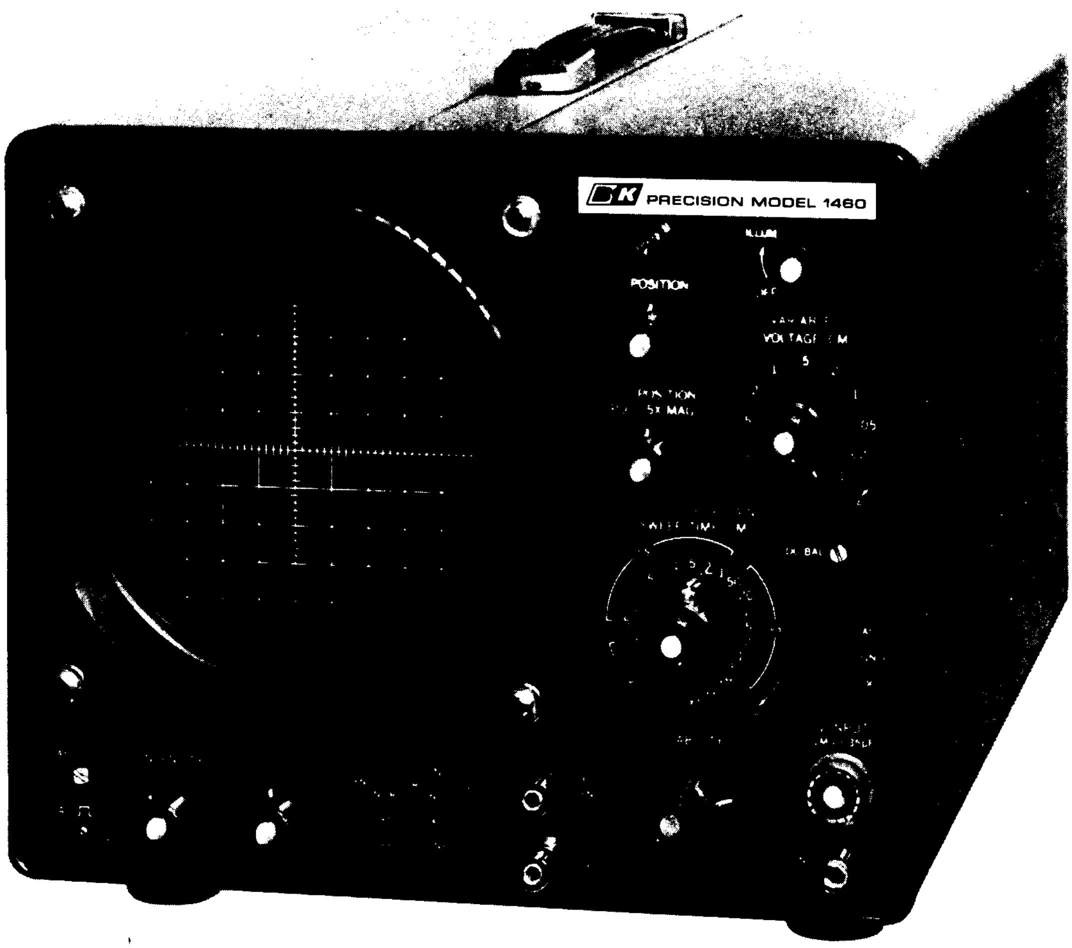
INSTRUCTION MANUAL

B+K PRECISION **1460**

SOLID STATE - TRIGGERED SWEEP

OSCILLOSCOPE



B+K PRECISION DYNASCAN CORPORATION

INSTRUCTION MANUAL

FOR

B & K/PRECISION

MODEL 1460

SOLID STATE TRIGGERED SWEEP OSCILLOSCOPE

B+K PRECISION DYNASCAN CORPORATION

6460 West Cortland Street
Chicago, Illinois 60635

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INTRODUCTION

The B & K Model 1460 Solid State, Triggered Sweep Oscilloscope is a laboratory quality, professional instrument for observing and measuring waveforms in electronic circuits. It performs all measurements made on conventional oscilloscopes, usually with greater stability and better resolution. Additionally, it includes greater bandwidth, sweep speed, and sensitivity, plus extra features to provide the electronic sophistication required for servicing color television and other state-of-the-art devices.

FEATURES

FULLY SOLID STATE — Only the cathode ray tube uses a filament. All other stages use transistors, diodes, and FET's (field effect transistors). Among the advantages of solid state construction are:

No stabilization warm-up time required.

Low power drain.

Dependability—reliability.

Ruggedness.

Light Weight.

Compactness.

TRIGGERED SWEEP — The stability of waveform presentation is beyond comparison with non-triggered sweep oscilloscopes. The sweep remains at rest until triggered by the signal being observed to assure that they are always synchronized, even when the waveform is of varying period recurrance. Fully adjustable trigger threshold allows the desired portion of the waveform to be used for triggering.

LARGE SCREEN — The 130 mm (approx. 5.1 inches) diameter cathode ray tube gives easy-to-read presentation.

CALIBRATED VOLTAGE SCALES — Accurate measurement of instantaneous voltages on 11 different ranges.

CALIBRATED SWEEP SPEED — Accurate time measurements on 19 different ranges.

TV HORIZONTAL — Special sync and sweep speed positions specifically designed for observing television horizontal lines.

TV VERTICAL — Special sync and sweep speed positions specifically designed for observing television vertical frames.

VECTORSCOPE — Vectorscope inputs and controls on the front panel, plus a vector overlay supplied with the oscilloscope provide a color demodulator display exactly as specified by color television manufacturers.

WIDE BANDWIDTH — DC to 10 MHz bandwidth and 35 nSEC rise time give distortion free, high resolution presentation at high freqquencies.

WIDE RANGE OF SWEEP SPEED — Sweep speeds of 0.5 μSEC/cm to 0.5 SEC/cm provides every speed necessary for viewing waveforms from DC to 10 MHz.

EXPANDED SCALE — A five time magnification (5X) of the horizontal sweep allows close-up examination of a portion of the waveform.

HIGH SENSITIVITY — Allows the low capacitance, high impedance, 10:1 attenuation probe to be used for virtually all measurements, thus offering less circuit loading.

CALIBRATION SOURCE — A built-in calibrated 5 volt peak-to-peak square wave permits checking and recalibration of the vertical amplifiers without additional equipment.

Z-AXIS INPUT — Intensity modulated capability included for time or frequency markers.

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

SPECIFICATIONS

VERTICAL AMPLIFIER

Deflection factor	0.01 V/cm to 20 V/cm, ± 5%, divided for all ranges each providing means for fine adjustment.
Frequency response	DC – DC to 10 MHz (–3dB)
	AC – 2 Hz to 10 MHz (–3dB)
Risetime	35 nanoseconds
Overshoot	3% or less
Input resistance	1 Megohm (approximate)
Input capacity	35pF (approximate)
Tilt	5% or less
Max. input voltage	300 V (DC + AC peak) or 600 Vp-p

SWEEP CIRCUIT

Sweep system	TRIGGERED and AUTOMATIC
Sweep time	0.5 μSEC/cm to 0.5 SEC/cm (±5%), divided for 19 ranges each providing means for fine adjustment. TVH (13 μSEC/cm) and TVV (3.6 mSEC/cm)
Sweep magnification	As obtained by enlarging the above sweep 5 times from center

TRIGGERING

Type	Internal, line frequency and external (2Vp-p or higher) triggering
Trace Slope	Positive and negative
Triggering range	20 Hz to 10 MHz (minimum 10mm of deflection, as measured on cathode ray tube scope)
TV synchronization	HORIZONTAL 100 Hz to 1 MHz minimum 10mm of deflection VERTICAL 100 Hz to 3 KHz minimum 10mm of deflection Any portion of complex TV waveforms can be synchronized and expanded for viewing

HORIZONTAL AMPLIFIER

Deflection factor	300 mV/cm
Frequency response	DC to 800 KHz (–3 dB)
Input resistance	100K ohm (Approximately)
Input capacity	40pF or less

CALIBRATION VOLTAGE

1 KHz square wave of 5Vp-p (± 5%)

INTENSITY MODULATION

Voltage	30Vp-p minimum

POWER REQUIREMENTS

117 VAC, 50/60 Hz, 20W (3-wire line cord)

SEMICONDUCTOR

Complement	5 FET's 40 Transistors 14 Diodes

ACCESSORIES (Not Included)

Probe: B&K-Precision Models PR-16 and PR-20

Attenuation	Combination 10:1 and Direct
Input Impedance 10:1 (Low capacity)	10 MEGΩ, 18pf
Direct	1 MEGΩ, 120pf

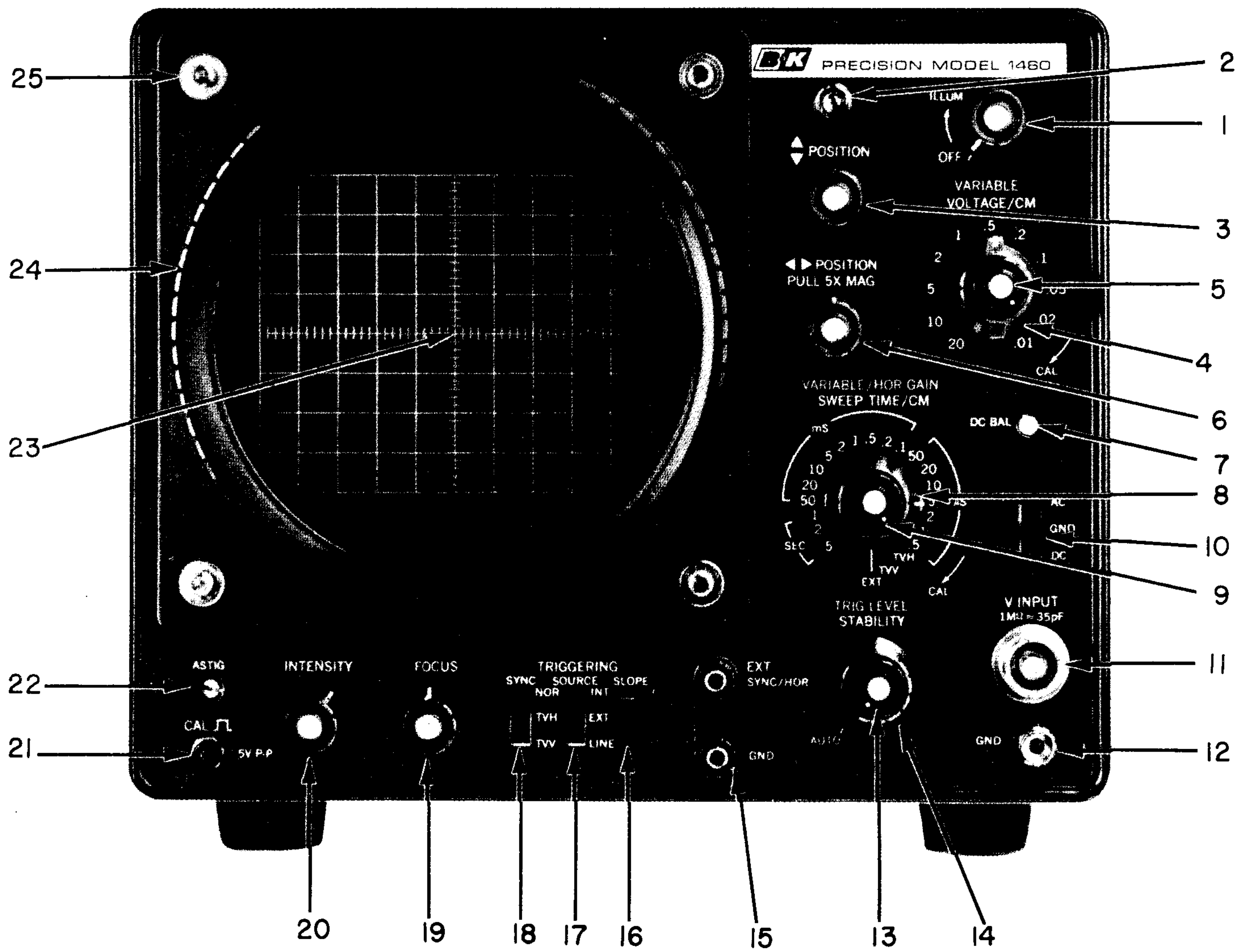


Figure 1. Controls and Indicators

CONTROLS AND INDICATIONS

1 OFF/scale illumination control. Fully counter-clockwise turns off oscilloscope. Clockwise turns on oscilloscope and increases scale illumination.

2 Pilot lamp. Lights when oscilloscope is on.

3 ▲▼ POSITION control. Vertical position adjustment.

4 VOLTAGE/CM switch. Vertical attenuator. Coarse adjustment of vertical sensitivity. Vertical sensitivity is calibrated in 11 steps from .01 to 20 volts per cm when VARIABLE **5** is set to the CAL position.

5 VARIABLE control. Vertical attenuator adjustment. Fine control of vertical sensitivity. In the extreme clockwise (CAL) position, the vertical attenuator is calibrated.

6 ◄► POSITIOIN control. Rotation adjusts horizontal position of trace. Push-pull switch selects 5X magnification when pulled out; normal when pushed in.

7 DC BAL adjustment. Vertical dc balance adjustment.

8 SWEEP TIME/CM switch. Horizontal coarse sweep time selector. Selects calibrated sweep times of 0.5 μSEC/cm to 0.5 SEC/cm in 19 steps when VARIABLE/HOR GAIN control **9** is set to CAL. Selects proper sweep time for television composite video waveforms in TVH (television horizontal) and TVV (television vertical) positions. Disables internal sweep generator and displays external horizontal input in EXT position.

9 VARIABLE/HOR GAIN control. Fine sweep time adjustment (horizontal gain adjustment when SWEEP TIME/CM switch **8** is in EXT position). In the extreme clockwise position (CAL) the sweep time is calibrated.

10 AC-GND-DC switch. Vertical input selector switch.
- AC position—blocks dc component of input signal.
- GND position—opens signal input 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.
- DC position—direct input of ac and dc component.

11 V INPUT jack. Vertical input.

12 GND terminal. Chassis ground.

13 TRIG LEVEL control. Sync level adjustment determines point on waveform slope where sweep starts. In fully counterclockwise (AUTO) position, sweep is automatically synchronized to the average level of the waveform.

14 STABILITY control. Sync stability adjustment.

15 EXT SYNC/HOR jack. Input terminal for external sync or external horizontal input.

16 TRIGGERING SLOPE switch. Selects sync polarity (+) or (−).

17 TRIGGERING SOURCE switch.
- INT—waveform being observed is used as sync trigger.
- EXT—signal at EXT SYNC/HOR jack **15** is used as sync trigger.
- LINE—power line frequency sync (50/60 Hz).

18 SYNC switch.
- NOR—normal.
- TVH—syncs on horizontal components of composite video.
- TVV—syncs on vertical component of composite video.

19 FOCUS control.

20 INTENSITY control. Adjusts brightness of trace.

21 CAL ⎍ jack. Provides calibrated 5 Vp-p square wave output at approximately 1 KHz.

22 ASTIG adjustment. Astigmatism adjustment provides roundness to spot on cathode ray tube.

23 Scale. Provides calibration marks for voltage and time measurements. Scale can be removed and replaced wth vector overlay. **26**.

24 Observation bezel.

25 Bezel retaining nuts (4).

26 Vector overlay. Used in place of scale **23** for vectorscope applications. (Not illustrated)

27 Probe (Not illustrated). Combination 10:1 and direct probe available for vertical input.

28 INT MOD jack. Intensity modulation (Z axis) input.

29 Fuse.

30 Power cable storage compartment.

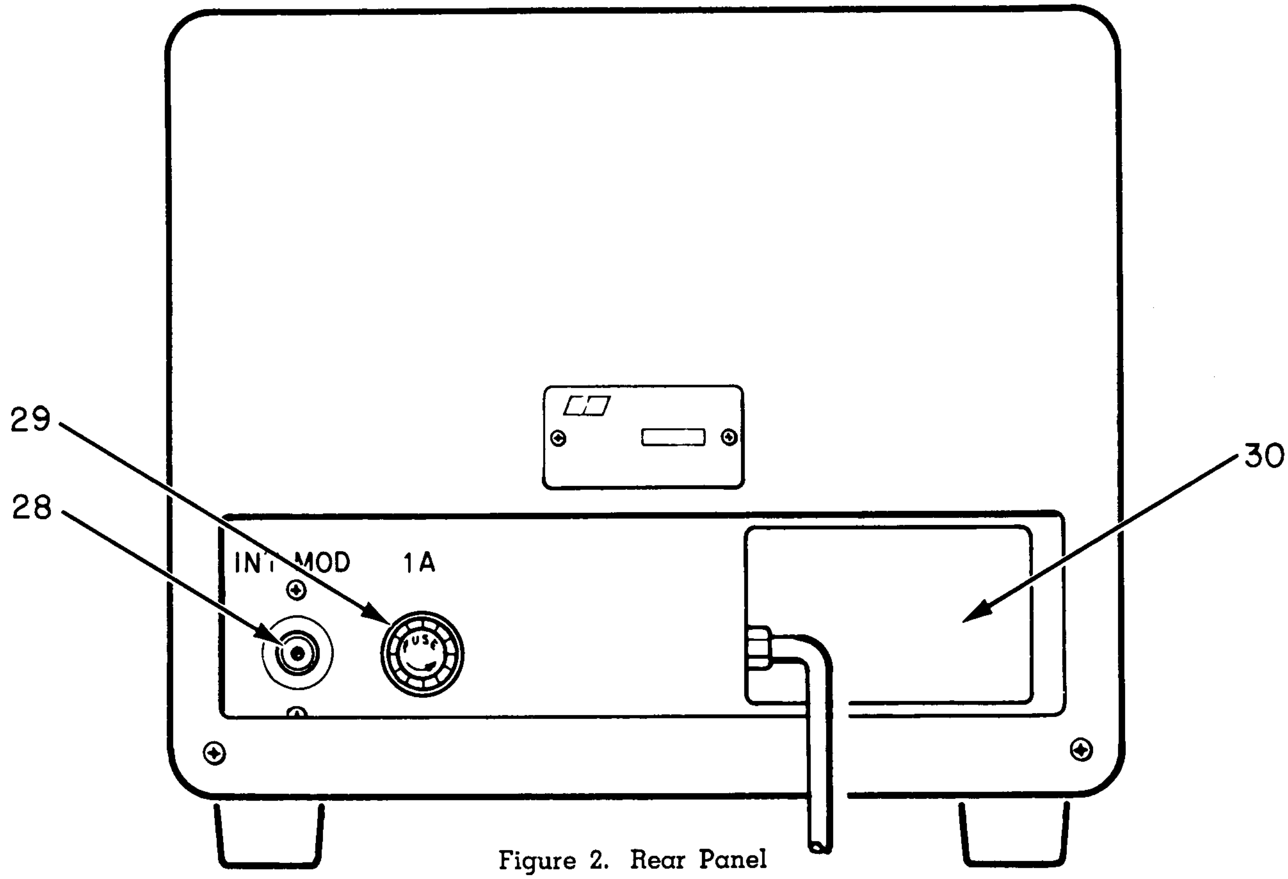


Figure 2. Rear Panel

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

INITIAL STARTING PROCEDURE

1. Set the OFF/scale illumination control **1** to the OFF position (fully counterclockwise).
2. Connect the power cord to a 117 volt, 60 Hz AC outlet.
3. Set the ⬍ POSITION control **3** and ◂▸ POSITION control **6** to the center of their ranges.
4. Set the TRIG LEVEL control **13** to the AUTO position (fully counterclockwise).
5. Set the AC-GND-DC switch **10** to the GND position.
6. Turn on the oscilloscope by rotating the OFF/scale illumination control **1** clockwise. It will "click" on and the pilot lamp **2** will light. Turn the control clockwise to the desired scale illumination.
7. Wait a few seconds for the cathode ray tube (CRT) to warm up. A trace should appear on the face of the CRT.
8. If no trace appears, increase (clockwise) the INTENSITY control **20** setting until the trace is easily observed. If trace is still not visible, turn STABILITY control **14** fully clockwise, which places the sweep generator in a free-running mode (no sync trigger required to produce sweep).
9. Adjust the FOCUS control **19** and INTENSITY control **20** for the thinnest, sharpest trace.
10. Readjust the POSITION controls **3** and **6**, if necessary, to center the trace.
11. Check for proper adjustment of the ASTIG **22** and DC BAL **7** controls and CRT positioning as instructed in the MAINTENANCE and CALIBRATION" portion of this manual. These adjustments require checking only periodically.

The oscilloscope is now ready for making waveform measurements.

WAVEFORM OBSERVATION

1. Perform the steps of the initial starting procedure, then connect the probe cable to the V INPUT receptacle **11**.
2. For all except low amplitude waveforms, the probe **27** is set for 10:1 attenuation. For low amplitude waveforms (below 0.5 volt peak-to-peak), set the probe for DIRECT. See Figure 3 for changing the probe from 10:1 to DIRECT, or vice versa. The probe has a 10 megohm input impedance with only 18pF shunt capacitance in the 10:1 position and 1 megohm with 120pF shunt capacitance in the DIRECT position. The higher input impedance (low capacity position) should be used when possible to decrease circuit loading.
3. Set the AC-GND-DC switch **10** to AC for measuring only the ac component (This is the normal

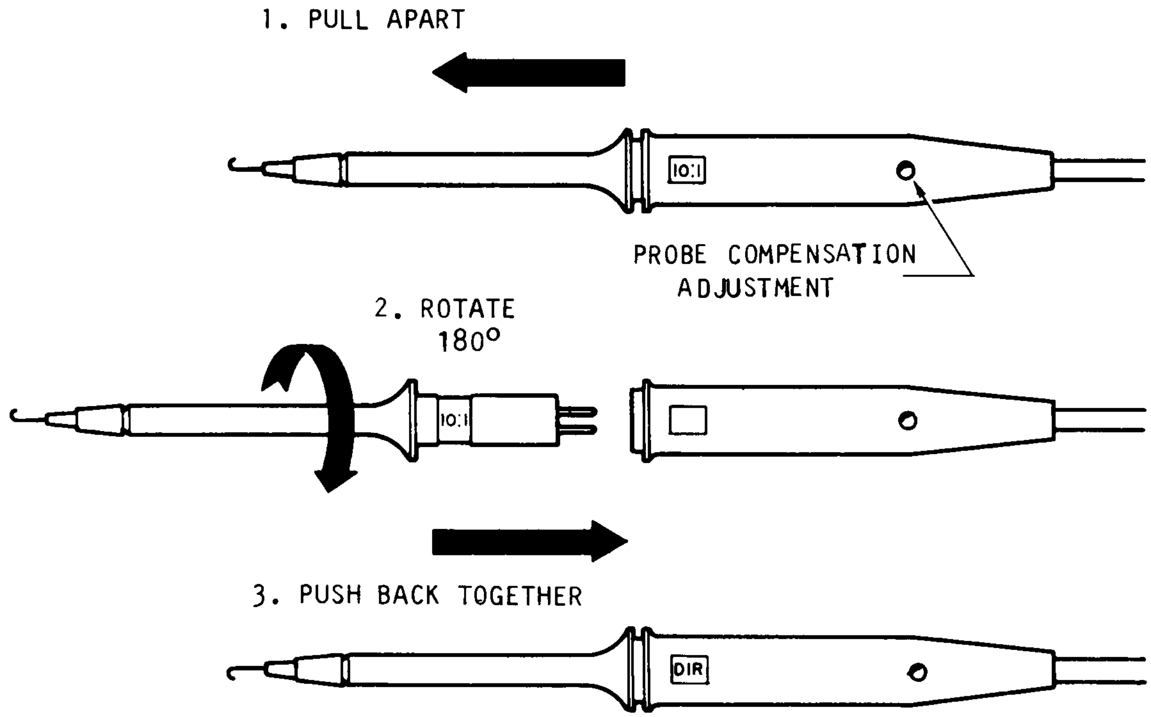


Figure 3. Changing Probe from 10:1 to DIRECT

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 5 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 the ground clip of the probe **27** 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

1. If the equipment under test is a transformerless ac powered item, use an isolation transformer to prevent dangerous electrical shock.
2. The peak-to-peak voltage at the point of measurement should not exceed 600 volts.

5. Set the VOLTAGE/CM control **4** to a position that gives 2 cm 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 the SYNC switch **18** to the TVV position for observing television composite video waveforms synchronized with vertical sync pulses, to the TVH position for observing television composite video waveforms synchronized with horizontal sync pulses, or the NOR position for all other waveforms.

7. Set the TRIGGERING SOURCE switch **17** to the INT (internal) position when the waveform being observed is also to be used to trigger the sweep. Most waveforms should be viewed with this switch in the INT position. When an external sync source is required, use the EXT position. When observing waveforms in power circuits or other circuits that can be synchronized with 60 Hz, use the LINE position. This position synchronizes the sweep with the ac input power frequency.

8. Set the TRIGGERING SLOPE switch **16** to (+) if the sweep is to be triggered by a positive going wave, and to (—) if the sweep is to be triggered by a negative going wave. For observing television composite video signals it is desired to sync the sweep to the horizontal line sync pulses or the vertical blanking pulses. Because the polarity of the composite video signals varies according to the point at which it is observed, use the following procedure:

   a. If the observed sync pulses or blanking pulses are positive going (upward trace deflection is produced by a positive voltage), use the (—) position of the TRIGGERING SLOPE switch.

   b. If the observed pulses are negative, use the (+) position of the TRIGGERING SLOPE switch.

9. Set the SWEEP TIME/CM control **8** and VARIABLE/HOR GAIN control **9** 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 proportionately smaller portion is displayed. This is because the writing 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.

   The TVH and TVV positions are ideal for observing television video waveforms. These positions select the correct sweep time to display two complete horizontal lines or two complete vertical frames when **9** is set to CAL.

10. To synchronize the waveform, set the TRIG LEVEL control **13** fully counterclockwise to the AUTO position. Next turn the STABILITY control **14** counterclockwise until the trace disappears. Now turn the STABILITY control clockwise just past the point where the trace reappears. This should provide a stable waveform free of jitter. Do not turn the STABILITY control too far clockwise, as it will go into a free-running (non-synchronized) mode.

11. Step 10 assumes that you desire to use automatic sync, wherein the predominant point of the waveform is automatically selected as the sync trigger. If another point on the waveform is desired as the sync trigger (as is often the case in viewing sinusoidal waves), turn the TRIG LEVEL control **13** clockwise away from the AUTO position. Set the control by observing the waveform and note that it starts at the desired time. It may also be necessary to readjust the STABILITY control **14**. This control has three general "modes" when rotated from one extreme to the other. On the counterclockwise end, no trace is produced, for the sync threshold level is set so none of the input signal is sufficient to trigger the sweep. At the clockwise extreme, the sync threshold is so low that anything will trigger the sweep, resulting in a free-running, unsynchronized mode. The center range provides the proper threshold for synchronization and results in the desired stable presentation. The boundaries of this center range depend upon the strength and type of signal input and the setting of the TRIG LEVEL control. However, the setting of the STABILITY control is not critical; it operates properly over this entire "center" area and the proper setting is easy to attain.

12. For a close-up view of a portion of the waveform, pull outward on the ◂▸ POSITION control **6**. 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 **6** 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.

CALIBRATED VOLTAGE MEASUREMENT

Peak voltages, peak-to-peak voltages, dc voltages and voltages of a specific portion of a complex waveform are easily and accurately measured on this oscilloscope.

1. Adjust controls as previously instructed to display the waveform to be measured.
2. Be sure the vertical VARIABLE control **5** is set fully clockwise to the CAL position.
3. Set the VOLTAGE/CM control **4** for the largest vertical deflection possible without exceeding the limits of the vertical scale.
4. Read the amount of vertical deflection (in cm) from the scale. The ⬍ POSITION control **3** may be readjusted to shift the reference point for easier scale reading if desired. When measuring a dc voltage, adjust the ⬍ POSITION control **3** to a convenient reference with the AC-GND-DC switch **10** 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 5 MHz, it is important that the probe be used in the 10:1 position to reduce circuit loading and that the oscilloscope controls be set so that the height of the pattern does not exceed 4 centimeters and that the trace be centered vertically.

5. Calculate the voltage reading as follows: Multiply the vertical deflection (in cm) by the VOLTAGE/CM control **4** setting (see example in Figure 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 the oscilloscope may be occasionally checked by observing the 5 volt peak-to-peak square wave signal available at the CAL ⎍ jack **21**. This calibrated source should read exactly 5 volts peak-to-peak. If a need for recalibration is indicated, see the "MAINTENANCE and CALIBRATION" section of the manual for complete procedures.

CALIBRATED TIME MEASUREMENT

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 seconds down to .1 microsecond (μS) 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.

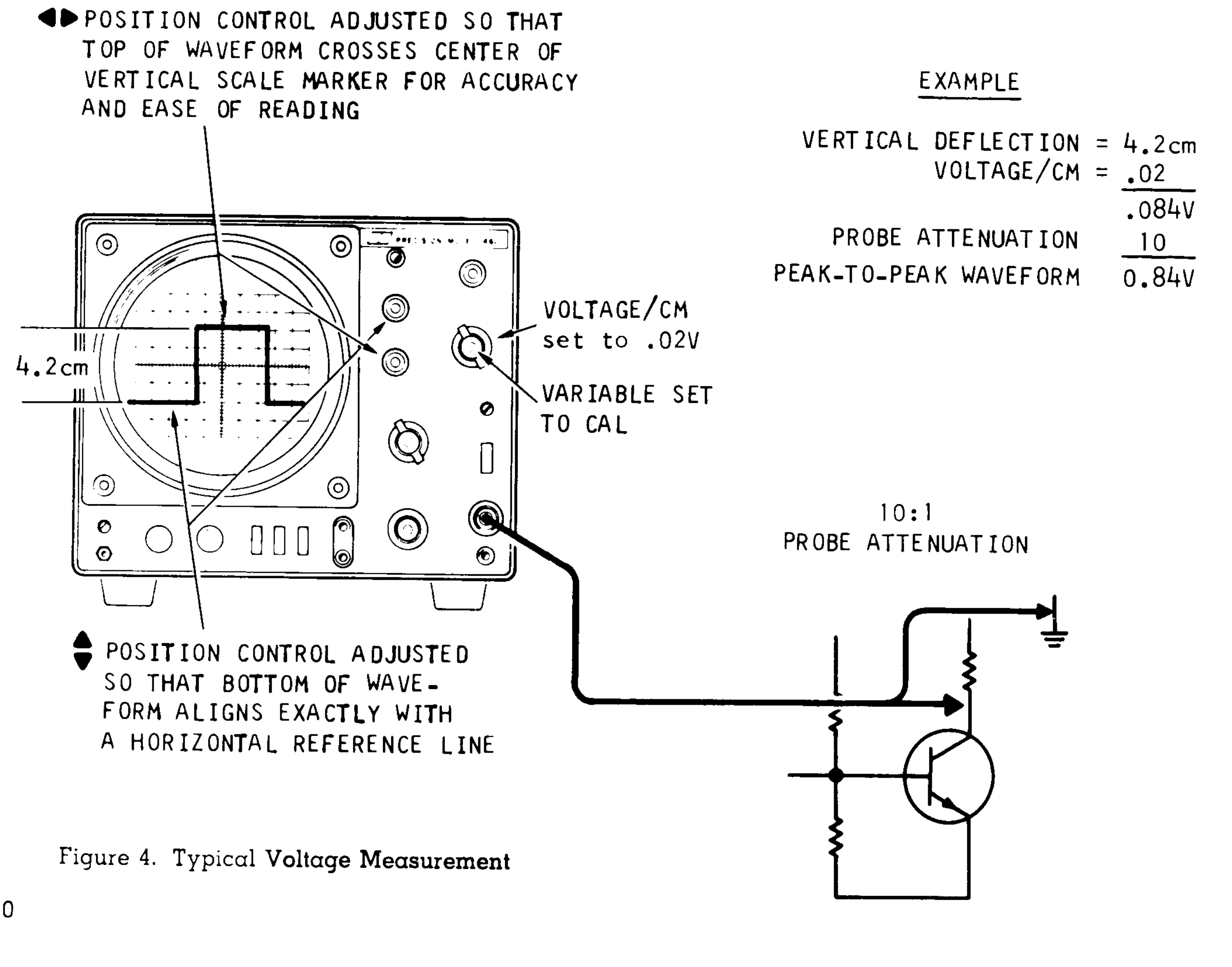


Figure 4. Typical Voltage Measurement

1. Adjust controls as previously described for a stable display of the desired waveform.
2. Be sure the VARIABLE/HOR GAIN control **9** is fully clockwise to the CAL position.
3. Set the SWEEP TIME/CM control **8** for the largest possible display of the waveform segment to be measured, usually one cycle.
4. If necessary, readjust the TRIG LEVEL and STABILITY controls **13** and **14** for the most stable display.
5. Read the amount of horizontal deflection (in cm) between the points of measurement. The ◀▶ POSITION control **6** may be readjusted to align one of the measurement points with a vertical scale marker for easier reading.
6. Calculate the time duration as follows: Multiply the horizontal deflecton (in cm) by the SWEEP TIME/CM control **8** setting (see example in Figure 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 delay between the sync pulse and the subsequent waveform. To perform such measurements using external sync, use the following steps:
   a. Set the TRIGGERING SOURCE switch **17** to the EXT position.
   b. Connect a lead from the EXT SYNC/HOR jack **15** to the source of sync signal. Use a short shielded cable.
   c. Set the TRIGGERING SLOPE switch **16** to the proper polarity (+) or (−) for the sync signal.
   d. Readjust the TRIG LEVEL and STABILITY controls **13** and **14**, if necessary, for a stable waveform.
   e. Set the SWEEP TIME/CM control **8** as for other time measurements. Do not set it to the EXT position. This position is for external horizontal deflection, not external sync.
   f. If measuring a delay, measure the time from the start of the sweep to the start of the waveform.

EXTERNAL HORIZONTAL INPUT

For some measurements, an external horizontal deflection signal is required. This may be a sinu-

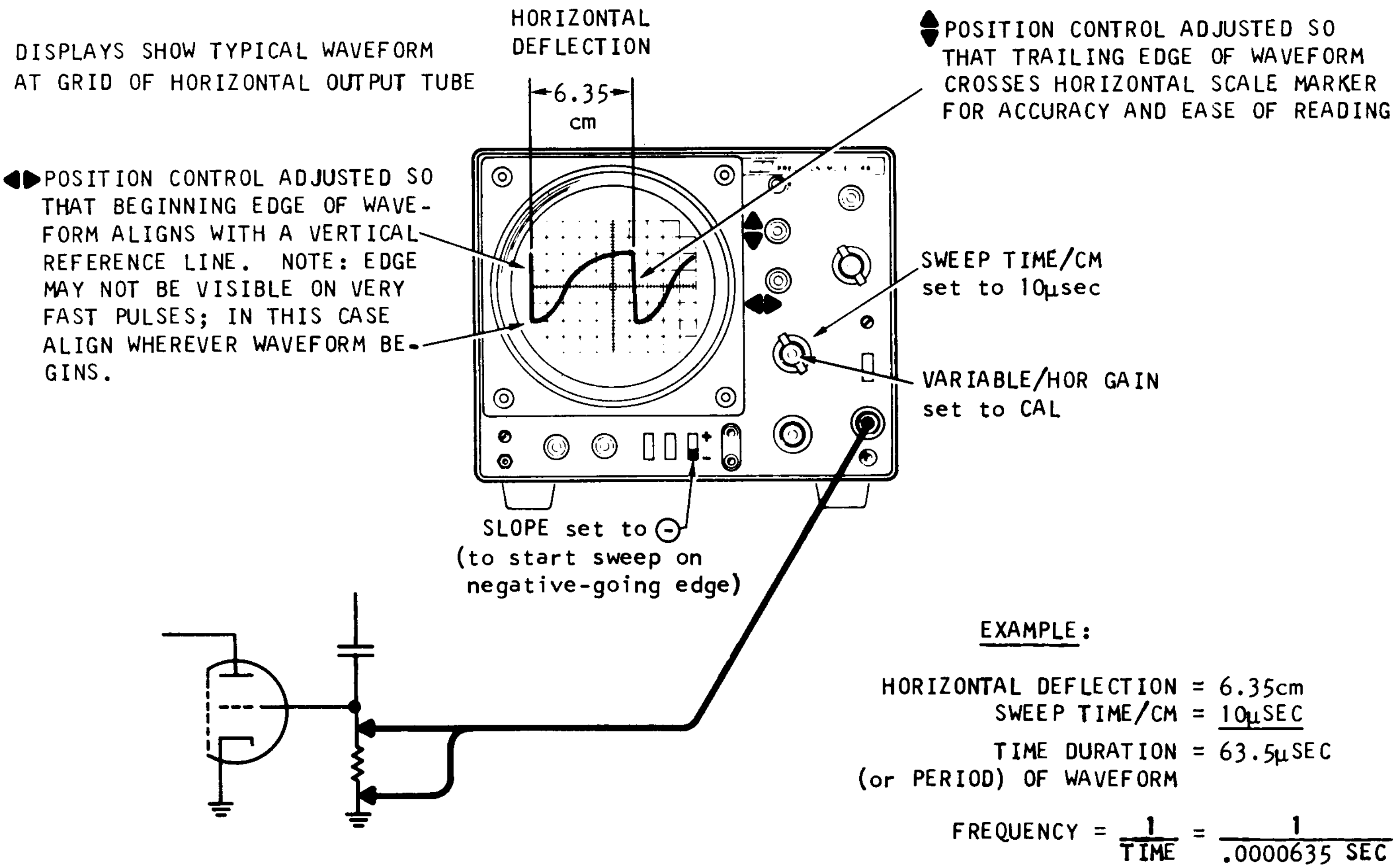


Figure 5. Typical Time Measurement

soidal wave, such as used for phase measurement, or an external sweep voltage. This input voltage must be about 250 millivolts per cm of deflection (usually 2 volts or more peak-to-peak will provide satisfactory results). To use an external horizontal input, use the following procedure:

1. Set the SWEEP TIME/CM control **8** to the EXT position.
2. Connect the external horizontal signal source through a cable to the EXT SYNC/HOR jack **15**.
3. Adjust the amount of horizontal deflection with the VARIABLE HOR GAIN control **9**, which adjusts the gain of the horizontal amplifier.
4. 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 markers are required. A 30-volt peak-to-peak or greater signal applied at the INT MOD (intensity modulation) jack **22** on the rear of the oscilloscope will provide alternate brightness and blanking of the trace. (See Figure 6.)

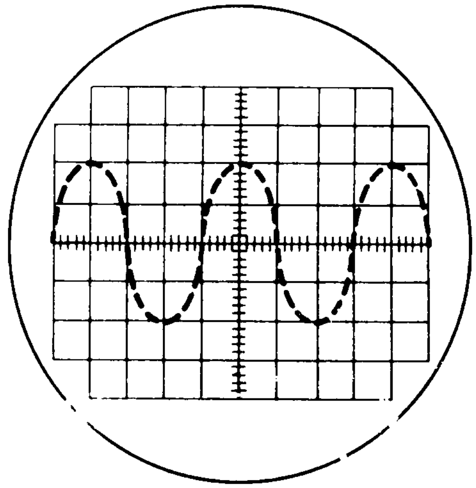


Figure 6. Oscilloscope Trace with Z-axis Input

APPLICATIONS

TELEVISION SERVICING

A triggered sweep oscilloscope is advantageous in servicing and aligning television receivers. This oscilloscope also includes several features that were incorporated to make television servicing easier and more comprehensive. These features include:

- Sync separator and selection of TVV (vertical) or TVH (horizontal) sync to trigger the sweep for observing vertically or horizontally synchronized video.

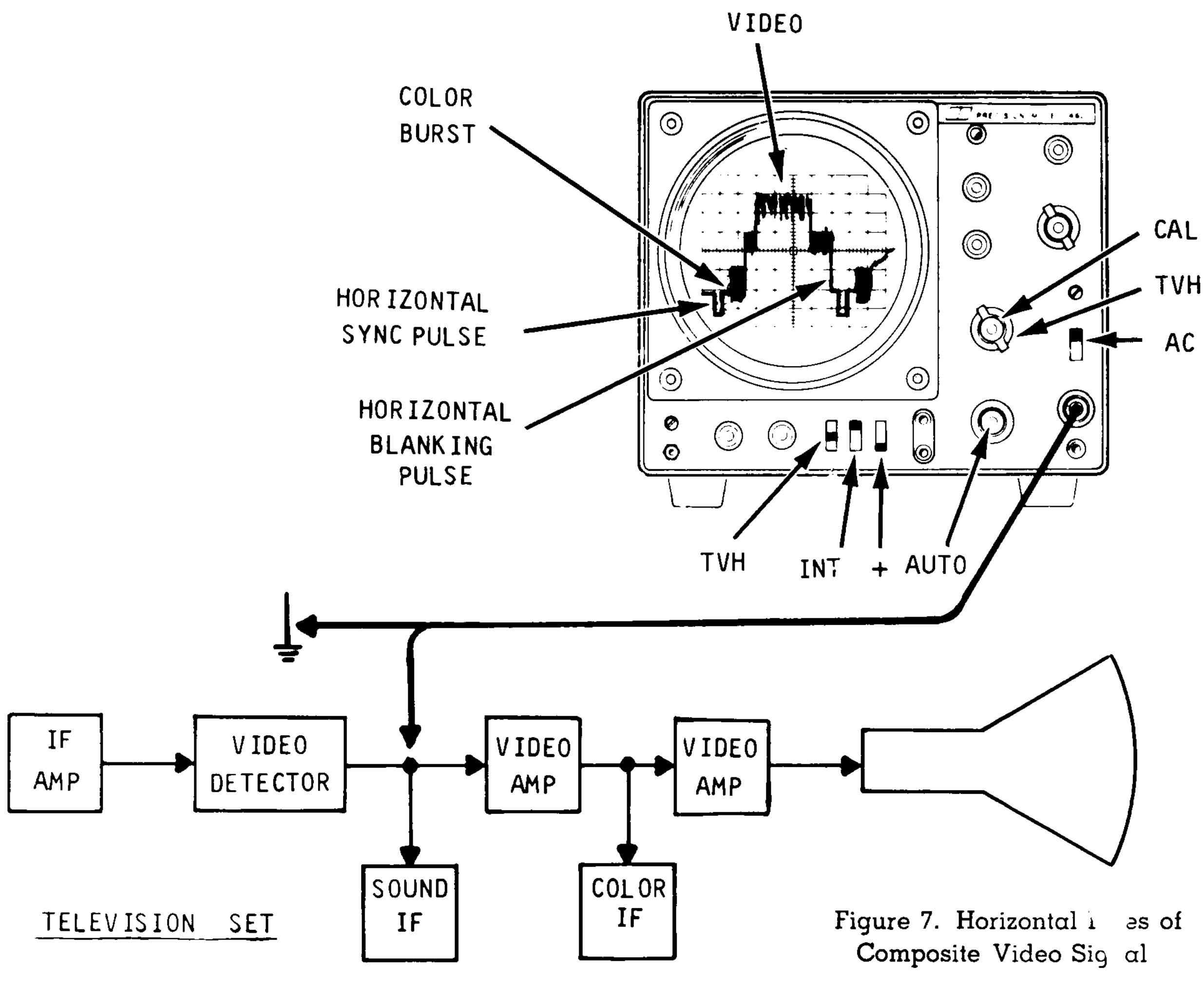


Figure 7. Horizontal Lines of Composite Video Signal

- Sweep speed automatically set to display two horizontal lines or two vertical frames of video in the TVH and TVV positions of the SWEEP TIME/CM control.
- Vector overlay for color demodulator checks.
- Wide bandwidth for high resolution video and pulse presentation.
- High impedance (10 megohm), low capacitance (18pF) probe (in 10:1 position) does not appreciably load circuit, shift frequency, or distort waveforms.

SIGNAL TRACING AND PEAK-TO-PEAK VOLTAGE READINGS

For general troubleshooting and isolation of troubles in television receivers (or almost any other electronic equipment for that matter), the oscilloscope is an indispensible 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-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 reading 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.

COMPOSITE VIDEO WAVEFORM ANALYSIS

Probably the most imporant waveform in television servicing is the composite waveform consisting of the video signal, the blanking pedestals and the sync pulses. Figures 7 and 8 show typical oscilloscope traces when observing composite video signals synchronized with horizontal sync pulses and vertical sync pulses. Composite video signals can be observed at various circuits of the television receiver to determine whether circuits are performing normally. Knowledge of waveform makeup, the appearance of a normal waveform, and the causes of various abnormal waveforms help the technician

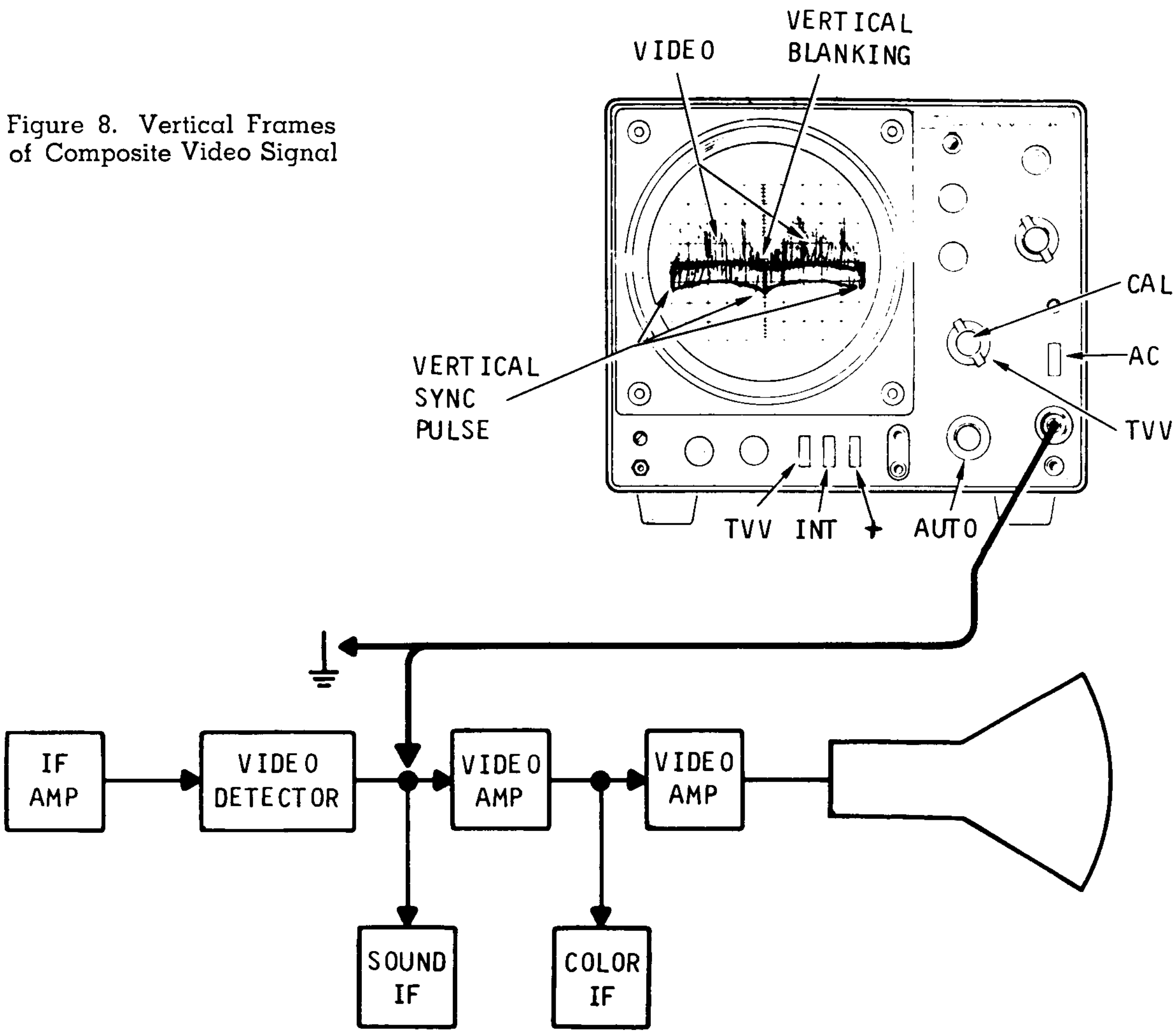


Figure 8. Vertical Frames of Composite Video Signal

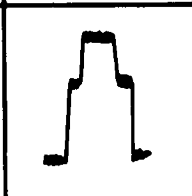
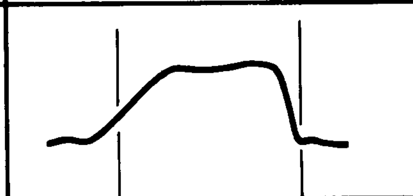
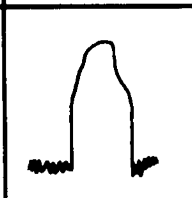
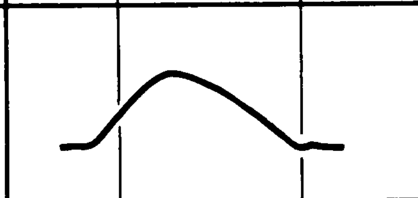
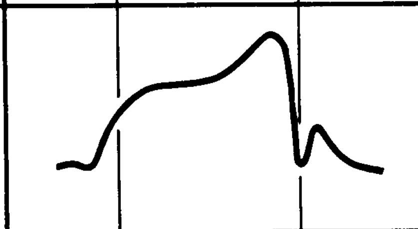
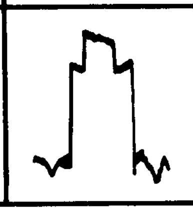
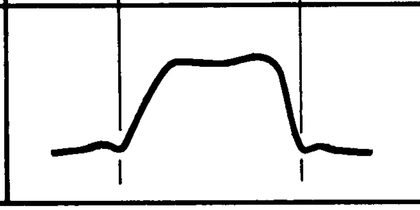
CIRCUIT DEFECT	HORIZONTAL PULSE DISTORTION	OVERALL RECEIVER FREQUENCY RESPONSE	EFFECT ON PICTURE
NORMAL CIRCUIT			PICTURE NORMAL
LOSS OF HIGH FREQUENCY RESPONSE			LOSS OF PICTURE DETAIL
EXCESSIVE HIGH FREQUENCY RESPONSE, NON-LINEAR PHASE SHIFT			FINE VERTICAL BLACK & WHITE STRIATIONS FOLLOWING A SHARP CHANGE IN PICTURE SHADING
LOSS OF LOW FREQUENCY RESPONSE			CHANGE IN SHADING OF LARGE PICTURE AREAS; SMEARED PICTURE

Figure 9. Analysis of Sync Pulse Distortion

locate and correct many problems. The technician should study such waveforms in a television receiver known to be in good operating condition, noting the waveform at various points in the video amplifier.

To set up the oscilloscope for viewing television composite video waveforms, use the following procedure:

1. Tune the televison set to a local channel.
2. Set the SYNC switch to TVH for horizontal pulse sync or TVV for vertical pulse sync. Also set the SWEEP TIME/CM control to TVH for horizontal line viewing or to TVV for vertical frame viewing.
3. Set the TRIGGERING SOURCE switch to INT.
4. With the TRIG LEVEL control initially set to AUTO, adjust the INTENSITY for a trace.
5. Set the AC-GND-DC switch to AC and connect the probe to the V INPUT jack. Connect the ground clip of the probe to the television set chassis. With the probe set at 10:1, connect the tip of the probe to the video detector output.
6. Set the VOLTAGE/CM control for largest vertical deflection without going-off scale.
7. Set the TRIGGERING SLOPE switch as follows:
   a. If the sync and blanking pulses of the observed video signal are positive, use the (—) switch position.
   b. If the sync and blanking pulses are negative, use the (+) switch position.

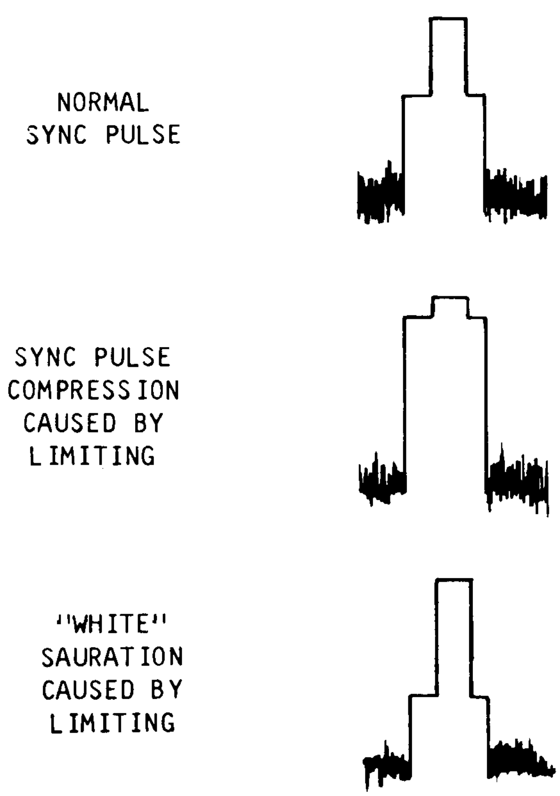


Figure 10. Sync Pulse Waveforms

8. Turn the STABILITY control counterclockwise until no sweep appears. Finally, increase the STABILITY setting (clockwise) until the sweep reappears. This should provide a very stable waveform presentation.
9. Adjust INTENSITY and FOCUS for desired brightness and best focus.
10. To view a specific postion of the waveform, such as the color burst, pull outward on the ◂▸ POSITION control for 5 x magnification. Rotate the same control left or right to select the desired portion of the waveform to be viewed.
11. Composite video waveforms may be checked at other points on the video circuits by moving the probe tip to those points and changing the VOLTAGE CM control setting as required to keep the display within the limits of the scale, and by readjusting the STABILITY control to maintain stabilization. The polarity of the observed waveform may be reversed when moving from one monitoring point to another; therefore, it is important to remember that best synchronization of the observed waveform is obtained if the TRIGGERING SLOPE switch is used as outlined in preceding Paragraph 7.

SYNC PULSE ANALYSIS

The i-f amplifier response of a television receiver can be evaluated to some extent by careful observation of the horizontal sync pulse waveform. The appearance of the sync pulse waveform is affected by the i-f amplifier bandpass characteristics. Some typical waveform symptoms and their relation to i-f amplifier response are indicated in Figure 9. Sync pulse waveform distortions produced by positive or negative limiting in i-f overload conditions are shown in Figure 10.

VITS (VERTICAL INTERVAL TEST SIGNAL)

Most network television signals contain a built-in test signal (the VITS) that can be a very valuable tool in troubleshooting and servicing television sets. This VITS can localize trouble to the antenna, tuner, i-f or video sections and shows when realignment may be required. The following procedures show how to analyze and interpret oscilloscope displays of the VITS.

The VITS is transmitted during the vertical blanking interval. On the television set, it can be seen as a bright white line above the top of the picture, when the vertical linearity or height is adjusted to view the vertical blanking interval (on TV sets with internal retrace blanking circuits, the blanking circuit must be disabled to see the VITS).

The transmitted VITS is a precision sequence of specific frequency, amplitude, and waveshape as shown in Figures 11 and 12. The television networks use the precision signals for adjustment and check-

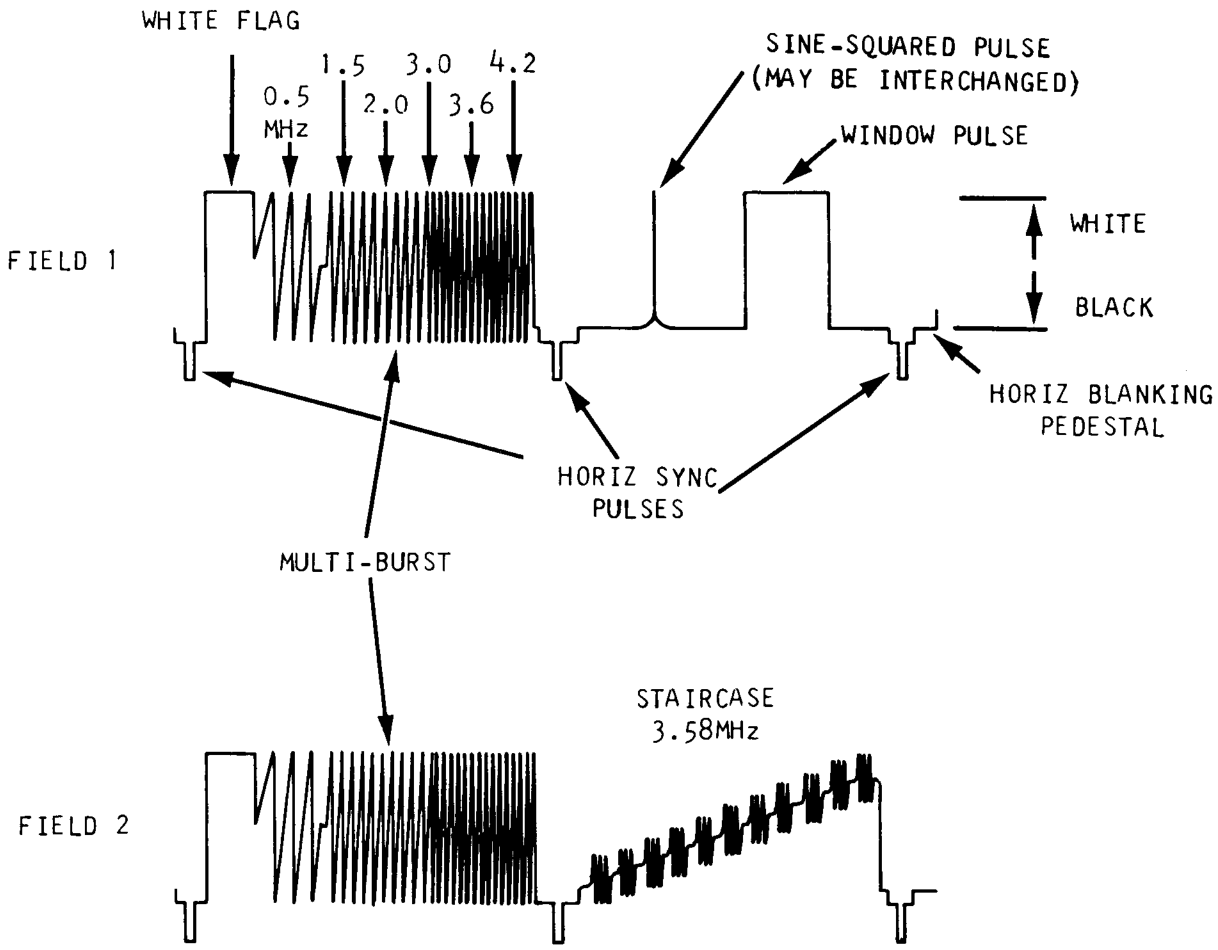


Figure 11. VITS Signal, Field 1 and Field 2

ing of network transmission equipment, but the technician can use them to evaluate television set performance. The first frame of the VITS (line 17) begins with a "flag" of white video, followed by sine wave frequencies of 0.5 MHz, 1.5 MHz, 2 MHz, 3 MHz, 3.6 MHz, (3.58 MHz), and 4.2 MHz. This sequence of frequencies is called the "multi-burst". The first frame of field #2 (line 279) also contains an identical multi-burst. This multi-burst portion of the VITS is the portion that can be most valuable to the technician. The second frame of the VITS (lines 18 and 280), which contains the sine-squared pulse, window pulse and the staircase of 3.58 MHz bursts at progressively lighter shading, are valuable to the network, but have less value to the technician. As seen on the television screen, field #1 is interlaced with field #2 so that line 17 is followed by line 279 and line 18 is followed by line 280. The entire VITS appears at the bottom of the vertical blanking pulse and just before the first line of video.

Each of the multi-burst frequencies is transmitted at equal strength. By observing the comparative strengths of these frequencjes after the signal is processed through the television receiver, the frequency response of the set is checked.

Set up the oscilloscope as follows to view the VITS:

1. Connect the probe (set at 10:1) to the output of the video detector or other desired test point in the video section of the television set.
2. If the television set has a vertical retrace blanking circuit, bypass this circuit during the measurement.
3. Set up the oscilloscope for TVV sync and TVV sweep time as previously described. Two vertical frames will be visible.
4. Place the VARIABLE/HOR. GAIN control in the CAL position.
5. Reduce sweep time to .1 millisecond per centimeter (.1 ms/CM) with the SWEEP TIME/CM switch. This expands the display by increasing the sweep speed. The VITS information will appear to the right on the expanded waveform display.
6. Further expand the sweep with the 5X magnification (pull outward on the ◄► POSITION control). Rotate the ◄► POSITION control in a counterclockwise direction, moving the trace to the left, until the expanded VITS appears.
NOTE: The brightness level of the signal display will be reduced because, although the repetition rate is only 60 Hz (a 16,000 μsec. period), the writing speed is 20 μsec/cm (.1 ms/cm magnified five times).

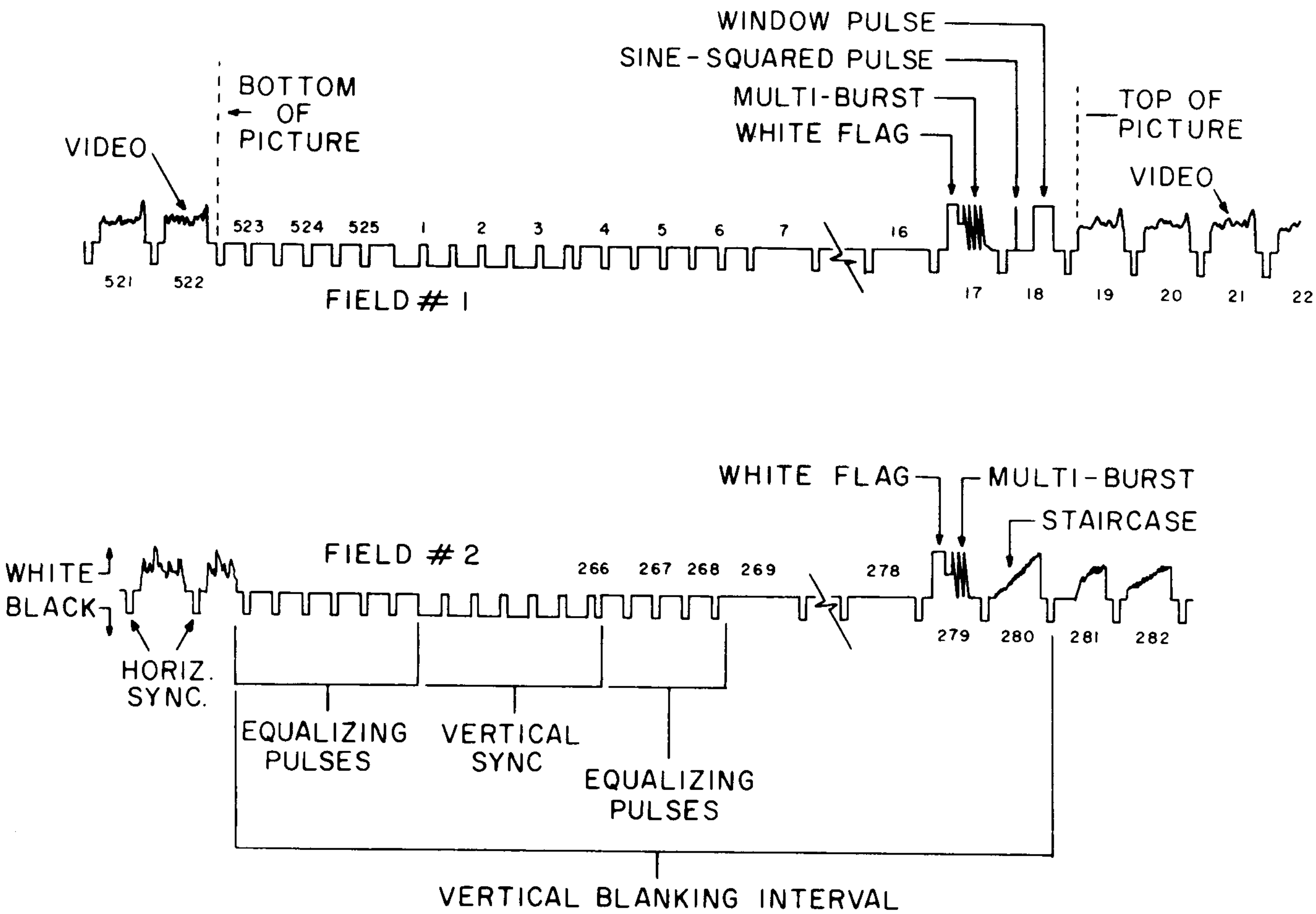


Figure 12. Vertical Blanking Interval showing VITS Signal

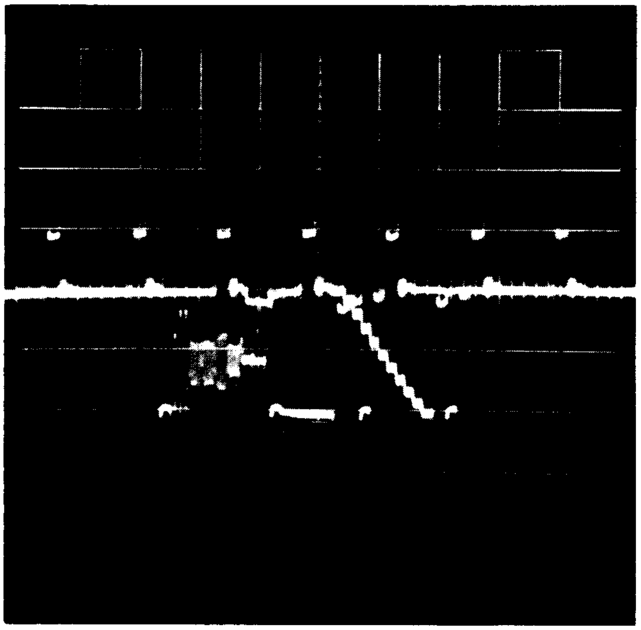


Figure 13. VITS as seen on Oscilloscope

7. The waveform should be similar to that shown in Figure 13. For the oscilloscope display, each vertical sync pulse starts a new sweep. This causes line 17 and line 279 (multi-burst) to be superimposed, as are lines 18 and 280. The multi-burst signals are identical which reinforces the trace. However, lines 18 and 280 are not identical and both signals are superimposed over each other. This should present no problem, since the multi-burst is normally the signal of interest.

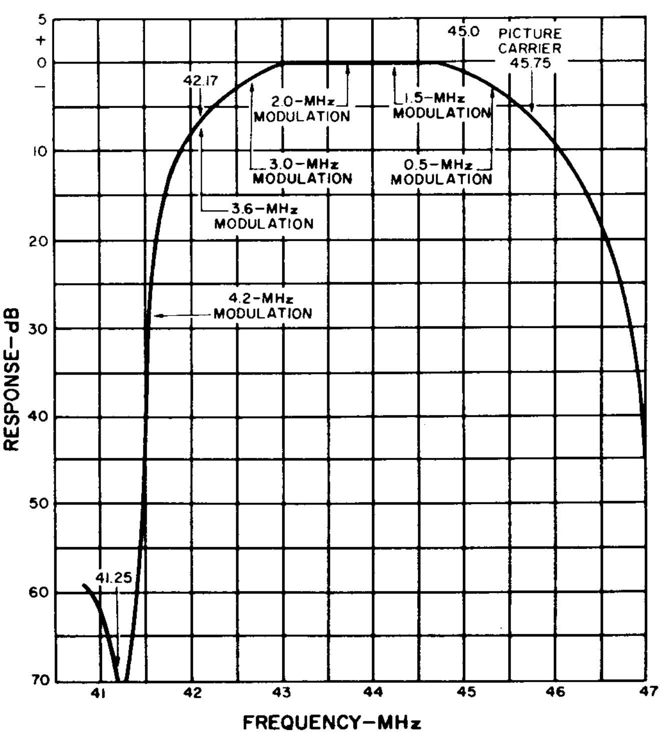


Figure 14. Color TV I-F Amplifier Response Curve

Now to analyze the waveform. All frequencies of the multi-burst are transmitted at the same level, but should not be equally coupled through the receiver due to its response curve. Figure 14 shows the desired response for a good color television receiver, identifying each frequency of the multi-burst and showing the allowable amount of attenuation for each. Remember that −6 dB equals half the reference voltage (the 2.0 MHz modulation should be used for reference).

To localize trouble, start by observing the VITS at the video detector. This will localize trouble to a point either before or after the detector. If the multi-burst is normal at the detector, check the VITS on other channels. If some channels look okay but others do not, you probably have tuner or antenna-system troubles. Don't overlook the chance of the antenna system causing "holes" or tilted response on some channels. If the VITS is abnormal at the video detector on all channels, the trouble is probably in the i-f amplifier stages.

As another example, let us assume that we have a set on the bench with a very poor picture. Our oscilloscope shows the VITS at the video detector to be about normal except that the burst at 2.0 MHz is low compared to the bursts on either side. This suggests an i-f trap is detuned into the passband, chopping out frequencies about 2 MHz below the picture carrier frequency. Switch to another channel carrying VITS. If the same thing is seen, then our reasoning is right, and the i-f amplifier requires realignment. If the poor response at 2 MHz is not seen on other channels, maybe an FM trap at the tuner input is misadjusted, causing a bite on only one channel. Other traps at the input of the set could similarly be misadjusted or faulty.

If the VITS response at the detector output is normal for all channels, the trouble will be in the video amplifier. Look for open peaking coils, off-value resistors, solder bridges across foil patterns, etc.

VECTORSCOPE OPERATION

Performance testing and adjustment of the color circuits in color television receivers is simplified by using the vectorscope operation of the oscilloscope. The additional equipment needed is a color bar generator. The B & K color bar generators are ideally suited.

First the horizontal and vertical gain of the oscilloscope must be equalized (See Figure 15).

1. Remove the linear scale and replace it with the vector overlay (Simply remove the four bezel retaining nuts and lift off the bezel and linear scale as in Figure 42).
2. Connect the color bar generator to the television set and tune in the color bar pattern.
3. Adjust the television set's hue and brilliance controls to mid-range.
4. Set the SWEEP TIME/CM control to the EXT position.
5. Connect the probe cable to the V INPUT receptacle and another coaxial or shielded test lead

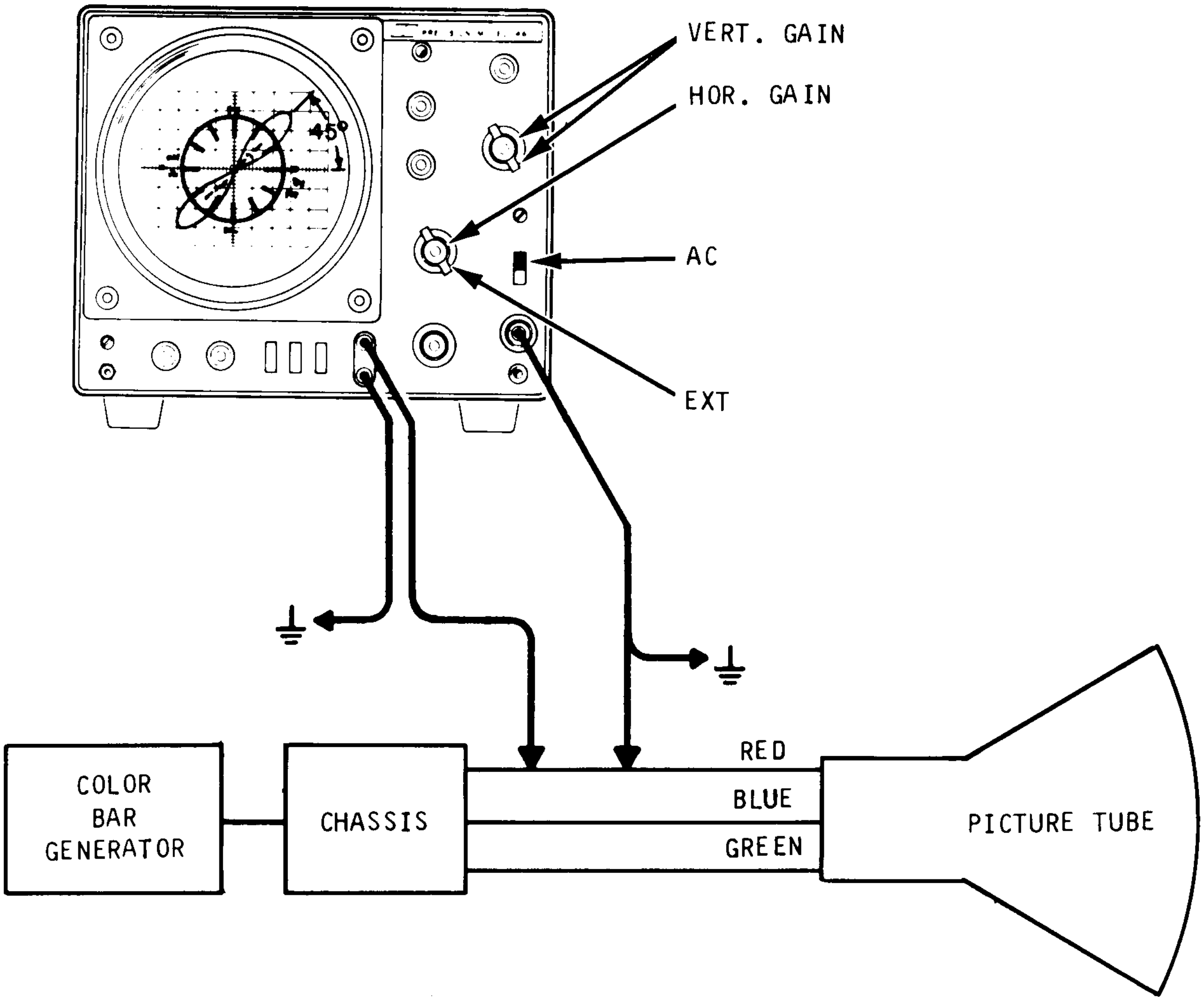


Figure 15. Equalizing Horizontal and Vertical Gain for Vectorscope Operation

to the EXT SYNC/HOR jack. Connect both probes to the driven element of the red gun, usually the grid. If the cathode is the driven element, then connect to the cathode. (The driven element is the element to which the output signal of the color amplifier is applied.)

6. Adjust the vertical and horizontal gain controls to obtain a compressed 45° pattern that approximately fills the vector overlay. The oscilloscope is now set up for vectorscope operation.

7. For vectorscope presentation, merely move the horizontal probe to the driven element of the blue gun. The color vector pattern is the same type as given by the television set manufacturer. Figures 16A through D show typical displays obtained for sets using 105 degree systems and 90 degree systems with either grid drive or cathode drive.

NOTE: If the picture tube uses cathode drive, the burst will appear on the right side of the screen. Just rotate the vector overlay 180° so the BURST label is on the right side. The color bars will then align with the vector overlay.

The vector display provides a very quick measurement of the functions of the demodulators in a color TV set. The serviceman should familiarize himself with the effect on the pattern produced by the color controls. He should observe that the color amplitude control will vary the size of the petals but not their position. The hue control changes the position of the petals but not their amplitude. Lastly, 105° of the petals but not their amplitude. Lastly, 105° sets will have a more eliptical pattern than 90° sets. The table below lists some common troubles and their effect on the pattern.

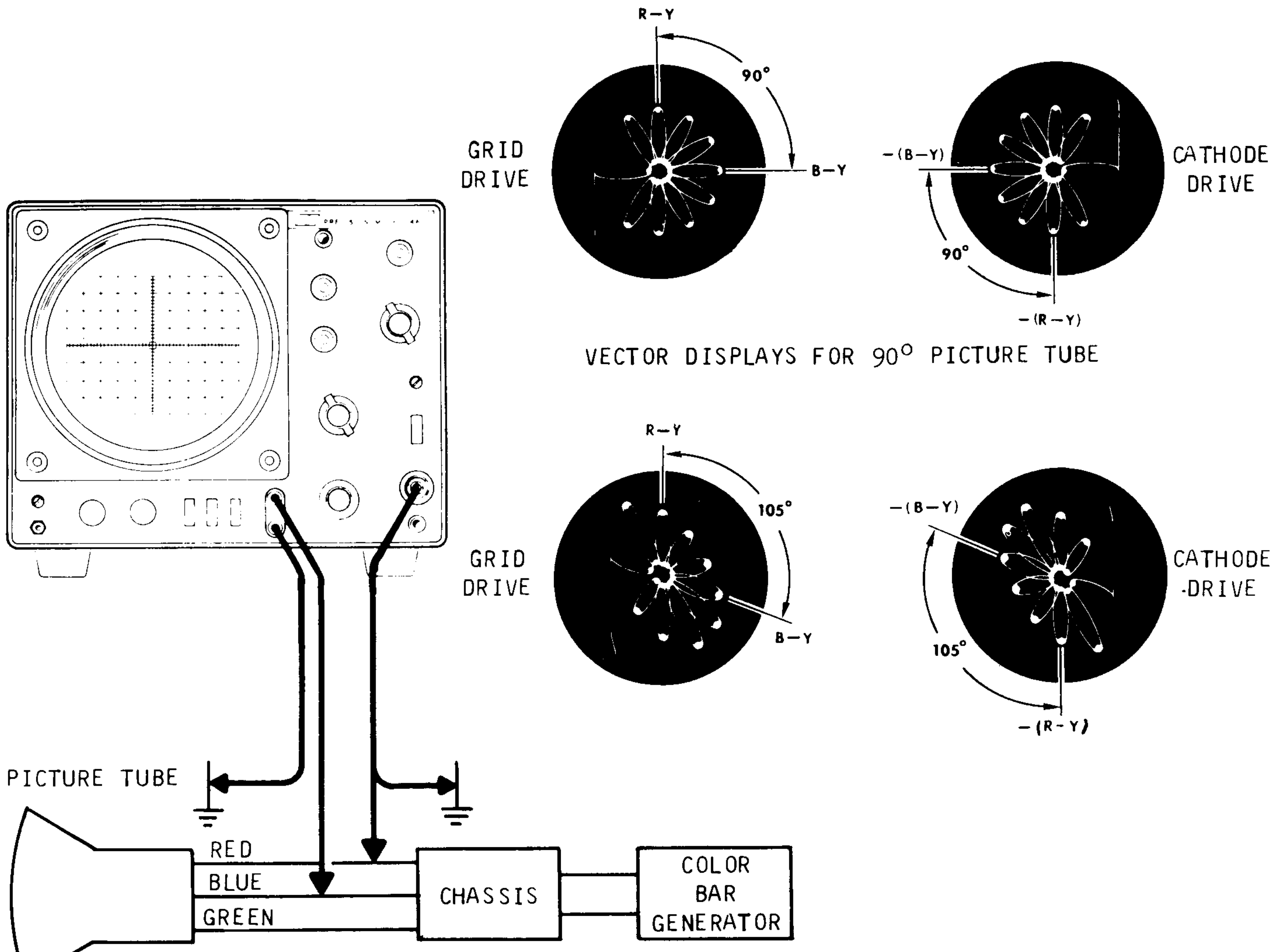


Figure 16. Vectorscope Operation

TROUBLE	EFFECT ON PATTERN	EFFECT ON T.V.
Loss of color sync.	Petals of pattern will rotate.	Varying Colors
Overloading of color amplifiers.	Petals are crushed or flattened.	Color Distortion
Color amplifiers unbalanced or weak.	Flower pattern very eliptical.	Color Distortion
Lack of Range of Hue Control.	R-Y petal cannot be made to be vertical.	Hue control won't adjust flesh-tones
Demodulator out of Alignment.	Angle between R-Y petal and B-Y petal not to manufacturer's specification (90° or 105° General Specification.)	Wrong colors

The vector display can be used to check the range of the color sets hue control. It should be possible to rotate the R-Y petal about the vertical axis. At the center of the hue control the R-Y petal should be vertical. If it is not, locate the CHROMA reference oscillator. In most sets this oscillator is transformer coupled to the demodulators.

A slight touch up of this transformer is all that is necessary to bring the R-Y petal to a vertical position. Do not attempt to make any adjustments on the chroma bandpass amplifiers. This amplifier is aligned by a sweep generator and cannot in general be aligned by just a vector display.

If the set has adjustable demodulators the vector display can also be used for demodulator alignment. Follow the manufacturer's alignment procedure to locate the proper coils and instead of counting bars simply adjust for the correct angle between R-Y and B-Y.

TELEVISION ALIGNMENT

INTRODUCTION

Alignment of tuners, the video i-f strip, and chroma circuits in television receivers requires a high quality oscilloscope, such as this instrument. The additional pieces of test equipment required are sweep generators for video sweep, i-f sweep and r-f sweep, marker generators, dc bias supplies and a VTVM. The sweep generator method of alignment displays a bandpass response curve on the screen of the oscilloscope of the type always shown in theory books and in the television set manufacturer's alignment instructions (typical response curves are shown in Figure 17).

The ideal instruments for television alignment are this oscilloscope and the B & K Sweep/Marker Generator. The B & K Sweep/Marker Generator provides all necessary sweep ranges, markers and dc bias voltages, all from one instrument. The simplified operating procedure and calibrated accuracy of the instrument results in precision alignment.

For complete alignment instructions of each particular television set, follow the manufacturer's instructions. However, the following general set-up instructions tell how to use the oscilloscope for sweep-frequency alignment.

In this manual, only the proper use of the oscilloscope in television is emphasized. Proper use of the sweep generator and other equipment required for alignment should be provided in the instruction manuals for those instruments.

NOTE: For a comprehensive analysis of television alignment, we recommend the instruction manual for the B & K Model 415 Sweep/Marker Generator. This "handbook of television alignment" includes not only the procedures for using the instrument, but all the how and why answers about television alignment in general. Even if you use other sweep generators, this book provides valuable procedures, insights and tips that will make alignment easier and more professional. The many illustrations and easy-to-understand step-by-step approach qualify it as the "how to align" textbook. Copies are available from your B & K distributor or the factory.

IMPORTANCE OF SWEEP ALIGNMENT

The most rapid way to determine the overall condition of the tuner, i-f and chroma portions of the television receiver is to provide a constant-amplitude signal which sweeps through the entire bandwidth of a given television channel at a controlled, repetitive rate. As this signal is processed through the tuned portions of the receiver, it is shaped by the gain and bandpass properties of the various sections. Because the signal is channeled from one series of tuned circuits to another it is important that each section has the proper characteristics. If the signal is demodulated at certain points and the envelope observed, the gain and bandwidth properties up to that point can be determined.

Figure 17 shows the sweep signal with basic response curves of the tuner, i-f amplifiers and chroma bandpass circuits below it. The bandwidths shown are approximately to scale. These outlines are similar to the curves that would be obtained if the outputs of the various sections of the TV receiver were demodulated and the curve observed on an oscilloscope. Because of the relative bandwidths, the tuner response is least critical.

Some reference frequencies are identified to show the importance of proper alignment. Notice that the chroma frequencies are on the slope of the i-f response curve. This area is the most critical because improper i-f alignment in this area will affect the amplitude and shape of the chroma response curve and this in turn affects color picture quality.

Notice that the chroma information is located on a constant-amplitude portion of the transmitted television spectrum. Notice that the relative amplitudes of the chroma information are modified by passing through the tuned circuits of the television receiver tuner and i-f amplifiers. This is shown by reference to the overall i-f response curve. Notice that the signal information at the upper end of the chroma frequency range (4.08 MHz) is reduced in amplitude with respect to the signal level at the lower end of the chroma frequency range (3.08 MHz). To compensate for this frequency-versus-amplitude characteristic of the overall i-f response curve, a chroma takeoff coil is used between the i-f output and the bandpass amplifier of the chroma portion of the receiver. The chroma takeoff coil is tuned to the upper end of the chroma frequency range, usually 4.08 MHz and provides a response as shown in Figure 17. This compensates for the amplitude-versus-frequency characteristic of the chroma portion of the overall i-f response curve. The result of combining the response of the i-f curve and the response of the chroma takeoff coil is to produce a flat overall response in the chroma frequency range (3.08 MHz to 4.08 MHz). The resultant signal is then applied to the bandpass amplifier which has the response indicated by the overall chroma response curve.

Alignment of the chroma takeoff coil is sometimes specified as a separate step in manufacturer's test procedures. In other procedures, adjustment of the chroma takeoff coil is performed together with the adjustment of the bandpass transformer.

SWEEP ALIGNMENT METHODS

The best method of checking alignment and determining which stages require alignment is to inject an r-f sweep frequency signal at the tuner antenna terminals. The agc bias line must be clamped by application of bias or grounding the agc line. The outputs of the i-f and chroma circuits are then observed on an oscilloscope and compared to the manufacturer's recommended response curves.

The technician can then decide which portions of the receiver require alignment. For example, if the i-f response is satisfactory but the chroma response

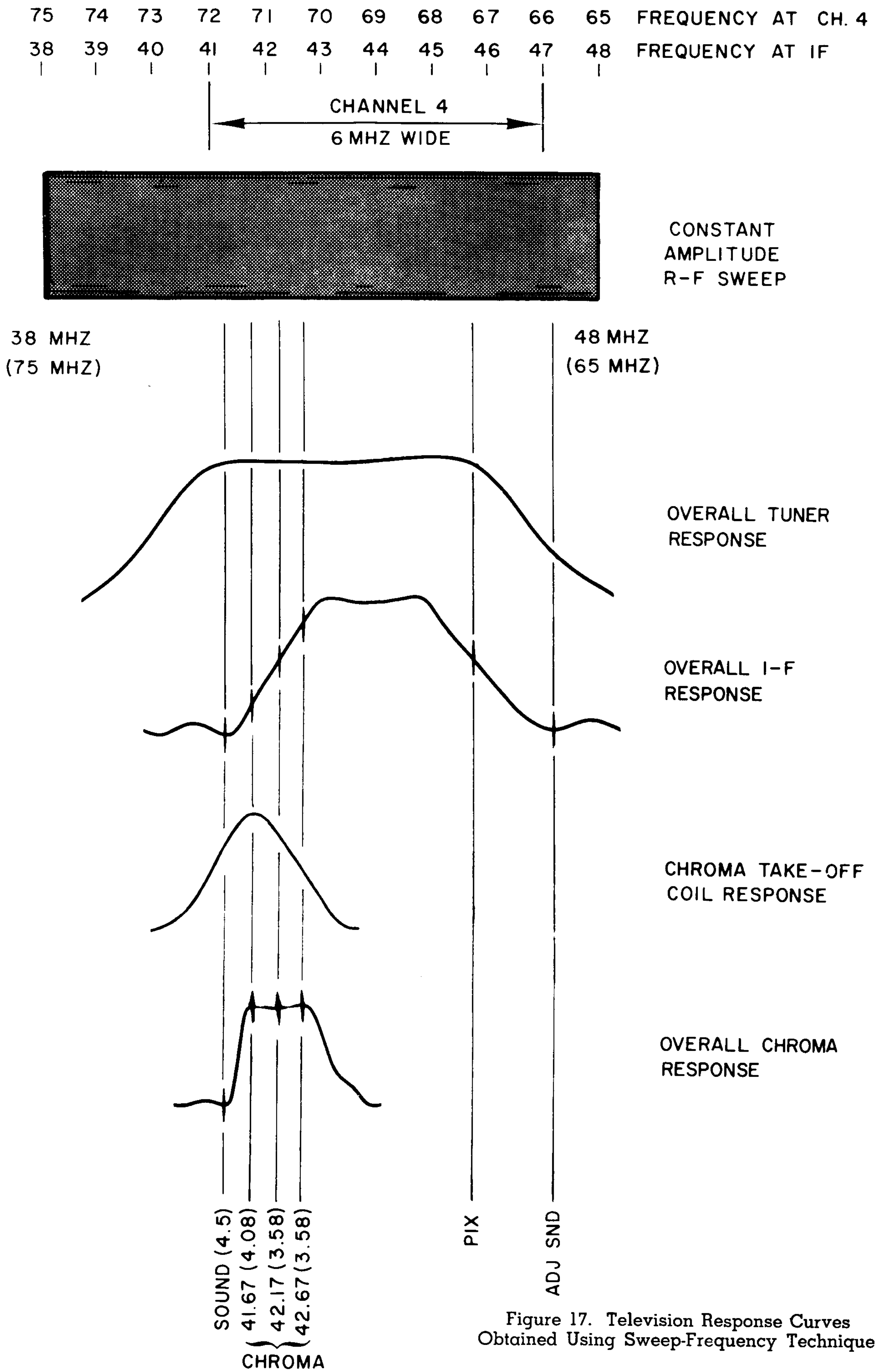


Figure 17. Television Response Curves Obtained Using Sweep-Frequency Technique

is not, then the problem is between the video detector output of the i-f strip and the output of the bandpass amplifier. If the i-f response and the chroma response are poor then it is most likely that the i-f requires touch-up, particularly if the response is poor on the slope affecting chroma response.

The r-f portion of the tuner seldom creates an alignment problem because the passband is so much greater that that of the i-f section; however, the mixer output circuit, which is located on the tuner, may require attention. This is part of the tuned matching network between the tuner and the first i-f stage. A separate prealignment procedure is given for the link circuits by some manufacturers.

Once the deficient portion of the receiver is determined, an alignment check of that section can be performed. The alignment procedures vary with manufacturers. Some suggest signal combinations at the tuner antenna terminals which can generate i-f and video sweep frequencies in the receiver so that overall alignment can be done by selecting the right combination of input signals. One way of doing this is to first connect an r-f sweep generator for i-f alignment. After this is complete, the picture carrier frequency for the channel being used is selected and this is modulated by a video sweep signal (This is the VSM, or video sweep modulation, method.) This video sweep modulation is demodulated at the video detector of the TV receiver and applied to the chroma bandpass circuits for the alignment of these stages.

Other manufacturers recommend an i-f sweep frequency injected at the mixer grid (or base, if transistorized) for i-f alignment. The i-f picture carrier frequency (45.75 MHz) is then modulated with a video sweep voltage (VSM again). As before this is detected at the video detector of the TV receiver and the recovered sweep voltage is used for the chroma circuit alignment.

Another method is to first video-sweep align the chroma circuits directly. The i-f is then aligned and then video sweep modulation of the i-f pix frequency (45.75 MHz) is used to check the combined effect on the chroma response of i-f alignment and chroma alignment. Usually a touch-up of the chroma circuits is done to obtain the desired final overall chroma response.

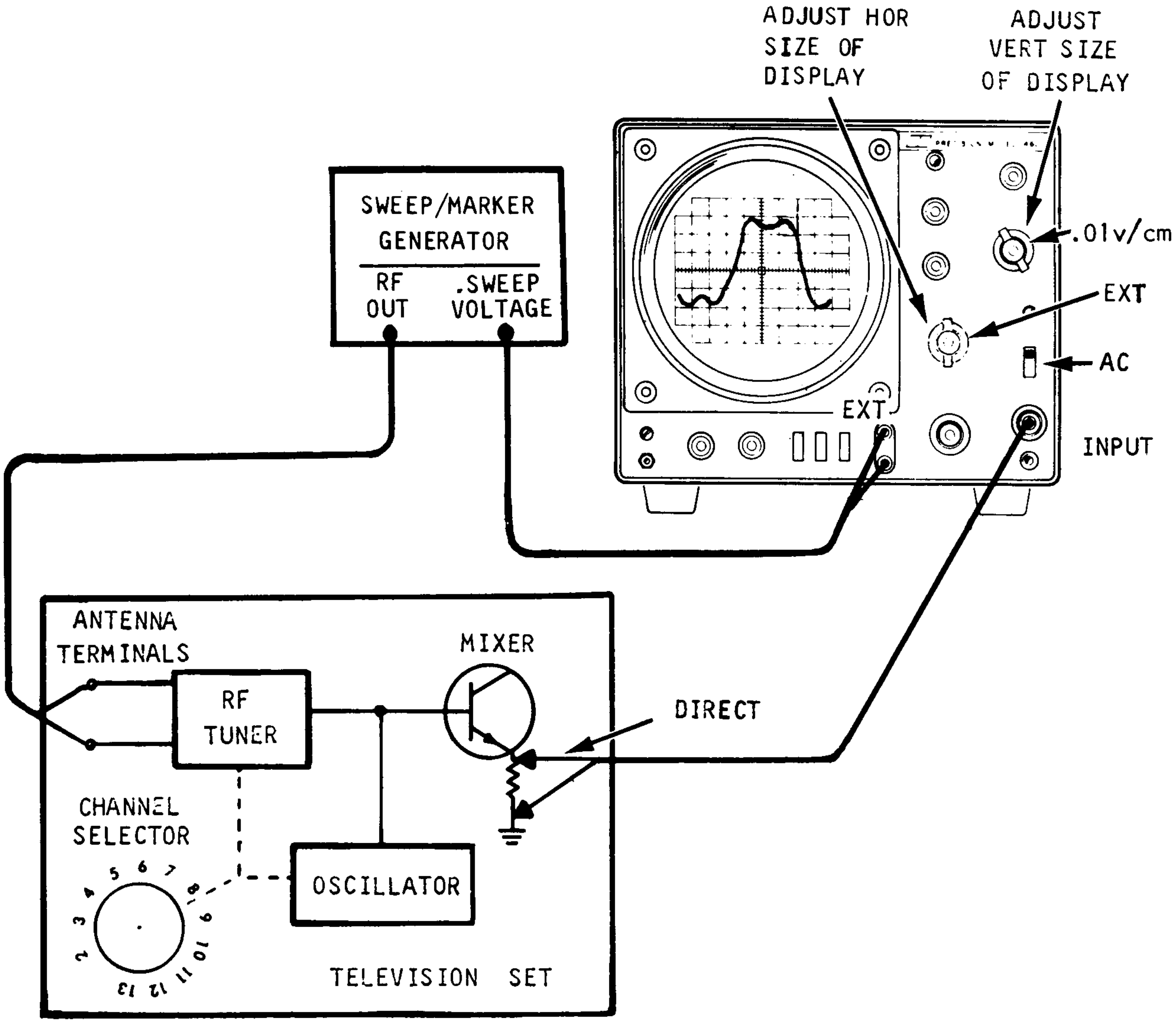


Figure 18. Typical Tuner Alignment Set-Up

In conjunction with i-f alignment practically all manufacturers recommend pretuning i-f traps by injecting spot frequencies into the i-f (usually at a specified tuner test point). Other procedures outline a prealignment of all tuned circuits in the i-f before sweep alignment procedures.

In all cases the manufacturer's method is the best for his particular receiver and the manufacturer's service manual is preferred for alignment. SAMS PHOTOFACT procedures are also reliable and in most cases repeat the manufacturer's procedure. If complete realignment of an apparently deficient receiver does not restore the required response, the technician must then consider that a component failure has occurred and must employ standard trouble shooting procedures.

TUNER ALIGNMENT

Refer to Figure 18

1. Connect the output of the sweep generator to the antenna terminals of the television set. Adjust the sweep generator to sweep one of the TV channels.
2. Tune the TV set to the same channel.
3. Connect the ground clip of the oscilloscope probe directly to the tuner shield to minimize hum pickup. Connect the vertical probe (set to DIRECT) to the tuner test point. The tuner test point is normally the grid of the mixer tube or equivalent, where a demodulated signal is present.
4. Set the vertical controls for maximum sensitivity and operate the sweep generator at low level to avoid overloading the television receiver, which would distort the response curve and provide an erroneous picture of alignment on the oscilloscope screen.
5. The oscilloscope sweep and sweep generator must be in exact synchronization and phase with each other for proper presentation of the response curve. This is easily accomplished for sinusoidal or sawtooth sweep by setting the oscilloscope for external horizontal input and connecting the horizontal sweep voltage from the sweep generator to the external horizontal input terminals on the oscilloscope.
6. Select the marker generator frequencies required to measure the upper and lower response of the tuner.
7. The tuner response curve is now displayed on the oscilloscope. See the manufacturer's instructions for the response curve specifications and the necessary adjustments for realignment.

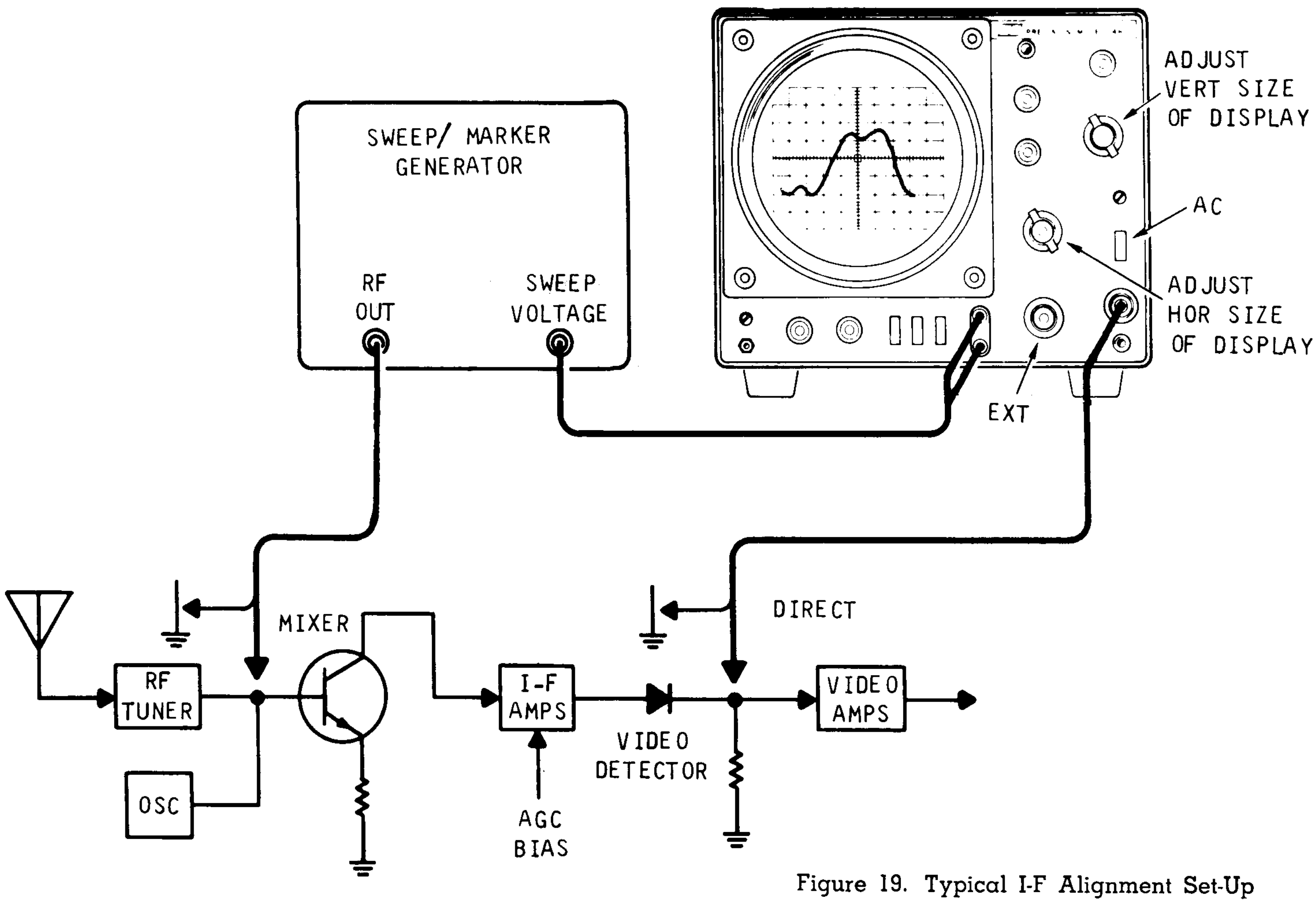


Figure 19. Typical I-F Alignment Set-Up

I-F ALIGNMENT

Refer to Figure 19

1. Connect the output of the sweep generator to the signal injection point of the mixer. Adjust the sweep generator to sweep the i-f frequency band. (If the tuner has been properly aligned, r-f sweep may be applied at the antenna terminals.)
2. Synchronize the oscilloscope sweep with the sweep generator as previously described in the TUNER ALIGNMENT procedure.
3. Connect the ground clip of the oscilloscope vertical probe to the television set chassis.
4. Connect the vertical probe of the oscilloscope to the video detector output.
5. Set the vertical gain controls (VOLTS/CM and VARIABLE) for suitable viewing of the response curve.
6. Keep the sweep generator output level low to prevent overloading. Follow the manufacturer's recommendations on disabling AGC.

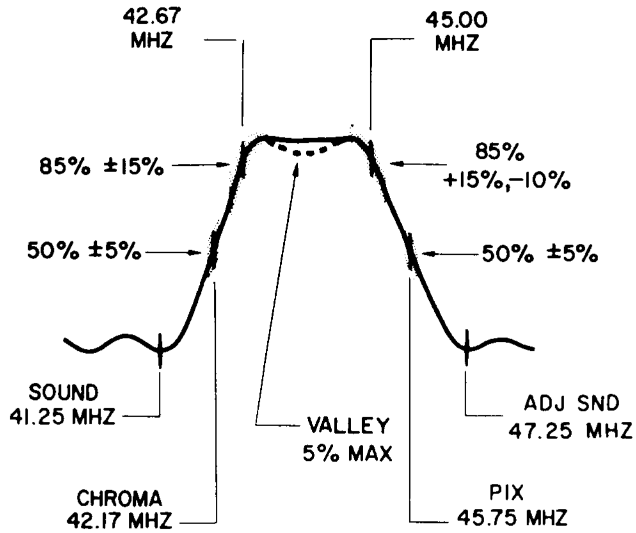


Figure 20. Typical I-F Response Curve Showing Tolerance Ranges of Response Levels

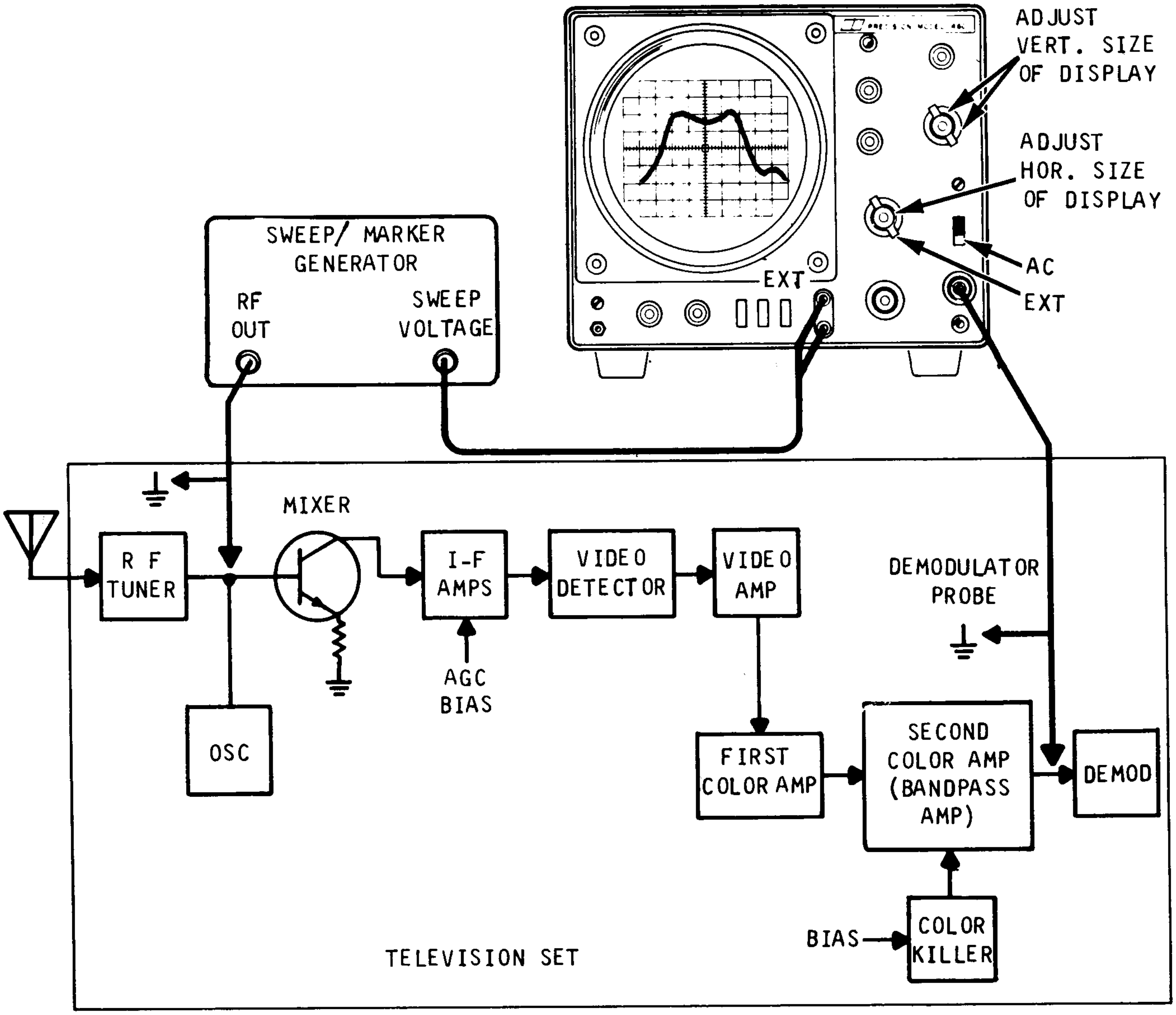


Figure 21. Typical Chroma Alignment Set-Up

7. Select the marker generator frequencies required to check the critical frequencies of interest (see Figure 20). A sweep and marker generator capable of displaying all the markers simultaneously, such as the B & K Model 415, is a big advantage.
8. Follow the manufacturer's instructions for evaluating the response curve and making the alignment.

CHROMA ALIGNMENT

Refer to Figure 21.

The i-f alignment must be satisfactorily completed before starting this chroma alignment procedure. If direct injection of video sweep is used, rather than the i-f sweep injection specified herein, the response curve is altered drastically. Follow the manufacturer's procedure explicitly for such direct injection of video sweep for chroma alignment.

1. Leave the sweep/marker generator and AGC bias connected as for i-f alignment. Set the sweep generator to sweep approximately the 41 to 44 MHz band of frequencies. Use the same i-f injection level that was used for i-f alignment.
2. Apply the proper dc bias to the color killer to enable the color amplifiers (bandpass amplifiers). Refer to the manufacturer's instructions for the correct bias level.
3. Synchronize the oscilloscope sweep as previously described for tuner alignment.
4. Use a demodulator probe for the vertical input to the oscilloscope. Measure the response curve at the input to the demodulators.

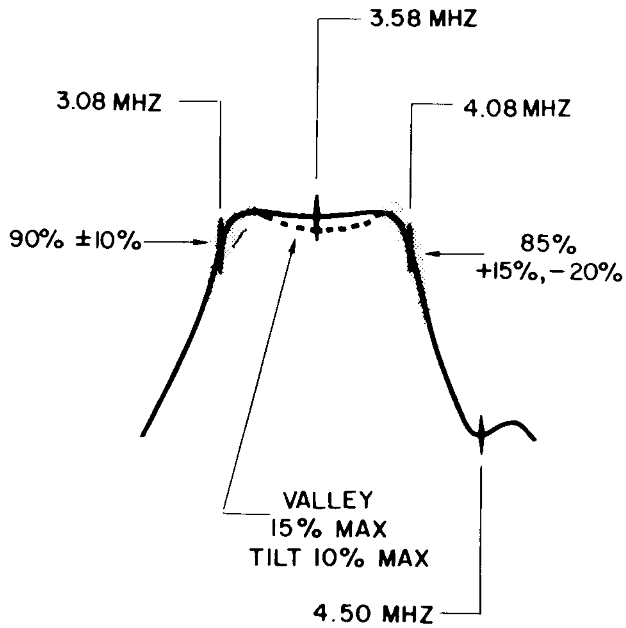


Figure 22. Typical Chroma Response Curve Showing Tolerance Ranges of Response Levels

5. Set the vertical gain controls of the oscilloscope (VOLTS/CM and VARIABLE) for a convenient viewing size on the screen.
6. A response curve similar to that shown in Figure 22 should be seen. Select the marker generator frequencies of interest. Refer to the manufacturer's instructions for bandpass specifications and alignment procedure.

FM RECEIVER ALIGNMENT

Refer to Figure 23.

1. Connect a sweep generator to the mixer input of the FM receiver. Set the sweep generator for a 10.7 MHz centered sweep.
2. Connect the sweep voltage output of the sweep generator to the external horizontal input jack of the oscilloscope and set the oscilloscope controls for external horizontal sweep.
3. Connect the vertical input probe to the demodulator input of the FM receiver.
4. Adjust the oscilloscope vertical and horizontal gain controls for a display similar to that shown in Figure 23. The narrow bandpass is easier to interpret if 5X magnification is used.
5. Set the marker generator precisely to 10.7 MHz. The marker "pip" should be in the center of the bandpass.
6. Align the i-f amplifiers according to the manufacturer's specifications.
7. Move the probe to the demodulator output. The "S" curve should be displayed, and the 10.7 MHz "pip" should appear exactly in the center. Adjust the demodulator according to the manufacturer's instructions so the marker moves equal distances from center as the marker frequency is increased and decreased equal amounts from the 10.7 MHz center frequency.

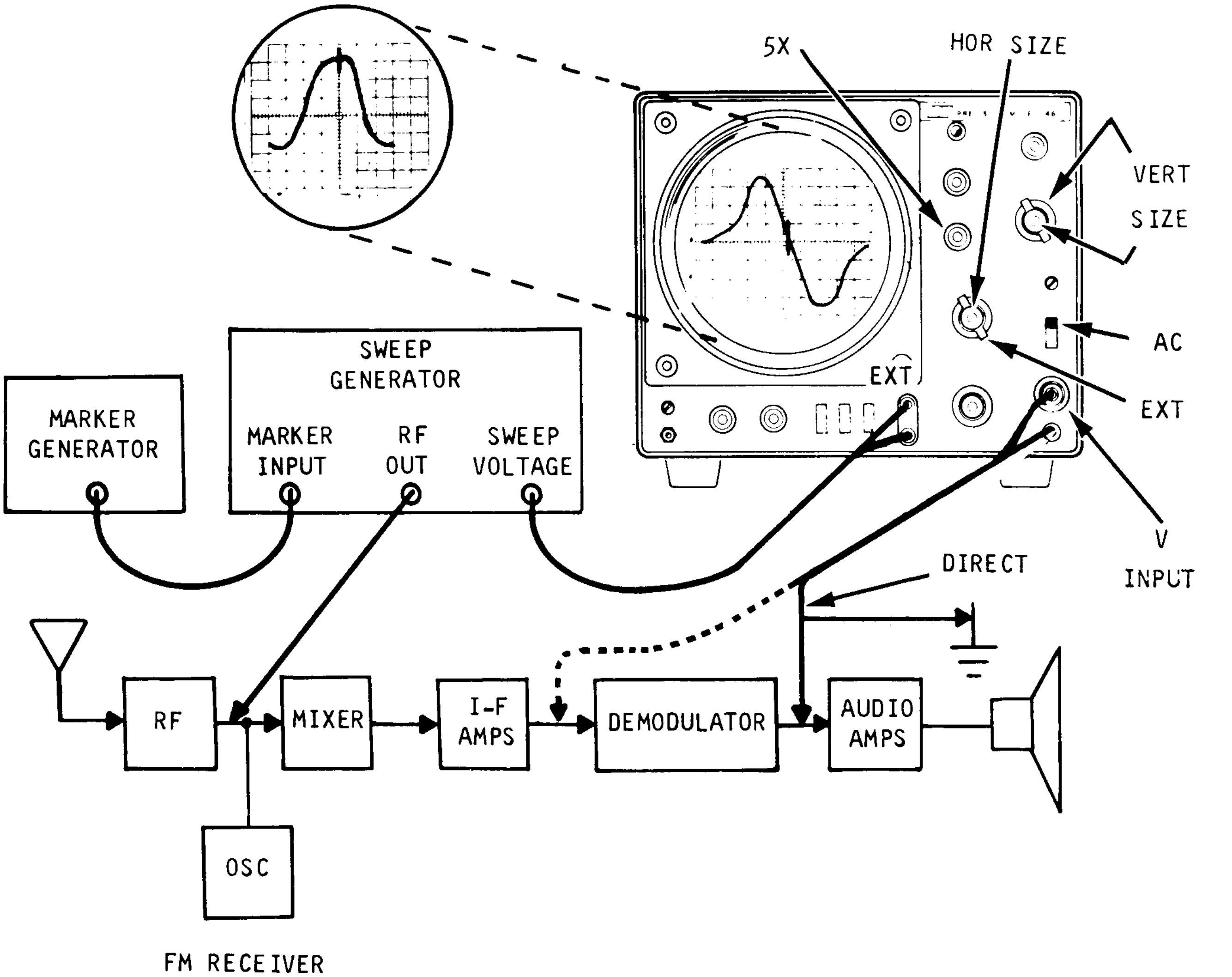


Figure 23. Typical FM Receiver Alignment Set-Up

FREQUENCY MEASUREMENT

1. Connect the sine wave of known frequency to the EXT SYNC/HOR jack of the oscilloscope and set the SWEEP TIME/CM control to EXT. This provides external horizontal input.
2. Connect the vertical input probe to the unknown frequency.
3. Adjust the vertical and horizontal 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 Figure 24.

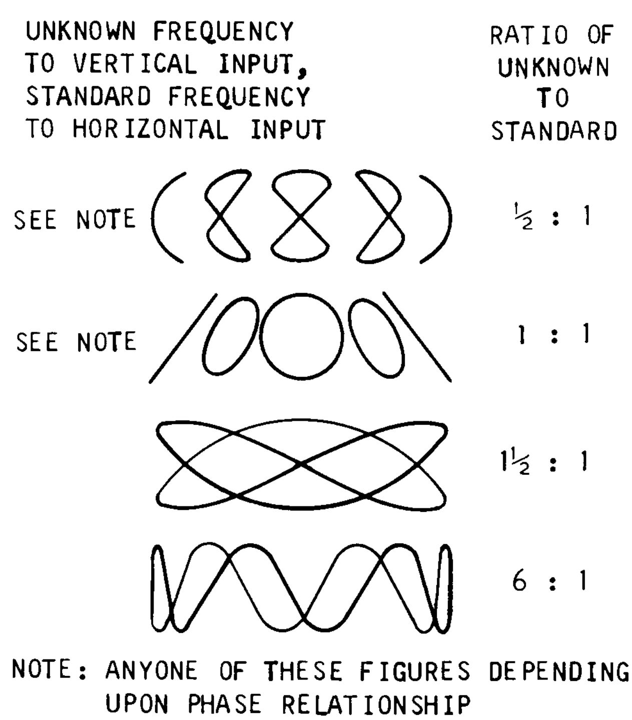


Figure 24. Lissajous Waveforms Used for Frequency Measurement.

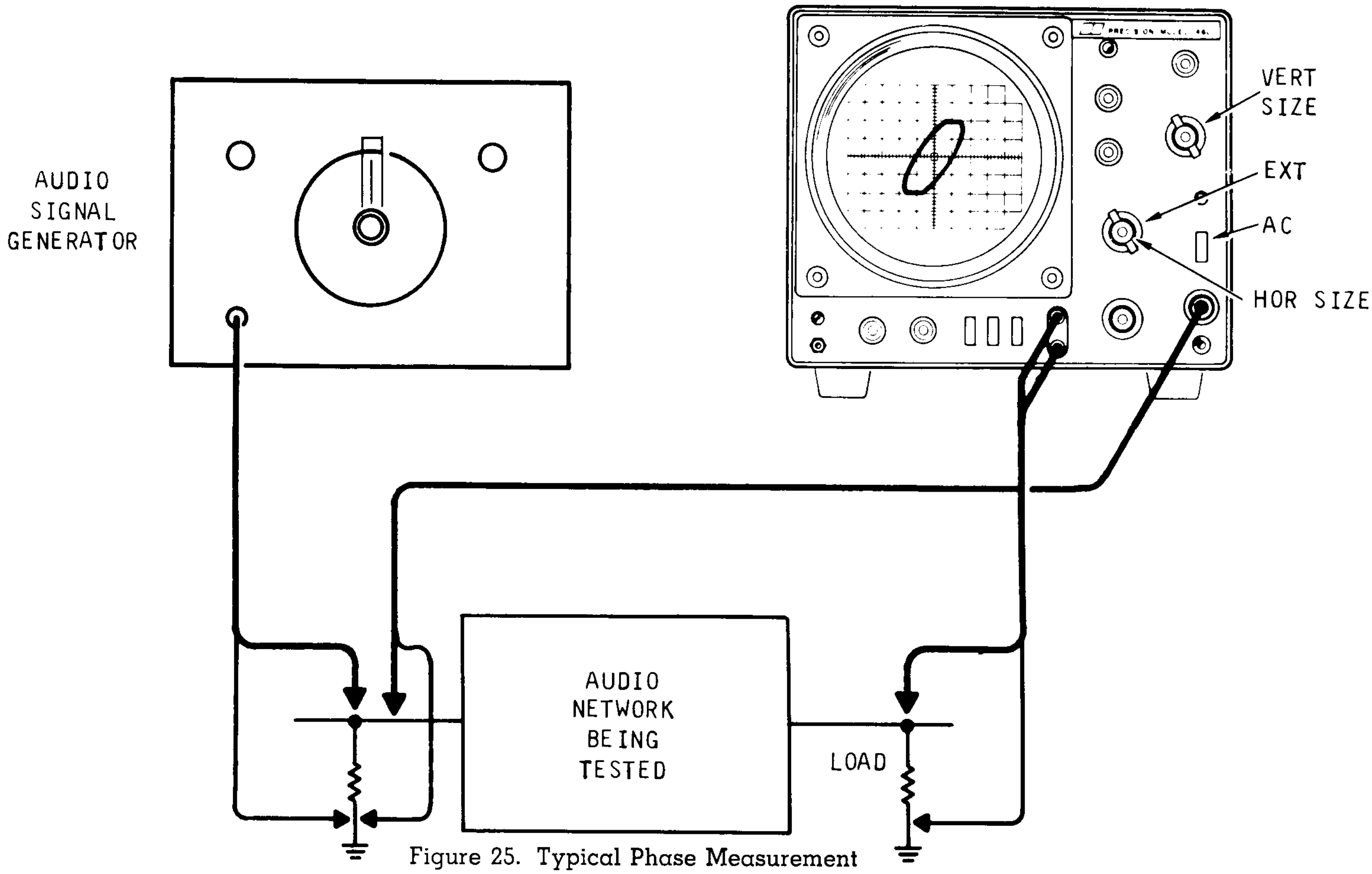


Figure 25. Typical Phase Measurement

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 Figure 25):

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.

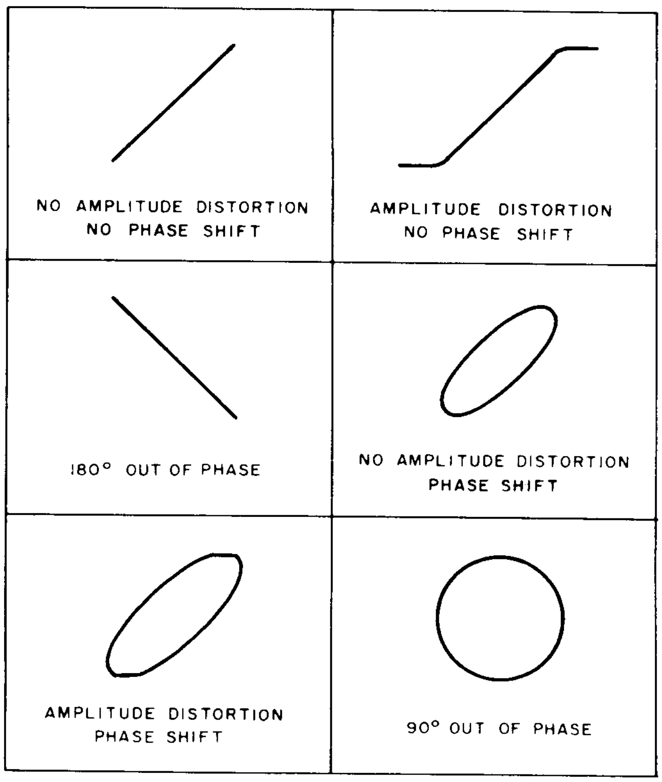


Figure 26. Typical Phase Measurement Oscilloscope Displays

3. Connect an external horizontal input cable from the output of the test circuit to the EXT SYNC/HOR jack of the oscilloscope.
4. Set the SWEEP TIME/CM control to EXT for external horizontal sweep.
5. Connect the V 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. Use the higher vertical gain of the oscilloscope for the lower level signal.)
6. Adjust the vertical and horizontal gain controls for a suitable viewing size.
7. Some typical results are shown in Figure 26. 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 Figure 27.

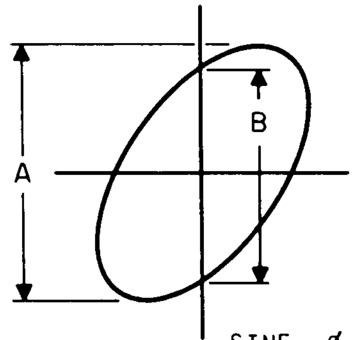


Figure 27. Phase Shift Calculation.

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 is injected into a circuit, frequency components of 1.5 KHz, 2.5 KHz, 3.5 KHz, are also 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 considerable 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 instrument 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 will also 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.

TESTING PROCEDURE

Refer to Figure 28.

1. Connect the output of the square wave generator to the input of the amplifier being tested.
2. Connect the vertical test probe of the oscilloscope to the output of the amplifier being tested.

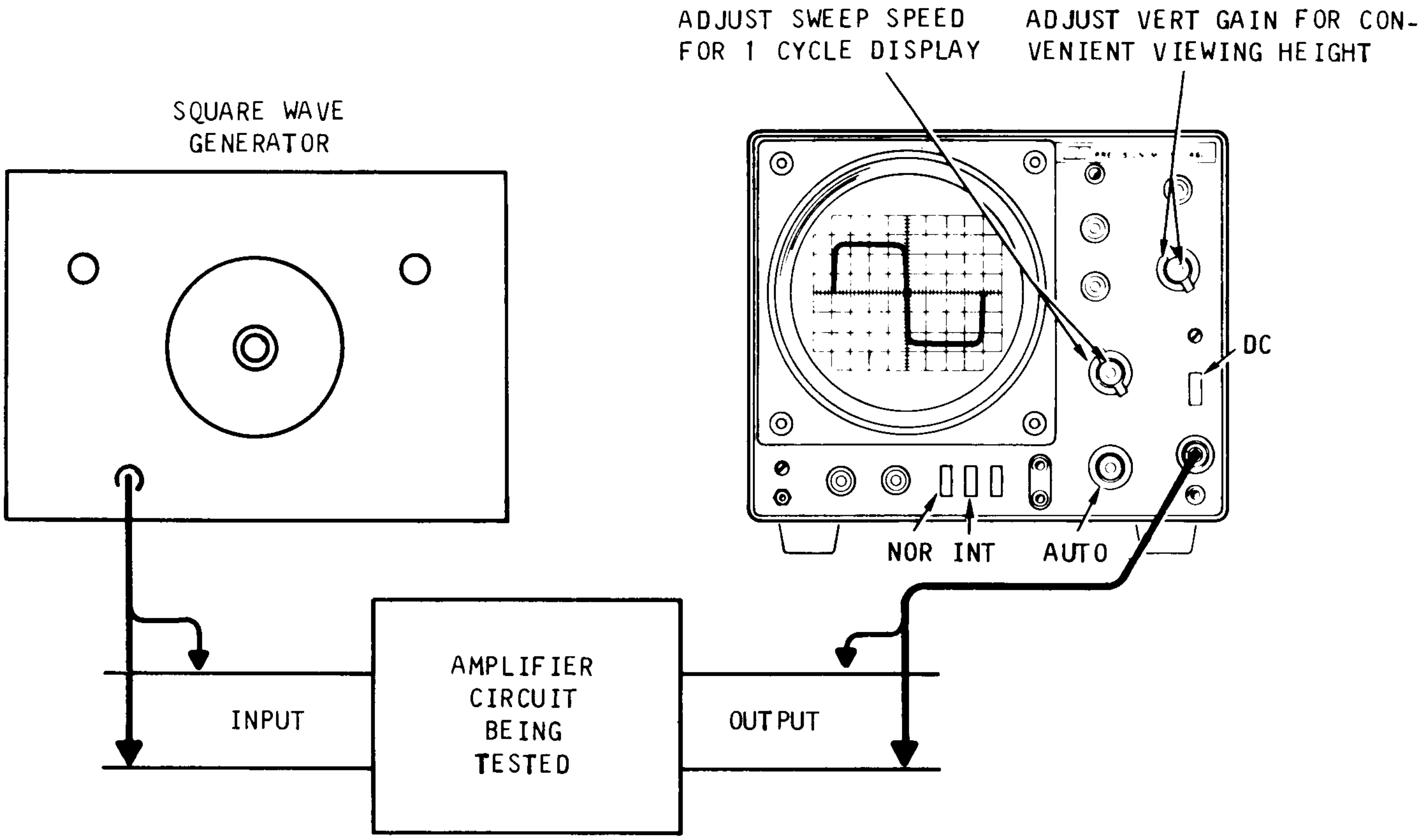


Figure 28. Equipment Set-Up For Square Wave Testing of Amplifiers

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 5 Hz).
4. Adjust the vertical gain controls for a convenient viewing height.
5. Using INT sync and AUTO triggering, adjust the sweep time controls for one cycle of square wave output 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 ½ 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 ½ cycle from maximum amplitude to zero amplitude at the 180° or ½ 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 Figure 29).

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.
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.

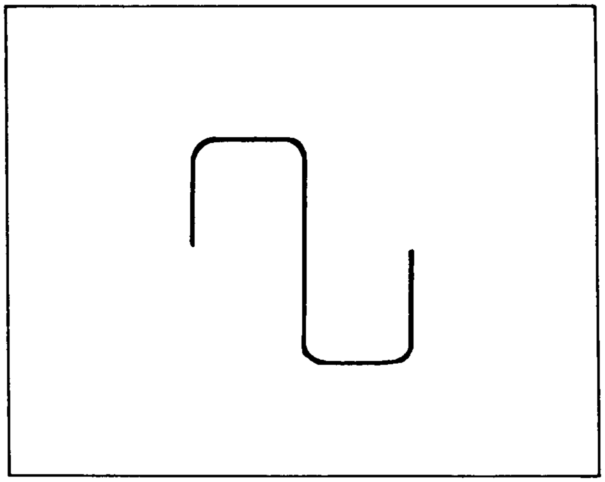


Figure 29. Square Wave Response With High Frequency Losses.

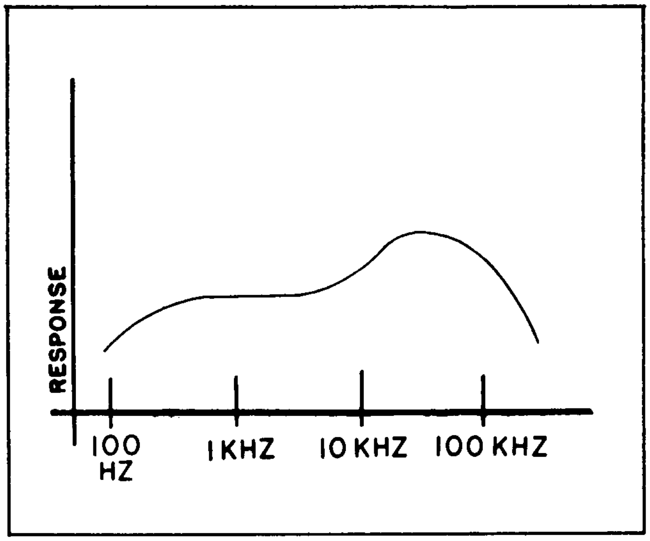


Figure 30. Response of Amplifier Having Poor Low Frequency Response and High Frequency Boost

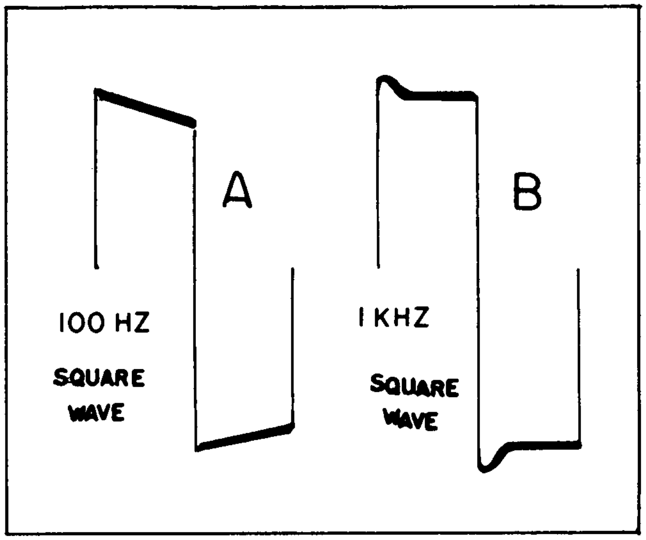


Figure 31. Resultant 100 Hz and 1 KHz Square Waves From Amplifier in Figure 28.

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 Figure 30, revealing poor low frequency response along with overcompensated high frequency boost. A 100 Hz square wave applied to the input of this amplifier will appear as in Figure 31A. 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 Figure 31B. 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 Figure 30, 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.

Now, the region between 100 Hz and 4000 Hz in Figure 30 shows a rise from poor low frequency response to a flattening out from between 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 Figure 31A.

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 Figure 32 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

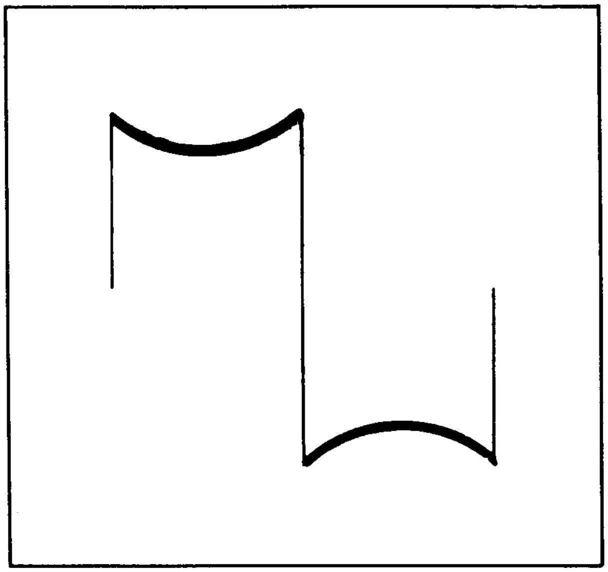


Figure 32. Reduction of Square Wave Fundamental Frequency Component in a Tuned Circuit.

strong tilt of Figure 31A. Figure 33 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.

Figure 34 indicates the tilt in square wave shape produced by a 10° phase shift of a low frequency element in a leading direction. Figure 35 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 checkd through algebraic addition of components.

Figure 36 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.

Figure 31B, previously discussed, revealed high-

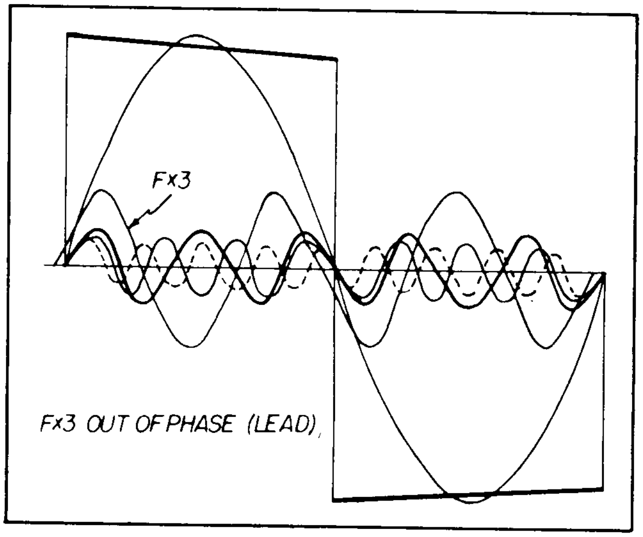


Figure 33. Square Wave Tilt Resulting From 3rd Harmonic Phase Shift.

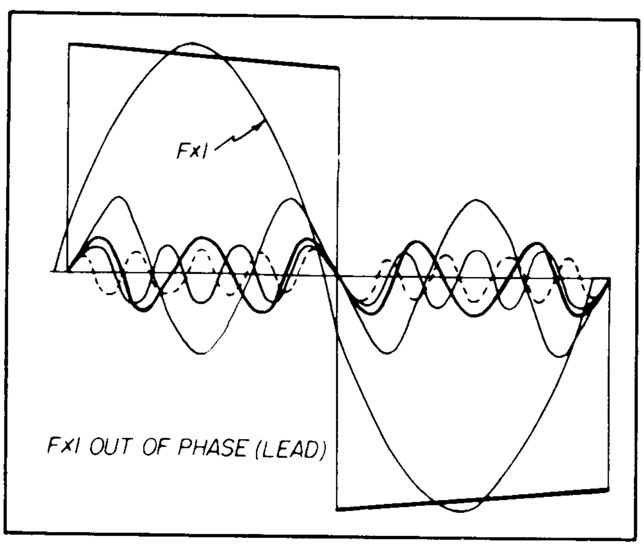


Figure 34. Tilt Resulting From Phase Shift of Fundamental Frequency in a Leading Direction

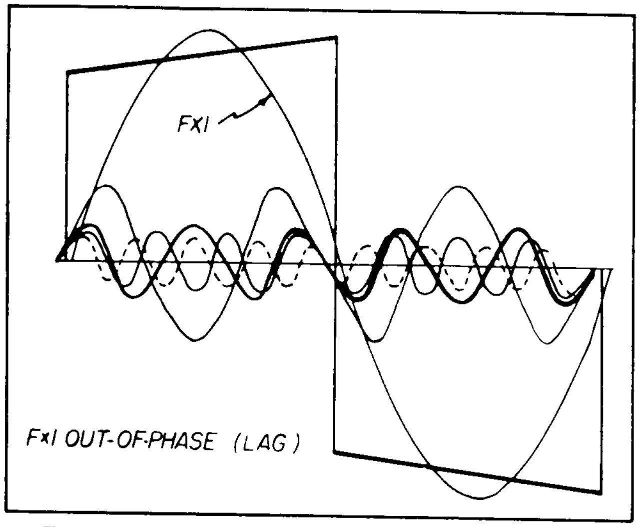


Figure 35. Tilt Resulting From Phase Shift of Fundamental Frequency in a Lagging Direction

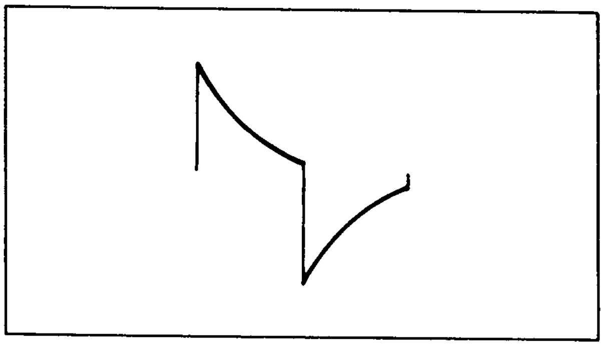


Figure 36. Low Frequency Component Loss and Phase Shift

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 disproportionately greater than other components creating a higher algebraic sum along the leading edge.

Figure 37 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 Figure 38.

Figure 39 summarizes the preceding explanations and figures as a handy reference.

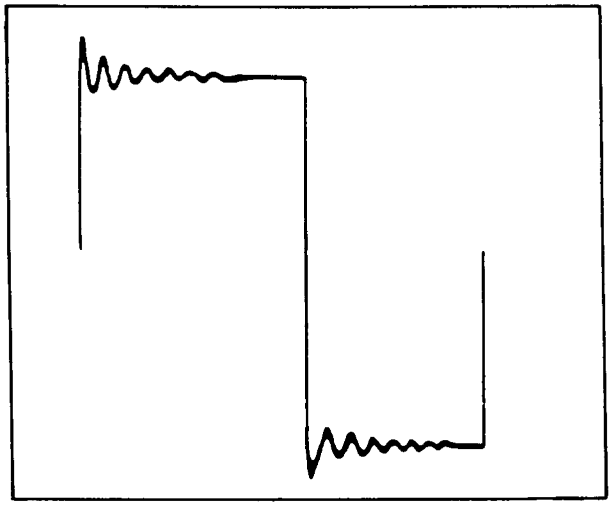


Figure 37. Effect of High Frequency Boost and Poor Damping

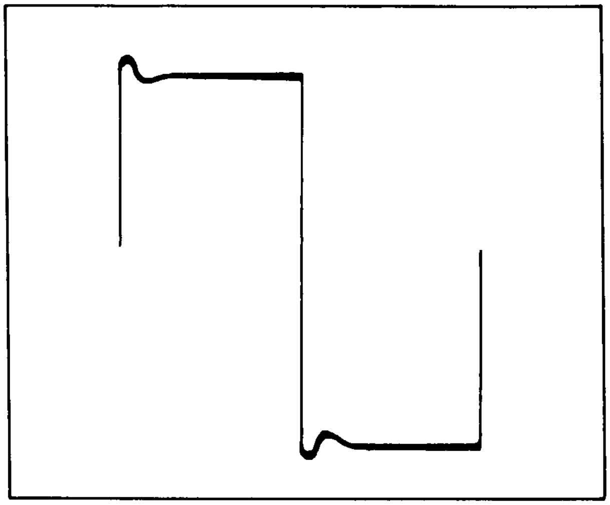


Figure 38. High Frequency Boost and Good Damping

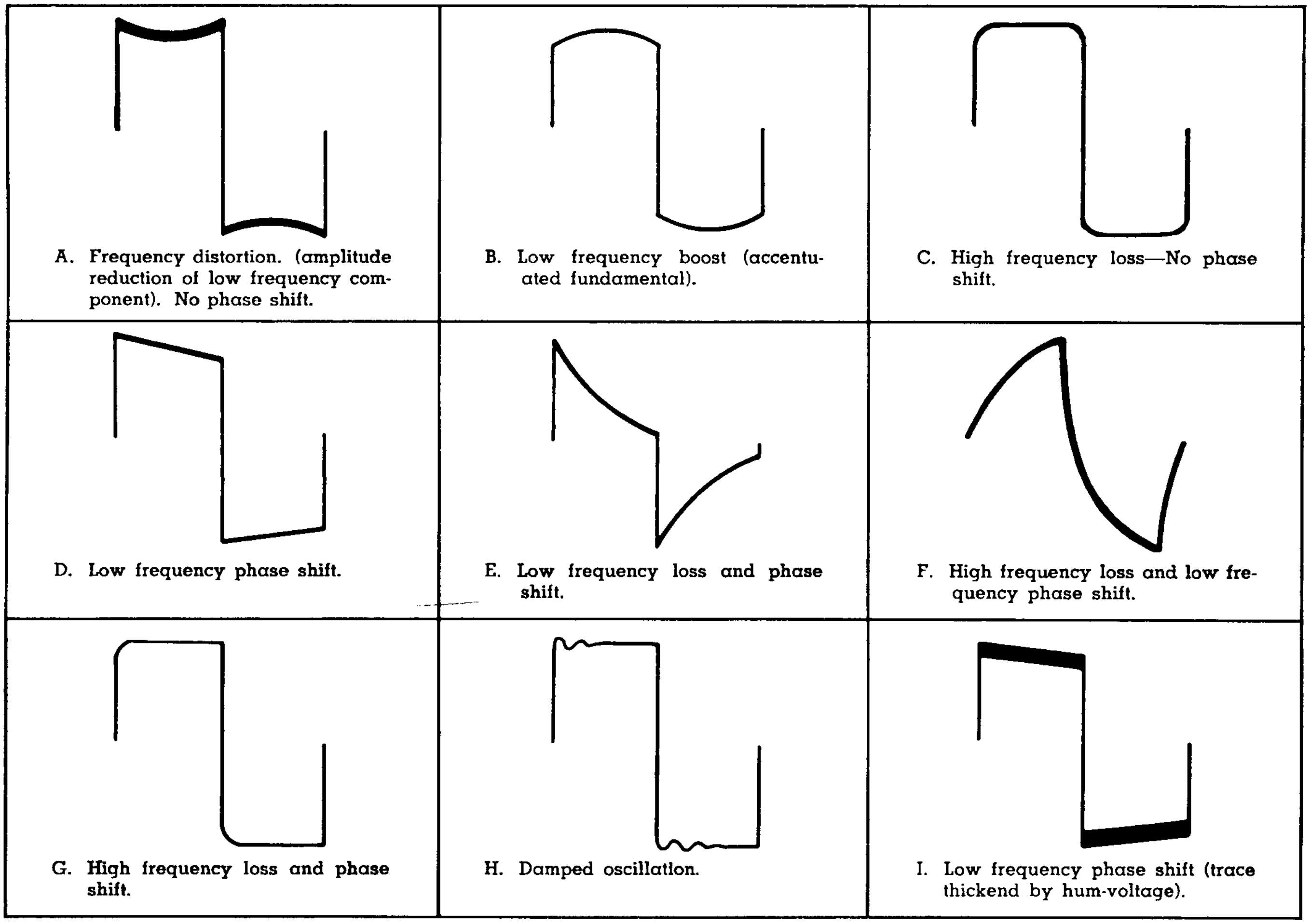


Figure 39. Summary of Waveform Analysis for Square Wave Testing of Amplifiers

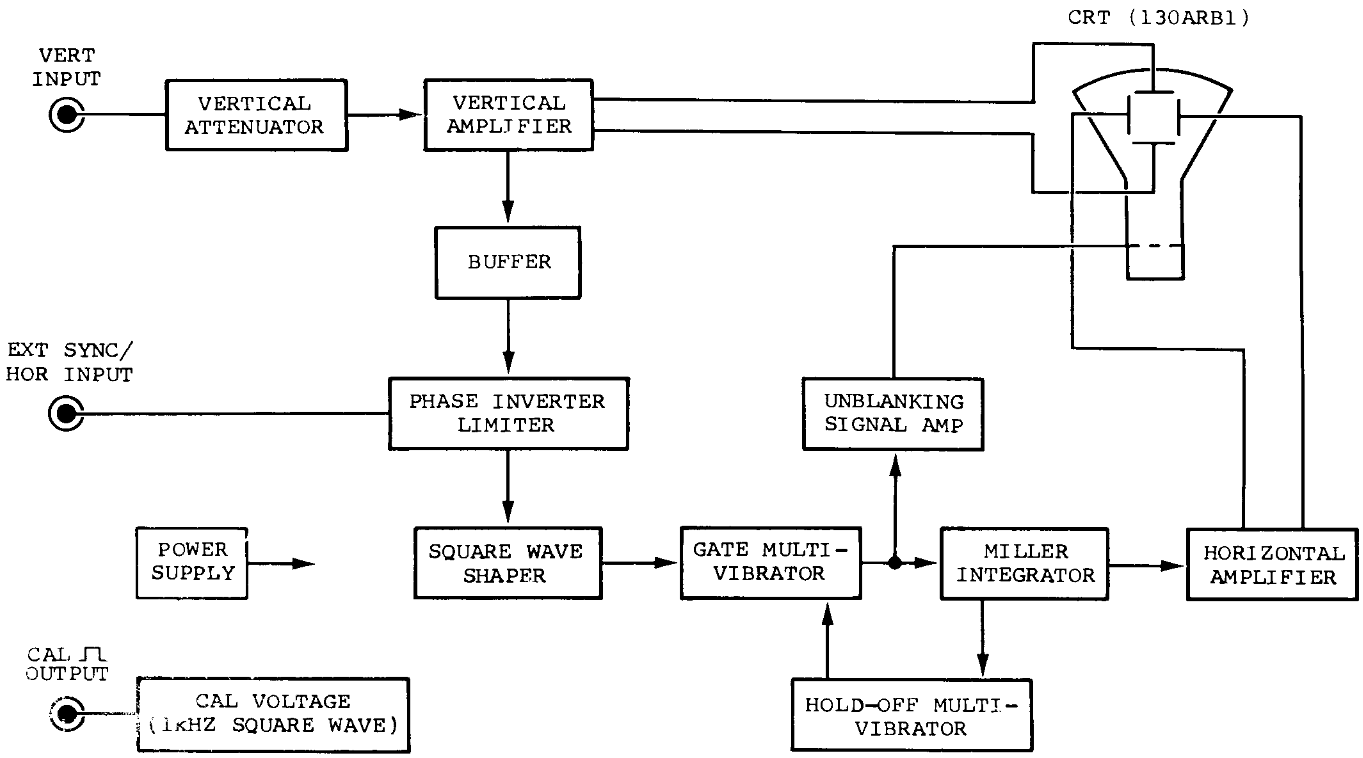


Figure 40. Block Diagram

CIRCUIT DESCRIPTION

GENERAL

(Refer to Figure 40)

The input signal to be displayed passes through an attenuator to the vertical amplifier. It is then applied through DC BAL, GAIN and POSITION controls to the vertical deflection plates of cathode ray tube.

The vertical section uses direct-coupling differential amplifiers throughout its circuitry from the initial to the final stages.

Part of the vertical amplifier output voltage is used as the internal triggering voltage, which is selected by the triggering circuit depending on its type and polarity and then conducted to the square-wave shaping circuit.

The output of the square-wave shaping circuit is differentiated to turn into a trigger signal which, together with the sawtooth wave conducted from the hold-off circuit, drives the gate multi-vibrator circuit.

The gate multivibrator circuit, forming a dc loop with the Miller integrating circuit and the hold-off circuits, is driven from the trigger pulse to generate the sawtooth sweep voltage. This sweep voltage is applied through the horizontal amplifier to the horizontal deflection plates.

Refer to schematic diagram for detailed circuit information.

VERTICAL AMPLIFIER CIRCUIT

INPUT CIRCUIT AND ATTENUATOR

The input signal is selected as AC or DC signal by the input selector switch (AC-GND-DC) and applied to the attenuator having 11 ranges.

The attenuator offers an input impedance of 1 megohm and an input capacitance of 35pF for all positions of the VOLTAGE/CM switch.

AMPLIFIER

The output from the attenuator passes through an input protection circuit comprised of FET Q2 to the vertical amplifier.

The above input protection circuit, utilizing the high quality diode characteristic of the FET, suppresses excessive input signals to approximately ± 1 volt.

Transistor Q3 employed as the initial stage of the vertical amplifier is a source follower with high input impedance. Further, transistor Q3 forms a balanced circuit with transistor Q4 to reduce the drift due to variations of power source voltage and temperature.

The output of the balanced amplifier is fed to succeeding emitter followers Q5 and Q6 where its impedance is lowered further, and then applied to a differential amplifier Q7 and Q8.

The dc level of the balanced signal may be adjusted by FET source variable resistor VR101 (DC BAL).

Variable resistors VR102 (vertical VARIABLE) and VR1 in the emitter circuits of transistors Q7 and Q8 provide adjustment of the gain of the differential amplifier. Variable resistor VR103 (⬍ POSITION) adjusts the balance of the dc signal level of the differential amplifier for adjustment of the vertical position of the signal represented on the cathode ray tube.

The output of transistors Q7 and Q8 is fed through emitter follower Q9 and Q10 to another differential amplifier comprised of transistors Q11, 12, 13 and 14. These transistors are connected in a cascode arrangement and, therefore, reduce their Miller effect to the signal at higher rf frequencies. This allows the differential amplifier to provide a sufficient bandwidth.

Variable resistor VR2 in the emitter circuit of transistors Q11 and Q12 establishes the range of the front panel vertical position control.

The output signals of the differential amplifier transistors Q11, 12, 13 and 14 are fed to transistors Q15 and Q16. Here their impedances are further lowered, and then applied to the final stage amplifier as well as to emitter follower transistor Q17 serving as a buffer to the triggering circuit. The output from Q17 is used as the internal trigger signal to the triggering circuit.

The final stage amplifier, a cascode differential amplifier consisting of transistors Q18 and Q19 connected in cascode with transistors Q20 and Q21, is provided wth tuning capacitors TC21 and TC22, which provide adjustment of the frequency response.

The signal is sufficiently amplified by the vertical amplifier to be applied directly to the vertical deflection plates of cathode ray tube. The overall gain of the entire vertical amplifier circuit is approximately 60 dB, which corresponds to a deflection sensitivity of 10 mV/cm.

TRIGGERING CIRCUIT

PHASE INVERTER AND LIMITER CIRCUIT

In this circuit, the input signal is selected as INT (internal), EXT (external) or LINE by the TRIGGERING SOURCE switch. This inverter and limiter circuit (Q6 and Q7) is a sort of differential amplifier which, because of its narrowed dynamic range, limits the level of its input signal as well as inverts the phase of the signal. Polarity of the signal is easily reversed by the TRIGGERING SLOPE switch.

The input circuit provides adjustment of the bias voltage, as performed through the use of variable resistor VR104 (TRIG LEVEL). Thus, the sync threshold level is established.

SYNC SEPARATOR CIRCUITS

To improve the sync reliability of this instrument when viewing composite video information, a sync separator circuit (Q101 and Q102) is provided. This circuit is operative when the TRIGGERING SYNC is in the TVV and TVH positions. Signal input is provided from the polarity reversing amplifier Q7. Q101 operates as an impedance transformer stage which drives Q102. In the absence of input signal, Q102 is biased near cut-off. Positive going input signals cause increased base current to flow in Q102, charging capacitor C132. Because of the large time constant in the base circuit of Q102, an average negative voltage is developed between the base of Q102 and ground, so that the transistor is cut off until a positive signal peak of sufficient amplitude to override the developed cut-off bias is applied. As the input signal amplitude varies, the average base voltage adjusts automatically so that transistor Q102 conducts only on positive signal peaks. An output pulse corresponding to the conduction interval of the transistor is obtained at the Q102 collector.

Because the circuit generates output pulses corresponding to the peak amplitudes of input signals, it is ideally suited for generating sync pulses corresponding to the tips of vertical and horizontal pulses of the composite video signal. The sync pulse output of Q102 is applied directly to the base of Q8 when the TRIGGERING SYNC switch is in the TVH position. When the TRIGGERING SYNC switch is in the TVV position, the horizontal sync information is removed from the composite video signal by integrator capacitor C134 and a sync pulse output corresponding to the tip of the vertical blanking pulse is generated. This is also applied to the base of Q8.

SQUARE WAVE SHAPING CIRCUIT

The square wave shaping circuit is essentially a Schmitt trigger comprised of transistors Q8 and Q9.

This circuit delivers a square wave from its output when the level of its triggering signal is raised to a certain value. The square wave output of this circuit is coupled to a differentiator circuit, where it is turned into the trigger signal to the gate multivibrator.

When switch S106 is in the AUTO position, the gate multivibrator, which normally operates as a bistable multivibrator, turns into an astable multivibrator operating at 40 to 50 Hz. Since this astable multivibrator oscillates weakly, it is easily pulled into synchronization with the input signal to generate the trigger signal for automatic triggering.

SWEEP CIRCUIT

GATE MULTIVIBRATOR, MILLER INTEGRATING CIRCUIT AND HOLD-OFF CIRCUIT

The gate multivibrator is a bistable multivibrator comprised of transistors Q10 through Q13, driven under control of the trigger signal from the square wave shaping circuit. The Miller integrating circuit consisting of transistors Q17 through Q20, and the hold-off circuit (transistor Q14) form a dc loop which generates a sweep sawtooth voltage.

The gate multivibrator circuit is set at the threshold of operation by use of the STABILITY control. As soon as the multivibrator receives a trigger signal from the square wave shaping circuit, it inverts the state of its transistors and turns off switching diodes D3 and D4. This charges the time base capacitors in the gate circuit of FET Q17 at a rate which is determined by the combination of the time base capacitors and resistors as selected by the SWEEP TIME/CM control. This charging signal is applied through high impedance FET Q17 to the Miller integrating circuit composed of transistors Q18, Q19 and Q20. This integrating circuit not only amplifies its input charging signal but also inverts the phase of the signal.

The low impedance output circuit of transistor Q20 is fed to horizontal amplifier Q21, from which it is fed as the sweep voltage via Q22 and Q23 to horizontal deflection plates of cathode ray tube.

Part of the Miller integrating circuit output is fed back to one side of the time base capacitors mentioned previously. This enables the capacitors to be charged with constant current, thereby providing the charging waveform with a better linearity.

Another part of the integrating circuit output is coupled through capacitor C14 and diode D5 to hold-off circuit transistor Q14. Hence, the hold-off circuit feeds back the integrating circuit output with a delay to the input of the gate multivibrator until the output reaches a specified level. It then inverts the state of the transistors of the gate multivibrator to their original condition to complete the sweep.

HORIZONTAL AMPLIFIER CIRCUIT

The horizontal amplifier circuit consists of emitter follower Q21 and differential amplifier transistors Q22 and Q23.

The sawtooth wave output from the Miller circuit is applied to emitter follower Q21. The ouput of the emitter follower is fed to the differntial amplifier.

The differential amplifier circuit contains variable resistor VR6 (MAG CENT) which is in the base circuit of transistor Q23. VR6 balances the DC output voltages of the amplifier which may be unbalanced when the magnification is switched from the X1 position to the X5 positions or vice versa. The amplifier also contains variable resistor VR7 (◄► POSITION) which provides horizontal position adjustment of the sweep.

The magnification switch (push-pull switch on ◄► POSITION control) selects gain adjustment variable resistors VR8 (GAIN ADJ) or VR9 (MAG ADJ), inserted in the emitter circuit of transistors Q22 and Q23. Each resistor is adjusted for specified horizontal amplifier gain of X1 and X5.

When external sweep operation is used, the signal is fed from the EXT SYNC/HOR terminal to variable resistor VR105b (VARIABLE/HOR GAIN). The output of variable resistor VR105b is applied to FET Q16, the output of which is then applied to the horizontal amplifier circuit.

Variable resistor VR4 (POS ADJ 2) is provided to adjust the dc voltage of the external signal to the same level as the mean voltage of the internal sweep signal at the center of cathode ray tube scope about its horizontal position. The horizontal amplifier provides a deflection sensitivity of 300 mV cm and a frequency band of dc to 800 KHz (—3 dB).

CALIBRATION VOLTAGE CIRCUIT

The calibration voltage circuit consists mainly of a 1KHz multivibrator and a Schmitt trigger circuit.

The 1 KHz multivibrator (transistors Q1 and Q2) delivers its 1 KHz output to the Schmitt Trigger circuit (transistors Q3 and Q4).

The Schmitt trigger circuit converts the 1KHz output of the multivibrator into a square wave signal. Thus, a calibration voltage of 5Vp-p is delivered to the CAL terminals.

POWER SUPPLY CIRCUIT

The ac source voltage is applied to the primary winding of the power transformer.

The high voltage induced across the secondary winding is rectified by voltage doubler rectifiers D101 and D102 which provide high voltage for the cathode ray tube.

The voltage induced across the low voltage secondary winding of the transformer is rectified by diodes D103, D104, D9 and D10 to provide the B+ supply voltage.

The low voltages for the vertical and horizontal amplifiers are supplied by stabilizing the B+ supply voltage through regulator transistor Q24 and Zener diode D7.

MAINTENANCE AND CALIBRATION

WARNING: Voltages as high as 1600 volts are present on the cathode ray tube and in the power supply circuits. Use extreme caution when the cabinet is removed from this instrument.

HOUSING REMOVAL

(See Figure 41)

1. Remove the two screws from the lower rear corners of the housing.
2. Remove the screw on the underside of the housing. This screw is located at the rear center of the housing.
3. With the oscilloscope located on a flat surface, push the chassis forward, applying pressure on the chassis at the cut-out at the rear of the housing. Carefully apply pressure until the front panel flange clears the front of the housing.
4. Supporting the front panel and chassis assembly at the lower edge of the front panel, pull forward until the chassis clears the housing.

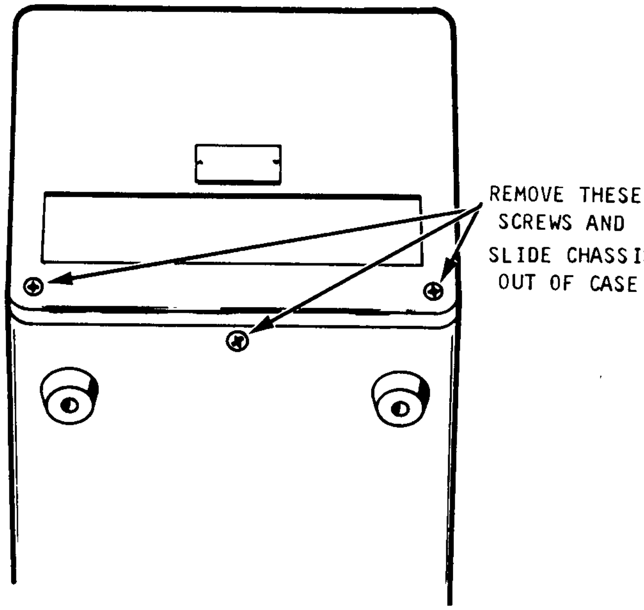


Figure 41. Housing Removal

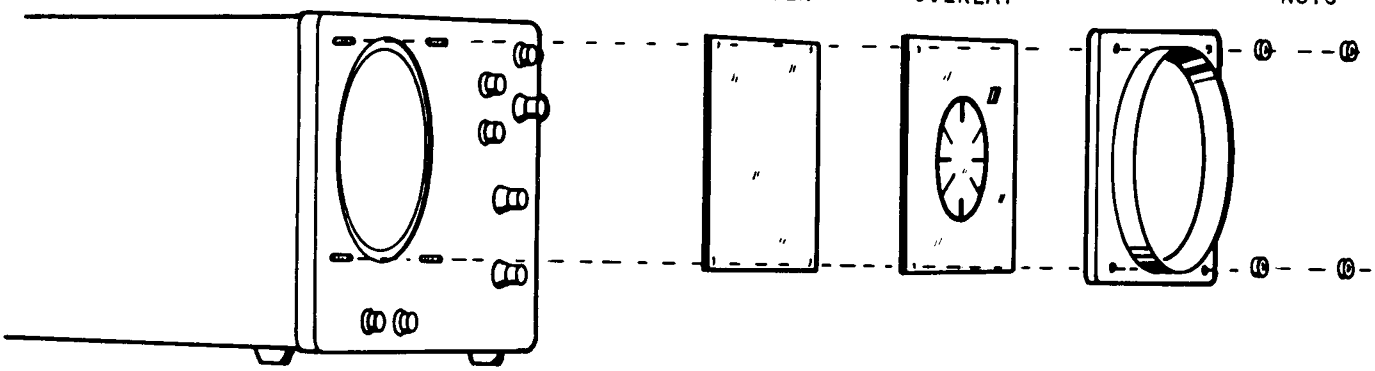


Figure 42. Graticule Removal and Replacement

GRATICULE REMOVAL AND REPLACEMENT

(See Figure 42)

Two bulbs, located behind the bezel illuminate the scale. To replace these bulbs:

1. Remove all four bezel retaining nuts.
2. Lift off the bezel.
3. Lift off the scale.

SCALE ILLUMINATION LAMP REPLACEMENT

1. Remove chassis from case.
2. Remove bezel and graticule.
3. Gently push on bulb from front of unit until it is free of retaining grommet.
4. Unsolder wires and replace bulb.

CRT POSITIONING

Checking proper positioning as follows:

1. Set the AC-GND-DC switch to GND.
2. Set the TRIG LEVEL control fully counterclockwise to AUTO.
3. Adjust intensity and FOCUS controls for fine trace on CRT.
4. Adjust ⬍ POSITION control to place trace in center of CRT.
5. The trace should align exactly with the center horizontal marker scale.

If the trace on the CRT is not in alignment with the horizontal scale, correct it as follows:

1. Remove the oscilloscope chassis from the case as outlined previously.
2. Loosen the screws in the mounting clamps over the neck of the CRT. (See Figure 43).
3. Turn CRT for proper alignment of trace with scale.
4. Tighten CRT clamping screws. Tighten evenly to keep CRT properly positioned.

CLEANING AND REPAIRING

As with any piece of equipment using high voltages, the electrical charge tends to capture some dust particles from the air. An occasional cleaning to remove the dust accumulation will allow components to operate cooler and give longer life. Use a soft brush and be careful not to disturb components.

If the oscilloscope does not operate properly, double check that all operator's controls have been properly set. If trouble persists, the malfunction may be isolated by conventional troubleshooting techniques including voltage and resistance checks. Compare voltage readings with those on the schematic diagram. Please refer to the Warranty Service Instructions on the last page of this manual if the reason for the malfunction cannot be determined.

DC BALANCE ADJUSTMENT

1. Place the AC-GND-DC switch in the GND position.
2. Set the vertical VARIABLE control fully counterclockwise.
3. Adjust the ⬍ POSITION control to center the trace over the center horizontal line on the scale.
4. Now, turn the vertical VARIABLE control fully clockwise. If the trace shifts its position, return it to its original position with the DC BAL adjustment (screwdriver adjustment on the front panel).
5. Repeat steps 2, 3, and 4 until the trace remains stationary as the vertical VARIABLE control is rotated from one extreme to the other.

ASTIGMATISM ADJUSTMENT

1. Adjust controls to display a stable horizontal line on the face of the CRT.
2. Adjust the INTENSITY and FOCUS controls for as fine a trace as possible.
3. Adjust the ASTIG adjustment (screwdriver adjustment on front panel) for the finest trace.

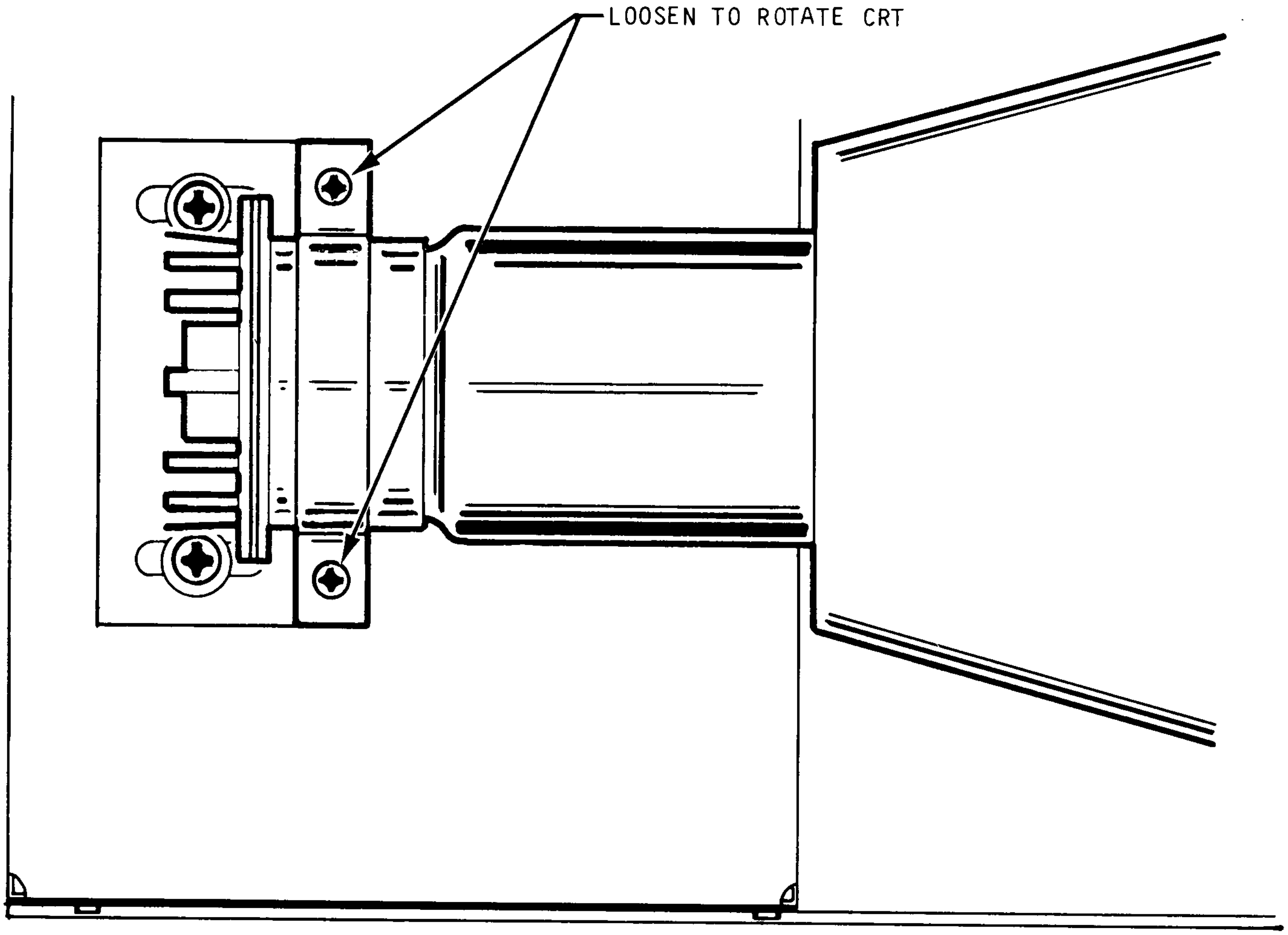
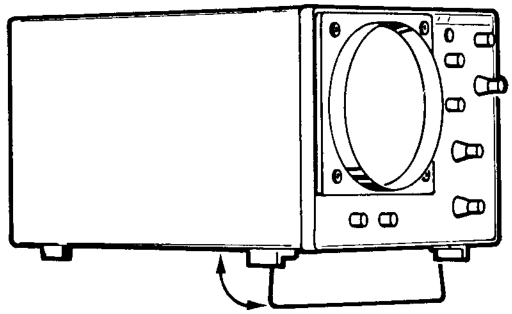


Figure 43. CRT Positioning

VERTICAL CALIBRATION

1. Set the VOLTAGE/CM control to the .1 V/cm position.
2. Set the vertical VARIABLE control fully clockwise to the CAL position.
3. Connect the probe cable to the V INPUT receptacle and set the probe for 10:1 attenuation.
4. Connect the tip of the probe to the CAL⎍ jack so that the 5Vp-p square wave is displayed on the oscilloscope.
5. Adjust the sync and sweep speed controls to display two full cycles of the square wave signal.
6. The vertical amplitude of the display should be exactly 5 cm. If calibration is required, remove the oscilloscope from the case and adjust variable resistor VR1 (GAIN ADJ) for exactly 5 cm vertical deflection. VR1 is an internal adjustment located on the vertical amplifier printed circuit board. This board is horizontally located in the upper right-hand portion of the oscilloscope assembly.

Model 1460 with Tilt Stand



Tilt stand included under unit.
Pull wire foot down to tilt unit.

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, Dynascan Corporation
Factory Service Operations
4050 North Ravenswood Avenue
Chicago, Illinois 60613
Tel (312) 327-7270
Telex: 25-3475

Also use this address for technical inquiries and replacement parts orders.

LIMITED ONE-YEAR WARRANTY

DYNASCAN CORPORATION warrants to the original purchaser that its **B & K-Precision** product, and the component parts thereof, will be free from defects in workmanship and materials for a period of one year from the date of purchase.

DYNASCAN will, without charge, repair or replace, at its option, defective product or component parts upon delivery to an authorized **B & K-Precision** service contractor or the factory service department, accompanied by proof of the purchase date in the form of a sales receipt.

To obtain warranty coverage in the U.S.A., this product must be registered by completing and mailing the enclosed warranty registration card to DYNASCAN, **B & K-Precision,** 6460 West Cortland Street, Chicago, Illinois 60635 within fifteen (15) days from the date of purchase.

Exclusions: This warranty does not apply in the event of misuse or abuse of the product or as a result of unauthorized alterations or repairs. It is void if the serial number is altered, defaced or removed.

DYNASCAN shall not be liable for any consequential damages, including without limitation damages resulting from loss of use. Some states do not allow limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you.

This warranty gives you specific rights and you may also have other rights which vary from state to state.

For your convenience we suggest you contact your **B & K-Precision** distributor, who may be authorized to make repairs or can refer you to the nearest service contractor. If warranty service cannot be obtained locally, please send the unit to **B & K-Precision** Service Department, 4050 North Ravenswood Avenue, Chicago, Illinois 60613, properly packaged to avoid damage in shipment.

B & K-Precision Test Instruments warrants products sold only in the U.S.A. and its overseas territories. In other countries, each distributor warrants the **B & K-Precision** products which it sells.