TEKTRONIX®

211 OSCILLOSCOPE

OPERATORS MANUAL

Tektronix, Inc. P.O. Box 500 Beaverton, Oregon 97005

070-1163-00 971

TABLE OF CONTENTS

CONTENTS (cont)

211 OSCILLOSCOPE

INTRODUCTION

General

The 211 Oscilloscope is a single-channel, 500 kilohertz portable instrument using only solid state and integrated circuit components (except CRT). The small size of the 211 makes it an extremely portable oscilloscope for on-location maintenance in many fields of application. The instrument is mechanically constructed to withstand the shock, vibration, and other extreme conditions associated with portability. The DC to 500 kilohertz vertical system provides vertical deflection factors from one millivolt (at reduced bandwidth) to 50 volts/division at the tip of the integral high-impedance probe. The trigger circuits provide stable triggering over the full bandwidth capabilities of the vertical system.

The horizontal deflection system provides calibrated sweep rates from 200 milliseconds to five microseconds/division. A continuously variable sweep magnifier provides uncalibrated sweep rates to at least five times the indicated sweep rate, for a maximum sweep rate of at least one microsecond/division. In addition, external horizontal amplifier operation provides horizontal deflection factors of one and 10 volts/division. The resultant CRT display produced by the vertical and horizontal deflection systems is presented on a 6 x 10 division graticule (each division equals 0.203 inch).

The 211 can be operated either from AC line voltage or from internal rechargeable batteries. Maximum total power consumption is two watts. The internal batteries can be recharged from the AC power line by the integral battery charger (instrument off).

OPERATING VOLTAGE

Internal Battery Operation

The 211 is designed primarily for operation from the internal rechargeable batteries. The operating time provided from the internal batteries depends on trace intensity, charge temperature, and discharge temperature. Typical operating time from fully charged batteries at maximum trace intensity when charged and operated at +20°C to +30°C (+68°F to +86°F) is 4.5 hours. Extended operating time is provided at lower trace intensity.

The BATTERY meter provides an indication of relative charge level. When the meter indicates in the FULL range, the internal batteries are chargeo to a sufficient level to operate the instrument. However, if the BATTERY meter is out of the FULL region, not more than 15 minutes of instrument operation remains. The 211 incorporates an automatic battery protection circuit to prevent deep discharge and the resulting battery damage if the instrument is operated after the battery charge level falls to about 10 volts.

AC Operation

All power line voltages must be sinusoidal. If the internal batteries of the 211 become discharged to the minimum operating level, continued operation can be obtained by connecting the instrument to an AC power source with the attached power cord. Due to the circuitry connected with the internal battery charger, the AC power line voltage must be at least 110 volts for operation in this manner. Also, when operated with fully-charged batteries from an AC line below about 110 volts and at maximum true intensity, the internal batteries slowly discharge; approximately 36 hours of continuous operation can be obtained with fully charged batteries at maximum intensity and 104-volt line. The internal batteries cannot be recharged while the instrument is operated from the AC line.

If the 211 is to be operated on a power line other than 115 VAC 60 Hz, two considerations arise. The electrical value of capacitors (C204, C210, C212, and C215) in the instrument's power input circuitry must be changed. Refer to the Maintenance Section of the Maintenance Manual for the appropriate values of capacitance to be used.

Also, when operating the 211 on other power sources, in all likelihood it will be necessary to adapt the power plug of the instrument's attached power cord to the power outlet receptacle of the power line being used. Those instruments ordered specifically for use outside of the United States will have included as an additional standard accessory a power cord with a female connector on one end that mates with the plug on the 211's power cord, and no plug or connector on the other end. The user can install the appropriate plug on the open end of this additional cord, and then use this cord to connect the 211 to the various power outlet receptacles.

Battery Charging

The charging characteristics of the nickel-cadmium (NiCd) cells used in this instrument vary with the temperature at which they are charged. Batteries charged at about +20°C to +30°C (+68°F to +86°F) will deliver more energy than when the same batteries are charged at a higher or lower temperature.

To charge the batteries, connect the instrument to an AC line and set the POWER switch to the OFF position. Allow at least 16 hours for the batteries to reach full charge. For longest operating life of the batteries, increase the charge time of the instrument to at least 24 hours about once a month. This procedure balances the charge on all cells in the battery, and reduces the possibility of any individual cell becoming reverse charged.

When the instrument is stored and not used for extended periods of time, the nickel-cadmium batteries may self-discharge. The rate at which this self-discharge occurs is dependent upon the storage temperature and humidity. If this instrument is to be stored for extended periods of time, particularly at either high ambient temperature or high humidity, it is recommended that the batteries be run through a full charge cycle (16 hours) about every two weeks, or that the instrument be left connected to the AC line.

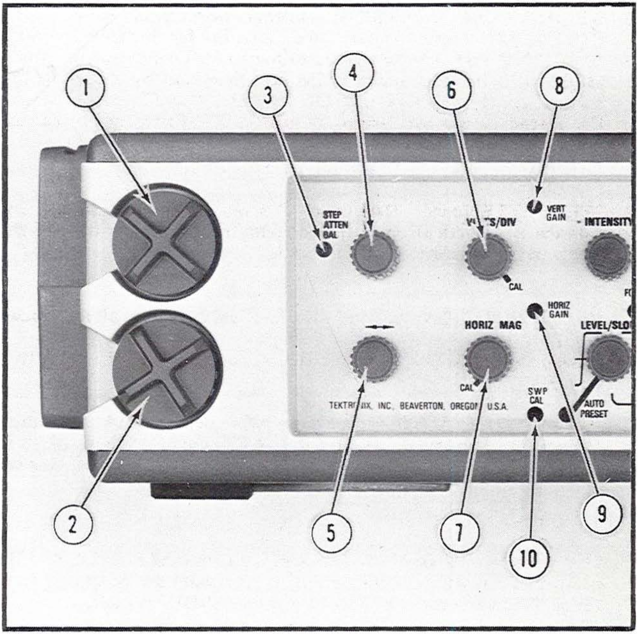
Operating Temperature

The 211 can be operated where the ambient air temperature is between −15°C and +55°C (+5°F and +131°F). The batteries should be charged only in ambient temperatures between 0°C and +40°C (+32°F and +104°F).

CONTROLS AND CONNECTORS

General

The controls and connectors for operation of the 211 are located on the right side of the instrument. To make full use of the capabilities of this instrument, the operator should be familiar with the function and use of each of these controls and connectors. A brief description of each control and connector is given here. Some of the more important instrument specifications are included here also.



1. VOLTS/DIV—selects vertical deflection factor (variable control must be in CAL position for indicated deflection). Calibrated position accuracy within 5%. Vertical system bandwidth: 1 mV/div, 100 kHz; 2 mV/div, 200 kHz; 5 mV/div, 400 kHz; 10 mV/div to 50 V/div, 500 kHz.

2. SEC/DIV OR VOLTS/DIV—selects horizontal sweep rate (HORIZ MAG must be in CAL position for indicated sweep rate). 10 V and 1 V positions allow external horizontal operation with the horizontal deflection provided by a signal connected to the EXT TRIG OR HORIZ INPUT banana jack. Calibrated sweep rate accuracy within 5%. External horizontal deflection factor accuracy within 10%.

3. STEP ATTENuator BALance—a screwdriver adjustment to balance the vertical amplifier system for minimum trace shift when switching deflection factors.

4. Vertical POSITION—controls the vertical position of the trace.

5. Horizontal POSITION—controls the horizontal position of the trace.

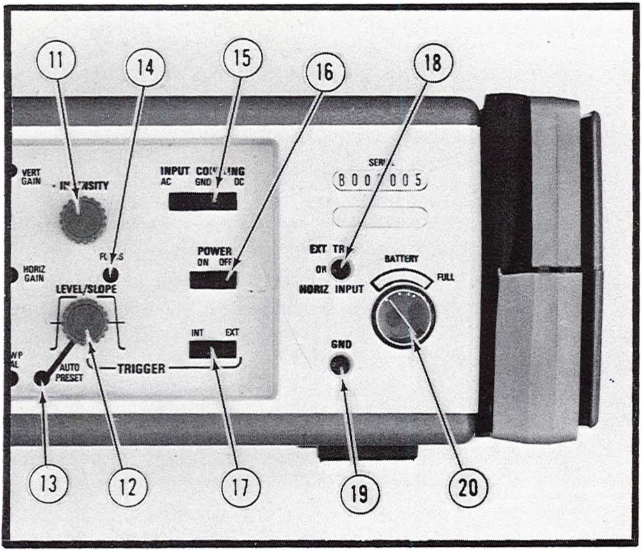
6. VOLTS/DIV VARiable—provides continuously variable deflection factors between the calibrated settings of the VOLTS/DIV switch. Extends the maximum deflection factor to at least 150 volts/div.

7. HORIZontal MAGnifier—provides continuously variable (uncalibrated) sweep magnification to a maximum of about five times the sweep rate indicated by the SEC/DIV switch.

8. VERTical GAIN—screwdriver adjustment to set the gain of the vertical amplifier system.

9. HORIZontal GAIN—screwdriver adjustment to set the basic gain of the horizontal amplifier system.

10. SWP CAL—screwdriver adjustment to provide calibrated sweep timing.



11. INTENSITY—controls brightness of CRT display.

12. LEVEL/SLOPE—selects the amplitude point and the slope of a trigger signal on which the sweep is triggered. When the indicator dot is to the left of center, the sweep is triggered on the positive-going slope of the trigger signal; to the right of center, on the negative-going slope. When the LEVEL/SLOPE control is set to the AUTO PRESET detent, the sweep is automatically triggered at a preset level on the positive-going slope. Stable triggering requires a minimum of 0.2 division internal or 1.0 volt external signal amplitude.

13. AUTO PRESET—screwdriver adjustment to set the AUTO PRESET trigger point for automatic trigger operation.

14. FOCUS—screwdriver adjustment to obtain a well-defined display.

15. INPUT COUPLING—selects the method used to couple the input signal to the vertical amplifier system.

    AC—The DC component of input signal is blocked. Low frequency limit (−3 dB point) is approximately 2 Hz.

    GND—vertical amplifier input circuit is grounded. The applied input signal is connected to ground through a large resistor to provide a pre-charge path for the AC input coupling capacitor.

    DC—all components of the input signal are passed to the vertical amplifier system input.

16. POWER—controls power to the instrument. Does not interrupt charging current to the internal batteries when the instrument is connected to an AC line voltage.

17. INT-EXT—selects the source of the trigger signal.

    INTernal—the sweep is triggered from a sample of the vertical deflection signal.

    EXTernal—the sweep is triggered from the signal applied to the EXT TRIG OR HORIZ INPUT banana jack.

18. EXT TRIG OR HORIZ INPUT—banana jack for external trigger or external horizontal signal input.

19. GND—banana jack to establish common ground between the 211 and the external signal source or equipment under test.

20. BATTERY—expanded-scale meter to indicate the charge level of the internal batteries.

OPERATOR'S ADJUSTMENTS

General

There are several basic instrument parameters that should be checked occasionally and, if necessary, adjusted to meet specifications in order to assure measurement accuracy. These are readily accessible as screwdriver adjustments on the instrument side panel. The following provides brief calibration information for these external adjustments. The operator should be familiar with instrument operation before attempting to make these adjustments.

Vertical Gain

Connect the 211 probe tip to an accurate 0.2-volt source such as a Tektronix 067-0502-01 Standard Amplitude Calibrator. Set the VOLTS/DIV switch to 50 m and set the VERT GAIN adjustment for exactly four divisions of deflection.

Step Attenuator Balance

Obtain a free-running trace with no signal applied to the vertical system input. While switching the VOLTS/DIV switch between 50 m and 1 m, adjust the STEP ATTEN BAL adjustment for minimum trace shift between switch positions.

Horizontal Gain

Set the SEC/DIV switch to 1 V. Connect an accurate five-volt source (such as Tektronix 067-0502-01 Standard Amplitude Calibrator) to the EXT TRIG OR HORIZ INPUT banana jack. Adjust the HORIZ GAIN adjustment for exactly five divisions of deflection.

Horizontal Timing

Connect the 211 probe tip to some accurate timing standard (such as the Tektronix 2901 Time-Mark Generator). With the SEC/DIV switch set to 1 m, apply one millisecond time marks. Adjust the TRIGGER controls for a stable display. Adjust the SWP CAL adjustment for exactly eight divisions of deflection between the second and tenth time mark.

Focus

Set the SEC/DIV switch to 10 V and the INPUT COUPLING switch to GND. With no signal applied to the EXT TRIG OR HORIZ INPUT banana jack, adjust the FOCUS screwdriver adjustment for optimum focus of the CRT display (a single dot).

Auto Preset

Connect the 211 probe tip to a sine-wave signal source within the bandwidth limits of the 211. Set the LEVEL/

SLOPE control to the AUTO PRESET detent and adjust the VOLTS/DIV and SEC/DIV switches for a display approximately four divisions in amplitude with one cycle of signal displayed every two or three divisions. Vertically center the display about the center horizontal graticule line, using the Vertical POSITION control. Adjust the AUTO PRESET adjustment so the CRT display starts on the center horizontal graticule line.

GENERAL OPERATING INFORMATION

Intensity Control

The INTENSITY control determines the brightness of the display presented on the CRT. Since the brightness of the CRT display affects the amount of current drained from the batteries, the INTENSITY control should be set to the minimum level that provides a usable display. This will allow the maximum operating time from the internal batteries. The setting of the INTENSITY control may affect the correct focus of the display. Slight re-adjustment of the FOCUS may be necessary when the intensity level is changed. To protect the CRT phosphor, do not turn the INTENSITY control higher than necessary to provide a satisfactory display. Be careful that the INTENSITY control is not set too high when changing the SEC/DIV switch from a fast to a slow sweep rate, or when changing to the external horizontal mode of operation.

Graticule

The graticule of the 211 is internally marked on the face-plate of the CRT to provide accurate, no-parallax measurements. The graticule is marked with six vertical and 10 horizontal divisions. Each major division is segmented into five minor divisions at the center vertical and horizontal lines. The vertical gain and horizontal timing are calibrated to the graticule, so accurate measurements can be made from the CRT display.

Deflection Factor

The amount of vertical deflection produced by a signal is determined by the signal amplitude, the setting of the VOLTS/DIV switch, and the setting of the VOLTS/DIV VAR control. The calibrated deflection factors indicated by the VOLTS/DIV switch apply only when the VOLTS/DIV VAR control is set to the CAL detent (fully clockwise).

The VOLTS/DIV VAR control provides variable (uncalibrated) vertical deflection factors between the calibrated settings of the VOLTS/DIV switch. The VOLTS/DIV VAR control extends the maximum vertical deflection factor of the 211 to at least 150 volts/division (50 volts position).

Signal Connections

A high-impedance signal probe is permanently attached to the 211. This probe provides a one-megohm input impedance and a shielded input cable to prevent pickup of electrostatic interference. Since the probe is permanently attached, the vertical deflection factors can be read directly from the VOLTS/DIV switch at all times.

Signals can be connected to the EXT TRIG OR HORIZ INPUT banana jack with short unshielded leads under most conditions. Be sure to establish a common ground between the 211 and the equipment under test. Attempt to position the unshielded leads away from any source of interference to avoid errors in triggering or in the external horizontal display. If interference is excessive with unshielded leads, use a coaxial cable with a suitable adapter.

Ground Considerations

Reliable signal measurements cannot be made unless both the oscilloscope 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 attached probe provides the best ground. Also, a ground lead can be connected to the 211 chassis GND banana jack to establish a common ground with the signal source.

Input Coupling

The INPUT COUPLING switch allows a choice of coupling method for the applied signal. The type of display desired and the applied signal determines the coupling method to use.

The DC coupling position can be used for most applications. This position allows measurement of the DC component of a signal, and must be used to display signals below about 10 hertz, as they will be attenuated in the AC position.

In the AC coupling position, the DC component of the signal is blocked by a capacitor in the input circuit. The low-frequency response in the AC position is about two hertz (−3 dB point). Therefore, some low-frequency attenuation can be expected near this frequency limit. Attenuation in the form of waveform tilt will also appear in square waves which have low-frequency components. The AC coupling position provides the best display of signals with a DC component which is much larger than the AC component.

The GND position provides a ground reference at the input of the 211 without the need to externally ground the probe. The signal applied to the probe is internally disconnected from the input circuit and connected to ground through a one-megohm resistor. The input circuit is held at ground potential.

Pre-Charging. The GND position can also be used to pre-charge the input coupling capacitor to the average voltage level of the signal applied to the probe. This allows measurement of only the AC component of signals having both AC and DC components. The pre-charging network incorporated in this unit allows the input-coupling capacitor to charge to the DC source voltage level when the INPUT COUPLING switch is set to GND. The pre-charge feature limits the amount of current which can be drawn from the signal source, and therefore protects it from damage due to excess current demand. The following procedure should be used whenever the probe tip is connected to a signal source having a different DC level than that previously applied.

1. Before connecting the probe to a signal source with a large DC component, set the INPUT COUPLING switch to GND. Then, connect the probe to the signal source.

2. Wait several seconds for the input coupling capacitor to charge.

3. Set the INPUT COUPLING switch to AC. The display will remain on the screen so the AC component of the signal can be measured in the normal manner.

Trigger Source

INT. For most applications, the sweep can be triggered internally. In the INT position of the Trigger Source switch, the trigger signal is obtained from the vertical deflection system. Therefore, the sweep is triggered from the same waveform that is displayed on the CRT.

EXT. An external signal connected to the EXT TRIG OR HORIZ INPUT banana jack can be used to trigger the sweep in the EXT position of the Trigger Source switch. The external signal must be time-related to the displayed signal to obtain a stable display. An external trigger signal can be used to provide a triggered display when the internal signal is too low in amplitude for correct triggering, or contains signal components on which it is not desired to trigger. It is also useful when signal tracing in amplifiers, phase-shift networks, wave-shaping circuits, etc. The signal from a single point in the circuit under test can be connected to the EXT TRIG OR HORIZ INPUT banana jack. Then the sweep is triggered by the same signal at all times to allow amplitude, time relationship, or waveshape changes or signals at various points in the circuit to be examined without resetting the trigger controls.

Trigger Coupling

For Normal triggering (LEVEL/SLOPE knob rotated out of AUTO PRESET detent) all internal trigger signals are AC coupled to the trigger circuit while all external trigger signals are DC coupled. Lower limit of internal coupling is about 2 Hz. When an adequate trigger signal is applied, the sweep is triggered to produce a stable display.

Trigger Slope

The LEVEL/SLOPE control determines whether the trigger circuit responds on the positive-going or negative-going portion of the trigger signal. When the indicator dot is to the left of center, the trigger circuits respond to the positive-going portion of the triggering waveform (notice positive-going waveform on left side of control). To the right of center, the trigger circuits respond to the negative-going portion of the triggering waveform (notice negative-going waveform). Since this instrument does not have an internal delay line, the display may not start on the selected slope, particularly when the displayed waveform has a high repetition rate. When several cycles of a signal appear in the display, the selection of the trigger slope is often unimportant. However, if only a certain portion of a cycle is to be displayed, correct setting of the LEVEL/SLOPE control is important to provide a display which starts on the desired slope of the input signal.

Trigger Level

In addition to selecting the trigger slope, the LEVEL/SLOPE control determines the voltage level on the trigger signal at which the display is triggered. The horizontal line marked on the waveforms to the left and right of the LEVEL/SLOPE control represent the zero-volt level of the trigger signal. As the LEVEL/SLOPE control is rotated away from this line, the displayed waveform starts at a point corresponding to the position of the indicator dot on the associated slope waveform. For example, if the LEVEL/SLOPE control is turned clockwise from the line on the positive-going slope, the displayed waveform starts at a more positive level.

The AUTO PRESET detent provides automatic selection of the triggering slope and level. When the LEVEL/SLOPE control is set to this position, the sweep is automatically triggered at the preset level on the positive-going slope. For lower frequency signals or in the absence of an adequate trigger signal, the sweep free runs to produce a reference trace. When an adequate trigger signal is applied, the free-running condition ends and the sweep is triggered to produce a stable display.

Horizontal Sweep Rate

The SEC/DIV switch provides 15 calibrated sweep rates ranging from 200 milliseconds to 5 microseconds/division (HORIZ MAG switch set to CAL). The HORIZ MAG control provides continuously variable sweep magnification to a minimum of about 5 times the sweep rate indicated by the SEC/DIV switch.

When making time measurements from the graticule, the area between the first-division and ninth-division vertical lines provides the most linear time measurement (see Fig.

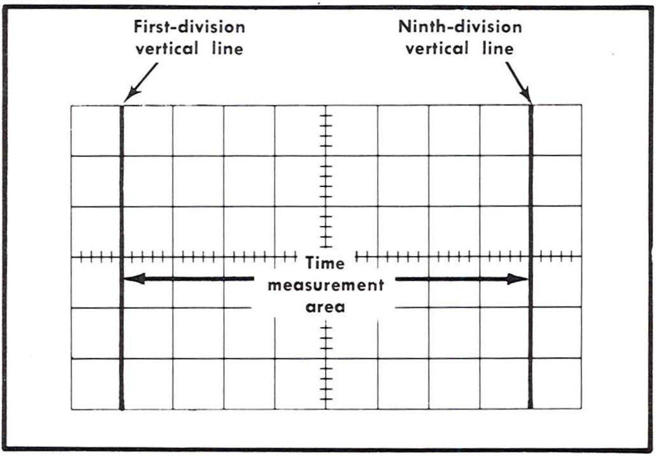


Fig. 1. Area of graticule used for accurate time measurements.

1). Therefore, the first and last division of the display should not be used for making accurate time measurements. Position the start of the timing area to the first-division vertical line and set the SEC/DIV switch so the end of the timing area falls between the first- and ninth-division vertical lines.

External Horizontal Operation

In some applications, it is desirable to display one signal versus another signal (X-Y) rather than against time (internal sweep). The external horizontal mode of operation provides a means for applying an external signal to the horizontal amplifier for this type of display.

To use the external horizontal mode of operation, connect the external signal to the EXT TRIG OR HORIZ INPUT banana jack. Set the SEC/DIV OR VOLTS/DIV (EXT) switch to the 10 V or 1 V position. The signal connected to the probe provides the vertical (Y) deflection, and the signal connected to the EXT TRIG OR HORIZ INPUT banana jack provides the horizontal (X) deflection. Since the X and Y channels of this instrument are not time matched, some inherent phase shift can be expected in the external horizontal display; take this inherent phase shift into account when making measurements.

APPLICATIONS

General

The following information describes the procedures and techniques for making measurements with a 211 Oscilloscope. These applications are not described in detail, since each application must be adapted to the requirements of the individual measurement. This instrument can also be used for many applications which are not described in this manual. Contact your local Tektronix Field Office or representative for assistance in making specific measurements with this instrument.

Peak-to-Peak Voltage Measurements—AC

To make a peak-to-peak voltage measurement, use the following procedure:

1. Set the INPUT COUPLING switch to GND.

2. Connect the probe tip to the signal source. Connect the probe ground strap to provide a common ground.

3. After several seconds, set the INPUT COUPLING switch to AC.

NOTE

For low-frequency signals below about 10 hertz, use the DC position.

4. Set the VOLTS/DIV switch to display about five divisions of the waveform.

5. Set the Triggering controls to obtain a stable display. Set the SEC/DIV switch to a position that displays several cycles of the waveform.

6. Set the vertical POS control so the lower portion of the waveform coincides with one of the horizontal graticule lines below the center horizontal line, and the top of the waveform is in the viewing area. Move the display with the horizontal POS control so one of the upper peaks lies near the center vertical line (see Fig. 2).

7. Measure the divisions of vertical deflection from peak to peak. Make sure the VAR VOLTS/DIV control is in the CAL position.

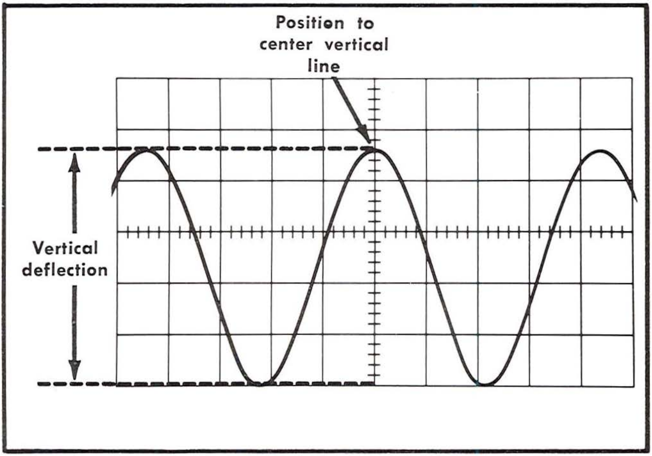


Fig. 2. Measuring peak-to-peak voltage of a waveform.

NOTE

This technique may also be used to make measurements between two points on the waveform, rather than peak to peak.

8. Multiply the distance measured in step 7 by the VOLTS/DIV switch setting.

Example. Assume a peak-to-peak vertical deflection of 4.6 divisions (see Fig. 2) using a VOLTS/DIV switch setting of .5.

Using the formula:

$$\text{Volts Peak to Peak} = \begin{matrix}\text{vertical deflection}\\ \text{(divisions)}\end{matrix} \times \begin{matrix}\text{VOLTS/DIV}\\ \text{setting}\end{matrix}$$

Substituting the given values:

Volts Peak to Peak = 4.6 X 0.5 V

The peak-to-peak voltage is 2.3 volts.

DC Voltage Measurements

Ground Reference. To measure the DC level at a given point on a waveform, use the following procedure:

1. Set the INPUT COUPLING switch to GND.

2. Connect the probe tip to the signal source. Use the probe ground strap to provide a circuit common.

3. Position the trace to the bottom line of the graticule or other reference line. If the voltage to be measured is negative with respect to ground, position the trace to the top line of the graticule. Do not move the vertical POS control after this reference line has been established.

NOTE

To measure a voltage level with respect to another voltage rather than ground, make the following changes in step 3. Set the INPUT COUPLING switch to DC and connect the probe tip to the reference voltage. Then position the trace to the reference line.

4. Set the INPUT COUPLING switch to DC. the ground reference line can be checked at any time by switching to the GND position (except when using a DC reference voltage).

5. Set the VOLTS/DIV switch to display about five divisions of the waveform.

6. Set the TRIGGER controls to obtain a stable display. Set the SEC/DIV switch to a setting that displays several cycles of the signal.

7. Measure the distance in divisions between the reference line and a point on the waveform at which the DC level is to be measured. For example, in Fig. 3 the measurement is made between the reference line and point A.

8. Establish the polarity of the signal. If the waveform is above the reference line, the voltage is positive; below the line negative.

9. Multiply the distance measured in step 7 by the VOLTS/DIV switch setting.

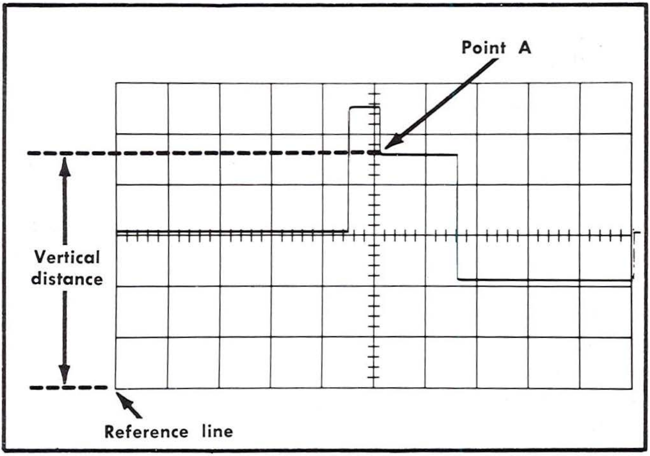


Fig. 3. Measuring instantaneous DC voltage with respect to a reference.

Example. Assume that the vertical distance measured is 4.6 divisions (see Fig. 3), the waveform is above the reference line, using a VOLTS/DIV setting of 2.

Using the formula:

$$\text{Instantaneous Voltage} = \text{vertical distance (divisions)} \times \text{polarity} \times \text{VOLTS/DIV setting}$$

Substituting the given values:

$$\text{Instantaneous Voltage} = 4.6 \times +1 \times 2\ \text{V}$$

The instantaneous voltage is +9.2 volts.

Elevated Reference. Another method of making a voltage measurement with reference to a voltage level, rather than to ground, is to connect the 211 probe ground clip directly to the desired reference voltage. This method of establishing a floating reference can be used when the instrument is connected to a power line, as long as the oscilloscope circuit common is not elevated from earth ground more than 250 V RMS sinusoidal minus the AC power line RMS voltage (i.e., when AC power line RMS voltage is 117 V, the maximum allowable potential on the probe common is 250 – 117 = 133 V RMS). When battery operated with the AC power plug secured in its insulated cover, the maximum safe potential between probe common and the 211 case exterior is 500 V RMS or 700 V DC + peak AC. Use the same measurement procedure given previously for Ground Reference. Remember that the DC reference line presented when the INPUT COUPLING switch is set to GND is an elevated voltage, and not ground. To determine the actual instantaneous voltage with respect to earth ground, add the reference voltage to the results of the Instantaneous Voltage formula.

Time-Duration Measurements

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

1. Connect the probe tip to the signal source. Use the probe ground strap to provide a common ground.

2. Set the VOLTS/DIV switch to display about five divisions of the waveform.

3. Set the TRIGGER controls to obtain a stable display.

4. Set the SEC/DIV switch to the fastest sweep rate that displays less than eight divisions between the time measurement points (see Fig. 4).

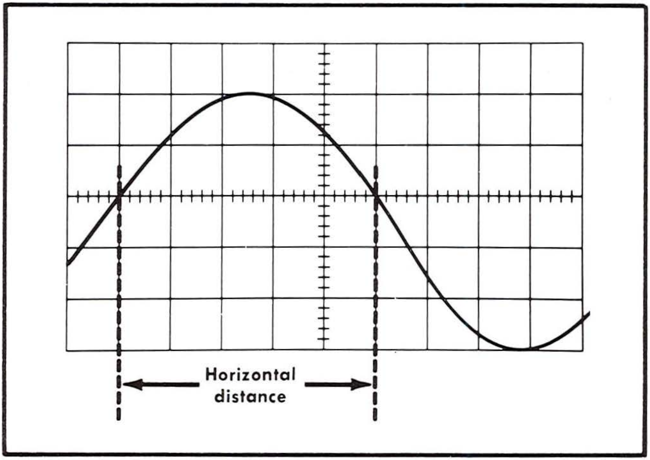


Fig. 4. Measuring the time duration between points on a waveform.

See the topic entitled HORIZONTAL SWEEP RATE concerning non-linearity of first and last divisions of display.

5. Adjust the vertical POS control to move the points between which the time measurement is made to the center horizontal line.

6. Adjust the horizontal POS control to center the display within the center eight divisions of the graticule.

7. Measure the horizontal distance between the time measurement points. Be sure the HORIZ MAG control is set to the calibrated position.

8. Multiply the distance measured in step 7 by the setting of the SEC/DIV switch.

Example. Assume that the horizontal distance between the time measurement points is five divisions (see Fig. 4) and the SEC/DIV switch is set to .1 ms.

Using the formula:

$$\text{Time Duration} = \begin{matrix}\text{horizontal}\\\text{distance}\\\text{(divisions)}\end{matrix} \times \begin{matrix}\text{SEC/DIV}\\\text{setting}\end{matrix}$$

Substituting the given values:

$$\text{Time Duration} = 5 \times 0.1 \text{ ms}$$

The time duration is 0.5 millisecond.

Determining Frequency

The time measurement technique can also be used to measure the frequency of a signal. The frequency of a periodically-recurrent signal is the reciprocal of the time duration (period) of one cycle.

Use the following procedure:

1. Measure the time duration of one cycle of the waveform as described in the previous application.

2. Take the reciprocal of the time duration to determine the frequency.

Example. The frequency of the signal shown in Fig. 4 which has a time duration of 0.5 ms is:

$$\text{Frequency} = \frac{1}{\text{time duration}} = \frac{1}{0.5\ \text{ms}} = 2\ \text{kHz}$$

Risetime Measurements

Risetime measurements employ basically the same techniques as time-duration measurements. The main difference is the points between which the measurement is made. The following procedure gives the basic method of measuring risetime between the 10% and 90% points of the waveform. Falltime can be measured in the same manner on the trailing edge of the waveform.

1. Connect the probe tip to the signal source. Use the probe ground strap to establish a common ground.

2. Set the VOLTS/DIV switch and VAR VOLTS/DIV control to produce a display an exact number of divisions in amplitude.

3. Center the display about the center horizontal line.

4. Set the TRIGGER controls to obtain a stable display.

5. Set the SEC/DIV switch to the fastest sweep rate that displays less than eight divisions between the 10% and 90% points on the waveform.

6. Determine the 10% and 90% points on the rising portion of the waveform. The figures given in Table 1 are for the points 10% up from the start of the rising portions and 10% down from the top of the rising portion (90% point).

Table 1

Risetime Measurement Points

Vertical display (divisions)	10% and 90% points	Divisions vertically between 10% & 90% points
4	0.4 and 3.6 divisions	3.2
5	0.5 and 4.5 divisions	4.0
6	0.6 and 5.4 divisions	4.8

7. Adjust the horizontal POS control to move the 10% point of the waveform to the first graticule line. For example, with a five-division display as shown in Fig. 5, the 10% point is 0.5 division up from the start of the rising portion.

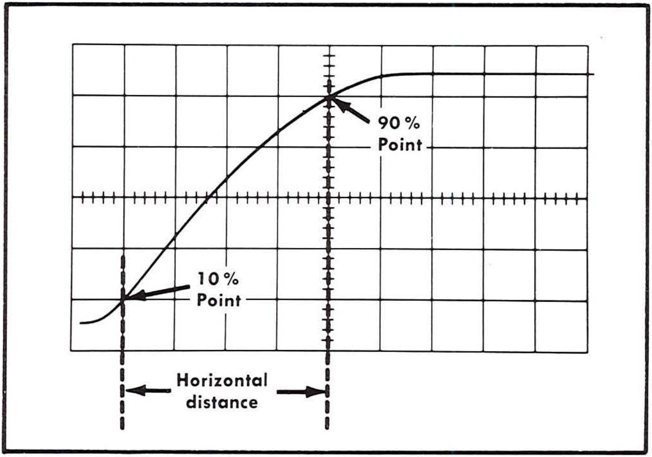


Fig. 5. Measuring risetime.

8. Measure the horizontal distance between the 10% and 90% points. Be sure the HORIZ MAG control is set to the calibrated position.

9. Multiply the distance measured in step 8 by the setting of the SEC/DIV switch.

Example. Assume that the horizontal distance between the 10% and the 90% points is four divisions (see Fig. 5) and the SEC/DIV switch is set to 10 μS.

Applying the time duration formula to risetime:

$$\underset{\text{(Time Duration)}}{\text{Risetime}} = \underset{\text{(divisions)}}{\text{horizontal distance}} \times \underset{\text{setting}}{\text{SEC/DIV}}$$

Substituting the given values:

Risetime = 4 X 10 μS

The risetime is 40 microseconds.