TEK

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Product Group 38

2467B
OSCILLOSCOPE and OPTIONS
OPERATORS

Please Check for CHANGE INFORMATION at the Rear of This Manual

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INSTRUMENT SERIAL NUMBERS

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

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

Certificate of the Manufacturer/Importer

We hereby certify that the _____

2467B 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 _____

2467B 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.

The 2467B

The TEKTRONIX 2467B portable oscilloscope has four vertical channels with DC to 400 MHz bandwidth. Deflection factors run from 2 mV to 5 V per division, in a 1-2-5 sequence, with either 1 MΩ or 50 Ω input resistance, in channels 1 and 2. Either AC or DC input coupling is available at 1 MΩ. Channels 3 and 4 give 0.1 V or 0.5 V per division, with 1 MΩ input resistance, and DC coupling. With the standard 10X probes, channels 1 and 2 display 20 mV to 50 V/division and channels 3 and 4 display 1 V or 5 V/division.

The trigger system works automatically for most signals. It operates in various modes, from any channel, with optimum couplings for a wide range of signals from DC to 500 MHz.

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

The 2467B *visually* writes at least 4 divisions per ns, about 100 times faster than conventional oscilloscopes. The 2467B easily displays low repetition-rate signals and single-shots including 1 ns steps at 500 ps/division, in typical room light.

The SETUP features, AUTO, SAVE, and RECALL, save time and prevent errors, whether you are a novice operator or a master. AUTO Setup works with almost any signal. For repeating measurements, the Save and Recall functions record and restore as many as 30 instrument setups, including the extended-function options. Setups can be recalled either immediately or sequentially.

Digital readouts of time, voltage, scale factors, trigger levels, and auxiliary information also save time and reduce errors.

With Parametric Measurements, common measurements such as frequency, period, amplitude, pulse width, duty factor, rise time, fall time, and propagation delay can be made automatically. Each measurement activation displays the results in the CRT readout. Measurement results remain on-screen until any other button is pressed.

For instruments with serial numbers B049999 and below with firmware Version 11 and above or for instruments serial numbers B050000 and above with firmware Version 2 and above the following function is available. The RECALL button resets the instrument into the mode of operation it was in prior to performing the parametric measurement or AUTO Setup.

With the available Counter/Timer/Trigger (*CTT*), Option 06 or Option 09, measurements require even less effort and give better accuracy. The *CTT* increases trigger selectivity, especially in digital systems. Option 09 includes the *CTT* and a 17-bit Word Recognizer (*WR*). The available Television/Video (*TV*) enhancement, Option 05, can trigger at any desired point in a frame and it can reduce the effects of ac coupling and hum in a video signal. The High Definition Television/Video (HDTV), Option 5H, enhances the TV Option by adding the ability to trigger on tri-level sync at HDTV line and field rates.

The *WR* adds a Word Recognizer Probe connector on the rear panel. The *TV* enhancement adds LINES, FLD1, and FLD2 Trigger Coupling. The HDTV enhancement adds TV autoset and presets.

The available GPIB interface accesses all controls and digital readings. The interface adds GPIB status indicators, just above the CRT. See the *24X5B/2467B GPIB (Option 10) Instrument Interfacing Guide* for information on integrating the instrument into a GPIB system.

Illustrations at the back of the manual show the instrument front and rear panels.

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Operators Safety Summary

The general safety information in this part of the summary is for both operating and servicing personnel. Specific warnings and cautions will be found throughout the manual where they apply and do not appear in this summary.

Terms

In This Manual

CAUTION statements identify conditions or practices that could result in damage to the equipment or other property.

WARNING statements identify conditions or practices that could result in personal injury or loss of life.

As Marked on Equipment

CAUTION indicates a personal injury hazard not immediately accessible as one reads the markings, or a hazard to property, including the equipment itself.

DANGER indicates a personal injury hazard immediately accessible as one reads the marking.

Symbols

In This Manual

This symbol indicates where applicable cautionary or other information is to be found. For maximum input voltage see Table 6-1.

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

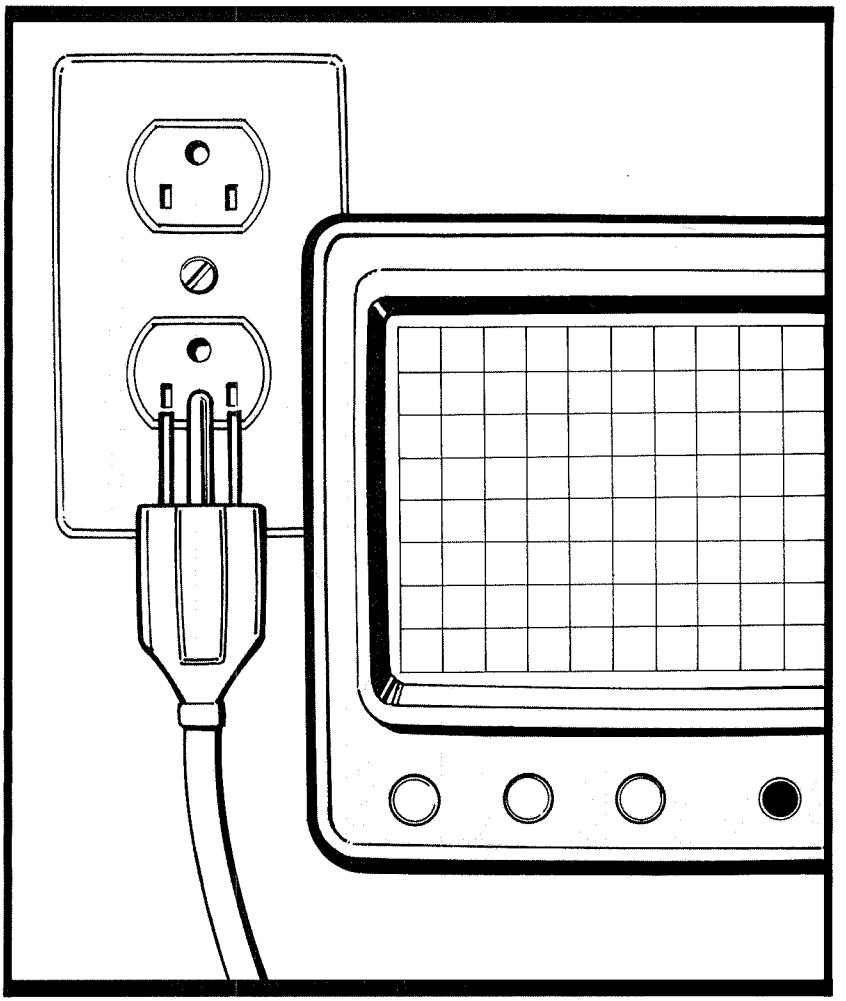
To avoid explosion, do not operate this product in an explosive atmosphere unless it has been specifically certified for such operation.

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.

SECTION 1

General Information



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.

Line Voltage Selection

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.

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.

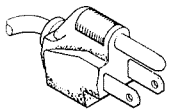
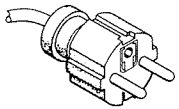
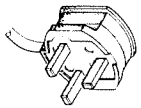
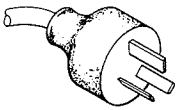
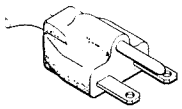
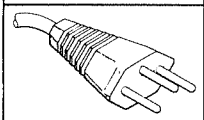
Line Fuse

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. For international power cord options, a 5x20 mm fuse holder cap is included in the accessory pouch for use with 1.6 A, 250 V, 5x20 mm (IEC 127) fuses (not supplied).

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. 120 V	115V	ANSI C73.11 NEMA 5-15-P IEC 83 UL 198.6
	A1	EURO 220 V	230V	CEE(7), II, IV, VII IEC 83 IEC 127
	A2	UK[a] 240 V	230V	BS 1363 IEC 83 IEC 127
	A3	Australian 240 V	230V	AS C112 IEC 127
	A4	North American 240 V	230V	ANSI C73.20 NEMA 6-15-P IEC 83 UL 198.6
	A5	Switzerland 220 V	230V	SEV IEC 127

[a]A 6 A, 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—Schweizervischer Elektrotechnischer Verein
UL—Underwriters Laboratories Inc.

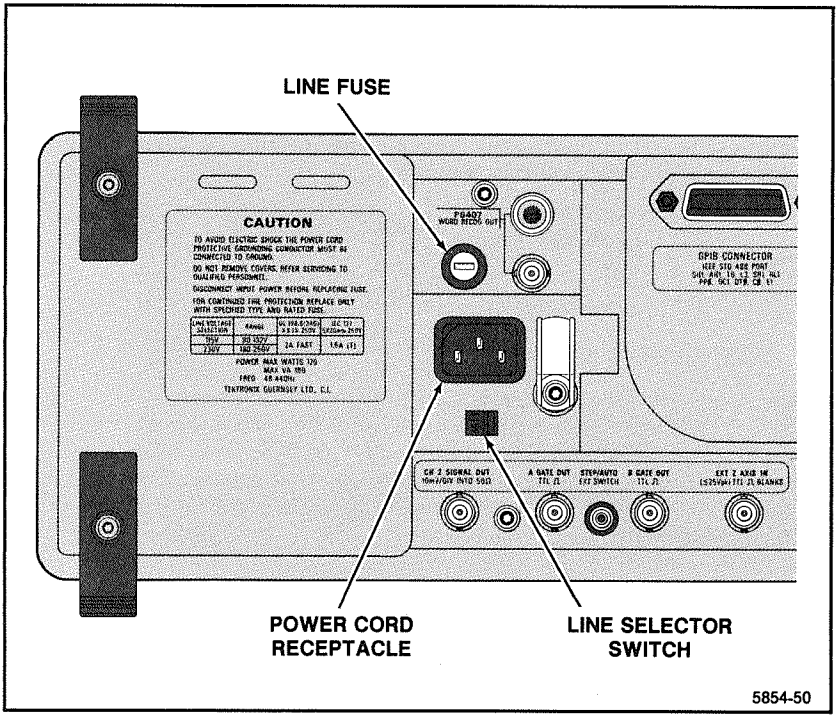


Figure 1-1. Line selector switch, line fuse, and detachable power cord.

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 C 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

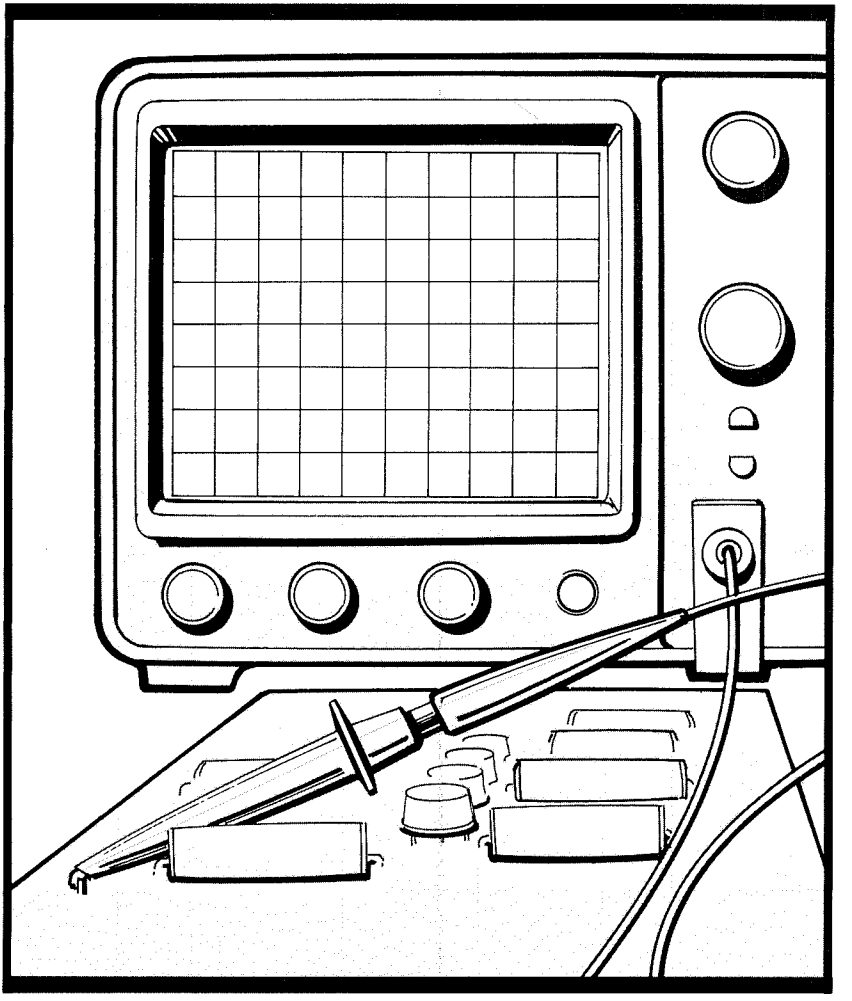
If this instrument is to be shipped by commercial transportation, it should be packaged in the original manner. The carton and packaging material in which your instrument was shipped to you should be retained for this purpose.

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.

SECTION 2

Operation



Operation

Fundamentals

Like any oscilloscope, this instrument draws a graph of voltage as a function of time. The VERTICAL controls, marked off by a heavy gray line, define the voltage axis of the display. SEC/DIV, X10 MAG, and horizontal POSITION control the time axis of the display. The TRIGGER controls, marked off by a green box, define the signals required to initiate sweeps across the time axis. The controls under the CRT affect the display but not the waveform.

Parametric Measurements

The Parametric Measurement functions provided in the instrument give quick access to the parameters of your input signal.

To obtain a parametric measurement, simply press the MEASURE button and select the desired function from the displayed menu. The function is selected by pressing the button in the VERTICAL MODE area that occupies the same relative position as the desired menu selection. The measurement function will automatically scale the input signal before making the measurement.

Parametric measurements require repetitive signals for reliable results. Measurements on non-repetitive signals will produce unpredictable results.

Repetitive signals that have periodic bursts of signal transitions will also produce unpredictable results.

Parametric measurements can only be performed on signals in CH 1 or CH 2. An error message will be displayed if CH 3, CH 4, or ADD are selected for parametric measurements.

Getting a Display

1. Connect a probe from the input of a Vertical channel to a signal.
2. Select the channel using the Vertical MODE buttons. You may select any combination of vertical channels. (If you are using the standard accessory probes, make sure the CH 1 and CH 2 input are not set at 50 Ω.)
3. Press AUTO Setup to initialize vertical, horizontal, trigger, and display intensity for a usable display. (If STEP is illuminated, first push RECALL to extinguish it.)
4. If the resulting display isn't exactly what you want, adjust the appropriate VOLTS/DIV, SEC/DIV, POSITION, or Trigger controls.

Characteristics of AUTO Setup

With one channel, Auto Setup centers the 0-volt level and makes the vertical display as large as possible, within the graticule. With more than one channel, 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. When ADD is displayed, the 0-volt level of CH 2 is set at −2 divisions.

AUTO sets Sec/Div within the range from 20 ns to 2 ms, to show two to five cycles of most signals. With narrow, low repetition-rate pulses, the sweep runs faster to stretch out the display, with the appropriate trigger slope.

AUTO Setup sets the trigger for Auto Lvl Mode, Vert Source, DC Coupling, and Min Holdoff, with level at the midpoint between signal peaks.

The STEP/AUTO EXT SWITCH connector on the rear panel produces the same functions as the STEP/AUTO button, in response to a switch closure or TTL-low signal.

The following function is available for instruments with serial numbers B049999 and below with firmware versions 11 and above or for instruments with serial numbers B050000 and above with firmware versions 2 and above (see Appendix A – EXER04 to determine firmware version). AUTO Setup can also be activated by pressing any probe ID button if configured to perform an AUTO Setup using the PROBE Configure menu. The operator can configure the probe ID to perform one of four possible outcomes (IDENT, AUTO Setup, INIT@50%, or STEP). Once configured, the instrument will maintain the selection until modified again by the operator.

The following function is available for instruments with serial numbers B049999 and below with firmware versions 10 and below or for instruments with serial numbers B050000 and above with firmware versions 1 and below (see Appendix A – EXER04 to determine firmware version). AUTO Setup can also be activated by pressing any probe ID button twice in 0.5 second.

See "Save and Recall Operation" for the sequence function of Step/Auto.

Assigning Parametric Measurements to the Auto Setup Function

Any of the Parametric Measurements can be assigned to the Auto Setup function. When Auto Setup is activated, the assigned function is performed as well as the Auto Setup.

To assign a function to Auto Setup:

1. Push MEASURE.
2. If the CTT is present, select MORE from the menu. Otherwise go to Step 3.

NOTE

To select items from a menu, simply press the vertical mode button that has the same position as the desired item in the menu.

3. Select CONFIGURE from the menu.
4. Select AUTO from the menu.
5. Select the function to be performed with each Auto Setup by pushing the appropriate MODE button.

Activating AUTO Setup from the Probe

The following function is available for instruments with serial numbers B049999 and below with firmware versions 11 and above or for instruments with serial numbers B050000 and above with firmware versions 2 and above (see Appendix A – EXER04 to determine firmware version). Pressing the probe identification button on any Tektronix, Inc. probe will shift the associated trace and replace the associated scale factor with ID, if IDENT has been selected from the PROBE CONFIGURE menu.

AUTO Setup, INIT@50% or STEP can also be assigned to the probe ID function. To assign a function to probe ID:

1. Push MEASURE
2. If CTT is present, select MORE from the menu. Otherwise, go to Step 3.

NOTE

To select items from a menu, simply press the vertical mode button that has the same position as the desired item in the menu.

3. Select CONFIGURE from the menu.

4. Select PROBE from the menu.

5. Finally, select the function to be performed with each probe ID by pressing the appropriate MODE button. If AUTO Setup function is selected, any measurement assigned to the AUTO Setup is also performed.

The following function is available for instruments with serial numbers B049999 and below with firmware versions 10 and below or for instruments with serial numbers B050000 and above with firmware versions 1 and below (see Appendix A – EXER04 to determine firmware version). Pressing the probe identification button on any Tek probe will shift the associated trace and replace the associated scale factor with ID. If the probe identification is pressed twice in 0.5 second, the Auto Setup function is activated. Any measurement assigned to the Auto Setup function is also performed.

Vertical

For voltage measurements, set VOLTS/DIV VAR fully clockwise. For best accuracy, set VOLTS/DIV for the largest display possible.

Input Coupling

Use 1 MΩ DC input mode for most applications. This mode is compatible with the standard accessory, high-impedance probes and it displays logic levels and dc levels of static signals. Use the pair of buttons near the CH 1 and CH 2 inputs to select input coupling. CH 3 and CH 4 inputs are fixed at 1 MΩ DC.

GND input mode shows where the 0-volt level will be displayed with DC coupling.

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

Use the 50 Ω DC input mode for the best possible vertical performance with active probes, 50-Ω signal sources, and low-impedance passive probes. A low-impedance probe can present less than 2 pF load to the signal-source, in parallel with 500 Ω or 5000 Ω with 10X or 100X attenuation.

Input Conditioning for Video Signals

Video signals can be distorted by ac coupling or by low-frequency interference. The available Television/Video *(TV)* and High Definition Television/Video *(HDTV)* enhancement adds a TV CLAMP to the CH 2 input to eliminate such distortion.

To use the TV clamp:

1. Apply a composite video signal to CH 2.

2. Select CH 2 Trigger Source and set SLOPE to the displayed polarity of the sync pulses.

3. Set the CH 2 input to TV CLAMP by pressing the upper input-coupling button for CH 2 until the readout shows "TVC". The "back porch" of the video signal will be locked to a fixed level.

Keep the TV Clamp turned off when the trigger source is not composite video or sync, to preserve normal operation of Channel 2. Leave the rear-panel CH 2 SIGNAL OUT unloaded to avoid a minor distortion in the video signal when TV Clamp is on.

Channel Selection

Using the Vertical MODE buttons, you can display any combination of the four vertical channels. To manually switch between CH 1 and another channel, with minimum button pushing, deselect CH 1 and press the button for the other channel to turn it on and off; CH 1 is displayed when all other verticals are off.

ADD and INVERT

Press ADD to display the algebraic sum of CH 1 and CH 2. 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 use ADD, the CH 1 and CH 2 VOLTS/DIV settings should be equal. Parametric measurements will not work if ADD is selected.

Choosing CHOP or ALT

With two or more channels, the display is time-shared. Chop mode displays each channel for a short time and multiplexes during the sweep to give the appearance of displaying all channels at once. Chop works better than Alt for sweeps slower than 1 ms/division and for low repetition-rate signals that make the display flicker, up to 2 µs/division.

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

20 MHz BW Limit (50 MHz BW Limit for HDTV)

This mode can give you a sharper trace by eliminating high-frequency interference. Before using it, check to make sure it doesn't distort the waveform.

Horizontal

The A Sweep is the only horizontal function you need for most applications. The A SWP indicator is on when the A-Sweep is displayed. To make sure the A-Sweep is displayed, press AUTO Setup and push SEC/DIV in. You can also restore the A-Sweep display by pushing the SEC/DIV knob in and turning it counterclockwise until the A SWP indicator lights. If both A SWP and B SWP indicators are off, push SEC/DIV in and turn it clockwise to escape the X/Y display mode.

The X10 MAGnifier expands the center of the unmagnified waveform.

For best measurement accuracy, set SEC/DIV for the fastest sweep that will display the interval of interest and set VAR fully clockwise.

See "Delayed Sweep Operation" for more information about B Sweep, B Trigger, and trace separation.

Trigger Controls

For "hands-off" triggering with most signals, select Auto Lvl Mode, Vert Source, DC Coupling, and MINimum Holdoff.

Auto Lvl mode, with LEVEL in the center half of its range, sets the trigger point near the midpoint between signal peaks. When LEVEL is set to the - or + end of its range, this mode initiates triggering near the 10% or 90% point between signal peaks. You can select a level anywhere in about the middle 80% of the signal amplitude. Once set, the level doesn't change unless the signal ceases to trigger the sweep. The sweep free-runs without a trigger signal. With signals below 50 Hz, AUTO LVL may not find the correct level. If the signal is below 50 Hz but greater than 10 Hz, you can change the minimum frequency at which Auto Level will work by using the MINFREQ entry under the measurement CONFIGURE menu. See "Frequency Limit for Auto Level or Parametric Measurements" for more information.

With Auto Lvl mode and Vert Source, the displayed channel or the first one of a multichannel display supplies the trigger signal.

Auto mode maintains the trigger level setting and the sweep free-runs if the signal doesn't meet the triggering requirements.

Use Auto for monitoring logic signals. Set the LEVEL control to the mean threshold of the logic system, +1.4 V for TTL. The sweep then triggers on valid transitions and free-runs to show static highs and lows.

Normal mode produces a sweep only when the trigger signal meets the Level and Slope criteria.

Use Normal mode for infrequent events and erratic signals.

Sgl Seq mode accepts one trigger for each sweep in the display. Press the lower Mode button to arm the trigger and illuminate the READY indicator for each sequence. With a multi-trace display, a sequence comprises up to sixteen sweeps.

Use Sgl Seq to detect a rare event or to eliminate all but the first one of a chaotic burst of pulses. Set the trigger for the signal of interest in Normal mode. Then press the lower Mode button to select Sgl Seq and illuminate the READY indicator. To detect the occurrence of a rare event, display a single trace and arm Sgl Seq with the trigger set for the event. Periodically check to see if READY is on. If a burst of trigger events occurs, the sweep runs once for each trace displayed and READY extinguishes.

Trigger Source

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

With Vert trigger source, Auto Lvl trigger mode or Chop vertical mode automatically selects a single trigger source, the first one of the displayed channels.

Use a composite A-Trigger source to compare asynchronous signals. To generate a composite trigger, select Vert trigger source, a trigger mode other than Auto Lvl, and Alt vertical mode.

Trigger Coupling

For 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.

Trigger Slope

Press SLOPE to select the rising (+) or falling (-) edge of the signal to trigger the sweep.

Trigger Level

INIT@50% sets the trigger level near the midpoint between signal peaks, in any mode. Some signals below 50 Hz may not produce the correct level setting. If the signal is below 50 Hz but greater than 10 Hz, the minimum frequency at

which INIT@50% will work can be changed using the MINIFREQ entry located below the measurement CONFIGURE menu. See "Frequency Limit for Auto Level or Parameteric Measurements" for more information.

LEVEL gives you complete freedom to choose the most appropriate threshold voltage on a signal to initiate sweeps, in case neither the Auto Lvl mode nor INIT@50% provides a suitable threshold.

Trigger Holdoff

With irregular signals such as bursts, the Trigger HOLDOFF setting can improve display stability. Also, if the signal has a fixed pattern of variation from cycle to cycle, some modes of the signal may be omitted from the display. Changing the Holdoff setting can force the instrument to display all the modes of the signal. Normally, HOLDOFF should be set at MIN. If you use HOLDOFF to achieve a stable display, parametric measurements will not function correctly.

Video Triggering

The available Television/Video *(TV)* and High Definition Television/Video *(HDTV)* enhancement adds TV LINES, FLD1, and FLD2 Coupling to the A-Trigger. See Appendix A to change the line-number format and the sync polarity automatically selected when you select TV triggering.

To trigger at the video line rate:

1. Select a composite video signal as the trigger source.
2. Select LINES coupling.
3. Set SLOPE to the polarity of the sync.

To trigger at a specific video line:

1. Select a composite video signal as the trigger source.
2. Select FLD1, FLD2, or ALT coupling.
3. Set SLOPE to the polarity of the sync.
4. Turn FLD LINE # (Δ) to the desired line number.

When you increment or decrement the line number outside the range of the selected field, the other field is automatically selected.

With ALT field coupling, the line number is referred to the beginning of both fields.

The trigger level can be adjusted to vary the actual sync trigger point. This can be useful when triggering on noisy video signals. INIT@50% resets the trigger point to mid-range.

To compare two video signals with the same format that are not perfectly synchronized, such as from a camera and a VCR or from the input and output of a time base corrector:

1. Display the signals on CH 1 and CH 2, with Alt Vertical mode.
2. Select VERT Trigger Source, and ALT field trigger coupling.
3. The CH 1 display triggers on field 1 and the CH 2 display triggers on field 2.

TV Lines trigger coupling with multiple vertical channels, Alt Vertical mode, and Vert Trigger source produce unpredictable results.

A "Δ" symbol with the line number display shows when the Δ/FLD LINE # control can change the line number. If ΔV, Δt, or 1/Δt is on, press a trigger Coupling button to redirect the control to line number selection. Press ΔV or Δt to redirect the control to cursor or delay adjustment. The first push redirects the control. A second push will change the Δ function or trigger coupling.

If you magnify the vertical display beyond the graticule, the trigger may be degraded. To avoid trigger overload, use one channel for display and another channel with an appropriate video signal as the trigger source. A composite sync signal can be used for the trigger source as well as composite video.

HDTV VIDEO TRIGGERING ENHANCEMENTS

In addition to the above trigggering enhancements, High Definition Television/Video (HDTV) adds the following enhancements:

- Ability to trigger on tri-level sync
- Ability to clamp on tri-level sync signals
- Autosetup on TV signals
- Automatic line numbering format selection
- TV presets
- Line-to-field display quick switch

Readout

To aid waveform interpretation, the readout shows scale factors, delta measurements, delay times, trigger settings, and other information. To display all readout information, set the READOUT INTENSITY control clockwise from OFF (SCALE FACTORS ON). See Figure 2-1.

Trigger Readout

The trigger readout shows which trigger (A or B) is affected by the controls (Mode, Source, Coupling, Slope, Level, and INIT@50%), which channel (1-4) is supplying the trigger signal, and the voltage at which triggering takes place, with the following settings:

Trigger Coupling	DC or Noise Reject
Trigger Source	Any Single Channel
Vertical Input	DC or GND
VOLTS/DIV VAR	Fully Clockwise.

If the trigger comes from the word recognizer, which is available with the *CTT*, the readout shows the defined word.

For instruments with serial numbers B049999 and below with firmware version 11 and above or for instruments with serial numbers B050000 and above with firmware version 2 and above (see Appendix A - EXER04 to determine firmware version), then all AC trigger couplings (HF Reject, LF Reject, and AC or AC input coupling provide an indication of the trigger level setting. The readout in these modes indicates a reference level (not absolute value) XXXX and is followed by a "V?" to indicate the relative nature of the readout.

For instruments with serial numbers B049999 and below with firmware version 10 and below or for instruments with serial numbers B050000 and above with firmware version 1 and below (see Appendix A – EXER04 to determine firmware version), 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.

All AC trigger couplings (HF Reject, LF Reject, AC, and TV Triggering modes) provide an indication of the trigger level setting. The readout in these modes indicates that a reference level (not absolute value) is followed by a "V?" to indicate the relative nature of the readout.

In TV Triggering modes the trigger level readout is displayed in percent instead of voltage. This readout refers to plus or minus 100 percent of the trigger level control and indicates a reference level only. It does not refer to a percentage of the incoming signal.

Readout Intensity

To display nothing but measurements, set the READOUT INTENSITY control counterclockwise from OFF (SCALE FACTORS OFF). Rotate the control toward OFF to decrease readout brightness. When the sweep is faster than 50 µs/division, random 2-µs segments of the waveform may be missing. Set the control near the center of the word "OFF" to eliminate this interference between the waveform and the readout.

Scale Factors

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 assume volts/division units.

The A-Sweep and B-Sweep time-scale readouts are always calibrated, combining the effects of SEC/DIV, VAR, and X10 MAG. If SEC/DIV VAR is not at its clockwise setting, the time scale factor includes a decimal point.

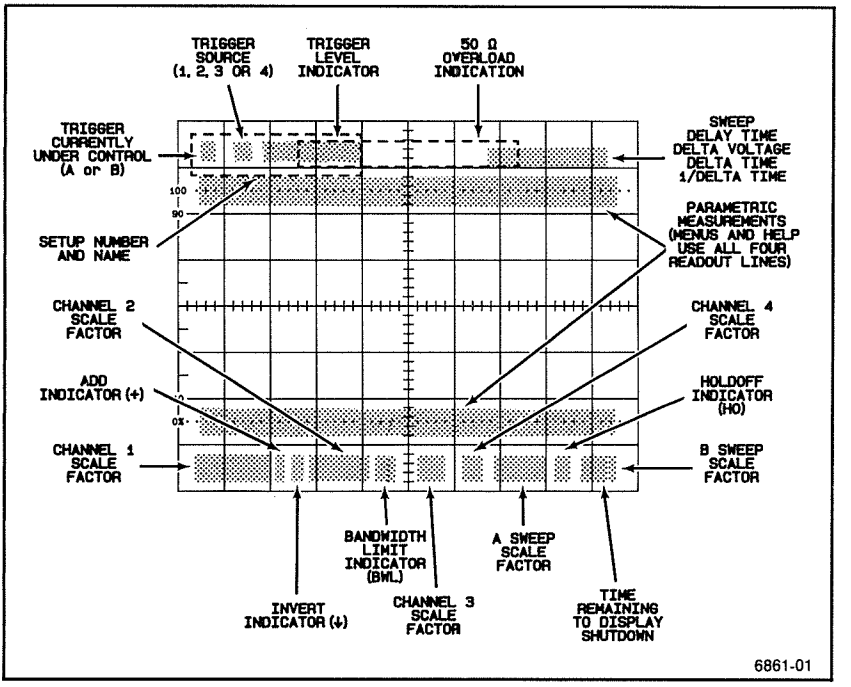


Figure 2-1. Readout display locations.

Holdoff Indicator

The holdoff indicator, "HO," is displayed when the HOLDOFF control is not at minimum.

Parametric Measurements

Parametric measurements (rise time, fall time, frequency, etc.) are displayed on the second and third lines of the readout. Help and menu information can use all four lines of the readout.

Probe Effects

Probe attenuation effects are included in scale factors, trigger levels, and delta volts readouts, if you use the standard accessory probes or other compatible probes. Pressing the identification button on Tektronix probes replaces the scale factor for the channel with "ID" and shifts the trace.

Shutdown Warning

See "Display Operation" for a description.

Measurements with Cursors

The controls in the gray box (ΔV, Δt, TRACK/INDEP, Δ REF OR DLY POS, and Δ) operate cursors and sweep delays. With the cursors, you can measure voltage, time, frequency, ratios, and phase. We often refer to the Δ REF OR DLY POS control as "Δ REF" for convenience.

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.

For best ΔV accuracy, display the signal on either CH 1 or CH 2 with VOLTS/DIV set for three to eight divisions of waveform amplitude. For best Δt and 1/Δt accuracy, use the fastest sweep that will include the interval of interest.

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 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.

Measure Time, with A-Sweep or B-Sweep Alone (SEC/DIV 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.

Measure Frequency with Cursors

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 either Δ button twice to turn off the 1/Δt cursors and readout.

Measure Voltage Ratio, Time Ratio (such as Duty Factor), or Phase

1. Set VOLTS/DIV or SEC/DIV so a feature of the waveform which you consider the 100% reference covers more than five divisions of the graticule.

2. Turn the VOLTS/DIV VAR or SEC/DIV VAR counterclockwise from the detent until the 100% reference feature covers exactly five divisions. You can use one signal as a reference and compare others to it. For phase, set one cycle, which is the 360 degree reference, to five divisions.

3. Press ΔV to measure voltage ratio, Δt for time ratio, or ΔV and Δt together for phase. The VAR must be counterclockwise from the detent position to turn on the RATIO or PHASE readout.

4. Turn Δ REF and Δ to align the cursors with the portion of the waveform to be compared to the reference portion. Phase is usually a two-channel measurement between zero crossings. (Be sure zero crossings for phase measurements are positioned at the graticule center.)

5. The readout shows the ratio or phase shift.

6. Press the same ΔV or Δt button, or both, to turn off the cursors and readout.

Choosing Tracking or Independent Delta Mode

Use the INDEP mode for most measurements, with each cursor independently adjustable. Use TRACK mode, where the Δ REF knob moves both cursors as a pair, to compare waveform features. The Δ control moves only the Δ cursor.

Voltage Measurements

Automatic voltage measurements can be made through the measurement menus. Set the oscilloscope up for automatic voltage measurement by:

1. Pressing the MEASURE button.
2. Selecting VOLTS from the menu by pressing button number 2.

The + peak, -peak, average, and peak-to-peak volts are measured and displayed in the readout.

If the voltage measured has an extremely small peak-to-peak value, only the average volts will be displayed.

If the input signal is AC coupled, only the peak-to-peak value will be displayed.

The voltage measurement is sensitive to input frequency. Signal frequencies above 1 MHz will have measurement errors greater than 5%.

For accurate voltage measurements using VOLTS, it is important that a DC balance has been done at a temperature within 5°C of the operating environment temperature. See "Auto DC Balance Routine" in the "Checks and Adjustments" section for more information.

Display Operation

The 2467B 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.

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.

Differential Aging

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 aging," can be visible with a flooded-screen display, but it usually has little or no effect on waveform displays.

When a front panel switch is changed, you may notice that the readout display shifts slightly. This is due to the position offset of the readout which is an internal function that shifts the readout over a larger area of the screen each time a change is made to a front panel switch, but not more than once every five seconds. By doing this the life of the readout is extended. The readout has four positions in either the x or y direction, giving a total of 16 possible readout positions.

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 aging.

To avoid excessive CRT aging, the instrument limits intensity to a low level, after a time with no front panel control changes. After an additional time without front panel activity, the display shuts down completely except for a brief display of the word "SHUTDOWN" every few seconds. Press BEAM FIND or move any other control, except FOCUS, to restore the original intensity level. Pressing the probe identification button will also restore the intensity. The time you have to observe the display without moving a control decreases with higher INTENSITY control settings and higher trigger rates.

Shutdown Warning

If the B Sweep is not displayed, the readout can show, in the lower-right corner, how much display time remains at a given intensity as the time approaches zero. The reading is in seconds unless an "m" or "H" suffix indicates minutes or hours. See EXER 09 in Appendix A to set the parameters of the shutdown warning.

Signal Connections

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.

Waveform Fidelity and Probe Grounds

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

The standard-accessory probe is a compensated 10X voltage divider. 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.

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.

Probe Compensation

Misadjustment of probe compensation is a common source of measurement error. Due to variations in oscilloscope input characteristics, probe compensation should be checked whenever the probe is moved from one oscilloscope to another or between channels of a multichannel oscilloscope. See the procedure in the "Checks and Adjustments" section of the manual.

Probe Handling

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

Coaxial Cables

To maintain good waveform fidelity and accuracy, 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.

Magnify Waveform Details with Delayed-Sweep

1. Display a waveform with the A Sweep, then pull SEC/DIV out to activate B Sweep and light both the A SWP and B SWP indicators (INTEN mode).

2. If a B-Trigger Mode indicator is on, select RUN AFT DLY. (If an A-Trigger Mode indicator is on, the B Trigger has been set previously to RUN AFT DLY.)

3. Set Δ REF OR DLY POS to place the small intensified zone at a point of interest. (This zone may be more apparent with a lower Intensity setting.) If the A Sweep terminates just after the intensified zone, you can move the HOLDOFF control and set it at MIN. (Two intensified zones appear if you have selected Δt or 1/Δt. See "Delta-Delay-Time.")

4. Turn SEC/DIV clockwise, with the knob pulled out, to expand the point of interest on the B Sweep, while observing its relationship to everything else on the A Sweep (ALT mode). Use TRACE SEP to separate the A-Sweep and B-Sweep traces.

5. If you want to simplify the display and obtain the best possible view of the magnified details, push the SEC/DIV knob in to display only the B Sweep. If you want the brightest trace possible, set HOLDOFF to B ENDS A, which makes the sweep repetition rate as high as possible.

6. Select ΔV, Δt, or 1/Δt when the SEC/DIV knob is pushed in to measure waveform details with cursors. The Δ REF and Δ controls have no effect on sweep delay while cursors are displayed.

B-Trigger Operation

Use the B Trigger to eliminate jitter in B-Sweep displays. With the available Counter/Timer/Trigger (*CTT*), the B Trigger locks a delay-time or delta-delay-time measurement to the signal, so any variations are tracked automatically. However, without the *CTT*, the B Trigger obscures delay or delta-delay measurements and the readout includes a question mark.

Distinguishing RUN AFT DLY and TRIG AFT DLY

With RUN AFT DLY mode, the Δ REF OR DLY POS and Δ controls adjust the delay-time or delta-delay-time. The intensified zones on the A-Sweep trace move continuously as the controls are adjusted. If the B-Trigger mode is TRIG AFT DLY and a signal triggers the B Sweep, the delay times and intensified zones jump to successive B-Trigger points as delay time is adjusted. With TRIG AFT DLY, the actual delay time is controlled by the signal, as enabled by the A Sweep and the Δ REF and Δ settings.

Setting the B Trigger

1. When the B SWP indicator is on, press A/B TRIG to illuminate a B-Trigger Mode indicator. (If B-Trigger mode is not RUN AFT DLY, a B-Trigger Mode indicator will be on when the B SWP indicator is on.)

2. Select TRIG AFT DLY Mode.

3. Set SOURCE, COUPLING, SLOPE, INIT@50%, and LEVEL controls as required.

Changing the A Trigger while B Trigger is Active

1. Press and hold A/B/TRIG while adjusting SOURCE, COUPLING, SLOPE, INIT@50%, and LEVEL controls for the A Trigger.

2. Alternatively, choose RUN AFT DLY B-Trigger mode and momentarily press A/B TRIG, then adjust A Trigger. With RUN AFT DLY B-Trigger mode or SGL SEQ A-Trigger mode (or an active *CTT* function that uses the B Trigger), the trigger controls alternate between A Trigger and B Trigger each time A/B TRIG is momentarily pressed.

Delta-Delay-Time

Use the delayed (B) sweep to magnify both ends of a time interval for the best measurement accuracy available. Appendix D gives relative accuracies of the various time-measurement techniques.

Measure Time or Frequency with Delta-Delay-Time

1. Display the time interval or signal period with the A Sweep running as fast as possible, unmagnified, up to one speed slower than the fastest SEC/DIV setting. If the ihterval is a propagation delay or other two-signal measurement, display the signals on CH 1 and CH 2 and trigger A Sweep on the earlier of the two.

2. Pull SEC/DIV out to activate B Sweep and light the A SWP and B SWP indicators (INTEN mode). (If you inadvertently chose the fastest A-Sweep speed, the CH2 Delay Match function will be active. See the "Operator Checks and Adjustments" section.)

3. If a B-Trigger Mode indicator is on, select RUN AFT DLY. (If an A-Trigger Mode indicator is on, the B-Trigger has been set previously to RUN AFT DLY.)

4. Select Δt or $1/\Delta t$ while the SEC/DIV knob is out.

5. Adjust Δ REF OR DLY POS and Δ to place the pair of intensified zones at the beginning and end of the interval of interest. If the A Sweep terminates just after the intensified zones, you can move the HOLDOFF control and set it at MIN.

6. Turn SEC/DIV clockwise with the knob pulled out to magnify the ends of the interval on the B Sweep while observing the entire interval on the A Sweep (ALT mode). Use TRACE SEP to separate the A-Sweep and B-Sweep traces as desired.

7. Set Δ REF and Δ to superimpose the magnified displays of the beginning and end of the interval. The readout shows the interval.

Without the *CTT*, make delta-delay-time measurements only in the TRIG AFT DLY trigger 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 differ from the delay or Δt readout by as much as twice the signal period.

Delta-Delay-Time Measurement Characteristics

A delta-delay-time measurement is valid between a pair of points superimposed on the pair of B Sweeps, regardless of display positions, Trace Sep setting, and CRT-distortion errors. In other words, the only points that can be superimposed are those points that are separated by the delta-time value. (Good accuracy for short intervals does depend on correct CH 2 DLY adjustment. See "Operator Checks and Adjustments" section.)

The main sweep trigger event begins the interval of interest for many measurements. The delta-delay-time measurement can include the A-Sweep trigger event with A SEC/DIV set faster than 50 µs. If an interval begins less than 0.05 division from the beginning of A Sweep, the readout shows a question mark. Move Δ REF clockwise and change the A-Trigger controls as required to eliminate the question mark and still see a suitable waveform feature for the beginning of the interval.

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. Compared to delta-delay-time measurements, some accuracy will be lost, unless you can take the difference between one delay time and another.

1. Display the time interval with the A Sweep running as fast as possible, unmagnified. If the interval is a propagation delay or other two-signal measurement, apply the signals to CH 1 and CH 2. For maximum display repetition rate, display only the channel with the end of the interval. Trigger the A Sweep at the beginning of the interval. Turn off Δt or 1/Δt.

2. Pull SEC/DIV out to activate B Sweep and light both the A SWP and B SWPindicators (INTEN mode).

3. If a B-Trigger Mode indicator is on, select RUN AFT DLY. (If an A-TriggerMode indicator is on, the B-Trigger has been set previously to RUN AFT DLY.)

4. Set Δ REF OR DLY POS to place the intensified zone at the end of the interval.

5. Turn SEC/DIV clockwise with the knob pulled out to magnify the end of the interval on the B Sweep while observing its relationship to the beginning of the interval on the A Sweep (ALT mode). Use TRACE SEP to separate the A-Sweep and B-Sweep traces.

6. Set Δ REF OR DLY POS to align the end of the interval with the left end of the B Sweep. The DLY reading is the length of the interval.

7. If you want to simplify the display and obtain the best possible view of the end of the interval, push the SEC/DIV knob in when A and B SEC/DIV settings are unequal to display only the B Sweep.

Time Interval Measurement

The Parametric Measurement feature automatically makes time interval measurements between any two selected points. To make a time interval measurement:

1. Push the MEASURE button.
2. Select TIME from the displayed menu by pushing button 6 in the Vertical mode area.

Before making the first measurement using the Time Function, configure the measurement by:

1. Pushing the MEASURE button.
2. If the *CTT* option is present, select MORE from the menu. Then, select CONFIGURE from the displayed menu. Otherwise, select CONFIGURE from the menu.
3. Select TIME from the menu
4. Using the Δ REF OR DLY POS and the Δ controls select the channel, slope, and level of the start and stop events that define the time interval.

The Δ REF OR DLY POS control moves the underlining cursor among the various items. When an item is underlined, turning the Δ control will change its value.

Pressing any one of the VERT mode buttons will exit from this menu, leaving the time-measurement configuration you have defined.

Pressing MEASURE with a measurement menu displayed will display additional help messages, if available.

To make a measurement with these configuration values, press MEASURE, then select TIME from the menu. The configuration values will remain the same until changed using the above procedure.

Precision Timing

The available Counter/Timer/Trigger *(CTT)* directly and precisely measures any interval defined by the delayed (B) Sweep and the B-Trigger. The *CTT* also reduces the effort required for repetitive measurements or measurements on changing signals.

Direct and Indirect Measurements

As the counter completes each *direct* measurement, the last character of the units symbol blinks. If the readout includes the word "SET," it indicates an *indirect*

measurement of delay-time, including delta-delay-time or 1/delta-delay-time. Indirect measurements are inferred from the A Sweep and control settings.

Indirect delay-time measurements are displayed when any Count, Delay-by-Events, or Logic-Trigger function of the *CTT* is active, except B Sweep triggered by the Word Recognizer. Indirect measurements are also displayed for a few seconds when Δ REF or Δ are adjusted. Moving any control that affects direct measurements produces an indirect reading until a new, direct measurement is complete.

Direct, counted measurements may be different from indirect ("SET") measurements for any of the following reasons:

1. Direct measurements are more accurate and show more digits of resolution;

2. When B Sweep is triggered, both the waveform display and the direct measurement respond to the signal. Indirect measurements respond only to control settings, regardless of the signal, and they include a question mark when B Sweep is triggered;

3. Both direct and indirect measurements in RUN AFT DLY Mode suffer from offset errors. Direct delay measurements, without Δt or $1/\Delta t$, are accurately calibrated in TRIG AFT DLY Mode, from the A-Trigger event to the B-Trigger event.

Condition Messages

One of the following messages, indicating the described condition, may appear instead of a measurement:

AVERAGING	The selected resolution requires more sweeps.
NO A TRIGGER	The A-Trigger event has not occurred.
MISSING B TRIG	At least one A Sweep occurred without a B-Trigger event during the A Sweep.
NO ATRIG VERT SRC	Multiple A-Trigger sources are selected.

Triggered Delta-Delay-Time Measurements

The available Counter/Timer/Trigger *(CTT)* directly measures intervals defined by the B-Sweep delays and B Trigger. B Trigger with Δt and $1/\Delta t$ can have different sources, levels, and slopes for the pair of B-sweeps. Repeatedly pressing the lower Mode button selects the following sequence of B-Trigger modes with the noted characteristics:

With or without Δt or $1/\Delta t$:

RUN AFT DLY

B Sweep runs immediately after the set delay.

Without Δt or $1/\Delta t$:

TRIG AFT DLY

B Sweep runs at the first trigger after the set delay.

With Δt or $1/\Delta t$:

TRIG AFT DLY and TRIG Δ DLY (both indicators on)

SLOPE and LEVEL settings for triggering at Δ REF delay and Δ delay are common.

TRIG Δ DLY

SLOPE and LEVEL for Δ delay can be set independent of the setting for Δ REF delay.

TRIG AFT DLY

SLOPE and LEVEL for Δ REF can be set independent of the setting for Δ delay

TRIG Δ DLY

Repeated operation of the lower Mode button toggles between TRIG AFT DLY and TRIG Δ DLY.

With Δt or 1/Δt and TRIG AFT DLY or TRIG Δ DLY. the upper Mode button selects the TRIG AFT DLY and TRIG Δ DLY mode, where Slope and Level are common for both delays.

Measure a Time Interval Defined by the B-Trigger

1. Follow the first five steps of the procedure in "Measure Time or Frequency with Delta-Delay-Time," earlier in this section.

2. If the interval is a propagation delay or other two-signal measurement, select ALT Vertical Mode and be sure A-Trigger Source is a single channel. Note that Δ REF controls the intensified zone on the CH 1 trace.

3. Select TRIG Δ DLY B-Trigger Mode. For the special case of a measurement on one signal where the beginning and end of the interval have the same slope and threshold, select TRIG AFT DLY and TRIG Δ DLY (both indicators on).

4. Set B-Trigger Source to VERT. If the measurement is limited to one signal and more than one signal is displayed, either deselect the other signals or set Source to the appropriate channel. If two channels are used, only those two channels should be displayed.

5. Set B-Trigger Coupling to DC. For unusual applications, other couplings may be preferred.

6. Press INIT@50%. If necessary, adjust LEVEL for the desired trigger threshold.

7. Select TRIG AFT DLY Mode and repeat Step 6. (For the special case noted in Step 3, skip this step.)

8. If required, readjust Δ REF and Δ to intensify the transitions that mark the beginning and end of the interval In some cases, A-Trigger or B-Trigger settings may need to change in order to trigger on the beginning of the interval.

9. Turn SEC/DIV clockwise to magnify the ends of the interval and readjust LEVEL as required to superimpose them. (Skip this step if signal transition times are much shorter than the required accuracy.)

10. Read the measurement from the readout when "SET" disappears.

Time Interval Resolution

The available Counter/Timer/Trigger *(CTT)* measures Delay-Time, Delta-Delay-Time, and 1/Delta-Delay-Time, with the delayed sweep. You can choose the optimum time-interval resolution for these measurements.

1. Press the MEASURE button.
2. Select MORE from the menu.
3. Select CONFIGURE from the menu.
4. Select RESOLUTION from the menu.
5. Select the desired resolution by pushing the appropriate menu (VERTICAL MODE) button.

Measurement Updating

AUTO updates the measurement either every 1/2 second or when a measurement is available, whichever is longer. With 1 ns, 100 ps, and 10 ps resolution, the measurement is updated after enough sweeps have occurred for a valid average, as indicated under "N for Average" in Table 2-1.

Table 2-1
Resolution Selections

A SEC/DIV	Selection	Least Digit	N for Average
10 ns to 500 ms	AUTO	See Table 2-2	See Table 2-2
10 ns to 5 μs	10 ps	10 ps	> 10^6
	100 ps	100 ps	> 10^4
	1 ns	1 ns	> 100
10 μs to 50 μs	10 ps or 100 ps	100 ps	> 10^4
	1 ns	1 ns	> 100
100 μs to 500 μs	10 ps to 1 ns	1 ns	> 100
1 ms to 5 ms	Any	10 ns	> 1
10 ms to 50 ms	Any	100 ns	> 1
100 ms to 500 ms	Any	1 μs	> 1

Table 2-2
Auto Resolution

A SEC/DIV	Trigger Rate	Least Digit	N for Average
10 ns to 2 μs	> 20 kHz	100 ps	> 10^4
10 ns to 2 μs	200 Hz to 20 kHz	1 ns	> 100
5 μs to 200 μs	> 200 Hz	1 ns	> 100
10 ns to 200 μs	< 200 Hz	10 ns	> 1
500 μs to 5 ms	Any	10 ns	> 1
10 ms to 50 ms	Any	100 ns	> 1
100 ms to 500 ms	Any	1 μs	> 1

Frequency, Period, and Totalize Counting

With Parametric Measurements, the Frequency and Period of the signal on the lowest numbered channel that is displayed can be measured by:

1. Pushing the MEASURE button.
2. Selecting FREQ from the menu.

Frequency and period measurements appear in the second and third lines of the display.

The source of the A trigger that is counted is shown on the far left of the second line of the display as CHn: where n can be either 1 or 2.

If the CTT is present:

1. Press the MEASURE button.
2. Select COUNTER from the menu.
3. Select FREQUENCY or PERIOD from the menu.
4. Frequency or period measurements will be displayed in the upper right hand corner of the display. Measurements will be updated 3 times per second or once per period whichever is slower. The input frequency must be 150 MHz or less.

Totalize Random or Low Repetition Rate Events

1. Press the MEASURE button.
2. Select COUNTER from the menu.
3. Select TOTAL from the menu.
4. Move any front panel switch to reset the displayed count.

Canceling Menu Functions

To exit from any MEASURE menu, select OFF from the menu or press any other front panel switch except VERTICAL MODE or MEASURE.

Pressing MEASURE while in a menu will cycle HELP text lines through the bottom line of the readout.

Frequency Measurement with External Reference (Option 1E)

1. Connect a precision frequency standard signal (must have an accuracy better than 10 ppm) to BNC connector EXT REF IN, located on rear panel. The reference signal must be greater than 2 V peak-to-peak into a 50 Ω or 75 Ω load with frequency of 1 MHz, 3.579545 MHz, 4.4336188 MHz, 5 MHz, or 10 MHz.
2. Select FREQUENCY as described above.
3. After 100 measurements (approximately 1 minute), the frequency readout will display the applied input signal frequency in 8 digits.

Delay Sweeps by Event Counts

The available Counter/Timer/Trigger (Option 09 or 06) includes delay-by-events for either the A Sweep or the B Sweep. Event counting begins at a starting event on a vertical input, defined by the A Trigger. Delay-counting events are defined by the B Trigger. In addition, the available Word Recognizer *(WR)* can define either start or delay-counting events. The combinations available are shown in Table 2-3.

Which Sweep to Delay

When the A Sweep is delayed by events, the event count can accumulate for unlimited time. Then the B Sweep can be delayed by time to magnify waveform details.

When the B Sweep is delayed by events, the event count must accumulate during the A Sweep. Then the intensified A Sweep can show the timing between the start event and the delay count.

Table 2-3
Delay-by-Events Combinations

Sweep to Delay	Start At	Event to Delay by	Explanation
A	A Trigger	B Trigger	Delay begins at the A-Trigger event; then A Sweep runs after the selected number of B-Trigger events.
B	A Trigger	B Trigger	Delay begins when the A Sweep is triggered by the A-trigger event; then B Sweep runs after the selected number of B-Trigger events, if the A Sweep has not terminated.
Added Delay-by-Events Combinations with the Word Recognizer			
A	A Trigger	Word Recognizer	Delay begins at the A Trigger; then A Sweep runs after the selected number of words are recognized.
B	A Trigger	Word Recognizer	Delay begins when the A Sweep is triggered by the A-Trigger event; then B Sweep runs after the selected number of words are recognized, if the A Sweep has not terminated.
A	Word Recognizer	B Trigger	Delay begins when a word is recognized; then A Sweep runs after the selected number of B-Trigger events.
A	Word Recognizer	Word Recognizer	The A Sweep runs after the selected number of words are recognized.

Initiate a Sweep by an Event Count (Delay-by-Events)

1. Press the MEASURE button.
2. Select MORE from the menu.
3. Select DELAY-BY-EVENTS from the menu.
4. The sweep that you wish to delay, either A Sweep (A SWP) or B Sweep (B SWP), is selected by pressing either VERT MODE button 1 or 5.

The starting event, either the A Trigger (ATR-START) or the Word Recognizer (WR-START), is selected by pressing VERT MODE button 2 or 6.

When the A Sweep is delayed by events, the event count can accumulate for unlimited time. Then the B Sweep can be delayed by time to magnify waveform details.

The event that is counted for the delay, either the B Trigger events (DLY-BY-B) or the Word Recognizer event (DLY-BY-WR), is selected by pressing VERT MODE button 3 or 7.

5. Press VERT MODE button 8 to exit the menu after making your selections.

VERT MODE button 4 (OFF) will turn off the delay-by-events function.

If B Sweep is delayed by events, the message "PULL SEC/DIV" appears until the B Sweep is activated.

The display shows "A" or "B" to identify the sweep delayed, "DBE" to indicate the Delay-by-Events function, and the number of events required to initiate the sweep, for example:

A DBE 1234567

Change the Number of Events

1. Turn off any competing function, such as Δt, so the Delay-by-Events display appears on the right-hand side of the CRT.
2. Turn the Δ REF OR DLY POS knob to underline a digit.
3. Turn the Δ knob to change the value of the digit.

Reset the Number of Events to One

1. Turn the Δ REF OR DLY POS knob to underline the most significant digit of the number.

2. Turn the △ knob counterclockwise until all digits are 0, except the rightmost digit. The smallest value of the rightmost digit is 1.

Decrementing the most significant digit when it is 0 or incrementing a digit when it and higher order digits are at maximum moves the underline cursor to the right.

Avoid Ambiguous Event Counts

With slow signal transitions, the start event detected by the A Trigger may also be detected as a delaying event by the B Trigger, depending on SLOPE and LEVEL settings of the two triggers.

When the time between the start event and the first delaying event is less than 4 ns, the first delaying event may or may not be counted. In most cases, the ambiguity can be resolved by choosing appropriate trigger slopes for the start and delaying events.

To see exactly which event is counted as the first event, select B-Sweep Delayed-by-Events, pull SEC/DIV out to display the intensified A Sweep, and set the event count to 1. The intensified zone will show which event is counted first.

Canceling Menu Functions

To exit from any MEASURE menu, select OFF from the menu or press any other front panel switch except VERTICAL MODE or MEASURE.

Pressing MEASURE while in a menu cycles HELP text lines through the bottom line of the readout.

Logic Triggering

The available Counter/Timer/Trigger *(CTT)* enhances trigger selectivity. Sweeps can be initiated by combinations of two vertical signals, defined by A Trigger and B Trigger. The available Word Recognizer *(WR)* expands logic triggering to 17-bit patterns, either synchronous or asynchronous.

Initiate a Sweep with the Logic Trigger

1. Press the MEASURE button.
2. Select MORE from the menu.
3. Select LOGIC-TRIGGER from the menu.
4. Select the desired triggering function by pushing the appropriate menu (VERTICAL MODE) button:
   a. A-AND-B – Triggers the A sweep only on the coincidence of the A trigger event and the B trigger event. The A and B trigger events are considered to be logically true if the trigger input signal is more positive than the trigger level and + slope is selected. If - slope is selected, a true state exists only when the input signal is more negative than the trigger level.
   b. A-OR-B – Trigger the A sweep on the occurrence of either the A trigger event or the B trigger event. The same rules for logic conversion of the trigger signal apply here as they do for A-AND-B.
   c. A:WR – Triggers the A sweep upon recognition of the specified digital word for the Word Recognizer.
   d. B:WR – Triggers the B sweep upon recognition of the specified digital word.
5. Set the A-Trigger and B-Trigger controls or the *WR* pattern for the desired trigger.

When the B Sweep is triggered by the *WR*, delay-time or delta-delay-time time is measured by the crystal-controlled timer. With any other logic-trigger function, delay-time and delta-delay-time measurements are derived from delay settings or cursors.

Table 2-4

Sweep Triggering

Selection	Triggers	When
A-AND-B	A Sweep	AND of A and B Triggers A: A·B changes from FALSE to TRUE.
A-OR-B	A Sweep	OR of A and B Triggers A:A + B changes from FALSE to TRUE.
A:WR	A Sweep	Word Recognizer detects the selected word.
B:WR	B Sweep	Word Recognizer detects the selected word.

Canceling Menu Functions

To exit from any MEASURE menu, select OFF from the menu or press any other front panel switch except VERTICAL MODE or MEASURE.

Pressing MEASURE while in a menu cycles HELP text lines through the bottom line of the readout.

When a logic trigger is active, selecting AUTO LVL Trigger Mode cancels the function.

Word Recognizer Operation

Count functions, Delay-by-Events, and Logic Trigger functions can invoke the available Word Recognizer *(WR)*, if it is included in the instrument. The *WR* requires a data radix, clock parameters, and a data pattern.

To change the WR display radix:

1. Press MEASURE.
2. Select MORE from the menu.
3. Select CONFIGURE from the menu.
4. Select WR-RADIX from the menu.
5. Select desired display radix from the menu by pushing the appropriate menu (VERTICAL MODE) button.
6. Connect the *WR* probe to the system under test. Note that bits 0 to 7 and the clock appear on one side of the probe and bits 8 to 15 and the qualifier appear on the other. Be sure to connect at least one of the GND terminals to a good signal ground in the system, as close to the signal test points as possible.

If a word is defined in one radix then displayed in another, some but not all bits of a hexadecimal or octal digit may be X (irrelevant), rendering the digit ambiguous. Ambiguous digits are displayed as question marks.

A↑011XX XXX0	A↑0 1?X077	A↑0 ??3F
BIN	OCT	HEX

When the *WR* defines the starting event or the counting event for Delay-by-Events, the display shows both the *WR* status and the delay count.

7. Specify the desired pattern. During operation of the function driven by the *WR*, the *WR* status is displayed in this format:

   scq word

   where the "s" character indicates the affected sweep (A or B); "c" is the clock mode (↑, ↓, or X); "q" is the qualifier bit (0, 1, or X); and "word" is a 16-bit pattern in the selected radix.

   a. Turn the Δ REF or DLY POS control to the clock mode character, the qualifier bit, or a digit of the word.

   b. Turn the Δ control to define the underlined character. Digits of the word can be set to 0, 1, or X with BIN radix, 0 to 7 or X with OCT, and 0 to F or X with HEX. Note that the clocking edge can be redefined here.

The Word Out Signal

The available Word Recognizer *(WR)* generates a WORD OUT signal at a BNC connector on the rear panel. The output is TTL-high when the selected word is recognized. The most recent word definition controls the signal, whether or not the function that invoked the *WR* is active. The timing of the word occurrence, relative to other signals, can be observed by connecting the WORD OUT signal to one vertical channel and using the remaining vertical channels for the other signals.

Propagation delay of word recognition prevents the oscilloscope from displaying the signal transition that generates the trigger, when triggered by the *WR* or the WORD OUT signal.

Frequency Limit for Auto Level or Parametric Measurements

The minimum frequency of operation for Auto Level, INIT@50%, or parametric measurements is selectable. The minimum limits are 50 Hz and 10 Hz. Selecting 10 Hz causes all measurements to be significantly .slower. These can be selected by the following steps:

1. Press the MEASURE button.
2. If the *CTT* is present, select MORE from the menu; otherwise, go to Step 3.
3. Select CONFIGURE from the menu.
4. Select MINFREQ from the menu.
5. Push the appropriate mode button to select the desired minimum frequency limit. This selection will be reset to 50 Hz whenever power is turned off.

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. Twenty-two 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.

Save and Recall Help

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 repeating sequence.

Save a Setup (Direct Save setups 1–8)

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

Top Row Cursor	--	SAVE 1-8 DIRECTLY. NAME:xxxxxxx
Bottom Rows	--	PUSH ANY OF 1-8 TO SAVE SETUP. PUSH SAVE FOR HELP.

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

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, up to seven. A small cursor marks the character selected for definition.

If you wish to save a measurement, simply push the MEASURE button.

The NAME area will change to MEAS: °FREQ with FREQ underlined by the cursor.

To select among the various measurements, turn the Δ control until the desired measurement is displayed.

The TIME measurement is unique in that you may define unique measurements by adding a suffix to the °TIME.. label. To change the suffix, turn

the Δ REF OR DLY POS control until the cursor underlines the first space with a " " in it. Then rotate the Δ control to obtain the character you want.

This allows you to define multiple TIME measurements which have different configurations. (For information on configuring the TIME measurement, see "Time Interval Measurement" in this section.)

Pressing the MEASURE button toggles back to the NAME: format which allows saving instrument setups. Subsequent presses of the MEASURE button toggle between the measurement saving mode and the setup saving mode.

4. Press one of the setup number buttons. In the upper left corner of the CRT, the readout will show 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.

Save a Setup (Extended Save setups 9-30)

You can also save more than 8 setups by pressing STEP/AUTO (after pressing SAVE to enter Save mode), and turning Δ to the desired extended setup location. To name the selected setup, follow Step 3 of Save a Setup (Direct Save setups 1-8), pressing STEP/AUTO when finished. If the name for the setup is to remain the same, then just press STEP/AUTO.

Save a Sequence

See Appendix B for sequence programming instructions.

Recall a Setup (Direct Recall setups 1-8)

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 second row. For example:

   Top Row -- SKEW ADJ.PLL TP-2467 CLOCK

   Second 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.

Recall a Setup (Extended Recall setups 9–30)

You can also recall any of the setups beyond 8, while in Recall mode, by turning Δ to the desired step number, then pressing STEP/AUTO. This does not establish the Step mode.

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.
5. Press RECALL to cancel the sequence mode.

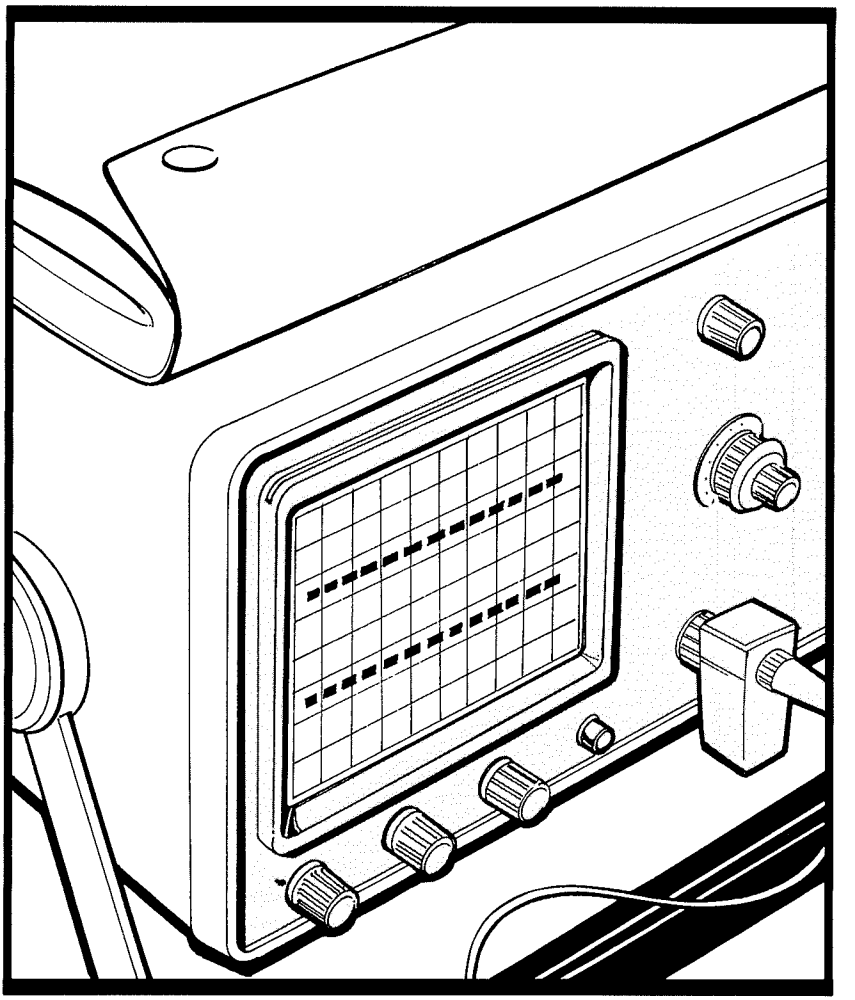
The STEP Indicator

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.

The following function is available for instruments with serial numbers B049999 and below with firmware versions 11 and above or for instruments with serial numbers B050000 and above with firmware versions 2 and above (see Appendix A – EXER 04 to determine firmware version). If the STEP indicator is on, the STEP function can be activated by pressing any probe ID button if configured to perform a STEP using the PROBE configure menu. The operator can configure the probe ID to perform one of four possible outcomes (IDENT, AUTO Setup, INIT@50%, or STEP). Once configured, the instrument will maintain the selection until modified again by the operator.

SECTION 3

Applications



Applications

Peak-to-Peak Voltage

Using Cursors

With ΔV turned on and VOLTS/DIV VAR fully clockwise, align the Δ REF cursor with the bottom of a waveform and align the Δ cursor with the top. The readout shows the equivalent voltage between the cursors anywhere on a waveform. Accuracy is degraded at frequencies approaching the instrument bandwidth.

Using Parametric Measurements

With the Parametric Measurement feature, +peak, −peak, average, and peak-to-peak voltage can be measured by:

1. Pushing the MEASURE button.
2. Selecting VOLTS from the menu.

Overshoot and undershoot on fast transitions will often be only partially detected by the VOLTS measurement. If your measurements require accurate representation of overshoot or undershoot, cursors will provide a better result.

Absolute Voltages Using Cursors

1. Position the waveform as desired for convenient viewing, with VOLTS/DIV VAR fully clockwise and with VOLTS/DIV set for the largest usable display amplitude.
2. Momentarily switch Input Coupling to GND and align the Δ REF cursor with the trace.
3. Switch Input Coupling to DC and set the Δ cursor to the point of interest. (See Figure 3-1.)

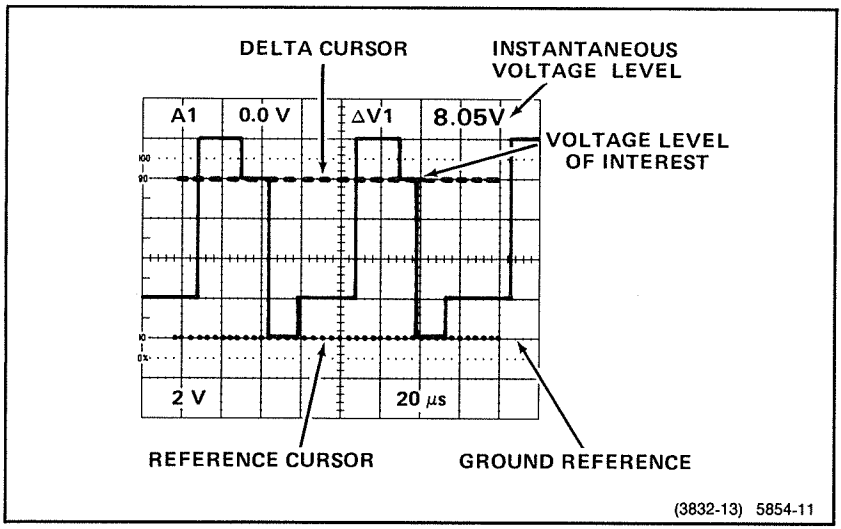


Figure 3-1. Instantaneous voltages.

Noise Immunity

Set the ΔV cursors to the upper and lower threshold limits of a digital circuit. For example, with TTL:

1. Superimpose the Δ REF cursor on the trace with input coupling at GND.
2. Set the Δ cursor for a 2.0 V readout.
3. Set the Δ REF cursor for 1.2 V readout, the difference between the 0.8 V lower-threshold limit and the 2.0 V upper-threshold limit.
4. Set Input Coupling to DC and observe the relationship between the signal and the cursors. The signal is faulty if it changes direction between cursors or if either the high level or the low level appears between cursors.

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, or verify the state of a control system.

1. Display either CH 1 or CH 2, and connect it to the voltage.
2. Push AUTO Setup and read the voltage in the trigger level readout. For voltages in the same range, simply touch the probe to the voltage. For best accuracy, set VOLTS/DIV so the measured voltage is five to fifteen divisions.

OR

1. Push MEASURE.
2. Select VOLTS from the menu.

The AVERAGE VOLTS readout is a good measure of the DC voltage present.

Amplitude Modulation

1. Set VOLTS/DIV and VAR for five divisions of carrier amplitude. Carrier amplitude is the difference between positive peaks of the modulated signal and negative peaks of the minimum-amplitude part of the envelope.
2. Align the reference ΔV cursor with the positive peaks of the minimum-amplitude part of the envelope and the Δ cursor with the positive peaks of the signal envelope.
3. The RATIO readout shows the modulation index in percent.

Frequency Modulation

For modulation index more than 1%:

1. Set SEC/DIV and VAR so the average signal period covers five divisions.
2. If deviation is less than 1 division in one cycle (20%), turn on X10 MAG.
3. Align Δt cursors with the extremes of the deviation.
4. The readout shows the peak-to-peak deviation in percent. If X10 MAG is on, divide the reading by 10.

For modulation index from 0.1% to 2%:

1. Measure the carrier period.
2. Display the A Sweep with SEC/DIV between 1 and 2.5 times the period.
3. Turn off Δt, pull SEC/DIV, and turn Δ REF for a DLY reading 10 times the carrier period. If a B-Trigger mode indicator is on, select RUN AFT DLY.
4. Turn and push SEC/DIV to display the B Sweep and set SEC/DIV at 0.2 times the period, using the switch and VAR. (The display will show one cycle in five horizontal divisions.) If the DLY setting is less than 200 ns, turn Δ REF to zero DLY, then turn Δ REF to move ten cycles past a point in the display.
5. Align Δt cursors with the deviation extremes.
6. Divide the reading by 10 to determine the peak-to-peak deviation in percent.

For modulation index from 0.01% to 0.2%, proceed as above for 0.1% to 2% except:

- at Step 2 set SEC/DIV between 10 and 25 times the period;
- at Step 3 set Δ REF for 100 times the carrier period; and
- at Step 6 divide the reading by 100.

The instrument adds about 0.01% spurious modulation to the display. This error can be minimized by measuring the apparent frequency modulation of an unmodulated carrier, at the same frequency and with the same control settings, and subtracting that value from very low modulation-index readings.

Measuring Video Signals in IRE Units

1. Display a video signal with VOLTS/DIV VAR adjusted out of detent for five divisions amplitude from the white level to the black level. (The black level is defined by the front and back "porches.")
2. Measure the features of interest with ΔV cursors. The RATIO readings in percent are equivalent to IRE units.

Avoiding False Displays with Multi-Mode Signals

A signal that has two characteristic forms on alternate cycles can produce incomplete displays. 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. Also, if a signal's period is less than the total duration of the sweep plus the trigger holdoff, the display could show only one of several signal modes.

1. You can display all the modes of a multi-mode waveform by changing the setting of Trigger HOLDOFF, so the modes are superimposed in the display.
2. CHOP Vertical Mode often will superimpose the multiple modes of waveforms in multi-channel displays. Signals with these characteristics should not be measured with the parametric functions since results are unpredictable.

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 Channel 2 is Inverted, 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. Signal peaks should not exceed ±8 times the VOLTS/DIV setting.
2. Position both Channel 1 and Channel 2 waveforms near center screen, when viewed separately. This ensures the greatest dynamic range for the Add trace.
3. To obtain similar responses from each channel, set Channel 1 and Channel 2 input couplings the same.

Observing Coincidence of Digital Signals

With digital signals applied to CH 1 and CH 2, the Add 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 high and the other one low, 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 to +. If the coincidence is low-low, set SLOPE to −. (If CH 2 is inverted, consider the inverse of the CH 2 signal in the high-high or low-low combination.) 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 Canceling 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, Invert CH 2, 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 3-2 shows an example.

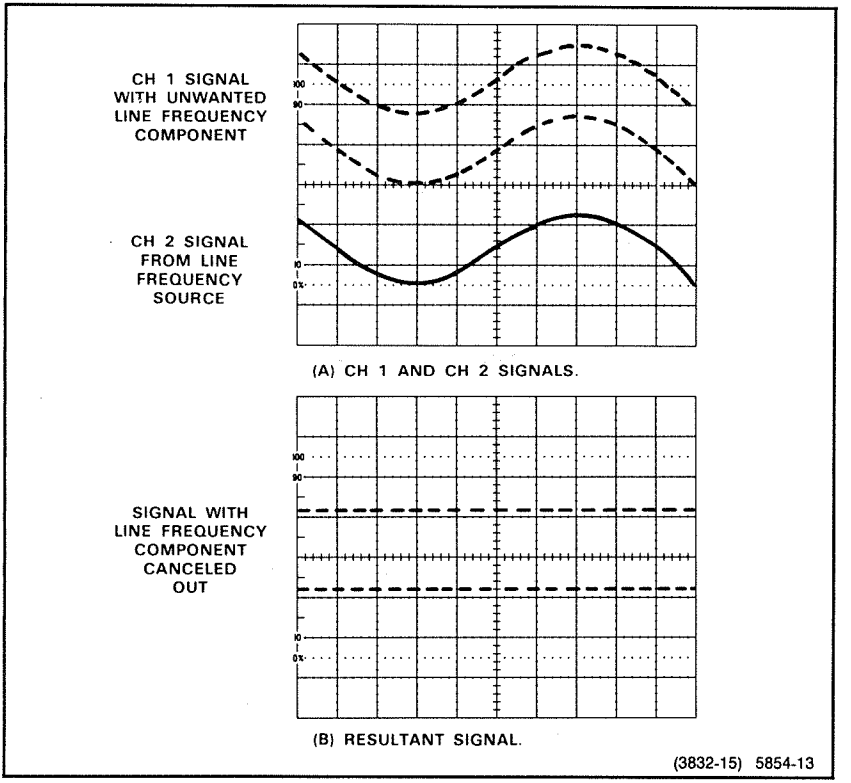


Figure 3-2. Eliminating common-mode signals.

Period and Frequency

Using Parametric Measurements

To measure Period and Frequency using the Parametric Measurement feature:

1. Push the MEASURE button.
2. Select FREQUENCY from the menu.

The oscilloscope automatically scales the amplitude and timing for the best measurement. Parametric measurements can only be done on repetitive signals. Signals with multiple valid trigger points will give erroneous results if measured with parametric measurements.

Using the Counter/Timer/Trigger (CTT)

1. Push the MEASURE button.
2. Select COUNTER from the menu.
3. Select FREQuency from the menu.

Without Parametric Measurements or CTT

1. Set SEC/DIV and, if necessary, X10 MAG to spread one cycle over as wide a span as possible.
2. Turn on Δt or $1/\Delta t$ and align the cursors with identical, fast-slewing points on consecutive cycles, such as zero-crossings.

Rise Time and Fall Time

Using Parametric Measurements

To measure rise or fall times with the parametric Measurements feature:

1. Push the MEASURE button.
2. Select from the menu either RISE-t for rise times or FALL-t for fall times.

The oscilloscope will automatically scale the amplitude and timing for the best measurement. The measurement results will be displayed once each time the measurement is selected.

If rise or fall time measurements are desired between points other than the 10% and 90% points, use the TIME measurement as described in Section 2. Signals that have relatively slow transitions at the 10% or 90% points with a fast transition between the 10% and 90% points can give erratic measurement results using RISETIME or FALLTIME.

Without Parametric Measurements or for Maximum Accuracy

1. Set VOLTS/DIV, VAR, and POSITION to align the bottom of the waveform with the 0% graticule line and the top with the 100% line.
2. Set Trigger SLOPE to + for rise time or to − for fall time.
3. Set SEC/DIV and, if necessary, X10 MAG to spread the transition over as wide a span as possible.
4. Turn on Δt and align the cursors with the points where the transition intersects the 10% and 90% graticule lines.

For best accuracy, observe the considerations given in the Signal Connection parts of the "Operation" section and be sure TRACE ROTATION is set correctly, as described in the "Checks and Adjustments" section.

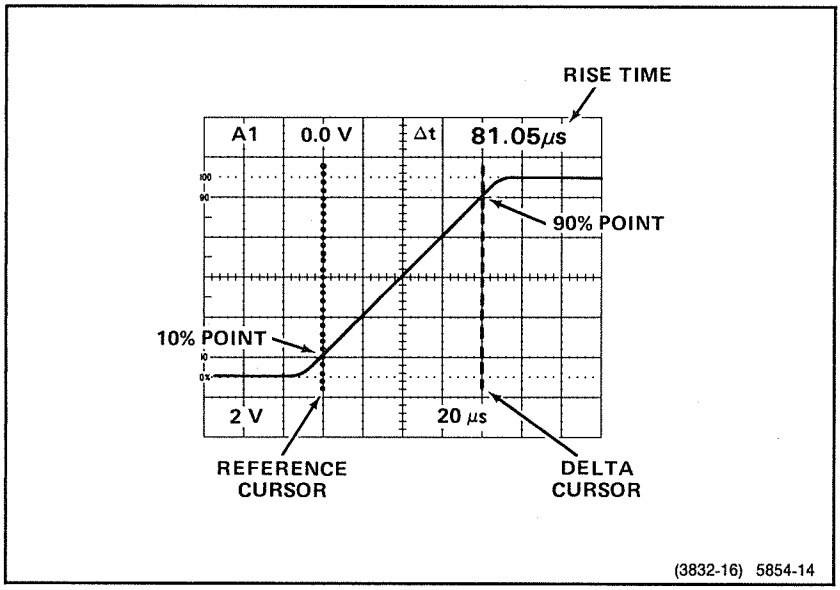


Figure 3-3. Measuring rise times.

Propagation Delay

Using Parametric Measurements

With the Parametric measurements feature, you can measure propagation delay by:

1. Displaying the input on CH 1 and the output on CH 2, trigger the oscilloscope on the input signal.
2. Pushing the MEASURE button.
3. Selecting TIME from the menu.

Prior to using this measurement, the time interval measurement must be configured to measure from the 50% point of the input event to the 50% point of the output event. See "Time Interval Measurement" in Section 2.

Without Parametric Measurements or for Maximum Accuracy

1. Display the input to the device under test on one channel and the output on another, with the largest practical vertical amplitude while keeping the zero-volt level on screen.
2. Trigger the sweep on the input signal.
3. Vertically position each waveform so the appropriate threshold voltage or the 50% point on transitions is aligned with a horizontal graticule line. You can use the same or different graticule lines for each waveform.
   a. Turn on ΔV and adjust Δ for the desired threshold voltage.
   b. Press TRACK/INDEP to select TRACK.
   c. Adjust Δ REF to align the Δ cursor, the one with dashes, with the graticule line you want the signal to cross.
   d. Select GND vertical input coupling and adjust POSITION to align the trace with the Δ REF cursor, the one with dots.
   e. Select DC vertical input coupling.
4. Set SEC/DIV as fast as possible while containing the measured time on screen. Use X10 MAG if needed.
5. Turn on Δt and align the cursors with the intersections of the waveforms with the chosen graticule lines.

For best accuracy, observe the considerations in the Signal Connection parts of the "Operation" section and make sure the vertical delays are matched by connecting both probes to one signal. If the delays are not precisely matched, see "Matching Channel 2 Delay" in "Checks and Adjustments."

Setup and Hold Times

Proceed as if measuring propagation delay, treating the clock as an input and the data signal as an output. Use high settings of INTENSITY to observe variations. If setup time exceeds 30 or 40 ns, you may prefer to treat the data as input and the clock as output.

If the data pattern is not repetitive giving a single valued display, do not use the parametric measurements for measuring setup or hold time.

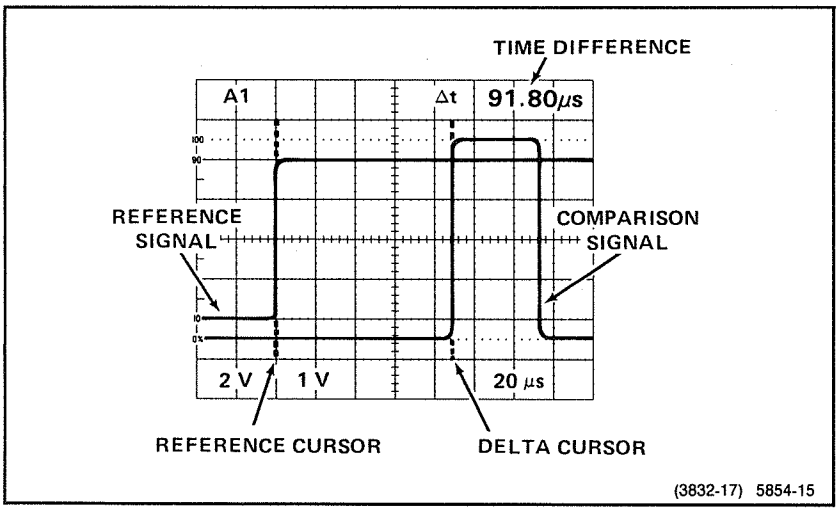


Figure 3-4. Time between two pulses (cursor method).

Slew Rate

Slew rate is the slope of a signal in volts/second.

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 (Duty Factor)

With Parametric Measurement

With the Parametric Measurements feature, duty factor can be measured by:

1. Displaying the signal on CH 1 or CH 2 and selecting only that channel for display.
2. Pushing the MEASURE button.
3. Selecting WIDTH from the menu.

The oscilloscope will automatically scale amplitude and timing for the best measurement. The pulse width and duty factor will both be measured and displayed.

Without Parametric Measurement

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.

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 3-5).

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.

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%.

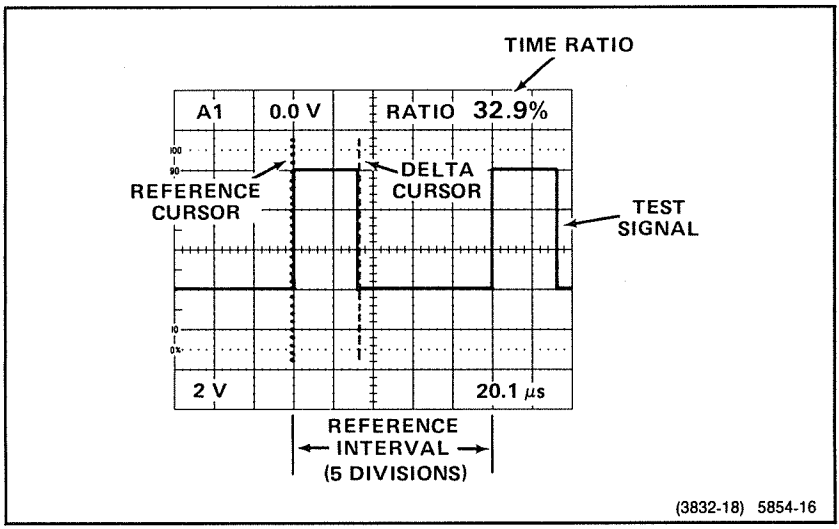


Figure 3-5. Time ratio (duty factor).

Phase Difference Between Two Signals

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. Set Vertical POSITION controls to center both displays vertically. Phase measurement accuracy 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 3-6). Use the center horizontal graticule line as the reference for aligning the zero-crossings.

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

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 3-7).

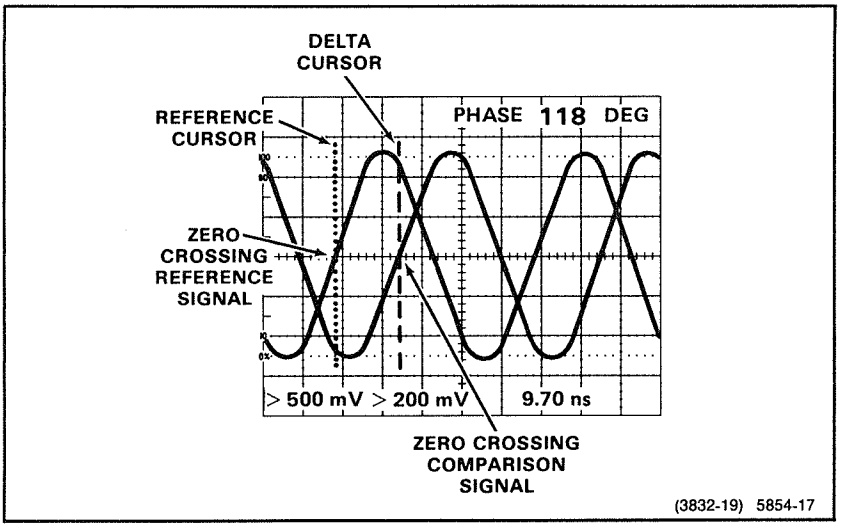


Figure 3-6. Phase difference between two signals.

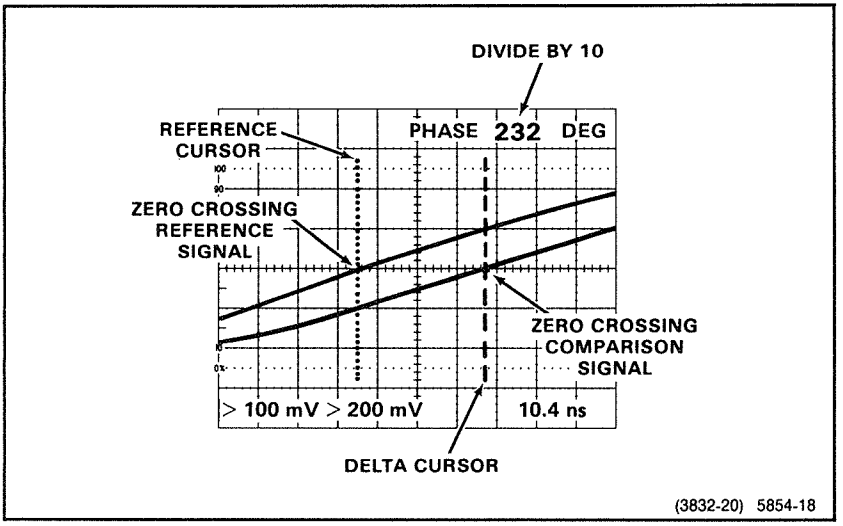


Figure 3-7. Small-angle phase difference.

Measuring Millivolt Signals

With the standard, 10X-attenuation probes, deflection factors range down to 20 mV/division. To increase the vertical sensitivity by a factor of ten, either use a 1X probe or cascade CH 2 with CH 1. To obtain 200 μV/division, use a 1X probe or coaxial cable to connect the signal to CH 2 and cascade CH 2 with CH 1. To cascade CH 2 with CH 1:

1. Connect the CH 2 output on the rear panel, through a 50-Ω cable, to the CH 1 input on the front panel.

2. Set the CH 1 input at 1 MΩ DC or AC.

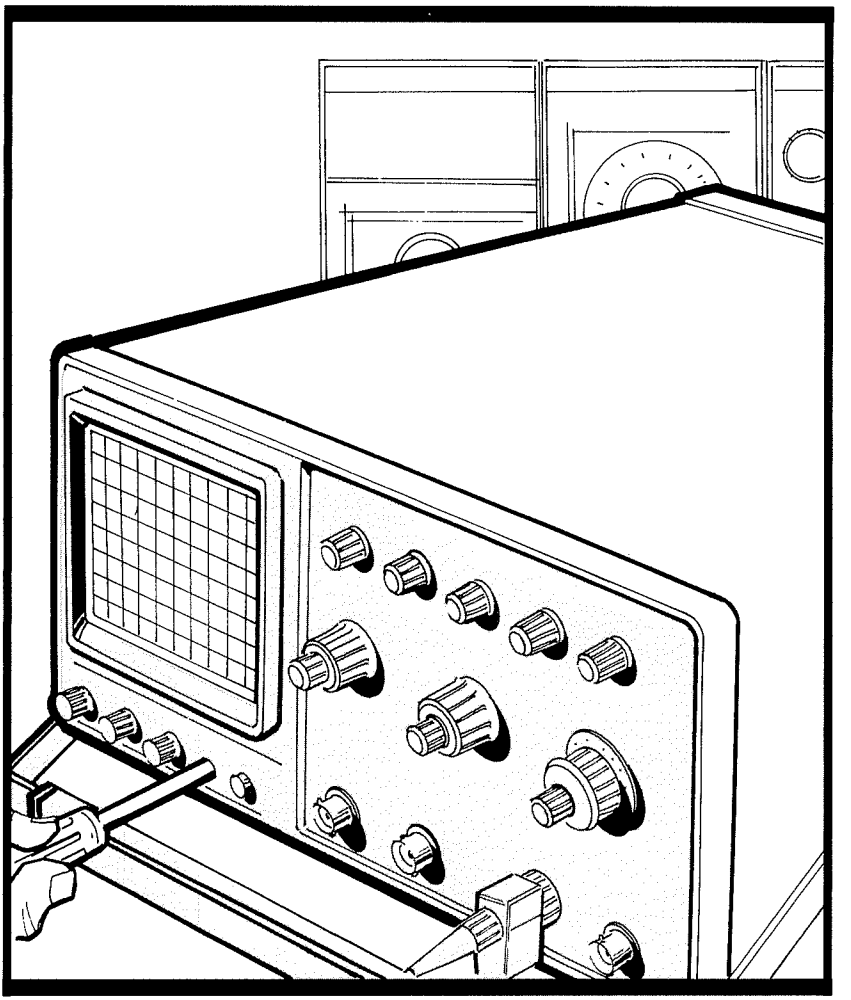
3. Set 20 MHz BW LIMIT on. This will reduce the trace "thickening" caused by wide-band noise and avoid oscillation of the vertical system. If you trigger from CH 1 source, you probably need to use HF REJ coupling.

4. Set CH 2 VOLTS/DIV at 2 mV (20 mV with 10X probe) and set CH 1 at 5 mV or 2 mV/division.

5. Note that the CH 1 scale factor and delta-volts readings agree with the signal at the CH 2 probe-tip with a 10X probe. With a 1X probe, the scale factor and delta-volts readings should be divided by ten.

SECTION 4

Checks and Adjustments



Checks and Adjustments

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 (50 MHz BW LIMIT for HDTV). 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 (50 MHz BW LIMIT for HDTV) 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 has had a 20-minute warm-up period.

NOTE

This DC balance is required for accurate measurements with Parametric Measurements.

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 (50 MHz BW LIMIT for HDTV). 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.

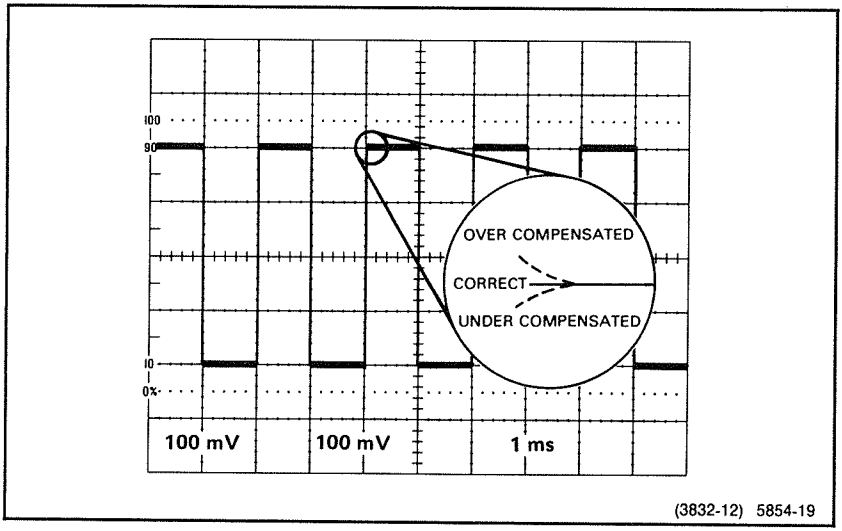


Figure 4-1. Probe low-frequency compensation.

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. It also has no effect on time interval measurements with either the CTT or Parametric Measurements. 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 the same 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 SEC/DIV to 5 ns.
8. Pull out the SEC/DIV knob 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.

To reduce channel-to-channel signal delay errors with Parametric Measurements:

1. Follow Steps 1-3, above.
2. Measure the time interval from CH1 to CH2 using the TIME function from the MEASURE menu.
3. Use this number as a reference and subtract its value from all subsequent time interval measurements.

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 (50 MHz BW LIMIT for HDTV).
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 the A SEC/DIV setting within the range of 100 ms to 100 ns. 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:

NOTE

Auto Setup and Parametric measurements will not work using the calibrator signal.

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 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%.