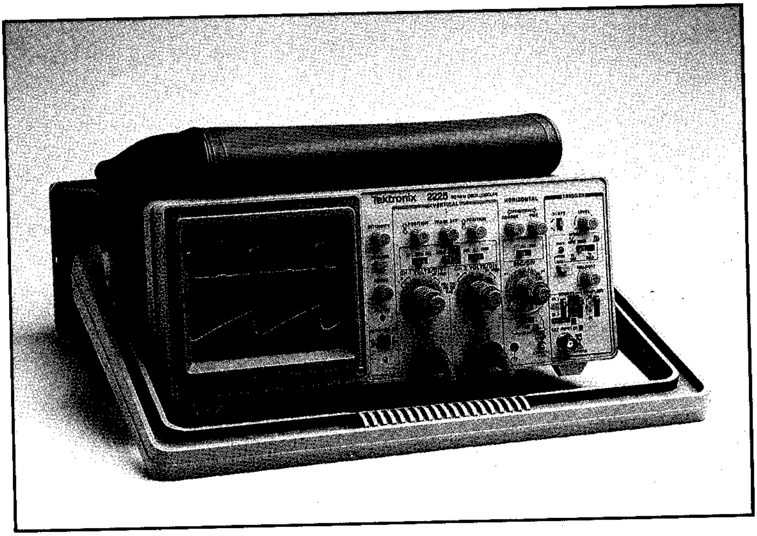
104-168

TEK

OPERATOR'S MANUAL
070-6298-01

2225 OSCILLOSCOPE AND OPTIONS



Tektronix®
COMMITTED TO EXCELLENCE


Tektronix
2225 50 MHz OSCILLOSCOPE
VERTICAL
HORIZONTAL
TRIGGER
INTENSITY
BEAM FIND
FOCUS
TRACE ROTATION
POWER
ON
OFF
POSITION
TRACE SEP
POSITION
MODE
CH 1 BOTH CH 2
NORM CH 2 INVERT
ADD ALT CHOP
CH 1 VOLTS/DIV
CH 2 VOLTS/DIV
1X
10X PROBE
PULL 'CAL' FOR X10 MAG
CAL
AC GND DC
CH 1 OR X
CH 2 OR Y
1MΩ 25pF
≤400Vpk
POSITION
COARSE
FINE
MODE
X1 ALT MAG
SEC/DIV
ms
sec
MAG
X5 X10 X50
EXCEPT
PROBE ADJUST
≈500mV P-P
SLOPE
LEVEL
MODE
P-P AUTO NORM
READY
RESET
TV LINE
TV FIELD
HOLDOFF
MIN
SOURCE
CH 1
VERT MODE
CH 2
EXT
COUPLING
AC
LF REJ
HF
DC
EXT INPUT OR Z
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FRONT PANEL ORGANIZATION

The front panel on the 2225 is organized to make it easy for you to set up displays and make measurements. Referring to the foldout illustration at the front of this manual, or to the oscilloscope itself, notice that the front panel is partitioned into four major control sections—Display, VERTICAL, HORIZONTAL, and TRIGGER.

Just to the right of the cathode-ray tube (crt) screen are the Display controls. They are used to adjust brightness and focus of the trace, to align the trace horizontally, and to help you find off-screen signals quickly. These controls affect the display, but not the waveform.

Like any oscilloscope, the 2225 draws a graph of voltage as a function of time. The VERTICAL section, enclosed within shaded gray lines, contain the controls that define the voltage (or vertical) axis of the display. Also a part of this section are the two BNC input connectors, which are used to apply the signals that you want to view.

The HORIZONTAL controls are to the right of the VERTICAL section. They are used to set and move the time (or horizontal) axis for the displayed traces.

On the extreme right of the front panel, enclosed within shaded green lines, is the TRIGGER section. Trigger controls define the signals and the conditions that are needed to initiate (or trigger) every sweep across the time axis. An indicator light shows whether the sweep is validly triggered or not. At the bottom of the TRIGGER section is a BNC input connector that can be used to apply either an external trigger signal or an external Z-axis (display intensity) control signal.

CONTROLS, CONNECTORS, AND INDICATORS

Table 2-1 gives you a summary of all the controls, connectors, and indicators on your 2225 Oscilloscope. Following the table is a short procedure describing how to get a display. The remainder of this section offers suggestions and tips for using the controls to obtain the most effective displays and to make the most accurate measurements.

Table 2-1
Summary of Controls, Connectors, and Indicators

No.	Title	Function	Recommended Use
1	INTENSITY	Adjusts trace brightness.	Compensate for ambient lighting, trace speed, trigger frequency.
2	BEAM FIND	Compresses display to within CRT limits.	Locate off-screen phenomena.
3	FOCUS	Adjusts for finest trace thickness.	Optimize display definition.
4	TRACE ROTATION	Adjusts trace parallel to centerline.	Compensate for earth's field.
5	POWER	Turns power on and off.	Control power to the instrument.
6	Power Indicator	Illuminates when power is turned on.	Know power condition.
7, 9	POSITION	Moves trace up or down screen.	Position trace vertically and compensate for dc component of signal.
8	TRACE SEP	Moves the magnified trace vertically with respect to the unmagnified trace when HORIZONTAL MODE is set to ALT.	Position unmagnified and horizontally magnified traces for convenient viewing and measurement.
10	CH 1 - BOTH - CH 2	Selects signal inputs for display.	View either channel independently or both channels simultaneously.
11	NORM - INVERT	Inverts the Channel 2 signal display.	Provide for differential (CH 1 − CH 2) or summed (CH 1 + CH 2) signals when ADD is selected.
12	ADD - ALT - CHOP	ADD shows algebraic sum of CH 1 and CH 2 signals. ALT displays each channel alternately. CHOP switches between CH 1 and CH 2 signals during the sweep at 500 kHz rate.	Display summed or individual signals.
13	VOLTS/DIV	Selects vertical sensitivity.	Adjust vertical signal to suitable size.
14	Variable (CAL)	Provides continuously variable deflection factors between calibrated positions of the VOLTS/DIV switch. Reduces gain by at least 2.5:1.	Match signals for common-mode readings. Adjust height of pulse for rise-time calculations.
		The CAL control can be pulled out to vertically magnify the trace by a factor of 10. Limits bandwidth to 5 MHz.	Inspecting small signals.
15	AC-GND-DC	In AC, isolates dc component of signal. In GND, gives reference point and allows precharging of input-coupling capacitor. In DC, couples all components of signal.	Selects method of coupling input signals to the vertical deflection system.
16	CH 1 OR X CH 2 OR Y	Provides for input signal connections. CH 1 gives horizontal deflection when SEC/DIV is in X-Y.	Apply signals to the vertical deflection system.

Table 2-1 (cont'd)

No.	Title	Function	Recommended Use
17	POSITION COARSE	COARSE is convenient for moving unmagnified traces.	Control trace positioning in horizontal direction.
18	POSITION FINE	FINE is convenient for moving magnified traces when either ALT or MAG is selected.	
19	X1 - ALT - MAG	X1 displays only normal (horizontally unmagnified) waveform. ALT displays normal and magnified waveforms alternately. MAG displays only the magnified waveform.	Select normal, comparative or expanded waveforms.
20	SEC/DIV	Selects time-base speed.	Set horizontal speed most suited to requirements.
21	Variable (CAL)	Provides continuously variable uncalibrated sweep speeds to at least 2.5 times the calibrated setting.	Extend the slowest speed to at least 1.25 s/div.
22	MAG (X5 - X10 - X50)	Selects degree of horizontal magnification.	Examine small phenomena in detail.
23		Provides safety earth and direct connection to signal source.	Chassis ground connection.
24	PROBE ADJUST	Provides approximately 0.5-V, 1-kHz square wave.	Match probe capacitance to individual circuit. This source may be used to check the basic functioning of vertical and horizontal circuits but is not intended to check their accuracy.
25	SLOPE	Selects the slope of the signal that triggers the sweep.	Provide ability to trigger from positive-going or negative-going signals.
26	LEVEL	Selects trigger-signal amplitude point.	Select actual point of trigger.
27	TRIG'D	Indicator lights when sweep is triggered in P-P AUTO, NORM, or TV FIELD.	Indicate trigger state.
28	MODE	P-P AUTO/TV LINE triggers from waveforms and television lines having repetition rates of at least 20 Hz. NORM triggers from adequate signal, with no trace in absence of trigger signal. TV FIELD triggers from TV Field signals; trigger polarity must be observed. SGL SWP triggers sweep only once when armed by RESET button; used for displaying or photographing nonrepetitive or unstable signals.	Select trigger mode.
29	RESET	Arms trigger circuit for SGL SWP.	
30	HOLDOFF	Varies sweep holdoff time 10:1.	Improve ability to trigger from aperiodic signals.

Table 2-1 (cont'd)

No.	Title	Function	Recommended Use
31	SOURCE	CH 1, CH 2, and EXT trigger signals are selected directly. In VERT MODE, trigger source is determined by the VERTICAL MODE switches as follows: CH 1: trigger comes from Channel 1 signal. CH 2: trigger comes from Channel 2 signal. BOTH-ADD and BOTH-CHOP: trigger is algebraic sum of Channel 1 and Channel 2 signals. BOTH-ALT: trigger comes from Channel 1 and Channel 2 on alternate sweeps.	Select source of signal that is coupled to the trigger circuit.
32	COUPLING	AC blocks dc components and attenuates signals below 15 Hz. LF REJ blocks dc components and attenuates signals below about 30 kHz. HR REJ attenuates signals above about 30 kHz. DC couples all signal components.	Select how the triggering signal is coupled to the trigger circuit.
33	EXT INPUT	Connection for applying external signal that can be used as a trigger.	Trigger from a source other than vertical signal. Also used for single-shot application.
		Connection for applying external signal that can be used for intensity modulation.	Provide reference blips by intensity modulation from independent source.

LEARNING THE CONTROLS

If you have not read Section 1 yet, you should do so now. Then, after turning the power on, let the oscilloscope warm up for a few minutes before starting this procedure.

1. Set instrument controls as follows:

Display	
INTENSITY	Midrange
FOCUS	Midrange
Vertical (both channels)	
POSITION	Midrange
MODE	CH 1
VOLTS/DIV	0.5 V (10X PROBE)
VOLTS/DIV Variable	CAL detent (fully clockwise)
Input Coupling	AC
Horizontal	
COARSE POSITION	Midrange
MODE	X1
SEC/DIV	0.2 ms
SEC/DIV Variable	CAL detent (fully clockwise)
Trigger	
SLOPE	_/‾
LEVEL	Midrange
MODE	P-P AUTO
HOLDOFF	MIN
SOURCE	CH 1
COUPLING	AC

2. Connect a probe to the input BNC connector for Channel 1 (labeled CH 1 OR X). Attach the probe ground lead to the collar of the EXT INPUT connector and apply the probe tip to the PROBE ADJUST terminal. If necessary, adjust the TRIGGER LEVEL control to get a stable display.
3. Change the Channel 1 input coupling switch to GND and use the Channel 1 POSITION control to align the baseline trace to the center horizontal graticule line. This sets the zero reference for the display.
4. Switch input coupling back to AC. Notice that the square wave is centered vertically on the screen. Now switch input coupling to DC and observe what happens to the waveform. The zero reference is maintained at the center horizontal graticule line.

NOTE

More information about using the controls is contained at the end of this procedure. Refer to it as often as needed while learning the front-panel controls.

5. Use the following controls and notice the effect each has on the displayed waveform as the settings are changed.

    Each POSITION control
    CH 1 VOLTS/DIV
    CH 1 VOLTS/DIV Variable (CAL)
    SEC/DIV
    SEC/DIV Variable (CAL)
    HORIZONTAL MODE
    HORIZONTAL MAG
    TRACE SEP
    TRIGGER SLOPE

6. At this point, connect the second probe to the CH 2 OR Y input connector. Set the VERTICAL MODE switch to CH 2 and TRIGGER SOURCE to CH 2, then follow steps 2 through 5 again, using the channel 2 controls.
7. Now set the VERTICAL MODE switches to BOTH-NORM-ALT and return both VOLTS/DIV switches to 0.5V (10X PROBE). Rotate all variable controls clockwise to their CAL detents. Set the TRIGGER SOURCE switch to VERT MODE. Set HORIZONTAL MODE switch to ALT and MAG switch to X5. Then use the VERTICAL POSITION and TRACE SEP controls to position the four traces to convenient locations on the screen.
8. While watching the Channel 2 waveforms, set the middle VERTICAL MODE switch to CH 2 INVERT and notice the effect. Then set the right MODE switch to ADD. What happens to the waveforms? Finally, return the middle MODE switch to NORM. What waveform is displayed now?

Congratulations! You now know how to use the 2225 front-panel controls to display signals and move them about on the screen. The remainder of this section gives you more information about the controls and offers suggestions for their use. Section 3 explains how to make specific types of measurements and how to use the remaining controls not covered in the preceding exercise.

DISPLAY CONTROLS

Set the INTENSITY control for comfortable viewing, but no brighter than you need. Use high-intensity settings to observe low-repetition-rate signals, narrow pulses in long time intervals, or occasional variations in fast signals.

VERTICAL CONTROLS

When making voltage measurements, rotate the VOLTS/DIV CAL control fully clockwise (in detent). Best accuracy can be achieved by setting the VOLTS/DIV control for the largest display possible.

Input Coupling

For most applications use DC input coupling. This mode is compatible with the standard-accessory, high-impedance probes and it displays logic levels and dc levels of static signals.

Use GND input coupling to show where the 0-volt level will be located when you shift to DC coupling.

Use AC coupling for the special cases where you need to see small signals on large dc voltage levels.

Channel Selection

With the three VERTICAL MODE buttons, you can display combinations of the two vertical channels. When CH 1 is selected, the other two MODE switches are not active. When CH 2 is selected, the middle MODE switch (NORM/CH 2 INVERT) becomes active. And when BOTH channels are selected for display, all three MODE switches are active.

ADD and INVERT

Select ADD mode to display the algebraic sum of the CH 1 and CH 2 signals. When you use ADD, the CH 1 and CH 2 VOLTS/DIV settings should be equal.

Selecting CH 2 INVERT changes the sense of the CH 2 waveform. This allows you to see the difference between the CH 1 and CH 2 signals on the ADD trace.

CHOP or ALT?

When BOTH channels are selected, the display is time-shared. The CHOP mode displays each channel for a short time and multiplexes during the sweep to give the appearance of displaying both channels at once. This mode (CHOP) works better than ALT for sweep speeds slower than 1 ms per division and for low-repetition-rate signals that make the display flicker (up to 2 μs/division).

The ALT mode displays each channel for the duration of a complete sweep. It gives a cleaner display of multiple channels than CHOP does and is usually preferred at moderate to high sweep speeds.

Increasing the Sensitivity

Pulling the VOLTS/DIV CAL control out (towards you) magnifies the vertical axis by a factor of 10, increasing the sensitivity to 500 µV per division. This function is useful for investigating small-amplitude signals (in general, less than 5 mV p-p) or small-amplitude details on larger signals.

HORIZONTAL CONTROLS

Sweep-Speed Selection

The unmagnified sweep (MODE set to X1) is the horizontal function needed for most applications. Best measurement accuracy is achieved by setting the SEC/DIV control for the fastest sweep that will display the interval of interest. The variable control (CAL) should be in its detent (fully clockwise).

Magnifying Waveform Details

Each of the two magnified modes—ALT or MAG—expands the unmagnified trace. When ALT is chosen, both the unmagnified and the magnified waveforms appear together on the crt screen. Vertical separation between them is adjusted with the TRACE SEP control. If MAG is selected, only the magnified trace is displayed on screen. This is useful for eliminating unwanted clutter from the crt when you are making accurate timing measurements or looking at waveform details.

Whenever ALT or MAG is set on the upper HORIZONTAL MODE switch, the amount of waveform expansion is determined by the setting of the HORIZONTAL MAG switch located beneath the SEC/DIV control. Three magnifications are available—5X, 10X, and 50X. Having the ability to select various combinations of waveform expansion and SEC/DIV control setting lets you extend the time-base range out to a maximum of 5 ns per division. Appendix A lists the sweep speeds for each magnifications level at every SEC/DIV control setting.

The marker that links the timing of the unmagnified and magnified traces with each other is the center vertical graticule line. The intersections of that line with the unmagnified and the magnified waveforms are the points of equal time duration from sweep start. With the center vertical graticule as the reference line, the investigation of waveform details around any point on the unmagnified trace as well as the measurement of time with greater accuracy then become easy tasks.

TRIGGER CONTROLS

For most signals, the trigger-control settings that will yield hands-off triggering are:

MODE	P-P AUTO
HOLDOFF	MIN
SOURCE	VERT MODE
COUPLING	DC

Which Mode to Use

P-P AUTO/TV LINE—With this mode set, the range of the LEVEL control is confined to the values between the triggering-signal peaks. For example, selecting P-P AUTO and rotating the LEVEL control to the center half of its range establishes a trigger point that is about midway between the peaks of the triggering signal.

In this mode, the absence of a triggering signal causes the sweep to free-run. And with signals below 20 Hz, the P-P AUTO circuit may not find the correct level.

Whenever P-P AUTO is active and VERT MODE source selected, the triggering signal is supplied by the channel that is being displayed—or by Channel 1 in a two-channel display.

The P-P AUTO mode is effective for monitoring logic signals and television lines having at least a 20-Hz repetition rate. Selecting P-P AUTO at the instrument front panel also sets the TV LINE triggering mode.

NORM—This mode produces a sweep only when the triggering signal meets the criteria set by the LEVEL and SLOPE controls. With NORM mode selected, range of the LEVEL control is sufficient to set any voltage threshold that can be displayed by the instrument. In the absence of a triggering signal, there is no sweep.

Use the NORM mode for viewing infrequent events and erratic signals.

SGL SWP—When this mode is selected, the sweep is triggered only once. Press the RESET button once to arm the trigger circuit and illuminate the READY indicator. When a trigger event occurs, the sweep runs once and the READY light extinguishes.

Use the SGL SWP mode to display or photograph nonrepetitive or unstable signals.

TV FIELD—This mode triggers the sweep at the beginning of a television field. To change the TV field being displayed, you must interrupt the trigger signal by setting the input coupling switch momentarily to GND then back to either DC or AC until the desired field is displayed.

To display Field 1 and Field 2 at the same time, connect the same television signal to both the CH 1 and CH 2 inputs; set VERTICAL MODE to BOTH and ALT; set the SEC/DIV control to 0.5 ms or faster sweep speed.

If you magnify the vertical display beyond the graticule, the trigger may be degraded. To avoid trigger overload, use either CH 1 or CH 2 for display and use the EXT INPUT channel with an appropriate video signal as the trigger source. A composite sync signal can be used for the trigger source as well as composite video.

Source

Choose a single trigger source to correctly display the timing relationships between two channels. Choose the channel with the lowest-frequency signal to avoid ambiguous displays.

With VERT MODE TRIGGER SOURCE and either P-P AUTO TRIGGER MODE or CHOP VERTICAL MODE, the triggering signal is the algebraic sum of the Channel 1 and Channel 2 input signals.

Use a composite trigger source only to compare asynchronous signals. To generate a composite trigger: select VERT MODE TRIGGER SOURCE, BOTH-ALT VERTICAL MODE, and any TRIGGER MODE except P-P AUTO.

Coupling

For signals with strongly interfering components, HF Reject and LF Reject coupling give added selectivity. When AC coupling is selected, triggering continues as the dc level of the signal changes.

Slope

Use the SLOPE control to select either the rising (_/‾) or the falling (‾_) edge of the signal to trigger the sweep.

Level

The LEVEL control gives you complete freedom to choose the most appropriate threshold voltage on a signal to initiate sweeps whenever any trigger mode except P-P AUTO is selected.

Holdoff

With irregular signals such as bursts, the HOLDOFF setting can improve display stability. Also, if the signal has a fixed pattern of variation from cycle to cycle, some modes of the signal may be omitted from the display. Changing the HOLDOFF setting can force the instrument to display all the modes of the signal. Normally, the HOLDOFF control should be set at MIN.

CONNECTING SIGNALS

A probe is usually the most convenient way to connect an input signal to the instrument. Shielded to prevent pickup of electromagnetic interference, the standard 10X probes supplied with the instrument present a high impedance to a circuit under test. While the 10 MΩ and 13 pF of the probe-scope system present a negligible load on most circuits, very fast circuits or very high impedance circuits may be seriously affected.

Waveform Fidelity and Probe Grounds

A probe ground must be used for accurate measurements and observations. Use the shortest ground connection possible if you want good waveform fidelity.

The standard-accessory probe is a compensated 10X voltage divider. To a circuit under test, it appears resistive for low-frequency signals and capacitive for high-frequency components. The probe input capacitance can interact with the inductance of either a long signal lead or a long ground lead to form a series-resonant circuit. This circuit can affect system bandwidth and can ring if driven by a fast step. Always keep both the ground lead and the probe signal-input connections as short as possible to maintain the best waveform fidelity.

In some cases, a separate ground from the unit under test to the ground receptacle on the oscilloscope front panel can reduce interference from low-frequency hum and noise. For rough checks of larger signals, such as 5 V logic, a ground lead separate from the probe—or even the safety ground connection, which is shared with the unit under test—may work for a signal ground. Fast signal transitions will be highly distorted, and extraneous noise will be induced without the probe ground connection.

Probe Compensation

Misadjustment of probe compensation is a common source of measurement error. Due to variations in oscilloscope input characteristics, probe compensation should be checked whenever the probe is moved from one oscilloscope to another or from one channel to another on the same oscilloscope. Always compensate the probe to the channel on which it will be used. See the procedure in Section 4, *Checks and Adjustments*.

Probe Handling

Both the probe and the probe accessories should be handled carefully to prevent damage. Striking a hard surface can damage both the probe body and the probe tip. Exercise care to prevent the cable from being crushed, kinked, or excessively strained.

Coaxial Cables

To maintain good waveform fidelity and accuracy, use only high-quality, low-loss coaxial cables. When you use 50Ω or 75Ω coaxial cable, attach a matching external terminator. Some high frequency response will be lost with external termination.

SECTION 3

APPLICATIONS

This section describes how to make specific types of measurements with your 2225 Oscilloscope. Before performing any procedure, be sure you are familiar with the information contained in the *Operator's Safety Summary* and in Section 1. Preset the instrument front-panel controls, using the setup on page 2-5 as a guideline, and then turn on the power. For maximum measurement accuracy, allow a 20-minute warm-up period.

AMPLITUDE MEASUREMENTS

Peak-to-Peak Voltage

This procedure may be used to make peak-to-peak voltage measurements, and voltage measurements between any two points on the waveform.

1. Apply the ac signal to either the CH 1 or the CH 2 input connector and set the VERTICAL MODE switch to display the channel used.
2. Set the appropriate VOLTS/DIV switch to display about 5 divisions of the waveform and ensure that the VOLTS/DIV variable control is in the CAL detent.
3. Adjust the TRIGGER LEVEL control to obtain a stable display.
4. Rotate the SEC/DIV switch to a setting that displays several cycles of the waveform.

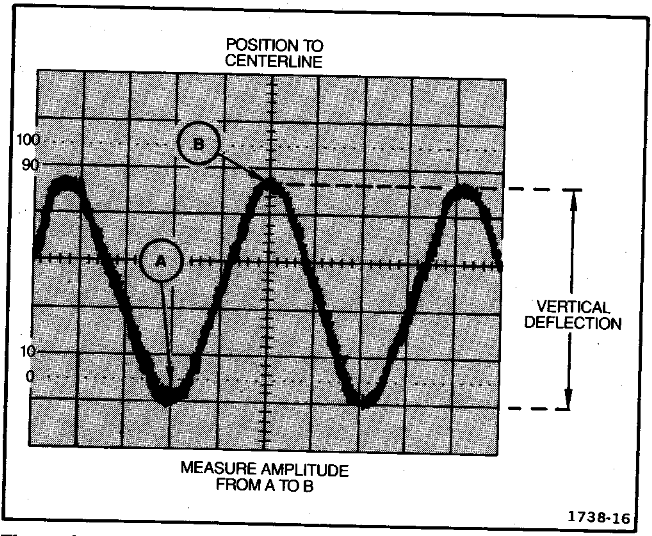

Figure 3-1. Measuring peak-to-peak voltage of a waveform.

5. Vertically position the display so that the negative peak of the waveform coincides with one of the horizontal graticule lines (see Figure 3-1, Point A).
6. Horizontally position the display so that one of the positive peaks coincides with the center vertical graticule line (Figure 3-1, Point B).
7. Measure the divisions of vertical deflection from peak to peak (Figure 3-1, Point A to Point B).

NOTE

If the amplitude measurement is critical or if the trace is thick (because of hum or noise on the signal), a more accurate result 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.

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

$$V_{p\text{-}p} = \begin{matrix}\text{vertical}\\ \text{deflection}\\ \text{(divisions)}\end{matrix} \times \begin{matrix}\text{VOLTS/DIV}\\ \text{setting}\\ \text{(10X PROBE)*}\end{matrix}$$

*If a 1X probe is being used for the measurement, use the 1X VOLTS/DIV setting.

EXAMPLE. In Figure 3-1, the measured peak-to-peak vertical deflection is 4.6 divisions using a 10X attenuator probe with the VOLTS/DIV switch set to 5 V (10X PROBE).

Substituting the given values:

$$V_{p\text{-}p} = 4.6\ \text{div} \times 5\ \text{V/div} = 23\ \text{V}.$$

Instantaneous Voltage

To measure the instantaneous voltage level at a given point on a waveform, referred to ground, use the following procedure:

1. Apply the ac signal to either the CH 1 or the CH 2 input connector and set the VERTICAL MODE switch to display the channel used.
2. Verify that the VOLTS/DIV variable control is in the CAL detent and set input coupling to GND.
3. Vertically position the trace to the center horizontal graticule line. This establishes the ground reference location.

NOTE

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

4. 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 center VERTICAL MODE switch is set to NORM.

5. If necessary, repeat Step 3 using a different horizontal ground-reference line that allows the waveform in Step 4 to be displayed on screen.
6. Adjust the TRIGGER LEVEL control to obtain a stable display.
7. Set the SEC/DIV switch to a position that displays several cycles of the signal.
8. 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 3-2).

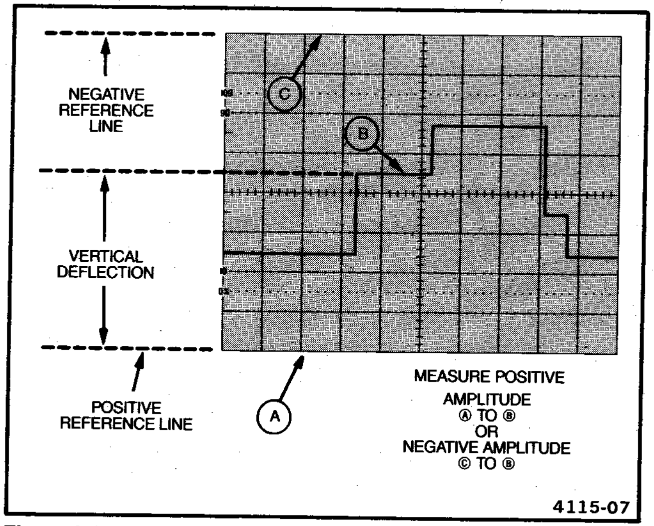

Figure 3-2. Instantaneous voltage measurement.

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

$$\text{Instantaneous Voltage} = \text{vertical deflection (divisions)} \times \text{polarity } (+ \text{ or } -) \times \text{VOLTS/DIV setting (10X PROBE)}^{*}$$

*If a 1X probe is being used for the measurement, use the 1X VOLTS/DIV setting.

EXAMPLE. In Figure 3-2, the measured vertical deflection from the reference line is 4.5 divisions, and 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 (10X PROBE).

Substituting the given values.

$$\text{Instantaneous Voltage} = 4.5 \text{ div} \times (+1) \times 2 \text{ V/div} = 9.0 \text{ V.}$$

Algebraic Addition

With the VERTICAL MODE switches set to BOTH-NORM-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 middle MODE switch is then set to CH 2 INVERT, the waveform displayed is the difference between the signals applied to the Channel 1 and Channel 2 inputs (CH 1—CH 2). When both VOLTS/DIV switches are set to the same deflection factor, the deflection factor of the ADD trace is equal to the deflection factor indicated by either VOLTS/DIV switch.

The following general precautions should be observed when using ADD VERTICAL MODE.

1. Do not exceed the input voltage rating of the oscilloscope.
2. Do not apply signals whose peaks exceed the equivalent of about ± 8 times the VOLTS/DIV switch settings, since large voltages may distort the display. For example, with a VOLTS/DIV setting of 0.5 V, the voltage applied to that channel should not exceed approximately 4 V.
3. Position the Channel 1 and Channel 2 waveforms near center screen, when viewed separately. This ensures the greatest dynamic range for ADD mode operation.
4. To attain similar responses from both channels, set 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 to eliminate other unwanted frequency components or to provide a dc offset.

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

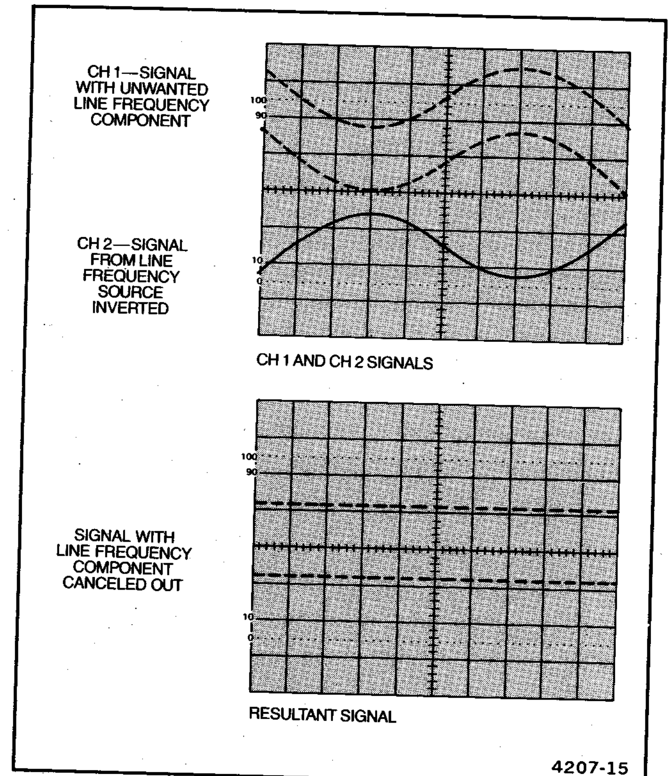

Figure 3-3. Common-mode rejection.

3. Set VERTICAL MODE switches to BOTH-NORM-ALT; set both VOLTS/DIV switches equally to produce displays of approximately four or five divisions amplitude.
4. 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 3-3 top).
5. Now set the middle and right VERTICAL MODE switches to CH 2 INVERT and ADD. Slightly readjust the CH 2 VOLTS/DIV variable control for maximum cancellation of the undesired signal component (Figure 3-3 bottom).

Amplitude Comparison (Ratio)

In some applications it may be necessary to establish a set of deflection factors in between step settings of the VOLTS/DIV switch. 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 (CAL) control. Unknown signals can then be quickly and accurately compared to the reference signal without disturbing the setting of the VOLTS/DIV variable control.

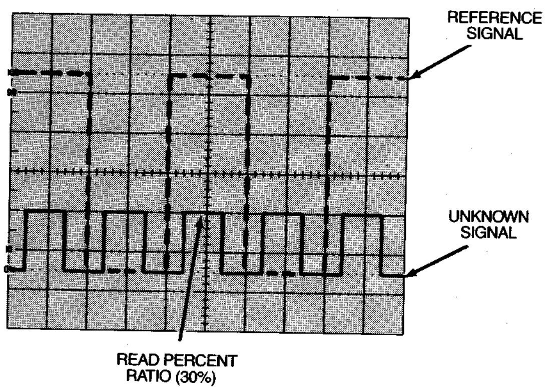

Figure 3-4. Determining voltage ratio.

1. Apply the reference signal to either the CH 1 or the CH 2 input connector and set the VERTICAL MODE switch to display the channel used.
2. Set the amplitude of the reference signal to five vertical divisions by adjusting the VOLTS/DIV switch and VOLTS/DIV variable (CAL) control.
3. Disconnect the reference signal and apply the unknown signal 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.
4. Horizontally position the waveform so that its top-most features cross the center vertical graticule line (see Figure 3-4).
5. Read the percent ratio directly from the graduations on the vertical centerline, referring to the 0% and 100% percentage marks on the left edge of the graticule (1 minor division equals 4% for a 5-division display).

TIME MEASUREMENTS

Time Duration

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

1. Apply the signal to either the CH 1 or the CH 2 input connector and set the VERTICAL MODE switch to display the channel used.
2. Adjust the TRIGGER LEVEL control to obtain a stable display.
3. Set the SEC/DIV switch to display between one and two complete periods of the waveform. Ensure that the SEC/DIV variable control is in the CAL detent.
4. Position the display to place the time-measurement points on the center horizontal graticule line (see Figure 3-5).
5. Measure the horizontal distance between the time-measurement points.

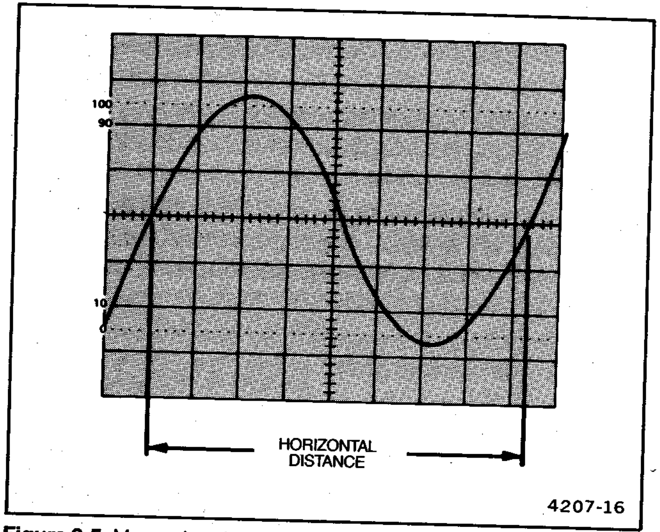

Figure 3-5. Measuring time duration.

6. Calculate time duration using the following formula:

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

EXAMPLE. In Figure 3-5, the distance between the time measurement points is 8.3 divisions, and the SEC/DIV setting is 2 ms per division. Horizontal MODE is set to X1.

Substituting the given values:

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

Period and Frequency

In the preceding example, you measured the time duration of one complete waveform cycle. This particular measurement is called the waveform period (T). The frequency (f) of a recurrent signal can be determined from its period as follows:

1. Measure the time duration of one waveform cycle (period) using the preceding time-duration measurement procedure.
2. Calculate the reciprocal of the period to determine the waveform frequency.

EXAMPLE. The signal in Figure 3-5 has a period (T) of 16.6 ms. Calculating frequency (f):

$$f = \frac{1}{T} = \frac{1}{16.6 \times 10^{-3}\ s} = 60\ Hz$$

Rise Time

Rise time measurements use the same methods as time duration, except that the measurements are made between the 10% and 90% points on the 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. Apply a signal to either the CH 1 or the CH 2 input connector and set the VERTICAL MODE switch to display the channel used.
2. Set the appropriate VOLTS/DIV switch and variable (CAL) control for an exact five-division display.
3. 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.
4. Horizontally position the display so the 10% point on the waveform intersects the second vertical graticule line (Figure 3-6, Point A).

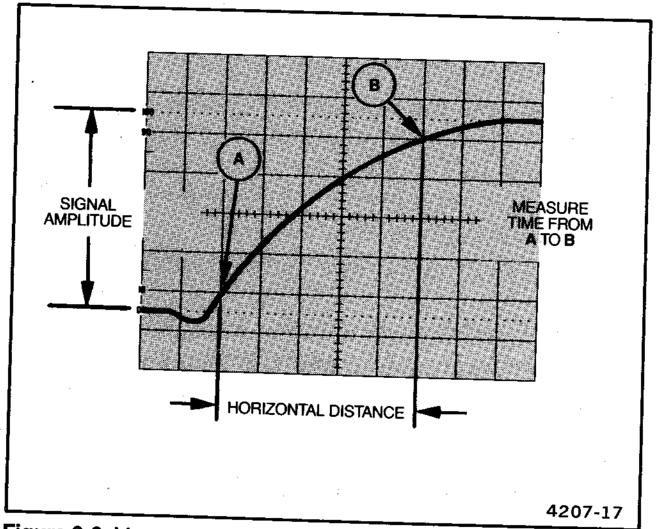

Figure 3-6. Measuring rise time.

NOTE

You can achieve better accuracy by using the SEC/DIV control or horizontal magnification to expand the waveform transition so that it occupies from four to six horizontal divisions between the 10% and 90% amplitude points.

5. Measure the horizontal distance between the 10% and 90% points (Figure 3-6, Points A and B) and calculate time duration using the following formula:

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

EXAMPLE: In Figure 3-6, the horizontal distance between the 10% and 90% amplitude points is 5 divisions, and the SEC/DIV switch is set to 1 μs per division. Horizontal MODE is set to X1.

Substituting 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 the 2225 allow measurement of the time difference between two separate events. To measure time difference, use the following procedure:

1. Set the 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, apply a known reference signal to the CH 1 input connector and apply the comparison signal to the CH 2 input.
4. Set both VOLTS/DIV switches for either 4-division or 5-division displays.
5. Set VERTICAL MODE to BOTH; then select either ALT or CHOP, depending on the frequency of the input signals.
6. If the two signals are opposite in polarity, set the middle VERTICAL MODE switch to CH 2 INVERT to invert the Channel 2 display.
7. Adjust the TRIGGER LEVEL control for a stable display.
8. Set the SEC/DIV switch to a sweep speed that provides three or more divisions of horizontal separation between measurement points on the two displays. Center each of the displays vertically (see Figure 3-7).
9. Determine the horizontal difference between the two signal measurement points and calculate the time difference using the following formula:

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

EXAMPLE. In Figure 3-7, the SEC/DIV switch is set to 50 μs per division, HORIZONTAL MODE is set to MAG, and the MAG switch is set to X10. The horizontal difference between waveform measurement points is 4.5 divisions.

Substituting the given values in the formula:

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

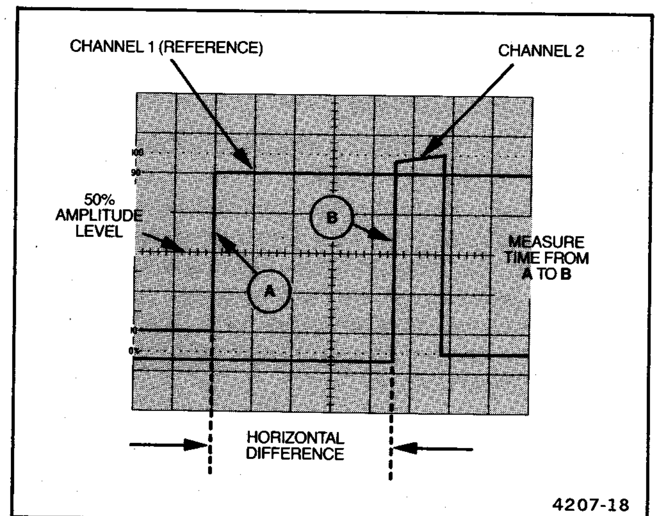

Figure 3-7. Time difference between pulses on time-related signals.

Phase Difference

In a similar manner to the preceding measurement, you can make a phase comparison between two signals of the same frequency using the dual-trace feature of the 2225. This method of phase-difference measurement can be used for signals with frequencies up to the limit of the vertical deflection system. To make a phase comparison, perform the following procedure:

1. Set the 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, apply a known reference signal to the CH 1 input connector and apply the unknown signal to the CH 2 input.
4. Set VERTICAL MODE to BOTH; then select either ALT or CHOP, depending on the frequency of the input signals. The reference signal should precede the comparison signal in time.
5. If the two signals are opposite in polarity, set the middle VERTICAL MODE switch to CH 2 INVERT to invert the Channel 2 display.
6. Set both VOLTS/DIV switches and adjust both variable (CAL) controls to display equal-amplitude waveforms.
7. Adjust the TRIGGER LEVEL control for a stable display and center the display vertically.
8. Set the SEC/DIV switch to a sweep speed that displays about one full cycle of the waveforms.
9. Position the displays and adjust the SEC/DIV variable (CAL) control so that one cycle of the reference signal occupies exactly eight horizontal graticule divisions at the 50% rise-time points (see Figure 3-8). Each horizontal division of the graticule now represents 45° of the cycle (360° divided by 8 divisions), and the horizontal graticule calibration can be stated as 45° per division.
10. Measure the horizontal difference between corresponding points on the two waveforms at the 50% rise-time points and calculate the phase difference using the following formula:

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

EXAMPLE. In Figure 3-8, the horizontal difference is 0.6 division with a graticule calibration of 45° per division.

Substituting the given values into the phase-difference formula:

Phase Difference = 0.6 div x 45°/div = 27°.

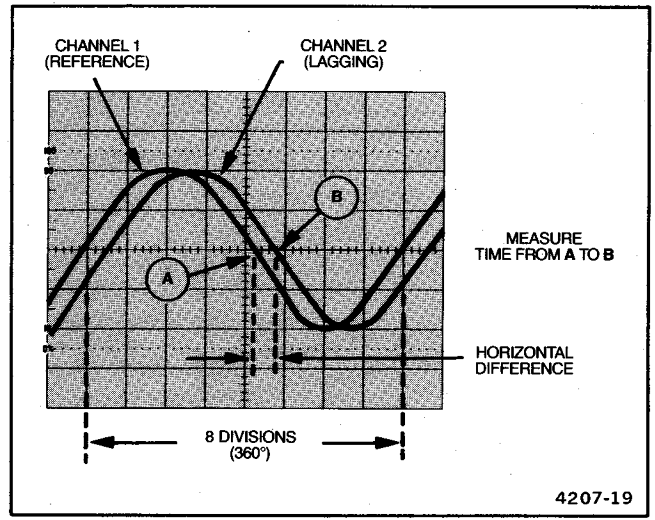

Figure 3-8. Phase difference.

More accurate phase measurements can be made by using the horizontal magnifier function to increase the sweep speed without changing the SEC/DIV variable control setting. To do this, set the HORIZONTAL MODE switch to MAG and set the MAG switch to either X5, X10, or X50.

If the sweep speed were increased 10 times (MAG set to X10), the magnified horizontal graticule calibration then would be 4.5° per division (45°/division divided by 10). Figure 3-9 shows the same signals illustrated in Figure 3-8, but horizontally magnified by a factor of 10.

EXAMPLE. In Figure 3-9 the 10X magnified display results in a horizontal difference of six divisions between the two signals.

Substituting the given values into the phase difference formula:

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

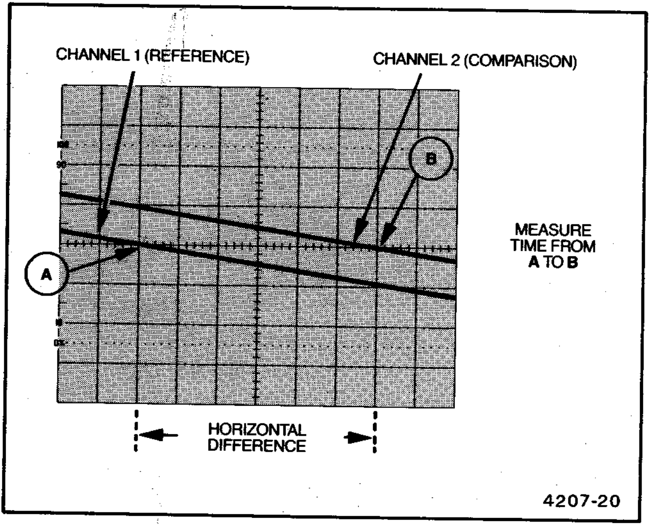

Figure 3-9. High-resolution phase difference.

The electrical characteristics listed in Table 5-1 are valid for the 2225 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 +40°C (unless otherwise noted).

Environmental characteristics are given in Table 5-2. The 2225 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.

Mechanical characteristics of the instrument are listed in Table 5-3.

Table 5-1
Electrical Characteristics

Characteristics	Performance Requirements
VERTICAL DEFLECTION SYSTEM	
Deflection Factor Range	5 mV per division to 5 V per division in a 1-2-5 sequence of 9 steps. Sensitivity increases to 500 μV per division with X10 vertical magnification.
Accuracy	±3%. With X10 vertical magnification, accuracy is ±5%.
Variable Control Range	Continuously variable and uncalibrated between step settings. Increases deflection factor by at least 2.5 to 1.
Step Response (Rise Time)	Applicable from 5 mV per division to 5 V per division. Rise times calculated from: $t_r = \frac{0.35}{BW}$
+5°C to +35°C	7.0 ns or less.
0°C to +5° C +35°C to +40°C	8.8 ns or less.
Step Response Aberrations 5 mV per division to 0.5 V per division	+5%, −5%, 5% p-p or less.

Table 5-1 (cont'd)

Characteristics	Performance Requirements
VERTICAL DEFLECTION SYSTEM (cont'd)	
Bandwidth (−3 dB) +5°C to +35°C	50 MHz or more.
0°C to +5°C 35°C to +40°C	40 MHz or more.
X10 Magnification	5 MHz or more.
AC Coupled Lower Cutoff Frequency	10 Hz or less at −3 dB.
CHOP Mode Switching Rate	500 kHz ±30%.
Input Characteristics Resistance	1 MΩ ±2%.
Capacitance	25 pF ±2 pF.
Maximum Safe Input Voltage (DC or AC Coupled)	400 V (dc + peak ac) or 800 V ac p-p to 10 kHz or less.
Common-Mode Rejection Ratio (CMRR)	At least 10 to 1 at 20 MHz in X1. At least 10 to 1 at 1 MHz with X10 vertical magnification.
Trace Shift With VOLTS/DIV Switch Rotation	0.75 division or less (Variable control in CAL detent).
With VOLTS/DIV Variable Control Rotation	1.0 division or less.
With Channel 2 Inverted	1.5 divisions or less.
With X10 Vertical Magnification	2.0 divisions or less.
Channel Isolation	Greater than 100 to 1 at 10 MHz.
Trace Separation Range	At least ±3 divisions.

Table 5-1 (cont'd)

Characteristics	Performance Requirements	
TRIGGER SYSTEM		
Trigger Sensitivity P-P AUTO/TV LINE and NORM Modes	**5 MHz**	**50 MHz**
Internal Signal	0.3 div.	1.0 div
External Signal	40 mV	200 mV
Lowest Usable Frequency in P-P AUTO Mode	≥20-Hz 1.0-division internal signal or 100-mV external signal will lock.	
TV FIELD Mode	1.0 division of composite sync.	
External Input Resistance	1 MΩ ±10%.	
Capacitance	25 pF ±2.5 pF.	
Maximum Voltage	400 V (dc + peak ac) or 800 V ac p-p at 10 kHz or less.	
AC Coupled Lower Cutoff Frequency	10 Hz or less at −3 dB with internal signal. 20 Hz or less at −3 dB with external signal.	
Trigger Level Range NORM Mode	Can be set to any point on the trace that can be displayed.	
EXT Source	At least ±1.6 V, 3.2 V p-p.	
EXT/10 Source	At least ±16 V, 32 V p-p.	
Variable Holdoff Range	Can increase sweep holdoff time by at least a factor of 10, with SEC/DIV set to 1 ms.	
LF Reject Lower 3 dB Point	30 kHz ±25%.	
HF Reject 3 dB Point	30 kHz ±25%.	

Table 5-1 (cont'd)

Characteristics	Performance Requirements			
HORIZONTAL DEFLECTION SYSTEM				
Sweep Rate				
Calibrated Range	0.5 s per division to 0.05 μs per division in a 1-2-5 sequence of 22 steps. Magnification extends maximum usable sweep speed to 5 ns per division.			
Accuracy		**Magnified**		
	X1	**X5**	**X10**	**X50**
+15°C to +35°C	±3%	±4%	±4%	±5%
0°C to +40°C	±4%	±5%	±5%	±8%
Variable Control Range	Continuously variable and uncalibrated between calibrated step settings. Decreases calibrated sweep speeds at least by a factor of 2.5.			
Sweep Linearity		**Magnified**		
	X1	**X5**	**X10**	**X50**
	±5%	±7%	±7%	±9%
Position Control Range	Start of sweep to 10th division in X1, to 50th division in X5, to 100th division in X10, and to 500th division in X50 will position past the center vertical graticule line.			
Registration of Unmagnified and Magnified Traces	0.2 division or less, aligned to central vertical graticule line.			
Trace Shift Between ALT and MAG Modes	Less than 1 division.			
Z-MODULATION				
Sensitivity	5 V causes noticeable modulation. Positive-going input decreases intensity.			
Usable Frequency Range	Dc to 5 MHz.			
Maximum Safe Input Voltage	400 V (dc + peak ac) or 800 V ac p-p to 10 kHz or less.			

Table 5-1 (cont'd)

Characteristics	Performance Requirements
X-Y OPERATION (X1 MODE)	
Deflection Factors	Same as Vertical Deflection System with Variable controls in CAL detents.
Accuracy	
X-Axis	±5%.
Y-Axis	Same as Vertical Deflection System.
Bandwidth (−3 dB)	
X-Axis	Dc to at least 2 MHz.
Y-Axis	Same as Vertical Deflection System.
Phase Difference Between X- and Y-Axis Amplifiers	±3° from dc to 150 kHz.
PROBE ADJUSTMENT SIGNAL OUTPUT	
Voltage into 1 MΩ Load	0.5 V ±5%.
Repetition Rate	1 kHz ±20%.
POWER REQUIREMENTS	
Line Voltage Ranges	
115 V Setting	95 V ac to 128 V ac.
230 V Setting	185 V ac to 250 V ac.
Line Frequency	48 Hz to 440 Hz.
Maximum Power Consumption	40 W (60 VA).
Line Fuse	UL198.6, 3AG (¼ x 1¼ inch)
115 V Setting	1.0 A, Slow
230 V Setting	0.5 A, Slow
CATHODE-RAY TUBE	
Display Area	80 by 100 mm.
Standard Phosphor	GH (P31).
Nominal Accelerating Voltage	12,600 V ±60 V

Table 5-2
Environmental Characteristics

Characteristics	Description
Temperature	
Operating	0°C to +40°C (+32° F to +104°F).
Nonoperating	−55°C to +75°(−67°F to +167°F).
Altitude	
Operating	To 4500 m (15,000 ft.). Maximum operating temperature decreases 1°C per 300 m (1,000 ft.) above 1,500 m (5,000 ft.).
Nonoperating	To 15,250 m (50,000 ft.).
Relative Humidity	
Operating (+30°C to + 40°C)	95% +0%, −5%
Nonoperating (+30°C to +60°C)	95% +0%, −5%
Vibration (Operating)	15 minutes along each of three major axes at a total displacement of 0.015 inch p-p (2.4 g at 55 Hz) with frequency varied from 10 Hz to 55 Hz to 10 Hz in one-minute sweeps. Hold for 10 minutes at 55 Hz in each of the three major axes. All major resonances must be above 55 Hz.
Shock (Operating and Nonoperating)	30 g, half-sine, ll-ms duration, three shocks per axis each direction, for a total of 18 shocks.
Radiated and Conducted Emission Requirements	Meets VDE 0871 Class B and FCC Regulations.

Table 5-3
Mechanical Characteristics

Characteristics	Description
Weight With Power Cord	6.6 kg (14.6 lbs) or less.
Domestic Shipping Weight	9.0 kg (19.8 lb) or less.
Height	138 mm (5.4 in).
Width	
With Handle	380 mm (15.0 in).
Without Handle	327 mm (12.9 in).
Depth	
Without Front Cover	438 mm (17.2 in).
With Optional Front Cover	445 mm (17.5 in).
With Handle Extended	511 mm (20.1 in).

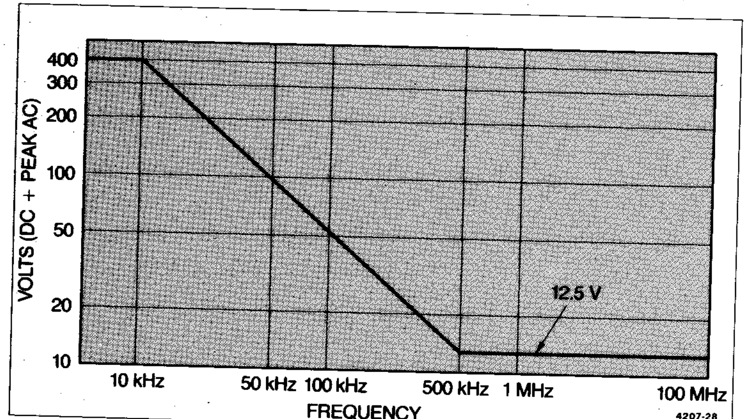

Figure 5-1. Derating curve for CH 1 OR X, CH 2 OR Y, and EXT INPUT OR Z connectors.