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This equipment generates and uses radio frequency energy and, if not installed and used in strict accordance with the instructions in this manual, may cause interference to radio and television reception. This equipment has been tested and found to comply with the following two regulatory agencies:

Federal Communications Commission

This device complies with Part 15 of the Federal Communications Commission (FCC) Rules for a Class A digital device. Operation is subject to the following two conditions:

1. This device may not cause harmful interference in commercial environments.
2. This device must accept any interference received, including interference that may cause undesired operation.

Canadian Department of Communications

This device complies with the limits for radio noise emissions from digital apparatus set out in the Radio Interference Regulations of the Canadian Department of Communications (DOC).

Le présent appareil numérique n’émet pas de bruits radioélectriques dépassant les limites applicables aux appareils numériques de classe A prescrites dans le règlement sur le brouillage radioélectrique édicté par le ministère des communications du Canada.

Instructions to Users

These regulations are designed to provide reasonable protection against harmful interference from the equipment to radio reception in commercial areas. Operation of this equipment in a residential area is likely to cause harmful interference, in which case the user will be required to correct the interference at his own expense.

There is no guarantee that interference will not occur in a particular installation. However, the chances of interference are much less if the equipment is installed and used according to this instruction manual.

If the equipment does cause interference to radio or television reception, which can be determined by turning the equipment on and off, one or more of the following suggestions may reduce or eliminate the problem.

- Operate the equipment and the receiver on different branches of your AC electrical system.
• Move the equipment away from the receiver with which it is interfering.
• Reorient or relocate the receiver’s antenna.
• Be sure that the equipment is plugged into a grounded outlet and that the grounding has not been defeated with a cheater plug.

**Notice to user:** Changes or modifications not expressly approved by National Instruments could void the user’s authority to operate the equipment under the FCC Rules.

If necessary, consult National Instruments or an experienced radio/television technician for additional suggestions. The following booklet prepared by the FCC may also be helpful: *How to Identify and Resolve Radio-TV Interference Problems.* This booklet is available from the U.S. Government Printing Office, Washington, DC 20402, Stock Number 004-000-00345-4.
## Contents

**About This Manual** ........................................................................................................... xi
  - Organization of This Manual ...................................................................................... xi
  - Conventions Used in This Manual .............................................................................. xii
  - Related Documentation ............................................................................................. xiii
  - Customer Communication ............................................................................................ xiii

**Chapter 1**

**Introduction** .................................................................................................................. 1-1
  - What Your Kit Should Contain ..................................................................................... 1-1
  - Optional Equipment ...................................................................................................... 1-1
  - Hardware Description ..................................................................................................... 1-2

**Chapter 2**

**Connection** .................................................................................................................... 2-1
  - Configure the DIP Switch ............................................................................................ 2-1
  - Connect the Hardware ................................................................................................. 2-1
    - Step 1. Connect the Cables ..................................................................................... 2-1
    - Step 2. Switch On Your GPIB Extender ................................................................. 2-2
  - Optional Self-Test .......................................................................................................... 2-3

**Chapter 3**

**Configuration and Operation** ....................................................................................... 3-1
  - Data Transfer Modes .................................................................................................. 3-1
    - Unbuffered Mode ...................................................................................................... 3-1
    - Buffered Mode ......................................................................................................... 3-1
    - Setting the Data Transfer Mode ............................................................................... 3-1
  - HS488 Mode ................................................................................................................ 3-2
    - HS488 Disabled ........................................................................................................ 3-2
    - HS488 Enabled ........................................................................................................... 3-2
    - Setting the HS488 Mode .......................................................................................... 3-3
  - Parallel Poll Response (PPR) Modes ............................................................................ 3-3
    - Immediate PPR Mode ............................................................................................. 3-4
    - Latched PPR Mode .................................................................................................... 3-4
    - Choosing the PPR Mode .......................................................................................... 3-4
    - Setting the PPR Mode .............................................................................................. 3-5
  - Operating the Extension System ................................................................................... 3-5
    - POWER LED ............................................................................................................ 3-5
    - LINK LED ................................................................................................................ 3-6
    - ERROR LED ............................................................................................................. 3-6
Appendix E  
Customer Communication ................................................................. E-1

Glossary ................................................................................................. G-1

Figures

Figure 1-1. Typical Extension System (Physical Configuration) ......................... 1-2
Figure 1-2. Typical Extension System (Logical Configuration) ............................. 1-2
Figure 2-1. DIP Switch Default Setting .......................................................... 2-1
Figure 2-2. GPIB Extenders with Fiber Optic Cable Connected .......................... 2-2
Figure 2-3. GPIB Extender Configured for Optional Self-Test ............................ 2-3
Figure 3-1. Switch Setting for Buffered Data Transfer Mode .............................. 3-2
Figure 3-2. Switch Setting for HS488 Mode (Enabled) ...................................... 3-3
Figure 3-3. Switch Setting for Immediate Parallel Poll Response (PPR) Mode ....... 3-5
Figure 4-1. GPIB Extender Block Diagram ...................................................... 4-2
Figure A-1. GPIB Connector and the Signal Assignment .................................. A-4
Figure A-2. Linear and Star System Configuration ........................................... A-5
Figure C-1. IEEE 488.1 and HS488 Transfers ................................................. C-3
Figure C-2. Talker and Listener are HS488 Capable ........................................ C-4
Figure C-3. Talker is HS488 Capable, But Listener Is Not HS488 Capable .......... C-5
Figure C-4. Talker is Not HS488 Capable, But Listener Is 488 Capable............. C-6

Tables

Table A-1. GPIB Handshake Lines ............................................................... A-3
Table A-2. GPIB Interface Management Lines .............................................. A-3
Table B-1. System Configuration ............................................................... B-1
Table B-2. Performance Characteristics ...................................................... B-1
Table B-3. Operation Characteristics .......................................................... B-2
Table B-4. Electrical Characteristics .......................................................... B-2
Table B-5. Environmental Characteristics ................................................... B-2
Table B-6. Physical Characteristics .............................................................. B-3
About This Manual

This manual describes how to install, configure, and operate the National Instruments GPIB-140 or GPIB-140/2 bus extender.

Organization of This Manual

This manual is organized as follows:

- Chapter 1, *Introduction*, lists what your kit should contain and optional equipment you can order, and gives a brief description of the GPIB extender.
- Chapter 2, *Connection*, describes how to connect the GPIB extender and verify that it is operating properly.
- Chapter 3, *Configuration and Operation*, describes how to configure and operate a GPIB-140 or GPIB-140/2 system.
- Chapter 4, *Theory of Operation*, describes how the GPIB extender circuitry operates.
- Appendix A, *Operation of the GPIB*, describes some basic concepts you should understand to operate the GPIB. It also contains a description of the physical and electrical characteristics and the configuration requirements of the GPIB.
- Appendix B, *Specifications*, lists the specifications of the GPIB extender.
- Appendix C, *Introduction to HS488*, describes HS488 and the sequence of events in data transfers.
- Appendix D, *Multiline Interface Messages*, lists the multiline interface messages and describes the mnemonics and messages that correspond to the interface functions.
- Appendix E, *Customer Communication* contains forms you can use to request help from National Instruments or to comment on our products and manuals.
- The *Glossary* contains an alphabetical list and a description of terms used in this manual, including abbreviations, acronyms, metric prefixes, mnemonics, and symbols.
Conventions Used in This Manual

The following conventions are used in this manual.

**bold**
- Bold text denotes light-emitting diodes (LEDs).

**italic**
- Italic text denotes emphasis, a cross reference, or an introduction to a key concept.

**bold italic**
- Bold italic text denotes a note, caution, or warning.

**monospace**
- Text in this font denotes text or characters that are to be literally input from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, directories, programs, subprograms, subroutines, device names, functions, variables, field names and filenames.

< >
- Angle brackets enclose the name of a key on the keyboard—for example, <Shift>.

-
- A hyphen between two or more key names enclosed in angle brackets denotes that you should simultaneously press the named keys—for example, <Control-Alt-Delete>.

**GPIB-140**
- GPIB-140 refers to a National Instruments GPIB extender that extends the GPIB to a maximum distance of 1 km.

**GPIB-140/2**
- GPIB-140/2 refers to a National Instruments GPIB extender that extends the GPIB to a maximum distance of 2 km.

**GPIB extender**
- GPIB extender refers generically to either the GPIB-140 or the GPIB-140/2 in cases where the material can apply to either extender.

**IEEE 488 and IEEE 488.2**
- IEEE 488 and IEEE 488.2 refer to the ANSI/IEEE Standard 488.1-1987 and the ANSI/IEEE Standard 488.2-1992, respectively, which define the GPIB.

Abbreviations, acronyms, metric prefixes, mnemonics, symbols, and terms are listed in the *Glossary*. 
Related Documentation

The following documents contain information that you may find helpful as you read this manual.


Customer Communication

National Instruments wants to receive your comments on our products and manuals. We are interested in the applications you develop with our products, and we want to help if you have problems with them. To make it easy for you to contact us, this manual contains comment and configuration forms for you to complete. These forms are in Appendix E, *Customer Communication*, at the end of this manual.
Chapter 1
Introduction

This chapter lists what your kit should contain and optional equipment you can order, and gives a brief description of the GPIB extender.

What Your Kit Should Contain

Your kit should contain the following components.

- One of the following GPIB-140 or GPIB-140/2 bus extenders:
  - U.S. 100-120 VAC
  - Switzerland 220-240 VAC
  - Australia 220-240 VAC
  - Universal European 220-240 VAC
  - North American 220-240 VAC
  - U.K. 220-240 VAC

- One of the following standard 3-wire power cables:
  - 100-120 VAC
  - 220-240 VAC

Optional Equipment

You can contact National Instruments to order any of the following equipment to go with your kit.

- Transmission cable:
  - Type T7 fiber optic cable – up to 1 km (used with GPIB-140)
  - Type T8 fiber optic cable – up to 2 km (used with GPIB-140/2)

- Shielded GPIB cables*:
  - Type X1 single-shielded GPIB cables – 1 m, 2 m, or 4 m
  - Type X2 double-shielded GPIB cables – 1 m, 2 m, or 4 m

* To meet FCC emission limits for this Class A device, you must use a shielded (Type X1 or X2) GPIB cable. Operating this equipment with a non-shielded cable may cause interference to radio and television reception in commercial areas.
Hardware Description

The GPIB-140 and GPIB-140/2 are high-speed bus extenders that are used in pairs with fiber optic cable to connect two separate GPIB (IEEE 488) bus systems in a functionally transparent manner.

Although the two bus systems are physically separate, as shown in Figure 1-1, devices logically appear to be located on the same bus, as shown in Figure 1-2.

![Figure 1-1. Typical Extension System (Physical Configuration)](image1)

![Figure 1-2. Typical Extension System (Logical Configuration)](image2)
The GPIB-140 and GPIB-140/2 bus extenders comply with the specifications of the ANSI/IEEE Standard 488.1-1987 and the ANSI/IEEE Standard 488.2-1992, including the Find Listeners protocol. With the GPIB extenders, you can overcome the following two configuration restrictions imposed by ANSI/IEEE Standard 488.1-1987:

• A cable length limit of 20 m total per contiguous bus or 2 m times the number of devices on the bus, whichever is smaller.

• An electrical loading limit of 15 devices per contiguous bus.

Each GPIB-140 system extends the GPIB to a maximum distance of 1 km, and each GPIB-140/2 system extends the GPIB to a maximum distance of 2 km. Both types of systems extend the loading limit to 28 devices (including the GPIB extenders), without sacrificing speed or performance. These point-to-point extension systems can be connected in series for longer distances or in star patterns for additional loading.

The maximum data transfer rate over the extension is 2.2 Mbytes/s using HS488 protocol. The GPIB extender uses a buffered transfer technique with a serial extension bus to get maximum performance while keeping the cabling cost at a minimum. Furthermore, there is no speed degradation for transfers between devices on the same side of the extension. The GPIB extender also has error-checking capabilities to ensure successful data transmission over the fiber optic link.

Because the GPIB-140 and the GPIB-140/2 are functionally transparent extenders, the same GPIB communications and control programs that work with an unextended system can work with an extended system. The Parallel Poll Response (PPR) Modes section of Chapter 3, Configuration and Operation, discusses one minor exception to this transparency in conducting parallel polls.
Chapter 2
Connection

This chapter describes how to connect the GPIB extender and verify that it is operating properly.

Configure the DIP Switch

The 3-bit DIP switch selects the operation mode of the GPIB extender. Each GPIB extender is shipped from the factory with the DIP switch set for unbuffered transfer mode, latched parallel poll (PPR) response, and HS488 disabled mode. Figure 2-1 shows the factory default setting of the DIP switch. Refer to Chapter 3, Configuration and Operation, for information on setting the operating mode for your application.

![DIP Switch Default Setting](image)

Figure 2-1. DIP Switch Default Setting

Connect the Hardware

Step 1. Connect the Cables

Follow these steps to connect the cables to both GPIB extenders:

1. Make sure that the power switch on each GPIB extender is in the OFF position.

2. Connect the fiber optic cable to both GPIB extenders. The fiber optic cable has two connectors on each end. Connect the connector marked T (transmit) to the connector marked TRANS on the side panel of the GPIB extender. Connect the connector marked R (receive) to the connector marked RCVR on the side panel of the GPIB extender.
a. Remove the caps on the connectors.

b. Align the notch on each cable connector to the slot on the side panel connector.

c. Firmly push in the cable connector and rotate clockwise until the sleeve locks on to the side notch of the side panel connector.

![Diagram of GPIB Extenders with Fiber Optic Cable Connected](image)

Figure 2-2. GPIB Extenders with Fiber Optic Cable Connected

3. Connect a GPIB cable to each GPIB extender and tighten the thumb screws on the connector. Connect the other end to your GPIB system. Be sure to follow all IEEE 488.1 cabling restrictions. Refer to the Configuration Requirements section of Appendix A, Operation of the GPIB, for typical restrictions.

4. Plug the utility power cord of each GPIB extender into an AC outlet of the correct voltage. Then plug the other end of the power cord into the GPIB-140.

**Step 2. Switch On Your GPIB Extender**

Power on each GPIB extender. The POWER LED should come on immediately. The LINK LED comes on only when both extenders are on and the fiber optic cable has been properly connected between them.

If the POWER LED does not come on immediately, check to make sure that power is supplied to the extender.
Optional Self-Test

Each GPIB extender is equipped with a self-test that determines if the GPIB extender receivers, transmitters, and packet transmission and reception circuitry are operating correctly.

Complete the following steps to run the self-test with the fiber optic cable.

1. Turn the GPIB extender power switch to the OFF position.

2. Disconnect the fiber optic cable from the GPIB extender.

3. Turn the GPIB extender power switch to the ON position.

   At this point, the POWER LED lights up, indicating that power is supplied to the extender. The LINK LED remains off.

4. Connect the connector marked T (transmit) on one end of the fiber optic cable to the connector marked TRANS on the side panel of the GPIB extender.

5. Connect the connector marked R (receive) on the opposite end of the fiber optic cable to the connector marked RCVR on the side panel of the GPIB extender.

   Figure 2-3. GPIB Extender Configured for Optional Self-Test

   At this point, the LINK LED should light up, indicating that the cable has been connected. The ERROR LED should remain off to show that the GPIB extender is operating properly.
Chapter 3
Configuration and Operation

This chapter describes how to configure and operate a GPIB-140 or GPIB-140/2 system.

Data Transfer Modes

The GPIB extender has two data transfer modes: unbuffered mode and buffered mode. The data transfer mode determines how data is transmitted across the extension.

Unbuffered Mode

In unbuffered mode, each data byte is transmitted using the GPIB double-interlocked handshaking protocol. For long data streams, transfers using unbuffered mode are slower than transfers using buffered mode. However, the GPIB extension is transparent in unbuffered mode.

Buffered Mode

In buffered mode, the GPIB extenders use FIFO (first-in-first-out) buffers to buffer data between the remote and local units. For long data streams, you can obtain a much higher data throughput with buffered mode than with unbuffered mode.

Consider the following situation: a GPIB device on the local side of the extension is addressed to talk, another device on the remote side is addressed to listen. When the talking device sources data bytes, the GPIB extenders accept the data bytes and store them in a FIFO buffer. At the same time, the GPIB extenders read data from the FIFO buffer and source data bytes to the Listener. Whenever the FIFO buffer contains data, the number of bytes sourced by the Talker differs from the number of bytes accepted by the Listener. Because of this behavior, a few applications may not operate properly in buffered mode.

GPIB command bytes are not stored in the FIFO buffers; they are transmitted using the GPIB double-interlocked handshaking protocol.

Setting the Data Transfer Mode

The two GPIB extenders in the extension system do not need to be set to the same data transfer mode. Use switch position 1 on the DIP switch of each GPIB extender to set the data transfer mode. Slide the switch down to the ON position to set buffered mode; slide the switch up to set unbuffered mode. See Figure 3-1.
HS488 Mode

The GPIB extender has the capability to handle data transfers using the HS488 protocol. HS488 specifies a means of transferring data among two or more devices using a noninterlocked handshake protocol. By using HS488, you can transfer data at rates higher than rates possible using the IEEE 488.1 protocol. For more information on HS488, refer to Appendix C, Introduction to HS488.

HS488 Disabled

With HS488 disabled, the GPIB extender sources and accepts data using a three-wire handshake protocol, even if both the Talker and Listener are able to transfer data using the HS488 protocol.

HS488 Enabled

When HS488 is enabled, the GPIB extender accepts data using the HS488 protocol after the Talker indicates that it wants to issue high-speed transfers. When functioning as a Talker, the GPIB extender always attempts to use the high-speed mode when HS488 is enabled. FIFO buffers are always used to buffer data during HS488 transfers, even if the switch that controls the data transfer mode is set to unbuffered mode. While using HS488 protocol with the GPIB extender, the GPIB cable length should be set to 5 m in the configuration utility of your IEEE 488.2 driver software for both the local and the remote system.
Setting the HS488 Mode

The two GPIB extenders in the extension system do not need to be set to the same HS488 mode. However, the maximum data transfer rate is achieved when both sides in the extension system are doing transfers using HS488.

Use switch position 2 on the DIP switch of each GPIB extender to set the HS488 mode. Slide the switch down to the ON position to enable the HS488 mode; slide the switch up to disable the HS488 mode. See Figure 3-2.

Parallel Poll Response (PPR) Modes

According to ANSI/IEEE Standard 488.1-1987, devices must respond to a parallel poll within 200 ns after the Identify (IDY) message—Attention (ATN) and End or Identify (EOI)—is asserted by the Controller-In-Charge (CIC). The Controller waits at least 2 μs before reading the Parallel Poll Response (PPR). In many cases, a remote device on an extended system cannot respond to parallel polls this quickly because of cable propagation delays. You can solve this problem using one of the following two approaches in your application program:

- Specify in your program that the Controller must allow enough time to receive the response. If you are able to do this, it is the easiest solution. For more information about this option, see the Immediate PPR Mode section, later in this chapter. If you are using National Instruments IEEE 488.2 driver software, you can use your software configuration utility to set the amount of time the Controller waits.

- Conduct two consecutive parallel polls and use the second response. For more information about this option, see the Latched PPR Mode section, later in this chapter.
Immediate PPR Mode

In immediate PPR mode, the GPIB extenders do not use the internal PPR data register. When a Controller on the local GPIB system asserts IDY, the local GPIB extender sends the IDY message to the remote bus and the response is returned as fast as propagation delays permit. In your application program or driver configuration utility, the Controller must allow time to receive the response.

Latched PPR Mode

In latched PPR mode, the GPIB extenders use an internal PPR data register. When a Controller on the local GPIB system asserts IDY, the local GPIB extender responds by outputting the contents of the PPR data register to the local GPIB data lines. At the same time, a parallel poll message is sent to the remote bus. When the local IDY signal is unasserted, the PPR from the remote system is loaded into the internal PPR data register. Consequently, the register always contains the response of the previous complete poll. To obtain the response of both local and remote GPIB systems, your application should execute two consecutive parallel polls and use the second response.

The software driver library of most Controllers contains an easy-to-use parallel poll function. If, for example, the function is called `ibrpp` and your application is written in BASIC, the sequence to conduct a poll in latched PPR mode might be similar to the following sequence:

```
CALL ibrpp (brd0%, ppr%)
CALL ibrpp (brd0%, ppr%)
IF ppr > 0 GOTO 300
```

Choosing the PPR Mode

Choosing the right PPR mode depends on the type of Controller present in the GPIB system and the length of cable between the GPIB-140 extenders. However, if your application does not use parallel polls, the PPR mode does not matter.

Some Hewlett-Packard GPIB Controllers remain in a parallel poll state with IDY asserted whenever they are not performing another function. A change in the response causes an interrupt of the application program. In some Controllers, the IDY signal is toggled on and off, and the duration of the signal can be varied to accommodate delayed responses over extenders. When used with any of these types of Controllers, the GPIB extender should be set to immediate PPR mode.

Most other Controllers pulse the IDY signal for about 2 μs and expect a response within that time. When used with this type of Controller, the GPIB extender should use latched PPR mode if the cable between the extenders is longer than 60 m. For shorter cable distances, you should use immediate PPR mode.
The two GPIB extenders in the extension system do not need to be set to the same PPR mode. The PPR mode of the local GPIB extender should be chosen to accommodate the Controllers on the local GPIB system. Likewise, the PPR mode of the remote GPIB extender should be chosen to accommodate the Controllers on the remote GPIB system. If no Controllers are physically connected to one of the GPIB extenders, the PPR mode of that GPIB extender has no effect on the system.

**Setting the PPR Mode**

Use switch position 3 on the DIP switch of each GPIB extender to set the PPR mode. Slide the switch down to the ON position to set immediate PPR mode; slide the switch up to set latched PPR mode. See Figure 3-3.

![Figure 3-3. Switch Setting for Immediate Parallel Poll Response (PPR) Mode](image)

**Operating the Extension System**

The GPIB-140 or GPIB-140/2 extension system is fully operational when power is supplied to both units and the fiber optic cable has been properly connected.

Three indicator LEDs labeled **POWER**, **LINK**, and **ERROR**, give information about the operational status of the GPIB extender.

**POWER LED**

The **POWER** LED is lit whenever power is supplied to the GPIB extender and the power switch is in the ON position.
LINK LED

The **LINK** LED is lit when both GPIB extenders are powered on and the transmission cable is properly connected to both extenders. During operation, the **LINK** LED turns off if the cable is disconnected from the receiver of the GPIB extender, or if either GPIB extender is powered off.

ERROR LED

The **ERROR** LED is lit if the GPIB extender receives corrupted data. The **ERROR** LED turns off after the GPIB extender starts re-transmission and has received the first re-transmitted data byte without error.
Chapter 4
Theory of Operation

This chapter describes how the GPIB extender circuitry operates.

The information in this chapter assumes that you have a basic knowledge of the GPIB. If you are a first-time user or you would like to review the basics, refer to Appendix A, Operation of the GPIB.

Figure 4-1 shows a model of a GPIB extender. The extender is made up of five layers. Each layer can be connected to the corresponding layer of another extender at the remote side to form a complete link.
Message Interpreter Layer

The Message Interpreter Layer handles the handshake between the GPIB extender and other devices on the GPIB. At the same time, it monitors the activities occurring on the GPIB and translates them into equivalent GPIB local and remote messages. These messages are sent to the Packet Translation Layer.
Packet Translation Layer

The Packet Translation Layer converts the messages it receives to packets and sends them to the Link Management Layer. It can also receive packets from the Link Management Layer and convert them back to local or remote GPIB messages.

Link Management Layer

The Link Management Layer receives packets from the Packet Translation Layer. It sends the packets to the Parallel-to-Serial Conversion Layer, and at the same time, it stores them in a local buffer. If a transmission error occurs, the Link Management Layer can re-send the packets from this local buffer. The Link Management Layer also receives packets from the Parallel-to-Serial Layer and checks the packets for transmission errors. If no error is detected, the packets are sent to the Packet Translation Layer. If a transmission error is detected, the Link Management Layer will initiate re-transmission.

Parallel-to-Serial Translation Layer

The Parallel-to-Serial Conversion Layer accepts packets from the Link Management Layer, converts them into serial data, and sends the data out to the Physical Layer. It also extracts serial bits from the Physical Layer, reconstructs them back into packets, and presents them to the Link Management Layer.

Physical Layer

The Physical Layer handles the transmitting and receiving of serial data over the fiber optic link.
Appendix A
Operation of the GPIB

This appendix describes some basic concepts you should understand to operate the GPIB. It also contains a description of the physical and electrical characteristics and the configuration requirements of the GPIB.

Types of Messages

Communication among interconnected GPIB devices is achieved by passing messages through the interface system. The GPIB carries device-dependent messages and interface messages.

- Device-dependent messages, often called *data* or *data messages*, contain device-specific information such as programming instructions, measurement results, machine status, and data files.

- Interface messages manage the bus itself. They are usually called *commands* or *command messages*. Interface messages perform such tasks as initializing the bus, addressing and unaddressing devices, and setting device modes for remote or local programming.

The term *command* as used here should not be confused with some device instructions which can also be called commands. Such device-specific instructions are actually data messages.

Talkers, Listeners, and Controllers

A Talker sends data messages to one or more Listeners. The Controller manages the flow of information on the GPIB by sending commands to all devices.

Devices can be Listeners, Talkers, and/or Controllers. A digital voltmeter, for example, is a Talker and may be a Listener as well.

The GPIB is a bus like an ordinary computer bus, except that the computer has its circuit cards interconnected via a backplane bus, whereas the GPIB has stand-alone devices interconnected via a cable bus.

The role of the GPIB Controller can also be compared to the role of the CPU of a computer, but a better analogy is to the switching center of a city telephone system. The switching center (Controller) monitors the communications network (GPIB). When the center (Controller) notices that a party (device) wants to make a call (send a data message), it connects the caller (Talker) to the receiver (Listener).
The Controller addresses a Talker and a Listener before the Talker can send its message to the Listener. After the message is transmitted, the Controller may unaddress both devices.

Some bus configurations do not require a Controller. For example, one device may always be a Talker (called a Talk-only device) and there may be one or more Listen-only devices.

A Controller is necessary when the active or addressed Talker or Listener must be changed. The Controller function is usually handled by a computer.

With the GPIB interface board and its software your personal computer plays all three roles.

- Controller – to manage the GPIB
- Talker – to send data
- Listener – to receive data

**The Controller-In-Charge and System Controller**

Although there can be multiple Controllers on the GPIB, only one Controller at a time is active or Controller-In-Charge (CIC). Active control can be passed from the current CIC to an idle Controller. Only one device on the bus, the System Controller, can make itself the CIC. The GPIB interface board is usually the System Controller.

**GPIB Signals and Lines**

The interface system consists of 16 signal lines and 8 ground return or shield drain lines.

The 16 signal lines are divided into the following three groups.

- Eight data lines
- Three handshake lines
- Five interface management lines

**Data Lines**

The eight data lines, DIO1 through DIO8, carry both data and command messages. All commands and most data use the 7-bit ASCII or ISO code set, in which case the eighth bit, DIO8, is unused or used for parity.
Handshake Lines

Three hardware handshake lines asynchronously control the transfer of message bytes between devices. This process is a three-wire interlocked handshake, and it guarantees that devices send and receive message bytes on the data lines without transmission error. Table A-1 summarizes the GPIB handshake lines.

Table A-1. GPIB Handshake Lines

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRFD (not ready for data)</td>
<td>Listening device is ready/not ready to receive a message byte. Also used by the Talker to signal high-speed transfers (HS488).</td>
</tr>
<tr>
<td>NDAC (not data accepted)</td>
<td>Listening device has/has not accepted a message byte.</td>
</tr>
<tr>
<td>DAV (data valid)</td>
<td>Talking device indicates signals on data lines are stable (valid) data.</td>
</tr>
</tbody>
</table>

Interface Management Lines

Five GPIB hardware lines manage the flow of information across the bus. Table A-2 summarizes the GPIB interface management lines.

Table A-2. GPIB Interface Management Lines

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATN (attention)</td>
<td>Controller asserts ATN when it sends commands and unasserts ATN when it sends data messages.</td>
</tr>
<tr>
<td>IFC (interface clear)</td>
<td>System Controller drives the IFC line to initialize the bus and make itself CIC.</td>
</tr>
<tr>
<td>REN (remote enable)</td>
<td>System Controller drives the REN line to place devices in remote or local program mode.</td>
</tr>
<tr>
<td>SRQ (service request)</td>
<td>Any device can drive the SRQ line to request service from the Controller asynchronously.</td>
</tr>
<tr>
<td>EOI (end or identify)</td>
<td>Talker uses the EOI line to mark the end of a data message. Controller uses the EOI line when it conducts a parallel poll.</td>
</tr>
</tbody>
</table>
Physical and Electrical Characteristics

Devices are usually connected with a cable assembly consisting of a shielded 24 conductor cable with both a plug and receptacle connector at each end. This design allows devices to be linked in either a linear or a star configuration, or a combination of the two. See Figures A-1 and A-2.

The standard connector is the Amphenol or Cinch Series 57 Microribbon or Amp Champ type. An adapter cable using a non-standard cable and/or connector is used for special interconnection applications.

The GPIB uses negative logic with standard TTL (transistor-transistor logic) level. When DAV is true, for example, it is a TTL low level (≤ 0.8V), and when DAV is false, it is a TTL high level (≥ 2.0V).

![GPIB Connector and the Signal Assignment](Image)

Figure A-1. GPIB Connector and the Signal Assignment
Configuration Requirements

To achieve the high data transfer rate that the GPIB was designed for, the physical distance between devices and the number of devices on the bus are limited.

The following restrictions are typical.

- A maximum separation of 4 m between any two devices and an average separation of 2 m over the entire bus.
• A maximum total cable length of 20 m.

• No more than 15 devices connected to each bus, with at least two-thirds powered on.
Appendix B
Specifications

This appendix lists the specifications of the GPIB extender.

Table B-1. System Configuration

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance per GPIB-140 extension</td>
<td>Up to 1 km</td>
</tr>
<tr>
<td>Distance per GPIB-140/2 extension</td>
<td>Up to 2 km</td>
</tr>
<tr>
<td>Loading per extension</td>
<td>Up to 13 additional devices (28 total devices in the extension system, including the extenders)</td>
</tr>
<tr>
<td>Multiple extensions</td>
<td>Permitted in any combination of star or linear pattern</td>
</tr>
</tbody>
</table>

Table B-2. Performance Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum transfer rate</td>
<td></td>
</tr>
<tr>
<td>Buffered mode, non-HS488</td>
<td>1.05 Mbytes/s</td>
</tr>
<tr>
<td>HS488 handshake</td>
<td>2.2 Mbytes/s</td>
</tr>
<tr>
<td>Unbuffered mode</td>
<td>200 kbytes/s</td>
</tr>
<tr>
<td>Functionality</td>
<td>Transparent GPIB operation except for latched parallel polls</td>
</tr>
<tr>
<td>Interlocked IEEE 488 handshake</td>
<td>Maintained across the extension in unbuffered mode</td>
</tr>
<tr>
<td>IEEE 488 capability identification codes</td>
<td></td>
</tr>
<tr>
<td>SH1</td>
<td>Complete Source Handshake</td>
</tr>
<tr>
<td>AH1</td>
<td>Complete Acceptor Handshake</td>
</tr>
<tr>
<td>T5, TE5</td>
<td>Complete Talker</td>
</tr>
<tr>
<td>L3, LE3</td>
<td>Complete Listener</td>
</tr>
<tr>
<td>SR1</td>
<td>Complete Service Request</td>
</tr>
<tr>
<td>RL1</td>
<td>Complete Remote Local</td>
</tr>
<tr>
<td>PP1,2</td>
<td>Complete Parallel Poll</td>
</tr>
<tr>
<td>DC1</td>
<td>Complete Device Clear</td>
</tr>
<tr>
<td>DT1</td>
<td>Complete Device Trigger</td>
</tr>
<tr>
<td>C1-5</td>
<td>Complete Controller</td>
</tr>
<tr>
<td>E2</td>
<td>Tri-state GPIB driver</td>
</tr>
<tr>
<td>HS488 capability identification codes</td>
<td></td>
</tr>
<tr>
<td>SHE</td>
<td>HS488 Source Handshake</td>
</tr>
<tr>
<td>AHE</td>
<td>HS488 Acceptor Handshake</td>
</tr>
</tbody>
</table>
### Table B-3. Operation Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture</td>
<td>Point-to-point (not multi-drop) transmission</td>
</tr>
<tr>
<td>Operating modes</td>
<td>Buffered or unbuffered (interlocked) mode</td>
</tr>
<tr>
<td>HS488 modes</td>
<td>HS488 enabled or HS488 disabled mode</td>
</tr>
<tr>
<td>Parallel Poll Response modes</td>
<td>Immediate Parallel Poll Response mode or Latched Parallel Poll Response mode</td>
</tr>
</tbody>
</table>

### Table B-4. Electrical Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission interface circuit for the GPIB-140</td>
<td>Optical transmitter and receiver (HFBR1414, HFBR2416, or equivalent) with ST-style optical cable connectors</td>
</tr>
<tr>
<td>Transmission interface circuit for the GPIB-140/2</td>
<td>Optical transmitter and receiver (HFBR1312, HFBR1316, or equivalent) with ST-style optical cable connectors</td>
</tr>
<tr>
<td>GPIB interface load</td>
<td>Two standard loads, AC and DC</td>
</tr>
<tr>
<td>Power supply unit</td>
<td>100-120 VAC, 50-60 Hz or 220-240 VAC, 50-60 Hz</td>
</tr>
<tr>
<td>Maximum current requirement</td>
<td>100-120 VAC, 120 mA or 220-240 VAC, 80 mA</td>
</tr>
<tr>
<td>Fuse rating and type</td>
<td>100-120 VAC, 300 mA, UL/CSA approved or 220-240 VAC, 500 mA, IEC approved</td>
</tr>
</tbody>
</table>

### Table B-5. Environmental Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating temperature</td>
<td>0° to 40° C</td>
</tr>
<tr>
<td>Storage temperature</td>
<td>-20° to 70° C</td>
</tr>
<tr>
<td>Humidity</td>
<td>10% to 90% noncondensing conditions</td>
</tr>
<tr>
<td>EMI</td>
<td>FCC Class A Verified</td>
</tr>
</tbody>
</table>
Table B-6. Physical Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case dimensions</td>
<td>8.89 cm by 14.35 cm by 4.11 cm</td>
</tr>
<tr>
<td></td>
<td>(3.5 in. by 5.65 in. by 1.62 in.)</td>
</tr>
<tr>
<td>Case material</td>
<td>All metal enclosure</td>
</tr>
<tr>
<td>Weight</td>
<td>.25 kg (.55 lb)</td>
</tr>
<tr>
<td>GPIB cable</td>
<td>Type X1 or X2 shielded GPIB cable</td>
</tr>
<tr>
<td>Transmission cable for the GPIB-140</td>
<td>3.0 x 6.5 mm cable diameter</td>
</tr>
<tr>
<td></td>
<td>62.5/125 micron core/clad with NA=0.275</td>
</tr>
<tr>
<td></td>
<td>850 nm operating wavelength</td>
</tr>
<tr>
<td></td>
<td>3.0 dB/km attenuation</td>
</tr>
<tr>
<td></td>
<td>Duplex style, terminated with ST-style connectors</td>
</tr>
<tr>
<td>Transmission cable for the GPIB-140/2</td>
<td>3.0 x 6.5 mm cable diameter</td>
</tr>
<tr>
<td></td>
<td>62.5/125 micron core/clad with NA=0.275</td>
</tr>
<tr>
<td></td>
<td>1300 nm operating wavelength</td>
</tr>
<tr>
<td></td>
<td>1 dB/km attenuation</td>
</tr>
<tr>
<td></td>
<td>Duplex style, terminated with ST-style connectors</td>
</tr>
</tbody>
</table>
Appendix C
Introduction to HS488

This appendix describes HS488 and the sequence of events in high-speed data transfers.

HS488 is a proposed addition to the ANSI/IEEE Standard 488.1-1987. HS488 specifies using a noninterlocked handshake protocol to transfer data between two or more devices. By using the HS488 protocol, devices can transfer data at rates that are higher than the rates that are possible by using the IEEE 488.1 protocol.

Objectives of HS488

Fast Transfer Rates

HS488 enables transfer rates that are substantially faster than the IEEE 488.1 standard transfer rates. In small systems, the raw transfer rate can be up to 8 Mbytes/s. The faster raw transfer rates improve system throughput in systems where devices send long blocks of data. The physical limitations of the cabling system, however, limit the transfer rate.

Compatibility with Existing IEEE 488.1 Devices

HS488 devices are compatible with 488.1 devices. IEEE 488.1 devices and HS488 devices can exist in the same system, and they communicate with each other using 488.1 protocols.

A Controller does not need to be capable of HS488 noninterlocked transfers when connected to an HS488 device. While ATN is asserted, a Controller sources multiline messages to HS488 devices just as it sources multiline messages to any 488.1 devices.

No Additional Software Overhead—Automatic HS488 Detection

Addressed HS488 devices detect whether other addressed devices are also HS488 capable without the interaction of the Controller.

No Changes to the IEEE 488.2 Standard

The HS488 protocol requires no changes to the IEEE 488.2 standard. HS488 devices do not need to be 488.2 compliant.
No Added Cabling Restrictions beyond IEEE 488.1

Systems that meet the IEEE 488.1 requirements for higher speed operation meet the HS488 requirements.

You should be aware of the limitations that affect HS488 usage:

- Cabling requirements: Same as IEEE 488.1.
- Does not reduce software overhead.
- System throughput increases depend on data block size.

IEEE 488.1 Requirements for Higher Speed Operation
(T1 Delay $\geq$ 350 ns)

The IEEE 488.1 standard specifies that devices intending high-speed operation must use three-state, 48-mA drivers on most signals. Each device must add no more than 50-pF capacitance on each signal, and all devices must be powered on.

The total cable length in a system must be no more than 15 m, or 1 m times the number of devices in the system.

Additional HS488 System Requirements

An HS488 system must meet the IEEE 488.1 standard requirements described in the preceding section, and HS488 devices must implement three new interface functions. Talking devices must use the Source Handshake Extended (SHE) interface function, which is an extension of the IEEE 488.1 SH function. Listening devices use the Acceptor Handshake Extended (AHE) interface function, which is an extension of the IEEE 488.1 AHE function. Accepting devices must have at least a small buffer to store received data. HS488 devices must implement the Configuration (CF) interface function. At system power on, the Controller uses previously undefined multiline messages to configure HS488 devices. The CF function enables devices to interpret these multiline messages.

Sequence of Events in Data Transfers

Figure C-1 shows a typical IEEE 488.1 data transfer and an HS488 data transfer. The HS488 protocol modifies the 488.1 Source Handshake and Acceptor Handshake functions. At the beginning of each data transfer, the HS488 source and acceptor functions determine whether all active Talkers and Listeners are capable of HS488 transfers. If the addressed devices are HS488 capable, they use the HS488
noninterlocked handshake protocol for that data transfer. If any addressed device is not HS488 compliant, the transfer continues using the standard three-wire handshake.

The following sections describe the sequence of events for data transfers that involve HS488 devices. There are three HS488 transfer cases:

- Talker is HS488—Listener is HS488.
- Talker is HS488—Listener is not HS488.
- Talker is not HS488—Listener is HS488.
Case 1: Talker and Listener Are HS488 Capable

The following steps describe a typical sequence of events in an HS488 data transfer in which the Talker and Listener are both HS488 capable. Refer to Figure C-2.

1. The Controller addresses devices and becomes Standby Controller by unasserting ATN.
2. The Listener asserts NDAC and NRFD.
3. The Listener unasserts NRFD as it becomes ready to accept a byte.
4. After allowing time for the Listener to detect NRFD unasserted, the Talker indicates that it is capable of HS488 operation by sending the HSC message. To send the HSC message true, the Talker asserts the NRFD signal.
5. After allowing time for the Listener to respond to the HSC message, the Talker sends the HSC message false. To send the HSC message false, the Talker unasserts the NRFD signal.
6. When the Talker has a byte ready to send, it drives the data on the DIO signal lines, allows some settling time, and asserts DAV.
7. The Listener unasserts NDAC. HS488 Listeners do not assert NRFD as 488.1 devices would. Because of this behavior, the Talker determines that the addressed Listener is capable of HS488 transfers.

8. The Talker unasserts DAV and begins to drive the next data byte on the GPIB.

9. After allowing some settling time, the Talker asserts DAV.

10. The Listener latches the byte in response to the assertion (falling) edge of DAV.

11. After allowing some hold time, the Talker unasserts DAV and drives the next data byte on the DIO signal lines.

12. Steps 9–11 are repeated for each data byte.

**Case 2: Talker Is HS488 Capable, But Listener Is Not HS488 Capable**

The following steps describe a typical sequence of events in an HS488 data transfer in which the Talker is HS488 capable, but the Listener is not. Refer to Figure C-3.

Steps 1–6 are identical to steps 1–6 in case 1, *Talker and Listener Are HS488 Capable*. The Listener ignores the HSC message from the Talker.

Step 7: The IEEE 488.1 Listener enters ACDS and asserts NRFD. Because of this behavior, the Talker determines that the addressed Listener is not capable of HS488 transfers. The Talker sources bytes using the IEEE 488.1 protocol.
Case 3: Talker Is Not HS488 Capable, But Listener Is HS488 Capable

The Talker does not send an HSC message to the Listener, but begins sourcing bytes by using the IEEE 488.1 protocol.

The Addressed Listener (HS488 or 488.1) accepts bytes by using the IEEE 488.1 standard three-wire handshake. Refer to Figure C-4.

![Figure C-4. Talker Is Not HS488 Capable, But Listener Is HS488 Capable](image)

System Configuration

The HS488 Acceptor Handshake and Source Handshake interface functions depend on several time delays. Some of these delays are a function of the total system cable length.

The Controller must communicate this system configuration data to HS488 devices after the system powers on. The Controller configures HS488 devices by sourcing two multiline messages while ATN is true.

The first message is the Configuration Enable (CFE) message. The Controller sends the CFE message by driving a bit pattern (1E hex) that the IEEE 488.1 standard does not define on the DIO signal lines. The CFE message enables HS488 devices to interpret the SCG message that follows. The second message is a Secondary Command Group (SCG) message that contains the configuration data. The Secondary Command has the bit pattern 6n hex, where n is the meters of cable in the system. The Secondary Command Group includes CFG1-CFG15 in Appendix D, Multiline Interface Messages.
Appendix D
Multiline Interface Messages

This appendix lists the multiline interface messages and describes the mnemonics and messages that correspond to the interface functions.

The multiline interface messages are IEEE 488 defined commands that are sent and received with ATN asserted. The interface functions include initializing the bus, addressing and unaddressing devices, and setting device modes for local or remote programming. For more information on these messages, refer to the ANSI/IEEE Standard 488.1-1987, *IEEE Standard Digital Interface for Programmable Instrumentation*. 
# Multiline Interface Messages

## Message Definitions

<table>
<thead>
<tr>
<th>CFE†</th>
<th>Configuration Enable</th>
<th>MLA</th>
<th>My Listen Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFG†</td>
<td>Configure</td>
<td>MSA</td>
<td>My Secondary Address</td>
</tr>
<tr>
<td>DCL</td>
<td>Device Clear</td>
<td>MTA</td>
<td>My Talk Address</td>
</tr>
<tr>
<td>GET</td>
<td>Group Execute Trigger</td>
<td>PPC</td>
<td>Parallel Poll Configure</td>
</tr>
<tr>
<td>GTL</td>
<td>Go To Local</td>
<td>PPD</td>
<td>Parallel Poll Disable</td>
</tr>
<tr>
<td>LLO</td>
<td>Local Lockout</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

†This multiline interface message is a proposed extension to the IEEE 488.1 specification to support the HS488 high-speed protocol.
### Multiline Interface Messages

<table>
<thead>
<tr>
<th>Hex</th>
<th>Oct</th>
<th>Dec</th>
<th>ASCII</th>
<th>Msg</th>
<th>Hex</th>
<th>Oct</th>
<th>Dec</th>
<th>ASCII</th>
<th>Msg</th>
</tr>
</thead>
<tbody>
<tr>
<td>04</td>
<td>100</td>
<td>64</td>
<td>@</td>
<td>MTA0</td>
<td>60</td>
<td>140</td>
<td>96</td>
<td>~</td>
<td>MSA0,PPE</td>
</tr>
<tr>
<td>01</td>
<td>101</td>
<td>65</td>
<td>A</td>
<td>MTA1</td>
<td>61</td>
<td>141</td>
<td>97</td>
<td>a</td>
<td>MSA1,PPE,CFG1</td>
</tr>
<tr>
<td>02</td>
<td>102</td>
<td>66</td>
<td>B</td>
<td>MTA2</td>
<td>62</td>
<td>142</td>
<td>98</td>
<td>b</td>
<td>MSA2,PPE,CFG2</td>
</tr>
<tr>
<td>03</td>
<td>103</td>
<td>67</td>
<td>C</td>
<td>MTA3</td>
<td>63</td>
<td>143</td>
<td>99</td>
<td>c</td>
<td>MSA3,PPE,CFG3</td>
</tr>
<tr>
<td>04</td>
<td>104</td>
<td>68</td>
<td>D</td>
<td>MTA4</td>
<td>64</td>
<td>144</td>
<td>100</td>
<td>d</td>
<td>MSA4,PPE,CFG4</td>
</tr>
<tr>
<td>05</td>
<td>105</td>
<td>69</td>
<td>E</td>
<td>MTA5</td>
<td>65</td>
<td>145</td>
<td>101</td>
<td>e</td>
<td>MSA5,PPE,CFG5</td>
</tr>
<tr>
<td>06</td>
<td>106</td>
<td>70</td>
<td>F</td>
<td>MTA6</td>
<td>66</td>
<td>146</td>
<td>102</td>
<td>f</td>
<td>MSA6,PPE,CFG6</td>
</tr>
<tr>
<td>07</td>
<td>107</td>
<td>71</td>
<td>G</td>
<td>MTA7</td>
<td>67</td>
<td>147</td>
<td>103</td>
<td>g</td>
<td>MSA7,PPE,CFG7</td>
</tr>
<tr>
<td>08</td>
<td>110</td>
<td>72</td>
<td>H</td>
<td>MTA8</td>
<td>68</td>
<td>150</td>
<td>104</td>
<td>h</td>
<td>MSA8,PPE,CFG8</td>
</tr>
<tr>
<td>09</td>
<td>111</td>
<td>73</td>
<td>I</td>
<td>MTA9</td>
<td>69</td>
<td>151</td>
<td>105</td>
<td>i</td>
<td>MSA9,PPE,CFG9</td>
</tr>
<tr>
<td>0A</td>
<td>112</td>
<td>74</td>
<td>J</td>
<td>MTA10</td>
<td>6A</td>
<td>152</td>
<td>106</td>
<td>j</td>
<td>MSA10,PPE,CFG10</td>
</tr>
<tr>
<td>0B</td>
<td>113</td>
<td>75</td>
<td>K</td>
<td>MTA11</td>
<td>6B</td>
<td>153</td>
<td>107</td>
<td>k</td>
<td>MSA11,PPE,CFG11</td>
</tr>
<tr>
<td>0C</td>
<td>114</td>
<td>76</td>
<td>L</td>
<td>MTA12</td>
<td>6C</td>
<td>154</td>
<td>108</td>
<td>l</td>
<td>MSA12,PPE,CFG12</td>
</tr>
<tr>
<td>0D</td>
<td>115</td>
<td>77</td>
<td>M</td>
<td>MTA13</td>
<td>6D</td>
<td>155</td>
<td>109</td>
<td>m</td>
<td>MSA13,PPE,CFG13</td>
</tr>
<tr>
<td>0E</td>
<td>116</td>
<td>78</td>
<td>N</td>
<td>MTA14</td>
<td>6E</td>
<td>156</td>
<td>110</td>
<td>n</td>
<td>MSA14,PPE,CFG14</td>
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- **PPE**: Parallel Poll Enable
- **PPU**: Parallel Poll Unconfigure
- **SDC**: Selected Device Clear
- **SPD**: Serial Poll Disable
- **SPE**: Serial Poll Enable
- **TCT**: Take Control
- **UNL**: Unlisten
- **UNT**: Untalk
- **UNT**: Untalk

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Appendix E  
Customer Communication

For your convenience, this appendix contains forms to help you gather the information necessary to help us solve technical problems you might have as well as a form you can use to comment on the product documentation. Filling out a copy of the *Technical Support Form* before contacting National Instruments helps us help you better and faster.

National Instruments provides comprehensive technical assistance around the world. In the U.S. and Canada, applications engineers are available Monday through Friday from 8:00 a.m. to 6:00 p.m. (central time). In other countries, contact the nearest branch office. You may fax questions to us at any time.

**Corporate Headquarters**
(512) 795-8248  
Technical support fax: (800) 328-2203  
(512) 794-5678

**Branch Offices**

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Technical Support Form

Photocopy this form and update it each time you make changes to your software or hardware, and use the completed copy of this form as a reference for your current configuration. Completing this form accurately before contacting National Instruments for technical support helps our applications engineers answer your questions more efficiently.

If you are using any National Instruments hardware or software products related to this problem, include the configuration forms from their user manuals. Use additional pages if necessary.

Name
Company
Address
Fax (___)____________ Phone (___)____________

Computer brand ______________________________

Model ___________________ RAM ________________ MB
Processor ___________________ Speed ________________ MHz
Operating system ______________________________
Display adapter ______________________________
Mouse _______yes _______no
Other adapters installed ______________________________

Hard disk capacity _______MB Brand _______________________
Instruments used ______________________________

National Instruments hardware product model _______________________
Revision ______________________________
Configuration ______________________________

National Instruments software product _______________________
Version ______________________________
Configuration ______________________________

(continues)
The problem is

List any error messages

The following steps will reproduce the problem
GPIB Extender Hardware and Software Configuration Form

Record the settings and revisions of your hardware and software on the line to the right of each item. Update this form each time you revise your software or hardware configuration, and use this form as a reference for your current configuration.

National Instruments Products

• GPIB Extender and Revision Number
  – GPIB-140 Revision ________________________________
  or
  – GPIB-140/2 Revision ________________________________

• DIP Switch Settings ________________________________

• National Instruments GPIB Interface ________________________________

• National Instruments Software ________________________________

Other Products

• Computer Make and Model ________________________________

• Operating System Version ________________________________

• Number of GPIB Devices on Bus ________________________________

• Other GPIB Devices in System ________________________________
Documentation Comment Form

National Instruments encourages you to comment on the documentation supplied with our products. This information helps us provide quality products to meet your needs.

Title: GPIB-140 User Manual
Edition Date: June 1995
Part Number: 320911B-01

Please comment on the completeness, clarity, and organization of the manual.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

(continues)
If you find errors in the manual, please record the page numbers and describe the errors.

____________________________________________________

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____________________________________________________

Thank you for your help.

Name _______________________________________________

Title ________________________________________________

Company ____________________________________________

Address _____________________________________________

____________________________________________________

Phone (_____ ) ____________________

Mail to: Technical Publications
National Instruments Corporation
6504 Bridge Point Parkway, MS 53-02
Austin, TX 78730-5039

Fax to: Technical Publications
National Instruments Corporation
MS 53-02
(512) 794-5678
### Glossary

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°  
- degrees

%  
- percent

A  
- amperes

AC  
- alternating current

ANSI  
- American National Standards Institute

ASCII  
- American Standards Code for Information Interchange

ASIC  
- application-specific integrated circuit

ATN  
- Attention

CIC  
- Controller-In-Charge

CPU  
- central processing unit

CSA  
- Canadian Standards Association

DAV  
- data valid

dB  
- decibels

DC  
- direct current

DIO  
- digital input/output

DIP  
- dual inline package

EOI  
- End or Identify

EOS  
- End of String

F  
- Farads

FCC  
- Federal Communications Commission

FIFO  
- first-in-first-out

g  
- grams

GPIB  
- General Purpose Interface Bus

hex  
- hexadecimal

Hz  
- hertz

IDY  
- Identify

IEC  
- International Electrotechnical Commission

IEEE  
- Institute of Electrical and Electronic Engineers

IFC  
- Interface Clear

lb  
- pounds

LED  
- light-emitting diode
m 
MB 
NA 
NDAC 
NRFD 
PPR 
RAM 
REN 
s 
SRQ 
TTL 
UL 
VAC 
meters 
megabytes of memory 
Numerical Aperture 
Not Data Accepted 
Not Ready For Data 
Parallel Poll Response 
random-access memory 
Remote Enable 
seconds 
Service Request 
transistor-transistor logic 
Underwriters Laboratories 
volts alternating current