Tektronix®

2235
AN/USM-488
OSCILLOSCOPE
OPERATORS

INSTRUCTION MANUAL

Tektronix®
COMMITTED TO EXCELLENCE

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OPERATORS

INSTRUCTION MANUAL

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

Serial Number ______________

070-4976-00
Product Group 46

First Printing AUG 1984
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INSTRUMENT SERIAL NUMBERS

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

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

Certificate of the Manufacturer/Importer

We hereby certify that the 2235 AN/USM-488 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 2235 AN/USM-488 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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LIST OF TABLES

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 1-1.

Symbols As Marked on Equipment

⚡ DANGER — High voltage.

⏚ Protective ground (earth) terminal.

⚠ ATTENTION — Refer to manual.

Power Source

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

Grounding the Product

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

Danger Arising From Loss of Ground

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

Use the Proper Power Cord

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

Use only a power cord that is in good condition.

For detailed information on power cords and connectors see Figure 2-1.

Use the Proper Fuse

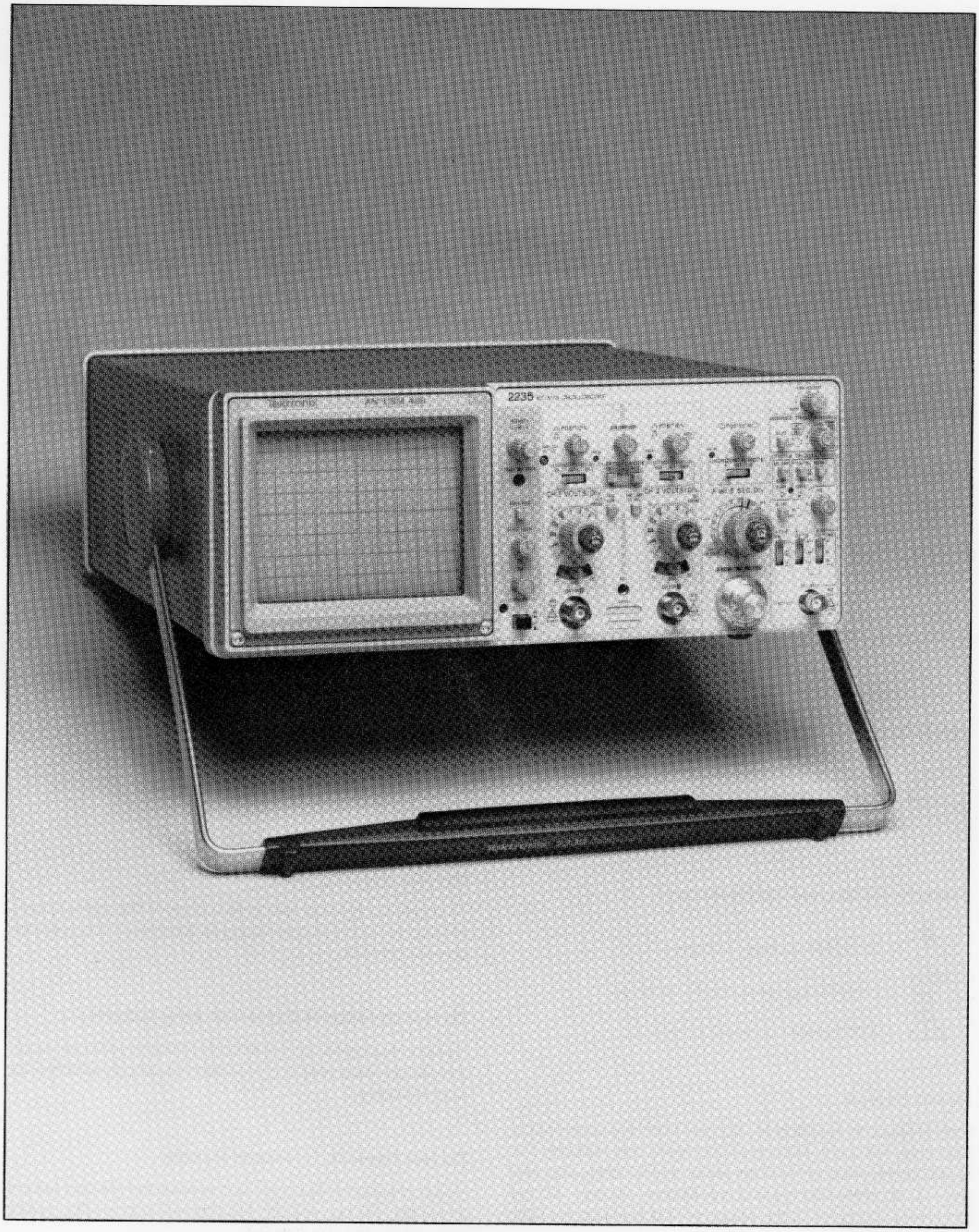
To avoid fire hazard, use only a fuse of the correct type, voltage rating and current rating as specified in the parts list for your product.

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.



4976-01

The 2235 Oscilloscope.

GENERAL INFORMATION

INTRODUCTION

The TEKTRONIX 2235 Oscilloscope is a rugged, lightweight, dual-channel 100-MHz instrument that features a bright, sharply defined trace on an 80- by 100-mm cathode-ray tube (crt). Its vertical system supplies calibrated deflection factors from 2 mV per division to 5 V per division. Trigger circuits enable stable triggering over the full bandwidth of the vertical system. The horizontal system provides calibrated sweep speeds from 0.5 s per division to 50 ns per division, along with delayed-sweep features. A X10 magnifier circuit extends the maximum sweep speed to 5 ns per division when the A and B SEC/DIV switch is set to 0.05 μs per division.

The instrument is shipped with the following standard accessories:

1 Operators manual	1 BNC Male to binding post
1 Service manual	1 Protective front-panel cover
2 10X Probe packages	1 Accessory Pouch
1 1X Probe package	1 Viewing Hood
1 Power cord	2 IC Grabber tips
1 BNC T connector	1 Fuse

For Accessory Pouch attachment, refer the instrument to a qualified service person. This procedure is covered in the service manual

For part numbers and further information about both standard and optional accessories, refer to the "Options and Accessories" section (Section 5) of this manual. Your Tektronix representative, local Tektronix Field Office, or Tektronix product catalog can also provide accessories information.

SPECIFICATION

The following electrical characteristics (Table 1-1) are valid for the 2235 when it 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, while items listed in the "Supplemental Information" column are either explanatory notes, calibration setup descriptions, performance characteristics for which no absolute limits are specified, or characteristics that are impractical to check.

Environmental characteristics are given in Table 1-2. The 2235 meets the requirements of MIL-T-28800C, paragraphs 4.5.5.1.3, 4.5.5.1.4, and 4.5.5.1.2.2 for Type III, Class 5 equipment, except where otherwise noted.

Physical characteristics of the instrument are listed in Table 1-3.

Table 1-1
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.
Accuracy	
+10°C to +35°C	±2%.
0°C to +50°C	±3%.
Range of VOLTS/DIV Variable Control	Continuously variable between settings. Increases deflection factor by at least 2.5 to 1.
Step Response	
Rise Time	
0°C to +35°C	
5 mV per Division to 5 V per	3.5 ns or less.[a]
2 mV per Division	3.9 ns or less.[a]
+35°C to +50°C	
5 mV per Division to 5 V per Division	3.9 ns or less.[a]
2 mV per Division	4.4 ns or less.[a]
Aberrations	
Positive-Going Step	
2 mV per Division to 0.5 V per Division	+4%, −4%, 4% p-p.
1V per Division to 5 V per Division	+12%, −12%, 12% p-p.
Bandwidth (−3 dB)	
0°C to +35°C	
5 mV per Division to 5 V per Division	Dc to at least 100 MHz.
2 mV per Division	DC to at least 90 MHz.
+35°C to +50°C	
5 mV per Division to 5 V per Division	DC to at least 90 MHz.
2 mV per Division	Dc to at leat 80 MHz.
AC Coupled Lower Limit	10 Hz or less at −3 dB.
Bandwidth Limiter	Upper limits (−3 dB bandpass at 20 MHz ±10%).
Chop Mode Switching Rate	500 kHz ±30%.
Input Characteristics	
Resistance	1 MΩ ±2%.
Capacitance	20 pF ±2 pF.

[a]**Rise time is calculated from the formula:**

$$\text{Rise Time} = \frac{0.35}{\text{Bandwidth } (-3\ \text{dB})}$$

Table 1-1 (cont)

Characteristics	Performance Requirements		
VERTICAL DEFLECTION SYSTEM (cont)			
Maximum Safe Input Voltage ⚠	See Figure 1-1 for derating curve.		
DC Coupled	400 V (dc + peak ac) or 800 V ac p-p to 10 kHz or less.		
AC Coupled	400 V (dc + peak ac) or 800 V ac p-p to 10 kHz or less.		
Common-Mode Rejection Ratio	At least 10 to 1 at 80 MHz.		
Input Current	1.0 nA or less (0.5 division trace shift at 2 mV per division).		
Trace Shift with VOLTS/DIV switch Rotation	0.75 division or less. (VOLTS/DIV Variable control in CAL detent).		
Trace Shift as VOLTS/DIV Variable Control is Rotated	1.0 division or less.		
Trace Shift with Invert	1.5 division or less.		
Channel Isolation	Greater than 100 to 1 at 50 MHz.		
POSITION Control Range	At least ±11 divisions from graticule center.		
TRIGGER SYSTEM			
A TRIGGER Sensitivity			
P-P AUTO/TV LINE and NORM Modes (A TRIG BW Switch in FULL Position)	**10 MHz**	**60 MHz**	**100 MHz**
Internal	0.35 div.	1.0 div.	1.5 div.
External	35 mV	120 mV	150 mV
HF REJ	Attenuates signals above 40 KHz (−3 dB point at 40 KHz ±25%).		
LF REJ	Attenuates signals below 40 KHz (−3 dB point at 40 KHz ±25%).		
Lowest Useable Frequency in P-P AUTO Mode	20 Hz with 1.0 division internal or 100 mV external.		
TV FIELD Mode	1.0 division of composite sync.		
B TRIGGER Sensitivity (Internal Only)	**10 MHz**	**60 MHz**	**100 MHz**
	0.35 div	1.0 div	1.5 div
EXT INPUT			
Maximum Input Voltage ⚠	400 V (dc + peak ac) or 800 V ac p-p (see Figure 1-1 for derating curve).		
Input Resistance	1 MΩ ±2%.		
Input Capacitance	20 pF ±2.5 pF.		
AC Coupled	10 Hz or less at lower −3 dB point.		
LEVEL Control Range			
A TRIGGER (NORM)			
INT	Can be set to any point of the trace that can be displayed.		
EXT, DC	At lease ±1.6 V, 3.2 V p-p.		
EXT, DC ÷ 10	At least ±16 V, 32 V p-p.		

Table 1-1 (cont)

Characteristics	Performance Requirements	
TRIGGER SYSTEM (cont)		
B TRIGGER (Internal)	Can be set to any point of the trace that can be displayed.	
VAR HOLDOFF Control	Increases A Sweep holdoff time by at least a factor of 10.	
Trigger View System		
Deflection Factor		
Internal	Same as vertical.	
External		
AC and DC	100 mV per division.	
DC÷10	1 V per division.	
Accuracy	±20%.	
Delay Difference Between EXT INPUT and Either Vertical Channel	Less than 2.0 ns	
HORIZONTAL DEFLECTION SYSTEM		
Sweep Rate		
Calibrated Range		
A Sweep	0.5 s per division to 0.05 μs per division in a 1-2-5 sequence. X10 magnifier extends maximum sweep speed to 5 ns per division.	
B Sweep	50 ms per division to 0.05 μs per division in a 1-2-5 sequence. X10 magnifier extends maximum sweep speed to 5 ns per division.	
Accuracy	**Unmagnified**	**Magnified**
+10°C to +35°C	±2%	±3%
0°C to +50°C	±3%	±4%
POSITION Control Range	Start of sweep to 10th division will position past the center vertical graticule line in X1 or 100th division in X10.	
Sweep Linearity	±5%.	
Variable Control Range	Continuously variable between calibrated settings. Reduces the A and B sweep speeds by at least a factor of 2.5.	
Sweep Length	Greater than 10 divisions.	
A/B SWP SEP Range	±3.5 divisions or greater.	
Delay Time	Applies to 0.5 μs per division and slower.	
Dial Control Range	<0.5 +300 ns to >10 divisions.	
Jitter	One part or less in 20,000 (0.005%) of the maximum available delay time.	
Differential Time Measurement Accuracy		
+15°C to +35°C	±1% +0.01 major dial division.	
0°C to +50°C	±2% +0.01 major dial division.	

Table 1-1 (cont)

Characteristics	Performance Requirements
X-Y OPERATION (X1 MAGNIFICATION)	
Deflection Factors	Same as Vertical Deflection System (with VOLTS/DIV Variable controls in CAL detent).
Accuracy	
X-Axis	
+15°C to +35°C.	±3%.
0°C to +50°C	±4%.
Y-Axis	Same as Vertical Deflection System.
Bandwidth (−3 dB)	
X-Axis	Dc to at least 2.5 MHz.
Y-Axis	Same as Vertical Deflection System.
Phase Difference Between X- and Y-Axis Amplifiers	±3° from dc to 150 kHz.
AMPLITUDE CALIBRATOR	
Output Voltage of AMP CAL Jack	0.5 V ±2%.
Repetition Rate	1 kHz ±20%.
Z-AXIS INPUT	
Sensitivity	5 V causes noticeable modulation. Positive-going input decreases intensity.
Maximum Safe Input Voltage ⚠	30 V (dc + peak ac) or 30 V p-p ac at 1 kHz or less.
Input Resistance	10 kΩ ±10%.
POWER SOURCE	
Line Voltage Ranges	90 V to 250 V.
Line Frequency	48 Hz to 440 Hz.
Maximum Power Consumption	40 W (70 VA).
Line Fuse	1.0 A, 250 V, slow-blow.
CATHODE-RAY TUBE	
Display Area	80 by 100 mm.
Standard Phosphor	P31.
Nominal Accelerating Voltage	14 kV.

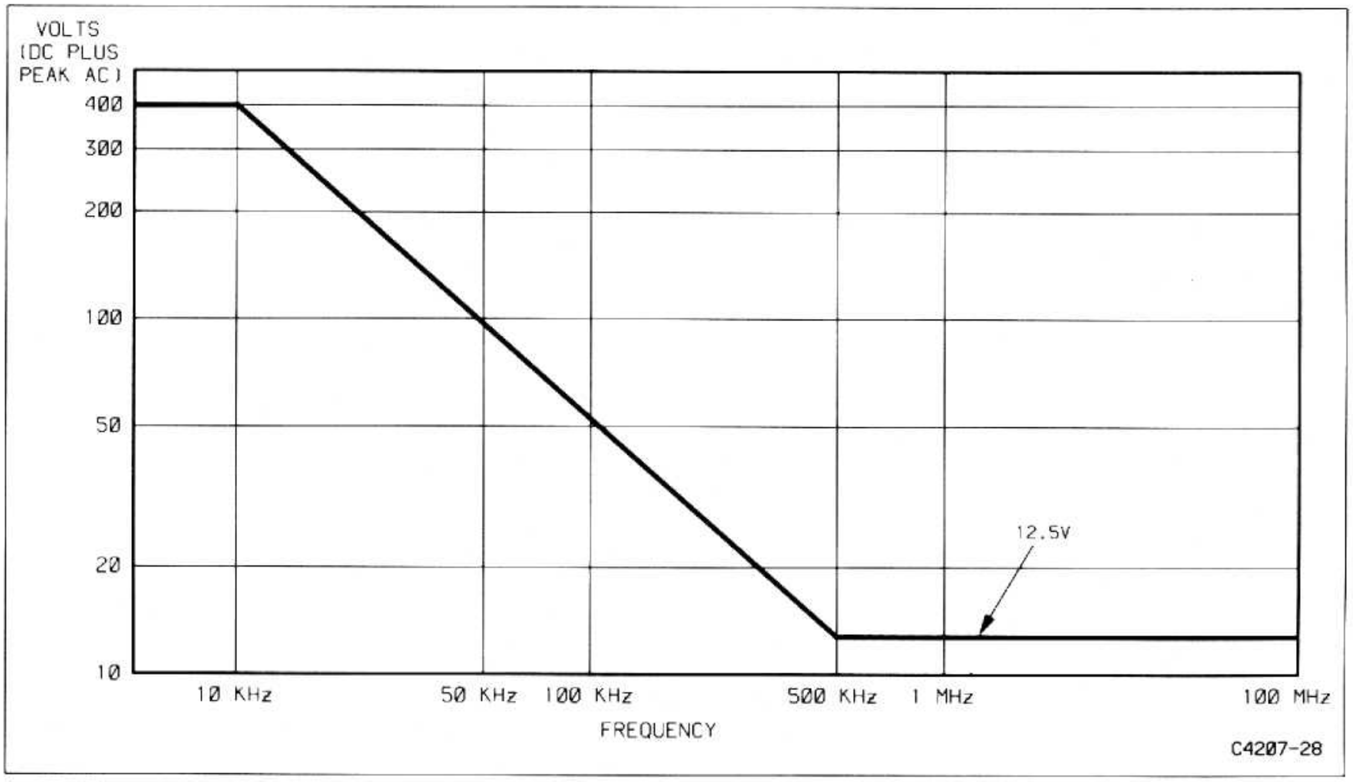


Figure 1-1. Maximum input voltage vs. frequency derating curve for CH 1 OR X, CH 2 OR Y, and EXT INPUT connectors.

Table 1-2
Environmental Characteristics

Characteristics	Description
	NOTE *The instrument meets the requirements of MIL-T-28800C, paragraphs 4.5.5.1.3, 4.5.5.1.4, and 4.5.5.1.2.2 for Type III, Class 5 equipment, except where otherwise noted.*
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 paragraphs 4.5.5.1.3 and 4.5.5.1.4, except in 4.5.5.1.3 steps 4 and 5 (0°C operating test) are performed ahead of step 2 (−55°C nonoperating test). Equipment shall remain off upon return to room ambient during step 6. Excessive condensation shall be removed before operating during step 7.
Altitude	
Operating	To 4,500 m (15,000 ft). Maximum operating temperature decreased 1°C per 1,000 ft above 5,000 ft.
Nonoperating	To 15,000 m (50,000 ft).
Humidity (Operating and Nonoperating)	5 cycles (120 hours) referenced to MIL-T-28800C paragraph 4.5.5.1.2.2 for Type III, Class 5 instruments. Operating and non-operating at 95% +0% to −5% relative humidity. Operating at +30°C to +50°C. Non-operating at +30°C to +60°C.
Vibration (Operating)	15 minutes along each of 3 major axes at a total displacementof 0.015 inch p-p (2.4 g's at 55 Hz) with frequency varied from 10 Hz to 55 Hz to 10 Hz in 1-minute sweeps. Hold for 10 minutes at 55 Hz in each of the 3 major axes. All major resonances must be above 55 Hz.
Shock (Operating and Nonoperating)	30 g's, half-sine, 11-ms duration, 3 shocks per axis each direction, for a total of 18 shocks.
Radiated and Conducted Emission Requirements Per VDE 0871	Meets Class B.
Electromagnetic Interference	Meets the requirements of MIL STD-461B: CE03, CS01, CS02, CS06, RE02 up to 1 GHz, RS03 for a field of 1 V/meter up to 1 GHz.

Table 1-3
Physical Characteristics

Characteristics	Description
Weight	
With Accessories	9.1 kg (20.0 lb).
Without Accessories	6.1 kg (13.5 lb).
Domestic Shipping Weight	10.9 kg (24.1 lb).
Height	
With Pouch (Empty)	150 mm (5.9 in).
Without Pouch	137 mm (5.4 in).
Width	
With Handle	360 mm (14.2 in).
Without Handle	328 mm (12.9 in).
Depth	
With Front Cover	445 mm (17.5 in).
Without Front Cover	440 mm (17.3 in).
With Handle Extended	511 mm (20.1 in).

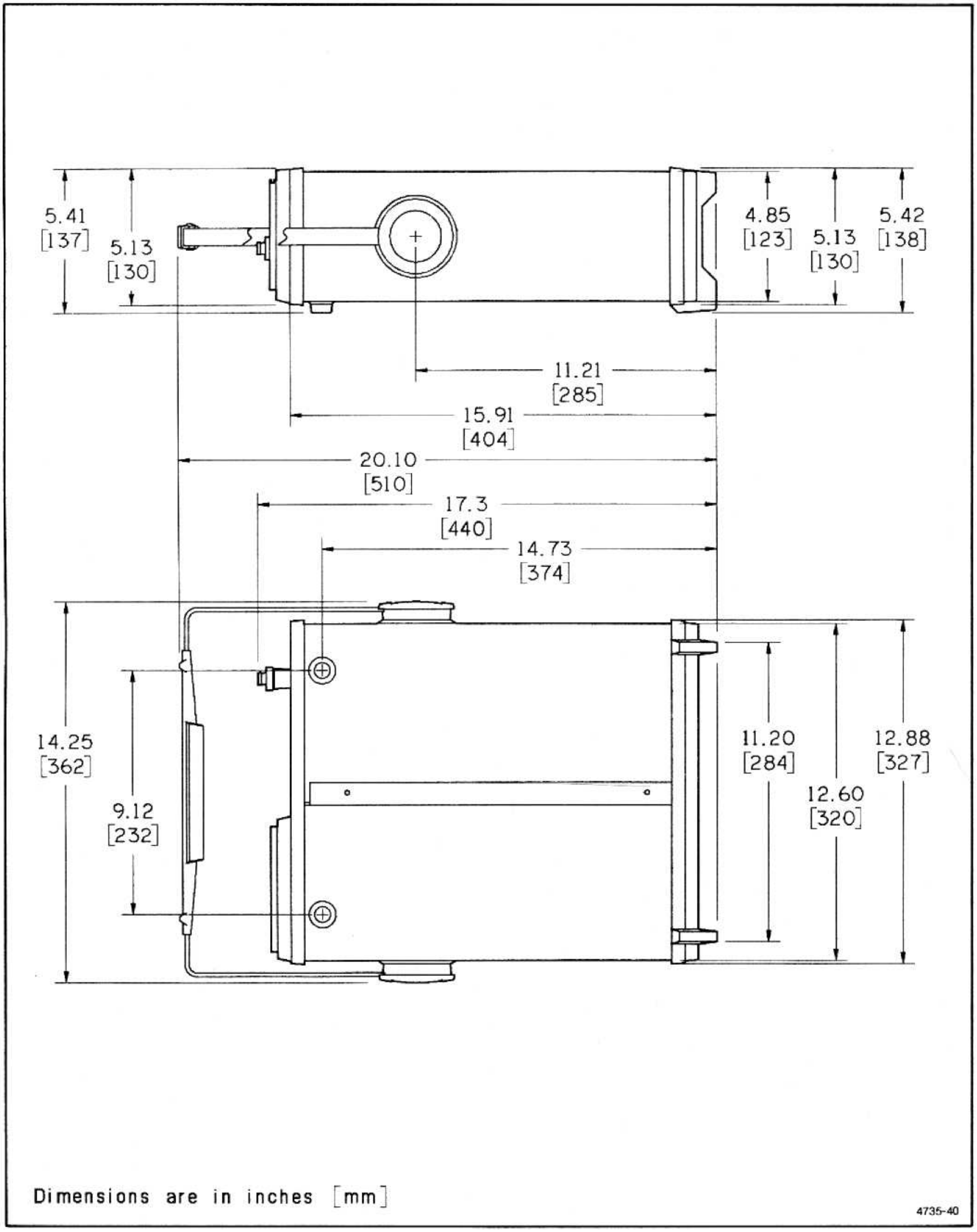


Figure 1-2. Physical dimensions of the 2235 Oscilloscope.

PREPARATION FOR USE

FIRST-TIME START UP

SAFETY

Refer to the "Operators Safety Summary" at the front of this manual for power source, grounding, and other safety considerations pertaining to the use of this instrument. Before connecting the instrument to a power source, carefully read the following about line voltages, power cords, and fuses.

LINE VOLTAGE

The instrument is capable of continuous operation using input voltages that range from 90 V to 250 V nominal at 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 to permit connection to both the power source and protective ground. The plug protective-ground contact 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 outlet that has a securely grounded protective-ground contact. To secure the power cord to the instrument, use the power cord clamp as illustrated in Figure 2-1A.

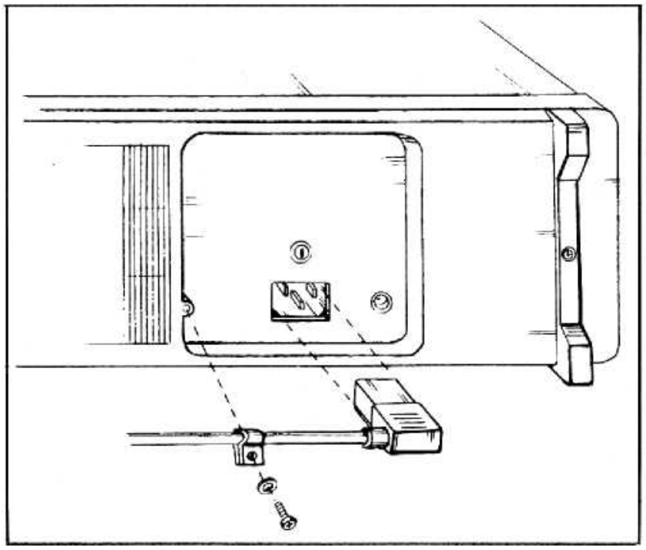
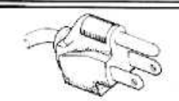
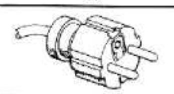
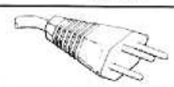


Fig. 2-1A. Power Cord Clamp

Instruments are shipped with the required power cord as ordered by the customer. Available power-cord options are illustrated in Figure 2-1B, and part numbers are listed on the "Accessories" page at the back of this manual. Contact your Tektronix representative or local Tektronix Field Office for additional power-cord information.

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/ 10A	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

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Fig. 2-1B. Optional Power Cords

LINE FUSE

The instrument fuse holder is located on the rear panel (see Figure 2-2) and contains the line fuse. The following procedure can be used 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 applicable).

2. Press in and slightly rotate the fuse-holder cap counterclockwise to release it.

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

4. Verify proper fuse value (1.0A, 250 V, slow blow).

5. Reinstall the fuse (or replacement fuse) and the fuse-holder cap.

INSTRUMENT COOLING

Always maintain adequate instrument cooling. The ventilation holes on both sides of the instrument cabinet and on the rear panel must remain free of obstruction.

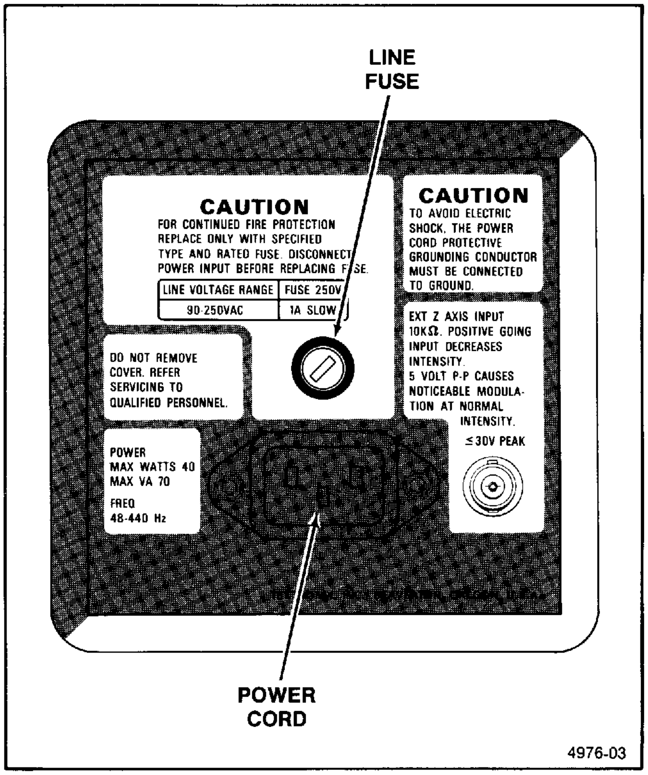

Figure 2-2. Fuse holder and power cord connector.

LONG-TERM CARE

INSPECTION

Inspect the instrument for damage, wear, and missing parts; use Table 2-1 as a guide. Instruments that have been abused should be checked thoroughly to verify correct operation and performance. Instruments that are damaged or do not perform correctly should be referred to qualified service personnel.

Accumulation of dirt in the ventilation holes located on both sides of the cabinet and on the rear panel may cause overheating of the instrument. The ventilation holes should be checked routinely and kept clean.

Table 2-1
External Inspection Checklist

Item	Inspect For
Cabinet and Front Panel	Cracks, scratches, deformations, and damaged hardware or gaskets.
Front-Panel Controls	Missing, damaged, or loose knobs, buttons, and controls.
Connectors	Broken shells, cracked insulation, and deformed contacts. Dirt in connectors.
Carrying Handle	Correct operation.
Accessories	Missing items or parts of items, bent pins, broken or frayed cables, and damaged connectors.

CAUTION

Avoid the use of chemical cleaning agents which might damage the plastics used in this instrument. Use a nonresidue-type cleaner, preferably isopropyl alcohol, denatured ethyl alcohol, or a solution of 5% mild detergent with 95% water. Before using any other type of cleaner, consult your Tektronix Service Center or representative.

To prevent getting moisture inside the instrument during external cleaning, use only enough liquid to dampen the cloth or applicator.

CLEANING

Loose dust on the outside of the instrument can be removed with a soft cloth or small soft-bristle brush. The brush is particularly useful for dislodging dirt on and around the controls and connectors. Dirt that remains can be removed with a soft cloth dampened in a mild detergent-and-water solution. Do not use abrasive cleaners. Clean the light filter and the crt face with a soft lint-free cloth dampened with either isopropyl alcohol, denatured ethyl alcohol, or a mild detergent-and-water solution. The crt filter mesh should be washed only with either isopropyl alcohol or ethyl alcohol.

CALIBRATION

Instrument performance should be checked by a qualified service person after every 2000 hours of operation or once each year if used infrequently. A more frequent interval may be necessary if the instrument is subjected to harsh environments or severe usage.

STORAGE

Instruments that are to be stored outside of the original shipping carton and polyethylene bag in extremely adverse humidity conditions should be placed in an area with adequate ventilation.

NOTE

Instruments have been environmentally tested for 5 days at 90% to 95% relative humidity to ensure minimal degradation after being exposed to high humidity storage.

The front-panel cover should be used whenever the instrument is stored. This will provide protection for the front panel and crt face.

INSTRUMENT REPACKAGING

To ship an instrument, it is recommended that it be packaged in the original manner. The carton and packaging material in which the instrument was shipped should be saved and used for this purpose. The Accessory Pouch should be removed by a qualified service person before being shipped in the original carton.

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 to be shipped to a Tektronix Service Center for service or repair, attach a tag to the instrument showing the following: owner of the instrument (with address), the name of a person who can be contacted, 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 three inches on each side.

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

6. Mark the address of the Tektronix Service Center and the 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, operation, and function of the instrument's controls, connectors, and indicators.

DISPLAY AND POWER

Refer to Figure 2-3 for location of items 1 through 8.

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

(2) **POWER Switch**—Turns instrument power on and off. Press in for ON; press again for OFF.

(3) **Power Indicator**—An LED that illuminates when the instrument is operating.

(4) **FOCUS Control**—Adjusts for optimum display definition.

(5) **SCALE ILLUM Control**—Adjusts the light level of the graticule illumination.

(6) **BEAM FIND Switch**—When held in, compresses the display to within the graticule area and provides a visible viewing intensity to aid in locating off-screen displays.

(7) **TRACE ROTATION Control**—Screwdriver adjustment used to align the crt trace with the horizontal graticule lines.

(8) **A and B INTENSITY Controls**—Determines the brightness of the A and B Sweep traces.

VERTICAL

Refer to Figure 2-4 for location of items 9 through 21.

(9) **CH 1 VOLTS/DIV and CH 2 VOLTS/DIV Switches**—Used to select the vertical deflection factor in a 1-2-5 sequence. To obtain a calibrated deflection factor, the VOLTS/DIV variable control must be in the calibrated (CAL) detent (fully clockwise).

1X—Indicates the deflection factor selected when using either a 1X probe or a coaxial cable.

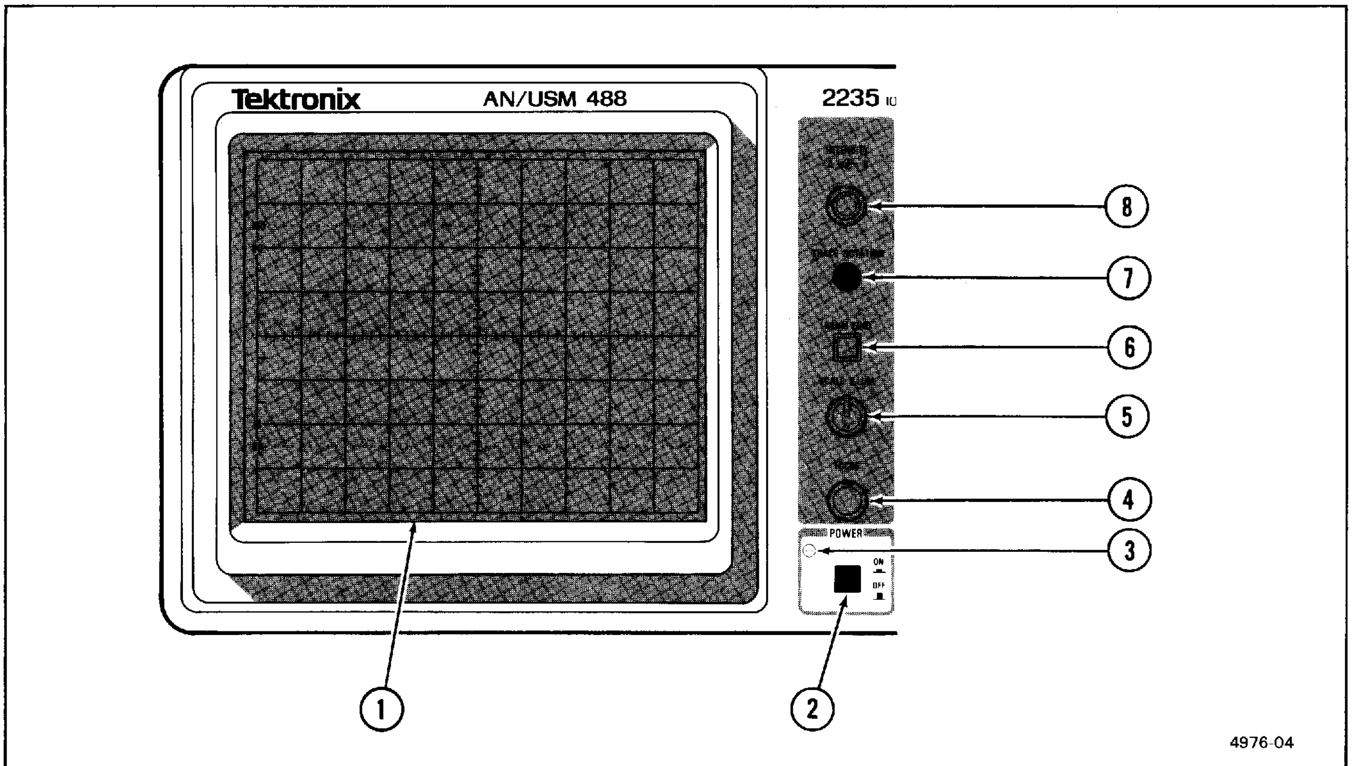

Figure 2-3. Power and display controls and indicator.

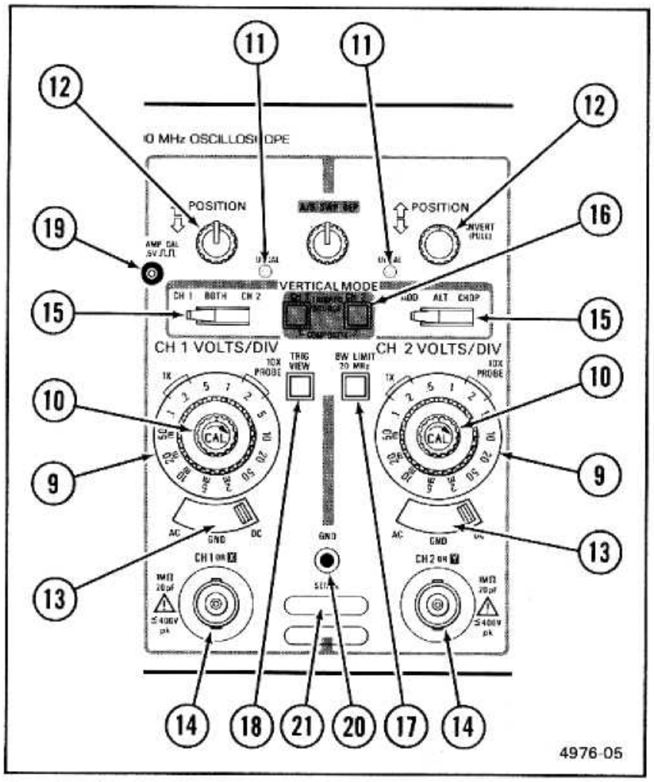

Figure 2-4. Vertical controls, connectors, and indicators.

10X PROBE—Indicates the deflection factor selected when using a 10X probe.

(10) **VOLTS/DIV Variable Controls**—When rotated counterclockwise out of their calibrated detent positions, these controls provide continuously variable, uncalibrated deflection factors between the calibrated settings of the VOLTS/DIV switches.

(11) **UNCAL Indicator**—The LED illuminates to indicate that the VOLTS/DIV Variable control is out of the calibrated position.

(12) **POSITION Controls and Channel 2 INVERT (PULL) Switch**—The POSITION controls are used to vertically position the display on the crt. When the SEC/DIV switch is set to X-Y, the Channel 2 POSITION control moves the display vertically (Y-axis), and the Horizontal POSITION control moves the display horizontally (X-axis).

To invert Channel 2 display, pull out the Channel 2 POSITION control knob. With the Channel 2 display inverted, the instrument can be operated as a differential amplifier when the VERTICAL MODE switches are in BOTH and ADD positions.

(13) **Input Coupling (AC-GND-DC) Switches**—Three-position switches that select the method of coupling the input signals to the instrument deflection system.

AC—Input signal is capacitively coupled to the vertical amplifier. The dc component of the input signal is blocked. Low-frequency limit (−3 dB point) is approximately 10 Hz.

GND—The input of the vertical amplifier is grounded to provide a zero (ground) reference-voltage display (does not ground the input signal). This switch position allows precharging the input coupling capacitor.

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

(14) **CH 1 OR X and CH 2 OR Y Input Connectors**—Provide for application of external signals to the vertical deflection system or for an X-Y display. In the X-Y mode (SEC/DIV switch set to X-Y), the signal connected to the CH 1 OR X input connector provides horizontal deflection (X-axis) and the signal connected to the CH 2 OR Y input connector provides vertical deflection (Y-axis).

(15) **VERTICAL MODE Switches**—Two three-position switches are used to select the mode of operation for the vertical amplifier system.

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

BOTH—Selects both Channel 1 and Channel 2 input signals for display. The CH 1-BOTH-CH 2 switch must be in the BOTH position for either ADD, ALT, or CHOP operation.

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

ADD—Displays the algebraic sum of the Channel 1 and Channel 2 input signals.

ALT—Alternately displays Channel 1 and Channel 2 input signals. The alternation occurs during retrace at the end of each sweep. This mode is useful for viewing both input signals at sweep speeds from 0.05 μs per division to 0.2 ms per division.

CHOP—The display switches between the Channel 1 and Channel 2 input signals during the sweep. The switching rate is approximately 500 kHz. This mode is useful for viewing both Channel 1 and Channel 2 input signals at sweep speeds from 0.5 ms per division to 0.5 μs per division.

(16) **TRIGGER SOURCE Switches**—Two buttons that select the source of the internal triggering signal for the A Trigger when the A SOURCE switch is set to INT.

CH 1—The signal applied to the CH 1 OR X input connector is the source of the trigger signal.

CH 2—The signal applied to the CH 2 OR Y input connector is the source of the trigger signal. The Channel 2 POSITION control, when pulled out, will invert the Channel 2 trigger signal.

COMPOSITE—The signal applied to either or both vertical input connectors is the source of the trigger signal. COMPOSITE TRIGGER SOURCE is selected when both CH 1 and CH 2 buttons are either out or pressed in. The trigger source is determined by signals selected for display by the VERTICAL MODE switches. See Table 2-2 for COMPOSITE TRIGGER SOURCE.

Table 2-2
Composite Trigger Source

VERT MODE	Trigger Source
CH 1	CH 1 OR X input signal.
CH 2	CH 2 OR Y input signal.
BOTH and ADD	Algebraic sum of CH 1 OR X and CH 2 OR Y input signals.
BOTH and CHOP	Algebraic sum of CH 1 OR X and CH 2 OR Y input signals.
BOTH and ALT	Alternates between Channel 1 and Channel 2 on every other sweep (i.e. CH 1 OR X input signal triggers the sweep that displays Channel 1, and CH 2 OR Y input signal triggers the sweep that displays Channel 2).

(17) **BW LIMIT**—When pressed in, this button switch limits the bandwidth of the vertical amplifier and the A Trigger system to approximately 20 MHz. Button must be pressed a second time to release it and regain full 100 MHz bandwidth operation. Provides a method for reducing interference from high-frequency signals when viewing low-frequency signals.

(18) **TRIG VIEW Switch**—Press and hold the button in to display a sample of the signal present in the A Trigger amplifier (for all A SOURCE switch settings). All other displays are removed while the TRIG VIEW button is held in.

(19) **AMP CAL Connector**—Provides an approximately 0.5 V, negative-going, square-wave voltage (at approximately 1 kHz) that permits an operator to compensate voltage probes and to check operation of the oscilloscope vertical system. It is not intended for verifying the accuracy of the vertical gain or time-base circuitry.

(20) **GND Connector**—Provides direct connection to the instrument chassis ground.

(21) **SERIAL and Mod Slots**—The SERIAL slot is imprinted with the instrument's serial number. The Mod slot contains the option number that is installed in the instrument.

HORIZONTAL

Refer to Figure 2-5 for location of items 22 through 28.

(22) **A and B SEC/DIV Switches**—Used to select the sweep speeds for the A and B Sweep generators in a 1-2-5 sequence. To obtain calibrated sweep speeds, the A and B SEC/DIV Variable control must be in the calibrated detent (fully clockwise).

A SEC/DIV—The calibrated sweep speed is shown between the two black lines on the clear plastic skirt. This switch also selects the delay time for delayed-sweep operation when used in conjunction with the B DELAY TIME POSITION control.

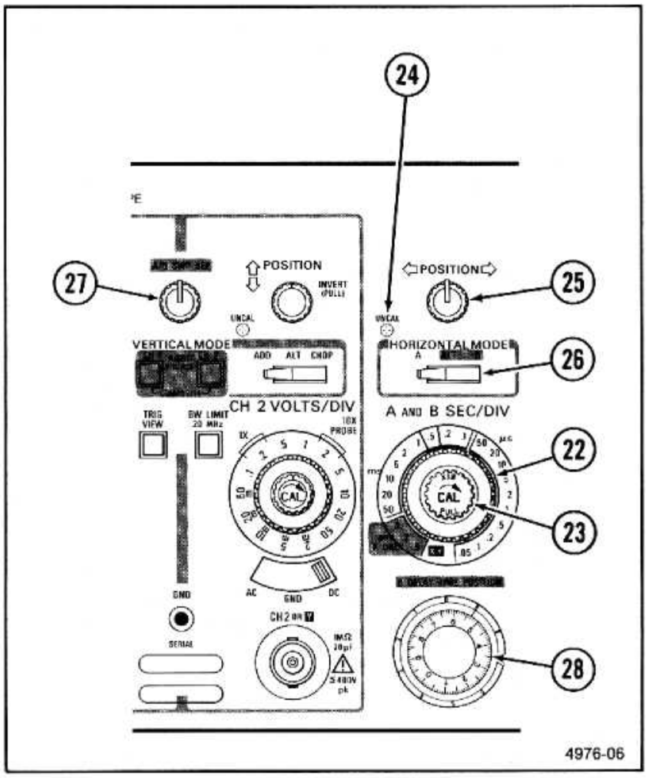

Figure 2-5. Horizontal controls and indicator.

B SEC/DIV—The B Sweep speed is set by pulling out the DLY'D SWEEP knob and rotating it clockwise to a setting opposite the white line scribed on the knob. The B Sweep circuit is used only for delayed-sweep operation.

(23) **SEC/DIV Variable Control and X10 Magnifier Switch**—The SEC/DIV Variable control provides continuously variable, uncalibrated A and B Sweep speeds to at least 2.5 times slower than the calibrated setting. It extends the slowest A Sweep speed to at least 1.25 s per division.

To expand the crt display by a factor of 10, pull out the X10 Magnifier control (SEC/DIV Variable control knob). The display portion of the sweep will be 10 times faster than the A and B SEC/DIV switch settings. This allows a maximum sweep speed of 5 ns per division. Push in the SEC/DIV Variable knob to regain the X1 (normal) sweep speed.

(24) **UNCAL Indicator**—The LED illuminates to indicate that the SEC/DIV Variable control is out of the calibrated position.

(25) **POSITION Control**—Horizontally positions both the A Sweep and the B Sweep displays and horizontally positions X-axis in the X-Y mode.

(26) **HORIZONTAL MODE Switch**—Three-position switch determines the mode of operation for the horizontal deflection system.

A—Horizontal deflection is provided by the A Sweep generator at a sweep speed determined by the A SEC/DIV switch setting.

ALT—Alternates the horizontal displays between the A Sweep (with an intensified zone) and the B Delayed Sweep. The A Sweep speed is determined by the setting of the A SEC/DIV switch. The B Sweep speed and the length of the intensified zone on the A Sweep are both determined by the B SEC/DIV switch setting.

B—Horizontal deflection is provided by the B Sweep generator at a sweep speed determined by the B SEC/DIV switch setting. The start of the B Sweep is delayed from the start of the A Sweep by a time determined by the settings of both the A SEC/DIV switch and the B DELAY TIME POSITION control.

(27) **A/B SWP SEP Control**—Vertically positions the B Sweep trace with respect to the A Sweep trace when ALT HORIZONTAL MODE is selected.

(28) **B DELAY TIME POSITION Control**—Selects the amount of delay time between the start of the A Sweep and the start of the B Sweep. Delay time is variable from 0.5 times to 10 times the A SEC/DIV switch setting.

TRIGGER

Refer to Figure 2-6 for location of items 29 through 38.

(29) **A TRIGGER Mode Switches**—Three-section switch that determines the trigger mode for the A Sweep.

P-P AUTO-TV LINE—Permits triggering on waveforms and television lines having repetition rates of at least 20 Hz. Sweep free-runs in the absence of an adequate trigger signal or when the repetition rates are below 20 Hz. The range of the A TRIGGER LEVEL control is restricted to the peak-to-peak range of the trigger signal.

NORM—Sweep is initiated when an adequate trigger signal is applied. In the absence of a trigger signal, no baseline trace will be present.

TV FIELD—Press in both P-P AUTO and NORM buttons. Permits triggering on television field signals. TRIGGER LEVEL control should be rotated fully counterclockwise when triggering on TV signals with negative-going sync and clockwise for positive-going sync.

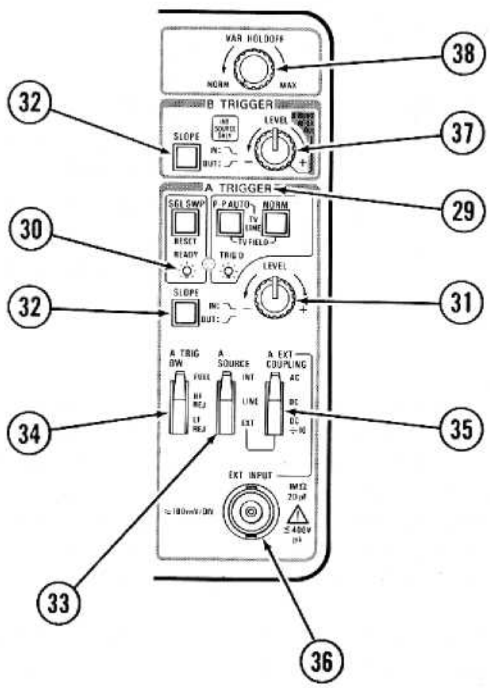

Figure 2-6. Trigger controls, connector, and indicator.

SGL SWP RESET—Press in the spring-return button momentarily to arm the A Trigger circuit for a single-sweep display. In this mode, the trigger system operates the same as NORM, except only one sweep is displayed for each trigger signal. Another sweep cannot be displayed until the SGL SWP RESET button is momentarily pressed in again to reset the A Trigger circuit. This mode is useful for displaying and photographing either nonrepetitive signals or signals that cause unstable conventional displays (e.g., signals that vary in amplitude, shape, or time).

(30) **TRIG'D-READY Indicator**—LED illuminates when either P-P AUTO or NORM Trigger Mode is selected and the A Sweep has been triggered (TRIG'D). In single-sweep display, the LED illuminates to indicate that the A Trigger circuit is armed (READY).

(31) **A TRIGGER LEVEL Control**—Selects the amplitude point on the trigger signal at which the sweep is triggered.

(32) **SLOPE Switch**—Selects the slope of the signal that triggers the sweep.

OUT—When button is released out, sweep is triggered from the positive-going slope of the trigger signal.

IN—When button is pressed in, sweep is triggered from the negative-going slope of the trigger signal.

(33) **A SOURCE Switch**—Determines the source of the trigger signal coupled to the input of the A Trigger circuit.

INT—Permits triggering on signals that are applied to the CH 1 OR X and CH 2 OR Y input connectors. The source of the internal signal is selected by the TRIGGER SOURCE switches.

LINE—The power-source waveform is the source of the trigger signal. This trigger source is useful when vertical input signals are time related (multiple or submultiple) to the frequency of the power-input source voltage.

EXT—Permits triggering on signals applied to the EXT INPUT connector.

(34) **A TRIG BW Switch**—Three-section switch that selects the trigger bandpass frequencies for the A Trigger circuit.

FULL—All frequency components are passed to the A Trigger circuit.

HF REJ—Attenuates trigger-signals above approximately 40 kHz. This position is useful for providing a stable display of the low-frequency components of a complex waveform.

LF REJ—Attenuates trigger-signals below approximately 40 kHz. This position is useful for providing a stable display of the high-frequency components of a complex waveform.

(35) **A EXT COUPLING Switch**—Determines the method used to couple external signals to the A TRIGGER circuit from the EXT INPUT connector.

AC—Signals above 60 Hz are capacitively coupled to the input of the A Trigger circuit. Any dc components are blocked, and signals below 60 Hz are attenuated.

DC—All frequency components of the signal are coupled to the input of the A Trigger circuitry. This position is useful for displaying low-frequency or low-repetition-rate signals.

DC÷10—External trigger signals are attenuated by a factor of 10. All frequency components of the signal are coupled to the input of the A Trigger circuit.

(36) **EXT INPUT Connector**—Provides a means of introducing external signals into the A Trigger circuit through the A EXT COUPLING switch.

(37) **B TRIGGER LEVEL Control**—Selects the amplitude point on the trigger signals at which the sweep is triggered. When fully clockwise (B RUNS AFTER DLY), the B Sweep circuit runs immediately following the delay time selected by the A SEC/DIV and the B DELAY TIME POSITION control.

(38) **VAR HOLDOFF Control**—Provides continuous control of holdoff time between sweeps. Increases the holdoff time by at least a factor of 10. This control improves the ability to trigger on aperiodic signals (such as complex digital waveforms).

REAR PANEL

Refer to Figure 2-7 for location of item 39.

(39) **EXT Z-AXIS Connector**—Provides a means of connecting external signals to the Z-Axis amplifier to intensity modulate the crt. Applied signals do not affect display waveshape. Signals with fast rise times and fall times provide the most abrupt intensity change, and a 5 V p-p signal will produce noticeable modulation. The Z-Axis signals must be time-related to the display to obtain a stable presentation on the crt.

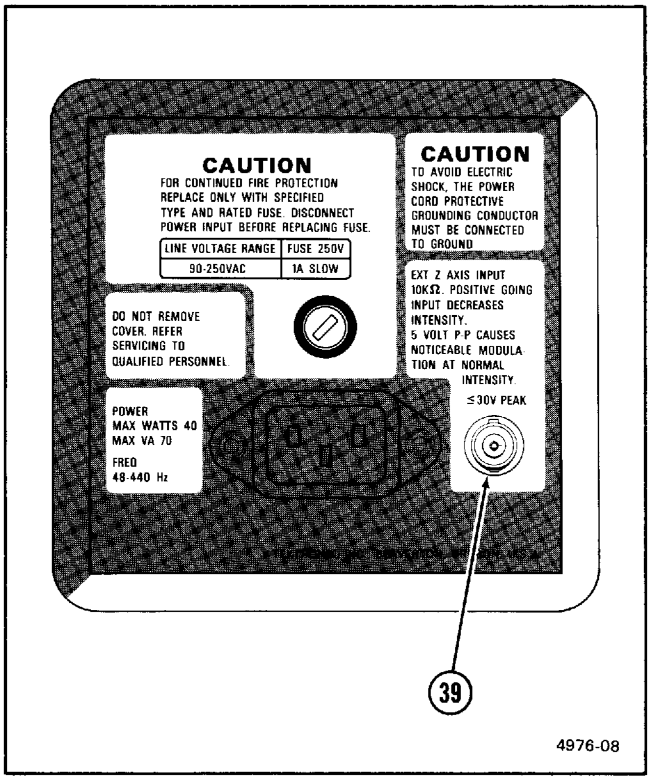

Figure 2-7. Rear-panel connector.

OPERATING CONSIDERATIONS

GENERAL OPERATING INFORMATION

GRATICULE

The graticule is internally marked on the faceplate of the crt to enable accurate measurements without parallax error (see Figure 3-1). It is marked with eight vertical and ten horizontal major divisions. 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 markers for the measurement of rise and fall times are located on the left side of the graticule.

GROUNDING

The most reliable signal measurements are made when this instrument 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 connector located on the front panel.

SIGNAL CONNECTIONS

Generally, probes offer the most convenient means of connecting an input signal to the instrument. They are shielded to prevent pickup of electromagnetic interference, and the supplied 10X probe offers a high input impedance that minimizes circuit loading. This allows the circuit under test to operate with a minimum of change from its normal condition as measurements are being made.

Coaxial cables may also be used to connect signals to the 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 GND, the input signal is connected to ground through the input coupling capacitor in series with a 1 MΩ resistor to form a precharging network. This network allows the input coupling capacitor to charge to the average dc-voltage level of the signal applied to the probe. Thus any large voltage transients that may accidentally be generated will not be applied to the amplifier input when the Input Coupling switch is moved from GND to AC. The precharging network also provides a measure of protection to the external circuitry by reducing the current levels that can be drawn from the external circuitry during capacitor charging.

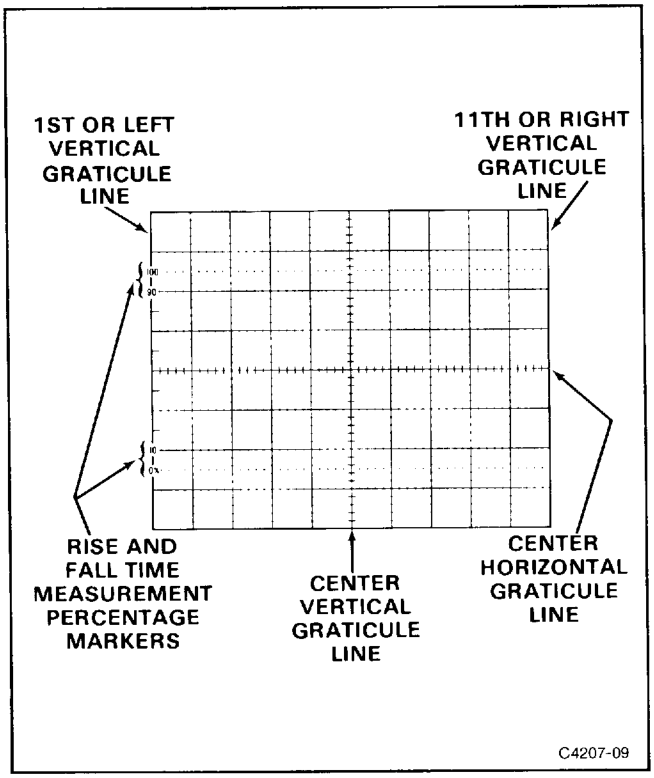

Figure 3-1. Graticule measurement markings.

The following procedure should be used whenever the probe tip is connected to a signal source having a different dc level than that previously applied, especially if the dc-level difference is more than 10 times the VOLTS/DIV switch setting:

1. Set the Input Coupling switch to GND.

2. Insert the probe tip into the oscilloscope GND connector and wait several seconds for the input coupling capacitor to discharge.

3. Connect the probe tip to the signal source and wait several seconds for the input coupling capacitor to charge.

4. Set the Input Coupling switch to AC. The display will remain on the screen, and the ac component of the signal can be measured in the normal manner.

OPERATOR'S CHECKS AND ADJUSTMENTS

INTRODUCTION

To verify the operation and accuracy of this instrument before making measurements, perform the following adjustment procedures. If adjustments are required beyond the scope of the operator's adjustments, refer the instrument to a qualified service person.

Before proceeding with these instructions, refer to "Preparation for Use" (Section 2).

Verify that the POWER switch is OFF (button out), then plug the power cord into the power-source outlet.

If indications specified in these procedures cannot be obtained, refer the instrument to a qualified service person.

TRACE ROTATION

Normally, the resulting trace will be parallel to the center horizontal graticule line, and the Trace Rotation adjustment should not be required. If adjustment is needed, perform the following procedure:

1. Preset instrument controls and obtain a baseline trace (refer to "Instrument Familiarization" in Section 4).

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

3. If the resulting trace is not parallel to the center horizontal graticule line, use a small flat-bit screwdriver to adjust the TRACE ROTATION control and align the trace with the center horizontal graticule line.

PROBE COMPENSATION

Misadjustment of probe compensation is a common source of measurement error. Most attenuator probes are equipped with a compensation adjustment. To ensure optimum measurement accuracy, always compensate the oscilloscope probes before making measurements. Probe compensation is accomplished as follows:

1. Preset instrument controls and obtain a baseline trace (refer to "Instrument Familiarization").

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

3. Set both VOLTS/DIV switches to 0.1 V 10X PROBE setting and set both Input Coupling switches to DC.

4. Select CH 1 VERTICAL MODE and insert the tip of the Channel 1 probe into the AMP CAL output jack.

5. Using the approximately 1 kHz AMP CAL square-wave signal as the input, obtain a 5-division display of the signal.

6. Set the A SEC/DIV switch to display several cycles of the AMP CAL signal. Use the Channel 1 POSITION control to vertically center the display.

7. Check the waveform presentation for overshoot and rolloff (see Figure 3-2). If necessary, adjust the probe compensation for flat tops on the waveforms. Refer to the instructions supplied with the probe for details of compensation adjustment.

8. Select CH 2 VERTICAL MODE and connect the Channel 2 probe tip to the AMP CAL output jack.

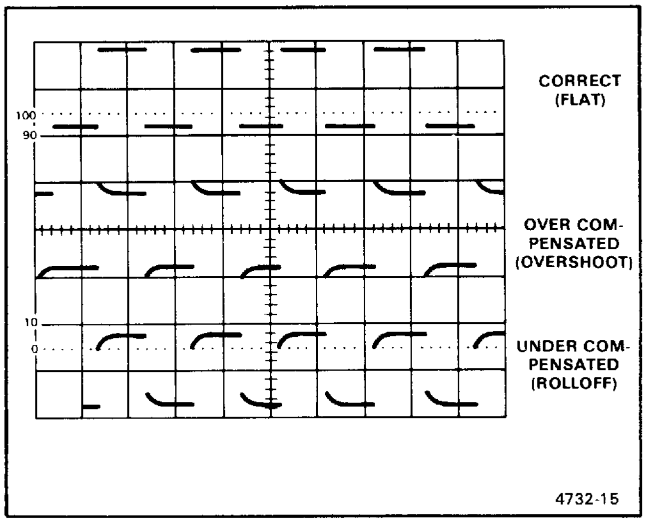

Figure 3-2. Probe compensation.

9. Use the Channel 2 POSITION to vertically center the display and repeat step 7 for the Channel 2 probe.

10. Disconnect the probes from the instrument.

VERTICAL DEFLECTION CHECK

The AMP CAL signal can be used as a convenient way of checking the instrument vertical deflection system with the following checks:

1. Preset instrument controls and obtain a baseline trace (refer to "Instrument Familiarization").

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

3. Set both VOLTS/DIV switches to 0.1 V 10X PROBE setting and set both Input Coupling switches to DC.

4. Select CH 1 VERTICAL MODE and insert the tip of the Channel 1 probe into the AMP CAL output jack.

5. Using the approximately 1-kHz AMP CAL square-wave signal as the input, obtain a 5-division display of the signal.

6. Set the A SEC/DIV switch to display several cycles of the AMP CAL signal. Use the Channel 1 POSITION control to vertically center the display.

7. Check for a vertical display amplitude of approximately 5 divisions.

8. Select CH 2 VERTICAL MODE and connect the Channel 2 probe tip to the AMP CAL output jack.

9. Use the Channel 2 POSITION to vertically center the display and repeat step 7 for the Channel 2 probe.

10. Disconnect the probes from the instrument.

OPERATING PROCEDURES

INSTRUMENT FAMILIARIZATION

INTRODUCTION

The procedures in this part are designed to assist the user in quickly becoming familiar with this instrument. They provide information which demonstrates the use of all the controls, connectors, and indicators and will enable the user to efficiently operate the instrument.

Before proceeding with these instructions, verify that the POWER switch is OFF (button out); then plug the power cord into the power-source outlet.

Should an improper indication or instrument malfunction be noted during the performance of these procedures, first verify correct operation of associated equipment. If the malfunction persists, refer the instrument to qualified service personnel for repair or adjustment.

The equipment listed in Table 4-1, or equivalent equipment, is required to complete these familiarization procedures.

Table 4-1
Equipment Required for Instrument Familiarization Procedure

Description	Minimum Specification
Square-Wave Generator	Signal Amplitude: 2 mV to 50 V. Output signal: 1 kHz square wave. Fast-rise repetition rate: 1 kHz to 100 kHz. Signal amplitude: 100 mV to 1 V.
Dual-Input Coupler	Connectors: bnc-female-to-dual-bnc-male.
Cable (2 required)	Impedance: 50 Ω. Length: 42 in. Connectors: bnc.
Adapter Termination	Connectors: bnc-female-to-bnc female. Impedance: 50 Ω. Connectors: bnc.

BASELINE TRACE

First obtain a baseline trace, using the following procedure.

1. Preset the instrument front-panel controls as follows:

Display

A and B INTENSITY	Fully counterclockwise
FOCUS	Midrange

Vertical (Both Channels)

POSITION	Midrange
INVERT (PULL)	Off (knob in)
VERTICAL MODE	CH 1
TRIGGER SOURCE	COMPOSITE
BW LIMIT	Off (button out)
VOLTS/DIV	50 mV (1X)
VOLTS/DIV Variable	CAL detent
Input Coupling	AC

Horizontal

A/B SWP SEP	Midrange
POSITION	Midrange
HORIZONTAL MODE	A
A and B SEC/DIV	0.5 ms
SEC/DIV Variable	CAL detent
X10 Magnifier	Off (knob in)
B DELAY TIME POSITION	Fully counterclockwise

B TRIGGER

SLOPE	OUT
LEVEL	Fully clockwise

A TRIGGER

VAR HOLDOFF	NORM
Mode	P-P AUTO
SLOPE	OUT
LEVEL	Midrange
A TRIG BW	FULL
A SOURCE	INT
A EXT COUPLING	AC

2. Press in the POWER switch button (ON).

3. Adjust the A INTENSITY control for desired display brightness.

4. Adjust the Vertical and Horizontal POSITION controls to center the trace on the screen.

NOTE

Normally, the resulting trace will be parallel with the center horizontal graticule line and should not require adjustment. If trace alignment is required, see the "Trace rotation" adjustment procedure in the "Operator's Adjustments" part.

DISPLAYING A SIGNAL

After obtaining a baseline trace, you are now ready to connect an input signal and display it on the crt screen.

1. Connect the square-wave generator output to both the CH 1 and CH 2 inputs as shown in Figure 4-1.

2. Set the square-wave generator for a 1 kHz square-wave signal and adjust its output to obtain a 4-division vertical display.

3. Adjust the Channel 1 POSITION control to center the display vertically on the crt screen.

4. Adjust the A TRIGGER LEVEL control, if necessary, to obtain a stable triggered display.

NOTE

The READY-TRIG'D indicator should illuminate to indicate that the A Sweep is triggered.

5. Rotate the FOCUS control between its maximum clockwise and counterclockwise positions. The display should become blurred on either side of the optimum control setting.

6. Set the FOCUS control for a sharp, well-defined display over the entire trace length.

7. Move the display off the crt screen using the Channel 1 POSITION control.

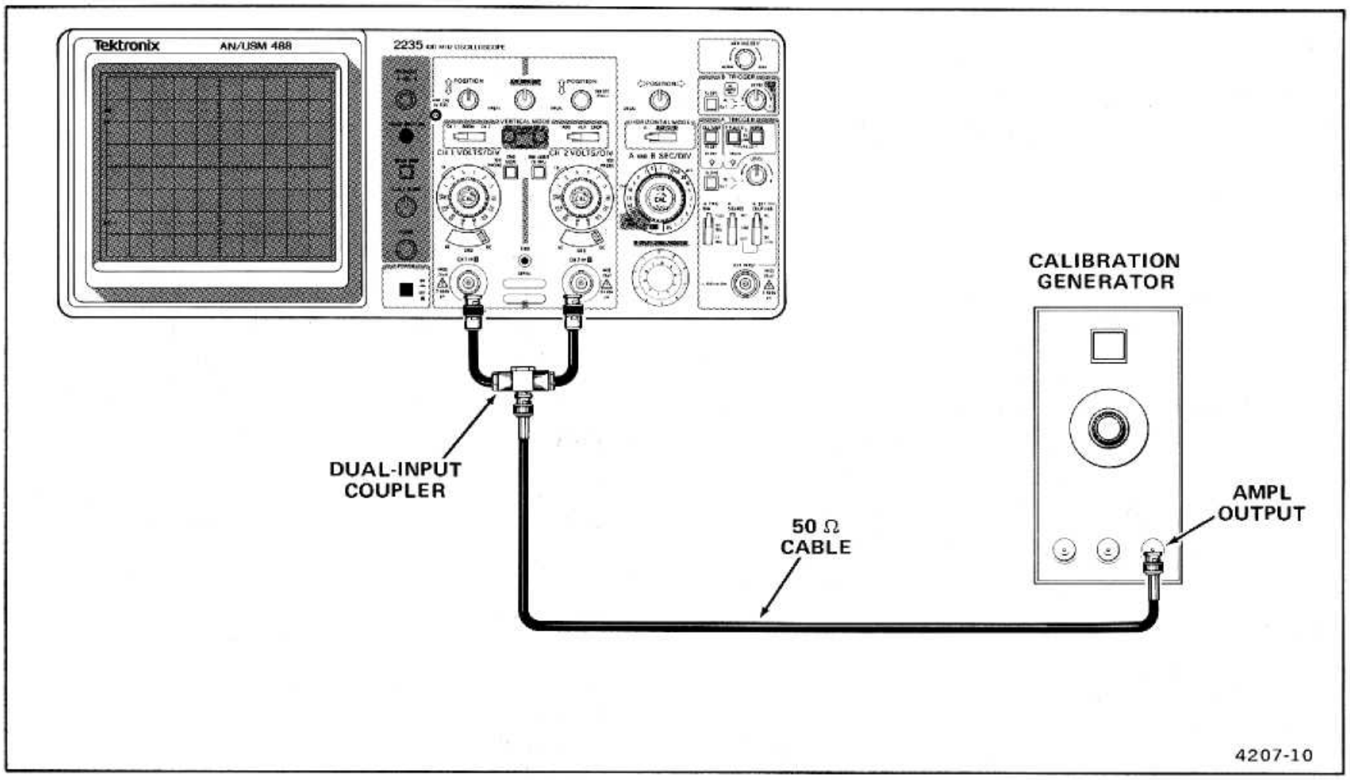

Figure 4-1. Initial setup for instrument familiarization procedure.

8. Press in and hold the BEAM FIND button; the display should reappear on the screen. Adjust both the Channel 1 and the Horizontal POSITION controls to center the trace both bertically and horizontally. Release the BEAM FIND button; the display should remain within the viewing area.

9. Adjust the A INTENSITY control counterclockwise until the display disappears.

10. Press in and hold the BEAM FIND button; the display should reappear. Release the BEAM FIND button and adjust the A INTENSITY control to desired display brightness.

Using the Vertical Section

1. Set the Channel 1 Input Coupling switch to GND.

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

3. Set the Channel 1 Input Coupling switch to DC.

4. Observe that the bottom of the display remains at the center horizontal graticule line (ground reference).

5. Set the Channel 1 Input Coupling switch to AC.

6. Observe that the display is centered approximately at the center horizontal line.

7. Rotate the CH 1 VOLTS/DIV Variable control fully counterclockwise.

8. Observe that minimum vertical deflection occurs when the VOLTS/DIV Variable control is fully counterclockwise.

9. Rotate the CH 1 VOLTS/DIV Variable control fully clockwise to the CAL detent.

10. Select CH 2 VERTICAL MODE and again perform preceding steps 1 through 9 using Channel 2 controls. Performance should be similar to Channel 1.

11. Set both CH 1 and CH 2 VOLTS/DIV switches to 0.1 (1X) for 2-division displays.

12. Select BOTH and ADD VERTICAL MODE and observe that the resulting display is 4 divisions in amplitude. Both Channel 1 and Channel 2 POSITION controls should move the display. Recenter the display on the crt screen.

13. Pull out the Channel 2 POSITION control knob to invert the Channel 2 signal.

14. Observe that the display is a straight line, indicating that the algebraic sum of the two signals is zero.

15. Set the CH 2 VOLTS/DIV switch to 50 mV (1X).

16. Observe the 2-division display, indicating that the algebraic sum of the two signals is no longer zero.

17. Push in the Channel 2 POSITION control knob to release it. Observe a noninverted display having a 6-division signal amplitude.

18. Set both Channel 1 and Channel 2 Input Coupling switches to GND.

19. Set the CH 1 VOLTS/DIV switch to 50 mV (1X).

20. Select ALT VERTICAL MODE. Position the Channel 1 trace two divisions above the center graticule line and position the Channel 2 trace two divisions below the center graticule line.

21. Rotate the A SEC/DIV switch throughout its range (except X-Y). The display will alternate between Channel 1 and Channel 2 at all sweep speeds. This mode is most useful for sweep speeds from 0.05 μs to 0.2 ms per division.

22. Select CHOP VERTICAL MODE and rotate the A SEC/DIV switch throughout its range (except X-Y). A dual-trace display will be presented at all sweep speeds, but unlike the ALT mode, both Channel 1 and Channel 2 signals are displayed for each sweep on a time-shared basis. This mode is most useful for sweep speeds from 0.5 ms to 0.5 s per division.

23. Select CH 1 VERTICAL MODE and set Channel 1 Input Coupling switch to AC. Recenter the display on the screen.

24. Return the A SEC/DIV switch to 0.5 ms.

25. Press in and hold the TRIG VIEW button. Observe the Channel 1 trigger signal that is present in the A Trigger amplifier.

NOTE

When using TRIG, VIEW, trigger signals applied by any of the A SOURCE switch positions will be displayed on the crt screen. Trigger signals will remain stable when positioned in the center graticule area by the A TRIGGER LEVEL control.

26. Release the TRIG VIEW VERTICAL MODE button.

Using the Horizontal Section

1. Note the display at 0.5 ms sweep speed for future comparison in step 3.

2. Set the A SEC/DIV switch to 5 ms and pull the SEC/DIV Variable control knob out to obtain X10 sweep magnification.

3. Observe that the display is similar to that obtained in step 1.

4. Rotate the Horizontal POSITION control throughout its range. Observe that the display can be positioned to either side of the center vertical graticule line.

5. Push in the SEC/DIV Variable control knob to return to X1 sweep.

6. Set the A and B SEC/DIV switches to 0.1 ms.

7. Rotate the VAR HOLDOFF control fully clockwise.

8. Observe that the crt trace starts to flicker as the holdoff between sweeps is increased.

9. Return the VAR HOLDOFF control to its NORM position (fully counterclockwise).

10. Return the A and B SEC/DIV switches to 0.5 ms. Note the display for future comparison in step 12.

11. Rotate the SEC/DIV Variable control out of the CAL detent to its maximum counterclockwise position.

12. Observe that the sweep speed is approximately 2.5 times slower than in step 10, as indicated by more cycles displayed on the screen.

13. Return the SEC/DIV Variable control to the CAL detent (fully clockwise).

Using the A Trigger Section

1. Rotate the A TRIGGER LEVEL control between its maximum clockwise and counterclockwise positions. The display will remain triggered over the full range of the A TRIGGER LEVEL control.

2. Return the A TRIGGER LEVEL control to midrange.

3. Set the A TRIGGER SLOPE to IN. Observe that the display starts on the negative-going slope of the applied signal.

4. Return the A TRIGGER SLOPE switch to OUT. Observe that the display starts on the positive-going slope of the applied signal.

5. Set the TRIGGER SOURCE switch to CH 1, the VERTICAL MODE switch to CH 2, and the Channel 1 Input Coupling switch to GND. Observe that the display free-runs.

6. Return the Channel 1 Input Coupling switch to AC.

7. Set the TRIGGER SOURCE switch to CH 2, the VERTICAL MODE switch to CH 1, and the Channel 2 Input Coupling switch to GND. Observe that the display free-runs.

8. Return the Channel 2 Input Coupling switch to AC and set the TRIGGER SOURCE switch to CH 1.

9. Set the A TRIGGER Mode switch to NORM.

10. Rotate the A TRIGGER LEVEL control between its maximum clockwise and counterclockwise positions. Observe that the READY-TRIG'D light illuminates only when the display is correctly triggered.

11. Readjust the A TRIGGER LEVEL control for a stable display.

12. Remove the square-wave signal from the CH 1 input connector.

13. Press in the A TRIGGER SGL SWP button momentarily for single-sweep operation.

14. Observe that the READY-TRIG'D light illuminates, indicating that the A Trigger circuit is armed (READY) for a single-sweep display. No display should be present on the crt screen.

15. Reconnect the square-wave signal to the CH 1 input connector. A single sweep of the applied signal should appear on the screen. When the READY-TRIG'D light is out, another single sweep cannot be displayed until the SGL SWP button is pressed in again to reset the A Trigger circuit.

16. Set the A SOURCE switch to EXT. Move the square-wave signal from the CH 2 input connector to the EXT INPUT connector.

17. Set the A TRIGGER Mode switch to P-P AUTO.

18. Set the CH 1 VOLTS/DIV switch to 0.5 V (1X) and adjust the output of the square-wave generator to provide a 4-division display. Adjust the A TRIGGER LEVEL control for a stable display and note the range over which a stable display can be obtained (for comparison in step 20).

19. Set the A EXT COUPLING switch to DC÷10.

20. Observe that adjustment of the A TRIGGER LEVEL control provides a triggered display over a narrower range than in preceding step 18, indicating trigger-signal attenuation.

21. Move the square-wave signal from the EXT INPUT connector to the CH 2 input connector. Set the A SOURCE switch to INT and adjust the A TRIGGER LEVEL control to the midrange position.

NOTE

The A TRIGGER mode can be used to trigger on either the TV Line or TV Field. For familiarization with these functions see TV Line Signal and TV Field Signal in the "Basic Applications" part of this section.

Using the Delayed-Sweep Controls

1. Set the B SEC/DIV switch to 50 μs.

2. Select ALT HORIZONTAL MODE. Ensure that the B TRIGGER LEVEL control is fully clockwise (B RUNS AFTER DLY) and that the B DELAY TIME POSITION control is fully counterclockwise.

3. Adjust the B INTENSITY control for desired B Sweep display brightness.

4. Adjust the Channel 1 POSITION and the A/B SWP SEP controls as required to display the A Sweep (with the intensified zone) above the B Delayed Sweep. The displays alternate between the A Sweep (upper) and the B Delayed Sweep (Lower). Adjust the A and B INTENSITY controls as necessary to view the two displays.

5. Observe that the intensified zone is approximately one division in length at the start of the A Sweep and that the B Delayed Sweep displays the intensified portion of the A Sweep.

6. Rotate the B DELAY TIME POSITION control; the intensified zone of the A Sweep and the display of the B Delayed Sweep will move continuously across the crt screen.

7. Select the B HORIZONTAL MODE and observe that only the B Delayed Sweep is now displayed on the crt screen.

8. Observe that the display moves continuously across the crt screen as the B DELAY TIME POSITION control is rotated. Return the B DELAY TIME POSITION control to the fully counterclockwise position.

9. Select the ALT HORIZONTAL MODE and set the B SEC/DIV switch to 0.5 ms.

Using the B Trigger Section

1. Rotate the B TRIGGER LEVEL control counterclockwise to the midrange position, then adjust it for a stable display.

2. Observe that both the intensified zone and the B Delayed Sweep displays disappear and reappear as the B TRIGGER LEVEL control approaches midrange. Adjust the B TRIGGER LEVEL control for a stable display at the midrange position.

3. Rotate the B DELAY TIME POSITION control throughout its range. Observe that the intensified zone of the A Sweep appears to jump between the positive slopes of the display.

4. Set the B TRIGGER SLOPE switch to IN and observe that the intensified portion begins on the negative slope.

5. Observe that the length of the B Delayed Sweep decreases when the B DELAY TIME POSITION control is rotated clockwise and increases when the control is rotated counterclockwise.

6. Select the A HORIZONTAL MODE.

Using the X-Y Mode

1. Set both the CH 1 and CH 2 VOLTS/DIV switches to 1 V (1X) and adjust the generator output to provide a 5-division display.

2. Select X-Y mode by switching the A SEC/DIV switch to its fully counterclockwise position.

3. Adjust the A INTENSITY control for desired display brightness. Observe that two dots are displayed diagonally. This display can be positioned horizontally with the Horizontal POSITION control and vertically with the Channel 2 POSITION control. Note that the dots are separated by 5 horizontal divisions and 5 vertical divisions.

4. Set both the CH 1 and CH 2 VOLTS/DIV switches to 2 V (1X). Note that the dots are now separated by 2.5 horizontal divisions and 2.5 vertical divisions.

5. Return the A SEC/DIV switch to 0.5 ms and adjust the A INTENSITY control for desired display brightness.

Using the Z-Axis Input

1. Disconnect the dual-input coupler from the CH 2 input connector and connect a bnc-female-to-bnc-female adapter to the disconnected end of the coupler.

2. Connect a 42-inch, 50 Ω bnc cable from the Z-AXIS INPUT connector (located on the rear panel) to the dual-input coupler via the bnc-female-to-bnc-female adapter.

3. Set the Channel 1 VOLTS/DIV switch to 1 V (1X) and adjust the output of the square-wave generator to provide a 5-division display.

4. Observe that the positive peaks of the waveform are blanked, indicating intensity modulation (adjust the A INTENSITY control as necessary).

5. Disconnect the 50 Ω cable from the Z-AXIS INPUT connector and disconnect the dual-input coupler from the CH 1 input connector.

Using the Bandwidth Limit Feature

1. Connect a fast-rise positive-output calibration signal through a 42-inch, 50 Ω cable and a 50 Ω termination to the CH 1 input connector.

2. Set the CH 1 VOLTS/DIV switch to 50 mV (1X) and adjust the square-wave generator output to provide a 4-division display.

3. Set the A SEC/DIV switch to 0.5 μs and adjust the square-wave generator fast-rise positive-output signal frequency to 1 MHz. Adjust the generator frequency to provide approximately 5 cycles of the displayed signal.

4. Press in the BW LIMIT button and observe the rounding-off at the front corners of the display. This indicates a decrease in the frequency response of the vertical amplifier.

BASIC APPLICATIONS

INTRODUCTION

After becoming familiar with the capabilities of this oscilloscope, an operator can then easily develop convenient methods for making particular measurements. The information in this section is designed to enhance operator understanding and to assist in developing efficient techniques for making specific measurements. Recommended methods for making basic measurements with your instrument are described in the procedures contained in this section.

When a procedure first calls for presetting instrument controls and obtaining a baseline trace, refer to the "Instrument Familiarization" part at the beginning of this section and perform steps 1 through 4 under "Baseline Trace".

INDEX TO BASIC APPLICATION PROCEDURES

VOLTAGE MEASUREMENTS

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 switch 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 A TRIGGER LEVEL control to obtain a stable display.

5. Set the A SEC/DIV switch to a position that displays several cycles of the waveform.

6. Vertically position the display so that the negative peak of the waveform coincides with one of the horizontal graticule lines (see Figure 4-2, Point A).

7. Horizontally position the display so that one of the positive peaks coincides with the center vertical graticule line (see Figure 4-2, Point B).

8. Measure the vertical deflection from peak-to-peak (see Figure 4-2, Point A to Point B).

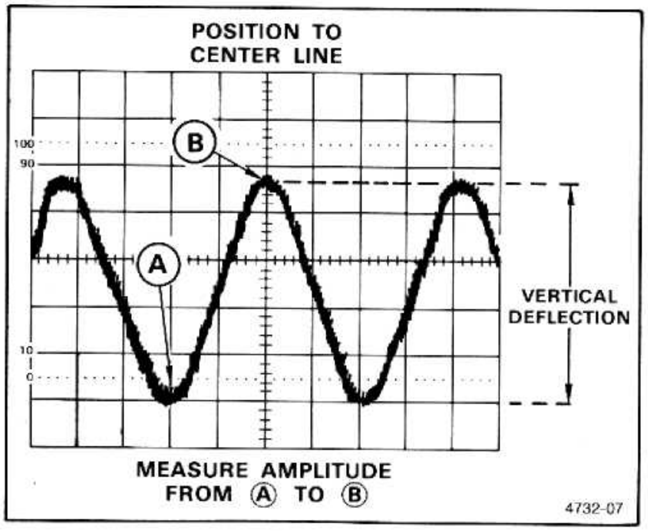

Figure 4-2. Peak-to-peak waveform voltage.

NOTE

If the amplitude measurement is critical or if the trace is thick (as a result of hum or noise on the signal), a more accurate value can be obtained by measuring from the top of a peak to the top of a valley. This will eliminate trace thickness from the measurement.

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

Volts (p-p) = vertical deflection (divisions) x VOLTS/DIV switch setting indicated by 1X (or 10X PROBE when 10X probe is used)

EXAMPLE: The measured peak-to-peak vertical deflection is 4.6 divisions (see Figure 4-2) using a 10X attenuator probe with the VOLTS/DIV switch set to 5 V (at 10X PROBE setting).

Substituting the given values:

Volts (p-p) = 4.6 div x 5 V/div = 23 V.

Instantaneous Voltage

To measure instantaneous level at a given point on a waveform, referred to ground, 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 switch to display the channel used.

3. Verify that the VOLTS/DIV Variable control is in the CAL detent and set the Input Coupling switch to GND.

4. Vertically position the baseline trace to the center horizontal graticule line. This establishes the ground reference location.

NOTE

If measurements are to be made relative to a voltage level other than ground, set the Input Coupling switch to DC instead, and apply the reference voltage to the input connector. Then position the trace to the reference (horizontal graticule) line.

5. Set the Input Coupling switch to DC. Points on the waveform above the ground reference location are positive. Those points below are negative.

NOTE

If using Channel 2, ensure that the Channel 2 INVERT mode is not selected (Channel 2 POSITION control knob is pushed in).

6. If necessary, repeat Step 4 using a different reference line which allows the waveform in Step 5 to be displayed on screen.

7. Adjust the A TRIGGER LEVEL control to obtain a stable display.

8. Set the A SEC/DIV switch to a position that displays several cycles of the signal.

9. Measure the divisions of vertical deflection between the ground reference line and the point on the waveform at which the level is to be determined (see Figure 4-3).

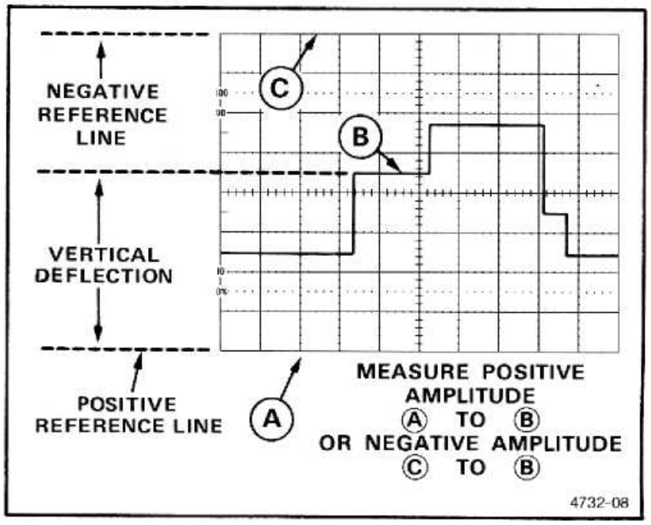

Figure 4-3. Instantaneous voltage measurement.

10. Calculate the instantaneous voltage, using the following formula:

$$\text{Instantaneous Voltage} = \text{vertical deflection (divisions)} \times \text{polarity } (+ \text{ or } -) \times \text{VOLTS/DIV switch setting indicated by 1X (or 10X PROBE when 10X probe is used)}$$

EXAMPLE: The measured vertical deflection from the reference line is 4.6 divisions (see Figure 4-3), the waveform point is above the reference line, a 10X attenuator probe is being used, and the VOLTS/DIV switch is set to 2 V (at 10X PROBE setting).

Substituting the given values:

Instantaneous Voltage = 4.6 div x (+1) x 2 V/div = 9.2 V.

Algebraic Addition

With the VERTICAL MODE switches set to BOTH and ADD, the waveform displayed is the algebraic sum of the signals applied to the Channel 1 and Channel 2 inputs (CH 1 + CH 2). If the Channel 2 INVERT mode is selected (Channel 2 POSITION control knob pulled out), the waveform displayed is the difference between the signals applied to the Channel 1 and Channel 2 inputs (CH 1 − CH 2). When both vertical channels are set to the same voltage settings, the deflection factor is equal to that indicated by either VOLTS/DIV switch.

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 settings, 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 should not exceed approximately 4 volts.

c. Use Channel 1 and Channel 2 POSITION control settings which most nearly position the signal on each channel to midscreen, when viewed in either CH 1 or CH 2 VERTICAL MODE. This ensures the greatest dynamic range for ADD mode operation.

d. To attain similar response from each channel, set both the Channel 1 and Channel 2 Input Coupling switches to the same position.

Common-Mode Rejection

The following procedure shows how to eliminate unwanted ac input-power frequency components. Similar methods could be used either to eliminate other unwanted frequency components or to provide a dc offset.

1. Preset instrument controls and obtain a baseline trace.

2. Apply the signal containing the unwanted line-frequency components to the CH 1 input connector.

3. Apply a line-frequency signal to the CH 2 input connector. To maximize cancellation, the signal applied to Channel 2 must be in phase with the unwanted line-frequency component on the Channel 1 signal.

4. Select BOTH and ALT VERTICAL MODE and set both VOLTS/DIV switches to produce displays of approximately 4 or 5 divisions in amplitude.

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

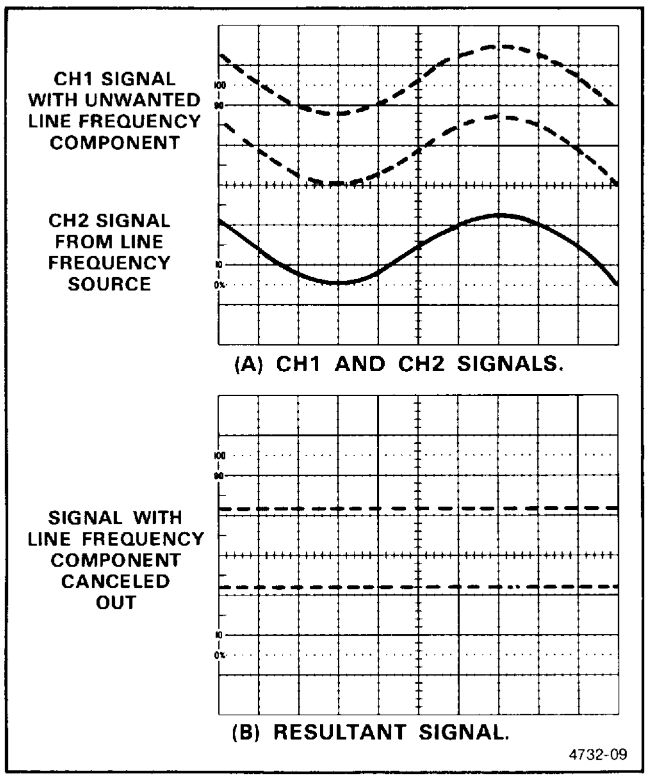

Figure 4-4. Common-mode rejection.

6. Select ADD VERTICAL MODE and pull out the Channel 2 POSITION control knob to invert the Channel 2 display. Slightly readjust the CH 2 VOLTS/DIV Variable control for maximum cancellation of the undesired signal component (see Figure 4-4B).

Amplitude Comparison (Ratio)

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. This 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 five vertical divisions by adjusting the VOLTS/DIV switch and VOLTS/DIV Variable control.

4. Disconnect the reference signal and apply the unknown signal to be measured to the same channel input. Adjust the vertical position of the waveform so that its bottom edge just touches the 0% line on the crt.

5. Horizontally position the waveform so that its topmost features cross the center vertical graticule line (see Figure 4-5).

6. Read the percent ratio directly from the graduations of the center line, referring to the 0% and 100% marks on the left edge of the graticule (1 minor division equals 4% for a 5-division display).

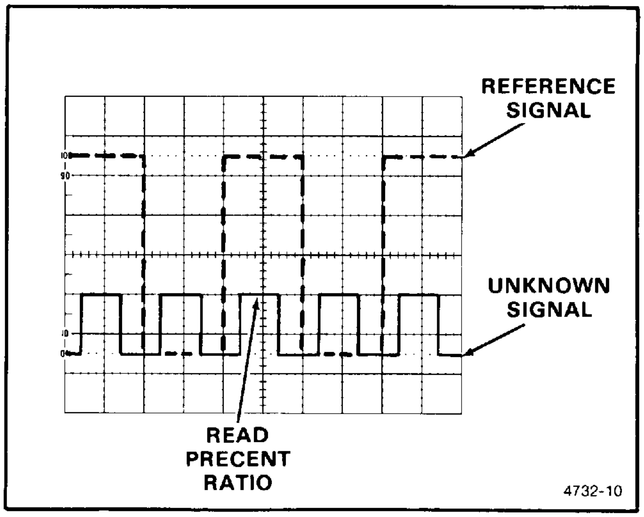

Figure 4-5. Voltage ratios.

NONDELAYED TIME MEASUREMENTS

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 switch to display the channel used.

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

4. Set the A SEC/DIV switch 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 4-6).

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

7. Calculate time duration using the following formula:

$$\text{Time Duration} = \frac{\text{horizontal distance (division)} \times \text{A SEC/DIV switch setting}}{\text{magnification factor}}$$

EXAMPLE: The distance between the time measurement points is 8.3 divisions (see Figure 4-6), and the A SEC/DIV switch is set to 2 ms per division. The X10 Magnifier is off (knob in).

Substituting the given values:

Time Duration = 8.3 div x 2 ms/div = 16.6 ms

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 4-6 has a time duration of 16.6 ms.

Calculating the reciprocal of time duration:

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

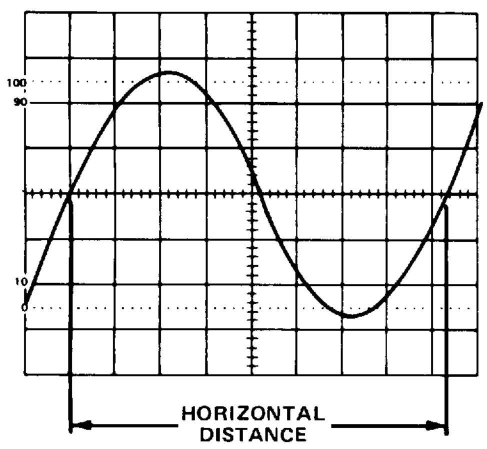

Figure 4-6. Time duration.

Rise Time

Rise-time measurements use the same methods as time duration, except that the measurements are made between the 10% and 90% points of the low-to-high transition of the selected waveform (see Figure 4-7). Fall time is measured between the 90% and 10% points of the high-to-low transition of the waveform.

1. Preset instrument controls and obtain a baseline trace. Ensure that the BW LIMIT is off (button out).

2. Apply an exact 5-division signal to either vertical-channel input connector and set the VERTICAL MODE switch to display the channel used.

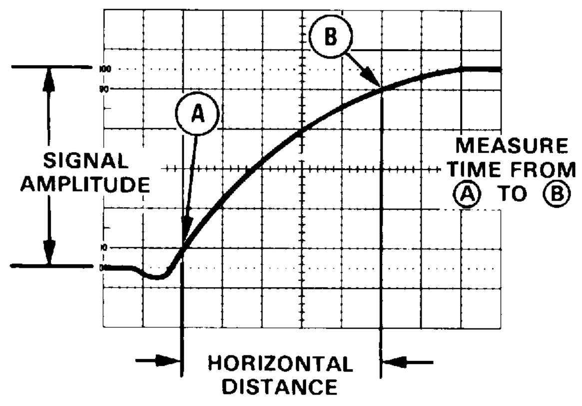

Figure 4-7. Rise time.

3. Set the appropriate VOLTS/DIV switch and Variable control for an exact 5-division display.

4. Vertically position the trace so that the zero reference of the waveform touches the 0% graticule line and the top of the waveform touches the 100% graticule line.

5. Horizontally position the display so the 10% point on the waveform intersects the second vertical graticule line.

6. Measure the horizontal distance between the 10% and 90% points (between Points A and B of Figure 4-7) and calculate the time duration using the following formula:

$$\text{Rise Time} = \frac{\text{horizontal distance (divisions)} \times \text{A SEC/DIV switch setting}}{\text{magnification factor}}$$

Example: The horizontal distance between the 10% and 90% points is 5 divisions, and the A SEC/DIV switch is set to 1 μs per division. A magnification factor of 1 is used.

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 Pulses on Time-Related Signals

The calibrated sweep speed and dual-trace features of this 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, then set the A TRIGGER SOURCE switch to CH 1.

2. Set both Input Coupling switches to the same position, depending on the type of input coupling desired.

3. 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.

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

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

6. If the two signals are of opposite polarity, pull out the Channel 2 POSITION control knob to invert the Channel 2 display (signals may be of opposite polarity due to 180° phase difference).

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

8. Set the A 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 4-8).

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

$$\text{Time Difference} = \frac{\text{A SEC/DIV switch setting} \times \text{horizontal difference (divisions)}}{\text{magnification factor}}$$

EXAMPLE: The A SEC/DIV switch is set to 50 μs per division, the X10 Magnifier is on (knob out) and the horizontal difference between waveform measurement points is 4.5 divisions.

Substituting the given values in the formula:

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

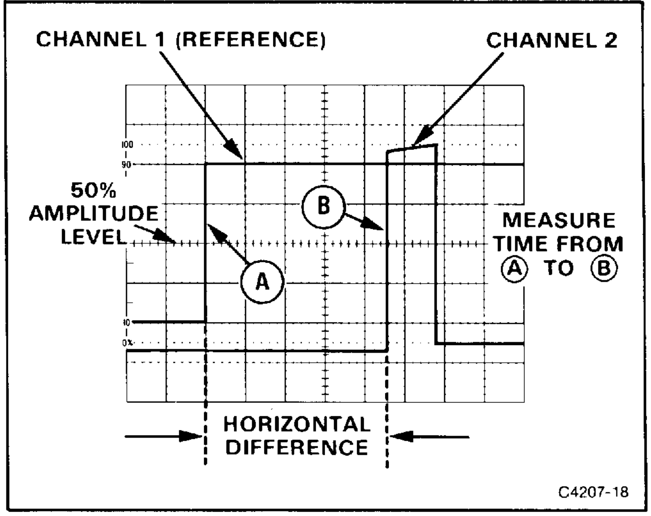

Figure 4-8. Time difference between pulses on time-related signals.

Phase Difference

In a similar manner to "Time Difference Between Pulses on Time-Related Signals," 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 deflection system. To make a phase comparison, use the following procedure:

1. Preset instrument controls and obtain a baseline trace, then set the Vertical TRIGGER SOURCE switches to CH 1.

2. Set both Input Coupling switches to the same position, depending on the type of input coupling desired.

3. Using either probes or 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 input signals. The reference signal should precede the comparison signal in time.

5. If the two signals are of opposite polarity, pull out the Channel 2 POSITION control knob 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 A TRIGGER LEVEL control for a stable display.

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

9. Position the displays and adjust the SEC/DIV Variable control so that one reference-signal cycle occupies exactly 8 horizontal graticule divisions at the 50% rise-time points (see Figure 4-9). 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 and calculate the phase difference using the following formula:

$$\text{Phase Difference} = \begin{matrix}\text{horizontal} \\ \text{difference} \\ \text{(divisions)}\end{matrix} \times \begin{matrix}\text{horizontal} \\ \text{calibration} \\ \text{(deg/div)}\end{matrix}$$

Example: The horizontal difference is 0.6 division with a graticule calibration of 45° per division as shown in Figure 4-9.

Substituting the given values into the phase difference formula:

Phase difference = 0.6 div x 45°/div = 27°

More accurate phase measurements can be made by using the X10 Magnifier function 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 knob out), the magnified horizontal graticule calibration would be 45°/division divided by 10 or 4.5°/division. Figure 4-10 shows the same signals illustrated in Figure 4-9, 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:

Phase difference = 6 div x 4.5°/div = 27°

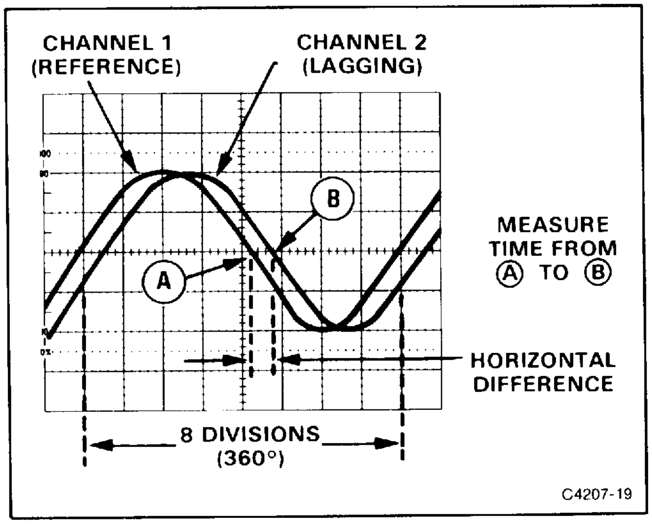

Figure 4-9. Phase difference.

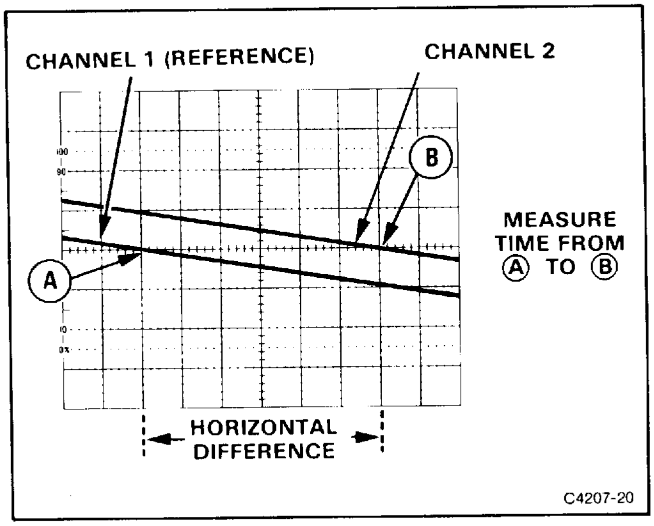

Figure 4-10. High-resolution phase difference.

TELEVISION DISPLAYS

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 A TRIGGER Mode.

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

3. Set the appropriate VOLTS/DIV switch to display 1 division or more of composite video signal.

4. Set the A SEC/DIV switch to 10 μs.

5. For positive-going TV signal sync pulses, set the A TRIGGER SLOPE switch to OUT and adjust the

A TRIGGER LEVEL control to its fully clockwise position; for negative-going TV signal sync pulses, set the A TRIGGER SLOPE switch to IN and adjust the A TRIGGER LEVEL control to its fully counterclockwise position.

NOTE

To examine a TV Line signal in more detail, either the X10 Magnifier or the Delayed-Sweep Magnification feature may be used.

TV Field Signal

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

1. Preset instrument controls and obtain a baseline trace.

2. Select TV FIELD A TRIGGER mode (push both P-P AUTO and NORM buttons in) and set the A SEC/DIV switch to 2 ms.

3. To display a signal 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 1-division or more of composite sync signal.

5. For positive-going TV signal sync pulses, set the A TRIGGER SLOPE switch to OUT and adjust the A TRIGGER LEVEL control to its fully clockwise position; for negative-going TV signal sync pulses, set the A TRIGGER SLOPE switch to IN and adjust the A TRIGGER LEVEL control to its fully counterclockwise position. It may be necessary to adjust the VAR HOLDOFF control to obtain a stable triggering of the desired TV field.

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

NOTE

To examine a TV Field signal in more detail, either the X10 Magnifier or Delayed-Sweep Magnification may be used.

7. To display a selected horizontal line, first trigger the sweep on a vertical (field) sync pulse, then use the "Magnified Sweep Runs After Delay" procedure in this part (steps 5 and 6) to magnify the selected horizontal line for a closer examination. This procedure is useful for examining Vertical Interval Test Signals (VITS).

8. To display Field 1 and Field 2 on separate channels, connect the TV signal to both input connectors, then select BOTH and ALT VERTICAL MODES. Set the A SEC/DIV switch to 0.5 ms or faster sweep speed (displays less than one full field). This will synchronize the Channel 1 display to one field and the Channel 2 display to the other field.

DELAYED-SWEEP MAGNIFICATION

The delayed-sweep feature of this instrument can be used to provide higher apparent magnification than is provided by the X10 Magnifier switch. Apparent magnification occurs as a result of displaying a selected portion of the A trace at a faster sweep speed (B Sweep speed). The A SEC/DIV switch setting determines how often the B trace will be displayed. Since the B Sweep can occur only once for each A Sweep, the A Sweep time duration sets the amount of time elapse between succeeding B Sweeps.

The intensified zone is an indication of both the location and length of the B Sweep interval within the A Sweep interval. Positioning of the intensified zone (i.e., setting the amount of time between start of the A Sweep and start of the B Sweep) is accomplished with the B DELAY TIME POSITION control. With either ALT or B HORIZONTAL MODE selected and B TRIGGER LEVEL control set fully clockwise (B RUNS AFTER DLY), the B DELAY TIME POSITION control provides continuously variable positioning of the start of the B Sweep. The range of this control is sufficient to place the B Sweep interval at any location within the A Sweep interval except the first 0.5 division. When ALT HORIZONTAL MODE is selected, the B SEC/DIV switch setting determines the B Sweep speed and concurrently sets the length of the intensified zone on the A trace.

Using delayed-sweep magnification may produce a display with some slight horizontal movement (pulse jitter). Pulse jitter includes not only the inherent uncertainty of triggering the delayed sweep at exactly the same trigger point each time, but also jitter that may be present in the input signal. If pulse jitter needs to be measured, use the "Pulse Jitter Time Measurement" procedure which follows the discussion of "Magnified Sweep Runs After Delay."

Magnified Sweep Runs After Delay

The following procedure explains how to operate the B Sweep in a nontriggered mode and to determine the resulting apparent magnification factor.

1. Preset instrument controls and obtain a baseline trace.

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

3. Set the appropriate VOLTS/DIV switch to produce a display of approximately 2 or 3 divisions in amplitude and center the display.

4. Set the A SEC/DIV switch to a sweep speed which displays at least one complete waveform cycle.

5. Select ALT HORIZONTAL MODE. Adjust both the appropriate channel POSITION control and the A/B SWP SEP control to display the A trace above the B trace.

6. Adjust the B DELAY TIME POSITION control to position the start of the intensified zone to the portion of the display to be magnified (see Figure 4-11).

7. Set the B SEC/DIV switch to a setting which intensifies the full portion of the A trace to be magnified. The intensified zone will be displayed as the B trace (see Figure 4-11). The B HORIZONTAL MODE may also be used to magnify the intensified portion of the A Sweep.

8. The apparent sweep magnification can be calculated from the following formula:

$$\text{Apparent Delayed Sweep Magnification} = \frac{\text{A SEC/DIV switch setting}}{\text{B SEC/DIV switch setting}}$$

EXAMPLE: Determine the apparent magnification of a display with an A SEC/DIV switch setting of 0.1 ms per division and a B SEC/DIV switch setting of 1 μs per division.

Substituting the given values:

$$\text{Apparent Magnification} = \frac{1 \times 10^{-4}}{1 \times 10^{-6}} = 10^2 = 100$$

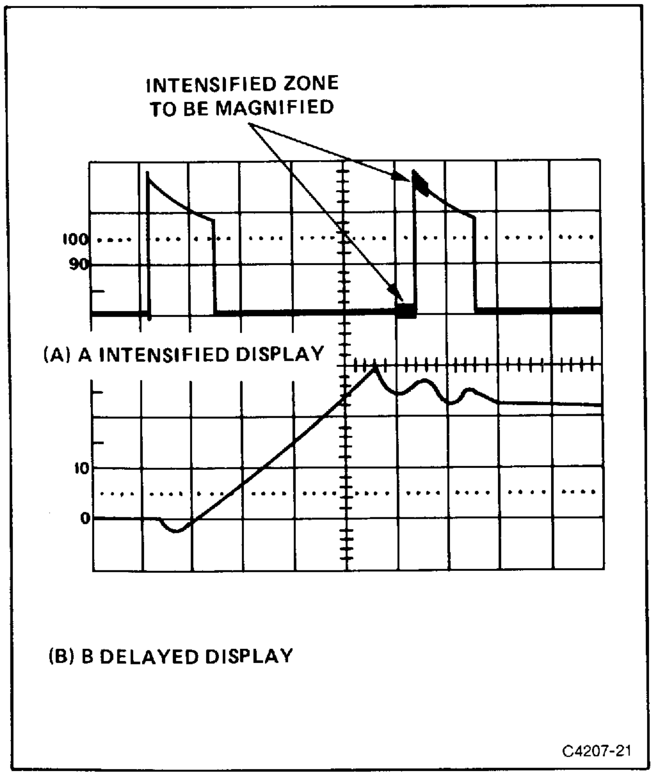

Figure 4-11. Delayed-sweep magnification.

Pulse Jitter Time Measurement

To measure pulse jitter time:

1. Perform steps 1 through 7 of the preceding "Magnified Sweep Runs After Delay" procedure.

2. Referring to Figure 4-12, measure the difference between Point C and Point D in divisions and calculate the pulse jitter time using the following formula:

$$\text{Pulse Jitter Time} = \text{Horizontal difference (divisions)} \times \text{B SEC/DIV switch setting}$$

Triggered Magnified Sweep

The following procedure explains how to operate the B Sweep in a triggered mode and to determine the resulting apparent magnification factor. Operating the B Sweep in a triggered mode provides a more stable display, since the delayed display is triggered at the same point each time.

1. Perform steps 1 through 7 of the preceding "Magnified Sweep Runs After Delay" procedure.

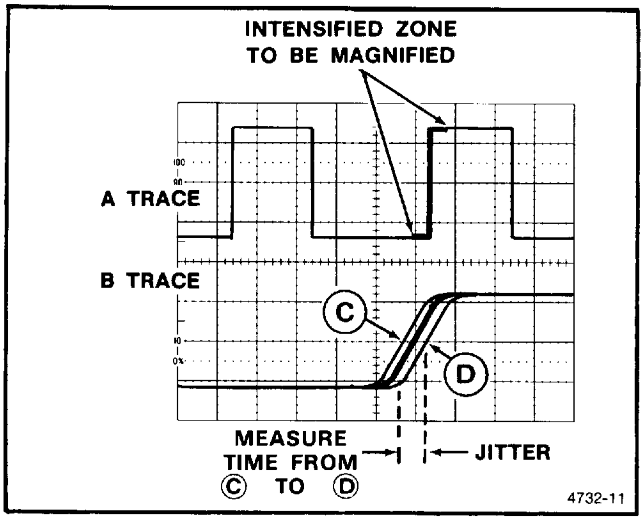

Figure 4-12. Pulse jitter.

2. Adjust the B TRIGGER LEVEL control so the intensified zone on the A trace is stable.

NOTE

The intensified zone seen in the ALT HORIZONTAL MODE display will move from trigger point to trigger point as the B DELAY TIME POSITION control is rotated.

3. The apparent magnification factor can be calculated from the formula shown in step 8 of the "Magnified Sweep Runs After Delay" procedure.

DELAYED-SWEEP TIME MEASUREMENTS

Operating this instrument with the HORIZONTAL MODE set to either ALT or B will permit time measurements to be made with a greater degree of accuracy than attained with HORIZONTAL MODE set to A. The following procedures describe how these measurements are accomplished.

Time Difference on Single Waveform

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 switch to display the channel used.

3. Set the appropriate VOLTS/DIV switch to produce a display of approximately 2 or 3 divisions in amplitude.

4. Set the A SEC/DIV switch to display the measurement points of interest on the waveform. Ensure that the SEC/DIV Variable control is in the CAL detent.

5. Select ALT HORIZONTAL MODE and adjust both the appropriate vertical POSITION control and A/B SWP SEP control to display the A trace above the B trace (see Figure 4-13).

6. Set the B SEC/DIV switch to the fastest sweep speed that provides a useable (visible) intensified zone.

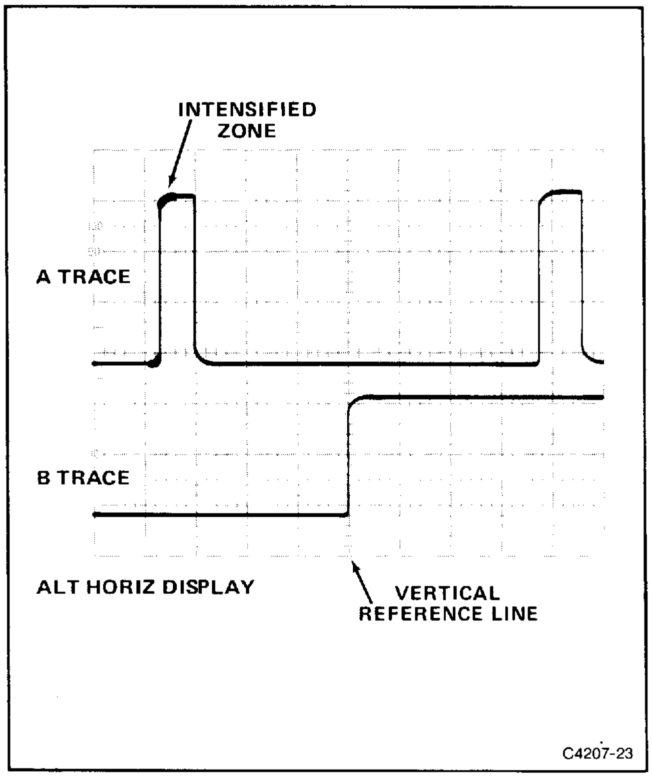

Figure 4-13. Time difference on single waveform.

7. Adjust the B DELAY TIME POSITION control to move the intensified zone to the leading edge on the first point of interest (on the A trace); then fine adjust until the selected portion (on the B trace) is centered at any convenient vertical graticule line (see Figure 4-13).

8. Record the B DELAY TIME POSITION dial setting.

9. Adjust the B DELAY TIME POSITION control clockwise to move the intensified zone to the leading edge of the second point of interest (on the A trace); then fine adjust until the rising portion (on the B trace) is centered at the same convenient vertical graticule used in preceding step 7.

10. Record the B DELAY TIME POSITION control dial setting.

11. Calculate the time difference between repetitive pulses using the following formula.

$$\begin{matrix}\text{Time}\\ \text{Difference}\\ \text{(Duration)}\end{matrix} = \left(\begin{matrix}\text{second}\\ \text{dial}\\ \text{setting}\end{matrix} - \begin{matrix}\text{first}\\ \text{dial}\\ \text{setting}\end{matrix}\right)\left(\begin{matrix}\text{A SEC/DIV}\\ \text{switch}\\ \text{setting}\end{matrix}\right)$$

EXAMPLE: With the A SEC/DIV switch set to 0.02 ms per division, the first B DELAY TIME POSITION dial setting is 1.20 and the second B DELAY TIME POSITION dial setting is 9.53 (see Figure 4-14).

Substituting the given values in the time difference formula:

Time Difference = (9.53 − 1.20) (0.2 ms/div) = 1.666 ms

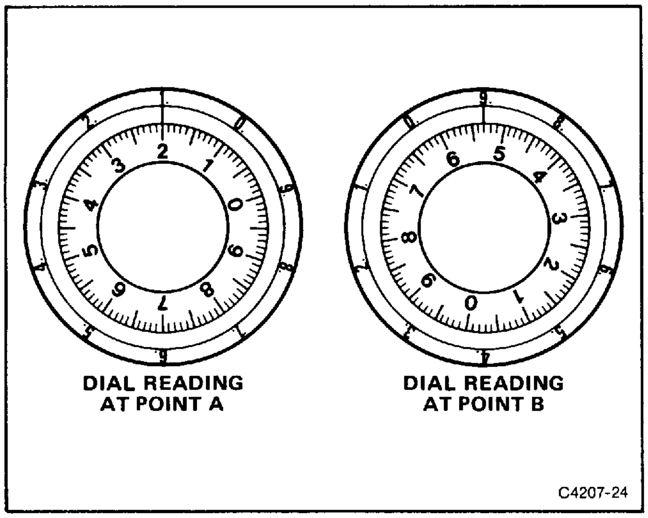

Figure 4-14. B DELAY TIME POSITION control settings.

Rise Time

Rise-time measurements use the same methods as time difference on single waveform, except that the measurements are made between the 10% and 90% points of the low-to-high transition of the selected waveform. Fall time is measured between the 90% and 10% points of the high-to-low transition 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 switch to display the channel used.

3. Set the appropriate VOLTS/DIV switch and Variable control for an exact 5-division display.

4. Vertically position the trace so that the zero reference of the waveform touches the 0% graticule line and the top of the waveform touches the 100% graticule line.

5. Set the A SEC/DIV switch so one transition of interest is displayed. Ensure that the SEC/DIV Variable control is in the CAL detent.

6. Select ALT HORIZONTAL MODE and adjust the B DELAY TIME POSITION control to intensify the transition of interest on A Sweep. Set the B SEC/DIV switch to spread the portion of the A display being measured as much as possible on the B Sweep.

7. Select the B HORIZONTAL MODE. Adjust the B DELAY TIME POSITION control until the display intersects the 10% point at the center vertical graticule line (see Figure 4-15, Point A).

8. Record the B DELAY TIME POSITION control dial setting.

9. Adjust the B DELAY TIME POSITION control until the display intersects the 90% point at the center vertical graticule line (see Figure 4-15, Point B).

10. Record the B DELAY TIME POSITION control dial setting.

11. Calculate rise time using the same formula listed in the "Time Difference On Single Waveforms" measurement procedure.

EXAMPLE: With the A SEC/DIV switch set to 1 μs per division, the first B DELAY TIME POSITION dial setting (Point A) is 2.50 and the second B DELAY TIME POSITION dial setting (Point B) is 7.50.

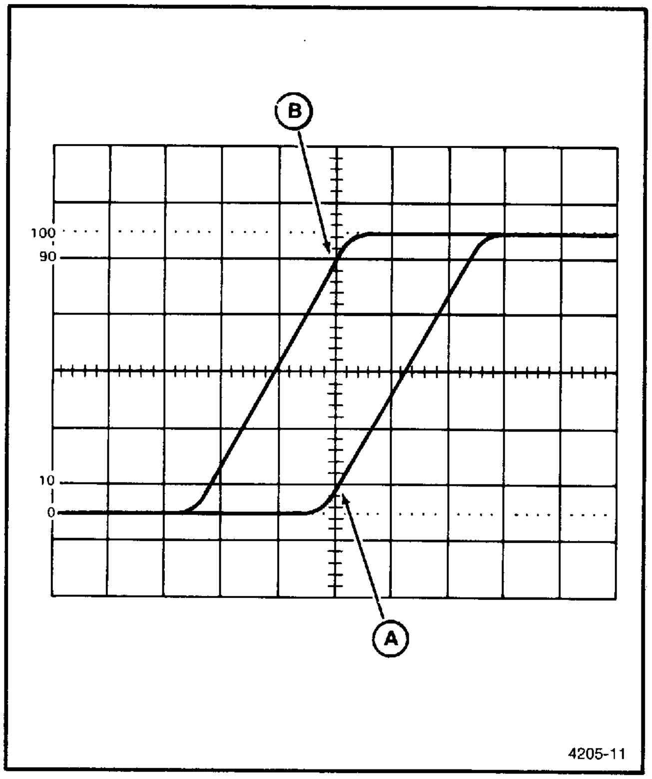

Figure 4-15. Rise time, differential time method.

Substituting the given values in the time difference formula:

Rise Time = (7.50 − 2.50) (1 μs/div) = 5 μs

Time Difference Between Two Pulses on Two Time-Related Signals

1. Preset instrument controls and obtain a baseline trace. Set the vertical TRIGGER SOURCE switches to CH 1 and the VERTICAL MODE switches to BOTH and ALT.

2. Using probes or cables having equal time delays, apply the reference signal to the Channel 1 input and apply the comparison signal to the Channel 2 input.

3. Set the appropriate VOLTS/DIV switch to produce a display of approximately 2 or 3 divisions in amplitude.

4. Set the A SEC/DIV switch to display the measurement points of interest within the graticule area.

5. Select ALT HORIZONTAL MODE and CH 1 VERTICAL MODE. Adjust both the Channel 1 POSITION control and the A/B SWP SEP control so that the A trace is displayed above the B trace.

6. Rotate the B DELAY TIME POSITION control to move the intensified zone to the appropriate edge of the reference signal (on the A trace); then fine adjust until the edge of the reference signal (on the B trace) is centered at any convenient vertical graticule line (see Figure 4-16, Part A).

7. Record the B DELAY TIME POSITION control dial setting.

8. Select CH 2 VERTICAL MODE and adjust both the Channel 2 POSITION control and the A/B SWP SEP control as necessary to display the A trace above the B trace.

9. Rotate the B DELAY TIME POSITION control to move the intensified zone to the appropriate edge of the comparison signal (on the A trace); then fine adjust until the edge of the comparison signal is at the same vertical reference point as used in preceding step 6 (see Figure 4-16, Part B). Do not change the setting of the Horizontal POSITION control.

10. Record the B DELAY TIME POSITION control dial setting.

11. Calculate the time difference between the reference signal (Channel 1) and comparison signal (Channel 2) as in the preceding "Time Difference On Single Waveforms" measurement procedure.

EXAMPLE: With the A SEC/DIV switch set to 50 μs per division, the dial reading for the reference pulse (Channel 1) is 2.60 and the dial reading for the comparison pulse (Channel 2) is 7.10.

Substituting the given values into the time-difference formula:

Time Difference = (7.10 − 2.60) (50 μs/div) = 225 μs

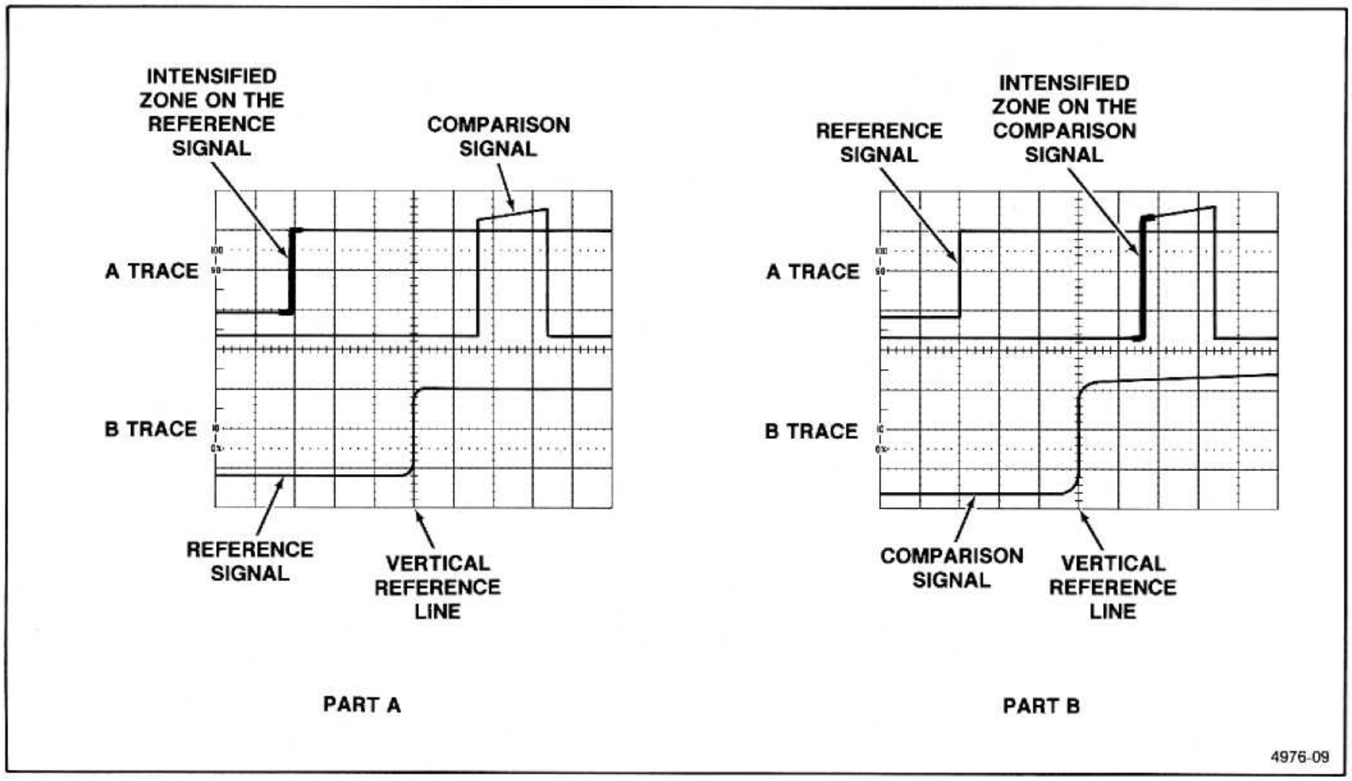

Figure 4-16. Time difference between two pulses on two time-related signals.

OPTIONS AND ACCESSORIES

INTRODUCTION

This section contains a general description of instrument options available at the time of publication of this manual. Also included is a complete list (with Tektronix part number) 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 Tektronix Field Office or representative.

OPTIONS

There are currently no options available for the instrument.

INTERNATIONAL POWER CORDS

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

Description	Order
Universal Euro 10-16A, 50 Hz	020-0859-00
UK 240 V/13A, 50 Hz	020-0860-00
Australian 240 V/10A, 50 Hz	020-0861-00
North American 240 V/15A, 60 Hz	020-0862-00
Switzerland 220 V/10A, 50 Hz	020-0863-00

STANDARD ACCESSORIES

The following standard accessories are provided with each instrument.

Qty	Description	Order
2	Probes, 10X 1.5-meter length, with accessories	010-6122-01
1	Probe, 1X 2-meter length, with accessories	010-6101-03
1	Power Cord	161-0104-00
1	Operators Manual	070-4976-00
1	Service Manual	070-4977-00
1	BNC T Connector	103-0030-00
1	BNC Male to Binding Post	103-0033-00
1	Front Panel Cover	200-2520-00
1	Accessory Pouch	016-0677-02
2	Grabber Tips	013-0191-00
1	Fuse (3AG, 1A, 250V, SLO-BLO)	159-0019-00
1	Viewing Hood	016-0566-00

OPTIONAL ACCESSORIES

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

Description	Order
Carrying Case	016-0792-00
Carrying Strap	346-0199-00
General-Purpose Camera	C-5C Option 02
Rackmount Adapter Kit	016-0466-00
SCOPE-MOBILE CART	200C or 200D

MANUAL CHANGE INFORMATION

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages.

A single change may affect several sections. Since the change information sheets are carried in the manual until all changes are permanently entered, some duplication may occur. If no such change pages appear following this page, your manual is correct as printed.

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MANUAL CHANGE INFORMATION

Date: 5-5-86 **Change Reference:** M60037

Product: 2235 AN/USM-488 OPERATORS **Manual Part No.:** 070-4976-00

DESCRIPTION Product Group 46

A new "Protective Rain Cover" is now available for the 2200 series so add the following to the Optional Accessories list:

Protective Rain Cover	016-0848-00