TEK OPERATORS MANUAL

070-5301-01
Product Group 41

2220
DIGITAL STORAGE OSCILLOSCOPE
OPERATORS

Please Check for CHANGE INFORMATION at the Rear of This Manual

First Printing APR 1986
Revised JUN 1987

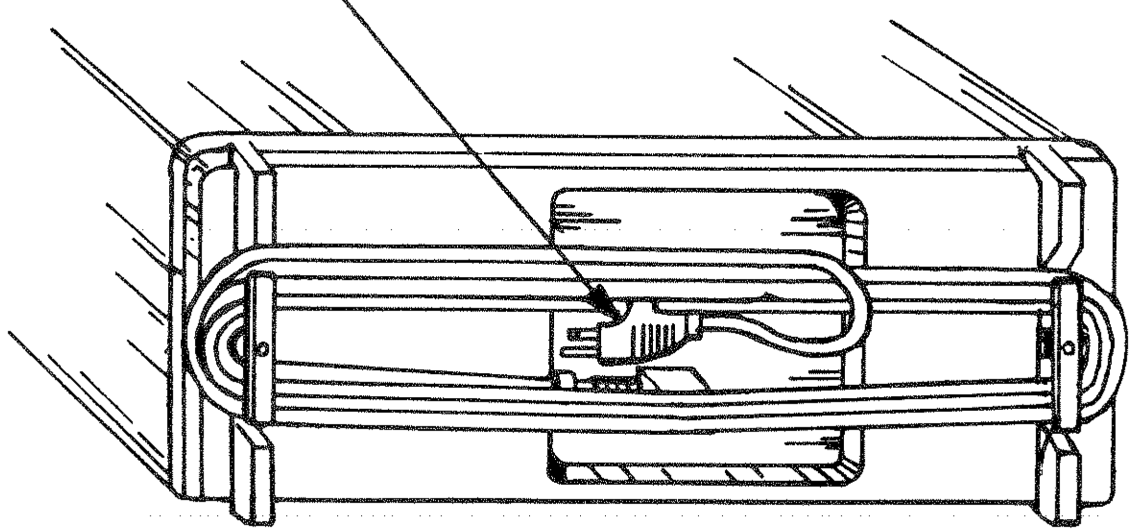
Tektronix®
COMMITTED TO EXCELLENCE

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

WIND POWER CORD TIGHT, THEN POSITION MALE RECEPTICAL IN RECESSED AREA OF REAR PANEL



2200 SERIES POWER CORD WRAP

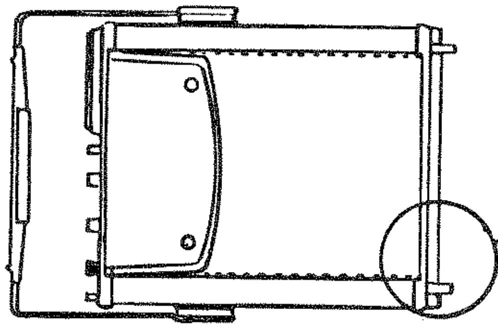


FIG - 2

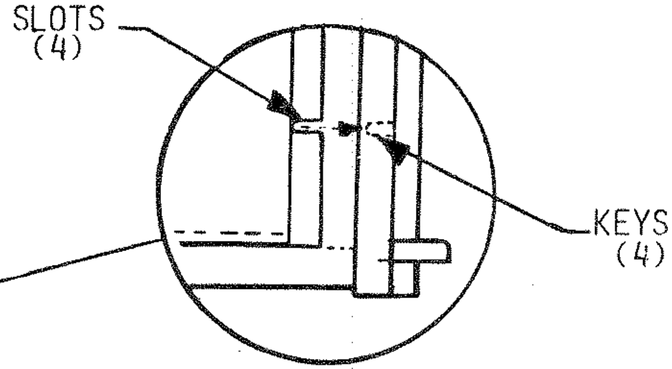


FIG - 3

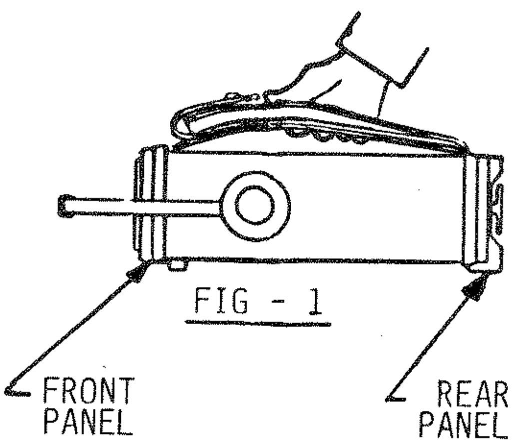


FIG - 1

POUCH MOUNTING - (2200 INST)

1. POUCH IS MOUNTED ON TOP, SECURED BY THE TWO END PANELS

2. POUCH CAN BE MOUNTED BY ARCHING THE POUCH & SLIDING THE TWO ENDS UNDER THE REAR & FRONT PANELS. (SEE FIG - 1)

3. WHEN POUCH IS SECURED PROPERLY THE (4) SLOTS IN THE METAL POUCH PLATE WILL MATE WITH THE (4) KEYS INSIDE THE FRONT & REAR PANELS (SEE FIG - 3)

Certificate of the Manufacturer/Importer

We hereby certify that the 2220 DIGITAL STORAGE OSCILLOSCOPE AND ALL INSTALLED OPTIONS complies with the RF Interference Suppression requirements of Amtsbl.-Vfg 1046/1984.

The German Postal Service was notified that the equipment is being marketed.

The German Postal Service has the right to re-test the series and to verify that it complies.

TEKTRONIX

Bescheinigung des Herstellers/Importeurs

Hiermit wird bescheinigt, daß der/die/das 2220 DIGITAL STORAGE OSCILLOSCOPE AND ALL INSTALLED OPTIONS in Übereinstimmung mit den Bestimmungen der Amtsblatt-Verfugüng 1046/1984 funkentstört ist.

Der Deutschen Bundespost wurde das Inverkehrbringen dieses Gerätes angezeigt und die Berechtigung zur Überprufüng der Serie auf Einhalten der Bestimmungen eingeräumt.

TEKTRONIX

NOTICE to the user/operator:

The German Postal Service requires that Systems assembled by the operator/user of this instrument must also comply with Postal Regulation, Vfg. 1046/1984, Par. 2, Sect. 1.

HINWEIS für den Benutzer/Betreiber:

Die vom Betreiber zusammengestellte Anlage, innerhalb derer dies Gerät eingesetzt wird, muß ebenfalls den Voraussetzungen nach Par. 2, Ziff. 1 der Vfg. 1046/1984 genugen.

NOTICE to the user/operator:

The German Postal Service requires that this equipment, when used in a test setup, may only be operated if the requirements of Postal Regulation, Vfg. 1046/1984, Par. 2, Sect. 1.7.1 are complied with.

HINWEIS für den Benutzer/Betreiber:

Dies Gerät darf in Meßaufbauten nur betrieben werden, wenn die Voraussetzungen des Par. 2, Ziff. 1.7.1 der Vfg. 1046/1984 eingehalten werden.

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OPERATORS SAFETY SUMMARY

The general safety information 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 in This Manual

⚠ This symbol indicates where applicable cautionary or other information is to be found. For maximum input voltage see Table 1-2.

Symbols as Marked on Equipment

ϟ DANGER — High voltage.

⏚ Protective gound (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.

For detailed information on power cords and connectors, see Figure 2-2.

Use the Proper Fuse

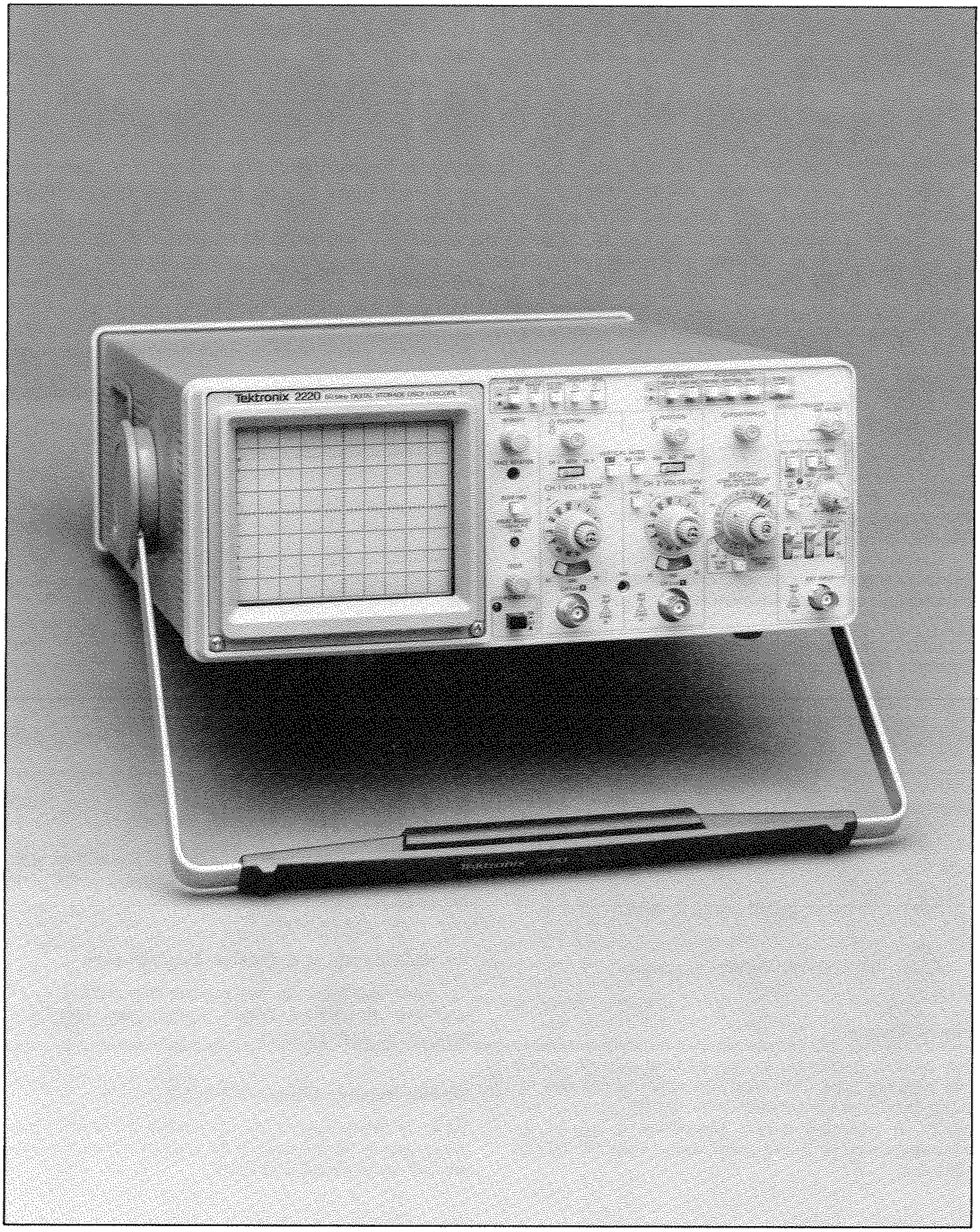
To avoid fire hazard, use only a fuse of the correct type, voltage rating and current rating as specified in the parts list for your product.

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 the product without the covers and panels properly installed.



5301-01

The 2220 Digital Storage Oscilloscope.

GENERAL INFORMATION

INTRODUCTION

The TEKTRONIX 2220 Oscilloscope is a combination nonstorage and digital storage dual-channel 60 MHz bandwidth instrument. The vertical system provides calibrated deflection factors from 2 mV to 5 V per division. The horizontal system provides calibrated sweep speeds from 0.5 s to 50 ns per division for NON STORE mode with three slower sweep speeds (1 s, 2 s, and 5 s per division) added for STORE mode operation. A X10 magnifier extends the maximum sweep speed to 5 ns per division.

The digital storage sampling rate is 20 megasamples-per-second maximum. The acquired record length is 4K samples for single-channel acquisitions or 2K samples for dual-channel acquisitions (ALT or CHOP). The storage acquisition system can capture a glitch with a pulse width of at least 100 ns.

One waveform set (CH 1 and/or CH 2) of 4K record length may be stored in the SAVE REF memory. A 4K compress feature enables a 4K acquisition record to be compressed on screen for ease in viewing. The SAVE store mode stops the waveform acquisition in progress, allowing a particular display to be stored or examined before further acquisitions cause a waveform update. The DISPLAY POS Controls are used to reposition the display window to any portion of the entire acquisition record. The effect of the X10 MAG and 4K Compress controls on the horizontal SEC/DIV, the number of displayable screens, and the acquisition record length is shown in Table 1-1.

Table 1-1
Displayable Record Length

Effective SEC/DIV	Displayable Screens	Active Controls	Display Window (=) Additional Displayable Windows (-)
(SEC/DIV)÷10	40 screens	×10	----------=-----------------------------
(SEC/DIV)×4÷10	10 screens	×10 and UNCAL	---=------
SEC/DIV	4 screens		--=-
(SEC/DIV)×4	1 screen	UNCAL	=

The instrument is shipped with the following standard accessories:

1	Operators Manual
1	Users Reference Guide
2	Probe Packages
1	Accessory Pouch
1	Front Panel Cover
1	Power Cord
1	Fuse
1	DB-9 Male Connector and Connector Shell
1	Loop Clamp
1	Flat Washer
1	Self-Tapping Screw

For part numbers and further information about both standard and optional accessories, refer to "Options and Accessories" (Section 7) of this manual. Your Tektronix representative, local Tektronix Field Office, or Tektronix products catalog can also provide additional accessories information.

SPECIFICATION

The following electrical characteristics (Table 1-2) are valid when the instrument has been adjusted at an ambient temperature between +20°C and +30°C, has had a warm-up period of at least 20 minutes, and is operating at an ambient temperature between 0°C and +50°C (unless otherwise noted).

Items listed in the "Performance Requirements" column are verifiable qualitative or quantitative limits that define the measurement capabilities of the instrument.

Environmental characteristics are given in Table 1-3. This instrument meets the requirements of MIL-T-28800C for Type III, Class 5 equipment, except where noted otherwise.

Physical characteristics of the instrument are listed in Table 1-4.

Table 1-2

Electrical Characteristics

Characteristics	Performance Requirements
VERTICAL DEFLECTION SYSTEM	
Deflection Factor Range	2 mV per division to 5 V per division in a 1-2-5 sequence of 11 steps.
DC Accuracy (NON STORE) +15°C to +35°C	Within ±2%.
0°C to +50°C	Within ±3%. For 5 mV per division to 5 V per division, the gain is set with the VOLTS/DIV switch at 10 mV per division. 2 mV per division gain is set with the VOLTS/DIV switch at 2 mV per division.
On Screen DC Accuracy (STORE) +15°C to +35°C	Within ±2%.
0°C to +50°C	Within ±3%. Gain set with VOLTS/DIV set to 5 mV per division.
Storage Acquisition Vertical Resolution	8-bits, 25 levels per division. 10.24 divisions dynamic range.
Range of VOLTS/DIV Variable Control	Continuously variable between settings. Increases deflection factor by at least 2.5 to 1.
Step Response (NON STORE Mode) Rise Time 0°C to +35°C 5 mV per division to 5 V per division	5.8 ns or less.
2 mV per division	7.0 ns or less.
+35°C to +50°C 5 mV per division to 5 V per division	7.0 ns or less.
2 mV per division	7.0 ns or less. Rise time is calculated from the formula: $\text{Rise Time} = \frac{0.35}{\text{Bandwidth } (-3\text{ dB})}$
Step Response (STORE Mode) Useful Storage Rise Time SAMPLE	**Single Trace**: $\frac{\text{SEC/DIV} \times 1.6}{100}$ s **CHOP/ALT**: $\frac{\text{SEC/DIV} \times 1.6}{50}$ s
PEAK DETECT	Single Trace: $\frac{\text{SEC/DIV} \times 1.6}{50}$ s CHOP/ALT: $\frac{\text{SEC/DIV} \times 1.6}{25}$ s Rise time is limited to 5.8 ns minimum with derating over temperature (see NON STORE Rise Time).

Table 1-2 (cont)

Characteristics	Performance Requirements
Aberrations (NON STORE and STORE in SAMPLE Mode)	
2 mV per division to 50 mV per division	+4%, −4%, 4% p-p. 3% or less at 25°C with cabinet installed.
0.1 V per division to 0.5 V per division	+6%, −6%, 6% p-p. 5% or less at 25°C with cabinet installed.
1 V per division to 5 V per division	+12%, −12%, 12% p-p. 10% or less at 25°C with cabinet installed. Measured with a five-division reference signal, with the top of the square wave centered vertically, from a 50-ohm source driving a 50-ohm coaxial cable terminated in 50 ohms at the input connector, and VOLTS/DIV Variable control in the CAL detent.
NON STORE Bandwidth (−3 dB)	
0°C to +35°C	
5 mV per division 5 V per division	Dc to at least 60 MHz.
2 mV per division	Dc to at least 50 MHz.
+35°C to +50°C	
5 mV per division to 5 V per division	Dc to at least 50 MHz.
2 mV per division	Dc to at least 50 MHz. Measured with a six-division reference signal, centered vertically, from a 50-ohm source driving a 50-ohm coaxial cable terminated in 50 ohms at the input connector and the probe input, and VOLTS/DIV Variable control in the CAL detent.
NON STORE BW LIMIT (−3 dB)	10 MHz ±15%.
AC Coupled Lower Cutoff Frequency	10 Hz or less at -3 dB.
Useful Storage Performance	
RECORD, SCAN, and ROLL Store Modes	
SAMPLE Acquisition, no AVERAGE	**Single Trace** — **CHOP/ALT**
5 μs/div to 5 s/div	Single Trace: $\frac{10}{\text{SEC/DIV}}$ Hz; CHOP/ALT: $\frac{5}{\text{SEC/DIV}}$ Hz
EXT CLOCK (up to 1 kHz)	Single Trace: $\frac{\text{EXT}}{10}$ Hz; CHOP/ALT: $\frac{\text{EXT}}{20}$ Hz Useful storage performance is limited to the frequency where there are ten samples per sine-wave signal period at the maximum sampling rate. This yields a maximum amplitude uncertainty of 5%. Max sampling rate is 20 MHz in Single trace and 10 MHz in CHOP or ALT at a SEC/DIV setting of 5 μs per division. Accuracy at useful storage performance limit is measured with respect to a six-division 50 kHz reference sine wave.

Table 1-2 (cont)

Characteristics	Performance Requirements	
Useful Storage Performance (cont)		
PEAK DETECT	**Single Trace and ALT**	**CHOP**
Sine-Wave Amplitude Capture (5% p-p maximum amplitude uncertainty)	1 MHz	1 MHz
Pulse Width Amplitude Capture (50% p-p maximum amplitude uncertainty)	100 ns	$\frac{\text{SEC/DIV}}{50}$
REPETITIVE Store Mode	**Single Trace**	**ALT**
0.05 μs per division	60 MHz (−3 dB)[a]	60 MHz (−3 dB)[a]
0.1 μs per division	60 MHz (−3 dB)[a]	50 MHz (−3 dB)
0.2 μs per division to 2 μs per division (5% maximum amplitude uncertainty)	$\frac{10}{\text{SEC/DIV}}$ Hz	$\frac{5}{\text{SEC/DIV}}$ Hz
AVERAGE Mode in Repetitive Store Only		
Weight of Last Acquisition	AVERAGE Mode weight is 1/4.	
NON STORE CHOP Mode Switching Rate	500 kHz ±30%.	
STORE Chop Rate		
10 μs per division	50/(SEC/DIV).	
5 s per division to and including 20 μs per division	25/(SEC/DIV).	
5 μs per division through 0.05 μs per division	No CHOP Mode; acts as in ALT.	
A/D Converter Linearity	Monotonic with no missing codes.	
STORE Mode Cross Talk	Less than 2%. Measured in CHOP at 10 μs per division and 10 mV per division using a 100 kHz square wave signal vertically centered and the other channel input coupling set to GND.	

[a]Sixty MHz bandwidth is derated for temperature outside 0°C to +35°C and at 2 mV per division as for NON STORE.

Table 1-2 (cont)

Characteristics	Performance Requirements
NON STORE Common-mode Rejection Ratio (CMRR)	At least 10 to 1 at 50 MHz. Checked at 10 mV per division for common-mode signals of six divisions or less with VOLTS/DIV Variable control adjusted for best CMRR at 50 kHz.
Input Current	1 nA or less (0.5 division or less trace shift when switching between DC and GND input coupling with the VOLTS/DIV switch at 2 mV per division.
Input Characteristics	
Resistance	1 MΩ ±2%.
Capacitance	20 pF ±2 pF.
Maximum Safe Input Voltage (CH 1 and CH 2) DC and AC Coupled ⚠	See Figure 1-1 for maximum input voltage vs. frequency derating curve. 400 V (dc + peak ac) or 800 V ac p-p at 10 kHz or less.
NON STORE Channel Isolation	Greater than 100 to 1 at 50 MHz.
STORE Channel Isolation	100 to 1 at 50 MHz.
POSITION Control Range	At least ±11 divisions from graticule center.
Trace Shift with VOLTS/DIV Switch Rotation	0.75 division or less; VOLTS/DIV Variable control in the CAL detent.
Trace Shift as the VOLTS/DIV Variable Control is Rotated	1 division or less.
Trace Shift with INVERT	1.5 division or less.

Table 1-2 (cont)

Characteristics	Performance Requirements
TRIGGERING SYSTEM	
TRIGGER Sensitivity	
P-P AUTO and NORM	**10 MHz** **60 MHz**
Internal	0.35 div 1.0 div
External	40 mV 120 mV External trigger signal from a 50-ohm source driving a 50-ohm coaxial cable terminated in 50 ohms at the input connector.
HF REJ Coupling	Reduces trigger signal amplitude at high frequencies by about 20 dB with rolloff beginning at 40 kHz ±15 kHz. Should not trigger with a 1-division peak-to-peak 250 kHz signal when HF REJ is ON.
P-P AUTO Lowest Useable Frequency	20 Hz with 1 division internal or 100 mV external.
TV LINE	
Internal	0.35 div
External	35 mV p-p
TV FIELD	⩾ 1 division of composite sync.
EXT INPUT	
Maximum Input Voltage ⚠	400 V (dc + peak ac) or 800 V ac p-p at 10 kHz or less. See Figure 1-1 for maximum input voltage vs frequency derating curve.
Input Resistance	1 MΩ ±2%.
Input Capacitance	20 pF ±2.5 pF.
AC Coupled Lower Cutoff Frequency	10 Hz or less at −3 dB.
LEVEL Control Range	
TRIGGER (NORM)	
INT	May be set to any voltage level of the trace that can be displayed.
EXT, DC	At least ±1.6 V, 3.2 V p-p.
EXT, DC÷10	At least ±16 V, 32 V p-p.
VAR HOLDOFF Control (NON STORE)	Increases Sweep holdoff time by at least a factor of 10. See "VAR HOLDOFF Control" in Section 3, "Controls, Connectors, and Indicators" for effect in STORE Mode.
Acquisition Window Trigger Point	
PRETRIG	Seven-eighths of the waveform acquisition window is prior to the trigger.
POSTTRIG	One-eighth of the waveform acquisition window is prior to the trigger.
MIDTRIG	One-half of the waveform acquisition window is prior to the trigger.

Table 1-2 (cont)

Characteristics	Performance Requirements	
HORIZONTAL DEFLECTION SYSTEM		
NON STORE Sweep Rates		
Calibrated Range		
Sweep	0.5 s per division to 0.05 μs per division in a 1-2-5 sequence of 22 steps. The X10 magnifier extends maximum sweep speed to 5 ns per division. The 4K COMPRESS multiplies the SEC/DIV by 4.	
STORE Mode Ranges	See Table 3-1 for Modes and Ranges and Default Acquisition Modes.	
NON STORE Accuracy	**Unmagnified**	**Magnified**
+15°C to +35°C	Within ±2%	Within ±3%
0°C to +50°C	Within ±3%	Within ±4%
	Sweep accuracy applies over the center eight divisions. Exclude the first 40 ns of the sweep for magnified sweep speed and anything beyond the 100th magnified division.	
NON STORE Sweep Linearity	±5%. Linearity measured over any two of the center eight divisions. Exclude the first 25 ns and anything past the 100th division of the X10 magnified sweeps.	
Digital Sample Rate	**Single Trace**	**CHOP/ALT**
5 μs per division (CHOP becomes ALT)	20 MHz	10 MHz
10 μs per division	10 MHz	5 MHz
20 μs per division to 5s per division (50% duty factor on each channel in CHOP)	10 MHz	10 MHz
REPETITIVE STORE		
0.05 μs per division to 1 μs per division	20 MHz	20 MHz
2 μs per division	10 MHz	10 MHz
External Clock		
Input Frequency	Up to 1 kHz.	
Digital Sample Rate	10 MHz.	
Store Rate	One peak detected data pair for every second falling edge.	
Duty Cycle	10% or greater (100 μs minimum hold time).	
Ext Clock Logic Thresholds	TTL Compatible.	
Maximum Safe Input Voltage ⚠	25 V (dc + peak ac) or 25 V p-p ac at 1 kHz or less.	
Input Resistance	>20 kΩ.	

Table 1-2 (cont)

Characteristics	Performance Requirements
STORE Mode Dynamic Range	10.24 divisions.
STORE Mode Resolution	
Acquisition Record Length	4096 data points.
Single Waveform Acquisition Display	1024 data points (100 data points per division across the graticule area).
CHOP or ALT Acquisition Display	512 data points (50 data points per division across the graticule area).
Horizontal POSITION Control Range (NON STORE)	Start of the 10th division will position past the center vertical graticule line; 100th division in X10 magnified.
Horizontal Variable Sweep Control Range	
NON STORE	Continuously variable between calibrated settings of the SEC/DIV control. Extends the Sweep speed by at least a factor of 2.5.
STORE	Has no affect on the STORE time base. Rotating the VAR SEC/DIV control out of the detent position horizontally compresses (4 X SEC/DIV) the 4 K display to be on screen (DISPLAY COMPRESS).
Displayed Trace Length	
NON STORE	Greater than 10 divisions.
STORE	10.24 divisions.

Table 1-2 (cont)

Characteristics	Performance Requirements
DIGITAL STORAGE DISPLAY	
Vertical Resolution	8 bits (1 part in 256).
Position Registration NON STORE to STORE	Within ±0.5 division at graticule center at VOLTS/DIV switch settings from 2 mV per division to 5 V per division.
CONTINUE to SAVE	Within ±0.5 division at VOLTS/DIV switch settings from 2 mV per division to 5 V per division.
Horizontal Resolution	10 bits. (1 part in 1024). Calibrated for 100 data points per division.
X-Y OPERATION (X1 MAGNIFICATION ONLY)	
Deflection Factors	Same as vertical deflection system with the VOLTS/DIV Variable controls in the CAL detent positions.
NON STORE Accuracy X-Axis +15°C to +35°C	Measured with a dc-coupled, five-division reference signal. Within ±3%.
0°C to +50°C	Within ±4%.
Y-Axis	Same as vertical deflection system.
NON STORE Bandwidth (−3 dB) X-Axis	Measured with a five-division reference signal. Dc to at least 2.5 MHz.
Y-Axis	Same as vertical deflection system.
NON STORE Phase Difference Between X-Axis and Y-Axis Amplifiers	±3° from dc to 150 kHz. Vertical Input Coupling set to dc.
STORE Accuracy Y-Axis and X-Axis	Same as digital storage vertical deflection system.
Useful Storage Bandwidth RECORD and REPETITIVE Store Modes (Up to 60 MHz)	$\frac{5}{\text{SEC/DIV}}$ Hz.
STORE Time Difference Between Y-Axis and X-Axis Signals RECORD, SCAN, and ROLL Modes	100 ns. X-Axis signal is sampled before the Y-Axis signal.
REPETITIVE Store	$\frac{\text{SEC/DIV}}{100} \times 4$.

Table 1-2 (cont)

Characteristics	Performance Requirements
PROBE ADJUST	
Output Voltage on PROBE ADJUST Jack	0.5 V ±5%.
Repetition Rate	1 kHz ±20%.
Z-AXIS	
Sensitivity (NON STORE Only)	5 V causes noticeable modulation. Positive-going input decreases intensity. Useable frequency range is dc to 20 MHz.
Maximum Safe Input Voltage ⚠	30 V (dc + peak ac) or 30 V p-p ac at 1 kHz or less.
Input Resistance	>10 kΩ.
POWER SUPPLY	
Line Voltage Range	90 Vac to 250 Vac.
Line Frequency	48 Hz to 440 Hz.
Maximum Power Consumption	85 watts (150 VA).
Line Fuse	2 A, 250 V, slow blow.
Primary Circuit Dielectric Requirement	Routine test to 1500 V rms, 60 Hz, for 10 seconds without breakdown.
CRT DISPLAY	
Display Area	8 x 10 cm.
Standard Phosphor	P31.
Nominal Accelerating Voltage	14 kV.
X-Y PLOTTER OUTPUT	
Maximum Safe Applied Voltage, Any Connector Pin ⚠	25 V (dc + peak ac) or 25 V p-p ac at 1 kHz or less.
X and Y Plotter Outputs Pen Lift/Down	Fused relay contacts, 100 mA maximum.
Output Voltage Levels	500 mV per division, ±10%. Center screen is 0 V ±0.2 divisions.
Series Resistance	2 kΩ ±10%.
4.2 V Output	4.2 V ±10% through 2 kΩ.

Table 1-3

Environmental Characteristics

Characteristics	Performance Requirements
Environmental Requirements	Instrument meets the requirements of Tektronix Standard 062-2853-00, Class 5, except EMI. The instrument meets the following MIL-T-28800C requirements for Type III, Class 5 equipment, except where noted otherwise.
Temperature	
Operating	0°C to +50°C (+32°F to +122°F).
Nonoperating	−55°C to +75°C (−67°F to +167°F). Tested to MIL-T-28800C, para 4.5.5.1.3 and 4.5.5.1.4, except that in para 4.5.5.1.3 steps 4 and 5 are performed before step 2 (−55°C nonoperating test). Equipment shall remain off upon return to room ambient temperature during step 6. Excessive condensation shall be removed before operating during step 7.
Altitude	
Operating	To 4,500 meters (15,000 feet). Maximum operating temperature decreases 1°C per 1,000 feet above 5,000 feet.
Nonoperating	To 15,000 meters (50,000 feet).
Humidity	
Operating and Nonoperating	5 cycles (120 hours) referenced to MIL-T-28800C para 4.5.5.1.2.2 for Type III, Class 5 instruments. Operating and nonoperating at 95%, −5% to +0% relative humidity. Operating, +30°C to +50°C; nonoperating, +30°C to +60°C.
EMI (electromagnetic interference)	Meets radiated and conducted emission requirements per VDE 0871, Class B. To meet EMI regulations and specifications, use the specified shielded cable and metal connector housing with the housing grounded to the cable shield on the AUXILIARY CONNECTOR.
Vibration	
Operating	15 minutes along each of three major axes at a total displacement of 0.015 inch p-p (2.4 g at 55 Hz) with frequency varied from 10 Hz to 55 Hz to 10 Hz in one-minute sweeps. Hold for 10 minutes at 55 Hz in each of the three major axes. All major resonances must be above 55 Hz.
Shock	
Operating and Nonoperating	30 g, half-sine, 11 ms duration, three shocks per axis each direction, for a total of 18 shocks.

Table 1-4

Physical Characteristics

Characteristics	Description
	See Figure 1-2 for dimensional drawing.
Weight	
With Power Cord, Cover, Probes, and Pouch	9.4 kg (20.7 lb).
With Power Cord Only	8.2 kg (18 lb).
Domestic Shipping Weight	12.2 kg (26.9 lb).
Height	137 mm (5.4 in).
Width	
With Handle	362 mm (14.3 in).
Without Handle	327 mm (12.9 in).
Depth	
With Front Cover	445 mm (17.5 in).
Without Front Cover	435 mm (17.1 in).
With Handle Extended	510 mm (20.1 in).

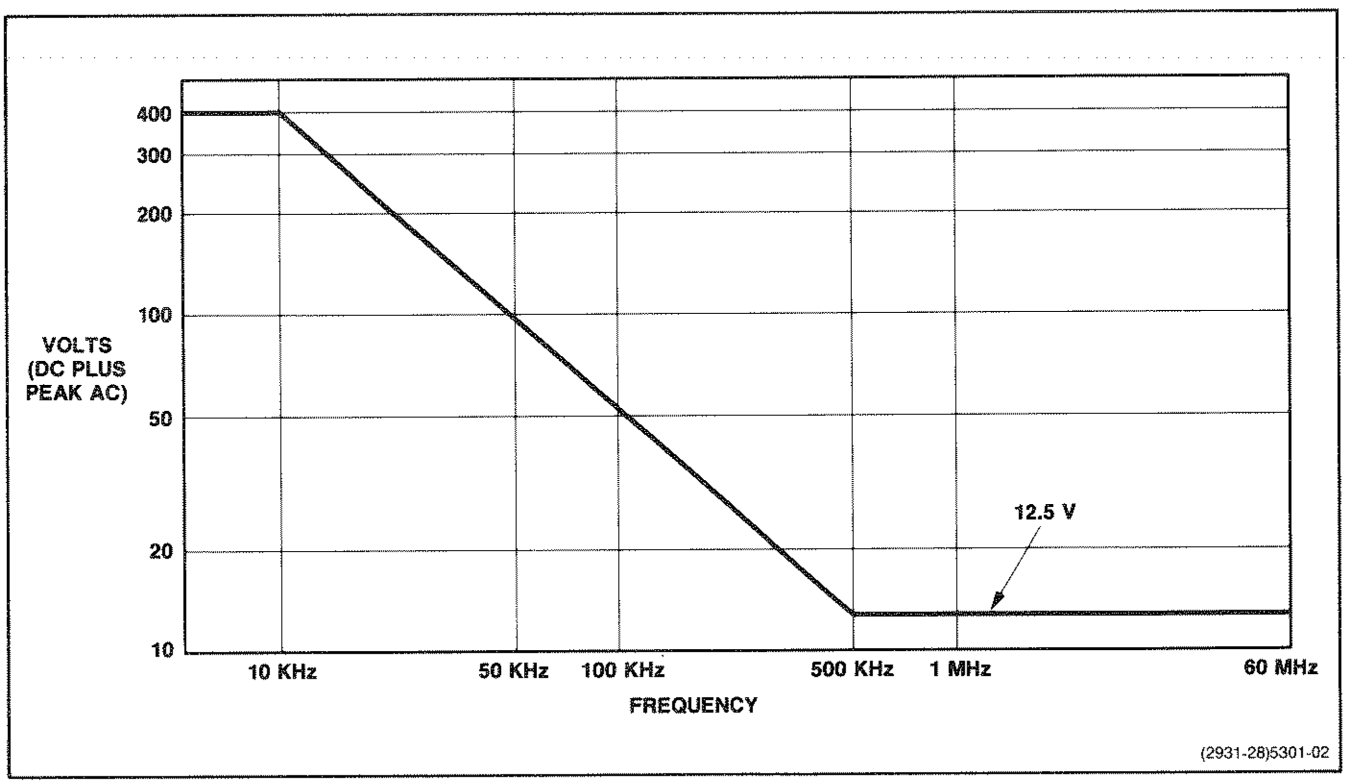


Figure 1-1. Maximum input voltage vs frequency derating curve for CH 1 OR X, CH 2 OR Y, and EXT INPUT connectors.

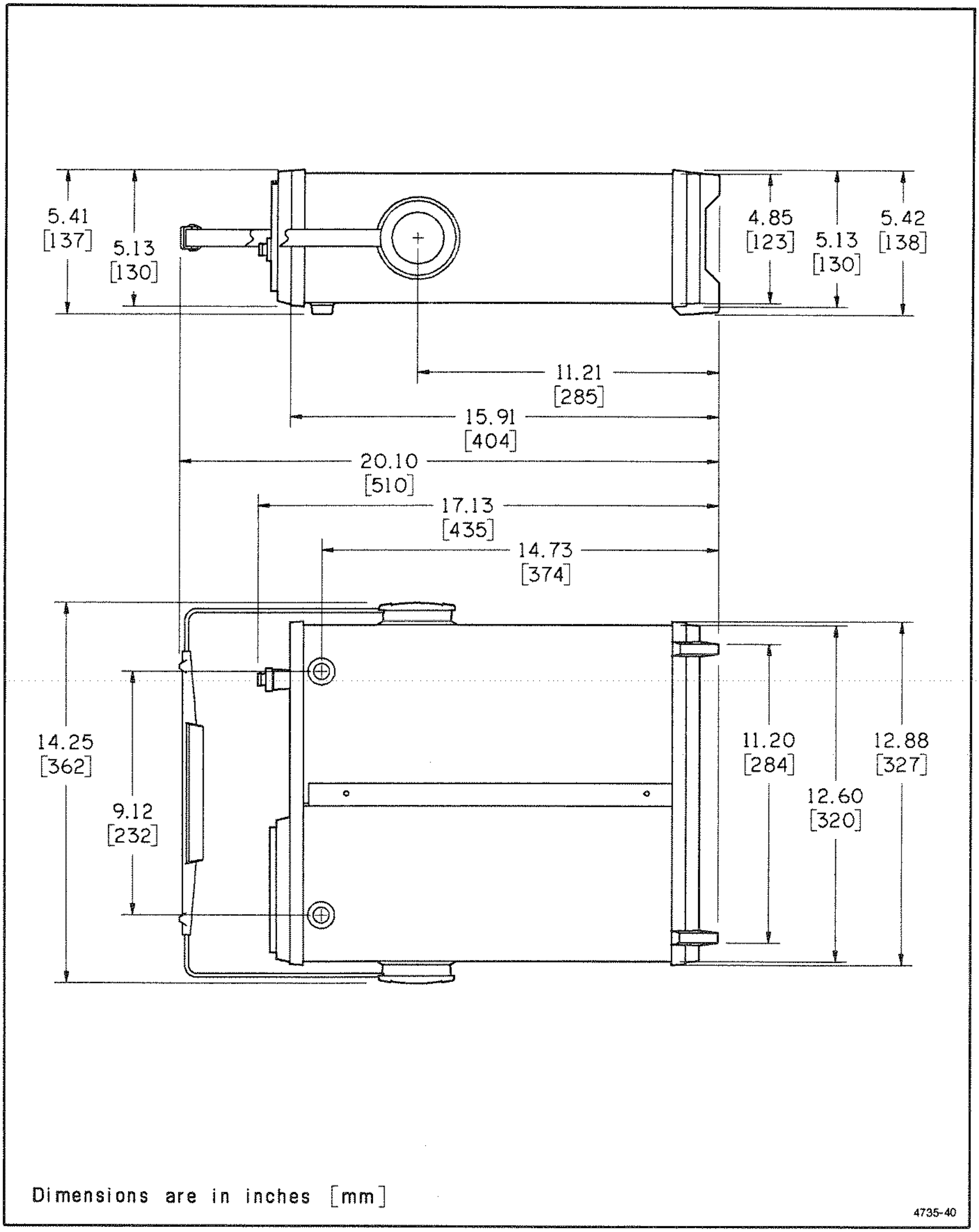


Figure 1-2. Physical dimensions of the 2220 Oscilloscope.

PREPARATION FOR USE

SAFETY

This section tells how to prepare for and to proceed with the initial start-up of the TEKTRONIX 2220 Digital Storage Oscilloscope.

Refer to the Safety Summary at the front of this manual for power source, grounding, and other safety considerations pertaining to the use of the instrument. Before connecting the oscilloscope to a power source, read entirely both this section and the Safety Summary.

LINE VOLTAGE

This instrument is capable of continuous operation with input voltages that range from 90 V to 250 V with source voltage frequencies from 48 Hz to 440 Hz.

POWER CORD

A detachable three-wire power cord with a three-contact plug is provided with each instrument for connecting to both the power source and protective ground. The power cord may be secured to the rear panel by a cord-set-securing clamp (see Figure 2-1). The protective-ground contact in the plug connects (through the protective-ground conductor) to the accessible metal parts of the instrument. For electrical-shock protection, insert this plug only into a power-source outlet that has a properly grounded protective-ground contact.

Instruments are shipped with the power cord ordered by the customer. Available power-cord information is presented in Figure 2-2, and part numbers are listed in "Options and Accessories" (Section 7). Contact your Tektronix representative or local Tektronix Field Office for additional power-cord information.

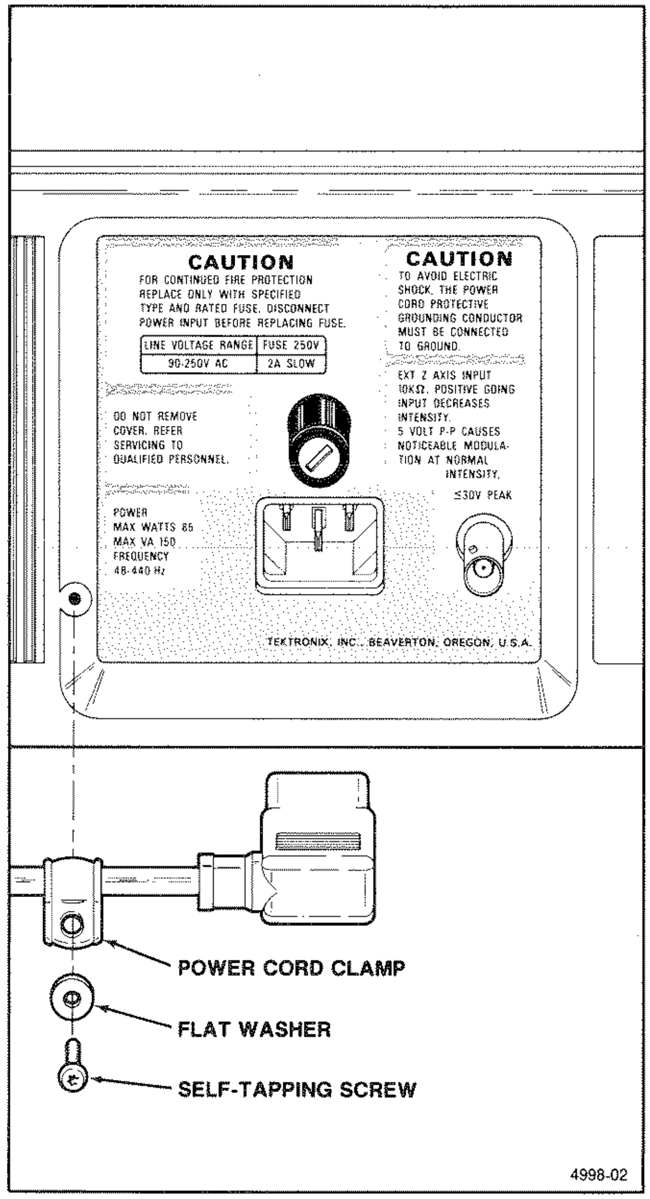
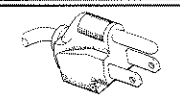
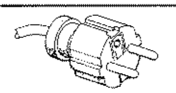
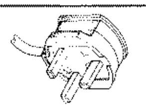
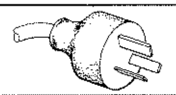
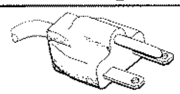
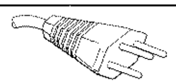


Figure 2-1. Securing the detachable power cord to the instrument.

Plug Configuration	Usage	Line Voltage	Reference Standards
	North American 120V/ 15A	120V	ANSI C73.11 NEMA 5-15-P IEC 83
	Universal Euro 240V/ 10-16A	240V	CEE (7),II,IV,VII IEC 83
	UK 240V/ 13A	240V	BS 1363 IEC 83
	Australian 240V/ 10A	240V	AS C112
	North American 240V/ 15A	240V	ANSI C73.20 NEMA 6-15-P IEC 83
	Switzerland 220V/ 6A	220V	SEV

Abbreviations:
ANSI — American National Standards Institute
AS — Standards Association of Australia
BS — British Standards Institution
CEE — International Commission on Rules for the Approval of Electrical Equipment
IEC — International Electrotechnical Commission
NEMA — National Electrical Manufacturer's Association
SEV — Schweizevischer Elektrotechischer Verein

(2931-21)4204-53

Figure 2-2. Optional power-cord data.

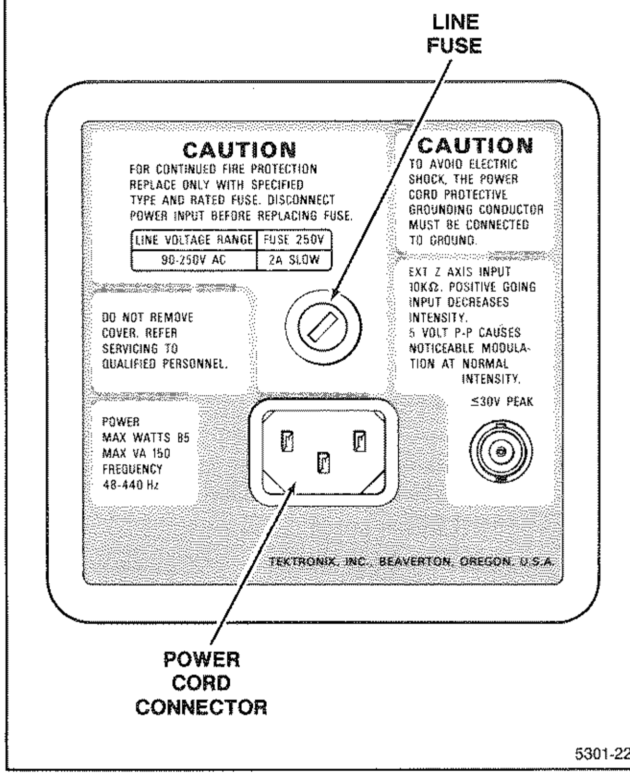


Figure 2-3. Fuse holder and detachable power-cord connector.

LINE FUSE

The instrument fuse holder is located on the rear panel (see Figure 2-3) and contains the line-protection fuse. The following procedure may be used either to verify that the proper fuse is installed or to install a replacement fuse.

1. Unplug the power cord from the power-input source (if plugged in).

2. Press in the fuse-holder cap and release it with a slight counterclockwise rotation.

3. Pull the cap (with the attached fuse inside) out of the fuse holder.

4. Verify that the proper fuse is installed (see the rear-panel fuse nomenclature).

5. Reinstall the proper fuse in the fuse cap and replace the cap and fuse in the fuse holder by pressing in and giving a slight clockwise rotation of the cap.

INSTRUMENT COOLING

To prevent instrument damage from overheated components, adequate internal airflow must be maintained at all times. Before turning on the power, first verify that both the fan-exhaust holes on the rear panel and the air-intake holes on the side panel are free from any obstructions to airflow. After turning on the instrument, verify that the fan is exhausting air.

START-UP

The 2220 automatically performs power-up tests of the digital portion of the circuitry each time the instrument is turned on. The purpose of these tests is to provide the user with the highest possible confidence level that the instrument is fully functional. If no faults are encountered during the power-up testing, the instrument enters the normal operating mode. If the instrument fails one of the power-up tests, the instrument attempts to indicate the cause of the failure.

If a failure of any power-up test occurs, the instrument may still be usable for some applications, depending on the nature of the failure. If the instrument functions for your immediate measurement requirement, it may be used, but refer it to a qualified service technician for repair of the problem at the earliest convenience. Consult your service department, your local Tektronix Service Center, or your nearest Tektronix representative if additional assistance is required.

REPACKAGING

If this instrument is shipped by commercial transportation, use the original packaging material. Unpack the instrument carefully from the shipping container to save the carton and packaging material for this purpose.

If the original packaging is unfit for use or is not available, repackage the instrument as follows:

1. Obtain a corrugated cardboard shipping carton having inside dimensions at least six inches greater than the instrument dimensions and having a carton test strength of at least 275 pounds.

2. If the instrument is being shipped to a Tektronix Service Center for repair or calibration, attach a tag to the instrument showing the following: owner of the instrument (with address), the name of a person at your firm who may be contacted if additional information is needed, complete instrument type and serial number, and a description of the service required.

3. Wrap the instrument with polyethylene sheeting or equivalent to protect the outside finish and prevent entry of packing materials into the instrument.

4. Cushion the instrument on all sides by tightly packing dunnage or urethane foam between the carton and the instrument, allowing for three inches of padding on each side (including top and bottom).

5. Seal the carton with shipping tape or with an industrial stapler.

6. Mark the address of the Tektronix Service Center and your return address on the carton in one or more prominent locations.

CONTROLS, CONNECTORS, AND INDICATORS

The following descriptions are intended to familiarize the operator with the location and function of the instrument's controls, connectors, and indicators.

POWER AND DISPLAY

See Figure 3-1 for the location of items 1 through 8.

(1) **Internal Graticule**—Eliminates parallax viewing error between the trace and the graticule lines. Rise-time amplitude and measurement points are indicated at the left edge of the graticule.

(2) **POWER Switch**—Turns instrument power on or off.

(3) **Power On Indicator**—Lights up while instrument is operating.

(4) **FOCUS Control**—Adjusts for optimum display definition. Once set, proper focusing is maintained over a wide range of display intensity.

(5) **PROBE ADJUST Connector**—Provides an approximately 0.5 V, negative-going, square-wave voltage (at approximately 1 kHz) for use in compensation voltage probes and checking the vertical deflection system. The PROBE ADJUST output is not intended as a reference in checking either the vertical or the horizontal accuracy of the instrument.

(6) **BEAM FIND Switch**—Compresses the vertical and horizontal deflection to within the graticule area and intensifies the display to aid the user in locating traces that are overscanned or deflected outside of the crt viewing area.

(7) **TRACE ROTATION Control**—Permits alignment of the trace with the horizontal graticule line. This control is a screwdriver adjustment that, once set, should require little attention during normal operation.

(8) **INTENSITY Control**—Adjusts the brightness of all displayed STORE and NON STORE waveforms.

VERTICAL

See Figure 3-2 for the location of items 9 through 16.

(9) **VOLTS/DIV Switches**—Select the vertical channel deflection factors from 2 mV to 5 V per division in a 1-2-5 sequence.

1X PROBE—Front-panel marking that indicates the deflection factor set by the VOLTS/DIV switch when a 1X probe or a coaxial cable is attached to the channel input connector.

10X PROBE—Front-panel marking that indicates the deflection factor set by the VOLTS/DIV switch when a properly coded 10X probe is attached to the channel input connector.

(10) **Variable VOLTS/DIV Controls**—Provide continuously variable deflection factors between calibrated positions of the VOLTS/DIV controls. The VOLTS/DIV sensitivity may be reduced by up to at least 2.5 times at the fully counterclockwise rotation of the variable knob. A detent position at full clockwise rotation indicates the calibrated VOLTS/DIV position of the variable knob.

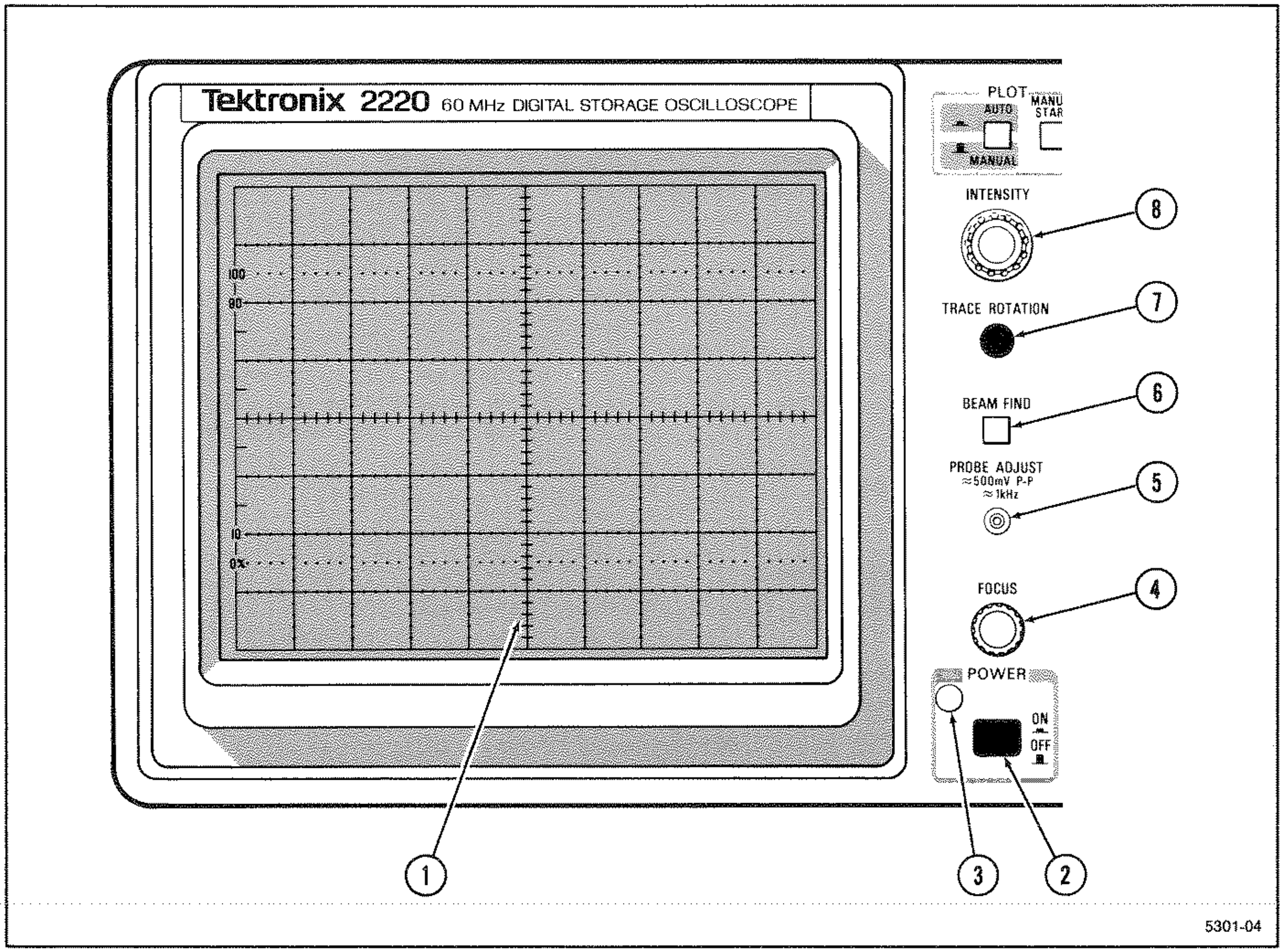


Figure 3-1. Power and display controls and power-on indicator.

(11) **CH 1 OR X and CH 2 OR Y Input Connectors**—Provide for application of signals to the inputs of the deflection systems and the storage acquisition system.

In X-Y mode, the signal connected to the CH 1 OR X input controls the horizontal deflection, and the signal connected to the CH 2 OR Y input controls the vertical deflection.

(12) **AC-GND-DC (Input Coupling) Switches**—Select the method of coupling the input signal from the CH 1 and CH 2 vertical input connectors to the vertical amplifiers and the storage acquisition system.

AC—Capacitively couples the input signal to the vertical deflection and signal acquisition systems. The dc component of the input signal is blocked. The lower −3 dB bandpass is 10 Hz or less.

GND—Grounds the input of the vertical deflection channel; provides a zero (ground) reference voltage display (does not ground the input signal). In STORE mode, the ground reference is acquired and displayed in the first sample location of the acquisition waveform display.

DC—All frequency components of the input signal are coupled to the vertical deflection and signal acquisition systems.

(13) **CH 2 INVERT Switch**—Inverts the Channel 2 display and STORE mode Channel 2 acquisition signal when pressed in. With CH 2 inverted, the oscilloscope may be operated as a differential amplifier when the BOTH-ADD VERTICAL MODE is selected.

(14) **VERTICAL MODE Switches**—Select the mode of operation of the vertical channels. There are two three-position switches and one, two-position switch

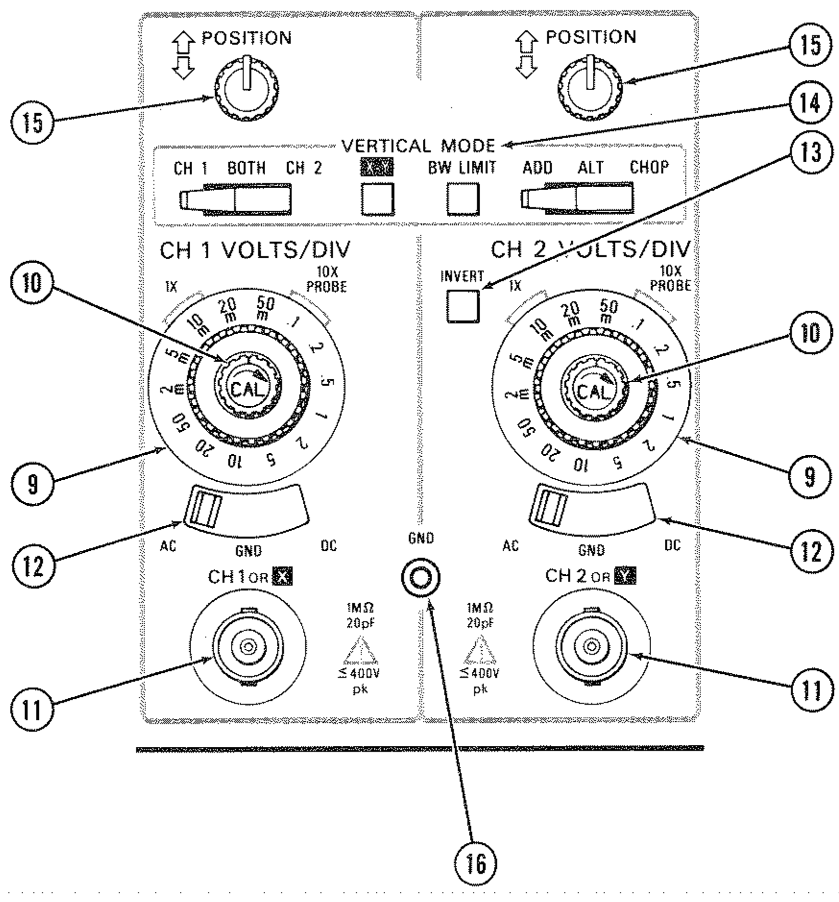


Figure 3-2. Vertical controls and connectors.

that determine display and acquisition modes and one, two-position push-button switch that controls the NON STORE bandwidth.

CH 1—Selects only the Channel 1 input signal for acquisition or display.

BOTH—Selects a combination of Channel 1 and Channel 2 input signals for acquisition or display (CH 1-BOTH-CH 2 switch must be in the BOTH position for ADD, ALT, and CHOP operation).

CH 2—Selects only the Channel 2 input signal for acquisition or display.

ADD—Displays and acquires the sum of Channel 1 and Channel 2 input signals when BOTH is also selected. The difference of the Channel 1 and Channel 2 inputs signals is displayed and acquired when the Channel 2 signal is inverted.

ALT—Alternately displays the NON STORE Channel 1 and Channel 2 input signals. The NON STORE alternation occurs during retrace at the end of each sweep. ALT Vertical MODE is most useful for acquiring and viewing both channel input signals at sweep rates of 0.5 ms per division and faster. Channel 1 and Channel 2 STORE mode signals are acquired on alternate acquisition cycles at one-half the sampling rate of a single-channel acquisition.

CHOP—Switches the NON STORE display between Channel 1 and Channel 2 vertical input signals during the sweep. The chopped switching rate for NON STORE mode (CHOP frequency) is approximately 500 kHz. Chopped STORE mode signals are acquired on alternate time-base clock cycles with each channel being acquired at one-half the sampling rate of a single-channel acquisition. In STORE mode at sweep speeds of 5 μs per division to 0.05 μs per division, CHOP becomes ALT mode.

BW LIMIT Switch—In NON STORE mode, limits the bandwidth of the vertical amplifier system and the A Trigger system to approximately 10 MHz when pressed in. This reduces interference from unwanted high-frequency signals when viewing low-frequency signals. In STORE mode, pressing in the BW LIMIT switch reduces only the trigger system bandwidth. Press a second time to release the switch and regain full bandwidth.

X-Y Switch—Automatically selects the X-Y mode when pressed in. The CH 1 input signal provides horizontal deflection for X-Y displays, and the CH 2 input signals provides vertical deflection. The STORE mode X-Y sampling rate is controlled by the SEC/DIV switch. The X-Y waveform is normally acquired in SAMPLING mode and displayed with dots. In STORE mode at SEC/DIV switch settings of 5 s per division to 10 μs per division, the CH 1 and CH 2 signals are acquired in a chopped manner with no more than 100 ns between corresponding sample points on opposite channels at the maximum sampling rate of 10 MHz per channel. The CH 1 signal is sampled before the CH 2 signal.

(15) **Vertical POSITION Controls**—Control the vertical display position of the CH 1 and CH 2 signals.

IN STORE mode, the controls determine the vertical position of displayed waveforms during acquisition and in SAVE mode. The STORE mode waveforms may also be vertically repositioned during the time between acquisitions. Any portions of a signal being acquired that are outside the dynamic range of the A/D converter are blanked when positioned on screen.

In NON STORE X-Y mode, the CH 2 POSITION control vertically positions the display, the horizontal POSITION control positions the display horizontally, and the CH 1 POSITION control is not active. In STORE mode, the CH 1 POSITION control is active, and both it and the Horizontal POSITION control affect the horizontal position of the displayed waveform.

(16) **GND Connector**—Provides an auxiliary ground connection directly to the instrument chassis via a banana-tip jack.

HORIZONTAL

See Figure 3-3 for the location of items 17 through 21.

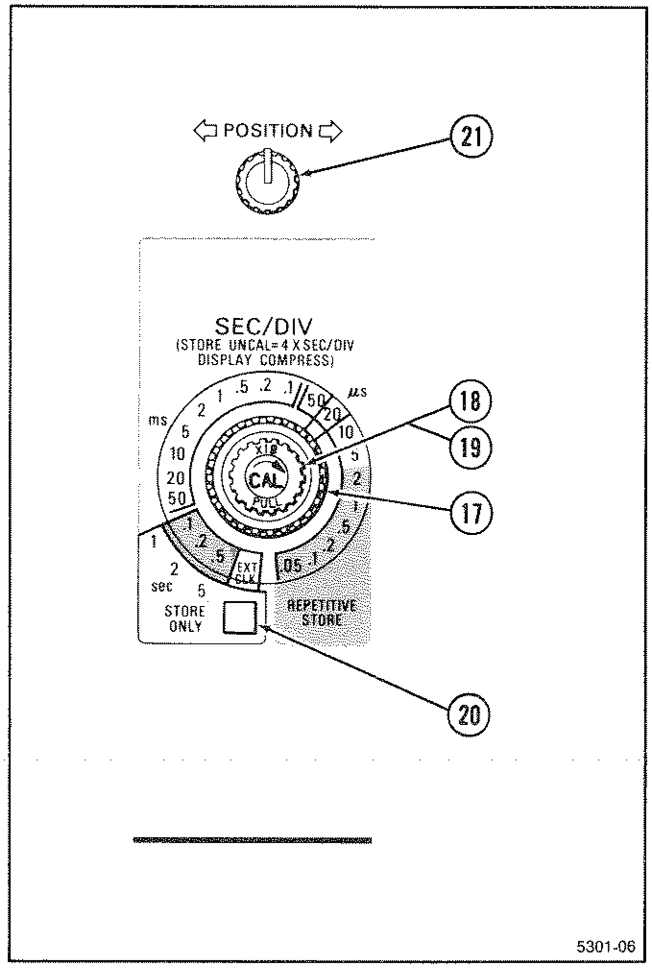


Figure 3-3. Horizontal controls.

(17) **SEC/DIV Switch**—Determines the SEC/DIV setting for the NON STORE sweeps and the STORE mode time base for acquiring and displaying waveforms.

In NON STORE, the SEC/DIV switch selects calibrated sweep rates from 0.5 s to 0.05 μs per division in a 1-2-5 sequence of 22 steps.

In STORE mode, the SEC/DIV switch determines the acquisition and display modes, set the sampling rate, and establish the time scale factor of the displayed waveforms.

Table 3-1 lists the Storage, Acquisition and Display modes with respect to the SEC/DIV switch setting and the selected Trigger mode.

REPETITIVE (2 μs/div to 0.05 μs/div) requires a repetitive signal. Sampling of the input signal occurs at the maximum A/D conversion rate. If a control affecting an acquisition parameter or function is changed, the acquisition is reset, and the waveform being acquired is cleared on the next sample acquired. On each valid trigger, 10 or more equally spaced samples are acquired and displayed on the waveform record, depending on the SEC/DIV setting (see Table 3-2). The random time delay from the trigger to the following sample is measured and used to place the acquired waveform samples in the correct display memory location. Any display location is equally likely to be filled. Table 3-2 gives the statistically expected number of trigger events required to completely fill the display, assuming a uniform distribution of trigger events relative to the sample interval.

FAST RECORD (5 μs/div to 10 μs/div) updates a full record of the acquired waveform. The Acquisition mode is Sample.

SLOW RECORD (20 μs/div to 50 ms/div) updates a full record of the acquired waveform. The Acquisition mode is Peak Detect.

SCAN (for NORM TRIGGER mode and 0.1 s/div to 5 s/div or EXT CLOCK) updates pretrigger data when a trigger is received. The waveform display then scans to the right from the trigger point to finish the post-trigger acquisition and then freezes. The Acquisition mode is Peak Detect.

ROLL (for P-P AUTO TRIGGER mode and 0.1 s/div to 5 s/div or EXT CLOCK) continuously acquires and displays signals. Triggers are disabled except in SGL SWP. The waveform display scrolls from right to left across the crt with the latest samples appearing at the right edge of the crt. The Acquisition mode is Peak Detect. In Roll Stop After Trigger, the display rolls from right to left until the trigger is received. Then, the display continues rolling until the post-trigger acquisition record is filled, and then the display freezes.

PEAK DETECT—The minimum and maximum levels of the input signal within the time represented by 1/50 of a division UN MAG (1/25 of a division in CHOP or ALT) are digitized and stored in acquisition memory as a data pair.

Table 3-1
2220 Digital Storage Modes

SEC/DIV Setting	Trig Mode Selected	Storage Mode Mode	Acquisition Mode	Display[a] Default
0.05 μs/div to 2 μs/div	All	REPETITIVE	AVERAGE[b]	Dots
5 μs/div to 10 μs/div	All	FAST RECORD	SAMPLE	Dots/Vector
20 μs/div to 50 ms/div	All	SLOW RECORD	PEAK DETECT	Dots/Vector
0.1 s/div to 5 s/div or EXT CLOCK to 1 kilo-sample/sec (cont)	Norm	SCAN	PEAK DETECT	Dots/Vector
	P-P Auto or SGL SWP	ROLL	PEAK DETECT	Dots/Vector

[a]In X-Y mode, the Display mode is always Dots.
[b]The AVERAGE mode weight is 1/4.

Table 3-2
Repetitive Store Sampling Data Acquisition

SEC/DIV Switch Setting	Samples Per Acquisition	Expected Acquisitions per Waveform[a]	
		One Channel	Two Channels
0.05 μs	40	519	450
0.1 μs	80	225	191
0.2 μs	160	96	83
0.5 μs	400	30	23
1 μs	800	12	11
2 μs	800	12	11

[a]For a 50% probability of fill.

SAMPLE—The signal is sampled at a rate that produces 100 samples per graticule division. In RECORD Sampling modes, the displayed sample points are displayed by vectors or dots.

AVERAGE—AVERAGE Acquisition mode is used for multiple record averaging in REPETITIVE Store mode. A normalized algorithm continuously displays the signal at full amplitude during the averaging process. The averaging weight (the number of weighted waveform acquisitions included in each average display) is 1/4.

(18) **Variable SEC/DIV and DISPLAY COMPRESS Control**—Continuously varies the uncalibrated NON STORE sweep time per division to at least 2.5 times the calibrated time per division set by the SEC/DIV switch (increases the slowest NON STORE Sweep time per division to at least 2 s).

The Variable SEC/DIV control does not affect the STORE time base for acquiring signals. If rotated out of the CAL detent position, the Variable SEC/DIV control has the effect of horizontally compressing (4 X SEC/DIV) the 4K display by a factor of four (DISPLAY COMPRESS). In PEAK DET acquisition mode, peaks are acquired but not displayed when DISPLAY COMPRESS is selected.

(19) **X10 Magnifier Switch**—When the Variable SEC/DIV knob is pulled to the out position (X10 PULL), displays are magnified by 10 times. In NON STORE, Magnification of the displays occurs around the center vertical graticule division. The display window for STORE mode X10 expanded waveforms may be positioned using the DISPLAY POS Controls to view any one-window portion of displayed records.

(20) **STORE ONLY Mode SEC/DIV Multiplier**—Functional in the STORE mode only at SEC/DIV switch settings of 0.1, 0.2, and 0.5 s per division. When pressed in, the Sweep time base of these three settings is increased by a factor of 10 to 1 s per division, 2 s per division, and 5 s per division. Releasing the button returns the STORE mode time base to X1. The normal X10 MAG feature is still functional on waveforms acquired at the slow STORE mode SEC/DIV settings.

(21) **Horizontal POSITION Control**—Positions all the NON STORE waveforms horizontally over a one-sweep-length range (either X1 or X10 Magnified). Using the Horizontal POSITION control, STORE mode waveforms may be positioned over a range of one display window. The DISPLAY POS controls are used to position the display window (the one-screen portion of the record to be viewed) to any position of the acquisition record.

TRIGGER

See Figure 3-4 for the location of items 22 through 31.

NOTE

The trigger system controls affect the acquisition of the next waveform. They are inactive in SAVE STORE mode.

(22) **Mode Switches**—Determine the NON STORE Sweep triggering mode. STORE mode triggering operation depends on the position of the SEC/DIV switch and the trigger mode selected.

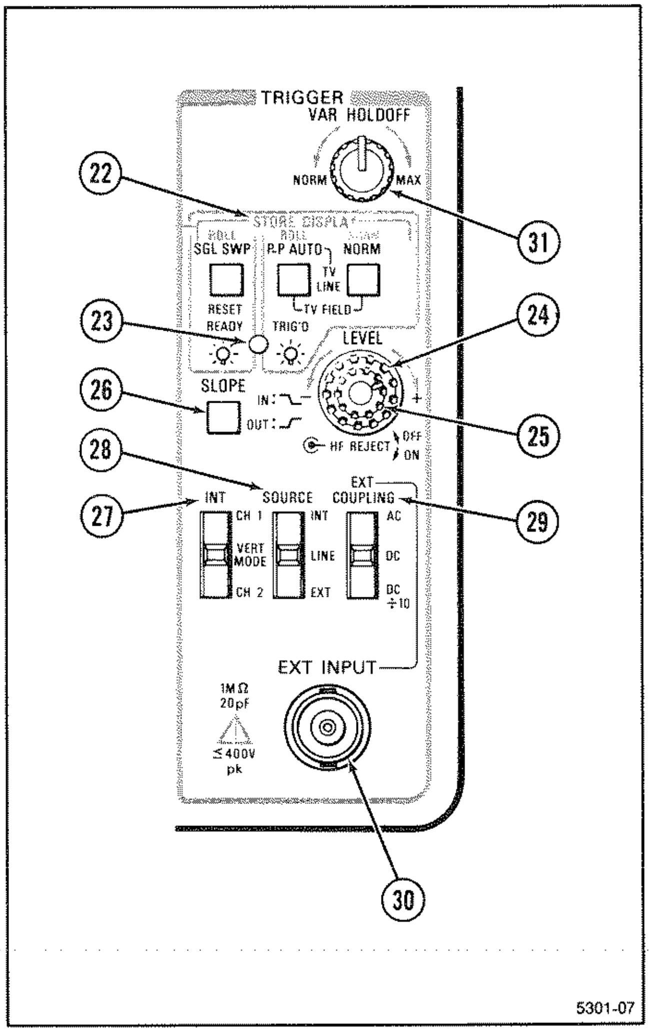


Figure 3-4. Trigger controls, connector, and indicator.

The trigger position is marked by a T on the acquired waveform. A symbol in the waveform display separates the new acquisition from the previous acquisition.

NORM—Permits triggering at all sweep rates (an autotrigger is not generated in the absence of an adequate trigger signal). NORM Trigger mode is especially useful for low-frequency and low-repetition-rate signals.

In STORE mode, the last acquired waveform is held on display between triggering events. The pretrigger portion of the acquisition memory is continually acquiring new pretrigger data until a trigger event occurs. How the waveform display is updated after the trigger occurs, depends on the SEC/DIV setting. SCAN mode is selected from 5 s per division to 0.1 s per division.

From 5 s per division to 0.1 s per division, the pretrigger portion of the displayed waveform is updated by the pretrigger data in the acquisition memory, then the post-trigger data points are placed in the display as they are acquired. For faster sweep speeds, the post-trigger data points are acquired in the acquisition memory prior to completely updating the waveform display, using the newly acquired data.

P-P AUTO–TV LINE—In the NON STORE mode, triggering occurs on trigger signals having adequate amplitude and a repetition rate of about 20 Hz or faster. In the absence of a proper trigger signal, an autotrigger is generated, and the sweep free runs.

In STORE mode, for SEC/DIV settings of 5 s per division to 0.1 s per division, the P-P AUTO Trigger mode is disabled, ROLL mode is selected, and the acquisition is free running. At faster SEC/DIV settings, triggering occurs under the same conditions as NON STORE mode P-P AUTO triggering, and acquisitions are auto triggered if proper triggering signal conditions are not met. The manner in which the display is filled and updated is the same as for NORM triggering.

When in ROLL mode, triggers are disabled and the signals are continuously acquired and displayed. The waveform display scrolls from right to left across the crt with the latest samples appearing at the right edge of the crt.

For either NON STORE or STORE mode, the range of the TRIGGER LEVEL control is automatically restricted to the peak-to-peak limits of the trigger signal for ease in obtaining triggered displays and acquisitions. P-P AUTO is the usual Trigger Mode selection for obtaining stable displays of TV Line information.

TV FIELD—Permits stable triggering on a television field (vertical sync) signal when the P-P AUTO and the NORM Trigger buttons are pressed in together (see VAR HOLDOFF Control). In the absence of an adequate trigger signal, the sweep (or acquisition) free-runs. The instrument otherwise behaves as in P-P AUTO.

SGL SWP—Arms the trigger circuit for a single sweep in NON STORE or a single acquisition in STORE. Triggering requirements are the same as in NORM Trigger Mode. After the completion of a triggered NON STORE sweep or STORE SGL SWP acquisition, pressing in the SGL SWP button rearms the trigger circuitry to accept the next triggering event or start the next storage acquisition.

In STORE mode, when the SGL SWP is armed, the acquisition cycle begins but the READY LED does not come on until the pretrigger portion of the acquisition memory is filled. At the time the READY LED comes on, the acquisition system is ready to accept a trigger. When a trigger event occurs, the post-trigger waveform data is stored to complete the single-sweep acquisition. After the acquisition completes, the READY LED goes out, and the Single Sweep can be rearmed.

The SEC/DIV switch setting and the STORE mode determine how the display is updated. For settings of 5 s per division to 0.1 s per division, a storage process known as Roll Stop After Trigger is used. The last acquired waveform is erased when SGL SWP is armed. In Roll Stop After Trigger, the display rolls from right to left until the trigger is received. Then, the display continues rolling until the post-trigger acquisition record is filled, and then the display freezes.

For SEC/DIV settings of 50 ms per division and faster, the display is updated as a full record. The previously displayed waveform remains on the crt until the post-trigger portion of the acquisition memory is filled after a triggering event. Then the waveform display is updated with the newly acquired data in its entirety.

(23) **READY—TRIG'D Indicator**—A dual-function LED indicator. In P-P AUTO and NORM Trigger modes, the LED is turned on when triggering occurs. In SGL SWP Trigger mode, the LED turns on when the trigger circuit is armed, awaiting a triggering event, and turns off again after the single sweep (or acquisition) completes.

In STORE mode, pressing the SGL SWP button to arm the trigger circuitry does not immediately turn on the READY LED. The pretrigger portion of the acquisition memory starts filling after the SGL SWP button is pressed in, and the READY LED is turned on when the filling is completed. The storage acquisition system is then ready to accept a triggering event. After an acquisition is completed, the READY LED is turned off.

(24) **TRIGGER LEVEL Control**—Selects the amplitude point on the Trigger signal that produces triggering. The Trigger point for STORE mode is identified by a T on the acquired waveform.

(25) **HF REJECT**—Rejects (attenuates) the high-frequency components (above 40 kHz) of the trigger signal when the control is in the ON position.

(26) **TRIGGER SLOPE Switch**—Selects either the positive or negative slope of the trigger signal to start the NON STORE Sweep or to reference the next STORE mode acquisition cycle.

(27) **INT Switch**—Determines the source of the internal trigger signal for the Trigger Generator circuits.

CH 1—Trigger signal is obtained from the CH 1 input.

VERT MODE—Trigger signals are automatically obtained alternately from the CH 1 and CH 2 input signals in ALT VERTICAL MODE. In CHOP VERTICAL MODE, the trigger signal source is the sum of the CH 1 and CH 2 input signals.

CH 2—Trigger signal is obtained from the CH 2 input. The CH 2 INVERT switch also inverts the polarity of the internal CH 2 trigger signal when the CH 2 display is inverted.

(28) **SOURCE Switch**—Determines if the SOURCE of the Trigger signal is internal, external, or from line.

INT—Routes the internal trigger signal selected by the INT switch to the Trigger circuit.

LINE—Routes a sample of the ac power line signal to the Trigger circuit.

EXT—Routes an external signal applied to the EXT INPUT connector to the Trigger circuit.

(29) **EXT COUPLING Switch**—Determines the method of coupling the external signal applied to the EXT INPUT connector to the input of the Trigger circuit.

AC—Input signal is capacitively coupled, and the dc component is blocked.

DC—All frequency components of the external signal are coupled to the Trigger circuit.

DC÷10—Attenuates the external signal by a factor of 10 before application to the Trigger circuit. As with DC COUPLING, all frequency components of the input signal are passed.

(30) **EXT INPUT Connector**—Provides for connection of external signals to the Trigger circuit.

(31) **VAR HOLDOFF Control**—Adjusts the NON STORE Variable Holdoff time. NON STORE Variable Holdoff starts at the end of the Sweep. STORE mode Holdoff starts at the end of the acquisition cycle, and ends after the waveform data has been transferred from acquisition to display memory and the pretrigger portion of the acquisition memory has been filled. After STORE mode Holdoff ends, the next acquisition can be triggered after the next (or current, if one is in progress) NON STORE Variable Holdoff ends. STORE mode Holdoff may be many times the length of the Sweep time so that several NON STORE Holdoffs may have occurred during STORE Holdoff time. *This ensures that STORE mode triggering is controllable by the VAR HOLDOFF control and will be stable if the NON STORE display is stable.*

STORAGE CONTROLS

See Figure 3-5 for the location of items 32 through 37.

(32) **STORE/NON STORE Switch**—Selects either the NON STORE or the STORE waveforms for display. The STORE acquisition system is turned off while NON STORE is selected so that the last acquired STORE waveform remains in memory. Selects NON STORE when out and STORE when pressed in.

(33) **ACQUISITION Controls**—Determine the method of acquiring and displaying the acquired STORE waveform.

SAVE/CONTINUE Switch—Stops the current acquisition and display update in progress when pressed in. If the SEC/DIV switch setting is 0.1 s per division or slower, the SAVE state is entered immediately upon pressing the button. At SEC/DIV settings of 50 ms per division and faster, if an acquisition has been triggered, the acquisition is allowed to complete before the SAVE state is entered. Pressing the SAVE/CONTINUE switch a second time releases it and restarts (continues) the acquisition process.

The pretrigger portion of an untriggered acquisition stops filling in SAVE mode. Upon leaving SAVE, a new acquisition is started, and a trigger will not be accepted until the pretrigger portion again refills.

PRETRIG, POSTTRIG, or BOTH=MIDTRIG Switches—Positions the trigger point for acquisitions either near the end (PRETRIG), the beginning (POSTTRIG), or the middle (BOTH=MIDTRIG) of the waveform. A T is displayed on the waveform to indicate the trigger point. Pressing the PRETRIG button in sets the trigger point to PRETRIG; pressing the POSTTRIG button in sets the trigger point to POSTTRIG; pressing both the PRETRIG and the POSTTRIG buttons in or out sets the BOTH=MIDTRIG position. The change in trigger point will only be seen on new acquisitions.

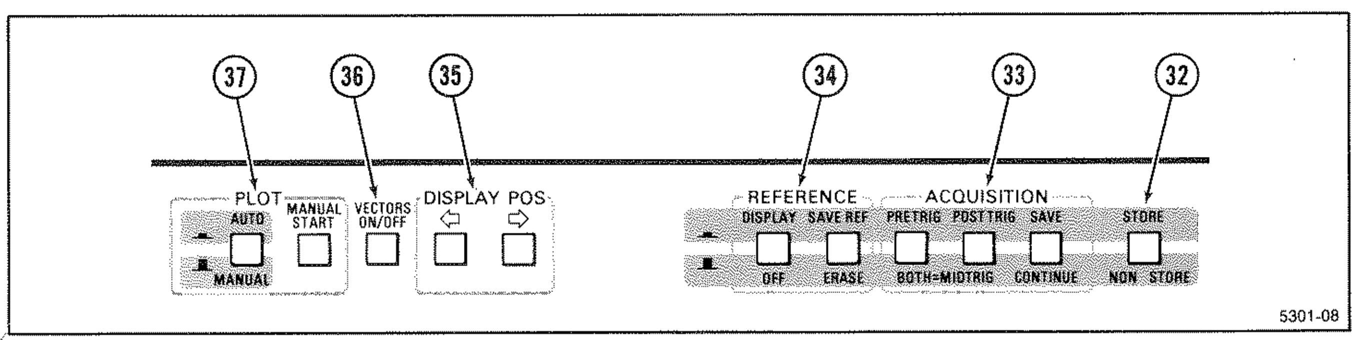


Figure 3-5. Storage controls.

(34) **REFERENCE Controls**—Control the saving and displaying of reference waveforms.

SAVE REF/ERASE Control—When pressed in while in STORE mode, causes the displayed acquisition waveform to be saved in the reference memory. The saved waveform is erased when the control is in the out position.

DISPLAY/OFF—When pressed in, the saved waveform in the reference memory is displayed. When the control is in the out position the saved reference waveform is not displayed.

(35) **DISPLAY POS Controls**—Position the display window within the 4K acquisition record length. These controls apply to all displayed STORE mode waveforms.

A window of the 4K acquisition record is displayed. A bar graph is used to indicate the position of the display window within the acquisition record. The scrolling action may be continued to the end of the record length in either direction so that observations and measurements can be made over the entire 4K acquisition record.

→ Control—Scrolls the display window to the right within the 4k acquisition record.

← Control—Scrolls the display window to the left within the 4k acquisition record.

(36) **VECTORS ON/OFF Control**—Provides a choice of either dots or vector-connected points in the display of acquired waveforms for STORE mode SEC/DIV switch settings from 5 s per division to 5 μs per division except in X-Y mode. The change occurs on new acquisitions after the button is pushed.

(37) **PLOT Controls**—Control waveform transmission over the X-Y PLOTTER output. While a plot is in progress it may be canceled (see "Canceling a Plot" in Section 4).

MANUAL START—Pushing this button starts the plotting process any time the instrument is in Store and is not presently plotting. Normally, only the displayed waveforms and trigger points are plotted (see "Plotting the Graticule and Bar Graph" in Section 4).

If a plot is in progress, this button controls plot speed. Each push of MANUAL START, while plotting, decrements the plot speed until the slowest speed is reached. The next button push causes the speed to increase to the highest speed. Ten speeds are available. At power-up, plot speed is set to the slowest speed.

AUTO/MANUAL—When pushed in (AUTO) a plot is started after the number of acquisitions or pairs of acquisitions (ALT VERTICAL MODE) defined in Table 3-3. In ALT VERTICAL MODE a plot does not start until both channels are acquired.

The first plot after this button is pushed also draws the graticule, the "TEKTRONIX 2220" label and the bar graph. Upon entering Auto Plot mode:

1. A waveform(s) is acquired.

2. Plotting begins.

3. On the first plot the graticule, bar graph, and "TEKTRONIX 2220" label are drawn first, then the waveform(s).

4. The instrument then acquires another waveform(s) and plots only the newly acquired data (waveform).

5. Acquisitions and waveform plots continue as long as valid triggers are available.

Table 3-3
Acquisitions Before a Plot

Acquisitions Required	Sweep Speed	Acquisition Mode
100	0.05 μs/div	REPETITIVE
50	0.1μs	REPETITIVE
50	0.2 μs/div	REPETITIVE
30	0.5 μs/div	REPETITIVE
12	1 μs/div	REPETITIVE
12	2 μs/div	REPETITIVE
1	50 ms/div to 5 μs/div	RECORD
1	EXT CLK to 0.1 s/div	SCAN
—	No AUTO PLOT	ROLL

REAR PANEL

Refer to Figure 3-6 for the location of items 38 through 40.

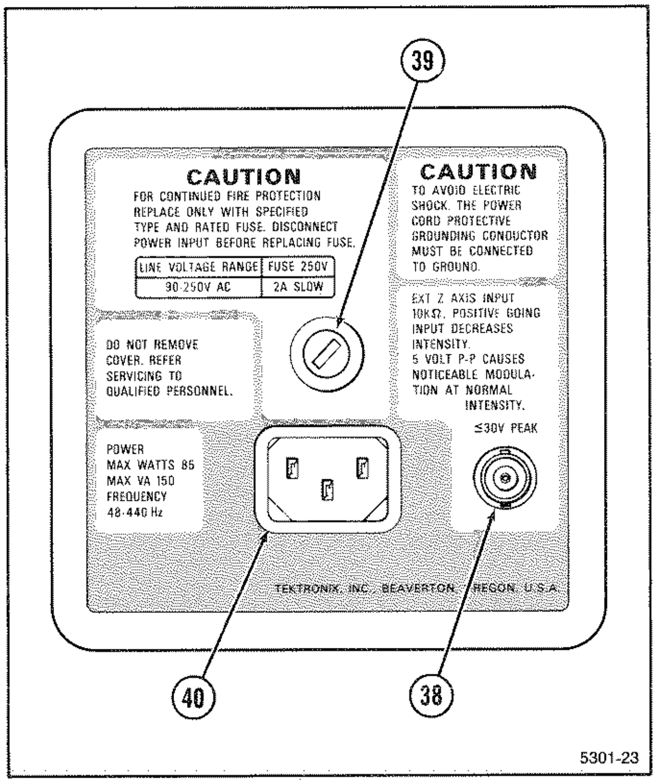


Figure 3-6. Rear Panel.

(38) **EXT Z-AXIS INPUT Connector**—Provides an input connector to allow external signals to be applied to the Z-Axis circuit to intensity modulate the NON STORE waveform display. Applied signals do not affect the display waveshape. External signals with fast rise and fall times provide the best defined intensity modulation. Noticeable intensity modulation will be produced at normal viewing intensity levels by a 5 V p-p signal. The Z-Axis signals must be time-related to the trigger signal to obtain a stable intensity-modulation pattern on the displayed waveform.

(39) **Fuse Holder**—Contains the ac-power-source fuse. See the rear panel nomenclature for fuse rating and line voltage range.

(40) **Detachable Power Cord Receptacle**—Provides the connection point for the ac power source to the instrument.

SIDE PANEL

The standard side panel includes one AUXILIARY CONNECTOR. Refer to Figure 3-7 for the location of item 41.

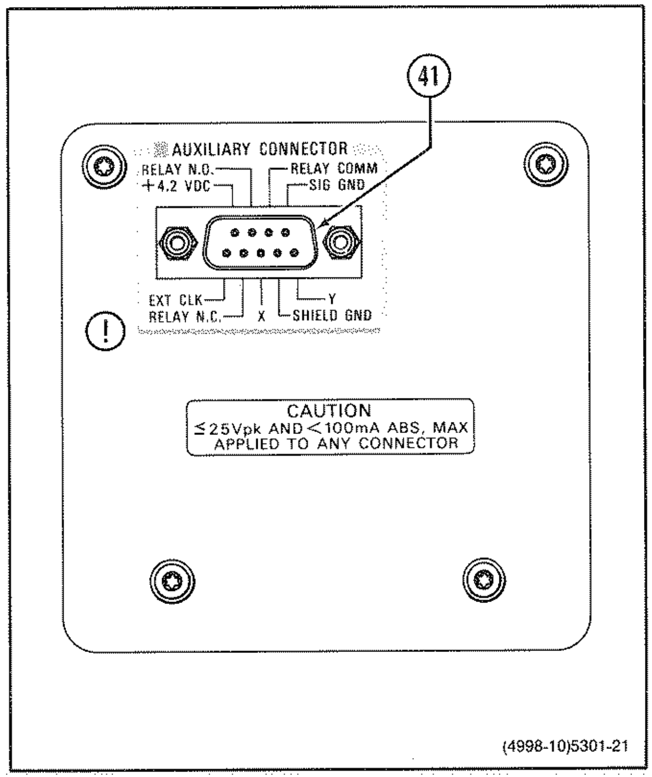


Figure 3-7. Left Side Panel.

NOTE

To meet EMI regulations and specifications, use the specified shielded cable and metal connector housing with the housing grounded to the cable shield for connections to the AUXILIARY CONNECTOR.

(41) **AUXILIARY CONNECTOR**—Provides connections for an X-Y Plotter and an External Clock input. The connector is shown in Table 3-4.

X-Y Plotter Connections—Provide connections for X-Axis output, Y-Axis output, and Pen Lift control to drive an external X-Y Plotter. All displayed waveforms are transmitted over the Plotter Interface. The settling time allowed for each movement is approximately proportional to the distance of the movement. Connections for Signal Ground and Shield Ground are also provided for grounding between the 2220 and the external X-Y Plotter. Waveforms and the Readout are plotted on the crt while a plot is in progress.

Table 3-4
Auxiliary Connector

Pin Number	Function
1	EXT CLK input
2	Pen Lift N.C.
3	X signal output
4	SHIELD GND
5	Y signal output
6	+4.2 V output
7	Pen Lift N.O.
8	Pen Lift RELAY COMM
9	SIG GND

To be fully compatible, the X-Y Plotter used must have both pen-lift control and X and Y inputs with sensitivitv control.

Signals available at the AUXILIARY connector allow the Pen-lift circuit to be wired for a plotter with either active HI or active LO drive requirements and several logic families. Examples for both an active HI and an active LO TTL drive are shown in Figure 3-8.

EXT CLK INPUT—Provides an input for EXT CLOCK signals to the storage acquisition circuit in conjunction with the EXT CLK position of the SEC/DIV switch. Samples are referenced by falling edges. Input is TTL compatible. Samples become visible by pairs, as SCAN or ROLL. Several clocks are required before the point associated with the first clock is visible.

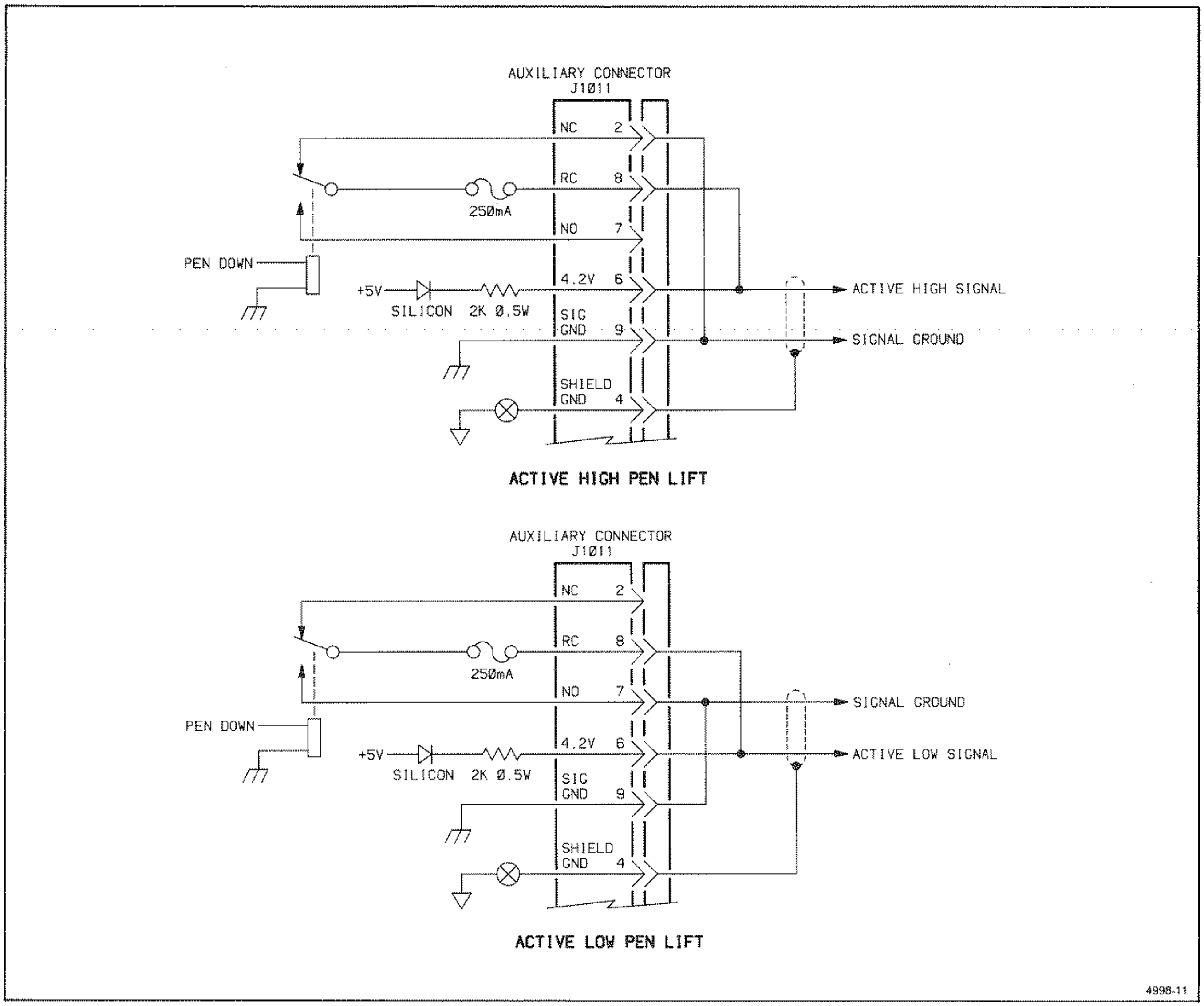


Figure 3-8. X-Y Plotter interfacing.

OPERATING CONSIDERATIONS

This part contains basic operating information and techniques that should be considered before attempting to make any measurements with the instrument.

GRATICULE

The graticule is internally marked on the faceplate of the crt to eliminate parallax-viewing errors and to enable measurements (see Figure 4-1). The graticule is marked with eight vertical and ten horizontal major divisions. In addition, each major division is divided into five subdivisions. The vertical deflection factors and horizontal timing are calibrated to the graticule so that accurate measurements can be made directly from the crt. Also, percentage marks for the measurement of rise and fall times are located on the left side of the graticule.

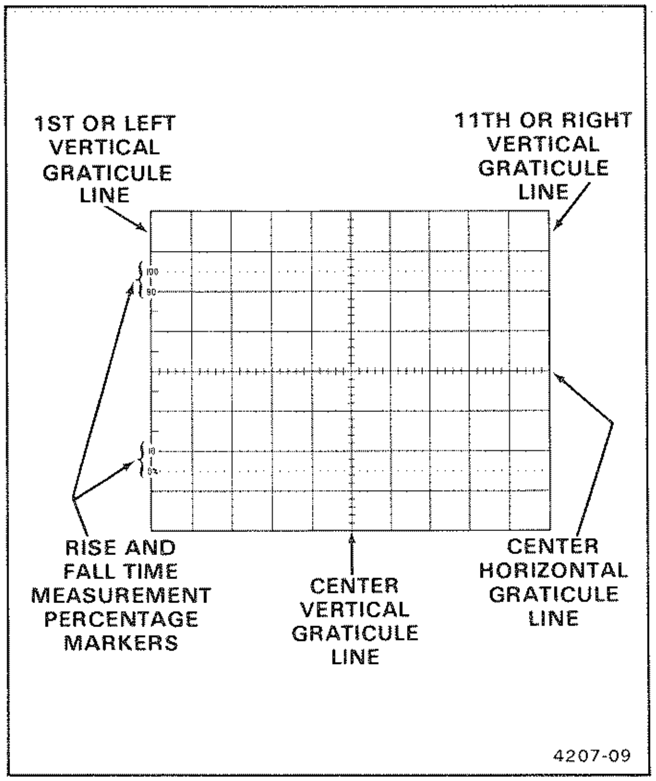


Figure 4-1. Graticule measurement markings.

GROUNDING

The most reliable signal measurements are made when the 2220 and the unit under test are connected by a common reference (ground lead) in addition to the signal lead or probe. The probe's ground lead provides the best grounding method for signal interconnection and ensures the maximum amount of signal-lead shielding in the probe cable. A separate ground lead can also be connected from the unit under test to the oscilloscope GND receptacle located on the oscilloscope's front panel.

SIGNAL CONNECTIONS

Probes

Generally, the accessory probes supplied with the instrument provide the most convenient means of connecting a signal to the vertical inputs of the instrument. The probe and probe lead are shielded to prevent pickup of electromagnetic interference, and the 10X attenuation factor of the probe offers a high input impedance that minimizes signal loading in the circuitry under test.

Both the probe itself and the probe accessories should be handled carefully at all times to prevent damage to them. Avoid dropping the probe body. Striking a hard surface can cause damage to both the probe body and the probe tip. Exercise care to prevent the cable from being crushed or kinked. Do not place excessive strain on the cable by pulling.

The standard-accessory probe is a compensated 10X voltage divider. It is a resistive voltage divider for low frequencies and a capacitive voltage divider for high-frequency signal components. Inductance introduced by either a long signal or ground lead forms a series-resonant circuit. This circuit will affect system bandwidth and will ring if driven by a signal containing significant frequency components at or near the circuit's resonant frequency.

Oscillations (ringing) can then appear on the oscilloscope waveform display and distort the true signal waveshape. Always keep both the ground lead and the probe signal-input connections as short as possible to maintain the best waveform fidelity.

Misadjustment of probe compensation is a common source of measurement error. Due to variations in oscilloscope input characteristics, probe compensation should be checked and adjusted, if necessary, whenever the probe is moved from one oscilloscope to another or between channels. See the "Probe Compensation" procedure in "Operator's Checks and Adjustments," or consult the instructions supplied with the probe.

Coaxial Cables

Cables may also be used to connect signals to the vertical input connectors, but they may have considerable effect on the accuracy of a displayed waveform. To maintain the original frequency characteristics of an applied signal, only high-quality, low-loss coaxial cables should be used. Coaxial cables should be terminated at both ends in their characteristic impedance. If this is not possible, use suitable impedance-matching devices.

INPUT-COUPLING CAPACITOR PRECHARGING

When the Input-Coupling switch is set to the GND position, the input signal is connected to ground through the input-coupling capacitor and a high value resistance. This series combination forms a precharging circuit that allows the input-coupling capacitor to charge to the average dc voltage level of the signal applied to the input connector. Thus, any large voltage transients that may accidentally be generated are not applied to the vertical amplifier's input when the input coupling is switched from GND to AC. The precharging network also provides a measure of protection to the external circuitry by reducing the current level that is drawn from the external circuitry while the input-coupling capacitor is charging.

If AC input coupling is in use, the following procedure should be followed whenever the probe tip is connected to a signal source having a different dc level than that previously applied. This procedure becomes especially useful if the dc-level difference is more than ten times the VOLTS/DIV switch setting.

1. Set the AC-GND-DC (input coupling) switch to GND before connecting the probe tip to a signal source.

2. Touch the probe tip to the oscilloscope GND connector.

3. Wait several seconds for the input-coupling capacitor to discharge.

4. Connect the probe tip to the signal source.

5. Wait several seconds for the input-coupling capacitor to charge to the dc level of the signal source.

6. Set the AC-GND-DC switch to AC. A signal with a large dc component can now be vertically positioned within the graticule area, and the ac component of the signal can be measured in the normal manner.

PLOTTING THE GRATICULE AND BAR GRAPH

The bar graph, graticule, and "TEKTRONIX 2220" label are normally only plotted on the the first acquisition after the AUTO PLOT button is depressed. Multiple plots may be avoided and the bar graph and graticule still plotted in one of the following ways:

1. If the instrument is acquiring normally, put the instrument in AUTO PLOT. Wait for the plot to start. Exit Auto Plot before the plot finishes.

2. In cases where no acquisitions are being made (Save, no valid triggers, etc.), the information can be plotted by putting the instrument in Auto Plot and pushing the MANUAL START button. The graticule and other information will be drawn as if it were the first plot of an Auto Plot cycle. Exit Auto Plot before making another acquisition unless Auto Plot mode is desired.

CANCELING A PLOT

Changing any of the following controls cancels plots in progress: VECTORS ON/OFF, PRETRIG, POSTTRIG, STORE/NONSTORE, VERTICAL MODE

OPERATOR'S CHECKS AND ADJUSTMENTS

To verify the operation and basic accuracy of your instrument before making measurements, perform the following checks and adjustment procedures. If adjustments are required beyond the scope of these operator's checks and adjustments, refer the instrument to qualified service personnel.

For new equipment checks, before proceeding with these instructions, refer to "Preparation for Use" in this manual to prepare the instrument for the initial start-up before applying power.

INITIAL SETUP

1. Verify that the POWER switch is OFF (switch is in the out position), then plug the power cord into the ac power outlet.

2. Press in the POWER switch (ON) and set the instrument controls to obtain a baseline trace:

Display

INTENSITY	Midrange
FOCUS	Best defined display

Vertical (Both Channels)

VERTICAL MODE	CH 1
POSITION	Midrange
VOLTS/DIV	5 mV
AC-GND-DC	DC
Var Volts/Div	CAL (in detent)
BW LIMIT	Off (button out)
X-Y Display	Off (button out)

Horizontal

SEC/DIV	0.5 ms
Var Sec/Div	CAL (in detent)
POSITION	Midrange
X10 Mag	Off (Var Sec/Div knob in)

Triggers

VAR HOLDOFF	NORM (fully counterclockwise)
INT	VERT MODE
SOURCE	INT
Mode	P-P AUTO
LEVEL	For a stable display (with signal applied)
SLOPE	OUT (plus—button out)
HF REJECT	OFF (fully counterclockwise)

Storage

STORE/NON STORE	NON STORE (button out)
SAVE/CONTINUE	CONTINUE (button out)
PRETRIG	Off (button out)
POST TRIG	POST TRIG (button in)
SAVE REF/ERASE	ERASE (button out)
DISPLAY/OFF	OFF (button out)
VECTORS ON/OFF	ON (button in)
AUTO/MANUAL	MANUAL (button out)

3. Adjust the INTENSITY and FOCUS controls for the desired display brightness and best focused trace.

4. Adjust the Vertical and Horizontal POSITION controls to position the trace within the graticule area.

5. Allow the instrument to warm up for 20 minutes before commencing the adjustment procedures. Reduce the INTENSITY level during the waiting time.

TRACE ROTATION ADJUSTMENT

NOTE

Normally, the trace will be parallel to the center horizontal graticule line, and TRACE ROTATION adjustment is not required.

1. Preset the instrument controls and obtain a baseline trace as described in "Initial Setup".

2. Use the Channel 1 POSITION control to move the baseline trace to the center horizontal graticule line.

3. If the baseline trace is not parallel to the center horizontal graticule line, use a small-bladed screwdriver or alignment tool to adjust the TRACE ROTATION control and align the trace with the graticule line.

PROBE COMPENSATION

Misadjustment of probe compensation is a source of measurement error. The attenuator probes are equipped with a compensation adjustment. To ensure optimum measurement accuracy, always check probe compensation before making measurements. Probe compensation is accomplished by:

1. Preset the instrument controls and obtain a baseline trace as described in "Initial Setup".

2. Connect the two 10X probes (supplied with the instrument) to the CH 1 OR X and CH 2 OR Y input connectors.

3. Remove the hook tip from the end of each probe.

NOTE

While the probe tip is in the PROBE ADJUST connector, use care not to to break off the probe tip.

4. Insert the Channel 1 probe tip into the PROBE ADJUST connector.

5. Use the CH 1 POSITION control to vertically center the display. If necessary, adjust the A TRIGGER LEVEL control to obtain a stable display on the plus (OUT) SLOPE.

NOTE

Refer to the instruction manual supplied with the probe for more complete information on the probe and probe compensation.

6. Check the waveform display for overshoot and rounding (see Figure 5-1); if necessary, use a small-bladed screwdriver to adjust the probe compensation for a square front corner on the waveform.

7. Remove the Channel 1 probe tip from the PROBE ADJUST connector.

8. Insert the Channel 2 probe tip into the PROBE ADJUST connector.

9. Use the VERT MODE Menu to select CH 2 for display.

10. Set the TRIGGER INT switch to CH 2.

11. Use the CH 2 POSITION control to vertically center the display.

12. Check the waveform display for overshoot and rounding (see Figure 5-1); if necessary, use a small-bladed screwdriver to adjust the probe compensation for a square front corner on the waveform.

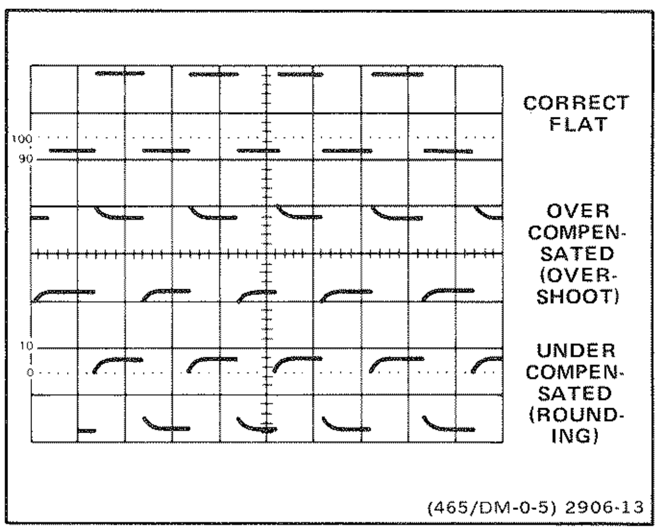


Figure 5-1. Probe compensation.

BASIC APPLICATIONS

INTRODUCTION

The procedures in this section enable the operator to make basic measurements using the capabilities of the oscilloscope. Many of these measurements can be obtained with either the nonstorage mode or one of the storage modes. After becoming familiar with the capabilities of the instrument, the operator can choose the best method for making a particular measurement. Read the "Operating Considerations" part of this manual for information on signal connections, grounding, and other general operating information that may be useful in your application.

When the procedures call for obtaining a baseline display, refer to Initial Setup in the "Operator's Checks and Adjustments" part of this manual. The initial control settings listed in the Initial Setup procedure are considered as the initial control setup. Alternate control settings are usually required for making a specific measurement. The operator must determine the correct control settings applicable to VOLTS/DIV, SEC/DIV, TRIGGER, and other controls to obtain a stable display of the desired display.

OSCILLOSCOPE DISPLAYS

The following procedures will allow the operator to set up and operate the instrument to obtain the most commonly used oscilloscope displays. Verify that the POWER switch is OFF (push button out), then plug the power cord into the ac-power-input source outlet.

NON STORE Displays

The following procedures are used to obtain the most commonly used conventional oscilloscope displays.

Normal Sweep Display

1. Preset the instrument controls and obtain a baseline display.

2. Using the supplied 10X probe or a properly terminated coaxial cable, apply a signal to the CH1 OR X input connector. The signal source output impedance determines the termination required when using a coaxial cable to interconnect test equipment.

NOTE

Instrument warm-up time required to meet all specification accuracies is 20 minutes.

3. Advance the INTENSITY control until the display is visible. If the display is not visible with the INTENSITY control at midrange, press the BEAM FIND button and hold it in while adjusting the Channel 1 VOLTS/DIV switch to reduce the vertical display size. Center the compressed display using the Vertical and Horizontal POSITION controls. Release the BEAM FIND button.

4. Set the Channel 1 VOLTS/DIV switch and the Vertical and Horizontal POSITION controls to locate the display within the graticule area.

5. Adjust the TRIGGER LEVEL control for a stable, triggered display.

6. Set the SEC/DIV switch for the desired number of cycles of displayed signal. Then adjust the FOCUS control for the best-defined display.

Magnified Sweep Display

1. Preset the instrument controls and obtain a baseline display.

2. Adjust the Horizontal POSITION control to move the area to be magnified to within the center crt graticule division (0.5 division on each side of the center vertical graticule line). Change the SEC/DIV switch setting as required.

3. Pull out the SEC/DIV Variable knob and adjust the Horizontal POSITION control for precise positioning of the magnified display.

X-Y Display

1. Preset the instrument controls and obtain a baseline display.

2. Rotate the INTENSITY control fully counterclockwise and disconnect the CH 1 input signal.

3. Use two coaxial cables or probes of equal delay and apply the vertical signal (Y-axis) to the CH 2 OR Y input connector and horizontal signal (X-axis) to the CH 1 OR X input connector.

4. Set the VERTICAL MODE switch to X-Y (button in).

5. Advance the INTENSITY control until the display is visible. If the display is not visible with the INTENSITY control at midrange, press and hold in the BEAM FIND button while adjusting the Channel 1 and Channel 2 VOLTS/DIV switches until the display is reduced in size, both vertically and horizontally. Center the compressed display with the POSITION controls (Channel 2 POSITION control for vertical movement; Horizontal POSITION control for horizontal movement). Release the BEAM FIND button. Adjust the FOCUS control for a well-defined display.

NOTE

The display obtained when sinusoidal signals are applied to the X- and Y-axis is called a Lissajous Figure. This display is commonly used to compare the frequency and phase relationship of the two input signals. The frequency relationship of the two input signals determines the pattern seen. The pattern will be stable only if a common divisor exists between the two frequencies.

6. Set the X-Y button to the out position and disconnect the input signals from the vertical input connectors.

Single Sweep Display

1. Preset the instrument controls and obtain a baseline display.

2. For random signals, set the TRIGGER LEVEL control to trigger the sweep on a signal that is approximately the same amplitude as the random signal.

3. Press in the SGL SWP RESET button for a moment. The next trigger pulse will initiate the sweep, and a single trace will be displayed. If no trigger signal is present, the READY indicator LED should illuminate to indicate that the SWEEP Generator circuit is set to initiate a sweep when a trigger signal is received.

4. When the single sweep has been triggered and the sweep is completed, the sweep logic circuitry is locked out. Another sweep cannot be generated until the SGL SWP RESET button is pressed in to set the Sweep Generator to the READY condition.

DIGITAL STORAGE DISPLAYS

The following procedures explain how to set up and use the digital storage capabilities of the instrument. The front-panel control selections sets the conditions under which a waveform is acquired for display. Display amplitude is controlled by the VOLTS/DIV switches. The storage time base is controlled by the SEC/DIV switch, and the DISPLAY POS controls. The SEC/DIV switch and the TRIGGER Mode switch will acquire and display waveforms using parameters of Table 3-1.

STORE Mode Display

1. Preset instrument controls and obtain a baseline trace.

2. Set the PRETRIG/POST TRIG/BOTH=MIDTRIG switches for the desired trigger position.

3. Set the STORE/NON STORE switch to the STORE position (button in).

4. A STORE mode display may be expanded horizontally by the X10 Magnifier switch.

SAVE Mode Display

1. Acquire a waveform using the "STORE Mode Display" procedure.

2. Set the SAVE/CONTINUE switch to the SAVE position (button in).

SAVE REF Display

1. Acquire the waveform to be used as a reference using the previous "SAVE Mode Display" procedure.

2. Set the SAVE REF/ERASE switch to the SAVE REF position (button in).

3. Push in the DISPLAY/OFF button to display the stored reference waveform. A new reference waveform is saved each time the SAVE REF/ERASE button is pushed in; the stored reference waveform is erased when the SAVE REF/ERASE button is in the ERASE (button out) position.

4. Pull out the X10 MAG switch to horizontally expand the SAVE REF display by 10 times, if desired.

MAKING NONSTORAGE MEASUREMENTS

The following procedures will enable the operator to perform some basic measurements and familiarize the operator with the conventional oscilloscope capabilities of the 2220.

AC PEAK-TO-PEAK VOLTAGE

To make a peak-to-peak voltage measurement, use the following procedure:

NOTE

This procedure may also be used to make voltage measurements between any two points on the waveform.

1. Preset instrument controls and obtain a baseline trace.

2. Apply the ac signal to either vertical-channel input connector and set the VERTICAL MODE switches to display the channel used.

3. Set the appropriate VOLTS/DIV switch to display about five divisions of the waveform, ensuring that the VOLTS/DIV Variable control is in the CAL detent.

4. Adjust the TRIGGER LEVEL control to obtain a stable display.

5. Adjust the SEC/DIV switch to display several cycles of the waveform.

6. Vertically position the displayed waveform so that the negative peak of the waveform coincides with one of the horizontal graticule lines (see Figure 6-1, Point A).

7. Horizontally position the display so that one of the positive peaks coincides with the center vertical graticule line (see Figure 6-1, Point B).

8. Measure the vertical deflection from peak to peak (see Figure 6-1, Point A to Point B).

NOTE

A more accurate value can be obtained by measuring from the top of a peak to the top of a valley. This eliminates trace thickness from the measurement.

9. Calculate the peak-to-peak voltage, using the following formula:

$$\text{Volts (p-p)} = \text{Vertical Deflection (Divisions)} \times \text{VOLTS/DIV Switch Setting} \times \text{Probe Attenuation Factor}$$

EXAMPLE: The measured peak-to-peak vertical deflection is 5 divisions (see Figure 6-1) with a VOLTS/DIV switch setting of 0.5 V, using a 10X probe.

Substituting the given values:

$$\text{Volts (p-p)} = 5 \text{ div} \times 0.5 \text{ V/div} \times 10 = 25 \text{ V}$$

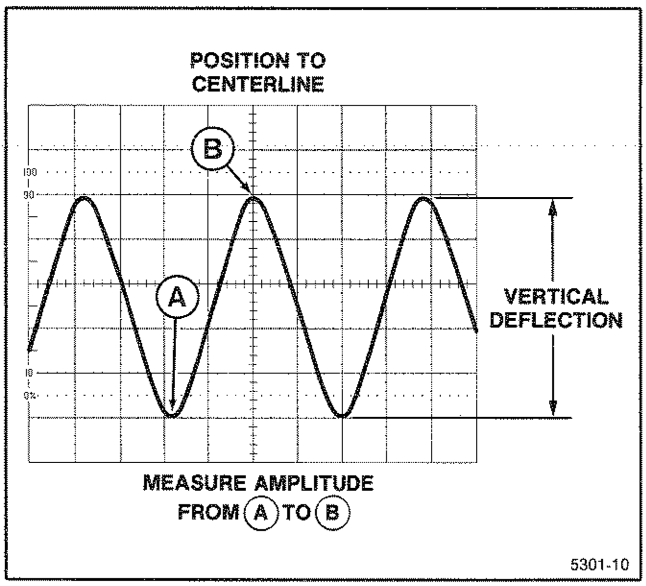


Figure 6-1. Peak-to-peak waveform voltage.

GROUND REFERENCED DC VOLTAGE

NOTE

Either channel input connector may be used for the signal input. Use the VERTICAL MODE switches to select the appropriate channel for display.

1. Apply the signal to be measured to the selected channel input and obtain a NON STORE display.

2. Ensure that the VOLTS/DIV Variable control is in the calibrated detent and determine the polarity of the voltage to be measured as follows:

   a. Set the AC-GND-DC switch to GND and vertically position the baseline trace to the center horizontal graticule line.

   b. Set the AC-GND-DC switch to DC. If the waveform moves above the center line of the crt, the voltage is positive. If the waveform moves below the center line of the crt, the voltage is negative.

3. Set the AC-GND-DC switch to GND and position the baseline trace to a convenient reference line. For example, if the voltage to be measured is positive, position the baseline trace to the bottom graticule line. If a negative voltage is to be measured, position the baseline trace to the top graticule line.

4. Set the AC-GND-DC switch to DC. Measure the divisions of vertical deflection between the reference line and the desired point on the waveform (see Figure 6-2).

5. Calculate the voltage, using the following formula:

$$\text{Voltage} = \text{Vertical Distance (Divisions)} \times \text{Polarity } (+ \text{ or } -) \times \text{VOLTS/DIV Switch Setting}$$

NOTE

The attenuation factor of the probe being used must be included if it is not a 10X scale-factor-switching probe.

EXAMPLE: The vertical distance measured is 4.6 divisions (see Figure 6-2). The waveform is above the reference line, the VOLTS/DIV switch is set to 2 V, and a 10X scale-factor-switching probe is used.

Substituting the given values into the formula:

$$\text{Voltage} = 4.6 \text{ divisions} \times (+1) \times 2 \text{ V/div} = +9.2 \text{ V}$$

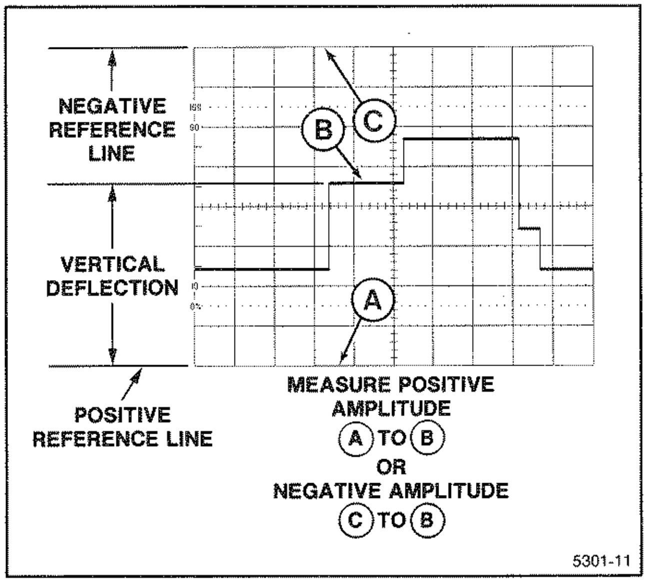


Figure 6-2. Ground referenced voltage measurement.

ALGEBRAIC ADDITION

With the VERTICAL MODE switches in the ADD position, the waveform displayed represents the algebraic sum of the signals applied to the Channel 1 and Channel 2 input connectors (CH 1 + CH 2). If the Channel 2 INVERT switch is pressed in, the resulting waveform is the difference of the signals applied to the Channel 1 and Channel 2 input connectors (CH 1−CH 2). The total deflection factor in the ADD mode is equal to the deflection factor indicated by either VOLTS/DIV switch (when both VOLTS/DIV switches are set to the same deflection factor). A common use for the ADD mode is to provide a dc offset for a signal riding on top of a dc level.

The following general precautions should be observed when using the ADD mode:

a. Do not exceed the input voltage rating of the oscilloscope.

b. Do not apply signals that exceed the equivalent of about eight times the VOLTS/DIV switch setting, since large voltages may distort the display. For example, with a VOLTS/DIV switch setting of 0.5 V, the voltage applied to that channel input should not exceed about 4 volts.

EXAMPLE: Using the graticule center line as 0 V, the Channel 1 signal is at a 3-division, positive dc level (see Figure 6-3A).

1. Multiply 3 divisions by the VOLTS/DIV switch setting to determine the dc-level value.

2. To the Channel 2 input connector, apply a negative dc level (or positive level, using the Channel 2 INVERT switch) whose value was determined in step 1 (see Figure 6-3B).

3. Select ADD and BOTH VERTICAL MODE to place the resultant display within the operating range of the Vertical POSITION controls (see Figure 6-3C).

COMMON-MODE REJECTION

The ADD mode can also be used to display signals that contain undesirable frequency components. The undesirable components can be eliminated through common-mode rejection. The precautions given under the preceding "Algebraic Addition" procedure should be observed.

EXAMPLE: The signal applied to the Channel 1 input connector contains unwanted frequency components (see Figure 6-4A). To remove the undesired components, use the following procedure:

1. Preset instrument controls and obtain a baseline trace.

2. Apply the signal containing the unwanted components to the Channel 1 input.

3. Apply the unwanted signal to the Channel 2 input.

4. Select BOTH and ALT VERTICAL MODE and press in the Channel 2 INVERT button.

5. Adjust the Channel 2 VOLTS/DIV switch and Variable control so the Channel 2 display is approximately the same amplitude as the undesired portion of the Channel 1 display (see Figure 6-4A).

6. Select ADD VERTICAL MODE and slightly readjust the Channel 2 VOLTS/DIV Variable control for maximum cancellation of the undesired signal component (see Figure 6-4B).

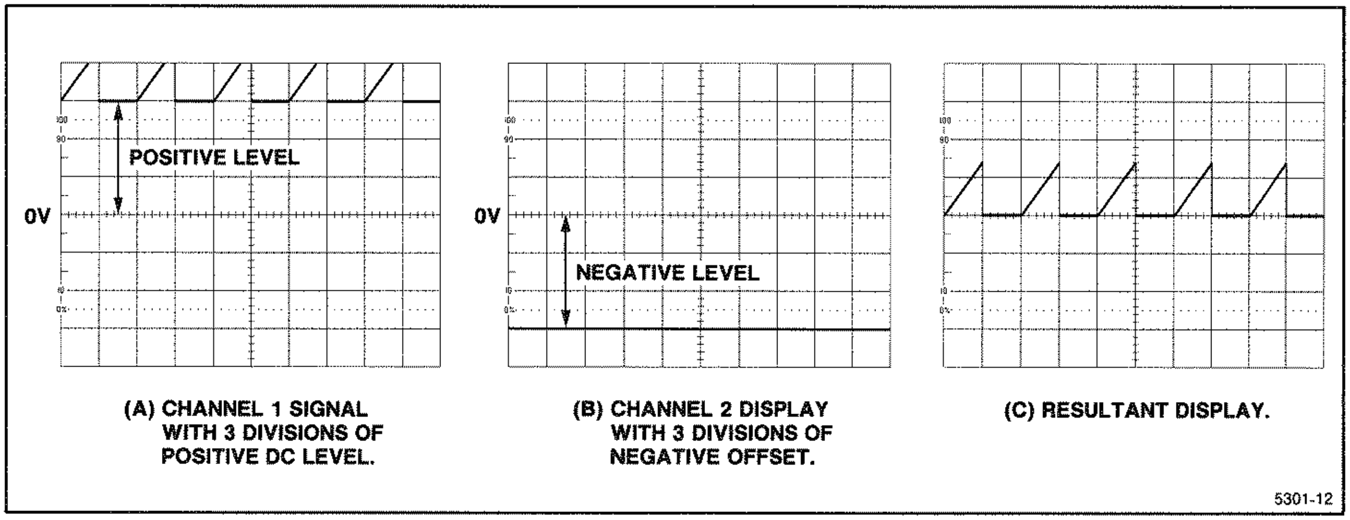


Figure 6-3. Algebraic addition.

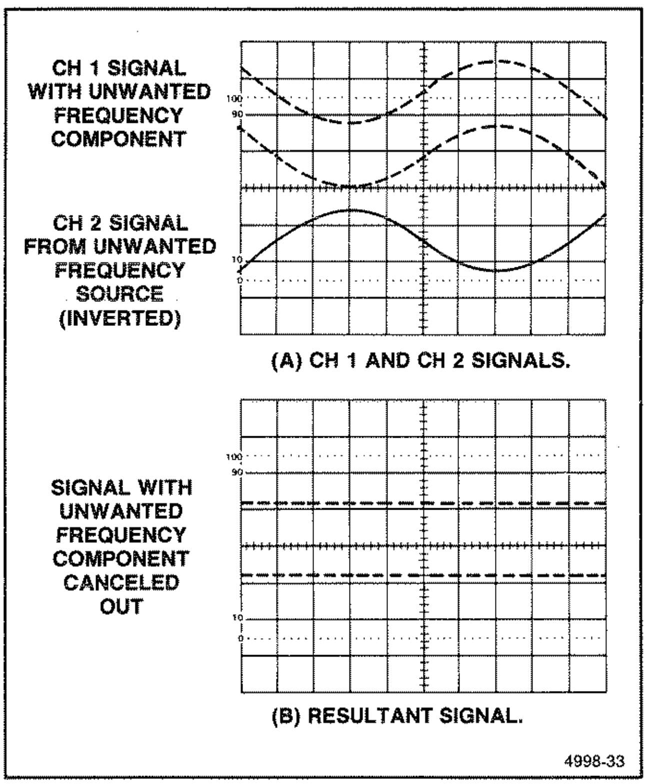


Figure 6-4. Common-mode rejection.

TIME DURATION

To measure time between two points on a waveform, use the following procedure:

1. Preset instrument controls and obtain a baseline trace.

2. Apply the signal to either vertical-channel input connector and set the VERTICAL MODE switches to display the channel used.

3. Adjust the TRIGGER LEVEL control to obtain a stable display.

4. Set the SEC/DIV control to display one complete period of the waveform. Ensure that the SEC/DIV Variable control is in the CAL detent.

5. Position the display to place the time-measurement points on the center horizontal graticule line (see Figure 6-5).

6. Measure the horizontal distance between the time-measurement points.

Substituting the given values:

$$\text{Time Duration} = 8.3 \text{ div} \times 2 \text{ ms/div} = 16.6 \text{ ms}$$

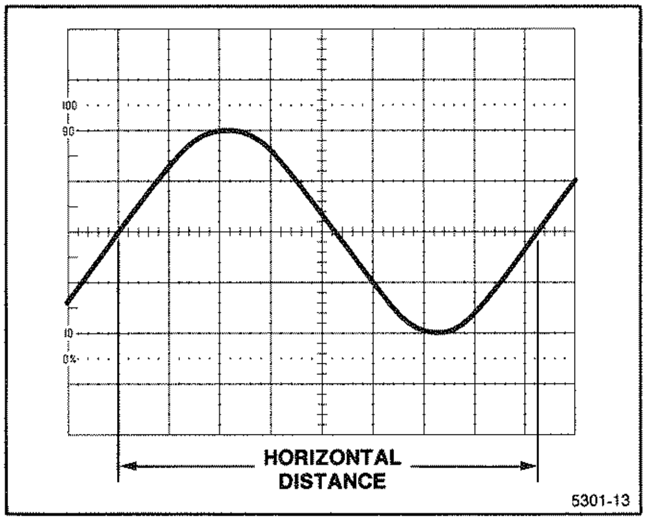


Figure 6-5. Time duration.

7. Calculate time duration, using the following formula:

$$\text{Time Duration} = \frac{\text{Horizontal Distance (Divisions)} \times \text{SEC/DIV Switch Setting}}{\text{Magnification Factor}}$$

EXAMPLE: The distance between the time-measurement points is 8.3 divisions (see Figure 6-5), and the SEC/DIV switch is set to 2 ms. The X10 Magnifier switch is pushed in (X1 magnification).

AMPLITUDE COMPARISON

In some applications it may be necessary to establish a set of deflection factors other than those indicated by the VOLTS/DIV switch settings. This is useful for comparing unknown signals to a reference signal of known amplitude. To accomplish this, a reference signal of known amplitude is first set to an exact number of vertical divisions by adjusting the VOLTS/DIV switch and Variable control. Unknown signals can then be quickly and accurately compared with the reference signal without disturbing the setting of the VOLTS/DIV Variable control. The procedure is as follows.

1. Preset instrument controls and obtain a baseline trace.

2. Apply the reference signal to either vertical channel input and set the VERTICAL MODE switch to display the channel used.

3. Set the amplitude of the reference signal to an exact number of vertical divisions by adjusting the VOLTS/DIV switch and VOLTS/DIV Variable control.

4. Establish a vertical conversion factor, using the following formula (reference signal amplitude must be known):

$$\text{Vertical Conversion Factor} = \frac{\text{Reference Signal Amplitude (Volts)}}{\text{Vertical Deflection (Divisions)} \times \text{VOLTS/DIV Switch Setting}}$$

5. Disconnect the reference signal and apply the unknown signal to be measured to the same channel input. Adjust the VOLTS/DIV switch to a setting that provides sufficient vertical deflection to make an accurate measurement. Do not readjust the VOLTS/DIV Variable control.

6. Establish an arbitrary deflection factor, using the following formula:

$$\text{Arbitrary Deflection Factor} = \text{Vertical Conversion Factor} \times \text{VOLTS/DIV Switch Setting}$$

7. Measure the vertical deflection of the unknown signal in divisions and calculate its amplitude using the following formula:

$$\text{Unknown Signal Amplitude} = \text{Arbitrary Deflection Factor} \times \text{Vertical Deflection (Divisions)}$$

EXAMPLE: The reference signal amplitude is 30 V, with a VOLTS/DIV switch setting of 5 V and the VOLTS/DIV Variable control adjusted to provide a vertical deflection of exactly 4 divisions.

Substituting these values in the Vertical Conversion Factor formula:

$$\text{Vertical Conversion Factor} = \frac{30\ \text{V}}{4\ \text{div} \times 5\ \text{V/div}} = 1.5$$

Continuing, for the unknown signal the VOLTS/DIV switch setting is 1, and the peak-to-peak amplitude spans five vertical divisions. The Arbitrary Deflection Factor is then determined by substituting values in the formula:

$$\text{Arbitrary Deflection Factor} = 1.5 \times 1\ \text{V/div} = 1.5\ \text{V/div}$$

The amplitude of the unknown signal can then be determined by substituting values in the unknown signal amplitude formula:

$$\text{Amplitude} = 1.5\ \text{V/div} \times 5\ \text{div} = 7.5$$

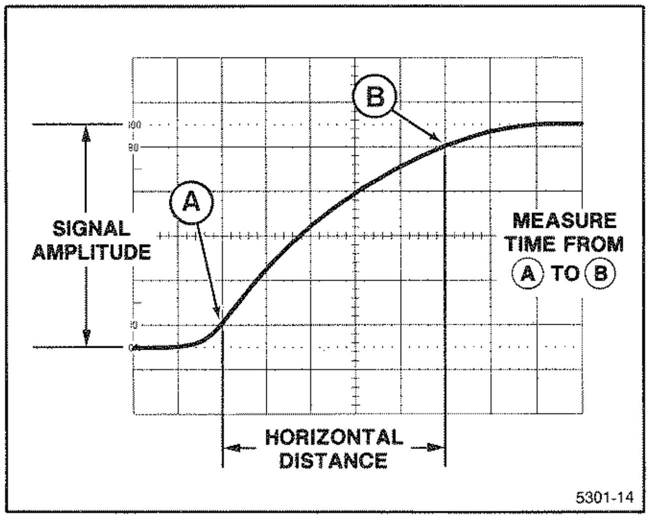


Figure 6-6. Rise time.

FREQUENCY

The frequency of a recurrent signal can be determined from its time-duration measurement as follows:

1. Measure the time duration of one waveform cycle using the preceding "Time Duration" measurement procedure.

2. Calculate the reciprocal of the time-duration value to determine the frequency of the waveform.

EXAMPLE: The signal in Figure 6-5 has a time duration of 16.6 ms.

Calculating the reciprocal of time duration:

$$\text{Frequency} = \frac{1}{\text{TimeDuration}} = \frac{1}{16.6\ \text{ms}} = 60\ \text{Hz}$$

RISE TIME

Rise-time measurements use the same methods as time duration, except that the measurements are made between the 10% and 90% points on the leading edge of the waveform (see Figure 6-6). Fall time is measured between the 90% and 10% points on the trailing edge of the waveform.

1. Preset instrument controls and obtain a baseline trace.

2. Apply an exact 5-division signal to either vertical-channel input connector and set the VERTICAL MODE switches to display the channel used. Ensure that the VOLTS/DIV Variable control is in the CAL detent.

NOTE

For rise time greater that 0.2 μs, the VOLTS DIV Variable control may be used to obtain an exact 5-division display.

3. Set the TRIGGER SLOPE switch to OUT. Use a sweep-speed setting that displays several complete cycles or events (if possible).

4. Adjust the vertical positioning so that the zero reference of the waveform touches the 0% graticule line and the top of the waveform touches the 100% graticule line (see Figure 6-6).

5. Set the SEC/DIV switch for a single-waveform display, with the rise time spread horizontally as much as possible.

6. Horizontally position the display so the 10% point on the waveform intersects the second vertical graticule line (see Figure 6-6, Point A).

7. Measure the horizontal distance between the 10% and 90% points and calculate the time duration using the following formula:

$$\text{Rise Time} = \frac{\text{Horizontal Distance (Divisions)} \times \text{SEC/DIV Switch Setting}}{\text{Magnification Factor}}$$

EXAMPLE: The horizontal distance between the 10% and 90% points is 5 divisions (see Figure 6-6), and the SEC/DIV switch is set to 1 μs. The X10 magnifier knob is pushed in (X1 magnification).

Substituting the given values in the formula:

$$\text{Rise Time} = \frac{5 \text{ div} \times 1\ \mu\text{s/div}}{1} = 5\ \mu\text{s}$$

TIME DIFFERENCE BETWEEN TWO TIME-RELATED PULSES

The calibrated sweep speed and dual-trace features of the instrument allow measurement of the time difference between two separate events. To measure time difference, use the following procedure:

1. Preset instrument controls and obtain a baseline trace.

2. Set the TRIGGER INT switch to CH 1.

3. Set both AC-GND-DC switches to the same position, depending on the type of input coupling desired.

4. Using either probes or cables with equal time delays, connect a known reference signal to the Channel 1 input and the comparison signal to the Channel 2 input.

5. Set both VOLTS/DIV switches for 4- or 5-division displays.

6. Select BOTH VERTICAL MODE; then select either ALT or CHOP, depending on the frequency of the input signals.

7. Adjust the TRIGGER LEVEL control for a stable display.

8. Set the SEC/DIV switch to a sweep speed which provides three or more divisions of horizontal separation between the reference points on the two displays. Center each of the displays vertically (see Figure 6-7).

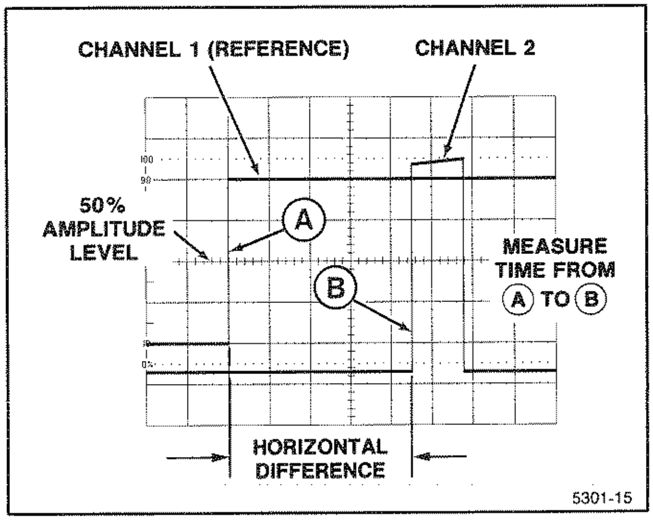


Figure 6-7. Time difference between two time-related pulses.

9. Measure the horizontal difference between the two signal reference points and calculate the time difference using the following formula:

$$\text{Time Difference} = \frac{\text{SEC/DIV Switch Setting} \times \text{Horizontal Difference (Divisions)}}{\text{Magnfication Factor}}$$

EXAMPLE: The SEC/DIV switch is set to 50 μs, the X10 magnifier knob is pulled out, and the horizontal difference between waveform measurement points is 4.5 divisions.

Substituting the given values in the formula:

$$\text{Time Difference} = \frac{50\ \mu\text{s/div} \times 4.5 \text{ div}}{10} = 22.5\ \mu\text{s}$$

TIME DIFFERENCE BETWEEN REPETITIVE PULSES

1. Preset instrument controls and obtain a baseline trace.

2. Select a VOLTS/DIV switch setting that gives about 5 divisions of display amplitude.

3. Use the selected channel Vertical POSITION control to center the display.

4. Set the SEC/DIV switch to display the points of interest between which the measurement is to be made.

5. Read the time difference between pulses at the points of interest (see Figure 6-8).

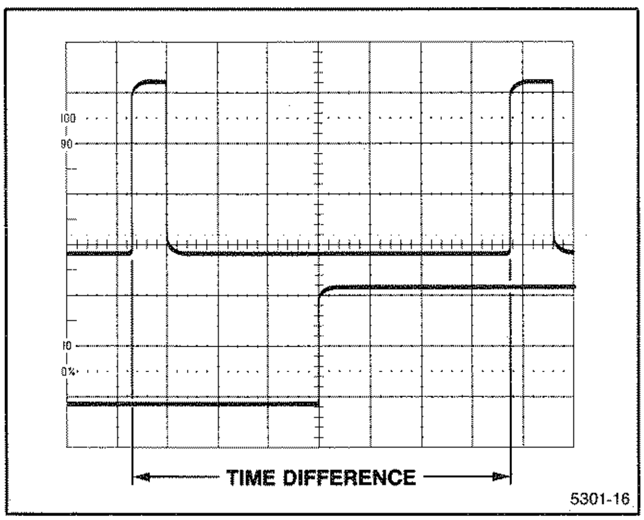


Figure 6-8. Time difference between repetitive pulses.

PHASE DIFFERENCE

In a similar manner to "Time Difference", phase comparison between two signals of the same frequency can be made using the dual-trace feature of the instrument. This method of phase difference measurement can be used up to the frequency limit of the vertical system. To make a phase comparison, use the following procedure:

1. Preset instrument controls and obtain a baseline trace, then set the TRIGGER INT switch to CH 1.

2. Set both AC-GND-DC switches to the same position, depending on the type of input coupling desired.

3. Using either probes or coaxial cables with equal time delays, connect a known reference signal to the Channel 1 input and the unknown signal to the Channel 2 input.

4. Select BOTH VERTICAL MODE; then select either ALT or CHOP, depending on the frequency of the input signals. The reference signal should precede the comparison signal in time.

5. If the two signals are of opposite polarity, press in the Channel 2 INVERT button to invert the Channel 2 display.

6. Set both VOLTS/DIV switches and both Variable controls so the displays are equal in amplitude.

7. Adjust the TRIGGER LEVEL control for a stable display.

8. Set the SEC/DIV switch to a sweep speed which displays about one full cycle of the waveforms.

9. Position the displays and adjust the SEC/DIV Variable control so that one reference-signal cycle occupies exactly eight horizontal graticule divisions at the 50% rise-time points (see Figure 6-9). Each division of the graticule now represents 45° of the cycle (360° ÷ 8 divisions), and the horizontal graticule calibration can be stated as 45° per division.

10. Measure the horizontal difference between corresponding points on the waveforms at a common horizontal graticule line (50% of rise time) and calculate the phase difference using the following formula:

$$\text{Phase Difference} = \begin{matrix}\text{Horizontal}\\ \text{Difference}\\ \text{(Divisions)}\end{matrix} \times \begin{matrix}\text{Horizontal}\\ \text{Graticule}\\ \text{Calibration (deg/div)}\end{matrix}$$

EXAMPLE: The horizontal difference is 0.6 division with a graticule calibration of 45° per division as shown in Figure 6-9.

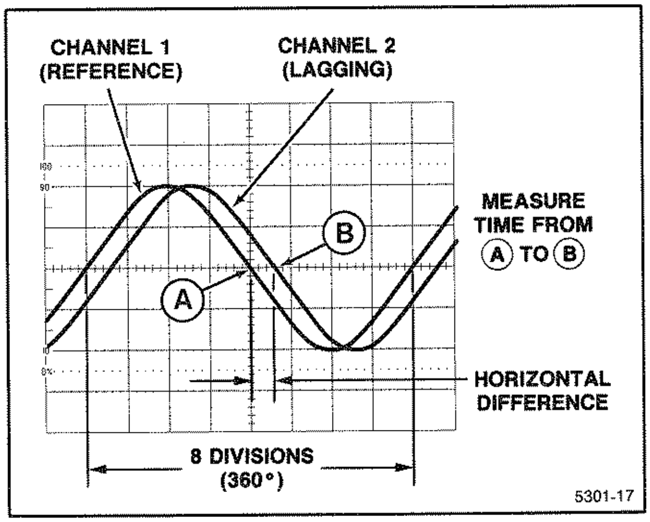


Figure 6-9. Phase difference.

Substituting the given values into the phase difference formula:

$$\text{Phase Difference} = 0.6 \text{ div} \times 45°/\text{div} = 27°$$

More accurate phase measurements can be made by using the X10 Magnifier to increase the sweep speed without changing the SEC/DIV Variable control setting.

EXAMPLE: If the sweep speed were increased 10 times with the magnifier (X10 Magnifier out), the magnified horizontal graticule calibration would be 45°/division divided by 10 (or 4.5°/division). Figure 6-10 shows the same signals illustrated in Figure 6-9, but magnifying the displays results in a horizontal difference of 6 divisions between the two signals.

Substituting the given values in the phase difference formula:

$$\text{Phase Difference} = 6 \text{ div} \times 4.5°/\text{div} = 27°$$

TIME COMPARISON

In a similar manner to "Amplitude Comparison", repeated time comparisons between unknown signals and a reference signal (e.g., on assembly-line test) may be easily and accurately measured with the instrument. To accomplish this, a reference signal of known time duration is first set to an exact number of horizontal divisions by adjusting the SEC/DIV switch and the SEC/DIV Variable control. Unknown signals can then be compared with the reference signal without disturbing the setting of the SEC/DIV Variable control. The procedure is as follows:

1. Set the time duration of the reference signal to an exact number of horizontal divisions by adjusting the SEC/DIV switch and the SEC/DIV Variable control.

2. Establish a horizontal conversion factor, using the following formula (reference-signal time duration must be known):

$$\begin{matrix}\text{Horizontal}\\ \text{Conversion}\\ \text{Factor}\end{matrix} = \frac{\begin{matrix}\text{Reference Signal}\\ \text{Time Duration (Seconds)}\end{matrix}}{\begin{matrix}\text{Horizontal Distance}\\ \text{(Divisions)}\end{matrix} \times \begin{matrix}\text{SEC/DIV}\\ \text{Switch Setting}\end{matrix}}$$

3. For the unknown signal, adjust the SEC/DIV switch to a setting that provides sufficient horizontal deflection to make an accurate measurement. Do not readjust the SEC/DIV Variable control.

4. Establish an arbitrary deflection factor, using the following formula:

$$\begin{matrix}\text{Arbitrary}\\ \text{Deflection}\\ \text{Factor}\end{matrix} = \begin{matrix}\text{Horizontal}\\ \text{Conversion}\\ \text{Factor}\end{matrix} \times \begin{matrix}\text{SEC/DIV}\\ \text{Switch}\\ \text{Setting}\end{matrix}$$

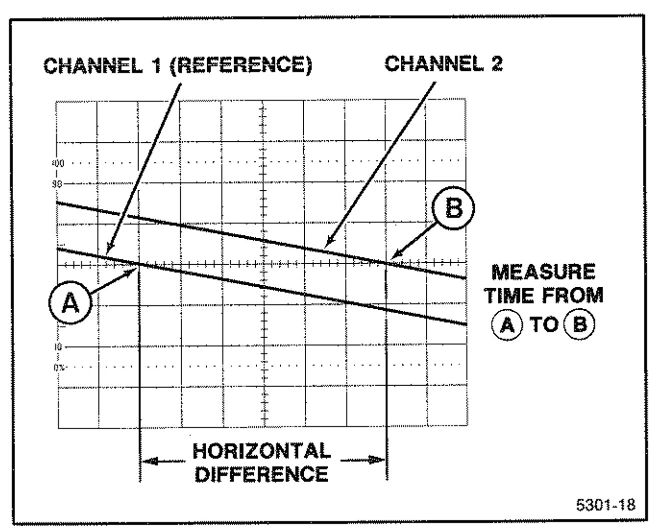


Figure 6-10. High-resolution phase difference.

5. Measure the horizontal distance of the unknown signal in divisions and calculate its time duration using the following formula:

$$\text{Time Duration} = \text{Arbitrary Deflection Factor} \times \text{Horizontal Distance (Divisions)}$$

EXAMPLE: The reference signal time duration is 2.19 ms, the SEC/DIV switch setting is 0.2 ms, and the SEC/DIV Variable control is adjusted to provide a horizontal distance of exactly 8 divisions.

Substituting the given values in the horizontal conversion factor formula:

$$\text{Horizontal ConversionFactor} = \frac{2.19 \text{ ms}}{8 \text{ div} \times 0.2 \text{ ms/div}} = 1.37$$

For the unknown signal the SEC/DIV switch setting is 50 μs, and one complete cycle spans seven horizontal divisions. The arbitrary deflection factor is then determined by substituting values in the formula:

$$\text{Arbitrary Deflection Factor} = 1.37 \times 50\ \mu\text{s/div} = 68.5\ \mu\text{s/div}$$

The time duration of the unknown signal can then be computed by substituting values in the formula:

$$\text{Time Duration} = 68.5\ \mu\text{s/div} \times 7 \text{ div} = 480\ \mu\text{s}$$

The frequency of the unknown signal is then calculated:

$$\text{Frequency} = \frac{1}{480\ \mu\text{s}} = 2.083 \text{ kHz}$$

SLOPE

The slope of a particular portion of a waveform is the rate of change of voltage with respect to time. The following procedure is useful for making the measurements required to determine the slope of a portion of a waveform.

1. Preset instrument controls and obtain a baseline trace.

2. Set the VOLTS/DIV switch to obtain about 5 divisions of vertical amplitude.

3. Set the SEC/DIV switch to horizontally spread the portion of the waveform to be measured across the width of the graticule area (see Figure 6-11).

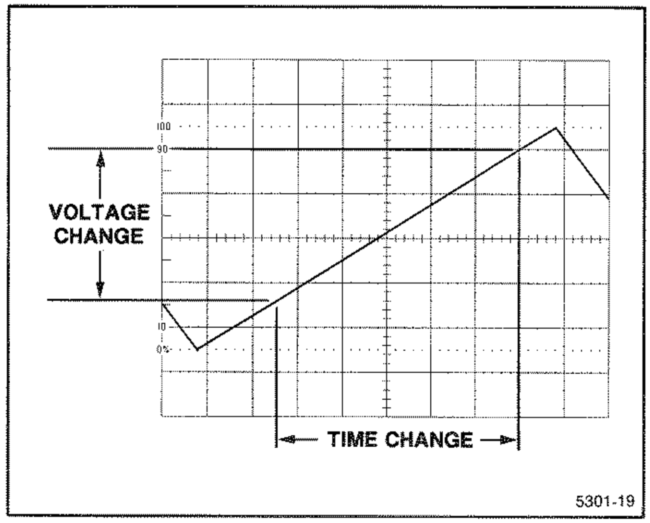


Figure 6-11. Slope.

4. Read the voltage difference between the waveform points of interest.

5. Read the time difference between the two measurement points of interest.

6. Slope is determined by using the measured voltage and time to calculate the rate of change using the following formula:

$$\text{Slope (rate of change)} = \frac{\text{Change in voltage}}{\text{Change in time}}$$

As an example, in Figure 6-11, the voltage difference between the measurement points is 1.74 V, and the time difference is 5.42 s.

Substituting these values into the formula:

$$\text{Slope} = \frac{1.74}{5.42 \text{ s}} = 0.32 \text{ V/s}$$

TV LINE SIGNAL

The following procedure is used to display a TV Line signal:

1. Preset instrument controls and select P-P AUTO/TV LINE TRIGGER Mode.

2. Apply the TV signal to either vertical-channel input connector and set the VERTICAL MODE switches to display the channel used.

3. Set the appropriate VOLTS/DIV switch to display 0.3 division or more of composite video signal.

4. Set the SEC/DIV switch to 10 μs.

5. Set the TRIGGER SLOPE switch to either OUT (for positive-going TV signal sync pulses) or IN (for negative-going TV signal sync pulses).

NOTE

To examine a TV Line signal in more detail, use the X10 Magnifier.

TV FIELD SIGNAL

The television feature of the instrument can also be used to display TV Field signals.

1. Preset instrument controls and obtain a baseline trace.

2. Set the TRIGGER Mode switch to TV FIELD (P-P AUTO and NORM buttons both pushed in) and set the SEC/DIV switch to 2 ms.

3. To display a single field, connect the TV signal to either vertical-channel input connector and set the VERTICAL MODE switch to display the channel used.

4. Set the appropriate VOLTS/DIV switch to display 2.5 divisions or more of composite video signal.

5. Set the TRIGGER SLOPE switch to either OUT (for positive-going TV signal sync pulses) or IN (for negative-going TV signal sync pulses).

6. To change the field that is displayed, momentarily interrupt the trigger signal by setting the AC-GND-DC switch to GND and then back to AC until the desired field is displayed.

NOTE

To examine a TV Field signal in more detail, use the X10 Magnifier.

7. To display either Field 1 or Field 2 individually, connect the TV signal to both CH 1 and CH 2 input connectors and select BOTH and ALT VERTICAL MODE.

8. Set the SEC/DIV switch to a faster sweep speed (displays of less than one full field). This will synchronize the Channel 1 display to one field and the Channel 2 display to the other field.

MAKING DIGITAL STORAGE MEASUREMENTS

The following procedures will enable the operator to perform some basic measurements and familiarize the operator with digital storage measurement techniques. The preceding NON STORE measurements may be performed in STORE mode by:

1. After presetting instrument controls and obtaining a baseline trace, set the STORE/NON STORE switch to the STORE position (button in).

2. Prior to making measurements on an acquired waveform, press in the SAVE ACQUISITION mode button to hold the acquired waveform and to provide a more stable display for measurement.

WAVEFORM COMPARISON

Repeated comparisons of newly acquired signals with a reference signal for amplitude, timing, or pulse-shaped analysis may be easily and accurately made using the SAVE REF function of the instrument.

1. Preset instrument controls and obtain a baseline trace.

2. Set the STORE/NON STORE switch to the STORE position (button in).

3. Select a VOLTS/DIV switch setting that gives the desired vertical deflection.

4. Set the SEC/DIV switch to display the reference signal with the desired sweep rate.

5. Push in the SAVE REF button to store the reference waveform into reference memory.

6. Set the DISPLAY/OFF switch to the DISPLAY position (button in) to display the saved reference waveform.

7. Acquire the waveform that is to be compared with the reference waveform.

NOTE

A stored reference will remain displayed until the DISPLAY/OFF button is set to the OFF position (button out). Switching the instrument to NON STORE removes stored waveforms from the display, but the saved reference waveforms remain in the digital memory for use upon return to a storage mode. Waveforms are erased from the SAVE REF digital memory when the SAVE REF/ERASE switch is set to the ERASE position (button out). A new reference waveform is saved when the SAVE REF/ERASE button is pushed in while in STORE mode.

8. Use the selected channel's Vertical POSITION control to overlay the newly acquired waveform on the reference waveform for making the comparison (see Fig. 6-12). The vertical deflection and sweep rate remain calibrated to allow direct measurement from the graticule.

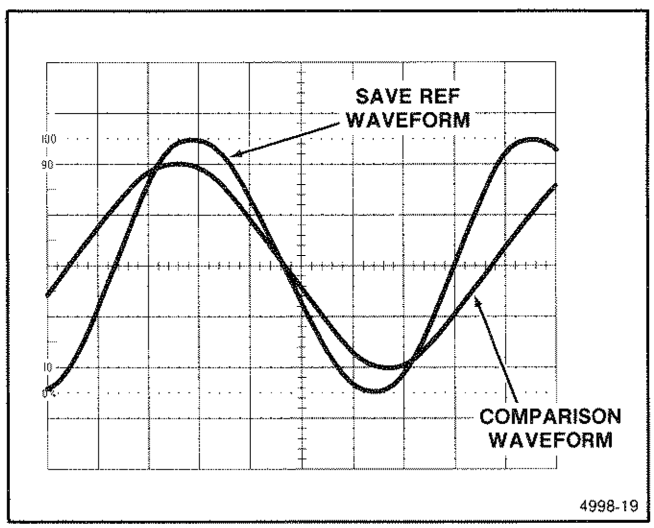


Figure 6-12. Waveform comparison.

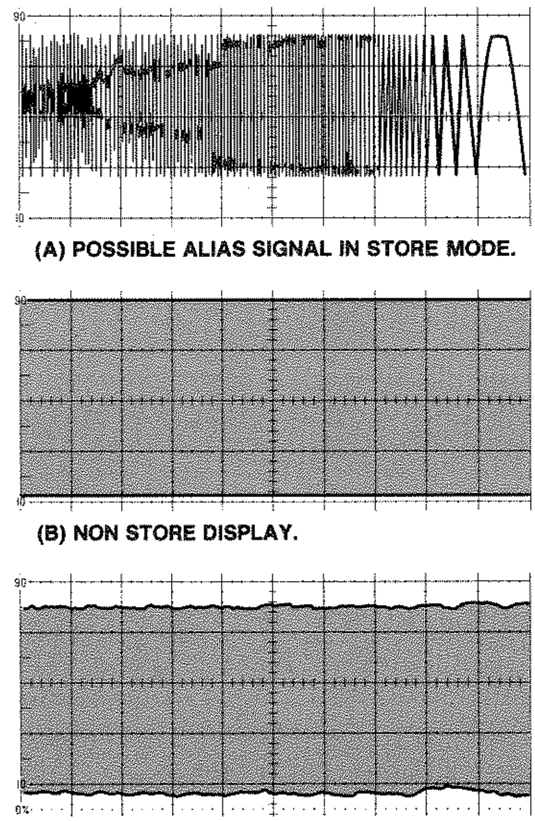
OBSERVING AND REMOVING ALIASES IN STORE MODE

ALIASING. This discussion assumes the acquisition mode is SAMPLE. In digital sampling, the accuracy of the reproduced waveform, when displayed, increases with the number of samples obtained during one full cycle of the signal. That is, a more accurate reproduction of a signal is possible when more samples of the signal are obtained. The instrument samples 1000 times across the full 10 horizontal divisions of the graticule. This means that a sine wave spread across the full screen will be sampled 1000 times, but if the sine wave is only one graticule division in width, it will be sampled one-tenth as many times (100 samples). This number is still adequate for accurate reproduction of the stored waveform.

If the SEC/DIV switch is set so that the entire sine-wave period fills one-tenth of a graticule division, it will be sampled only 10 times during its acquisition. This means that only ten samples of the waveform will be available to reproduce the waveform for display. In theory, if a sine wave is sampled at least two times during its period, it may be accurately reproduced. In practice, the sine wave can be reconstructed, using special filters, from slightly more than two samples.

At 5 μs per division, a signal of 2 MHz will be sampled 10 times during the sine-wave period. Consequently the waveform will be accurately reproduced within 98% of its true amplitude. This is the accuracy required for useful storage bandwidth.

If the input frequency is increased beyond 8 MHz, the samples will soon become less than two times per period. This occurs at 10 MHz for a 20 MHz sample rate. Past this point, information sampled from two different sine-wave periods will be used to reconstruct the displayed waveform. Obviously, this waveform cannot be a correct reproduction of the input signal. At certain input frequencies the data sampled will reproduce what appears to be a correct display, when in fact it is only related to the input signal by some multiple or part of a multiple of the input signal. This type of display is one type of "alias" (see Figure 6-13A).



(A) POSSIBLE ALIAS SIGNAL IN STORE MODE.

(B) NON STORE DISPLAY.

(C) ALIAS SIGNAL DISPLAY IN ACCPEAK STORE MODE.

Figure 6-13. Anti-aliasing.

The example given is for the maximum sampling rate of 20 MHz. However, the sampling rate is controlled by the SEC/DIV switch, and whenever it is set so that the input signal is sampled less than 10 times per period of the fastest frequency component, observable aliases will occur.

ANTI-ALIASING. At 20 μs and below, samples are always taken at 10 MHz. For each display interval the peaks are retained. From this information the display is reconstructed. This reconstructed display will accurately display a peak that has been maintained at least 100 ns even at SEC/DIV settings as slow as 5 s per division. If there are fewer than 2 display points per sine wave of the input signal the display will alternate between peaks resulting in a display of the envelope of the signal.

In the event that an alias is suspected determine whether the display is of an alias. Switch back to NON STORE mode to determine if the input signal is higher in frequency than the apparent signal being displayed (see Figure 6-13B). Ensure that this display is being triggered as indicated by the TRIG'D LED being illuminated.

The SEC/DIV switch may also be set for a faster sweep rate so that the number of samples per cycle of the input signal is increased. However, at sweep speeds of 2 μs per division and faster, the sampling rate is not increased; and if an alias signal is still present at 5 μs per division, the frequency limit of the digital circuitry has been exceeded for nonrepetitive signals. When the SEC/DIV switch is set for sweep speeds faster than 5 μs per division, Repetitive Store mode and Average are selected. On repetitive signals, the random phase between successive triggers and the time-base clock suppress aliased waveform displays as a result of the increased effective sample rate.

OPTIONS AND ACCESSORIES

INTRODUCTION

This section contains a general description of instrument options available at this time. Also included is a complete list (with Tektronix part numbers) of standard accessories included with each instrument and a partial list of optional accessories. Additional information about instrument options, option availability, and other accessories can be obtained either by consulting the current Tektronix Product Catalog or by contacting your local Tektronix Field Office or representative.

ACCESSORIES

STANDARD ACCESSORIES

The following standard accessories are provided with each instrument:

Qty	Description	Part Number
2	Probes, 10X, 1.5-meter	P6122
1	Power Cord	As Ordered
1	Operators Manual	070-5301-01
1	Users Reference Guide	070-5681-00
1	Front Panel Cover	200-2520-00
1	Accessory Pouch	016-0677-02
1	Fuse, 3AG, 2A, 250 V SLO-BLO	159-0023-00
1	DB-9 Male Connector and Connector Shell	131-3579-00
1	Loop Clamp	343-0003-00
1	Flat Washer	210-0803-00
1	Self-Tapping Screw	213-0882-00

OPTIONAL ACCESSORIES

The following optional accessories are recommended for use with the instrument.

Qty	Description	Part Number
1	Service Manual	070-5302-00
2	Probe Tips, with actuator (for P6122 probes)	013-0191-00
1	Rack Adapter	016-1003-00
1	Protective Rain Cover	016-0848-00
	Viewing Hood	016-0566-00
	Carrying Strap	346-0199-00
	Carrying Case	016-0792-01
	C5C Option 04 Camera	
	K117 Instrument Shuttle	
	K212 Portable Instrument Cart	
	1107 Dc Inverter	

OPTIONS

POWER CORD OPTIONS

Instruments are shipped with the detachable power-cord configuration ordered by the customer. Descriptive information about the international power-cord options is provided in "Preparation for Use" in Section 2. The following list identifies the Tektronix part numbers for the available power cords.

Standard (United States)	161-0104-00
Option A1 (Universal Euro)	161-0104-06
Option A2 (United Kingdom)	161-0104-07
Option A3 (Australian)	161-0104-05
Option A4 (North American)	161-0104-08
Option A5 (Switzerland)	161-0167-00

OPTION 33

Option 33, the **Travel Line** option, provides impact protection needed for rough industrial and service environments. When the instrument is ordered with Option 33, the instrument comes equipped with the Accessory Pouch and the Front Panel Cover, front and rear mounted shock absorbing rubber guards, an easy-to-use power cord wrap, and a carrying strap.

OPTION 10 AND OPTION 12

INTRODUCTION

Option 10 provides a communications interface for the instrument. 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.

Option 12 provides a communications interface for the instrument. The interface implemented conforms to RS-232-C specifications. It also complies with a subset of the Tektronix Codes, Formats, Conventions and Features standard.

Three indicators, displayed on the crt and labeled on the bezel tag, display the condition of the options.

The communication options allow remote control of oscilloscope functions. This remote control is accomplished by messages sent to the instrument via either the GPIB (IEEE-488 Standard Bus) or the RS-232-C interface. Messages used are defined either in ANSI/IEEE-488-1978 or in the Tektronix standard on Codes, Formats, Conventions, and Features. Messages to the option can have one of three purposes:

1. Query the state of the oscilloscope.
2. Query the results of measurements made.
3. Set the instrument operation mode.

The main purpose of the communication options is to allow digitized waveform data to be sent and received by the instrument.

STANDARD FUNCTIONS, FORMATS, AND FEATURES

The interface-function repertoire of a GPIB instrument, in terms of interface-function subsets, is identified in ANSI/IEEE Std 488-1978. The status of subsets applicable to this instrument with Option 10 are listed in Table 7-1.

Both the GPIB interface and the RS-232-C interface conform to a Tektronix standard on Codes, Formats, Conventions, and Features of messages sent over the bus to communicate with other instruments equipped with a like interface. Specific features implemented in this instrument are listed in Table 7-2, and specific formats implemented are shown in Table 7-3.

Table 7-1
Function Subsets Implemented

Function Subset	Capability	States Omitted	Other Requirements	Other Subsets Required
SH1 (Source Handshake)	Complete Capability	None	None	T6
AH1 (Acceptor Handshake)	Complete Capability	None	None	None
T6 (Talker)	Basic Talker, Serial Poll, Talker Only, Unaddress if MLA	None	Include [MLA (ACDS)]	SH1 and L3
L3 (Listener)	Basic Listener, Listen Only, Unaddress if MTA	None	Include [MTA (ACDS)]	AH1 and T6
SR1 (Service Request)	Complete Capability	None	None	T6
RL2 (Remote/Local)	No Local Lock Out	LWLS and RWLS	None	L3
PP0 (Parallel Poll)	No Capability	All	None	None
DC1 (Device Clear)	Complete Capability (Selective Device Clear)	None	None	L3
DT0 (Device Trigger)	No Capability	All	None	None
C0 (Controller)	No Capability	All	None	None
E2 (Drivers)	Three-state			

Table 7-2
Specific Format Choices

Format Parameter	Choice Made
Format Characters	Not transmitted; ignored on reception.
Message Terminator	Either EOI or LF modes can be selected for implementation.
Measurement Terminator	Follows program message-unit syntax.
Link Data (Arguments)	Used in Listen and Talk.
Multiple Event Reporting	Not implemented.
Instrument Identification Query	Descriptors added for all options, including GPIB.
Set Query	Extended by using other commands.
Device Trigger (DT)	Not implemented.
Init Command	Causes the instrument to return to a power-on condition. All operating modes will then agree with front-panel settings.
Time/Date Commands	Not implemented.
Stored Setting Commands	Not implemented.
Waveform Transmission	Implemented.
Return to Local (rtl)	Asserted when any front-panel control attempts to change a GPIB-controllable function.
IEEE 728	Compliance not intended.

PERFORMANCE CONDITIONS

The specifications for the GPIB Option and the RS-232-C Option are listed in Table 7-4. All other specifications for the instrument (including the performance conditions) are identical to those specified in "Specification" in Section 1 of this manual.

OPTIONS SIDE PANEL

The instrument is supplied with one of three possible side panels. The standard side panel (Figure 3-8) includes one AUXILIARY connector. The Option 10 side panel (Figure 7-1A) includes one AUXILIARY connector, one GPIB (IEEE 488-1978) interface port, and one PARAMETERS switch. The side panel for Option 12 instruments (Figure 7-1B) includes one AUXILIARY connector, one RS-232-C interface port (includes one DTE and one DCE connector), and one PARAMETERS switch. The Controls, Connectors, and Indicators part of this manual contains information on the use of the AUXILIARY Connector. Refer to Figure 7-1 for location of items 46 through 51.

(46) **AUXILIARY Connector**—Provides connections for an X-Y Plotter and an External Clock input (see Controls, Connectors, and Indicators).

(47) **GPIB Connector**—Provides the ANSI/IEEE Std 488-1978 compatible electrical and mechanical connection to the GPIB. The connector is only on instruments with Option 10. The function of each pin of the connector is shown in Table 7-5.

Table 7-3
Implementation of Specific Features

Feature	Choice Made	Comments
Secondary Addressing	Not implemented.	
Indicators	ADDR (addressed), SRQ (service request), and PLOT (acquisitions locked out) indicators are included.	
Parameter Selection	10 position switch. Instrument reinitializes to power-up state with exception of issuing power-on service request.	To retain the instrument's preinitialization setup, the controller should store the response to a SET query before a change is made; then return the settings afterwards.

Table 7-4
Option Electrical Characteristics

Characteristics	Performance Requirements
	GPIB OPTION
GPIB Requirements	Complies with ANSI/IEEE Standard 488-1978.[a]
	RS-232-C OPTION
RS-232-C Requirements	Complies with EIA Standard RS-232-C.[a]
Baud Rates Available Rates	110, 300, 600, 1200, 1800, and 2400 baud.
Accuracy	< 1% error.[a]

[a] Performance Requirement not checked in manual.

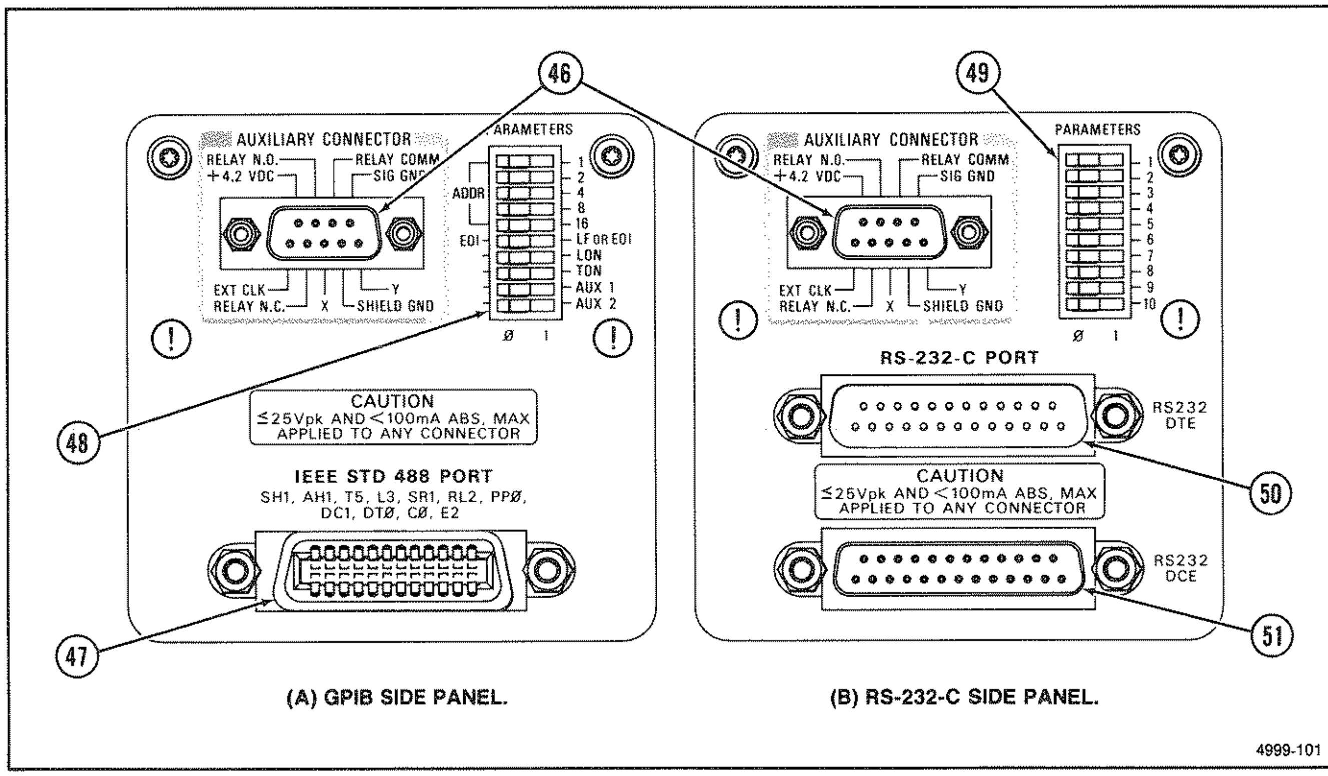


Figure 7-1. Option side panels.

(48) **GPIB PARAMETER Switch**—Allows the selection of setup options for the GPIB interface. The switch is read at power-up and when interface clear messages are received. Five sections of the switch select the GPIB address, one selects the terminator, two select talk/listen modes, and two are used for printer/plotter selection. The function of each switch section is shown in Table 7-6.

(49) **RS-232-C PARAMETER Switch**—Allows the selection of setup options for the RS-232-C interface. The switches are read at power-up and when interface clear messages are received. Four sections of the switch select the baud rate, three select parity, one selects the terminator, and two are for printer/plotter selection. The function of each switch section is shown in Table 7-7.

Table 7-5
GPIB Connector

Pin	Line Name	Description
1	DIO1	IEEE-488 Data I/O
2	DIO2	IEEE-488 Data I/O
3	DIO3	IEEE-488 Data I/O
4	DIO4	IEEE-488 Data I/O
5	EOI	IEEE-488 END or Identify
6	DAV	IEEE-488 Handshake
7	NRFD	IEEE-488 Handshake
8	NDAC	IEEE-488 Handshake
9	IFC	IEEE-488 Input
10	SRQ	IEEE-488 Output
11	ATN	IEEE-488 Input
12	SHIELD	System Ground (Chassis)
13	DIO5	IEEE-488 Data I/O
14	DIO6	IEEE-488 Data I/O
15	DIO7	IEEE-488 Data I/O
16	DIO8	IEEE-488 Data I/O
17	REN	IEEE-488 Input
18	GND	Digital Ground (DAV)
19	GND	Digital Ground (NRFD)
20	GND	Digital Ground (NDAC)
21	GND	Digital Ground (IFC)
22	GND	Digital Ground (SRQ)
23	GND	Digital Ground (ATN)
24	GND	Digital Ground (LOGIC)

(50) **RS-232-C DTE Connector**—Provides connection meeting the EIA RS-232-C standard for data terminal equipment. The connector is shown in Figure 7-1B. Table 7-10 lists the function of each pin of the connector. The connector is only on Option 12 instruments.

NOTE

Some controllers use nonstandard connectors and pin assignments. Consult your controller operators manual for specific interfacing information.

Table 7-6
GPIB PARAMETERS Switch

Switch Section	Switch Position	Function
1		Address selection
	0	0
	1	1
2		Address selection
	0	0
	1	2
3		Address selection
	0	0
	1	4
4		Address selection
	0	0
	1	8
5		Address selection
	0	0
	1	16
6		Terminator selection
	0	EOI
	1	LF or EOI
7	0	No function
	1	LON
8	0	No function
	1	TON
9		Printer/plotter selection[a]
10		Printer/plotter selection[a]

[a]Switches 9 and 10 select printer/plotter devices at power-up. The devices may be changed after power-up using Option commands, or by using the MENU. Two EPSON® formats are selectable. EPS7 uses seven print wires per head pass, and is usually slower. It is the chr$(27) "L" mode. EPS8 uses eight print wires per head pass, and is usually the faster print-head speed. It is the chr$(27) "Y" mode. In this mode most Epson and Epson-compatible printers will not strike any print wire more often than every second pixel. EPS8 is selected when parity is disabled. Devices are selected with the following switch positions:

Switch 9	Switch 10	Device Selected
0	0	HP-GL® plotter
1	0	[EPS7] or EPS8
0	1	ThinkJet® printer

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Table 7-7
RS-232-C PARAMETERS Switch

Switch Section	Switch Position	Function
1	--	Baud rate[a]
2	--	Baud rate[a]
3	--	Baud rate[a]
4	--	Baud rate[a]
5		Parity enable
	0	Parity error will NOT cause SRQ (also selects 8-bit character length)
	1	Parity error WILL cause SRQ (also selects 7-bit character length)
6		Parity select[b]
7		Parity select[b]
8		Line terminator selection
	0	Lines are terminated with carriage return (CR)
	1	Lines are terminated with carriage return-line feed (CR-LF)
9		Printer/plotter selection[c]
10		Printer/plotter selection[c]

[a] See Table 7-8

[b] See Table 7-9

[c] Switches 9 and 10 select printer/plotter devices at power-up. The devices may be changed after power-up using Option commands, or by using the MENU. Two EPSON® formats are selectable. EPS7 uses seven print wires per head pass, and is usually slower. It is the chr$(27) "L" mode. EPS8 uses eight print wires per head pass, and is usually the faster print-head speed. It is the chr$(27) "Y" mode. In this mode most Epson and Epson-compatible printers will not strike any print wire more often than every second pixel. EPS8 is selected when parity is disabled. Devices are selected with the following switch positions:

Switch 9	Switch 10	Device Selected
0	0	HP-GL® plotter
1	0	[EPS7] or EPS8
0	1	ThinkJet® printer

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Table 7-8
Baud Rate

Index	Switch Position 4 3 2 1	Baud Rate
0	0 0 0 0	50
1	0 0 0 1	75
2	0 0 1 0	110
3	0 0 1 1	134.5
4	0 1 0 0	150
5	0 1 0 1	300
6	0 1 1 0	600
7	0 1 1 1	1200
8	1 0 0 0	1800
9	1 0 0 1	2000
10	1 0 1 0	2400
11	1 0 1 1	3600
12	1 1 0 0	4800
13	1 1 0 1	7200
14	1 1 1 0	9600
15	1 1 1 1	Off Line

NOTE

Do not use both the DTE and DCE connectors at the same time.

(51) **RS-232-C DCE Connector**—Provides connection meeting the EIA RS-232-2 standard for data communications equipment. The connector is shown in Figure 7-1B. Table 7-11 lists the function of each pin of the connector. The connector is only on Option 12 instruments.

NOTE

Some controllers use nonstandard connectors and pin assignments. Consult your controller operators manual for specific information.

Table 7-9
Parity Selection[a]

Index	Switch Position 6 7	Parity Type	Comment
0	0 0	ODD	The most significant bit (MSB) is set or cleared so that the number of 1s per byte is ODD.
1	0 1	EVEN	The MSB is set or cleared so that the number of 1s per byte is even.
2	1 0	MARK	The MSB is set.
3	1 1	SPACE	The MSB is cleared.

[a]Characters are always accepted if possible. An SRQ is sent if the received parity doesn't match the parity selected. Parity must be disabled (switch position 5 set to 0) for binary transfers to take place.

Table 7-10
RS-232-C DTE Connector

Pin	Signal Name		Function
	Internal	External	
1	CHAS GND	CHAS GND	Chassis ground
2	ITXD	TXD	Transmitted data
3	IRXD	RXD	Received data
4	IRTS	RTS	Request to send
5	ICTS	CTS	Clear to send
6	IDSR	DSR	Data set ready
7	SIG GND	SIG GND	Signal ground
8	IRLSD2	RLSD	Received line signal detect
20	IDTR	DTR	Data terminal ready

Table 7-11
RS-232-C DCE Connector

Pin	Signal Name		Function
	Internal	External	
1	CHAS GND	CHAS GND	Chassis ground
2	IRXD	TXD	Transmitted data
3	ITXD	RXD	Received data
4	ICTS	RTS	Request to send
5	IRTS	CTS	Clear to send
6	IDTR	DSR	Data set ready
7	SIG GND	SIG GND	Signal ground
8	IRLSD1	RLSD	Received line signal detect
20	IDSR	DTR	Data terminal ready

INTERFACE STATUS INDICATORS

Three indicators appear in the crt readout to indicate the status of the communications options. The indicators are labeled SRQ, ADDR, and PLOT on the crt bezel, and appear as intensified lines in the crt under the labels. Refer to Figure 7-2 for the location of items 52 through 54.

(52) **SRQ Indicator**—Indicates the communications option requires service by the controller. Service requests are cleared when the instrument has been polled for its status and no further warning or error conditions are pending. The communication options assert Service Request (SRQ) when powered up.

(53) **ADDR Indicator**—Indicates the instrument is addressed to talk or listen on the GPIB option. Indicates carrier detect on the RS-232-C option.

(54) **PLOT Indicator**—Indicates the communication option is currently sending waveform data over its interface and acquisitions are inhibited.

GPIB PARAMETER SELECTION

Selection of GPIB parameters (primary address, message terminator, and talk/listen mode) can be made at any time using the GPIB PARAMETERS switch and Table 7-6.

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

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

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

Input End-of-Message Terminator

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

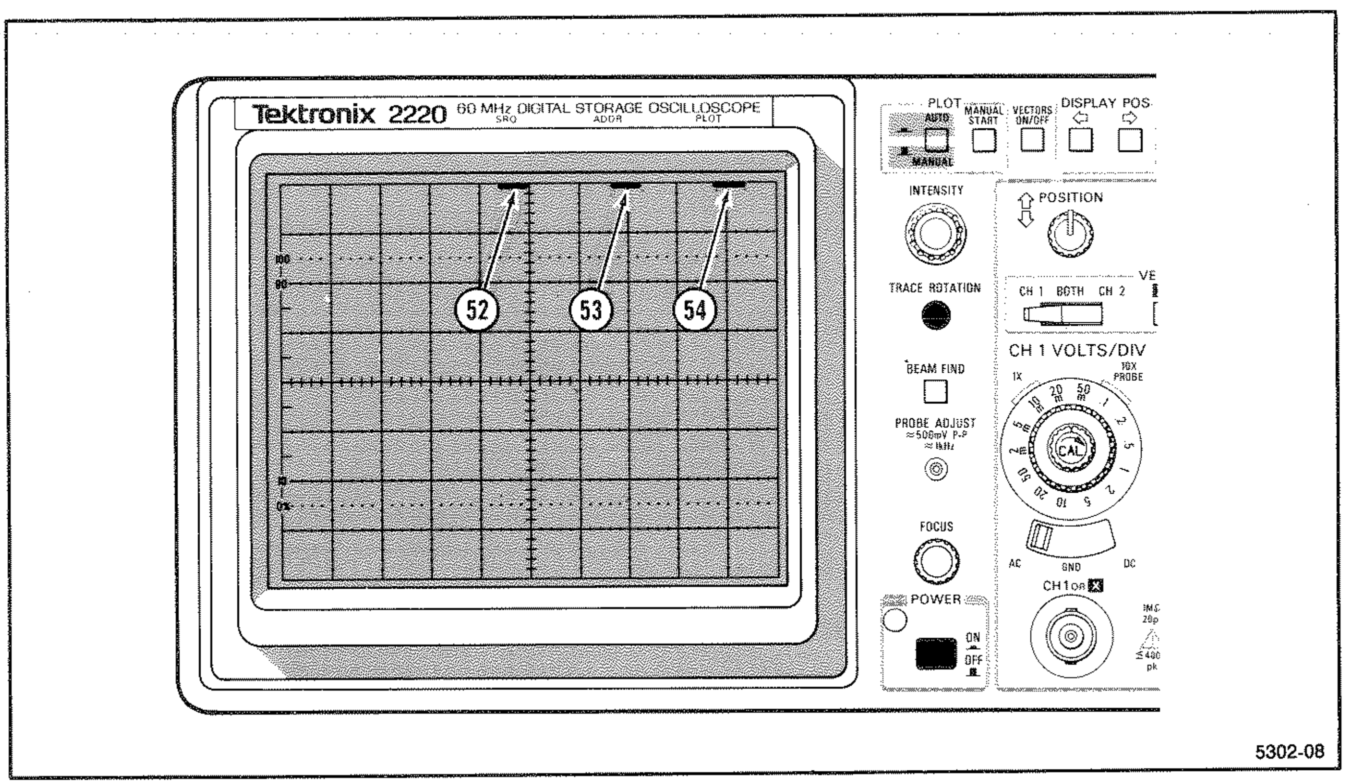

Figure 7-2. Interface status indicators.

When EOI (normal mode) is selected as the terminator, the instrument 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 instrument 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.

Talk/Listen Mode

Three talk/listen modes are selectable:

- TALK ONLY mode allows the instrument to send data over the GPIB.
- LISTEN ONLY mode permits the instrument to receive data over the GPIB.
- TALK/LISTEN mode (both TON and LON modes selected) allows the instrument to both send and receive data over the GPIB.

The default mode is TALK/LISTEN.

To select or change the talk/listen mode, select TON and/or LON using the GPIB PARAMETERS switch and Table 7-6.

RS-232-C PARAMETER SELECTION

Selection of RS-232-C parameters (baud rate, parity, and line terminator) can be made at any time using the RS-232-C PARAMETER switch and Table 7-7 through Table 7-9.

Baud Rate

The selected RS-232-C baud rate establishes the baud rate used by the instrument for both sending and receiving data. Baud rates selectable are listed in Table 7-9.

When OFF LINE is selected as the baud rate, the instrument still presents an active load but does not respond to nor interfere with any bus traffic. This is useful for changing the instrument's status without turning off the oscilloscope's power.

Use Table 7-7, Table 7-8 and the PARAMETERS switch to select the desired baud rate.

Parity

The parity parameters selected determine the instrument response to received parity errors and the parity of data sent by the instrument.

Section 5 of the PARAMETERS switch determines whether or not received parity errors will cause an SRQ (see Table 7-7).

Sections 6 and 7 of the PARAMETERS switch determine the parity used when transmitting data over the bus. ODD, EVEN, MARK, or SPACE are selectable (See Table 7-9).

Line Terminator

The line terminator can be selected to be either the carriage return (CR) or the CR and Line-Feed (LF) characters.

When CR (normal mode) is selected as the terminator, the instrument will:

- Accept only CR as the line terminator.
- Send CR as the last byte of a message.

When CR LF is selected as the terminator, the instrument will:

- Accept either CR or LF as the line terminator.
- Send Carriage Return (CR) followed by LF at the end of every message.

Section 8 of the PARAMETERS switch determines the line terminator. Select the desired line terminator using the PARAMETERS switch and Table 7-7.

MESSAGES AND COMMUNICATION PROTOCOL

Option commands can set the instrument operating mode, query the results of measurements made, or query the state of the oscilloscope. The commands are specified in mnemonics that are related to the functions 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.

NOTE

All measurement results returned by the options have the same accuracy as the main instrument.

Commands

Commands for this instrument, like those for other Tektronix 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 not ambiguous. Syntax is also standardized to make the commands easier to learn.

In the command lists (Tables 7-13 through 7-24), 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.,

```
INIt
OPC
```

Arguments

Some commands require the addition of arguments to their 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 a single word; e.g.,

```
REFF REF4
PLOt STArt
```

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

```
ACQuisition REPetitive:SAMple
WFMpre XINcr:1.0E-3
```

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.,

```
DATa ENCdg:BINary,CHAnnel:CH2
VMOde? CH1,CH2,ADD
```

Default Arguments

Arguments shown within brackets ([argument]) are defaults. In any command that has a default, omitting the default argument selects the default. Do not confuse default arguments with power-up default conditions; the power-up defaults may differ from the argument default in the same function. The default argument may be sent in any command. Do not send the brackets as part of the default argument. All commands that do not have a default must always include a argument, where one or more exists.

Command Separator

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

```
DATa ENCdg:BINary,CHAnnel:CH2;WFMpre
XINcr:1.0E-3
```

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 Line-Feed characters 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.

Message Terminator

As previously explained, GPIB 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.

RS-232-C messages may be terminated with either carriage return (CR) or the CR and Line-Feed (LF) characters. The RS-232-C Option can be set to accept either terminator. With CR selected, the instrument interprets a line ending in CR as the end of the input message: it also sends CR as the last byte of an output message. With the CR and LF setting, the instrument interprets either the CR character or the LF character as the end of an input message; it transmits a Carriage return character followed by a Line Feed to terminate output messages.

Numeric Arguments

Many commands have numeric arguments. The numeric arguments are shown in either <NR1>, <NR2>, or <NR3> notation. These symbols refer to the format of the numeric argument. All values must be decimal (base 10).

Table 7-12 depicts the number formats for numeric arguments in the command set. As shown in the table, both signed and unsigned numbers are accepted; but unsigned numbers are interpreted to be positive. Any command or query that has an <NR2> argument may have that argument sent to the the instrument in either <NR2> or <NR1> format. Likewise, an <NR3> argument may be sent in <NR3>, <NR2> or <NR1> format.

COMMAND LISTS

Tables 7-13 through 7-23 describe all commands available in the instrument equipped with either the GPIB or RS232 Option. Query and Response examples are shown in Table 7-24. 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.

Table 7-12

Numeric Argument Format for Commands

Numeric Argument Symbol	Number Format	Examples
<NR1>	Integers	+1, 2, −1, −10
<NR2>	Explicit decimal point (floating 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

One or more arguments, separated by commas, may be given in a query to request only the information wanted. For example: CH1? VOLts,COUpling. However, some headers in the command tables are Query only, that is, they may only be sent as queries; never as commands. The queries are listed in the same general format as command/query headers. The arguments returned by the instrument are shown in smaller type. Do not send these arguments as part of the query; they are returnable only. For example, AC, DC, or GND are returned in response to a CH1? COU.

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

Table	Command Group
7-13	Vertical Commands
7-14	Horizontal Commands
7-15	Trigger Commands
7-16	Display Commands
7-17	Acquisition Commands
7-18	Save and Recall References Commands
7-19	Waveforms Commands
7-20	Waveform Preamble Fields
7-21	Miscellaneous Commands
7-22	Service Request Group Commands
7-23	RS-232-C Specific Commands

Table 7-13
Vertical Commands

Header	Argument	Link Argument	Description
VMOde?	CH1 CH2 ADD CHOp ALT XY		Query only. Returns current state of the vertical display: VMO string;, where string is either CH1, CH2, ADD, CHOp, ALT, or XY.

Table 7-14
Horizontal Commands

Header	Argument	Link Argument	Description
HORizontal?			Query only. Returns all current Horizontal settings in the form: HOR ASE:<NR3>, EXT:string; where the EXTclk string is either ON or OFF.
	ASEcdiv	<NR3>	Query only. Returns the current A SEC/DIV setting. The <NR3> value returned is zero when the knob is set to EXT CLK.
	HMAg	ON OFF	Query only. Returns status of Horizontal Magnifier (X10 PULL) in the form: HOR HMA:string, where string is either ON or OFF.
	EXTclk	ON OFF	Query only. Returns status of EXTclk in the form: HOR EXT:string;, where string is either ON or OFF.

Table 7-15
Trigger Commands

Header	Argument	Link Argument	Description
ATRigger?			Query only. Returns current A Trigger status: ATR MOD:string, where the MODe string is either NORmal, PPAuto, or SGLswp.
	MODe	NORmal PPAuto SGLswp	Query only. Returns current A Trigger Mode setting in the form ATR MOD:string;, where string is either NORmal, PPAuto, or SGLswp. PPAuto is returned for both P-P AUTO and TV FIELD modes.
SGLswp	ARM DONe		As a query, SGLswp returns the status of the SGLswp trigger mode: SGL string;, where string is either ARM or DONe. ARM indicates that the sweep is armed or running. DONe indicates that a sweep is complete. An execution error SRQ is generated if SGL SWP is not ON. As a command, only SGLswp ARM; is legal. ARM re-arms a completed sweep. An execution warning SRQ is generated if SGL SWP is not ON or if ARM is active.
TRIggered?	ON OFF		Query only. Returns the status of the TRIG'D indicator, either TRI ON; or TRI OFF;.

Table 7-16
Display Commands

Header	Argument	Link Argument	Description
PLOt	STArt		Initiates a plot via the GPIB (Option 10) or RS-232-C (Option 12) interface port, or the XY Plotter Port. While the plot is in progress all commands or queries are ignored except for PLOt ABOrt, which terminates the plot. If enabled, an OPC SRQ is sent when the plot completes.
	ABOrt		Terminates a plot in progress and returns the instrument to its previous mode. PLOt ABOrt is the only command or query the instrument responds to during a plot.
	GRAt	[ON] OFF	Determines if a plot will include a graticule image.
	FORmat	[XY] HPGl EPS7 EPS8 TJEt	Defines plot format and output port. FORmat reverts to XY if port is not configured for plotting. HPGl formats for HP-GL™ compatible plotters. EPS7 and EPS8 format for 7 bit (low-speed, double density) and 8 bit (high-speed, double density) Epson™ format printers, respectively. TJEt formats for the Hewlett Packard ThinkJet™ printer. A GPIB Controller In Charge may issue PLOt STArt to the oscilloscope, My Listen Address (MLA) to the printer or plotter, then My Talk Address (MTA) to the oscilloscope to produce a plot.
	SPEed	<NR1>	SPEed changes the analog plotter pen speed. <NR1> must be an integer from 1 through 10. Units are roughly in divisions per second.

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Table 7-17
Acquisition Commands

Header	Argument	Link Argument	Description
STORe?	ON OFF		Query only. Returns the operating mode of the instrument; either STOR ON; for digital storage mode, or STOR OFF; for analog mode.
ACQuisition	REPetitive	[AVErage]	Selects the acquisition algorithm for 0.05 μ/div to 2 μs/div.
	HSRec	[SAMple]	Selects the acquisition algorithm for 5 μs/div and 10 μs/div.
	LSRec	SAMple [PEAkdet]	Selects the acquisition algorithm for 0.02 ms/div to 50 ms/div.
	SCAn	SAMple [PEAdet]	Selects the acquisition algorithm for 0.1 sec/div to 5 sec/div, when in SCAN Display mode.
	ROLl	SAMple [PEAkdet]	Selects the acquisition algorithm for 0.1 sec/div to 5 sec/div, when in ROLL Display mode.
	CURRent	SAMple AVErage PEAkdet DEFault	Without an argument, this command selects the default algorithm for the acquisition parameters that are currently active. With an argument, the command selects the specified algorithm. An SRQ is generated if the argument is not legal for the acquisition parameters that are active.
	RESet		Sets sampling modes at all sweep speeds to their default conditions.
	SMOoth	ON OFF	Applies the smoothing algorithm, when ON.
	WEIght	<NR1>	Sets the number of weighted acquisitions included in an AVErage display. The value of <NR1> must be either 1, 2, 4, 8, 16, 32, 64, 128, or 256.
	NUMsweeps	<NR1>	Sets the number of sweeps done before halting. 0 implies continuous mode (don't halt).
	TRIGCount	<NR1>	Sets the number of points before the trigger point in an acquisition. TRIGCount may range between 16 and 2048 when in post-trigger, and 2048 through 4080 when in pre-trigger. Resolution of <NR1> is 4.
	VECtors	ON OFF	Turns Vector Mode ON or OFF.
ACQuisition?	SWPcount	<NR1>	Query only. Returns the number of sweeps completed, in the form: ACQ SWP:<NR1>;.
	POInts	<NR1>	Query only. Returns the number of data points in the acquisition, 4096, in the form: ACQ POI:<NR1>;.
	TRIGMode	PRE POSt	Query only. Returns the current trigger mode in the form: ACQ TRIGM:string;, where string is either PRE or POSt.
	SAVE	ON OFF	Query only. Returns the current state of the acquisition system in the form: ACQ SAVE:string;, where string is ON when the acquisition system has halted or is in the process of halting, or OFF.
	DISplay	ROLl SCAn	Query only. Returns the current Acquisition Display mode in the form: ACQ DIS:string;, where string is either ROLl or SCAn.

Table 7-18
Save and Recall Reference Commands

Header	Argument	Link Argument	Description
REFFrom	[ACQ]		Source waveform for all waveform transfers.
SAVeref	[REF4]		Target reference for all waveform references.
REFDisp	[REF4]	ON OFF EMPty	Controls the display of the reference. EMPty causes the contents of the reference to be deleted and its display turned OFF.

Table 7-19
Waveform Commands

Header	Argument	Link Argument	Description
WAVfrm?	<string>		Query only. Response is a waveform from the oscilloscope, in the form: WFMpre <ascii string>; CURVe <string>;, which is a concatenation of the WFMpre and CURVe queries. The waveform pointed to by the DATa SOUrce and DATa CHAnnel pointers are sent in the current DATa ENCdg format.
CURVe	<Wfm Data>		The CURVe command or query is used to send or receive waveform data from the oscilloscope. The DATa SOUrce or DATa TARget pointers show where to get or put data, respectively. The DATa ENCdg pointer shows which format, HEX, BINary, or ASCii data is sent or expected. The DATa CHAnnel pointer selects either CH1 or CH2. <Wfm Data> is in the form: CURVE <Data>; where <Data> is either %<Byte Count><Binary Data><Checksum> for BINary, #H<Byte Count><Hexadecimal Data><Checksum> for HEX, or <ASCII Data> for ASCii ENCdg. For ASCii ENCdg, each data value is seperated by a comma.
DATa			Sets data parameters for data transmission and reception.
	SOUrce	REF4 [ACQ]	Selects which reference memory is source for the next WFMpre? or CURVe? query sent to the instrument. The default at power-up is ACQuisition.
	TARget	REF4	Selects reference memory to receive the next WFMpre or CURVe command sent to the instrument. The default at power-up is REF4.
	CHAnnel	[CH1] CH2	Points to the waveform that a CURVe? or WAVfrm? query will return. If there is no waveform for the CHAnnel and SOUrce selected (empty reference), an SRQ error is sent when the waveform is requested. Power-up default is CH1.
	ENCdg	ASCii [BINary] HEX	Sets the data encoding/decoding format. The default at power-up is BINary. All ENCdg formats represent an unsigned integer.

Table 7-20
Waveform Preamble Fields

<table>
<tr><th>Header</th><th>Argument</th><th>Link Argument</th><th>Description</th></tr>
<tr><td>WFMpre</td><td>WFId</td><td>“ascii str”</td><td>The WFId field includes labeling information to help you remember key features about the waveform. The information includes Vertical Mode, Time/Div, and Acquisition Mode. The scaling information is the same as in the corresponding preamble fields, but is labeled in the appropriate units. There is no command form of this argument. If received as a command, it is ignored.

The fields and their possible values for the WFId section of the preamble are:
<table>
<tr><th>Source</th><th>Chan</th><th>Horiz</th><th>Acq-Mode</th></tr>
<tr><td>ACQ</td><td>CH1</td><td>50NS</td><td>SMPL</td></tr>
<tr><td>REF4</td><td>CH2</td><td>.</td><td>AVG</td></tr>
<tr><td></td><td>XY</td><td>.</td><td>PKDET</td></tr>
<tr><td></td><td></td><td>.</td><td>PKDET-SMOOTH</td></tr>
<tr><td></td><td></td><td>5S</td><td></td></tr>
<tr><td></td><td></td><td>CLKS</td><td></td></tr>
</table></td></tr>
<tr><td></td><td>ENCdg</td><td>ASCii
[BINary]
HEX</td><td>Determines waveform encoding for waveform transmission or reception. WFMpre ENCdg and DATa ENCdg operate identically. Power-up default is BINary. All ENCdg formats represent unsigned integers.</td></tr>
<tr><td></td><td>NR.Pts</td><td><NR1></td><td>Number of points in waveform. Each point can be a single Y value (T implied), an X-Y pair, or an max-min pair. Although digitized record length is 4096 points, NR.Pts may be 1024, 2048, or 4096, depending on number of acquired channels, acquisition mode, whether or not smoothing is enabled.
<table>
<tr><th>Num Chan</th><th>Acquire Mode</th><th>SMOOTH ON/OFF</th><th>NR.pts to RECLEN Ratio</th></tr>
<tr><td>1</td><td>SMPL</td><td>N/A</td><td>RECLEN/1</td></tr>
<tr><td>1</td><td>AVG</td><td>N/A</td><td>RECLEN/1</td></tr>
<tr><td>1</td><td>PKDET</td><td>ON</td><td>RECLEN/1</td></tr>
<tr><td>2</td><td>SMPL</td><td>N/A</td><td>RECLEN/2</td></tr>
<tr><td>2</td><td>AVG</td><td>N/A</td><td>RECLEN/2</td></tr>
<tr><td>2</td><td>PKDET</td><td>ON</td><td>RECLEN/2</td></tr>
<tr><td>1</td><td>PKDET</td><td>OFF</td><td>RECLEN/2</td></tr>
<tr><td>2</td><td>PKDET</td><td>OFF</td><td>RECLEN/4</td></tr>
</table></td></tr>
<tr><td></td><td>PT.Off</td><td><NR1></td><td>Point offset identifies the trigger position relative to the first point of the waveform. Normal range with 4096 point records is between 4 and 4096. NOTE: PT.Off returns a negative value if the trigger occurred before the first point of the waveform. If the value is unknown, −10000 is returned.</td></tr>
</table>

Table 7-20 (cont)
Waveform Preamble Fields (cont)

Header	Argument	Link Argument	Description
WFMpre (cont)	PT.Fmt		Point format defines how to interpret the curve data.
		Y	Y format means that X information is implicit and that data points are Y values.
		XY	XY format means that data points are XY pairs, with X first.
		ENV	Format used for envelope waveforms. The data is sent in the form: ..., y1max, y1min, y2max, y2min,... ENV is valid for PEAkdet when SMOoth is OFF.
	XUNits	S CLKs	If the argument is S, the XINcr value is in seconds. If it is CLKs, the scaling is unknown (EXTCLK).
	XINcr	<NR3>	Value gives the time interval between points (sampling rate). If <NR3> does not correspond to a legitimate time/div setting, the nearest legitimate setting is substituted and a warning SRQ is issued if EXW is ON. For a query response with an unknown time/div (i.e. EXTCLK), <NR3> is set to 1.
	YUNits	V DIV	Indicates the units associated with YMUlt.
	YMUlt	<NR3>	This value gives the vertical "step" size of the digitizer (volts between points). If <NR3> does not correspond to a legitimate volts/div setting it is treated as a "variable" setting and a warning SRQ is sent. On a query response, an unknown vertical scaling (i.e. variable) sets <NR3> to 0.04 (25 pts/div).
	YOFf	<NR1>	YOFf is the Y coordinate of ground. If ground is unknown, −10000 is returned.
	XMUlt XOFf		XMUlt and XOFf are analogous to YMUlt and YOFf. They are used when an XY waveform is indicated. For all XY waveforms, the YUNits indicator is valid for both X and Y data. The XUNits value references sampling rate.
	BN.Fmt	RP	Binary format is always a right-justified, positive binary integer, also known as an unsigned binary integer.
	BYT/nr	<NR1>	Each data value is contained in 2 bytes for ACQuisition AVEerage or 1 byte otherwise. If 2 bytes are sent, the most sigificant byte is sent first. In HEX format, each data byte is represented by 2 ASCII encoded hex characters.
	BIT/nr	<NR1>	The data consists of 8 or 16 bits. NOTE: The least sigificant bits of a 16 bit waveform may not be valid, depending on the number of waveforms averaged.
	CRVchk	CHKsm0	CHKsm0 indicates that the last byte of a binary curve is a checksum. It is the 2's complement of the modulo 256 sum of the binary count and curve data bytes. It does not include the "CURVE %" that precedes the binary count.

Table 7-21
Miscellaneous Commands

Header	Argument	Link Argument	Description
ID?	<string>		Query only. Returns: ID <string>; where <string> is TEK/2220, V81.1, VERS:xx. "xx" is the firmware revision number of the instrument.
HELp?	<string>		Query only. Returns a list of all valid command headers available in the instrument.
INIt			Command only. Causes the instrument to go to an initialized state equivalent to power-on.
LONg	[ON] OFF		When LONg is ON, all queries respond with the full length versions of commands. When LONg is OFF, the shortest acceptable version of commands are used in query responses. Default argument is ON. At power-up, LONg is OFF.
SET?	<string>		Query only. Returns an ASCII string that reflects the current instrument state. The returned string can be sent to the instrument to recreate that state. In order to comply with Codes and Formats, SET? does not respond with its header. NOTE: This query has very limited capability because only settable values are returned in response to the SET? query. The status of LONg affects the length of the response to the SET? query.

Table 7-22
Service Request Group Commands

Header	Argument	Link Argument	Description
RQS	[ON] OFF		When enabled, the instrument asserts SRQ when it has an event to report. When disabled, the events are still accumulated and can be retrieved with an EVEnt? query. Default is ON with no argument and at power-up.
OPC	[ON] OFF		When enabled, the instrument asserts SRQ upon completion of certain commands. Commands that assert OPC service requests include REFTo, PLOt complete, and Self-test complete. Power-up default is OFF.
EVEnt?	<NR1>		Query only. Returns: EVE <NR1>;, where <NR1> is the oldest SRQ event held by the instrument, when multiple SRQs exist. If no error is pending, 0 is returned.

Table 7-23
RS-232-C Specific Commands

Header	Argument	Link Argument	Description
REMote	[ON] OFF		REMote must be ON in order to change the state of the instrument. REMote is similar to the GPIB Remote Enable (REN) and Go To Local (GTL) messages.
STOp	1 2		Selects the number of stop bits.
FLOw	[ON] OFF		Enables and disables DC1/DC3 flow control. When FLOw is ON, BINary data transfers cannot be made. Omitting the argument turns FLOw ON. Power-on default is OFF.
STAtus?	<NR1>		Query only. Returns the current status byte in the same manner as a GPIB Serial Poll.

Table 7-24
Query and Response Examples

QUERY	RESPONSE
Vertical Query Examples	
CH1? VOL	CH1 VOL:0.5E0;
CH2?	CH2 VOL:10.0E−3,COU:AC,INV:OFF;
VMO?	VMO ADD;
CH1? VOL	CH1 VOL:5.0E-3;
PROB?	PROB CH1:10,CH2:1;
Horizontal Query Examples	
HOR?	HOR MOD:ASW,ASE:2.0E-6, BSE:5.0E−9,HMA:OFF,EXT:OFF;
DELA?	DELA VAL:2.45E-3,UNI:S;
Trigger Query Examples	
ATR?	ATR MOD:PPA;
ATR? MOD	ATR MOD:NOR;
SGL?	SGL DON;
TRI?	TRI ON;
Acquisition Query Examples	
ACQ? HSR	ACQ HSR:AVE;
ACQ?	ACQ REP:AVE,HSR:SAM,LSR:PEA, SCA:SAM,ROL:PEA,SMO:ON,WEI:8, SWP:6,NUM:0,POI:4096,TRIGM:PRE, TRIGC:320,SAVE:OFF,DIS:SCA,VEC:ON;
Save and Recall Reference Query Examples	
REFO? VGA	REFO VGA:10.0E-3;
REFO?	REFO TAR:REF1,CHA:CH2,VGA:10.0E-3, VPO:0.0,HMA:ON,MODE:CHOP;
Waveform Query Examples	
WFM? WFI	WFM WFI:"REF1,CH1,10.0MV,DC, 50.0MS,SAMPLE-SMOOTH,CRV# 4";
WFM? PT.F	WFM PT.F:ENV;
WFM? ENC	WFM ENC:ASC;

WAVEFORM TRANSFERS

The instrument can transmit and receive waveforms. It can transfer these waveforms in binary, hexadecimal, or ASCII format. When sending waveforms to the instrument, the target is a reference memory. Waveforms transferred from the oscilloscope to the controller are selected from the same reference memories or the current acquisition. The data source and data target are selected independently.

Waveform Preamble

The waveform preamble indicates the waveform attributes, such as number of points per waveform, scale factors, offset, horizontal increment, scaling units, and data encoding. The preamble information is sent as an ASCII string. The length of the string depends on the characteristics of the waveform.

A typical response to the preamble query WFMpre? for a Y (time implied) acquisition is:

Query	Response
WFMpre?	WFM WFI:"ACQ, CH1, 0.2MS, SAMPLE - SMOOTH, CRV# 2", NR.P:4096, PT.O:122, PT.F:Y, XMU:0.0E0, XOF:0, XUN:S, XIN:2.0E-6, YMU:20.0E-3, YOF:-20, YUN:V, ENC:HEX, BN.F:RP, BYT:1, BIT:8, CRV:CHK;

A typical response to the preamble query WFMpre? for an XY acquisition is:

Query	Response
WFMpre?	WFM WFI:"ACQ, XY, 1.0US, SAMPLE, CRV# 19", NR.P:2048, PT.O:216, PT.F:XY, XMU:8.0E-3, XOF:0, XUN:S, XIN:20.0E-9, YMU:2.0E-3, YOF:0, YUN:V, ENC:BIN, BN.F:RP, BIT:8, BYT:1, CRV:CHK;

In these examples, the instrument response is shown on multiple lines. WFMpre? responses, as well as all other query responses, are sent as a single line of data ending with a carriage return line feed. With the GPIB interface, EOI is also sent if that message terminator mode is selected.

Transferring Waveforms

The oscilloscope can respond with either the Preamble only, Curve only, or both Preamble and Curve together:

Query	Response
CURVe?	Curve Data Only
WFMpre?	Preamble Only
WAVfrm?	Preamble and Curve data

When responding to the WAVfrm? query, the preamble is separated from the curve data with a ";".

The instrument digitizes data internally as an 8-bit, unsigned integer. Before data is sent over the GPIB or RS-232-C Option, it is changed into one of three formats, BINary, HEXADECIMAL, or ASCii. The resolution of data points sent over the bus may be either 8 or 16 bits. Waveform record length is 4096, but the number of data points per record depends on several variables. See the description of NR.Pts in the Command Tables for more information.

Binary Encoding

BINary data is transferred as an unsigned binary integer. Each record is 8 bits, or 16 bits when averaged.

In BINary format, the waveform curve data is in the form of: CURVE <space> % <Binary Count MSB> <Binary Count LSB> <Data> <Checksum> <Terminator>

Where:

%	is used as a header character to show the start of a binary block.
<Binary Count MSB>	is the most significant byte of the two-byte Binary Count. Binary Count is the length of the waveform, in bytes, plus the one byte Checksum.
<Binary Count LSB>	is the least significant byte of the Binary Count.
<Data>	is made up of 256, 512, 1024, 2048 or 4096 data points. Each data point iis either a 1 byte (8-bit) or 2 byte (16-bit) representation of each digitized value.
<Checksum>	is the two's-complement of the modulo 256 sum of the preceding data bytes and the binary count. The Checksum is used by the controller to verify that all data values have been received correctly.

Table 7-25 shows an example of data sent over the interface during a 4096 point, 8-bit BINary waveform transfer. The actual waveform point (Pt.) values will vary depending upon the signal acquired.

Table 7-25
Typical 8-Bit Binary Waveform Data

Byte	Contents	Decimal	GPIB EOI (1=Asserted)
1	C	67	0
2	U	85	0
3	R	82	0
4	V	86	0
5	E	69	0
6	<SP>	32	0
7	%	37	0
8	<Bin Count MSB>	16[a]	0
9	<Bin Count LSB>	01[a]	0
10	1st Pt	d_1	0
11	2nd Pt	d_2	0
.	.	.	0
.	.	.	0
.	.	.	0
4105	4096th Pt	d_{4096}	0
4106	<Checksum>	chk	1 When TERM=EOI
4107[b]	<CR>	13	0
4108[c]	<LF>	10	1

[a](1001_{16} or 4097_{10})

[b]All RS-232-C or GPIB with TERM = LF/EOI.

[c]RS-232-C with TERM = CR-LF.

Table 7-26 shows an example of data sent over the interface during a 4096 point, 16-bit BINary waveform transfer.

Hexadecimal Encoding

In HEXadecimal waveform encoding, characters representing an 8-bit or 16-bit data point are sent in a fixed ASCII hexadecimal format. There are no delimiters between data points. Data format is very similar to BINary format, with the following exceptions:

1. The curve header is "CURVE #H" instead of "CURVE %".

2. Each data point is 2 ASCII hexadecimal characters for 8-bit and 4 ASCII hexadecimal characters for 16-bit transfers.

3. The byte count is sent as four successive ASCII hexadecimal characters, but the value of the byte count is identical to a comparable BINary transfer.

4. The checksum is sent as two successive ASCII hexadecimal characters.

Table 7-26
Typical 16-Bit Binary Waveform Data

Byte	Contents	Decimal	GPIB EOI (1=Asserted)
1	C	67	0
2	U	85	0
3	R	82	0
4	V	86	0
5	E	69	0
6	<SP>	32	0
7	%	37	0
8	<Bin Count MSB>	32[a]	0
9	<Bin Count LSB>	01[a]	0
10	1st Pt MSB	d_{1H}	0
11	1st Pt LSB	d_{1L}	0
12	2nd Pt MSB	d_{2H}	0
13	2nd Pt LSB	d_{2L}	0
.	.	.	0
.	.	.	0
.	.	.	0
8200	4096th Pt MSB	d_{4096H}	0
8201	4096th Pt LSB	d_{4096L}	0
8202	<Checksum>	chk	1 When TERM=EOI
8203[b]	<CR>	13	0
8204[c]	<LF>	10	1

[a](1001_{16} or 4097_{10})

[b]All RS-232-C or GPIB with TERM = LF/EOI.

[c]RS-232-C with TERM = CR-LF.

Table 7-27 and Table 7-28 show 8-bit and 16-bit HEXadecimal waveform CURVe structures.

Table 7-27
Typical 8-Bit Hexadecimal Waveform Data

Byte	Contents	Decimal	GPIB EOI (1=Asserted)
1	C	67	0
2	U	85	0
3	R	82	0
4	V	86	0
5	E	69	0
6	<SP>	32	0
7	#	35	0
8	H	72	0
9	<Bin Count MS 4 bits>	49	0
10	.	48	0
11	.	48	0
12	<Bin Count LS 4 bits>	49	0
13	1st Pt MS 4 bits	d_{1H}	0
14	1st Pt LS 4 bits	d_{1L}	0
15	2nd Pt MS 4 bits	d_{2H}	0
16	2nd Pt LS 4 bits	d_{2L}	0
.	.	.	0
.	.	.	0
.	.	.	0
203	4096th Pt MS 4 bits	d_{4096H}	0
204	4096th Pt LS 4 bits	d_{4096L}	0
205	<Checksum MS 4 bits>	chk_H	0
206	<Checksum LS 4 bits>	chk_L	1 When TERM=EOI
207[a]	<CR>	13 (If term =LF/EOI)	0
208[b]	<LF>	10 (If term =CR-LF)	1

[a]All RS-232-C or GPIB with TERM = LF/EOI.

[b]RS-232-C with TERM = CR-LF.

Table 7-28
Typical 16-Bit Hexadecimal Waveform Data

Byte	Contents	Decimal	GPIB EOI (1=Asserted)
1	C	67	0
2	U	85	0
3	R	82	0
4	V	86	0
5	E	69	0
6	<SP>	32	0
7	#	35	0
8	H	72	0
9	<Bin Count MS 4 bits>	50	0
10	.	48	0
11	.	48	0
12	<Bin Count LS 4 bits>	49	0
13	1st Pt MS 4 bits	d_{1H}	0
14	.	.	0
15	.	.	0
16	1st Pt LS 4 bits	d_{1L}	0
17	2nd Pt MS 4 bits	d_{2H}	0
18	.	.	0
19	.	.	0
20	2nd Pt LS 4 bits	d_{2L}	0
.	.	.	0
.	.	.	0
.	.	.	0
6393	4096th Pt MS 4 bits	d_{4096H}	0
6394	.	.	0
6395	.	.	0
6396	4096th Pt LS 4 bits	d_{4096L}	0
6397	<Checksum MS 4 bits>	chk_H	0
6398	<Checksum LS 4 bits>	chk_L	1 When TERM=EOI
6399[a]	<CR>	13 (If term =LF/EOI)	0
6400[b]	<LF>	10 (If term =LF/EOI)	1

[a]All RS-232-C or GPIB with TERM = LF/EOI.

[b]RS-232-C with TERM = CR-LF.

ASCII Encoding

In ASCii encoding, ASCII characters representing the binary value of each data point are sent in variable length format, separated by commas.

In ASCII format, the curve data transfer is represented as:

CURVE<space>data,data,data,...,data<terminator>

Table 7-29 shows an example of an 8-bit ASCii waveform CURVe transfer. Transmission length depends on specific data values, acquisition mode and smoothing, and whether the acquisition was 1 or 2 channels.

Table 7-29
Typical ASCII Waveform Data

Byte	Contents	Decimal	GPIB EOI (1=Asserted)
1	C	67	0
2	U	85	0
3	R	82	0
4	V	86	0
5	E	69	0
6	<SP>	32	0
7	Pt^{100}_1*	d^{100}_1	0
8	Pt^{10}_1*	d^{10}_1	0
9	Pt^{1}_1*	d^{1}_1	0
10	.	44	0
.	.	.	0
.	.	.	0
.	.	.	0
XXX	Pt^{100}_{4096}*	d^{100}_{4096}	0
XXX	Pt^{10}_{4096}	d^{10}_{4096}	0
XXX	Pt^{1}_{4096}*	d^{1}_{4096}	0
XXX[a]	<CR>	13	0
XXX[b]	<LF>	10	1

*** Pt^{100} and Pt^{10} values are NOT sent when 0, so each Pt may be 1, 2, or 3 digits.**

[a]All RS-232-C or GPIB with TERM = LF/EOI.

[b]RS-232-C with TERM = CR-LF.

REMOTE-LOCAL OPERATING STATES

The following paragraphs describe the two operating states of the instrument: Local and Remote.

Local State (LOCS)

In LOCS, instrument parameters are both set and changed manually by operator manipulation of the front- and side-panel controls. Only option 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.

Remote State (REMS)

In this state, the oscilloscope executes all commands addressed to it over the communication options bus. Front-panel indicators and crt readouts are updated as applicable when commands are executed. Manually changing any option-controllable front-panel control causes the instrument to return to the Local State. If a waveform is being transmitted over the bus, the PLOT indicator is lit and acquisitions are prevented until the transmission is complete.

INSTRUMENT RESPONSE TO INTERFACE MESSAGES

The following explains 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)

Local Lockout is not supported by the instrument. In response to a LLO message via the GPIB, the option generates an SRQ error.

NOTE

The RS-232-C Option uses Option Interface Commands to implement the following GPIB (hardware) messages.

Remote Enable (REN)

When Remote Enable is asserted and the instrument receives its listen address, the oscilloscope is placed in the Remote State (REMS). When in the Remote State, the oscilloscope's Addressed (ADDR) indicator is lit.

Disasserting REN causes a transition 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 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 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 bus.

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

Interface Clear (IFC)

When IFC is asserted, both the Talk and Listen functions are placed in an idle state and the crt ADDR indicator is turned off. This produces the same effect as receiving both the UNL and the UNT messages.

Device Clear (DCL)

The 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.

GPIB PROGRAMMING

Programming considerations are provided in this part to assist in developing programs for interfacing to the oscilloscope via the GPIB. For additional information see the "Instrument Interfacing Guide". Before a program can be used for controlling the oscilloscope, the GPIB parameters (primary address, message terminator, and talk/listen mode) must be set. These parameters are selected and set at the oscilloscope using the GPIB PARAMETERS switch.

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 time 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 Table 7-31.

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.

RS-232-C PROGRAMMING

Programming considerations are provided in this part to assist in developing programs for interfacing to the oscilloscope via the RS-232-C. For additional information see the "Instrument Interfacing Guide". Before a program can be used for controlling the oscilloscope, the RS-232-C parameters (baud rate, line terminator, and parity) must be set. These parameters are selected and set at the oscilloscope using the RS-232- C PARAMETERS switch.

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.

1. Initialize the controller.
2. Check for a service request from the oscilloscope (by sending an EVEnt query); if not zero, service the request.
3. Get the command to send to the oscilloscope.
4. Send the command to the oscilloscope.
5. Check for a response from the oscilloscope.
6. If there is a response, perform the desired function. If there is also an error response, perform step 2.
7. You are ready for a new command. Repeat the functions in statements 2 through 7 as many time as desired.

Service-Request Handler

The typical service-request handler routine contains the necessary instructions to permit proper processing of service requests. For example, whenever power-on occurs, the oscilloscope an SRQ. If a GPIB program is operating on the controller when a power-on SRQ is generated, 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 events for which the oscilloscope generates SRQ are identified in Table 7-31.

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

1. Send an EVENT? query to the oscilloscope requesting service.

2. If the EVENT? query response is not zero, then perform the desired response to the event.

3. Return to the main program.

RESET UNDER COMMUNICATION OPTIONS CONTROL

The oscilloscope may be set to its power-up state by sending the INIt command via the communication option. 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. 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.

STATUS AND ERROR REPORTING

The status and error reporting system used by the Communication Options interrupts the bus controller. On the GPIB Option, the bus controller is interrupted by asserting the Service Request (SRQ) line on the bus. 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 GPIB controller performs a Serial Poll; in response, the instrument returns a Status Byte (STB), which indicates the type of event that occurred. On the RS-232-C Option, as soon as a change of status or an error occurs, the instrument returns a Status Byte (STB), which indicates the type of event that occurred. Bit 4 of the Status Byte is used to indicate that the command processor is active. This bit is 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 7-30.

Each time the GPIB controller performs a serial poll, it can cause a second SRQ if more than one error exists. The most serious error at the time of the serial poll is the error reported. An EVEnt? query returns a number indicating the specific type of error that occurred. Table 7-31 lists the EVEnt? codes generated by the communication options.

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's Status Byte is reported. The Device Clear (DCL) interface message may be used to clear all events, except the power-on event.

With the RQS OFF command invoked, all service requests (except the power-on SRQ) are inhibited. In this mode, the EVEnt? query allows the cOntroller to determine event status. 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) when using the GPIB is the use of the Device Clear (DCL) interface message.

Table 7-30
Status Event and Error Categories

Category	Status Byte					Description
	Binary[a]	Decimal				
		RQS Off		RQS On		
		Not Busy	Busy	Not Busy	Busy	
Command Error	0R1X 0001	33	49	97	113	The instrument received a command that it cannot understand.
Execution Error	0R1X 0010	34	50	98	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	0R1X 0011	35	51	99	115	The instrument detected a hardware condition or a firmware problem that prevents operation.
Power On	010X 0001	1	17	65	81	Instrument power was turned on.
Operation Complete	0R0X 0010	2	18	66	82	Operation complete.
Execution Warning	0R1X 0101	37	53	101	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 sending a reading anyway.
No Status to report	000X 0000	0	16	0	16	There is no status to report.

[a]R is set to 1 if RQS is ON; otherwise it is 0. X is the busy bit and is set if the oscilloscope is busy at the time the status byte is read. Anytime the instrument is actively processing a command or query, the bit is a 1, otherwise it is a 0.

Table 7-31

Event Codes

EVEnt? Code	Instrument Status
000	No status to report
Command Errors	
101	Command header error.
102	Header delimiter error.
103	Command argument error.
104	Argument delimiter error.
105	Non-numeric argument, numeric expected.
106	Missing argument.
107	Invalid message-unit delimiter.
108	Checksum error.
109	Byte-count error.
151	The argument is too large.
152	Illegal hex character.
153	Non-binary argument; binary or hex expected.
154	Invalid numeric input.
155	Unrecognized argument type.
Execution Errors	
201	Command cannot be executed when in LOCAL.
203	I/O buffers full, output dumped.
205	Argument out of range, command ignored.
206	Group execute trigger ignored.
251	Illegal command.
252	Integer overflow.
253	Input buffer overflow.
254	Invalid waveform preamble.
255	Invalid instrument state.
256	GPIB (Option 10) Command not allowed.
258	Command not allowed on a 2220.
259	Command not allowed on a 2230.
260	Cannot execute command with RQS OFF.
261	Reference memory busy with local (front-panel) command.
262	Reference memory non-existent or specified as different size than selected waveform.
263	Plot active; only PLOT ABORT allowed while plotting.
Internal Errors	
351	Firmware failure. Contact your nearest Tektronix Service Center for assistance.

Table 7-31 (cont)

EVEnt? Code	Instrument Status
	System Events
401	Power on.
451	Parity error.
452	Framing error.
453	Carrier lost.
454	End of acquisition OPC.
455	End of plot OPC.
456	Diagnostics test complete OPC.
	Execution Warnings
551	Single sweep is already armed.
552	No ground-dot measurement available.
553	Invalid probe code or identify.
554	Query not valid for current instrument state.
555	Requested setting is out of detent (uncalibrated).
556	MESsage display buffer is full.
557	Waveform preamble incorrect, has been corrected.
558	Waveform transfer ended abnormally.

Table 7-32
ASCII Code Chart

<table>
<tr><td>B7 B6 B5 BITS</td><td>Ø Ø Ø</td><td>Ø Ø 1</td><td>Ø 1 Ø</td><td>Ø 1 1</td><td>1 Ø Ø</td><td>1 Ø 1</td><td>1 1 Ø</td><td>1 1 1</td></tr>
<tr><td>B4 B3 B2 B1</td><td colspan="2">CONTROL</td><td colspan="2">NUMBERS SYMBOLS</td><td colspan="2">UPPER CASE</td><td colspan="2">LOWER CASE</td></tr>
<tr><td>Ø Ø Ø Ø</td><td>0
NUL
0 0</td><td>20
DLE
10 16</td><td>40 0
SP
20 32</td><td>60 16
0
30 48</td><td>100 0
@
40 64</td><td>120 16
P
50 80</td><td>140 0
`
60 96</td><td>160 16
p
70 112</td></tr>
<tr><td>Ø Ø Ø 1</td><td>1 GTL
SOH
1 1</td><td>21 LLO
DC1
11 17</td><td>41 1
!
21 33</td><td>61 17
1
31 49</td><td>101 1
A
41 65</td><td>121 17
Q
51 81</td><td>141 1
a
61 97</td><td>161 17
q
71 113</td></tr>
<tr><td>Ø Ø 1 Ø</td><td>2
STX
2 2</td><td>22
DC2
12 18</td><td>42 2
"
22 34</td><td>62 18
2
32 50</td><td>102 2
B
42 66</td><td>122 18
R
52 82</td><td>142 2
b
62 98</td><td>162 18
r
72 114</td></tr>
<tr><td>Ø Ø 1 1</td><td>3
ETX
3 3</td><td>23
DC3
13 19</td><td>43 3
#
23 35</td><td>63 19
3
33 51</td><td>103 3
C
43 67</td><td>123 19
S
53 83</td><td>143 3
c
63 99</td><td>163 19
s
73 115</td></tr>
<tr><td>Ø 1 Ø Ø</td><td>4 SDC
EOT
4 4</td><td>24 DCL
DC4
14 20</td><td>44 4
$
24 36</td><td>64 20
4
34 52</td><td>104 4
D
44 68</td><td>124 20
T
54 84</td><td>144 4
d
64 100</td><td>164 20
t
74 116</td></tr>
<tr><td>Ø 1 Ø 1</td><td>5 PPC
ENQ
5 5</td><td>25 PPU
NAK
15 21</td><td>45 5
%
25 37</td><td>65 21
5
35 53</td><td>105 5
E
45 69</td><td>125 21
U
55 85</td><td>145 5
e
65 101</td><td>165 21
u
75 117</td></tr>
<tr><td>Ø 1 1 Ø</td><td>6
ACK
6 6</td><td>26
SYN
16 22</td><td>46 6
&
26 38</td><td>66 22
6
36 54</td><td>106 6
F
46 70</td><td>126 22
V
56 86</td><td>146 6
f
66 102</td><td>166 22
v
76 118</td></tr>
<tr><td>Ø 1 1 1</td><td>7
BEL
7 7</td><td>27
ETB
17 23</td><td>47 7
'
27 39</td><td>67 23
7
37 55</td><td>107 7
G
47 71</td><td>127 23
W
57 87</td><td>147 7
g
67 103</td><td>167 23
w
77 119</td></tr>
<tr><td>1 Ø Ø Ø</td><td>10 GET
BS
8 8</td><td>30 SPE
CAN
18 24</td><td>50 8
(
28 40</td><td>70 24
8
38 56</td><td>110 8
H
48 72</td><td>130 24
X
58 88</td><td>150 8
h
68 104</td><td>170 24
x
78 120</td></tr>
<tr><td>1 Ø Ø 1</td><td>11 TCT
HT
9 9</td><td>31 SPD
EM
19 25</td><td>51 9
)
29 41</td><td>71 25
9
39 57</td><td>111 9
I
49 73</td><td>131 25
Y
59 89</td><td>151 9
i
69 105</td><td>171 25
y
79 121</td></tr>
<tr><td>1 Ø 1 Ø</td><td>12
LF
A 10</td><td>32
SUB
1A 26</td><td>52 10
*
2A 42</td><td>72 26
:
3A 58</td><td>112 10
J
4A 74</td><td>132 26
Z
5A 90</td><td>152 10
j
6A 106</td><td>172 26
z
7A 122</td></tr>
<tr><td>1 Ø 1 1</td><td>13
VT
B 11</td><td>33
ESC
1B 27</td><td>53 11
+
2B 43</td><td>73 27
;
3B 59</td><td>113 11
K
4B 75</td><td>133 27
[
5B 91</td><td>153 11
k
6B 107</td><td>173 27
{
7B 123</td></tr>
<tr><td>1 1 Ø Ø</td><td>14
FF
C 12</td><td>34
FS
1C 28</td><td>54 12
,
2C 44</td><td>74 28
<
3C 60</td><td>114 12
L
4C 76</td><td>134 28
\
5C 92</td><td>154 12
l
6C 108</td><td>174 28
|*
7C 124</td></tr>
<tr><td>1 1 Ø 1</td><td>15
CR
D 13</td><td>35
GS
1D 29</td><td>55 13
-
2D 45</td><td>75 29
=
3D 61</td><td>115 13
M
4D 77</td><td>135 29
]
5D 93</td><td>155 13
m
6D 109</td><td>175 29
}
7D 125</td></tr>
<tr><td>1 1 1 Ø</td><td>16
SO
E 14</td><td>36
RS
1E 30</td><td>56 14
.
2E 46</td><td>76 30
>
3E 62</td><td>116 14
N
4E 78</td><td>136 30
^
5E 94</td><td>156 14
n
6E 110</td><td>176 30
~
7E 126</td></tr>
<tr><td>1 1 1 1</td><td>17
SI
F 15</td><td>37
US
1F 31</td><td>57 15
/
2F 47</td><td>77 UNL
?
3F 63</td><td>117 15
O
4F 79</td><td>137 UNT
_
5F 95</td><td>157 15
o
6F 111</td><td>177
DEL (RUBOUT)
7F 127</td></tr>
<tr><td></td><td>ADDRESSED COMMANDS</td><td>UNIVERSAL COMMANDS</td><td colspan="2">LISTEN ADDRESSES</td><td colspan="2">TALK ADDRESSES</td><td colspan="2">SECONDARY ADDRESSES OR COMMANDS</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>(PPE)</td><td>(PPD)</td></tr>
</table>

*| on some keyboards or systems

KEY

octal	25 PPU	GPIB code
	NAK	ASCII character
hex	15 21	decimal

4999-103