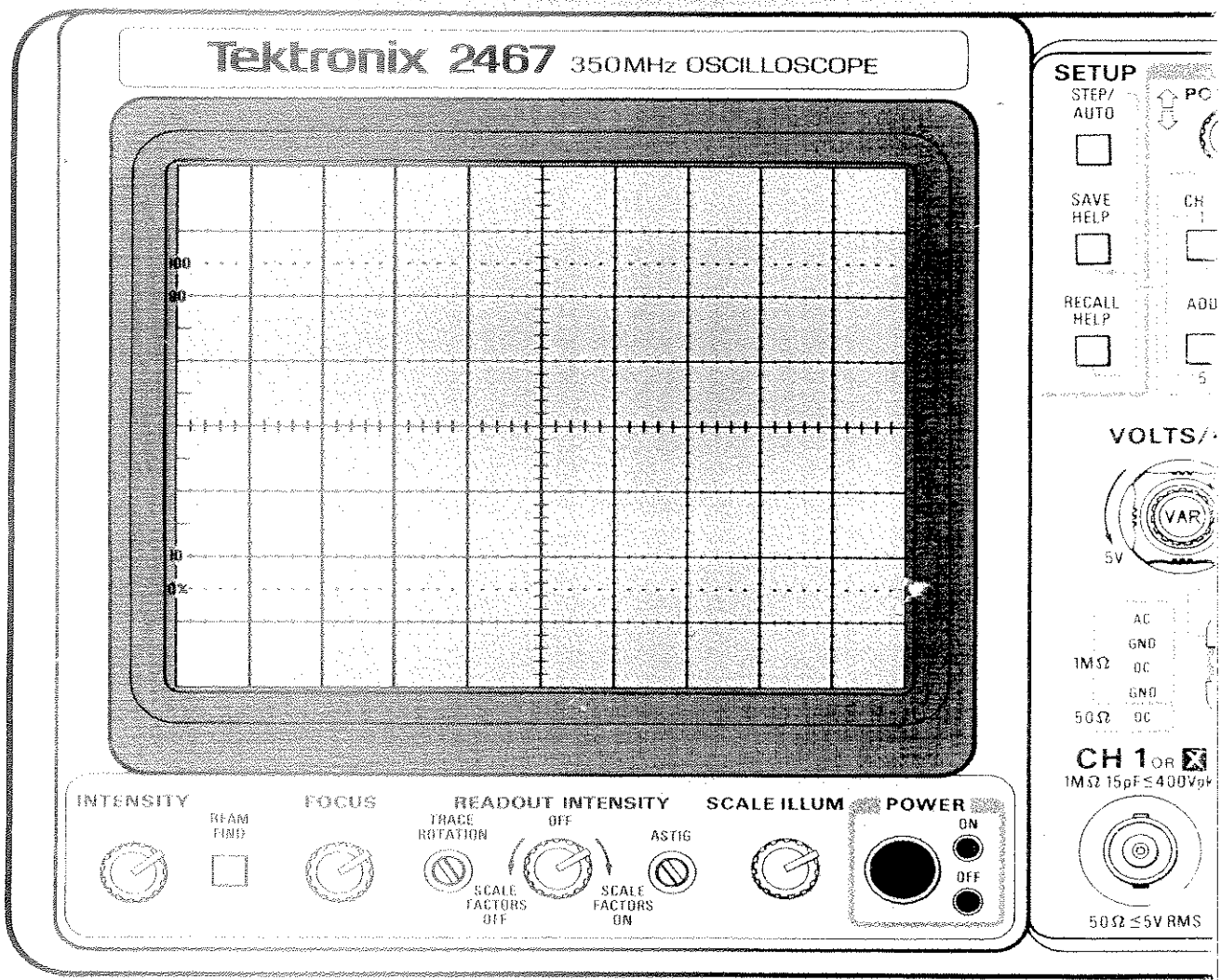
OSCILLOSCOPE



Tektronix®
COMMITTED TO EXCELLENCE

TEK OPERATORS MANUAL
070-5854-00
Product Group 38

2467 OSCILLOSCOPE

Please Check for CHANGE INFORMATION at the Rear of This Manual

First Printing APR 1986

Tektronix
COMMITTED TO EXCELLENCE

INSTRUMENT SERIAL NUMBERS

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

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

Certificate of the Manufacturer/Importer

We hereby certify that the 2467 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 2467 OSCILLOSCOPE AND ALL INSTALLED OPTIONS in Übereinstimmung mit den Bestimmungen der Amtsblatt-Verfügung 1046/1984 funkentstört ist.

Der Deutschen Bundespost wurde das Inverkehrbringen dieses Gerätes angezeigt und die Berechtigung zur Überprüfung 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.

Contents

3 Applications

4 Checks and Adjustments

5 Controls, Connectors, and Indicators

6 Performance Characteristics

Illustrations

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.

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 accessible cautionary or other information is to be found. For maximum input voltage see Table 5-1.

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 Table 1-1.

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.

Introduction

The TEKTRONIX 2467 portable oscilloscope has four vertical channels with 350 MHz bandwidth. Through channels 1 and 2, deflection factors from 2 mV to 5 V per division can be selected, in a 1-2-5 sequence, with either 1 MΩ or 50 Ω input resistance. With 1 MΩ input resistance, compatible with the standard accessory probes, either AC or DC input-signal coupling is available. Channels 3 and 4 give either 0.1 V or 0.5 V per division, with 1 MΩ input resistance, and DC input-signal coupling.

The trigger system works automatically for most signals. It operates with versatile mode selection, any of the four channels as a source, and optimum couplings for a wide range of signals. The trigger gives stable displays from dc to 500 MHz.

All sweep speeds are continuously calibrated, from 1.5 s to 500 ps per division, including the X10 magnifier and the variable range between 1-2-5 steps. Horizontal display choices include A-Sweep, B-Sweep (delayed), A alternated with B, and CH 1 (for X/Y displays).

The 2467 yields 4 divisions/ns *visual* writing rate. This is about 100 times faster than conventional, high-performance oscilloscopes. The 2467 visibly displays any signal, at any repetition-rate, at any sweep speed, in typical room light. Visible single-shots include 1 ns steps at 500 ps/division.

The AUTO, SAVE, and RECALL features save time and prevent errors, whether you are a novice operator or a master. Pressing the AUTO Setup button gives a workable setup for almost any signal. For repetitive measurements, the Save and Recall functions record and immediately or sequentially restore as many as 20 instrument setups. The SETUP buttons operate all instrument functions, including the extended function options.

Direct, on-screen readouts of time measurements, voltage measurements, scale factors, trigger levels, and auxiliary information also save time and improve operator confidence.

Preparation for Use

Safety

Before connecting the oscilloscope to a power source, read entirely both this section and the Safety Summary at the front of this manual. Be sure you have the training required to safely connect the instrument inputs to the signals you will be measuring. Refer to the Safety Summary for power source, grounding, and other safety considerations pertaining to the use of the instrument.

CAUTION

This instrument may be damaged if operated with the LINE VOLTAGE SELECTOR switch set for the wrong applied ac input-source voltage or if the wrong line fuse is installed.

Line Voltage Selection

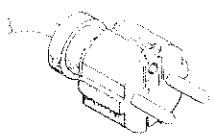
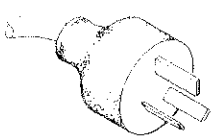
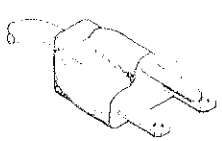
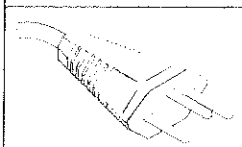
The oscilloscope operates from either a 115-V or a 230-V nominal ac power-line with any frequency from 48 Hz to 440 Hz. Before connecting the power cord to a power source, verify that the LINE VOLTAGE SELECTOR switch, located on the rear panel (see Figure 1-1), is set correctly (see Table 1-1) and that the line fuse is correct. To convert the instrument for operation on the other line-voltage range, move the LINE VOLTAGE SELECTOR switch to the correct nominal ac source-voltage setting. The detachable power cord may have to be replaced to match the particular power source.

Line Fuse

To verify the instrument power-input fuse rating, do the following steps:

1. Press the fuse-holder cap and release it with a slight counterclockwise rotation. Pull the cap (with the attached fuse inside) out of the fuse holder.
2. Verify that the fuse is of the type listed on the back of the instrument. Then install the proper fuse and reinstall the proper fuse-holder cap. The two types of fuses listed are not directly interchangeable; they require different types of fuse caps. Included in the accessory pouch is a 5x20 mm fuse holder cap for use with 1.6 A, 250 V, 5x20 mm (IEC 127) fuses.

Table 1-1
Power Cord and Voltage Data

Plug Configuration	Option	Power Cord/ Plug Type	Line Voltage Selector	Reference Standards[b]
	U.S. Std.	U.S. 120V 15A	115V	ANSI C73.11 NEMA 5-15-P IEC 83 UL 198.6
	A1	EURO 240V 10-16A	230V	CEE(7), II, IV, VII IEC 83 IEC 127
	A2	UK[a] 240V 6A	230V	BS 1363 IEC 83 IEC 127
	A3	Australian 240V 10A	230V	AS C112 IEC 127
	A4	North American 240V 15A	230V	ANSI C73.20 NEMA 6-15-P IEC 83 UL 198.6
	A5	Switzerland 220V 6A	230V	SEV IEC 127

[a] A 6A. Type C fuse is also installed inside the plug of the Option A2 power cord.

[b] Reference Standards 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
- UL—Underwriters Laboratories Inc.

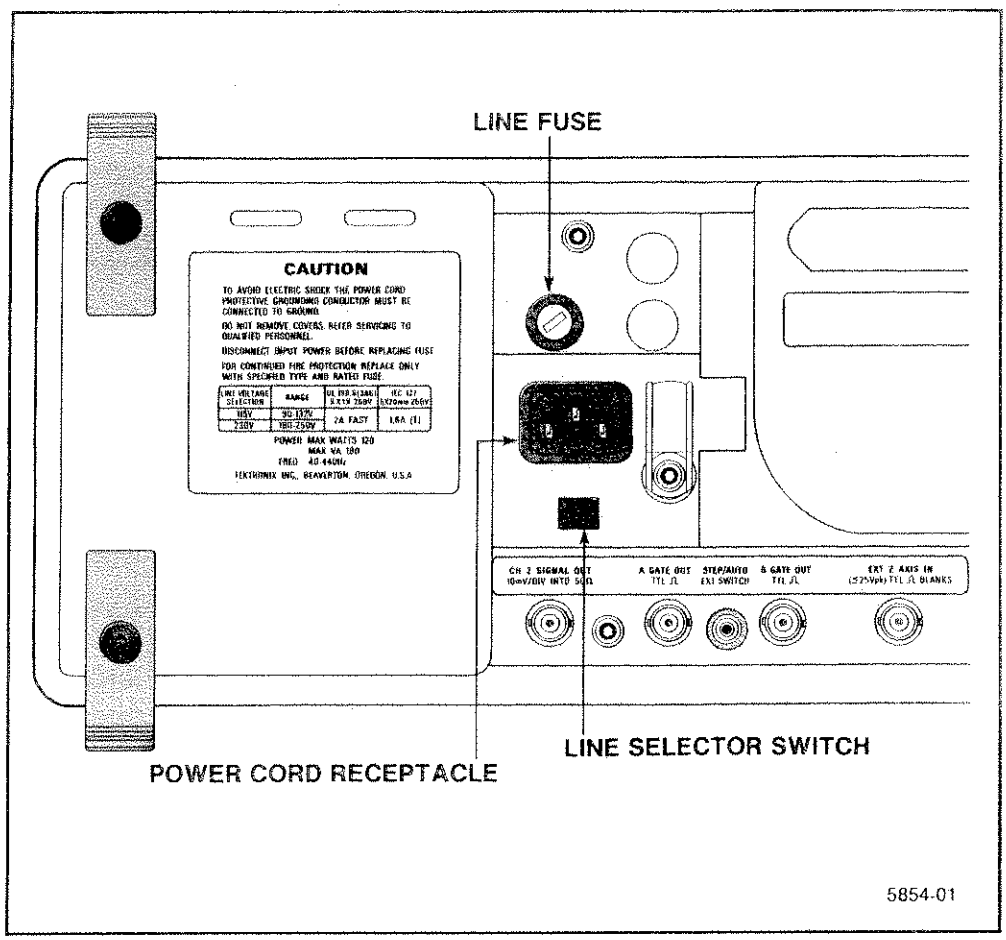


Figure 1-1. Line selector switch, line fuse, and detachable power cord.

Power Cord

This instrument has a detachable, three-wire power cord with a three-contact plug for connection to both the power source and protective ground. The power cord is secured to the rear panel by a cord-set-securing clamp. The protective-ground contact on the plug connects through the power-cord to the external metal parts of the instrument. For electrical-shock protection, insert this plug into a power-source outlet that has a properly grounded protective-ground contact.

Instruments are shipped with the required power cord as ordered by the customer. Available power-cord information is presented in Table 1-1, and part numbers are listed in "Options and Accessories" (Section 7). Contact your Tektronix representative or local Tektronix Field Office for additional power-cord information.

Instrument Cooling

To prevent instrument damage from internally generated heat, adequate air flow must be maintained. Before turning on the power, verify that the spaces around the air-intake holes on the bottom of the cabinet and the fan-exhaust holes in the rear panel are free of any obstruction to airflow.

Start-up

The oscilloscope automatically performs a set of diagnostic tests each time the instrument is turned on. These tests warn the user of any available indication that the instrument may not be fully functional. The tests run for several seconds after power is applied. If no faults are encountered, the instrument operates normally. A failure of any of the power-up tests will be indicated by either a flashing TRIG'D indicator on the instrument front panel or a bottom-line readout on the CRT in the form: **TEST XX FAIL YY** (where XX is the test number and YY is the failure code of the failed test).

If a failure of any power-up test occurs, the instrument may still be usable for some applications. To operate the instrument after a power-up test failure, press the A/B TRIG button. Even if the instrument then functions for your particular measurement requirement, it should be repaired by a qualified service technician at the earliest convenience. Additional information on the power-up tests may be found in Appendix A at the rear of this manual. Consult your service department, your local Tektronix Service Center, or nearest Tektronix representative if additional assistance is needed.

Repackaging For Shipment

If this instrument is to be shipped by commercial transportation, it should be packaged in the original manner. The carton and packaging material in which your instrument was shipped to you should be retained for this purpose.

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

1. Obtain a corrugated cardboard shipping carton having inside dimensions at least six inches greater than the instrument dimensions and having a carton test strength of at least 275 pounds.
2. If the instrument is 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 at your firm 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 your return address on the carton in one or more prominent locations.

Introduction

Basic measurements require only simple operations with a few controls. In addition, the instrument can also analyze the details of complex signals or measure the characteristics of unusual signals.

The best way to use this information is "hands-on" with the oscilloscope and a signal source. More detailed information may be found in the "Controls, Connectors, and Indicators" section of this manual. See Figure 2-1 for a drawing of the instrument front panel.

Fundamentals

Like any oscilloscope, this instrument draws a graph of voltage as a function of time. The controls in the VERTICAL section of the front panel, marked off by a heavy gray line, define the voltage axis of the display. The SEC/DIV, horizontal POSITION, and X10 MAG controls define the time axis of the display. The TRIGGER controls, marked off by a green box, define a reference point on a signal. The instrument locks the time axis (sweep) to this point. The controls under the crt affect the visual characteristics of the display, but do not affect the waveform.

Getting a Display

AUTO Setup initializes the vertical, horizontal, trigger, and intensity controls for a usable display. To display a waveform:

1. Connect a probe to a signal.
2. Select the channel to which the probe is attached, using the Vertical MODE buttons.
3. Push AUTO. (If STEP is illuminated, push RECALL first to extinguish it.)
4. If the display isn't exactly what you prefer, adjust the appropriate VOLTS/DIV, SEC/DIV, POSITION, or Trigger controls.

You can select any combination of vertical channels and AUTO will set them up for a useful display. If you are using the standard accessory probes, make sure the CH 1 or CH 2 inputs are not set at 50 Ω.

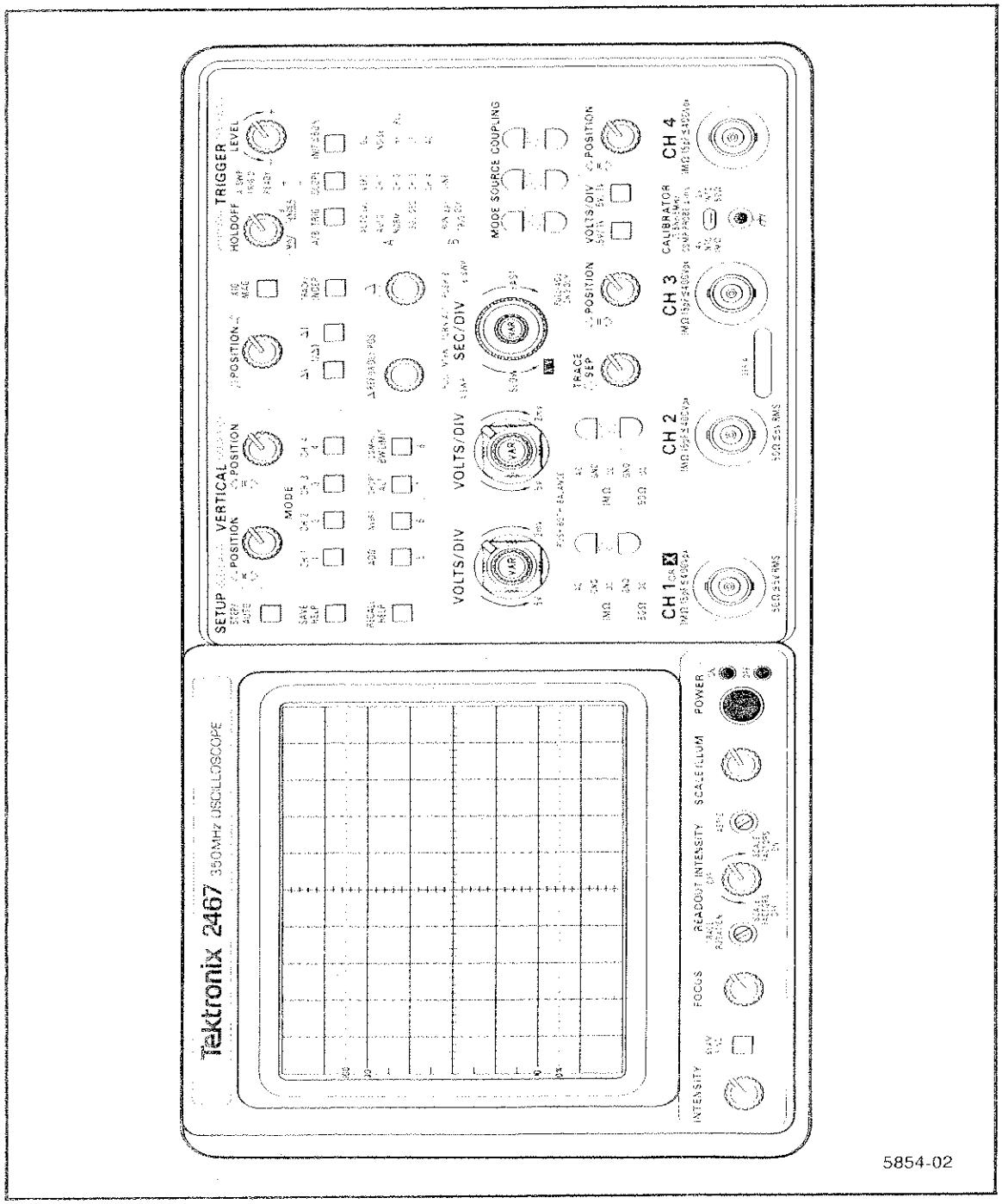


Figure 2-1. Instrument front panel.

Auto Setup, with one channel, centers the 0-volt level and makes the vertical display as large as possible, while keeping the peaks within the graticule. The sweep shows at least two and no more than five cycles of the signal, within the Sec/Div range from 20 ns to 2 ms. If the signal duty factor is less than 5% or more than 95%, the sweep spreads the narrow portion of the pulse over two to five divisions and Trigger Slope matches the leading edge of the narrow portion of the pulse. The trigger is set for Auto Lvl mode, Vert Source, DC Coupling, and Min Holdoff. The trigger level is initialized half way between the positive and negative signal peaks.

When more than one channel is selected by Vertical MODE, the 0-volt levels of CH 1, CH 2, CH 3, and CH 4 are set at +2, 0, −2, and −3 divisions from center, respectively. If ADD is displayed, the 0-volt level of CH 2 is set at −2 divisions.

A switch closure or TTL-low signal connected to the STEP/AUTO EXT SWITCH connector on the rear panel has the same effect as pushing the STEP/AUTO button. See the "Save and Recall Operation" part of this section for another function of Step/Auto.

Vertical

For most applications, the CH 1 and CH 2 inputs should be set at 1 MΩ DC. The dc level of a static signal is highly significant. For logic signals, the high and low voltage levels can mean as much as the transitions.

Using the Vertical MODE buttons, you can display any combination of the four vertical channels and the Add trace, which is the algebraic sum of CH 1 and CH 2. If no vertical is selected, CH 1 is displayed by default. Select INVERT to change the sense of the CH 2 waveform or to see the difference between CH 1 and CH 2 on the ADD trace. If you select ADD, the CH 1 and CH 2 VOLTS/DIV settings should be equal.

With two or more channels, the display is time-shared. With Chop mode, each channel is displayed for a fixed, short time. With Alt mode, each channel is displayed for the duration of a complete sweep. Generally, Chop mode works better for sweep speeds slower than 1 ms/division and for low repetition-rate signals that make the display flicker, up to 2 μs/division. Chop also prevents false displays that can result from multi-mode signals, for example a signal that has two characteristic forms on alternate cycles. With Alt Vertical mode and two displayed channels, the oscilloscope could show the same one of the two forms every time a particular channel is shown. However, Alt mode gives a "cleaner" display of multiple channels and is usually preferred at moderate to high sweep speeds.

Often, the signals you observe have only low to moderate speed components. If the 20 MHz BW Limit function doesn't distort the waveform, it can give you a sharper trace by eliminating higher frequency interference.

For the best measurement accuracy, set the VOLTS/DIV control for the largest display that will fit on the screen.

When you need to see small signals on large dc voltages, use AC coupling. The Gnd input coupling mode shows you where the zero-volt level will be displayed with DC coupling. The 50 Ω DC input mode gives the best possible vertical performance with active probes, 50-Ω signal sources, and low-impedance passive probes. A good, low-impedance probe can give you less than 2 pF signal-source loading, in parallel with 500 Ω or 5000 Ω, for 10X or 100X attenuation.

Horizontal

For most applications, the A Sweep is all you need. The A Sweep is displayed any time the A SWP indicator, next to the SEC/DIV switch, is illuminated. To select the A Sweep display, push AUTO Setup. Instead of pressing AUTO, you can restore the A Sweep display by pushing the SEC/DIV control in and turning it counterclockwise until the A SWP indicator lights. If both A SWP and B SWP indicators are off, turn the SEC/DIV control clockwise to escape the X/Y display mode.

The X10 MAGnifier expands the center of the unmagnified waveform.

For the best measurement accuracy, set the sweep to the fastest SEC/DIV setting that will display the time interval of interest. See the following part on Delayed Sweep Operation for more information about B Sweep, B Trigger, and trace separation.

Trigger

The best setup for most triggering is Auto Lvl mode, Vert Source, DC Coupling, and Minimum Holdoff. AUTO Setup sets the trigger this way. With LEVEL in the center half of its range, triggering automatically occurs near the midpoint between signal peaks.

With Auto Lvl mode and Vert Source, the trigger signal comes from the displayed channel or the lowest numbered one of multiple channels. You can set the LEVEL control anywhere in about the middle 80% of the span between signal peaks. The trigger level remains constant until the trigger signal no longer triggers the sweep or until the LEVEL control is moved. With signals below 50 Hz, AUTO LVL may not find the correct trigger level. The sweep free runs in the absence of a trigger signal.

Auto mode maintains the trigger level setting and the sweep free runs if the signal doesn't meet the triggering requirements. This mode is especially useful for monitoring logic signals. Set the LEVEL control to the mean threshold of the logic system; +1.4 V for TTL. The sweep will trigger on valid transitions and free-runs to show static highs and lows.

Normal mode sweeps only when the trigger signal meets the Level and Slope criteria. Use Normal mode for infrequent events and erratic signals.

The Sgl Seq mode accepts one trigger for each sweep and vertical combination in the display.

The INIT@50% control sets the trigger level near the midpoint between signal peaks, in any mode, for either the A Trigger or the B Trigger.

For unusually noisy signals or signals with strongly interfering components, Noise Reject, HF Reject, and LF Reject coupling give added selectivity. AC coupling continues triggering when the dc level of the signal changes.

If you are using a Trigger mode other than Auto Lvl, with more than one vertical channel and Alt Vertical mode, select a single trigger source so that the timing relationships among the channels are correctly displayed. Do not use Vert Trigger Source with multiple channels displayed and Auto, Norm, or Sgl Seq modes, except for the unusual cases where asynchronous signals are to be compared.

Auto, Norm, and Sgl Seq modes allow triggering on multiple, asynchronous sources, using Vert Trigger Source with Alt Vertical mode. With Chop Vertical mode and Vert Trigger Source, the trigger signal comes from the displayed channel or the lowest numbered one of multiple channels.

With some irregular signals, such as bursts, the Trigger HOLDOFF control can be set to improve display stability. Normally, HOLDOFF should be set at MIN.

Readout

An on-screen readout gives information for interpreting the waveform. The bottom row shows scale factors and other information. The top row shows trigger settings and delta measurements or delay times. To display all readout information, set the READOUT INTENSITY control clockwise from OFF (SCALE FACTORS ON). Delta measurements will be displayed with the scale factors either on or off. See Figure 2-2.

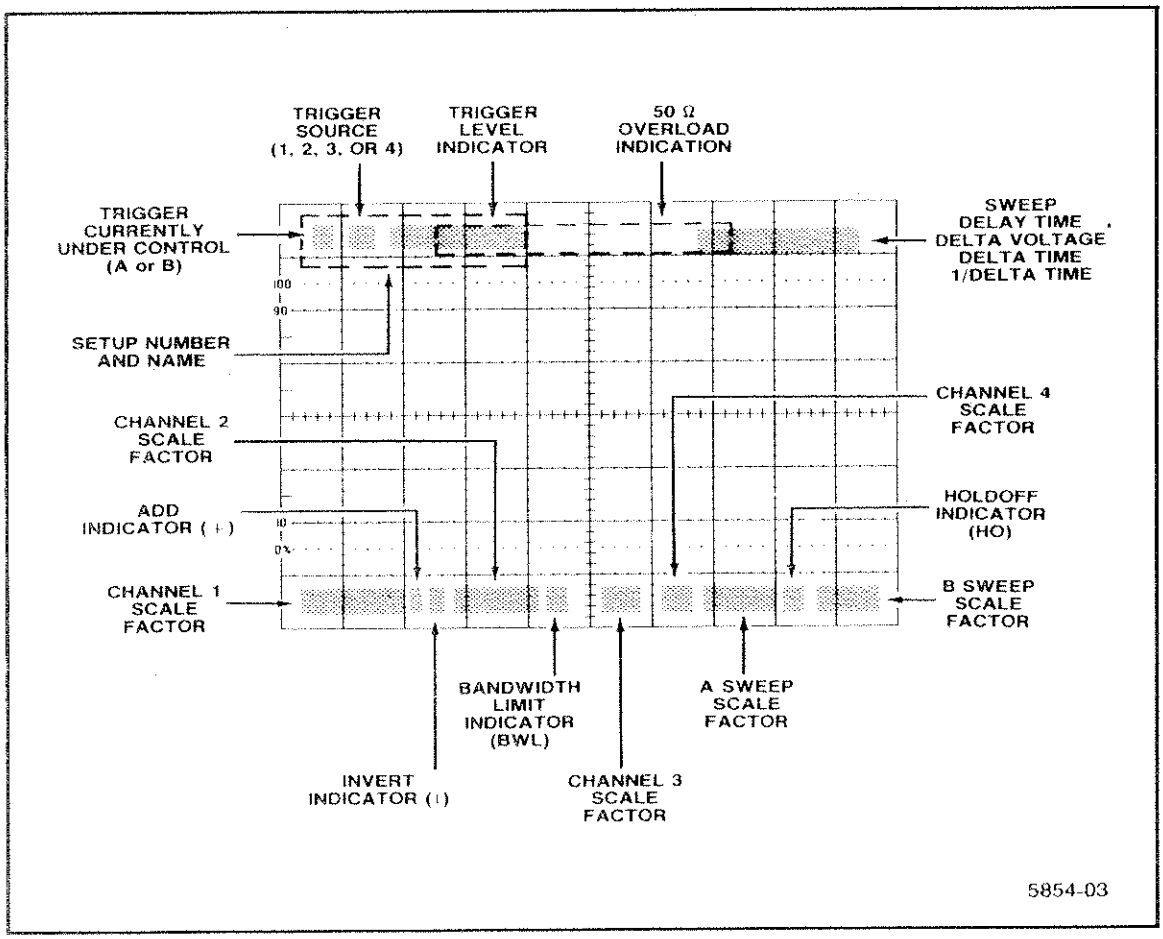


Figure 2-2. Readout display locations.

CH 1 and CH 2 scale factors include "mV" or "V" units indicators. A tilde (~) over the V indicates AC input coupling. A ground symbol in front of the number indicates Gnd input coupling. A greater-than symbol (>) indicates the VOLTS/DIV VAR control is not at its clockwise, calibrated position. A plus sign (+) shows that Add, the algebraic sum of CH 1 and CH 2, is displayed. A down arrow shows that CH 2 is inverted.

CH 3 and CH 4 scale factors are numbers with implied units of volts/division.

A-Sweep and B-Sweep scale factors include units, from "s" to "ps". The Sec/Div readout is always calibrated, combining the effects of the SEC/DIV, SEC/DIV VAR, and X10 MAG controls. If the VAR control is not at its clockwise setting, the scale factor includes a decimal point. The holdoff indicator is displayed when the HOLDOFF control is not at minimum.

The trigger readout works only when trigger coupling is DC or Noise Reject, when the trigger source is one, dc-coupled, vertical channel with VOLTS/DIV VAR in its calibrated position.

Probe attenuation effects are included in CH 1-4 scale factors, trigger level readout, and delta volts readouts, if you use the standard accessory probes or other compatible probes.

Measurements with Cursors

The delta controls, ΔV, Δt, TRACK/INDEP, Δ REF OR DLY POS, and Δ, contained in the gray box, control cursors and sweep delays. With the cursors, you can measure voltage, time, frequency, ratios, and phase.

To measure voltage:

1. Turn on the ΔV cursors and readout with the ΔV button.
2. Align the cursors with points of interest, such as waveform peaks, using the Δ REF (Δ REF OR DLY POS) and Δ knobs.
3. The readout shows the voltage between the points marked by the cursors.
4. Press ΔV to turn off the ΔV cursors and readout.

To measure time, with A Sweep or B Sweep alone (SEC/DIV control in):

1. Turn on the Δt cursors and readout with the Δt button.
2. Align the cursors with points of interest, such as waveform zero-crossings, using the Δ REF and Δ knobs.

3. The readout shows the time between the points marked by the cursors.
4. Press Δt to turn off the Δt cursors and readout.

To measure frequency:

1. Turn on the 1/Δt cursors and readout by pressing the ΔV and Δt buttons together.
2. Align the cursors with identical points, such as zero crossings, on adjacent cycles of the waveform using the Δ REF and Δ knobs.
3. The readout shows the frequency of the signal.
4. Press ΔV and Δt together or press ΔV twice to turn off the 1/Δt cursors and readout.

To measure voltage ratio, time ratio (such as duty factor), or phase:

1. Turn the VOLTS/DIV VAR or SEC/DIV VAR controls until the 100% reference feature of the waveform covers exactly five divisions of the graticule. For phase, set one cycle, 360 degrees, to five divisions.
2. Press ΔV to measure voltage ratio, Δt for time ratio, or ΔV and Δt together for phase.
3. Turn the Δ REF and Δ knobs to align the cursors with the portion of the waveform to be compared to the reference portion. Phase is usually a two-channel measurement to determine the phase shift between zero crossings. (Be sure zero crossings for phase measurements are positioned at the graticule center.)
4. The readout shows the ratio or phase shift.
5. Press the same ΔV or Δt button, or both, to turn off the cursors and readout.

Use the Indep cursor mode for most measurements. The Tracking mode helps when you are comparing similar features. With TRACK, the Δ REF knob moves both cursors. The Δ control always moves only the Δ cursor.

Cursors are more accurate and easier to use than the graticule. They eliminate the inconvenience and errors of counting and interpolating graticule markings and they avoid crt linearity errors. The graticule markings should be used for rough estimates and, with careful attention, for photographed waveforms.

For more information about various measurement techniques, see the "Applications" section of this manual.

Display Operation

The 2467 incorporates an advanced cathode-ray-tube. A micro-channel-plate electron-multiplier (MCP) amplifies the crt beam current, intensifying low repetition-rate waveforms at high sweep speeds.

Normal operation of the instrument gradually reduces beam-current amplification, in proportion to the duration and brightness of waveform and readout displays.

Eventually, if traces tend to be displayed in fixed locations, you may be able to distinguish those locations by their reduced amplification. This characteristic, called "differential ageing," can be visible with a flooded-screen display, but it usually has little or no effect on waveform displays.

With a flooded screen, you may also see a negative image of a high-intensity waveform that was displayed only a few minutes. This effect is temporary and the crt recovers within a few minutes to several hours.

Our warranty applies to the writing rate of the crt, which is a measure of its ability to display low repetition-rate waveforms. The warranty does not apply to differential ageing.

To avoid excessive crt ageing, the instrument limits intensity to a low level, after a time with no front panel control changes. The time you have to observe the display without moving a control decreases with higher INTENSITY control settings and higher trigger rates. Press BEAM FIND or move any other control, except FOCUS, to restore the original intensity level.

Set both INTENSITY and READOUT INTENSITY controls 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.

Signal Connection with Probes

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 11 pF of the probe are a negligible load on most circuits, very fast circuits or very high impedance circuits may be seriously affected.

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.

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

The standard-accessory probe is a compensated 10X voltage divider. It appears resistive at low frequencies and capacitive for high-frequency signal 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.

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 between channels of a multichannel oscilloscope. See the procedure in the "Checks and Adjustments" section of the manual.

Signal Connection with Coaxial Cables

To maintain good waveform fidelity and accuracy, only high-quality, low-loss coaxial cables should be used. The instrument is optimized for 50 Ω sources, driving the 50 Ω dc input through 50 Ω cable. If you use another signal source impedance, such as 75 Ω, use the appropriate coaxial cable and an external terminator to match, with the input set at 1 MΩ. Some high frequency response will be lost with external termination.

Delayed-Sweep Operation

With the SEC/DIV control out, both A SWP and B SWP indicators light. If A and B SEC/DIV settings are equal with the knob pulled out (Inten mode), a small intensified zone appears on the A Sweep at the point where the B Sweep runs. Two zones appear with Δt or $1/\Delta t$. Then you can set the Δ REF OR DLY POS and Δ controls to intensify the point or points of interest. B Trigger mode should be Run Aft Dly.

With the B Trigger set to RUN AFT DLY, turning the Δ REF OR DLY POS or Δ knobs continuously moves the intensified zone on the A Sweep trace. If the B Trigger mode is Trig Aft Dly and the signal triggers the B Sweep, the intensified zone jumps to each succeeding B trigger point within the A Sweep interval as delay time is changed.

Turning the SEC/DIV control clockwise with the knob pulled out displays both A Sweep intensified and B Sweep (Alt mode). Now you can expand the point of interest. With Δt or $1/\Delta t$, you can set the Δ REF and Δ controls to superimpose the points of interest on the B Sweep and confirm their relationship to everything else on the A Sweep. The A Sweep is not affected by X10 MAG in Alt horizontal mode.

Pushing the knob in when A SEC/DIV and B SEC/DIV settings are unequal displays only the B Sweep. The B SWP indicator lights and the A SWP indicator extinguishes. This simplifies the display and may reduce display flicker.

The B Sweep (delayed) expands waveform details. This leads to two techniques for improving time-measurement accuracy. First, the B Sweep can expand waveform details so they are easy to observe and accurately measure with cursors or against the graticule. Second, you can use the B Sweep in a dual-delay, delta-time mode.

Delta-Time with Delayed Sweep

The B Sweep expands the displays of both the beginning and the end of an interval, which are superimposed by the Δ REF and Δ controls. Dual-delay, delta-time eliminates the effects of B Sweep timing error and crt distortion and greatly enhances resolution.

Dual-delay delta-time measurements are generally useful only in the Run Aft Dly mode, where the B Sweep runs immediately after the set delays. If the B Sweep is triggered, it waits for a trigger after the set delay, so the actual delay time may be much different from the delay setting shown in the readout.

Delayed-sweep delta-time gives better accuracy than cursors when measuring moderate speed signals. However, cursors work better for intervals shorter than 10 ns, if you set the SEC/DIV and X10 MAG controls for 1 ns or 500 ps.

Measuring delta-time with delayed sweep requires several steps:

1. Set the A SEC/DIV control to the fastest rate that displays the time interval.
2. Pull the SEC/DIV knob out, set the B Trigger mode to Run Aft Dly, and select Δt.
3. Set the Δ REF control to intensify the beginning of the interval on the A Sweep. Set the Δ control to intensify the end of the interval on the A Sweep. Set the B SEC/DIV control to expand the start and stop details and readjust the Δ REF and Δt controls to superimpose the expanded start and stop points.
4. Read the interval from the digital readout.

The main sweep trigger event begins the interval of interest for many practical measurements. The instrument can measure delta-time beginning at the A Sweep trigger event with A SEC/DIV set faster than 50 μs.

It may be surprising to note that a delta-time measurement is valid between superimposed points, regardless of the TRACE SEPARATION control position. As vertical position changes, the points of superposition also change. However, the time between any of the superimposed pairs of points remains constant. In other words, the only points that can be superimposed are those points that are separated by the delta-time value.

Single-Delay Time Measurements

For intervals longer than 10 μs or for low repetition rate signals that make the display flicker, you may prefer to use the B Sweep without Δt. Without Δt, the display repetition rate is higher and the Dly readout shows the time from the start of A Sweep to the start of B Sweep. Some accuracy is lost compared to Δt.

1. Trigger A Sweep at the beginning of the interval, set A SEC/DIV to the fastest rate that will display the interval, and turn off Δt or 1/Δt.
2. Pull the SEC/DIV control out, set the B Trigger mode to Run Aft Dly, and set the DLY POS control to intensify the end of the interval.
3. Set the B SEC/DIV control to expand the end of the interval and set the DLY POS control to align the end of the interval with the left end of the B Sweep.
4. The Dly reading is the length of the interval.

Save and Recall Operation

You can easily record any instrument setup for unlimited future use. Eight setups are directly accessible by using SAVE and RECALL as prefixes to the setup number buttons, 1 through 8, which are also the Vertical MODE buttons. Twelve more setups are accessible using the Δ control to scroll through the list. You can arrange setups in sequence and recall them in order by pressing STEP/AUTO. Sequences automatically restart when they are completed. See Appendix B for sequence programming instructions.

Each setup carries a name with one to seven characters. The name of a setup can be defined when it is saved or redefined at any time. The names of setups one through eight appear on the screen as a user-defined menu when RECALL is pressed. The names appear on the screen in the same relative positions as the corresponding setup number buttons, also used as Vertical MODE buttons. When a setup is recalled, the setup number and name appear in the upper left of the readout until a control is moved or a measurement changes the readout.

Any time you need more information to proceed with a SAVE or RECALL operation, press SAVE/HELP or RECALL/HELP again. Each time you press SAVE/HELP or RECALL/HELP, the readout shows another message. The messages appear in a looping sequence as you repeatedly press the button.

To save a setup:

1. Set the instrument to make a particular measurement or observation.
2. Press SAVE. The readout will indicate the Direct Save mode.

   Top Row— SAVE 1-8 DIRECTLY. NAME:.....
   Cursor—

   Bottom Row— PUSH ANY OF 1-8 TO SAVE SETUP.

(If the Direct-Save mode displays "SAVE FUNCTIONS DISABLED," refer to EXER 07, described in Appendix C.)

3. If you want a new name for the setup, turn Δ to define the first character, then turn Δ REF to select and Δ to define each additional character. A small cursor marks the character selected for definition.
4. Press one of the setup number buttons. The readout will show, in the corner, the number of the button you pushed and either the new name you defined or the name of the setup previously associated with that setup number.

To recall a setup:

1. Press RECALL. The readout will indicate the Direct Recall mode by showing the NAMES of the four setups numbered 1 through 4 in the top row and the NAMES of the four setups numbered 5 through 8 in the bottom row. For example:

Top Row—	SKEW	ADJ.PLL	TP-2467	CLOCK
Bottom Row—	ACE	KING	QUEEN	JACK

2. Press the setup number button, 1 through 8, that occupies the same position among the buttons as the name of the desired setup occupies among the names display. The readout will show, in the upper left corner, the number of the button you pushed and the name of the setup associated with that setup number.

To RECALL a sequence:

1. Press RECALL. The readout will indicate the Direct Recall mode by showing the user-defined menu of the first eight setups.
2. Press STEP. The readout will show the name of the beginning step of the first sequence and the names of additional sequences, up to four.
3. Press the setup number button, 1 through 4, that occupies the same position among the buttons as the name of the desired sequence occupies among the names display. The readout will show, in the upper left corner, the number and the name of the first setup in the selected sequence. If more than four sequences have been saved and you want to run a sequence other than the first four, turn Δ to the number and name of the first step in the desired sequence.
4. Press STEP to recall each setup in the sequence, in turn. When the last setup in the sequence has been recalled, the next operation of STEP recalls the first step in the sequence.

If the STEP indicator is off, AUTO/STEP automatically establishes a waveform display, as described earlier. If the indicator is on, AUTO/STEP sequentially recalls setups. If the STEP indicator is on, press SAVE or RECALL to extinguish it. A switch closure or TTL-low signal connected to the STEP/AUTO EXT SWITCH connector on the rear panel has the same effect as pushing the STEP/AUTO button.

Introduction

This oscilloscope makes better measurements with less effort than most other instruments. As you become familiar with the instrument, you can easily develop your own convenient methods for making particular measurements. The information in this section can accelerate the processes of learning the instrument and developing your own techniques.

Refer to "Operation" for efficient waveform display methods and general control operation.

Voltage Measurement

The Delta Volts (ΔV) function simplifies voltage measurements.

1. Display the signal on either CH 1 or CH 2, for better accuracy than CH 3 or CH 4.
2. Set VOLTS/DIV for a waveform amplitude between three and eight divisions.
3. Activate ΔV, position the two cursors on the waveform at the points of interest, and read the voltage between the two cursors from the crt readout (see Figure 3-1).

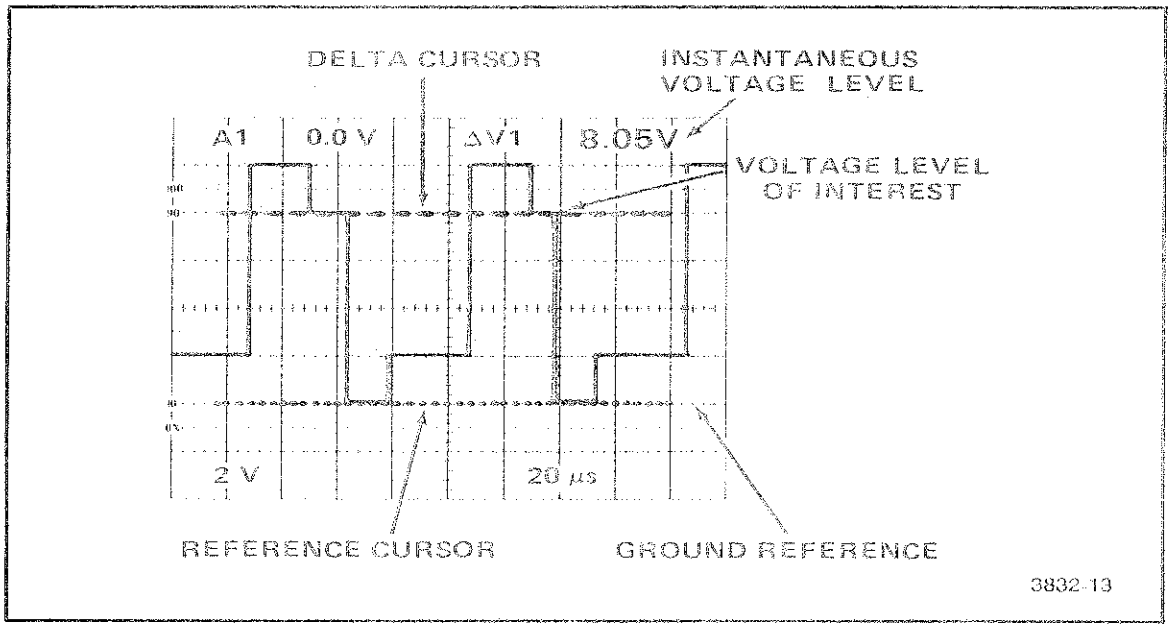


Figure 3-1. Instantaneous dc levels.

To measure peak-to-peak voltage, align the Reference cursor with the bottom of the waveform and align the Delta cursor with the top of the waveform.

To measure absolute voltage levels, align the Reference cursor with a ground reference, obtained by momentarily switching Input Coupling to GND.

To verify a logic signal noise immunity, set the ΔV cursors to the lower and upper input threshold limits. For example, for TTL:

1. Superimpose the Δ REF cursor on the trace with the input coupling at GND.
2. Set the Δ cursor so the readout shows 2.0 V, the upper limit of a TTL input logic-threshold.
3. Set the Δ REF cursor so the readout shows 1.2 V, the difference between the 0.8 V lower threshold limit and the previously set upper threshold-limit cursor.
4. Set the Input Coupling mode to DC and observe the relationship between the signal and the cursors. If the signal changes direction between cursors or if the high or low level appears between cursors, the signal is faulty.

Voltage Ratio

The Delta Volts (ΔV) function also measures the ratio, in percent, between two signal voltages. These voltages may be either part of the same waveform or parts of totally separate signals. To measure a voltage ratio, use the following procedure:

1. Display the signal on either CH 1 or CH 2. Apply the reference signal if it is separate from the test signal.
2. Set VOLTS/DIV to display more than five divisions of the waveform.
3. Adjust VOLTS/DIV VAR so that the reference portion of the waveform is exactly five divisions.
4. If the reference signal is separate from the test signal, replace the reference signal with the test signal in the same vertical channel.
5. Activate ΔV, align the cursors with the points of interest on the waveform, and read the ratio (see Figure 3-2).

The readout shows the ratio, in percent, between the separation of the cursors and the five-division reference. With five divisions of separation, the readout shows 100%.

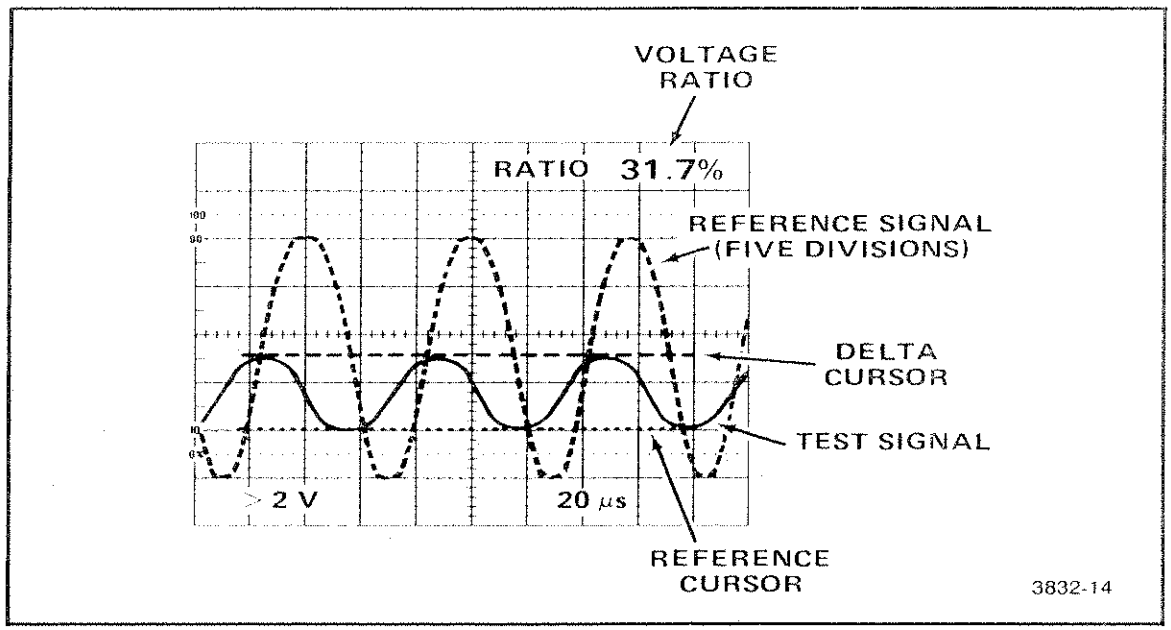


Figure 3-2. Voltage ratios.

"Quick and Dirty" DC Voltage Measurement

Sometimes a 5% estimate of a dc voltage is good enough to verify the operation of a power supply, trace power supply distribution on a board or panel, or verify the state of a control system. The Auto Lvl Trigger mode measures voltage peaks, sets the trigger to the midpoint, and displays the midpoint voltage in the trigger level readout, provided both the vertical input and trigger coupling are set to DC, the trigger source is a single channel, and VOLTS/DIV VAR is fully clockwise. If the signal is a dc voltage, the sweep will free-run. Simply touch a probe to the voltage to be measured and push AUTO. For best accuracy, set VOLTS/DIV so the measured voltage is five to fifteen divisions.

Algebraic Addition to Detect Coincidence or Cancel Interference

With the Add Vertical mode, the waveform is the algebraic sum of the signals applied to Channel 1 and Channel 2. If the Invert mode is selected, the Add waveform is the difference between the signals applied to Channel 1 and Channel 2. The deflection factor of the Add trace is the same as CH 1 and CH 2 VOLTS/DIV when they are equal.

The following general precautions should be observed when using Add mode:

1. Do not apply signals that exceed ±8 divisions amplitude, since extreme overdrive may distort the display. For example, with VOLTS/DIV at 500 mV, the signal should not exceed ±4 V.
2. Position both Channel 1 and Channel 2 waveforms near center screen, when viewed separately. This ensures the greatest dynamic range for Add mode operation.
3. To obtain similar responses from each channel, set Channel 1 and Channel 2 input couplings the same.

Observing Coincidence

The Add mode can show coincidence of two digital or analog signals; the waveform is high when both signals are high, low when both are low, and at an intermediate level when one signal is high and the other is low. By inverting CH 2, you can observe the coincidence of one signal and NOT the other. To observe coincidence of TTL signals:

1. Connect the signals of interest to CH 1 and CH 2. If the coincidence of interest has one signal in the opposite state from the other, connect the one preferred to be inverted to CH 2 and invert CH 2.
2. Display CH 1, CH 2, and Add. Set both VOLTS/DIV to 2 V and both inputs to GND. Position both channels on screen and the Add trace one division above the bottom of the graticule. Then deselect CH 1 and CH 2.
3. Set both inputs to DC. Set Trigger mode to Auto and Source to Vert. If the coincidence of interest is high-high, set trigger SLOPE +. If the coincidence is low-low, set SLOPE −. Press INIT@50%, then carefully adjust the trigger level to respond to the high-high or low-low state combination. (Trigger level readout doesn't operate with Add Source.)
4. Now you can observe and measure coincidence durations and other time intervals. Channels 3 and 4 can show relationships to other signals.

Measuring Off-Ground Signals And Cancelling Interference

The Add mode can measure voltage between a pair of points where neither point is ground. The technique can cancel interfering signals or uninteresting components of a signal through common-mode rejection.

1. Display the signal on CH 2 at the point you consider low, common, or inverse and display on CH 1 the high or active signal.
2. Set both VOLTS/DIV equally and for three to eight divisions of amplitude on the larger of the pair of signals.
3. Select the Add display with CH 2 Invert, connect the CH 1 probe temporarily to the CH 2 point, and adjust either the CH 1 or CH 2 VAR control, if necessary, to minimize the amplitude of the Add display.
4. Move the CH 1 probe back to the active signal and observe the desired, differential signal.

You may be able to increase vertical sensitivity by one VOLTS/DIV step, keeping CH 1 and CH 2 equal, without serious distortion. If the common mode signal has the same repetition rate as the signal of interest, CH 1 or CH 2 may be usable as the trigger source. Vert Trigger Source is often more desirable because it responds only to the differential signal. Figure 3-3 shows an example.

Time Interval

The Delta Time (Δt) function greatly simplifies timing measurements. To measure the time between any two points on a waveform or a pair of waveforms, such as rise time, fall time, propagation delay, setup time, or period, use the following procedure:

1. Display the waveform with the largest practical vertical amplitude and with the fastest sweep that will display the interval of interest. The X10 MAG or the B-Sweep can expand waveform details so the interval of interest covers several divisions of the horizontal scale. If you are measuring time from one signal to another, such as a propagation delay, trigger the sweep from a single channel to preserve the time relationship.
2. Activate Δt and position the two vertical cursors to align with the beginning and end of the time interval.
3. Read the time difference between the two cursors from the crt readout.

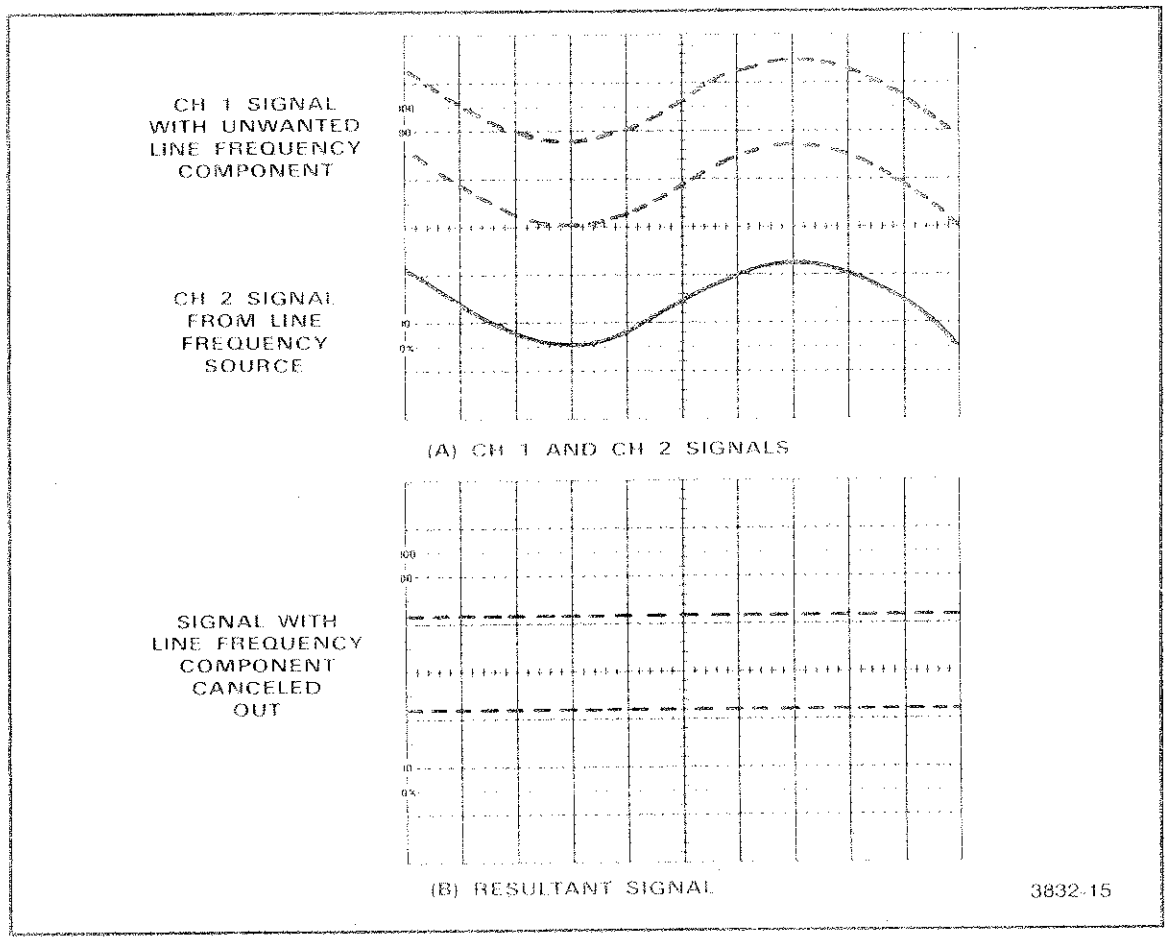


Figure 3-3. Eliminating common-mode signals.

To measure rise time, the Reference cursor should be aligned with the 10% point on the transition and the Delta cursor should be aligned with the 90% point. Locate the 10% and 90% points by adjusting VOLTS/DIV, VAR, and POSITION controls until the waveform exactly fits between the 0% and 100% graticule lines. Then measure transition time between the points where the signal crosses the 10% and 90% graticule lines.

To measure waveform periods, align the cursors to identical points on two adjacent cycles of the waveform.

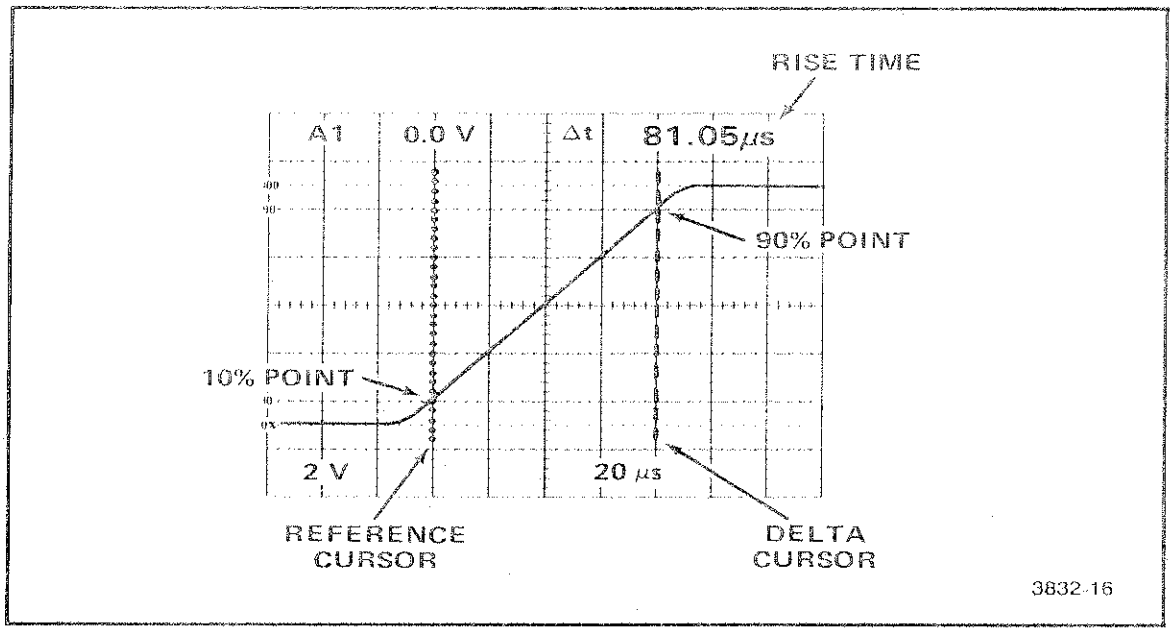


Figure 3-4. Measuring rise times.

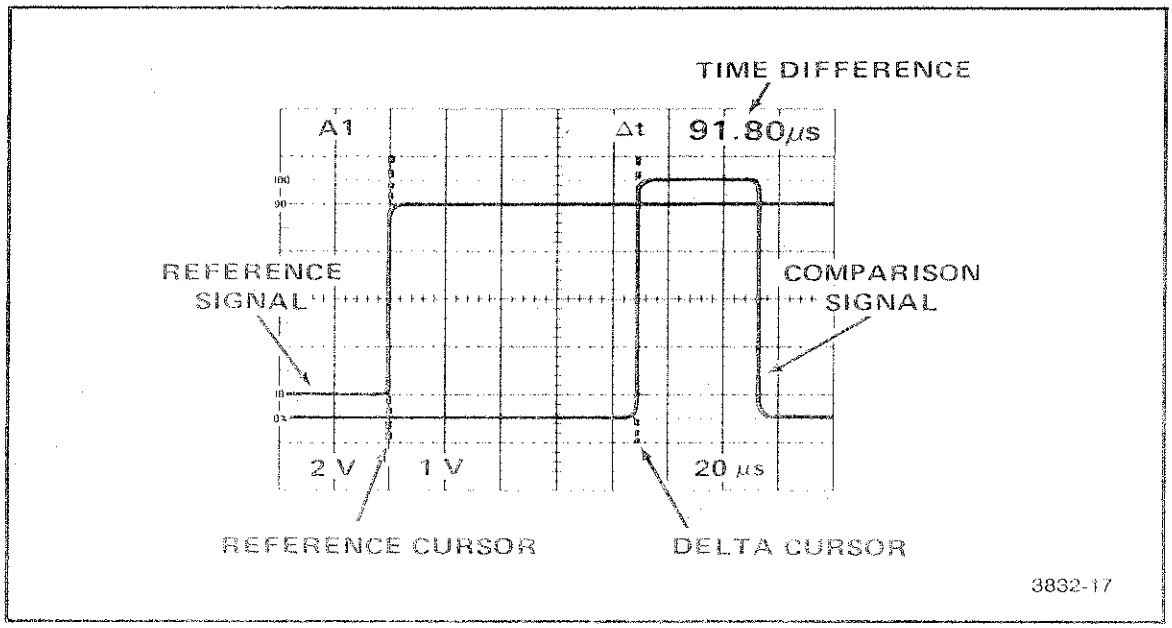


Figure 3-5. Time difference between two time-related pulses (cursor method).

Frequency

For frequency measurements, use the same method as previously described for period, under "Time Interval" measurements, except in step 2, push both the ΔV and Δt buttons together to activate the 1/Δt function.

Slew Rate

Slew rate is the slope of a signal in volts/second. To measure slew rate:

1. Display the slope of the signal over the largest practical span of horizontal deflection and vertical deflection.
2. Activate 1/Δt and set the cursors to intersect the signal slope at points that are separated by one volt or by a power-of-ten multiple or fraction of one volt.
3. Interpret the frequency (Hz) readout as volts/second instead of cycles/second (Hz). Multiply the result by the power-of-ten multiple of one volt between the cursors. For example, if the cursors intersect the waveform at points separated by one volt and the readout shows 173 kHz, the slew rate is 173 V/ms. With 10 mV between cursors and 55.3 MHz readout, the slew rate is 0.553 V/μs or 553 kV/s, etc.

Time Ratio

The Delta Time (Δt) function also can measure the percent ratio between two different time intervals, such as the period and width of a pulse, which define duty factor. To measure duty factor, use the following procedure:

1. Display the signal with SEC/DIV and VAR set for one cycle over exactly five horizontal divisions.
2. Activate Δt and align the two vertical cursors with the beginning and end of the high portion of the pulse. Measure the low portion of the pulse if you want to measure the portion of the cycle that is low (see Figure 3-6).

If the portion of the pulse you are measuring is less than 1 division wide (20%), you can improve the accuracy of the measurement. Activate the X10 MAG, without changing SEC/DIV or VAR, and align the cursors with the magnified pulse. The RATIO reading will be 10 times the actual ratio.

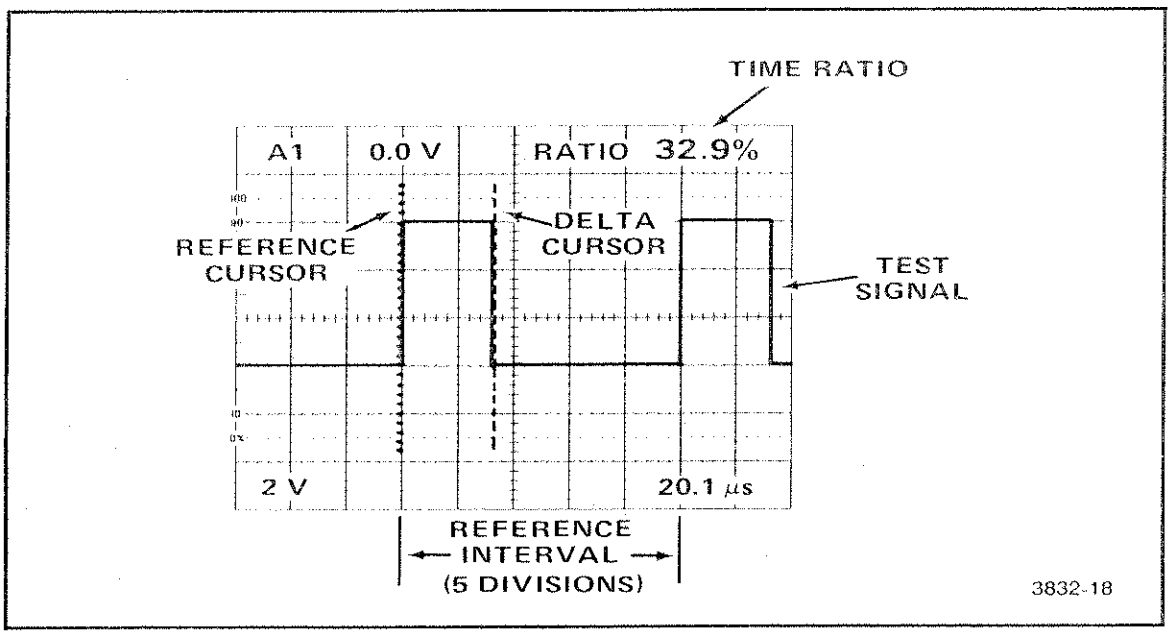


Figure 3-6. Time ratio (duty factor).

The crt readout displays the ratio, in percent, between the separation of the two cursors and the five-division reference interval. When the two cursors are separated by five divisions, the readout indicates 100%.

Of course, any time ratio can be measured. Simply set SEC/DIV and VAR to display the reference interval over 5 divisions and compare any other interval, in percent, with Δt cursors.

Phase Difference Between Two Signals

Phase measurements are similar to time ratio measurements. To measure phase shift, use the following procedure:

1. Using either probes or cables with equal time delays, display the reference signal on CH 1 and the comparison signal on CH 2. For higher frequencies, signal delay matching is more critical. The procedure for matching delays is found under "Matching Channel 2 Delay" in Section 4.

2. Set CH 1 and CH 2 VOLTS/DIV and VAR controls to obtain equal amplitudes of the reference and the comparison signals. Set the amplitudes as large as is practical.

3. Use the Vertical POSITION controls to center both displays vertically. The accuracy of the phase measurement depends on the accuracy of vertical centering.

4. Set SEC/DIV and VAR to display one cycle of the reference signal over five horizontal divisions.

5. Activate 1/Δt by pressing both the Δt and ΔV buttons together.

6. Align the Reference cursor with a zero-crossing of the reference signal. Align the Delta cursor with the nearest zero-crossing of the comparison signal, on the same slope as the reference signal zero-crossing (see Figure 3-7). Use the center horizontal graticule line as the reference for aligning the zero-crossings.

7. Read phase shift in degrees from the crt readout.

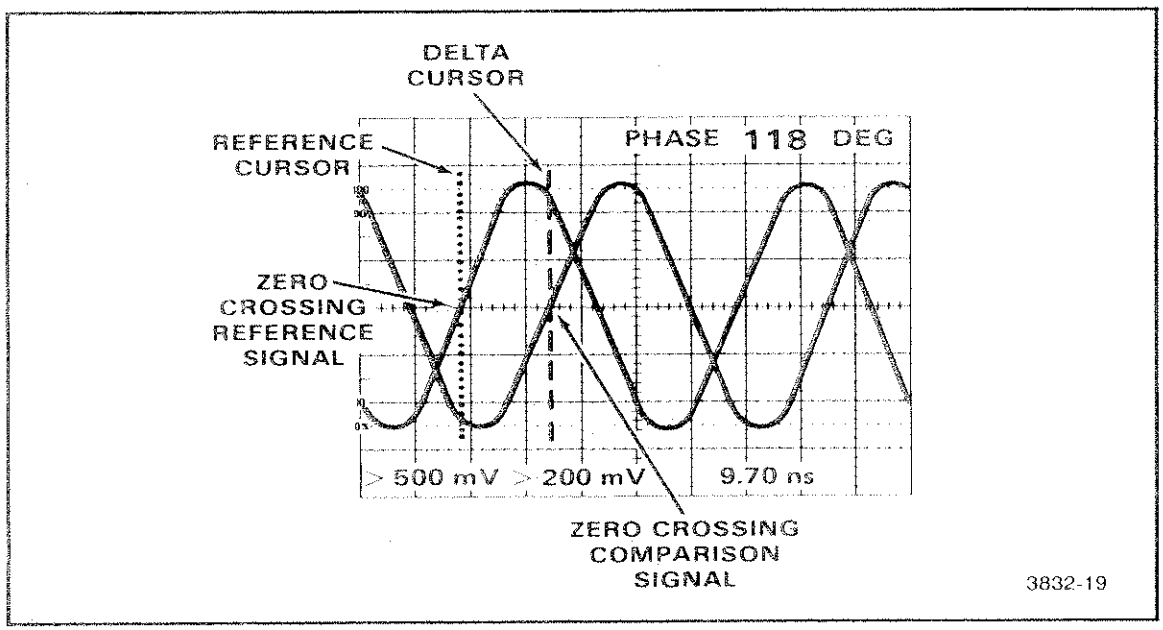


Figure 3-7. Phase difference between two time-related signals.

If the phase shift is less than 1 horizontal division (72 degrees), you can improve the accuracy of the measurement. Use the X10 MAGnifier, without changing SEC/DIV or VAR, to expand the display; align the cursors with the zero crossings; and divide the PHASE readout by 10 (see Figure 3-8).

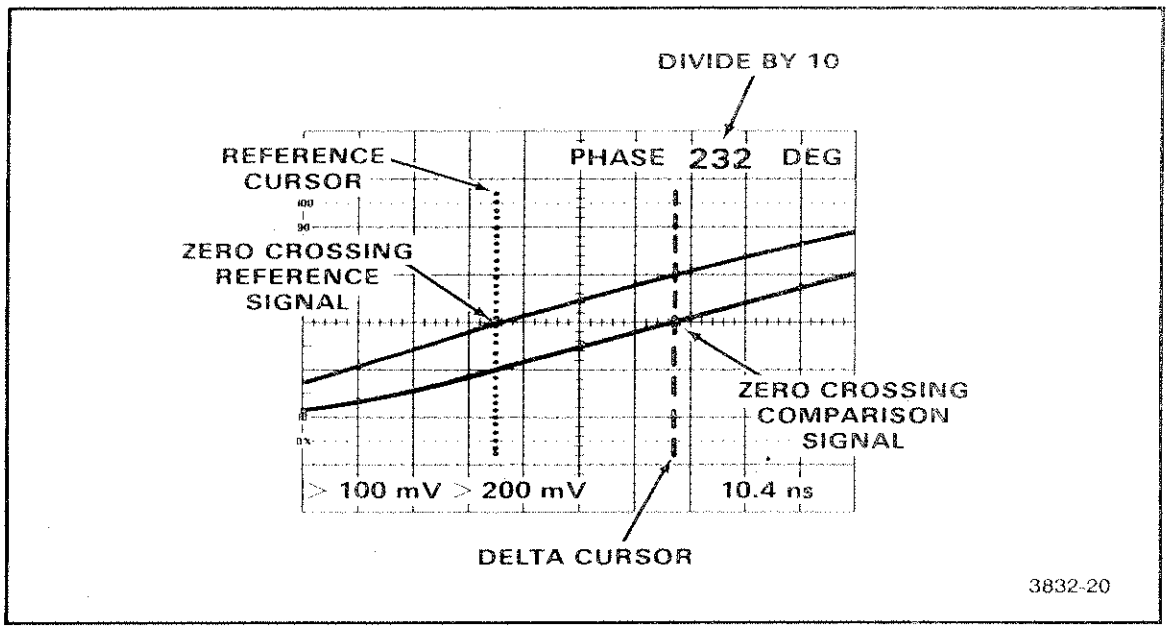


Figure 3-8. Small-angle phase difference.

Introduction

The checks and adjustments in this section eliminate some significant sources of measurement error and improve measurement confidence. If adjustments are required beyond the scope of this section, refer the instrument to a qualified service technician.

Initial Setup

1. Press in the POWER switch button (ON) and allow the instrument to warm up (20 minutes is recommended for maximum accuracy).
2. Set instrument controls to obtain a display:

READOUT INTENSITY	Midrange between "OFF" and fully clockwise
INTENSITY	Midrange
FOCUS	Midrange
VERTICAL MODE	CH 1
CH 1 Input Coupling	1 MΩ DC

3. Connect the Calibrator output to the CH 1 input with a standard accessory probe and ground the probe near the Calibrator output.
4. Press the AUTO Setup button to obtain a display. (If the STEP indicator is illuminated, press RECALL to cancel the Step mode, then press AUTO to obtain a display.) Adjust the INTENSITY and READOUT INTENSITY controls as desired. Set the FOCUS control for the best trace definition.

Trace Rotation and Adjustment

1. Preset instrument controls and obtain a display as described in "Initial Setup."
2. Set CH 1 Input Coupling to GND, 20 MHz BW LIMIT on, and adjust the CH 1 POSITION control to position the trace on the center horizontal graticule line.
3. If the trace is not parallel to the center horizontal graticule line, use a small-bladed screwdriver to adjust the TRACE ROTATION control and align the trace with the center horizontal graticule line.

Astigmatism Adjustment

1. Obtain a display as described in "Initial Setup."
2. Set 20 MHz BW LIMIT on and adjust the CH 1 POSITION control to center the display on the screen.
3. Select ΔV and position the cursors near the top and bottom of the screen.
4. Set SEC/DIV to 1 μs.
5. Slowly adjust the FOCUS control to its optimum setting (best defined display of cursor dots).
6. Use a small-bladed screwdriver to adjust the ASTIG control for best defined display of cursor dots. The waveform and the entire readout should be well defined.
7. Since the ASTIG and FOCUS adjustments interact, repeat steps 5 and 6 until the best-defined display over the entire graticule area is obtained.

NOTE

Once set, the ASTIG adjustment should be correct for any display. However, it may be necessary to reset the FOCUS control slightly when the INTENSITY control setting is changed.

Auto DC Balance Routine

The oscilloscope can automatically dc-balance Channel 1 and Channel 2. This routine minimizes trace shifts when adjusting the VOLTS/DIV and VOLTS/DIV VAR controls, and when switching Channel 2 between noninverted and inverted. This dc balance remains valid as long as the instrument is operating within 5°C of the ambient temperature at which the routine was performed, provided the instrument had had a 20-minute warm-up period.

To initiate the adjustment, press the upper, input-coupling buttons for both Channel 1 and Channel 2 at the same time. When the Auto DC Balance cycle is complete, the instrument will return to normal operation.

NOTE

If a circuit defect prevents accurate dc balance, the routine halts and ***LIMIT*** *is displayed. Press the upper Trigger COUPLING button to continue balancing the remainder of the circuitry.*

If power to the instrument is interrupted before the balancing cycle is complete, a DC balance error may be apparent in subsequent operation. When power is restored, restart the DC balance routine, after the instrument has warmed up.

Probe Compensation

Accurate measurements require accurate probe compensation. To ensure optimum measurement accuracy, check probe compensation any time a probe is attached to the instrument or any other time you are not certain of correct compensation. Because of minor differences between channels, CH 1 and CH 2 probes should be compensated on their respective channels. CH 3 and CH 4 probes should be compensated on CH 1 or CH 2. Check and adjust probe low-frequency compensation as follows:

1. Obtain a display as described in "Initial Setup."
2. Set the SEC/DIV control to 1 ms and 20 MHz BW LIMIT on. If the probe to be compensated is connected to CH 2, enable the Channel 2 display. Set the appropriate VOLTS/DIV control to 100 mV.
3. Connect the probe to the CALIBRATOR output.
4. Check the waveform for overshoot and rolloff (see Figure 4-1). If necessary, adjust the probe for a square front corner on the waveform, using the small adjustment tool supplied in the probe accessory package. Insert the tool through the small hole in the side of the box attached to the vertical input connector.

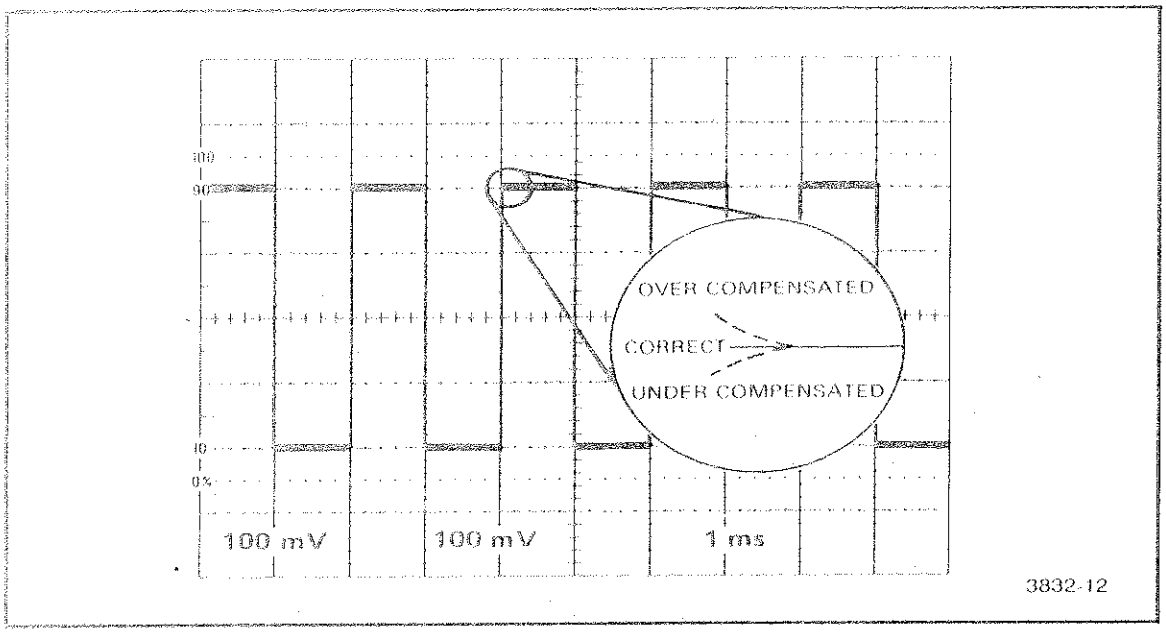


Figure 4-1. Probe low-frequency compensation.

Matching Channel 2 Delay

The apparent signal delay in Channel 2 may be adjusted up to ±500 ps to match the apparent delay present in any of the other three channels. This adjustment is most commonly used to eliminate delay differences between Channel 1 and Channel 2 that may be introduced by the probes. It has no effect on common-mode rejection when ADD Vertical Mode is selected. Match Channel 1 and Channel 2 as follows:

1. Connect two 10X probes supplied with the instrument to the CH 1 OR X and CH 2 inputs.
2. Check and adjust, if necessary, the probe's low-frequency compensation. Refer to "Probe Compensation" in this section.
3. Connect both probes via hook tips to a fast-rise pulse generator output.
4. Select both CH 1 and CH 2 Vertical mode displays.

5. Press AUTO Setup to obtain a display.
6. Set the CH 1 and CH 2 VOLTS/DIV and POSITION controls for 3 to 6 divisions of amplitude and superimposed displays.
7. Set the SEC/DIV switch to 5 ns.
8. Pull out the SEC/DIV switch and observe the message **CH 2 DELAY—TURN** Δ in the upper right-hand corner of the screen.

NOTE

If the message **CH 2 DLY DISABLED** *appears in the readout, the instrument has been set to disable the delay-offset adjusting feature. If adjustment of the delay matching is disabled, refer the adjustment to a qualified service technician.*

9. Set X10 MAG On and adjust the Δ control until the two fast edges are superimposed horizontally.

NOTE

The Δ REF OR DLY POS control can also be used to make the adjustment.

10. Push in the SEC/DIV switch. The adjustment is then permanently stored for future operation, even when power is interrupted.

Amplitude Check

1. Obtain a display as described in "Initial Setup."
2. Set the VOLTS/DIV switch to 100 mV, the SEC/DIV switch to 1 ms, and 20 MHz BW LIMIT on.
3. Adjust the CH 1 POSITION control to center the display on the screen.
4. CHECK—Amplitude of the CALIBRATOR signal is between 3.88 and 4.12 divisions as measured on the center vertical graticule line.
5. Select ΔV and carefully superimpose the cursors on the high and low levels of the waveform. CHECK—ΔV readout is between 392 mV and 408 mV.
6. Repeat this procedure using the Channel 2 connector and controls.

Timing Check

The period of the CALIBRATOR signal automatically tracks with the A SEC/DIV sweep setting within the range of 100 ms to 100 μs. Within that SEC/DIV range, the CALIBRATOR period is 200 ms to 200 ns, 5 cycles per 10 divisions of the A Sweep. To quickly check the operation and calibration of the oscilloscope timing, use the following procedure:

1. Obtain a display as described in "Initial Setup."
2. CHECK—Timing accuracy by confirming that five complete cycles of the square-wave signal are displayed over 10 major divisions (±0.1 division) along the center horizontal graticule line for all A SEC/DIV settings from 100 ms to 100 ns. Confirm that 2 cycles of the Calibrator signal cover 8 divisions at 50 ns/div and that 1 cycle covers 10 divisions at 20 ns/div. Observe that the displayed transition time of the signal remains approximately the same when A SEC/DIV is changed to 10 ns and 5 ns. (The number of horizontal divisions covered by the transition time at 10 ns per division should be two times the number covered at 20 ns, and the number of divisions at 5 ns should be four times the number at 20 ns.) Return A SEC/DIV to 1 ms, switch the X10 MAG on, and CHECK—that 1/2 cycle covers 9.8 to 10.2 divisions.
3. Set X10 MAG Off and carefully align the Δt cursors with the falling edges of the first and fifth cycles. CHECK—Δt reading is within 7.93 ms to 8.07 ms. Repeat the test at any desired A Sweep speed in the 100 ms to 100 ns range.
4. If desired, delay timing can be checked by using Alt horizontal display mode, RUN AFT DLY B-Trigger mode, and Δt. Set the Δ REF AND DLY POS and Δ controls to align the intensified zones with the falling edges of the first and fifth cycles and superimpose the expanded display of the edges on the B Sweep, running at least 10 times faster than the A Sweep. CHECK—Δt reading is 8 times the A SEC/DIV setting, ±0.5%.

Introduction

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

Power And Display

Refer to Figure 5-1 for the location of items 1 through 9.

(1) **INTENSITY Control**	Controls the brightness of the display. The 2467 automatically controls both waveform intensity and readout intensity to protect the crt from excessive ageing. Display intensity decreases after a time of inactivity of the instrument controls. The time of operation before reducing display intensity depends on whether the sweep is free running, the trigger repetition rate, and the display intensity settings. High trigger rates and high intensity settings reduce the time allowed before intensity is reduced by the crt protection timer. Operating any control except FOCUS, SCALE ILLUM, TRACE ROTATION, or ASTIGMATISM restores waveform and readout intensity levels and resets the crt protection timer.
(2) **BEAM FIND Button**	Limits the crt deflection both vertically and horizontally to within the graticule. Display intensity is not affected by the BEAM FIND button, except to restore automatically limited waveform and readout intensity levels and reset the crt protection timer.
(3) **FOCUS Control**	Adjusts the crt writing beam for optimum display definition.
(4) **TRACE ROTATION Control**	Operator-adjusted screwdriver control used to align the crt trace with the horizontal graticule lines. Relocating the instrument to a different magnetic ambient may result in slight misalignment of the trace and graticule, indicating a need to readjust the TRACE ROTATION control.

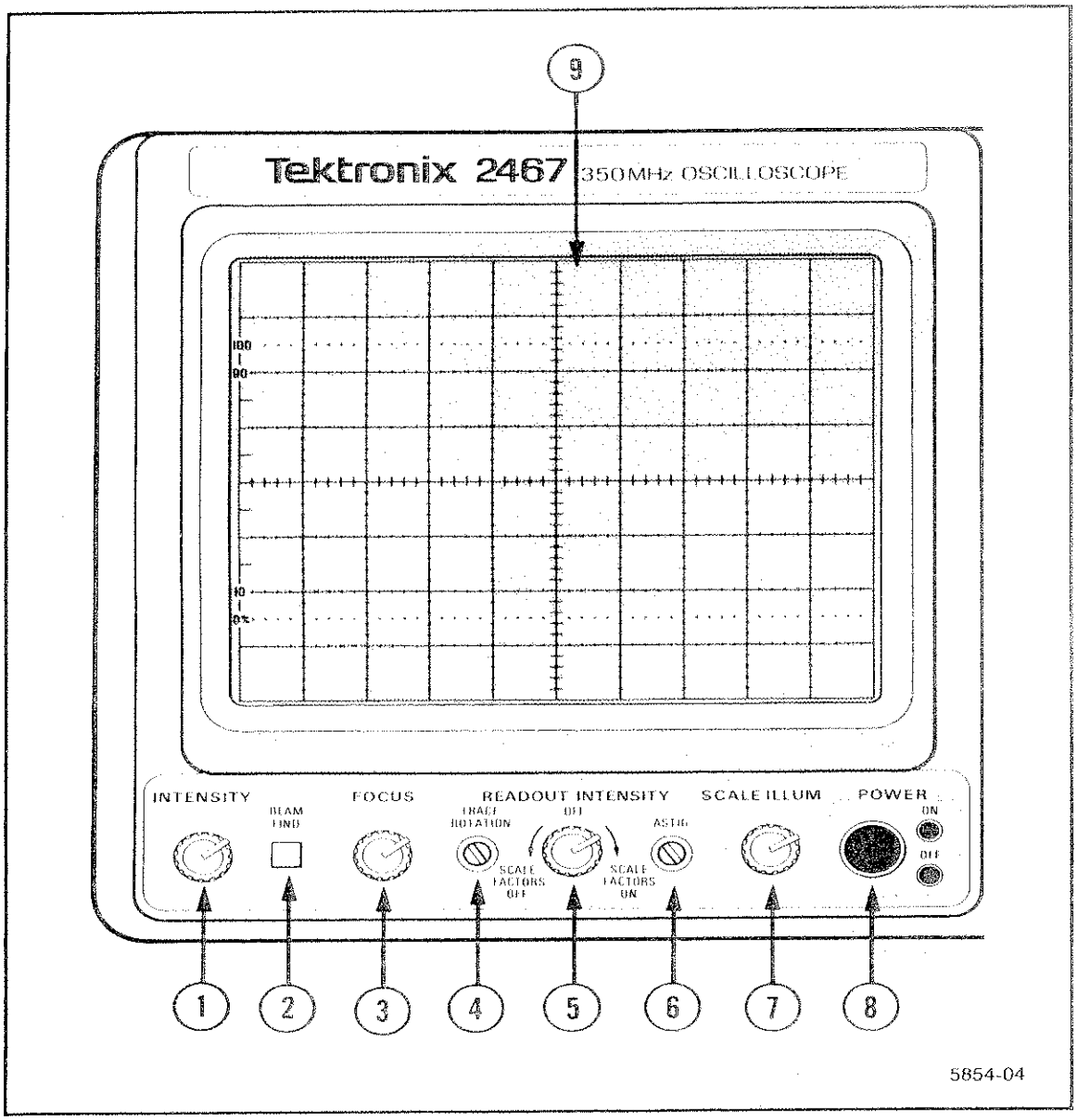


Figure 5-1. Power and display controls.

(5) **READOUT INTENSITY Control**

Adjusts the intensity of the crt readout display and either enables or disables the display of scale factors. Delta readouts and the "50 Ω OVERLOAD" message are always enabled.

Minimum intensity occurs at the control's midrange, OFF position. Clockwise rotation from midrange increases the intensity and enables the scale-factor and control message display. Counterclockwise rotation from midrange increases the intensity and disables the scale-factor and control message display.

(6) **ASTIG Control**

Operator-adjusted screwdriver control used in conjunction with the FOCUS control to obtain a well-defined display over the entire graticule area. Once adjusted, it does not require readjustment during normal operation of the instrument.

(7) **SCALE ILLUM Control**

Adjusts the light level of the graticule illumination.

(8) **POWER Switch**

Turns instrument power on and off. Press in for ON; press again for OFF. An internal indicator in the switch shows green when the switch is on and black when it is off. Front-panel settings are returned when power is reapplied to the instrument, unless saved setup number 1 is selected by the appropriate diagnostic exerciser.

(9) **CRT**

Has a 68-mm vertical and 85-mm horizontal display area. Internal graticule lines eliminate parallax-viewing error between the trace and the graticule lines. Rise-time measurement points are indicated at the left edge of the graticule.

Setup and Vertical

Refer to Figure 5-2 for the location of items 10 through 16.

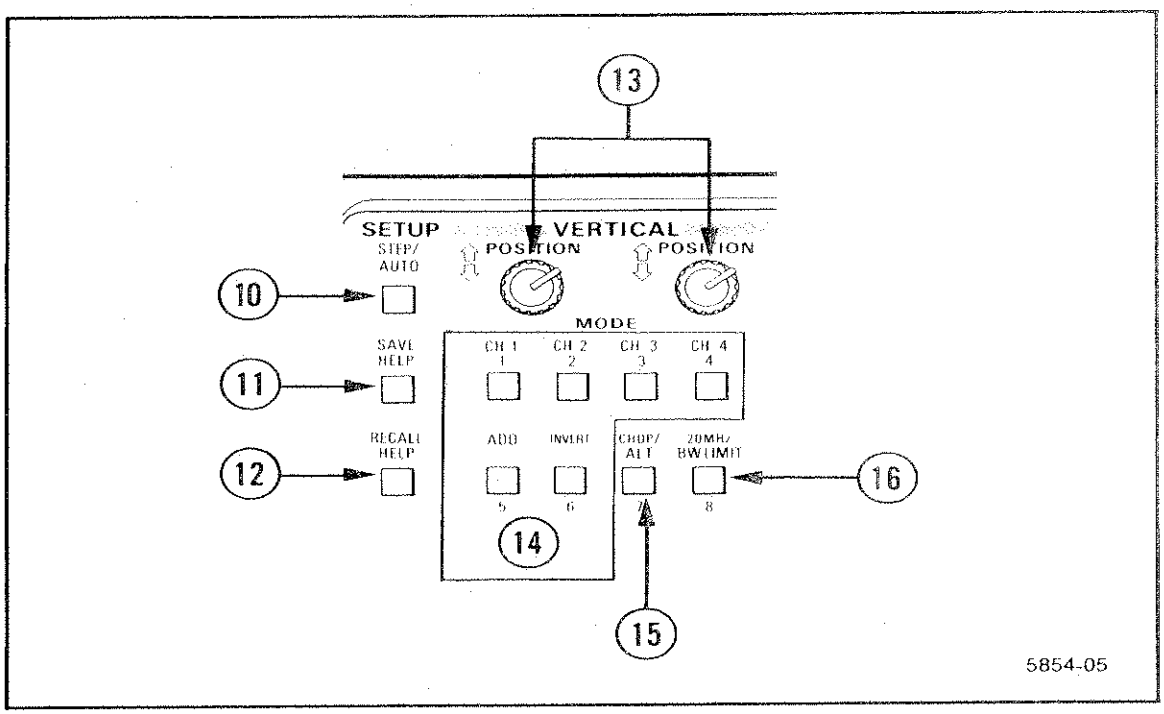


Figure 5-2. SETUP and MODE buttons, and CH 1 and CH 2 POSITION controls.

(10) STEP/AUTO Button

Recalls the next step in a stored sequence of setups, if the STEP indicator is illuminated. If the STEP indicator is not illuminated, the oscilloscope automatically establishes triggering and scales the waveform display vertically and horizontally (AUTO).

AUTO

AUTO initializes front panel controls settings to display the input waveform. See the "Operation" section for more information on the AUTO button.

STEP

Sets up the oscilloscope with the control settings stored in the next number setup.

(11) **SAVE/HELP Button**

Saves the current oscilloscope control settings in a numbered setup when followed by one of the setup-number buttons, 1 through 8, which are also the Vertical MODE buttons. Pushing the SAVE/HELP button replaces the top and bottom rows of the normal readout display with prompting and help messages. These help messages may be cycled through by repeatedly pushing the SAVE/HELP button. For operational information, see the "Operation" section and Appendix B.

(12) **RECALL/HELP Button**

Restores previous oscilloscope control settings saved in a numbered setup when followed by one of the setup-number buttons. Pushing the RECALL/HELP button replaces the top and bottom rows of the normal readout with the user defined menu. Repeated operation of the HELP button produces a cycle of help messages. For operational information, see the "Operation" section and Appendix B.

(13) **POSITION Controls**

Set vertical position of the Channel 1 and Channel 2 signal displays. Clockwise rotation of a control moves the associated trace upward. When the X-Y display feature is in use, Channel 1 POSITION control moves the display horizontally; clockwise moves it to the right. The Channel 2, Channel 3, and Channel 4 vertical POSITION controls move the associated X-Y display vertically.

(14) **MODE Buttons**

Selects the indicated channel(s) for display when latched in. Any combination of the five possible signal selections can be displayed by pressing the appropriate buttons. The Channel 1 signal will be displayed if none of the displays are selected. Each button has an associated indicator to show when the respective display or characteristic is active. Pressing a button toggles the display or characteristic on or off. These buttons have a secondary function of selecting setup memories (1) through (8) when pressed after pressing SAVE or RECALL.

The algebraic sum of Channel 1 and Channel 2 is displayed when the Add display is selected. When both Add and Invert displays are selected, the waveform displayed is the difference between the Channel 1 and Channel 2 signals. The INVERT button also inverts the polarity of the signal output at the CH 2 SIG OUT connector on the rear panel. At the same time, the Channel 2 trigger-signal polarity is inverted so that if CH 2 is selected as the TRIGGER SOURCE, the displayed slope will agree with the TRIGGER SLOPE setting.

When multiple channels are selected, they are displayed sequentially in order of priority. The established priority order is: CH 1, CH 2, ADD, CH 3, then CH 4.

(15) **CHOP/ALT Button**

Selects the vertical display mode for multiple-channel displays.

CHOP/ALT has no effect on the switching rate of X-Y function displays. If more than one vertical display is selected for X-Y, the display switches at 2.5 MHz.

CHOP

When more than one channel is selected, the vertical display switches sequentially through the selected channels at the chop-switching rate.

When more than one channel is selected, if the SEC/DIV setting for the displayed sweep is in the range of 20 μs/div to 2 μs/div, each channel is displayed for 400 ns. Otherwise, each channel is displayed for 1 μs. The chop switching rate is desynchronized from sweep repetitions to minimize waveform breaks when viewing repetitive signals.

ALT — When more than one channel is selected, the vertical display switches sequentially through the selected channels. Alternate switching occurs during sweep-retrace times. If both A and B Sweeps are displayed, in Alt horizontal mode, alternate switching occurs at the completion of the B Sweep. The Alt vertical mode enables a slaved delta-time mode for measuring time intervals between two channels. In the slaved delta-time mode, the first selected display in the sequence is displayed with the delta reference delay and the second selected display in the sequence is displayed with the delta delay. Any additional channels are displayed with both delays. The slaved delta-time mode also requires the following control conditions: either Δt or $1/\Delta t$ selected, Inten or Alt horizontal displays or B horizontal display with the dual delays and not cursors, multiple vertical displays, and a single A-Sweep trigger source.

(16) **20 MHz BW LIMIT Button** — Limits the bandwidth of the vertical deflection system to 20 MHz. Full instrument bandwidth is available when the bandwidth limit function is off. Neither the trigger signals nor the output from the CH 2 SIG OUT connector are affected by the 20 MHz BW LIMIT.

Refer to Figure 5-3 for the location of items 17 through 20.

(17) **VAR Controls** — Provide continuously variable, uncalibrated deflection factors between the calibrated settings of the VOLTS/DIV switches. These controls vary the deflection factors from calibrated (fully clockwise detent position) to at least 2.5 times the calibrated deflection factor (fully counterclockwise position). When out of the calibrated detent, a greater than (>) sign appears in front of the associated VOLTS/DIV readout display.

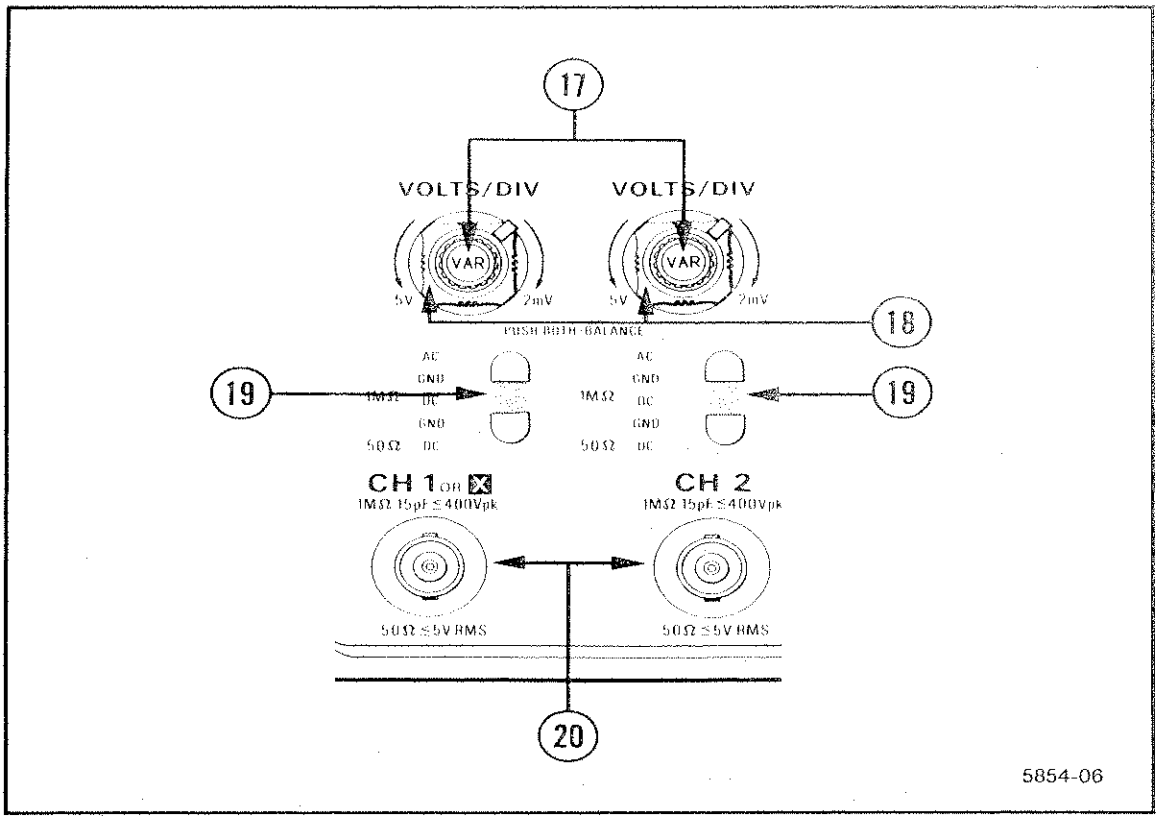


Figure 5-3. Channel 1 and Channel 2 controls and connectors.

(18) **VOLTS/DIV Switches**

Selects vertical deflection factor settings in a 1-2-5 sequence with 11 positions. The VAR control must be in the detent (fully clockwise) position to obtain a calibrated deflection factor. Basic deflection factors are from 2 mV per division to 5 V per division. The switches can rotate continuously, but have no effect beyond the extreme settings. Deflection factors shown in the crt readout reflect actual deflection factors in use when Tektronix attenuation-coded probes are connected to the inputs.

(19) **Input Coupling Buttons and Indicators**

Select the method of coupling input signals to the Channel 1 and Channel 2 and indicate the selection made. If the upper Channel 1 and Channel 2 Input Coupling buttons are both pressed together, the instrument automatically performs a dc balance of Channel 1 and Channel 2 vertical circuitry.

1 MΩ AC — Input signal is capacitively coupled to the vertical attenuator. The dc component of the input signal is blocked. The low-frequency limit (−3 dB point) is 10 Hz or less when using either a 1X probe or a coaxial cable and is 1 Hz or less when using a properly compensated 10X probe.

1 MΩ GND — The input of the vertical amplifier is grounded to provide a zero (ground) reference-voltage display. Input resistance is 1 MΩ to ground. This input selection allows precharging of the input-coupling capacitor to prevent a sudden shift of the trace if AC input coupling is selected later. The input signal is not grounded. If the input coupling of a channel selected as an A-Trigger source is set at GND, the A Sweep free runs. However, when A TRIGGER SOURCE is set to VERT and the Add vertical display is selected, the sweep free runs only if both Channel 1 and the Channel 2 input couplings are set to GND.

1 MΩ DC — All frequency components of the input signal are coupled to the vertical. Input resistance is 1 MΩ to ground.

1 MΩ GND — In this position, the instrument operates the same as previously described.

50 Ω DC — All frequency components of the input signal are coupled to the vertical, with the input terminated by 50 Ω to ground. If excessive signal is applied to either the CH 1 or the CH 2 input connector while 50 Ω DC input coupling is selected, input coupling will revert to 1 MΩ GND and a crt readout will indicate the overloaded condition. Changing the input coupling of the affected channel removes the overload the message. While power is off, coupling is at 1 MΩ GND.

(20) CH 1 OR X and CH 2 Input

Provide for application of external signals to the inputs of Channel 1 and Channel 2 vertical attenuators. A signal applied to the CH 1 OR X connector provides the horizontal deflection for an X-Y display. Any one or all of the channels (including Channel 1) may supply the signal for the X-Y display vertical deflection. These connectors each include a coding-ring contact for Tektronix-coded probes.

Refer to Figure 5-4 for the location of items 21 through 25.

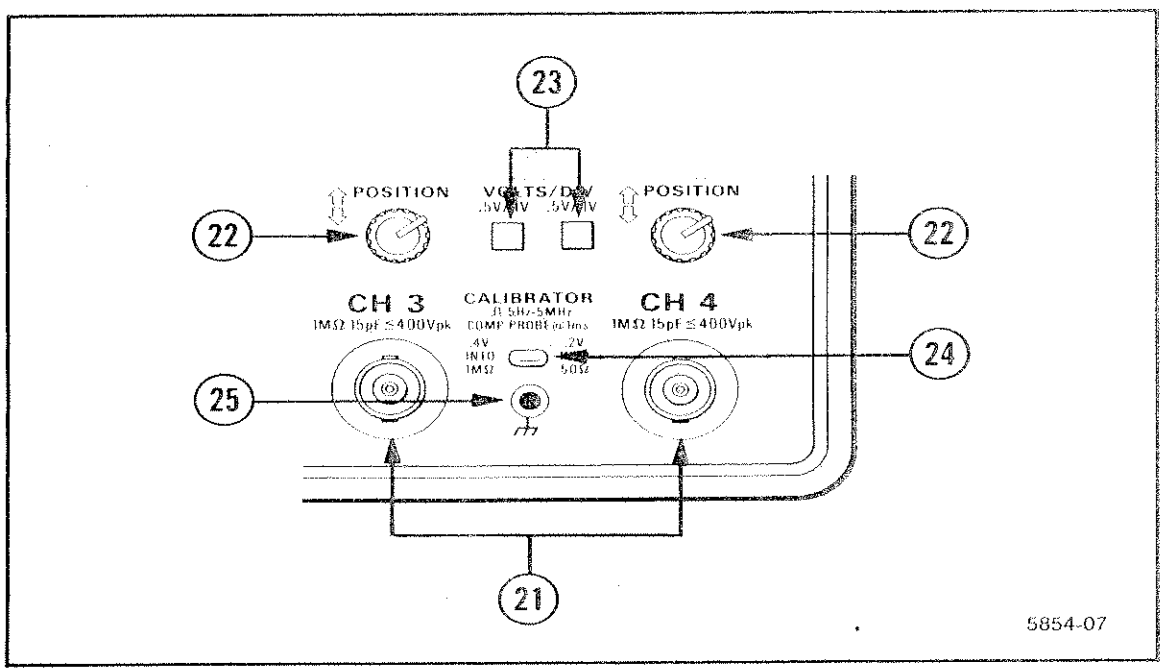


Figure 5-4. CH 3 and CH 4 controls and connectors and CALIBRATOR output.

(21) CH 3 and CH 4 Input Connectors

Provide for application of external signals to Channel 3 and Channel 4. Input coupling from these connectors is DC only. Coding-ring contacts, identical in operation to the CH 1 OR X and CH 2 input connectors, are also provided. Channel 3 and Channel 4 are most useful as digital signal and trigger signal input channels, given their limited choice of deflection factors.

(22) **POSITION Controls**

Set vertical position of the Channel 3 and Channel 4 signal displays. The controls operate identically to the Channel 2 POSITION control, but with less range on their associated traces.

(23) **VOLTS/DIV Switches**

Selects either of two basic deflection factors for Channel 3 and Channel 4. The basic deflection factor (using a 1X probe or a coaxial cable input connection) is 0.1 V per division; alternately, the deflection factor is 0.5/ V per division.

(24) **CALIBRATOR Connector**

Provides a 0.4-V p-p square-wave signal into a 1 MΩ load, a 0.2-V p-p square-wave signal into a 50 Ω dc-coupled load, or an 8-mA p-p square-wave current signal into a short circuit. The CALIBRATOR output signal is useful for checking the sweep, the delays, and the vertical deflection accuracies, as well as compensating voltage probes and checking the accuracy of current probes. The repetition rate of the square wave changes with the setting of the A SEC/DIV switch. For all sweep-speed settings from 100 ms per division to 100 ns per division, the A Sweep display, as seen on the instrument supplying the CALIBRATOR signal, will be five cycles per 10 divisions. At 100 ms per division and slower, the CALIBRATOR frequency will be 5 Hz; at 100 ns per division and faster, the frequency will be 5 MHz. The signal amplitude at 5 MHz will be at least 50% of the signal amplitude obtained when the sweep speed is set to 1 ms per division.

NOTE

Due to internal circuitry constraints, the calibrator signal is not synchronized during trace holdoff. This does not affect the accuracy of the calibrator signal that is present during a trace display. However, if the CALIBRATOR signal is used to calibrate other instruments, the sweep of the instrument must be shut off. If it is not, the signal will appear to jitter and will give false (low) frequency counts. The sweep of the instrument is easily shut off by setting TRIGGER MODE to SGL SEQ.

(25) **Auxiliary Ground Jack** — Provides an auxiliary signal ground when interconnecting equipment under test and the oscilloscope. Hookup is made via a banana-tip connector.

Horizontal

Refer to Figure 5-5 for the location of items 26 through 35.

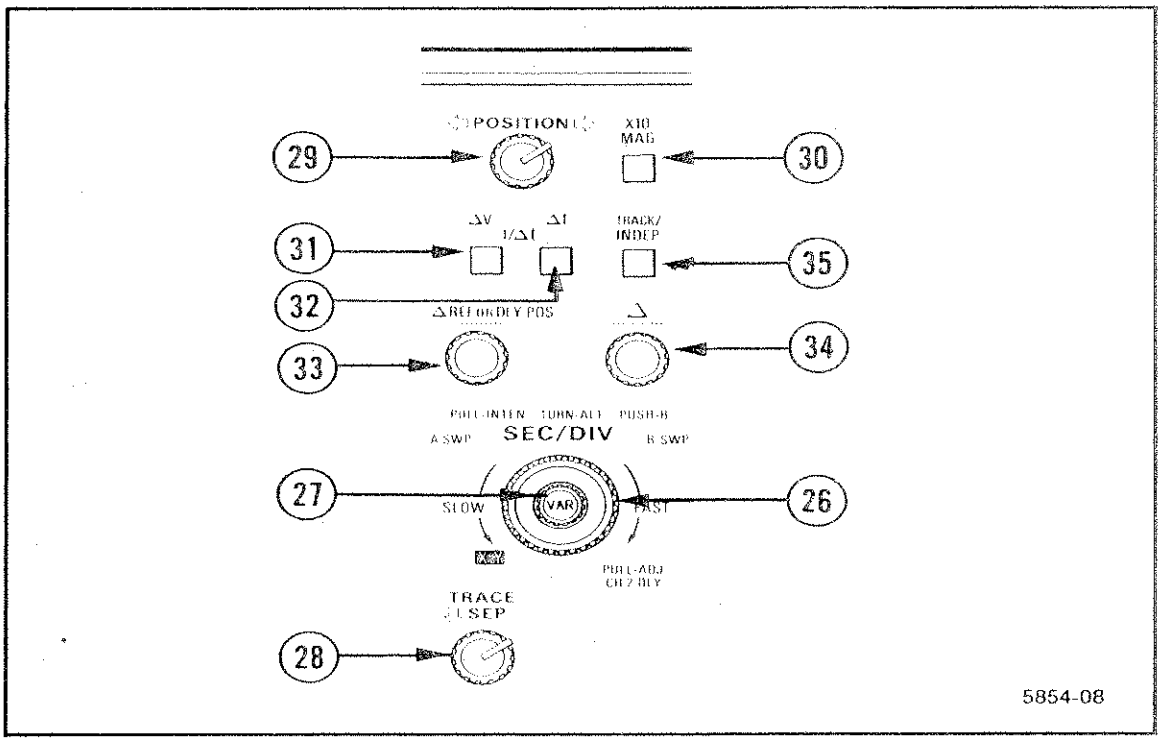


Figure 5-5. Horizontal and delta measurement controls.

(26) **SEC/DIV Switch and Indicators** — Selects A Sweep speeds, B Sweep speeds, Delay Time ranges, horizontal display mode, and CH 2 Delay Matching mode. The SEC/DIV switch can be rotated continuously in either direction, but further rotation has no effect when either extreme setting has been reached. The A SWP and B SWP indicators show which sweep or sweeps are displayed.

A SEC/DIV When the A-Sweep is displayed without the B-Sweep, it selects 25 calibrated A Sweep speeds or delay times from 500 ms/div to 5 ns/div in a 1-2-5 sequence. Full counterclockwise rotation of the SEC/DIV switch selects the X-Y display feature. In X-Y, the CH 1 OR X input drives the horizontal deflection system.

B SEC/DIV When the B-Sweep is displayed, the SEC/DIV switch selects B-Sweep speeds in 22 calibrated steps from 50 ms/div to 5 ns/div in a 1-2-5 sequence.

Horizontal Display Mode Selection (PULL-INTEN TURN-ALT PUSH-B):

A When the B Sec/Div setting is equal to the A Sec/Div setting, with the SEC/DIV knob in or when the knob is pushed in while the Intensified display is selected, only the A Sweep is displayed.

PULL-INTEN Pulling the SEC/DIV knob out while the A Sweep is displayed selects the Intensified horizontal display mode and cancels the Delta Volts function if it is active. The A Sweep display intensifies for the duration of the B Sweep time. The B Sweep is not displayed, but it runs either 100 times faster than the A Sweep or at 5 ns per division, whichever is slower. The Δ REF OR DLY POS control positions the B Sweep (intensified zone) on the A Sweep. In Alt horizontal display mode, setting B Sec/Div equal to A Sec/Div also selects the Intensified horizontal display mode.

With single channel or chopped vertical displays, or with multiple A trigger sources and Δt or 1/Δt, two intensified zones appear on each A Sweep trace. The Δ REF OR DLY POS control positions one zone and the Δ control positions the second zone, provided the B trigger mode is set at RUN AFT DLY. If the B Sweep is triggered (TRIG AFT DLY), the positions of the intensified zones are determined by the first triggering events that occur after the delay times have elapsed.

With multiple vertical displays, Alt vertical mode, and a single A-Trigger source (CH 1, CH 2, ADD, CH 3, or CH 4), the intensified zones appear as follows:

1. The reference zone appears on the first selected trace in the display sequence: CH 1, CH 2, ADD, CH 3, CH 4.
2. The delta zone appears on the second selected trace.
3. Both zones appear on additional traces when more than two traces are selected.

Pulling the SEC/DIV switch knob out at the fastest A Sec/Div rate selects the CH 2 delay offset adjustment. The readout displays one of two messages: "CH 2 DLY-TURN Δ" or "CH 2 DLY DISABLED." If the adjustment is not disabled, the Δ control or the Δ REF control can adjust the apparent delay between the Channel 1 signal and the Channel 2 signal. The adjustment range is sufficient to compensate for propagation delay variations up to + or −500 ps. Adjusting the delay offset between Channel 1 and Channel 2 signals has no effect on the common-mode rejection between Channel 1 and Channel 2.

TURN-ALT When the SEC/DIV knob is out, clockwise rotation activates the Alternate Horizontal Display mode. The Alt mode presents the intensified A Sweep alternating with the delayed B Sweep. The position of the intensified zone on the A Sweep indicates the time position of the B Sweep, and the length of the intensified zone indicates the B Sweep duration. A separate B Sweep runs for each intensified zone.

PUSH-B In the Alt horizontal display mode, pushing in the SEC/DIV knob displays only B Sweeps.

When the B Sweep speed is set equal to the A Sweep speed in Alt or B display mode, the mode changes from B to A or from Alt to Inten.

(27) **VAR Control** — Continuously varies the sweep speed between SEC/DIV switch settings, for either the A Sweep or B Sweep. The detent position (full clockwise rotation) produces the basic sweep speed selected by the SEC/DIV switch. The fully counterclockwise position slows the sweep by a nominal factor of three. The crt readout displays the actual time-per-division scale factor for all settings of the VAR control.

The VAR control affects the scale factor of the A Sweep with the A Sweep display. When the Intensified A Sweep or the B Sweep is displayed, the control affects only the B Sweep scale factor.

(28) **TRACE SEP Control** — Positions the B trace downward from the A trace in Alt horizontal display mode. In the B horizontal display mode, with dual delays associated with Δt or $1/\Delta t$, TRACE SEP positions the trace associated with the Δ control downward. At the fully clockwise position, there is no separation between the traces.

(29) **POSITION Control** — Horizontally positions the sweep displays.

(30) **X10 MAG Button** — Horizontally magnifies the portion of the sweep display positioned at the center vertical graticule line by a factor of 10. When in Alt or B horizontal display mode, only the B Sweep is affected.

Delay and Delta Controls

The ΔV, Δt, and TRACK/INDEP buttons, with the Δ REF OR DLY POS and Δ rotary controls, are used to make voltage, time, frequency, ratio, and phase measurements. These controls also affect the SAVE and RECALL functions and the CH 2 DLY matching function. The available measurement options give these controls additional functions.

(31) ΔV Button

Activates the Delta Volts measurement function and cancels the Δt or 1/Δt measurement function. When the ΔV function is active, two horizontal cursors are superimposed on the display. The crt readout shows the equivalent voltage between the two cursors. Cursors are positioned by the Δ REF OR DLY POS control and the Δ control. With multiple vertical displays, the deflection factor of the first selected channel in the display sequence determines the cursor scale factor. The cursor readout is displayed as a percent RATIO under either of the following conditions:

1. When the VOLTS/DIV VAR control of the channel determining the scale factor is out of the detent position.
2. When the Add vertical display mode is selected alone and the Channel 1 and Channel 2 VOLTS/DIV settings are not the same.

Pressing the ΔV button when the function is active cancels ΔV. Changing the horizontal display mode from A to Inten or from B to Alt also cancels the Delta Volts function.

(32) Δt Button

Activates the Delta Time measurement function and cancels the ΔV or 1/Δt measurement functions. When Δt is selected with Inten or Alt horizontal display modes, two delay times are defined. When Δt is selected with either A Sweep or B Sweep horizontal display, two vertical cursors are established. One delay time or cursor position is controlled by the Δ REF OR DLY POS control, and the other is controlled by the Δ control. The crt readout displays either the difference between the two delay times or the equivalent time between the vertical cursors.

If the SEC/DIV VAR control is not in the detent position, and either the A Sweep or the B Sweep horizontal display mode is selected, the crt readout displays the difference as a ratio, where five divisions correspond to 100% ratio.

When Δt is active, pressing the Δt button deactivates the function.

1/Δt Function

Momentarily pressing both the Δt and ΔV buttons activates the 1/Delta Time function and cancels the other Delta measurement functions. The waveform display and operation of the Delta controls are the same as for Δt operation, but the readout shows the reciprocal of the time difference in units of frequency.

If the SEC/DIV VAR control is not in the detent position (full clockwise rotation), and the A Sweep or B Sweep horizontal display mode is selected, the readout displays the time difference as degrees of phase, where five divisions are equal to 360 degrees.

When the 1/Delta Time function is active, pressing both the Δt and ΔV buttons together deactivates the function.

(33) **Δ REF OR DLY POS Control**

Sets the B-Sweep Delay Position. It sets the reference B Sweep delay or positions the reference cursor when Δt or 1/Δt is active. When any cursor mode is active, the Δ REF OR DLY POS control positions the reference cursor and has no effect on B Sweep delay.

(34) **Δ Control**

Positions the alternate B Sweep delay or time cursor (vertical line) when either the Delta Time or 1/Delta Time measurement mode is active. When ΔV is active, the Δ control positions one of the two cursors.

Sweep Delay Time (DLY), Delta Voltage (ΔV), Delta Time (Δt), and 1/Delta Time (1/Δt) Readouts:

Each of these readouts includes a function name, a signed, floating-point numeral, and the appropriate unit symbol. Numerals are displayed with larger sized characters. A numeral immediately following "ΔV" indicates which channel provides the delta voltage scaling, the lowest numbered of the displayed channels. Sweep Delay Time is displayed for the Inten, Alt, and B horizontal display modes when none of the delta functions are selected.

A question mark between the Δt or the 1/Δt function label and the associated numeral during Inten, Alt, or B Horizontal displays indicates that one of the sweep delay settings is less than 1% of maximum delay setting or that the B trigger mode is TRIG AFT DLY. A question mark between DLY and the delay time numeral indicates that the setting is less than 1% of the maximum delay or that the B trigger mode is TRIG AFT DLY. A question mark also appears after the ΔV function label when the function applies to CH 3 or CH 4.

The lowest 0.5% of the range of Delay Time is suppressed to zero. Higher readings are offset by −0.5% of the true range. This offset compensates for the nominal offset of delay time settings and is required to assure that the A Sweep triggering event is viewable at minimum delay.

(35) **TRACK/INDEP Button**

Selects either the Tracking or Indep (independent) mode for the Δ REF OR DLY POS control. When in the Tracking mode, the difference between alternate delay times or cursors (in either time or volts measurement mode) does not change with rotation of the Δ REF OR DLY POS control. When the Δ REF OR DLY POS control is rotated, the positions of both delays or of both cursors move equally until the limit of either is reached.

If INDEP is selected, the cursors (or delay positions) are independently movable using the Δ REF OR DLY POS and Δ controls. In either mode (Tracking or Indep) the Delta cursor remains independently movable using the Δ control.

Trigger

Refer to Figure 5-6 for the location of items 36 through 45.

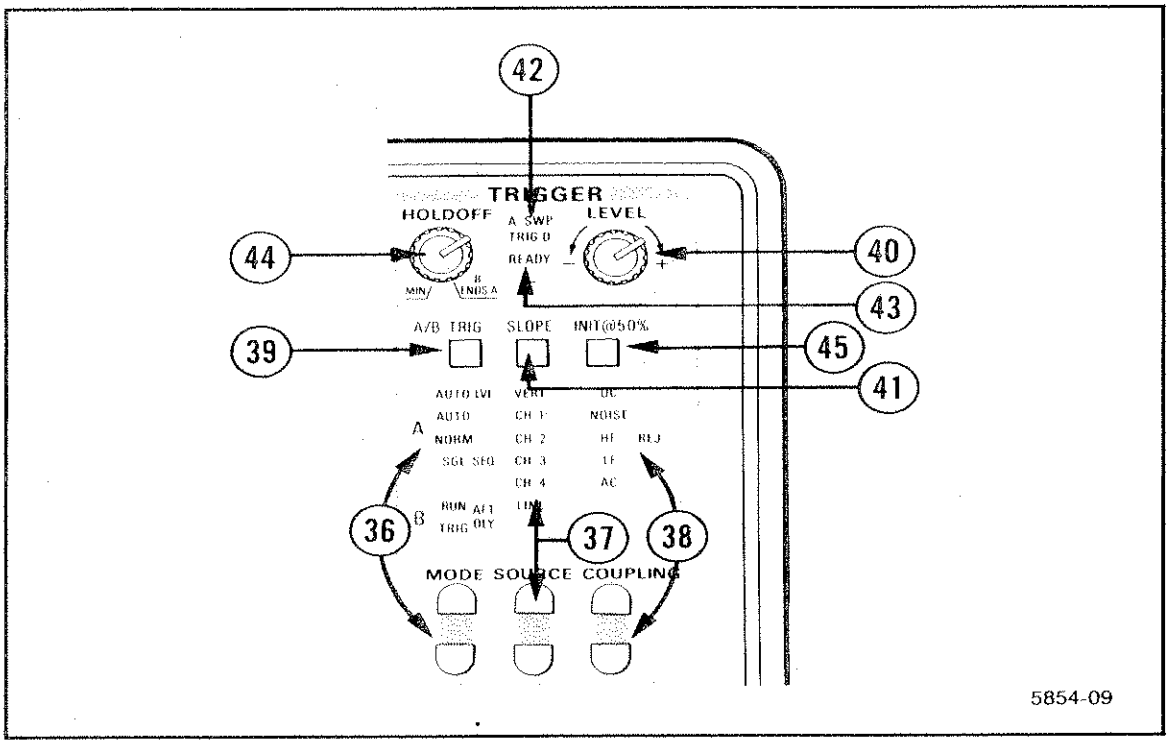


Figure 5-6. Trigger controls and indicators.

(36) **MODE Button and Indicators** Select the trigger mode of either the A Sweep or the B Sweep. A single push of a button steps the MODE selection once; holding the button causes the MODE selection to step repeatedly. Indicators show the selected trigger mode of either the A Sweep or the B Sweep according to the selected horizontal display mode and as directed by the A/B TRIG button.

A Trigger Modes:

AUTO LVL — Automatically establishes the trigger level on a triggering signal and free runs the sweep in the absence of a triggering signal.

In Auto Lvl mode, LEVEL covers the range between the positive and negative peaks of repetitive triggering signals. If the triggering signal amplitude changes, the trigger level does not change unless a trigger is no longer produced at the established level. The signal peaks are measured and the trigger level is redefined when triggering ceases, the LEVEL control is turned to either extreme, or the upper MODE button is pressed. If the LEVEL control is set near either end position, the trigger level is set near the corresponding signal peak. If LEVEL is in the midrange between either end, the trigger level set by AUTO LVL is near the midpoint between the trigger signal peaks. When INIT@50% is pressed, the trigger level is set near the midpoint of the signal, regardless of the setting of LEVEL. The established trigger level remains in effect when switching to Auto trigger mode.

To obtain triggered sweeps, the triggering signal repetition rate must be greater than a nominal limit, depending on the selected sweep speed.

With Auto Lvl mode and Vert trigger source, the lowest numbered channel displayed or Add, if it is displayed, provides the trigger signal. When the trigger mode is changed from Auto Lvl to Auto while more than one channel is displayed, the single channel trigger source is retained and the VERT indicator is turned off unless Add is being displayed. When Add is displayed, Vert source is retained when trigger mode changes to Auto.

AUTO Sweep free runs in the absence of a triggering signal. The trigger level changes only when the LEVEL control is adjusted to a new position or when INIT@50% is pressed.

NORM Sweep is triggered and runs when an adequate triggering signal is applied. In the absence of an adequate triggering signal, the A Sweep does not run, except when the input coupling of the trigger source channel is set to GND. If the selected source is Vert, and the Add vertical display is selected, the A Sweep free runs if Channel 1 and Channel 2 input coupling are both set to GND.

SGL SEQ — When armed by pushing the lower MODE button, the sweep runs once for each of the traces defined by the following controls: Vertical MODE, A and B SEC/DIV, and Δt or 1/Δt. Each sweep requires a distinct A-Sweep triggering event. The READY indicator remains illuminated until the final trace in the sequence is completed. At the end of the display sequence, scale-illumination flashes and the readout display is written once to present the scale factors and other readout data.

B Trigger Modes:

RUN AFT DLY — The B Sweep runs immediately after the delay time set by the A SEC/DIV, the Δ REF OR DLY POS, and the Δ controls.

TRIG AFT DLY — The B Sweep runs when triggered after the set delay, determined by the same controls as for RUN AFT DLY, provided the A Sweep has not terminated.

(37) **SOURCE Buttons and Indicators** — Select the trigger signal source for either the A or the B Sweep.

VERT — The sweep triggers on the displayed channel when only one channel is selected. If multiple vertical displays are selected, both the trigger mode and the Chop/Alt selection affect the triggering source. With Alt vertical mode and with A trigger modes other than Auto Lvl, each displayed channel in turn provides the triggering signal and the respective LED indicator for each displayed channel is illuminated. For Auto Lvl triggering, the lowest-numbered channel, or ADD if it is displayed, is the triggering-signal source. When Chop vertical mode is selected, Vert trigger source triggering selection is identical to that obtained with Auto Lvl mode. The SOURCE indicators show the source of the triggering signal in any case. When ADD is selected, both the CH 1 and the CH 2 indicators are illuminated.

CH 1, CH 2, CH 3, or CH 4 — A triggering signal is obtained from the corresponding vertical channel.

LINE (A Trigger Only) — A triggering signal is obtained from a sample of the ac power-source waveform. This trigger source is useful when vertical input signals are time related (multiple or submultiple) to the frequency of the ac power-source voltage.

(38) **COUPLING Buttons and Indicators** — Select the method of coupling the triggering signal to the A and B trigger generator circuitry.

DC — All frequency components of the signal are coupled to the trigger-generator circuitry. This coupling method is useful for triggering on most signals.

NOISE REJ — All frequency components of the input signal are coupled to the trigger-generator circuitry. This coupling method is useful for improving trigger stability of signals accompanied by low-level noise.

HF REJ — Attenuates high-frequency triggering-signal components above 50 kHz. This coupling method is useful for eliminating radio-frequency interference and high-frequency noise components from the signal applied to the trigger-generator circuitry; it allows stable triggering on the low-frequency components of a complex waveform.

LF REJ — Signals are capacitively coupled, and the dc component of the triggering signal is blocked. Attenuates the low-frequency signal components below 50 kHz. This coupling method is useful for producing stable triggering on the high-frequency components of a complex waveform. Low-frequency components such as power-supply hum are removed from the signal applied to the trigger-generator circuitry.

AC	Signals are capacitively coupled. Frequency components below 60 Hz are attenuated, and the dc component of the input signal is blocked. This coupling method is useful for signals that are superimposed on slowly changing dc voltages. This method will work for most signals when trigger-level readout is not desired.
(39) **A/B TRIG Button**	The MODE, SOURCE, COUPLING, SLOPE, LEVEL, and INIT@50% controls are normally directed to the A trigger. They are directed to the B trigger with Inten, Alt, or B Sweep horizontal displays, if B mode is Trig Aft Dly. The trigger controls are directed to the opposite trigger while the A/B TRIG button is pushed in. With Inten, Alt, or B Sweep horizontal displays, and with the B TRIGGER MODE set to RUN AFT DLY or with A TRIGGER MODE set to SGL SEQ, the trigger controls are alternately directed to the A or B trigger each time the button is pushed.
(40) **LEVEL Control**	Sets the amplitude point on the triggering signal at which A Sweep or B Sweep triggering occurs. When the A trigger mode is set to Auto Lvl, the effect of the LEVEL control is spread over the triggering signal amplitude from peak to peak. When the control is rotated to either extreme, the peak values are measured, and the control range is redefined to correspond to the peak values. If LEVEL is fully clockwise, the initial level is near the positive peak. If LEVEL is fully counterclockwise, the initial level is near the negative peak.
(41) **SLOPE Button and Indicators**	Determines whether the A or B Sweep is triggered on the positive-going or the negative-going slope of the triggering signal.
(42) **A SWP TRIG'D Indicator**	Illuminates to indicate that the A Sweep is triggered. It extinguishes after a nominal length of time when a triggering signal is not received following completion of the sweep.

(43) **READY Indicator** — Illuminates when Sgl Seq mode is selected and the A Sweep is armed and waiting for a triggering event to occur. It extinguishes following the completion of all the traces selected for the Sgl Seq display.

(44) **HOLDOFF Control** — Varies the amount of holdoff time between the end of the sweep and the time a triggering signal can initiate the next sweep. The ability to obtain stable triggering on some aperiodic signals is improved using this control. In the B ENDS A position (fully clockwise) trigger holdoff time is reduced to minimum, and A Sweep terminates immediately at the end of the B Sweep. This enables the fastest possible sweep-repetition rate at slow A Sweep speeds.

(45) **INIT@50% Button** — Initializes the trigger level at the midpoint between peaks, for either the A trigger or B trigger, in any mode.

If Vert trigger source is selected and more than one channel is displayed, INIT@50% automatically sets the trigger source to the lowest numbered of the displayed channels. If Sgl Seq mode is selected, the A trigger mode changes to Norm.

Rear Panel

Refer to Figure 5-7 for the location of items 46 through 53.

(46) **A GATE OUT and B GATE OUT Connectors** — Provide TTL-compatible, positive-going gate signals that are HI during their respective sweeps and LO while the sweep is not running. When the A SEC/DIV switch is set to 5 ns per division, an output gate is present at both the A GATE OUT and the B GATE OUT connectors.

(47) **Line Voltage Selector Switch** — Selects either 115 V or 230 V nominal ac-power-source voltage operation.

(48) **EXT Z-AXIS IN Connector** — Provides an input point to apply external signals to intensity modulate the display.

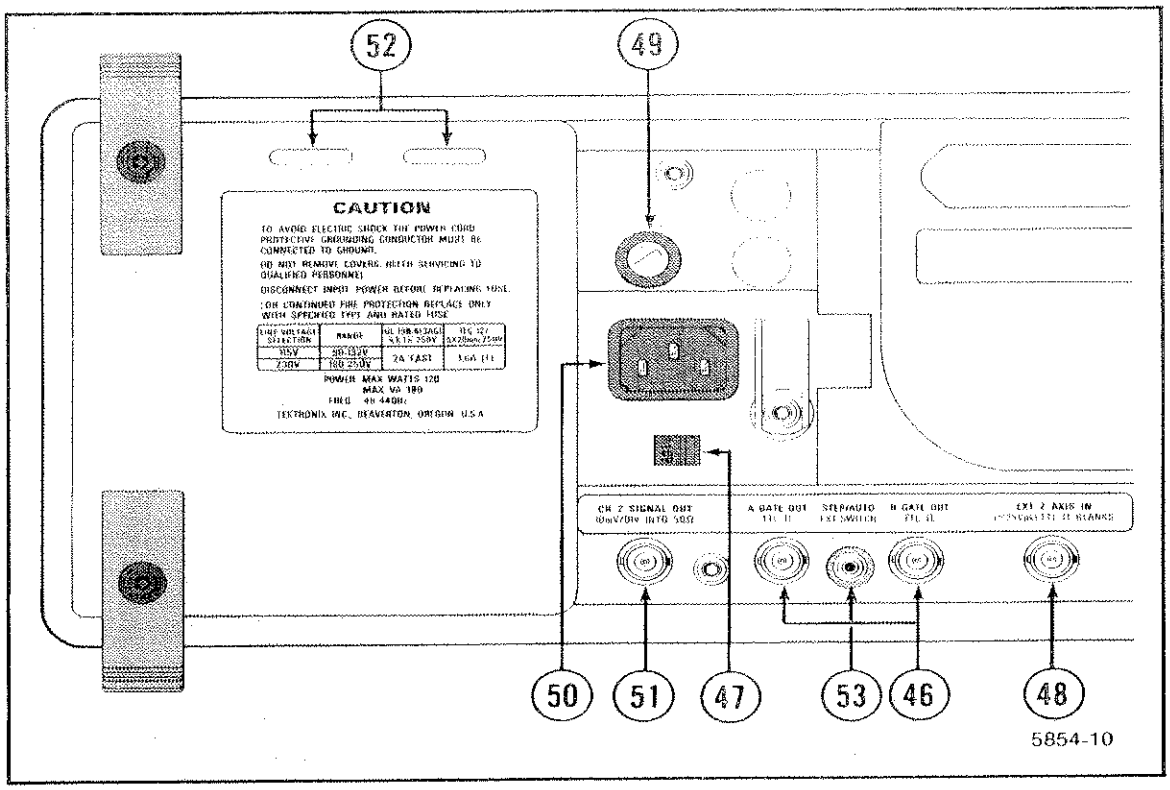


Figure 5-7. Rear panel controls and connectors.

(49)	**Fuse Holder**	Contains the ac power-source fuse.
(50)	**Detachable Power Cord Receptacle**	Provides the connection point for the ac power source to the instrument.
(51)	**CH 2 SIGNAL OUT Connector**	Provides an output signal that is a normalized representation of the Channel 2 input signal.
(52)	**Mod Slots**	Contains the identification numbers of any installed instrument modification.
(53)	**STEP/AUTO EXT Switch Connector**	A connector on the rear panel accepts a standard, cassette-recorder-style, remote-control switch. A contact closure at this input produces the same effect as operating the STEP/AUTO button.

Performance Conditions

The following electrical characteristics (Table 6-1) are valid for the instrument 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 −15°C and +55°C (unless otherwise noted).

Items listed in the "Performance Requirements" column define the measurement capabilities of the instrument.

Environmental characteristics are given in Table 6-2. The oscilloscope meets the environmental requirements of MIL-T-28800C for Type III, Class 3, Style C equipment, with the humidity and temperature requirements defined in paragraphs 3.9.2.2, 3.9.2.3, and 3.9.2.4.

Mechanical characteristics are listed in Table 6-3.

Table 6-1
Electrical Characteristics

Characteristics	Performance Requirements
VERTICAL DEFLECTION SYSTEM—CHANNEL 1 AND CHANNEL 2	
Deflection Factor	
Range	2 mV/division to 5 V/division in a 1-2-5 sequence of 11 steps.
Accuracy	
+15°C to +35°C, 1 MΩ input, noninverted	
On-Graticule Accuracy	Within ±2% at any VOLTS/DIV setting for a four or five-division signal centered on the screen.
ΔV Accuracy (using cursors over entire graticule area)	±(1.25% of reading +0.03 div + signal aberrtions).
−15°C to +15°C and +35°C to +55°C	Add 2% to +15°C to +35°C specification.
50 Ω Coupling	Add 1% to +15°C to +35°C specification.
CH 2 Inverted	Add 1% to +15°C to +35°C specification.
ΔV Range	±8 times the VOLTS/DIV setting.
V/DIV VARiable, noninverted	Continuously variable between VOLTS/DIV settings. Extends deflection factor to >12.5 V/division.
AC Coupled Lower −3 dB Point	
1X Probe	10 Hz or less.
10X Probe	1 Hz or less.
Step Response Rise Time	≤1 ns (calculated from $T_r = 0.35/BW$).
Common-mode Rejection Ratio (CMRR) (ADD Mode with Channel 2 inverted)	At least 20:1 at 50 MHz for common-mode signals of eight divisions or less, with VAR VOLTS/DIV control adjusted for best CMRR at 50 kHz at any VOLTS/DIV setting.

Table 6-1 (cont)

Characteristics	Performance Requirements
Displayed Channel 2 Signal Delay with Respect to Channel 1 Signal	Adjustable through a range of at least −500 ps to +500 ps.
Frequency Response (3 dB bandwidth)	
−15°C to +35°C	
−3 dB bandwidth with standard accessory probe or internal 50 Ω termination	Dc to 350 MHz.
−4.7 dB bandwidth with 50 Ω external termination on 1 MΩ input	Dc to 350 MHz.
+35°C to +55°C	
−3 dB bandwidth with standard accessory probe or internal 50 Ω termination	Dc to 300 MHz.
−4.7 dB bandwidth with 50 Ω external termination on 1 MΩ input	Dc to 300 MHz.
Input R and C (1 MΩ)	
Resistance	1 MΩ ±0.5%.
Capacitance	15 pF ±2 pF.
Maximum Input Voltage ⚠	
DC, AC, or GND Coupled	400 V (dc + peak ac). 800 V p-p ac at 10 kHz or less.
Input R (50 Ω)	
Resistance	50 Ω ±1%.
VSWR	<1.3:1 for Dc to 300 MHz. <1.5:1 for 300 MHz to 350 MHz.
Maximum Input Voltage ⚠	5 V rms, averaged for 1 second; ±50 V peak.

Table 6-1 (cont)

Characteristics	Performance Requirements
Channel Isolation	⩾100:1 attenuation of deselected channel at 100 MHz; ⩾50:1 at 350 MHz, for an eight-division input signal from 2 mV per division to 500 mV per division, with equal VOLTS/DIV settings on both channels.
Cascaded Operation	
Bandwidth (3 dB)	Dc to 50 MHz or more.
Deflection Factor	400 μV per division ±10%.
VERTICAL DEFLECTION SYSTEM—CHANNEL 3 AND CHANNEL 4	
Deflection Factor	
Values	100 mV and 500 mV per division.
Accuracy	Within ±10%.
Frequency Response (3 dB bandwidth)	
−15°C to +35°C	
−3 dB bandwidth with standard accessory probe	Dc to 350 MHz.
−4.7 dB bandwidth with 50 Ω external termination	Dc to 350 MHz.
+35°C to +55°C	
−3 dB bandwidth with standard accessory probe	Dc to 300 MHz.
−4.7 dB bandwidth with 50 Ω external termination	Dc to 300 MHz.
Step Response Rise Time	⩽1 ns (calculated from $T_r = 0.35/BW$).
Channel Isolation	⩾50:1 attenuation of deselected channel at 100 MHz with an 8-division input signal.
Signal Delay Between Channel 1 and Either Channel 3 or Channel 4	Within ±0.5 ns, measured at the 50% points.

Table 1-1 (cont)

Characteristics	Performance Requirements
Input R and C	
Resistance	1 MΩ ±1%.
Capacitance	15 pF ±3 pF.
Maximum Input Voltage ⚠	400 V (dc + peak ac). 800 V p-p ac at 10 kHz or less.
VERTICAL DEFLECTION SYSTEM—ALL CHANNELS	
Low-frequency Linearity	0.1 division or less compression or expansion of a two-division, center-screen signal when positioned anywhere within the graticule area.
Bandwidth Limiter	Reduces upper 3 dB bandpass to a limit of 13 MHz to 24 MHz.
Vertical Signal Delay	At least 30 ns of the sweep is displayed before the triggering event is displayed at any SEC/DIV ≥10 ns/div. At 5 ns/div, at least 10 ns of the sweep is displayed before the triggering event.
Chopped Mode Switching Rate	With displayed SEC/DIV in the 20 μs to 2 μs/div, the switching rate is 2.5 MHz ±0.2%. Otherwise, the switching rate is 1 MHz ±0.2%. The display cycle rate equals the chop switching rate divided by the number of channels displayed. The chop switching rate is modulated slightly to minimize waveform breaks with repetitive signals.
TRIGGERING	
Minimum P-P Signal Amplitude for Stable Triggering from Channel 1 or Channel 2 Source	
DC Coupled	0.35 division from dc to 50 MHz, 1.0 division at 300 MHz, and 1.5 divisions at 500 MHz.
NOISE REJ Coupled	≤1.2 divisions from dc to 50 MHz, 3 divisions at 300 MHz, and 4.5 divisions at 500 MHz.

Table 6-1 (cont)

Characteristics	Performance Requirements
AC Coupled	0.35 division from 60 Hz to 50 MHz, 1.0 division at 300 MHz, and 1.5 divisions at 500 MHz. Attenuates signals below 60 Hz.
HF REJ Coupled	0.5 division from dc to 30 kHz.
LF REJ Coupled	0.50 division from 80 kHz to 50 MHz, 1.0 division at 300 MHz, and 1.5 divisions at 500 MHz.
Minimum P-P Signal Amplitude for Stable Triggering from CH 3 or CH 4 Source	0.5 × CH 1 or CH 2 requirement.
Minimum P-P Signal Amplitude for Stable Triggering from Composite, Multiple Channel Source, ALT Vertical Mode	Add one division to the single-channel source specifications.
Maximum P-P Signal Rejected by NOISE REJ COUPLING Signals Within the Vertical Bandwidth	
CH 1 or CH 2 SOURCE	≥0.4 division for VOLTS/DIV settings of 10 mV/div and higher.
CH 3 or CH 4 SOURCE	≥0.2 division.
Jitter	≤100 ps with 5 divisions of 300 MHz at 500 ps/division.
LEVEL Control Range	
CH I or CH 2 SOURCE	±18 × VOLTS/DIV setting.
CH 3 or CH 4 SOURCE	±9 × VOLTS/DIV setting.
AUTO LVL Mode Maximum Triggering Signal Period	
A SEC/DIV Setting	
<10 ms	At least 20 ms.
10 ms to 50 ms	At least four times the A-SEC/DIV setting.
50 ms	At least 200 ms.

Table 6-1 (cont)

Characteristics	Performance Requirements
AUTO LVL Mode Trigger Acquisition Time	Eight to 100 times the AUTO LVL Mode maximum triggering signal period, depending on the triggering signal period and waveform.
Trigger Holdoff	
Minimum	The greater of the A-SEC/DIV setting value or 1 μs, within +33% +500 ns to −10%.
Variable	Increases trigger holdoff time to 10 to 25 times the minimum holdoff.
LEVEL Readout Accuracy (for triggering signals with transition times greater than 20 ns)	
CH 1 or CH 2 SOURCE	
+15°C to +35°C	Within ±[3% of setting + 3% of p-p signal + 0.2 division + 0.5 mV + (0.5 mV × probe attenuation factor)] with Vertical Input at 1 MΩ DC, CH 2 Source Not Inverted, and Trigger DC Coupled.
−15°C to +35°C and +35°C to +55°C	Add 1.5 mV × probe attenuation to +15°C to +35°C specification.
50 Ω Input	Add ±1% to 1 MΩ input specification.
CH 2 Inverted	Add ±1% of setting to non-inverted specification.
NOISE REJ Coupled	Add ±0.6 division to DC Coupled specifications.
CH 3 or CH 4 SOURCE	
DC Coupled	Within ±[3% of setting + 4% of p-p signal + 0.1 division + (0.5 mV × probe attenuation factor)].
NOISE REJ Coupled	Add ±0.3 division to the DC Coupled specification.

Table 6-1 (cont)

Characteristics	Performance Requirements
AUTO Mode Maximum Triggering Signal Period	
A-SEC/DIV Setting	
<10 ms	At least 80 ms.
10 ms to 50 ms	At least 16 times the A-SEC/DIV setting.
>50 ms	At least 800 ms.
SLOPE Selection	Conforms to trigger-source waveform or ac power-source waveform.
HORIZONTAL DEFLECTION SYSTEM	
A Sweep Time Base Range	500 ms/div to 5 ns/div in a 1-2-5 sequence of 25 steps. X10 MAG extends maximum sweep rate to 500 ps/div.
B Sweep Time Base Range	50 ms/div to 5 ns/div in a 1-2-5 sequence of 22 steps. X10 MAG extends maximum sweep rate to 500 ps/div.
Timing Accuracy (+15°C to +35°C, A-Sweep, with SEC/DIV at 100 ms/div or faster)	
Sweep Accuracy Unmagnified	±(0.7% of time interval + 0.6% of full scale).
Δt Accuracy With Cursors, Unmagnified	±(0.5% of time interval + 0.3% of full scale).
Δt Accuracy with Sweep Delay	±(0.3% of time interval + 0.1% of full scale).
Delay Accuracy, A Sweep Trigger to Start of B-Sweep	±(0.3% of delay setting + 0.6% of full scale) +0 to −25 ns.
B-Sweep Accuracy and Δt Accuracy with Cursors on B-Sweep	Add ±0.3% of time interval to A-Sweep specifications.
X10 MAG Accuracy	Add ±0.5% of time interval to unmagnified Sweep and Δt Cursors specifications. Exclude the first 1 division after the sweep starts (the first 1% of the full 100 division sweep).
500 ms or 200 ms Division Timing Accuracy (A Sweep only)	Add ±0.5% of interval to specifications for A SEC/DIV at 100 ms or faster.

Table 6-1 (cont)

Characteristics	Performance Requirements
SEC/DIV VAR Timing Accuracy	Add 2% of time interval to sweep accuracy specifications when VAR is out of detent.
Timing Accuracy (−15°C to +15°C and +35°C to +55°C)	Add ±0.2% of time interval to all Δt and delay specifications. Add ±0.5% of interval to sweep accuracy specification.
Δt Readout Resolution	Greater of either 10 ps or 0.025% of full scale.
Δt Range	±10 times A-SEC/DIV setting with Cursors, ±9.95 times A-SEC/DIV setting with Sweep Delay.
Sweep Delay Range	0 to 9.95 times the A SEC/DIV setting, from 500 ms to 10 ns. A-Sweep triggering event is observable on B-Sweep with zero delay setting for A SEC/DIV settings 50 μs or faster.
Delay Jitter	Within 0.01% (one part or less in 10,000) of the maximum available delay, plus 100 ps.
X10 MAG Registration	Within 0.5 division from graticule center at 1 ms SEC/DIV setting (X10 MAG on to X10 MAG off).
Horizontal POSITION Range	Start of 1 ms per division sweep can be positioned from right of graticule center to at least 10 divisions left of graticule center. Some portion of 1 ms per division sweep is always visible with X10 MAG off.
Sweep Length	10.1 to 11.5 divisions at 1 ms per division. The A Sweep may be shorter with the Trigger HOLDOFF control in the B ENDS A position.

Table 6-1 (cont)

Characteristics	Performance Requirements
X-Y Operation	
X-Axis Deflection Factor Range, Variable, and Input Characteristics	Same as Channel 1.
Deflection Factor Accuracy	Same as Channel 1.
X-Axis Bandwidth	Dc to 3 MHz.
Phase Difference Between X and Y with BW Limit Off	≤1° from dc to 1 MHz; ≤3 ° from 1 MHz to 2 MHz.
X-Axis Low-frequency Linearity	0.1 division or less compression or expansion of a two-division, center-screen signal when positioned within the graticule area.
DISPLAY	
Cursor Position Range	
Delta Volts (ΔV)	At least the center 7.6 vertical divisions.
Delta Time (Δt)	At least the center 9.6 horizontal divisions.
Graticule	
Size	68 mm X 85 mm.
Markings	8 major divisions vertically and 10 major divisions horizontally, with auxiliary markings.
Trace Rotation Range	Adequate to align trace with the center horizontal graticule line.
Standard Phosphor	P31.
Visual Writing Speed with 20 Foot-Candles Illumination, Normal to the Crt Faceplate	≥4 divisions/ns. No more than 5 bright spots will be visible at maximum intensity. No bright-spot halo is allowed within the center 7x9 divisions. Additional bright spots may be visible after displaying a high-intensity trace. These added spots will extinguish when intensity is set to minimum.

Table 6-1 (cont)

Characteristics	Performance Requirements
Photographic Writing Speed with C30B Camera at F1.9 with ASA 3000 Film, not Prefogged	≥10 divisions/ns.
Display Intensity Limitation	Control settings and trigger rate are monitored to limit the display intensity after a time of no control activity.
Z-AXIS INPUT	
Sensitivity	Positive voltage decreases intensity. From dc to 2 MHz, +2 V blanks a maximum-intensity trace; from 2 MHz to 20 MHz, +2 V modulates a normal-intensity trace.
Maximum Input Voltage ⚠	±25 V peak; 25 V p-p ac at 10 kHz or less.
Input Resistance	9 kΩ ±10%.
SIGNAL OUTPUTS	
CALIBRATOR (with A SEC/DIV set to 1 ms)	
Output Voltage and Current	0.4 V ±1% into a 1-MΩ load, 0.2 V ±1.5% into a 50-Ω load, or 8 mA ±1.5% into a short circuit, with the A SEC/DIV switch set to 1 ms per division.
Repetition Period	Two times the A SEC/DIV setting for SEC/DIV from 100 ns to 100 ms.
Accuracy	±0.1%, during sweep time.
CH 2 SIGNAL OUT	
Output Voltage	20 mV/division ±10% into 1 MΩ, 10 mV/division ±10% into 50 Ω.
Offset	±10 mV into 50 Ω, when dc balance has been performed within ±5°C of the operating temperature.

Table 6-1 (cont)

Characteristics	Performance Requirements
A GATE OUT and B GATE OUT	
Output Voltage	2.4 V to 5 V positive-going pulse, starting at 0 V to 400 mV.
Output Drive	Will supply 400 μA during HI state; will sink 2 mA during LO state.
AC POWER SOURCE	
Source Voltage	
Nominal Ranges	
115 V	90 V to 132 V.
230 V	180 V to 250 V.
Source Frequency	48 Hz to 440 Hz.
Fuse Rating	2 A, 250 V, AGC/3AG, Fast blow; or 1.6 A, 250 V, 5 × 20 mm Quick-acting.
Power Consumption	
Typical	70 watts (140 VA).
Maximum	120 watts (180 VA).
Primary Circuit Dielectric Voltage Withstand Test	1500 V rms, 60 Hz for 10 seconds without breakdown.
Primary Grounding	Type test to 0.1 Ω maximum. Routine test to check grounding continuity between chassis ground and protective earth ground.

Table 6-2
Environmental Characteristics

Characteristics	Performance Requirements
	Environmmental requirements qualify the electrical and mechanical specifications. When not rack mounted, the instrument meets the environmental requirements of MIL-T-28800C for Type III, Class 3, Style C equipment, with the humidity and temperature requirements defined in paragraphs 3.9.2.2, 3.9.2.3, and 3.9.2.4. Rack mounting changes the temperature, vibration, and shock capabilities. The rack mounted instruments meet or exceed the requirements of MIL-T-28800C with respect to Type III, Class 5, Style C equipment with the rack-mounting rear-support kit installed. Rack mounted instruments will be capable of meeting or exceeding the requirements of Tektronix Standard 062-2853-00, class 5.
Temperature	
Operating	−15°C to +55°C.
	For a rack mounted instrument, ambient temperature should be measured at the instrument's air inlet. Fan exhaust temperature should not exceed +65°C.
Nonoperating (Storage)	−62°C to +85°C.
Altitude	
Operating	To 15,000 feet. Maximum operating temperature decreases 1°C for each 1000 feet above 5000 feet.
Nonoperating (Storage)	To 50,000 feet.
Humidity	
Operating and Storage	Stored at 95% relative humidity for five cycles (120 hours) from 30°C to 60°C, with operation performance checks at 30°C and 55°C.

Table 6-2 (cont)

Characteristics	Performance Requirements
Packaged Transportation Drop	Meets the limits of the National Safe Transit Assn., test procedure 1A-B-2; 10 drops of 36 inches (Tektronix Standard 062-2858-00).
Packaged Transportation (Vibration)	Meets the limits of the National Safe Transit Assn., test procedure 1A-B-1; excursion of 1 inch p-p at 4.63 Hz (1.1 g) for 30 minutes (Tektronix Standard 062-2858-00).
EMI (Electro-magnetic Interference)	Meets MIL-T-28800C; MIL-STD-461B, part 4 (CE-03 and CS-02), part 5 (CS-06 and RS-02), and part 7 (CS-01, RE-02, and RS-03—limited to 1 GHz; VDE 0871, Category B; Part 15 of FCC Rules and Regulations, Subpart J, Class A; and Tektronix Standard 062-2866-00.
Electrostatic Discharge Susceptibility	Meets Tektronix Standard 062-2862-00. The instrument will not change control states with discharges of less than 10 kV.
X-Ray Radiation	Meets requirements of Tektronix Standard 062-1860-00.
Vibration	
Operating, Not Rack Mounted	15 minutes along each of three axes at a total displacement of 0.025 inch p-p (4 g at 55 Hz), with frequency varied from 10 Hz to 55 Hz in one minute sweeps. Hold 10 minutes at each major resonance, or if none exist, hold 10 minutes at 55 Hz (75 minutes total test time).
Rack Mounted	Change displacement to 0.015 inch p-p (2.3 g at 55 Hz).

Table 6-2 (cont)

Characteristics	Performance Requirements
Shock	
Operating and Nonoperating, Not Rack Mounted	50 g, half sine, 11 ms duration, three shocks on each face, for a total of 18 shocks.
Rack Mounted	30 g.
Transit Drop (not in shipping package)	8-inch drop on each corner and each face (MIL-T-28800C, para. 4.5.5.4.3).
Bench Handling	
Cabinet On and Cabinet Off	MIL-STD-810C, Method 516.2, Procedure V (MIL-T-28800C, para. 4.5.5.4.3).
Topple (Cabinet Installed)	
Operating	Set on rear feet and allow to topple over onto each of four adjacent faces (Tektronix Standard 062-2858-00).

Table 6-3
Mechanical Characteristics

Characteristics	Description
Weight	See Figure 6-1 for dimensional drawing.
With Accessories and Pouch	10.9 kg (24.0 lb).
Without Accessories and Pouch	9.7 kg (21.3 lb).
Domestic Shipping Weight	14.6 kg (32.1 lb).
Height	
With Feet and Accessories Pouch	190 mm (7.50 in).
Without Accessories Pouch	160 mm (6.29 in).
Width (with handle)	335 mm (13.20 in).
Depth	
With Front Panel Cover	472 mm (18.59 in).
With Handle Extended	533 mm (21.00 in).
Cooling	Forced-air circulation.
Finish	Tek Blue vinyl clad material on aluminum cabinet.
Construction	Aluminum-alloy chassis (sheet metal). Plastic-laminate front panel. Glass-laminate circuit boards.
Rackmounting Conversion Kit	
Weight	4.0 kg (8.8 lbs).
Domestic Shipping Weight	6.3 kg (13.8 lbs).
Height	178 mm (7 in).
Width	483 mm (19 in).
Depth	419 mm (16.5 in).
Rear Support Kit (Optional)	
Weight	0.68 kg (1.5 lbs).

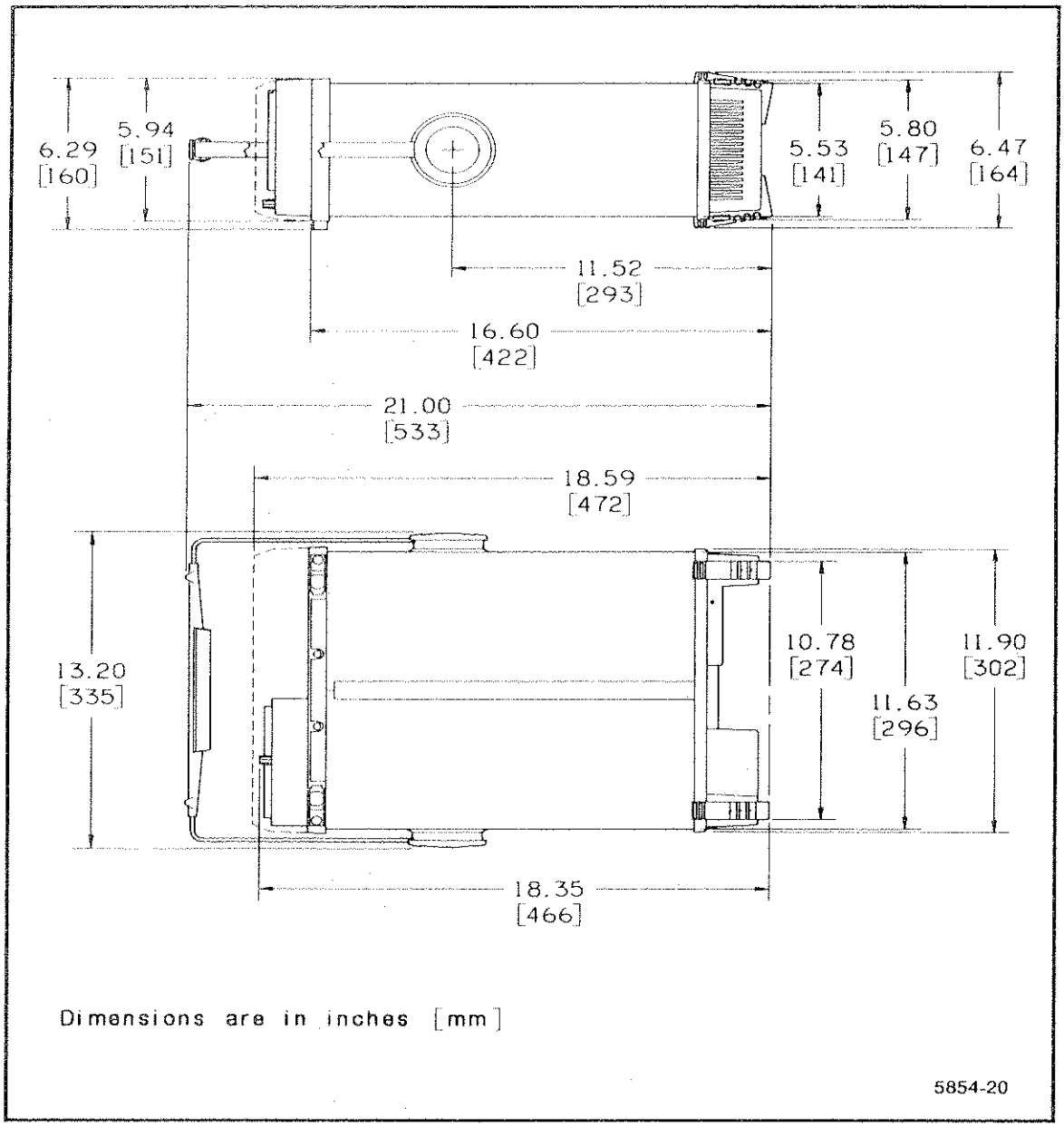


Figure 6-1. Dimensional drawing.

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 numbers) of standard accessories included with each instrument and a partial list of optional accessories. Additional information about instrument options, option availability, and other accessories can be obtained either by consulting the current Tektronix Product Catalog or by contacting your local Tektronix Field Office or representative.

Option 05

Option 05 provides additional hardware and software features to simplify triggering and viewing of television signals. The option adds TV (back-porch) clamp circuitry to the Channel 2 input and TV trigger coupling modes are provided, allowing a user to select either horizontal or vertical sync pulses to obtain horizontal-line-sync or field-sync pulse triggering. This option permits the user to trigger on a specific line number within a TV field and provides sync polarity switching for either sync-negative or sync-positive composite video signals.

Options 06 and 09

Options 06 (Counter/Timer/Trigger) and 09 (Counter/Timer/Trigger with Word Recognizer) allow precision time-interval measurement, event and frequency counting, delay-by-events triggering, and logic triggering. The 17-bit Word Recognizer probe of Option 09 extends the capabilities of these functions.

Option 10

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

Option 11

Option 11 provides two probe-power connectors on the rear panel of the instrument. Voltages supplied at these connectors meet the power requirements of standard Tektronix active oscilloscope probes.

Option 1R

When the oscilloscope is ordered with Option 1R, it is shipped in a configuration that permits easy installation into a 19-inch-wide electronic-equipment rack.

An optional rear-support kit also is available for use when rackmounting the instrument. Using this optional rear-support kit enables the rackmounted instrument to meet appropriate electrical and environmental specifications.

Connector-mounting holes are provided in the front panel of the rackmounted instrument. These enable convenient accessing of the four bnc connectors (CH 2 SIGNAL OUT, A GATE OUT, B GATE OUT, and EXT Z AXIS IN) and the two PROBE POWER connectors located on the rear panel. Additional cabling and connectors required to implement any front-panel access to the rear-panel connectors are supplied by the user; however, these items can be separately ordered from Tektronix.

Complete rackmounting instructions are provided in a separate document shipped with Option 1R. These instructions also contain appropriate procedures to convert a standard instrument into the Option 1R configuration by using the rackmounting conversion kit.

Power Cord Options

Instruments are shipped with the detachable power-cord configuration ordered by the customer. Descriptive information about the international power-cord options is provided in Section 1, "Preparation for Use". The following list identifies the Tektronix part numbers for the available power cords and associated fuses.

Option A1 (Universal Euro)

Power cord (2.5 m)	161-0104-06
Fuse (1.6 A, 250 V, 5 x 20 mm, Quick-acting)	159-0098-00

Option A2 (UK)

Power cord (2.5 m)	161-0104-07
Fuse (1.6 A, 250 V, 5 x 20 mm, Quick-acting)	159-0098-00

Option A3 (Australian)

Power Cord (2.5 m)	161-0104-05
Fuse (1.6 A, 250V, 5 x 20 mm, Quick-acting)	159-0098-00

Option A4 (North American)

Power Cord (2.5 m)	161-0104-08
Fuse (2 A, 250 V, AGC/3AG, Fast-blow)	159-0021-00

Option A5 (Switzerland)

Power Cord (2.5 m)	161-0167-00
Fuse (1.6 A, 250 V, 5 x 20 mm, Quick-acting)	159-0098-00

Standard Accessories

The following standard accessories are provided with each instrument:

Qty	Description	Part Number
4	Probes (10X, 1.3 m) with Accessories	010-6136-01
1	Banana Plug/ Binding Post Adaptor	134-0016-00
1	Accessory Pouch, Snap Fastener	016-0692-00
1	Accessory Pouch, Zip-lock Fastener	016-0537-00
1	Operators Manual	070-5854-00
1	Fuse (2 A, 250 V, AGC/3AG)	159-0021-00
1	Crt Filter, Blue Plastic (installed)	378-0199-00
1	Crt Filter, Clear Plastic	378-0208-00
1	Front Cover	200-3199-00

Optional Accessories

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

Description	Part Number
Service Manual	070-5855-00
Protective Cover, Waterproof, Blue Vinyl	016-0720-00
Probe Package (for use with Channels 3 and 4)	010-6131-01
Rackmounting Conversion Kit	016-0691-00
Rear-Support Kit (for use with rackmounted instruments)	016-0096-00
Polarized Collapsible Viewing Hood	016-0180-00
Folding Viewing Hood, Light-shielding	016-0592-00
Collapsible Viewing Hood, Binocular	016-0566-00
Oscilloscope Camera	See C30B Series
SCOPE-MOBILE Cart	200C
Carrying Strap	346-0058-00

Appendix A

Power Up Tests

Power-up tests are automatically performed each time the instrument is turned on. These tests provide the user with the highest possible confidence that the instrument is operational. They include a Kernel test and Confidence tests.

Kernel Test

A kernel test failure is considered "fatal" to the operation of the instrument. A Kernel test failure causes the TRIG'D indicator to flash and displays a binary code pattern on other front panel indicators. If a kernel test fails, the user can attempt to operate the instrument normally by pressing the A/B TRIG button. Operation is unpredictable; it depends on the nature of the failure.

Confidence Tests

Confidence tests are performed after the processor kernel has been found operational. These tests check a portion of the instrument for correct operation.

If a Confidence test fails, the readout will indicate the nature of the failure by a coded message in this format:

TEST XX FAIL YY

where XX is a two-digit test number and YY is a failure code. Table A-1 shows the function affected by detected failures.

Table A-1
Confidence Test Numbers and Affected Functions

Test Number	Description
01	Interrupt Request Missing or Wrong Period
02	Momentary Switch Stuck
03	Readout Interface or Memory Failure
04	Calibration Data Parity or Checksum Error
05	Main Board Failure Detected by Auto Level Trigger on LINE Source

Appendix B

Sequence Programming and Operation

As many as twenty stored setups can be organized into one or more sequences to be sequentially recalled by the STEP/AUTO button. Unless otherwise defined, all twenty setups can be recalled in one sequence.

A sequence is defined as a contiguous group of saved setups, where the first setup includes the BEGIN attribute and the last setup includes the END attribute. The Sequence-Save mode provides access to the BEGIN/END attributes and provides sequence editing facilities to REPLACE, INSERT, and DELETE setups.

Pressing SAVE establishes the Direct-Save mode, as described in the "Operation" section. Pressing STEP then establishes the Sequence-Save mode. The readout shows a definition mode, a step attribute, a setup number, the "NAME:" prompt, and the name argument in the top row and a HELP message in the bottom row. (If the Direct-Save mode displays "SAVE FUNCTIONS DISABLED" or if the Sequence-Save mode displays "SEQUENCE DEFINITION DISABLED," refer to EXER 07, described in Appendix C.)

Top Row	--	REPLACE STEP :nn	NAME:xxxxxxx
or	--	REPLACE BEGIN:nn	NAME:xxxxxxx
or	--	REPLACE END :nn	NAME:xxxxxxx
Bottom Row	--	PUSH STEP TO REPLACE SETUP.	

Δ REF moves a cursor to the definition mode field, the step attribute field, the setup number field, or any character in the NAME argument. The Δ control selects a definition mode, REPLACE, INSERT, or DELETE; a step attribute, STEP, BEGIN, or END; a setup number, 1-20; or a character for each position of the setup name.

The initial definition mode is REPLACE. Initial values of the step attribute and setup NAME are the values previously stored at the selected setup number, unless NAME was changed in the Direct-Save mode. The initial value of the setup number is one more than the previously defined or selected setup. The cursor initially remains in the NAME argument, as it was in the Direct-Save mode.

When STEP is pressed in the REPLACE definition mode, the current instrument setup, with the displayed step attribute and the displayed NAME, if the NAME has been changed, replaces setup "nn."

A step with the BEGIN attribute begins a sequence of setups. END defines a step that ends a sequence.

While REPLACE is selected, repeated operation of SAVE presents this cycle of HELP messages in the bottom row.

Top Row	--	REPLACE STEP :nn NAME:xxxxxxx
or	--	REPLACE BEGIN:nn NAME:xxxxxxx
or	--	REPLACE END :nn NAME:xxxxxxx
Bottom Row	--	PUSH STEP TO REPLACE SETUP.
or	--	TURN Δ REF TO FIELD, THEN--
or	--	TURN Δ TO DESIRED SETTING.
or	--	PUSH RECALL TO CANCEL THIS MODE.

When STEP is pressed in the INSERT definition mode, the numbers attached to the currently selected setup and each higher-numbered setup are increased by one and setup 20 is discarded. The current instrument setup, the displayed step attribute, and the displayed NAME are then stored in the selected memory location.

While INSERT is selected, repeated operation of SAVE presents this cycle of HELP messages in the bottom row.

Top Row	--	INSERT STEP :nn NAME:xxxxxxx
or	--	INSERT BEGIN:nn NAME:xxxxxxx
or	--	INSERT END :nn NAME:xxxxxxx
Bottom Row	--	INSERT WILL DESTROY STEP 20.
or	--	PUSH STEP TO INSERT SETUP.
or	--	TURN Δ REF TO FIELD, THEN--
or	--	TURN Δ TO DESIRED SETTING.
or	--	PUSH RECALL TO CANCEL THIS MODE.

In the DELETE definition mode, the attribute and NAME fields cannot be changed. When STEP is pressed, the currently selected setup is moved to step 20 and the numbers associated with each higher-numbered setup decreases by one.

While DELETE is selected, repeated operation of SAVE presents this cycle of HELP messages in the bottom row.

Top Row	--	DELETE STEP :nn NAME:xxxxxxx
or	--	DELETE BEGIN:nn NAME:xxxxxxx
or	--	DELETE END :nn NAME:xxxxxxx
Bottom Row	--	PUSH STEP TO DELETE SETUP.
or	--	TURN Δ REF TO FIELD, THEN--
or	--	TURN Δ TO DESIRED SETTING.
or	--	PUSH RECALL TO CANCEL THIS MODE.

Executing Sequences

Pressing RECALL establishes the Direct-Recall mode, as described in the Operation section. Then pressing STEP in the Direct-Recall mode enables the Sequence-Recall mode. The top row of the readout shows the names of the first four defined BEGIN steps. If no BEGIN steps are defined, step 1 is the beginning of a sequence, by default. Pressing a setup-number button initiates the corresponding sequence and illuminates the STEP indicator. The position of each button among the others corresponds to the position of a sequence name among the others on the screen. Pressing STEP initiates the first defined sequence and illuminates the STEP indicator.

Repeatedly pressing RECALL presents this cycle of HELP messages. In message 1, "—n" is blank, "—2," "—3," or "—4," depending on how many sequences are defined.

Bottom Row	--	PUSH 1—n OR STEP TO START SEQ.
or	--	TURN Δ TO SELECT ANY STEP.
or	--	PUSH SAVE TO CANCEL THIS MODE.

Turning Δ REF or Δ while in the Sequence-Recall mode accesses to any setup.

STEP recalls any selected setup, initiates sequential setups, and illuminates the STEP indicator. If the step number is decremented below 1, the Direct-Recall mode is reestablished.

Top Row	--	nn xxxxxxx TURN Δ TO SELECT.
Bottom Row	--	PUSH STEP TO BEGIN SEQ HERE.
or	--	PUSH SAVE TO CANCEL THIS MODE.

Repeated operation of STEP/AUTO sequentially steps through the sequentially stored setups. When an END step or step 20 is encountered, the sequence reverts to the previous BEGIN step, or to step 1, if no previous BEGIN step exists.

Appendix C

Extended Functions with Diagnostic Exercisers

Diagnostic exercisers provide access to an operating time log, instrument setup modes, and shutdown warning display control. EXER 05 through EXER 09 may be useful to an experienced operator. The Service Manual describes EXER 01 through 04, which are used only for instrument testing and troubleshooting.

EXER 05	Display Operating Time and Power Cycle Count
EXER 06	Select Setup to Use at Power Up
EXER 07	Enable/Disable Setup SAVE and Sequence Definition
EXER 08	Initialize Setups
EXER 09	Program Viewing Time Display

To operate these features, first enter the Diagnostic Monitor mode by pressing ΔV and Δt buttons together, then pressing Trigger SLOPE while holding ΔV and Δt. The readout will display "DIAGNSTIC. PUSH A/B TRIG TO EXIT," indicating the Diagnostic Monitor mode. Repeatedly press the upper or lower Trigger MODE button to sequence through the TEST and EXER routine labels and select the one you want to run. Then press the upper Trigger COUPLING button to execute the selected Exerciser. Within EXER 06 through EXER 08, repeatedly pressing the upper Trigger COUPLING button cycles through the available selections. To exit an exerciser, press the lower Trigger COUPLING button.

In the descriptions below, the lines marked with ">" are displays in the top row of the readout. A bottom row display line is marked by "<".

EXER 05 Display Operating Time and Power Cycle Count

> HRS ON nnnn OFF/ON CYCLES mmmm

nnnn = Accumulated Number of Hours with Power Applied
mmmm = Accumulated Number of Power Cycles

EXER 06 Select Setup to Use at Power Up

> POWER UP TO POWER DOWN SETUP

Instrument will power up with the setup in effect at power down.

> POWER UP TO SETUP 1

Instrument will power up with the setup stored as setup 1. If setup 1 has been cleared by EXER 08, the instrument will power up with a default setup.

EXER 07 Enable/Disable Setup SAVE and Sequence Definition

> ENABLE SAVE AND SEQUENCE-CHANGE

All Save and Sequence functions are enabled.

> DISABLE SAVE AND SEQUENCE-CHANGE

All Save and Sequence-definition functions are disabled.

> ENABLE SAVE 1 - 8, NO SEQ-CHANGE

Only setups 1 through 8 can be changed.
BEGIN/STEP/END attributes cannot be changed for any setup.

EXER 08 Initialize Setups

> COUPLING UP CLEARS SAVED SETUPS

Press upper Trigger COUPLING to clear all saved setups.
Press lower Trigger COUPLING to retain saved setups.

EXER 09 Program Viewing Time Display

> SHUTDOWN WARNING AT nn SECONDS

When the remaining time before display intensity reduction is less than nn seconds, a number indicating the time remaining is displayed in the lower, right hand corner of the CRT.

> SHUTDOWN WARNING DISABLED

nn = 0 inhibits timer display.

> SHUTDOWN WARNING ENABLED

nn > 90 gives continuous timer display.

The bottom row displays:

< EXER 09 TURN Δ CONTROL

If the time remaining is more than 90 seconds, the display shows nM or nH, indicating the number of minutes or hours remaining.

Tektronix
COMMITTED TO EXCELLENCE

MANUAL CHANGE INFORMATION

Date: 4-24-86 **Change Reference:** C1/0486

Product: 2467 OPERATORS **Manual Part No.:** 070-5854-00

DESCRIPTION Product Group 38

EFFECTIVE ALL SERIAL NUMBERS

Change the following sections of Table 6-1 to:

PAGE 6-3 VERTICAL DEFLECTION SYSTEM—CHANNEL 1 AND CHANNEL 2

Frequency Response (3 dB bandwidth)	
+15°C to +35°C	
−3 dB bandwidth with standard accessory probe or internal 50 Ω termination	Dc to 350 MHz.
−4.7 dB bandwidth with 50 Ω external termination on 1 MΩ input	Dc to 350 MHz.
−15°C to +15°C and +35°C to +55°C	
−3 dB bandwidth with standard accessory probe or internal 50 Ω termination	Dc to 300 MHz.
−4.7 dB bandwidth with 50 Ω external termination on 1 MHz input	Dc to 300 MHz.

PAGE 6-6 TRIGGERING

Add the following information after LF REJ Coupled:

Minimum P-P Signal Amplitude for Stable Triggering from ADD Source	Add 0.5 division to CH1 or CH2 requirement at 300 MHz and 500 MHz.

PAGE 6-10 DISPLAY

Visual Writing Speed with 20 Foot-Candles Illumination, Normal to the Crt Faceplate	≥4 divisions/ns. Using the standard-accessory, color filter, no more than 5 bright spots will be visible at maximum intensity and no bright-spot halo is allowed within the center 7x9 divisions. Additional bright spots may be visible after displaying a high-intensity trace. These added spots will extinguish when intensity is set to minimum.