Tektronix®

COMMITTED TO EXCELLENCE

INSTRUCTION MANUAL

BEFORE READING—

THIS MANUAL REPRINTED JULY 1980

PLEASE CHECK FOR CHANGE INFORMATION AT THE REAR OF THIS MANUAL.

TEKTRONIX®

442 OSCILLOSCOPE

OPERATORS

INSTRUCTION MANUAL

Serial Number ______________ First Printing AUG 1977

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070-2373-00

WARRANTY

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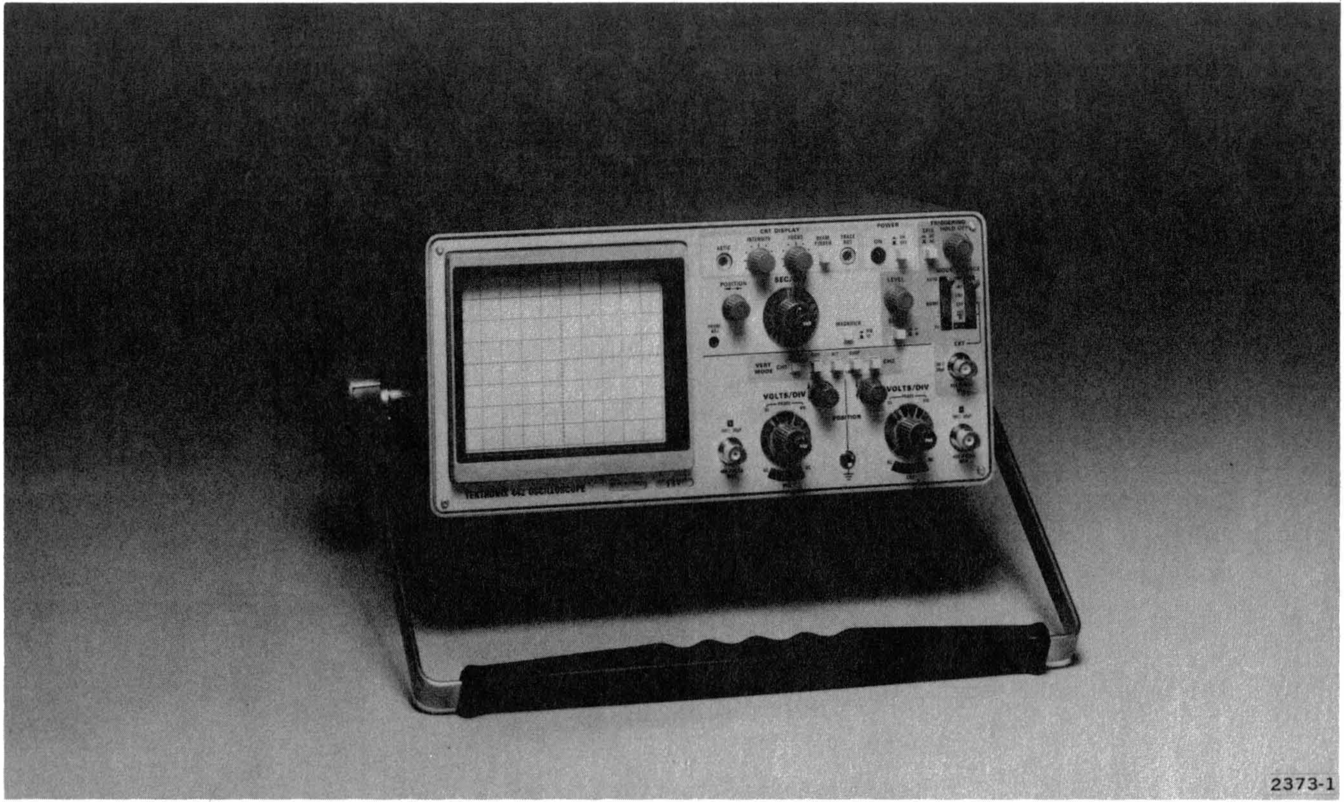

Fig. 1. 442 Oscilloscope

BEFORE OPERATING

INTRODUCTION

The Tektronix 442 Oscilloscope is a 35 MHz maximum bandwidth instrument with dual trace capability. A dual trace dc to 35 megahertz vertical system provides calibrated deflection factors from 2 millivolts/division to 10 volts/division. Trigger circuits provide stable triggering over the full vertical bandwidth. A horizontal deflection system provides calibrated sweep rates from 0.5 second/division to 0.1 microsecond/division. An X10 magnifier circuit (pushbutton switch) extends maximum sweep to 10 nanoseconds/division. In X-Y mode of operation, vertical and horizontal deflection factors are the same as vertical amplifiers.

SAFETY INFORMATION

The 442 Oscilloscope is designed to be operated from a single phase power source which has one of its current carrying conductors at ground potential (earth ground). Operation from other power sources where both current carrying conductors are live with respect to ground (such as phase-to-phase, a multi-phase system, or across the legs of a 117-234 V single-phase three-wire system) is not recommended because only the Line Conductor has overcurrent (fuse) protection within the instrument.

Each instrument is provided with a three-wire power cord with a three-terminal, polarized plug for connection to power source. The grounding terminal of the receptacle is directly connected to the instrument chassis and cabinet as recommended by national and international safety codes. Color coding of cord conductors follows the I.E.C. which specifies: Line, brown; Neutral, blue; Safety Earth or Ground, green with a yellow stripe (or solid green).

OPERATING VOLTAGE

Power Operation

The 442 operates from either 120 V or 240 V ac input — at 48 to 62 Hz. Selection of input function is made with screwdriver adjusted switches accessible through bottom of cabinet (see Fig. 2). Adjustment for high or low power input can be made with same tool at same cabinet position.

WARNING

Do not plug instrument into power source until the following settings are made or checked.

Set the Line Voltage Selector switch to the nominal line voltage available (see Fig. 2).

Set the Regulating Range Selector Switch (see Fig. 2) so expected line-voltage fluctuations remain within the Regulating Range selected (see Table 1).

Table 1
Ac Regulating Ranges

Regulating Range Selector Switch Position	Regulating Range 120 V Nominal	Regulating Range 240 V Nominal
HI	108 to 132 V RMS	216 to 250 V RMS
LO	90 to 110 V RMS	198 to 242 V RMS

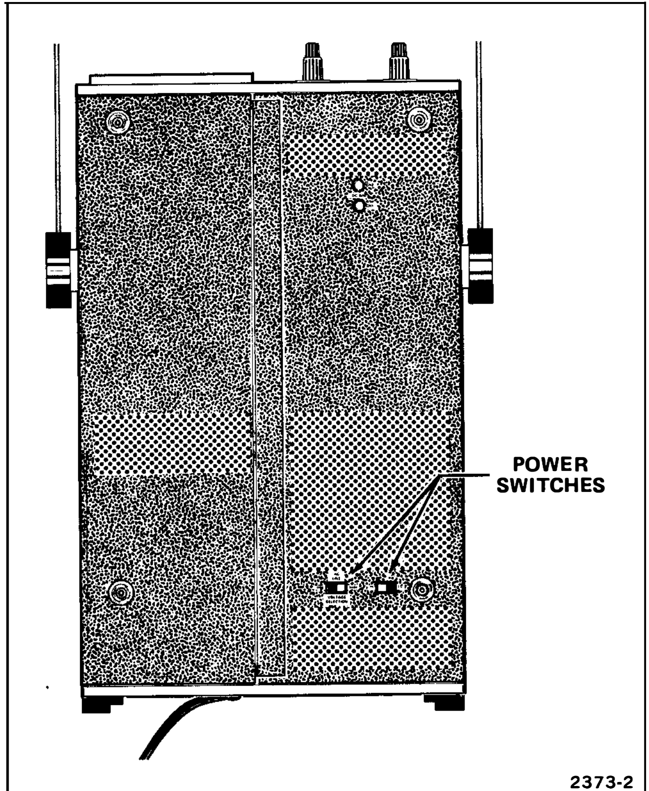

Fig. 2. Power switches at bottom.

Fuse Information

The 442 contains a power fuse located in a fuseholder on the Rear Panel (see Table 2 and Fig. 3).

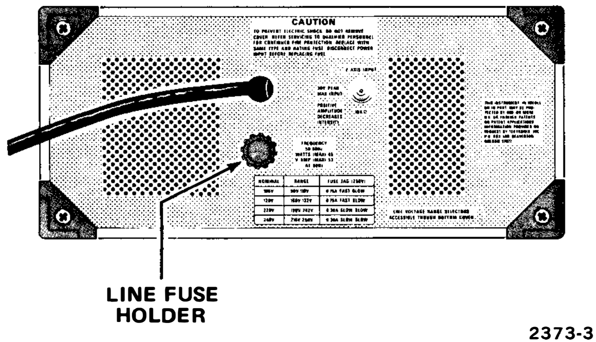

Fig. 3. Line fuse location on Rear Panel.

WARNING

Dangerous potentials exist at several points throughout this instrument. Qualified personnel, only, are authorized to remove cabinet.

Table 2
Ac Fusing

Fused Line	F700
120 V ac	0.75 A Fast Blow
240 V ac	0.30 A Slow Blow

LOCATION AND OPERATION OF EXTERNAL CONTROLS, CONNECTORS AND INDICATORS

INTRODUCTION

The following information will familiarize an operator with location and operation of external controls, connectors and indicators. These controls, connectors, and indicators are accessible from outside the instrument with its cabinet in place. All other controls are internal and should not be adjusted except during instrument calibration and service. Procedures and suggestions for calibration and maintenance are presented in the 442 Service Manual.

CRT DISPLAY AND POWER
(Front Panel. See Fig. 4)

(1) ASTIGmatism

Recessed screwdriver control adjusts crt writing beam for optimum definition.

(2) INTENSITY

Turn control clockwise to increase display brightness. Set for lowest visible display to prolong crt life.

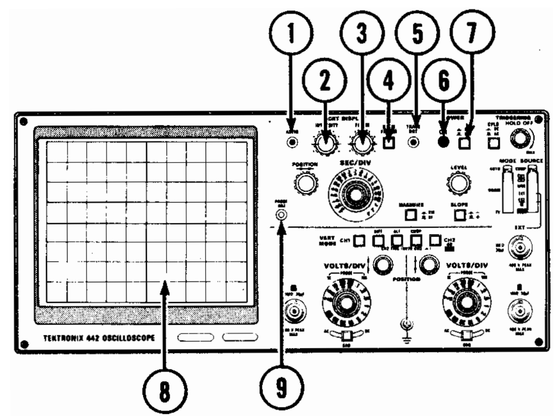

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Fig. 4. CRT DISPLAY and POWER front panel controls and indicators.

③ **FOCUS**

Provides optimum display definition.

④ **BEAM FINDER**

Spring-loaded push-button switch to locate off-screen displays. When engaged crt display is electrically compressed to within graticule area independently of position controls or applied signals. To locate an off-screen display:

a. Set vertical POSITION and INTENSITY controls to midrange and rotate horizontal POSITION control clockwise.

b. If a display or dot still is not visible, press BEAM FINDER and hold in. A compressed display or dot should appear. If not, increase INTENSITY until a display appears.

If a dot or vertical line appears, the sweep is not triggered. Set trigger MODE switch to AUTO and obtain a display. Center the display with vertical and horizontal POSITION controls. Release BEAM FINDER push button and adjust trigger LEVEL control for a stable display.

After releasing BEAM FINDER, adjust VOLTS/DIV switch, horizontal, and vertical POSITION controls for a readable, stable display.

⑤ **TRACE ROTation**

Recessed screwdriver adjustment aligns crt trace with horizontal graticule line.

⑥ **ON Indicator (LED)**

Lights when the power is on.

⑦ **ON–OFF Push Button Switch**

Turns instrument on (in) and off (out).

⑧ **Internal Graticule**

Eliminates parallax. Risetime, amplitude and measurement points are indicated at the left of graticule.

⑨ **PROBE ADJust**

Pin connector supplies internally generated square wave of approximately 0.5 volts at approximately 1 kHz for use in checking attenuation factors and compensation of probes.

EXTERNAL BLANKING
(Rear Panel. See Fig. 5)

(10) External Z-AXIS INPUT

BNC connector accepts signals from external sources for modulating intensity of crt display. Signals must be time-related to the display for stability. Positive signals decrease intensity. Input specification at connector is 30 V peak with 10,000 ohms impedence.

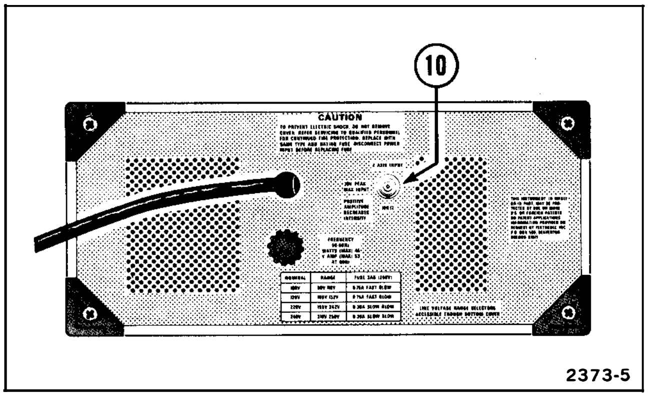

Fig. 5. External Z-AXIS INPUT on Rear Panel.

POWER SELECTORS AND DC BALANCE
(Bottom of Cabinet. See Fig. 6)

CAUTION

Make sure instrument is unplugged from power source and appropriate fuse is installed in fuse holder at rear of instrument—considering ac power input (see Table 2).

(11) Line Voltage Selector

Two-position, screwdriver actuated, slide switch which can be set to allow operation from an ac source of either 120 V or 240 V. Position left for 120 V ac and position right for 240 V ac.

(12) Regulating Range Selector

Two-position, screwdriver actuated, slide switch which can be set to allow operation from one of two ac ranges (see Table 1). Position left for HI and position right for LO.

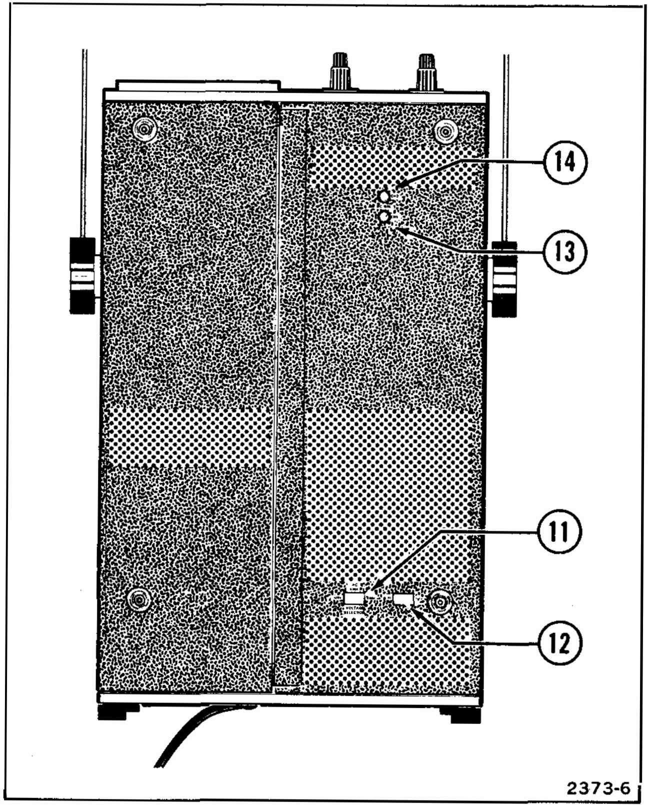

Fig. 6. Controls through bottom of cabinet.

(13) Channel 1 DC Balance

Screwdriver adjustment (through cabinet). When properly adjusted, prevents trace shift when switching between adjacent positions of channel 1 VOLTS/DIV switch.

(14) Channel 2 DC Balance

Screwdriver adjustment (through cabinet). When properly adjusted, prevents trace shift when switching between adjacent positions of channel 2 VOLTS/DIV switch.

VERTICAL
(Front Panel. See Fig. 7)

(15) Channel 1 (X) Input

BNC connector for the application of external signal to channel 1 vertical deflection system. In X-Y operation, channel 1 or X is horizontal input. Display mode is selected by VERT MODE switches.

NOTE

Channel 1 (X) is horizontal input and Channel 2 (Y) is vertical input when instrument is used in SOURCE X-Y.

(16) **Channel 2 (Y) Input**

BNC connector for the application of external signal to channel 2 vertical deflection system. In X-Y operation, channel 2 or Y is vertical input. Display mode is selected by VERT MODE switches.

(17) **VOLTS/DIV (Both Channels)**

Controls which select the vertical deflection factors in 1-2-5 sequence. (VAR control must be in detent position to obtain the indicated deflection factors.) Read the correct deflection factor for a 1X probe from the 1X (left) position; and for a 10X probe from the 10X position (right).

(18) **VARiable (Both Channels)**

Controls—out of detent left—which provide continuously variable (uncalibrated) deflection factors between calibrated positions of the VOLTS/DIV switches. Rotate controls clockwise to detent position for calibrated deflection factors. Extends maximum deflection factor to 25 V/div in 10 V position. (Notice that VAR decreases size of display.)

(19) **Input Coupling AC-GND-DC (Both Channels)**

Three-position slide switch which selects the circuit method of coupling input signals to vertical input amplifier.

AC: Signals are coupled capacitively. Any dc signal component is blocked. Low frequencies are attentuated (3 dB down at about 1 Hz using a 10X probe). Ac coupling causes tilting of square waves below 1 kHz.

GND: Disconnects input of vertical amplifier from the input signal and connects amplifier input to ground to provide a ground reference display. Connects input signal to ground through input coupling capacitor and a 1 MΩ resistor to allow input coupling capacitor to be precharged by input signal.

DC: All frequency components of input signal are passed to vertical amplifier.

(20) ↕ POSITION (Both Channels)

Controls which position the related channel signal displays in a vertical position.

(21) External Ground Connector

Banana plug connected directly to chassis and cabinet provides instrument ground.

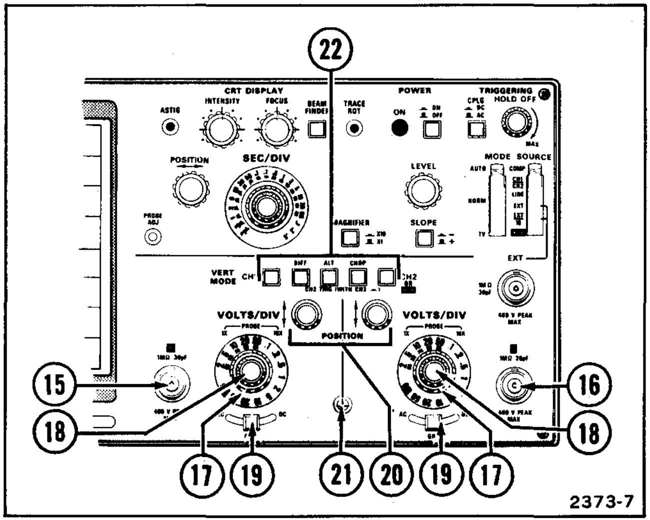

Fig. 7. Vertical system controls.

(22) VERT MODE (Vertical Display Mode)

Series of five in line push-button switches to select vertical channel display and operating mode. (Triggering signals are derived from channel 1 input except when CH 2 and one of DIFF, ALT, or CHOP switches are engaged simultaneously.)

CH 1: Displays only signals applied to Channel 1 input connector.

DIFF: Provides a display of the algebraic difference between Channel 1 and Channel 2 input signals. Trigger signal is derived from Channel 1 unless CH 2 and DIFF push-buttons are depressed simultaneously.

ALT: Provides a display of Channel 1 and Channel 2 alternately. Display is switched between channels at the end of each sweep. Trigger signal is automatically derived from Channel 1 input signal unless CH 2 and ALT push buttons are depressed simultaneously.

CHOP: Provides a display of signals from both channels switched from Channel 1 to Channel 2 at a frequency of approximately 250 kHz. Trigger signal is automatically derived from Channel 1 input signal unless CH 2 and CHOP push buttons are depressed simultaneously.

CH 2: Displays only signals applied to the Channel 2 input connector. CH 2 push-button must be engaged for X-Y operation.

HORIZONTAL
(Front Panel. See Fig. 8)

(23) SEC/DIV

Control selects calibrated sweep rates from 0.5 seconds/division to 0.1 microseconds/division in a 1-2-5 sequence.

(24) VAR

Control, inside SEC/DIV control, provides continuously variable uncalibrated sweep rates to at least 2.5 times the calibrated setting (extends the slowest sweep rate to at least 1.25 sec/div).

(25) MAGNIFIER X10—X1

Push-button switch (in, X10) increases each sweep rate by a factor of 10. Extends the fastest sweep rate to 10 nanoseconds/division.

(26) ↔ POSITION

Control to horizontally position the crt display.

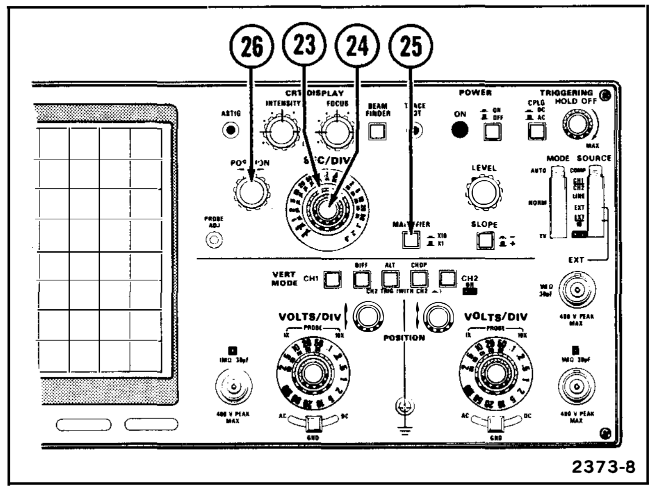

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Fig. 8. Horizontal system controls.

TRIGGERING
(Front Panel. See Fig. 9)

(27) SOURCE

The source of the signal supplied to trigger input amplifier is determined by six-position SOURCE switch and associated circuitry.

COMP (Composite Triggering): In this position the trigger signal is obtained from signal(s) displayed on crt. Does not show the time relationship of Channel 1 and Channel 2 in ALTernate vertical mode. Do not use composite triggering in CHOP vertical mode because display will trigger on switching transients, not on desired signal.

CH 1/CH 2 (Internal Triggering): In this position the trigger signal is a sample of channel signal displayed on crt—Channel 1 or Channel 2 in single-trace. In CHOP, ALT, or DIFF vertical mode, the trigger signal is a sample of Channel 1 input unless CH 2 is depressed simultaneously with CHOP, ALT, or DIFF.

LINE: In this position the trigger signal is a sample of the line voltage applied to instrument.

EXT (External Triggering): This position permits triggering on signals applied to the external triggering input connector (item 28).

EXT/10: External trigger signals are attenuated by a factor of 10.

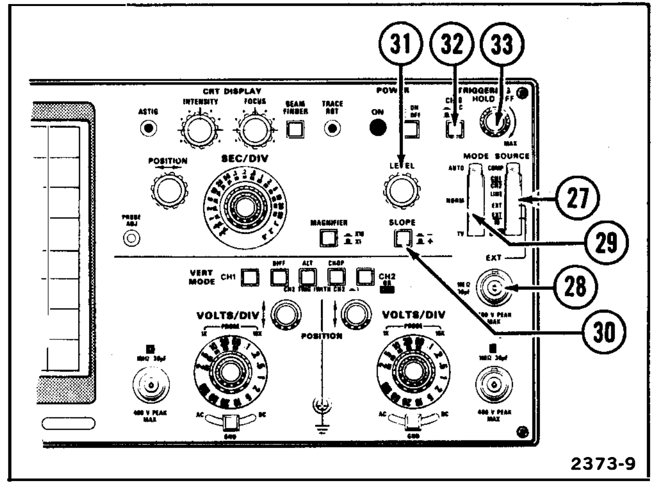

Fig. 9. Triggering system controls.

X-Y: This position permits X-Y displays. X input is through Channel 1 input.

NOTE

X-Y deflection factors are the same as Channel 1 and Channel 2 attenuator position when MAGNIFIER is in X1. When using X10, X (Channel 1) deflection is changed by approximately X10.

(28) **EXT**

BNC connector for use while triggering from an external source.

(29) **MODE**

Three-position switch to select triggering mode.

AUTO: Allows normal triggering—with proper LEVEL control setting. A sweep will be initiated by input signals that have repetition rates above 20 Hz and are within the frequency range set by Coupling Switch. In the absence of an adequate trigger signal, or when trigger controls are misadjusted, the sweep free-runs to provide a reference display.

NORM: With proper LEVEL control setting, this position insures that a sweep is initiated by input signals that are within the frequency range selected by CPLG Switch. In the absence of an adequate trigger signal, or when trigger controls are misadjusted, the sweep does not run and there is no sweep display.

TV: This position allows triggering on television signals. Instrument triggers on TV field when SEC/DIV switch is set at .1 ms or slower. Triggers on TV line when SEC/DIV is set at 50 μs or faster. Set SLOPE switch to +OUT for sync-positive input signals and to —IN for sync-negative signals.

(30) **SLOPE**

Push-button switch to select either the positive-going or negative-going slope of the trigger waveform.

+OUT: Allows triggering from the positive-going portion of a trigger signal.

—IN: Allows triggering from the negative-going portion of a trigger signal.

(31) LEVEL

Control which selects the amplitude point on trigger signal at which sweep is triggered. Usually adjusted for desired display after trigger SOURCE and SLOPE have been selected.

(32) CPLG (Coupling)

Push-button switch allows choice of capacitive or direct coupling to trigger input circuits.

AC: Push-button switch (out) provides circuitry to block dc component of the triggering signal and allows triggering only on ac portion. Signals below approximately 60 Hz are attenuated.

DC: Push-button switch (in) provides direct coupling so frequency components from dc to above 35 MHz of triggering signal are seen at trigger input circuit.

(33) HOLDOFF

A control which allows control of holdoff time between sweeps. Provides stable triggering on low repetition pulses or aperiodic signals. To obtain the best display, use all other trigger controls before adjusting HOLDOFF control. HOLDOFF increases clockwise to MAXimum.

BASIC OSCILLOSCOPE OPERATION

The following procedures will familiarize the operator with basic 442 Oscilloscope operation.

PRELIMINARY

Signal Ground

The most reliable signal measurements are made when the 442 and unit under test are connected together by a common reference (ground) lead in addition to signal lead or probe. A ground strap on probe provides the best ground. Also, you can connect a ground lead to chassis ground connector on 442 front panel (item 21).

Input Coupling Capacitor Precharging

In AC positions of the AC-GND-DC switches, voltage transients exceeding 400 V maximum input voltage can be generated if you take successive measurements on 2 signals with different dc levels—even though both dc levels are within the maximum input voltage specification. For instance, after measuring ripple on a +300 V dc supply, if you connect the probe to a −250 V dc supply the resulting transient amplitude is 550 V.

Setting the AC-GND-DC switch to GND disconnects the input signal from vertical preamplifier circuit and connects it to ground through input coupling capacitor and a 1 MΩ resistor. This allows the input coupling capacitor to precharge to average dc level of signal applied to probe. Use the following procedure to prevent accidently generated voltage transients from reaching preamplifier circuit and also reduce the amount of charging current drawn from circuit under test.

1. Before connecting probe tip to a signal source, set AC-GND-DC switch to GND in order to establish reference.

2. Touch probe tip to 442 instrument ground. Wait several seconds for input coupling capacitor to discharge.

3. Connect probe tip to test signal source.

4. Wait several seconds for coupling capacitor to charge.

5. Set AC-GND-DC switch to AC. The display will remain on screen so ac component of signal can be measured in normal manner.

OPERATOR'S ADJUSTMENTS AND CHECKS

To verify basic accuracy of the 442, make the following checks and adjustments.

Probe Compensation

Improper probe compensation is the most common source of operator error. Recheck probe compensation when moving a probe from one scope to another or from one channel to another.

To compensate probe, obtain a normal sweep display using the 0.5 V PROBE ADJ signal. Set VOLTS/DIV switch to .1. Set SEC/DIV to .1 ms. Adjust probe compensation for a flat-top waveform (see Fig. 10). See the respective probe Data Sheet for specific probe compensation instructions.

Vertical Gain Check

Obtain a normal sweep display using the 0.5 V PROBE ADJ output. Set the VOLTS/DIV switch to .1. Be sure VAR of VOLTS/DIV is in calibrated (fully cw) position. Check the display for a vertical deflection of about 5 divisions.

Any signal of known amplitude may be used to check vertical gain. Check displayed amplitude to be the same as known signal within 3%.

Basic Timing Check

Be sure VAR of SEC/DIV is in calibrated (cw) position. Obtain a normal sweep display of any signal of any known frequency.

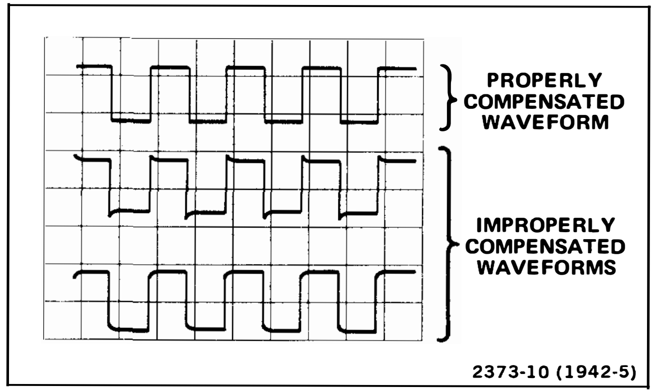

Fig. 10. Probe compensation.

WARNING

To prevent possible cross grounding when using line voltage, do not use ground clip on probe. The 442 instrument ground provides an adequate ground reference.

Set SEC/DIV control to display one cycle over several horizontal divisions. Check displayed duration of one cycle to be the same as the duration of one cycle of known signal within 3% (duration = 1/frequency). If a 60 Hz line voltage is being used, check duration of one cycle to be 8.35 divisions with SEC/DIV at 2 m: or with SEC/DIV in 10 m, exactly 6 cycles should display in graticule area.

NORMAL SWEEP OPERATION

1. Preset the 442 controls as follows:

NOTE

See Location and Operation of External Controls, Connectors, and Indicators for detailed instructions concerning control operation.

VERT MODE	CH 1
VOLTS/DIV (both)	.1
VAR (all)	Calibrated (cw)
POSITION (all)	Midrange
SEC/DIV	1 m
POWER	ON
INTENSITY	As desired
FOCUS	As desired
HOLDOFF	ccw
SLOPE	+OUT
LEVEL	ccw
SOURCE	CH 1/CH 2
CPLG	AC (out)
MODE	AUTO

2. Connect a signal, –0.5 V PROBE ADJ output will suffice, via probe supplied with 442 to Channel 1 or X input connector.

3. Set Channel 1 AC-GND-DC switch to select desired method of coupling input signal to preamplifier circuit. With PROBE ADJ output signal use DC. AC coupling will cause tilting (integration) of square waves below about 1 kHz (100 Hz with a 10X probe).

4. Adjust Channel 1 VOLTS/DIV switch to obtain desired display amplitude while adjusting Channel 1 POSITION control to locate display within crt viewing area.

5. Adjust LEVEL control for a stable display.

6. Adjust SEC/DIV switch to obtain desired display. Using 0.5V PROBE ADJ output signal, display should look as illustrated in Fig. 11 (using a 10X probe with a VOLTS/DIV switch setting of 10 m and a SEC/DIV switch setting of .5 m).

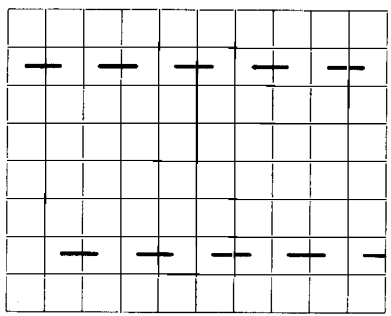

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Fig. 11. Display of .5V PROBE ADJ output signal.

NOTE

Verify correct probe compensation (see beginning of Operator's Adjustments and Checks).

APPLICATIONS

Peak-to-Peak Voltage Measurements

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

1. Connect test signal to either Channel 1 or Channel 2 input connector.

2. Set VERT MODE to display channel selected.

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

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

5. Turn vertical POSITION control so lower portion of waveform coincides with one of the graticule lines below center horizontal line, and top of the waveform is in the viewing area. Move display with horizontal POSITION control, so one of the upper peaks aligns with center vertical graticule line (see Fig. 12).

6. Measure divisions of vertical deflection from peak-to-peak. Make sure VAR control of VOLTS/DIV control is in calibrated (cw) position.

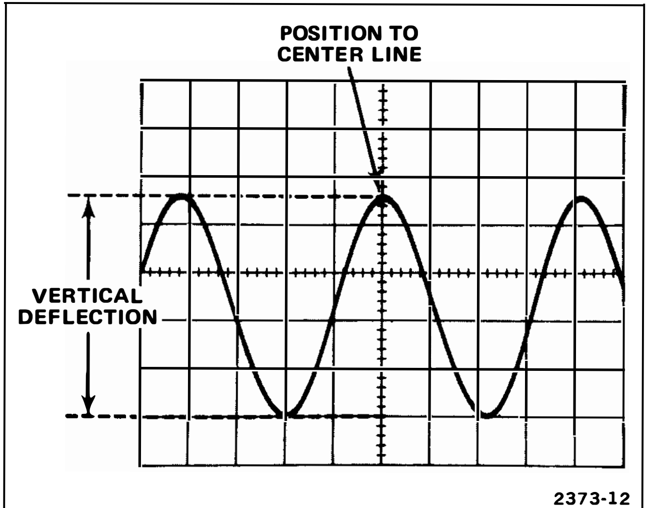

Fig. 12. Measuring peak-to-peak voltage of a waveform.

NOTE

This procedure may be used to measure between two points on the waveform, also, rather than peak-to-peak.

7. Multiply distance measured in step 6 by VOLTS/DIV switch reading.

EXAMPLE: Assume a peak-to-peak vertical deflection of 4.6 divisions (see Fig. 12) and a VOLTS/DIV switch setting of 5. Using the formula (assuming use of 1X probe or cable):

$$\text{Volts Peak-to-Peak} = \text{vertical deflection (divisions)} \times \text{VOLTS/DIV setting} \times \text{probe attenuator factor}$$

Substituting the given values:

Volts Peak-to-Peak = 4.6 X 5 V X1 (probe)

The peak-to-peak voltage is 23 volts.

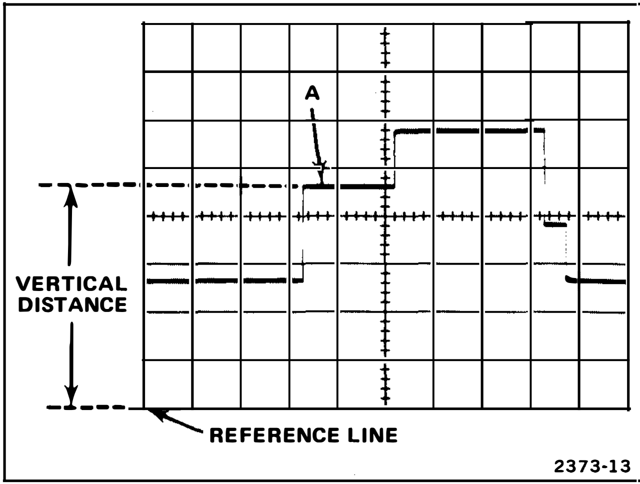

Fig. 13. Measuring instantaneous dc voltage with respect to a reference voltage.

Instantaneous Voltage Measurements — DC

To measure dc level at a given point on a waveform, use the following procedure:

1. Connect test signal to either Channel 1 or Channel 2 input connector.

2. Set VERT MODE to display channel selected.

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

4. Set Input Coupling switch to GND.

5. Set sweep MODE switch to AUTO trigger.

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

NOTE

To measure a voltage level with respect to a voltage other than ground, make the following changes in step 6: Set Input Coupling switch to DC and apply reference voltage to selected channel input connector. Then position trace to reference line.

7. Set Input Coupling switch to DC. The ground reference line can be checked at any time by switching to GND position.

8. Set Triggering controls to obtain a stable display. Set SEC/DIV switch to a setting that displays several cycles of signal.

9. Measure distance in divisions between reference line and point on waveform at which dc level is to be measured. For example, in Fig. 13 measurement is made between reference line and point A.

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

11. Multiply distance measured in step 9 by VOLTS/DIV switch reading of step 3.

EXAMPLE: Assume that vertical distance measured is 4.6 divisions (see Fig. 13), waveform is above reference line, and VOLTS/DIV switch reads 2.

Using the formula (assuming use of 1X probe or cable):

Instantaneous Voltage =

vertical distance (divisions) X polarity X VOLTS/DIV setting X probe attenuator factor

Substituting the given values:

Instantaneous Voltage = 4.6 X +1 X 2 V X 1 (probe)

The instantaneous voltage is 9.2 volts.

Comparison Measurements

In some applications it may be desirable to establish arbitrary units of measurement other than those indicated by VOLTS/DIV switch or SEC/DIV switch. This is particularly useful when comparing unknown signals to a reference amplitude or repetition rate. One use for the comparison-measurement technique is to facilitate calibration of equipment (e.g., on an assembly-line test) where desired amplitude or repetition rate does not produce an exact number of divisions of deflection. The adjustment will be easier and more accurate if arbitrary units of measurement are established so that correct adjustment is indicated by an exact number of divisions of deflection. Arbitrary sweep rates can be useful for comparing harmonic signals to a fundamental frequency, or for comparing the repetition rate of input and output pulses in a digital count-down circuit. The following procedure describes how to establish arbitrary units of measure for comparison measurements. Although the procedure for establishing vertical and horizontal arbitrary units of measurement is much the same, both processes are described in detail.

Vertical Deflection Factor. To establish an arbitrary vertical deflection factor based upon a specific reference amplitude, proceed as follows:

1. Connect reference signal to Channel 1 or Channel 2 input connector. Set SEC/DIV switch to display several cycles of signal.

2. Set VOLTS/DIV switch and VAR control (selected channel) to produce a display of an exact number of graticule divisions in amplitude. Do not change VAR control after obtaining desired deflection. This display can be used as a reference for amplitude comparison measurements.

3. To establish an arbitrary vertical deflection factor so the unknown amplitude of a signal can be measured accurately at any setting of VOLTS/DIV switch, amplitude of reference signal must be known. If it is not known, it can be measured before VAR control is set in step 2.

4. Divide amplitude of reference signal (volts) by the product of vertical deflection established in step 2 (divisions) and setting of VOLTS/DIV switch. This is the vertical conversion factor.

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

5. To measure amplitude of an unknown signal, disconnect reference signal and connect unknown signal to selected channel input connector. Set VOLTS/DIV switch to a setting that provides sufficient vertical deflection to make an accurate measurement. Do not readjust VAR control.

6. Measure vertical deflection in divisions and calculate amplitude of unknown signal using the following formula:

$$\text{Signal Amplitude} = \text{VOLTS/DIV switch setting} \times \text{vertical conversion factor} \times \text{vertical deflection (divisions)}$$

EXAMPLE: Assume a reference signal amplitude of 30 volts, a VOLTS/DIV switch of 5, and VAR control is adjusted to provide a vertical deflection of four divisions.

Substituting these values in the vertical conversion factor formula (step 4):

$$\text{Vertical Conversion Factor} = \frac{30\text{ V}}{4 \times 5\text{ V}} = 1.5$$

Then with a VOLTS/DIV switch setting of 1, peak-to-peak amplitude of an unknown signal which produces a vertical deflection of 5 divisions can be determined by using the signal amplitude formula (step 6):

$$\text{Signal Amplitude} = 1\text{ V} \times 1.5 \times 5 = 7.5\text{ volts}$$

Sweep Rates. To establish an arbitrary horizontal sweep rate based upon a specific reference frequency, proceed as follows:

1. Connect reference signal to selected Channel 1 or Channel 2 input connector. Set VOLTS/DIV switch for four or five divisions of vertical deflection.

2. Set SEC/DIV switch and VAR control so one cycle of signal covers an exact number of horizontal divisions. Do not change VAR control after obtaining desired deflection. This display can be used as a reference for frequency comparison measurements.

3. To establish an arbitrary sweep rate so the unknown period of a signal can be measured accurately at any setting of the SEC/DIV switch, the period of reference signal must be known. If it is not known, it can be measured before VAR control is set in step 2.

4. Divide period of reference signal (seconds) by product of horizontal deflection established in step 2 (divisions) and setting of SEC/DIV switch. This is the horizontal conversion factor:

$$\text{Horizontal Conversion Factor} = \frac{\text{reference signal period (seconds)}}{\text{horizontal deflection (divisions)} \times \text{SEC/DIV switch setting}}$$

5. To measure the unknown period of a signal, disconnect the reference signal and connect the questioned signal to the selected channel input connector. Set the SEC/DIV switch to a setting that provides sufficient horizontal deflection to make an accurate measurement. Do not readjust the VAR control.

6. Measure the horizontal deflection in divisions and calculate the period of the unknown signal using the following formula:

$$\text{Period} = \begin{matrix}\text{TIME/DIV} \\ \text{switch} \\ \text{setting}\end{matrix} \times \begin{matrix}\text{horizontal} \\ \text{conversion} \\ \text{factor}\end{matrix} \times \begin{matrix}\text{horizontal} \\ \text{deflection} \\ \text{(divisions)}\end{matrix}$$

EXAMPLE: Assume a reference signal frequency of 455 Hz (period 2.19 milliseconds), and a SEC/DIV switch setting of .2 ms, with the VAR control adjusted to provide a horizontal deflection of eight divisions. Substituting these values in the horizontal conversion factor formula (step 4):

$$\begin{matrix}\text{Horizontal} \\ \text{Conversion} \\ \text{Factor}\end{matrix} = \frac{2.19 \text{ milliseconds}}{.2 \times 8} = 1.37$$

Then, with a SEC/DIV switch setting of 50 μs the unknown period of a signal, which completes one cycle in seven horizontal divisions, can be determined by using period formula (step 6):

$$\text{Period} = 50\ \mu s \times 1.37 \times 7 = 480\ \mu s$$

This answer can be converted to frequency (repetition rate) by taking the reciprocal of the period.

Time-Duration Measurements

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

1. Connect signal to either Channel 1 or Channel 2 input connector.

2. Set VERT MODE to display selected channel.

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

4. Set Triggering controls to obtain a stable display.

5. For best accuracy use SEC/DIV setting that gives the greatest number of divisions between time measurement points (see fig. 14). Sweep MAGNIFIER (to obtain more displayed divisions) should be used when measuring portions of more complex waveforms.

6. Adjust vertical POSITION control to move points between which time measurement is made to center horizontal line.

7. Adjust horizontal POSITION control to center display within center eight divisions of graticule.

8. Measure horizontal distance between time measurement points. Be sure VAR control is set in detent (calibrated, cw).

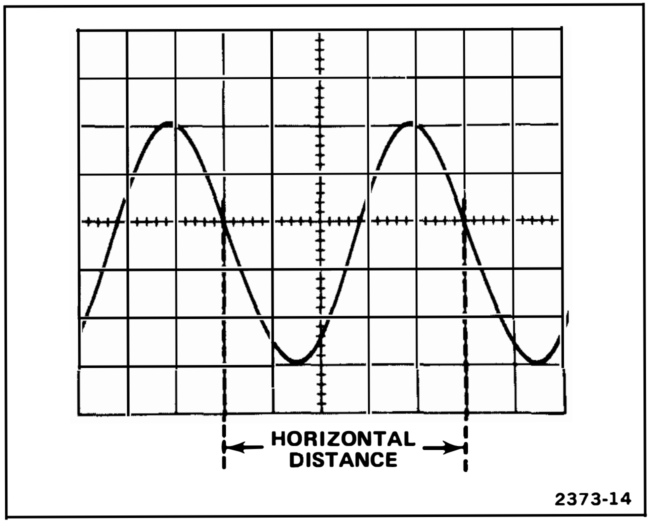

Fig. 14. Measuring the time duration between points on a waveform.

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

EXAMPLE: Assume that distance between time measurement points is five divisions (see Fig. 14) and SEC/DIV switch is set at .1 ms.

Using the formula:

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

Substitute given values:

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

The time duration is 0.5 millisecond.

Frequency Measurement

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

Use the following procedure:

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

2. Take reciprocal of time duration to determine frequency.

EXAMPLE: The frequency of signal shown in Fig. 5 which has a time duration of 0.5 millisecond is:

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

Rise Time Measurements

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

1. Connect signal to either Channel 1 or Channel 2 input.

2. Set VERT MODE to display channel selected.

3. Set SEC/DIV switch and VAR control to display an exact number of divisions in amplitude.

4. Center display about center horizontal line.

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

Determine 10% and 90% points on rising portion of waveform. The figures given in Table 3 are for points 10% up from start of rising portion and 10% down from top of rising portion (90% point).

Table 3
Rise Time Measurements

Vertical display (divisions)	10% and 90% points	Divisions vertically between 10% and 90% point
4	0.4 division	3.2
5	0.5 division	4.0
6	0.6 division	4.8

NOTE

For a signal amplitude of 5 divisions, 10% and 90% points are indicated on graticule.

7. Adjust horizontal POSITION control to move 10% point of waveform to first graticule line. For example, with a five-division display as shown in Fig. 15, the 10% point is 0.5 division up from the start of the rising portion.

8. Measure horizontal distance between 10% and 90% points. Be sure VAR control is set to detent (calibrated,cw).

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

EXAMPLE: Assume that horizontal distance between 10% and 90% points is four divisions (see Fig. 15) and SEC/DIV switch is set at 1 µs. Applying time duration formula to rise time:

$$\text{Rise Time Time Duration} = \text{horizontal difference (divisions)} \times \text{SEC/DIV setting}$$

Substituting the given values:

$$\text{Risetime} = 4 \times 1\ \mu s$$

The risetime is 4 microseconds.

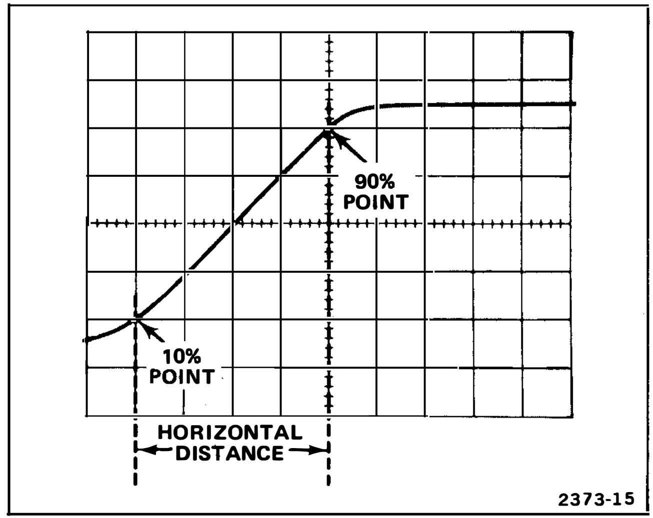

Fig. 15. Measuring rise time.

Time-Difference Measurements

The calibrated sweep rate and dual-trace features of the 442 allow measurement of time difference between two separate events. To measure time difference, use the following procedure:

1. Set Input Coupling switches (AC-GND-DC) to desired coupling positions.

2. Set VERT MODE to either CHOP or ALT. In general, CHOP is more suitable for low-frequency signals and ALT position is more suitable for high-frequency signals.

3. Connect reference signal to Channel 1 input; and comparison signal to Channel 2 input. The reference signal should precede comparison signal in time. Use coaxial cables or probes which have equal time delay to connect signals to input connectors.

4. Set VOLTS/DIV switches to produce four or five divisions of display.

5. Set LEVEL control for a stable display.

6. If possible, set SEC/DIV switch for a sweep rate which shows three or more divisions between two waveforms.

7. Adjust vertical POSITION controls to center each waveform (or points on the display between which measurement is made) in relation to center horizontal line.

8. Adjust horizontal POSITION control so Channel 1 (reference) waveform crosses center horizontal line at a vertical graticule line.

9. Measure horizontal difference between Channel 1 waveform and Channel 2 waveform (see Fig. 16).

10. Multiply measured difference by setting of SEC/DIV switch.

EXAMPLE: Assume that SEC/DIV switch is set to 50 μs, and horizontal difference between waveforms is 4.5 divisions (see Fig. 16).

Using the formula:

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

Substituting the given values:

$$\text{Time Delay} = 50\ \mu s \times 4.5$$

The time delay is 225 microseconds.

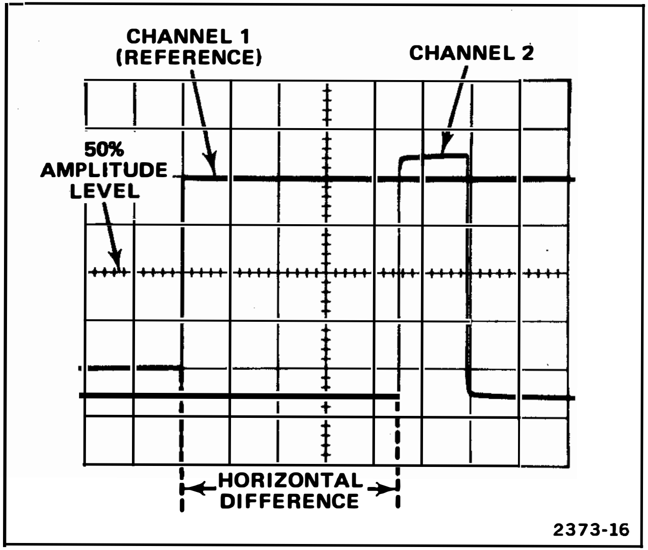

Fig. 16. Measuring time difference between two pulses.

Multi-Trace Phase Difference Measurements

Phase comparison between two signals of the same frequency can be made using dual-trace feature of the 442. This method of phase difference measurement can be used up to frequency limit of vertical system. To make that comparison, use the following procedure:

1. Set Input Coupling switches (AC-GND-DC) to same position, depending on type of coupling desired.

2. Set VERT MODE to either CHOP or ALT. In general, CHOP is more suitable for low-frequency signals; and ALT position more suitable for high-frequency signals.

3. Connect reference signal to Channel 1 input connector and comparison signal to Channel 2 input connector. The reference signal should precede comparison signal in time. Use coaxial cables or probes which have equal time delay to connect signals through input connectors.

4. Set channel VOLTS/DIV switches and respective VAR controls so displays are equal and about five divisions in amplitude.

5. Set Triggering controls to obtain a stable display.

6. Set SEC/DIV switch to a sweep rate which displays about one cycle of waveform.

7. Move waveforms to center of graticule with channel POSITION controls.

8. Turn sweep VAR control until one cycle of reference signal (Channel 1) occupies exactly eight divisions between second and tenth graticule lines (see Fig. 17). Each division of graticule represents 45° of the cycle (360° ÷ 8 divisions = 45°/ division). The sweep rate can be stated in terms of degrees as 45°/ division.

9. Measure horizontal difference between corresponding points on waveforms.

10. Multiply measured distance (in divisions) by 45°/ division (sweep rate) to obtain exact amount of phase differences.

EXAMPLE: Assume a horizontal difference of 0.6 division with a sweep rate of 45°/division as shown in Fig. 17. Using the formula:

$$\text{Phase Difference} = \begin{matrix}\text{horizontal}\\ \text{difference}\\ \text{(divisions)}\end{matrix} \times \begin{matrix}\text{sweep rate}\\ \text{(degrees/div)}\end{matrix}$$

Substituting the given values:

$$\text{Phase Difference} = 0.6 \times 45^\circ$$

The phase difference is 27°.

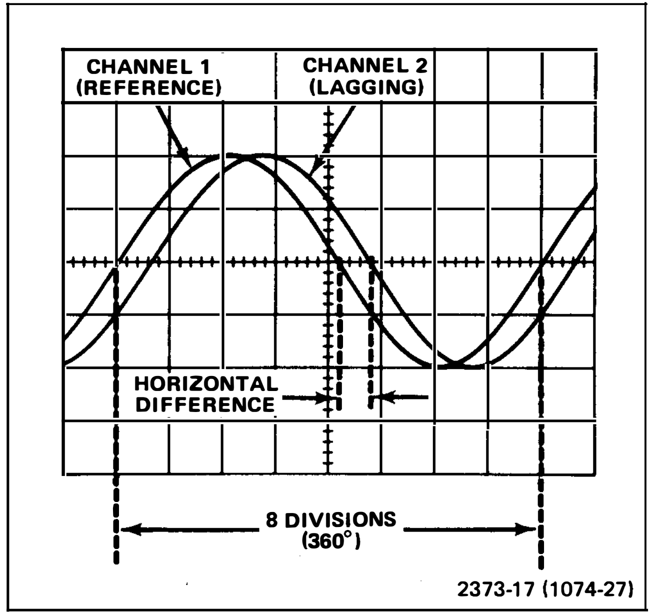

Fig. 17. Measuring phase difference.

X-Y Phase Measurement

The X-Y phase measurement method can be used to measure phase difference between two signals of same frequency. This method provides an alternate method of measurement for signal frequencies up to four megahertz. However, above this frequency the inherent phase difference between vertical and horizontal system makes accurate phase measurement difficult. In this mode, one of the sinewave signals provides horizontal deflection (X) while the other signal provides vertical deflection (Y). The phase angle between the two signals can be determined from the lissajous pattern as follows:

1. Connect one of the sinewave signals to Channel 1 or X connector; and the other signal to Channel 2 or Y input connector.

2. Set Triggering SOURCE to X-Y and VERT MODE to CH 2.

3. Position display to center of crt screen and adjust Channel 1 and Channel 2 VOLTS/DIV switches to produce a display less than six divisions vertically (Y) and less than 10 divisions horizontally (X). The Channel 1 VOLTS/DIV switch controls horizontal deflection (X) and Channel 2 VOLTS/DIV switch controls vertical deflection (Y).

4. Center display in relation to center graticule lines. Measure distance A and B as shown in Fig. 18. Distance A is horizontal measurement between two points where trace crosses center horizontal line. Distance B is maximum horizontal width of display.

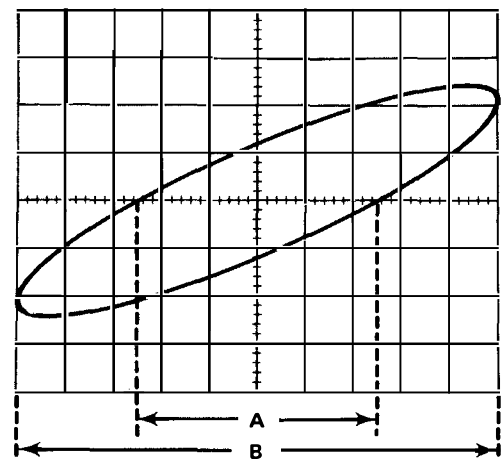

Fig. 18. Phase difference measurement from an X-Y display.

5. Divide A by B to obtain sine of phase angle (ϕ) between two signals. The angle can then be obtained from a trigonometric table.

6. If display appears as a diagonal straight line, two signals are either in phase (tilted upper right to lower left) or 180° out of phase (tilted upper left to lower right). If display is a circle, signals are 90° out of phase.

EXAMPLE: To measure phase of display shown in Fig. 18 where A is 5 divisions and B is 10 divisions, use the formula:

Substituting the given values:

$$\text{Sine } \phi = \frac{A}{B}$$

Substituting the given values:

$$\text{Sine } \phi = \frac{5}{10} = 0.5$$

From trigonometric tables:

$$\phi = 30^\circ$$

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