. Factory default is CR-LF with EOI disabled.

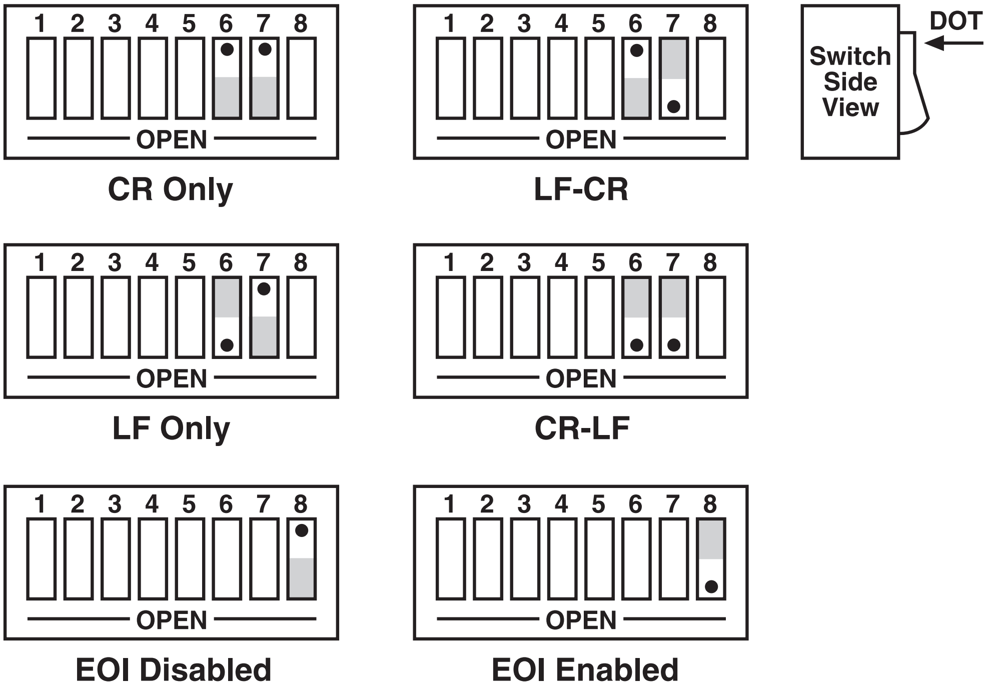


Figure 3-11. Switch SW3: Selecting the IEEE Bus Terminator.

3.5 Selecting the Mode

SW2-1 and SW2-2 set the major operating mode of the 488 Controller. There are four distinct modes of operation.

1. System Controller
2. Peripheral
3. Controller Pass-Thru
4. Peripheral Pass-Thru

As a System Controller, the 488 Controller accepts simple high-level ASCII commands from a serial host. It interprets these commands and performs the required bus action to bi-directionally communicate with up to 14 IEEE devices. As a Peripheral, the 488 Controller becomes a bus device. It accepts simple high-level ASCII commands from a serial host and interprets these commands and status to communicate with another IEEE controller. Applications include computer controlled automatic test systems. These modes of operation are discussed in **Chapters 4** and **5**.

The IEEE Controller Pass-Thru (RS-232 to IEEE Converter) mode allows a serial host device to send data to a single IEEE bus peripheral. Applications include interfacing a listen-only or addressable IEEE printer/plotter to a serial printer port. Refer to **Chapter 6** for more detailed information on the Controller Pass-Thru mode of operation.

The Peripheral Pass-Thru mode is used when interfacing a serial device to an IEEE controller. Data which is sent by the IEEE controller to the 488 Controller is transmitted out its serial port. Data received from the serial device is buffered by the 488 Controller until read by the IEEE controller. Refer to **Chapter 7** for more detailed information on the Peripheral Pass-Thru mode of operation.

The factory default is the System Controller mode.

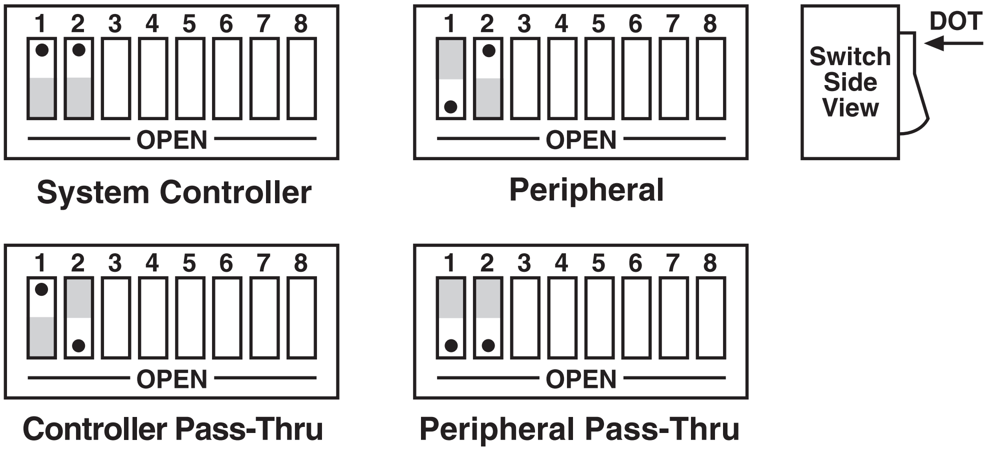


Figure 3-12. Switch SW2: Selecting the Mode.

3.6 Selecting the IEEE Address

SW3-1 through SW3-5 select the IEEE bus address of the 488 Controller when in the System Controller, Peripheral and Peripheral Pass-Thru modes. These same switches are used in the Controller Pass-Thru mode to select the address of the device that will be controlled. (Refer to **Chapter 7** for additional information.) The address is selected by simple binary weighting, with SW3-1 being the least significant bit and SW3-5 the most significant. The factory default is address 10.

Listen Only is a special type of Peripheral Pass-Thru operation. In the Listen Only mode the 488 Controller accepts all data transmitted on the bus, ignoring any bus addressing, and transfers it out its serial port. The 488 Controller is set to Listen Only mode by setting its address to 31. If the IEEE address is set to 31 in the System Controller, Peripheral, or Peripheral Pass-Thru mode, it is adjusted to address 30.

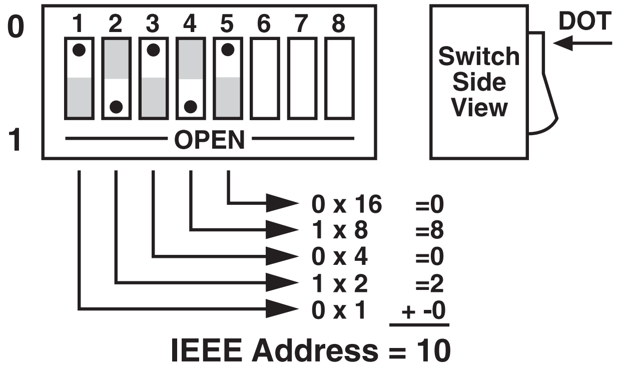


Figure 3-13. Switch SW3: Selecting the IEEE Address.

3.7 Feature Selections

The functions of the remaining switches are dependent on the mode selected. A brief description of each of these features follows. You should refer to the listed sections for additional information.

3.7.1 Controller Pass-Thru Features

In the IEEE Controller (RS-232-to-IEEE-488 converter) mode, SW1-7 is used to determine whether the interface should, after sending the IEEE bus terminators, address the attached bus device to talk. The factory default is Talk-back On Terminator enabled.

Refer to **Chapter 6** for complete details on these features.

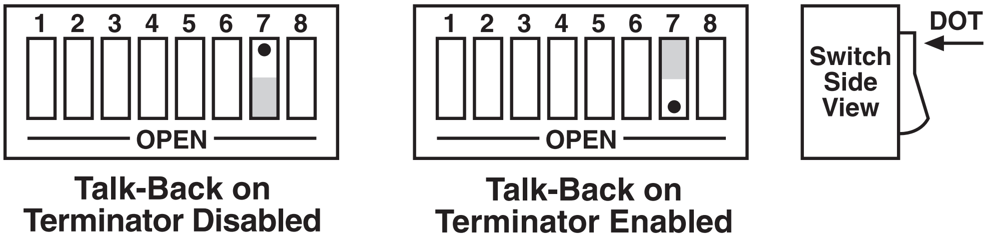

1 2 3 4 5 6 7 8
OPEN
Talk-Back on Terminator Disabled
1 2 3 4 5 6 7 8
OPEN
Talk-Back on Terminator Enabled
DOT
Switch Side View

Figure 3-14. Switch SW1: Enabling or Disabling “Talk Back on Terminator” in Controller Mode.

3.7.2 Peripheral Pass-Thru Features

In the Peripheral Pass-Thru (IEEE-488-to-RS-232 converter) mode, SW1-7 enables the interface to assert the SRQ IEEE bus interface line to indicate that it has received the last switch selected serial terminator character from the serial device.

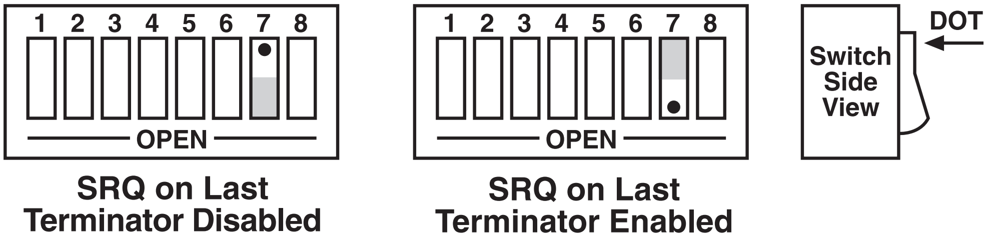

1 2 3 4 5 6 7 8
OPEN
SRQ on Last Terminator Disabled
1 2 3 4 5 6 7 8
OPEN
SRQ on Last Terminator Enabled
Switch Side View
DOT

Figure 3-15. Switch SW1: Enabling or Disabling SRQ on Last Serial Terminator in Peripheral Mode.

3.8 Serial Interface

The 488 Controller has the ability to output signal levels that are compatible with either RS-232 or RS-422. An internal DIP shorting plug determines which electrical specification is chosen. If the interface is to be connected to an IBM® PC or compatible, the RS-232 level should be selected. If it will be connected to a Macintosh®, the RS-422 level should be used. For connection to other computers, refer to the manufacturer's manual to determine which levels are supported.

3.8.1 RS-232/RS-422 Signal Level Selection

The 488 Controller's factory default signal levels are compatible with RS-232. To select RS-422 levels, carefully remove the 8-position shorting plug with a small flat blade screwdriver from J106. Install the DIP jumper into J205 making certain that all of the pins on the shorting plug are inserted correctly.

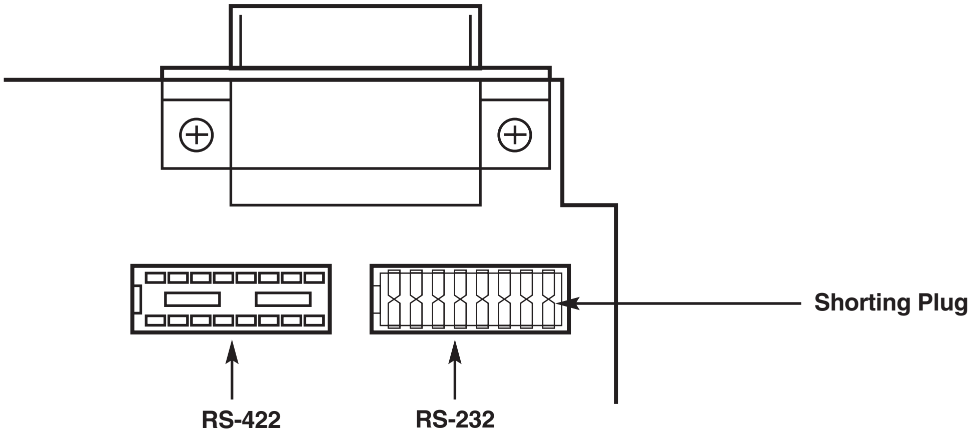


Figure 3-16. Selecting RS-232 or RS-422 Signal Levels.

3.8.2 Serial Signal Descriptions

The 488 Controller is equipped with a standard DB25 female connector on its rear panel and requires a standard DB25 male mating connector. The 488 Controller's connector is configured as DCE type equipment for RS-232 communications, which means the 488 Controller always transmits data on Pin 3 and receives data on Pin 2. The following lists and describes the RS-232 and RS-422 signals provided on the 488 Controller.

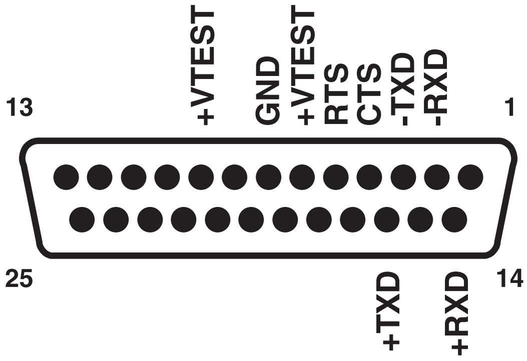


Figure 3-17. Rear View of the 488 Controller's Serial Connector.

-RxD **Receive Data—Input—Pin 2**
This pin accepts serial data sent by the RS-232 or RS-422 host. The serial data is expected with the word length, baud rate, stop bits, and parity selected by the internal switches. The signal level is low true.

-TxD **Transmit Data—Output—Pin 3**
This pin transmits serial data to the RS-232 or RS-422 host. The serial data is sent with the word length, baud rate, stop bits, and parity selected by the internal switches. The signal level is low true.

CTS **Clear To Send—Input—Pin 4**
The CTS input is used as a hardware-handshake line to prevent the 488 Controller from transmitting serial data when the RS-232 host is not ready to accept it. When RTS/CTS handshake is selected on the internal switches, the 488 Controller will not transmit data out -TxD while this line is un-asserted (lowered). If the RS-232 host is not capable of driving this line it can be connected to the Vtest output (Pin 6) of the 488 Controller. If X-ON/X-OFF handshake is selected, the CTS line is not tested to determine if it can transmit data.

RTS **Request To Send—Output—Pin 5**
The RTS output is used as a hardware handshake line to prevent the RS-232/RS-422 host from transmitting serial data if the 488 Controller is not ready to accept it. When RTS/CTS handshake is selected on the internal switches, the 488 Controller will drive the RTS output high when there are more than 1000 character locations available in its internal buffer. If the number of available locations drops to less than 1000, the 488 Controller will un-assert (lower) this output. If X-ON/X-OFF handshake is selected, the RTS line will be permanently driven active high.

Vtest **Test Voltage—Output—Pin 6**
This pin is connected to +5 volts through a 1K resistor. It is also common to Vtest on pin 9.

Gnd **Ground—Pin 7**
This pin sets the ground reference point for the other RS-232 inputs and outputs.

Vtest **Test Voltage—Output—Pin 9**
This pin is connected to 5 volts through a 1K resistor. It is also common to Vtest on pin 6.

+RxD **Receive Data Plus—Input—Pin 14**
This pin accepts serial data sent by the RS-422 host. The serial data is expected with the word length, baud rate, stop bits, and parity selected by the internal switches. The signal level is high true and only connected to this pin when RS-422 operation is selected. It is 180 degrees out of phase with -RxD.

+TxD **Transmit Data Plus—Output—Pin 16**
This pin transmits serial data to the RS-422 host. The serial data is sent with the word length, baud rate, stop bits, and parity selected by the internal switches. The signal level is high true and only connected to this pin when RS-422 operation is selected. It is 180 degrees out of phase with -TxD.

3.8.3 Serial-Cable Wiring Diagrams

If a cable was not purchased with the 488 Controller, the following diagrams will be helpful in making your own cable. Simple soldering skills and an attention to detail will ensure successful construction.

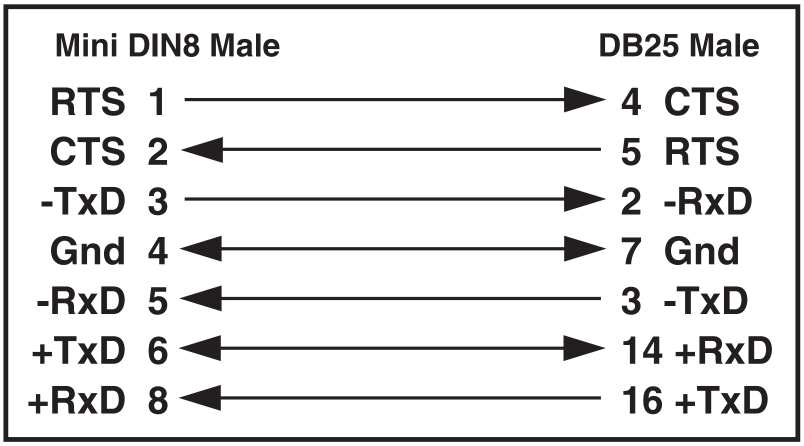


Figure 3-18. Wiring Diagram: Macintosh to 488 Controller.

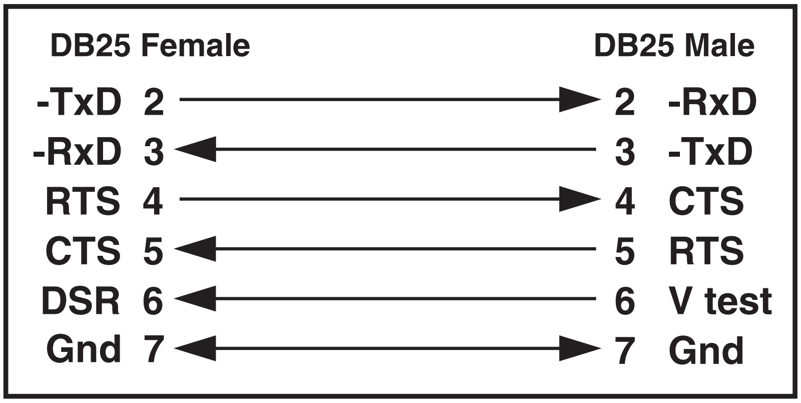


Figure 3-19. Wiring Diagram: IBM PC or Compatible with DB25 Serial Connector to 488 Controller (RS-232).

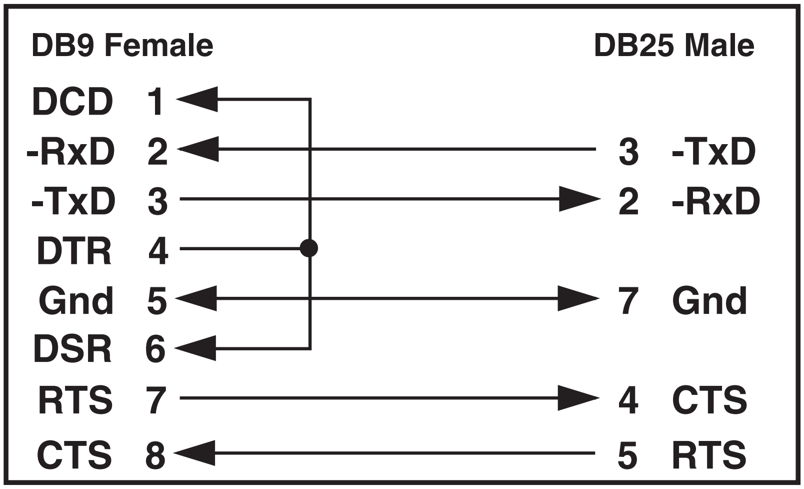


Figure 3-20. Wiring Diagram: IBM AT® or Compatible with DB9 Serial Connector to 488 Controller (RS-232).

NOTE

Standard AT 9-pin-to-25-pin adapter cables are not wired as shown above and will not work with the 488 Controller.

3.9 General Operation

Refer to the following sections for specific operational modes. This section gives a general test of functionality. After setting the power-on defaults and reassembling the 488 Controller, plug the power-supply connector into the rear jack on the interface.

CAUTION

Never plug the power supply into the 488 Controller while it is connected to AC line power. If you do, you could damage the 488 Controller.

WARNING

The power supply provided with the interface is intended for *indoor use only*. Using it outdoors could result in equipment failure, personal injury, or death.

After plugging the power supply connector into the 488 Controller, plug the power supply into AC line power. Turn the rear-panel power switch ON (the “1” position). All the front-panel indicators should light momentarily while the 488 Controller performs an internal ROM and RAM self-check. At the end of this self-check, all indicators except POWER should turn off.

If there is an error in the ROM checksum, all of the LEDs will remain on. Flashing LEDs indicate a RAM failure. Should such an error occur, turn the rear panel switch to the OFF [0] position and retry the above procedure.

If the front-panel indicators do not flash and the POWER indicator does not remain lit, there may not be any power supplied to the interface. In this event, check the AC line and the rear-panel connection of the power supply.

If proper operation is obtained, connect an interface cable to the rear of the 488 Controller (25-Pin Sub-D). Connect the other end to the host’s serial port. Except for connecting IEEE bus instruments, the 488 Controller is installed and ready to use.

WARNING

The 488 Controller makes its earth ground connection through the serial interface cable. It should only be connected to IEEE bus devices after being first connected to the host. Failure to do so may allow the 488 Controller to float to a bus device test voltage. This could result in damage to the 488 Controller, personal injury, or death.

3.10 Is Anyone Out There?

Before connecting any IEEE bus devices to the 488 Controller, try this simple operational check. The 488 Controller must be configured for either System Controller or Peripheral mode operation. This test will not work in either of the Pass-Thru modes.

Running BASIC on the host, or any programming language which supports the serial ports, type the following (or its equivalent).

```
OPEN "COM1:9600, N, 8, 2, cd, ds" AS 1      [Return]

PRINT #1,"HELLO"                            [Return]

LINE INPUT #1,A$                            [Return]

PRINT A$                                    [Return]
```

The 488 Controller will respond with (and the host will display):

488 Controller Revision N.N Copyright (C) 1988

where N.N is the release and revision number of the firmware.

If you obtain the response above, then your 488 Controller is alive and well and ready to connect your host to the powerful IEEE-488 General Purpose Interface Bus. If you did not receive the message above, check for proper connection and fit of the interface cable. If, after reviewing the 488 Controller for proper installation, call your supplier.

4. IEEE Operating Modes

4.1 Introduction

There are four types of IEEE bus devices: Active Controllers, Peripherals, Talk-Only devices, and Listen-Always devices. Talk-Only and Listen-Always devices are usually used together, in simple systems, such as a Talk-Only digitizer sending results to a Listen-Always plotter. In these simple systems, no controller is needed, because the talker assumes that it is the only talker on the bus, and the listener(s) assume that they are all supposed to receive all the data sent over the bus. This is a simple and effective method of transferring data from one device to another, but is not adequate for more complex systems where, for example, one computer is controlling many different bus devices.

In more complex systems, the Active Controller sends commands to the various bus Peripherals telling them what to do. Commands such as Unlisten, Listen Address Group, Untalk, and Talk Address Group are sent by the controller to specify which device is to send data, and which devices are to receive it. For more details about the IEEE bus protocols see **Chapter 8**.

When an IEEE bus system is first turned on, some device must be the Active Controller. This device is the System Controller and always keeps some control of the bus. In particular, the System Controller controls the Interface Clear (IFC) and Remote Enable (REN) bus management lines. By asserting Interface Clear, the System Controller forces all the other bus devices to stop their bus operations, and regains control as the Active Controller.

4.2 Operating Mode Transitions

The System Controller is initially the Active Controller. It can, if desired, pass control to another device and thereby make that device the Active Controller. Note that the System Controller remains the System Controller, even when it is not the Active Controller. Of course, the device to which control is passed must be capable of taking on the role of Active Controller. It would make no sense to try to pass control to a printer. Control should only be passed to other computers that are capable, and ready, to become the Active Controller. Further, note that there must be exactly one System Controller on the IEEE bus. All other potential controllers must be configured as Peripherals when they power up.

The state diagram on the next page shows the relationships between the various operating modes. The top half of the state diagram shows the two operating states of a System Controller. At power-on, it is the active controller. It directs the bus transfers by sending the bus commands mentioned previously. It also has control of the Interface Clear and Remote Enable bus lines. The System Controller can pulse Interface Clear to reset all of the other bus devices.

As shown in the diagram, the System Controller can pass control to some other bus device and thereby become a Peripheral to the new Active Controller. If the System Controller receives control from the new Active Controller, then it will once again become the Active Controller. The System Controller can also force the Active Controller to relinquish control by asserting the Interface Clear signal.

The bottom half of the state diagram shows the two operating states of a Not System Controller device. At power on, it is a Peripheral to the System Controller, which is the Active Controller. If it receives control from the Active Controller, it becomes the new Active Controller. Even though it is the Active Controller, it is still not the System Controller. The System Controller can force the Active Controller to give up control by asserting Interface Clear. The Active Controller can also give up control by passing control to another device, which may or may not be the System Controller.

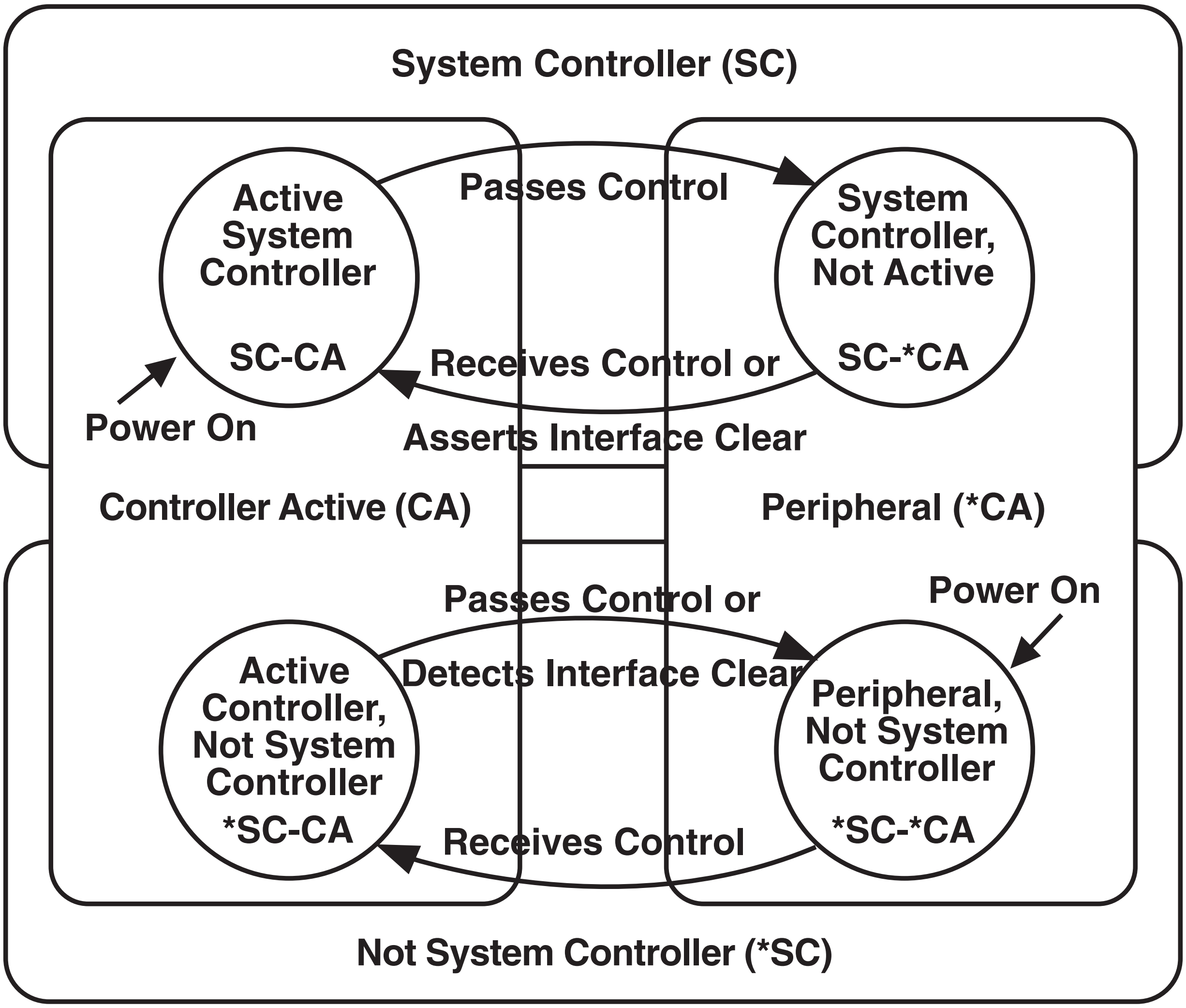


Figure 4-1. IEEE Bus Operating Modes State Diagram.

In summary, a bus device is set in hardware as either the sole System Controller in the system, or as a non-System Controller. At power on, the System Controller is the Active Controller, and the other devices are Peripherals. The System Controller can give up control by Passing Control, and can regain control by asserting Interface Clear, or by receiving control. A Peripheral can become the Active Controller by receiving control, and can give up control by Passing Control, or upon detecting Interface Clear.

4.3 System Controller Mode

The most common 488 Controller configuration is as the System Controller, controlling several IEEE-bus instruments. In this mode, the 488 Controller can perform all of the various IEEE-bus protocols necessary to control and communicate with any IEEE-488-bus devices. As the System Controller in the Active Controller mode, the 488 Controller can use all of the commands available for the Active Controller state, plus control the Interface Clear and Remote Enable lines. The allowed bus commands and their actions are as follows:

ABORT	Pulse Interface Clear.
LOCAL	Unassert Remote Enable, or send Go To Local to selected devices.
REMOTE	Assert Remote Enable, optionally setting devices to Remote.
LOCAL LOCKOUT	Prevent local (front-panel) control of bus devices.
CLEAR	Clear all or selected devices.
TRIGGER	Trigger selected devices.
ENTER	Receive data from a bus device.
OUTPUT	Send data to bus devices.
PASS CONTROL	Give up control to another device which becomes the Active Controller.
SPOLL	Serial Poll a bus device, or check the Service Request state.
PPOLL	Parallel Poll the bus.
PPOLL CONFIG	Configure Parallel Poll responses.
PPOLL DISABLE	Disable the Parallel Poll response of selected bus devices.
PPOLL UNCONFIG	Disable the Parallel Poll response of all bus devices.
SEND	Send low-level bus sequences.
RESUME	Unassert Attention. Used to allow Peripheral-to-Peripheral transfers.

4.4 System Controller, Not Active Controller Mode

After Passing Control to another device, the System Controller is no longer the Active Controller. It acts as a Peripheral to the new Active Controller, and the allowed bus commands and their actions are modified accordingly. However, it still maintains control of the Interface Clear and Remote Enable lines. The available bus commands and their actions are:

ABORT	Pulse Interface Clear.
LOCAL	Unassert Remote Enable.
REMOTE	Assert Remote Enable.
ENTER	Receive data from a bus device as directed by the Active Controller.
OUTPUT	Send data to bus devices as directed by the Active Controller.
REQUEST	Set own Serial Poll request (including Service Request) status.
SPOLL	Get own Serial Poll request status.

As a bus Peripheral, the 488 Controller must respond to the commands issued by the Active Controller. The controller can, for example, address the 488 Controller to listen in preparation for sending data. There are two ways of detecting our being addressed to listen: through the STATUS command, or by detecting an event with the ARM or ON DOMACRO commands.

The STATUS 1 command can be used to watch for commands from the Active Controller. The Operating Mode, which is a “P” while the 488 Controller is a Peripheral, will change to a “C” if the Active Controller Passes Control to the 488 Controller. The Addressed State will go from Idle (“I”) to Listener (“L”) or Talker (“T”) if the 488 Controller is addressed to listen or to talk, and will go back to Idle (“I”) when the Active Controller issues Unlisten (UNL), Untalk (UNT), or specifies another talker (TAG). The Triggered (“T1”) and Cleared (“C1”) indicators will be set when the 488 Controller is triggered or cleared, and reset when STATUS 1 is read. The Address Change indicator will be set (“G1”) when the address state changes. These indicators allow the program to sense the commands issued to the 488 Controller by the Active Controller. The following BASIC program fragment illustrates the use of the Address Change and Addressed State indicators to communicate with the Active Controller:

First we check STATUS until it indicates that there has been an address change:

```
200     PRINT#1,"STATUS1"
210     INPUT#2 ST$
220     'Has there been no Address Change?
230     IF MID$(ST$,7,1)="0" THEN 200
240     'Are will still in the idle state?
250     STATE$=MID$(ST$,9,1)
260     IF STATE$="I" THEN 200
270     'Are we addressed to listen?
280     IF STATE$="L" THEN 400
290     'Are we addressed to talk?
300     IF STATE$="T" THEN 500
310     PRINT "BAD ADDRESSED STATE VALUE: ";ST$: STOP
```

If we are addressed to listen then we ENTER a line from the controller and print it out.

```
400     'Listen state
410     PRINT#1,"ENTER"
420     LINE INPUT#1,A$
430     PRINT A$
440     GOTO 200
```

If we are addressed to talk then we INPUT a line from the keyboard and OUTPUT it to the controller.

```
500     'Talk state
510     LINE INPUT A$
520     PRINT#1,"OUTPUT;";A$
530     GOTO 200
```

It is also possible to detect these conditions with the ARM or ON DOMACRO commands and handle them in an exception as described in **Chapter 5**. The various arm conditions and their meanings are as follows:

SRQ	The internal Service Request state is set. See the SPOLL command in **Chapter 5**.
PERIPHERAL	The 488 Controller is in the Peripheral (*CA) operating mode.
CONTROLLER	The 488 Controller is the Active Controller (CA).
TRIGGER	The 488 Controller, as a Peripheral, has received a Trigger bus command.
CLEAR	The 488 Controller, as a Peripheral, has received a Clear bus command.
TALK	The 488 Controller is in the Talk state and can OUTPUT to the bus.
LISTEN	The 488 Controller is in the Listen state and can ENTER from the bus.
IDLE	The 488 Controller is in neither the Talk nor Listen state.
CHANGE	An Address Change has occurred, i.e. a change between Peripheral and Controller, or among Talk, Listen, and Idle has occurred.
ERROR	An error, either command or bus, has been detected by the 488 Controller.

4.5 Not System Controller Mode

If the 488 Controller is configured as not the System Controller then, at power on, it will be a bus Peripheral. It might use a program like the one described previously to communicate with the Active Controller. The bus commands available to the 488 Controller when it is not the System Controller and not the Active Controller (*SC*CA) are:

ENTER	Receive data from a bus device as directed by the Active Controller.
OUTPUT	Send data to bus devices as directed by the Active Controller
REQUEST	Set own Serial Poll request (including Service Request) status.
SPOLL	Get own Serial Poll request status.

4.6 Active Controller, Not System Controller Mode

If the Active Controller passes control to the the 488 Controller, then the 488 Controller will become the new Active Controller. This can be detected by the STATUS command or as an ARMed event. As an Active Controller, but not the System Controller, the following bus commands are available:

ABORT	Assert Attention and send My Talk Address to stop any bus transfers.
LOCAL	Send Go To Local to selected devices.
LOCAL LOCKOUT	Prevent local (front-panel) control of bus devices.
CLEAR	Clear all or selected devices.
TRIGGER	Trigger selected devices.
ENTER	Receive data from a bus device.
OUTPUT	Send data to bus devices.
PASS CONTROL	Give up control to another device, which becomes the Active Controller.
SPOLL	Serial-Poll a bus device, or check the Service Request state.
PPOLL	Parallel-Poll the bus.
PPOLL CONFIG	Configure Parallel-Poll responses.
PPOLL DISABLE	Disable the Parallel-Poll response of selected bus devices.
PPOLL UNCONFIG	Disable the Parallel-Poll response of all bus devices.
SEND	Send low-level bus sequences.
RESUME	Unassert Attention. Used to allow Peripheral-to-Peripheral transfers.

4.7 Controller Pass-Thru Mode

This mode is intended to provide bi-directional data-transparent conversion between an RS-232/RS-422 host computer and an IEEE 488 peripheral, such as a printer or an HP®-IB plotter. The operation of this mode is covered in **Chapter 6** of this manual.

4.8 Peripheral Pass-Thru Mode

This mode is intended to provide bi-directional data transparent conversion between an IEEE 488 controller and a serial device. This Peripheral Pass-Thru mode does not require the serial device to control data to it. There is no command line, so this mode requires no serial commands. This mode of operation is described in **Chapter 7** of this manual.

5. Command Descriptions

5.1 Introduction

This section contains a detailed description of each of the high-level commands available for the 488 Controller. There are two types of commands: bus commands and system commands. Bus commands communicate with the IEEE 488 bus. System commands configure or request information from the 488 Controller.

Bus Commands:

ABORT
CLEAR
ENTER
LOCAL
LOCAL LOCKOUT
OUTPUT
PASS CONTROL
PPOLL
PPOLL CONFIG
PPOLL DISABLE
PPOLL UNCONFIG
REMOTE
REQUEST
RESUME
SEND
SPOLL
TRIGGER

System Commands:

ARM
COMMENT
COUNT
DELAY
DISARM
DOMACRO
ERASE
ERROR
HELLO
ID
MACROENDM
MASK
MEMORY
ON <event> DOMACRO
READ
RESET
STATUS
STERM
TERM
TIME OUT
TRACE

5.2 Command-Description Format

Each command description is divided into several areas:

5.2.1 Syntax

The syntax section of the command description describes the proper command syntax which must be sent to the 488 Controller using the IBM BASIC PRINT# command, or its equivalent in other languages, to the COM port. The following conventions are used in the syntax descriptions:

No command, along with its options, may be more than 127 characters long. The data part of the OUTPUT command is not constrained by this length. It is, however, limited to the available USER MEMORY. The OUTPUT #count;data may be as long as necessary. Refer to the OUTPUT command for more information on this.

Items in capital letters, such as **ENTER** or **OUTPUT**, must be entered exactly as stated, except that abbreviations may be used with some commands to reduce serial transmission traffic.

Items in lower case, such as **addr** or **count**, represent parameters which must be substituted with an appropriate value.

Blank spaces in commands are generally ignored. Thus, **LOCAL LOCK OUT** is the same as **LOCALLOCKOUT**. Spaces are not ignored in four places: the data part of an **OUTPUT** command, within quoted strings in a **SEND** command, after an apostrophe (') in a terminator specification (**term**), and after the semi-colon following the **ID** command.

The number sign (**#**) and the semicolon (**;**) must be present exactly as shown. A comma (,) represents an address separator. The slash (/) or period (**.**) may be used in its place as the address separator.

Optional semicolons ([;]) may be used, if desired.

Items enclosed in square brackets (**[item]**) are optional. Multiple items enclosed in square brackets separated by vertical lines (**[item1|item2|item3]**) are optional; any one or none may be chosen. No more than one item may be selected.

Ellipses (**...**) within square brackets mean that the items in the brackets may be repeated as many times as desired. For example [**,addr**] means that any number, to a maximum of 15, of address-separator/address combinations may be used.

Braces, or curly brackets (**{item1|item2}**), mean that exactly one of the enclosed items is required.

Combinations of brackets are possible. For example, **{term[term] [EOI] |EOI}** allows the choice of "term," "term EOI," "term term," "term term EOI," or just "EOI," but does not allow the choice of "nothing."

Numeric parameters (those that are given as numbers) are decimal unless preceded by &H, in which case they are considered to be hexadecimal. Thus 100 is decimal 100, &H64 is hexadecimal 64 which equals decimal 100, &HFF is decimal 255, and 0FF is invalid because F is not a valid decimal digit. The only exception to this rule is that bus addresses, both primary and secondary, must be specified as two-digit decimal numbers. Hexadecimal bus addresses are not allowed.

Several of the commands require additional or optional parameters. These are further described with each command, but discussion of the more common ones follows.

Bus Addressing

pri-addr A two-digit primary device address in the range of 00 to 30.

sec-addr An optional two-digit secondary device address in the range of 00 to 31.

addr An IEEE bus address. A numeric primary address optionally followed by a secondary address. Thus **addr** is of the form...

{pri-addr [sec-addr]}

where **pri-addr** is a two-digit primary address in the range from 00 through 30 and **sec-addr** is a two-digit secondary address from 00 through 31. Numeric addresses must be given as two-digit numbers: for example, 05 for address 5, and 1601 for primary address 16, secondary address 1.

[,addr] An optional list of bus addresses, each one preceded by an address separator: either a comma (,), a slash (/) or a period (.).

No more than 15 bus addresses are allowed in any single command.

Character Count

#count The number of characters to be transferred. A pound sign (#) followed by an integer in the range of 1 to 65535 (2^{16}-1). May be specified in hexadecimal by preceding it with &H. The hexadecimal range is &H1 to &HFFFF. A character count of zero is invalid.

ASCII Characters

$char A single character whose ASCII value is the number **char**, a decimal number in the range of 0 to 255 or a hexadecimal number in the range of &H0 to &HFF. For example, $65 is the letter “A,” as is $&H41.

CR The carriage return character ($13, $&H0D).

LF The line feed character ($10, $&H0A).

'X Any printable character. The apostrophe is immediately followed, without any intervening spaces, by a single character which is taken to be the character specified.

ASCII Character Strings

data An arbitrary string of characters. None of the special forms given above (**$char**, **CR**, **LF**, or **'X**) are used. For example, **CRLF** as data is taken as the letters “C,” “R,” “L,” and “F,” not as carriage return and line feed.

'data' An arbitrary string of characters enclosed in apostrophes (') or quotes (").

Terminators

term — Any single character, specified as **CR**, **LF**, **'X**, or **$char** as described previously. Part of terminator sequence used to mark the end of lines of data and commands.

[term] — An optional **term** character. t**erm[term]**, means that one or two terminators may be specified.

EOI — The IEEE bus End-Or-Identify signal. When asserted during the transfer of a character, EOI signals that that character is the last in the transfer. On input, EOI, if specified, causes the input to stop. On output, EOI causes the bus EOI signal to be asserted during transmission of the last character.

NONE — The no-end-of-line-character indicator. When STERM NONE is specified, the 488 Controller does not append any serial output terminator(s) to serially transmitted data.

5.2.2 RESPONSE

The response section of the command description describes the response that the user's program should read from the serial host's COM port after sending the command. If a response is provided, it must be read to maintain proper program sequence.

5.2.3 MODE

This section of the command description specifies the operating modes in which the command is valid. The 488 Controller may be configured as the System Controller, in which case it will initially be the Active Controller, or as a Not System Controller, in which case it will initially be in the Peripheral state. The 488 Controller configuration as System Controller or Not System Controller is fixed by a hardware switch setting and cannot be changed by software, but the 488 Controller can change between Active Controller and Peripheral as required (see **Chapter 4**).

The modes are referred to by their names and states, as given in the table below:

Description	State
System Controller	SC
Not System Controller	*SC
Active Controller	CA
Peripheral (Not Active Controller)	*CA
Active System Controller	SCCA
System Controller, Not Active Controller	SC*CA
Not System Controller, Not Active Controller	*SC*CA
Not System Controller, Active Controller	*SCCA

5.2.4 Bus States

This section describes the bus command and data transfers using IEEE bus mnemonics, abbreviated as follows:

		DIO lines							
		8	7	6	5	4	3	2	1
ATN	Attention								
data	Data String								
DCL	Device Clear	x	0	0	1	0	1	0	0
GET	Group Execute Trigger	x	0	0	0	1	0	0	0
GTL	Go To Local	x	0	0	0	0	0	0	1
IFC	Interface Clear								
LAG	Listen Address Group	x	0	1	a	d	d	r	n
LLO	Local Lock Out	x	0	0	1	0	0	0	1
MLA	My Listen Address	x	0	1	a	d	d	r	n
MTA	My Talk Address	x	1	0	a	d	d	r	n
PPC	Parallel Poll Configure	x	0	0	0	0	1	0	1
PPD	Parallel Poll Disable	x	1	1	1	0	0	0	0
PPE	Parallel Poll Enable	x	1	1	0	S	P3	P2	P1
PPU	Parallel Poll Unconfigure	x	0	0	1	0	1	0	1
REN	Remote Enable								
SDC	Selected Device Clear	x	0	0	0	0	1	0	0
SPD	Serial Poll Disable	x	0	0	1	1	0	0	1
SPE	Serial Poll Enable	x	0	0	1	1	0	0	0
SRQ	Service Request								
TAG	Talker Address Group	x	1	0	a	d	d	r	n
TCT	Take Control	x	0	0	0	1	0	0	1
UNL	Unlisten	x	0	1	1	1	1	1	1
UNT	Untalk	x	1	0	1	1	1	1	1

(x = "don't care")

If a command is preceded by an asterisk, then that command is unasserted. For example, *REN states that the remote enable line is unasserted. Conversely, REN without the asterisk states that the line becomes asserted.

5.3 Memory Use

Memory in the 488 Controller is dynamically allocated for the serial input, serial output and Macro buffers. This allows for the most efficient partitioning of memory for any given application. This memory is kept in the user "heap" (a vernacular for heap of memory) until required by the system.

At power on, each serial buffer is allocated a 127-byte minibuffer or queue. When the serial input (or output) requires more buffer space, additional queues are allocated. When a queue is empty, it is released from the input buffers so that it may be re-allocated when, and where, required. Macro queues are not allocated unless a macro is defined.

There are approximately 240 available queues for a total of 29,000 bytes of buffer (character) space. Queues are continually allocated and released as required. Of the 240 available queues, 230 are issued without regard to controlling the receipt of additional serial input data.

When the serial input buffer requests one of the last 10 queues (1270 character locations left), it signals the serial host that it should stop sending data. This is accomplished by either unasserting RTS or issuing "X-OFF," depending on which serial handshake control has been switch selected. When more than 10 queues become available, it asserts RTS or issues "X-ON."

5.4. The Commands

The commands provided in the 488 Controller, in alphabetical order, are described on the following pages.

@ Command

The system command @, followed by a CR and/or LF, is used to unlock the 488 Controller from an inappropriate command. An example of such a command would be requesting data from a nonexistent device with timeouts disabled.

When the @ command is received, the serial handshake line (RTS) is un-asserted. It is asserted when the 488 Controller is capable of buffering commands. If X-ON/X-OFF handshake is selected, the software handshake state is not modified.

Issuing the @ command clears the serial input (pending commands) and output (pending data) buffers. It also is equivalent to issuing the following commands

DISARM

ERASE

ERROR OFF

ID;@

MASK OFF

REQUEST 0 (with *SRQ)

TIME OUT 0

TRACE OFF

The @ character, referred to as the “ID” character, can be changed or disabled by using the ID command. If it is anticipated that the ID character may be part of the data within an OUTPUT or SEND command, it should be disabled.

SYNTAX	@
RESPONSE	None
MODE	Any
BUS STATES	None
EXAMPLE	PRINT #1,"@"

@@ Command

Sending the system command @@ causes the 488 Controller to return to power-on conditions. All data buffers are cleared, and any software programmable terminators are returned to the power-on conditions.

This is the only command which does not require a serial terminator to execute. Reset is executed upon receipt of the second @.

When the @@ command is received, the serial handshake line (RTS) is un-asserted. It is asserted when the 488 Controller is capable of buffering commands. If XON/XOFF handshake is selected, the software handshake state is reset.

The @ character, referred to as the “ID” character, can be changed or disabled by using the ID command. If it is anticipated that the ID character may be part of the data within an OUTPUT or SEND command, it should be disabled.

SYNTAX	@@	
RESPONSE	None	
MODE	Any	
BUS STATES:	IFC,*IFC	(SC)
EXAMPLE:	PRINT #1,"@@"	

ABORT Command

As the System Controller (SC), whether the 488 Controller is the Active Controller or not, the ABORT command causes the Interface Clear (IFC) bus management line to be asserted for at least 500 microseconds. By asserting IFC, the 488 Controller regains control of the bus even if one of the devices has locked it up during a data transfer. Asserting IFC also makes the 488 Controller the Active Controller. If a Non-System Controller was the Active Controller, it will be forced to relinquish control to the 488 Controller. ABORT forces all IEEE bus device interfaces into a quiescent idle state.

If the 488 Controller is a Non-System-Controller in the Active Controller state (*SCCA), it asserts attention (ATN), which halts any bus transactions, and sends its talk address to "untalk" any other talkers on the bus. It does not (and cannot) assert IFC if in the *SC state.

SYNTAX	ABORT or AB	
RESPONSE	None	
MODE	SC or *SCCA	
BUS STATES	IFC, *IFC	(SC)
	ATNMTA	(*SCCA)
EXAMPLES	PRINT#1,"ABORT"	
	PRINT#1,"AB"	Using abbreviated form

ARM Command

The ARM command allows the 488 Controller to automatically send event messages to the serial host when one or more of the specified events occur. The event messages that are returned are the same non-abbreviated strings as those used to program the events.

There are two types of events, level sensitive and edge sensitive. Level-sensitive events, such as SRQ, will be reported every time they are ARMed while the event condition persists. Usually, some action must be taken (for example, SPOLL) to clear the condition before re-issuing the ARM. Edge-sensitive events, such as TRIGGER, are cleared when reported.

Regardless of the event sensitivity, the ARM command must be resent after the event message is reported to re-activate the ARMed condition. The optional events include

SRQ The event message "SRQ" is returned to the serial host when the state of the Service Request Bus Line is detected in the asserted state. This event is level sensitive. If the condition exists at the time the ARM SRQ command is issued, the 488 Controller will return the event message immediately. If the ARM command is issued without any specified events, the SRQ event is assumed. This provides upward compatibility with the 488 Controller in previous 488 Controller systems.

PERIPHERAL The event message "PERIPHERAL" is returned to the serial host when the 488 Controller is forced from the Controller Active State (*SC-CA) to the Peripheral State (*SC-*CA) by receipt of IFC from the System Controller. This can be useful in detecting receipt of IFC when in the *SC-CA state. This event is edge-sensitive.

CONTROLLER The event message "CONTROLLER" is returned to the serial host when the 488 Controller receives control of the bus and transitions from the Peripheral State (*SC-*CA) to the Controller Active State (*SC-CA) . This occurs when the Take Control interface message is received by the 488 Controller. This event is edge-sensitive.

TRIGGER The event message "TRIGGER" is returned to the serial host when the 488 Controller, as a Peripheral (*CA), receives a Group Execute Trigger (GET) command from the Active Controller. This event is edge-sensitive. When the event message is sent, the internal status, as read by the STATUS 1 command, is cleared.

CLEAR

The event message “CLEAR” is returned to the serial host when the 488 Controller, as a Peripheral (*CA), receives a Device Clear (DCL) or a Selected Device Clear (SDC) command from the Active Controller. This event is edge-sensitive. When the event message is sent, the internal status, as read by the STATUS 1 command, is cleared.

TALK

The event message “TALK” is returned to the serial host when the 488 Controller, as a Peripheral (*CA), detects its My Talk Address (MTA) command from the Active Controller. It indicates that the controller has requested information from the 488 Controller. This event is edge-sensitive.

LISTEN

The event message “LISTEN” is returned to the serial host when the 488 Controller, as a Peripheral (*CA), detects its My Listen Address (MLA) command from the Active Controller. It indicates that the controller has information it wants to send to the 488 Controller. This event is edge-sensitive.

IDLE

The event message “IDLE” is returned to the serial host when the 488 Controller, as a Peripheral (*CA), transitions from a Talker or Listener state to an idle state (neither talker or listener). It indicates that the controller has unaddressed the 488 Controller with either an UNT or UNL command. This event is edge-sensitive. When the event message is sent, the internal address-change status, as read by the STATUS 1 command, is cleared. This event is tested before the CHANGE event and will clear the internal CHANGE status only when the addressed-to-unaddressed transition occurs.

CHANGE

The event message “CHANGE” is returned to the serial host when the 488 Controller, as a Peripheral (*CA), detects an addressed state change. This occurs on transitions from a Talker or Listener state to an idle state (neither talker or listener), or from a idle state to a talker or listener state. This event is edge-sensitive. When the event message is sent, the internal status, as read by the STATUS 1 command, is cleared. This event is tested after the IDLE event. If IDLE is ARMed, the CHANGE event will only be reported when an unaddressed-to-addressed transition occurs.

ERROR

The event message “ERROR” is returned to the serial host when the 488 Controller detects an error condition. The error condition may be an unrecognized command from the serial host, an invalid parameter, or a bus error. Refer to **Appendix B** for a listing of the error conditions which can be detected and reported by the 488 Controller. This event is level-sensitive. When the event message is sent, the error status, as read by any of the STATUS commands, must be read before ARMing this event again.

Once a condition is ARMed, it remains ARMed until it is DISARMed, the event specified has occurred, or the 488 Controller is reset.

The ARM and ON <event> DOMACRO commands are mutually exclusive. The last command issued takes precedence.

SYNTAX **ARM [;] [event[event]]** or **AR [;] [event[event]]**

where **event** may include

Event	Abbreviated Form
SRQ	SRQ
PERIPHERAL	PE
CONTROLLER	CO
TRIGGER	TR
CLEAR	CL
TALK	T
LISTEN	L
IDLE	I
CHANGE	CH
ERROR	ER

If no event is specified, ARM SRQ is assumed for upward compatibility with the 488 Controller.

RESPONSE Event string sent when event occurs

MODE any

BUS STATES None

EXAMPLE:

```
10    PRINT#1,"ARM TALK"                Enable Talk Condition
20    INPUT#1,A$                        Input “TALK” Status Message
30    PRINT#1,"OUTPUT;This is a test"
40    GOTO 10                           Output data and try again
```

CLEAR Command

The CLEAR command causes the Device Clear (DCL) bus command to be issued by the 488 Controller. If the optional addresses are included, the Selected Device Clear (SDC) command is issued to all specified devices. IEEE 488 bus devices which receive a Device Clear or Selected Device Clear command normally reset to their power-on state.

SYNTAX	CLEAR [addr[,addr]]	
	or	
	CL [addr[,addr]]	
	addr is a device address (primary with optional secondary). **,** is the address separator—either a comma, a slash [/], or a period [.].	
RESPONSE	None	
MODE	CA	
BUS STATES	ATNDCL	(all devices)
	ATNUNL,MTA,LAG,SDC	(selected devices)
EXAMPLES:	PRINT #1,"CLEAR"	Issue a Device Clear to all devices.
	PRINT #1, "CL 12, 18"	Issue a Selected Device Clear to devices 12 and 18.

COUNT Command

The COUNT command returns the loop count, appended with the serial output terminator(s), of the last invoked Macro buffer. If Macro 1 requests a COUNT then calls Macro 0, any subsequent COUNT requests made by Macro 1 will return the Macro 0 loop COUNT. The following contents of Macro 1's buffer should illustrate this.

MACRO 1	Creates Macro Buffer #1.
COUNT	This will return Macro #1's loop count.
DOMACRO 0	This command executes Macro #0.
COUNT	This will return Macro #0's loop count, since it was the last Macro to be invoked.
ENDM01	

If Macro #1, in the previous example, was invoked multiple times, each time the loop counts will be reported as described. This is due to the fact that looping is a re-invocation of the looped Macro.

This command is only valid when contained within a Macro. Execution outside of a Macro will generate an “INVALID COMMAND” error.

SYNTAX COUNT

RESPONSE numeric loop count (1 to 255) of last invoked Macro buffer.

MODE Any

BUS STATES None

EXAMPLE:

```
10    PRINT #l,"MACRO"                        Build Macro #0
20    PRINT #l,"COMMENT 'Loop Number =\' "
30    PRINT #l,"COUNT"
40    PRINT #l,"ENDM"
50    PRINT #l,"DOMACRO0,5"                   Execute the Macro five times
60    FOR N=1 TO 5
70    INPUT #l,L$:PRINT L$                    Read Comment & Count
80    NEXT N
```

COMMENT Command

The COMMENT command is provided to allow the user to place comment lines in a Macro buffer. The COMMENT string is enclosed in either apostrophes (') or quotation marks ("). When the Macro is executed, the COMMENT string is sent to the serial host, with the serial output terminators appended. The serial output terminators may be suppressed by including a back-slash [\] as the last character of the string.

SYNTAX COMMENT [;] 'data' or COM [;] 'data'
'data' is an ASCII string delimited by apostrophes or quotation marks.

RESPONSE **data** is returned to the serial host

MODE Any

BUS STATES None

EXAMPLES:

```
PRINT #1,"COMMENT 'This is a test comment' "
INPUT #1, C$                     Read the comment string
PRINT C$                         Print it to the screen
PRINT #1,"COMMENT 'Available Memory = \' "
PRINT #1,"MEMORY"
INPUT #1, C$                     Read the comment string with suppressed serial output terminators
                                 and appended memory value
PRINT C$                         Print it to the screen
```

DELAY Command

The DELAY command is provided to allow the user to place time delays in the execution of a Macro. The amount of time delayed is specified in seconds in the range of 0 to 65535 (2^{16}-1) seconds.

SYNTAX	DELAY [;] time
	time is specified in seconds, 0 to 65535 (2^{16}-1)
RESPONSE	None
MODE	Any
BUS STATES	None

EXAMPLE:

```
PRINT#1,"DELAY 20"
PRINT #1,"COMMENT 'I am back' "
INPUT #1, C$                    Read the comment string
PRINT C$                        Printed to the screen 20 seconds later
```

DISARM Command

The DISARM command prevents the 488 Controller from sending the event's status message to the serial host, even when the specified conditions occur. It is also used to disable the ON <event> DOMACRO response. The user's program can still check for the events by using the STATUS 1 command.

If the DISARM command is invoked without specifying any events, then all events will be disabled.

The ARM or ON <event> DOMACRO command may be used to re-enable the event responses.

SYNTAX	DISARM [;] [event[event]] or DI[;] [event[event]]
	event is one of SRQ, PERIPHERAL, CONTROLLER, TRIGGER, CLEAR, TALK, LISTEN, IDLE, CHANGE or ERROR.
RESPONSE	None
MODE	Any
BUS STATES	None

EXAMPLES:

```
PRINT#1,"DISARM"                Disable all conditions
PRINT#1,"DISARM SRQ"            Do not respond to SRQ
```

DOMACRO Command

This command is used to execute the contents of a Macro buffer. A “NO MACRO” error will occur if the specified Macro buffer is empty. If the optional Macro buffer number is omitted, Macro 0 is assumed. By specifying an optional count, the same Macro will execute count number of times, up to 255. Macros can execute other Macros but cannot execute already executing Macros. If a Macro tries to invoke itself or an already executing Macro, a “MACRO RECURSION” error will be generated.

Refer to the Macro command for a description of the Macro features.

SYNTAX DOMACRO [;] [number[,count]] or DO [;] [number[,count]]

number is a Macro buffer number, from 0 to 99. If omitted, buffer #0 is assumed.
count is the number of times to execute the Macro, from 1 to 255.

RESPONSE Dependent on the contents of the Macro buffer.

MODE Any

BUS STATES Defined within the specified Macro buffer commands

EXAMPLES:

PRINT #l;"DOMACRO"	Execute the commands in Macro0 Buffer.
PRINT #l;"DO20"	Execute the commands in Macro20 Buffer.
PRINT #l;"DO6,30"	Execute the commands in Macro6 Buffer 30 times.

ENTER (Controller mode) Command

The ENTER command reads data from the IEEE bus. If a device address (with optional secondary address) is specified, that device will be addressed to talk. If no address is specified, the 488 Controller must already be configured to receive data, either as a result of an immediately preceding ENTER command, or as a result of a SEND sub-command. A time-out error will occur (if enabled) if the 488 Controller does not receive a data byte within the time out period after issuing the ENTER command.

If the character count, count, is specified, then exactly that number of characters will be read from the device with the serial output terminators appended. Otherwise, ENTER terminates reception on detection of the line feed (LF) character, which may be overridden by specifying the terminator in the ENTER command.

If a terminator, term, option is specified, all CR and LF characters in the input data are unconditionally discarded. When the specified terminator is detected, it is discarded and replaced with the serial terminator (s) before being returned to the serial host. The optional terminator applies ONLY to the ENTER command it is sent with. The terminator returns to a Line Feed on subsequent ENTER commands.

If the EOI option is specified, all characters are returned to the host until the EOI line is detected. The character sent with EOI asserted is also returned followed by the serial output terminator(s).

SYNTAX ENTER [addr] [#count | term | EOI|; count |; term |; EOI]
or
EN [addr] [#count | term | EOI|; count |; term |; EOI]

addr is the IEEE bus device address. **count** is the number of characters to ENTER. term and EOI override the normal IEEE bus input LF terminator.

RESPONSE Device-dependent data. If **count** is specified, then **count** characters will be returned, followed by the serial output terminators. Otherwise, the response ends when the IEEE bus input terminator is detected and the serial output terminators are appended to the returned data.

MODE CA

BUS STATES	ATNUNL,MLA,TAG,*ATN, data, ATN	(With **addr**)
	*ATN, data, ATN	(Without **addr**)

EXAMPLES:

PRINT#1,"ENTER16" INPUT#1,A$	Read data from device 16.
PRINT#1,"ENTER16" LINE INPUT#l,A$	Read an entire line of data from device 16 even if it contains commas or other punctuation.
PRINT#1,"ENTER16;CR" INPUT#1,A$	Read data from device 16 until CR is encountered.
PRINT#1,"ENTER16 EOI" INPUT#1,A$	Read data until EOI is detected.
PRINT#1,"ENTER 0702" INPUT#1,A$	Read data from device 7, secondary address 2.
PRINT#1,"EN 12 #5" A$=INPUT$(5,#1)	Read 5 bytes from device 12. INPUT$ gets 5 bytes from file #1
PRINT#1,"ENTER #20" A$=INPUT$(20,#1)	Read 20 more bytes.
PRINT#1,"ENTER ;20" A$=INPUT$(20,#l)	Read 20 more bytes.

ENTER (Peripheral mode) Command

In Peripheral mode, the ENTER command receives data from the bus under control of the Active Controller. The Active Controller must put the 488 Controller into the Listen state and configure some bus device to provide the 488 Controller with data. The Listen state can be checked with the STATUS 1 command, can cause a reported event message with the ARM command, or can force a Macro execution with the ON <event> DOMACRO command. A time-out error will occur (if enabled) if the 488 Controller does not receive a data byte within the time out period after issuing the ENTER command.

If the character count, **count**, is specified, then exactly that number of characters will be read from the device with the serial output terminators appended. Otherwise, ENTER terminates reception on detection of the line feed (LF) character, which may be overridden by specifying the terminator in the ENTER command.

If a terminator, **term**, option is specified, all CR and LF characters in the input data are unconditionally discarded. When the specified terminator is detected, it is discarded and replaced with the serial terminator(s) before being returned to the serial host. The optional terminator applies ONLY to the ENTER command it is sent with. The terminator returns to a Line Feed on subsequent ENTER commands.

If the EOI option is specified, all characters are returned to the host until the EOI line is detected. The character sent with EOI asserted is also returned followed by the serial output terminator(s).

SYNTAX ENTER[#count|term|EOI|;count|;term|;EOI]
or
EN [#count|term|EOI|;count|;term|;EOI]

count is the number of characters to ENTER. **term** and **EOI** override the normal IEEE bus input LF terminator.

RESPONSE Device-dependent data. If count is specified, then count characters will be returned followed by the serial output terminators. Otherwise the response ends when the IEEE bus input terminator is detected and the serial output terminators are appended to the returned data.

MODE *CA

BUS STATES Determined by the Active Controller

EXAMPLES:

PRINT#1,"ENTER" INPUT#1,A$	Read data into A$ until the default bus input terminator is detected.
PRINT#1,"ENTER CR" INPUT#1,A$	Read data until CR is encountered.
PRINT#1,"EN $000" INPUT#1,A$	Read data until a NULL is encountered.
PRINT#1,"ENTER EOI" INPUT#1,A$	Read data until EOI is detected.
PRINT#1,"ENTER #5" A$=INPUT$(5,#1)	Read 5 bytes. INPUT$ gets 5 bytes from file #1.

ERASE Command

The ERASE command is used to delete previously defined Macro Buffers and return the memory they occupy back to the USER heap. Macro Buffers can be individually specified by their number, or all Macro Buffers may be erased and returned by a single ERASE command without a buffer number specifier.

SYNTAX	ERASE[;][number]
	number is a Macro Buffer number from 0 to 99. If not specified, all Macro Buffers are erased.
RESPONSE	None
MODE	Any
BUS STATES	None

EXAMPLES:

```
PRINT#1,"ERASE"          Erase all Macro buffers
PRINT#1,"ERASE 20"       Erase Macro buffer #20
```

ERROR Command

The ERROR command enables or disables automatic reporting of the 488 Controller error messages on command completion. ERROR MESSAGE enables error message string reporting, ERROR NUMBER enables error message number reporting and ERROR OFF disables it. ERROR OFF is the default condition.

While Macros are executing, error reporting is suspended until Macro completion.

SYNTAX	ERROR[;]{MESSAGE|NUMBER |OFF}
RESPONSE	None
MODE	Any
BUS STATES	None

EXAMPLES

```
PRINT#1,"ERROR OFF"          Disable error message reporting.
PRINT#1,"ERROR MESSAGE"      Enable error message reporting.
PRINT#1,"ERROR NUMBER"       Enable error number reporting.
```

HELLO Command

The HELLO command is used to verify communication with the 488 Controller, and to read the software revision number. When the command is sent, the 488 Controller returns a string similar to the following:

488 Controller Revision N.N Copyright 1988

where N.N is the revision and release number of the firmware.

SYNTAX	HELLO or HE
RESPONSE	488 Controller Revision N.N Copyright 1988
	N.N is the revision and release number of the firmware
MODE	Any
BUS STATES	None

EXAMPLE:

```
PRINT#1,"HELLO"                 Get the HELLO response
INPUT#1,A$
PRINT A$                        and display it.
```

ID Command

The ID command allows the user to change the @ or the @@ command character to any printable ASCII character. If the double ID character command is issued, the ID character will default back to “@.”

The desired character must immediately follow the semi-colon without intervening spaces. The @ and @@ command can be disabled by not including the character following the required semicolon. It can be re-enabled by issuing the ID command with a valid character.

If the ID character and TIME OUTs are disabled, and an invalid bus address is specified within a command, the only way to recover control is by re-powering the interface. If you anticipate that the data part of an OUTPUT or SEND command may contain the presently programmed ID character, it should be disabled.

SYNTAX	ID; [ASCII]
	ASCII is any printable ASCII character immediately following the semi-colon (;)
RESPONSE	None
MODE	Any
BUS STATES	None

EXAMPLES

```
PRINT #1, "ID;#"                change the ID character to #
PRINT #1, "ID;"                 disable the ID commands
PRINT #1, "ID;@"                re-enable the ID character to @
```

LOCAL Command

In the System Controller mode, the LOCAL command without optional addresses causes the 488 Controller to un-assert the Remote Enable line. This causes devices on the bus to return to manual operation. As the Active Controller, with bus addresses specified, bus devices are placed in the local mode by the Go To Local (GTL) bus command. If addresses are specified, the state of the Remote Enable line is not affected.

SYNTAX	LOCAL or LO	
RESPONSE	None	
MODE	SC	
BUS STATES	*REM	
EXAMPLE:		
PRINT#1,"LOCAL"		Un-assert the REN Line
SYNTAX	LOCAL addr[,addr] or LO addr[,addr]	
	addr is a bus device address.	
RESPONSE	None	
MODE	CA	
BUS STATES	ATNUNL, MTA, LAG,GTL	
EXAMPLE:		
PRINT#1,"LOCAL 12,16"		Send Go To Local to devices 12 and 16

LOCAL LOCKOUT or LOL Command

The LOCAL LOCKOUT command causes the 488 Controller to issue a Local Lockout IEEE bus command. Bus devices that support this command are thereby inhibited from being controlled manually from their front panels.

SYNTAX	LOCAL LOCKOUT or LOL	
RESPONSE	None	
MODE	CA	
BUS STATES	ATNLLO	
EXAMPLES:		
PRINT#1,"LOCAL LOCKOUT"		Send Local Lockout command.
PRINT#1,"LOL"		Same as above.

MACROENDM Command

The MACRO command allows the user to build a file of sequential commands and execute them with a single DOMACRO command. The 488 Controller is capable of storing up to 100 different Macros.

Defining a Macro is initiated by issuing the MACRO command. Each subsequent character following this command, including terminators and intervening spaces, is saved in a buffer up to, and including, the ENDM. After the ENDM, the 488 Controller appends the macro number to the Macro buffer as a two-digit decimal number. The macro can then be executed by issuing a DOMACRO command. Any syntax errors that are included within the Macro are not checked until the Macro is executed.

If a Macro has not been defined, it does not consume any memory from the USER heap. If a Macro has been defined, any Macro buffer previously allocated is returned to the USER heap prior to requesting memory to re-define the Macro. The initial size of an allocated Macro buffer is 127 character locations (bytes). If more than 127 bytes are required to store the Macro, additional memory is allocated in 127-byte increments. If there is no available memory in the USER heap, an “OUT OF MEMORY” error occurs and any memory allocated to that Macro is returned to the heap.

Other useful commands with Macros follow. You should refer to the command description for complete information.

COMMENT The COMMENT command allows the user to send a predefined ASCII string to the serial host when the Macro is executed.

COUNT The COUNT command returns the Macro loop count of the last executed macro. This command is only valid during Macro execution.

DOMACRO The DOMACRO command executes a Macro. An optionally specified loop count can be included with this command to execute the Macro multiple times. This loop count is the value returned with the COUNT command.

ERASE The ERASE command is used to delete a Macro and return its memory to the USER heap. A specific Macro can be deleted or all can be ERASEd.

ONDOMACRO The ON <event> DOMACRO command enables macro execution upon detection of an event, such as SRQ being asserted by a bus device. This feature is mutually exclusive with the ARM command.

READ The READ command allows the Macro buffer to be transmitted back to the serial host. It is sent exactly as it was built with the exception of the Macro number appended to the ENDM portion. This command requires making a copy of the specified Macro buffer. If there is no available memory in the USER heap for this copy, an “OUT OF MEMORY” error occurs.

TRACE The TRACE ON command allows the embedded Macro commands within the Macro buffer to be echoed out the serial port to the host computer as the Macro is executed. This allows trace debugging during Macro execution. This feature is disabled with the TRACE OFF command.

SYNTAX

```
MACRO[;][number]
 [command list]
 ENDM
 or
 MA[;][number]
[command list]
ENDM
```

number is a Macro Buffer number from 0 to 99. If no number is specified, Macro 0 is assumed.

RESPONSE Dependent on the included command list

MODE Any

BUS STATES Defined by the included command list

EXAMPLE:

```
 10    PRINT #1,"MACRO 10"                  Build Macro #10
 20    PRINT #1,"OUTPUT16;Q00B1X"
 30    PRINT #1,"COMMENT 'Memory Left =\"
 40    PRINT #1,"MEMORY"
 50    PRINT #1,"TRIGGER16/10"
 60    PRINT #1,"ENTER16"
 70    PRINT #1,"ENTER10"
 80    PRINT #1,"ENDM"                      End Macro Mode

 90    PRINT #1,"DOMACRO 10"                Execute the Macro
 100   INPUT #1,M$:PRINT M$                 Read Comment & Memory
 110   INPUT #1,R$:PRINT R$                 Read data from 'ENTER16'
 120   INPUT #1,R$:PRINT R$                 Read data from 'ENTER10'

 130   PRINT #1,"DOMACRO 10;8               Execute it 8 more times
 140   FOR N = 1 TO 8                       Read data 8 times
 150   INPUT #1,M$:PRINT M$                 Read Comment & Memory
 160   INPUT #1,R$:PRINT R$                 Read data from 'ENTER16'
 170   INPUT #1,R$:PRINT R$                 Read data from 'ENTER10'

 180   NEXT N

 190   PRINT #1,"READ 10"                   Request a copy of Macro
 200   WHILE NOT EOF(1)                     Loop until entire Macro
 210   MA$=MA$+INPUT$(1,#1)                 Buffer has been received
 220   WEND
 230   PRINT MA$
```

MASK Command

The MASK command is used to mask the high bit (MSB) of serial input data. Some serial host computers set the most significant bit when using eight-bit serial data lengths. When the MASK ON command is issued, each serial character received is logically ANDed with &H7F (127 decimal).

MASK OFF is the power-on default. In default operation, all serial input data is automatically masked with &H7F. The exception to this is any data which follows a semi-colon (;), an apostrophe ('), or a quotation mark ("). After a MASK ON command, all characters are masked.

SYNTAX	MASK {ON | OFF}
RESPONSE	None
MODE	Any
BUS STATES	None

EXAMPLE:

```
PRINT#1,"MASK ON"
```

MEMORY Command

The MEMORY command returns the amount of memory which, at the time the command is executed, is available in the USER heap.

SYNTAX	MEMORY or ME
RESPONSE	numeric value of the remaining memory in the USER heap
MODE	Any
BUS STATES	None

EXAMPLE:

```
PRINT#1,"MEMORY"               Request amount of available memory
INPUT#1,M : PRINT M
```

ON <event> DOMACRO Command

The ON <event> DOMACRO command allows the 488 Controller to automatically execute a Macro when one or more of the specified events occur. The events are polled between commands; when one of the events is detected as true, its assigned Macro is executed. Once executed, the event is disabled from further execution and must be re-enabled with another ON <event> DOMACRO command.

There are two types of events, level-sensitive and edge-sensitive. Level-sensitive events, such as SRQ, will cause Macro execution every time they are enabled while the event condition persists. Usually, some action must be taken (for example, SPOLL) to clear the condition prior to re-issuing the ON <event> DOMACRO command. Edge sensitive events, such as TRIGGER, are cleared when the Macro executes.

Regardless of the event sensitivity, the ON <event> DOMACRO command must be re-sent after the Macro executes to re-activate the event condition. The optional events include

SRQ — This event is level-sensitive. If the condition exists at the time the ON SRQ DOMACRO command is issued, the 488 Controller will execute the assigned Macro immediately.Domacro>

PERIPHERAL — This event occurs when the 488 Controller is forced from the Controller Active State (*SC-CA) to the Peripheral State (*SC-*CA) by receipt of IFC from the System Controller. This can be useful in detecting receipt of IFC when in the *SC-CA state. This event is edge-sensitive.

CONTROLLER This event occurs when the 488 Controller receives control of the bus and transitions from the Peripheral State (*SC-*CA) to the Controller Active State (*SC-CA). This occurs when the Take Control interface message is received by the 488 Controller. This event is edge-sensitive.

TRIGGER This event occurs when the 488 Controller, as a Peripheral (*CA), receives a Group Execute Trigger (GET) command from the Active Controller. This event is edge sensitive. When the Macro is executed, the internal status, as read by the STATUS 1 command, is cleared.

CLEAR This event occurs when the 488 Controller, as a Peripheral (*CA), receives a Device Clear (DCL) or a Selected Device Clear (SDC) command from the Active Controller. This event is edge-sensitive. When the Macro is executed, the internal status, as read by the STATUS 1 command, is cleared.

TALK This event occurs when the 488 Controller, as a Peripheral (*CA), detects its My Talk Address (MTA) command from the Active Controller. It indicates that the controller has requested information from the 488 Controller. This event is edge-sensitive.

LISTEN This event occurs when the 488 Controller, as a Peripheral (*CA), detects its My Listen Address (MLA) command from the Active Controller. It indicates that the controller has information it wants to send to the 488 Controller. This event is edge-sensitive.

IDLE This event occurs when the 488 Controller, as a Peripheral (*CA), transitions from a Talker or Listener state to a idle state (neither talker or listener). It indicates that the controller has unaddressed the 488 Controller with either an UNT or UNL command. This event is edge-sensitive. When the Macro is executed, the internal status, as read by the STATUS 1 command, is cleared. This event is tested prior to the CHANGE event and will clear the internal CHANGE status only when the addressed to un-addressed transition occurs.

CHANGE This event occurs when the 488 Controller, as a Peripheral (*CA), detects an addressed state change. This occurs on transitions from a Talker nor Listener state to an idle state (neither talker or listener), or from an idle state to a talker or listener state. This event is edge-sensitive. When the Macro is executed, the internal status, as read by the STATUS 1 command, is cleared. This event is tested after the IDLE event. If IDLE is enabled, the CHANGE event's Macro will only execute when an un-addressed to an addressed transition occurs.

ERROR This event occurs when the 488 Controller detects an error condition. The error condition may be an unrecognized command from the serial host, an invalid parameter or a bus error. Refer to **Appendix B** for a listing of the error conditions which can be detected by the 488 Controller. This event is level sensitive. When the Macro is executed, the error status, as read by any of the STATUS commands, must be read before enabling this event again.

Once a condition is enabled it remains enabled until it is DISARMed, the event specified has occurred or until the 488 Controller is reset.

The ON <event> DOMACRO and ARM commands are mutually exclusive. The last command issued takes precedence.

SYNTAX ON {<event>} DOMACRO[number] or ON {<event>} DO[number]

where <event> must include one of the following options

Event	Abbr Form
SRQ	SRQ
PERIPHERAL	PE
CONTROLLER	CO
TRIGGER	TR
CLEAR	CL
TALK	T
LISTEN	L
IDLE	I
CHANGE	CH
ERROR	ER

RESPONSE None

MODE any

BUS STATES None

EXAMPLE:

```
10    PRINT#1,"MACRO 0"                   Create Macro #0
20    PRINT#1,"COMMENT 'I have received an SRQ' "
30    PRINT#1,"ENDM"
40    PRINT#1,"ON SRQ DOMACRO 0"
                                          Enable Macro 0 for On SRQ
```

As a peripheral, the ON LISTEN DOMACRO can be used to input data from the active controller.

```
10    PRINT#1,"MACRO 20"                  Create Macro # 20
20    PRINT#1,"ENTER"
30    PRINT#1,"ON LISTEN DOMACRO 20"
                                          Re-enable for the next MLA
40    PRINT#1,"ENDM"
50    PRINT#1,"ON LISTEN DOMACRO 20"
                                          Enable it for Listen
```

The data will be transmitted out to the serial host without having to re-issue an ENTER command from the host each time.

The next example is an abbreviated form of the previous. Although not as clear, it would require less user-heap memory if there were more being done in the Macro.

```
10     PRINT#1,"MA20"                       Create Macro # 20
20     PRINT#1,"EN"
30     PRINT#1,"ON L DO20"
                                            Re-enable for the next MLA
40     PRINT#1,"ENDM"
50     PRINT#1,"ON L DO20"
                                            Enable it for Listen
```

OUTPUT (Controller mode) Command

The OUTPUT command sends data to the IEEE bus. The Remote Enable line is first asserted if the 488 Controller is the System Controller. If device addresses are specified, those devices will then be addressed to listen. If addresses are not specified, the 488 Controller must already be configured to send data, either as a result of an immediately preceding OUTPUT command or as the result of a SEND command.

If the character count, **count**, is specified, then exactly that number of characters will be sent to the bus devices. Otherwise, OUTPUT terminates data transfer upon detection of a serial CR of LF terminator from the serial input. The serial input terminator(s) are replaced with the bus output terminator(s) before being sent to the bus devices.

The number of characters that can be set to a bus device is limited by the available user heap. The exception to this is OUTPUT #count, in which the number of bytes is limited to 65,535.

The IEEE bus output terminators can be modified with the TERM command. Refer to this command description for complete information.

SYNTAX OUTPUT[addr[,addr]][#count];data
or
OU[addr[,addr]][#count];data

addr is a bus-device address. Up to 15 addresses may be specified.
count is the number of characters to OUTPUT.
data is a string of characters to OUTPUT terminated by the serial terminator(s).
(unless **count** is specified, in which case no terminator is needed).

RESPONSE None

MODE CA

BUS STATES REN (if SC), *ATN, data (without **addr**)
REN (if SC), ATNMTA, UNL, LAG, *ATN, data (with **addr**)

EXAMPLES:

```
PRINT#1,"OUTPUT 22;R0C0T1X" Send "R0C0T1X" to device 22.
PRINT#1,"OUTPUT 06,12;ABC"          Send "ABC" to devices 6 and 12.
PRINT#1,"OUTPUT;XYZ"                And send them "XYZ".
PRINT#1,"OUTPUT 0602;DEF"           Send "DEF" to device 6, sec addr 2.
PRINT#1,"OUTPUT06#26;abcdefghijklmnopqrstuvwxyz"
                              Send the 26 letters of the alphabet terminators to device 6.
```

OUTPUT (Peripheral mode) Command

In Peripheral mode the OUTPUT command sends data to the IEEE bus under control of the Active Controller. The Active Controller must put the 488 Controller into the Talk state and configure some bus device to accept the transferred data. The Talk state can be checked with the STATUS 1 command, can cause a reported condition via the ARM command or force execution of a Macro with the ON TALK DOMACRO command. A time-out error will occur, if enabled, if no bus device accepts the data within the time out period after issuing the OUTPUT command.

If the character count, count, is specified then exactly that number of characters will be sent to the bus devices. Otherwise, OUTPUT terminates data transfer upon detection of the serial CR of LF terminator(s) from the serial input. The serial terminator(s) are replaced with the bus output terminator(s) before being sent to the bus devices.

The number of characters that can be set to a bus device is limited by the available user heap. The exception to this is OUTPUT #count, in which the number of bytes is limited to 65,535.

The IEEE bus output terminators can be modified with the TERM command. Refer to the description of the TERM command for complete information.

Even as a Peripheral, the 488 Controller might be the System Controller. If it is, then it will assert Remote Enable before sending any data.

SYNTAX	OUTPUT [#count];data or OU [#count];data
	count is the number of characters to OUTPUT. **data** is a string of characters to OUTPUT terminated by the serial output terminator(s) unless **count** is specified.
RESPONSE	None
MODE	*CA
BUS STATES	Determined by the Controller, REN asserted if SC

EXAMPLES:

PRINT#1,"OUTPUT;DC VOLTS"	Send "DC VOLTS".
PRINT#1,"OUTPUT#5;ABCDE"	Send "ABCDE" without any bus terminators.

PASS CONTROL Command

The PASS CONTROL command allows the 488 Controller to give control to another controller on the bus. After passing control, the 488 Controller enters the Peripheral mode (*CA). If the 488 Controller was the System Controller, then it remains the System Controller but it is no longer the Active Controller. The Controller now has command of the bus until it passes control to another device or back to the 488 Controller. The System Controller can regain control of the bus at any time by issuing an ABORT command.

SYNTAX	PASS CONTROL addr or PA addr
	addr is the bus address of the device to which control is passed.
RESPONSE	None

MODE	CA
BUS STATES	ATNUNL, MLA, TAG, UNL,TCT, *ATN

EXAMPLES:

```
100   PRINT#1,"PASS CONTROL 22"          Control is passed to device 22.
110   PRINT#1,"STATUS 1"                 Wait until we are controller again.
120   INPUT#1,A$
130   IF LEFT$(A$,1)<>"C" THEN 110       Use STATUS 1 to check
140   <rest of program>
```

The next example uses the ARM command to determine when control been given back to the 488 Controller.

```
100   PRINT#1,"PA 22"                    Control is passed to device 22.
110   PRINT#1,"ARM CO"
120   INPUT#1,A$                         Wait until we are controller
130   <rest of program>
```

PPOLL Command

The Parallel Poll command, PPOLL, is used to request status information from many bus devices simultaneously. If a device requires service then it will respond to a Parallel Poll by asserting one of the eight IEEE bus data lines (DIO1 through DIO8, with DIO1 being the least significant). In this manner, up to eight devices may simultaneously be polled by the controller. More than one device can share any particular DIO line. In this case it is necessary to perform further Serial Polling to determine which device actually requires service.

Parallel polling is often used upon detection of a Service Request (SRQ), though it may also be performed periodically by the controller. In either case, PPOLL will respond with a number from 0 to 255 corresponding to the eight binary DIO lines.

Not every device supports parallel polling. Refer to the manufacturer's documentation for each bus device to determine if Parallel Poll capabilities are supported.

SYNTAX	PPOLL
RESPONSE	Number in the range of 0 to 255
MODE	CA
BUS STATES	ATNEOI,<parallel poll response>, *EOI

EXAMPLE:

```
PRINT#1 "PPOLL"               Conduct a Parallel Poll
INPUT#1,PPSTAT                Receive the PPOLL status
PRINT PPSTAT
```

PPOLL CONFIG or PPC Command

PPOLL CONFIG (Parallel Poll Configure) configures the Parallel Poll response of a specified bus device. Not all devices support Parallel Polling and, among those that do, not all support software control of their Parallel Poll response. Some devices are configured by internal switches.

The Parallel Poll response is set by a four-bit binary number (S P2 P1 P0), response. The most significant bit of response is the Sense (S) bit. The Sense bit is used to determine when the device will assert its Parallel Poll response. Each bus device has an internal individual status (**ist**). The Parallel Poll response will be asserted when this **ist** equals the Sense bit value. **ist** is normally a logical “1” when the device requires attention, so the S bit should normally also be a logical “1.” If the S bit is “0,” then the device will assert its Parallel Poll response when its **ist** is a logical “0,” i.e. it does not require attention. However, the meaning of **ist** can vary between devices, so refer to your IEEE bus device documentation.

The remaining 3 least significant bits of response, P2, P1, and P0, specify which DIO bus data line will be asserted by the device in response to a Parallel Poll. These bits form a binary number with a value from 0 through 7, specifying data lines DIO1 through DIO8, respectively.

SYNTAX

PPOLL CONFIG addr;response
or
PPOLL C addr;response
or
PPC addr;response

addr is a bus address.
response is the decimal equivalent of the four binary bits S, P2, P1, and P0.

RESPONSE None

MODE CA

BUS STATES ATNUNL, MTA, LAG, PPC, PPE

EXAMPLES:

PRINT #1,"PPC23;&H0D"
Configure device 23 to assert DIO6 when it desires service and it is Parallel Polled (&H0D = 1101 binary; S = 1, P2P1P0 = 101 = 5 decimal = DIO6).

PPOLL DISABLE or PPD Command

PPOLL DISABLE disables the Parallel Poll response of selected bus devices.

SYNTAX

PPOLL DISABLE addr[,addr]
or
PPOLL D addr[,addr]
or
PPD addr[,addr]

addr is a bus device address

RESPONSE None

MODE CA

BUS STATES ATNUNL, MTA, LAG, PPC, PPD

EXAMPLE:

PRINT#1,"PPOLL DISABLE18,06,13"
Disable Parallel Poll response of devices 18, 6, and 13.

PPOLL UNCONFIG or PPU Command

PPOLL UNCONFIG (Parallel Poll Unconfigure) disables the Parallel Poll response of all bus devices.

SYNTAX	PPOLL UNCONFIG or PPOLL U or PPU
RESPONSE	None
MODE	CA
BUS STATES	ATNPPU

EXAMPLE:

PRINT #1,"PPOLL UNCONFIG
Disable the Parallel Poll response of all bus devices.

READ Command

The READ command is used to inspect the contents of a defined Macro Buffer. Macro Buffers can be individually specified by their number. When a READ command is received, a copy of the Macro buffer requested is sent to the serial output. If there is not enough memory in the user heap to make the copy, an “OUT OF MEMORY” error is generated.

SYNTAX	READ[;][number]
	number is a Macro Buffer number from 0 to 99. If not specified, Macro 0 is assumed.
RESPONSE	The contents of the Macro buffer are returned to the serial output.
MODE	Any
BUS STATES	None

EXAMPLES:

PRINT#1,"READ"	Read the contents of Macro 0
PRINT#1,"READ 20"	Read the contents of Macro 20

REMOTE Command

The REMOTE command asserts the Remote Enable (REN) bus management line. If the optional bus addresses are specified, then REMOTE also addresses those devices to listen, placing them in the Remote addressed state.

SYNTAX	REMOTE or REM
RESPONSE	None
MODE	SC
BUS STATES	REN
EXAMPLES:	

PRINT #1,"REMOTE"   Assert Remote Enable

SYNTAX	REMOTE addr[,addr] or REM addr [,addr]
	addr is a bus device address
RESPONSE	None
MODE	SCCA
BUS STATES	REN, ATNUNL, MTA, LAG

PRINT #1,"REMOTE16,28"   Assert Remote Enable and address devices 16 and 28 to listen.

REQUEST Command

In Peripheral mode, the 488 Controller is able to request service from the Active Controller by asserting the Service Request bus signal. The REQUEST command sets the Serial Poll status (including Service Request) of the 488 Controller. REQUEST takes a numeric argument in the range of 0 to 255 (&H0 to &HFF) that is used to set the Serial Poll status. When the 488 Controller is Serial Polled by the Controller, it returns this byte on the DIO data lines.

The data lines are numbered DIO8 through DIO1. DIO8 is the most and corresponds to a value of 128 (&H80). DIO7 is the next most significant line and corresponds to a value of 64 (&H40). DIO7 has a special meaning: It is the Request For Service (rsv) bit. REQUEST always forces this bit to a “1” which generates a service request (SRQ) to the controller.

When the 488 Controller is Serial Polled, all eight bits of the Serial Poll status are returned to the Controller. The rsv bit is cleared when the 488 Controller is Serial Polled by the Controller. This causes the 488 Controller to stop asserting SRQ.

SYNTAX	REQUEST [;][status] or REQ [;][status]
	status is the service request status in the range of 0 to 255. If **status** is not specified, only rsv (DIO7) is asserted.
RESPONSE	None
MODE	*CA

BUS STATES	SRQ

EXAMPLES:

PRINT#1,"REQUEST";2+4	Generate an SRQ (64) with DIO2 (2) and DIO3 (4) set in the Serial Poll Response.
PRINT#1,"REQUEST"	Generate an SRQ (64)

RESET Command

The system command RESET provides a warm start of the interface. Issuing the RESET command clears the serial input (pending commands) and output (pending data) buffers and re-initializes the internal IEEE controller hardware. It is equivalent to issuing the following commands:

ABORT (If System Controller)
DISARM
ERASE
ERROR OFF
LOCAL (If System Controller)
REQUEST 0 (With rsv cleared if peripheral)
TIME OUT 0
TRACE OFF
Clear CHANGE, TRIGGER, and CLEAR STATUS.

The RESET command provides a warm start of the interface as well as clearing all error conditions. Upon detection of the RESET command, the 488 Controller un-asserts its serial output handshake line (RTS). It re-asserts it when it is capable of accepting serial input data. If XON/XOFF handshake is selected, the handshake state is not affected by the RESET command.

SYNTAX	RESET or RESE
RESPONSE	None
MODE	Any
BUS STATES	IFC,*IFC,*REN (if SC)

EXAMPLE:

```
PRINT#1,"RESET"
```

RESUME Command

The RESUME command un-asserts the Attention (ATN) bus signal. As the Active Controller, Attention is normally kept asserted by the 488 Controller but it must be un-asserted to allow transfers to take place between two Peripheral devices. In this case, the 488 Controller SENDs the appropriate talk and listen addresses, and the must un-assert Attention with the RESUME command.

SYNTAX	RESUME or RESU
RESPONSE	None
MODE	CA
BUS STATES	*ATN

EXAMPLE:

PRINT#1,"RESUME"	Un-assert ATTENTION line.

SEND Command

The SEND command provides byte-by-byte control of data and control transfers on the bus and gives greater flexibility than the other commands. The command can specify exactly which operations will be executed by the 488 Controller.

The following sub-commands are available within the SEND command:

UNT	Send the multiline Untalk command. ATN is asserted.
UNL	Send the multiline Unlisten command. ATN is asserted.
MTA	Send My (the 488 Controller's) Talk Address. ATN is asserted.
MLA	Send My (the 488 Controller's) Listen Address. ATN is asserted.
TALK addr	Send Talk Address addr device (TAG). ATN is asserted.
LISTEN addr [,addr]	Send Listen Addresses (LAG). ATN is asserted.
DATA {'data'|char[,char]}	Send character strings data or characters with numeric ASCII values char with ATN unasserted.
EOI {'data'|char[,char]}	Send character strings data or characters with numeric ASCII values char with ATN unasserted. EOI is asserted on the last character.
CMD {'data'|char[,char]}	Send character strings data or characters with numeric ASCII values char with ATN asserted.
ENTER	Request data from a device terminating on LF. ATN is unasserted.

The DATA, EOI and, CMD sub-commands send data bytes or characters over the bus. The characters to be sent are specified either as a quoted string ('data') or as individual ASCII values (char[,char]). For example, DATA'R0X' sends the characters R, 0, and X to the active listeners, and DATA 13,&H0A sends carriage-return and line-feed. Multiple ASCII char bytes may be specified by separating them with commas.

The EOI subcommand is identical to the DATA subcommand except that the End Or Identify (EOI) signal is asserted on the transfer of the last character.

The CMD subcommand sends the data bytes with Attention (ATN) is asserted. This tells the bus devices that the characters are to be interpreted as IEEE bus commands, rather than as data. EOI is not asserted during CMD transfers. For example CMD &H3F same as Unlisten (UNL). Note that it is not possible to assert EOI during the transfer of a command byte because EOI and ATN together specify parallel poll.

The ENTER subcommand inputs data from the active talker, setup from either a TALK **addr** sub-command or a previous ENTER command. Addresses are not allowed to be specified as options to this subcommand. The ENTER subcommand will terminate upon detection of a Line Feed (LF) character.

Note that the maximum length of the SEND command, including any subcommands, is 127 characters. If large amounts of data must be transferred using the SEND command, then multiple SEND commands must be used so that they are each less than 127 characters long. For example:

```
PRINT#1,"SEND UNT UNL MTA LISTEN 16 DATA 1,2,3,4,5,6"
```

is equivalent to

```
PRINT#1,"SEND UNT UNL MTA LISTEN 16"
PRINT#1,"SEND DATA 1,2,3"
PRINT#1,"SEND DATA 4,5,6"
```

In this way, a long SEND command can be broken up into shorter commands.

SYNTAX	SEND [;] subcommand [subcommand] or SE [;] subcommand [subcommand]	
RESPONSE	None or device data	
MODE	CA	(any subcommands)
	Any	(DATA, EOI and ENTER subcommands only)
BUS STATES	user defined	

EXAMPLES:

```
PRINT#1,"SEND MTA UNL LISTEN 16 DATA 'T1S0R2X' "
```

is the same as

```
PRINT#1,"OUTPUT16;T1S0R2X"
```

```
PRINT#1,"SEND CMD128,0,10 DATA156,35 EOI'ABC' "
```

sends the following byte sequence:

Data	ATN	EOI
10000000	ATN	*EOI
00000000	ATN	*EOI
00001010	ATN	*EOI
10011100	*ATN	*EOI
00100011	*ATN	*EOI
01000001	*ATN	*EOI
01000010	*ATN	*EOI
01000011	*ATN	EOI

SPOLL Command

In Active Controller mode the SPOLL command performs a Serial Poll of the bus device specified and responds with a number from 0 to 255 representing the decimal equivalent of the eight-bit device response. If rsv (DIO7, decimal value 64) is set, then that device is signaling that it requires service. The meanings of the other bits are device-specific. Serial Polls are normally performed in response to assertion of the Service Request (SRQ) bus signal by some bus device. If multiple addresses are specified, the 488 Controller will serial poll each device in sequence and output each device's response to the serial port with the serial output terminator(s) appended.

In Active Controller mode, with no bus address specified, the SPOLL command returns the external SRQ status. If the SRQ line is asserted, the 488 Controller will return a "64." If it is not asserted, the 488 Controller will return a "0."

In Peripheral mode the SPOLL command is issued without an address and returns 488 Controller's own serial poll status. If rsv (DIO7, decimal value 64) is set, then the 488 Controller has not been Serial Polled since issuing the last REQUEST command. rsv is reset whenever the 488 Controller is Serial Polled by the Controller.

SYNTAX	SPOLL [addr[,addr]] or SP [addr[,addr]]
	addr is the bus device(s) to be Serial Polled
RESPONSE	0 or 64 (without **addr**) 0 to 255 (with **addr**)
MODE	CA
BUS STATES	ATNUNL, MLA, TAG, SPE, *ATN, data, ATNSPD, UNT

EXAMPLES:

```
PRINT#1,"SPOLL 16"            Serial Poll device 16
INPUT#1,SPSTAT                Receive the Spoll status
IF SPSTAT AND 64 THEN         Test rsv

PRINT#1,"SPOLL"               Check the SRQ status
INPUT#1,SRQ
IF SRQ<>0 THEN                If SRQ is asserted then

PRINT#1,"SPOLL 10,12,16"
INPUT#1,SP10,SP12,SP16        Get SPOLL response from devices 10, 12, and 16.
```

SYNTAX	SPOLL or SP
RESPONSE	0 to 255
MODE	*CA
BUS STATES	None

EXAMPLES:

```
PRINT#1,"SPOLL"               Get own Spoll Status
INPUT#1,SPSTAT
IF (SPSTAT AND 64) = 0 THEN
                              rsv will be reset if we have been Spolled.
```

STATUS Command

STATUS is a system command which is useful for determining which mode the 488 Controller is in, its current address or the type of ERROR that has occurred. At power-up, issuing the STATUS command will cause the 488 Controller to return the string...

CONTROLLER 10

After issuing a PASS CONTROL or PERIPHERAL command the 488 Controller will respond with...

PERIPHERAL 10

If PASS CONTROL was issued and the 488 Controller then receives control again it will respond with....

CONTROLLER 10

This is useful for checking when control is returned after a PASS CONTROL has been issued.

If an ERROR has occurred, as indicated on the front panel of the 488 Controller, issuing the STATUS command will cause an error message to be returned to the host. Once the error message is sent by the 488 Controller the error condition is cleared. Refer to **Appendix B** for explanations of error messages.

The 488 Controller also includes an extended status command, STATUS 1. The STATUS 1 command returns various items detailing the current state of the 488 Controller. They are returned as one long character string as follows:

Item	Starting Col	# Cols.	Values
Operating mode	1	1	C: Controller P: Peripheral
Bus address	3	2	Two-digit decimal number 00 to 30
Address change	6	2	G0: Address status change has not occurred. G1: Address status change has occurred.
Addressed state	9	1	T: Talker L: Listener I: Idle
Service Request	11	2	S0: SRQ is not asserted. S1: SRQ is asserted.
Error code	14	3	Enn: Letter “E” followed by 2-digit error code. Refer to **Appendix B** for Error explanations.
Triggered	18	2	T0: No IEEE Trigger command received. T1: Received the IEEE Trigger command.
Cleared	21	2	C0: No IEEE Clear command received. C1: Received the IEEE command.
Error description	24	17	Text of error message

The Operating Mode (C or P) indicates whether or not the 488 Controller is the Active Controller. If the 488 Controller Passes Control to another device, then the Operating Mode indicator will change from “C” to “P.” When the 488 Controller regains control, then the indicator will again be “C.” If the 488 Controller is not the System Controller, then it will initially be a Peripheral, and thus the indicator will be “P.” It will, of course, become “C” when the 488 Controller receives control from the Active Controller.

The Bus Address is the IEEE bus device address assigned to the 488 Controller by the internal hardware switch.

The Address Change (G0, G1) indicator is set whenever the 488 Controller transitions from the idle state to a Talker or Listener, or from a Talker or Listener state to an idle state. It will not indicate when a change is made from a listener to a talker or a talker to a listener. The address change is reset when STATUS 1 is read.

The Addressed State is the current talker/listener state of the 488 Controller. As a Peripheral, the 488 Controller can check this status to see if it has been Addressed to Talk or Addressed to Listen by the Active Controller. In this way the desired direction of data transfer can be determined.

The Service Request indicator reflects the external SRQ status. If the SRQ line is asserted, S1 will be reported. If it is unasserted, S0 will be reported.

The Error Code is 00 when no error has occurred. If it is nonzero, then the appropriate error message is appended to the STATUS 1 response. For more details about the individual errors, refer to **Appendix B**. The Error Code is reset to 00 when STATUS is read.

The Triggered (T0, T1) and Cleared (C0, C1) indicators are set when, as a Peripheral, the 488 Controller has received a GET (Group Execute Trigger) or SDC/DCL (Selected Device Clear/Device Clear) bus command. These two indicators are cleared when STATUS1 is read.

By issuing the STATUS 2 command, only the numeric error value is returned to the serial output port. If no error has occurred, the value sent is 0. The error condition is clear when reported.

SYNTAX	STATUS [;][number] or ST [;][number]
	number is 0 to 2. If not specified, 0 is assumed.
RESPONSE	Character string as described previously
MODE	Any
BUS STATES	None

EXAMPLES:

```
PRINT#1,"STATUS"             Read the 488 Controller status
INPUT#1,A$
PRINT A$                     and display it.
CONTROLLER 10                Example of displayed STATUS 0

PRINT#1, "STATUS1"           Read the 488 Controller extended status and display it.
INPUT#1,A$
PRINT A$
C 10 G0 I S0 E00 T0 C0 OK    Example of STATUS 1

PRINT#1,"STATUS2"            Read the 488 Controller error status and display it.
INPUT#1,A
PRINT A
0                            Example of displayed STATUS 2
```

STERM Command

The STERM command sets the end-of-line terminators for output to the serial host. All output to the serial port is terminated by the serial output terminator(s). All input from the serial host must be terminated by either a Line Feed (LF) or Carriage Return (CR) except OUTPUT #count.

During INPUT, the 488 Controller takes the data it receives from the bus device until it detects the LF of other optionally specified input terminating condition. It strips all CR and LF from the input data and appends the serial output terminator(s) before sending it to the serial host. The default serial terminators for output are set by internal DIP switches and are factory set for CR LF.

SYNTAX	STERM[;]{term[term]|[NONE]} or STE[;]{term[term]|[NONE]}
	term is one of CR, LF, $char, or 'X, specifying a terminator character.
RESPONSE	None
MODE	Any
BUS STATES	None

EXAMPLES:

PRINT#1,"STERM CR"	Set the serial output terminator to carriage return.
PRINT#1,"STERM NONE"	Disable sending any serial output terminators.
PRINT#1,"STERM $&H0D"	Set the serial output terminator to carriage-return.
PRINT#1,"STERM $0"	Set the serial output terminator to NULL.

TERM Command

The TERM command sets the end-of-line terminators for output to IEEE bus devices. All output to IEEE bus devices, except OUTPUT #count, is terminated by the IEEE bus output terminator. All ENTER input from IEEE bus devices is terminated on a Line Feed (LF) or optionally specified with the ENTER command.

During OUTPUT, the 488 Controller takes the data it receives from the user's program, strips all CR and LE characters from it (except OUTPUT #count) and appends the IEEE bus output terminator before sending it to the IEEE bus device. The default terminators for output are set by internal DIP switches and are factory-set to CR LF, which is appropriate for most bus devices.

EOI has a different meaning when specified for input than when it is specified for output. During input, EOI specifies that input will be terminated upon detection of the EOI bus signal, regardless of which characters have been received. During output, EOI specifies that the EOI bus signal is to be asserted during the last byte transferred.

SYNTAX TERM[;]{term[term][EOI]|[EOI]|[NONE]}
or
TE[;]{term[term][EOI]|[EOI]|[NONE]}

term is one of CR, LF, $char, or 'X, specifying a terminator character.

RESPONSE None

MODE Any

BUS STATES None

EXAMPLES:

PRINT#1,"TERM CR LF EOI"	Set output bus terminators to carriage-return line-feed, with EOI asserted on line-feed.
PRINT#1,"TERM LF EOI"	Set output terminator to LF with EOI.
PRINT#1,"TERM 'Z"	Set bus terminator to the letter "Z."
PRINT#1,"TERM $0 EOI"	Set output term to NULL with EOI.

TIME OUT Command

The TIME OUT command sets the number of seconds that the 488 Controller will wait for a transfer before declaring a timeout error. The 488 Controller checks for timeout errors on every byte (including command bytes as a controller) it transfers.

Timeout checking may be suppressed by specifying time out after zero seconds. The default timeout is 0 seconds, or timeout disabled.

SYNTAX TIME OUT[;][n] or TI[;][n]

n is the number of seconds to allow in the range of 0 to 65535. If **n** is zero or unspecified, ignore timeouts.

RESPONSE None

MODE Any

BUS STATES	None

EXAMPLES:

PRINT#1,"TIME OUT 10"	Wait 10 seconds before timeout
PRINT#1,"TIME OUT 3600"	Wait an hour before timeout
PRINT#1,"TIME OUT 0"	Ignore timeouts.

TRACE Command

The TRACE ON command allows the embedded macro commands within the macro buffer to be echoed out the serial port to the host computer as the Macro is executed. This allows trace debugging during Macro execution. This feature is disabled with the TRACE OFF command.

SYNTAX	TRACE{ON |OFF}
RESPONSE	Echoes Macro commands during Macro execution
MODE	Any
BUS STATES	None

EXAMPLES:

PRINT#1,"TRACR ON"	Enable Tracing
PRINT#1,"DOMACRO 0"	Execute and trace macro #0

TRIGGER Command

The TRIGGER command issues a Group Execute Trigger (GET) bus command to the specified devices. If no addresses are specified, then the GET will only affect those devices that are already in the listen state as a result of a previous OUTPUT or SEND command.

SYNTAX	TRIGGER[addr[,addr]] or TR[addr[,addr]]	
	addr is a bus device address to be triggered.	
RESPONSE	None	
MODE	CA	
BUS STATES	ATNGET	(without **addr**)
	ATNUNL, MTA, LAG, GET	(with **addr**)

EXAMPLES:

PRINT#1,"TRIGGER02,04,16"	Issue Group Execute Trigger to devices 2, 4, and 16.
PRINT#1,"TRIGGER"	Trigger all current listeners.

6. Controller Pass-Thru Operation

6.1 Introduction

The Controller Pass-Thru mode allows a serial RS-232 or RS-422 host device to transparently send data to a single IEEE bus peripheral or to multiple peripherals if they occupy the same bus address. Applications include interfacing a listen-only or addressable IEEE printer/plotter to a serial printer port.

Once the 488 Controller has initialized itself after power-on, it waits for several input data. When the data are received, it addresses the selected IEEE device to listen with the following bus sequence:

ATNUNL,MTA,LAG,*ATN

The data received from the serial host is placed into a circular serial input buffer. Simultaneously, characters are removed from that buffer and sent to the IEEE bus device. The serial terminator(s), if present, are not sent. Instead, the IEEE terminators are substituted and sent in their place.

So long as the serial input buffer is not empty, the 488 Controller will continue to send data from it to the IEEE bus device. If the serial input buffer becomes emptied, the 488 Controller will command the IEEE bus device to talk if the talk-back feature is enabled. This allows the 488 Controller to be used as a controller with devices, such as plotters or instruments, that return status and other information to the host computer.

When the 488 Controller addresses the IEEE bus device to talk it uses the following bus sequence:

ATNUNL,MLA,TAG,*ATN

The 488 Controller then accepts data from the IEEE device and returns it to the host until the last selected IEEE terminator is detected. The IEEE bus terminators are replaced by the serial terminators, and these are then sent to the serial host.

If the IEEE device has been addressed to talk but does not respond or finish transmission by the time additional characters are received into the circular serial input buffer, the talk sequence will be aborted to allow additional serial information to be sent to the IEEE device.

6.2 Serial and IEEE Terminator Substitution

The 488 Controller can be configured to provide serial-to-IEEE-488 and IEEE-488-to-serial terminator substitution. This is useful when interfacing a serial host that only issues carriage return [CR] as an output terminator to an IEEE peripheral that expects a carriage return followed by a line feed [CR-LF].

In this previous example, the serial terminator should be selected for CR Only while the IEEE terminator is set for CR-LF. When a serial CR character is received, it is discarded and replaced by an IEEE CR followed by an IEEE LF. In the IEEE-to-serial direction, the IEEE CR is unconditionally discarded. Upon receipt of the IEEE LF, a serial CR is substituted.

The 488 Controller can be made totally data transparent by setting both the serial and IEEE terminators to be CR Only or LF Only. Refer to **Chapter 3** for the proper switch settings for both the IEEE and serial terminators.

6.3 IEEE Address Selection

SW3-1 through SW3-5 select the IEEE bus address of the IEEE peripheral the 488 Controller will be communicating with. *In Pass-Thru mode, these switches set the address of the IEEE device that will be controlled, not the address of the 488 Controller.* The address of the 488 Controller is automatically adjusted so that address conflicts will not occur. The address is selected by simple binary weighting, with SW3-1 being the least significant bit and SW3-5 the most significant. If address 31 (reserved on the IEEE bus) is selected in the controller mode, address 30 is assigned as the device it will be communicating with. The following figure shows the IEEE address selection of 10.

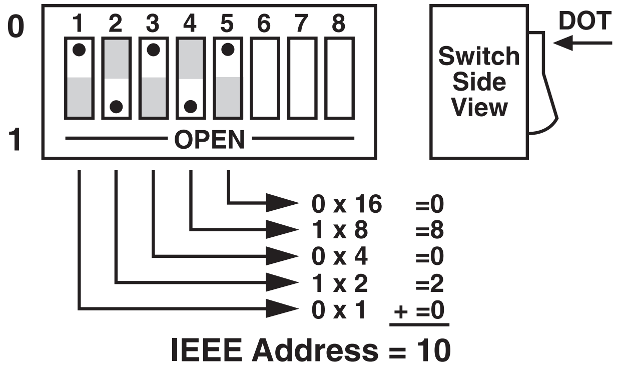


Figure 6-1. SW3 View for IEEE Address Selection.

6.4 Talk Back On Terminator

A switch-selectable talk-back feature is included to provide bidirectional communication with the IEEE device. Whether the talk-back feature should be enabled depends on the application.

SW1-7 is used to determine whether the interface should address the attached bus device to talk after sending the selected IEEE bus terminator(s). This feature is commonly used to provide bidirectional communication with a single IEEE instrument. Talk back will only occur if there is no serial data to output to the IEEE device.

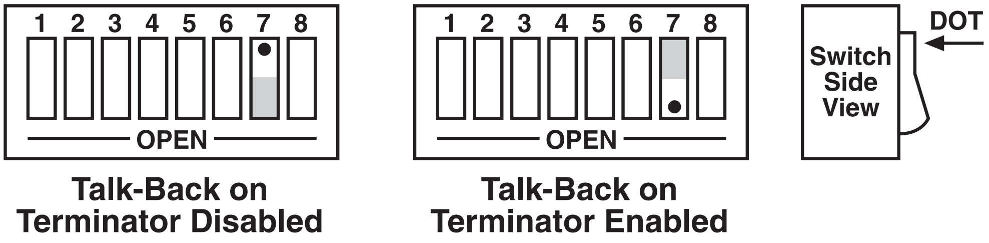

1 2 3 4 5 6 7 8
OPEN
Talk-Back on Terminator Disabled
1 2 3 4 5 6 7 8
OPEN
Talk-Back on Terminator Enabled
Switch Side View
DOT

Figure 6-2. SW1 View for Talk-Back Selection.

When the serial input buffer becomes empty, the 488 Controller checks the last characters sent to the IEEE bus device. If these were the IEEE bus terminators and Talk-Back is enabled, the IEEE bus device is addressed to talk. Any data received by the 488 Controller from the bus device is sent to the serial host.

When the last IEEE bus terminator is detected from the IEEE device, the 488 Controller disables the device from sending additional information by asserting Attention (ATN) on the bus.

If the IEEE device does not respond or finish transmission by the time additional characters are received into the serial input buffer, the talk sequence will be aborted to allow additional serial information to be sent to the IEEE device.

The following is an example of how this feature can be used to communicate with a single IEEE instrument. The program example is written in BASIC on an IBM PC or compatible and communicates with a Keithley Model 196 DMM.

```
10    '
20    '   Example Program using 488 Controller with the Talk Back on Terminator Feature
25    '   Enabled to Communicate with a Keithley Model 196 DMM
30    '
40    '
50    '   Open BASIC's serial communications port
60    OPEN "COM1: 9600, N, 8, 2" AS 1
70    '   Set the Model 196 DMM to the 30-VDC range
80    PRINT #l,"F0R3X"; ' The ; suppresses terminators
90    '   Request 10 Readings from 196
100   FOR N=1 to 10
110       PRINT #l," " ' Output terminator
120       LINE INPUT #l, A$ ' Get Reading from 196
130       PRINT A$ ' Print it on the screen
140   NEXT N
150   END
```

6.5 Plotter Applications

To use the 488 Controller to interface an HP-IB plotter to a serial computer port, you will need the following information about your system.

l. The serial data format that the application (plotting or graphics) program expects the plotter to communicate with. These parameters include baud rate, word length, stop bits, parity, and serial control.

   Some programs allow these parameters to be selected by the user. Other graphics programs depend on the RS-232 version of the plotter defaults. Usually, Hewlett-Packard plotters use 9600 baud, 7 data bits, 1 stop bit, even parity, and XON/XOFF serial control. Since these plotters are available with serial interfaces, the operator's manual of your IEEE plotter should contain this information.

2. The IEEE bus address of your plotter. This address is usually set by a DIP switch located on the rear of the plotter. The first five switches set the address which, for Hewlett-Packard plotters, is usually address 5. Refer to the plotter's operator's manual for exact information.

Set the 488 Controller's internal DIP switches to match the parameters determined above. Other parameters which should be selected include:

1. Talk Back Enabled.
2. Serial Terminators set to CR Only.
3. IEEE Terminators set to CR Only with EOI enabled.

The following shows the 488 Controller's internal switch settings required to use a Hewlett-Packard 7580A plotter on an IBM PC or compatible. Because PCs and compatibles output RS-232 levels, the shorting DIP jumper should be set to the RS-232 position (J206).

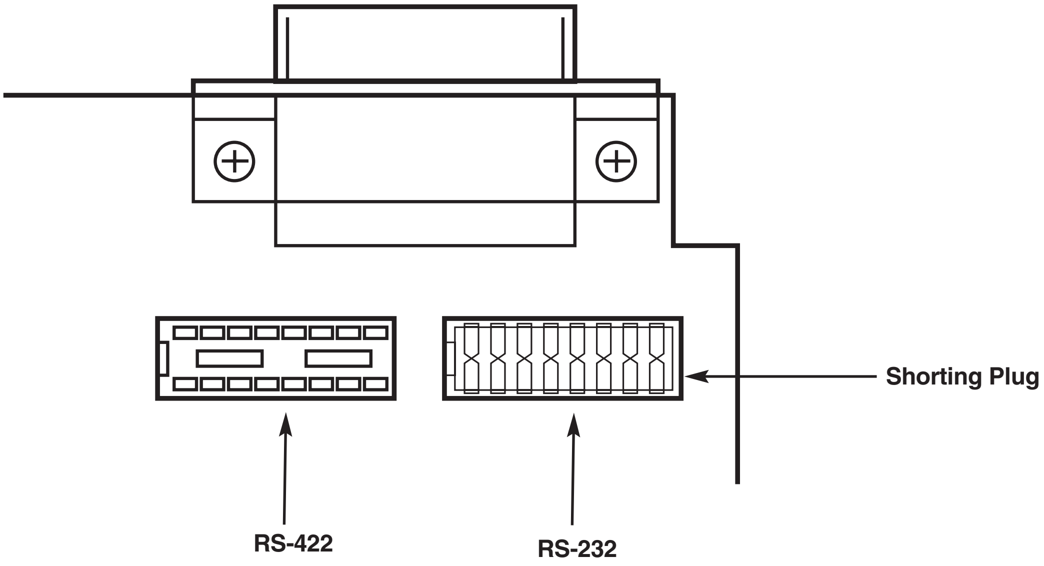


Figure 6-3. Selecting RS-232 Signal Levels.

After configuration, turn on the plotter and the 488 Controller. The 488 Controller's front-panel LEDs should all light momentarily while it performs an internal ROM and RAM test. All LEDs should go out except for the Power and Talk LED. The Talk LED indicates that the 488 Controller has detected the plotter on the IEEE bus and has addressed it to listen.

When the serial host begins to send data to the 488 Controller, the Receive LED will flash. If it does not, this indicates that the 488 Controller is not receiving data from the serial host. Verify the cables are connected properly and the serial cable wiring. Verify the serial data format, word length, stop bits and parity.

6.6 Printer Applications

Most of the information given for plotter applications applies to applications for interfacing IEEE 488 printers to a serial host. Some high-end printers have a secondary command setting, which must be disabled for the 488 Controller to control them. The 488 Controller does not use secondary commands to control IEEE peripherals, such as printers or plotters. Refer to the printer's instruction manual if there is a question as to whether the printer requires secondary commands.

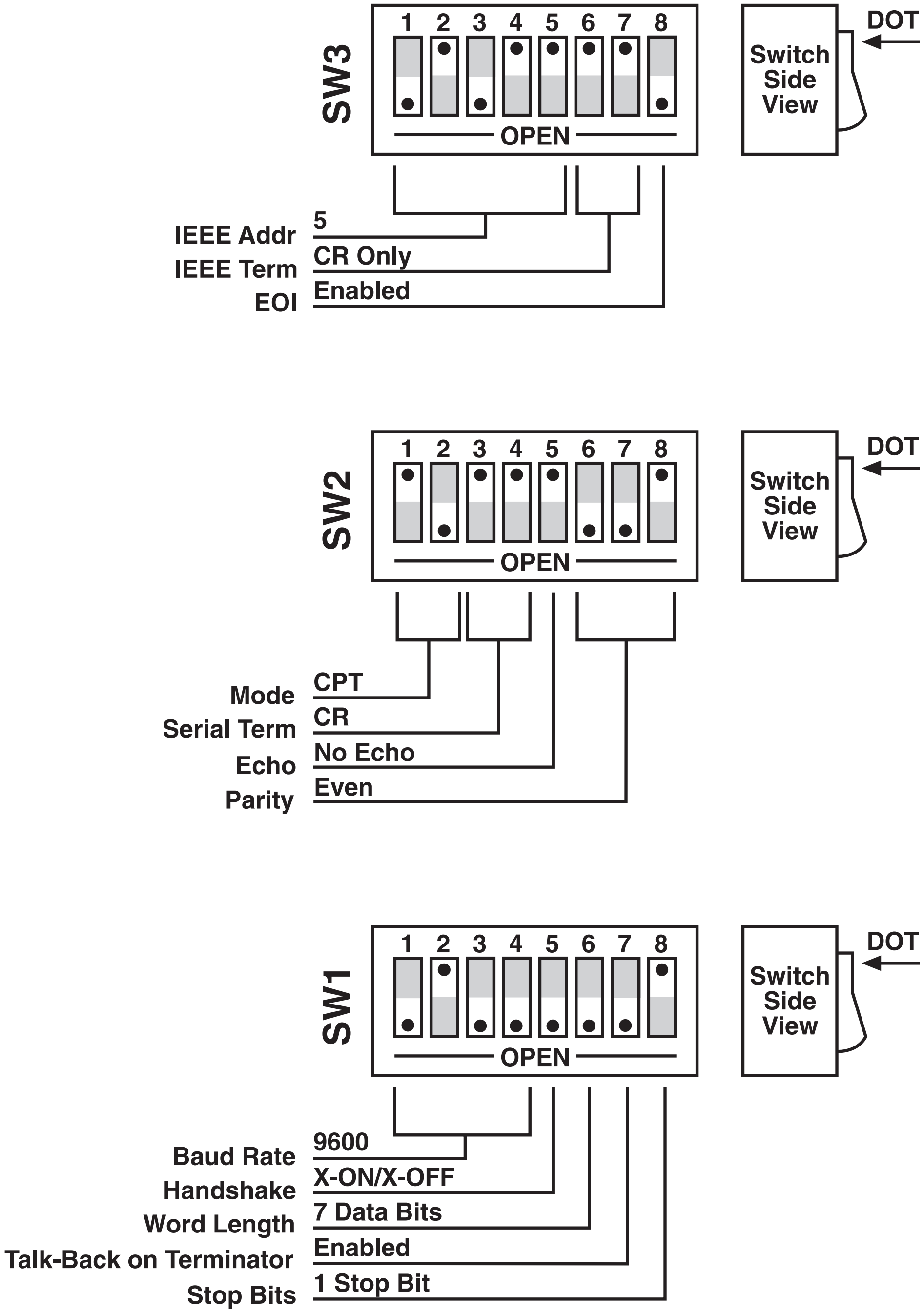


Figure 6-4. 488 Controller Settings for Use with an HP 7580A Plotter on an IBM PC.

7. Peripheral Pass-Thru Operation

7.1 Introduction

The Peripheral Pass-Thru mode of operation is useful in interfacing a serial device, such as a serial printer, plotter, or instrument, to an IEEE controller. Data sent by the IEEE controller to the 488 Controller is buffered and transmitted out its serial port. Data received from the serial device is buffered by the 488 Controller until read by the IEEE controller. The 488 Controller can buffer approximately 30,000 bytes of data from both the IEEE input and the serial input.

The 488 Controller will refuse to accept more data from the IEEE controller when its buffer memory is full. It does this by preventing completion of the bus handshaking sequences. It will also request that additional serial data not be sent by negating its Request To Send (RTS) output or by transmitting the XOFF ASCII character. The serial handshake used depends on the handshake selection (refer to **Chapter 3**).

7.2 Serial and IEEE Input Buffers

Memory in the 488 Controller is dynamically allocated for the serial input and IEEE input buffers. This allows for the most efficient partitioning of memory for any given application.

At power on, or device clear, each buffer is allocated a 127-byte mini-buffer or queue. When the serial input [or IEEE input] requires more buffer space, additional queues are allocated. When a queue is empty, it is released from the input buffers so that it may be re-allocated when, and where, required.

There are approximately 240 available queues for a total of 30,000 bytes of buffer (character) space. Queues are continually allocated and released as required by the serial and IEEE input. Of the 240 available queues, 230 are issued without regard to controlling the receipt of additional serial or IEEE input data.

When the serial input buffer requests one of the last 10 queues (in other words, when there are 1270 character locations left), it signals the serial host that it should stop sending data. This is accomplished by either unasserting RTS or issuing XOFF, depending on which serial handshake control has been switch selected. When more than 10 queues become available, it asserts RTS or issues XON.

The IEEE bus input signals that the IEEE input (or serial output) buffer is full when the number of queues available drops below 10 (1280 character locations left). When the number of available queues drops to 4 or less (512 character locations left), the IEEE interface of the 488 Controller stops accepting data from the bus. This bus hold-off will only occur until additional queues (more than 4) become available. At that time it will resume accepting bus data.

7.3 IEEE Data Transfers

The following methods may be used by the IEEE controller when sending data to the 488 Controller:

7.3.1 Blind Bus Data Transfers

If the IEEE controller does not mind waiting an indefinite time for data space in the buffer to become available, the data can simply be sent to the 488 Controller. This is referred to as blind data transfer, because the IEEE controller is blind as to whether or not the 488 Controller is capable of accepting data. In this case, the bus controller's output data transfer will be held off by the 488 Controller if it is unable to buffer the data. It will resume accepting IEEE input data when memory becomes available. This type of control might be appropriate in a single-user environment.

To illustrate how this would appear, let's assume the 488 Controller is connected to a serial device which will accept data at 1200 baud or 110 bytes per second. The IEEE bus controller is capable of sending data to the 488 Controller at a rate of 5000 bytes per second. The data would be transferred on the bus at 5000 characters per second for slightly over six seconds, filling over 31,000 locations. At that time, the IEEE input would hold off additional data transfers until 128 characters are sent out the serial port at a rate of 110 characters per second. This 110 cps would then become the average bus-data acceptance rate of the 488 Controller.

If the controller is set to detect a data time-out error, then it will do so if the 488 Controller holds off IEEE input data transfers for too long. The error can be used to alert the operator to the problem, such as a printer out of paper, so that it can be corrected. If the controller then restarts transmission exactly where it left off, no data will be lost.

If data is requested by the controller and no serial input data is available in the 488 Controller, the bus will hang until serial data is received. If no serial data is received it will hang forever or until the controller times out.

7.3.2 Controlled Bus Data Transfers

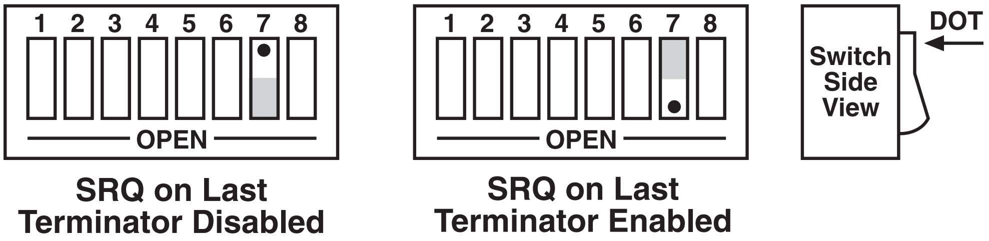
If the controller must avoid waiting for the serial device, it can “serial-poll” the 488 Controller. Serial poll is a method by which the controller can inquire the internal status of the interface without disturbing any data being transferred, slowing data transfers or locking up the bus. You should refer to the programming manual of your controller to determine the method of performing serial polls.

When serial polled, the 488 Controller provides eight bits of status information to the controller. The most significant bit (DIO8) of the 488 Controller’s serial-poll byte is set to a logical “1” when the IEEE input buffer is NOT EMPTY. The term NOT EMPTY is used to signify that not all of the previous data sent to the interface has been transmitted to the serial device. If it is NOT EMPTY, the controller may avoid sending any more data to the 488 Controller. If this bit is a logical “0,” then the serial device has accepted all previous data and the IEEE controller may send more.

Another bit (DIO4) of the serial-poll byte is used to indicate additional information concerning the IEEE input buffer. This bit is set to a logical “1” when there are 1280 or fewer locations in the buffer for data. It is cleared, set to a logical “0,” when there are more than 1280 locations available. This bit is referred to as the IEEE input buffer FULL bit.

When serial data is received, DIO5 of the serial-poll byte is set, “1,” to indicate to the IEEE controller that the serial input buffer is NOT EMPTY. If set, it indicates that at least one character is available in the serial input buffer to be read by the IEEE controller. Once all of the serial input data is read by the IEEE controller this bit is reset.

The 488 Controller can generate a request for service on the bus when it receives the last serial terminator. To enable this feature, the Pass-Thru Feature switch, located on the internal switch bank of SWl, must be set to open. When enabled, the 488 Controller will assert the IEEE bus SRQ line and set serial-poll status bits DIO7 and DIO3 when the last serial terminator is detected. The IEEE controller must perform a serial poll on the interface to clear the SRQ. If the Pass-Thru Feature switch is in the closed position, there will not be any indication in the serial-poll status byte that a serial terminator has been received.



SRQ on Last Terminator Disabled

SRQ on Last Terminator Enabled

Figure 7-1. SW1 View for Selecting SRQ on Last Terminator.

7.4 Serial Poll Status Byte Register

The following shows and describes the serial-poll status information provided by the 488 Controller.

DIO8 IEEE Input Buffer NOT EMPTY

This bit is set when the IEEE input buffer contains one or more data bytes that have not been sent out the serial port. It is cleared, set to “0,” when the buffer is empty.

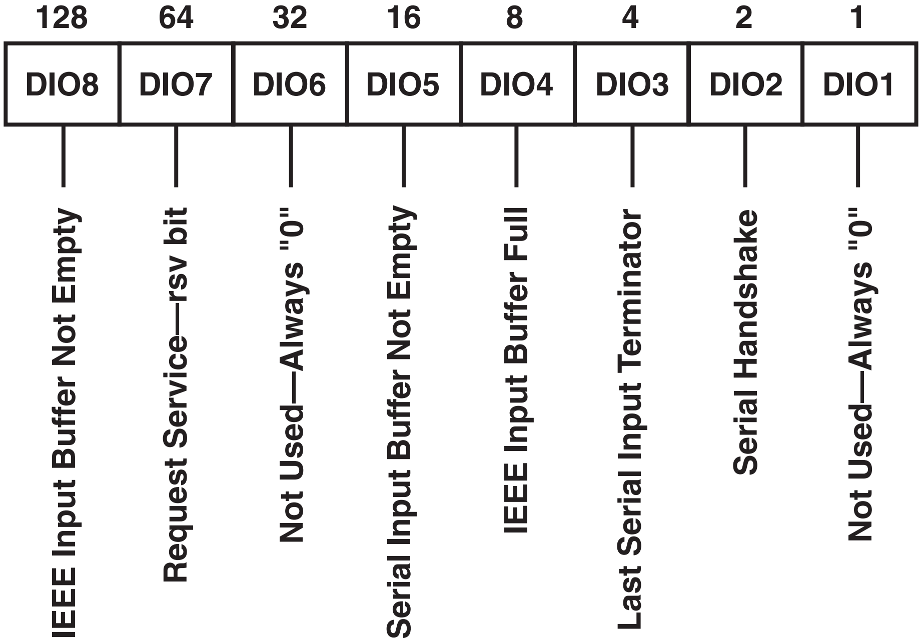


Figure 7-2. Serial Poll Status Byte.

DIO7 rsv

This bit is defined by the IEEE 488 Specification and is used to indicate to the bus controller that the 488 Controller is the bus device that requested service. It is cleared when the interface is serial polled by the controller.

DIO6 Not Defined—Always “0”

DIO5 Serial Input Buffer NOT EMPTY

This bit is set when the serial input buffer contains one or more data bytes which have not been sent out the IEEE bus. It is cleared, set to “0,” when the buffer is empty.

DIO4 IEEE Input Buffer FULL

When this bit is set, it indicates that the 488 Controller may hold off the controller on subsequent data transfers. The interface may continue to accept an additional 512 characters, but this is depends on the serial input buffer size.

DIO3 Received Last Serial Terminator

If the Peripheral SRQ feature is enabled, the 488 Controller will issue a request for service by asserting the SRQ line and setting this bit along with the rsv bit (DI07). It is cleared, along with rsv, when serial-polled by the controller. If this feature is not enabled, this bit is always “0.”

DIO2 Serial Handshake

This bit indicates the present state of the serial handshake. If it is set to "1," the serial device connected to the 488 Controller is capable of accepting serial data. If it is set to "0," the RTS line is unasserted, if the 488 Controller is configured for hardware handshake, or the XOFF character has been received, if the 488 Controller is configured for X-ON/X-OFF software handshake.

DIO1 Not Used—Always "0"

7.5 Use of Serial and Bus Terminators

The 488 Controller can be configured to provide serial-to-IEEE-488 and IEEE-488-to-serial terminator substitution. This is useful when interfacing a serial device that only issues carriage return [CR] as an output terminator to an IEEE controller that expects a carriage return followed by a line feed [CR-LF].

In this previous case, the serial terminator should be selected for CR Only while the IEEE terminator is set to CR-LF. When a serial CR character is received, it is discarded and replaced with an IEEE CR followed by an IEEE LF. In the IEEE-to-serial direction, the IEEE CR is unconditionally discarded. Upon receipt of the IEEE LF, a serial CR is substituted.

The 488 Controller can be made totally data-transparent by setting both the serial and IEEE terminators to be CR Only or LF Only. To decide which terminators are appropriate, see the instruction manuals for the serial device and the IEEE controller. For selection of the 488 Controller's serial and bus terminators, refer to **Chapter 3**.

7.6 IEEE 488 Bus Implementation

As a pass-thru bus peripheral, the 488 Controller implements many of the capabilities defined by the IEEE 488 1978 specification. These are discussed in the following subsections. The 488 Controller does not support or respond to these bus uniline and multiline commands:

Remote Enable (REN)
Go to Local (GTL)
Group Execute Trigger (GET)
Local Lockout (LLO)
Take Control (TCT)
Parallel Poll (PP)
Parallel Poll Configure (PPC)
Parallel Poll Unconfigure (PPU)
Parallel Poll Disable (PPD)

7.6.1 My Talk Address (MTA)

When the 488 Controller is addressed to talk, it retrieves data from the serial input buffer and outputs it to the IEEE 488 bus. It substitutes the selected IEEE bus terminators for the received serial terminators. The 488 Controller will continue to output serial input-buffer data as long as the IEEE controller allows.

7.6.2 My Listen Address (MLA)

When the 488 Controller is addressed to listen, it accepts data from the active talker and outputs this data through the serial interface. It substitutes the selected serial terminators for the received IEEE bus terminators.

7.6.3 Device Clear (DCL and SDC)

Device Clear resets the 488 Controller's IEEE input and serial input buffers. Any pending data and Service Requests (SRQ), including the information they convey, are lost. In addition, the XON serial control character is transmitted if XON/XOFF is enabled.

7.6.4 Interface Clear (IFC)

IFC places the 488 Controller in the Talker/Listener Idle State. It clears any pending requests for service (SRQ). The condition which caused the SRQ remains unmodified.

7.6.5 Serial Poll Enable (SPE)

When Serial Poll Enabled, the 488 Controller 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 488 Controller will continue to try to output its serial-poll response until it is "Serial Poll Disabled" by the controller.

7.6.6 Serial Poll Disable (SPD)

Disables the 488 Controller from responding to serial polls by the controller.

7.6.7 Unlisten (UNL)

UNL places the 488 Controller in the Listener Idle State.

7.6.8 Untalk (UNT)

UNT places the 488 Controller in the Talker Idle State.

7.7 IEEE Address Selection

SW3-1 through SW3-5 select the IEEE bus address of the 488 Controller when in the Peripheral Pass-Thru mode. The address is selected by simple binary weighting, with SW3-1 being the least significant bit and SW3-5 the most significant. The following figure shows the IEEE address of the 488 Controller set to 10.

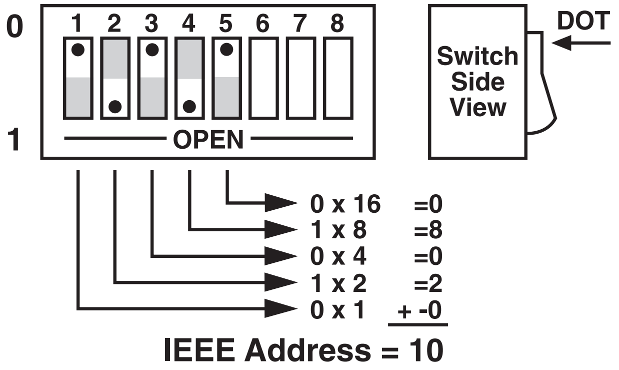


Figure 7-3. SW3 View for IEEE Address Selection.

7.7.1 Listen Only Mode

Listen Only is a special type of Peripheral operation. In the Listen Only mode the 488 Controller accepts all data transmitted on the bus and transfers it out its serial port. The 488 Controller is set to Listen Only mode by setting its address to 31 (switches SW3-1 through SW3-5 all open).

8. IEEE 488 Primer

8.1 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 488 Controller conforms to this most recent revision, designated IEEE 488-1978.

Before this standard was adopted, most instrumentation manufacturers offered their own versions of computer interfaces. This placed the burden of system hardware design on the end user. If your application required the products of several different manufacturers, then you 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.

8.2 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 that 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 cannot 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.

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 that 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. The students are told to raise their hands 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.

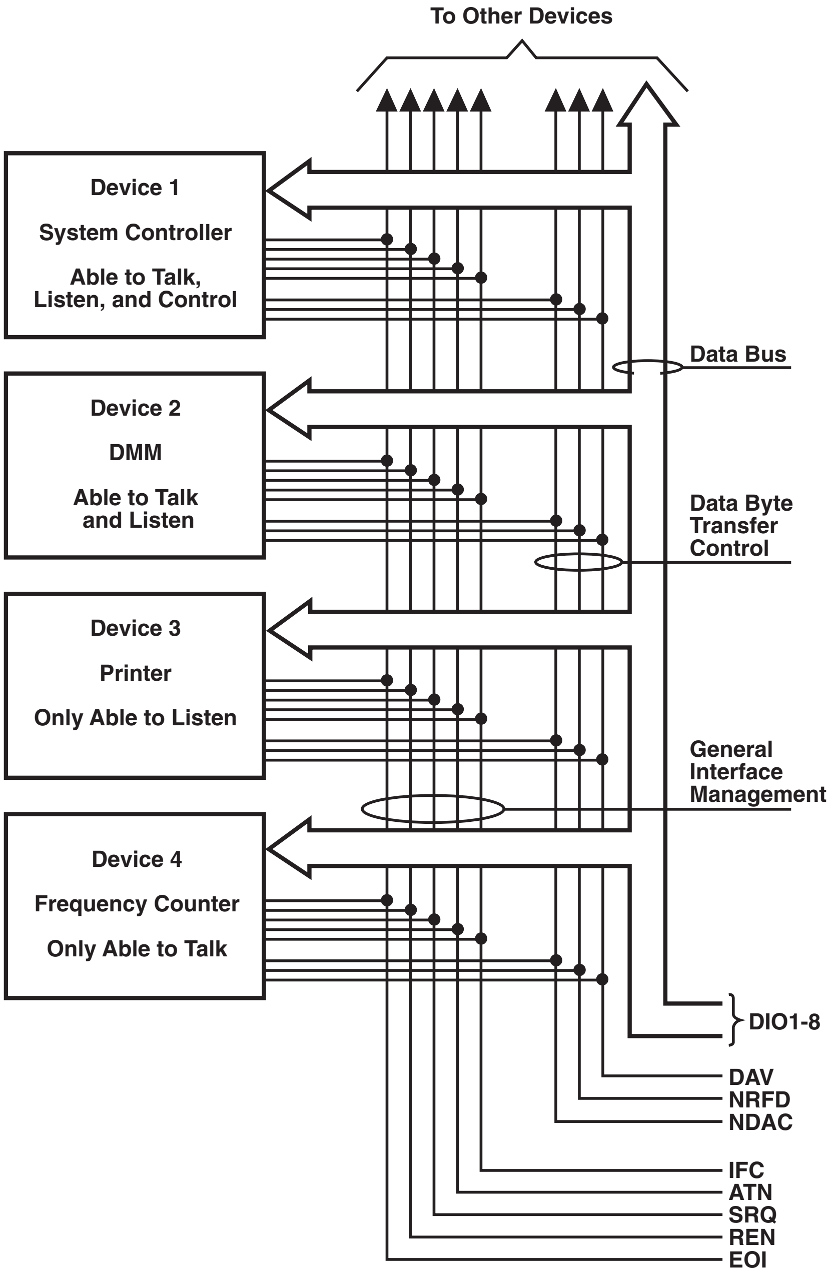


Figure 8-1. IEEE 488 Bus Structure.

8.3 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 device’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).

8.4 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”: a low voltage represents a logical “1” (asserted), and a high voltage represents a logical “0” (unasserted).

8.4.1 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.

8.4.2 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).

8.4.3 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.

8.4.4 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.

8.4.5 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.

8.5 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.

8.5.1 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.

8.5.2 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.

8.5.3 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.

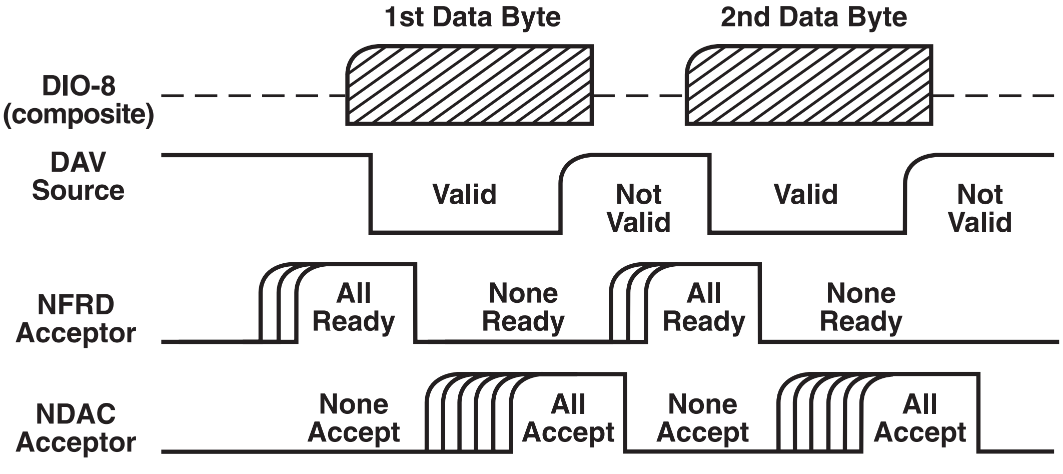


Figure 8-2. IEEE Bus Handshaking.

8.6 Data Lines

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

8.7 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.

8.7.1 Go To Local (GTL)

This command allows the selected devices to be manually controlled. (&H01)

8.7.2 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.

8.7.3 Unlisten (UNL)

This command tells all bus devices to Unlisten. The same as Unaddressed to Listen. (&H3F)

8.7.4 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.

8.7.5 Untalk (UNT)

This command tells bus devices to Untalk. The same as Unaddressed to Talk. (&H5F)

8.7.6 Local Lockout (LLO)

Issuing the LLO command prevents manual control of the instrument’s functions. (&H11)

8.7.7 Device Clear (DCL)

This command causes all bus devices to be initialized to a predefined or power up state. (&H14)

8.7.8 Selected Device Clear (SDC)

This causes a single device to be initialized to a pre-defined or power up state. (&H04)

8.7.9 Serial Poll Disable (SPD)

The SPD command disables all devices from sending their Serial Poll status byte. (&H19)

8.7.10 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. (&H18)

8.7.11 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. (&H08)

8.7.12 Take Control (TCT)

This command passes bus control responsibilities from the current Controller to another device which has the ability to control. (&H09)

8.7.13 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. (&H60 to &H7F)

8.7.14 Parallel Poll Configure (PPC)

For devices capable of performing a Parallel Poll, this command determines which data bit they are to assert in response to a Parallel Poll. (&H05)

8.7.15 Parallel Poll Unconfigure (PPU)

This disables all devices from responding to a Parallel Poll. (&H15)

8.8 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.

8.8.1 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 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.

8.8.2 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.

9. Theory of Operation & Board Layout

9.1 Theory of Operation

The heart of the 488 Controller is a 6809 microprocessor [U101] supported by 8K bytes of firmware EPROM [U102 (2764)] and 32K bytes of static RAM [U103 (58256)]. A Versatile Interface Adapter [U104 (65B22)] is used to generate real-time interrupts for the firmware operating system.

The front-panel annunciators are also driven by U104 through an inverter [U113 (74LS04)]. The IEEE 488 bus interface is accomplished by a TMS9914A [U106] controller with drivers U107 and U108. The serial interface is provided by the UART [6551 (U105)]. If RS-232 levels are chosen, they are provided by the RS-232 transceiver (U209). If RS-422 levels are selected, the differential driver [26LS30 (U207)] and receiver [26LS33 (U208)] are used.

The internal DIP switches [SWl, SW2, and SW3] are read via 74HCT244 tri-state buffers [U201, U202, and U203]. Power is supplied by an external unregulated 9-volt wallmount supply. Regulation to the required +5 volts is provided by U206 [7805].

Decoding of the microprocessor address space is accomplished with a Programmable Logic Array [U110 (16L8)]. The Memory space allocation is:

Address	Device	Part Number	Function
$0000-$7FFF	U103	58258	Static RAM
$A000-$A007	U106	9914A	IEEE Controller
$A800-$A807	U105	6551	UART
$B000-$B00F	U104	65B22	VIA
$B800	U201	74HCT244	SW1 (S201)
$B801	U202	74HCT244	SW2 (S202)
$B802	U203	74HCT244	SW3 (S203)
$E000-$FFFF	U102	2764	Programmed EPROM

9.2 Board Layout

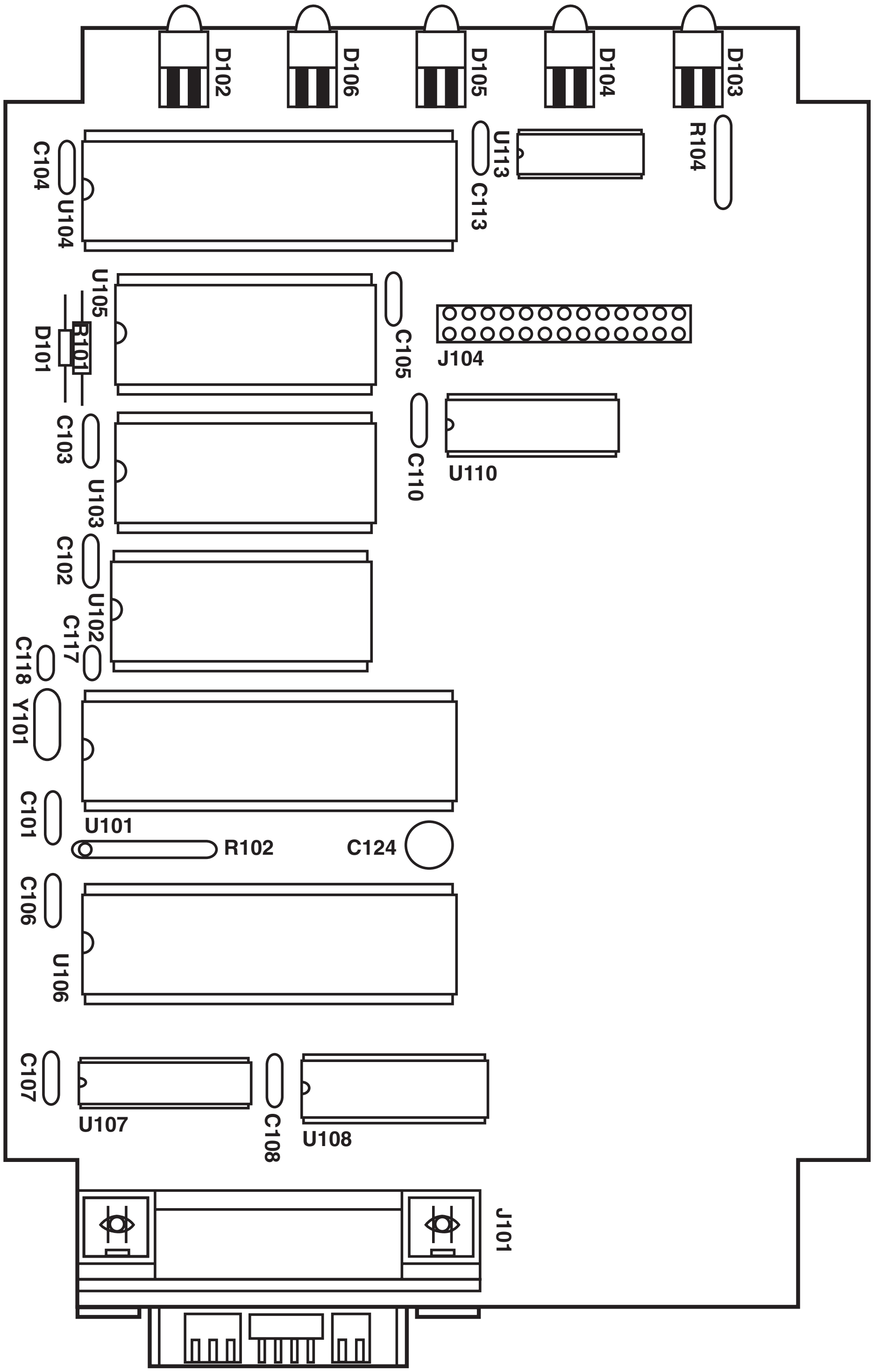


Figure 9-1. Component Layout of the 488 Controller's Motherboard.

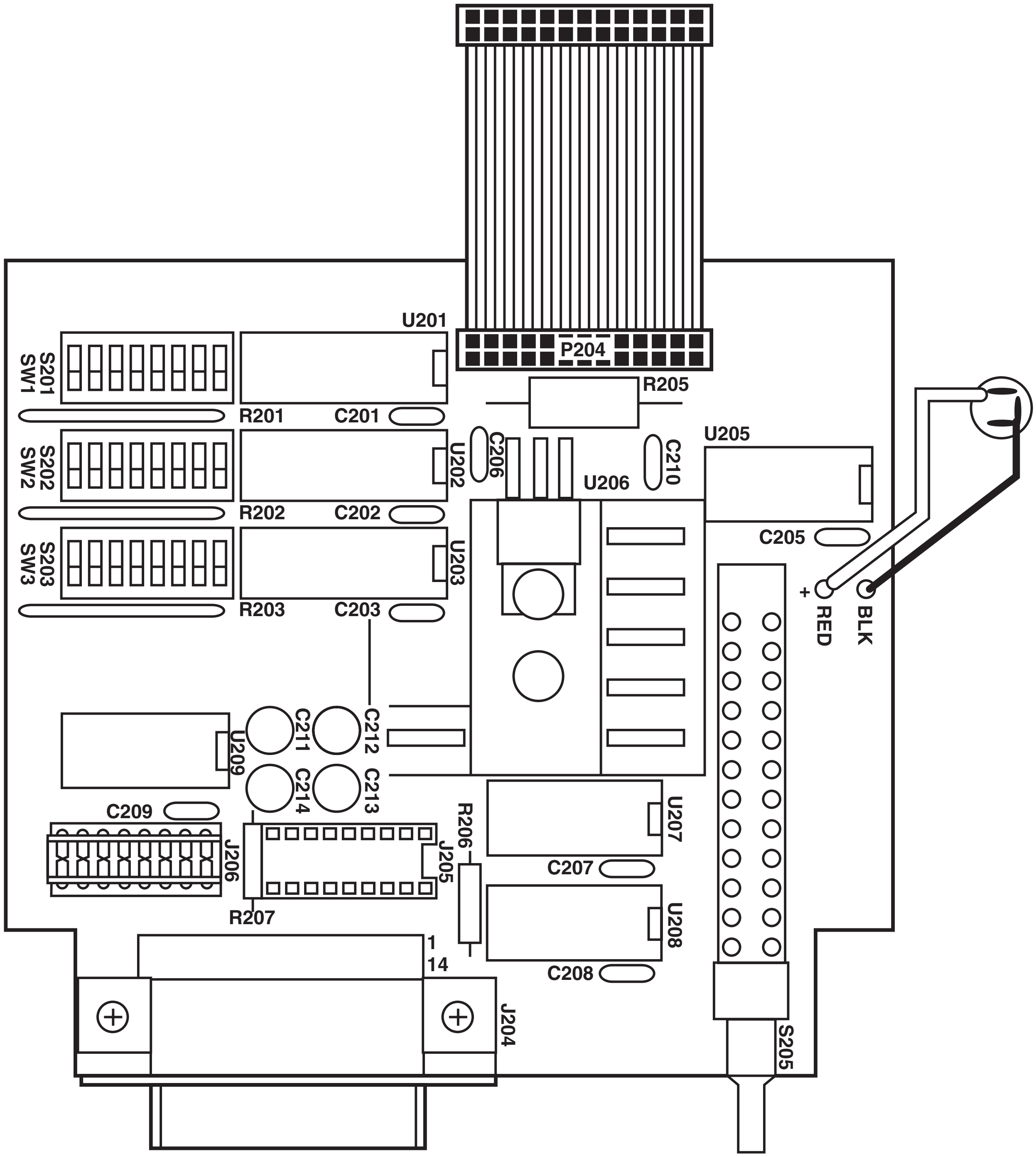


Figure 9-2. Component Layout of the Interface Converter's Serial I/O Board.

Appendix A: 488 Controller Command Summary

@

@

If followed immediately by a CR or LF, unlocks the 488 Controller from an inappropriate command, such as an ENTER from a non-existent bus device.

@@

@@

Return 488 Controller to power-on conditions.

ABORT

AB[ORT]

Send IFC (SC) or MTA (*SCCA). Stops bus activity.

ARM

AR[M][;][event[event]]

Enables transmission of event serial messages.

CLEAR

CL[EAR][addr[,addr]]

Clear all or selected devices.

COUNT

COUNT

Returns the loop count of the last invoked Macro buffer.

COMMENT

COM[MENT][;]'data'

Sends data to the serial host when executed.

DELAY

DELAY[;]time

Waits until time (in seconds) has elapsed before continuing.

DISARM

DI[SARM][;][event[event]]

Disables transmission of event messages and ON <event> DOMACRO actions.

DOMACRO

DO[MACRO][;][number[,loop]]

Execute commands in the number MACRO buffer loop number of times.

ENTER

EN[TER][addr][#count|term|EOI]

EN[TER][addr][;count|;term|;EOI]

Direct I/O. Read from bus device.

ERASE

ERASE[;][number]

Erase selected or all MACRO buffers.

ERROR

ERROR[;]{MESSAGE|NUMBER|OFF}

Select automatic error reporting.

HELLO

HE[LLO]

Read the 488 Controller revision identification.

ID

ID;[ASCII]

Change the ID character to ASCII.

LOCAL

LO[CAL][addr[,addr]]

Un-assert REN line (SC) or send Go To Local commands (CA).

LOCAL LOCKOUT
LOCAL L[OCKOUT] or LOL
Prevent bus devices from acting upon manual (front panel) controls.

MACROENDM
MA[CRO][command list]ENDM
Build a MACRO with all the commands between MACRO and ENDM.

MASK
MASK{ON|OFF}
Enable or disable serial input mask [&H7F] on OUTPUT and delimited string data.

MEMORY
ME[MORY]
Report the amount of memory in the user heap.

OUTPUT
OU[TPUT][addr[,addr]][#count];data
Direct I/O. Send data to bus device(s).

ONDOMACRO
ON <event> DO[MACRO][number]
Enable Macro buffer number execution on <event>.

PASS CONTROL
PA[SS CONTROL] addr
Make another bus device the Active Controller.
Enter the Peripheral (*CA) state.

PPOLL
PPOLL
Read the Parallel Poll response from all bus devices.

PPOLL CONFIG
PPOLL C[ONFIG] addr,response or PPC addr,response
Set the Parallel Poll response of a bus device. response is the decimal equivalent of four bits: S P2 P1 P0.

PPOLL DISABLE
PPOLL D[ISABLE]addr[,addr] or PPD addr[,addr]
Prevent bus device(s) from responding to a Parallel Poll.

PPOLL UNCONFIG
PPOLL U[NCONFIG] or PPU
Prevent all devices from responding to a Parallel Poll.

READ
READ[;][number]
Send a copy of the specified number Macro buffer out to the serial host.

REMOTE
REM [OTE] [addr [, addr]]
Assert the Remote Enable line. Optionally address the specified devices to listen, placing them in the Remote State.

REQUEST
REQ[UEST] [;] [status]
Generate a service request (SRQ) with the status value in the serial-poll status register.

RESET
RESE[T]
Warm-start the 488 Controller to default parameters. Also ABORT if SC.

RESUME
RESU [ME]
Un-assert Attention. Used to allow Peripheral-to-Peripheral data transfers.

SEND
SE[ND] [;] [subcommand [subcommand]]
Send low-level bus sequences. Sub-commands include: UNT, UNL, MTA, MLA, LISTEN addr [,addr], TALK addr, ENTER, DATA'data', char, EOI 'data', char and CMD 'data', char.

SPOLL

SP [OLL] [addr [,addr]
Read device (s ') Serial Poll response. Get internal SRQ state (CA), or Serial Poll status (*CA).

STATUS

ST [ATUS] [;] [number]
Read the status of 488 Controller. Used to reset error conditions.

STERM

STE [RM] [;] { term [term] | NONE}
Set the serial output terminator.

TERM

TE [RM] [;] { term [term] [EOI] | EOI | NONE}
Set the serial output terminator.

TIME OUT

TI [ME OUT] [;] [time]
Set the number of time seconds to wait for a bus transfer before a time out error will be declared. Checking for Time Out is suppressed by specifying 0 seconds.

TRACE

TRACE {ON | OFF}
Enable or disable tracing during Macro buffer execution.

TRIGGER

TR [IGGER] [addr [,addr]]
Trigger bus devices by optionally listen addressed followed by Group Execute Trigger.

Appendix B: 488 Controller Error Messages

The following error messages are returned if an error condition exists and the STATUS command is executed. The error condition is reset after the message is sent. Only the most recent error is maintained.

Error No. **Error Text and Description**

00 OK

01 INVALID ADDRESS
Caused by an invalid address outside the allowable IEEE 488 bus range of 00 to 30 for primary addresses and 00 to 31 for secondary addresses.

02 INVALID COMMAND
Caused by an unrecognized command or invalid parameter.

03 WRONG MODE
Caused by trying to execute a command not allowed within the present state of the interface (for example, REMOTE16 as a peripheral).

04 Unassigned—Reserved

05 Unassigned—Reserved

06 NO MACRO
A DOMACRO or READ command was received but the Macro buffer specified is empty.

07 MACRO OVERFLOW
No memory is available to allocate as a Macro buffer.

08 COMMAND OVERFLOW
More than 127 characters were received and interpreted as a command.

09 ADDRESS OVERFLOW
More than 15 primary-address/secondary-address pairs were received.

10 MESSAGE OVERFLOW
No memory is available to buffer the received data of the OUTPUT command.

11 NOT A TALKER
As the Active Controller, an un-addressed OUTPUT, a SEND DATA, or a SEND CMD was received and the 488 Controller was not in the Talk Addressed State.

12 NOT A LISTENER
As the Active Controller, an un-addressed ENTER or a SEND ENTER was received and the 488 Controller was not in the Listen Addressed State.

13 BUS ERROR
The 488 Controller tried to output data to the bus but there was no active listener to accept it.

14 TIMEOUT—WRITE
The specified TIME OUT time has elapsed before the last command or data byte sent by the 488 Controller was accepted by an external device.

15 TIMEOUT—READ
The specified TIME OUT time has elapsed while the 488 Controller was waiting for a data byte from an external device.

16 OUT OF MEMORY
The 488 Controller was unable to perform the last command requested because of the lack of sufficient memory in the USER heap.

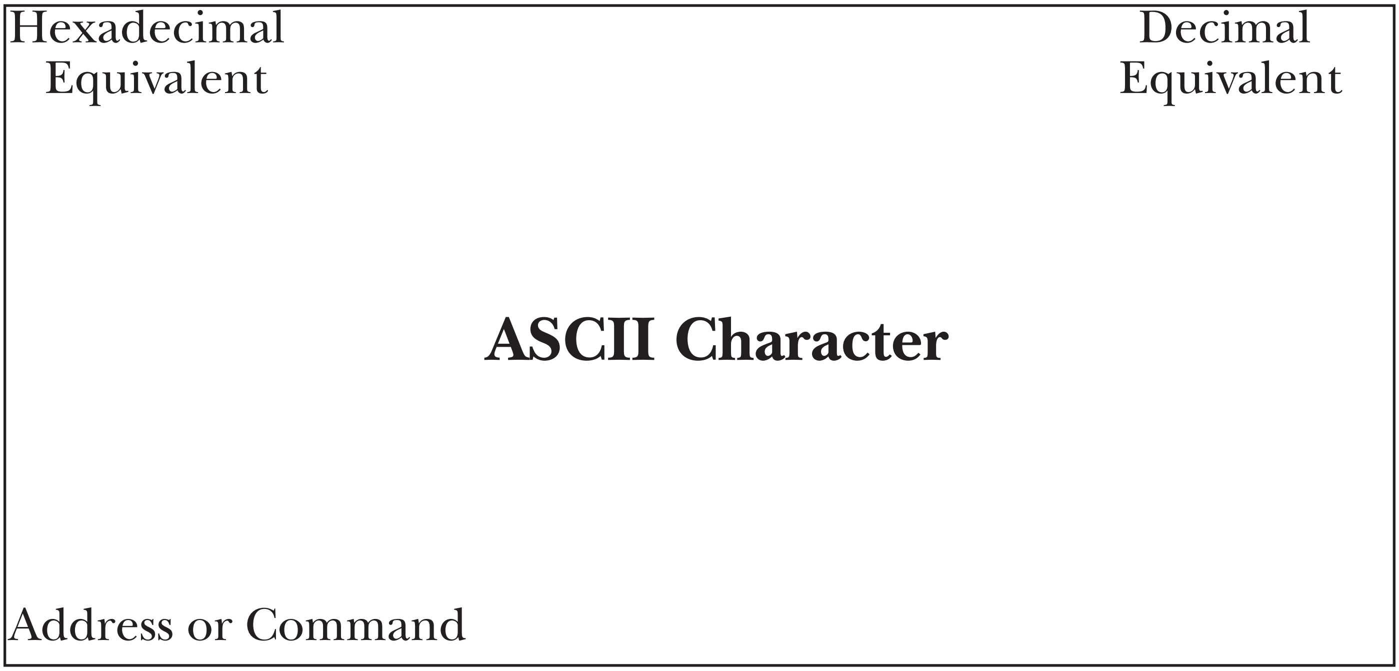
17 MACRO RECURSION
A DOMACRO command specified a Macro buffer that was already executing.

Appendix C: Character Codes and IEEE Multiline Messages

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

ACG = Addressed Command Group
UCG = Universal Command Group
LAG = Listen Address Group
TAG = Talk Address Group
SCG = Secondary Command Group

How To Read the Chart



Hexadecimal Equivalent

Decimal Equivalent

ASCII Character

Address or Command

Appendix D: Sample Programs

```
10      REM ***     Keyboard Controller Program for the 488 Controller
20      REM ***             Running under IBM BASIC.
30      REM ***     This program allows direct interaction between the IBM PC and bus
40      REM ***     device(s) with the 488 Controller.
50      REM ***     The 488 Controller must be configured as the System Controller.
60      REM ***
70      REM ***
80      REM ***
90      REM ***
100             CLS
110     ' Open the serial communications port and set parameters
120             OPEN "COM1: 9600, n, 8, 2, cs, ds" AS 1
130     ' Display any characters received from the COM1 port
140             IF LOC (1)  THEN PRINT INPUT$ (LOC (1), 1);
150     ' Transmit key presses from keyboard to the COM1
160     K$ = INKEY$
170     PRINT #1,K$; : PRINT K$;
180     GOTO 140 ' Do it again
```

```
10     REM ***     Keyboard Controller Program for the 488 Controller
20     REM ***     Running under IBM BASIC using XON/XOFF
30     REM ***     serial control protocol
40                CLS
50         ' Open the serial communications port and set parameters
60     OPEN "COM1: 9600, N, 8, 2, cs, ds" AS 1
70     'XON LOOP
80     K$=INKEY$: PRINT #1, K$; : PRINT K$;
90     WHILE NOT EOF (1)
100              PRINT INPUT$ (1,1);
110              IF LOC (1) < 70 THEN PRINT #1,CHR$ (19) : GOSUB 140
120    WEND
130    GOTO 80
140    'XOFF LOOP
150    WHILE NOT EOF (1)
160              PRINT INPUT$ (1,1);
170              IF LOC (1) < 30 THEN PRINT #1,CHR$ (17) : RETURN
180    WEND
190    RETURN
```

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