Tektronix®

305 DMM OSCILLOSCOPE

OPERATORS

INSTRUCTION MANUAL

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305 DMM OSCILLOSCOPE

OPERATORS

INSTRUCTION MANUAL

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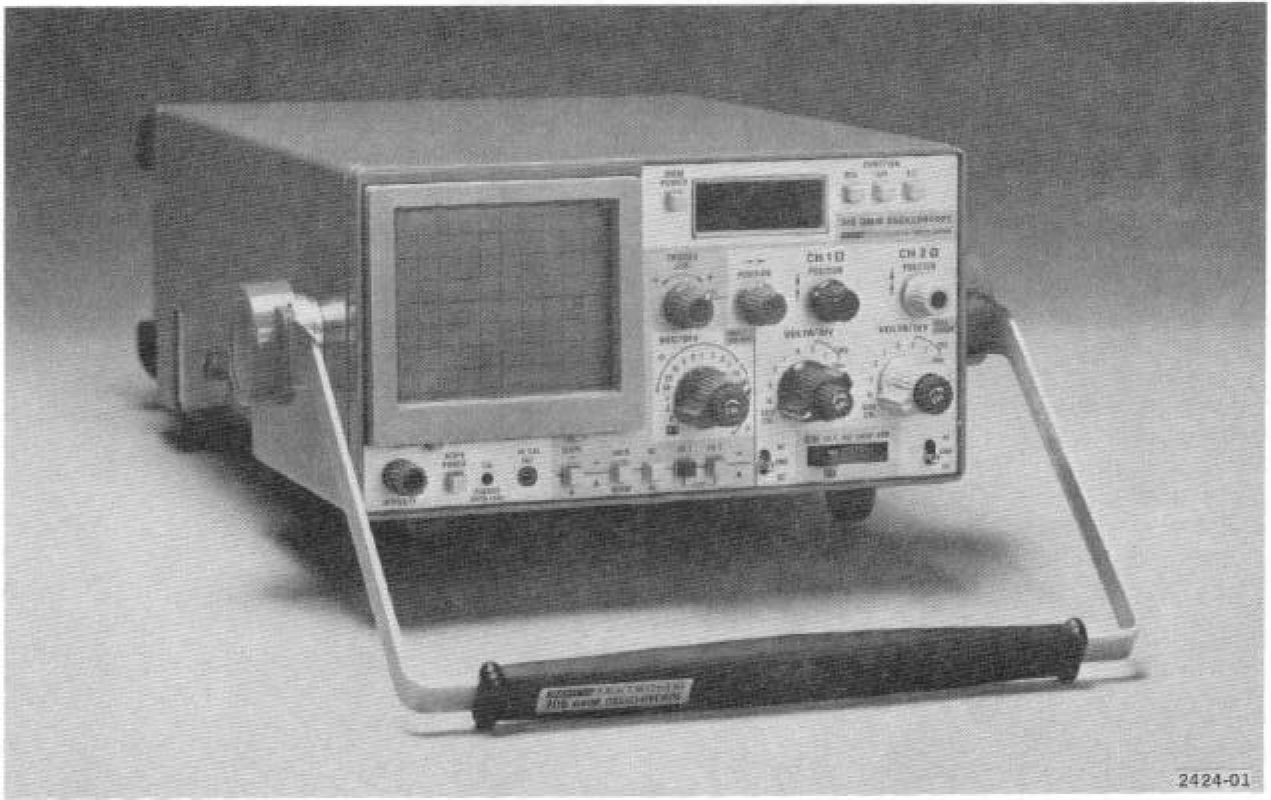

305 DMM Oscilloscope

GENERAL INFORMATION

INTRODUCTION

The Sony/Tektronix 305 DMM Oscilloscope is a versatile solid-state (except crt) portable instrument that combines small size and light weight with the ability to make precision waveform and digital measurements associated with industrial, military, computer maintenance, and business machine applications. The 305 is mechanically constructed to withstand shock, vibration and other environmental extremes associated with portability. Operating power for the instrument is provided by external dc, rechargeable batteries, or normal power-line voltage. Internal circuitry recharges the batteries whenever the instrument is connected to power-line voltage. Selection of the DMM or oscilloscope function (or both) is made with front panel push buttons.

The DMM is autoranging and measures resistance, ac voltage and dc voltage. Full scale measurements are 2 megohms, 700 Vac and 1000 Vdc. The front panel digital readout is a 3-½ digit display containing an automatic negative polarity indicator and decimal point locator. No polarity indication is shown for positive measurements. Input connectors for the multimeter are located on the right side of the instrument cabinet.

Oscilloscope functions provide dual-channel, dc to 5 megahertz vertical deflection with calibrated deflection factors of 5 millivolts/division to 10 volts/division in a 1-2-5 sequence. The horizontal deflection system provides calibrated sweep rates from 0.5 second to 1 microsecond per division. A X10 magnifier increases the indicated sweep rate by a factor of ten, extending the fastest sweep rate of 0.1 microsecond/division. The trigger input may be internal or external, with triggering effective over the full bandwidth of the vertical deflection system. Calibrated X-Y measurements are made with Channel 2 (Y) providing the vertical deflection and Channel 1 (X) horizontal deflection. Oscilloscope signal input connectors are located on the left side of the instrument cabinet. The crt display is an 8 X 10 division graticule with each division measuring 0.632 centimeters (approximately 0.25 inches).

SAFETY INFORMATION

This operating manual contains information which the user must follow to ensure safe operation of the instrument. Warning information is intended to protect the operator while Caution information protects the instrument.

WARNING

High voltage is present inside this instrument. To avoid electric-shock hazard, operating personnel must not remove the protective instrument cover. Component replacement and internal adjustments must be made by qualified personnel only.

In the ac power source mode, the 305 DMM Oscilloscope operates from a single-phase power source, which has one of its current carrying conductors at ground (earth) potential. Operation from other power sources where both current carrying conductors are live with respect to ground (such as phase-to-phase on a multi-phase three wire system) is not recommended because only the line conductor has over-current (fuse) protection within the instrument.

This instrument has a 3-wire power cord with a 3-contact plug for connection to the power source and to protective ground. The plug protective-ground contact connects (through the cord protective grounding conductor) to the accessible metal parts of the instrument. For electric-shock protection, insert this plug into a socket outlet that has a securely grounded protective-ground contact.

Do not defeat the grounding connection. Any interruption of the grounding connection can create an electric-shock hazard. Before making external connections to this instrument, always ground the instrument first by connecting the power-cord to a proper mating power outlet, that is known to be properly grounded.

OPERATING VOLTAGE

This instrument may operate from an external dc source, rechargeable batteries (supplied with the instrument), or a 115 or 230 volt ac nominal line voltage.

External DC Power Source Operation

The 305 can operate from an external dc power source of +9 to +32 volts. Set the Power Source Selector switch to the EXT DC position (Figure 1). Apply external dc voltage to the two banana jack inputs using the cable assembly supplied with the instrument.

Internal Battery Power Source Operation

To operate the instrument from the internal battery source, set the Power Source Selector switch to the BATTERY position (Figure 1). Battery voltage is indicated on the DMM digital readout when all DMM FUNCTION push buttons are in the out position.

AC LINE VOLTAGE RANGE INDICATOR

(A) (B) INDICATES NOMINAL AC INPUT VOLTAGE (115 OR 230 V) FROM WHICH INSTRUMENT MAY BE OPERATED.

POWER SOURCE SELECT SWITCH

(C) OPERATES 305 FROM AC OR EXT DC POWER SOURCE WITH FULL CHG APPLIED TO INTERNAL BATTERIES.

(D) OPERATES FROM AC OR EXT DC POWER SOURCE WITH TRICKLE CHG APPLIED TO BATTERIES.

(E) OPERATES 305 FROM INTERNAL BATTERY POWER SOURCE.

AC POWER SOURCE OPERATION

(F) CHECK THAT THE AC LINE VOLTAGE RANGE INDICATOR DISPLAYS THE NOMINAL AC LINE VOLTAGE AVAILABLE (115 OR 230 V AC).

(G) SET THE POWER SOURCE SELECT SWITCH TO AC, FULL OR TRICKLE CHG.

WARNING

(H) **WHEN OPERATING FROM EXTERNAL DC OR INTERNAL BATTERIES THE INSTRUMENT GROUND CONNECTOR MUST BE CONNECTED TO A PROTECTIVE EARTH GROUND.**

BATTERY POWER SOURCE OPERATION

(I) SET THE POWER SOURCE SELECT SWITCH TO BATTERY POSITION.

EXTERNAL DC POWER SOURCE OPERATION

(J) SET THE POWER SOURCE SELECT SWITCH TO ONE OF THE EXT DC POSITIONS.

(K) APPLY EXTERNAL DC POWER SOURCE (+9 TO +32 V DC) TO THE BANANA JACK INPUT.

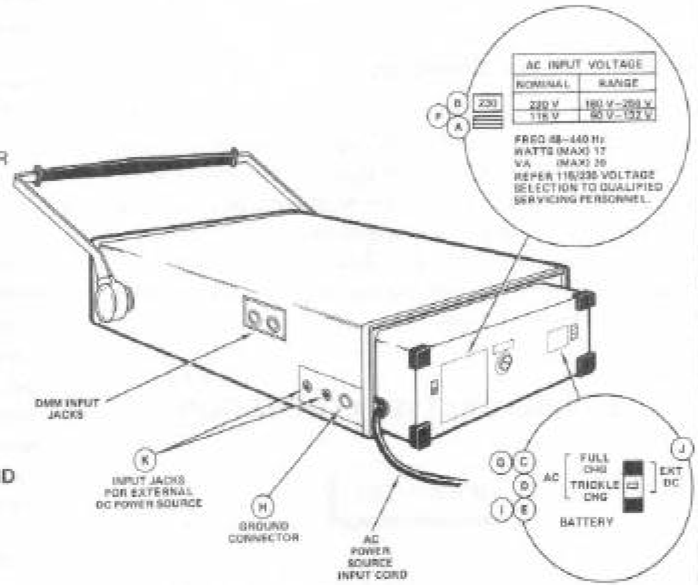

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Figure 1. Description of power source operation.

WARNING

Change of ac voltage must be accomplished by qualified service personnel.

AC Power Source Operation

The AC Input Voltage Selector switch permits the 305 to be operated from a 115 or 230 volt ac nominal line voltage source, at 48 to 440 hertz (Figure 1). The Power Source Selector switch must be set to the proper AC position. The ac line voltage fuse must be changed when selecting a different nominal line voltage. Any fuse change requires removal of the instrument cabinet and must be accomplished by qualified service personnel.

INTERNAL BATTERY OPERATION

WARNING

Change or replacement of batteries must be accomplished by qualified service personnel.

The 305 features battery operation from six rechargeable nickel-cadmium cells (1.2 volts each, total nominal voltage of 7.2 Vdc). The operating time of the internal batteries depends upon display intensity, state of battery charge, discharge temperatures, and the instrument function being used; oscilloscope, DMM, or both. When the instrument is operated at +20°C to +30°C (+68°F to +86°F), the typical operating time of fully charged batteries with both oscilloscope and DMM in operation is approximately 1.6 hours.

A light-emitting diode (LED), labeled 'ON (FLASHES WHEN LOW)', is steadily illuminated to indicate that the instrument oscilloscope function is on, and the battery charge is sufficient for operation. When battery charge is low, the LED flashes on and off indicating that batteries require recharge or possible replacement. An automatic battery over-discharge protection circuit will turn the instrument off to prevent excessive discharge, which could result in permanent battery damage.

During DMM operation, the digital readout alternates between a normal display and – · – – – if the power source voltage drops too low for proper DMM operation.

BATTERY CHARGING

To apply full charge to the batteries, connect the instrument to a power line, turn SCOPE POWER and DMM POWER off, switch the Power Source Selector switch to AC FULL CHG position, and allow at least 16 hours for the batteries to become fully charged. To obtain the longest operating life for the batteries, the instrument should be turned on at least once a month and the batteries discharged to where the oscilloscope SCOPE POWER LED flashes, and then recharged for 24 hours. This procedure balances the charge on the batteries and reduces the possibility of any cell becoming reverse charged. The instrument may be operated while batteries are being charged.

The energy capacity of nickel-cadmium cells varies with the temperature at which they are charged and operated. Table 1 shows the percentage of full charge capacity at various charging and operating temperatures.

TABLE 1

Battery charge related to operating temperature and charging temperature.

Charging Temperature	Operating Temperature		
	-15° C	$+20^\circ$ to $+25^\circ$ C	$+55^\circ$ C
0° C	40%	60%	50%
$+20^\circ$ to $+25^\circ$ C	65%	100%	85%
$+40^\circ$ C	40%	65%	55%

BATTERY CARE

Nickel-cadmium cells will self-discharge when the instrument is not used often or stored for extended periods of time. The rate of self-discharge is dependent upon temperature and humidity. When the instrument is to be stored for extended periods of time, particularly at high temperature or humidity, the batteries should be charged for at least 16 hours every two weeks, or leave the 305 connected to a power line with the Power Selector switch set to AC TRICKLE CHG position.

CONTROLS AND CONNECTORS

Controls and connectors necessary for proper operation of the instrument are located on the front, side, and rear cabinet panels. To make full use of the capabilities of this instrument, the operator should be familiar with the function and use of each external control and connector. A brief description and use of each external control and connector is given herein.

POWER SOURCE AND CONNECTORS

WARNING

Change of ac input voltage must be accomplished by qualified service personnel only.

1. **Power Source Selector switch**—Three position switch provides operator selection of ac line voltage, external dc voltage or battery operation. The ac position, in conjunction with the AC Input Voltage Selector switch, allows the 305 to be operated over a range of ac line voltages. Power Source Selector switch also provides operator selection of a Full or Trickle charge rate to internal batteries (Figure 2).

2. **AC Input Voltage Selector switch**—In conjuction with the Power Source Selector switch, allows the instrument to be operated from 115 or 230 nominal ac line voltage (Figure 2).

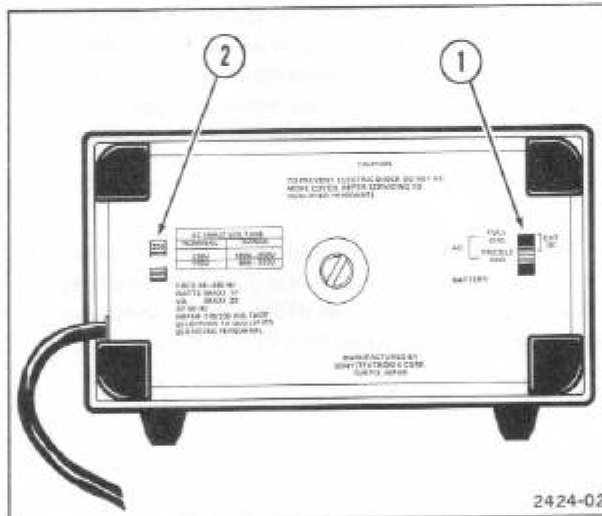


Figure 2. View of rear cover.

3. **+ and –** Inputs for applying external dc power source (+9 to +32 volts) (Figure 3).

4. **DMM INPUT**—Connector to apply external voltages or resistance to be measured to the digital multimeter (Figure 3).

5. **Ground Connector**—Connector for common ground connection from the power source or associated instruments or devices under test (Figure 3).

6. **CH1 (X) INPUT**—BNC connector to apply an external signal to the input of the CH1 vertical system, or X-axis deflection (horizontal) in the X-Y mode of operation (Figure 4). The maximum safe ac or dc voltage coupled to the CH1 (CH2 or EXT TRIG INPUT, if applicable) input connector should not exceed 250 V (dc + peak ac).

7. **CH2 (Y) INPUT**—BNC connector to apply an external signal to the CH2 vertical system, or Y-axis (vertical) in the X-Y operation mode (Figure 4).

8. **EXT TRIG INPUT**—BNC connector to apply an external trigger input signal (Figure 4).

9. **Ac Line Cord**—Connects the instrument to an ac power source (Figure 3). The cord may be conveniently stored by wrapping it around the feet on the rear cover (Figure 4).

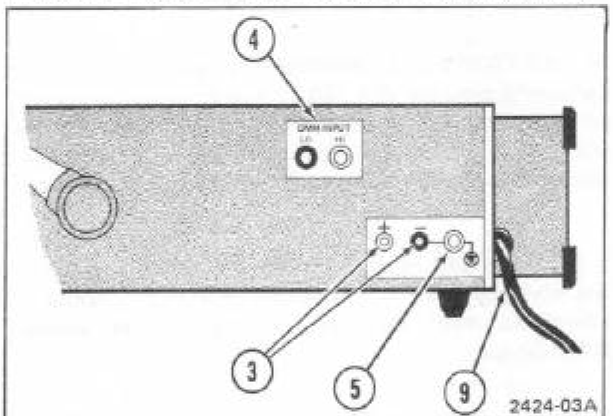


Figure 3. Right side view of instrument cabinet.

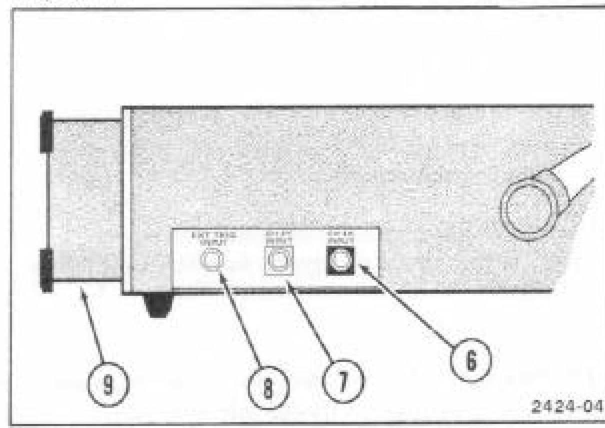


Figure 4. Left side view of instrument cabinet.

CALIBRATOR AND DISPLAY CONTROLS (FIGURE 5)

10. SCOPE POWER—Push-button switch turns the oscilloscope on (in) and off (out).

11. INTENSITY—Controls the brightness of the crt display. Turn the control clockwise to increase display brightness.

The intensity level should be set to the lowest visible display to prolong life of the crt.

12. ON (FLASHES WHEN LOW)—LED indicator that glows green when SCOPE POWER is on and power is applied to the oscilloscope.

The LED flashes on and off when batteries require recharging and then goes out when the batteries are completely discharged.

13. .3V CAL OUT (Calibrator)—Pin connector output provides an internally generated 0.3 volt, 1 kHz square wave. Calibrated voltage is useful for checking vertical deflection factor and probe compensation.

VERTICAL CONTROLS (FIGURE 6)

14. POSITION (CH1 or X and CH2 or Y)—Controls the vertical position of the crt display for each channel. In the X-Y mode of operation, the CH1 (X) controls the position of the display horizontally and CH2 (Y) controls the position of the display in the vertical direction.

15. VOLTS/DIV (CH1 and CH2)—Selects vertical deflection factor of signals applied to the CH1 and/or CH2 INPUT connectors. The CAL (Variable) control must be in the CALibrated detent for the indicated deflection factor.

16. VOLTS/DIV CAL (Variable) (CH1 and CH2)—Control (concentric with the VOLTS/DIV switch) provides continuously variable uncalibrated deflection factors between the calibrated settings of the VOLTS/DIV switch. Extends the maximum deflection factor to at least 25 volts per division.

17. 5 DIV CAL—Position on the VOLTS/DIV switch that internally connects a calibrated signal to the vertical preamplifier circuit. Useful for checking instrument vertical deflection gain.

18. PULL INVERT—Pull the Variable knob to the out position to invert the CH2 signal display.

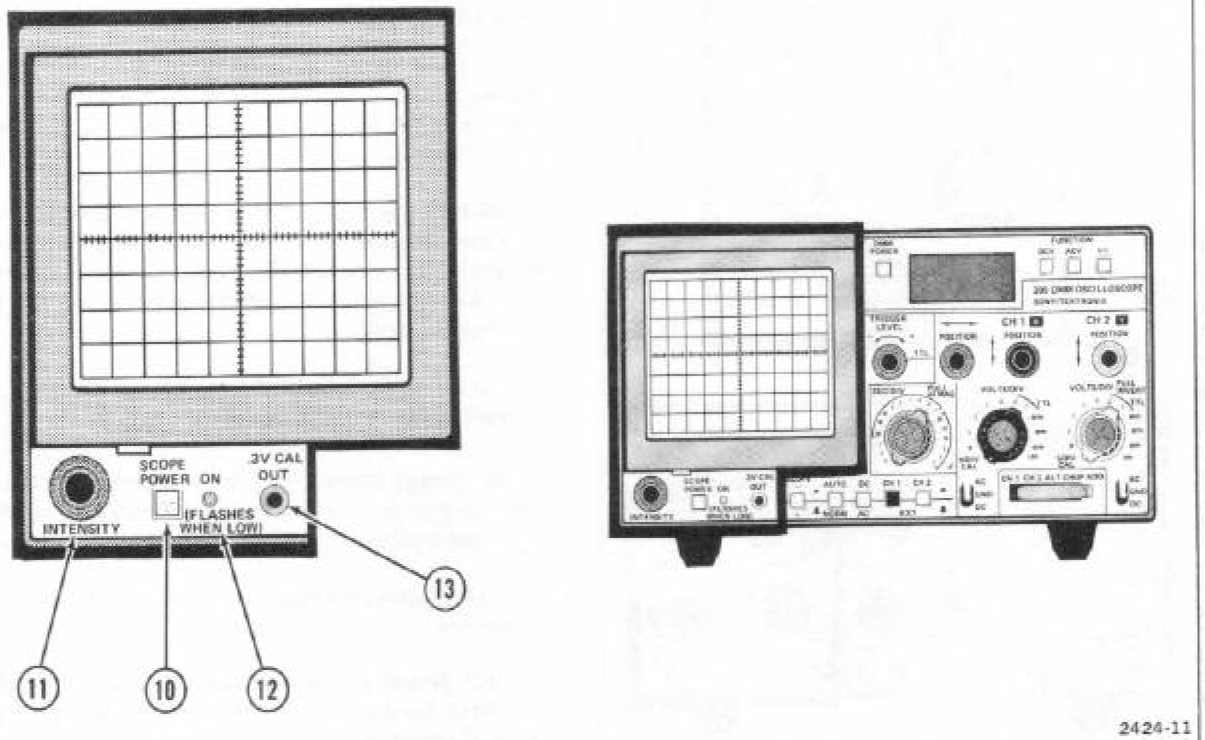


Figure 5. Location of display and calibrator controls.

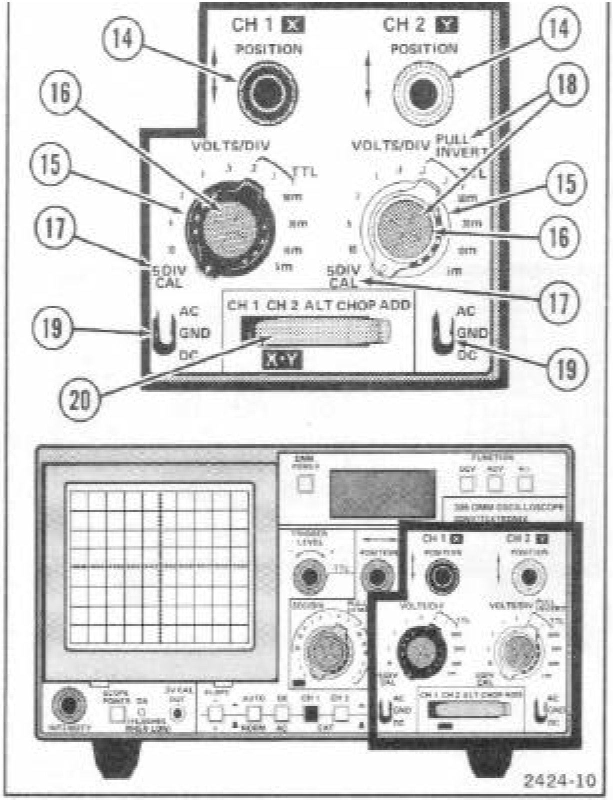


Figure 6. Location of vertical deflection system controls.

19. Vertical Coupling—Three position switch that selects method of coupling the input signal to the vertical deflection system.

AC: Input signal is capacitively coupled to the vertical attenuator circuit. Dc component of the input signal is blocked. Lower frequency limit (lower −3 dB point) is about 10 hertz.

GND: Connects the input attenuator to ground providing a zero (ground) reference voltage display (does not ground the input signal). Allows precharging of the vertical input coupling capacitor by applying the input signal via a one megohm resistor.

DC: All components of the input signal are directly coupled to the vertical attenuators.

20. Display Mode—Five position lever switch that selects the operation mode of the vertical deflection system (signal displayed on the crt).

CH1: Displays the signal applied to the CH1 (X) INPUT connector.

CH2: Selects the signal applied to the CH2 (Y) INPUT connector for display. The CH2 mode position is selected for X-Y operation (in conjunction with X-Y position of SEC/DIV switch) and provides vertical deflection from the CH2 INPUT.

tween the signals applied to the CH1 and CH2 INPUT connectors. This switching between channels occurs at the completion of each sweep. This operating mode is useful when viewing both input signals at sweep rates of 1 millisecond/division or faster.

CHOP (Chopped): The dual-trace crt display alternates between the CH1 and CH2 input signals at a fixed rate of about 50 kHz. This mode is useful when viewing input signals at sweep rates of 0.5 millisecond/division or slower.

ADD: Crt display is the algebraic sum of the signals applied to the CH1 (X) and CH2 (Y) INPUT connectors (CH1 plus CH2). When the PULL: INVERT control is pulled out, the CH2 input signal is inverted providing a difference display of signals applied to the CH1 and CH2 INPUT connectors (CH1 minus CH2).

HORIZONTAL SWEEP CONTROLS (FIGURE 7)

21. POSITION—Controls horizontal positioning of the crt display, except in the X-Y mode of operation when the CH1 (X) POSITION control provides horizontal positioning.

22. SEC/DIV—Selects the calibrated sweep rate of the sweep generator circuit. The CAL (Variable) control must be in its CALibrated detent position for the indicated time base sweep rate.

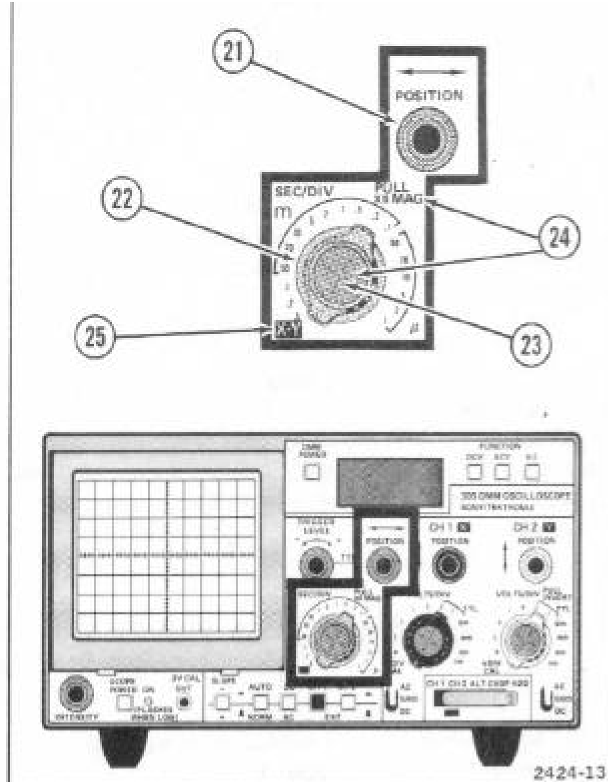


Figure 7. Location of horizontal deflection system controls.

23. SEC/DIV CAL (Variable)—Control (concentric with the SEC/DIV switch) provides continuously variable uncalibrated sweep rates between the calibrated settings of the SEC/DIV switch. Extends the slowest sweep rate to at least 1.25 seconds per division.

24. PULL X10 MAG—Pull the CAL (Variable) control knob to the out position to magnify the sweep rate by a factor of 10. Extends the fastest sweep rate to 0.1 microsecond/division.

25. X-Y—Selects the X-Y display operating mode when SEC/DIV switch is rotated to the X-Y position. X-axis signal is provided by the CH1 (X) INPUT connector, and Y-axis signal input is through the CH2 (Y) INPUT connector. Vertical Display Mode switch must be in the CH2 position for X-Y operation.

TRIGGERING CONTROLS (FIGURE 8)

26. Source—Push-button switches to select signal source applied to the trigger generator circuit.

CH1 (in): Signal connected to the CH1 INPUT connector is used as the trigger signal.

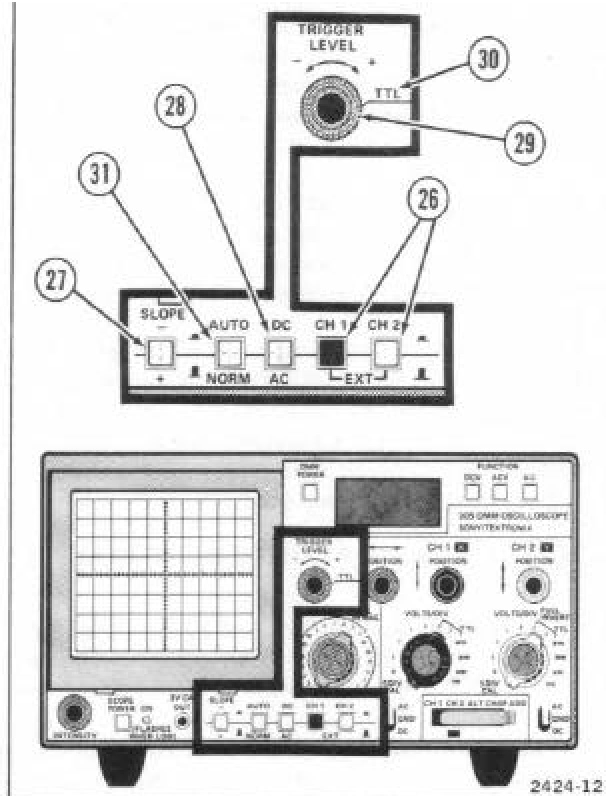


Figure 8. Location of trigger and sweep controls.

CH2 (in): The signal connected to the CH2 INPUT connector is the trigger signal.

EXT (External Trigger) (CH1 and CH2 push buttons out): Signal connected to the EXT TRIG INPUT connector is the trigger signal.

27. Slope—Push-button switch selects either the positive-going or negative-going slope of the trigger signal.

+ (out): Sweep triggers on the positive-going portion of the trigger signal.

– (in): Sweep triggers on the negative-going portion of the trigger signal.

28. Coupling—Push-button switch selects method of coupling the signal to the trigger generator circuit.

AC (out): Rejects dc and attenuates signals below about 60 Hz. Accepts signals from about 60 Hz to 5 MHz.

DC (in): Provides direct coupling for signals within the vertical bandpass (dc to about 5 MHz).

29. TRIGGER LEVEL—Selects the amplitude point on the triggering signal at which sweep is triggered. It is usually adjusted after Trigger Source, Coupling and Slope have been selected.

30. TTL—In conjunction with TTL positions of the CH1/CH2 VOLTS/DIV switch, presets the trigger for a stable display from an input TTL source. Trigger Coupling must be in DC and Mode switch in the NORM position.

31. Trigger Mode—Push-button switch that determines the operating mode of the trigger circuit.

AUTO (Automatic) (in): Sweep is triggered when a signal with sufficient amplitude and a repetition rate of at least 200 Hz (to 5 MHz) is applied to the vertical system. In the absence of an adequate signal, sweep free-runs to produce a reference display trace.

NORM (Normal) (out): Sweep is initialized if the following circuit conditions are met: TRIGGER LEVEL set correctly; sufficient signal amplitude applied to vertical system; input signal frequency within the vertical bandpass limits when Coupling is in the DC position, or signal frequency is between 60 Hz to 5 MHz in AC Coupling mode. In the absence of an adequate trigger signal or when trigger controls are misadjusted, there is no sweep or trace.

DIGITAL MULTIMETER CONTROLS (FIGURE 9)

32. DMM POWER—Push-button switch turns the digital multimeter on (in) and off (out). The digital readout lights when power is applied to the multimeter.

33. FUNCTION—Self cancelling switches select the voltage or resistance measurement functions of the digital multimeter.

ACV (in): Measures ac voltages connected to the DMM input jacks.

DCV (in): Measures dc voltages connected to the DMM input jacks.

kΩ (in): Measures resistance connected to the DMM input jacks.

34. Digital Readout—Displays measurement selected by the FUNCTION control switch. Negative polarity indicator is automatic. No polarity indication for positive voltage measurements.

Decimal point locator is automatic. The readout displays "– . – – –" when voltage of the applied power source (either external, or internal batteries) is insufficient.

Internal Battery Voltage Indicator—When all the DMM FUNCTION push-buttons are in the out position and power is being supplied from internal battery source, the digital readout indicates battery voltage (7.2 Vdc nominal).

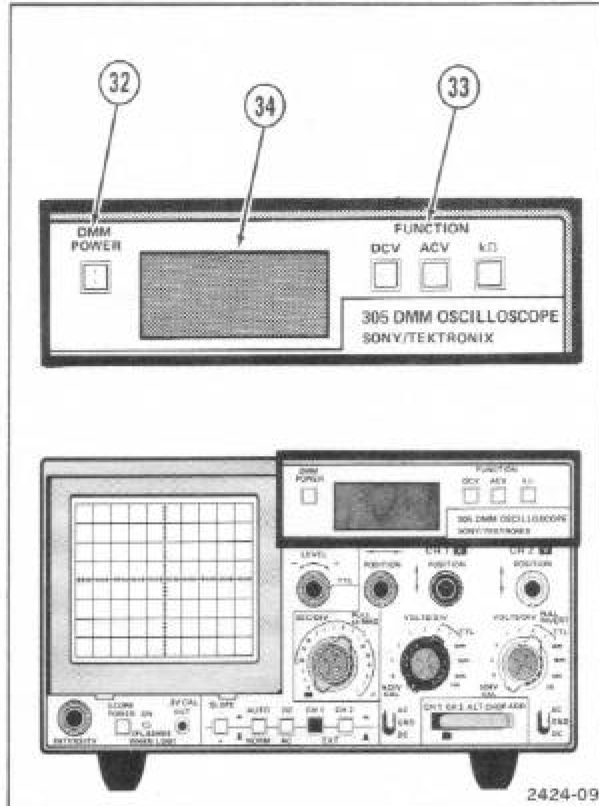


Figure 9. Location of digital multimeter controls.

BASIC INSTRUMENT OPERATION

OPERATING CONSIDERATIONS

To ensure optimum measurement accuracy, the following information should be considered before operating the instrument.

Signal Connections

Generally, probes offer the most convenient means of connecting an input signal to the instrument. Oscilloscope probes are shielded to prevent pickup of electrostatic interference. The supplied 10X probe offers a high input impedance, which minimizes circuit loading and allows the circuit under test to operate very close to normal conditions providing accurate measurements. Conversely, it also attenuates the input signal amplitude by a factor of 10.

Coaxial Cables

Cables used to connect signals to the input connectors have a considerable effect on the accuracy of a displayed waveform. To maintain the original frequency characteristics of an applied signal, high quality, low loss coaxial cable should be used. Also, the cable should be terminated at both ends in its characteristic impedance. If this is not possible, use suitable impedance matching devices.

Grounding

The most reliable signal measurements are made when the 305 and the unit under test are connected together by a common reference (ground) lead in addition to the signal lead or probe. The ground strap on the probe provides the best ground. Also, you can connect a ground lead to the chassis ground connector located on the right side panel of the instrument.

Graticule

The graticule is internally marked on the faceplate of the crt to provide accurate measurements without parallax. The graticule is marked with eight vertical and ten horizontal major divisions. In addition, each major division is divided into five minor divisions. The vertical deflection and horizontal timing are calibrated to the graticule, so accurate measurements can be made directly from the crt.

Probe Compensation

To ensure that measurements are accurate, always compensate the probe before using. To compensate the probe, touch the probe tip to the .3V CAL OUT jack on the 305 front panel and display several cycles of calibrator square wave at approximately 4 divisions in amplitude. Adjust probe compensation through hole in the compensation box for the best front-corner response to the signal as shown in Figure 10.

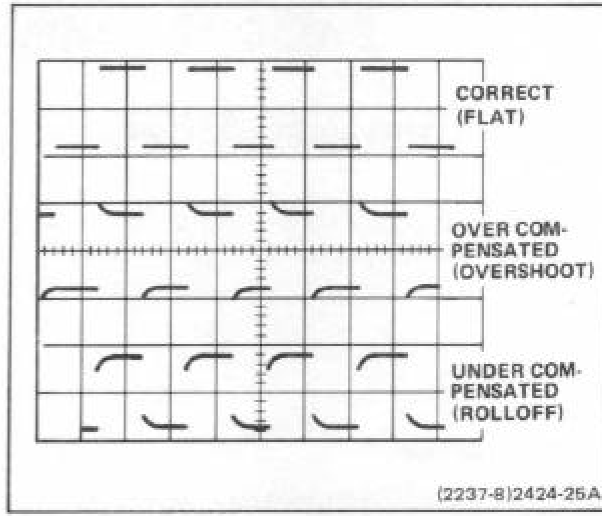


Figure 10. Probe compensation.

To verify the operation and accuracy of the 305, confirm the following checks and adjustments.

OSCILLOSCOPE DISPLAY

Before operating the 305 oscilloscope, preset the controls as listed below:

Display Mode	CH1
VOLTS/DIV	10m
VOLTS/DIV CAL (Variable)	Detent
POSITION (Vertical)	Midrange
AC/DC (Coupling)	DC
INVERT	Off (in)
SEC/DIV	.5m
SEC/DIV CAL (Variable)	Detent
PULL: X10 MAG	Off (in)
POSITION (Horizontal)	Midrange
Source	CH1 (in)
AC/DC (Trigger coupling)	DC
AUTO/NORM (Mode)	AUTOmatic (in)
Slope	+ (out)
TRIGGER LEVEL	Midrange
SCOPE POWER	On (in)

Intensity

Demonstrate normal intensity operation as follows:

1. Rotate the INTENSITY control between its maximum clockwise and counterclockwise positions. The display should vary from full intensity to no display.

2. Reset the INTENSITY control to a comfortable viewing level.

CAUTION

To protect the crt phosphor, do not leave the INTENSITY control set any higher than necessary to provide a satisfactory display.

Focus and Astigmatism

Figure 11 shows the location of external operator adjustments.

1. Adjust FOCUS for optimum crt trace definition.

2. In conjunction with FOCUS adjustment, obtain optimum definition of the crt trace with the ASTIGmatism adjustment.

1. Position trace to the center horizontal graticule line.

2. Adjust TRACE ROTATION so the trace is parallel to the center horizontal graticule line.

Channel 1 and Channel 2 Step Attenuator Balance (Figure 11)

1. Obtain a free-running trace.

2. While switching the CH1 (CH2, if applicable) VOLTS/DIV switch between the 20m and 5m position, adjust the CH1 STEP ATTEN BAL for minimum trace shift between these positions.

Vertical System

Demonstrate the operation of the vertical deflection system controls as follows:

1. Connect 10X probe from CH1 INPUT connector to the .3V CAL OUT jack.

2. Set Trigger Mode to NORMal and TRIGGER LEVEL for a stable square wave display.

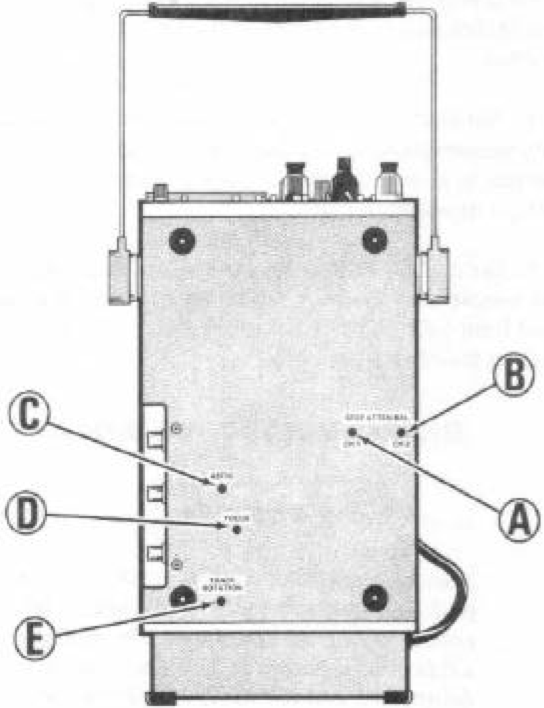
VOLTS/DIV to 10m.

4. Adjust the horizontal POSITION control so the display begins at the left vertical graticule line.

5. Rotate CH1 POSITION control fully counterclockwise and fully clockwise settings. The display should move off screen in both vertical directions. Adjust for a normal centered display.

6. Adjust the CH1 POSITION for an equal deflection above and below the center horizontal graticule line. The display should total approximately three vertical divisions in amplitude and full cycle pulse width approximately two divisions wide. This corresponds to .3 volts, 1 kilohertz calibrated square wave output (refer to Application and Measurements Section of this manual for peak-to-peak amplitude, time duration and frequency measurement formulas).

7. Set CH1 Vertical Coupling to GND and note position of the baseline trace. Set Coupling to AC. The display should be equally deflected above and below the reference baseline trace position. Reset Coupling to DC.



CAUTION

USE AN INSULATED SCREWDRIVER WHEN MAKING THESE ADJUSTMENTS.

(A) CH1 STEP ATTN BAL

(B) CH2 STEP ATTN BAL

RECESSED SCREWDRIVER ADJUSTMENTS TO ELIMINATE CRT TRACE SHIFT WHEN SWITCHING BETWEEN ADJACENT POSITIONS OF THE VOLT/DIV CONTROL SWITCH.

(C) ASTIG (ASTIGMATISM)

RECESSED SCREWDRIVER ADJUSTMENT USED IN CONJUNCTION WITH THE FOCUS ADJUSTMENT TO OBTAIN OPTIMUM DEFINITION OF THE CRT.

(D) FOCUS

RECESSED SCREWDRIVER ADJUSTMENT FOR OPTIMUM CRT TRACE DEFINITION.

(E) TRACE ROTATION

RECESSED SCREWDRIVER ADJUSTMENT TO HORIZONTALLY ALIGN THE CRT DISPLAY TRACE.

2424-06

Figure 11. Location of external operator adjustments.

8. Rotate the CH1 VOLTS/DIV CAL (Variable) control to its fully counterclockwise position. The display should decrease in vertical amplitude to at least 1.2 divisions or less. Return CAL (Variable) control to the detent position.

9. To demonstrate operation of the CH2 vertical system, set Vertical Display Mode to CH2, connect probe to the CH2 INPUT connector, and perform steps 1 through 8. Check the INVERT function by pulling the PULL INVERT knob. The display should be inverted. Return the INVERT function to its off position.

10. Return the probe to CH1 INPUT connector and Vertical Display to CH1.

Horizontal and Triggering System

Demonstrate the operation of the horizontal and triggering system controls as follows.

1. Adjust the horizontal POSITION control so the display starts at the left vertical graticule line. Observe that the display begins with a positive pulse.

2. Push the Slope switch to the in position. Observe the display now starts with a negative pulse. Push in and release the Slope switch. The display should again be in the positive position.

3. Rotate the SEC/DIV switch one or two positions on either side of the .5 ms position. The display sweep rate should change accordingly. Reset the SEC/DIV to the .5 ms position.

4. Rotate the SEC/DIV CAL (Variable) control to its fully counterclockwise position. The pulse width should decrease to at least 0.8 divisions or less. Return CAL (Variable) to its detent position.

5. Set the SEC/DIV to 1m and pull the X10 MAG knob. The magnified square wave display pulse width should expand from 1 division to 10 divisions. Return the X10 MAG knob to the off position.

DIGITAL MULTIMETER DISPLAY

CAUTION

The maximum input voltage is ±1000 V (dc + peak ac) between the HI and LO input or between the HI input and chassis. The maximum LO floating voltage is ±500 V (dc + peak ac) between LO and chassis. The DMM may be damaged by attempting to measure voltage if the meter is in the kΩ FUNCTION mode of operation and the applied voltage is in excess of ±100 V (dc + peak ac).

DC Voltage

1. Set DMM POWER switch on (in).

2. Push in the DCV FUNCTION push button. The readout should display −.000 ±2 counts with no signal connected to DMM INPUT

3. Connect the LO test probe to the reference test point (usually ground or a test point) and the HI test probe to the unknown positive dc voltage to be measured.

4. The display represents the value of the dc voltage source.

5. Reverse the HI and LO test probes and observe the numeric reading remains the same but the negative polarity sign is indicated.

6. Disconnect DMM from the dc source.

AC Voltage

1. Set DMM POWER switch on.

2. Push in the ACV FUNCTION push button. The readout should display .000 ±10 counts with no signal connect to the DMM INPUT and the two test probes touching each other.

3. Connect the LO test probe to the reference test point (usually circuit ground or to a test point) and the HI test probe to the unknown ac voltage to be measured.

4. The display represents the value of the ac voltage source.

5. Disconnect DMM from the ac voltage source.

Resistance

1. Push the kΩ FUNCTION push button. The readout should display a flashing −1999. overrange condition with no signal input connected to the DMM INPUT.

2. Touch the two DMM test probes together. The display should read .000 ±3 counts indicating proper operation of the kΩ FUNCTION.

3. Connect the DMM test probes across the unknown resistance to be measured.

4. The display represents the value of the unknown resistance.

5. Set DMM POWER switch off (out).

APPLICATION AND MEASUREMENTS

Once the operator becomes familiar with the instrument and makes the initial operator's adjustments, this section will aid in making measurements. Basically, this instrument is used the same as if it were an individual multimeter and individual general purpose oscilloscope with the added convenience of having both functions in one cabinet.

The procedures for making the basic voltage and resistance measurements with the digital multimeter are the same as those in the Adjustments and Basic Displays section and will not be duplicated here.

Instantaneous Amplitude Measurement—DC (Figure 12)

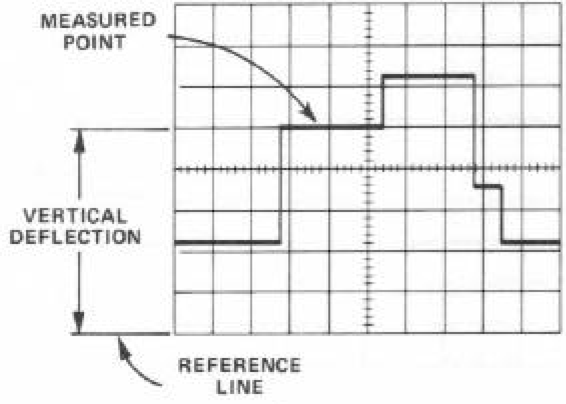
Measure the amplitude of any point on a waveform with respect to ground as follows:

1. Set Vertical Coupling to DC.

2. Apply the signal to be measured to either vertical input connector. Set Vertical Mode to the channel being used.

3. Obtain a stable display.

4. Set SEC/DIV switch to display several cycles of signal.



FORMULA:

VERTICAL DEFLECTION FROM REFERENCE LINE TO MEASURED POINT × VOLTS/DIV SETTING = INSTANTANEOUS AMPLITUDE

EXAMPLE:

5 DIVISIONS × 10 MILLIVOLTS/DIVISION = 50 MILLIVOLTS

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Figure 12. Example of instantaneous voltage measurement with VOLTS/DIV set at 10M position.

5. Set Vertical Coupling to GND. Position trace to a reference line.

6. Set Vertical Coupling to DC. If waveform appears above reference line, voltage is positive. If waveform appears below reference line, voltage is negative.

7. Measure vertical difference (in divisions) between reference line and desired point on waveform and multiply by the VOLTS/DIV setting (CAL-Variable-must be in detent setting).

Peak-to-Peak Amplitude Measurement—AC (Figure 13)

Use the following procedures for peak-to-peak amplitude measurements:

1. Apply the signal to be measured to either vertical input connector. Set the Vertical Mode to the channel to be used.

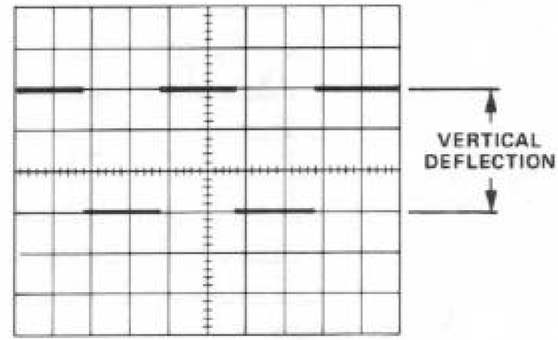
2. Set SEC/DIV to display several cycles of waveform. Adjust triggering controls for a stable display.

3. Set VOLTS/DIV switch to display about three vertical divisions of waveform. Confirm that the CAL (Variable) control is in the detent position.

4. Adjust vertical POSITION so that the lower portion of the waveform coincides with a horizontal graticule line and that display remains within the viewing area.

5. Horizontally position the display so that one of the peaks coincides with the center vertical graticule line.

6. Measure the peak-to-peak amplitude of the signal by multiplying vertical deflection (in divisions) by the VOLTS/DIV settings.



FORMULA:

VERTICAL DEFLECTION (IN DIVISIONS) X VOLTS/DIV SETTING = AMPLITUDE

EXAMPLE:

3 DIVISIONS SETTING X .5 VOLTS/DIVISION = 1.5 VOLTS PEAK-TO-PEAK

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Figure 13. Example of peak-to-peak voltage measurement.

Voltage Comparison Measurements

For application where signal voltage is compared to some signal reference amplitude, it may be desirable to use a different deflection factor than available with settings of the VOLTS/DIV switch. To establish an arbitrary vertical deflection factor, proceed as follows:

1. Connect a known amplitude reference signal to either vertical input connector. Set Vertical Mode to the channel being used.

2. Adjust VOLTS/DIV and CAL(Variable) control for desired vertical deflection. DO NOT change this setting after the reference has been established.

3. Determine vertical converison factor using this formula:

$$\text{Vertical Conversion Factor} = \frac{\text{Reference signal amplitude (in volts)}}{\text{Vertical deflection (in divisions)} \times \text{VOLTS/DIV setting}}$$

Substituting example values:

Reference signal amplitude is 30 volts with a VOLTS/DIV switch set to 5 and the VOLTS/DIV Variable adjusted to provide a vertical deflection of 4 divisions:

$$1.5 = \frac{30 \text{ volts}}{4 \times 5}$$

4. To measure an unknown signal, set the VOLTS/DIV switch to provide sufficient vertical deflection for an accurate measurement. DO NOT change or adjust the VOLTS/DIV Variable knob. Determine the vertical deflection (in divisions) and calculate the amplitude of the unknown signal using the following formula:

$$\text{Signal amplitude} = \text{VOLTS/DIV Setting} \times \text{Vertical Conversion Factor} \times \text{Vertical deflection (in divisions)}$$

Substituting example values:

VOLTS/DIV switch set at 1 and vertical deflection of the unknown signal is 5 divisions. Conversion factor is 1.5.

$1 \times 1.5 \times 5 = 7.5$ volts.

Time Duration and Frequency Measurement (Figure 14)

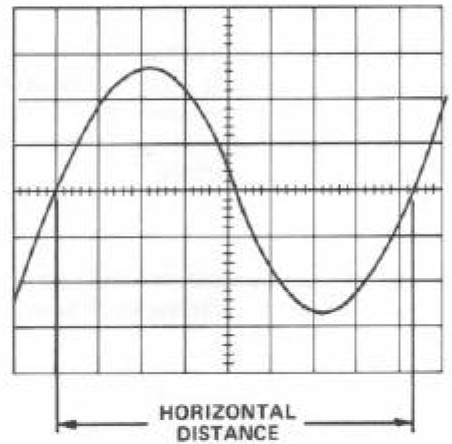
Set the SEC/DIV control to display one complete waveform. Check that the CAL (Variable) control is in the detent position. Measure the horizontal distance between the two time measurement points (in divisions) and multiply this distance by the setting of the SEC/DIV control.

The frequency of this signal can be calculated by taking the reciprocal of the measured time duration of one event. For example, the time duration of the waveform is 16.6 milliseconds. Using the formula:

$$\text{Frequency} = \frac{1}{\text{Time duration}}$$

Substituting the values:

$$60 \text{ Hertz} = \frac{1}{16.6 \text{ milliseconds}}$$



FORMULA:

HORIZONTAL DISTANCE X SEC/DIV SETTING = TIME DURATION

EXAMPLE:

8.3 DIVISIONS X 2 MILLISECONDS/DIVISION = 16.6 MILLISECONDS

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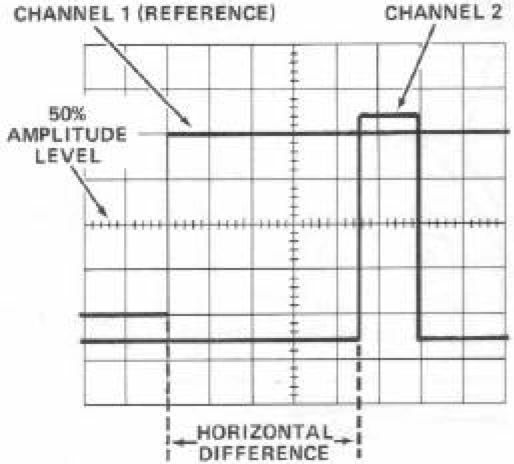
Figure 14. Example of time duration and frequency measurement.



FORMULA:

$$\text{TIME DIFFERENCE} = \frac{\text{SEC/DIV SETTING} \times \text{HORIZONTAL DIFFFERENCE (IN DIVISIONS)}}{\text{MAGNIFICATION (IF APPLICABLE)}}$$

EXAMPLE:

$$\text{22.5 MICROSECONDS} = \frac{\text{50 MICROSECONDS} \times 4.5}{10}$$

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Figure 15. Time difference between two pulses from different sources.

Time Difference Measurement Between Two Pulse Waveforms From Different Sources (Figure 15)

1. Obtain a normal sweep display.

2. Confirm SEC/DIV CAL (Variable) control is in the CALibrated detent position.

3. Set Trigger Source to CH1.

4. Connect known reference signal to the CH1 INPUT connector and the comparison signal to CH2 INPUT connector.

5. Set Vertical Mode to either CHOP or ALT mode and center each of the displays vertically.

6. Measure the horizontal difference between the two signals.

7. Multiply this distance by the SEC/DIV switch setting. If X10 MAG control is used, divide the difference by 10.

Dual Trace Phase Difference Measurements (Figure 16)

Phase comparison between any two signals of the same frequency can be determined using the dual trace feature of the instrument. To make these comparisons, use the following procedures:

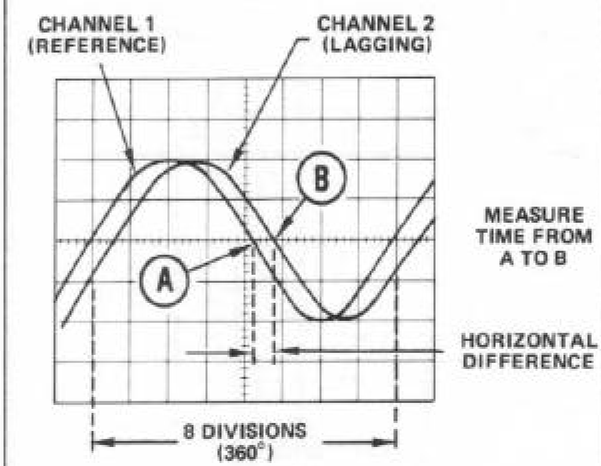
1. Set both the CH1 and CH2 Vertical Coupling to AC.

2. Set Vertical Mode to CHOP or ALT (CHOP is more suitable for low frequency signals; ALT for the higher frequency signals). Position both display traces to the center horizontal graticule line.

3. Set Trigger Source to CH1, and Trigger Mode to AUTO.

4. Adjust the TRIGGER LEVEL for a stable display.

5. Connect the reference signal to CH1 INPUT connector, and comparison signal to CH2 INPUT connector.



FORMULA:

HORIZONTAL DIFFERENCE (A TO B) X DEGREES/ DIVISION = PHASE DIFFERENCE

EXAMPLE:

0.6 DIVISION X 45°/ DIVISION = 27°

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Figure 16. Example of dual trace phase difference measurement.

@

6. If input signals are of opposite polarity, pull the CH2 INVERT knob to invert the CH2 display (signals may be of opposite polarity due to 180° phase difference; if so, take this into account in the final calculation).

7. Adjust CH1 and CH2 VOLTS/DIV and associated CAL (Variable) controls for displays that are equal and about five divisions in amplitude.

8. Set the SEC/DIV switch for a sweep rate which displays about one cycle of reference waveform.

9. Adjust the SEC/DIV CAL (Variable) control for a one cycle reference signal (CH1) of exactly 8 divisions between the 2nd and 10th graticule lines.

NOTE

Each division of graticule represents 45° of cycle (360° ÷ 8 divisions = 45° /division). Therefore, the sweep rate may be stated in terms of degrees as 45° /division.

10. Measure the horizontal difference (in divisions) between corresponding points on the two waveforms.

11. Multiply the difference (in divisions) by 45° /division to obtain the exact amount of phase difference.

High Resolution Phase Difference Measurement (Figure 17)

For phase differences less than 45° measurement accuracy may be improved by using the PULL: X10 MAG control as follows:

1. Perform steps 1 through 8 of the Dual Trace measurement procedures.

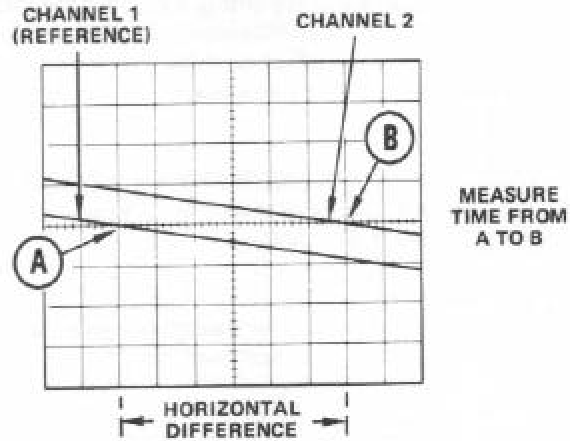
2. Center measurement points on the vertical graticule line.

3. Pull the X10 MAG knob. The sweep rate is now 4.5°/division (45°/division ÷ 10).

4. Adjust the horizontal POSITION control to move measurement points within the graticule area.

5. Measure horizontal difference (in divisions) between corresponding points of the two waveforms.

6. Multiply horizontal difference by the magnified sweep rate (4.5°/division).



FORMULA:

HORIZONTAL DIFFERENCE (A TO B) X DEGREES/ DIVISION = PHASE DIFFERENCE

EXAMPLE:

6 DIVISIONS X 4.5°/ DIVISION = 27°

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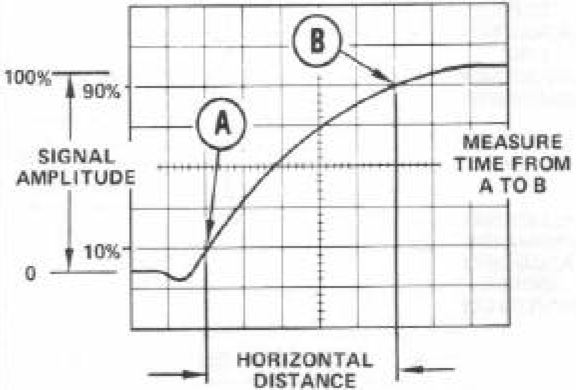
Figure 17. Example of high resolution phase difference measurement.



FORMULA:

HORIZONTAL DISTANCE (A TO B) × SEC/DIV SETTING = RISE TIME

EXAMPLE:

5 DIVISIONS × 1 MICROSECOND/ DIVISION = 5 MICROSECONDS

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Figure 18. Example of rise time measurement.

Rise Time Measurement (Figure 18)

Rise time measurements are made in the same manner as time duration measurements, except the horizontal measurements are made between the 10% and 90% points of the waveform amplitude. Rise time measurements are made as follows:

1. Set the VOLTS/DIV and Variable control for a 5 division display.

2. Adjust vertical POSITION so that display bottom crosses midpoint of the second division.

3. Measure horizontal distance (in divisions) between the 10% and 90% points on the waveform (points A and B).

4. To find the rise time, multiple the horizontal distance (in divisions) by the SEC/DIV setting.

Common Mode Rejection

Some signals may contain undesirable frequency components, as shown in Figure 19. Common mode rejection can eliminate or reduce these components from the measurement. Use the following procedure to reduce or eliminate an undesirable line frequency component:

1. Apply signal to CH1 INPUT connector.

2. Apply line frequency signal to CH2 INPUT connector.

3. Set the Vertical Mode to ALTernate position.

4. Pull the PULL: INVERT knob to invert the channel 2 display.

5. Adjust the CH2 CAL (Variable) control so that the amplitude of the channel 2 signal compares or is equal to the undesired signal component of channel 1 display.

6. Set the Vertical Mode to ADD and readjust CH2 Variable control for maximum rejection of the undesired signal component.

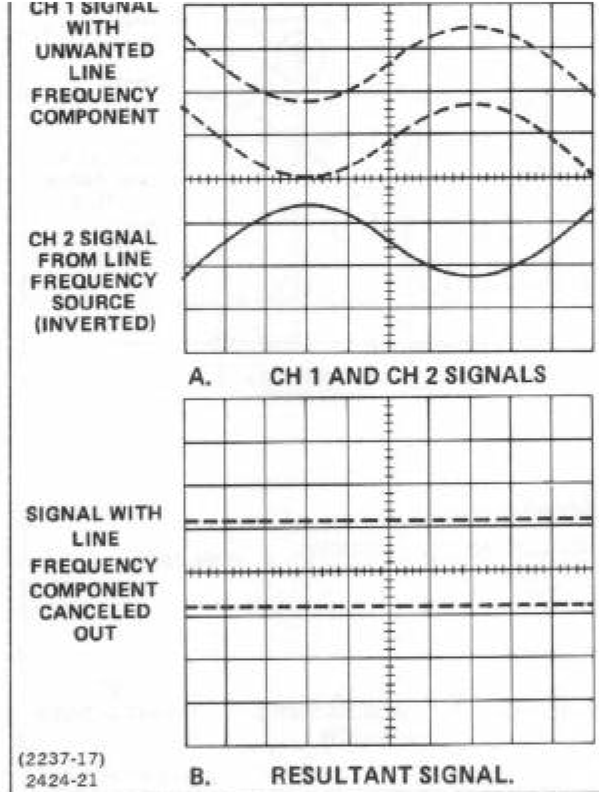

Figure 19. Common mode rejection of an undesired line-frequency.

SPECIFICATION

NOTE

Refer to the service manual for complete specifications. Specification given for an operating range of +20°C to +30°C unless otherwise stated.

TABLE 2

Electrical Characteristics

Characteristic	Performance Requirement	Supplemental Information
CALIBRATOR		
Output Voltage		
+20°C to +30°C	0.3 V within 1%.	
−15°C to +55°C	0.3 V within 2%.	
Repetition Rate		Approximately 1 kHz.
VERTICAL		
Deflection Factor		
Range	5 mV/div to 10 V/div.	11 steps in 1-2-5 sequence.

TABLE 2 (cont)

Characteristic	Performance Requirement	Supplemental Information
Deflection Factor (cont)		
Accuracy		
0°C to +40°C	Within 3%.	
−15°C to 0°C	Within 4%.	
+40°C to +55°C	Within 4%.	
Uncalibrated (Variable)	Continuously variable between calibrated settings.	Extends deflection factor to at least 25 volts/div.
Frequency Response		4-division reference signal vertically centered. VOLTS/DIV CAL (Variable) in detent.
Upper Bandwidth Limit		
5 mV/div to 10 V/div	Dc to at least 5 MHz (−3 dB point).	
Add Mode	Dc to at least 4.5 MHz (−3 dB point).	VOLTS/DIV CAL (Variable) in detent.
Lower Bandwidth Limit		
Ac Coupled (capacitive)	Approximately 10 Hz all deflection factors.	

TABLE 2 (cont)

Characteristic	Performance Requirement	Supplemental Information
VERTICAL		
Input R and C		
Input Resistance	1 MΩ within 2%.	
Input Capacitance	Approximately 47 pF.	
Maximum Input Voltage		
Dc Coupled	250 V (dc + peak ac).	
Ac Coupled	250 V (dc + peak ac) or 250 V p-p ac at 1 kHz or less.	
Chopped Mode Repetition Rate	Approximately 50 kHz.	
TRIGGERING		
Trigger Sensitivity		
Dc Coupled	0.3 division internal or 15 mV external from dc to 0.5 MHz, increasing to 0.75 divisions internal or 50 mV external from 0.5 MHz to 5 MHz.	

TABLE 2 (cont)

Characteristic	Performance Requirement	Supplemental Information
Trigger Sensitivity (cont)		
Ac Coupled	0.3 division internal or 15 mV external from 60 Hz to 0.5 MHz, increasing to 0.75 division internal or 50 mV external from 0.5 MHz to 5 MHz. Attenuates all signals below about 60 Hz.	
Maximum Input Voltage	250 V (dc + peak ac) at 1 kHz or less.	
Display Time Jitter Due to Triggering	20 ns or less.	
External Input		
Resistance	Approximately 1 MΩ.	
Capacitance	Approximately 47 pF.	

TABLE 2 (cont)

Characteristic	Performance Requirement		Supplemental Information
TTL Trigger (Trigger Mode: Normal and Dc Coupling, V/Div: 50 m, 0.1 or 0.2)			
Threshold Voltage			
Int (with 10X probe)	1.4 V within ±0.3 V.		
Ext (with 10X probe)	1.4 V within ±0.2 V.		
Minimum Input Swing			
Int	0.5 div.		
Ext	500 mV p-p.		
AUTO Operation Sensitivity (Ac or Dc Coupling)	**Internal**	**External**	
500 Hz to 0.5 MHz	0.5 div	35 mV	
0.5 MHz to 5 MHz	1.0 div	70 mV	
Low Frequency Response (Down to 200 Hz or less)	2.0 div	140 mV	

TABLE 2 (cont)

Characteristic	Performance Requirement	Supplemental Information
HORIZONTAL		
Sweep Range		
Range	.5 s/div to 1 μ/div.	18 steps in 1-2-5 sequence. X10 MAG extends fastest sweep rate to .1 μs/div.
Accuracy		SEC/DIV Variable in Cal detent position. Timing set at 1 ms/div or 1 μs/div. Disregard first 0.5 μs of sweep.
0°C to +40°C	Within 3%.	Over center 8 division display.
−15°C to 0°C	Within 4%.	
+40°C to +55°C	Within 4%.	
Linearity		Over any 2 division portion within center 8 divisions. Disregard first 1 μs of total sweep.
0°C to +40°C	Within 4%.	
−15°C to 0°C	Within 5%.	
+40°C to +55°C	Within 5%.	

Characteristic	Performance Requirement	Supplemental Information
SEC/DIV CAL (Variable) Range	Continuously variable between calibrated settings.	Extends slowest sweep range to at least 1.25 second/division (2.5:1).
Horizontal Magnifier X10: Calibrated Magnifier		
Accuracy		Over center 8 division display. Exclude the first 10 divisions and all the divisions past 90th division.
0°C to +40°C	Within 5%.	
−15°C to 0°C	Within 6%.	
+40°C to +55°C	Within 6%.	
Linearity		Over any 2 division portion within center 8 divisions. Exclude the first 10 divisions and all the divisions past 90th division.
0°C to +40°C	Within 6%.	
−15°C to 0°C	Within 7%.	
+40°C to +55°C	Within 7%.	

Characteristic	Performance Requirement	Supplemental Information
X-Y Mode		X-Y position of SEC/DIV switch and X-Y (CH2) position of display mode switch must be selected.
X Sensitivity	Same as vertical.	Over the center 8-divisions of display.
Accuracy (0°C to +40°C)	Within 4%.	
Variable Range	Same as vertical.	
X-Axis Bandwidth	Dc to 150 kHz.	8-division reference signal.
Input R and C		
Resistance	Same as vertical.	
Capacitance	Same as vertical.	
Maximum Input Voltage	Same as vertical.	
DIGITAL MULTIMETER		
DC Voltmeter		
Range	2 V, 20 V, 200 V, 1000 V.	
Accuracy (+15°C to +35°C)	Within 0.1% of reading, ±2 counts.	

Characteristic	Performance Requirement	Supplemental Information
DC Voltmeter (cont)		
Common Mode Rejection	At least 100 dB at dc, 80 dB at 60 Hz with 1 kΩ unbalance.	
Normal Mode Rejection	At least 30 dB at 60 Hz increasing 20 dB per decade to 2 kHz, when maximum input signal voltage is within range X2.	
Step Response Time	No more than 1 second plus the range step time (no more than 1 second / step).	
Input Resistance	10 MΩ within 2%.	
AC Voltmeter		
Range	2 V, 20 V, 200 V, 700 V.	
Accuracy (+15°C to +35°C)	Within 0.5% of reading, ±10 counts 40 Hz to 500 Hz.	
Response Time	No more than 5 seconds plus the range step time (no more than 1 second/step).	
Input Impedance	10 MΩ within 3% paralleled by at least 70 pF.	

TABLE 2 (cont)

Characteristic	Performance Requirement	Supplemental Information
Ohmmeter		
Range	2 kΩ, 20 kΩ, 200 kΩ, 2000 kΩ.	
Accuracy (+15°C to +35°C)	Within 0.6% of reading, ±3 counts.	
Measurement Current	2 V ÷ range setting.	
Response Time	No more than 5 seconds plus the range step time (no more than 1 second/step).	
Battery Check Function (Internal batteries only)		
Accuracy	Within 5% of reading at 5.5 V to 8 V battery voltage.	
Range	Fixed 20 V range.	
Maximum Safe Input Voltage at DMM INPUT Connector		
DCV FUNCTION Setting	±1000 V (dc + peak ac) between HI and LO inputs or between HI and chassis.	

TABLE 2 (cont)

Characteristic	Performance Requirement	Supplemental Information
Maximum Safe Input Voltage at DMM INPUT Connector (cont)		
ACV FUNCTION Setting	700 V rms if sinusoidal. ±1000 V (dc + peak ac) between HI and LO inputs or between HI and chassis. ±500 V (dc component) between HI and LO inputs.	
kΩ FUNCTION Setting	±100 V (dc + peak ac) between HI and LO inputs.	
LO Floating Voltage	+500 V (dc + peak ac) between LO and chassis.	
INTERNAL BATTERY SUPPLY		
Operating Time		
Oscilloscope only operating		
Calibrator waveform displayed	5.4H.	

TABLE 2 (cont)

Characteristic	Performance Requirement	Supplemental Information
Operating Time (cont)		
INTENSITY, maximum 8 div, 5 MHz signal displayed	2.0H.	
DMM only operating	10.0H.	
Oscilloscope and DMM		
Calibrator waveform displayed	3.2H.	
INTENSTIY, maximum 8 div, 5 MHz signal displayed	1.6H.	
ENVIRONMENTAL		
Temperature		
Operating	-15°C to $+55^{\circ}$C (Oscilloscope)	
	0°C to $+55^{\circ}$C (DMM)	
Altitude		
Operating	To 30,000 feet.	