2225 OSCILLOSCOPE
AND OPTIONS
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

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Function</th>
<th>Recommended Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>INTENSITY</td>
<td>Adjusts trace brightness.</td>
<td>Compensate for ambient lighting, trace speed, trigger frequency.</td>
</tr>
<tr>
<td>2</td>
<td>BEAM FIND</td>
<td>Compresses display to within CRT limits.</td>
<td>Locate off-screen phenomena.</td>
</tr>
<tr>
<td>3</td>
<td>FOCUS</td>
<td>Adjusts for finest trace thickness.</td>
<td>Optimize display definition.</td>
</tr>
<tr>
<td>4</td>
<td>TRACE ROTATION</td>
<td>Adjusts trace parallel to centerline.</td>
<td>Compensate for earth's field.</td>
</tr>
<tr>
<td>5</td>
<td>POWER</td>
<td>Tums power on and off.</td>
<td>Control power to the instrument.</td>
</tr>
<tr>
<td>6</td>
<td>Power Indicator</td>
<td>Illuminates when power is turned on.</td>
<td>Know power condition.</td>
</tr>
<tr>
<td>7, 9</td>
<td>POSITION</td>
<td>Moves trace up or down screen.</td>
<td>Position trace vertically and compensate for dc component of signal.</td>
</tr>
<tr>
<td>8</td>
<td>TRACE SEP</td>
<td>Moves the magnified trace vertically with respect to the unmagnified trace when HORIZONTAL MODE is set to ALT.</td>
<td>Position unmagnified and horizontally magnified traces for convenient viewing and measurement.</td>
</tr>
<tr>
<td>10</td>
<td>CH 1-BOTH-CH 2</td>
<td>Selects signal inputs for display.</td>
<td>View either channel independently or both channels simultaneously.</td>
</tr>
<tr>
<td>11</td>
<td>NORM - INVERT</td>
<td>Inverts the Channel 2 signal display.</td>
<td>Provide for differential (CH 1 - CH 2) or summed (CH 1 + CH 2) signals when ADD is selected.</td>
</tr>
<tr>
<td>12</td>
<td>ADD - ALT - CHOP</td>
<td>ADD shows algebraic sum of CH 1 and CH 2 signals.</td>
<td>Display summed or individual signals.</td>
</tr>
<tr>
<td>13</td>
<td>VOLT/DIV</td>
<td>Selects vertical sensitivity.</td>
<td>Adjust vertical signal to suitable size.</td>
</tr>
<tr>
<td>14</td>
<td>Variable (CAL)</td>
<td>Provides continuously variable deflection factors between calibrated positions of the VOLT/DIV switch.</td>
<td>Match signals for common mode readings. Adjust height of pulse for rise-time calculations.</td>
</tr>
<tr>
<td>15</td>
<td>AC-GND-DC</td>
<td>In AC, isolates dc component of signal.</td>
<td>Inspecting small signals.</td>
</tr>
<tr>
<td>16</td>
<td>CH 1 OR X CH 2 OR Y</td>
<td>Provides for input signal connections. CH 1 gives horizontal deflection when SEC/DIV is in X-Y.</td>
<td>Selects method of coupling input signals to the vertical deflection system.</td>
</tr>
</tbody>
</table>

Table 2-1 (cont'd)

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Function</th>
<th>Recommended Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>POSITION COARSE</td>
<td>Coarse is convenient for moving unmagnified traces.</td>
<td>Control trace positioning in horizontal direction.</td>
</tr>
<tr>
<td>18</td>
<td>POSITION FINE</td>
<td>Fine is convenient for moving magnified traces when either ALT or MAG is selected.</td>
<td>Select normal, comparative or expanded waveforms.</td>
</tr>
<tr>
<td>19</td>
<td>X1 - ALT - MAG</td>
<td>X1 displays only normal (horizontally unmagnified) waveform. ALT displays normal and magnified waveforms alternately. MAG displays only the magnified waveform.</td>
<td>Select normal, comparative or expanded waveforms.</td>
</tr>
<tr>
<td>20</td>
<td>SEC/DIV</td>
<td>Selects time-base speed.</td>
<td>Set horizontal speed most suited to requirements.</td>
</tr>
<tr>
<td>21</td>
<td>Variable (CAL)</td>
<td>Provides continuously variable uncalibrated sweep speeds to at least 2.5 times the calibrated setting.</td>
<td>Examine small phenomena in detail.</td>
</tr>
<tr>
<td>22</td>
<td>MAG (X5-X10-X50)</td>
<td>Selects degree of horizontal magnification.</td>
<td>Chassis ground connection.</td>
</tr>
<tr>
<td>23</td>
<td>PROBE ADJUST</td>
<td>Provides approximately 0.5V, 1kHz square wave.</td>
<td>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.</td>
</tr>
<tr>
<td>24</td>
<td>SLOPE</td>
<td>Selects the slope of the signal that triggers the sweep.</td>
<td>Provide ability to trigger from positive-going or negative-going signals.</td>
</tr>
<tr>
<td>25</td>
<td>LEVEL</td>
<td>Selects trigger-signal amplitude point.</td>
<td>Select actual point of trigger.</td>
</tr>
<tr>
<td>26</td>
<td>TRIG'D</td>
<td>Indicator lights when sweep is triggered in P-P AUTO, NORM, or TV FIELD.</td>
<td>Indicate trigger state.</td>
</tr>
<tr>
<td>27</td>
<td>MODE</td>
<td>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 the RESET button; used for displaying or photographing nonrepetitive or unstable signals.</td>
<td>Select trigger mode.</td>
</tr>
<tr>
<td>28</td>
<td>RESET</td>
<td>Arms trigger circuit for SGL SWP.</td>
<td>Improve ability to trigger from aperiodic signals.</td>
</tr>
<tr>
<td>29</td>
<td>HOLDOFF</td>
<td>Varies sweep holdoff time 10:1.</td>
<td></td>
</tr>
</tbody>
</table>
**Table 2-1 (cont'd)**

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

**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: X 1
     - 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 0.5 V (10X PROBE). Rotate all variable controls clockwise to their CAL detents. Set the TRIGGER SOURCE switch to VERT MODE. 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 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 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 or AC 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.

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**TRIGGER CONTROLS**

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

<table>
<thead>
<tr>
<th>MODE</th>
<th>P-P AUTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOLD OFF</td>
<td>M/N</td>
</tr>
<tr>
<td>SOURCE</td>
<td>VERT MODE</td>
</tr>
<tr>
<td>COUPLING</td>
<td>DC</td>
</tr>
</tbody>
</table>

**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.
Operation

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 inductive elements 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.
Operation

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.
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:

\[
V_{pp} = \text{deflection} \times \text{setting} \times (10X \text{PROBE})
\]

*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:

\[
V_{pp} = 4.6 \text{ div} \times 5 \text{ V/div} = 23 \text{ V}
\]

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

\[
\text{Instantaneous Voltage} = \text{deflection} \times (+ \text{ or } -) \times \text{setting (divisions)} \times (10 \times \text{PROBE})*
\]

*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.
TIME MEASUREMENTS

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

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).

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.
Applications

6. Calculate time duration using the following formula:

\[
\text{Time Duration} = \frac{\text{horizontal distance}}{\text{magnification factor}} \times \frac{\text{SEC/DIV}}{\text{switch setting}}
\]

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:

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

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 \(f\):

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

Rise Time

Rise time measurements use the same methods as time duration, except that the measurements are made between the 10% and 90% points on the low-to-high transition of the selected waveform. Fall time is measured between the 90% and 10% points on 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).
Time Difference Between Pulses On Time-Related Signals

The calibrated sweepspeed 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:

\[
\text{Time} = \frac{\text{horizontal SEC/DIV difference} \times \text{switch setting}}{\text{magnification factor}}
\]

**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:

\[
\text{Time} = \frac{50 \, \mu s/\text{div} \times 4.5 \, \text{div}}{10} = 22.5 \, \mu s
\]

**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:

\[
\text{Rise Time} = \frac{5 \, \text{div} \times 1 \, \mu s/\text{div}}{1} = 5 \, \mu s
\]

**Time Difference Between Pulses On Time-Related Signals**
The calibrated sweepspeed 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.
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:

\[
\text{Phase Difference} = \frac{\text{horizontal difference}}{\text{calibration per division}} \times 360°
\]

**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:

\[
\text{Phase Difference} = 0.6 \text{ div} \times 45°/\text{div} = 27°.
\]

![Figure 3-8. Phase difference.](image)
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.

**TELEVISION DISPLAYS**

**TV Field Signals**

The television feature of the 2225 can be used to display TV Field signals.

1. Set the TRIGGER MODE switch to TV FIELD and set the SEC/DIV switch to 2 ms.
2. Apply the television signal to either the CH 1 or the CH 2 input connector and set the VERTICAL-MODE switch to display the channel used.
3. For positive-going TV signal sync pulses, set the TRIGGER SLOPE switch to J and rotate the LEVEL control fully clockwise. For negative-going sync pulses, set the SLOPE switch to J and rotate the LEVEL control fully counterclockwise.
4. Set the appropriate VOLTS/DIV switch to display one division or more of composite video signal.
5. To change the TV field that is displayed, momentarily interrupt the trigger signal by setting the input coupling switch to GND then back to DC or AC until the desired field is displayed.

**NOTE**

To examine a TV Field signal in more detail, set the HORIZONTAL MODE switch to either ALT or MAG and select either X5, X10, X50 magnification.

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

**TV Line Signals**

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

1. Verify that TRIGGER MODE is set to P-P AUTO/TV LINE.
2. Apply the Television signal to either the CH 1 or the CH 2 input connector and set the VERTICAL-MODE switch to display the channel used.
3. Set the SEC/DIV switch to 10 μs.
4. For positive-going TV signal sync pulses, set the TRIGGER SLOPE switch to J and rotate the LEVEL control fully clockwise. For negative-going sync pulses, set the SLOPE switch to J and rotate the LEVEL control fully counterclockwise.
5. Set the appropriate VOLTS/DIV switch to display 0.3 division or more of composite sync signal.
NOTE
To examine a TV Line signal in more detail, set the HORIZONTAL MODE switch to either ALT or MAG and select either X5, X10, X50 magnification.

6. To display a selected TV Line pulse, first trigger the sweep from a TV Field sync pulse. If necessary, use HF REJ TRIGGER COUPLING to improve the trigger. Switch HORIZONTAL MODE to ALT and select X50 MAG to provide the normal display together with the expanded trace. Select the desired line pulse, using the HORIZONTAL COARSE and FINE POSITION controls. Then switch MODE to MAG to eliminate the normal (unmagnified) waveform.

Z-MODULATION
The Z-modulation system can be used to display time markers, since it is entirely dependent upon the accuracy of the signal source. It can also be used in any condition where external control of the brightness of either the whole or part of the trace is required.

The Z—or intensity—modulation feature is operated in the following manner:

1. Set the left TRIGGER SOURCE switch to EXT and the right SOURCE switch to EXT Z.
2. Set the TRIGGER COUPLING switch to the desired setting. This setting will couple both the Z-modulation signal and the vertical triggering signal.
3. Apply a signal to either the CH1 or the CH2 connector and set the VERTICAL MODE switch to display the channel used.
4. Apply the Z-modulation signal to the connector labeled EXT INPUT OR Z.

When the Z-modulation and the vertical-input signals are synchronized, Z-modulation is seen as gaps in the trace at the modulation frequency. The size of the gap depends upon the mark-to-space ratio of the Z-modulation signal. The positive-going portion of the Z-modulation signal decreases brightness.