

OPERATORS HANDBOOK

This Operators Handbook supplements the complete Instruction Manual provided for this instrument. For more detailed information, refer to the Instruction Manual.



TEKTRONIX®



P.O. Box 500

Beaverton, Oregon 97005

432

OSCILLOSCOPE

TABLE OF CONTENTS

	Page		Page
Introduction		Basic Timing	11
General	1	Applications	
Operating Voltage	1	DC Voltage Level Measurement	12
Operating Position	2	Peak-To-Peak Voltage Measurement—AC	13
Controls and Connectors	2	Comparison Measurements	14
Basic Operation	9	Time-Duration Measurements	17
User's Calibration		Frequency Measurement	19
Trace Rotation	10	Risetime Measurements	19
STEP ATTENuator BALance	10	Time-Difference Measurements	20
Probe Compensation	10	Multi-Trace Phase Difference Measurements	21
Vertical GAIN	10	X-Y Phase Measurement	24
ASTIGmatism	11	Common-Mode Rejection	25

Copyright © 1971 by Tektronix, Inc., Beaverton, Oregon. Printed in the United States of America. All rights reserved. Contents of this publication may not be reproduced without permission of the copyright owner.

432 OSCILLOSCOPE

INTRODUCTION

General

The Tektronix 432 Oscilloscope is a solid-state portable instrument that combines small size and light weight with the ability to make precision waveform measurements. The instrument contains two vertical signal inputs, both of which are capable of 25-megahertz bandwidth; trigger circuitry to permit obtaining stable CRT displays; and a horizontal deflection system that provides calibrated sweep rates from 5 seconds to 0.2 microsecond/division (20 nanoseconds/division magnified).

To effectively use the 432 Oscilloscope, the operation and capabilities of the instrument must be known. This Operator's Handbook is intended to give the necessary information to allow a user to become familiar with the instrument's power requirements, functions of controls and connectors, and methods of making several different measurements of electrical phenomena. Also included is a rudimentary procedure for checking basic instrument calibration.

Operating Voltage

The 432 can be operated on all nominal line voltages from 100 volts to 240 volts AC, 50 to 400 Hertz. It can

also be operated from a 100 volts to 250 volts DC power source. No range switching or selection is necessary.

CAUTION

This instrument is designed for operation from a power source with its neutral at or near earth (ground) potential (for both AC and DC power sources) with a separate safety-earth conductor. It is not intended for operation from two phases of a multi-phase AC system, or across the legs of a single-phase, three-wire AC system.

The 432 is designed to be used with a three-wire AC power system. If a three- to two-wire adapter is used to connect this instrument to a two-wire AC power system, be sure to connect the ground lead of the adapter to earth (ground). Failure to complete the ground system may allow the chassis of this instrument to be elevated above ground potential and pose a shock hazard.

When operating the instrument from an external DC power source, polarity of the external voltage is unimpor-

tant. Again, it is imperative to complete the ground system to prevent accidental elevation of the instrument chassis and posing a shock hazard.

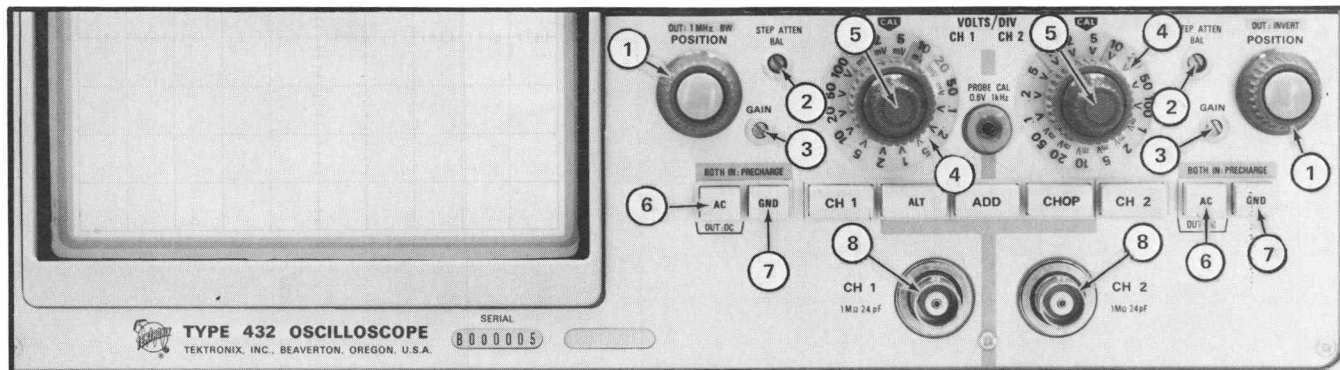
Operating Position

The handle of the 432 can be positioned for carrying or as a tilt-stand for the instrument. To position the handle, press in at both pivot points and turn the handle to the desired position. Fourteen positions are provided for convenient carrying or viewing. The instrument can also be set on the rear feet for operation or storage.

CONTROLS AND CONNECTORS

General

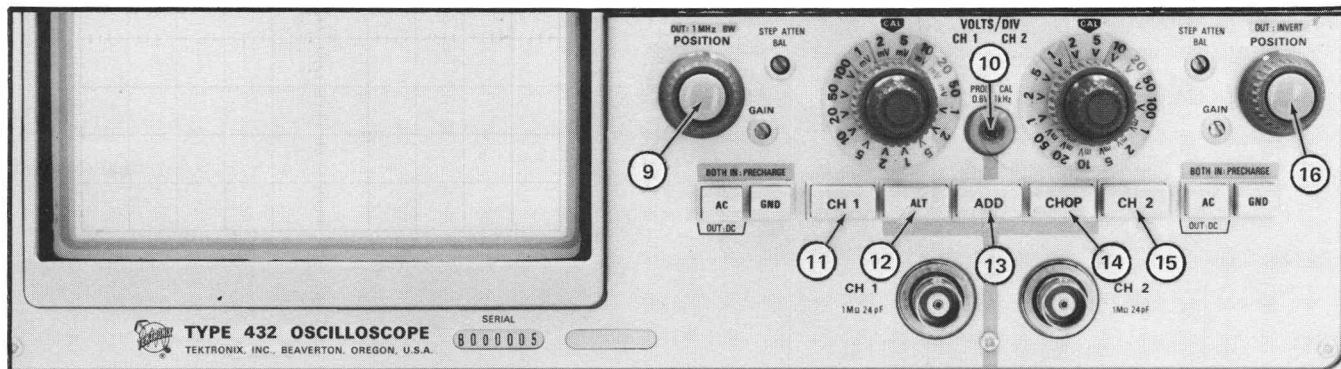
The major controls and connectors for operation of the 432 are located on the front panel of the instrument. Several auxiliary functions are provided on the rear panel. To make full use of the capabilities of this instrument, the operator should be familiar with the function and use of each of these 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. **POSITION**—positions the display vertically.
2. **STEP ATTEN BAL**—balances the input amplifier in the 1 mV, 2 mV, 5 mV, and 10 mV positions of the VOLTS/DIV switch.
3. **GAIN**—sets the gain of the input amplifier.
4. **VOLTS/DIV**—selects vertical deflection factor in a 1-2-5 sequence (variable control must be in the CAL position for indicated deflection). Calibrated position accuracy within 3%.
5. **Variable**—provides continuously variable uncalibrated deflection factors between the calibrated settings of the VOLTS/DIV switch.
6. **AC/DC**—in the AC position (button in) of this push-push switch, signals are capacitively coupled to the vertical ampli-

fier. The DC component of the input signal is blocked. Low frequency -3 dB point is about 10 hertz. In the DC position (button out), all components of the input signal are passed to the input amplifier.

7. **GND**—in the GND position (button in) of this push-push switch, the input of the vertical amplifier is disconnected from the input connector and grounded. Allows precharging of the input coupling capacitor. When the button is out coupling is determined by the AC-DC button.
8. **CH 1 and CH 2**—input connectors for application of external signals to the inputs of the vertical amplifier. Input impedance is 1 megohm paralleled by approximately 24 picofarads. Minimum bandwidth: 5 mV and up - 25 megahertz; 2 mV - 22 megahertz; 1 mV - 20 megahertz.

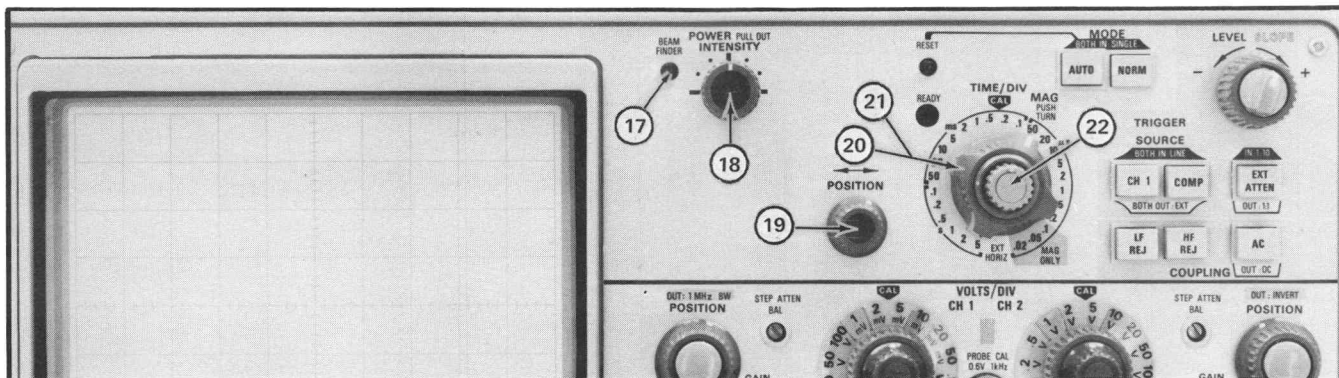


9. 5 MHz BW—in the out position of this push-push switch, the bandwidth of the complete vertical amplifier system is limited to approximately 5 megahertz.
10. PROBE CAL 0.6 V 1 kHz—provides a 0.6 volt calibrator signal to permit probe compensation, adjustment of amplifier gain, and checking basic horizontal timing.

Vertical Mode Switch

11. CH 1—Channel 1 only is displayed.
12. ALternate—dual-trace display of signals of both channels. Display switched between channels at the end of each sweep.

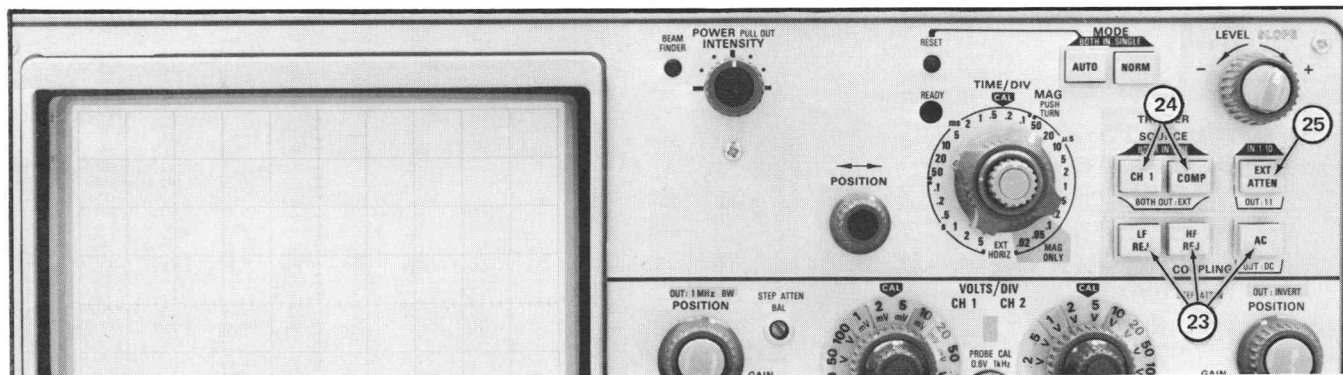
13. ADD—Signals applied to the CH 1 and CH 2 input connectors are algebraically added, and the algebraic sum is displayed on the CRT. The INVERT switch in Channel 2 allows the display to be CH 1 plus CH 2 or CH 1 minus CH 2.
14. CHOP—dual-trace display of signals on both channels. Display is switched at a repetition rate of approximately 100 kilohertz.
15. CH 2—Channel 2 only is displayed.
16. INVERT—Channel 2 display is inverted in the INVERT (button out) position.



17. **BEAM FINDER**—compresses an overscanned display to within the graticule area, independently of display position or applied signals.
18. **POWER/INTENSITY**—a combination control that turns on instrument power when pulled, and controls brightness of the display when rotated.
19. **POSITION**—positions the display horizontally.
20. **TIME/DIVision**—selects the sweep rate of the sweep generator (variable control must be in the **CAL** position for indicated sweep rate). Calibrated position accuracy within 3%.

The extreme counterclockwise position of the switch selects External Horizontal mode of operation.

21. **MAGnifier**—a six-position, push-to-turn switch (concentric with the **TIME/DIV** switch) that provides sweep magnification up to a maximum of 50 times. Extends fastest sweep rate to 0.02 microsecond/division.
22. **Variable**—provides uncalibrated sweep rates between the calibrated settings selected by the **TIME/DIV** switch. The sweep rate in each **TIME/DIV** switch position can be reduced to at least the sweep rate of the next adjacent position to provide continuously variable sweep rates.



23. **COUPLING**—determines method of coupling trigger signal to trigger circuit.

AC—in the in position of this push-push switch, DC is rejected and signals below about 20 hertz are attenuated. Accepts signals between about 20 hertz and 25 megahertz.

DC—when both the AC and the LF REJ push-push switches are in the out position, signals are directly coupled to the trigger circuit. Accepts all signals from DC to 25 megahertz.

LF REJ—rejects DC and attenuates signals below approximately 30 kilohertz. Accepts signals between about 30 kilohertz and 25 megahertz.

HF REJ—attenuates signal above approximately 50 kilohertz. Accepts signals between DC and approximately 50 kilohertz.

24. **SOURCE**—selects source of trigger signal.

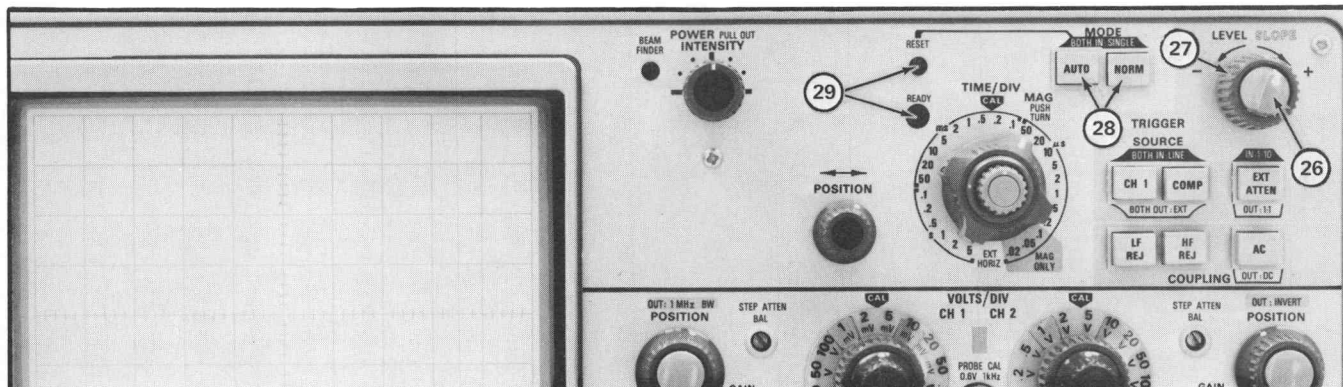
CH 1—A push-push switch that in the CH 1 position (button in) selects Channel 1 as an internal trigger source.

COMPOSITE—a push-push switch that in the COMP position (button in) allows the internal trigger source to be determined by the vertical mode of operation.

LINE—when both the CH 1 and COMP switches are pushed in, a portion of the line frequency is used as a trigger signal.

EXTERNAL—when the CH 1 and COMP switches are both out, signals applied to the EXT TRIG input connector are used for triggering.

25. **EXT ATTENUATOR**—in the 1:10 position (button in) of this push-push switch, external: trigger signals are attenuated by a factor of ten. In the 1:1 position (button out) of this switch, external trigger signals are not attenuated.



26. **SLOPE**—selects slope of trigger signal which starts the sweep.

+ —sweep can be triggered from positive-going portion of trigger signal.

— —sweep can be triggered from negative-going portion of trigger signal.

27. **LEVEL**—selects the amplitude point on the trigger signal at which the sweep is triggered.

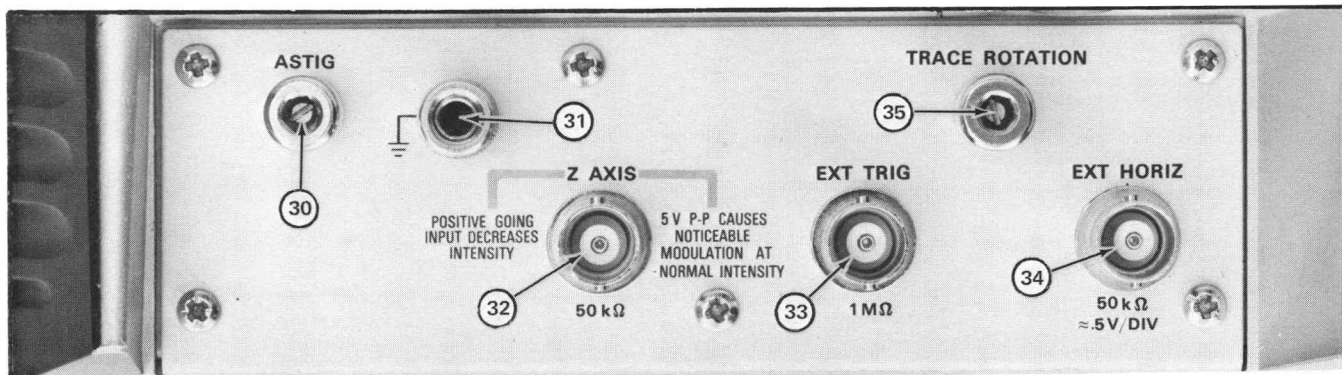
28. **MODE**—determines the operating mode for the sweep generator.

AUTOMATIC—in the **AUTO** position (button in) of this pushbutton switch, the sweep is initiated by the applied trigger signal. In the absence of an adequate trigger signal, the sweep free runs and provides a bright reference trace.

NORMAL—in the **NORM** position (button in) of this push-button switch, the sweep is initiated by the applied trigger signal. In the absence of an adequate trigger signal, there is no trace.

BOTH IN: SINGLE sweep—when both the **AUTO** and **NORM** switches are pushed in, the sweep operates in the Single Sweep Mode. After a sweep is displayed, further sweeps cannot be presented until the **RESET** button is pressed.

29. **RESET**—when the **RESET** button is pressed (in the **SINGLE SWEEP** mode), a single display will be presented (with correct triggering). After the sweep is completed, the **RESET** button must be pressed again before another sweep can be displayed. If there is not an adequate trigger signal present when the **RESET** button is pressed, the sweep generator circuit will remain armed as indicated by the **READY** light.



30. **ASTIG**matism—adjusts CRT beam for optimum display definition.
31. **Ground Post**—connects to oscilloscope chassis. Provides a common ground return for signal source to insure measurement reliability.
32. **Z AXIS**—input connector for external blanking signals. A five volt peak to peak signal will cause noticeable modulation at normal intensity. A positive-going signal decreases intensity.
33. **EXT**ernal **TRIG**ger—input connector for external trigger signals. Nominal input signal level required for correct trigger operation is between 35 and 40 millivolts at frequencies below about five megahertz, increasing to 125 millivolts at 25 megahertz.
34. **EXT**ernal **HORIZ**ontal—input connector for external horizontal signal when **TIME/DIV** switch is set to **EXT HORIZ**. Input impedance is approximately 50 kilohms with a sensitivity of approximately 0.5 volt/division.
35. **TRACE ROTATION**—adjusts trace to align with horizontal graticule lines.

BASIC OPERATION

General

The following procedure is given as a method of obtaining a basic display on the CRT of the 432. Calibrated measurements can be made in most applications using this procedure. Specific techniques required to make more involved measurements are given in the Applications section. The following procedure is intended for use until the user becomes familiar with instrument operation.

1. Set the instrument controls as follows:

POWER/INTENSITY	Pushed in and rotated fully counterclockwise.
POSITION (horizontal and vertical)	Set to mid-range
Sweep MODE	AUTO
TIME/DIV	1 ms (unmagnified)
TRIGGER SOURCE	COMP
TRIGGER COUPLING	AC
SLOPE	+
LEVEL	Mid-range
Vertical Mode	CH 1
Input Coupling	DC
VOLTS/DIV	.1 V

All remaining pushbuttons should be out.

2. Connect the instrument to a power source that meets the requirements of the instrument (see Operating Voltage section).

3. Turn on the instrument power and allow several minutes warmup.

4. Advance the INTENSITY control until the free-running trace is visible at the desired viewing level.

5. Connect the signal to be observed to the CH 1 input connector.

6. If display is not now visible with the INTENSITY control at mid-range, press the BEAM FINDER pushbutton and adjust the VOLTS/DIV switch until display is reduced in size vertically; then center the compressed display with the vertical and horizontal POSITION controls; release the BEAM FINDER pushbutton.

7. Set the VOLTS/DIV switch and vertical POSITION controls for a display which remains within the display area vertically.

8. Set the LEVEL control for a stable display.

9. Set the TIME/DIV and horizontal POSITION controls for a display which remains within the display area horizontally.

10. To magnify the display, position the area of interest to the center vertical graticule line. Push in the TIME/DIV knob, and turn clockwise until the desired amount of magnification is achieved.

USER'S CALIBRATION

General

To insure measurement accuracy, certain portions of the instrument calibration should be checked before making the measurement. The following is a procedure for checking the basic measurement capabilities of the 432. See the Calibration section of the Instruction Manual for more detailed calibration information.

Trace Rotation

Use steps 1-4 of the Basic Operation procedure to obtain a free-running trace. Adjust the TRACE ROTATION adjustment (located on the rear panel) to align the trace with the horizontal graticule lines.

STEP ATTENUATOR BALANCE

Use steps 1-4 of the Basic Operation procedure to obtain a vertically centered free-running trace. Rotate the Channel 1 VOLTS/DIV switch from 10 mV to 1 mV (CH 1 vertical mode of operation). Adjust the Channel 1 STEP ATTEN BAL adjustment (located on front panel) for no trace shift when switching from 10 mV to 1 mV. Repeat this procedure for Channel 2.

Probe Compensation

Variations in total input capacitance and resistance occur with different combinations of oscilloscopes and probes. Therefore, most attenuator probes are equipped with adjustments to insure optimum measurement accuracy. Probe compensation is accomplished as follows:

Connect the probe to one of the oscilloscope's input connectors. Use steps 1-9 of the Basic Operation procedure to obtain a display about three divisions in amplitude with one cycle of the calibrator signal displayed each two divisions. Check the waveform presentation for overshoot or rolloff, and readjust compensation for flat tops on the waveforms if necessary. See Fig. 1.

Vertical GAIN

Use steps 1-4 of the Basic Operation procedure to obtain a free-running trace. Connect the PROBE CAL 0.6 V 1 kHz

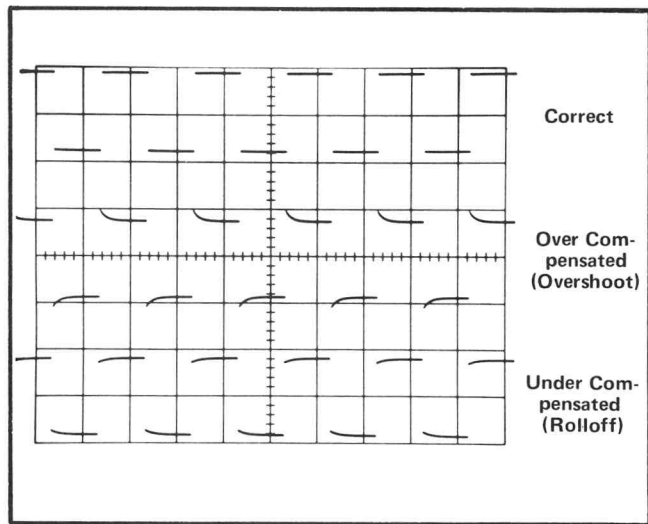


Fig. 1. Probe compensation.

output signal to the CH 1 input connector (if the signal is connected through a 10X probe that does not have a scale factor switching connector, reduce the setting of the VOLTS/DIV switch from .1 V to 10 mV). Adjust the Channel 1 GAIN adjustment (located on front panel) for exactly 6 divisions of vertical deflection. Repeat this procedure for Channel 2.

ASTIGmatism

Use steps 1-9 of the Basic Operation procedure to obtain a stable display of the calibrator waveform. Set the INTENSITY control for normal brightness of the display (approximately mid-range). Adjust the ASTIG adjustment (located on rear panel) so the vertical and horizontal portions of the calibrator waveform are equally focused.

Basic Timing

Use steps 1-9 of the Basic Operation procedure to obtain a stable display of the calibrator waveform. Set the TIME/DIV switch to .5 ms/div. Check the display for one cycle of calibrator waveform for each two horizontal divisions. For a more complete timing check, refer to the calibration procedure given in the Instruction Manual.

APPLICATIONS

General

The following information describes the procedures and techniques for making basic measurements with a 432 Oscilloscope. These applications are not described in detail, since each application must be adapted to the requirements of the individual measurements. This instrument can also be used for many applications which are not described in this handbook. Contact your local Tektronix Field Office or

representative for assistance in making specific measurements with this instrument.

DC Voltage Level Measurement

To measure a DC voltage level, use the following procedure:

1. Connect the voltage source to either input connector.
2. Set the instrument for the vertical mode that will display the channel being used.
3. Set the VOLTS/DIV switch to display about five or six divisions of deflection if possible.
4. Set the input coupling to GND.
5. Set the Sweep MODE switch to AUTO.
6. 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 POSITION control after this reference has been established.

NOTE

To measure a voltage level with respect to another voltage rather than ground, make the following changes in step 6: Set the input coupling to DC and apply the reference voltage to the input connector. Then position the trace to this reference line.

7. Set the input coupling to DC. The ground reference line can be checked at any time by switching the input coupling to GND.
8. Measure the distance in divisions between the reference line and the free-running trace.

NOTE

This technique can also be used to make instantaneous DC voltage level measurements on a waveform, rather than fixed DC levels.

9. Establish the polarity of the voltage. If the trace is above the reference line, the voltage is positive; below the line, negative (when the INVERT switch is pushed in if using Channel 2).

10. Multiply the distance measured in step 8 by the VOLTS/DIV switch setting. Also multiply by the attenuation factor of the probe, if any, when using a probe that does not have a scale factor switching connector.

Example. Assume that the vertical distance measured is 5.2 divisions, the trace is above the reference line, and a VOLTS/DIV switch setting of 50 mV.

Using the formula:

$$\text{DC Voltage} = \frac{\text{vertical distance (Divisions)}}{\text{VOLTS/DIV setting}} \times \text{polarity}$$

Substituting the given values:

$$\text{DC Voltage} = 5.2 \times +1 \times .05$$

The DC voltage is +0.26 volts.

Peak-To-Peak Voltage Measurements — AC

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

1. Connect the signal to either input connector.

2. Set the vertical mode to display the channel being used.

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

4. Set the Input Coupling to AC.

NOTE

For low-frequency signals below about 100 hertz, use DC coupling.

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

6. Turn the vertical POSITION control so the lower portion of the waveform coincides with one of the graticule lines below the center horizontal line, and the top of the waveform is on the viewing area. Move the display with the horizontal POSITION 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 Variable VOLTS/DIV control is in the CAL position.

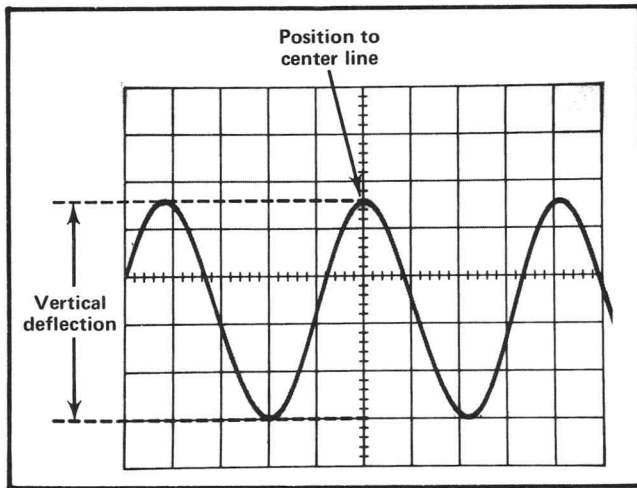


Fig. 2. Measuring peak-to-peak voltage of a waveform.

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. Also multiply by the attenua-

tion factor of the probe, if any, when using a probe that does not have a scale factor switching connector.

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

Using the formula:

$$\text{Volts Peak to Peak} = \frac{\text{vertical deflection (divisions)}}{\text{VOLTS/DIV setting}}$$

Substituting the given values:

$$\text{Volts Peak to Peak} = 4.6 \times 0.5 \text{ V}$$

The peak-to-peak voltage is 2.3 volts.

Comparison Measurements

In some applications it may be desirable to establish arbitrary units of measurement other than those indicated by the VOLTS/DIV switch or TIME/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 calibra-

tion of equipment (e.g., on an assembly-line test) where the 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 the 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 the reference signal to the input connector. Set the TIME/DIV switch to display several cycles of the signal.

2. Set the VOLTS/DIV switch and the Variable VOLTS/DIV control to produce a display an exact number of graticule divisions in amplitude. Do not change the Var-

iable VOLTS/DIV control after obtaining the desired deflection. This display can be used as a reference for amplitude comparison measurements.

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

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

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

5. To measure the amplitude of an unknown signal, disconnect the reference signal and connect the unknown signal to the input connector. Set the VOLTS/DIV switch to a setting that provides sufficient vertical deflection to

make an accurate measurement. Do not readjust the Variable VOLTS/DIV control.

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

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

Example. Assume a reference signal amplitude of 30 volts, a VOLTS/DIV switch setting of 5, and the Variable VOLTS/DIV control is adjusted to provide a vertical deflection of four divisions.

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

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

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

Signal

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

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

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

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

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

4. Divide the repetition rate of the reference signal (seconds) by the product of the horizontal deflection estab-

lished in step 2 (divisions) and the setting of the TIME/DIV switch. This is the horizontal conversion factor:

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

5. To measure the repetition rate of an unknown signal, disconnect the reference signal and connect the unknown signal to the input connector. Set the TIME/DIV switch to a setting that provides sufficient horizontal deflection to make an accurate measurement. Do not readjust the Variable TIME/DIV control.

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

$$\text{Repetition Rate} = \frac{\text{TIME/DIV switch setting} \times \text{horizontal conversion factor} \times \text{horizontal deflection (divisions)}}$$

Example. Assume a reference signal frequency of 455 hertz (repetition rate 2.19 milliseconds), and a TIME/DIV switch setting of .2 ms, with the Variable TIME/DIV

control adjusted to provide a horizontal deflection of eight divisions. Substituting these values in the horizontal conversion factor formula (step 4):

$$\text{Horizontal Conversion Factor} = \frac{2.19 \text{ ms}}{0.2 \text{ ms} \times 8} = 1.37$$

Then, with a TIME/DIV switch setting of 50 μ s, the repetition rate of an unknown signal which completes one cycle in seven horizontal divisions can be determined by using the repetition rate formula (step 6):

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

This answer can be converted to frequency by taking the reciprocal of the repetition rate (see applications on Determining Frequency).

Time-Duration Measurements

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

1. Connect the signal to either input connector.

2. Set the vertical mode of operation to display the channel used.

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

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

5. Set the TIME/DIV switch to the fastest sweep rate that displays less than eight divisions between the time measurement points (see Fig. 3).

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

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

8. Measure the horizontal distance between the time measurement points. Be sure the Variable TIME/DIV control is set to CAL.

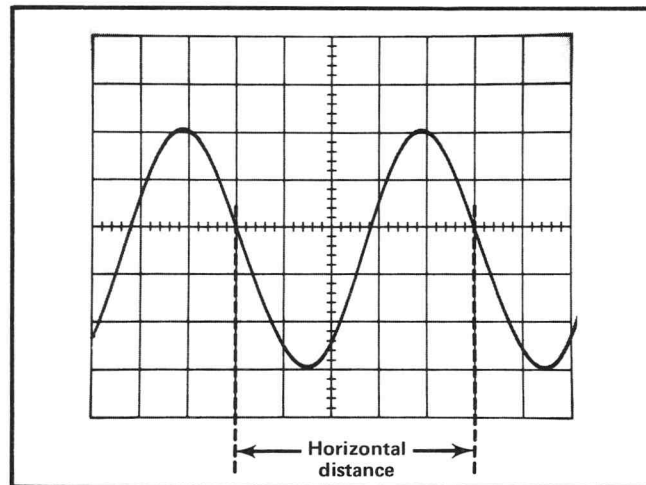


Fig. 3. Measuring the time duration between points on a waveform.

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

Example. Assume that the distance between the time measurement points is five divisions (see Fig. 3) and the TIME/DIV switch is set to .1 ms.

Using the formula:

$$\text{Time Duration} = \frac{\text{horizontal distance (divisions)}}{\text{TIME/DIV setting}} \times \text{setting}$$

Substitute the 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 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. 3 which has a time duration of 0.5 millisecond is:

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

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 signal to either input connector.
2. Set the vertical mode of operation to display the channel used.
3. Set the VOLTS/DIV switch and the Variable control to produce a display exactly six divisions in amplitude.
4. Center the display about the center horizontal graticule line. See Fig. 4.

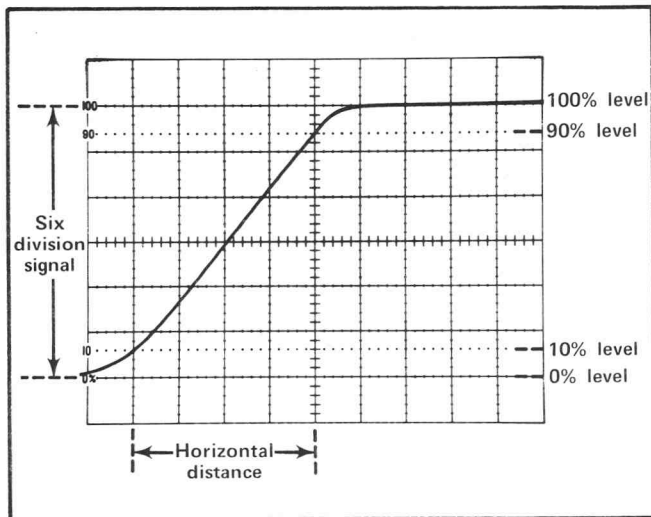


Fig. 4. Measuring risetime.

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

6. Adjust the horizontal POSITION control to move the 10% point of the waveform to the first graticule line. See Fig. 4.

8. Measure the horizontal distance between the 10% and 90% points. Be sure the Variable control is set to CAL.

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

Example. Assume that the horizontal distance between the 10% and 90% points is four divisions (see Fig. 4) and the TIME/DIV switch is set to 1 μ s.

$$\begin{array}{lcl} \text{Risetime} & \text{horizontal} & \text{TIME/DIV} \\ \text{(Time Duration)} & = \text{distance} & \times \text{setting} \\ & \text{(divisions)} & \end{array}$$

Substituting the given values:

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

The risetime is 4 microseconds.

Time-Difference Measurements

The calibrated sweep rate and dual-trace features of the 432 allow measurement of time difference between two separate events. To measure time difference, use the following procedure:

1. Set the Input Coupling switches to the desired coupling positions.

2. Set the vertical mode of operation to either CHOP or ALT. In general, CHOP is more suitable for low-frequency signals and the ALT position is more suitable for high-frequency signals.

3. Set the TRIGGER SOURCE to CH 1.

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

5. If the signals are of opposite polarity, set the INVERT switch out to invert the Channel 2 display (signals may be of opposite polarity due to 180° phase difference; if so, take this into account in the final calculation).

6. Set the VOLTS/DIV switches to produce four- or five-division displays.

7. Set the LEVEL control for a stable display.

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

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

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

11. Measure the horizontal difference between the Channel 1 waveform and the Channel 2 waveform (see Fig. 5).

12. Multiply the measured difference by the setting of the TIME/DIV switch.

Example. Assume that the TIME/DIV switch is set to $50 \mu\text{s}$ and the horizontal difference between waveforms is 4.5 divisions (see Fig. 5).

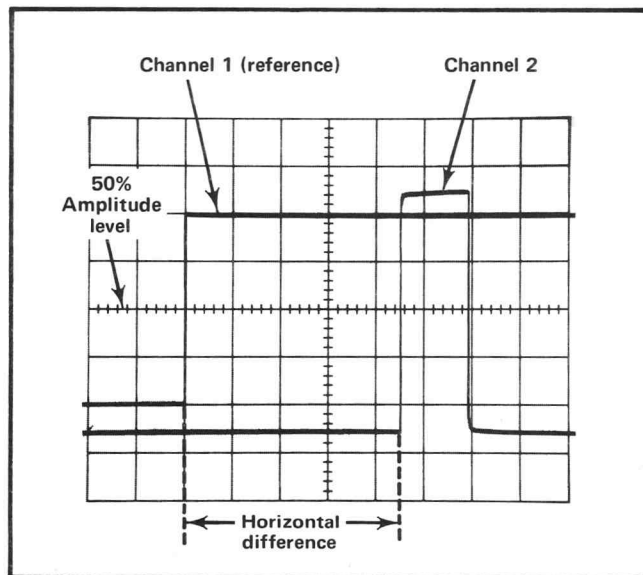


Fig. 5. Measuring time difference between two pulses.

Using the formula:

$$\text{Time Delay} = \frac{\text{TIME/DIV}}{\text{setting}} \times \text{horizontal difference (divisions)}$$

Substituting the given values:

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

The time delay is 225 microseconds.

Multi-Trace Phase Difference Measurements

Phase comparison between two signals of the same frequency can be made using the dual-trace feature of the 432. This method of phase difference measurement can be used up to the frequency limit of the vertical system. To make the comparison, use the following procedure.

1. Set the Input Coupling switches to the same position, depending on the type of coupling desired.

2. Set the vertical mode of operation to either CHOP or ALT. In general, CHOP is more suitable for low-frequency signals and the ALT position is more suitable for high-frequency signals.

3. Set the TRIGGER SOURCE to CH 1.

4. Connect the reference signal to the CH 1 input connector and the comparison signal to the CH 2 input

connector. The reference signal should precede the comparison signal in time. Use coaxial cables or probes which have equal time delay to connect the signals to the input connectors.

5. If the signals are of opposite polarity, set the INVERT switch out to invert the Channel 2 display. (Signals may be of opposite polarity due to 180° phase difference; if so, take this into account in the final calculation.)

6. Set the CH 1 and CH 2 VOLTS/DIV switches and the CH 1 and CH 2 Variable controls so the displays are equal and about five divisions in amplitude.

7. Set the Triggering controls to obtain a stable display.

8. Set the TIME/DIV switch to a sweep rate which displays about one cycle of the waveform.

9. Move the waveforms to the center of the graticule with the CH 1 and CH 2 POSITION controls.

10. Turn the VARIABLE TIME/DIV control until one cycle of the reference signal (Channel 1) occupies exactly

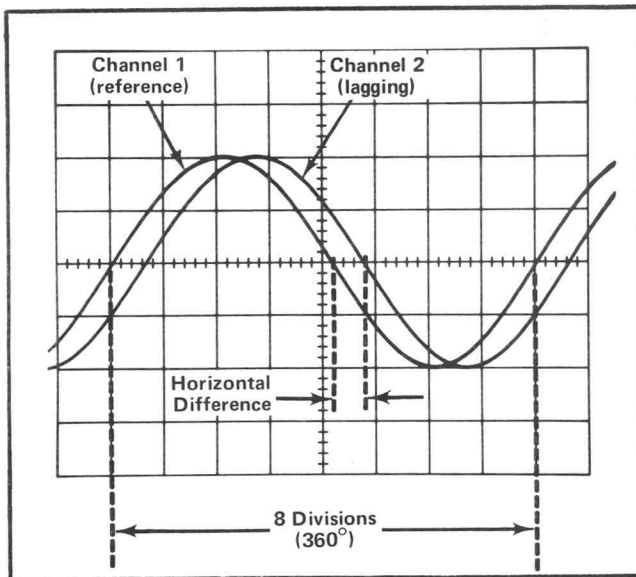


Fig. 6. Measuring phase difference.

eight divisions between the first and ninth graticule lines (see Fig. 6). Each division of the graticule represents 45° of the cycle ($360^\circ \div 8 \text{ divisions} = 45^\circ/\text{division}$). The sweep rate can be stated in terms of degrees as $45^\circ/\text{division}$.

11. Measure the horizontal difference between corresponding points on the waveforms.

12. Multiply the measured distance (in divisions) by $45^\circ/\text{division}$ (sweep rate) to obtain the exact amount of phase difference.

Example. Assume a horizontal difference of 0.6 division with a sweep rate of $45^\circ/\text{division}$ as shown in Fig. 6.

Using the formula:

$$\text{Phase Difference} = \frac{\text{horizontal difference (divisions)}}{\text{sweep rate (degrees/division)}} \times \text{X (degrees/division)}$$

Substituting the given values:

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

The phase difference is 27° .

X-Y Phase Measurement

The X-Y phase measurement method can be used to measure the phase difference between two signals of the same frequency. This method provides an alternative method of measurement for signal frequencies up to approximately 50 kilohertz. However, above this frequency the inherent phase difference between the vertical and horizontal system makes accurate phase measurement difficult.

In this mode, one of the sine-wave signals provides the horizontal deflection (X) while the other signal provides the vertical deflection (Y). The phase angle between the two signals can be determined from the lissajous pattern as follows:

1. Connect one of the sine-wave signals to the CH 1 input connector and the other signal to the EXT HORIZ input connector.

2. Set the TIME/DIV switch to EXT HORIZ and the Sweep MODE to AUTO.

3. Position the display to the center of the screen and adjust the CH 1 VOLTS/DIV switch to produce a display less than eight divisions vertically (Y). Reduce the horizontal (X) deflection to less than 10 divisions by reducing the amplitude of signal applied to the EXT HORIZ input connector.

4. Center the display in relation to the center graticule lines. Measure the distance A and B as shown in Fig. 7. Distance A is the horizontal measurement between the two points where the trace crosses the center horizontal line. Distance B is the maximum horizontal width of the display.

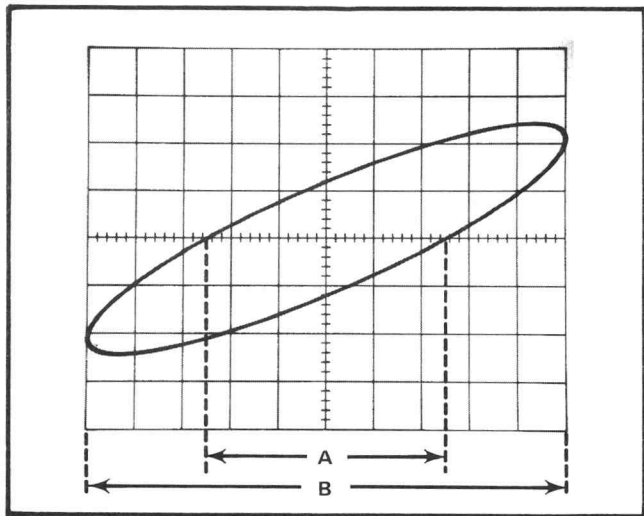


Fig. 7. Phase-difference measurement from an X-Y display.

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

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

Example. To measure the phase of the display shown in Fig. 7 where A is 5 divisions and B is 10 divisions, use the formula:

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

Substituting the given values:

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

From the trigonometric tables:

$$\Phi = 30^\circ$$

Common-Mode Rejection

The ADD feature of the 432 can be used to display signals which contain undesirable components. These undesirable components can be eliminated through common-mode rejection.

1. Connect the signal containing both the desired and undesired information to the CH 1 input connector.

2. Connect a signal similar to the unwanted portion of the Channel 1 signal to the CH 2 input connector.

3. Set both Input Coupling switches to DC (AC if DC component of input signal is too large).

4. Set the vertical mode of operation to ALT. Set the VOLTS/DIV switches so the signals are about equal in amplitude.

5. Set the TRIGGER SOURCE to COMP.

6. Set the vertical mode of operation to ADD. Invert the Channel 2 display (INVERT button out) so the common-mode signals are of opposite polarity.

7. Adjust the CH 2 VOLTS/DIV switch and CH 2 Variable control for maximum cancellation of the common-mode signal.

8. The signal which remains should be only the desired portion of the Channel 1 signal. The undesired signal is cancelled out.

Example. An example of this mode of operation is shown in Fig. 8. The signal applied to Channel 1 contains unwanted line-frequency components (see Fig. 8A). A corresponding line-frequency signal is connected to Channel 2 (see Fig. 8B). Fig. 8C shows the desired portion of the signal as displayed when common-mode rejection is used.

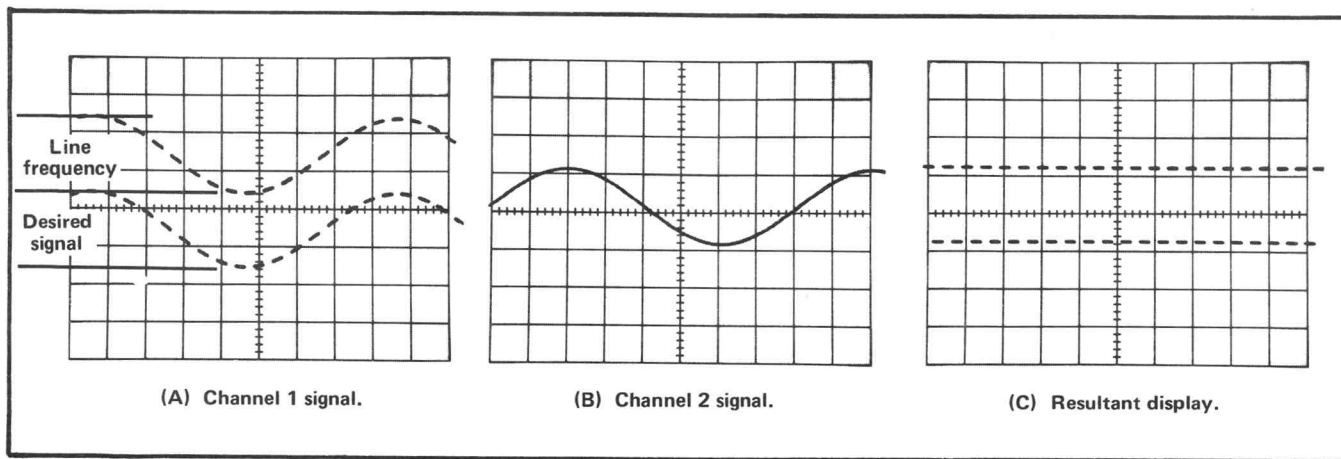


Fig. 8. Using the ADD feature for common-mode rejection. (A) Channel 1 signal contains desired information along with line-frequency component. (B) Channel 2 signal contains line-frequency only, (C) CRT display using common-mode rejection.





