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PLEASE CHECK FOR CHANGE INFORMATION AT THE REAR OF THIS MANUAL.

2445/2465
OPTION 10
GPIB OPTION
OPERATORS

INSTRUCTION MANUAL

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

070-4633-00
Product Group 38

Serial Number _____

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INSTRUMENT SERIAL NUMBERS

Each instrument has a serial number on a panel insert, tag, or stamped on the chassis. The first number or letter designates the country of manufacture. The last five digits of the serial number are assigned sequentially and are unique to each instrument. Those manufactured in the United States have six unique digits. The country of manufacture is identified as follows:

B000000	Tektronix, Inc., Beaverton, Oregon, USA
100000	Tektronix Guernsey, Ltd., Channel Islands
200000	Tektronix United Kingdom, Ltd., London
300000	Sony/Tektronix, Japan
700000	Tektronix Holland, NV, Heerenveen, The Netherlands

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OPERATORS SAFETY SUMMARY

The general safety summary in this part of the summary is for both operating and servicing personnel. Specific warnings and cautions will be found throughout the manual where they apply and do not appear in this summary.

Terms in This Manual

CAUTION statements identify conditions or practices that could result in damage to the equipment or other property.

WARNING statements identify conditions or practices that could result in personal injury or loss of life.

Terms as Marked on Equipment

CAUTION indicates a personal injury hazard not immediately accessible as one reads the markings, or a hazard to property, including the equipment itself.

DANGER indicates a personal injury hazard immediately accessible as one reads the marking.

Symbols as Marked on Equipment

This symbol indicates where applicable cautionary or other information is to be found.

Protective ground (earth) terminal.

ATTENTION — Refer to manual.

Power Source

This product is intended to operate from a power source that does not apply more than 250 volts rms between the supply conductors or between either supply conductor and ground. A protective ground connection by way of the grounding conductor in the power cord is essential for safe operation.

Grounding the Product

This product is grounded through the grounding conductor of the power cord. To avoid electrical shock, plug the power cord into a properly wired receptacle before connecting to the product input or output terminals. A protective ground connection by way of the grounding conductor in the power cord is essential for safe operation.

Danger Arising From Loss of Ground

Upon loss of the protective-ground connection, all accessible conductive parts (including knobs and controls that may appear to be insulating) can render an electric shock.

Use the Proper Power Cord

Use only the power cord and connector specified for your product.

Use only a power cord that is in good condition.

Use the Proper Fuse

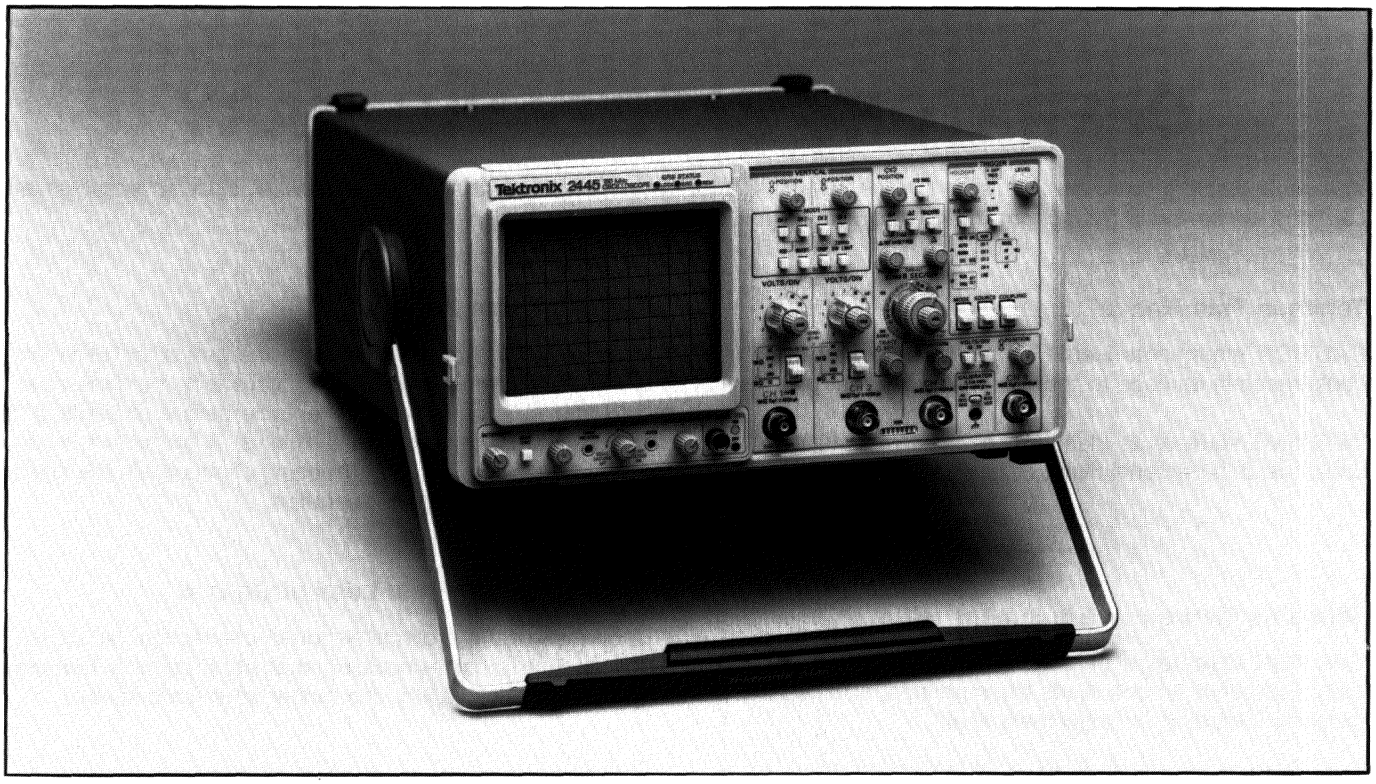
To avoid fire hazard, use only a fuse of the correct type, voltage rating and current rating as specified in the parts list for your product.

Do Not Operate in Explosive Atmospheres

To avoid explosion, do not operate this product in an explosive atmosphere unless it has been specifically certified for such operation.

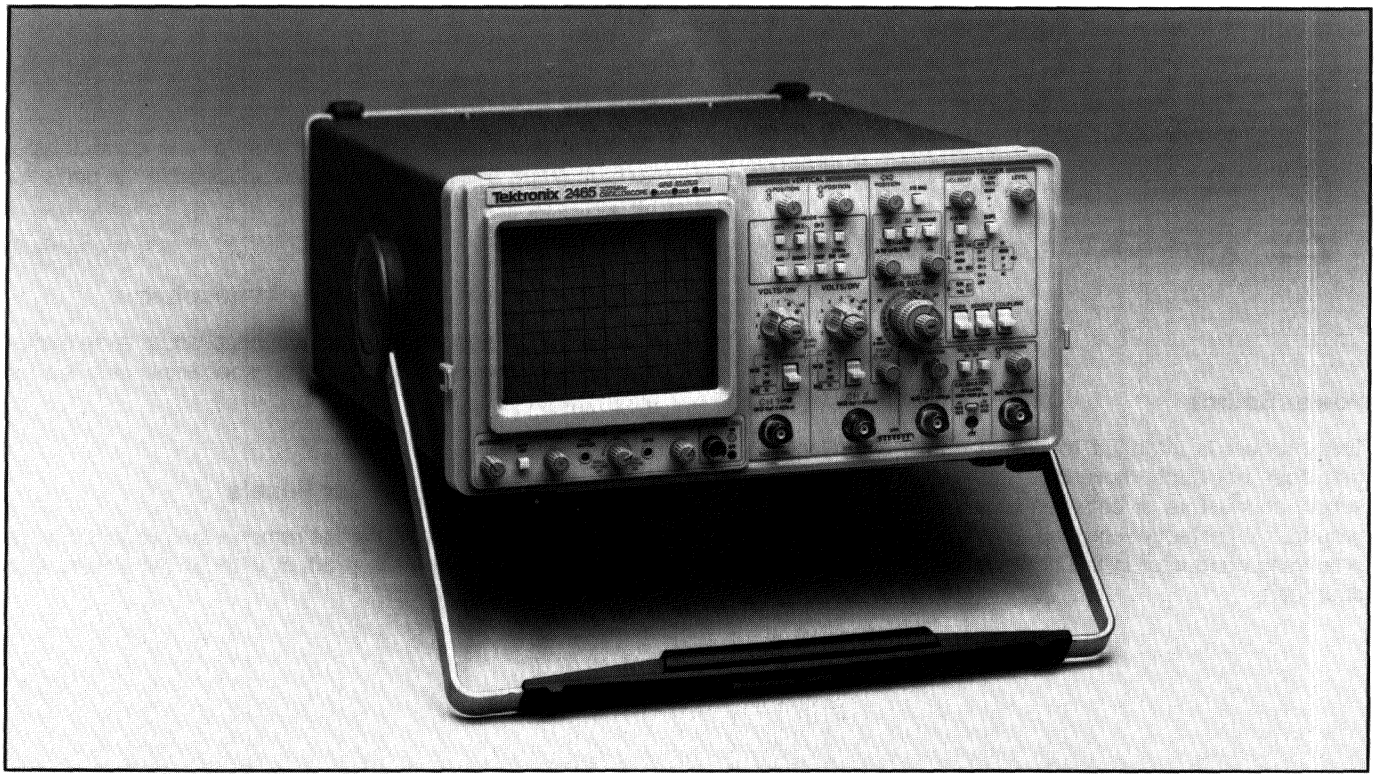
Do Not Remove Covers or Panels

To avoid personal injury, do not remove the product covers or panels. Do not operate product without the covers and panels properly installed.



4633-01

The 2445 Option 10 (GPIB) Oscilloscope.



4633-02

The 2465 Option 10 (GPIB) Oscilloscope.

SPECIFICATION

INTRODUCTION

Option 10 to the TEKTRONIX 2445 and 2465 Oscilloscopes adds the hardware and the software that allows these instruments to be remotely controlled and queried using a standard interface system. The interface implemented conforms to the specifications contained in *IEEE Standard Digital Interface for Programmable Instrumentation (ANSI/IEEE Std 488-1978)*, commonly referred to as the General Purpose Interface Bus (GPIB). It also complies with a Tektronix Standard relating to GPIB Codes, Formats, Conventions and Features.

This manual describes GPIB operational elements only in relation to communication between the oscilloscope and the remote controller by way of the bus. For complete information regarding GPIB electrical, mechanical, and functional aspects, refer to ANSI/IEEE Std 488-1978, which is published by:

The Institute of Electrical and Electronics Engineers, Inc.
345 East 47th Street
New York, New York 10017

Messages originating from a remote controlling device and transmitted over the GPIB perform one of three functions:

1. Set the oscilloscope operating mode;
2. Query the state of the oscilloscope; or
3. Query the results of measurements made.

All oscilloscope front-panel functions are controllable through the GPIB interface, except the power and display controls (INTENSITY, BEAM FIND, FOCUS, READOUT INTENSITY, TRACE ROTATION, ASTIG, SCALE ILLUM, and POWER). Structure and format of the commands and queries executable by the GPIB Option are explained in Section 4, "Controlling Oscilloscope Functions over the GPIB". A listing of command headers and arguments, along with concise descriptions, is also provided in Section 4.

The alphanumeric crt readout is used to display measurement results, diagnostic test messages, exercise messages, and calibration messages. Any measurement result that is displayed on the crt readout can also be transmitted over the GPIB. While the READOUT INTENSITY control itself is not GPIB controllable, scale-factor readouts can be turned on and off over the bus.

STANDARD ACCESSORIES

In addition to the standard accessories listed in the basic oscilloscope manuals, one copy each of the following Option 10 accessories is also provided:

Description	Part Number
2445/2465 Option 10 Operators Manual	070-4633-00
2445/2465 Option 10 Service Manual	070-4640-00
2445/2465 Option 10 Reference Guide	070-5364-00

STANDARD FUNCTIONS, FORMATS, AND FEATURES

The total interface-function repertoire of an instrument on the GPIB, in terms of interface-function subsets, is identified in ANSI/IEEE Std 488-1978. The status of subsets applicable to 2445 and 2465 Oscilloscopes with Option 10 are listed in Table 1-1.

A Tektronix standard identifies the format and features of messages sent over the bus to communicate with other instruments equipped with a GPIB interface. Specific features implemented in the 2445 and 2465 Oscilloscopes are listed in Table 1-2, and specific formats are shown in Table 1-3.

Table 1-1
ANSI/IEEE Std 488-1978 (GPIB) Functions

Function	Description
SH1	Source Handshake. Complete capability.
AH1	Acceptor Handshake. Complete capability.
T6	Basic Talker. Responds to Serial Poll. Unaddress if My Listen Address (MLA) is received.
L3	Basic Listener. Listen Only. Unaddress if My Talk Address (MTA) is received.
SR1	Service Request. Complete capability.
RL1	Remote-Local. Complete capability.
DC1	Device Clear. Complete capability.
PP0	Parallel Poll. Does not respond to Parallel Poll.
DT0	Device Trigger. Does not have Device Trigger capability.
C0	Controller. Does not have Controller capabilities.

NOTE

Open collector bus drivers (E1) are used by this instrument.

Table 1-2
Specific Features Implemented

Feature	Description
Indicators	REM (remote), SRQ (service request), and LOCK (front-panel lockout) indicators are included.
Parameter Selection	Selection is via diagnostic menu and crt readout. Nonvolatile storage is in EAROM. No hard-wired switches are provided for this feature.
Secondary Addressing	Not implemented.

Table 1-3
Specific Format Choices

Format Parameter	Description
Format Characters	Not transmitted; ignored on reception.
Message Terminator	Either the End-or-Identify (EOI) or the Line-Feed (LF) mode can be selected.
Measurement Terminator	Follows program message-unit syntax, which allows numeric characters in headers and alphabetic data arguments for reporting.
Link Data (Arguments)	Used in Listen and Talk modes.
Instrument Identification Query	Descriptors are added for other installed options.
SETtings Query	Extended, using LLSet commands, to allow block binary response.
INIt Command	Causes the oscilloscope to return to a power-on condition. All operating modes then agree with actual front-panel settings.
Return to Local (rtl) Message	Asserted when any front-panel control attempts to change a GPIB-controllable function.
Time/Date Commands	Not implemented.
Stored Setting Commands	Not implemented.
Waveform Transmission	Not implemented.
Device Trigger (DT)	Not implemented.
Multiple Event Reporting	Not implemented.
IEEE 728	Compliance not intended.

PERFORMANCE CONDITIONS

Except as noted in Tables 1-4 and 1-5 of this manual, the electrical, environmental, and mechanical characteristics of Option 10 instruments (including the performance conditions) are identical to those specified in the respective 2445 and 2465 Oscilloscope Operators Manual.

Table 1-4
Option 10 Electrical Characteristics

Characteristics	Performance Requirements
Vertical Position Accuracy	Position accuracy is only valid when: 1. Positioning occurs after a BALance command is invoked at the ambient temperature in which the instrument is operating. 2. The VOLTS/DIV VAR control is in the calibrated detent.
CH 1, CH 2 (noninverted)	
+15°C to +35°C	±(0.3 div + 3% of distance from center screen in divs + .5 mV/V/DIV setting.)
CH 2 Inverted	Add 0.2 div.
−15°C to +55°C (excluding +15°C to +35°C)	Add 1.5 mV/V/DIV setting
CH 3, CH 4	
−15°C to +55°C	±(0.7 div + 3% of distance from center screen in divs.)
IEEE 488 Outputs	
Volts Out for True (I_{QT} = 48 mA)	Max 0.5 V.
Volts Out for False (I_{OF} = −5.2 mA)	Min 2.5 V.
Volts Out with Output Disabled	Max 3.7 V, Min 2.5 V.
Output Leakage Current with Power OFF (0 V<V_{IN}<2.5 V)	Max 40 μA.
IEEE 488 Inputs	
Volts In for True	Max 0.8 v, Min 0 V.
Volts in for False	Max 5.5 V, Min 2.0 V.
Current in for True (V_{IT} = 0.5 V)	Max −0.1 mA.
Current in for False (V_{IT} = 2.7 V)	Max 20 μA.

Table 1-5
Option 10 Mechanical Characteristics

Characteristics	Description
Weight With Power Cord, Cover, Pouch, Probes, Operators Manual, and Options	⩽ 12.0 kg (26.4 lb).
Domestic Shipping Weight	⩽ 17.6 kg (38.8 lb).

CONTROLS, CONNECTORS, AND INDICATORS

FRONT-PANEL CONTROLS

Controls used to set up the instrument for GPIB operation (i.e., selecting the instrument's GPIB address, end-of-message terminator, and talk/listen mode) are described in Section 3, "GPIB Preparation For Use". The use of all other controls for operating the instrument remains the same as explained in the oscilloscope Operators Manual.

REAR PANEL

See Figure 2-1 for the location of the following connector.

(50) **GPIB CONNECTOR**—This connector provides the IEEE Std 488-1978 compatible electrical and mechanical connection to the GPIB.

INDICATORS

See Figure 2-2 for the location of the indicators (LOCK, SRQ, and REM) added to the front panel above the crt.

(51) **LOCK (Local Lockout)**—Illuminates to indicate that the Local Lockout universal command has been sent over the GPIB. If the instrument has been addressed and the Remote Enable line asserted, the front-panel controls, except display and power, will be locked out.

(52) **SRQ (Service Request)**—Illuminates to indicate that the instrument has detected either an error or a warning condition and is requesting service by the bus controller.

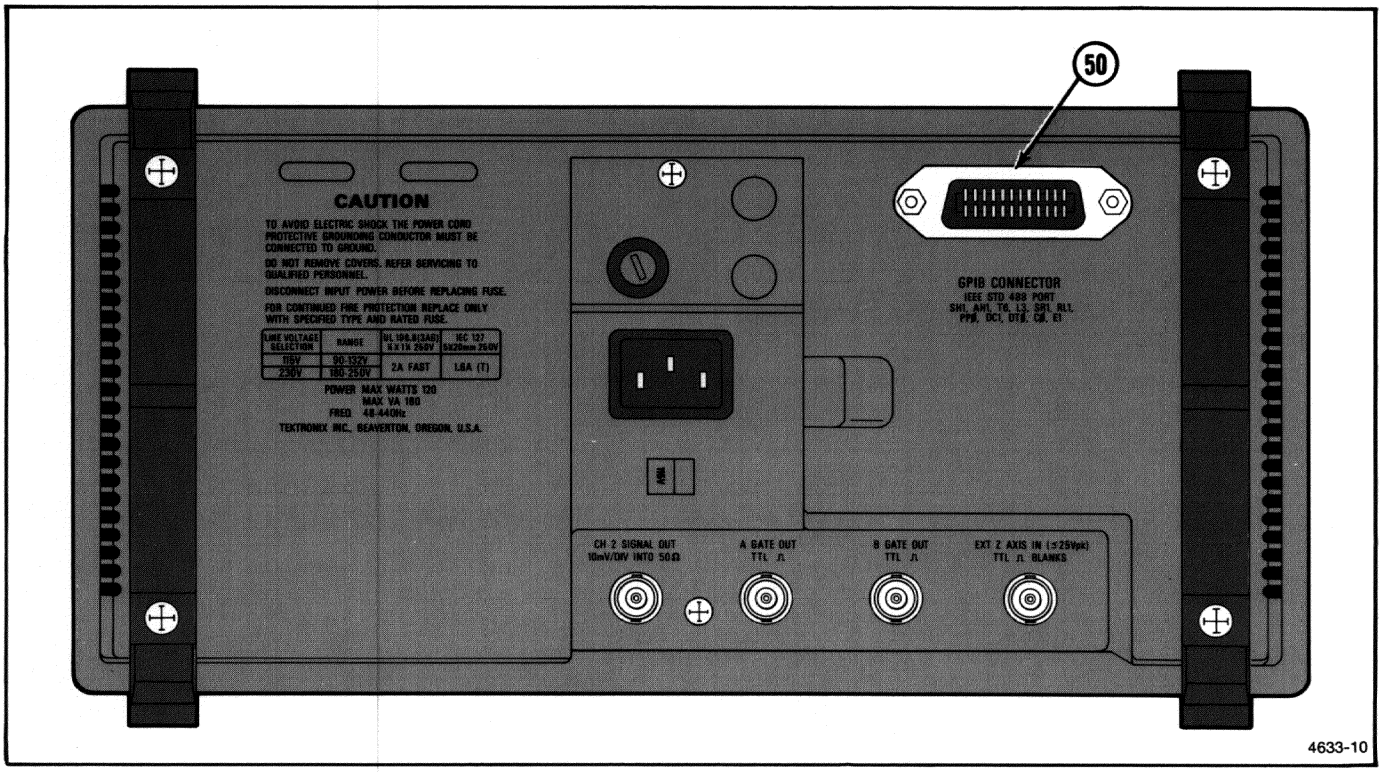


Figure 2-1. Rear Panel GPIB CONNECTOR.

(53) **REM (Remote)**—Illuminates to show that the instrument's GPIB interface is in a Remote state. The interface enters a Remote state at the request of the bus controller. It leaves the Remote state either at the controller's request or when a GPIB-controllable front-panel control is changed while the instrument is not in a Local Lockout state.

READOUT DISPLAYS

Readout displays of GPIB-controllable oscilloscope functions are identical to crt readout displays for non-GPIB-equipped instruments. Consult Sections 3 and 6 in the oscilloscope Operators Manual for readout display information and typical examples. The additional displays associated with the operator's GPIB functions are illustrated in Section 4 of this manual.

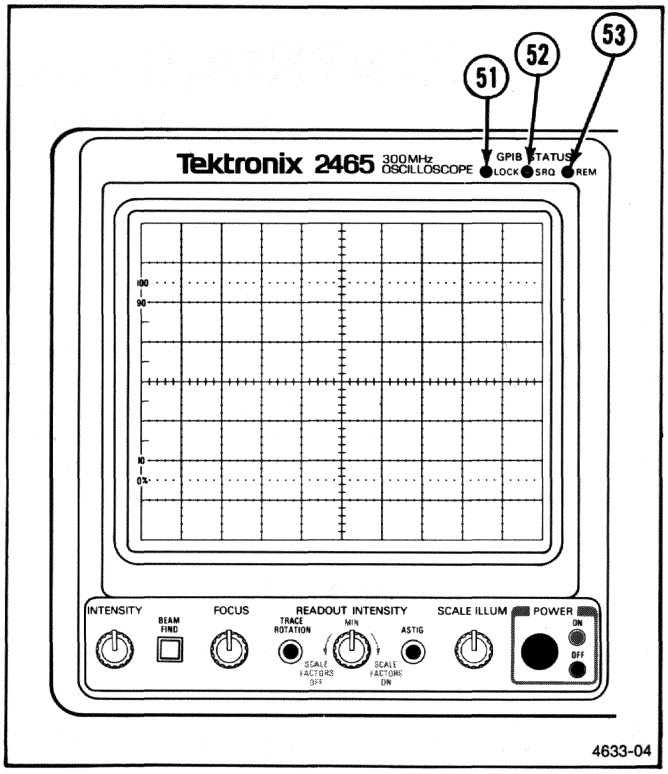


Figure 2-2. GPIB STATUS indicators.

GPIB PREPARATION FOR USE

POWER-UP SEQUENCE

Before initially turning on power to the instrument, read Section 2, "Preparation for Use", in the oscilloscope Operators Manual and follow the safety and precautionary information described there.

The power-up tests, automatically performed each time the oscilloscope is turned on, examines both the oscilloscope circuitry and the Option 10 GPIB circuitry. Tests specifically applicable to Option 10 are integrated into the power-up tests for the host oscilloscope and likewise consist of two main parts: Kernel tests and a Confidence test.

Kernel Tests

The Option 10 memory (ROM) is checked by standard instrument Kernel tests. Kernel test failures will result in an attempt to flash the front-panel A SWP TRIG'D indicator.

Even with a Kernel failure, pressing in the A/B TRIG switch may still place the instrument in the normal operating mode. However, if the operating mode is successfully entered, instrument operation may be unpredictable.

NOTE

On some instruments with other options installed, the A/B TRIG button may be labeled A/B/MENU.

Confidence Test

Failure of the GPIB Confidence test during power-up is indicated in the bottom line of the crt readout. The failure display has the following format:

GP TEST 11 FAIL YY

where **YY** represents the code for the failed test segment.

A Confidence test failure may not render the GPIB interface inoperable. Pressing in the A/B TRIG button may still place the instrument into the normal operating mode; however, it may not meet all GPIB specifications.

Successful Power-Up Sequencing

When the power-up routine is successfully completed without a failure indication, five instrument events occur:

1. The oscilloscope enters the normal operating mode.
2. The GPIB interface enters the Local State (LOCS).
3. The GPIB interface asserts Service Request (SRQ).
4. The oscilloscope functions are set to the values which were established at least 15 seconds before the instrument was last turned off, with front-panel switch settings taking precedence.
5. The GPIB interface responds to a controller's serial poll with a status byte of 65 (decimal), meaning that all tests were successful and power is on.

The instrument is now ready to make measurements as required.

Unsuccessful Power-Up Sequencing

If power-up tests fail, four instrument events occur:

1. The oscilloscope does not enter the normal operating mode.
2. The GPIB interface enters the Local State (LOCS).
3. The GPIB interface asserts Service Request (SRQ).
4. The GPIB interface responds to a controller's serial poll with a status byte of 65 (decimal), meaning that power is on.

As explained in preceding paragraphs, it may be possible, after a power-up test failure, to place the instrument into the normal operating mode by pressing in the A/B TRIG switch. If it then functions adequately for your particular measurement requirement, the instrument can be used, but refer it to a qualified service technician for repair of the problem as soon as possible.

POWER-DOWN SEQUENCE

There are no special sequences associated with powering down the instrument. When the POWER switch is set to OFF, the instrument powers down and SRQ is not asserted.

CONTROLLING OSCILLOSCOPE FUNCTIONS OVER THE GPIB

INTRODUCTION

This section provides information for controlling the TEKTRONIX 2445 and 2465 Oscilloscopes via the IEEE Std 488-1978 digital interface. With Option 10 installed, all basic instrument functions (as explained in the oscilloscope Operators Manual) remain unchanged. Consult the oscilloscope Operators Manual to acquire a thorough understanding of the operation of the basic instrument before trying to control it via the GPIB.

All measurement results returned by GPIB commands have the same accuracy as the main instrument or instrument option being accessed by the GPIB interface.

GPIB PARAMETER SELECTION

After power-up sequencing is complete and the oscilloscope is in the normal operating mode, selection of GPIB parameters (primary address, message terminator, and talk/listen mode) can be made.

Primary Address

The selected GPIB address establishes both the primary talk and listen addresses for the oscilloscope. It can be set to any value between 0 and 31, inclusive.

NOTE

Option 10 has no provisions for secondary addressing as defined by ANSI/IEEE Std 488-1978.

With an address of 31, the option still presents an active load but does not respond to nor interfere with any bus traffic. This feature is useful for changing the instrument's status without turning off the oscilloscope's power.

Perform the following procedure to either set or change the primary GPIB address:

1. Hold in both the ΔV and Δt switches while pushing the TRIGGER SLOPE switch to access diagnostic mode.
2. Repeatedly push up on the TRIGGER MODE switch until **GP EXER 11** appears in the bottom line of the crt readout.
3. Push up on the TRIGGER COUPLING switch to initiate the routine.
4. Rotate the Δ control until the desired address is displayed in the top row of the crt readout; for example:

GPIB ADDRESS 29

NOTE

*Trying to select an address outside the range of 0 to 31 will cause **LIMIT** to appear on the top right side of the crt display.*

5. Push down on the TRIGGER COUPLING switch to end the routine and update the stored copy of the address to its new value.
6. Push the A/B TRIG switch (or the A/B/MENU switch, if applicable) to exit diagnostic mode.

Input End-of-Message Terminator and Talk/Listen Mode

The end-of-message terminator can be selected to be either the End-or-Identify (EOI) interface signal or the Line-Feed (LF) character.

When EOI (normal mode) is selected as the terminator, the option will:

- Accept only EOI as the end-of-message terminator.
- Assert EOI concurrently with the last byte of a message.

When LF is selected as the terminator, the option will:

- Accept either LF or EOI as the end-of-message terminator.
- Send Carriage Return (CR) followed by LF at the end of every message, with EOI asserted concurrently with the LF.

Two talk/listen modes are selectable:

- TALK LISTEN mode allows the oscilloscope to both send and receive data over the GPIB.
- LISTEN ONLY mode permits the oscilloscope to only receive data over the GPIB.

The default mode is TALK LISTEN.

To select or change the end-of-message terminator and the talk/listen modes perform the following procedure:

1. Hold in both the ΔV and Δt buttons while pushing the TRIGGER SLOPE switch to access the diagnostic mode.
2. Repeatedly push up on the TRIGGER MODE switch until **GP EXER 12** appears in the bottom line of the crt readout.
3. Push up on the TRIGGER COUPLING switch to initiate the routine.
4. Push the TRIGGER MODE switch up repeatedly until the desired terminator appears in the top line of the crt readout. Push the TRIGGER SOURCE switch up repeatedly until the desired Talk/Listen mode appears in the top line of the crt readout. Four terminator/mode combinations are available:

   TERMINATOR EOI MODE TALK LISTEN

   or

   TERMINATOR LF MODE TALK LISTEN

   or

   TERMINATOR EOI MODE LISTEN ONLY

   or

   TERMINATOR LF MODE LISTEN ONLY
5. Push down on the TRIGGER COUPLING switch to end the routine and update the stored copy of the settings.
6. Push the A/B TRIG switch (or the A/B/MENU switch, if applicable) to exit diagnostic mode.

MESSAGES AND COMMUNICATION PROTOCOL

The GPIB Option commands can set the instrument operating mode, query the results of measurements made, or query the state of the oscilloscope. These commands are specified in mnemonics that are related to the functions intended to be implemented. For example, the command INIt initializes instrument settings to states that would exist if the instrument's power was cycled. To further facilitate programming, command mnemonics are similar to front-panel control names.

Commands

Commands for the 2445 and 2465 Oscilloscopes, like those for other Tektronix GPIB-controllable instruments, follow the conventions established in a Tektronix Codes and Formats Standard. The command words were chosen to be as understandable as possible, while still allowing a familiar user to shorten them as much as necessary, as long as the result is unambiguous. Syntax is also standardized to make the commands easier to learn.

In the command lists (Tables 4-2 through 4-7), headers and arguments are listed in a combination of uppercase and lowercase characters. The instrument accepts any abbreviated header or argument containing at least the characters shown in uppercase. Any characters added to the abbreviated (uppercase) version must be those shown in lowercase. For a query, the question mark must immediately follow the header. For example, any of the following formats are acceptable:

VMO?
VMOd?
VMOde?

Headers

A command consists of at least a header. Each command has a unique header, which may be all that is needed to invoke a command; e.g.,

NORmal
GO

Arguments

Some commands require the addition of arguments to the headers to describe exactly what is to be done. If there is more to the command than just the header (including the question mark if it is a query), then the header must be followed by at least one space.

In some cases, the argument is either a single word or a numeric value; e.g.,

DELay 1.0E−03
HMOde XY

In other cases, the argument itself requires another argument. When a second argument is required, a colon must separate the two arguments; e.g.,

CH1 VOLts:10
ATRigger MODe:AUTOLevel

Where a header has multiple arguments, the arguments (or argument pairs, if the argument has its own argument) must be separated by commas; e.g.,

CH1 VOLts:10,COUpling:DC,POSition:1.2
VMOde CH1:OFF,CH2:ON,ADD:ON

Command Separator

It is possible to put multiple commands into one message by separating the individual commands with a semicolon; e.g.,

CH1 VOLTS:10,COUPLING:DC;VMODE ADD:ON

Message Terminator

As previously explained, messages may be terminated with either EOI or LF. Some controllers assert EOI concurrently with the last data byte; others use only the LF character as a terminator. The GPIB interface can be set to accept either terminator. With EOI selected, the instrument interprets a data byte received with EOI asserted as the end of the input message; it also asserts EOI concurrently with the last byte of an output message. With the LF setting, the instrument interprets the LF character without EOI asserted (or any data byte received with EOI asserted) as the end of an input message; it transmits a Carriage Return character followed by Line Feed (LF with EOI asserted) to terminate output messages.

Command Formatting

Commands sent to the oscilloscope must have the proper format (syntax) to be understood; however, this format is flexible in that many variations are acceptable. The following paragraphs describe this format and the acceptable variations.

The oscilloscope expects all commands to be encoded as either uppercase or lowercase ASCII characters. All data output is in uppercase.

Spaces, Carriage Returns, and Linefeeds are all formatting characters that can be used to enhance the readability of command sequences. As a general rule, these characters can be placed either after commas and semicolons or after the space that follows a header.

Numeric Arguments

Table 4-1 depicts the number formats for numeric arguments in the GPIB command set. As shown in the table, both signed and unsigned numbers are accepted; but unsigned numbers are interpreted to be positive.

The symbol <nrx> indicates that any of the three formats is allowed. When only one specific format is permitted, it is represented by nr1, nr2, or nr3.

Table 4-1

Numeric Argument Format for GPIB Commands

Numeric Argument Symbol		Number Format	Examples
<nrx>	<nr1>	Integers	+1, 2, −1, −10
	<nr2>	Explicit decimal point	−3.2, +5.1, 1.2
	<nr3>	Floating point in scientific notation	+1.E−2, 1.0E+2, 1.E−2, 0.02E+3

GPIB COMMAND LISTS

Tables 4-2 through 4-7 describe all GPIB commands available in 2445 and 2465 Oscilloscopes equipped with only the GPIB Option. The first column lists the name (or header) of the command. The capitalized letters must be present to identify the command, while those shown in lowercase are optional. The second column lists arguments that can be associated with the command. The third column lists arguments associated with the first argument. Finally, descriptions of each command and its arguments are contained in the last column.

One or more arguments, separated by commas, may be given in a query to request only the information wanted. For example,

CH1? COUpling,VARiable

Instrument commands are presented in tables divided into the following functional groups:

COMMAND TABLE INDEX

Other 2445 and 2465 options (if installed) use Option 10 for GPIB access. When present, these options add their own command sets to the GPIB commands listed in Tables 4-2 through 4-7. For information on the additional GPIB command sets, consult the respective option operators manual.

Table 4-2
Vertical Commands

Header	Argument	Argument	Description
CH1			Selects Channel 1 vertical parameters.
	COUpling:	AC DC FIFTY GND	Sets Vertical Coupling to the selected mode.
	POSition:	<nrx>	Sets Vertical Position to the value of <nrx> in divisions. Range is ± 10 divisions, with center screen at 0.
	VARiable:	<nrx>	Sets Vertical Volts/Div Var gain control circuitry to the value of <nrx>. Values range from 0 to 10 and are not calibrated. Zero represents the calibrated position.
	VOLts:	<nrx>	Sets Vertical Volts/Div gain to the value of <nrx>. The argument must be valid for the installed probe. If the value does not correspond to a calibrated position, the next higher calibrated value will be used and an SRQ warning will be issued.
CH1?			Query returns: CH1 VOLTS:<nr3>, VAR:<nr1>, POS:<nr3>, COUPL:string
	COUpling POSition VARiable VOLts		
	PROBe		PROBe must be queried explicitly, e.g., CH1? PROBe. The string returned for PROBe corresponds to the probe attenuation coding (X1, X10, X100 or X1000).

Table 4-2 (cont)

Header	Argument	Argument	Description
CH2			Same as CH1 plus INVert: argument.
	INVert:	ON OFF	Turns Channel 2 inversion on or off. Default is ON. This command has the same effect as VMOde INVert:string.
CH2?			Same as CH1, except query also returns INV:string, where string is either ON or OFF.
	INVert		
CH3 CH3?			Same as CH1, except COUpling and VARiable arguments are invalid and POSition range is ±4 divisions.
CH4 CH4?			Same as CH1, except COUpling and VARiable arguments are invalid and POSition range is ±4 divisions.
VMOde			Selects channels to be displayed, chopped or alternated display mode, limited or not limited vertical bandwidth, and Channel 2 inversion. When all channels are deselected, Channel 1 is displayed.
	BWLimit:	ON OFF	Sets state of the bandwidth limit function. With no arguments, defaults to ON.
	CHOp:	ON OFF	Selects chopped or alternate display mode. Default is ON.
	CH1:	ON OFF	Turns Channel 1 on or off. Default is ON.
	CH2:	ON OFF	Turns Channel 2 on or off. Default is ON.
	CH3:	ON OFF	Turns Channel 3 on or off. Default is ON.
	CH4:	ON OFF	Turns Channel 4 on or off. Default is ON.
	ADD:	ON OFF	Turns Channel 1 plus Channel 2 on or off. Default is ON.
	INVert:	ON OFF	Turns Channel 2 inversion on or off. Default is ON.
VMOde?	CHOp CH1 CH2 CH3 CH4 ADD INVert BWLimit		Query returns current state of the vertical display: VMO CH1:string, CH2:string, CH3:string, CH4:string, ADD:string, BWL:string, INV:string, CHO:string.

Table 4-3
Horizontal Commands

Header	Argument	Argument	Description
HORizontal			Selects Horizontal sweep system parameters.
	ASEcdiv:	<nrx>	Selects the A sweep speed in seconds per division. Range for the 2465 is from 5E−9 to 1.5. For the 2445, range is from 10E−9 to 1.5. If the resulting speed is faster than the current B sweep, the B sweep will be set equal to the A sweep. The effects of MAGnify: are independent of ASEcdiv:. See Appendix D for additional command considerations.
	BSEcdiv:	<nrx>	Selects the B sweep speed in seconds per division. Range for the 2465 is from 5E−9 to 0.15. For the 2445, range is from 10E−9 to 0.15. The sweep speed is updated whether the B sweep is active or not. If the B sweep requested is slower than the current A sweep speed, the A sweep will be set equal to the B sweep speed. The effects of MAGnify: are independent of BSEcdiv:. See Appendix D for additional command considerations.
	MAGnify:	ON OFF	Turns the X10 horizontal magnification function on or off. Default is ON.
	POSition:	<nrx>	Selects the starting position of the sweep. Units are divisions from the left edge of the screen and cover a range of approximately ± 5.4 divisions.
	TRACEsep:	<nrx>	Offsets the B sweep from the A sweep by the indicated amount. Range is from 0 to −4, and units are approximately divisions.
HORizontal?			Query returns the current state of the horizontal selections: HOR ASE:<nr3>, BSE:<nr3>, MAG:string, POS:<nr3>, TRACE:<nr3>;, where the string is either ON or OFF.
	ASEcdiv BSEcdiv MAGnify POSition TRACEsep		
HMOde			Selects Horizontal display mode from the list. Choices are mutually exclusive.
	ALTernate		Selects both normal and delayed sweeps for display. This is equivalent to pulling the SEC/DIV knob out.
	ASWeep		Selects only the A sweep for display.
	BSWeep		Selects only the B sweep for display. If both the A and the B sweeps are set to the same rate, then a settings conflict SRQ error is generated.
	XY		Selects XY mode.
HMOde?			Query returns: HMO string;, where the string represents one of the possible Horizontal display modes.

Table 4-4
Trigger Commands

Header	Argument	Argument	Description
ATRigger			Selects the A Trigger parameters.
	MODe:	AUTOBaseline AUTOLevel NORmal SGLseq	Selects Trigger Mode from the list of arguments.
	SOUrce:	CH1 CH2 CH3 CH4 LINe VERtical	Selects Trigger Source from the list of arguments.
	COUpling:	AC DC HFRej LFRej NOIserej	Selects Trigger Coupling Mode from the list of arguments.
	LEVel:	<nrx>	Sets Trigger Level in units of volts; range depends on the gain setting of the current Trigger Source. Range is ± 18 divisions when the Source is either Channel 1 or Channel 2, and ± 9 divisions when the Source is either Channel 3 or Channel 4. LINe SOUrce uses a fixed range of ± 10 divisions.
	SLOpe:	MINUs PLUs	Selects Slope of the trigger signal.
	BENdsa:	ON OFF	Sets the B ENDS A TRIGGER Mode to either ON or OFF.
	HOLdoff:	<nrx>	Sets Holdoff to the value of <nrx>. Range is from 0 to 10, with 0 representing minimum holdoff. This command is not calibrated.
ATRigger?	COUpling LEVel MODe SLOpe SOUrce BENdsa HOLdoff		Query response is: ATR BEN:string, COU:string, HOL:string, LEV:<nr3>, MOD:string, SLO:string, SOU:string. Arguments TRIGD, READY, MAX, and MINI must be requested explicitly, e.g. ATR? MINI,MAX.
	MINImum		Query only. Returns the current minimum level of the A Trigger channel in volts: ...,MINI:<nr3>,.... Data returned by MINI is valid only in AUTO LVL and only immediately following completion of an Auto Level cycle. An Auto Level cycle can be initiated by sending ATRigger MODe:AUTOLevel.

Table 4-4 (cont)

Header	Argument	Argument	Description
	MAXimum		Query only. Returns the current maximum level of the A Trigger channel in volts: ...,MAX:<nr3>,.... Data returned by MAX is valid only in AUTO LVL and only immediately following completion of an Auto Level cycle. An Auto Level cycle can be initiated by sending ATRigger MODe:AUTOLevel.
	TRIGD		Query only. Determines whether TRIG'D indicator is illuminated. Returns: TRIGD: string, where string is either ON or OFF.
	READY		Query only. Determines whether the single-sequence READY indicator is illuminated. Returns: READY string, where string is either ON or OFF.
BTRigger			Selects the B Trigger parameters.
	MODe:	RUN TRIGGerable	Selects the B Trigger Mode.
	SOUrce:	CH1 CH2 CH3 CH4 VERtical	Selects the B Trigger Source.
	COUpling:	AC DC HFRej LFRej NOIserej	Selects the B Trigger Coupling Mode.
	LEVel:	<nrx>	Sets the Trigger Level in units of volts, with the range depending on the VOLTS/DIV switch setting of the current trigger source. Range is either ± 18 divisions when the source is either Channel 1 or Channel 2, and ± 9 divisions otherwise.
	SLOpe:	MINUs PLUs	Selects slope of the trigger signal.
BTRigger?			Query response is: BTR COU:string, LEV:<nr3>, MOD:string, SLO:string, SOU:string.
	COUpling LEVel MODe SLOpe SOUrce		

Table 4-5
Delay and Delta Commands

Header	Argument	Argument	Description
DELAy	<nrx>		Sets value of the sweep delay in units of divisions. This command has the same effect as DTIME REF: <nrx>. Range is from −0.05 to 9.95. The value of −0.05 is used to guarantee the ability to view A trigger events with the B Sweep.
DELAy?			Query returns the current delay setting in divisions: DELA <nr3>. This response is not included in a SET? query.
DELTa			Sets parameters relating to the Delta displays.
	MODE:	OFF PERTime TIMe VOLts	Selects a Delta mode or turns off the Delta display.
	TRACKing:	ON OFF	Turns TRACKING on or off. Default is ON.
DELTa?	MODE TRACKing		Query returns: DELT MOD:string, TRACK:string, where the first string is either OFF, PERTIME, TIME, or VOLTS, and the second is either ON or OFF.
DTIme	REFerence:	<nrx>	Sets position of the first Delta Time cursor in units of divisions. Left edge of the display corresponds to −0.05, and the maximum value is 9.95. If TRACKING is on, the second cursor will also attempt to move.
	DELTa:	<nrx>	Sets position of the second Delta Time cursor relative to the first cursor in units of divisions. Range depends on the current position of the first cursor.
DTIme?	REFerence DELTa		Query returns the current Delta Time settings: DTI REF:<nr3>, DELT:<nr3>.
DVOlts	REFerence:	<nrx>	Sets position of the first Delta Volts cursor in units of divisions. The center of the display corresponds to zero, and the range is ± 4. If TRACKING is on, the second cursor will also attempt to move.
	DELTa:	<nrx>	Sets position of the second Delta Volts cursor relative to the first cursor in units of divisions. Range depends on the current position of the first cursor.
DVOlts?	REFerence DELTa		Query returns the current Delta settings: DVO REF:<nr3>, DELT:<nr3>.

Table 4-6
System Commands

Header	Argument	Argument	Description
ERRor?			Query returns: ERR <nr1>;. Response is identical to EVEnt? query. Command is included for compatibility with earlier instruments.
EVEnt?			Query returns: EVE <nr1>; where <nr1> is the most severe of the currently existing errors. Errors are prioritized into three levels, but only the most recent error is maintained for each level. If there is no error pending, 0 is returned. A list of other codes can be found in Appendix B.
ID?			Query returns: ID TEK/24w5,V81.1,SYS:FVx, BB:FVy, [string:FV<nr1>,] GPIB:,FVz; Where w is either 4 or 6; x, y, and z are the version numbers of the oscilloscope, Buffer board, and GPIB option, respectively; and the section in brackets is repeated for each installed option. String V81.1 indicates that the GPIB interface is compatible with the V81.1 version of the Tektronix Codes and Formats standard.
INIt			Causes the instrument and all options (except the GPIB message processor) to go to an initialized state equivalent to a power-up condition. All internal settings will agree with the front-panel switch settings. Since the GPIB message processor is not initialized, GPIB system-command states (OPC, RQS, WARning, and LONgform) are not initialized. Commands following INIt in the same message may not be executed. This command should be immediately followed with EOI.
LLMessage	%<byte><byte>...		This command allows the character equivalent of a binary block to be written to the top line of the crt readout. The binary block must be in the same format as data returned by the LLMessage? query. The following TEKTRONIX 4050 series controller statements will write **HELLO** in large letters on the crt readout of an oscilloscope with a GPIB address of 1. 100 DIM H(19) 110 I=33 120 READ H 130 WBYTE @I:H 140 DATA 76,76,77,32,37,0,11,162,161 150 DATA 210,209,174,173,174,173,186 160 DATA 185,230,−59 See Appendix E for a description of the character set available for use with this command.
LLMessage?			Returns the contents of the top line of the crt readout. Response is a binary block of data in the form: LLM %<byte><byte>...<byte>. The first two bytes following the % character are a 16-bit count of the bytes that follow. The last byte of the block is the two's complement of the least significant byte of the sum of data bytes.

Table 4-6 (cont)

Header	Argument	Argument	Description
LLSet	%<byte><byte>...,		Returns the oscilloscope to a previous setup. The data can only be generated by a LLSet? query.
LLSet?			Queries instrument settings. Response is a block of binary data in the form: LLSET %<byte><byte>...,% <byte><byte>...,... The number of blocks depends on the installed oscilloscope options. The first two bytes following the % character are a 16-bit count of the bytes that follow. Each % block has its own count. The last byte of the block is the two's complement of the least significant byte of the sum of data bytes.
MESsage	"string"		This command will allow strings to be written to the top line of the crt. Up to 32 symbols may be displayed at one time. The string must be enclosed in quotes. See Appendix C for a description of the character set available for use with this command.
MESsage?			Returns an ASCII representation of the top line of the display: MES "message", where the message may be more than 32 characters due to character translations (See Appendix C).
OPC	ON OFF		When enabled, the instrument will assert SRQ on completion of certain commands. Only diagnostic commands and some options assert OPC service requests. Default is ON with no argument, but initializes to OFF at power-up.
OPC?			Query returns either: OPC ON or OPC OFF.
READOut	ON OFF		Turns the crt SCALE FACTORS readout ON or OFF. Default is ON.
READOut?			Query returns state of the SCALE FACTORS readout: READO string, where string is either ON or OFF.
RQS	ON OFF		When enabled, the instrument will assert SRQ on detection of an error condition. Default is ON, with no argument, and initializes to ON at power-up.
RQS?			Query returns either: RQS ON or RQS OFF.
SETtings?			Queries instrument settings. Response is an ASCII string that can be sent to the instrument to return it to the state it was when the query was received. The ASCII string consists of a series of properly formatted commands, which should not be preceded by SETtings when sent back to the instrument. *NOTE* *The SETtings? query will have an inconsistency when using variable sweep speeds. If the variable is used to set the A Sweep slower than the next slowest sweep speed, transfers via SETtings? will result in the variable being attached to the B Sweep, and the A Sweep will be set to its next slowest sweep speed.*

Table 4-6 (cont)

Header	Argument	Argument	Description
LONgform	ON OFF		When LONgform is ON, all queries will respond with the full length versions of commands. When LONgform is OFF, the shortest acceptable version of commands are used in query responses. Default is OFF.
LONgform?			Query returns either: LONGFORM ON or LONG OFF.
WARning	ON OFF		When enabled, the instrument asserts SRQ on detection of a warning condition. Default is ON, with no argument, and initializes to ON at power-up.
WARning?			Query returns either: WARN ON or WARN OFF.

Table 4-7
Calibration and Diagnostic Commands

Header	Argument	Argument	Description
BALance			Causes the oscilloscope to initiate its Automatic Balance procedure. An automatic initialization (see INIt) will occur after BALance. Available only from normal mode, not Diagnostic.
CALibrate	<nrx>:	<nrx>	Causes oscilloscope to go to Diagnostic mode and the Calibration routine indicated by the arguments. The first argument represents the option and is the most significant digit of the displayed routine number. The second represents the routine number and is the least significant digit of the displayed routine number. The option numbers are shown in hexadecimal in the crt readout of the Diagnostic menu. Option numbers are: Standard Oscilloscope 0 Option 10 (GPIB) 1 Option 05 (TV) 6 Option 01 (DMM) 7 Option 06 (C/T/T) 8 Option 09 (Word Recognizer) 8 Buffer Board 15

Table 4-7 (cont)

Header	Argument	Argument	Description
GO			Causes the currently selected CALIBRATION, EXERCISE, or TEST routine to begin execution. This command has the same effect as pushing up on the TRIGGER COUPLING switch when in Diagnostic mode.
LOOping	ON OFF		When in Diagnostic mode, this command causes looping of diagnostics to be either enabled or disabled. Default is ON.
LOOping?			Query returns: LOO string; where string is either ON or OFF.
NORmal			Causes instrument to exit Diagnostic mode. It has no effect if already in normal mode. Commands following NORmal in the same message may not be executed. It is recommended that NORmal be immediately followed with EOI.
STEp			Causes the currently executing Diagnostic routine to proceed to its next step.
STEp?			Query returns: STEP <nr1>; where nr1 is the current step.
STOp			Causes the currently executing Diagnostic routine to stop executing and return control to the Diagnostic monitor. This command should not be used to exit EXErcise 1:1 and EXErcise 1:2.
TESt	<nrx>:	<nrx>	Controls Diagnostic mode test sequences. The first argument represents the option, and the second is the routine number. See CALibrate command for option numbers.
TESt?	<nrx>:	<nrx>	Executes the requested test and returns the test's status value: TES <nr1>. Zero is returned for a passed test.

REMOTE-LOCAL OPERATING STATES

The following paragraphs describe the four operating states of the Option 10 instrument: Local, Local With Lockout, Remote, and Remote With Lockout.

Local State (LOCS)

In LOCS, instrument parameters are both set and changed manually by operator manipulation of the front-panel controls. Only IEEE-488 interface messages can be received and executed. Device-dependent commands (without REN asserted) will cause SRQ errors since their functions are under front-panel control while in LOCS. Additional information about GPIB errors is contained in Appendix B.

Local With Lockout State (LWLS)

The oscilloscope operates the same as it does in LOCS, except that manual manipulation of front-panel controls will not cause the instrument to return to the Local State. The interface will enter the Remote With Lockout State (RWLS) if it receives its listen address (MLA).

Remote State (REMS)

In this state, the oscilloscope executes all commands addressed to it over the GPIB. Front-panel indicators and crt readouts are updated as applicable when commands are executed. Manually changing any GPIB-controllable front-panel control causes the instrument to return to the Local State.

Remote With Lockout State (RWLS)

In RWLS, oscilloscope operation is identical to REMS operation, except that manual manipulation of any front-panel control does not change the previously established value of that parameter.

INSTRUMENT RESPONSE TO INTERFACE MESSAGES

The following paragraphs explain effects on the oscilloscope of standard interface messages received from a remote controller. Message abbreviations used are from ANSI/IEEE Std 488-1978.

Local Lockout (LLO)

In response to the Local Lockout (LLO) message, the instrument assumes a lockout state in accordance with the following table:

Before LLO	After LLO
Local State (LOCS)	Local With Lockout State (LWLS)
Remote State (REMS)	Remote With Lockout State (RWLS)

Remote Enable (REN)

When the Remote Enable (REN) line is asserted and the instrument receives its listen address, the oscilloscope is placed in either the Remote State (REMS) or the Remote With Lockout State (RWLS). When in either remote state, the oscilloscope's REM indicator is illuminated.

Disasserting the REN line causes a transition from any state to LOCS; the instrument remains in LOCS as long as REN is false. The transition may occur after processing of a different message has begun. In this case, execution of the message being processed is not interrupted by the transition.

Go To Local (GTL)

Instruments that are already listen-addressed respond to the Go To Local message (GTL) by assuming a local state. Remote-to-local transitions caused by GTL do not affect the execution of any message being processed when GTL was received.

My Listen and My Talk Addresses (MLA and MTA)

The primary Talk/Listen address is established as previously explained in this section.

Unlisten (UNL) and Untalk (UNT)

When the Unlisten (UNL) message is received, the oscilloscope's listen function is placed in an idle (unaddressed) state. In the idle state, the instrument will not accept commands over the GPIB.

The talk function is placed in an idle state when the oscilloscope receives the Untalk (UNT) message. In this state, the instrument cannot transmit data via the GPIB.

Interface Clear (IFC)

When the Interface Clear (IFC) line is asserted, both the Talk and Listen functions are placed in an idle state and the front-panel REM indicator is turned off. This produces the same effect as receiving both the UNL and the UNT messages.

Device Clear (DCL)

The Device Clear (DCL) message reinitializes communication between the instrument and the controller. In response to DCL, the instrument clears any input and output messages as well as any unexecuted control settings. Also cleared are any errors and events waiting to be reported (except the power-on event). If the SRQ line is asserted for any reason (other than power-on), it becomes unasserted when the DCL message is received.

Selected Device Clear (SDC)

This message performs the same function as DCL; however, only instruments that have been listen-addressed respond to SDC.

Serial Poll Enable and Disable (SPE and SPD)

The Serial Poll Enable (SPE) message causes the instrument to transmit its serial-poll status byte when it is talk-addressed. The Serial Poll Disable (SPD) message switches the instrument back to its normal operation.

PROGRAMMING

Programming considerations and program examples are provided in this part to assist you in developing your own unique programs for controlling 2445 and 2465 Oscilloscopes over the GPIB. Program examples were designed using TEKTRONIX 4050-series and TEKTRONIX 4041 controllers with 2445 and 2465 Oscilloscopes containing Option 10. While programming was done using Tektronix controllers, other controllers capable of being programmed to perform the same functions can also be used.

Before a program can be used for controlling the oscilloscope, the GPIB parameters (primary address, message terminator, and talk/listen mode) must be set. Section 3, "GPIB Preparation for Use", contains the procedures describing how these parameters are selected and set at the oscilloscope.

Programs are usually composed of two main parts (or routines), which can be generally categorized as a command handler and a service-request handler.

Command Handler

Basically, a command handler should establish communication between the controller and oscilloscope, send commands and queries to the oscilloscope, receive responses from the oscilloscope, and display responses as required. The following outline indicates the general sequence of functions that the command-handling routine should perform to accommodate communications between the controller and oscilloscope over the GPIB.

1. Initialize the controller.
2. Disable the service-request handler until the program is ready to handle them.
3. Get the GPIB address of the oscilloscope.
4. Enable the service-request handler.
5. Get the command to send to the oscilloscope.
6. Send the command to the oscilloscope.
7. Check for a response from the oscilloscope.
8. If there is a response, perform the desired function.
9. You are ready for a new command. Repeat the functions in statements 5 through 9 as many times as desired.

Service-Request Handler

The typical service-request handler routine contains the necessary instructions to permit proper processing of interrupts. For example, whenever power-on occurs, the oscilloscope asserts an SRQ interrupt. If a GPIB program is operating on the controller when a power-on SRQ is received, the program should be able to determine that the oscilloscope's power was interrupted at some time during program operation. This event could cause improper program execution, unless the program was written to adequately handle the possibility of a power-on SRQ occurring.

Other interrupts (or events) for which the oscilloscope asserts SRQ are identified in Appendix B.

While some controllers have the capability of ignoring service requests, others require that all SRQs be managed. The programmer should understand the controller being used. If service requests are to be handled in the program, the interrupts must first be enabled.

A service-request handler routine can be developed to service interrupts when they occur during program operation. It basically should consist of an interrupt-enabling statement (ON SRQ) near the beginning of the program and a serial-poll subroutine somewhere in the program. The ON SRQ statement directs program control to the serial-poll subroutine whenever an SRQ interrupt occurs. For each interrupt received by the controller, the program should perform a serial-poll subroutine.

The following general steps are required to handle service requests from the oscilloscope:

1. Perform a serial poll.
2. Send an EVENT? query to the oscilloscope requesting service.
3. If the EVENT? query response is not zero, then perform the desired response to the event.
4. Return to the main program.

Sample Program A

The program that follows is written to run on TEKTRONIX 4050-series controllers. It first asks for the GPIB address of the oscilloscope, then repeatedly asks for a command to be entered. When a command is entered at the controller, the program sends it to the oscilloscope. Any response from the oscilloscope is printed on the controller's display. If there are any service requests, a serial poll is

performed. The service request and the EVENT codes are then printed before returning to the main part of the program.

```
100 REM   Program to send commands and queries
    to and receive
110 REM   responses from TEKTRONIX 2445 and
    2465 Oscilloscopes
120 INIT
125 PAGE
130 REM   Disable SRQ Handler until ready
140 ON SRQ THEN 570
150 REM * Page when screen is full *
160 PRINT @32,26:2
170 REM
180 REM
190 PRINT "Enter address of the
    oscilloscope ";
200 REM * Get address and put in variable A *
210 INPUT A
220 REM * Enable SRQ handler *
230 ON SRQ THEN 440
235 DIM S$(2000)
240 REM
250 PRINT
260 PRINT "*******"
270 PRINT "ENTER COMMAND OR QUERY: ";
280 REM * Put command or query in string Z$ *
290 INPUT Z$
300 REM * Send string Z$ to the oscilloscope *
310 PRINT @A:Z$
320 REM * Get response (if any) and put in
    string S$ *
330 INPUT @A:S$
340 REM * Check if there is a response *
350 REM *   If not then ready to send another
    command or query *
360 REM *   If yes then print the response *
370 IF LEN(S$)=0 THEN 250
380 PRINT
390 PRINT "RESPONSE FROM THE OSCILLOSCOPE
    IS: "
400 PRINT S$
410 REM * Ready to send another command or
    query *
420 GO TO 250
430 REM *** SRQ HANDLER ***
440 POLL D,C;A
450 REM * Look for an Event and put Event in E *
460 REM *     If EVENT=0 then no error *
470 REM *     If EVENT<>0 then warn the user
and
480 REM *           print SRQ Code and
    EVENT NO.
490 REM *
500 PRINT @A: "EVENT?"
510 INPUT @A:E
520 IF E=0 THEN 570
530 PRINT " ERROR - SRQ CODE ";
540 PRINT C;
550 PRINT " - EVENT NO. ";
560 PRINT E
570 RETURN
```

Sample Program B

The program example that follows performs functions similar to Sample Program A, but is written to run on a TEKTRONIX 4041 controller.

```
100   !     Program to send commands and
    queries to and receive
110   !     responses from TEKTRONIX 2445 and
    2465 Oscilloscopes
120   !
130     Init all
140   !     Disable SRQ handler until ready
150     Disable srq
160   ! Get address of the oscilloscope
170     Print "Enter the GPIB address of the
    2445/65: ";
180     Input addr$
190   ! Set up physical and logical unit -
200   ! Set up so only EOI can terminate the
    communication.
210   !
220     Set driver "gpib0(eom=<0>):"
230     Open
    #1:"gpib0(pri="&addr$&",eom=<0>):"
240   !
250   !  Enable SRQ handler
260     On srq then gosub srqhdl
270     Enable srq
280   !
290 Repeat:   ! Sending command or query
300     Print "******"
310     Print
320     Print "Enter command or query :";
330   ! Get the command
340     Input a$
350   ! Send command or query to scope
360     Print #1:a$
370   ! Get response if there is any
380     DIM resp$ to 2000
390     Input #1:resp$
400     Print
410   ! If no response then prompt for another
    command
420     If len(resp$)=0 then goto repeat
```

```
430   ! If yes then print the response
440     Print "Response from the oscilloscope
    is:"
450     Print resp$
460     Goto repeat
470 Srqhdl:   ! routine to handle the srq
480             Poll stb,dev
490             Print #dev:"event?"
500       ! Get event number
510             Input #dev:event
520             Print "Instrument #";dev;"
    status byte = ";stb;", event = ";event
530             Resume
```

Using SETtings? and LLSet? Queries

Using the SETtings? and LLSet? queries simplifies programming. These queries return a string that, in turn, can be sent back to the oscilloscope to set its front-panel parameters to the values that existed when the query was received.

The string returned from the SETtings? query is in user-readable ASCII and allows easy verification by the programmer. When simply sent back to the instrument using no other command, this string will return the instrument parameters to the previous state.

The LLSet? query returns a binary string that is not easily read by the programmer, but is much shorter. It therefore allows faster instrument setup using the LLSet command. This binary string, returned via the LLSet? query, may only be sent back to the instrument using the LLSet command.

Sample Program C

The following program illustrates use of the LLSet command and query to transfer the front-panel control set up from one 2445/2465 Oscilloscope to another. It is written for use on TEKTRONIX 4050-series GPIB controllers.

```
4 GOTO 100
100 INIT
110 ON SRQ THEN 720
120 REM: DISABLE SRQ HANDLER UNTIL READY
130 PAGE
140 PRINT "THIS PROGRAM TRANSFERS A
    FRONT-PANEL SETUP FROM ONE"
150 PRINT " 2445/2465 TO ANOTHER 2445/2465."
160 PRINT
170 PRINT "SET THE GPIB ADDRESS OF THE
    'REFERENCE' INSTRUMENT TO 2, AND"
180 PRINT "THE ADDRESS OF THE 'INSTRUMENT TO BE
    SET UP' TO 4."
190 PRINT
200 PRINT "PRESS RETURN TO CONTINUE"
210 INPUT I$
220 X=2
230 REM: X= ADDRESS OF 'REFERENCE' INSTRUMENT
240 Y=4
250 REM: Y= ADDRESS OF 'INSTRUMENT TO BE
    SET UP'
260 ON SRQ THEN 570
270 REM: ENABLE SRQ HANDLER
280 DELETE F
290 DIM F(400 )
300 REM: DIMENSION F LARGE ENOUGH TO HANDLE ANY
    POSSIBLE SETUP
310 F=0
320 PRINT @X:"LLSET?"
330 REM: TELL THE 2445/2465 TO SEND A BINARY
    PANEL SETUP
340 WBYTE @64+X:
350 REM: ASSIGN DEVICE #X ON THE BUS TO BE
    A TALKER
360 C=0
370 REM: INITIALIZE COUNTER
380 REM: T= TEMPORARY STORAGE FOR INCOMING
    BYTE
390 RBYTE T
400 REM: READ IN A BYTE
410 C=C+1
420 REM: INCREMENT COUNTER
430 F(C )=T
440 REM: STORE BYTE IN ARRAY
450 IF T<0 THEN 500
460 REM: CHECK TO SEE IF BYTE IS NEGATIVE. IF IT
    IS, THEN THE ARRAY
470 REM: TRANSFER IS COMPLETE.
480 GO TO 390
490 REM: GO GET ANOTHER BYTE UNTIL THE ARRAY
    TRANSFER IS COMPLETE
500 DIM F(C )
510 REM: RE-DIMENSION ARRAY TO THE EXACT SIZE
    OF THE DATA.
520 WBYTE @63,95,32+Y:F
530 REM: SEND SET-UP TO GPIB DEVICE #Y
540 PRINT
550 PRINT "PRESS UDK #1 TO RESTART PROGRAM"
560 END
570 REM
580 REM SRQ HANDLER ROUTINE
590 REM
600 POLL A,B;X;Y
610 REM: PERFORM SERIAL POLL
620 IF A=2 THEN 680
630 PRINT @X: "EVENT?"
```

```
640 REM: GET "EVENT" RESPONSE IF DEVICE #X
    ASSERTED SRQ
650 INPUT @X:D
660 PRINT "INSTRUMENT #";X;" STATUS BYTE =
    ";B;", EVENT = ";D
670 RETURN
680 PRINT @Y:"EVENT?"
690 REM: GET "EVENT" RESPONSE IF DEVICE #Y
    ASSERTED SRQ.
700 INPUT @Y:D
710 PRINT "INSTRUMENT #";Y;" STATUS BYTE =
    ";B;", EVENT = ";D
720 RETURN
```

Sample Program D

The following program is similar to Sample Program C, except that it is written for use on the TEKTRONIX 4041 controller. It assumes a terminal has been connected to the 4041 and is properly set up. The 4041 technical manuals should be consulted for complete information regarding 4041 operation and programming.

```
100   ! PROGRAM TO TRANSFER A FRONT-PANEL SETUP
    FROM ONE 2445/2465 TO
110   ! ANOTHER 2445/2465.
120   !
130     INIT ALL
140     DISABLE SRQ
150   !
220   !
230     PRINT
240     PRINT "SET THE GPIB ADDRESS OF THE
    'REFERENCE' INSTRUMENT TO 2, "
250     PRINT "AND THE ADDRESS OF THE
    'INSTRUMENT TO BE SET UP' TO 4."
260     PRINT
270     REF$="2"
280     SET$="4"
290   !
300   ! SET UP PHYSICAL AND LOGICAL UNITS -
310   ! SET UP TERMINATOR FOR EOI
320   !
330     SET DRIVER "GPIBO (EOM=<0> )"
340     OPEN
    #2:"GPIBO (PRI="REF$&",EOM=<0> )"
350     OPEN
    #4:"GPIBO (PRI="SET$&",EOM=<0> )"
360   !
370     ON SRQ THEN GOSUB SRQHAND
380     ENABLE SRQ
390   !
400 TRANSFER:    ! ROUTINE TO TRANSFER SETUP
410     INPUT PROMPT "PRESS RETURN TO TRANSFER
    FRONT-PANEL SETUP ":START$
420   !
430    DIM STRING$ TO 400
440   ! DIMENSION "STRING$" LARGE ENOUGH TO
    HANDLE ANY POSSIBLE SETUP
450     PRINT #2:"LLSET?"
460     INPUT #2:STRING$
470     DIM STRING$ TO LEN (STRING$ )
480     PRINT #4:STRING$
490     PRINT "TRANSFER COMPLETE"
500     PRINT
510     INPUT PROMPT "DO YOU WISH TO CONTINUE:
    (Y OR N )":CONT$
520     IF CONT$="N" THEN STOP
530     GOTO TRANSFER
540 SRQHAND:    ! ROUTINE TO HANDLE THE SRQ
550     POLL STB,DEV
560     PRINT #DEV:"EVENT?"
570   ! GET EVENT NUMBER
580     INPUT #DEV:EVENT
590     PRINT "INSTRUMENT #";DEV;" STATUS BYTE
    = ";STB;", EVENT = ";EVENT
600     RESUME
```

Front Panel Lockout

The front panel may be locked out so that only the controller is able to change instrument settings. To lock out the front panel, first assert REN (true). The REN line must remain true as long as lockout is desired. For 4050-series controllers, the RUN statement automatically asserts REN; the END statement unasserts REN.

Next, send the LLO interface message. In the 4050-series controller this is accomplished with the WBYTE statement.

Finally, address the instrument by sending any setting command or query and use a Print @D statement; or send only the Listen address, using the WBYTE statement.

After these three steps are executed, the front panel is locked out and remains so until either REN goes false or a GTL interface message is sent. While the front panel is locked out, moving any front-panel switch will generate an SRQ. In a program, this event may be used to indicate to a controller that an operator is ready for the next setup.

Reset Under GPIB Control

The oscilloscope may be set to its power-up state by sending the INIt command via the GPIB. This command always initiates the power-up self tests. On completion of power-up tests, SRQ code 65 (operation complete) is generated, and the oscilloscope enters the normal operating state. If there is a self-test error, the option also generates SRQ code 65 and does not shift the instrument to the normal operating state (see "Power-up Sequence", Section 3). Invoking the INIt command can simplify a program. When using INIt, fewer commands will usually be needed to set the instrument state, since all front-panel settings may not need to be individually specified.

APPENDIX A

GPIB COMMAND REFERENCE

Table A-1
GPIB Command Summary

Header	Argument	Argument
Vertical Commands		
CH1	COUpling:	AC
		DC
		FIFTY
		GND
	POSition:	<nrx>
	VARiable:	<nrx>
	VOLts:	<nrx>
	PROBe	
CH1?		
CH2	INVert:	ON
		OFF
CH2?		
CH3		
CH3?		
CH4		
CH4?		
VMOde	BWLimit:	ON
		OFF
	CHOp:	ON
		OFF
	CH1:	ON
		OFF
	CH2:	ON
		OFF
	CH3:	ON
		OFF
	CH4:	ON
		OFF
	ADD:	ON
		OFF
	INVert:	ON
		OFF
VMOde?		

Table A-1 (cont)
GPIB Command Summary

Header	Argument	Argument
Horizontal Commands		
HORizontal	ASEcdiv:	<nrx>
	BSEcdiv:	<nrx>
	MAGnify:	ON
		OFF
	POSition:	<nrx>
	TRACEsep:	<nrx>
HORizontal?		
HMOde	ALTernate	
	ASWeep	
	BSWeep	
	XY	
HMOde?		
Trigger Commands		
ATRigger	MODe:	AUTOBaseline
		AUTOLevel
		NORmal
		SGLseq
	SOUrce:	CH1
		CH2
		CH3
		CH4
		LINe
		VERtical
	COUpling:	AC
		DC
		HFRej
		LFRej
		NOIserej
	LEVel:	<nrx>
	SLOpe:	MINUs
		PLUS
	BENdsa:	ON
		OFF
	HOLdoff:	<nrx>
ATRigger?		
	MINImum	
	MAXimum	
	TRIGD?	
	REAdy?	

Table A-1 (cont)
GPIB Command Summary

Header	Argument	Argument
BTRigger	MODe:	RUN TRIGGerable
	SOUrce:	CH1 CH2 CH3 CH4 VERtical
	COUpling:	AC DC HFRej LFRej NOIserej
	LEVel:	<nrx>
	SLOpe:	MINUs PLUS
BTRigger?		
Delay and Delta Commands		
DELAy DELAy?	<nrx>	
DELTa	MODE:	OFF PERTime TIMe VOLts
	TRACKing:	ON OFF
DELTa?	MODE TRACKing	
DTIme	REFerence: DELTa:	<nrx> <nrx>
DTIme?	REFerence DELTa	
DVOlts	REFerence: DELTa:	<nrx> <nrx>
DVOlts?	REFerence DELTa	
System Commands		
ERRor?		
EVEnt?		
ID?		
INIt		

Table A-1 (cont)
GPIB Command Summary

Header	Argument	Argument
LLMessage LLMessage?	%<byte><byte>...	
LLSet LLSet?	%<byte><byte>...,%<byte><byte>...	
MESsage MESsage?	"string"	
OPC OPC?	ON OFF	
REAdout REAdout?	ON OFF	
RQS RQS?	ON OFF	
SETtings?		
LONgform LONgform	ON OFF	
WARning WARning?	ON OFF	
Calibration and Diagnostic Commands		
BALance		
CALibrate	<nrx>:	<nrx>
GO		
LOOping LOOping?	ON OFF	
NORmal		
STEp STEp?		
STOp		
TESt TESt?	<nrx>: <nrx>:	<nrx> <nrx>

APPENDIX B

STATUS AND ERROR REPORTING

The status and error reporting system used by the GPIB Option interrupts the bus controller by asserting the Service Request (SRQ) line on the GPIB. This SRQ provides the means of indicating that an event (either a change in status or an error) has occurred. To service a request, the controller performs a Serial Poll; in response, the instrument returns a Status Byte (STB), which indicates the type of event that occurred. Bit 4 of the Serial-Poll Status Byte is used to indicate that the command processor is active. This bit will be set when the command processor is executing a command, and reset when it is not. The Status Byte, therefore, provides a limited amount of information about the specific cause of the SRQ. The various status events and errors that can occur are divided into several categories as defined in Table B-1.

Each serial poll can in turn cause a second SRQ assertion, if more than one error exists. The most serious error at the time of the serial poll is the reported error. An EVEnt? query returns a number which can be used as an index to the specific type of error that occurred. Table B-2 lists the Serial-Poll Status Bytes and the associated EVEnt? codes generated by the GPIB Option.

If there is more than one event to be reported, the instrument reasserts SRQ until it reports all events. Each event is automatically cleared when it is reported via serial poll. The Device Clear (DCL) interface message may be used to clear all events, except the power-on event.

Table B-1
Status Event and Error Categories

Category	Serial-Poll Status Byte	Description
Command Error	97 or 113	The instrument received a command that it cannot understand.
Execution Error	98 or 114	The instrument received a command that it cannot execute. This is caused by either out-of-range arguments or settings that conflict.
Internal Error	99 or 115	The instrument detected a hardware condition or a firmware problem that prevents operation.
System Events	65-67 and 81-83	Events common to instruments in a system (e.g., Power-on and User Request).
Execution Error Warning	101 or 117	The instrument received a command and is executing it, but a potential problem may exist. For example, the instrument is out of range, but is sending a reading anyway.
Internal Warning	102 or 118	The instrument detected a problem. It remains operational, but the problem should be corrected (e.g., out of calibration).
Device Status	0 or 16, 193-238, and 209-254	Device-dependent events.

With both the RQS OFF and the WARning OFF commands invoked, all service requests (except the power-on SRQ) are inhibited. In this mode, the EVEnt? query allows the controller to determine event status without first performing a serial poll. The controller may then send the EVEnt? query at any time, and the instrument returns the code for an event waiting to be reported. The controller can clear all events by repeatedly sending the EVEnt? query until a zero Status Byte is returned. An alternative method for clearing all events (except power-on) is the use of the Device Clear (DCL) interface message.

Table B-2
GPIB Status Codes

Serial-Poll Status Byte	EVENT? Code	Instrument Status
00, 16	000	No status to report
65, 81	401	Power on
66, 82	402	Operation complete
67, 83	403	User request
97, 113	101	Command header error
97, 113	102	Header delimiter error
97, 113	103	Command argument error
97, 113	104	Argument delimiter error
97, 113	105	Non-numeric argument, numeric expected
97, 113	106	Missing argument
97, 113	107	Invalid message-unit delimiter
97, 113	108	Checksum error
97, 113	109	Byte-count error
98, 114	201	Remote-only command in Local mode
98, 114	202	Pending settings lost on rtl
98, 114	203	I/O deadlock detected
98, 114	204	Setting conflict
98, 114	205	Argument out of range
98, 114	250	Diagnostic in progress
98, 114	251	Diagnostic step in progress
98, 114	252	In normal mode
98, 114	253	Option not installed
98, 114	254	Option not in correct mode
98, 114	255	GPIB command lost to local override
99, 115	302	System error
99, 115	350	Math pack error

Table B-2 (cont)
GPIB Status Codes

Serial-Poll Status Byte	EVENT? Code	Instrument Status
101, 117	550	Warning of possible conflict
102, 118	650	Warning that measurement not yet available
193, 209	750	Asynchronous option error
194, 210	751	Overrange error
195, 211	752	No probe installed
196, 212	753	Fifty-ohm overload
200, 216	770	Oscilloscope test/cal/exer complete, passed
201, 217	779	Oscilloscope test complete, failed
231, 247	771	Option 1 measurement complete
232, 248	772	Option 2 measurement complete
233, 249	773	Option 3 measurement complete
234, 250	774	Option 4 measurement complete
235, 251	775	Option 5 measurement complete
236, 252	776	Option 6 measurement complete
237, 253	777	Option 7 measurement complete
238, 254	778	Option 8 measurement complete

APPENDIX C

MESSAGE COMMAND CHARACTER TRANSLATIONS

Character translations performed by the MESsage command and query, when sending data to or receiving data from the crt readout, are indicated in Table C-1. The following notes apply:

1. ASCII values that are not specified in Table C-1 (i.e., those less than 20 Hex) are ignored when sent to the readout.
2. Values in Table C-1 that have no crt equivalent are translated into spaces when sent to the display.
3. Lowercase characters are translated into uppercase equivalents.
4. Character pairs (i.e., digits followed by periods) sent to the readout are translated into single characters with embedded decimal points. The embedded decimal points are displayed as carets. Single characters with embedded decimal points read from the display are received as character pairs.

Table C-1
MESsage Command Character Translations.

ASCII		CRT	Description
Hex	Char	Readout	
20			space
21	!	p	pico
22	"		
23	#	μ	micro
24	$	m	milli
25	%	%	percent
26	&	k	kilo
27	'		
28	(	1/	one-over symbol
29	)	Δ	delta
2A	*	Δt	delta t
2B	+	+	plus symbol
2C	,	,	comma
2D	–	–	minus symbol
2E	.	.	period
2F	/	/	slash

Table C-1 (cont)
MESsage Command Character Translations.

ASCII		CRT	Description
Hex	Char	Readout	
30	0	0	0
31	1	1	1
32	2	2	2
33	3	3	3
34	4	4	4
35	5	5	5
36	6	6	6
37	7	7	7
38	8	8	8
39	9	9	9
3A	:	:	colon
3B	;		
3C	<	<	less than
3D	=	=	equal to
3E	>	>	greater than
3F	?	?	question mark

Table C-1 (cont)
MESsage Command Character Translations.

ASCII		CRT	Description
Hex	Char	Readout	
40	@	°	degrees
41	A	A	A
42	B	B	B
43	C	C	C
44	D	D	D
45	E	E	E
46	F	F	F
47	G	G	G
48	H	H	H
49	I	I	I
4A	J	J	J
4B	K	K	K
4C	L	L	L
4D	M	M	M
4E	N	N	N
4F	O	O	O
50	P	P	P
51	Q	Q	Q
52	R	R	R
53	S	S	S
54	T	T	T
55	U	U	U
56	V	V	V
57	W	W	W
58	X	X	X
59	Y	Y	Y
5A	Z	Z	Z
5B	[	Ω	omega
5C	\	⏚	ground symbol
5D	]	V̰	volts ac
5E	↑	↑	up arrow
5F	_	_	underscore

Table C-1 (cont)
MESsage Command Character Translations.

ASCII		CRT	Description
Hex	Char	Readout	
60	‘	°	degrees
61	a	A	A
62	b	B	B
63	c	C	C
64	d	D	D
65	e	E	E
66	f	F	F
67	g	G	G
68	h	H	H
69	i	I	I
6A	j	J	J
6B	k	K	K
6C	l	L	L
6D	m	M	M
6E	n	N	N
6F	o	O	O
70	p	P	P
71	q	Q	Q
72	r	R	R
73	s	S	S
74	t	T	T
75	u	U	U
76	v	V	V
77	w	W	W
78	x	X	X
79	y	Y	Y
7A	z	Z	Z
7B	{		
7C	|		
7D	}		
7E	~	~	ac symbol
7F			

APPENDIX D

SWEEP SPEED COMMAND CONSIDERATIONS

Table D-1 provides information on the results of various sweep speed commands received over the GPIB. The left column indicates the desired effect of the GPIB command that was sent. The headings for the right three columns reflect the oscilloscope's Horizontal mode just prior to receipt of the command. Each block in the table shows the resulting sweep speed values and the Horizontal mode after the command is received.

Table D-1
Horizontal Command Results

Command Attempts to Make	Horizontal Mode Before Command		
	A Only	A ALT B	B Only
A faster than B	A = NV B = NV A only	A = NV B = NV A INTEN	A = NV B = NV A only
A = B and faster than 0.1 s	A = NV B = NV A only	A = NV B = NV A INTEN	A = NV B = NV A only
A slower than B	A = NV B = NV A only	A = NV B = PV A ALT B	A = NV B = PV B only
B faster than A	A = PV B = NV B only	A = PV B = NV A ALT B	A = PV B = NV B only
B = A	A = NV B = NV A only	A = NV B = NV A INTEN	A = NV B = NV A only
B slower than A and			
B equal to or faster than 50 ms	A = NV B = NV A only	A = NV B = NV A INTEN	A = NV B = NV A only
B slower than 50 ms and B faster than 0.15 s	B = 50 ms A = 50 ms A only	B = NV A = 50 m A INTEN	B = 50 ms A = NV A only
B slower than 0.15 s	A = 50 ms B = 50 ms A only	A = 50 ms B = 50 ms A INTEN	A = 50 ms B = 50 ms A only
B = 1 s/div (2445 only)	B = 500 ms A = 500 ms A only	B = 500 ms A = 500 ms A INTEN	B = 500 ms A = 500 ms A only

NV = New value of sweep speed sent over the GPIB.
PV = Previous value of sweep speed.

APPENDIX E

LLMESSAGE COMMAND CHARACTER TRANSLATIONS

Character translations performed by the LLMessage command and query, when sending data to or receiving data from the crt readout, are indicated in Tables E-1 and E-2. The following notes apply:

1. Most large size characters are formed with a left half and a right half.

2. Code for the right half of large size characters is given first, followed by the code for the left half of the character.

3. Not all codes are assigned. Use of the unlabeled (not assigned) codes will result in a nonsensical display.

4. The two tables cross-reference each other.

5. Character pairs (i.e., digits followed by periods) sent to the readout are translated into single characters with embedded decimal points. For normal-size characters, the decimal points are displayed as carets. For large characters, the decimal points are displayed as periods. Single characters with embedded decimal points read from the display are received as character pairs.

Table E-1
LLMessage? Query Character Set (Code-Sequenced)

Decimal	Hex	Character Description
0	00	1
1	01	large 0
2	02	large 0
3	03	
4	04	4
5	05	large 1
6	06	large 1
7	07	
8	08	7
9	09	large 2
10	0A	large 2
11	0B	
12	0C	t
13	0D	large 3
14	0E	large 3
15	0F	k
16	10	Z
17	11	large 4
18	12	large 4
19	13	Horizontal cursor 1
20	14	n (nano)
21	15	large 5

Table E-1 (cont)
LLMessage? Query Character Set (Code-Sequenced)

Decimal	Hex	Character Description
22	16	large 5
23	17	
24	18	m (micro)
25	19	large 6
26	1A	large 6
27	1B	
28	1C	/
29	1D	large 7
30	1E	large 7
31	1F	Horizontal cursor 2
32	20	Δ (delta)
33	21	large 8
34	22	large 8
35	23	
36	24	↑
37	25	large 9
38	26	large 9
39	27	
40	28	0
41	29	
42	2A	2
43	2B	↓

Table E-1 (cont)
LLMessage? Query Character Set (Code-Sequenced)

Decimal	Hex	Character Description
44	2C	3
45	2D	<
46	2E	5
47	2F	
48	30	6
49	31	>
50	32	8
51	33	
52	34	9
53	35	$\tilde{V}$ (volts ac)
54	36	1.
55	37	large 0 dot
56	38	large 0 dot
57	39	
58	3A	4.
59	3B	large 1 dot
60	3C	large 1 dot
61	3D	
62	3E	7.
63	3F	large 2 dot
64	40	large 2 dot
65	41	
66	42	%
67	43	large 3 dot
68	44	large 3 dot
69	45	
70	46	s (seconds)
71	47	large 4 dot
72	48	large 4 dot
73	49	
74	4A	z
75	4B	large 5 dot
76	4C	large 5 dot
77	4D	
78	4E	Vertical cursor 2
79	4F	large 6 dot
80	50	large 6 dot
81	51	
82	52	–
83	53	large 7 dot
84	54	large 7 dot
85	55	
86	56	~ (approximately)
87	57	large 8 dot
88	58	large 8 dot
89	59	
90	5A	,
91	5B	large 9 dot
92	5C	large 9 dot

Table E-1 (cont)
LLMessage? Query Character Set (Code-Sequenced)

Decimal	Hex	Character Description
93	5D	
94	5E	0.
95	5F	
96	60	2.
97	61	
98	62	3.
99	63	
100	64	5.
101	65	
102	66	6.
103	67	
104	68	8.
105	69	
106	6A	9.
107	6B	
108	6C	U
109	6D	large R
110	6E	large R
111	6F	
112	70	V
113	71	large S
114	72	large S
115	73	
116	74	X
117	75	large T
118	76	large T
119	77	
120	78	MNL (manual)
121	79	
122	7A	large V
123	7B	large V
124	7C	Y
125	7D	DEG (degrees)
126	7E	HO (holdoff)
127	7F	
128	80	large X
129	81	large X
130	82	0 over 0
131	83	
132	84	0 over 1
133	85	
134	86	1 over 0
135	87	
136	88	A
137	89	
138	8A	B
139	8B	
140	8C	D
141	8D	

Table E-1 (cont)
LLMessage? Query Character Set (Code-Sequenced)

Decimal	Hex	Character Description
142	8E	H
143	8F	
144	90	M
145	91	
146	92	N
147	93	
148	94	R
149	95	
150	96	W
151	97	
152	98	I
153	99	large F
154	9A	large F
155	9B	
156	9C	J
157	9D	large Ω (omega)
158	9E	large Ω (omega)
159	9F	
160	A0	K
161	A1	large H
162	A2	large H
163	A1	
164	A4	large d
165	A5	large d
166	A6	=
167	A7	+
168	A8	L
169	A9	Ω (omega)
170	AA	⏚ (ground symbol)
171	AB	
172	AC	O
173	AD	large L
174	AE	large L
175	AF	
176	B0	P
177	B1	:
178	B2	1 over 1
179	B3	
180	B4	Q
181	B5	?
182	B6	0 over x
183	B7	
184	B8	S
185	B9	large O
186	BA	large O
187	BB	
188	BC	T
189	BD	d
190	BE	x over 0

Table E-1 (cont)
LLMessage? Query Character Set (Code-Sequenced)

Decimal	Hex	Character Description
191	BF	
192	C0	(space)
193	C1	large A
194	C2	large A
195	C3	
196	C4	C
197	C5	large B
198	C6	large B
199	C7	
200	C8	E
201	C9	large C
202	CA	large C
203	CB	
204	CC	F
205	CD	large D
206	CE	large D
207	CF	
208	D0	G
209	D1	large E
210	D2	large E
211	D3	
212	D4	.
213	D5	large n (nano)
214	D6	large n (nano)
215	D7	large u (micro)
216	D8	large u (micro)
217	D9	large k
218	DA	large k
219	DB	large m (milli)
220	DC	large m (milli)
221	DD	
222	DE	large +
223	DF	large +
224	E0	low underline
225	E1	large DLY (delay)
226	E2	large DLY (delay)
227	E3	
228	E4	HLD (hold measurement)
229	E5	
230	E6	1 over x
231	E7	
232	E8	x over 1
233	E9	
234	EA	BWL (bandwidth limit)
235	EB	
236	EC	1/
237	ED	superscript dash
238	EE	p (pico)
239	EF	

Table E-1 (cont)
LLMessage? Query Character Set (Code-Sequenced)

Decimal	Hex	Character Description
240	F0	underline
241	F1	dotted underline
242	F2	large s (seconds)
243	F3	large s (seconds)
244	F4	large z
245	F5	large z
246	F6	Vertical cursor 1
247	F7	Logical AND symbol
248	F8	Δt (delta t)
249	F9	
250	FA	Large minus symbol
251	FB	high underline
252	FC	x over x
253	FD	
254	FE	m (milli)
255	FF	

Table E-2
LLMessage Command Character Set
(Character-Sequenced)

Character Description	Character Size and Code			
	Normal Size		Large Size	
	Decimal	Hex	Decimal	Hex
0	40	28	1	01
			2	02
1	0	00	5	05
			6	06
2	42	2A	9	09
			10	0A
3	44	2C	13	0D
			14	0E
4	4	04	17	11
			18	12
5	46	2E	21	15
			22	16
6	48	30	25	19
			26	1A
7	8	08	29	1D
			30	1E
8	50	32	33	21
			34	22
9	52	34	37	25
			38	26

Table E-2 (cont)
LLMessage Command Character Set
(Character-Sequenced)

Character Description	Character Size and Code			
	Normal Size		Large Size	
	Decimal	Hex	Decimal	Hex
A	136	88	193	C1
			194	C2
B	138	8A	197	C5
			198	C6
C	196	C4	201	C9
			202	CA
D	140	8C	205	CD
			206	CE
E	200	C8	209	D1
			210	D2
F	204	CC	153	99
			154	9A
G	208	D0		
H	142	8E	161	A1
			162	A2
I	152	98		
J	156	9C		
K	160	A0		
L	168	A8	173	AD
			174	AE
M	144	90		
N	146	92		
O	172	AC	185	B9
			186	BA
P	176	B0		
Q	180	B4		
R	148	94	109	6D
			110	6E
S	184	B8	113	71
	114	72		
T	188	BC	117	75
			118	76
U	108	6C		
V	112	70	122	7A
			123	7B
W	150	96		
X	116	74	128	80
			129	81
Y	124	7C		
Z	16	10		

Table E-2 (cont)
LLMessage Command Character Set
(Character-Sequenced)

Character Description	Character Size and Code			
	Normal Size		Large Size	
	Decimal	Hex	Decimal	Hex
d	189	BD	164	A4
			165	A5
k	15	0F	217	D9
			218	DA
t	12	0C		
z	74	4A	244	F4
			245	F5
space	192	C0		
%	66	42		
+	167	A7	223	DF
,	90	5A		
–	82	52	250	FA
.	212	D4		
/	28	1C		
:	177	B1		
<	45	2D		
=	166	A6		
>	49	31		
?	181	B5		
↑	36	24		
↓	43	2B		
0.	94	5E	55	37
			56	38
1.	54	36	59	3B
			60	3C
2.	96	60	63	3F
			64	40
3.	98	62	67	43
			68	44
4.	58	3A	71	47
			72	48
5.	100	64	75	4B
			76	4C
6.	102	66	79	4F
			80	50
7.	62	3E	83	53
			84	54
8.	104	68	87	57
			88	58
9.	106	6A	91	5B
			92	5C

Table E-2 (cont)
LLMessage Command Character Set
(Character-Sequenced)

Character Description	Character Size and Code			
	Normal Size		Large Size	
	Decimal	Hex	Decimal	Hex
p (pico)	238	EE		
n (nano)	20	14	213	D5
			214	D6
μ (micro)	24	18	215	D7
			216	D8
m (milli)	254	FE	219	DB
			220	DC
s (seconds)	70	46	242	F2
			243	F3
DEG (degrees)	125	7D		
Ω (omega)	169	A9	157	9D
			158	9E
⏚ (ground symbol)	170	AA		
$\tilde{V}$ (volts ac)	53	35		
~ (approximately)	86	56		
MNL (manual)	120	78		
0 over 0	130	82		
0 over 1	132	84		
1 over 0	134	86		
1 over 1	178	B2		
0 over x	182	B6		
x over 0	190	BE		
1 over x	230	E6		
x over 1	232	E8		
x over x	252	FC		
1/	236	EC		
Underline	240	F0		
Dotted underline	241	F1		
Low underline	224	E0		
High underline	251	FB		
Superscript dash	237	ED		
Logical AND symbol	247	F7		
Hold measurement	228	E4		
HO (holdoff)	126	7E		
BWL (bandwidth limit)	234	EA		
Horizontal cursor 1	19	13		
Horizontal cursor 2	31	1F		
Vertical cursor 1	246	F6		
Vertical cursor 2	78	4E		
Δ(delta)	32	20		
Δt (delta t)	248	F8		
DLY (delay)			225	E1
			226	E2