INSTRUCTION MANUAL

FOR

B & K-PRECISION

MODEL 1535A

35 MHz, TRIGGERED SWEEP DUAL-TRACE OSCILLOSCOPE WITH BUILT-IN SIGNAL DELAY LINE

BK PRECISION®

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Chicago, Illinois 60635

TABLE OF CONTENTS

INTRODUCTION

The B & K-Precision Model 1474 Triggered Sweep Dual-Trace Oscilloscope is a laboratory quality, professional instrument for observing and measuring waveforms in electronic circuits. Dual vertical inputs are provided for simultaneous viewing of two waveforms. Low-frequency, low repetition-rate waveforms are chopped at a 200 kHz rate to provide for simultaneous viewing. Alternate sweep of the two inputs permits simultaneous viewing of high-speed, high repetition-rate waveforms. In addition, the sum or difference of the two input waveforms can be displayed as a single trace. The built-in signal delay line insures that the leading edges of fast rise-time, short-duration pulses are always visible.

The dual-trace feature, together with the 30 MHz bandwidth, wide range of sweep speeds, and high sensitivity provided, make this the ideal oscilloscope for a broad range of applications, including troubleshooting and repairing electronic equipment, research and development, and laboratory instruction.

FEATURES

DUAL TRACE	Two input waveforms can be viewed either singly or simultaneously, as desired. Individual vertical sensitivity and positioning controls are provided for completely independent adjustment of the two signal amplitudes.
30 MHz BANDWIDTH	DC to 30 MHz bandwidth and 11.7 nSEC rise time assure distortion-free, high-resolution presentation at high frequencies.
USABLE TO 50 MHz	Triggers on signals up to 50 MHz. Smooth response well beyond 30 MHz.
11.7 nSEC RISE TIME	Short-duration pulses not viewable on other lab scopes are clearly viewable on the 1474 when expanded on 5X magnification.
BUILT-IN DELAY LINE	Permits viewing of leading edge of high-frequency, fast risetime pulses.
DIGITAL LOGIC APPLICATIONS	Design, analysis and troubleshooting of mini-computers, microprocessors, computer terminals, electronic organs, calculators, and most digital logic circuitry using TTL, DTL, RTL and most ECL logic.
RADIO APPLICATIONS	Development, manufacturing, and servicing of CB radios and communications radios to 50 MHz. Direct RF and IF measurements, AM and SSB modulation patterns, digital data transmission.
HIGH SENSITIVITY	Permits the low-capacitance, high-impedance, 10:1 attenuation probes to be used for virtually all measurements, thus assuring minimum circuit loading.
CALIBRATED VOLTAGE SCALES	Accurate measurement (±3%) of instantaneous voltages on 10 different attenuator ranges for both Channel A and Channel B.
TRIGGERED SWEEP	Fully adjustable trigger threshold allows the desired portion of the waveforms to be used for triggering. A single waveform, or both waveforms in dual-trace operation, can be synchronized to the signal displayed on Channel A or Channel B or to an external sync trigger.
20 CALIBRATED SWEEP SPEEDS	Accurate time measurements on 20 different ranges. Sweep speed range of 0.2 μSEC/cm to 0.5 SEC/cm provides every speed necessary for viewing waveforms from DC to 30 MHz.
EXPANDED SCALE	A five time magnification (5X) of the horizontal sweep allows close-up examination of a portion of the waveform. In addition, the 5X magnification provides a maximum sweep speed of 40 nSEC/cm.
DIFFERENTIAL INPUT CAPABILITY	Capability to algebraically add or subtract Channel A and Channel B and display as a single trace. Useful for differential voltage and distortion measurements.
LF AND HF REJECT SYNC COUPLING	Sync coupling (to attenuate low- or high-frequency component of signal) may be selected.
105-130 VAC	Maintains calibration accuracy over entire 105 to 130 VAC input range.
FULLY SOLID STATE	Only the cathode ray tube uses a filament.

CALIBRATION SOURCE — A built-in calibrated 0.5 volt peak-to-peak square wave permits checking and recalibration of the vertical amplifiers without additional equipment.

X-Y OPERATION — Channel B input can be applied as horizontal deflection (X axis) while Channel A input provides vertical deflection (Y axis).

Z-AXIS INPUT — Intensity modulation capability included for time or frequency markers, compatible with 5V p-p solid state logic circuits.

BRIGHT PHOSPHOR — Bright blue P31 phosphor, usually found only in more expensive oscilloscopes.

LARGE SCREEN — The 130 mm (approx. 5.1 inches) diameter cathode ray tube gives easy-to-read presentation on an 8 x 10 cm rectangular viewing area.

ILLUMINATED SCALE — Fully variable illumination for the scale. Vertical and horizontal markers on the scale make voltage and time measurements easy to read.

NOTES

SPECIFICATIONS

VERTICAL AMPLIFIERS (CH A and CH B)

Deflection Factor	5 mV/cm to 5V/cm, ± 3%, in 10 ranges, each providing for fine adjustment.
Frequency Response	DC: DC to 30 MHz (-3 dB). AC: 10 Hz to 30 MHz (-3 dB).
Risetime	11.7 nanoseconds or less.
Overshoot	3% or less.
Input Resistance	1 megohm, ±2%.
Input Capacity	22 pF (±3 pF).
Tilt	Less than 5%.
Max. Input Voltage	300 V (DC + AC peak) or 600 V p-p.
Operating Modes	Channel A only. Channel B only. Dual trace; automatically chopped at all sweep times of 1 mS/cm and slower; alternate trace automatically selected for all faster sweep times. Add (single-trace algebraic sum of Channels A and B).
Chop Frequency	200 kHz (±20%).
Channel Separation	Better than 70 dB @ 1 kHz.
Signal Delay	Fixed, 12 nSEC minimum visible delay.
CH B Polarity	Normal or inverted. When inverted, provides CH A minus CH B presentation, when in the ADD mode.
Non-Distorted Maximum Amplitude	More than 4 cm at 30 MHz; more than 8 cm at 10 MHz.

HORIZONTAL AMPLIFIER (Horizontal input thru CH B input)

Deflection Factor	5 mV/cm to 5V/cm, ±3%.
Frequency Response	DC: DC to 2 MHz (-3 dB). AC: 10 Hz to 2 MHz (–3 dB).
Input Resistance	1 megohm (nominal).
Input Capacity	22 pF (±3 pF).
Input Protection	300 V (DC + AC peak) or 600 V p-p.
X-Y Operation	With SWEEP TIME/CM switch in CH B position, the CH A input becomes the Y input (vertical) and the CH B input becomes the X input (horizontal). The CH B position control becomes the horizontal position control.

SWEEP CIRCUITS (Common to CH A and CH B)

Sweep System	Triggered and automatic. In automatic mode, sweep is obtained without input signal.
Sweep Time	0.2 μSEC/cm to 0.5 SEC/cm (±3%), in 20 ranges, in 1-2-5 sequence. Each overlapping range provides for fine adjustment.
Sweep Magnification	Obtained by enlarging the above sweep 5 times (±5%) from center. Maximum sweep speed becomes 40 nSEC/cm.
Linearity	3% or better.

TRIGGERING

Source	CH A, CH B, EXT and AM DET. During single trace operation, CH A and CH B are triggered automatically by the operating modes. The AM DET provides an internal synchronization of the amplitude modulated waves with their carrier frequency range from 3 MHz to 30 MHz.
Method	NORM, AUTO; when the AUTO LEVEL button is in the AUTO mode, the sweep triggers automatically at the average level of the displayed waveform.
Slope	Positive or negative, continuously variable level control; pull for adjustable level AUTO.
Coupling	AC, DC, LF REJ, and HF REJ. AC: 20 Hz-30 MHz. DC: DC to 30 MHz. LF REJ: Attenuate below 10 kHz. HF REJ: Attenuate above 300 kHz.

Trigger
Sensitivity

Coupling		Bandwidth	Minimum Sync Voltage INT	EXT	EXT/10
AC		20Hz - 15MHz 10Hz - 30MHz	0.3 Div 1 Div	0.1Vpp 0.5Vpp	1VPP 5Vpp
LF Rej		20kHz - 15MHz 10kHz - 30MHz	0.3 Div 1 Div	0.1Vpp 0.5Vpp	1Vpp 5Vpp
HF Rej		20Hz 50kHz 10Hz - 300kHz	0.3 Div 1 Div	0.1Vpp 0.5Vpp	1Vpp 5Vpp
DC	NORM	DC - 15MHz DC - 30MHz	0.3 Div 1 Div	0.1Vpp 0.5Vpp	1Vpp 5Vpp
DC	AUTO	20Hz - 15MHz 10Hz - 20MHz	0.3 Div 1 Div	0.1Vpp 0.5Vpp	1Vpp 5Vpp

CALIBRATION VOLTAGE
Amplitude: .5V p-p, ±1%.
Frequency: 1kHz, ±3%.

INTENSITY MODULATION
Input Voltage — Minimum: 5 V p-p (TTL compatible). Maximum: 50 V.

Input Impedance — 10k ohms.

Bandwidth — DC - 5 MHz.

POWER REQUIREMENTS
Input — 117/234 VAC, 50/60 Hz, 25 watts. (3-wire line cord, CSA-approved for oscilloscopes.)

Regulation — 105 to 130 VAC.

MISCELLANEOUS

Scale — Variable illumination.

Dimensions (WXHXD) — 260 x 190 x 375 mm. 14.5 x 9.8 x 17.8 inches.

Weight — 8.5 Kg; 19 lbs.

CRT — 130 mm diameter (approx. 5"). PDA type, approx. 4 kV.

PROBES

Model No. — PR-36 (two required).

Attenuation — Combination 10:1 and direct.

Input Impedances — 10:1 = 10 megohms, 18 pF. Direct = 1 megohm, 120 pF.

Connector — BNC male.

Tip — Spring-loaded hook-on tip.

NOTES

OPERATOR'S CONTROLS, INDICATORS AND FACILITIES

1. Cathode Ray Tube (CRT). This is the screen on which the waveforms are viewed.

2. Scale. The 8 x 10 cm graticule provides calibration marks for voltage (vertical) and time (horizontal) measurements. Illumination of the scale is fully adjustable.

3. **POWER/ILLUM** control. Fully counterclockwise rotation of this control (OFF position) turns off oscilloscope. Clockwise rotation turns on oscilloscope. Further clockwise rotation of the control increases the illumination level of the scale.

4. Pilot lamp. Lights when oscilloscope is turned on.

5. **SWEEP TIME/CM** switch. Horizontal coarse sweep time selector. Selects calibrated sweep times of 0.2 µSEC/cm (microsecond per centimeter) to 0.5 SEC/cm in 20 steps when VARIABLE control (6) is set to the CAL position (fully clockwise). In the CH B position, this switch disables the internal sweep generator and permits the CH B input to provide horizontal sweep.

6. Sweep speed **VARIABLE** control. Fine sweep time adjustment. In the extreme clockwise (CAL) position the sweep time is calibrated.

7. **CAL** 1 kHz ⎍ 0.5 V p-p jack. Provides calibrated 1 kHz, 0.5 volt peak-to-peak square wave input signal. This is used for calibration of the vertical amplifier attenuators and to check the frequency compensation adjustment of the probes used with the oscilloscope.

8. **◄► POSITION** control. Rotation adjusts horizontal position of trace (both traces when operated in the dual trace mode). Push-pull switch selects 5X magnification when pulled out (PULL 5X MAG); normal when pushed in.

9. **TRIGGERING LEVEL** control. Sync level adjustment determines point on waveform slope when sweep starts; (-) equals most negative point of triggering and (+) equals most positive point of triggering. Push-pull switch selects automatic triggering when pulled out (PULL AUTO). When automatic triggering, a sweep is generated even without an input signal.

10. **SLOPE** switch. Two-position lever switch with the following positions:

    (+) Sweep is triggered on positive-going slope of waveform.

    (-) Sweep is triggered on negative-going slope of waveform.

11. **AUTO LEVEL** pushbutton switch. In the NORM position (button out), the triggering level is selected by TRIGGERING LEVEL control (9). In the AUTO position (button in), the triggering level is automatically set at the average level of the waveform used for triggering.

12. **COUPLING** switch. Four-position lever switch with the following positions:

    AC — Trigger is AC-coupled, 20 Hz to 30 MHz response.

    LF REJ — Triggering below 10 kHz is attenuated.

    HF REJ — Triggering above 30 kHz is attenuated.

    DC — Trigger is DC-coupled.

13. **EXT TRIG** jack. Input for external trigger signal.

14. **SOURCE** switch. Four-position lever switch selects triggering source for the sweep. Both sweeps are triggered by the same source in dual trace operation.

    INT (internal)
    - Mode Switch (22) in Dual or Add position,
      - CH A Sweep is triggered by Channel A signal.
      - CH B Sweep is triggered by Channel B signal.
    - Mode Switch (22) in CH A or CH B position,
      - Sweep is triggered automatically.

    EXT (external)
    Sweep is triggered by an external signal applied to EXT TRIG jack (13). The amplitude of an external signal should not exceed 2Vpp.

    AM DET
    The AM DET is provided with an internal AM detecting circuit to synchronize the amplitude modulated waves with their carrier frequency (from 3 MHz to 30 MHz). CH A provides the synchronization source for a dual channel measurement.

15. Chassis ground (⏚) terminal/binding post.

16. **CH B POLARITY** pushbutton switch. In the NORM position (button out), the Channel B signal is non-inverted. In the INV position (button in), the Channel B signal is inverted. When MODE switch (22) is in the ADD position and this switch is in the INV position, the Channel B signal is subtracted from the Channel A signal and the difference is displayed as a single trace.

17. Channel B **POSITION** control. Vertical position adjustment for Channel B trace. Becomes horizontal position adjustment when SWEEP TIME/CM switch (5) is in the CH B position.

18. Channel B **INPUT** Jack. Vertical input jack of Channel B. Jack becomes external horizontal input when SWEEP TIME/CM switch (5) is in the CH B position.

19. Channel B **DC-GND-AC** switch.

    DC — Direct input of AC and DC component of input signal.

    GND — Opens signal path and grounds input to vertical amplifier. This provides a zero-signal base line, the position of which can be used as a reference when performing DC measurements.

    AC — Blocks DC component of input signal.

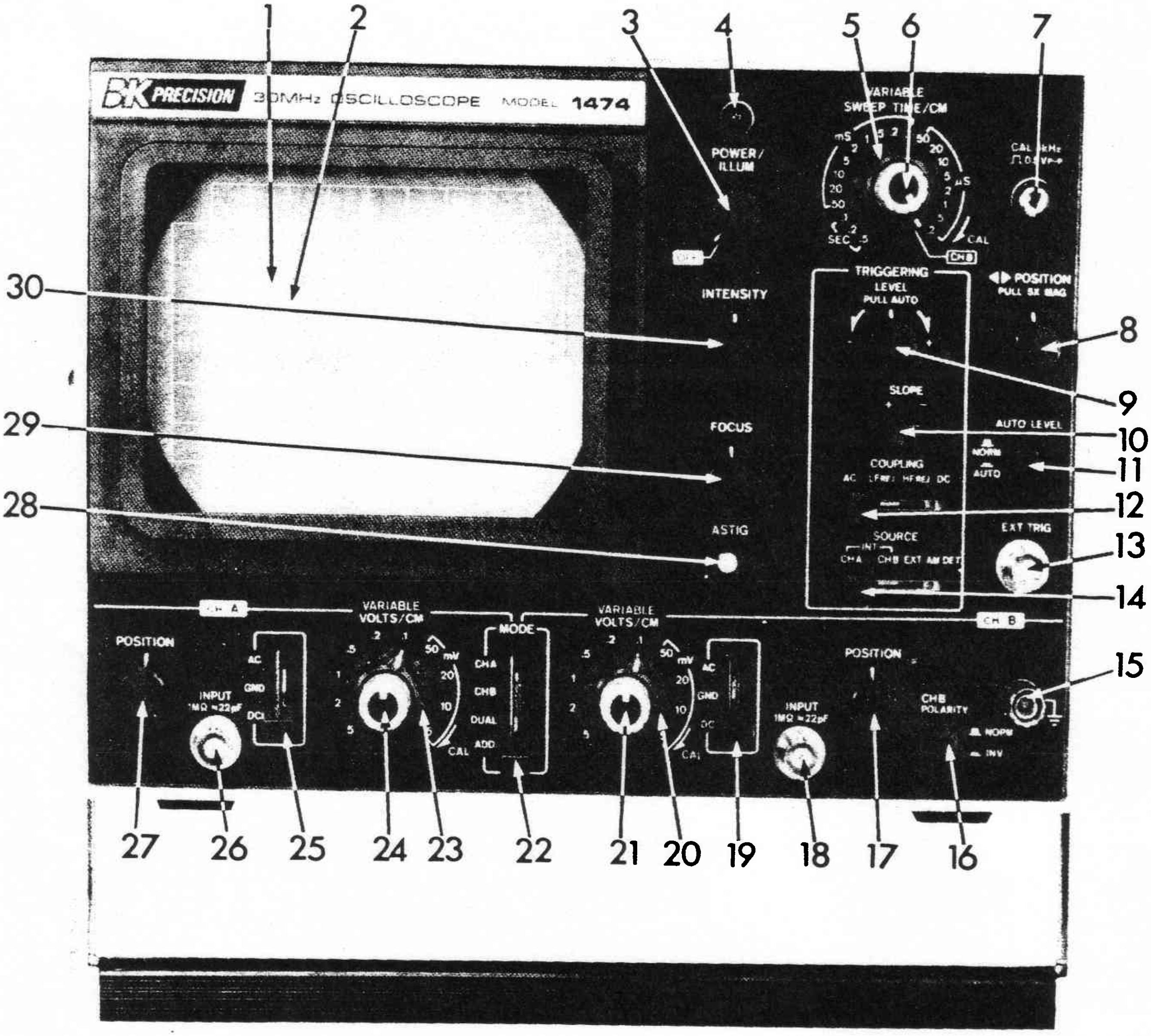


Fig. 1. Front panel controls and indicators.

20. Channel B **VOLTS/CM** switch. Vertical attenuator for Channel B which provides step adjustment of vertical sensitivity. Vertical sensitivity is calibrated in 10 steps from 5 mV to 5 volts per cm when VARIABLE control (21) is set to CAL position. This control adjusts horizontal sensitivity when the SWEEP TIME/CM switch (5) is in the CH B position.

21. Channel B **VARIABLE** control. Vertical attenuator adjustment provides fine control of vertical sensitivity. In the extreme clockwise (CAL) position, the vertical attenuator is calibrated. This control becomes the fine horizontal gain control when the SWEEP TIME/CM switch (5) is in the CH B position.

22. **MODE** switch. Four-position lever switch; selects the basic operating modes of the oscilloscope.

    CH A — Only the input signal to Channel A is displayed as a single trace.
    With Source Switch (14) in INT, the CH B is displayed automatically as a trigger signal.

    CH B — Only the input signal to Channel B is displayed as a single trace.
    With Source Switch (14) in INT, the CH A is displayed as a trigger signal.

    DUAL — Dual-trace operation; both the Channel A and Channel B input signals are displayed on two separate traces.

    ADD — The waveforms from Channel A and Channel B inputs are added and the sum is displayed as a single trace.

23. Channel A **VOLTS/CM** switch. Vertical attenuator for Channel A which provides coarse adjustment of vertical sensitivity. Vertical sensitivity is calibrated in 10 steps from 5 mV to 5 volts per cm when VARIABLE control (24) is set to the CAL position.

24. Channel A **VARIABLE** control. Vertical attenuator adjustment provides fine control of vertical sensitivity. In the extreme clockwise (CAL) position, the vertical attenuator is calibrated.

25. Channel A **DC-GND-AC** switch.

    DC — Direct input of AC and DC component of input signal.

    GND — Opens signal path and ground input to vertical amplifier. This provides a zero-signal base line, the position of which can be used as a reference when performing DC measurements.

    AC — Blocks DC component of input signal.

26. Channel A **INPUT** jack. Vertical input jack of Channel A.

27. Channel A **POSITION** control. Vertical position adjustment for Channel A trace.

28. **ASTIG** adjustment. Astigmatism adjustment provides optimum spot roundness when used in conjunction with the FOCUS control (29) and INTENSITY control (30). Very little readjustment of this control is required after initial adjustment.

29. **FOCUS** control.

30. **INTENSITY** control. Adjusts brightness of trace.

31. Combination carrying handle and tilt stand. When the handle is folded upward, the oscilloscope rests on rubber feet. When the handle is folded downward, it elevates the front of the oscilloscope to a convenient viewing angle.

32. AC line changer. Sets up instrument to operate from 100, 120, 220 or 240 VAC.

33. AC line receptacle.

34. AC line cord. CSA approved for oscilloscopes.

35. Fuse holder.

36. **INT MOD** jack. Intensity modulation (Z axis) input.

37. CRT rotation adjustment.

38. Feet (4). Support oscilloscope when unit is in vertical position (face up); and serve as storage wrap anchors for line cord.

39. VR106. **CH B DC BAL** control (under rubber button). Vertical DC balance adjustment for Channel B trace.

40. VR108. **CH B ATTEN BAL** control (under rubber button). Step attenuator balance adjustment for Channel B trace.

41. VR103. **CH A ATTEN BAL** control (under rubber button). Step attenuator balance adjustment for Channel A trace.

42. VR101. **CH A DC BAL** control (under rubber button). Vertical DC balance adjustment for Channel A trace.

43. Probe (two required, see Fig. 3). The **B & K-Precision** Model PR-36 probes have been designed for use with this oscilloscope. These are combination 10:1/direct probes designed for oscilloscopes with input impedance of 1 megohm, shunted by 22 pF (±3) and capable of operation up to and beyond 30 MHz. Equivalent oscilloscope probes may be used.

NOTES

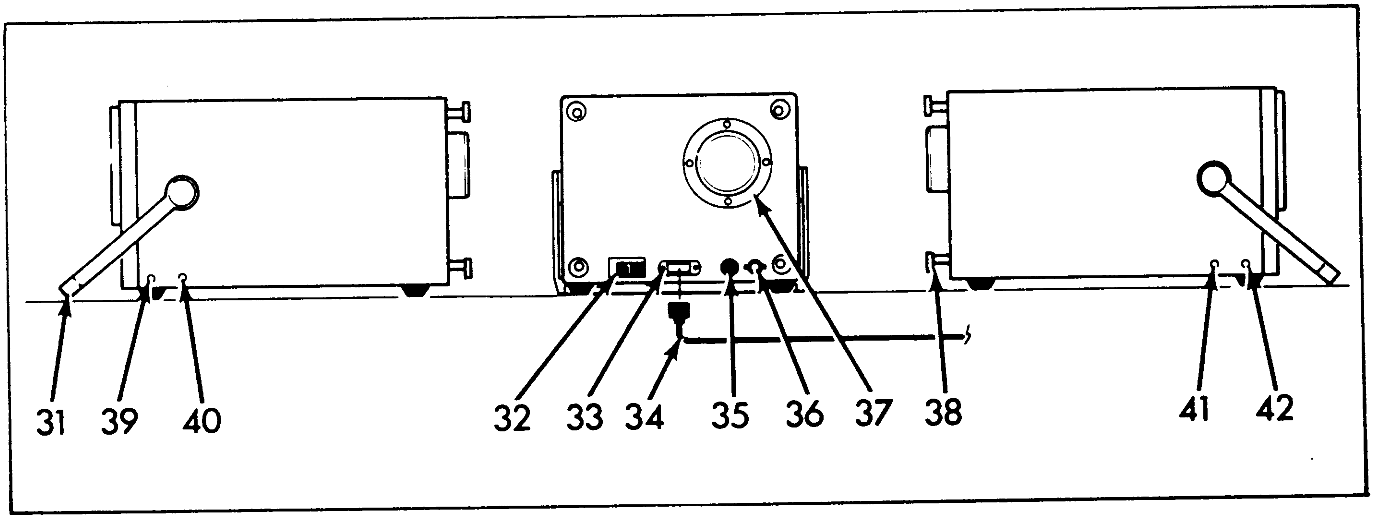


Fig. 2. Rear and side panel facilities.

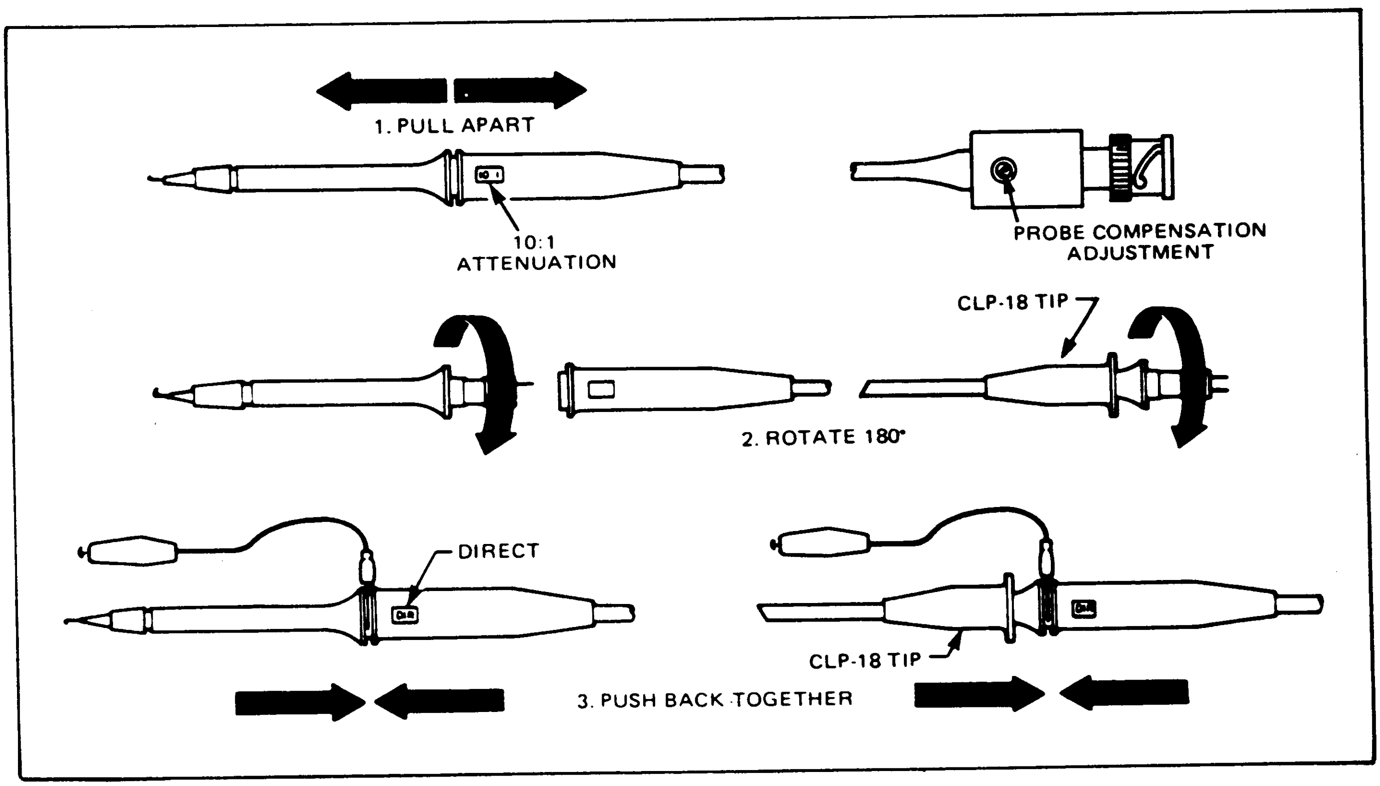


Fig. 3. Probe details.

OPERATING INSTRUCTIONS

INITIAL STARTING PROCEDURE

1. Set POWER ILLUM control (3) to OFF position (fully counterclockwise).

2. Plug the AC line changer (32) into the position that corresponds to the AC line voltage from which the oscilloscope will be operated as follows: (This information also appears on a label on the back of the unit.)

AC LINE CHANGER POSITION	AC LINE VOLTAGE
100 V	100 V, ±10%
120 V	105 V to 130 V
220 V	220 V, ±10%
240 V	240 V, ±10%

3. Connect AC power cord (34) to the AC line receptacle (33), then to a 50/60 Hz AC power outlet.

4. Set CH A POSITION control (27), CH B POSITION control (17) and ◄► POSITION (8) to the centers of their ranges.

5. Press the AUTO LEVEL pushbutton (11), leaving it in the AUTO position.

6. Set CH A DC-GND-AC switch (25) and CH B DC-GND-AC switch (19) to the GND positions.

7. Set the MODE switch (22) to the CH B position for single-trace operation or the DUAL position for dual-trace operation.

8. Turn on oscilloscope by rotating the POWER/ILLUM control (3) clockwise. It will "click" on and pilot lamp (4) will light. Turn control clockwise to the desired scale (2) illumination.

9. Wait a few seconds for the cathode ray tube (CRT) to warm up. A trace (two traces if operating in the DUAL mode) should appear on the face of the CRT.

10. If no trace appears, increase (clockwise) the INTENSITY control (30) setting until the trace is easily observed.

11. Adjust FOCUS control (29) and INTENSITY control (30) for the thinnest, sharpest trace.

12. Readjust position controls (8), (27) and (17) if necessary, to *center* the traces.

13. Check for proper adjustment of ASTIG control (28), CH A and CH B ATTEN BAL controls (41) and (40), and CH A and CH B DC BAL controls (42) and (39) as described in the MAINTENANCE AND CALIBRATION portion of this manual. These adjustments require checking only periodically.

The oscilloscope is now ready for making waveform measurements.

CAUTION

Never allow a small spot of high brilliance to remain stationary on the screen for more than a few seconds. The screen may become permanently burned. Reduce intensity or keep the spot in motion by causing it to sweep.

SINGLE-TRACE WAVEFORM OBSERVATION

Either Channel A or Channel B can be used for single-trace operation. The advantage of using Channel B is that the polarity of the observed waveform can be inverted if desired, with CH B POLARITY switch (16). For convenience, Channel B is used in the following instructions:

1. Perform the steps of the "Initial Starting Procedure" with the MODE switch (22) in the CH B position. Then connect the probe cable to the CH B INPUT jack (18). The following instructions assume the use of the **B & K-Precision** Model PR-36 combination probes.

2. For all except low-amplitude waveforms, the probes are set for 10:1 attentuation. For low-amplitude waveforms (below 50 mV peak-to-peak), set the probe for DIRect. See Fig. 3 for changing the probes from 10:1 to DIRect, or vice versa. The probe has a 10 megohm input impedance with only 18 pF shunt capacitance in the 10:1 position and 1 megohm with 120 pF shunt capacitance in the DIRect position. The higher input impedance (low-capacity position) should be used when possible, to decrease circuit loading.

3. Set CH B DC-GND-AC switch (19) to AC for measuring only the AC component (this is the normal position for most measurements and must be used if the point being measured includes a large DC component). Use the DC position for measuring both the AC component and the DC reference, and any time a very low frequency waveform (below 10 Hz) is to be observed. The GND position is required only when a zero-signal ground reference is required, such as for DC voltage readings.

4. Connect ground clip of probe to chassis ground of the equipment under test. Connect the tip of the probe to the point in the circuit where the waveform is to be measured.

WARNING

a. If the equipment under test is a transformerless AC powered item, use an isolation transformer to prevent dangerous electrical shock.

b. The peak-to-peak voltage at the point of measurement should not exceed 600 volts.

5. Set CH B VOLTS/CM switch (20) and the VARIABLE control (21) to a position that gives 2 to 6 cm (two to six large squares on the scale) vertical deflection. The

display on the screen will probably be unsynchronized. The remaining steps are concerned with adjusting synchronization and sweep speed, which presents a stable display showing the desired number of waveforms. *Any signal that produces at least 1 cm vertical deflection develops sufficient trigger signal to synchronize the sweep.*

6. Set SOURCE switch (14) to the CH A or CH B position. During single trace operation, the Trigger Signal selecting whether CH A signal or CH B is depended on Mode Switch. Then it is not necessary to adjust Source Switch (14) to CH A (or CH B) signal at the CH A (or CH B) position. Most waveforms should be viewed using internal sync. When an external sync source is required, the SOURCE switch should be placed in the EXT position; a cable should be connected from the EXT TRIG jack (13) to the external sync source.
   When an internal synchronization is required for an amplitude modulated wave, set SOURCE switch (14) to the AM DET position. The amplitude modulated waves of frequency 3 MHz to 30 MHz will be internally synchronized automatically. CH A is provided with a synchronization source for dual channel measurement.

7. Set SLOPE switch (10) to the (+) position if the sweep is to be triggered by a positive-going wave, or the (-) position if the sweep is to be triggered by a negative-going wave. If the type of waveform is unknown, the (+) position may be used.

8. If the waveform is symmetrical and sweep triggering on the average point of the waveform is acceptable, leave AUTO LEVEL pushbutton (11) in the AUTO position and skip step (9). However, to trigger the sweep on a specific portion of the waveform, push the AUTO LEVEL pushbutton (11) again to release it to the NORM position.

9. Adjust TRIGGERING LEVEL control (9) to obtain a synchronized display without jitter. As a starting point, the control may be pushed in and rotated to any point that will produce a sweep, which is usually somewhere in the center portion of its range. The trace will disappear if there is inadequate signal to trigger the sweep, such as when measuring DC or extremely low amplitude waveforms. If no sweep can be obtained, pull the control out (PULL AUTO) for automatic triggering.

10. Set COUPLING switch (12) to the AC position for triggering signals of 30 Hz to 30 MHz, or to the DC position for triggering signals of DC to 30 MHz. If the triggering signal contains noise or is a complex waveform made up of high and low frequency components, the LF REJect and HF REJect positions may be helpful in eliminating jitter from the display. The LF REJect position attenuates trigger signals below 10 kHz (useful to eliminate 60 Hz hum), and the HF REJect position attenuates trigger signals above 30 kHz (useful to eliminate high frequency noise).

11. Set SWEEP TIME/CM switch (5) and VARIABLE control (6) for the desired number of waveforms. These controls may be set for viewing only a portion of a waveform, but the trace becomes progressively *dimmer* as a smaller portion is displayed. This is because the sweep speed increases but the sweep repetition rate does not change.

NOTE

When using very fast sweep speed at low repetition rates, the operator may wish to operate with the intensity control toward maximum. Under these conditions, a retrace "pip" may appear at the extreme left of the trace. This does not in any way affect the oscilloscope operation and may be disregarded.

12. After obtaining the desired number of waveforms, as in step (11), it is sometimes desirable to make a final adjustment of the TRIGGERING LEVEL control (9). The (-) direction selects the most negative point on the waveform at which sweep triggering will occur and the (+) direction selects the most positive point on the waveform at which sweep triggering will occur. The control may be adjusted to start the sweep on any desired portion of the waveform.

13. For a close-up view of a portion of the waveform, pull outward on the ◀▶ POSITION control (8). This expands the sweep by a factor of five (5X magnification) and displays only the *center* portion of the sweep. To view a portion to the left of center, turn the ◀▶ POSITION control clockwise, and to view portions to the right of center, turn the control counterclockwise. Push inward on the control to return the sweep to the normal, non-magnified condition.

NOTES

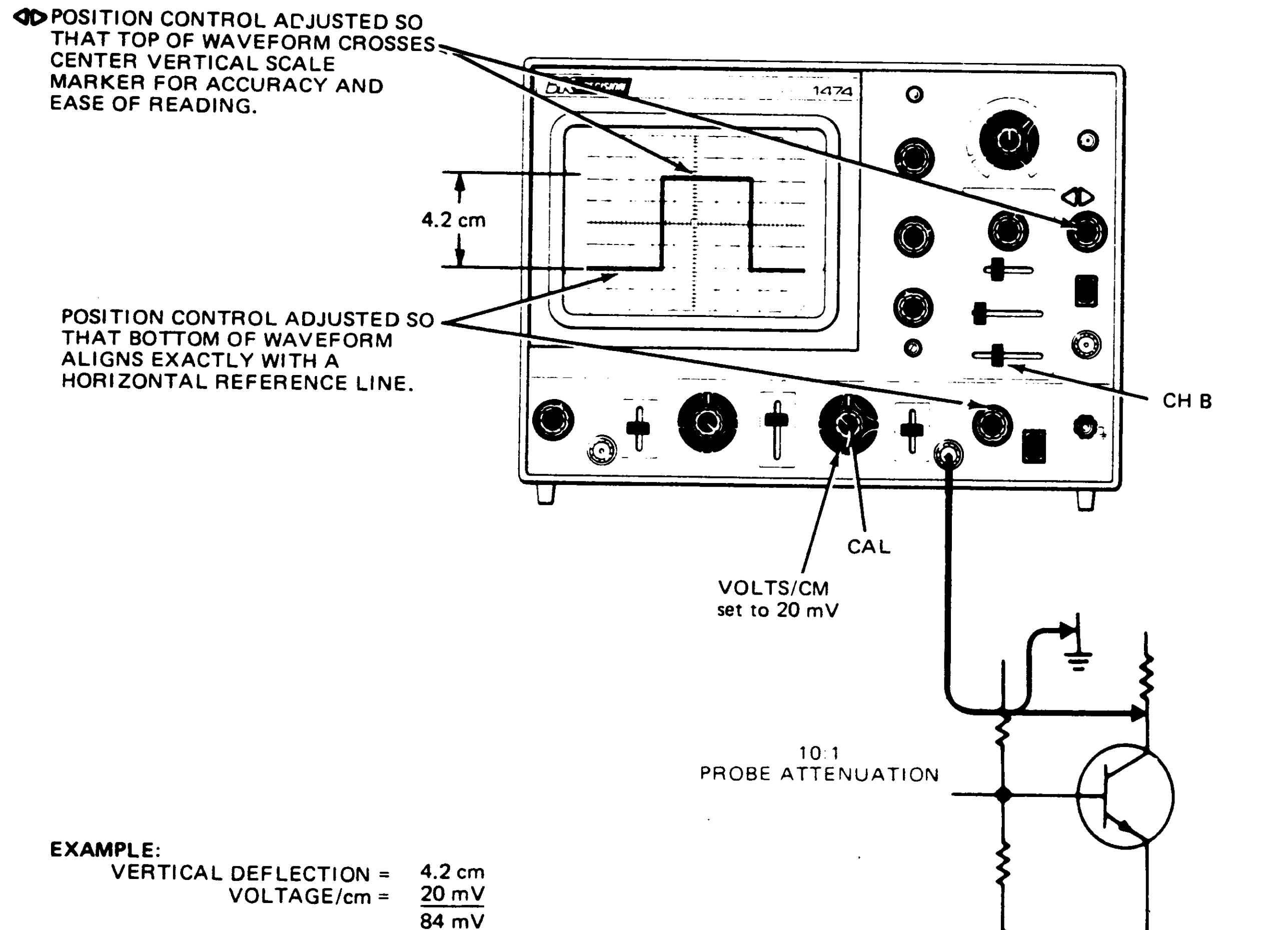
CALIBRATED VOLTAGE MEASUREMENT (See Fig. 4)

Peak voltages, peak-to-peak voltages, DC voltages and voltages of a specific portion of a complex waveform are easily and accurately measured on the Model 1474 oscilloscope.

1. Adjust controls as previously instructed to display the waveform to be measured.
2. Be sure the CH B vertical VARIABLE control (21) is set fully clockwise to the CAL position.
3. Set CH B VOLTS/CM switch (20) for the maximum vertical deflection possible without exceeding the limits of the vertical scale.
4. Read the amount of vertical deflection (in cm) from the scale. The CH B POSITION control (17) may be readjusted to shift the reference point for easier scale reading if desired. When measuring a DC voltage, adjust the CH B POSITION control (17) to a convenient reference with the CH B DC-GND-AC switch (19) in the GND position, then note the amount the trace is deflected when the switch is placed in the DC position. The trace deflects upward for a positive voltage input and downward for a negative voltage input.

NOTE
For an accurate display of high-frequency waveforms above 10 MHz, it is important that (1) the probe be used in the 10:1 position to reduce circuit loading; (2) the oscilloscope controls be set so that the height of the pattern does not exceed 4 cm; and (3) the trace be centered vertically.

5. Calculate the voltage reading as follows: Multiply the vertical deflection (in cm) by the VOLTS/CM control (20) setting (see example in Fig. 4). Don't forget that the voltage reading displayed on the oscilloscope is only 1/10th the actual voltage being measured when the probe is set for 10:1 attenuation. The actual voltage is displayed when the probe is set for DIRect measurement.
6. Calibration accuracy of this oscilloscope may be occasionally checked by observing the 0.5 volt peak-to-peak square wave signal available at the CAL 1kHz ⎍ 0.5 V p-p jack (7). This calibrated source should read exactly 0.5 volt peak-to-peak. If a need for recalibration is indicated, see the MAINTENANCE AND CALIBRATION section of the manual for complete procedures.



EXAMPLE:

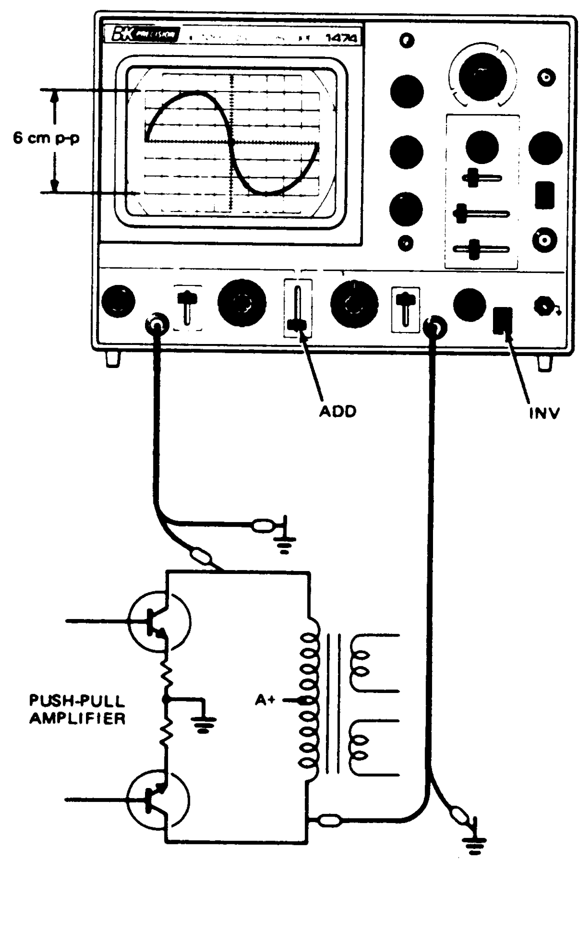
VERTICAL DEFLECTION =	4.2 cm
VOLTAGE/cm =	20 mV
	84 mV
PROBE ATTENUATION =	10
PEAK TO PEAK WAVEFORM =	840 mV or 0.84V

Fig. 4. Typical voltage measurement.

DIFFERENTIAL VOLTAGE MEASUREMENT (See Fig. 5)

This oscilloscope may be used to observe waveforms and measure voltages between two points in a circuit, neither of which is circuit ground. Such measurements as the inputs to a differential amplifier, the output of a phase splitter or push-pull amplifier, the amount of signal developed across a single section of voltage divider or attenuator, and many others, require this technique.

1. Adjust controls as previously described und INITIAL STARTING PROCEDURE.
2. Connect a probe cable to both the CH A and CH B INPUT jacks (26) and (18).
3. Connect ground clips of the two probes to the chassis of equipment under test, and connect tips of the probes to the points in the curcuit where measurements are to be made. It is usually desirable to connect the CH A probe to the higher potential or higher amplitude point in the circuit and the CH B probe to the lower potential or lower amplitude point in the circuit.
4. Set the MODE switch (22) to the CH A position and the SOURCE switch (14) to the CH A position and adjust the controls as previously instructed in the SINGLE-TRACE WAVEFORM OBSERVATION procedure to obtain a synchronized single waveform of 2 to 6 cm vertical height with the CH A VARIABLE control (24) set to CAL.
5. If only the AC component of the waveform is of interest, use the following procedure:
   a. Set CH A and CH B DC-GND-AC switches (25) and (19) both to the AC position.
   b. Set CH B VARIABLE control (21) to CAL and the CH B VOLTS/CM switch (20) to the same sensitivity as the CH A VOLTS/CM switch (23).
   c. If the Channel A and Channel B inputs are in phase, set the MODE switch (22) to the ADD position and the CH B POLARITY pushbutton to the INV position. The displayed waveform is the peak-to-peak difference between the two points of measurement. If the waveform is small, the vertical sensitivity may be increased but the CH A and CH B VOLTS/CM switches must both be set to the same sensitivity.
   d. If the Channel A and Channel B inputs are 180° out of phase, such as the output of a push-pull amplifier, set the MODE switch (22) to the ADD position and the CH B POLARITY pushbutton to the INV position to measure the full peak-to-peak waveform. Set the CH B POLARITY switch to the NORM position to measure any imbalance between the two points of measurement. Readjust the VOLTS/CM switches (20) and (23) as required to obtain as large a waveform as possible without exceeding the limits of the vertical scale, but always keep the CH A and CH B switches set to the same sensitivity.
   e. Position the waveform as desired with the positioning controls and calculate the peak-to-peak voltate as described in the CALIBRATED VOLTAGE MEASUREMENT procedure.
6. If a DC voltage, or the DC component of the waveform is of interest, use the following procedure:
   a. Set CH A DC-GND-AC switch (25) to the DC position.
   b. Position the CH A VOLTS/CM switch (23) to keep the trace within the limits of the vertical scale. Use the CH A POSITION control (27) to align the trace with one of the lines on the scale for reference.



EXAMPLE:
VERTICAL DEFLECTION = 6 cm
VOLTAGE/cm = 20 mV
120 mV
PROBE ATTENUATION = 20
(2 PROBES @ 10:1)
PEAK TO PEAK WAVEFORM = 2400 mV or 2.4V

Fig. 5. Typical differential voltage measurement.

c. Set CH B VOLTS/CM switch (20) to the same sensitivity as the CH A VOLTS/CM switch.

d. Set the MODE switch (22) to the ADD position, CH B DC-GND-AC switch (19) to the GND position and adjust out any error that may be introduced by the Channel B positioning control as follows: Alternately set the CH B POLARITY switch to the NORM and INV positions, adjusting the CH B POSITION control until the trace position does not shift as the switch position changes. Remember that this step is *not* necessary if the DC component of the signal is not measured (switches 19 and 25 in the AC position).

e. Return CH B DC-GND-AC switch (19) to the DC position.

f. Momentarily return the MODE switch (22) to the CH A position and note the trace position for reference. You may readjust it with the Channel A vertical positioning control, but not the Channel B control. Place the MODE switch in the ADD position and the CH B POLARITY switch in the INV position. The amount of displacement of the trace from the Channel A reference represents the voltage differential between the two points of measurement.

CALIBRATED TIME MEASUREMENT (See Fig. 6)

Pulse width, waveform periods, circuit delays and all other waveform time durations are easily and accurately measured on this oscilloscope. Calibrated time measurements from .5 second per centimeter down to 40 nanoseconds per centimeter are possible. At low sweep speeds, the entire waveform is not visible at one time However, the bright spot can be seen moving from left to right across the screen, which makes the beginning and ending points of the measurement easy to spot.

1. Adjust controls as previously described for a stable display of the desired waveform.
2. Be sure the sweep time VARIABLE control (6) is fully clockwise to the CAL position.
3. Set the SWEEP TIME/CM control (5) for the largest possible display of the waveform segment to be measured, usually one cycle.
4. If necessary, readjust the TRIGGERING LEVEL control (9) for the most stable display.
5. Read the amount of the horizontal deflection (in cm) between the points of measurement. The ◄► POSITION control (8) may be readjusted to align one

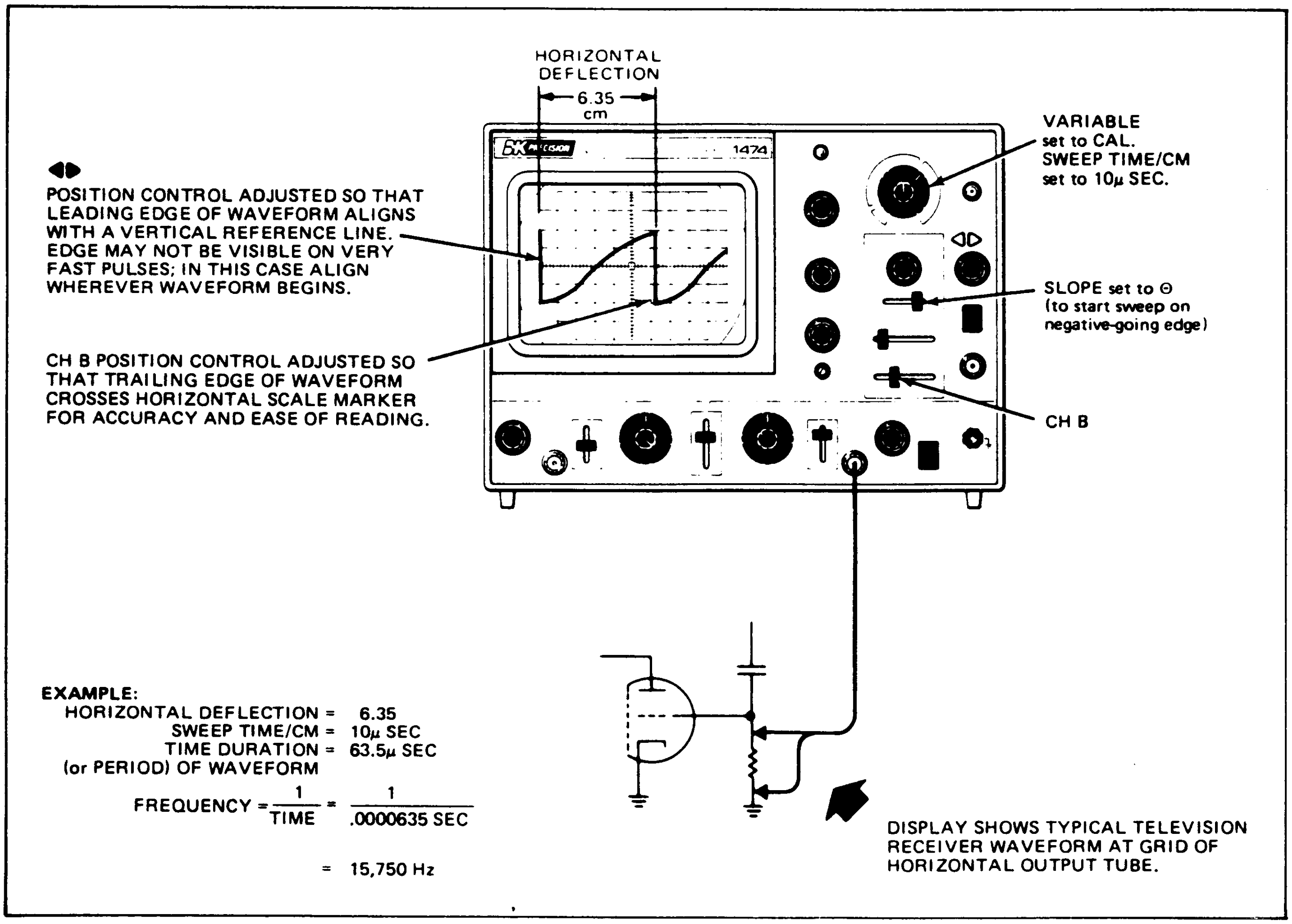


Fig. 6. Typical time measurement.

of the measurement points with a vertical scale marker for easier reading.

6. Calculate the time duration as follows: Multiply the horizontal deflection (in cm) by the SWEEP TIME/CM switch (5) setting (see example in Fig. 5). Remember, when the 5X magnification is used, the result must be divided by 5 to obtain the actual time duration.

7. Time measurements often require external sync. This is especially true when measuring delays. The sweep is started by a sync signal from one circuit and the waveform measured in a subsequent circuit. This allows measurement of the display between the sync pulse and the subsequent waveform. To perform such measurements using external sync, use the following steps:

   a. Set the SOURCE switch (14) to EXT.

   b. Connect a cable from the EXT TRIG jack (13) to the source of sync signal.

   c. Set the SLOPE switch (10) to the (+) or (-) position for the proper polarity for the sync signal.

   d. Readjust the TRIGGERING LEVEL control (9) if necessary for a stable waveform.

   e. If measuring a delay, measure the time from the start of the sweep to the start of the waveform.

8. Another excellent method for measuring time delays is with dual-trace operation. The procedures are given in the DUAL-TRACE APPLICATIONS section of the manual.

EXTERNAL HORIZONTAL INPUT (X-Y OPERATION)

For some measurements, an *external* horizontal deflection signal is required. This is also referred to as an X-Y measurement, where the Y input provides vertical deflection and the X input provides horizontal deflection. The horizontal input may be a sinusoidal wave, such as for phase measurement, or an external sweep voltage. This input must be 5 mV to 5 V per cm of deflection; thus any voltage of 50 mV or greater is sufficient for satisfactory operation. With a 10:1 probe, voltage up to 500 V p-p may be used. To use an external horizontal input, use the following procedure:

1. Set the SWEEP TIME/CM switch (5) fully clockwise to the CH B position.

2. Use the Channel A probe for the vertical input and the Channel B probe for the horizontal input.

3. Adjust the amount of horizontal deflection with the CH B VOLTS/CM and VARIABLE controls (20) and (21).

4. The CH B (vertical) POSITION control (17) now serves as the horizontal position control, and the ◂▸ POSITION control is disabled.

NOTE

Do NOT use the PULL 5X MAG control during X-Y operation. Use the CH B VARIABLE and VOLTS/CM controls to adjust horizontal gain.

5. All sync controls are disconnected and have no effect.

Z-AXIS INPUT

The trace displayed on the screen may be intensity modulated (Z-axis input) where frequency or time-scale marks are required. A 5-volt peak-to-peak or greater signal applied at the INT MOD (intensity modulation) jack (36) on the rear of the oscilloscope will provide alternate brightness and blanking of the trace. See Fig. 7.

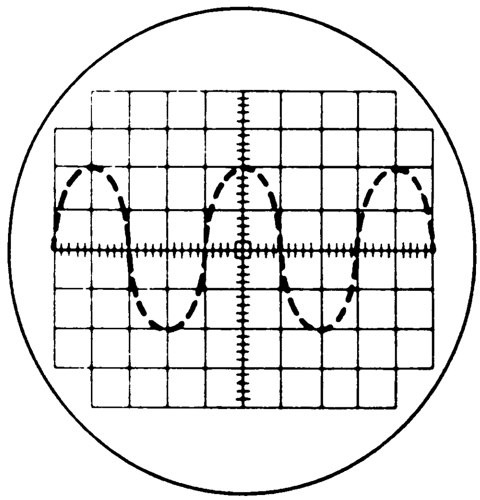


Fig. 7. Oscilloscope trace with Z-axis input.

DUAL-TRACE WAVEFORM OBSERVATION (Refer to Fig. 8)

In observing simultaneous waveforms on Channels A and B, it is necessary that the waveforms be related in frequency or that one of the waveforms by synchronized to the other although the basic frequencies may be different. An example of this is in checking a frequency divider or multiplier. The reference, or "clock" frequency can be used on Channel A, for example, and the multiple or submultiple of this reference frequency will be displayed on Channel B. In this way, when the waveform display of Channel A is synchronized, the display on Channel B will also be in sync with the Channel A display. If two waveforms having no phase or frequency relationship to each other are displayed simultaneously, it will be difficult if not impossible to lock both waveforms in sync for any useful observation.

To display two waveforms simultaneously for observation, use the following procedure:

1. Perform the steps of INITIAL STARTING PROCEDURE.

2. Connect oscilloscope probe cables to both the CH A and CH B INPUT jacks (26) and (18).

3. If the recommended **B & K-Precision** Model PR-36 oscilloscope probes are used, 10:1 attenuation should be used except for waveforms of 50 mV peak-to-peak or less. For the lower amplitude waveforms the DIRect position should be used. See Fig. 3 for changing the probe from 10:1 to DIR or vice versa. Whenever possible, use the high impedance, low capacity 10:1 position to minimize circuit loading.

4. Set MODE switch (22) to the DUAL position. Two traces should appear on the screen.

5. Adjust CH A and CH B POSITION controls (27) and (17) to place the Channel A trace above the Channel B trace, and adjust both traces to a convenient reference mark on the scale.

6. Set both the CH A and CH B DC-GND-AC switches (25) and (19) to the AC position. This is the position used for most measurements and must be used if the points being measured include a large DC component.

7. Connect the ground clips of the probes to the chassis ground of the equipment under test. Connect the tips of the probes to points in the circuit where the waveforms are to be measured. It is preferred that the signal to which the waveform will be synchronized be applied to the Channel A input.

WARNING

a. If the equipment under test is a transformerless AC unit, use an isolation transformer to prevent dangerous electrical shock.

b. The peak-to-peak voltage at the point of measurement should not exceed 600 volts.

8. Set the VOLTS/CM controls (23) and (20) or Channel A and B to a position that gives 2 to 3 cm vertical deflection. The displays on the screen will probably be unsynchronized. The remaining steps, although similar to those outlined for single-trace operation, describe the procedure for obtaining stable, synchronized displays.

9. Set the SOURCE switch (14) to the CH A position. This provides internal sync so that the Channel A waveform being observed is also used to trigger the sweep. If desired, the Channel B waveform may be used to trigger the sweep by setting the SOURCE switch to the CH B position. Often in dual-trace operation, a sync source other than the measurement point for Channel A or B is required. In this case set the SOURCE switch to the EXT position and connect a cable from the EXT TRIG jack (13) to the sync source.

10. Set the SLOPE switch (10) to the (+) position if the sweep is to be triggered by a positive-going wave, or to the (-) position if the sweep is to be triggered by a negative-going wave.

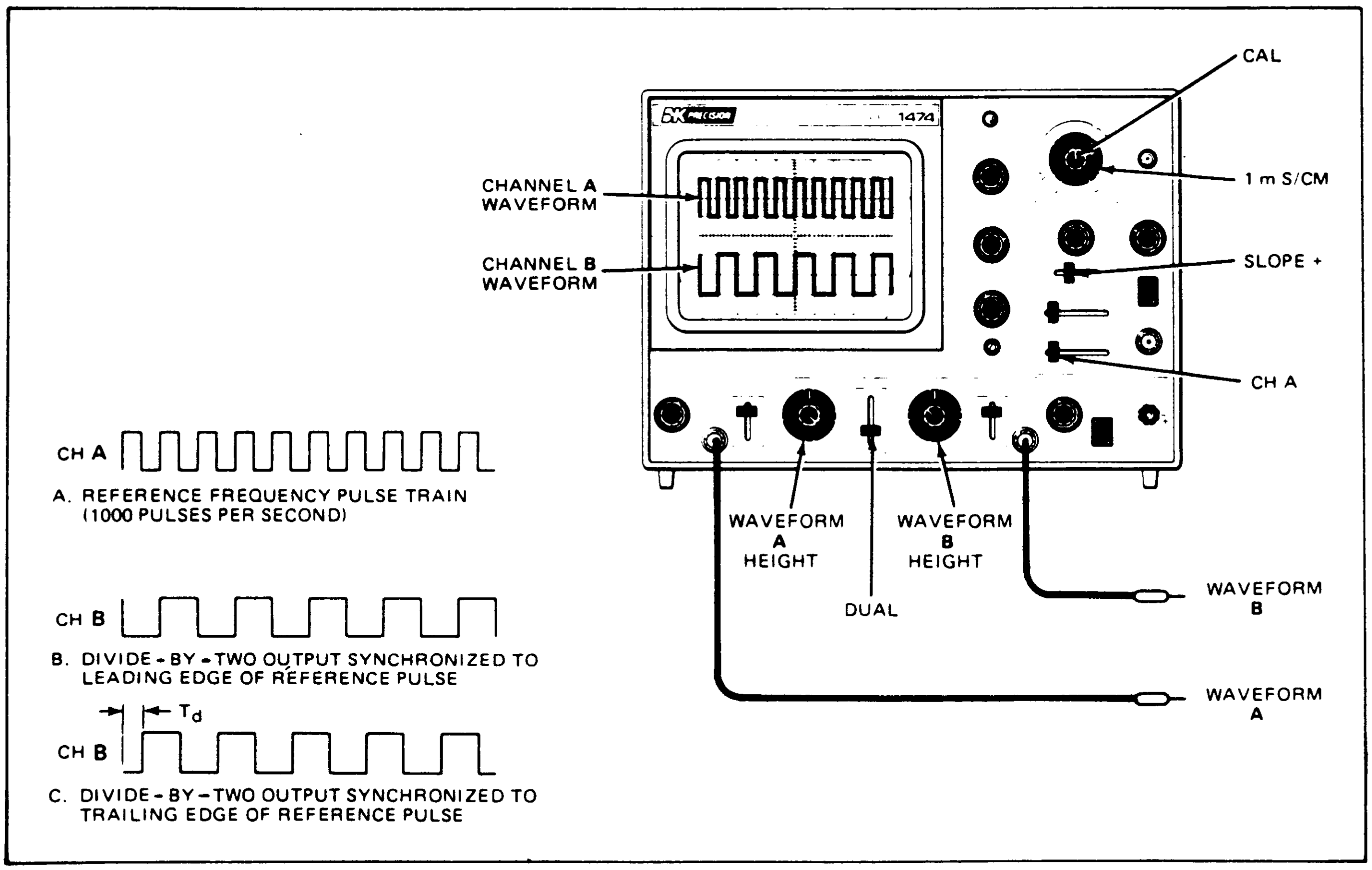


Fig. 8. Waveforms in divide-by-two circuit.

11. If sweep triggering on the average level of the waveform is acceptable, leave AUTO LEVEL pushbutton (11) in the AUTO position and skip step 12. However, to trigger the sweep on a specific portion of the waveform, push the AUTO LEVEL pushbutton, releasing it to the NORM position.

12. Adjust TRIGGERING LEVEL control (9) to obtain a stable, synchronized sweep. As a starting point, the control may be pushed in and rotated to any point that will produce a sweep, which is usually somewhere in the center portion of its range. The trace will disappear if there is inadequate signal to trigger the sweep, such as when measuring extremely low amplitude signals. If no sweep can be obtained, pull out the control (PULL AUTO) for automatic triggering.

13. Set COUPLING switch (12) to the AC position for AC coupling of sync signals from 30 Hz to 30 MHz, and to the DC position for DC coupling of sync signals from DC to 30 MHz. If the sync signal contains noise or is a complex waveform made up of high and low frequencies, the LF REJect and HF REJect positions may be helpful in eliminating jitter from the display. The LF REJ position attenuates sync signal components below 10 kHz, and the HF REJ position attenuates sync signal components above 30 kHz.

14. Set SWEEP TIME/CM switch (5) and VARIABLE control (6) for the desired number of waveforms. These controls may be set for viewing only a portion of a waveform, but the trace becomes progressively dimmer as a smaller portion is displayed.

15. After obtaining the desired number of waveforms as in step 14, it is sometimes desirable to make a final adjustment of the TRIGGERING LEVEL control (9). The (-) direction of rotation selects the most negative point on the sync waveform at which sweep triggering will occur and the (+) direction selects the most positive point on the sync waveform at which sweep triggering will occur. The control may be adjusted to start the sweep on any desired portion of the sync waveform.

16. The observed waveforms of Channels A and B can be expanded by a factor of 5 by pulling outward on the ◀▶ POSITION control (8). This control can then be rotated clockwise or counterclockwise to view the left and right extremes of the waveform displays as desired. Push inward on the control to return the sweep to the normal, non-magnified condition.

17. Calibrated voltage measurements, calibrated time measurements and operation with Z-axis input are identical to those previously described for single-trace operation. Either the Channel A or Channel B vertical adjustment controls can be used as required in conjunction with the horizontal sweep controls to obtain the required amplitude or time interval measurements. This can be done either by using the dual display facilities such as the DUAL position of the MODE switch or by reverting to single-trace operation, using the CH A or CH B positions of the MODE switch.

18. The Channel A and Channel B waveform displays can be added algebraically by placing the MODE switch in the ADD position, and the CH B POLARITY switch is in the NORM position, or algebraically subtracted with the CH B POLARITY switch in the INV position.

DUAL-TRACE APPLICATIONS

INTRODUCTION

The most obvious and yet the most useful feature of the dual-trace oscilloscope is that it has the capability for viewing simultaneously two waveforms that are frequency-or-phase-related, or that have a common synchronizing voltage, such as in digital circuitry. Simultaneous viewing of "cause and effect" waveforms is an invaluable aid to the circuit designer or the repairman. Several possible applications of the dual-trace oscilloscope will be reviewed in detail to familiarize the user further in the basic operation of this oscilloscope.

FREQUENCY DIVIDER WAVEFORMS

Fig. 8 illustrates the waveforms involved in a basic divide-by-two circuit. Fig. A indicates the reference or "clock" pulse train. Fig. B and Fig. C indicate the possible outputs of the divide-by-two circuitry. Fig. 8 also indicates the settings of specific oscilloscope controls for viewing these waveforms. In addition to these basic control settings, the TRIGGERING LEVEL control, as well as the Channel A and Channel B vertical position controls should be set as required to produce suitable displays. In the drawing of Fig. 8, the waveform levels of 2 cm are indicated. If the exact voltage amplitudes of the Channel A and Channel B waveforms are desired, the Channel A and Channel B VARIABLE controls must be placed in the CAL position. The Channel B waveform may be either that indicated in Fig. 8B or 8C. In Fig. 8C the divide-by-two output waveform is shown for the case where the output circuitry responds to a negative-going waveform. In this case, the output waveform is shifted with respect to the leading edge of the reference frequency pulse by a time interval corresponding to the pulse width.

DIVIDE-BY-8 CIRCUIT WAVEFORMS

Fig. 9 indicates waveform relationships for a basic divide-by-eight circuit. The basic oscilloscope settings are identical to those used in Fig. 8. The reference frequency of Fig. 9A is supplied to the Channel A input, and the divide-by-eight output is appliced to the Channel B input. Fig. B indicates the ideal time relationship between the input pulses and the output pulse.

In an application where the logic circuitry is operating at or near its maximum design frequency, the accumulated rise time effects of the consecutive stages produce a built-in time propagation delay which can be significant in a critical circuit and must be compensated for. Fig. 9C indicates the possible time delay which may be introduced into a frequency divider circuit. By use of the dual-trace oscilloscope the input and output waveforms can be superimposed to determine the exact amount of propagation delay that occurs.

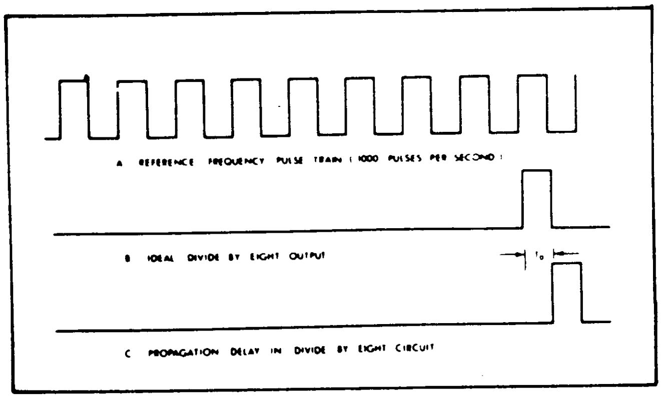


Fig. 9. Waveforms in divide-by-eight circuit.

PROPAGATION TIME MEASUREMENT

An example of propagation delay in a divide-by-eight circuit was given in the previous paragraph. Significant propagation delay may occur in any circuit with several consecutive stages. This oscilloscope has features which simplify measurement of propagation delay. Fig. 10 shows the resultant waveforms when the dual-trace presentation is combined into a single-trace presentation by selecting the ADD position of the MODE switch. With the CH B POLARITY switch in the NORM position the two inputs are algebraically added in a single trace display. Similarly, in the INV position the two inputs are algebraically substracted. Either position provides a precise display of the propagation time (T_p). Using the procedures given for calibrated time measurement, T_p can be calculated. A more precise measurement can be obtained if the Tp portion of the waveform is expanded horizontally. This may be done by pulling the PULL 5X MAG control. It also may be possible to view the desired portion of the waveform at a faster sweep speed.

DIGITAL CIRCUIT TIME RELATIONSHIPS

A dual-trace oscilloscope is a necessity in designing, manufacturing and servicing digital equipment. A dual-trace oscilloscope permits easy comparison of time relationships between two waveforms.

In digital equipment it is common for a large number of circuits to be synchronized, or to have a specific time relationship to each other. Many of the circuits are frequency dividers as previously described, but waveforms are often time-related in may other combinations. In the dynamic state, some of the waveforms change, depending upon the input or mode of operation. Fig. 11 shows a typical digital circuit and identifies several of the points at which waveform measurements are appropriate. The accompanying Fig. 12 shows the normal waveforms to be expected at each of these points and their timing relationships. The individual waveforms have limited value unless their timing relationship to one or more of the other waveforms is known to be correct. The dual-trace oscilloscope allows this comparison to be made. In typical fashion, waveform No. 3 would be displayed on Channel A and waveform No. 4 thru No. 8, and No. 10, would be successively displayed on Channel B, although other timing comparisons may be desired. Waveforms No. 11 through No. 13 would probably be displayed on Channel B in relationship to waveform No. 8 or No. 4 on Channel A.

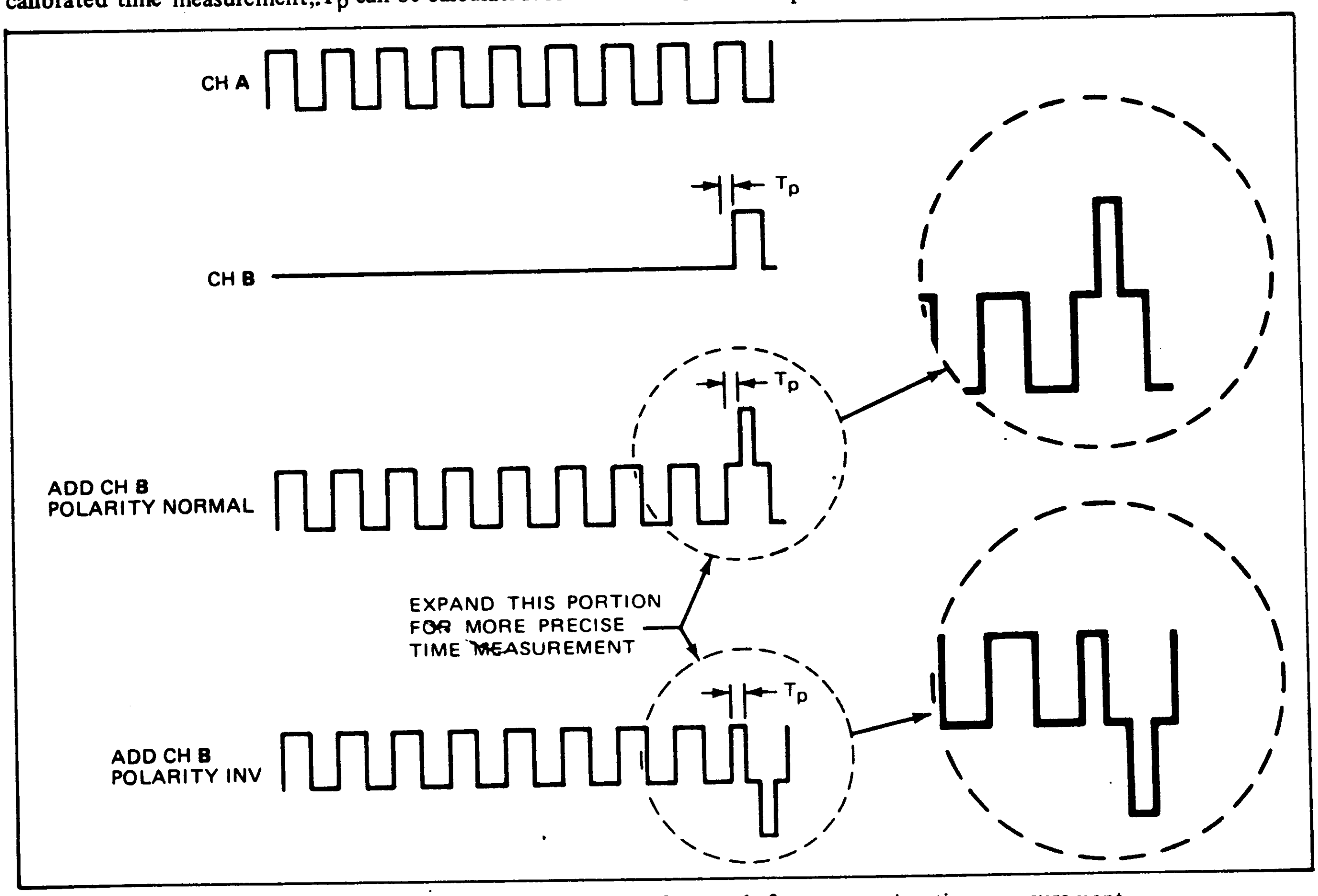


Fig. 10. Using ADD and CH B POLARITY controls for propagation time measurement.

In the family of time-related waveforms shown in Fig. 12, waveform No. 8 or No. 10 is an excellent sync source for viewing all of the waveforms; there is but one triggering pulse per frame. For convenience, external sync using waveform No. 8 or No. 10 as the sync source may be desirable. With external sync, any of the waveforms may be displayed without readjustment of the sync controls. Waveforms No. 4 thru No. 7 should not be used as the sync source because they do not contain a triggering pulse at the start of the frame. It would not be necessary to view the entire waveforms as shown in Fig. 12 in all cases. In fact, there are many times when a closer examination of a portion of the waveforms would be appropriate. In such cases, it is recommended that the sync remain unchanged while the sweep speed or 5X magnification be used to expand the waveform display.

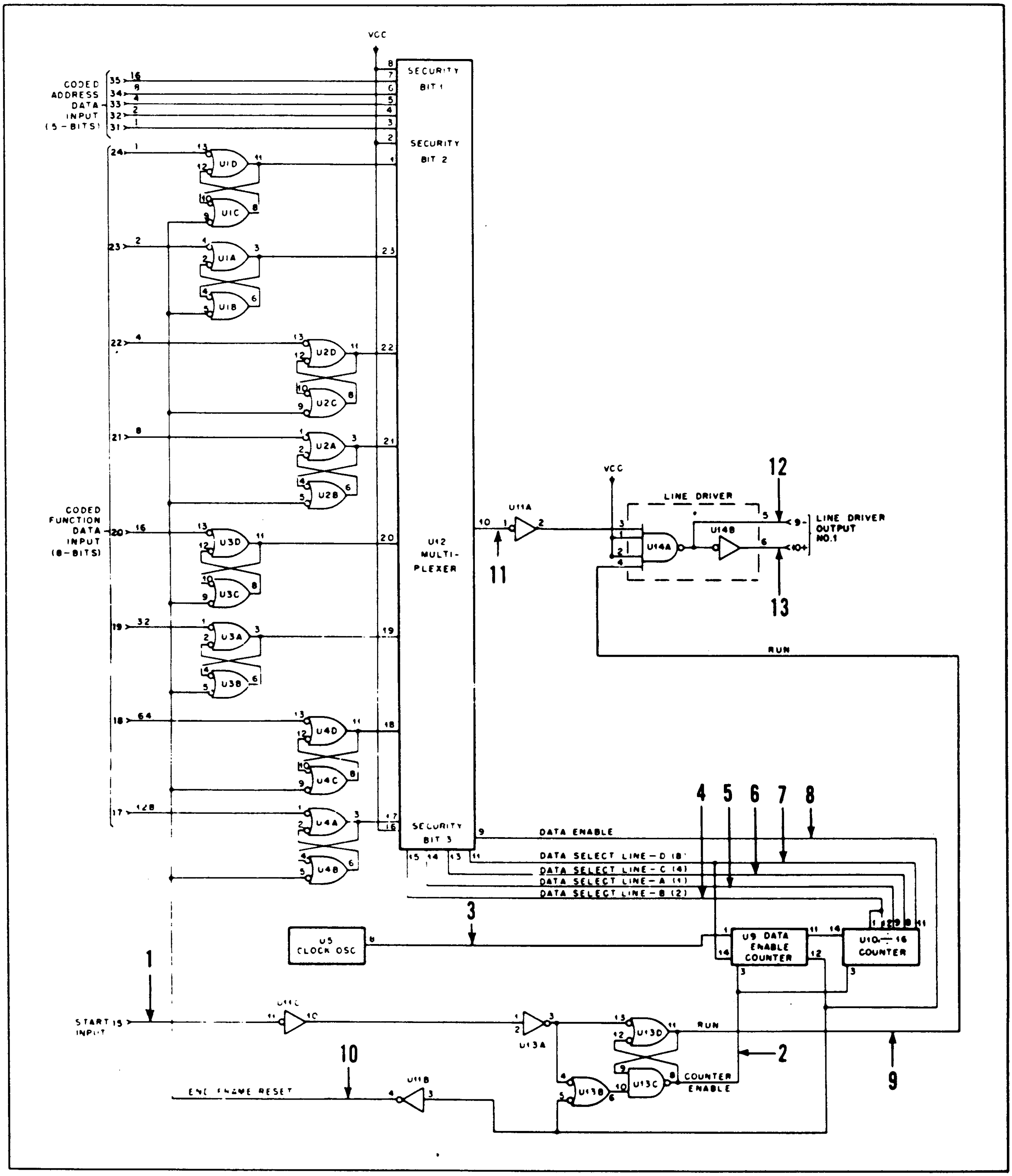


Fig. 11. Typical digital circuit using several time-related waveforms.

DISTORTION MEASUREMENT

An amplifier stage, or an entire amplifier unit, may be tested for distortion with this oscilloscope. This type of measurement is especially valuable when the slope of a waveform must be faithfully reproduced by an amplifier. Fig. 13 shows the testing of such a circuit using a triangular wave, such as is typically encourntered in the recovered audio output of a limiting circuit which precedes the modulator of a transmitter. The measurement may be made using any type of signal; merely use the type of signal for testing that is normally applied to the amplifier during normal operation. The procedure for distortion testing follows:

1. Apply the type of signal normally encountered in the amplifier under test.
2. Connect Channel A probe to the input of the amplifier and Channel B probe to the output of the amplifier. It is preferable if the two signals are not inverted in relationship to each other, but inverted signals can be used.
3. Set CHA and CH B DC-GND-AC switches to AC.
4. Set MODE switch to DUAL.
5. Set sync SOURCE switch to CH A and adjust controls as described in waveform viewing procedure for synchronized waveforms.
6. Adjust the CH A and CH B POSITION controls to superimpose the waveforms directly over each other.
7. Adjust the CH A and CH B vertical sensitivity controls (VOLTS/CM and VARIABLE) so that the waveforms are as large as possible without exceeding the limits of the scale, and so that both waveforms are exactly the same height.
8. Now set the MODE switch to the ADD position and the CH B POLARITY switch to the INV position (if one waveform is already inverted in relationship to the other, use the NORM position). Adjust the fine vertical sensitivity (CH B VARIABLE) slightly for the mini-

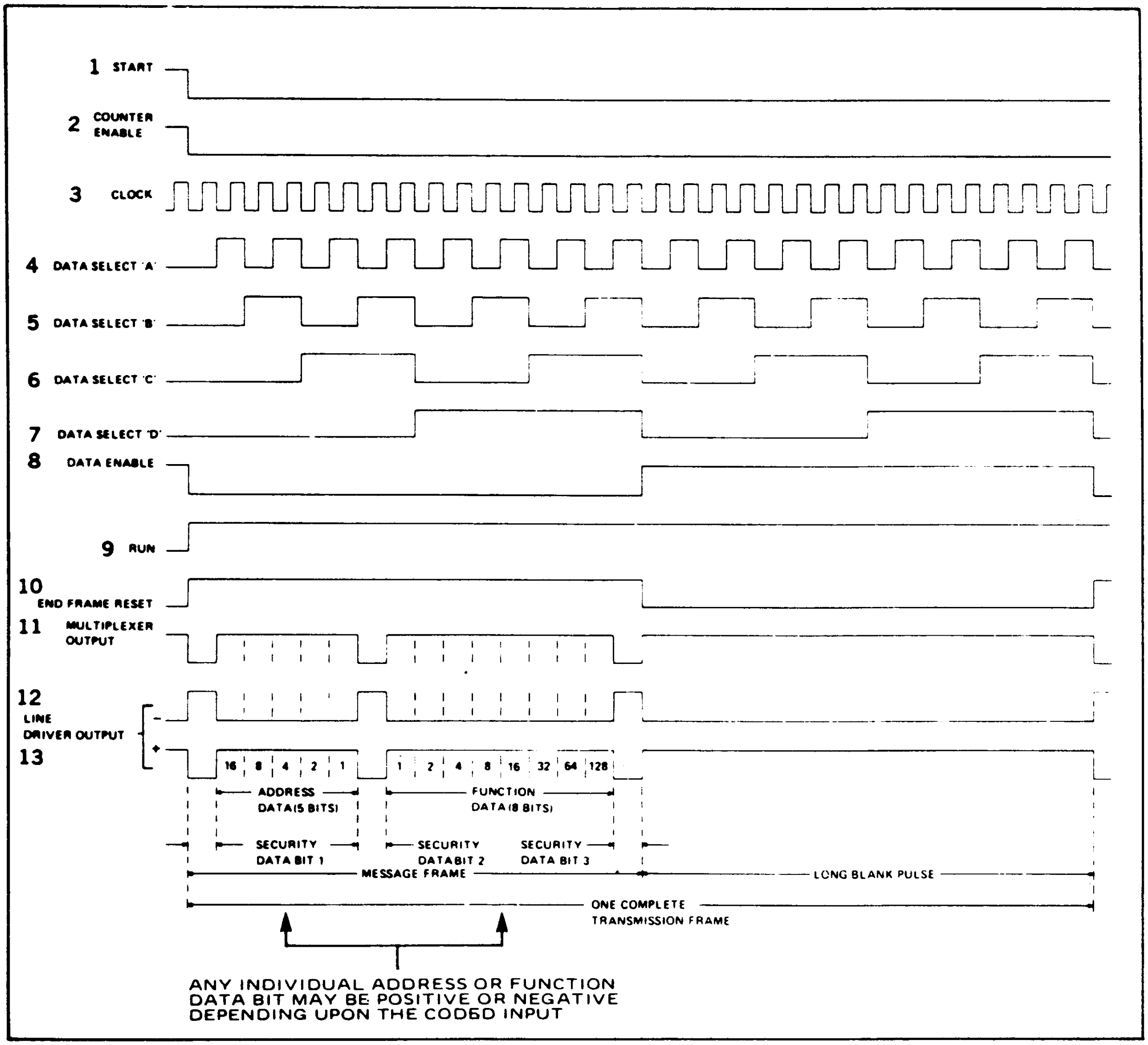


Fig. 12. Family of time-related waveforms from typical digital circuit in Fig. 11.

mum remaining waveform. Any waveform that remains equals distortion; if the two waveforms are exactly the same amplitude and there is no distortion, the waveforms will cancel and there will be only a straight horizontal line remaining on the screen.

GATED RINGING CIRCUIT

The circuit and waveforms of Fig. 14 are shown to demonstrate the type of circuit in which the dual-trace oscilloscope is effective both in design and troubleshooting applications. The basic oscilloscope control settings are identical to those of Fig. 8. Waveform A is the reference waveform and is applied to Channel A input. All other waveforms are sampled at Channel B and compared to the reference waveform of Channel A. The frequency burst signal can be examined more closely either by increasing the sweep time per centimeter to .5 mSEC per centimeter or by pulling out on the ◄► POSITION control to obtain 5 times magnification. This control can then be rotated as desired to center the desired waveform information on the oscilloscope screen.

DELAY LINE TESTS

The dual-trace feature of the oscilloscope can also be used to determine the delay times of transmission type delay lines as well as ultrasonic type delay lines. The input pulse can be used to trigger or synchronize the Channel A display and the delay line output can be observed on Channel B. A repetitive type pulse will make it possible to synchronize the displays. The interval between repetitive pulses should be large compared to the delay time to be

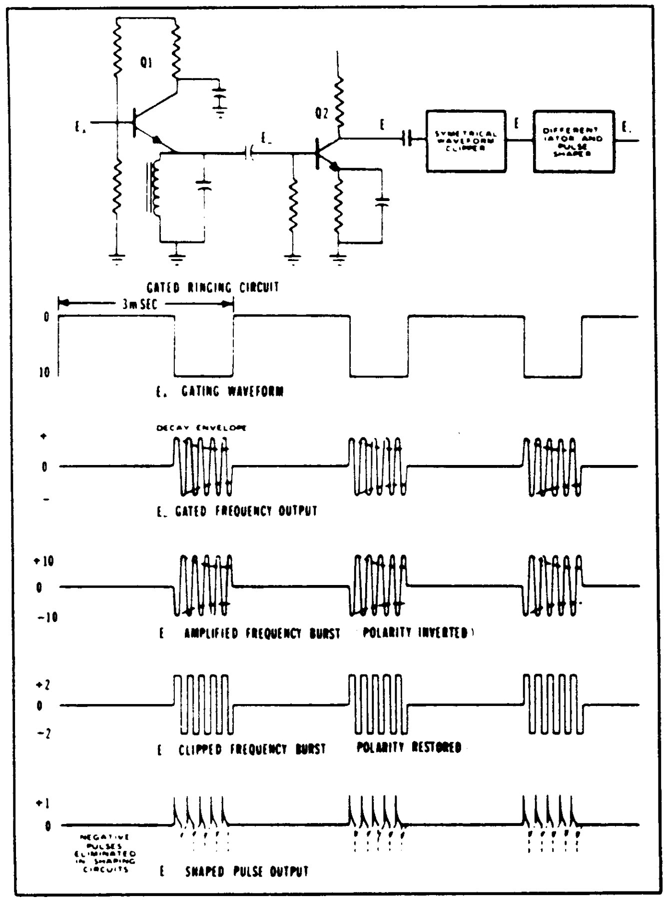


Fig. 14. Gated ringing circuit and waveforms.

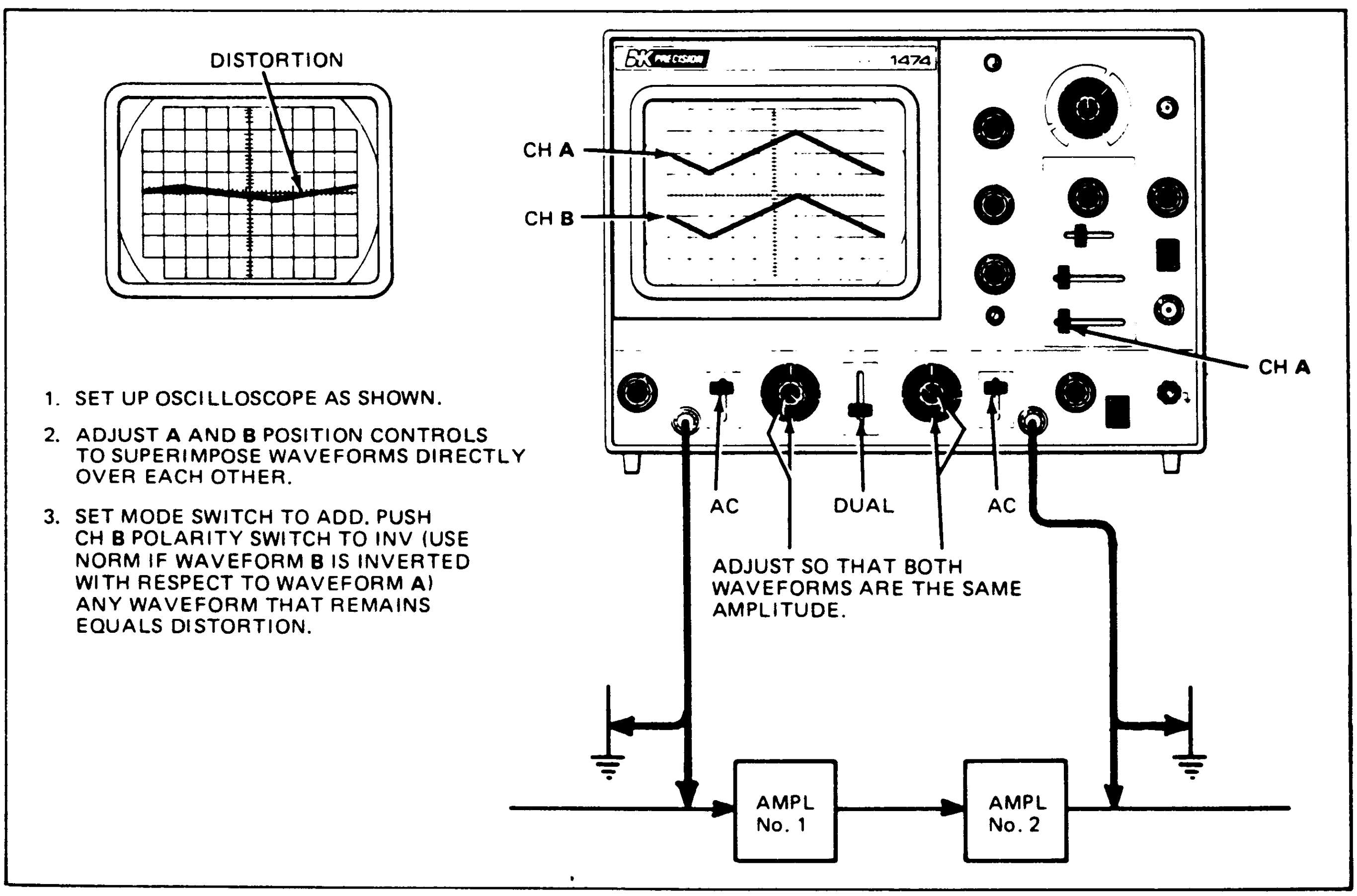


Fig. 13. Distortion measurement.

investigated. In addition to determining delay time, the pulse distortion inherent in the delay line can be determined by examination of the delayed pulse observed on the Channel B waveform display. Fig. 15 demonstates the typical oscilloscope settings as well as the basic test circuit. Typical input and output waveforms are shown on the oscilloscope display. Any pulse stretching and ripple can be observed and evaluated. The results of modifying the input and output terminations can be observed directly.

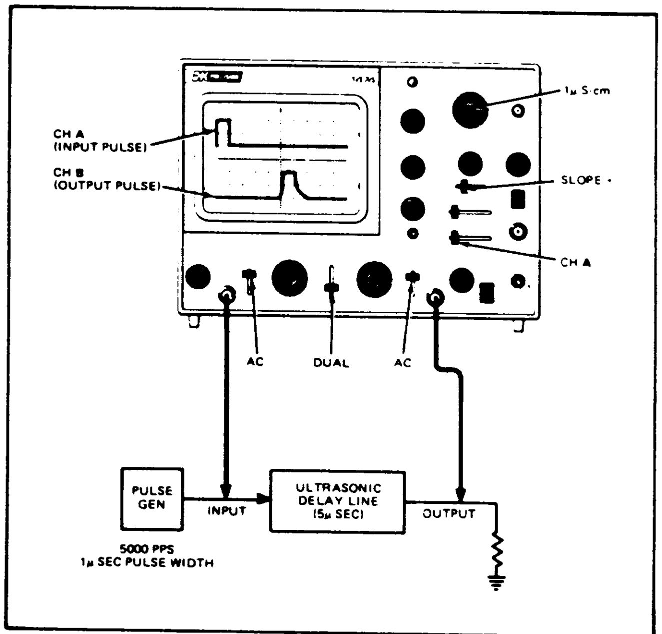


Fig. 15. Delay line measurements.

STEREO AMPLIFIER SERVICING

Another convenient use for dual-channel oscilloscopes is in troubleshooting stereo amplifiers. If identical channel amplifiers are used and the output of one is weak, distorted or otherwise abnormal, the dual trace oscilloscope can be efficiently used to localize the defective state. With an identical signal applied to the inputs of both amplifiers, a side-by-side comparison of both units can be made by progressively sampling identical signal points in both amplifiers. When the defective or malfunctioning stage has been located, the effects of whatever troubleshooting and repair methods are employed can be observed and analyzed immediately.

IMPROVING THE RATIO OF DESIRED-TO-UNDESIRED SIGNALS

In some applications, the desired signal may be riding on a large undesired signal component such as 60 Hz. It is possible to minimize or for practical purposes eliminate the undesired component. Fig. 16 indicates the oscilloscope control settings for such an application. The waveform display of Channel A indicates the desired signal and the dotted line indicates the average amplitude variation corresponding to an undersired 60 Hz component. The Channel B display indicates a 60 Hz waveform of equal amplitude and identical phase to the average of the Channel 1 waveform. With the MODE switch set to ADD, and the CH B POLARITY switch set to INV, and by adjusting the CH B vertical attenuator controls, the 60 Hz component of the Channel A signal can be cancelled by the Channel B input and the desired waveform can be observed without the 60 Hz component.

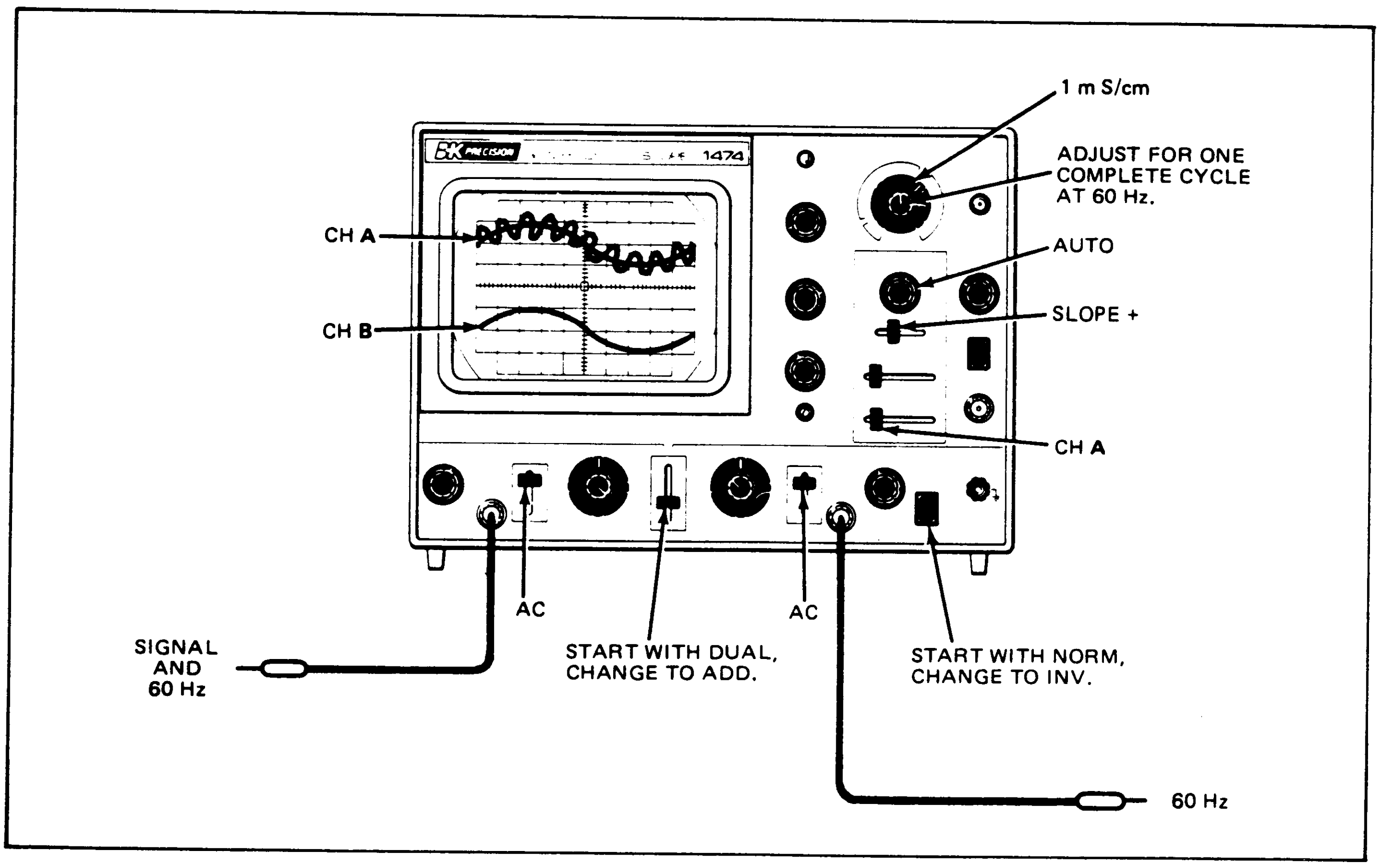


Fig. 16. Improving desired-to-undesired signal ratio.

In the single-trace application section of this manual phase shift measurements using a single trace are described. In addition, in the square wave testing section, square wave distortion is explained in terms of phase shift of the signal components which comprise the square wave. These phase shifts can be verified directly by providing a sine wave input signal to the amplifier and observing the phase of the output signal with respect to the input signal.

In all amplifiers, a phase shift is always associated with a change in amplitude response. For example, at the -3 dB response points, a phase shift of 45° occurs. Fig. 17 illustrates a method of determing amplifier phase shift directly. In this particular case, the measurements are being made at approximately 5000 Hz. The input signal to the audio amplifier is used as a reference and is applied to the CH A INPUT jack.

The sweep time VARIABLE control is adjusted as required to provide a complete cycle of the input waveform displayed on 8 cm horizontally. A waveform height of 2 cm is used. The 8 cm display represents 360° at the displayed frequency and each centimeter represents 45° of the waveform. The signal developed across the output of the audio amplifier is applied to the Channel B INPUT jack. The vertical attenuator controls of Channel B are adjusted as required to produce a peak-to-peak waveform of 2 cm as shown in Fig. 17B.

The CH B POSITION control is then adjusted so that the Channel B waveform is displayed on the same horizontal axis as the Channel A waveform as shown in Fig. 17B. The distance between corresponding points on the horizontal axis for the two waveforms then represents the phase shift between the two waveforms. In this case, the zero crossover points of the two waveforms are compared. It is shown that a difference of 1 centimeter exists. This is then interpreted as a phase shift of 45°.

INTRODUCTION

In addition to the dual-trace applications previously outlined, there are, of course, many service and laboratory applications where only single-trace operation of the oscilloscope is required. After gaining experience with the oscilloscope, the user will be able to make the judgment as to whether a job can be performed more efficiently by using the single-trace or the dual-trace method of operation. The following are applications in which single-trace operation is adequate. In several cases, it will be found that an alternate method using the dual-trace application has been described for the same application. For all the following applications the most flexible operation will be achieved if the Channel B vertical amplifier is used with the MODE switch in the CH B position. This arrangement provides complete triggered sweep as well as free-running operation of the oscilloscope, and, in addition, by using the CH B POLARITY switch, whatever waveform is obtained can be inverted in polarity if desired by the operator.

SIGNAL-TRACING AND PEAK-TO-PEAK VOLTAGE READINGS

For general troubleshooting and isolation of troubles in almost any electronic equipment, the oscilloscope is an indispensable instrument. It provides a visual display of absence or presence of normal signals. This method (signal-tracing) may be used to trace a signal by measuring several points in the signal path. As measurements proceed along the signal path, a point may be found where the signal disappears. When this happens, the source of trouble has been located.

However, the oscilloscope shows much more than the mere presence or absence of signal. It provides a peak-to-peak voltage measurement of the signal. The cause of poor performance can often be located by making such peak-to-

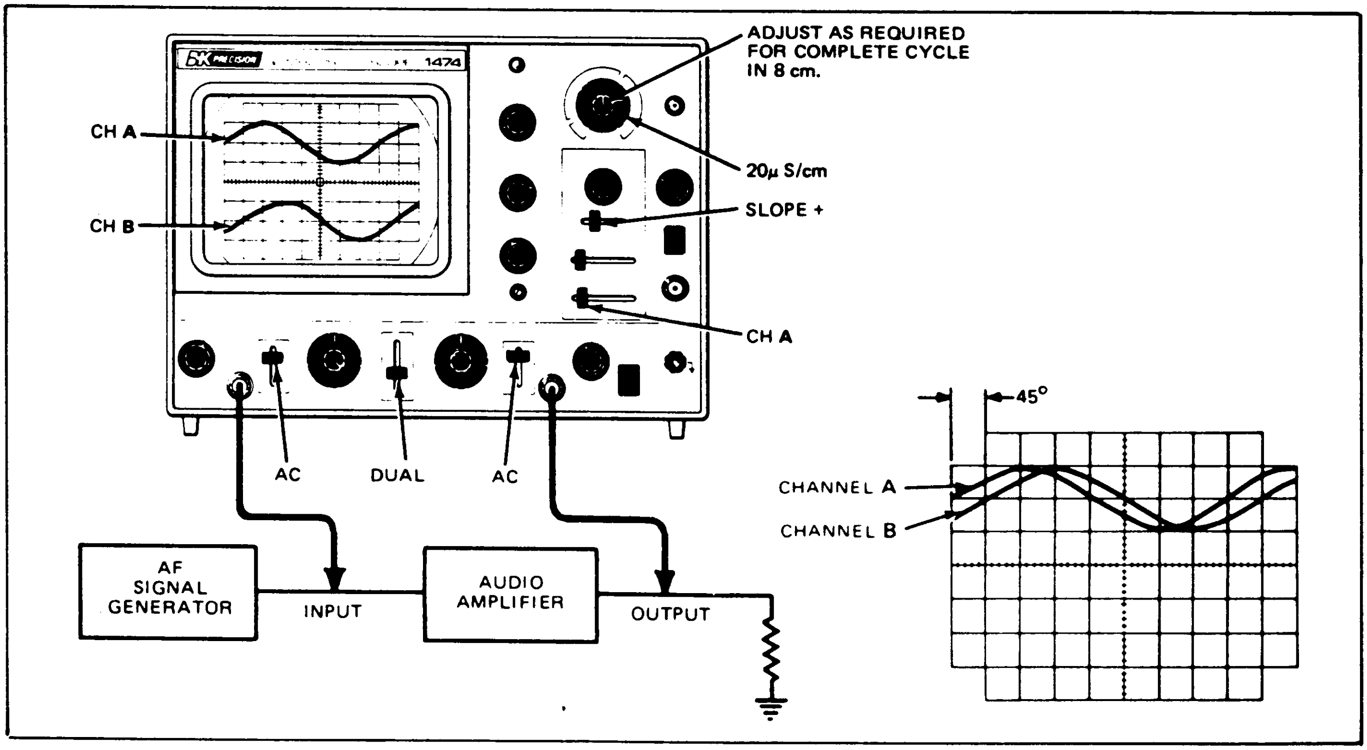


Fig. 17. Measuring amplifier phase shift.

peak voltage measurements. The schematic diagram or accompanying service data on the equipment being serviced usually includes waveform pictures. These waveform pictures include the required sweep time and the normal peak-to-peak voltage. Compare the peak-to-peak voltage readings on the oscilloscope with those shown on the waveform pictures. Any abnormal readings should be followed by additional readings in the suspected circuits until the trouble is isolated to as small an area as possible. The procedures for making peak-to-peak voltage measurements are given earlier in the CALIBRATED VOLTAGE MEASUREMENT paragraph.

CB RADIO APPLICATIONS

INTRODUCTION

1474 oscilloscope is particularly well suited for 27 MHz Citizens Band transceiver development laboratories, manufacturing, testing and analyzing facilities, and well-equipped service shops. Its 30 MHz bandwidth is required for thorough waveform analysis of either AM or AM/SSB CB transceiver. Direct signal measurement in practically all RF, IF, and audio circuits of both transmitter and receiver is possible, as well as accurate timing measurements in switching circuits. The 10:1 attenuation setting of the probe should be used for all RF and IF circuit measurements. The high impedance (10 megohms) of the probe should not affect normal circuit operation, except in highly sensitive circuits.

TRANSMITTER MODULATION

The most reliable method of checking transmitter modulation is with an oscilloscope. Fig. 18 shows the typical method of measurement and interpretation of the modulation envelope for AM CB transmitters. Most transceivers include some type of protection against overmodulation, which has no effect until modulation exceeds at least 75%, then progressively compresses any increase in audio amplitude. The effectiveness of this compression-type circuit and the degree of resultant distortion can be measured on the oscilloscope.

Fig. 19 shows how to check SSB modulation. Apply two simultaneous, equal-amplitude audio signals for modulation, such as 500 Hz and 2400 Hz. The audio signals must be free from distortion, noise and transients. The two audio signals should not have a direct harmonic relationship such as 500 Hz and 1500 Hz. The modulation envelope resembles the 100% AM modulation envelope, except the amplitude of the entire waveform varies with the strength of the audio signal. When peak SSB power output is reached, the modulation envelope "flat tops," that is, the instantaneous RF peaks reach the saturation, even with less than peak audio signal applied. This over-modulated condition results in distortion.

OTHER CB MEASUREMENTS

Some of the additional applications for this oscilloscope in transceivers follow:

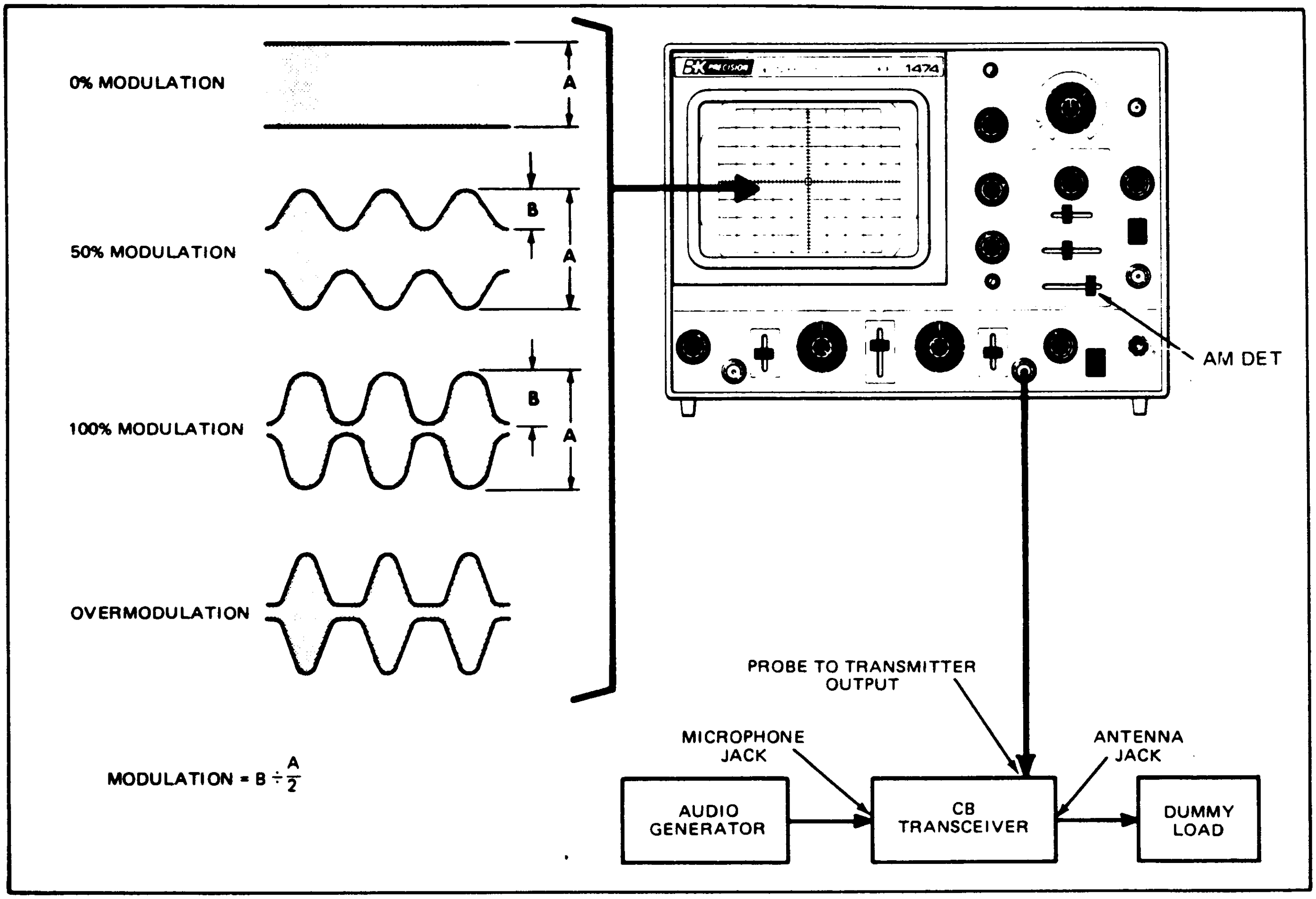


Fig. 18. Typical test set-up for AM modulation check.

- Transmitter carrier signal analysis.
- RF and IF gain measurements (dual-trace display preferred).
- Audio distortion measurements (dual-trace display preferred).
- Audio frequency response check.
- Bandpass filter, notch filter, low-pass or high-pass filter frequency response check, including SSB suppressed carrier filter (sweep generator method preferred).
- Synthesizer circuit analysis and troubleshooting. Dual-trace display preferred for digital phase-locked-loop (PLL) type synthesizer.
- Noise blanker circuit analysis and troubleshooting.
- Signal attenuation measurements.
- Isolating sources of noise, ripple, or transients.
- Signal tracing.

COMMUNICATIONS RADIO APPLICATIONS

This oscilloscope is also excellent for servicing two-way communications transceivers, receivers and transmitters. For radios that operate on carrier frequencies up to approximately 50 MHz, the oscilloscope is capable of direct measurement, although voltage readings are uncalibrated. IF signals can be measured without using a demodulator probe. Most of the checks and measurements described for CB transceivers are applicable to other types of communications equipment.

PHASE MEASUREMENT

Phase measurements may be made with an oscilloscope. Typical applications are in circuits designed to produce a specific phase shift, and measurement of phase shift distortion in audio amplifiers or other audio networks. Distortion due to non-linear amplification is also displayed in the oscilloscope waveform.

A sine wave input is applied to the audio circuit being tested. The same sine wave input is applied to the vertical input of the oscilloscope, and the output of the tested circuit is applied to the horizontal input of the oscilloscope. The amount of phase difference between the two signals can be calculated from the resulting waveform.

To make phase measurements, use the following procedure (Refer to Fig. 20):

1. Using an audio signal generator with a pure sinusoidal signal, apply a sine wave test signal at the desired test frequency to the audio network being tested.

2. Set the signal generator output for the normal operating level of the circuit being tested. If desired, the circuit's output may be observed on the oscilloscope. If the test circuit is overdriven, the sine wave display on the oscilloscope is clipped and the signal level must be reduced.

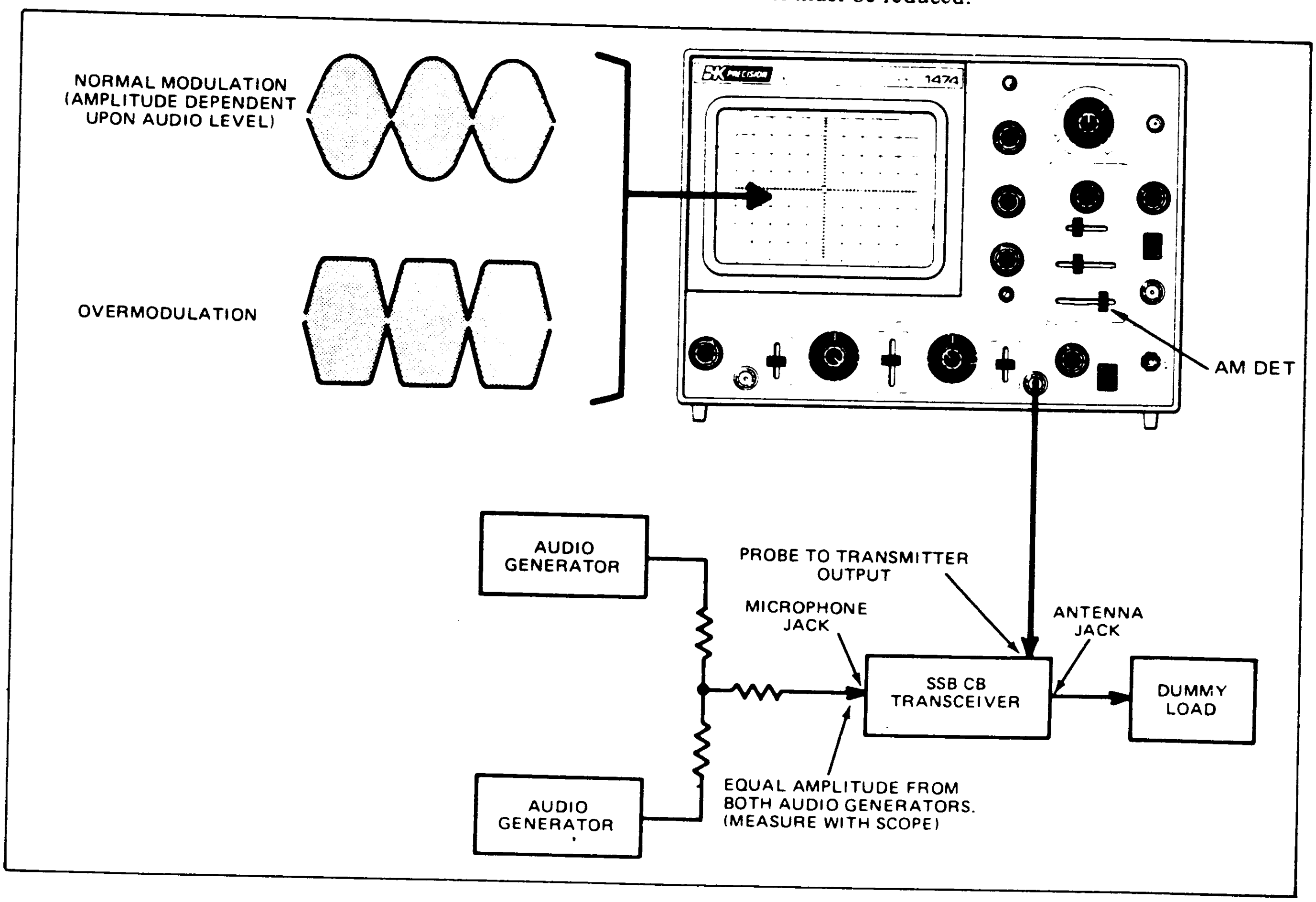


Fig. 19. Typical test set-up for SSB modulation check.

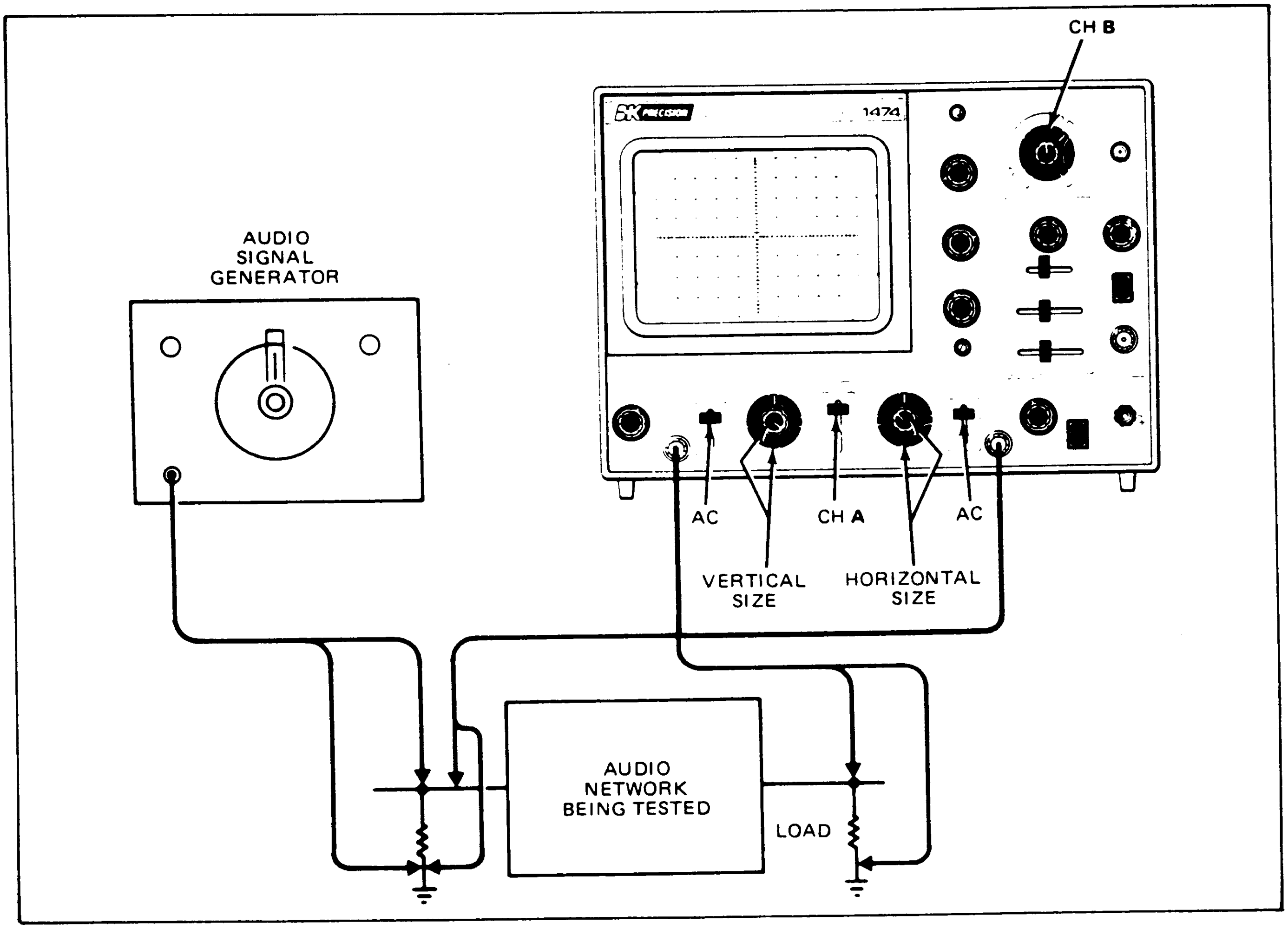


Fig. 20. Typical phase measurement set-up.

3. Connect the Channel B probe to the output of the test circuit.
4. Set the SWEEP TIME/CM control to CH B.
5. Connect the Channel A INPUT probe to the input of the test circuit. (The input and output test connections to the vertical and horizontal oscilloscope inputs may be reversed.)
6. Adjust the Channel A and B gain controls for a suitable viewing size.
7. Some typical results are shown in Fig. 21. If the two signals are in phase, the oscilloscope trace is a straight diagonal line. If the vertical and horizontal gain are properly adjusted, this line is at a 45° angle.

   A 90° phase shift produces a circular oscilloscope pattern.

Phase shift of less (or more) than 90° produces an elliptical oscilloscope pattern. The amount of phase shift can be calculated from the oscilloscope trace as shown in Fig. 22.

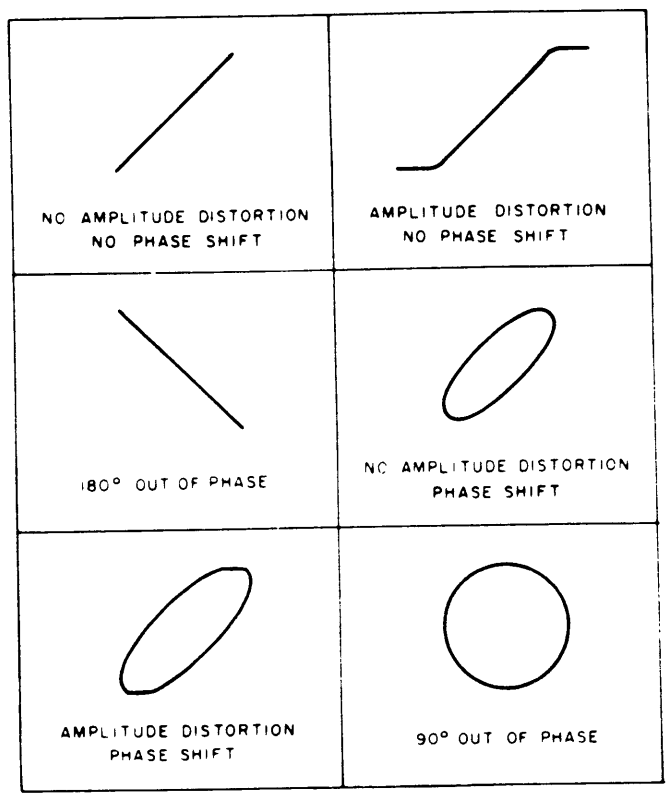


Fig. 21. Typical phase measurement scope displays.

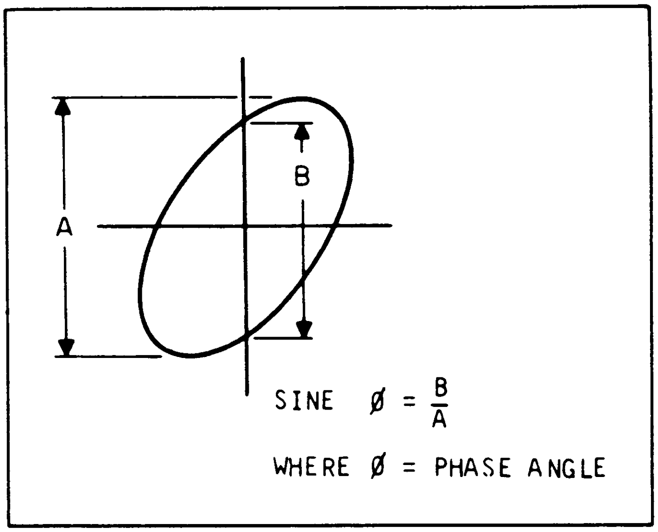


Fig. 22. Phase shift calculation.

FREQUENCY MEASUREMENT

Procedure:

1. Connect the sine wave of known frequency to the CH B INPUT jack of the oscilloscope and set the SWEEP TIME/CM control to CH B. This provides external horizontal input.

2. Connect the vertical input probe (CH A INPUT) to the unknown frequency.

3. Adjust the Channel A and B size controls for a convenient, easy-to-read size of display.

4. The resulting pattern, called a Lissajous pattern, shows the ratio between the two frequencies. See Fig. 23.

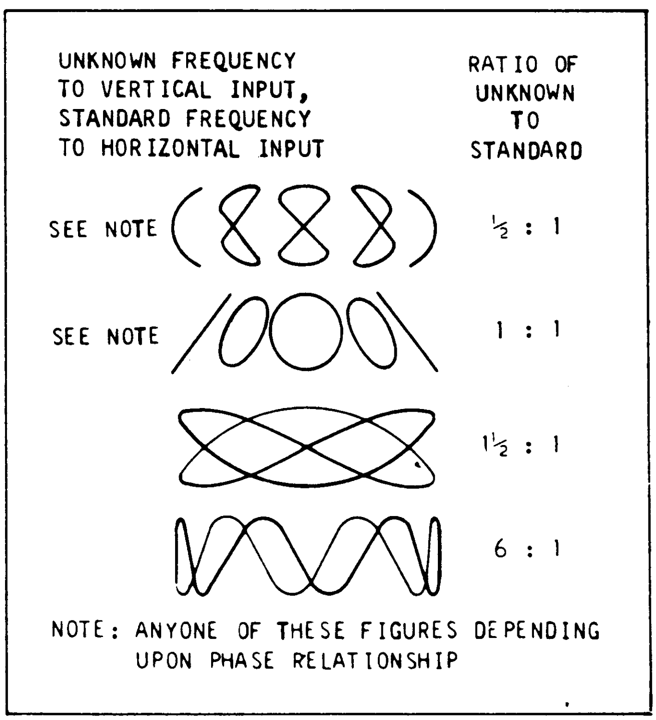


Fig. 23. Lissajous waveforms used for frequency measurement.

SQUARE WAVE TESTING OF AMPLIFIERS

INTRODUCTION

A square wave generator and a low-distortion oscilloscope, such as this instrument, can be used to display various types of distortion present in electronic circuits. A square wave of a given frequency contains a large number of odd harmonics of that frequency. If a 500 Hz square wave in injected into a circuit, frequency components of 1.5 kHz, 2.5 kHz, 3.5 kHz, also are provided. Since vacuum tubes and transistors are non-linear, it is difficult to amplify and reproduce a square wave which is identical to the input signal. Interelectrode capacitances, junction capacitances, stray capacitances as well as limited device and transformer response are a few of the factors which prevent faithful reproduction of a square wave signal. A well-designed amplifier can minimize the distortion caused by these limitations. Poorly designed or defective amplifiers can introduce distortion to the point where their performance is unsatisfactory.

As stated before, a square wave contains a large number of odd harmonics. By injecting a 500 Hz sine wave into an amplifier, we can evaluate amplifier response at 500 Hz only, but by injecting a square wave of the same frequency we can determine how the amplifier would respond to input signals from 500 Hz up to the 15th or 21st harmonic.

The need for square wave evaluation becomes apparent if we realize that some audio amplifiers will be required during normal use to pass simultaneously a large number of different frequencies. With a square wave, we have a controlled signal with which we can evaluate the input and output quality of a signal of many frequencies (the harmonics of the square wave) which is what the amplifier sees when amplifying complex waveforms of musical instruments or voices.

The square wave output of the signal generator must be extremely flat so that it does not contribute to any distortion that may be observed when evaluating amplifier response. The oscilloscope vertical input should be set to DC as it will introduce the least distortion, especially at low frequencies. When checking amplifier response, the frequency of the square wave input should be varied from the low end of the amplifier bandpass up toward the upper end of the bandpass; however, because of the harmonic content of the square wave, distortion will occur before the upper end of the amplifier bandpass is reached.

It should be noted that the actual response check of an amplifier should be made using a sine wave signal. This is especially important in limited bandwidth amplifiers (voice amplifiers). The square wave signal provides a quick check of amplifier performance and will give an estimate of overall amplifier quality. The square wave also will reveal some deficiencies not readily apparent when using a sine wave signal. Whether a sine wave or square wave is used for testing the amplifier, it is important that the manufacturer's specifications on the amplifier be known in order to make a better judgment of its performance.

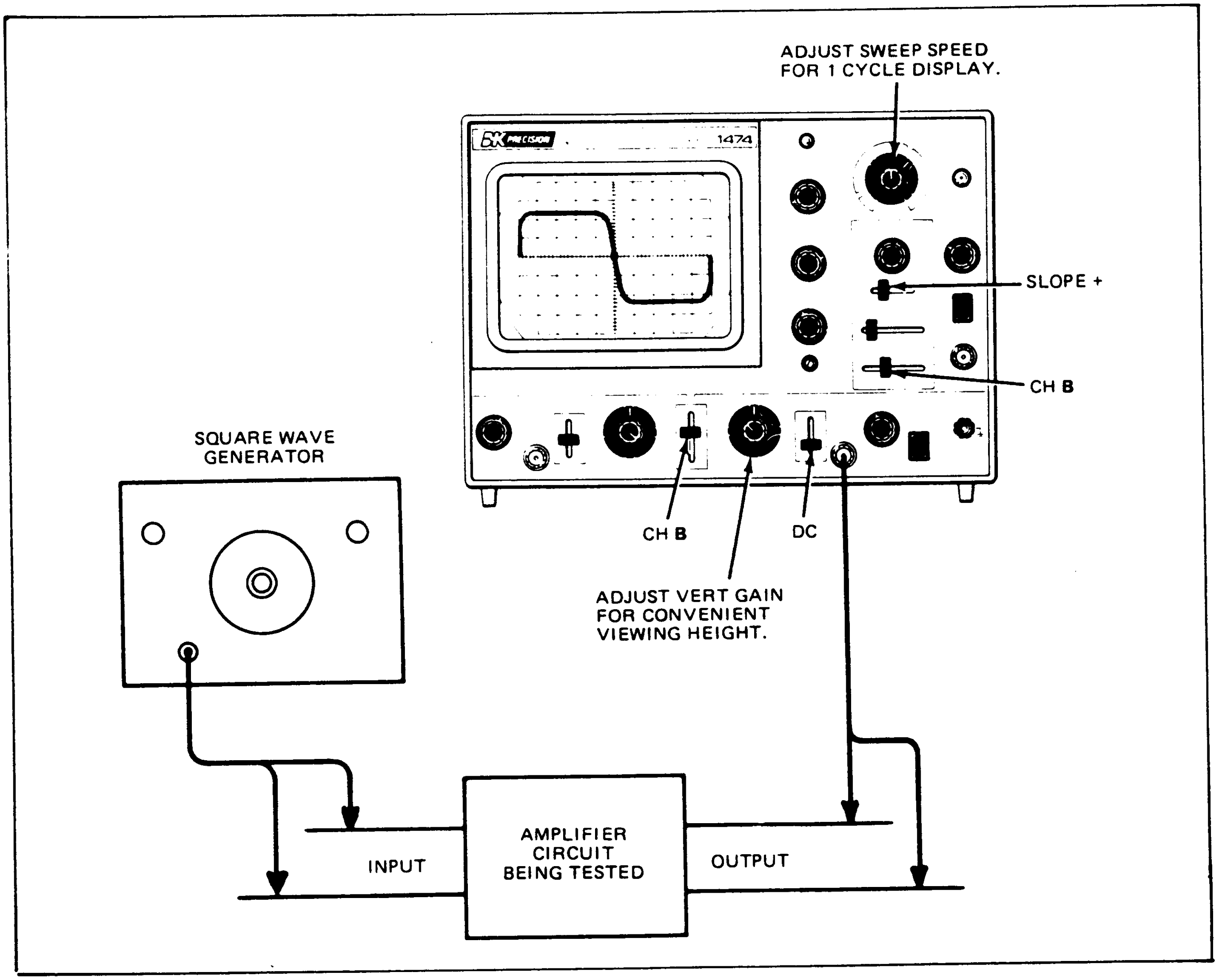


Fig. 24. Equipment set-up for square wave testing of amplifiers.

TESTING PROCEDURE (Refer to Fig. 24)

1. Connect the output of the square wave generator to the input of the amplifier being tested.

2. Connect the CH B test probe of the oscilloscope to the output of the amplifier being tested.

3. If the DC component of the circuit being tested is sufficiently low to allow both the AC and DC component to be viewed, use the DC position of the AC-GND-DC switch. However, the AC position may be used without affecting the results except at very low frequencies (below 10 Hz).

4. Adjust the vertical gain controls for a convenient viewing height.

5. Adjust the sweep time controls for one cycle of square wave display on the screen.

6. For a close-up view of a portion of the square wave, use the 5X magnification.

ANALYZING THE WAVEFORMS

The short rise time which occurs at the beginning of the half-cycle is created by the in-phase sum of all the medium and high frequency sine wave components. The same holds true for the rapid drop at the end of the half-cycle from maximum amplitude to zero amplitude at the 180° or half-cycle point. Therefore, a theoretical reduction in amplitude alone of the high frequency components should produce a rounding of the square corners at all four points of one square wave cycle (See Fig. 25).

Distortion can be classified into three distinct categories:

1. The first is frequency distortion and refers to the change from normal amplitude of a component of a complex waveform. In other words, the introduction in an amplifier circuit of resonant networks or selective filters created by combination of reactive components will create peaks or dips in an otherwise flat frequency response curve.

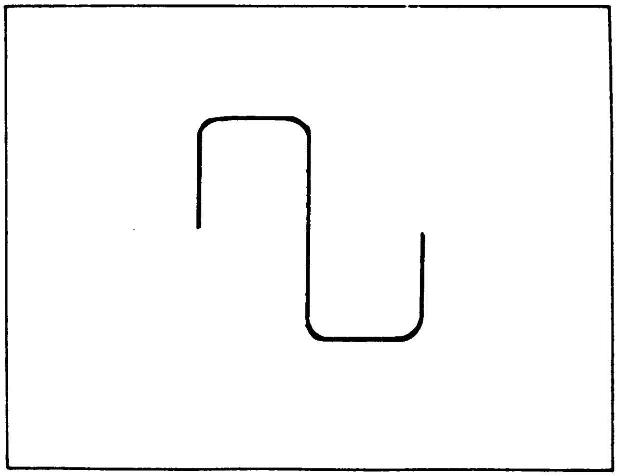


Fig. 25. Square wave response with high-frequency loss.

2. The second is non-linear distortion and refers to a change in waveshape produced by application of the waveshape to non-linear components or elements such as vacuum tubes, an iron core transformer, and in an extreme case, a deliberate non-linear circuit such as a clipper network.

3. The third is delay or phase distortion, which is distortion produced by a shift in phase between one or more components of a complex waveform.

In actual practice, a reduction in amplitude of a square wave component (sinusoidal harmonic) is usually caused by a frequency-selective network which includes capacity, inductance or both. The presence of the C or L introduces a difference in phase angle between components, creating phase distortion or delay distortion. Therefore, in square wave testing of practical circuitry, we will usually find that the distorted square wave includes a combination of amplitude and phase distortion clues.

In a typical wide band amplifier, a square wave check accurately reveals many distortion characteristics of the circuit. The response of an amplifier is indicated in Fig. 26, revealing poor low-frequency response along with over-compensated high-frequency boost. A 100 Hz square wave applied to the input of this amplifier will appear as in Fig. 27A. This figure indicates satisfactory medium frequency response (approximately 1 kHz to 2 kHz) but shows poor low-frequency response. Next, a 1000 Hz square wave applied to the input of this same amplifier will appear as in Fig. 27B. This figure displays good frequency response in the region of 1000 to 4000 Hz but clearly reveals the overcompensation at the higher 10 kHz region by the sharp rise at the top of the leading edge of the square wave.

As a rule of thumb, it can be safely said that a square wave can be used to reveal response and phase relationships up to the 15th or 20th odd harmonic or up to approximately 40 times the fundamental of the square wave. Using this rule of thumb, it is seen that wide-band circuitry will require at least a two-frequency check to properly analyze the complete spectrum. In the case illustrated by Fig. 26, a 100 Hz square wave will encompass components up to about 4000 Hz. To analyze above 4000 Hz and beyond 10,000 Hz, a 1000 Hz square wave should be satisfactory.

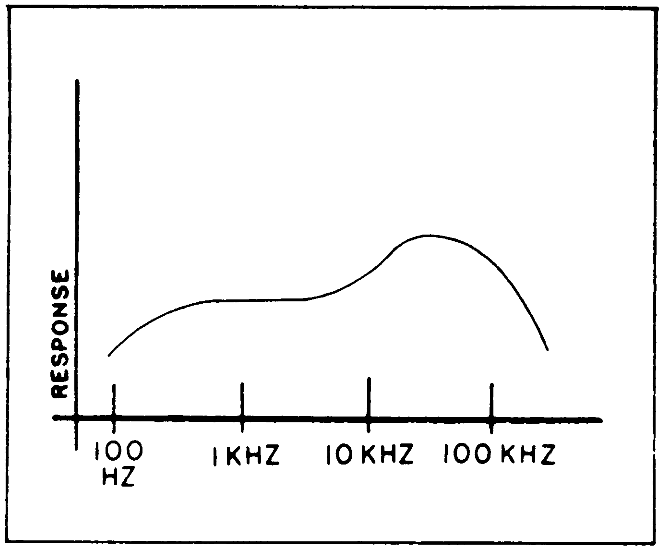


Fig. 26. Response curve of amplifier with poor low and high ends.

Now, the region between 100 Hz and 4000 Hz in Fig. 26 shows a rise from poor low-frequency response to a flattening out from beyond 1000 and 4000 Hz. Therefore, we can expect that the higher frequency components in the 100 Hz square wave will be relatively normal in amplitude and phase but that the lower frequency components in this same square wave will be strongly modified by the poor low-frequency response of this amplifier. See Fig. 27A.

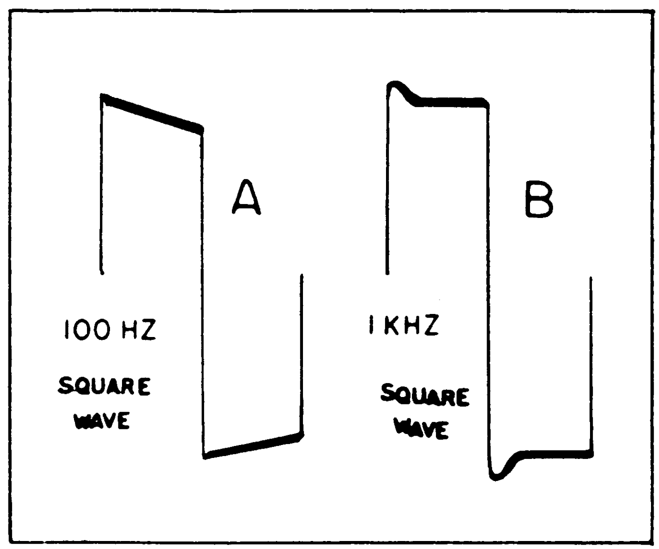


Fig. 27. Resultant 100 Hz and 1 kHz square waves from amplifier in Fig. 26.

If the combination of elements in this amplifier were such as to only depress the low frequency components in the square wave, a curve similar to Fig. 28 would be obtained. However, reduction in amplitude to a component, as already noted, is usually caused by a reactive element, causing, in turn, a phase shift of the component, producing the strong tilt of Fig. 27A. Fig. 29 reveals a graphical development of a similarly tilted square wave. The tilt is seen to be caused by the strong influence of the phase-shifted 3rd harmonic. It also becomes evident that very slight shifts in phase are quickly shown up by tilt in the square wave.

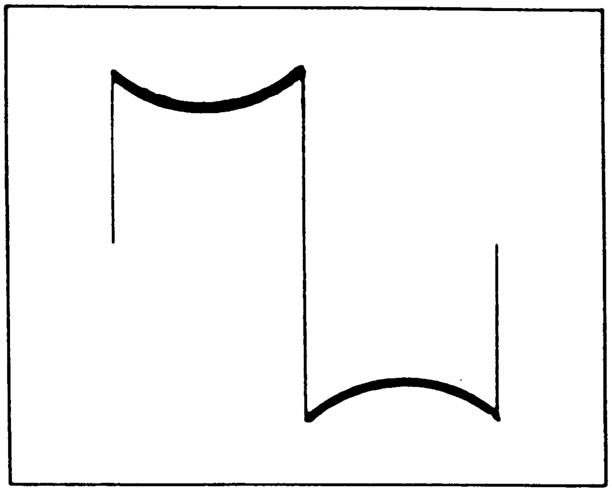


Fig. 28. Reduction of square wave fundamental frequency component in a tuned circuit.

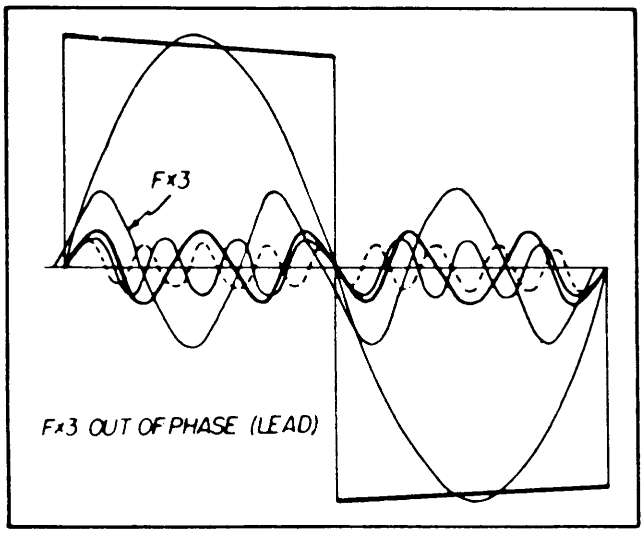


Fig. 29. Square wave tilt resulting from 3rd harmonic phase shift.

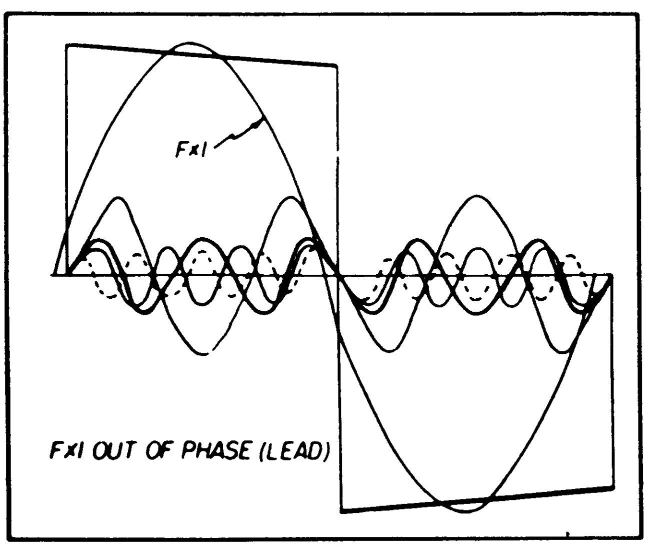


Fig. 30. Tilt resulting from phase shift of fundamental frequency in a *leading* direction.

Fig. 30 indicates the tilt in square wave shape produced by a 10° phase shift of a low-frequency element in a leading direction. Fig. 31 indicates a 10° phase shift in a low-frequency component in a lagging direction. The tilts are opposite in the two cases because of the difference in polarity of the phase angle in the two cases as can be checked through algebraic addition of components.

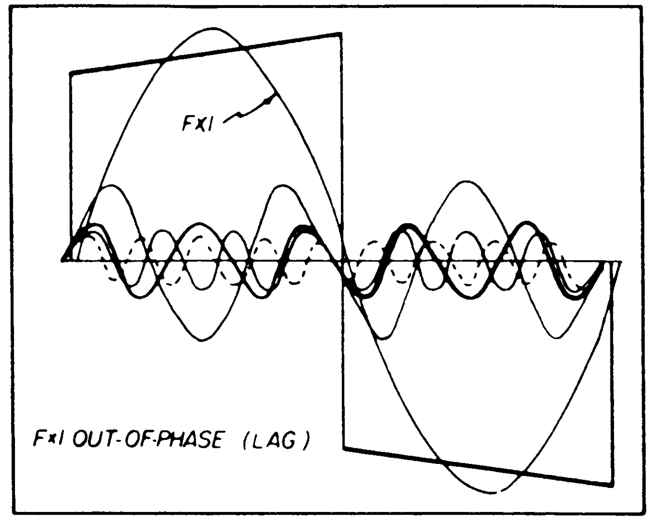


Fig. 31. Tilt resulting from a phase shift of fundamental frequency in a *lagging* direction.

Fig. 32 indicates low-frequency components which have been reduced in amplitude and shifted in phase. It will be noted that these examples of low-frequency distortion are characterized by change in shape of the flat top portion of the square wave.

Fig. 27B, previously discussed, revealed high-frequency overshoot produced by rising amplifier response at the higher frequencies. It should again be noted that this overshoot makes itself evident at the top of the leading edge of the square wave. This characteristic relationship is explained by remembering that in a normal well-shaped square wave, the sharp rise of the leading edge is created by the summation of a practically infinite number of harmonic components. If an abnormal rise in amplifier response occurs at high frequencies, the high frequency components in the square wave will be amplified disporportionately greater than other components creating a higher algebraic sum along the leading edge.

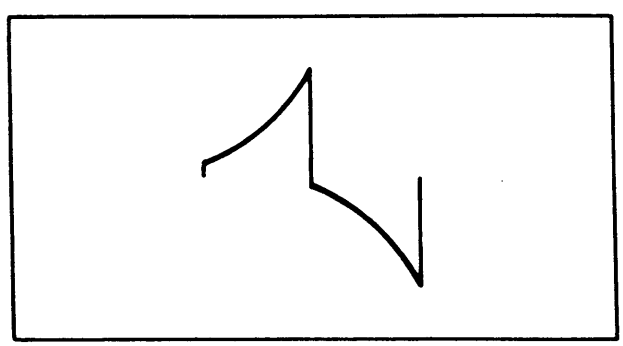


Fig. 32. Low-frequency component loss and phase shift.

Fig. 33 indicates high frequency boost in an amplifier accompanied by a lightly damped "shock" transient. The sinusoidal type of diminishing oscillation along the top of the square wave indicates a transient oscillation in a relatively high "Q" network in the amplifier circuit. In this case, the sudden transition in the square wave potential from a sharply rising, relatively high frequency voltage, to a level value of low frequency voltage, supplies the energy for oscillation in the resonant network. If this network in the amplifier is reasonably heavily damped, then a single cycle transient oscillation may be produced as indicated in Fig. 34.

Fig. 35 summarizes the preceding explanations and serves as a handy reference.

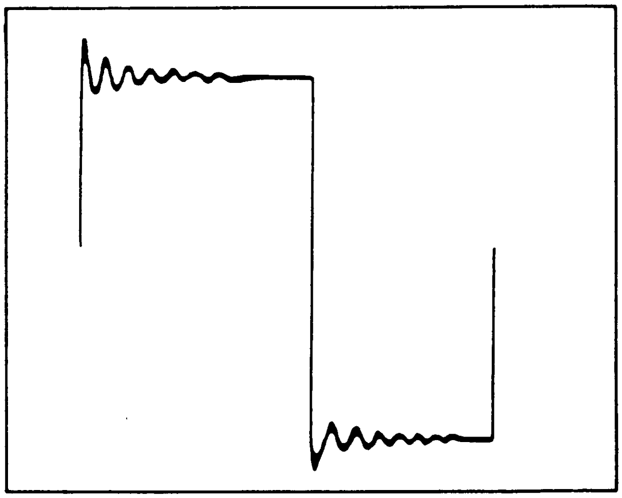


Fig. 33. Effect of high-frequency boost and *poor* damping.

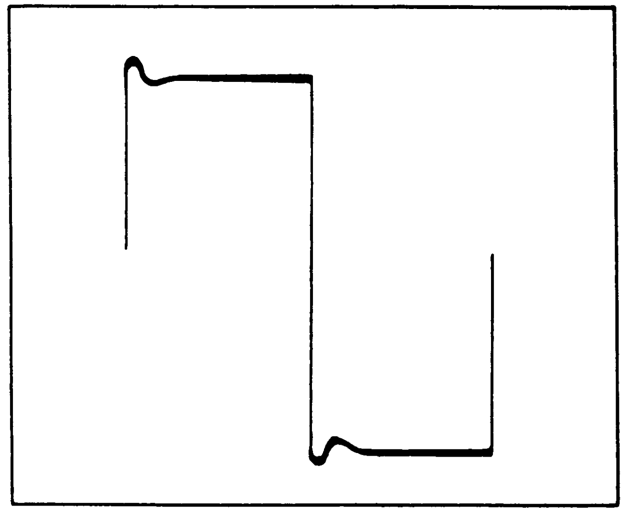


Fig. 34. Effect of high-frequency boost and *good* damping.

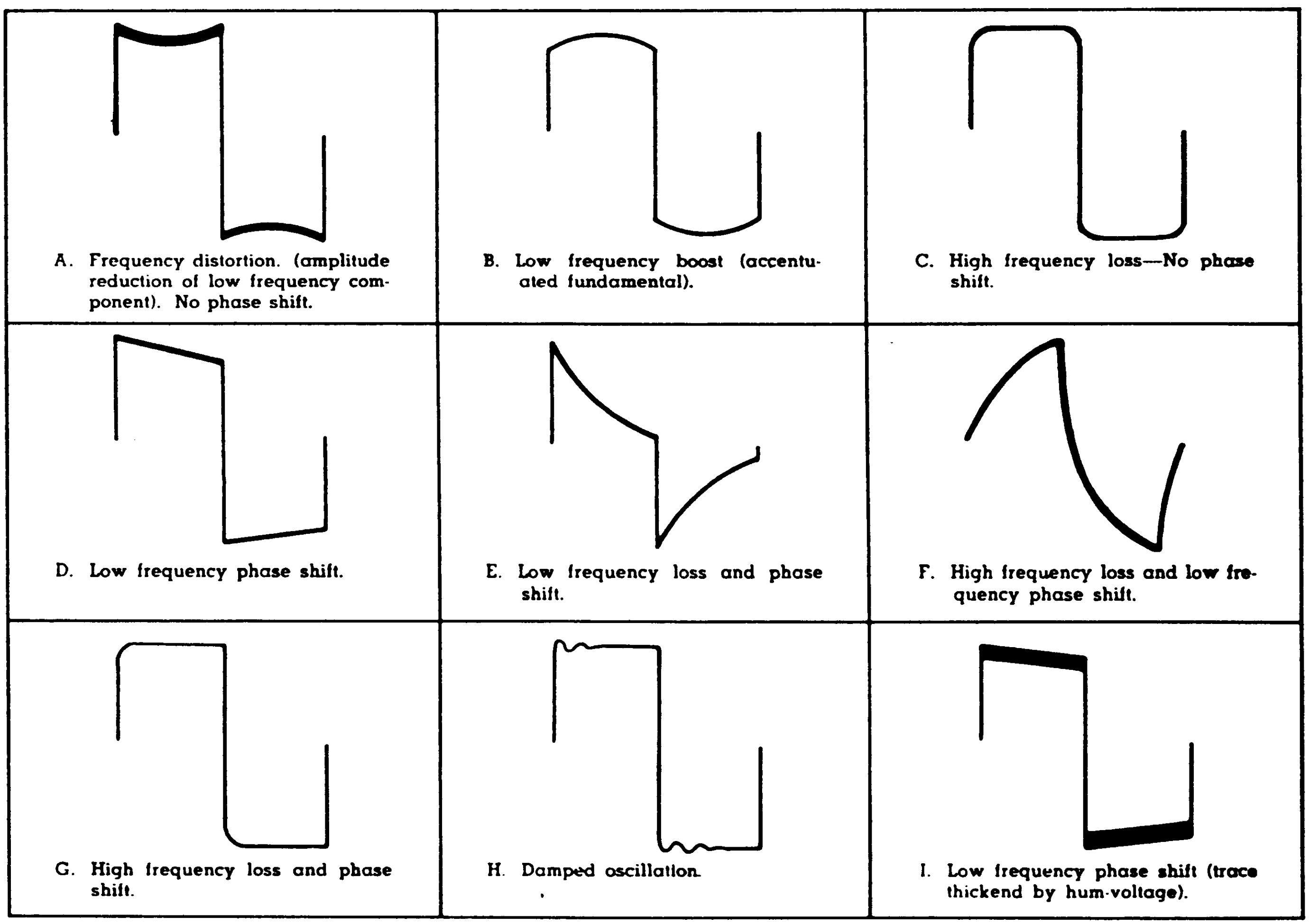


Fig. 35. Summary of waveform analysis for square wave testing of amplifiers.

1474 CIRCUIT DESCRIPTION

Refer to the block diagram of the oscilloscope, Fig. 36, for a circuit breakdown. Refer to the schematic diagram for circuit details.

GENERAL

Basically, the oscilloscope consists of two identical vertical preamplifiers, each having its own input attenuator. The outputs of the vertical preamplifiers are switched via the vertical switch matrix into the delay line driver. The type of switching, i.e., CH A, CH B, DUAL, or ADD, is determined by the mode of operation logic section.

The delay line driver feeds into the delay line, which delays the vertical preamplifier signals approximately 160 nanoseconds before they reach the main vertical amplifier. The main vertical amplifier drives the vertical deflection plates of the CRT.

The horizontal deflection plates of the CRT are in turn driven by the horizontal amplifier. The input to the horizontal amplifier comes from calibrated sweep speed circuits or from Channel B, via the Channel B trigger amplifier, when X-Y operation is selected.

The power supply voltages are fully regulated, and a DC-to-DC converter provides a regulated 4 KV accelerating potential to the CRT.

VERTICAL PREAMPLIFIERS

Channel A and Channel B preamplifiers contain identical circuitry and circuit operation is the same for both. Channel A is described below.

The vertical input attenuator, S103, has two sections. The first provides ratios of 1:1, 10:1, 100:1, and 1000:1. The second section provides ratios of 1:1, 2:1, and 5:1. Together, the two sections give an attenuation sequence of 1-2-5, with the appropriate exponent.

After the first attenuation section, FET's Q102a and Q102b form a high-impedance input stage of the vertical preamp. This balanced configuration provides compensation for thermal drift and power supply voltage fluctuations. Q101 and D122 are used for negative over-voltage protection. Positive over-voltage is clamped by Q102a.

The differential amplifier IC101 feeds the second attenuation section. Q103 thru Q106, Q109 and Q110 further amplify the vertical signal before it reaches the delay line driver, transistors Q123 to Q126. Trigger amplifier Q107 and Q108 amplify the signal from the emitters of Q105 and Q106 to provide a signal to the sweep trigger circuits.

The only difference between the CH A and CH B preamplifiers is that the CH B polarity switch, S105, reverses the polarity of the CH B signal when in the INV position. This is accomplished by switching on either transistor pair Q119/Q122, or Q120/Q121.

DELAY LINE

The delay line is a length of cable which delays the vertical signal from the delay line driver for approximately 160 nanoseconds before it reaches the input stage of the main vertical amplifier. The purpose of this delay is to enable the sweep to be triggered before vertical deflection begins, which allows one to see the leading portion of very fast rise-time signals.

MODE LOGIC

The mode of operation (CH A, CH B, DUAL, ADD), S106, is controlled by IC103, IC104, and diodes D101-D108. When CH A is selected, the IC104 Q output is high and the $\bar{Q}$ low, which reverse biases D101 and D104, allowing the CH A signal into the delay line driver. D107 and D108 are forward-biased, preventing the CH B signal from reaching the delay line driver. For CH B mode, the reverse is true.

For DUAL mode, both channels are displayed as follows: Below a sweep speed of 0.5 mSEC/cm, the IC104 output switches at a 200 KHZ rate, thus chopping the A and B vertical signals for simultaneous display. The chopping signal that switches IC104 comes from an oscillator formed by two gates from IC1. For sweep speeds greater than or equal to 0.5 mSEC/cm, the IC104 output switches state after every sweep, therefore alternating the A and B vertical signals for display.

When ADD mode is selected, the signals from both channels are added algebraically and then applied to the delay line driver. In this mode both the Q and $\bar{Q}$ outputs of IC104 must be high, which is done by setting both the set and reset lines of IC104 low.

VERTICAL AMPLIFIER

The output of the delay line feeds into the vertical output amplifier. Q401 and Q402 form a differential amplifier which goes to another differential stage Q403 and Q404. These connect to emitter followers Q405 and Q406, which drive cascode amplifiers Q408, Q410, and Q409, Q411. Negative feedback from the cascode amplifiers goes via inverters Q414 and Q415 to the bases of Q405 and Q406. Q412, Q418, and Q413, Q419 comprise current sources for the cascode amplifiers. Emitter followers Q416 and Q417 help drive the current-source transistors, Q418 and Q419, when extra current is required for fast signals.

TRIGGER CIRCUIT

The amplified trigger waveforms from CH A and CH B are connected to low-input impedance buffer amplifier Q127. The TRIGGERING SOURCE switch, S3, sets logic D116, D117, D120, D121 and IC103 (a and b), determining which channel is used as a trigger source. The output of Q127 reaches the trigger coupling section via amplifiers Q20 and Q16, whereupon it is fed to buffer FET Q12, either through a capacitor for AC coupling, or straight through for DC coupling. The TRIGGER coupling switch is S4.

If the AUTO LEVEL control, S201, is in the NORM position, the output of Q12 is DC-coupled to emitter follower Q13, which drives one input (pin 2) of op amp IC5. TRIGGERING LEVEL control R50 sets a DC level for the other input (pin 1) of IC5 via Q14. IC5 acts as a

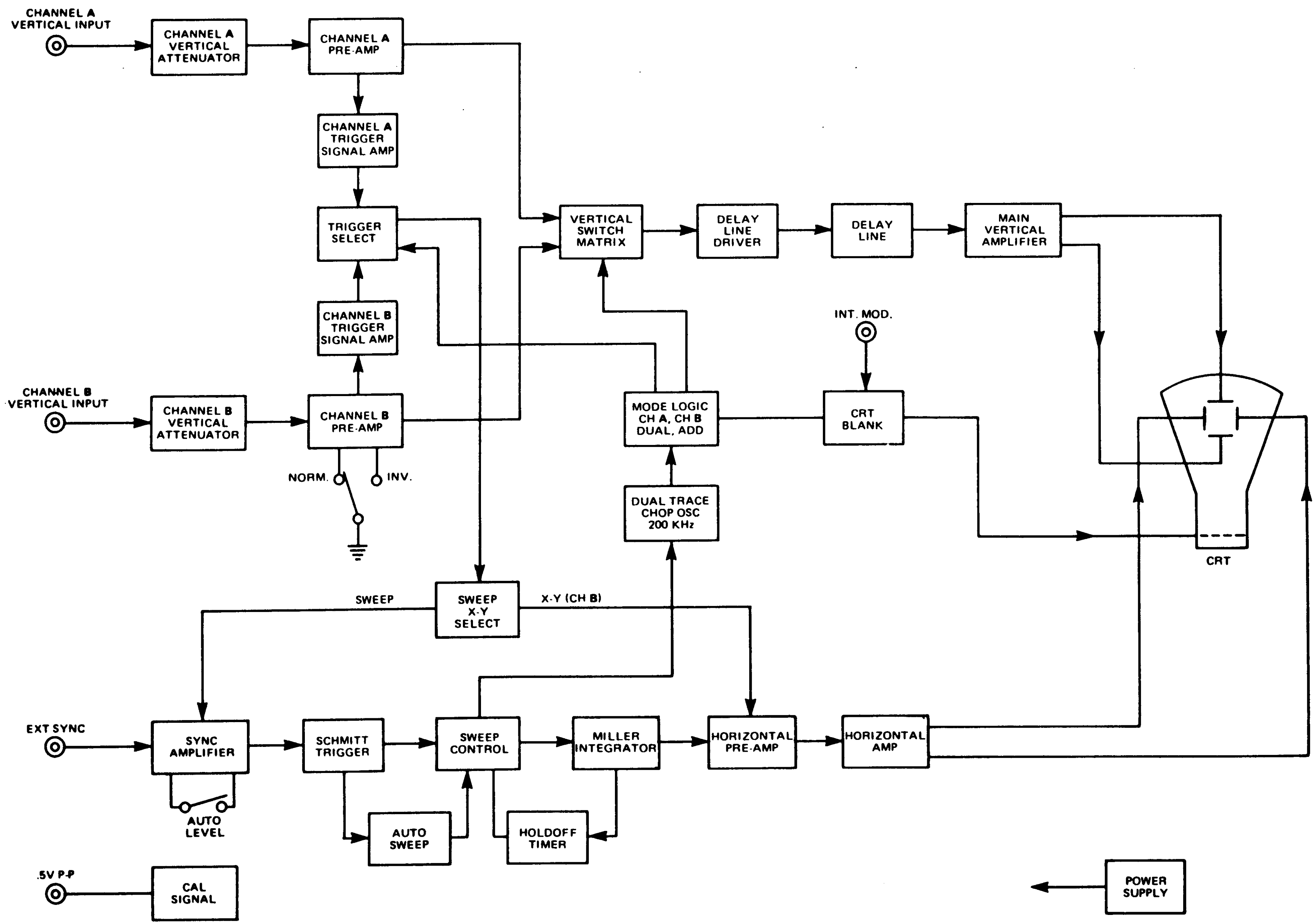


Fig. 36. Block diagram, Model 1474 dual-trace oscilloscope.

high-gain differential amp, and when the ratio of the triggering signal at pin 2 to DC level at pin 1 becomes great enough, the IC5 output turns on emitter follower Q15 whose output goes to two gates from IC1 that act as logic level buffers. The output from one of these gates initiates a sweep cycle via sweep control flip-flop IC1.

If the AUTO LEVEL control is in the AUTO position, the output of Q12 is AC-coupled to peak detector diodes D13 and D14. The filtered peak goes to Q14 which sets the DC level for the lower input of IC5. The output of Q12 is also now AC-coupled to Q13, which drives the upper input of IC5. This means that op amp IC5 will initiate a trigger signal to Q15 whenever the instantaneous voltage of the triggering waveform is a fixed percentage of the peak voltage of this same waveform. Because of the AC-coupling in this triggering mode, any steady-state DC levels the triggering waveform might be riding on are ignored.

When turned on by S1, the PULL AUTO TRIGGERING circuit (this is *not* the AUTO LEVEL circuit above), using transistors Q4, Q5 and Q6, will give a trigger pulse to the reset line of IC2, after a fixed time delay—if no vertical trigger signals have arrived from Q15 during that time. If vertical trigger signals remain absent, the sweep will automatically be fired after each sweep by IC3, at the end of the sweep hold-off period.

HORIZONTAL SWEEP

When a trigger pulse is received at the clock input or the reset input of IC2, the Q output (pin 8) goes low. This allows the horizontal ramp integrator to begin the sweep. The integrator consists of Q10, Q11 and the precision sweep timing resistors and capacitors. The sweep speed is determined by the RC time constant of the timing resistors and capacitors set by the SWEEP TIME/CM control, S2.

The output of the integrator, a decreasing linear ramp, is fed through transistors Q8 and Q9, and then to the horizontal amplifier section, Q17-Q24, which drives the horizontal deflection plates. Another output of the sweep integrator, giving an increasing linear ramp, is fed to the threshold input of sweep holdoff timer IC3 (pin 6). When the decreasing ramp voltage has swept the scope trace to the right-hand limit of the sweep cycle on the CRT, the corresponding increasing ramp voltage reaches the threshold setting of IC3. This causes the output of IC3 (pin 3) to go low, which sets the Q output of the sweep control flip-flop, IC2, high. A high at the Q output turns on transistor Q7, which discharges the integrating capacitor and resets the sweep back to the left-hand sweep limit. Simultaneously with the Q output going high, the $\bar{Q}$ output of IC2 goes low, which sends a high out of the blanking control gate (IC1 pin 11). This turns the trace intensity down, so you cannot see it being reset to the left side of the CRT.

The sweep holdoff time delay capacitor connected to IC3 pin 2 is discharging through R24 into IC3 pin 7, which went low when threshold was reached at IC3 pin 6. When the holdoff time delay cap has discharged to less than 1.6 volts, the timer output, IC3 pin 3, is triggered high. This arms IC2 for the next trigger pulse, coming either from the clock line input or from the reset input when Q6 of the AUTO TRIGGERING circuit is turned on. Along with pin 3, pin 7 of IC3 also goes high and allows the holdoff time delay capacitor to charge up again. The length of the sweep holdoff is determined by the capacitor tied to IC3 pin 2, and the optimum value for each sweep speed is automatically set by the SWEEP TIME/CM control.

During XY operation, set by the SWEEP TIME/CM switch, the CH B trigger amplifier output is fed to the horizontal amplifier via Q19 and Q18. In this mode, the CH B signal controls the horizontal position of the CRT trace.

BLANKING AND INTENSITY CONTROL

The DC voltage on the intensity grid (pin 4 of the CRT) sets the intensity of the oscilloscope trace. A square wave signal is pulled off the secondary of the high-voltage oscillator transformer T301 and amplified by Q302. The peak-to-peak limits of this square wave are determined by D306, D307, D309, and the intensity and blanking control circuitry Q303, Q304, Q305, and Q313. The square wave is AC-coupled into peak detector diodes D304 and D305. The negative peak of the square wave sets the DC voltage on the intensity grid. The more negative this voltage goes, the less the intensity. Intensity Adj., VR302, sets the maximum intensity of the trace. The front panel INTENSITY control VR201 adjusts the trace intensity during normal operation by controlling Q303.

The blanking pulse, which turns the trace intensity *down* during its return to the left-hand side of the CRT after each sweep, and which keeps the trace *off* prior to the beginning of a sweep, is generated by IC4. Blanking pulses during the chopping mode of dual-trace operation also come from IC4. The chopping oscillator is made up of two gates from IC4.

Intensity modulation, or the Z-axis signal, is provided by Q306, which DC-couples the Z-axis input jack to the intensity control circuit.

POWER SUPPLIES

+5 Volt Supply.
One output of the 14V secondary of the power transformer is rectified by diode bridge D319 and regulated by Q307, Q308, Q314 thru Q316.

-8 Volt Supply.
The other output of the 14V secondary is also rectified by diode bridge D319 and regulated to -8V by IC301a and Q309.

+120 Volt Supply.
The 120V secondary of the power transformer is rectified by diode bridge D320 and is regulated by zener diode D318.

+107 Volt Supply.
The 120V supply is regulated down to +107V by IC301b and Q310.

HIGH-VOLTAGE SUPPLY

Q301 and the primary of T301 form the oscillator of a DC-to-DC converter for the high-voltage supply. Regulation is achieved by feedback transistors Q312 and Q311. The secondary voltages of T301 are rectified and filtered to provide the voltages for the CRT focus grid, anode, cathode, and heater.

1474 CALIBRATION AND MAINTENANCE

The calibration adjustments outlined here are those which can be performed with a minimum of specialized test equipment. Additional internal adjustments of frequency compensation and horizontal sweep linearity should not be attempted without complete service information and specified test equipment. Requests for complete service information for this oscilloscope should be addressed to:

B & K-Precision, Factory Service Department
Maxtec International Corp.
6470 West Cortland Street
Chicago, Illinois 60635
Tel: (312) 889-1448

Internal adjustments outlined in the calibration procedure can be located by reference to Fig. 37 through 40.

LINE VOLTAGE SELECTION

1. Plug the AC Line Voltage Selector into the position that corresponds to the AC line voltage available:

Line Voltage Selector	Line Voltage	Fuse
100V	100V, ±10%	.7A
120V	105V to 130V	.7A
220V	220V, ±10%	.3A
240V	240V, ±10%	.3A

2. Install fuse of proper rating as indicated above.

HOUSING REMOVAL

1. Remove 6 screws and lift off top cover.
2. Remove 4 screws and lift off bottom cover.

GRATICULE REMOVAL

1. Grasp bezel with both hands at top and bottom. Pull bezel uniformly forward to unlock mounting legs from front panel. *Caution should be used to keep bezel parallel to front panel when removing to avoid breakage of mounting legs.*
2. Lift off graticule from bezel.
3. Re-insert graticule on bezel and snap bezel into front panel mounting holes.

CRT ROTATION ADJUSTMENT

1. Loosen two screws on rear panel CRT cover.
2. Grasp cover and rotate to align horizontal trace with horizontal graticule line.
3. Tighten two screws.

BALANCE ADJUSTMENTS

1. Adjust controls to obtain a horizontal trace (CH A or CH B).
2. Adjust POSITION control to center the trace vertically on the CRT.
3. Rotate VARIABLE control from maximum ccw to maximum cw while observing the trace.
4. If the trace moves vertically while performing Step 3, adjust CH A or CH B DC BAL control (VR101 or VR106) so that vertical movement of trace is minimized while performing Step 3.
5. Re-position trace vertically at center screen.
6. Rotate VOLTS/CM switch from .1V/cm to .2V/cm to .5V/cm while observing the trace.
7. If the trace moves vertically while performing Step 6, adjust the CH A or CH B ATTEN BAL control (VR103 or VR108) so that the vertical movement of the trace is minimized.

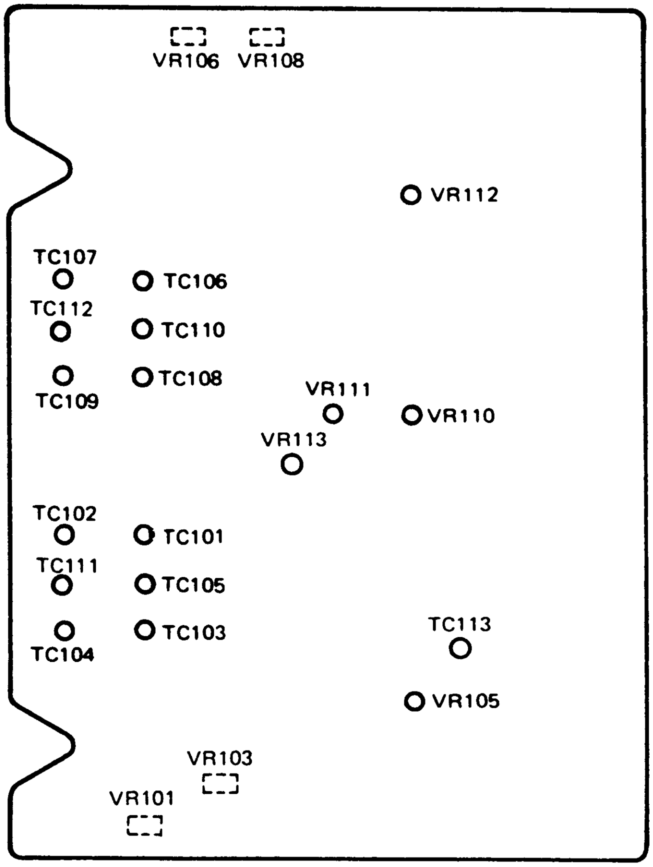
VERTICAL GAIN ADJUSTMENT

1. Connect CH A V input to the CAL signal jack.
2. Set CH A VOLTS/CM switch to .1V/cm and VARIABLE control to CAL. A square wave, 5 cm ± 2 mm high, should be seen.
3. If greater or less, rotate VR401 on Main Vertical Amplifier Board (Fig. 38) for 5 cm.
4. Connect CAL Signal to CH B.
5. Set CH B VOLTS/CM switch to .1V/cm and VARIABLE control to CAL. A square wave, 5 cm ± 2 mm high, should be seen.
6. If greater or less, rotate VR110 on Vertical Preamplifier Board (Fig. 37) for 5 cm.

HORIZONTAL TIMING ADJUSTMENT

The following adjustment should be attempted *only* if a pulse generator of better than 1% timing accuracy is available.

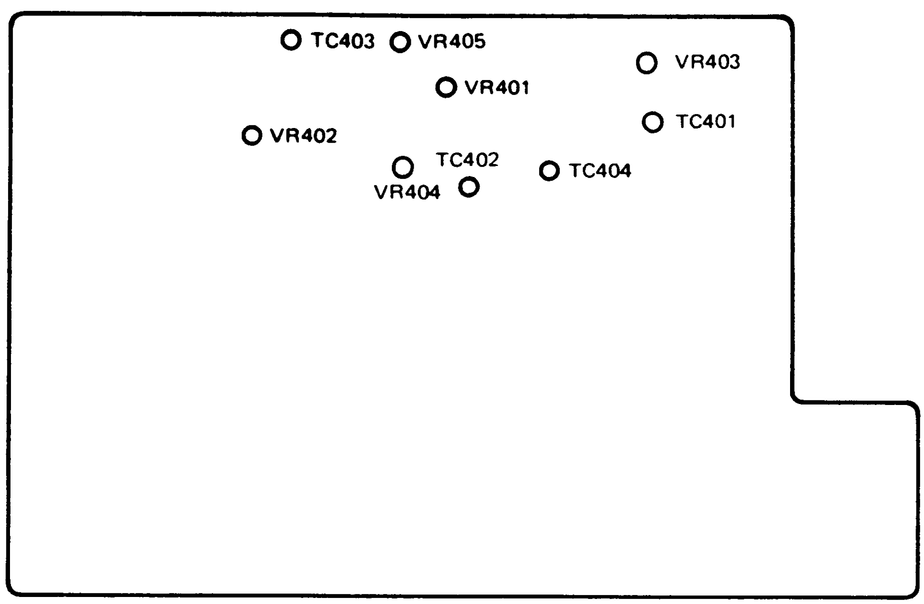
1. Connect a pulse generator to the CH A input. Rotate SWEEP TIME/CM to 1 mSEC/cm and VARIABLE control to CAL.
2. Adjust generator for 10 pulses, 1 mSEC apart.
3. Adjust VR15 on Horizontal Amplifier Sweep Board (Fig. 39) for 1 pulse every cm.
4. Adjust VR6 as required for a sweep length greater than 10 cm.



VR101-CH A VARI. ATT DC BAL
VR103-CH A STEP ATT DC BAL
VR106-CH B VARI. ATT DC BAL
VR108-CH B STEP ATT DC BAL
VR113-CH A DC TRIG. LEVEL ADJ.
VR105-CH A DISPLAY CENTER ADJ.
VR110-CH B GAIN ADJ.
VR111-CH B HORIZONTAL GAIN ADJ.
VR112-CH B DISPLAY CENTER ADJ.
VR113-CH A DC TRIGGERING LEVEL ADJ.
TC101-CH A 1/10 RANGE SQUARE WAVE ADJ.
TC102-CH A 1/10 RANGE INPUT CAPACITY ADJ.
TC103-CH A 1/100 RANGE SQUARE WAVE ADJ.
TC104-CH A 1/100 RANGE INPUT CAPACITY ADJ.
TC105-CH A 1/1000 RANGE SQUARE WAVE ADJ.
TC106-CH B 1/10 RANGE SQUARE WAVE ADJ.
TC107-CH B 1/10 RANGE INPUT CAPACITY ADJ.
TC108-CH B 1/100 RANGE SQUARE WAVE ADJ.
TC109-CH B 1/100 RANGE INPUT CAPACITY ADJ.
TC110-CH B 1/1000 RANGE SQUARE WAVE ADJ.
TC111-CH A 1/1000 RANGE INPUT CAPACITY ADJ.
TC112-CH B 1/1000 RANGE INPUT CAPACITY ADJ.
TC113-CH A HIGH FREQUENCY RESPONSE ADJ.

FOIL SIDE VIEW

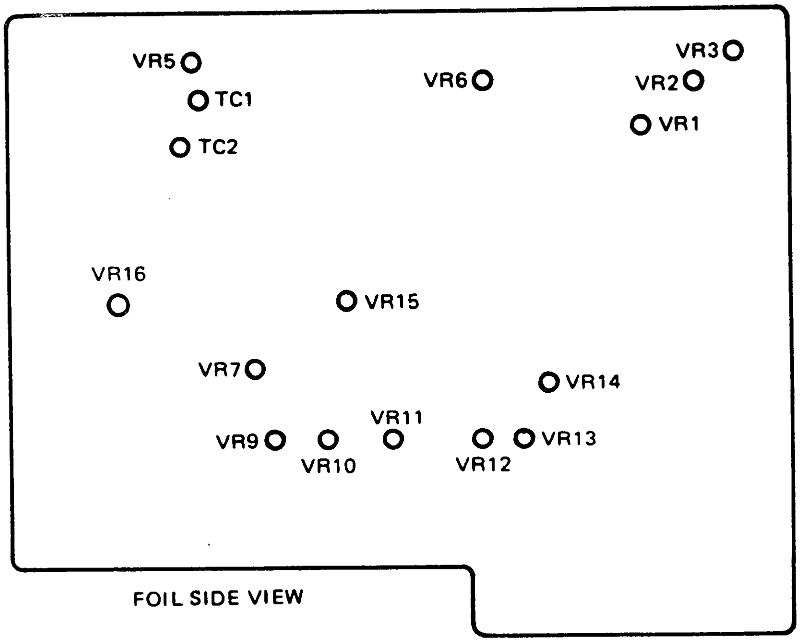
Fig. 37. Calibration locations, vertical pre-amplifier board.



FOIL SIDE VIEW

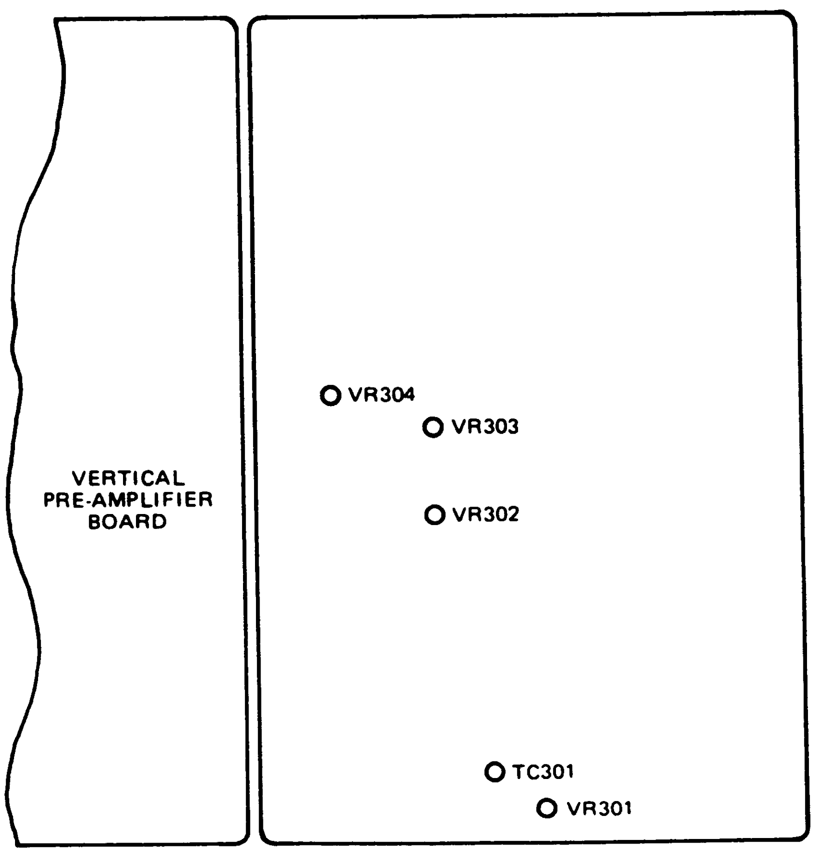
VR401 – VERTICAL GAIN ADJ.
VR402 – CRT CENTER ADJ.
TC401 – HIGH FREQUENCY RESPONSE ADJ. (1)
TC402 – HIGH FREQUENCY RESPONSE ADJ. (2)
TC403 – MID FREQUENCY RESPONSE ADJ.
TC404 – HIGH FREQUENCY RESPONSE ADJ.
VR403 – HIGH FREQUENCY RESPONSE ADJ.
VR404 – MID FREQUENCY RESPONSE ADJ.
VR405 – HIGH FREQUENCY RESPONSE ADJ.

Fig. 38. Calibration locations, main vertical amplifier board.



VR1 – CAL. (0.5 V P-P) VOLTAGE ADJ.
VR2 – CAL. OV LEVEL FREQUENCY ADJ.
VR3 – CAL. 0.5V LEVEL FREQUENCY ADJ.
VR5 – HIGH SPEED SWEEP (0.2 μ SEC) TIMING ADJ.
VR6 – SWEEP LENGTH ADJ.
VR7 – TRIGGERING SLOPE BALANCE ADJ. (1)
VR9 – AUTO LEVEL ADJ.
VR10 – MAG CENTER ADJ.
VR11 – DC TRIGGERING LEVEL ADJ.
VR12 – CH B (HORIZONTAL) POSITION ADJ.
VR13 – HORIZONTAL POSITION CENTER ADJ.
VR14 – MAG GAIN ADJ.
VR15 – TIMING ADJ.
TC1 – HIGH SPEED SWEEP (1 μ SEC - 50 μ SEC) TIMING ADJ.
TC2 – HIGH SPEED SWEEP (0.5 μ SEC) TIMING ADJ.
VR16 – TRIGGERING SLOPE BALANCE ADJ. (2)

Fig. 39. Calibration locations, horizontal amplifier/sweep board.



FOIL SIDE VIEW

VR301 – PATTERN DISTORTION COMPENSATION
VR302 – INTENSITY ADJ.
VR303 – -1.9 kV ADJ.
VR304 – +107 V ADJ.
TC301 – BLANKING PULSE COMPENSATION

Fig. 40. Calibration locations, power supply board.

WARRANTY SERVICE INSTRUCTIONS
(For U.S.A. and its Overseas Territories)

1. Refer to the MAINTENANCE section of your **B & K-Precision** instruction manual for adjustments that may be applicable.

2. If the above-mentioned does not correct the problem you are experiencing with your unit, pack it securely (preferably in the original carton or double-packed). Enclose a letter describing the problem and include your name and address. Deliver to, or ship PREPAID (UPS preferred in U.S.A.) to the nearest **B & K-Precision** authorized service agency (see list enclosed with unit).

If your list of authorized **B & K-Precision** service agencies has been misplaced, contact your distributor for the name of your nearest service agency, or write to:

B & K-Precision, Factory Service Department
Maxtec International Corp.
6470 West Cortland Street
Chicago, Illinois 60635
Tel: (312) 889-1448

Also use the above address for technical inquiries and replacement parts orders.