OPERATOR'S MANUAL

MODEL 459
GENERAL INDUSTRIAL OSCILLOSCOPE

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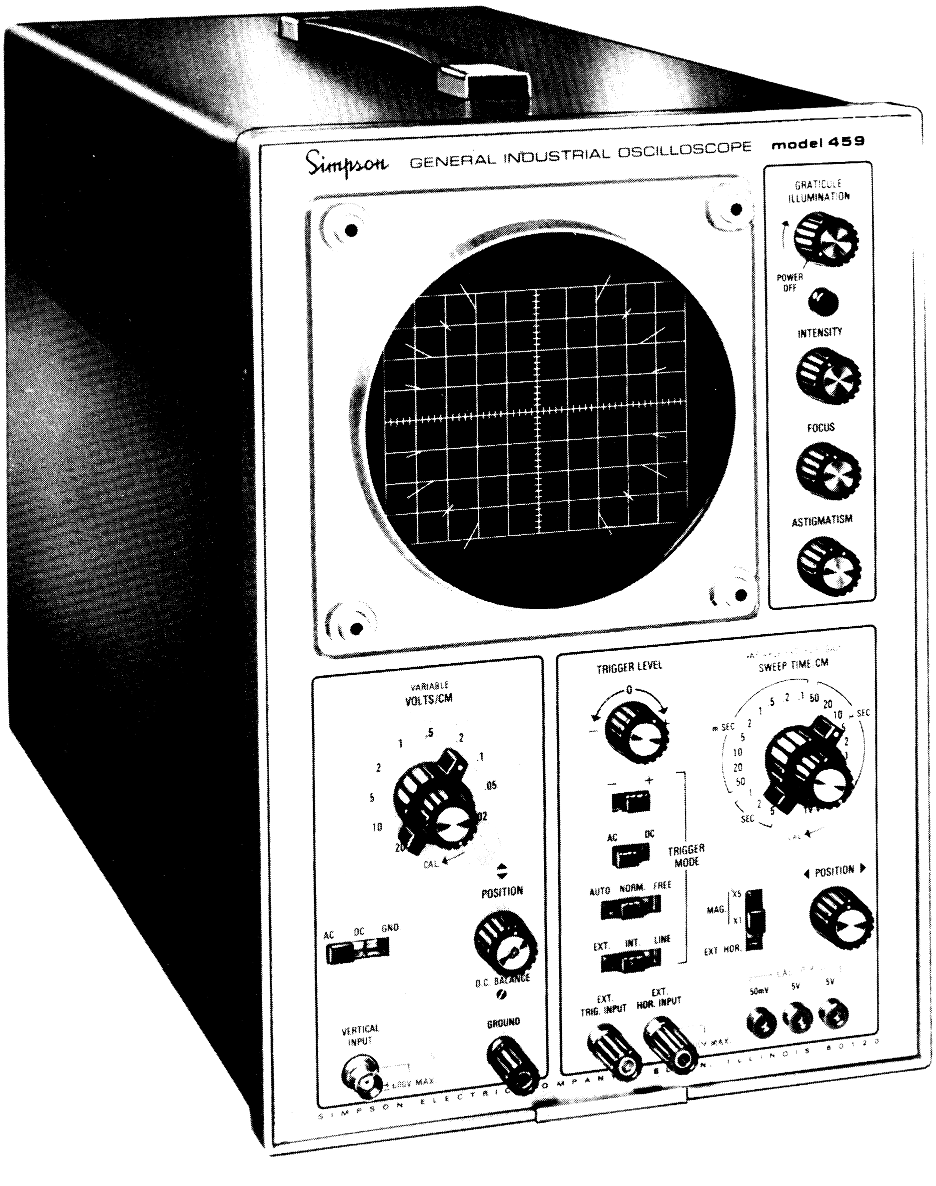

Figure 1-1. Simpson Model 459, General Industrial Oscilloscope

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WARNING

The Model 459 is designed to prevent accidental shock to the operator when properly used. However, no engineering design can render safe an instrument which is used carelessly. Therfore, this manual must be read carefully and completely prior to making any measurements. Failure to follow directions can result in a serious or fatal accident.

SHOCK HAZARD: As defined in American National Standard, C39.5, Safety Requirements for Electrical & Electronic Measuring & Controlling Instrumentation, a shock hazard shall be considered to exist at any part involving a potential in excess of 30 volts rms or 42.4 volts DC or peak, and where a leakage current from that part to ground exceeds 0.5 milliampere, when measured with an appropriate measuring instrument defined in Section 11.6.1 of ANSI C39.5.

(NOTE: The proper measuring instrument for the measurement of leakage current consists essentially of a network of a 1500 ohm non-inductive resistor shunted by a 0.15 microfarad capacitor connected between the terminals of the measuring instrument. The leakage current is that portion of the current that flows through the resistor. The Simpson Model 229-Series 2 AC Leakage Current Tester meets the ANSI C39.5 requirements for the measurement of AC leakage current and can be used for this purpose. To measure DC leakage current, connect a 1500 ohm non-inductive resistor in series with a Simpson 0-500 DC microammeter and use this as the measuring instrument.)

SECTION I

INTRODUCTION

1.1 GENERAL

1.1.1 The Simpson Model 459 General Industrial Oscilloscope (hereafter referred to as the Model 459, or simply as the Instrument), is a solid state laboratory type instrument. Its design fulfills all major requirements of accurate performance, excellent dependability and moderate cost. Among its many applications are industrial maintenance, production line circuit alignment, checkout and troubleshooting as well as color and black and white television servicing. Modern engineering methods and quality control provide high quality and reliable performance.

1.1.2 The Model 459 utilizes integrated circuits (IC's), field effect transistors (FETS) and bipolar transistors in operational amplifier feed-back configurations. The Instrument utilizes differential amplifiers from the input stage through the deflection stages for common mode and power supply noise rejection to reproduce a stable low distortion waveform. All power supplies affecting amplitude or time base are regulated.

1.1.3 Instrument features include a wide bandwidth (DC−15 MHz), high vertical sensitivity (10 mV/cm), wide horizontal sweep range (1 sec/cm to 40 nsec/cm), a high-gain wide-band vertical channel and triggered sweep. The vertical input attenuator is calibrated directly in volts so that it can be used as an instantaneous waveform voltmeter. An internal 1 kHz square wave signal provides three output voltages (.05V, 0.5V, 5V) for maintaining calibration of the voltage scales. A Z-Axis modulation input terminal on the back of the unit permits the insertion of time scale frequency markers on the pattern, and other applications.

1.1.4 A 4-foot RG62/U input cable with clip leads is supplied with the Model 459. A 3-1/2 foot accessory probe having switch selection of direct or low-capacitance (15 pF) high impedance (10 MΩ) operation is available.

1.2 ACCESSORIES AND SUPPLIES

All items furnished with the Instrument, and accessories, are listed in Table 8-1.

1.3 TECHNICAL DATA

Table 1-1 lists the technical specifications for the Model 459.

Table 1-1. Technical Data

1. POWER REQUIREMENTS	
AC Voltage	120 VAC ±10% or 240 VAC ±10%
Frequency	50 or 60 Hz
Average Power Consumption	90 VA
Fuse Ratings	3 Ampere 250V 3AG quick acting (120-Volt operation) 1.5 Ampere 250 V 3AG quick acting (240-Volt operation)
2. VERTICAL AXIS	
Deflection Sensitivity	10mV/cm to 20V/cm calibrated in 1-2-5 sequence in eleven steps; accuracy within ±3%; uncalibrated continuous control between steps.
Bandwidth, at −3 dB	
DC	DC to 15 MHz
AC	2 Hz to 15 MHz
Square wave response	
Risetime	24 nsec.
Aberration	±5%
Input Impedance	
Input terminals	1MΩ, ≈35pF
With shielded cable	1MΩ, ≈90pF
With probe-LO CAP	10MΩ, ≈15pF
With Probe-DIRECT	10MΩ, ≈135pF
Maximum Input Voltage	600V (DC + AC peak) or 1200V P-P
Calibration Voltage	5V, .5V and .05V P-P, ±3% Squarewave ≈1kHz

3. HORIZONTAL AXIS

Deflection Sensitivity	500 mV/cm to 25 v/cm with uncalibrated continuous control
Linearity	3%
Bandwidth, at −3 dB	DC to 1 MHz
Input Impedance	200kΩ, ≈40pF
Maximum Input Voltage	300V (DC + AC peak) or 600V P-P

4. SWEEP CIRCUIT

Time/cm Range	.2 μsec/cm to .5 sec/cm calibrated in 1-2-5 sequence in 20 steps; accuracy within ±5%; uncalibrated continuous control between steps.
TV — H	127 μsec/10 cm $\left(\frac{2}{\text{TV Line Rate}}\right)$
TV — V	33.3 msec/10cm $\left(\frac{2}{\text{TV Field Rate}}\right)$
Magnification	x 5

5. POWER SUPPLY Regulated high & low voltages, independent of line voltage changes.

CRT Acceleration Voltage	−1.7 kV

6. TRIGGERING

Source	External, Internal, Line
Mode	Automatic (no adjustment) Normal (adjustable trigger level) Free (free running or asynchronous)
Coupling	AC or DC (DC on normal only)
Slope	− or + (of trigger signal waveform)
Sensitivity	
Normal	1 cm P-P from DC to 15 mHz (adjust trigger level)
Automatic	.5 cm P-P from 50 Hz to 500 kHz (no adjustments)
External	.5V to 1.5V, P-P

7. Z AXIS INPUT Input voltage for blanking ≈25V P-P

8. COLOR TV VECTOR
R−Y & B−Y fed into vertical and horizontal inputs respectively.
Burst orientation: +X
R−Y orientation: +Y
30° angle reference marks provided

9. SEMICONDUCTOR & TUBE COMPLEMENT 1 dual FET, 2 IC's, 42 transistors, 71 diodes, 1 CRT (type 5 DEPI)

10. MISCELLANEOUS 8 x 10 cm graticule adjustable graticule illumination. High contrast green filter. Conventional light hood and scope camera mounting.

11. OPERATING TEMPERATURE RANGE 0°C to 40°C

12. WEIGHT 30 lbs. (13.6 kg)

13. DIMENSIONS 12-3/4" high, 8-3/4" wide, 20" deep (324 mm, 222 mm, 508 mm)

SECTION II

INSTALLATION

2.1 UNPACKING AND INSPECTION

2.1.1 Examine the shipping carton for obvious signs of damage prior to unpacking. If shipping carton is in good condition, then unpack and inspect the Instrument for possible damage incurred during shipment. If damage is noted, notify the carrier and supplier and do not attempt further use of the Instrument. If Instrument appears to be in good condition, read Operator's Manual in its entirety. Become familiar with the Instrument as instructed in the manual, then proceed to check the electrical performance as soon as possible.

2.2 FACILITIES REQUIRED

If possible use the Model 459 in a clean dry area, preferably one maintained at constant normal indoor temperature and humidity levels. Avoid dust and corrosive fumes. Isolate the oscilloscope from mechanical shock, vibration, and electrical interference.

2.3 POWER REQUIREMENTS

CAUTION

Do not connect the Instrument to a power source until instructed to do so. Check that the power source agrees with the voltage requirements of your Instrument.

The input power requirement of the Model 459 is pre-wired for 120 VAC, 50/60 Hz operation. To operate the Instrument from a 240 VAC 50/60 Hz source, the input power line connections to the primary windings of the power transformer must be changed. To change input power requirements, refer to paragraph 7.4. The required power source is a 3-wire, grounded outlet, wired according to the latest electrical code. The line voltage should be ±5% of the rated value of the Instrument.

NOTE: If the unit is operated on a 2-wire system, connect a ground lead from earth Ground to chassis GROUND terminal.

2.4 OPERATION

The Model 459 is equipped to operate in a horizontal or inclined position. A bracket, or bail, is located on the bottom near the front of the Instrument. With the bracket extended, the unit assumes the tilted position with the front panel facing toward operator. Assure at least three inches clearance on both sides of the Instrument for ventilation. Avoid operation with rubber feet missing because they provide for air clearance from the bottom. Although mu-metal CRT shielding is provided, the Instrument and test leads should be kept several feet away from strong electrical fields (such as associated with adjacent power transformers, radio transmitters, SCR power controllers, motors, blowers and heavy soldering irons). This will assure accurate waveforms and stable triggering.

SECTION III

CONTROLS, CONNECTORS AND INDICATORS

3.1 GENERAL

All controls, connectors, indicators and other operational items are described in Table 3-1, and shown in Figures 3-1 and 3-2. Become thoroughly familiar with the name and purpose of each item before operating the Instrument.

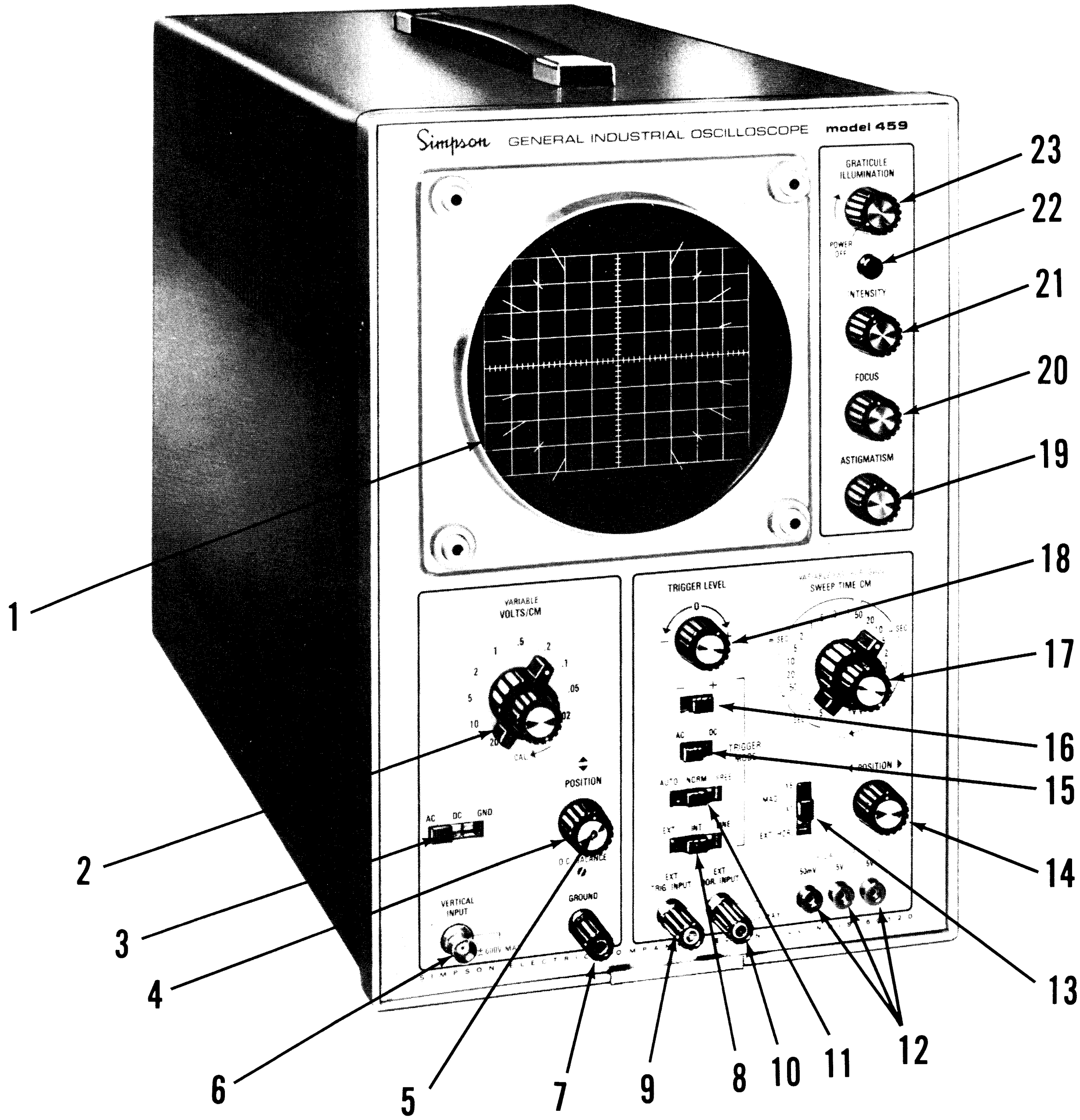


Figure 3-1. Front Panel Controls, Connectors and Indicators

Table 3-1. Controls, Connectors and Indicators

Switch Position	Description
1. Cathode Ray Tube	5" flat-faced cathode ray tube with 8 x 10 cm edge-lighted graticule.
2. VARIABLE VOLTS/CM	
Black Knob	An 11 position step attenuator for 10 mV/cm to 20 V/cm.
Red Knob	Variable attenuator with CAL (calibration) at max. CW. position.
3. AC/DC/GND	Controls input to vertical amplifier.
AC	Isolates input from DC.
DC	Direct coupled.
GND	Used to obtain DC reference on CRT, but does not short input probe to ground.
4. POSITION ▲↕▼	Adjusts vertical position of trace on CRT.
5. DC BALANCE	Adjusts DC balance at input of vertical differential amplifier.
6. VERTICAL INPUT	BNC connector for vertical input signal probe.
7. GROUND	Common ground connection for oscilloscope.
8. EXT./INT./LINE	Switch for selecting source of triggering signal.
EXT.	External trigger signal applied at EXT. TRIG. INPUT.
INT.	Internal trigger signal taken from vertical amplifier.
LINE	Line trigger signal taken from 60 Hz line voltage, internally.
9. EXT. TRIG. INPUT	External trigger source input jack.
10. EXT. HOR. INPUT	External signal to horizontal amplifier input jack.
11. AUTO/NORM./FREE	Selects type of synchronization.
AUTO	Automatic triggering under most conditions.
NORM.	Synchronization depends on settings of trigger level control.
FREE	Free running or asynchronous.
12. CAL P-P	Three jacks, each supply a 1 kHz square wave output of the designated .05V, .5V and 5V amplitude for calibration of vertical amplifier.
13. MAG. x5	Horizontal CRT trace expanded 5 times.
x1	Normal CRT horizontal trace.
EXT. HOR.	Use external source to drive CRT trace horizontally.
14. ◀POSITION▶	Adjust horizontal position of CRT trace.
TRIGGER MODE	
15. AC/DC	Selects input coupling of trigger signal
AC	Capacitor coupling.
DC	Direct coupling
16. −/+	Selects whether sweep is to be triggered on negative (−) or positive (+) slope of trigger signal.
17. VARIABLE/EXT. HORIZ. GAIN SWEEP TIME/CM	
Red knob	Used for ext. horizontal amplifier gain and fine adjustment of horizontal sweep frequency.
Black knob	Twenty-two position switch to select horizontal sweep speed from 2 μsec/cm to .5 sec/cm, plus two positions for displaying television signals at the horizontal line or vertical frame rate.
18. TRIGGER LEVEL	Adjusts level of trigger signal for proper sync.

19. ASTIGMATISM	Adjusts shape of spot to optimize line width of trace from top to bottom and side to side of screen.
20. FOCUS	Adjusts line width or sharpness of trace.
21. INTENSITY	Adjusts brightness of trace.
22. Red Pilot Lamp	Lamp lights when the power is turned on.
23. GRATICULE ILLUMINATION/POWER OFF	Adjusts intensity of graticule illumination. Turns AC power off in the full counterclockwise position.

NOTE: Items 24 through 27 refer to controls located on the rear panel of the Instrument (see Figure 3-2).

24. NORMAL/Z AXIS INPUT	
NORMAL	Scope is unaffected by input to Z AXIS jack.
Z AXIS INPUT	Permits the Instrument to be used to show intensity modulation.
25. Z INPUT 5-25V P-P	The input jack for the application of a beam intensity modulating voltage, for blanking the trace at timed intervals.
26. Fuse Holder	250V/3A, type 3AG quick acting fuse-holder for 120 VAC operation or 1.5A type for 240 volt operation.
27. 120V 50/60 Hz 90 VA Chassis AC Interconnect	Provides means to disconnect power cable from unit or to change power cord for 240V operation.

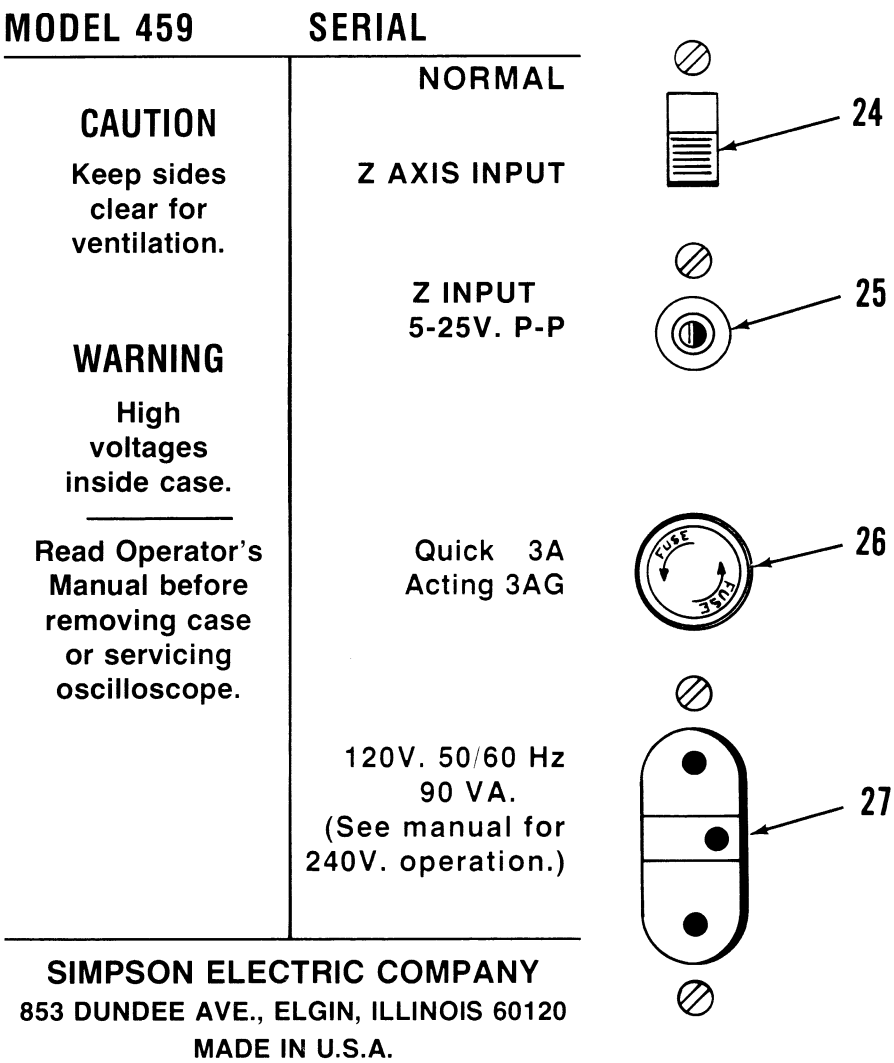


Figure 3-2. Rear Panel Controls and Connectors

SECTION IV

OPERATION

4.1 GENERAL

This section of the manual contains the operating procedures of the Model 459. Special notes and instructions also have been provided for added user safety and convenience.

4.2 SAFETY PRECAUTIONS

WARNING

In equipment known to be (or thought to be) "solid state", it can be very tempting to suppose that only low voltages are present. On the contrary, lethal shock situations are often present in transistor circuitry, and definitely in equipment which employs vacuum tubes. When servicing TV sets, do not suppose that the "high-voltage compartment" is the only place where you must be careful.

4.2.1 The Model 459 is intended to be used only by personnel qualified to recognize shock hazards and trained in the safety precautions required to avoid possible injury. Refer to SHOCK HAZARD definition on page iv.

4.2.2 Avoid making measurements or adjustments alone where a shock hazard can exist. Notify a nearby person that you are making, or intend to make, such measurements.

4.2.3 When using or servicing the Model 459 Oscilloscope insure that it is connected to a three-wire power line outlet that is correctly wired in accordance with the latest National Electrical Code. If not sure of the integrity of the power line outlet, or you are forced to use a 3-wire to 2-wire cheater plug, then be sure to ground the case of the Model 459 to a known good earth ground by means of the GROUND binding post located along the lower edge of the front panel.

4.2.4 Do not exceed the maximum input voltage ratings of the Model 459, which are tabulated in Table 1-1. To do so endangers personal safety and may also damage the Oscilloscope.

4.2.5 Do not attempt to float the grounded terminals (the GROUND binding post and the body of the BNC input connector which are all electrically connected to the case) or the case of the Model 459 above earth or power line ground. To do so risks personal safety and may damage the Model 459 as well as the equipment under test.

4.2.6 Voltages may appear unexpectedly in defective equipment. An open bleeder resistor can result in a capacitor's retaining a dangerous charge. Remove all power and discharge all capacitors in the circuit being measured **before** making connections or disconnecting the Instrument.

4.2.7 Locate all voltage sources and current accessibility paths prior to making any connections.

4.2.8 Hands, shoes, floor and workbench must be dry. Avoid using Instrument under humid or damp conditions.

4.3 PRELIMINARY PERFORMANCE CHECKS

Following a visual inspection for mechanical damage, the following tests and adjustments will provide a quick pre-operational check. This procedure requires no equipment or supplies other than those items supplied with the Model 459.

4.4 INITIAL CONTROL SETTINGS

Prior to performing any test or adjustments review paragraphs 4.1 and 4.2 then proceed as follows:

CAUTION

Use the Model 459 in an area which is free from magnetic disturbances, to prevent possible waveform distortion. Also avoid placing "gun type" soldering irons near the Instrument. During stand-by periods, when the beam of the cathode ray tube is concentrated in a particular spot on the screen, adjust the INTENSITY control to extinguish the spot, or keep the spot in motion with application of sweep voltage. This precaution prevents burning a spot on the face of the CRT.

a. Turn POWER OFF, GRATICULE ILLUMINATION control to POWER OFF position.
b. Turn INTENSITY control clockwise to about 80% maximum.
c. Rotate vertical and horizontal POSITION controls to mid-positions.
d. Set VOLTS/CM switch to .1.
e. Rotate VARIABLE control to CAL position.
f. Set SWEEP TIME/CM to 1 msec/cm.
g. Rotate VARIABLE control to cal-position.
h. Set TRIGGER MODE switches to +, AC, AUTO., and INT.
i. Set the MAG./EXT. HOR. switch to x 1.
j. Rotate FOCUS control to mid-position.

k. Connect shielded input probe to VERTICAL INPUT jack.

l. Connect signal probe to CAL. P-P .5V jack using a pin plug or a wire insert.

4.5 ADJUSTMENT OF CONTROLS

Proceed as follows:

a. Connect AC line cord to socket on rear panel of cabinet, and AC connector to AC power source.

b. Rotate POWER OFF, GRATICULE ILLUMINATION control clockwise until pilot light illuminates. After approximately 30 seconds, a trace appears on CRT.

c. Adjust INTENSITY and FOCUS controls to obtain a clear and well defined 5 cm high square wave signal. With any oscilloscope, maximizing brightness lessens the sharpness of the trace even with the best settings of the focusing and astigmatism control.

d. Remove input probe from .5V CAL P-P jack. The oscilloscope is now ready for waveform observation.

4.6 WAVEFORM OBSERVATION

Connect the shielded input probe to the signal source desired for observation and proceed as outlined below:

4.6.1 Internal Sweep

a. Set AC/DC/GND switch to correspond to type of input signal. Normally, DC coupling is used only when DC component of signal is to be measured.

b. Signal amplitude, frequency and number of cycles for display will determine setting of the following controls:

1. VOLTS/CM selector — Setting depends on input
2. SWEEP TIME/CM selector — Setting depends on input
3. TRIGGER MODE selectors — Set as follows:
   - (a) −/+ — Selects whether sweep is to be triggered on negative (−) or positive (+) slope of triggering signal.
   - (b) AC/DC — AC position provides DC blocking so only changing portion of signal triggers scope. DC position permits triggering on DC component of signal.
   - (c) AUTO/NORM/FREE — AUTO provides automatic triggering. NORM allows critical setting of trigger level. FREE provides spontaneous triggering and a reference trace or base line without signal.
   - (d) EXT/INT/LINE — EXT is for triggering with an external signal applied to EXT. TRIGGER INPUT jack. INT. uses part of vertical output signal for triggering. LINE uses AC line frequency for triggering.
4. TRIGGER LEVEL — Selects point of amplitude or DC level at which sweep triggering occurs. Used only with NORM. trigger mode.
5. MAG. x5, x1 — x1 is setting normally used. x5 is used to expand sweep by a factor of 5. As the full sweep is now off the CRT, the horizontal POSITION control is used to bring a desired magnified portion into view on the screen. The TV VITS signal is an application example (see paragraph 6.7.11).
   - (a) ◀POSITION▶ — Adjust horizontally to make a relative time period measurement of a portion of a waveform.
   - (b) POSITION ▲↕▼ — Adjust vertically to measure amplitude of a waveform portion.
   - (c) Variable Volts/CM — Used for amplitude comparisons or where absolute voltage values are not required.
   - (d) Variable SWEEP TIME/CM — Used where absolute time period is not being measured. For example, a definite number of cycles or a certain waveform portion is to be observed exclusively.

4.6.2 External Horizontal Signal

The MAG/EXT. HOR. switch is set to EXT. HOR. and an external signal connected to the EXT. HOR. INPUT jack whenever:

a. An externally generated sweep is desired. For example, the line sweep of an external TV sweep generator may be used so as to observe the response characteristics of an IF amplifier input to the VERTICAL INPUT (see Section VI — Applications).

b. An orthogonal pair of signals (XY) must be displayed to produce a vector pattern. The X Axis signal is applied to the EXT. HOR. INPUT while the Y Axis signal is fed into the VERTICAL INPUT. The VARIABLE VOLTS/CM and VARIABLE EXT. HOR. GAIN are used to adjust the initial amplitudes of vectors X and Y.

4.7 CALIBRATED VOLTAGE MEASUREMENTS

Peak voltages, peak-to-peak voltages, DC voltages and voltages of a specific portion of a complex waveform can be measured using the Model 459 as a voltmeter. Voltages can be measured as waveforms are observed. Proceed as follows:

a. Set controls of Model 459, as instructed in preliminary procedure, to display waveform desired.

NOTE: For the vertical calibration to be correct, the VARIABLE knob of the VARIABLE VOLTS/CM control must be in the CAL. position (fully clockwise).

b. Set VOLTS/CM control to obtain maximum vertical deflection within upper and lower limits of vertical scale.

c. For AC voltage, set AC/DC/GND switch to AC, and note the amount of vertical deflection in centimeters. Adjust the horizontal POSITION control to shift the reference point for easier scale reading, if desired.

d. For DC or complex signals, set the AC/DC/GND switch to GND, and adjust the vertical POSITION control to a convenient reference level. Set the AC/DC/GND switch to DC and observe the amount of deflection. A positive voltage input will deflect the trace upwards; a negative voltage input will deflect the trace downward.

NOTE: Use the accessory LOW CAPACITANCE PROBE in the LO CAP position for display of short rise-time waveforms.

e. To calculate the voltage reading, multiply the vertical deflection (in centimeters) by the setting of the VOLTS/CM switch.

NOTE: When the accessory LOW CAPACITANCE PROBE is set for x10 attenuator (LO CAP), the deflection displayed on the Model 459 is only 1/10 of the actual voltage measured. The actual voltage is displayed when the probe is set for DIRECT measurement (x1). See Calibration procedure for probe.

4.8 ACCESSORY LOW CAPACITANCE PROBE (See Figure 4-1)

For all testing procedures other than low-amplitude waveform (below .5 volt peak-to-peak) observations, the recommended accessory probe may be connected in place of the shielded input probe and set for x10 attenuation by setting the body switch to LO CAP. Thus, connection to the signal pick-up point is made with minimum disturbance to the test circuit and signal. The shunt resistance and capacitance of the probe is 10 megohms and 15 pF. A 10 to 1 reduction in voltage to the VERTICAL INPUT will result and must be taken into account in quantitative measure-

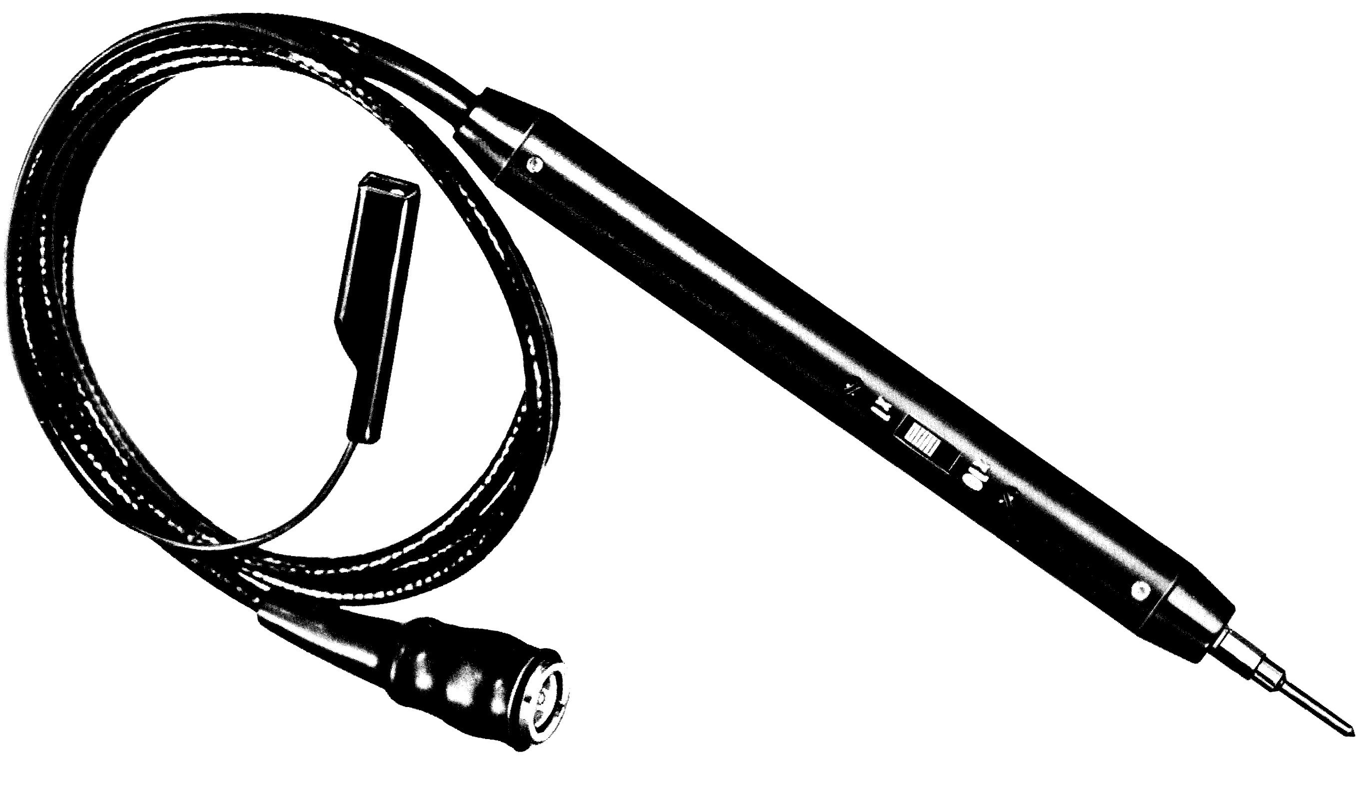


Figure 4-1. Low Capacitance Probe, Model 07548

ments. For low-amplitude waveforms the probe body switch may be set to DIRECT. In this position the probe has zero attenuation and is simply a shielded input cable. The probe, in this connection, and oscilloscope, together cause a shunt resistance and capacitance of 1 Megohm and 135 pF. The impedance for the standard shielded input probe with clip lead is 1 Megohm and 90 pF.

4.9 PROBE COMPENSATION TEST

a. Set probe switch to DIRECT position and place tip of probe into .05V CAL. output jack.

b. Adjust VOLTS/CM switch to .01 and VARIABLE control to CAL. Observe 5 cm deflection.

c. Adjust sweep rate for at least one complete rectangular waveform. Waveform will appear to have vertical sides and horizontal (flat) top and bottom (B, Figure 4-2).

d. Set probe switch to LO CAP. and put tip of probe into .5V CAL. output jack. If wave shape is square, as in B, Figure 4-2, probe is ideally compensated. If not, as in A or C, Figure 4-2, perform compensation procedure of paragraph 4.10.

4.10 COMPENSATION PROCEDURE

a. Remove three small nylon screws from probe lead.

b. Insert probe tip into .5V CAL. output jack and adjust capacitor set screw with a tuning wand or a non-ferrous screwdriver until a good sharp leading edge is obtained (B, Figure 4-2).

c. After compensation, insert probe head back into probe body and fasten with three small nylon screws. Check waveform again after re-assembly.

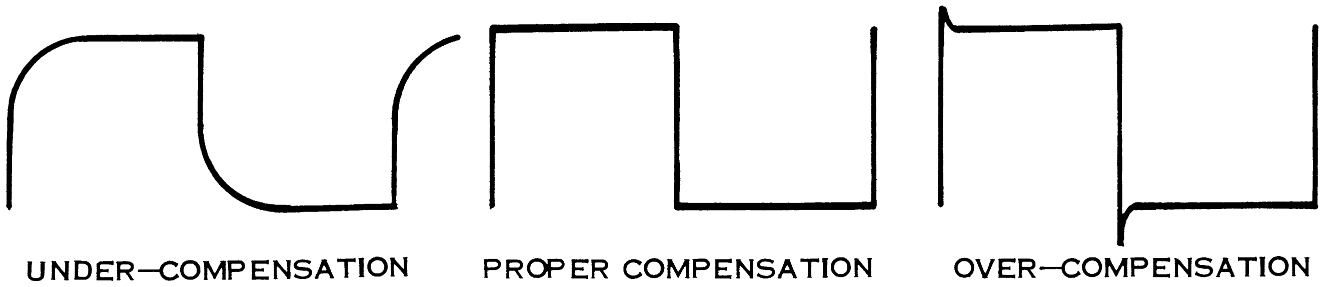


Figure 4-2. Compensation Waveforms

SECTION V

THEORY OF OPERATION

5.1 OVERALL SYSTEM BLOCK DIAGRAM

Figure 5-1 is a simplified block diagram of the Model 459. An input signal received at the vertical input jack passes through a frequency-compensated Vertical Attenuator to the Vertical Amplifier. In the Vertical Amplifier, the signal is routed through a FET buffer stage, and and is then amplified in a differential circuit before being applied to the vertical deflection plates of the Cathode Ray Tube (CRT). Horizontal sweep is derived from a Miller Integrator type saw-tooth generator. Sweep is triggered by the input signal from the Vertical Amplifier, which is routed through the Internal Trigger Pick-Off into the Comparator and Gated Multivibrator to the Schmitt Trigger or an external trigger input applied directly to the Comparator and Gated Multivibrator. Sweep starts (triggers) at the point in the waveform selected by the operator. The triggered sweep signal is then fed from the Miller Integrator to the Horizontal Amplifier where it is amplified before being applied to the Horizontal deflection plates of the CRT. During the sweep, the CRT beam is gated on (unblanked) by the Blanking Amplifier. The Hold-off circuit prevents triggering during the sweep by disabling the Schmitt trigger. An External Horizontal Input signal can be applied to the Horizontal Amplifier to display waveforms that do not require linear sweep. In this mode of operation, vector pattern, phase relationships, external time base, and Lissajous patterns may be displayed. External Z Axis Input modulation may be applied to the CRT cathode (AC coupled).

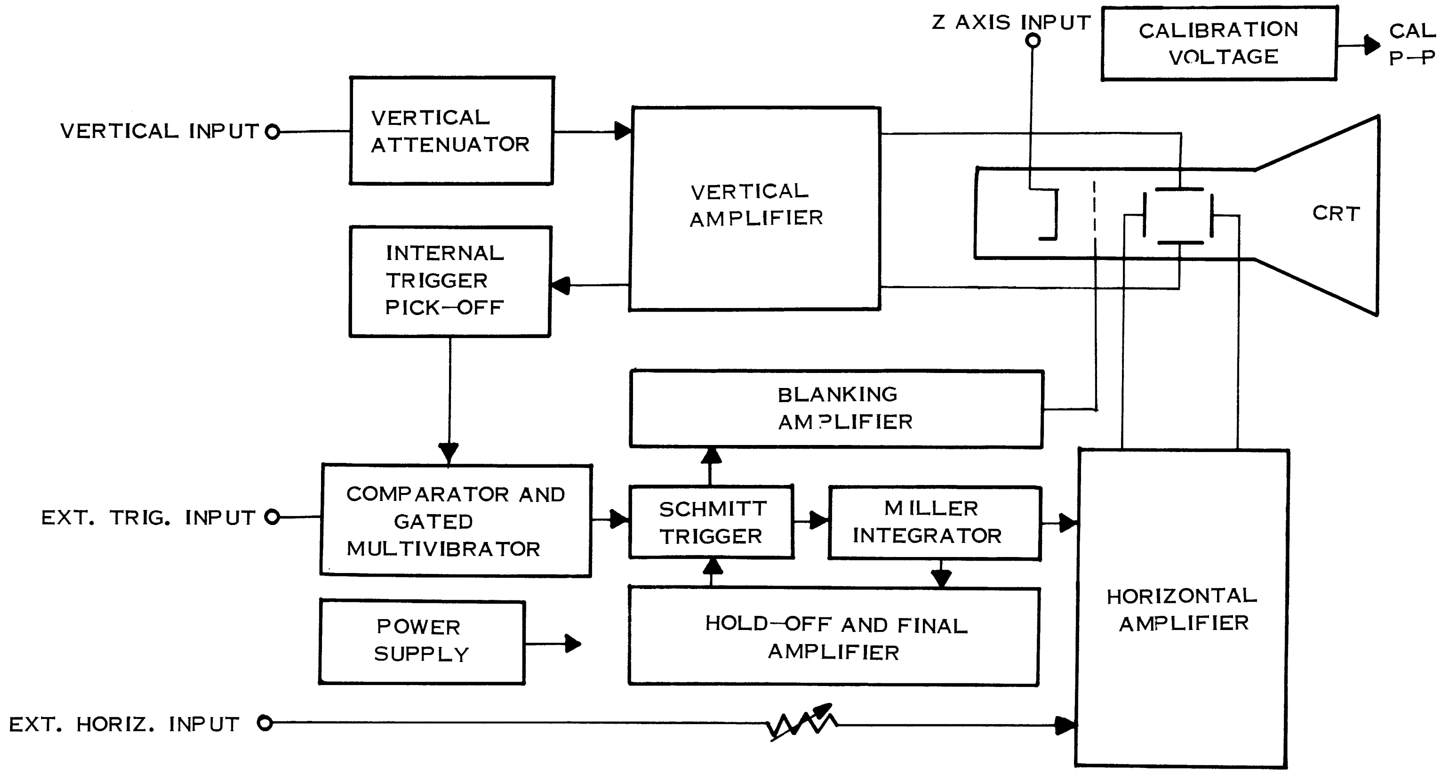


Figure 5-1. Simpson Model 459, Overall System Simplified Block Diagram

5.2 VERTICAL SYSTEM DETAILED BLOCK DIAGRAM (Refer to Figure 5-2)

5.2.1 Vertical Attenuator

A signal from the input probe at the VERTICAL INPUT jack is fed through a 3-position switch to a compensated eleven step Vertical Attenuator. The switch permits the selection of DC coupling, AC coupling or a ground reference. The attenuator maintains a constant 1 megohm input resistance shunted by 35 pF on all ranges and effectively maintains a constant input signal level to the Vertical Amplifier.

5.2.3 Vertical Amplifier

a. The output of the Vertical Attenuator is applied to a dual FET consisting of Stages Q101A and Q101B, as a source-follower to provide a high input impedance with low temperature drift. Protective diodes at the gate of Q101A protect the FET from overload, and VR11 sets the DC balance of the input stage. The balanced signal is fed to a gain-controlled differential amplifier IC101. VR102 is an internal gain setting (calibration) potentiometer: VR5 is the front panel gain control. Transistor stages Q102 and Q103 form a differential amplifier, followed by emitter-follower buffer

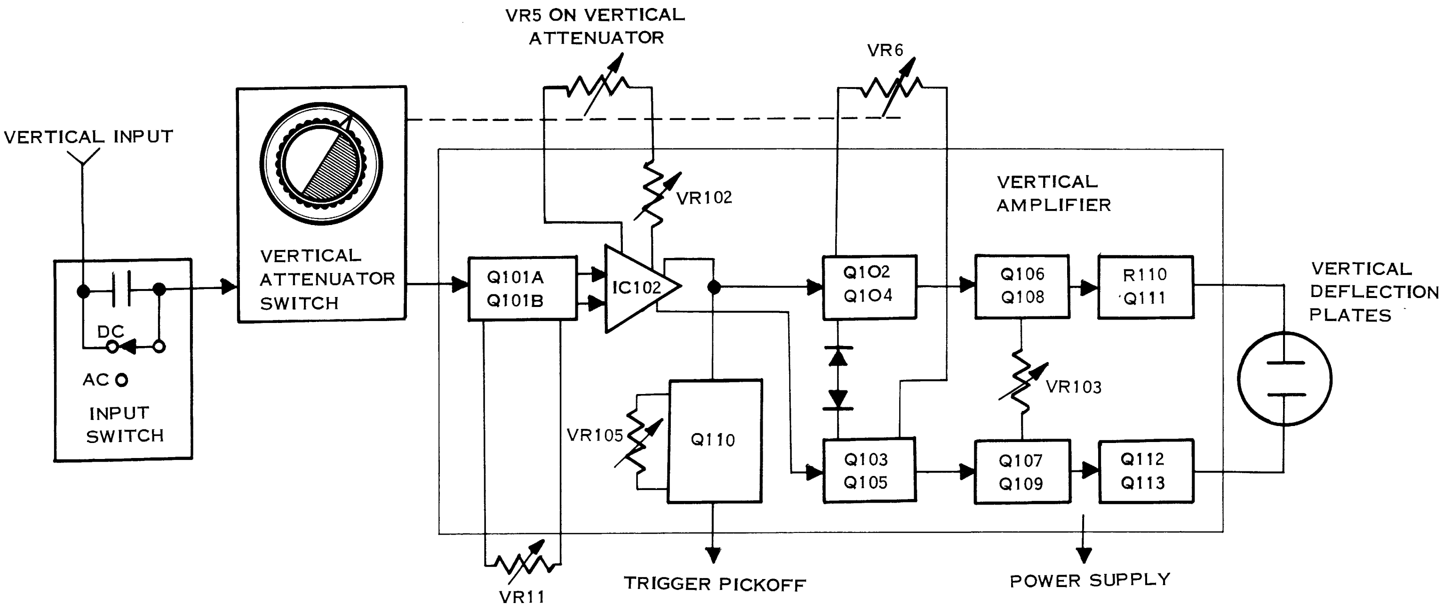


Figure 5-2. Vertical System Detailed Block Diagram

amplifiers Q104 and Q105. High-frequency compensation capacitors C110 and C121 improve amplifier frequency response. Diodes D103 and D104 limit the voltage swing and prevent transistor saturation. Front panel vertical position control VR6 adds DC offset bias to the differential amplifier. The trigger signal for internal sync is taken from the output of differential amplifier IC101 and buffered by Q114. VR105 sets the DC level of the trigger signal.

b. Transistor Q106 and Q107 form another differential pair with a DC centering control, VR103, to compensate for unequal gains. C122 provides high frequency compensation and Q108 and Q109 are emitter follower buffers for this stage. Parallel-connected differential deflection amplifiers Q110, Q111, Q112 and Q113 drive the vertical deflection plates of the CRT. C114 and C116 provide high frequency compensation. VR104 sets the bias current and controls the collector voltage for the driver transistors. R140 and R145 provide negative feedback. Under-damped peaking coils L101 and L102 compensate vertical deflection plate capacitance.

5.3 HORIZONTAL SYSTEM DETAILED BLOCK DIAGRAM (Refer to Figure 5-3).

5.3.1 Sweep Generator

Comparator and Gated Multivibrator IC401, Q401 and its associated circuitry produce a square wave output upon receipt of a trigger input signal. The square wave output signal is then differentiated and applied to Schmitt trigger Q404 and Q405. IC401 is a dual comparator with a single output. In the automatic trigger mode and in the absence of a trigger signal, one of the comparators acts as an astable multivibrator which produces a 40 to 50 Hz repetitive square wave output (to provide a baseline trace on the CRT screen). The trigger signal to the comparator may be AC or

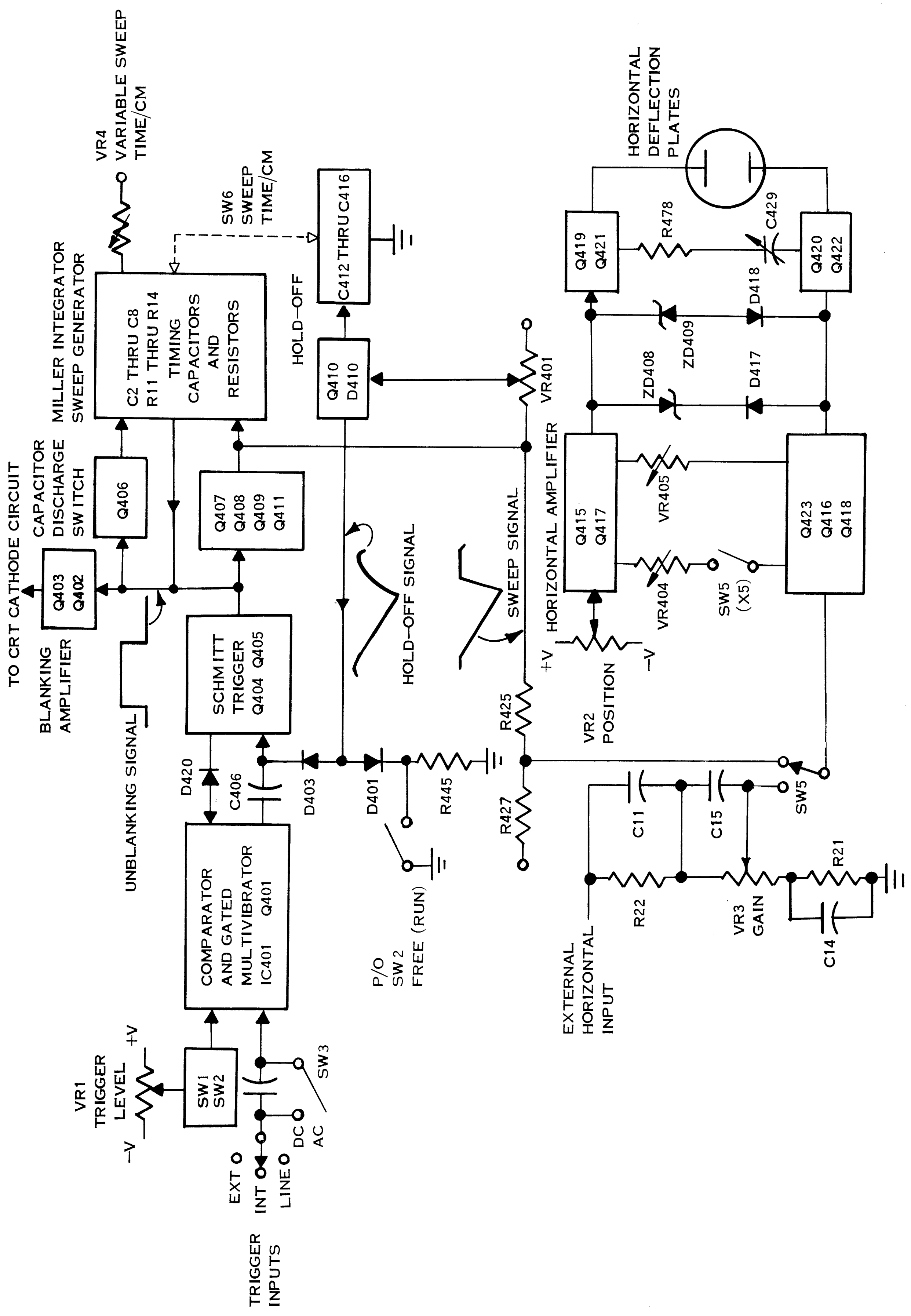


Figure 5-3. Horizontal System Simplified Block Diagram

DC coupled by switch SW3. Trigger Level Control VR1 sets the comparator threshold DC level to the trigger point. Switches SW1 and SW2 provide selection of either positive or negative slope triggering and AUTO, NORM. or FREE run trigger modes. In the NORM. mode the trigger level control is set manually. In the AUTO. mode, the trigger level control is disconnected and a preset trigger level is fed to the comparator. In the FREE run mode, the Schmitt trigger level is set to run synchronously. Here the cathode of D401 is grounded so that the Hold-off signal fed back (via D403) from the Miller Integrator causes it to turn ON after retrace of the sweep (without a trigger signal).

5.3.2 Schmitt Trigger

The positive-going signal at the emitter of Q401 sets Schmitt Trigger Q404 and Q405 through C406 to one of its two stable states. Transistor Q404 turns on and Transistor Q405 cuts off. Timing Capacitor Discharge Switch also Q406 cuts off. The Schmitt trigger stays in this state until the voltage at the base of Q404 decreases to a certain level, due to the feedback of the modified sweep waveform fed to sweep generator and CRT blanking amplifier Q402 and Q403. The trigger signal comparator is held cut-off via D420 so that trigger pulses cannot enter the Schmitt Trigger circuit during the sweep period.

5.3.3 Miller Intgrator, Hold-Off and Fixed Amplitude Control

The Miller integrator sweep generator consists of Q407 through Q411 and associated timing capacitors and resistors. This is a high voltage gain amplifier producing a linear, negative-going sweep. Sweep speed depends on the resistance-capacitance time constant controlled by SWEEP TIME/CM selector SW6 and the voltage applied through VARIABLE control VR4. The output of the Miller Integrator, buffered by Q410 feeds back to Q404. As soon as the ramp voltage reaches a certain level, depending on the adjustment of VR401, the Schmitt Trigger changes state and Q405 turns on, causing Q406 to conduct. Then, the timing capacitor discharges through Q406. The waveform, applied to the base of Q404 via D403 (hold-off signal), has a slower charge ramp than the output sweep. This is due to Hold-off capacitors C412 through C416. The positive trigger signal through C406 is superimposed on this slow-charge ramp. The ramp must rise to near the firing voltage of the Schmitt Trigger before one of the trigger pulses on the ramp causes Q404 to conduct again. This delay ramp allows time for the sweep timing capacitor to fully discharge before the next sweep is started.

5.3.4 Horizontal Amplifier

The output of the Sweep Generator is fed through a voltage divider and level shift circuit R425 - R427 to Horizontal Amplifier input buffer Q423. Variable resistor VR2 provides horizontal position control. The horizontal amplifier consists of two direct-coupled differential amplifier stages. Variable resistor VR405 in the emitter circuit of Q417 and Q418 provides adjustment of horizontal amplifier gain for x1 sweep speed, while VR404 adjusts gain in the x5 magnification circuit. External gain is controlled by VR3. ZD408, ZD409, D417 and D418 prevent transistor saturation. C429 provides high frequency compensation. When the EXT. HOR/MAG switch (SW5) is in EXT. HOR. position, the horizontal amplifier may be used as an amplifier for external input signals. Hence, the scope may be used to display vector patterns, externally generated sweeps and non linear displays.

5.3.5 Voltage Calibrator (Refer to Figure 5-4)

Transistors Q413 and Q414 form a free running multivibrator producing a 1 kHz square wave output. Buffer amplifier Q412 isolates the multivibrator from external loading. Potentiometer VR403 sets the output voltage at the taps to the exact value specified.

5.3.6 Power transformer T1 (in the Power Supply, see Figure 8-1) has 2 primary windings that can be connected for either 120 VAC or 240 VAC operation. Its secondary circuit supplies all power required for the Model 459. There are three secondary windings: 6.3 VAC CRT filament, 800 VAC and a multi-tapped winding to produce all other DC voltages. The high voltage power supply doubles the 800 VAC secondary voltage to produce 2200 VDC. This voltage is reduced and regulated by ZD301 to 1600 VDC and then applied to the cathode of the CRT. Zener diodes ZD302 and ZD303 regulate the grid voltage to −1668V. This regulated grid voltage is pulsed by the blanking transistor and zener diode ZD303 to unblank the trace during the sweep. The low-voltage power supply uses the tapped transformer winding and full-wave rectifiers to produce outputs of +310V, +210V, +60V and −60V. Each of the DC outputs has its own regulator. The regulated voltages are +260, +170, +40 and −45. The positive voltages are all shunt regulated. The negative −45V supply has a closed-loop series regulator.

5.3.7 CRT Bias (Refer to HV and LV Power Supply, Figure 8-1).

The CRT is of a design that combines high deflection sensitivity with a narrow bright trace on P1 phosphor. An anode to cathode potential of 1.7 kVDC is applied and holds constant at the setting due to regulation of the power supply voltages. The exact value of the #2 anode voltage is determined by the particular CRT and its requirements for ASTIGMATISM control (VR8). The FOCUS control VR10 adjusts proper bias of the 1st anode. Maximum acceleration voltage of the Model 459 is set at the factory, consistent with adequate cutoff during blanking. Therefore, VR302, CRT Bias, VR301 and intensity range are adjusted for maximum brightness of trace, with retrace blanking when INTENSITY control VR9 is turned fully clockwise.

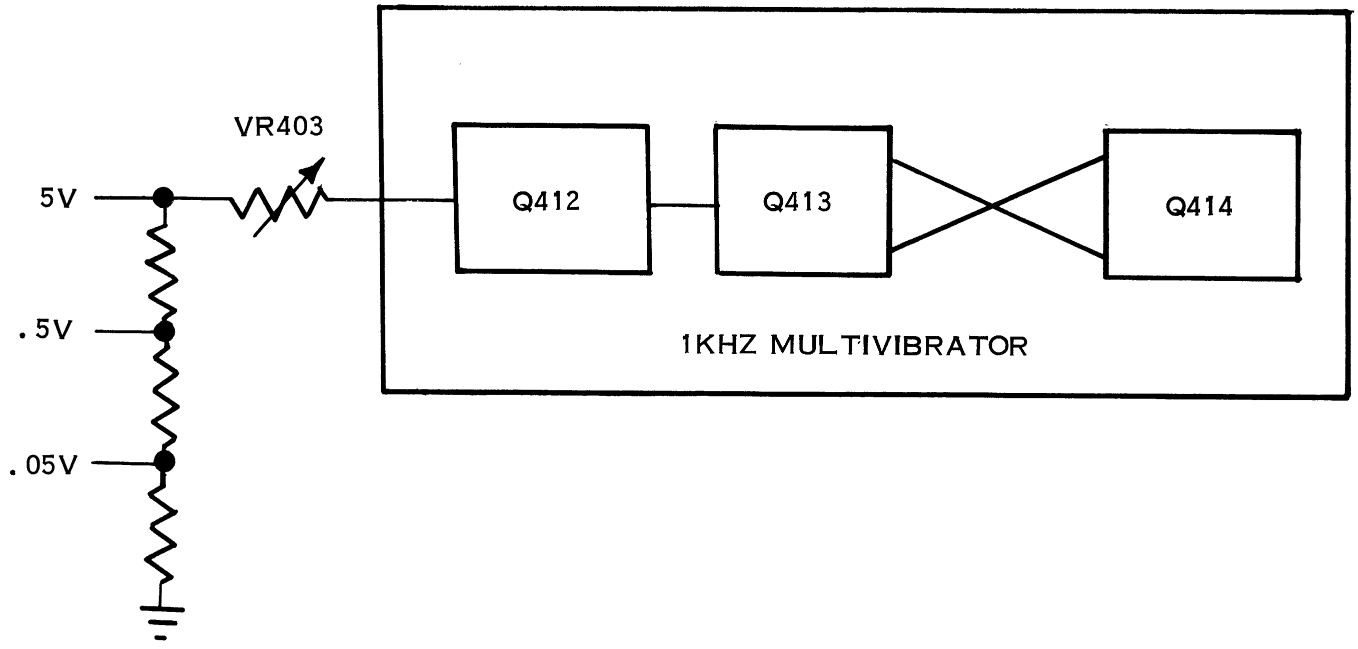


Figure 5-4. Voltage Calibrator Simplified Block Diagram

SECTION VI

APPLICATIONS

6.1 GENERAL

The complexity of much of today's electronics has made the modern wideband oscilloscope the backbone of a complement of test equipment for both the design laboratory and the service shop. Some of these applications are briefly reviewed here. A few specifics are given to indicate the variety of situations in which the oscilloscope is the best and possibly the only way to make meaningful measurements quickly.

6.2 SQUARE WAVE TESTING

6.2.1 One easily stated description of circuit performance is the faithfulness with which a square wave at specified frequency is transferred. The square wave testing method provides an easily applied and duplicated basis of comparing two circuits to determine whether a particular circuit still performs as it was designed to perform. The calibrator of the Model 459 provids a very good 1 kHz square wave signal source for use in calibration and circuit tests.

6.2.2 A square wave is equivalent to the summation of numerous sine waves; a fundamental component of largest amplitude and odd-order harmonics of ever decreasing amplitude (higher order harmonics). For an idealized square wave, all these component waveforms are exactly in phase; that is, at the instant the fundamental component is passing through zero, all of the harmonics are passing through zero in the same direction.

6.2.3 Assume the square wave is applied as an input signal to a circuit under test and the output is monitored on the Model 459. If the harmonic components do not get through the circuit with their original relative amplitudes, or if the phase relationships among the input frequencies are upset, the appearance of the circuit output signal on the CRT will be distorted from its original squareness.

6.2.4 A drop-off of response at low frequencies has the effect of imparting a downward slope or droop to the originally horizontal portions of the waveform. Vertical waveform transitions from high to low (and back again) customarily follow an exponential curve. The "risetime" of the circuit under test is the time required for the circuit output signal to go from 10% to 90% of its amplitude change. When resonance prevails in the signal path, the output squarewave might "ring"; that is, the display might show a suggestion of damped oscillation along portions of the wave that were originally horizontal. For example, the square wave response of a circuit might be specified as: 1 kHz square wave, with a droop of no greater than 5%, rise time not to exceed 15 μ seconds and 10% maximum overshoot. A very brief test with the Model 459 will disclose whether performance of the circuit is within those specified limits.

6.2.5 The rise time of the Model 459 is only 24 nanoseconds (.024 μ second). This rise time must be taken into consideration only in quite high-speed circuits. At very low frequencies (below 10 Hz), the optional coupling capacitor, at the vertical channel input, can introduce appreciable droop. In those cases be sure the vertical input switch is in the DC position.

6.3 PHASE SHIFT MEASUREMENTS

6.3.1 The familiar Lissajous figures are stationary patterns displayed when the vertical and horizontal signal inputs are of fundamental frequencies related to each other by a whole number ratio.

6.3.2 If the same frequency is applied at both inputs, the CRT beam traces an elipse. This elipse becomes a line which will slant upward to the left for a perfect in-phase condition, and upward to the right for 180 degrees out-of-phase. For intermediate phase relationships, elipses are displayed. The special case of a circular display results from sine waves of equal deflection amplitudes in a 90° phase relationship.

6.3.3 A simple way to obtain equal vertical and horizontal excursions of the trace is to note the ratio of minor axis to major axis length. The angle of phase shift is twice that angle, the tangent of which is the ratio of width to length of the ellipse. That is, $\phi = 2 \arctan (a/b)$, where ϕ is the phase difference in degrees, and a and b are the shorter and longer dimensions of the ellipse, respectively. For example, set the scope controls as directed above. The major axis of the ellipse slopes upward to the left and the ellipse is one-fourth as wide as it is long. The angle which has a tangent of ratio of 1:4 is about 14 degrees; the phase shift therefore, is twice 14°, or 28°.

6.3.4 The Model 459 has been designed and built with a far greater bandwidth in its vertical channel than in its horizontal channel. It is expected that somewhere in the supersonic range the scope will begin to introduce a phase difference between the two channels. Commonly, even very expensive oscilloscopes share this particular difficulty.

6.3.5 The frequency range range accurate phase shift measurements can be extended by calibrating the particular Instrument. Plot a curve of the scope's phase difference as a function of frequency. Correct your circuit readings accordingly.

6.4 STABILITY OF FEEDBACK AMPLIFIERS

6.4.1 To obtain the superlative performance common in today's high-quality servo-mechanisms and hi-fi audio amplifiers, heavy usage of negative (inverse, or degenerative) feedback is required. Using this technique, a portion of the output voltage of an amplifier is fed back to the input, in proper polarity, to reduce net gain. The advantage of applying feed-back is that the extent of distortion, of whatever nature, that originally occurred throughout most of the passband, will be reduced by approximately that factor by which the voltage amplification is reduced when the feedback is connected.

6.4.2 The presence of reactive elements (transformers, and various capacitances, both intended and stray) limit the amount of negative feedback that can be applied without regenerative trouble outside the intended passband. Often, there is some frequency (or frequencies) at which the phase shift around the overall loop will support oscillation. Oscillation will occur if the "gain" around the broken loop is at least unity at that frequency. Damped (transient) oscillations can occur, under signal conditions, if the loop gain is slightly less than one and if the phase requirement for sustained oscillation is almost satisfied.

6.4.3 The avoidance of oscillation, either sustained or damped, plus the general desirability of knowing what safety factors prevail, necessitate measurement with the proper instruments. The Model 459 can be very useful in this kind of measurement, especially if the phase calibration step, paragraph 6.3 has been performed.

6.4.4 Adequate safety margins for gain and phase stabilities are about 6 dB and 30°, respectively. To avoid spurious oscillations under signal conditions, limit the open-circuit loop again to no more than one half (6 dB down) the value that would result in sustained oscillations. For any frequency at which the open circuit loop gain exceeds unity, make sure the overall phase shift (around the open loop) differs by at least 30° from the in-phase condition that would produce oscillation, were the feedback loop actually closed. Since these measurements are made with the feedback disconnected, the feedback source and load impedances of the intended complete feedback loops must be simulated.

6.5 TUNING FOR MAXIMUM OR NULL

6.5.1 The Model 459 may be used for tuning frequency selective circuitry. When tuning a fitler or selective amplifier, the oscilloscope serves as a highly sensitive detector and also informs the user of whether the correct frequency component is being maximized or minimized. In the absence of this waveform indication, one can easily be misled by the presence of electrical noise (or a strong harmonic signal) and tune the circuit improperly. Consider the effect of the capacitance of the probe or input leads applied to the tuned circuit.

6.5.2 Equipment for measuring harmonic distortion usually involves measuring what remains when the fundamental frequency component has been nulled. By monitoring the null network with the Model 459, the nulling process can be simplified by observing the nature of the distortion products to determine what can be done to lessen them.

6.5.3 The oscilloscope is excellent as a null indicator when balancing an impedance bridge (used for inductance of capacitance measurements). The CRT is a more flexible indicator than a simple meter. It permits the user to achieve a sharper null more quickly. The bridge nulls only the fundamental frequency of the test voltage, leaving the harmonics to cloud the issue. Usually, the harmonics originate in the bridge generator, and the difficulty can be lessened by using a harmonic-free signal source. When measuring iron or ferrite core indicators, the nonlinearity of the sample can contribute harmonics in the bridge output. Use external sync. derived directly from the bridge signal source. You can easily follow your progress in nulling the fundamental component thereby bringing the bridge into proper balance.

6.6 TIME OR FREQUENCY MEASUREMENT

The measurement of frequency and time are closely related since frequency is the reciprocal of time (F = 1/T). With the highly stable and accurate horizontal sweep generator the Model 459, it is easy to approximate the time duration of a given wave form. After the time for one cycle is known, the frequency can be readily calculated as follows:

a. Adjust the TRIGGER MODE and TIME/CM switches to display one or two complete cycles. Be sure the TIME/CM switch is in the CAL position.

b. Count the number of cm (left to right) from the start of the first waveform to the start of the second.

c. Multiply the number of cm by the SWEEP TIME/CM switch setting. This gives you the time of this waveform (or portion of interest) and hence the frequency.

NOTE: If the MAG./EXT. HOR. switch is in the x5 position, remember to divide the time by 5.

6.7 TV SERVICING

6.7.1 The modern oscilloscope is invaluable for proper servicing and alignment of television receivers. The Model 459 is excellent for measuring signal levels, analyzing various signal waveforms, signal tracing and alignment of the many tuned circuits. This section is intended as a guide for some of the more common servicing procedures. Waveforms, test points, and procedures will vary with sets from different manufacturers and at times for sets by the same manufacturer. The first and most important step in television servicing is to obtain the manufacturers test procedure for the set. Otherwise it is on a guess as to whether a given waveform or procedure is correct.

6.7.2 The amplitudes and shapes of signal waveforms throughout the TV circuits are the best indications of normal operation or where trouble is occurring. The sensitivity of the Model 459's vertical channel permits making virtually all needed TV measurements. A recommended accessory is the Low-Capacitance Probe, with its thumb slideswitch in the LO CAP (approximately 15 pF) position. When the Low-Capacitance Probe is used in the LO CAP mode, take into account that the actual signal voltage is 10 times that displayed on the CRT and control setting on the Instrument. The shielded input cable supplied has about 90 pF capacitance and may interfere with normal operation of some TV circuits. Often an isolation resistor can be used to minimize the effect of this capacitance.

6.7.3 While the description presented here is typical of standard television sets, it must be realized that minor departures prevail among various manufacturer's equipment. Signal shapes are primarily determined by the output of related test equipment or of a transmitted composite signal. Refer to the manufacturer's service data for representative signal amplitudes. The signal amplitude usually is quoted on a peak-to-peak basis, and usually without regard to a DC component that often is present. Ordinarily it is wise to keep the input AC/DC slide switch in the AC position.

WARNING

Be especially cautious when working in strange equipment; a small AC signal might be riding on DC voltage of lethal proportions. Also do not exceed the input voltage ratings of the Model 459 (see maximum input voltage ratings in Table 1-1, the shielded input cable or the 10:1 Low Capacitance accessory probe.

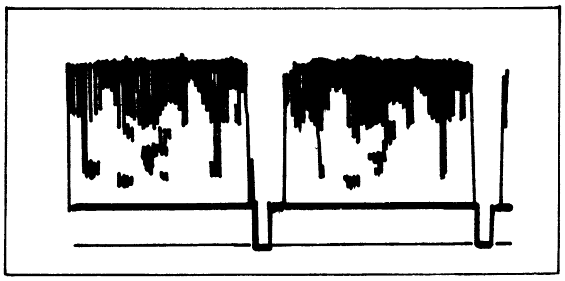
6.8 ANALYZING TV COMPOSITE VIDEO WAVEFORM

6.8.1 The composite video waveform is a combination of the video signal, blanking pedestals and synchronization pulses. Representative oscillograms of composite signals are shown in Figure 6-1. Naturally the display details differ depending on whether the scope's horizontal sweep is synchronized at the TV vertical or horizontal blanking rate.

a. For vertical: Set the sweep selector to TV-V. Set the trigger mode to NORM. and adjust TRIGGER LEVEL for a stable display. When noise prevents this, use line frequency sync. The display will move slowly due to the slight frequency difference between the local power line frequency and the vertical sync. rate established at the TV station.

b. For horizontal: Set the sweep selector to TV-H, Internal, either AUTO or NORM trigger modes.

6.8.2 When servicing any complex piece of electronic equipment, take the time to observe what waveforms prevail throughout a set known to be in good operating condition. It would be better to compare the waveforms with data from the manufacturer for the particular set being worked.



COMPOSITE SIGNAL SYNCHRONIZED AT HORIZONTAL BLANKING RATE

COMPOSITE SIGNAL SYNCHRONIZED AT VERTICAL BLANKING RATE

Figure 6-1. Representative Oscillograms of Composite Signals

6.8.3 To set-up a composite waveform display, proceed as follows:

a. Tune in a strong TV signal. Finding a station broadcasting a stationary test pattern is helpful, but a satisfactory display can be set-up when using regular TV program material.

b. Turn the INTENSITY control clockwise to give a suitable bright trace. Adjust FOCUS and ASTIGMATISM controls for minimum trace width. Set trigger mode switches to +, AC, AUTO, INT. and MAG. to x1.

c. Connect accessory Low-Capacitance Probe to VERTICAL INPUT connector. Be sure slide switch on probe is in the LO CAP position; otherwise, input capacitance of measuring set-up can load the TV video circuits and upset accuracy of display.

d. Connect ground clip of probe to chassis of TV set.

e. Connect the signal tip of probe to grid terminal on socket of TV picture tube.

f. Set Model 459 VOLTS/CM switch to .5 position.

g. To read vertical amplitude correctly, fine vertical gain must be in CAL position; however, to merely observe nature of waveform, adjust fine vertical gain for desired display height.

h. To synchronize at horizontal sweep rate, set SWEEP TIME/CM switch to TV-H position; if desired, adjust SWEEP TIME/CM VARIABLE control for expansion to less than two horizontal line periods. There are times when a better sweep synchronization can be obtained by selecting "−" instead of "+" on trigger mode switches.

i. To synchronize at vertical sweep rate on composite signal, set SWEEP FREQUENCY switch to TV-V position. When it becomes desirable to obtain complete signal independent sync., feed vertical sync. signal from TV set into EXT. TRIG. INPUT and switch to EXT. trigger source.

j. Typical composite signals for black-and-white TV are shown in Figure 6-1. Only synchronization pulses will show any resemblance of standing still on the display. The portion of the display which resembles electrical noise is the video signal. It continually varies and virtually never maintains at fixed appearance.

k. Figure 6-2 shows typical color TV signals. The colorburst is situated immediately to the right of the sync pulse. When a color bar generator is used, the composite display resembles that of Figure 6-3.

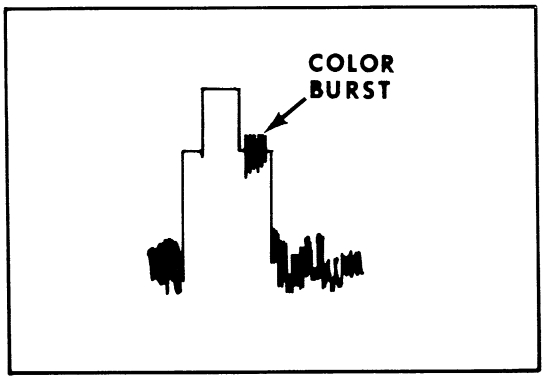


Figure 6-2. Color-Burst Shows to Right of Sync. Pulse

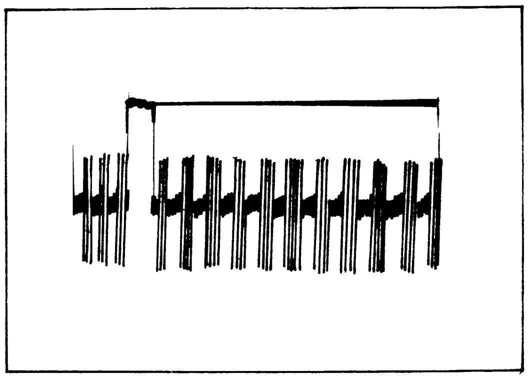


Figure 6-3. Typical Output From Color-Bar Generator

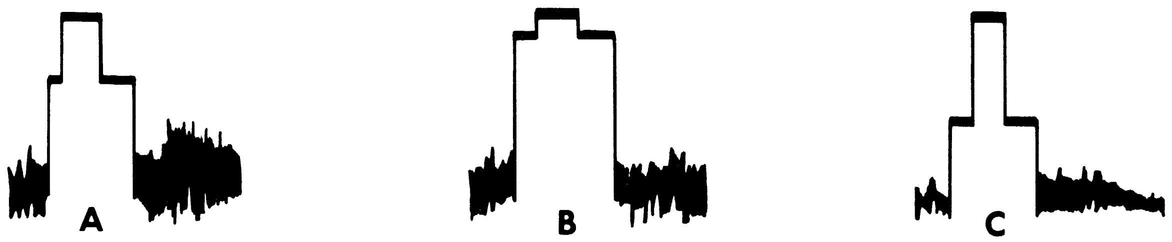


Figure 6-4. Sync. Pulse Suppression

l. Figure 6-4 shows variations possible in the shape of the sync. pulse when signal overload (or a biasing problem) prevails. Normally, the sync. pulse exceeds pedestal height by about 50%, as indicated in Figure 6-4A. If limiting occurs in the positive direction, clipping (sometimes referred to as "compression") occurs, as in Figure 6-4B. If limiting (or overload) occurs in the opposite polarity, the sync. pulse proportions are changed as shown in Figure 6-4C.

m. Inspection of the shape of the horizontal sync. pulse is a quick way to appraise the overall alignment of RF and IF circuits. Figure 6-5 indicates the correlation between a sync. pulse shape and frequency response of the tuned circuits in the following paragraphs (6.6.4 through 6.6.11). Figure 6-5 also provides a brief description of the likely effect upon picture quality.

6.9 ALIGNING TV TUNED CIRCUITS

NOTE: If the Low-Capacitance Probe is used, compensation must be checked. See paragraph 4.9 and 4.10 for test and calibration procedures.

6.9.1 The need for aligning a TV set can come from several common causes. Among these are drift due to aging of components, replacement of components and replacement of tubes. Sometimes the problem is merely maladjustment of accessible controls by someone who is not qualified or who does not have proper equipment.

6.9.2 The following information applies to aligning the tuner ("front end"), I-F and subsequent detector circuits. While the basic principles are common among TV sets; it is always necessary to hve the manufacturer's service procedures available for the particular set. You will save much time in evaluating the signals at the test points.

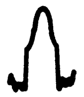
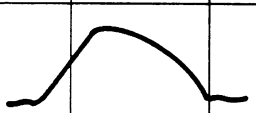
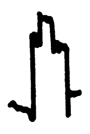
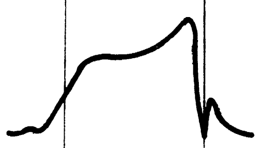
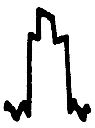
CIRCUIT ALIGNMENT SITUATION	SHAPE OF HORIZONTAL SYNC PULSE	OVERALL FREQ. RESPONSE OF RECEIVER	EFFECT ON PICTURE
NORMAL			NORMAL PICTURE
HIGH—FREQUENCY LOSS			PICTURE BLURRED LOSS OF DETAIL
HIGH—FREQUENCY BUMP OR BOOST			VERTICAL SHADOWS OR GHOSTS APPEAR TO RIGHT OF SHARP DETAILS IN PICTURE
LOW—FREQUENCY LOSS OR ROLL—OFF		 PICTURE CARRIER SOUND CARRIER	NON—UNIFORM SHADING OF LARGE PICTURE AREAS

Figure 6-5. Sync. Pulse and Frequency Response Waveforms

6.10 ALIGNING A TUNER

Proceed as follows:

a. Connect output of sweep generator antenna terminals on the TV set.

b. Connect ground clip of scope's accessory Low-Capacitance Probe to metal frame or shield of TV tuner.

c. Most of the time, hum interference can be reduced by making the probe ground connection as close as possible to the test signal pickup point. Usually service instructions include the signal in the mixer grid circuit, where a demodulated signal is present. The signal level at this point is only a small fraction of a volt peak-to-peak, so the scope must be operated at high gain with the probe in the direct mode. Therefore, the input capacitance of the overall scope becomes much higher (135 pF) and it might be preferable to use the shielded input lead (90 pF) furnished with the Model 459 as standard equipment. To avoid upsetting the tuner by the scope connection, use a series 1/2-watt carbon resistor of about 10k ohms as isolation. If the resistor connections are not kept short, there might be so much hum pick-up that it becomes impossible to obtain a clean trace.

WARNING

Even though RF signal levels are often low, a tuner might include dangerous DC voltages.

d. One advantage of high vertical sensitivity of the Model 459 is that the sweep generator can be operated at a low enough level so as not to overload the tuner circuits. Such overload could prevent obtaining a true picture of the circuit alignment. On the other hand, with too little signal input, hum and noise can become very troublesome.

e. When using a sweep generator, apply an RF test signal to the tuner input. The signal sweeps periodically across the channel being aligned. The marker generator places a marker ("pip") on the trace at the instant the sweep generator frequency passes through a calibrated value. The oscilloscope monitors the instantaneous amplitude of the signal that comes through the input tuned circuits.

f. Figure 6-6 shows a typical "front end" frequency response obtained during sweep frequency measurement. The somewhat saddle-backed shape is typical of slightly over-coupled tuned circuits, and of properly adjusted stagger-tuned channels. Become familiar with setting up such a display on a TV set known to be good. Only with the technique perfected can one be fairly sure that an improper display is the fault of the set. A minor departure usually can be remedied by tuning adjustments. A major departure might also indicate a loose connection in the tuner, or possibly the need to find and replace a faulty component.

NOTE: Sweep generators and marker generators are set-up in various ways, according to their particular characteristics. Sometimes the functions are combined into one package. Follow the manufacturer's recommendations.

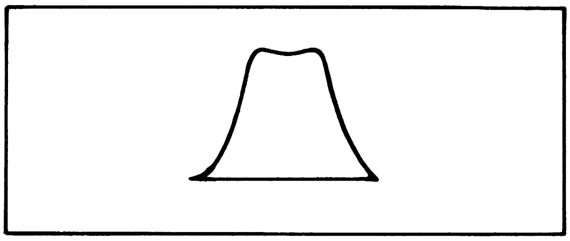


Figure 6-6. Typical Appearance of Detected Output with Sweep Generation Input

6.11 ALIGNING PICTURE I-F CIRCUITS

Proceed as follows:

a. When a good signal is present at the mixer, examine the frequency response of the I-F (Intermediate Frequency) portion of the set. Pick up the signal with the scope probe (or use the isolating resistor).

b. Use the load resistor of the video detector as a test point. Sometimes the test point is located at the input of the first video stage.

c. To minimize the influence of hum pick-up, connect the ground clip of the scope probe to a ground point near the signal test point on the set. Since the signal will be larger here than at the tuner, a 10:1 probe can be used to reduce circuit loading.

NOTE: With all R-F or I-F measurements, proper impedance matching (per manufacturer's recommendations) is preferable. If possible, use a connector similar to that used for interconnection in the set.

d. Follow manufacturer's instructions for adjusting the bias level of the I-F amplifier. The signal from the sweep generator is quite unlike the signal that the set's AGC (Automatic Gain Control) was designed to accommodate. AGC must be disabled during sweep frequency alignment. The service instructions might include applying a fixed bias from an external battery. Sometimes the set manufacturer will recommend temporary wiring changes within the TV set.

e. Except for less vertical gain and bandwidth being required, display of I-F frequency response is similar to that obtained at the mixer. The indicating bandwidth will usually be substantially less.

NOTE: Be sure the output of the sweep generator is kept low to avoid overloading the video detector.

6.12 ALIGNING THE SOUND I-F CIRCUITS

TV sound is transmitted via frequency modulation, for which the detector is either (usually) a discriminator or a ratio detector. Proceed as follows:

a. Connect the scope probe using a 10k ohm isolation resistor to output of sound detector.

b. Connect sweep and marker generators to receiver as directed in set manufacturers instructions. Figure 6-7A shows the nature of the response curve which will be displayed. Faithful sound reporduction requires that the central slope of the curve be essentially a straight line.

c. A curve, similar to that shown in Figure 6-7B, will be obtained if the probe is connected to the grid return of the limiter stage.

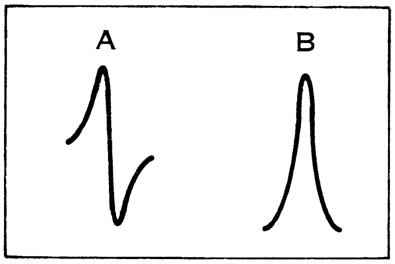


Figure 6-7. Ratio Detector and Sound I-F Response Curves

6.13 ALIGNING COLOR TV AFPC CIRCUITS

With proper adjustment of the AFPC (Automatic Frequency and Phase Control) circuits, the hue (tine) control of a color TV can accommodate all the hue variations present in the transmitted picture. When all controls are adjusted properly, the hue control will not affect intensity. Color sync. will hold even on weak signals, and color balance will not be upset as luminance is varied.

6.14 VECTOR DISPLAY OPERATION

The vector display operation of the Model 459 is a good way to check and adjust the chroma section in color television receivers. A color bar/pattern generator is required to simulate the composite video signal. Because of the sensitivity of the Model 459, the vector pattern can be traced from the demodulators, through the amplifiers, and to the guns of the color tube. Normally the vector pattern is obtained at the guns of the color tube as follows (refer to Vector Pattern Display, Figure 6-8):

a. Connect color bar/pattern generator to antenna terminals and adjust pattern on television set, following instruction manual of particular color bar generator.

b. Set MAG/EXT. HOR. switch on scope to EXT. HOR. position.

c. Connect accessory probe (in the LO CAP position) from vertical input of scope to red gun of color tube.

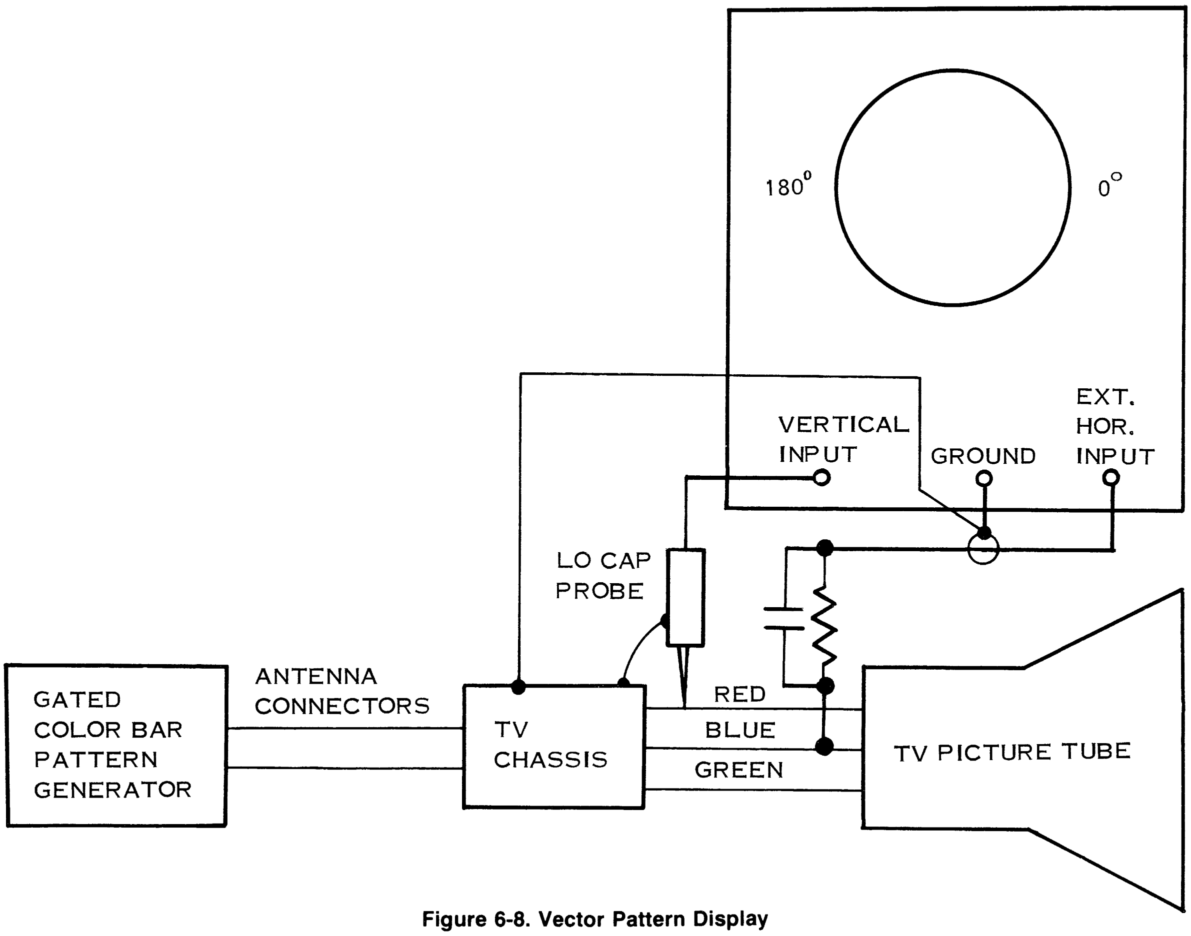


Figure 6-8. Vector Pattern Display

d. Connect a shielded test lead from the EXT/HOR. INPUT of scope, through a 2.2 megohm resistor, to blue gun of color tube. Also connect shield to chassis.

NOTE: Limit the signal input to the Horizontal amplifier to 5 volts peak-to-peak. A 2.2 megohm resistor in series with the input lead to the scope will attenuate the signal and provide isolation. Connect a capacitor of about 10 pF across the resistor to frequency compensate this external attenuator.

e. Turn on television set and adjust Model 459 horizontal and vertical gain controls for a round pattern perimeter. Refer to Figure 6-10.

f. Adjust Hue control of television set to mid-position. The third red color bar (from burst), normally appears at 90° straight up. The sixth bar (blue) usually will appear somewhere between 180° and 210°.

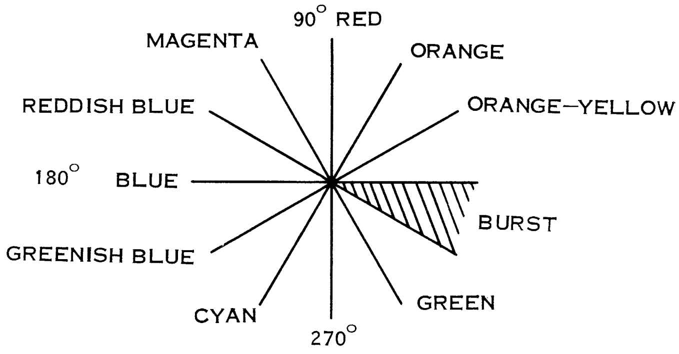


Figure 6-9. Vector Pattern Analysis

6.15 VECTOR PATTERN ANALYSIS

6.15.1 At the present time, very few manufacturers provide vector pattern information. They show the waveshape and voltage at each gun of the color tube. A typical representation of this information is shown in Figure 6-10BB (vector pattern 6-10A). The R-Y and B-Y waveforms differ in phase by about 90° and if the envelope (assume a continuous pair of waveforms rather than gated waveforms) alone was applied to the Model 459, a circular vector pattern would be formed as in Figure 6-10C. This is the pattern you would see with a pure rainbow color generator. With a gated rainbow pattern generator, each pulse will bring the trace to the edge of the circle and then drop back to the center during the blanked portion, giving a flower petal effect.

6.15.2 The idealized pattern most often shown rarely occurs on an actual television set. The reason is that intentional phase angle distortion is introduced in the demodulator to improve the flesh tones and to simplify tuning. This distortion moves the sixth color bar from its idealized 180° position to somewhere near 210°. The effect is to make the vector pattern slightly elliptical. When using the oscilloscope for most of your TV servicing, the best "teacher" is looking at the critical patterns in a set which is known to be properly adjusted.

6.16 VERTICAL INTERVAL TEST SIGNAL (VITS)

6.16.1 The VITS is incorporated in the composite video of most network color broadcasts to help insure invariant

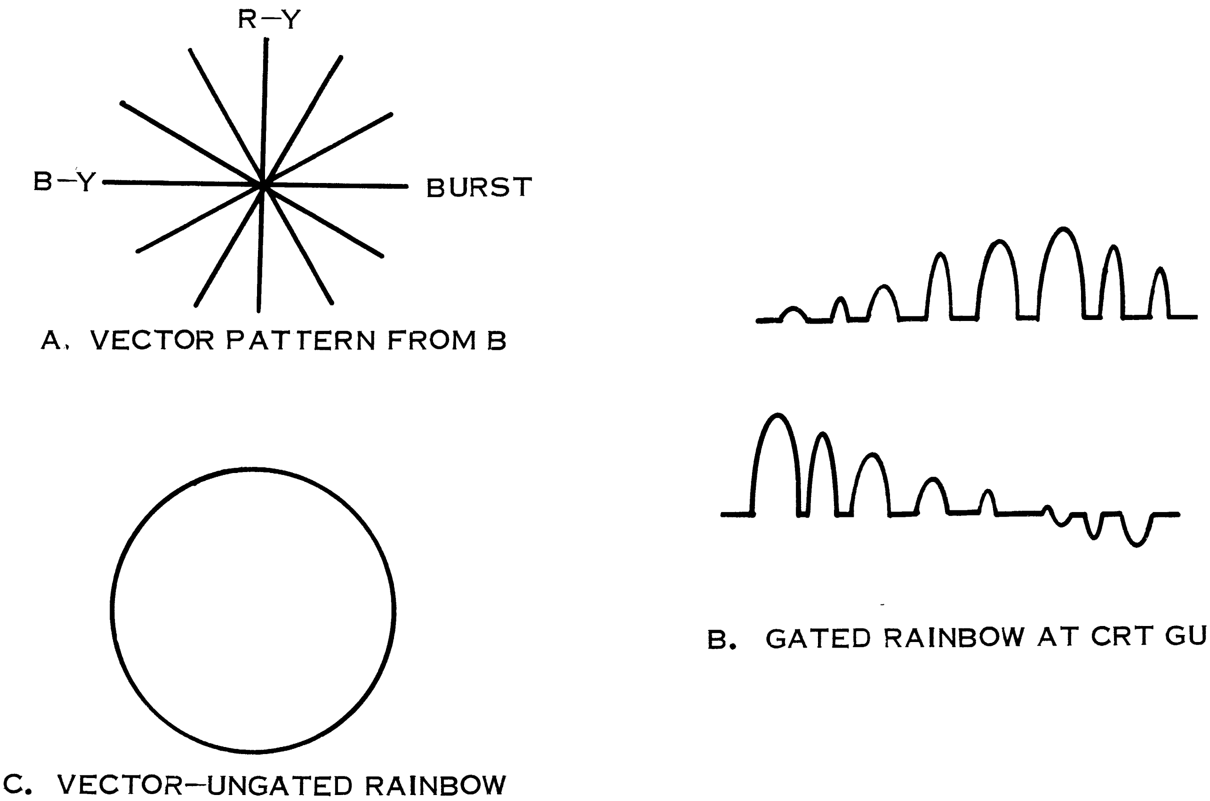


Figure 6-10. Vector and Gun Displays

high quality of the transmitted color picture. A part of this signal can be used for rapid analysis of color set performance. This is the multi-burst portion of VITS (see Figure 6-11). The multi-burst, as broadcast, consists of a white level signal followed by short bursts of frequencies from .5 MHz to 4.2 MHz, all of which are equal in amplitude. By looking at these bursts of frequencies at the video output of a TV set, it can be readily seen if the amplifiers and other circuits from the RF input are responding properly (see Figure 6-12).

6.16.2 If the bursts, monitored at a video output test point, are not of equal amplitude, the signal should be checked at the video detector. If they are still unequal, the TV channel should be changed and the bursts rechecked. By doing this, the distortion can be traced to the RF or IF stages. If the bursts are still unequal on a different channel, the I-F amplifier probably needs alignment. If they are equal, the R-F tuner needs alignment.

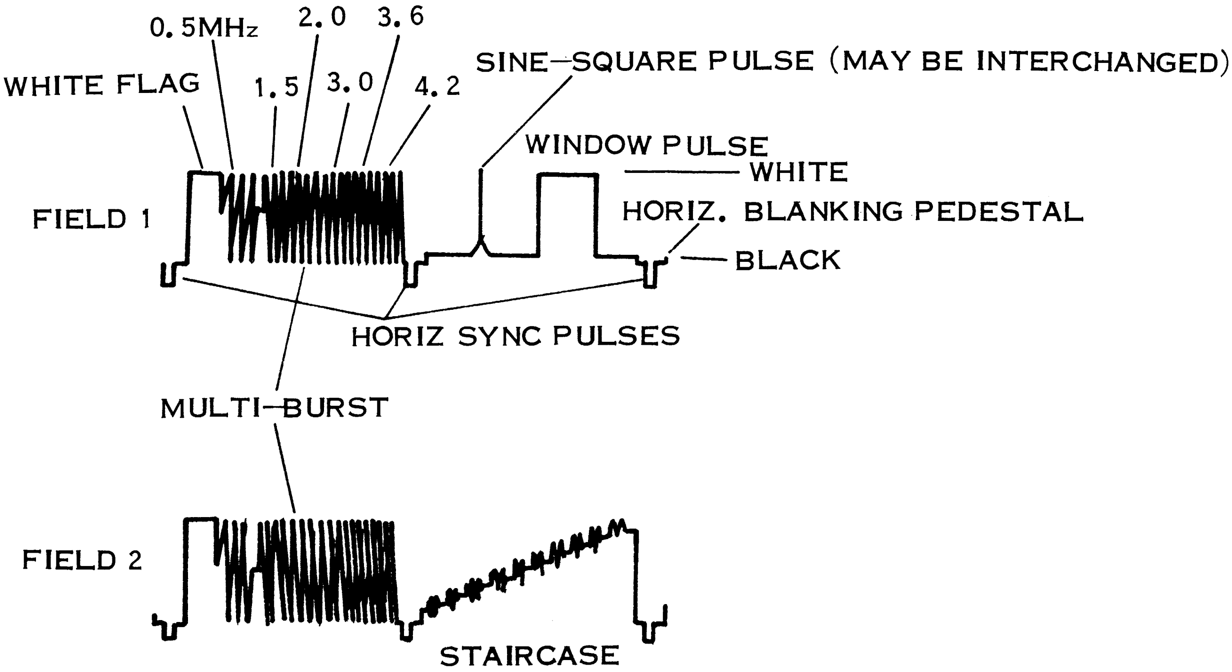


Figure 6-11. Standard Vertical Test Signal Waveform

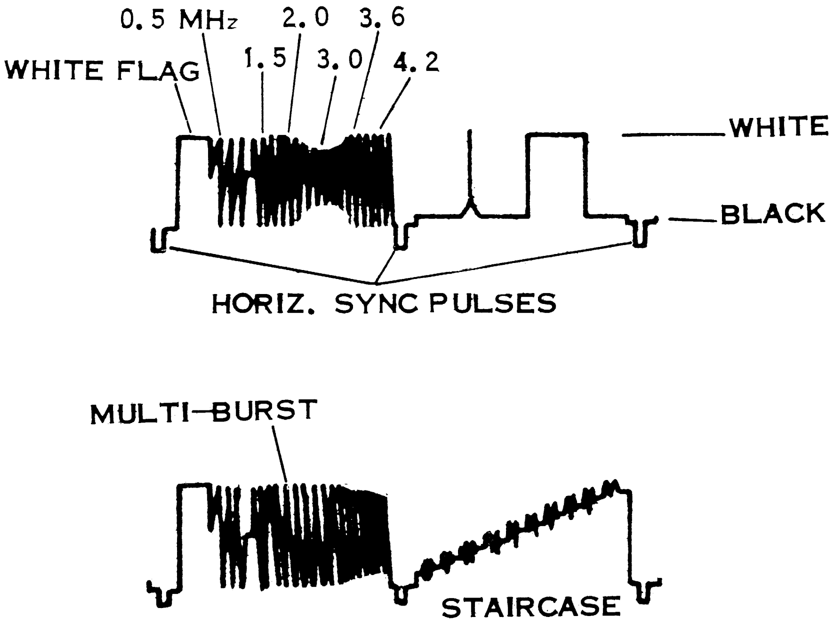


Figure 6-12. Distortion in Multi-Burst Waveform

6.16.3 The VITS is difficult to display on an oscilloscope because it occurs twice per frame (1/30 second) and only lasts for 2 line intervals (126 μ seconds, see Figure 6-13). It does not begin simultaneously with the vertical sync. pulse but occurs on lines 17 and 279. The trace brightness will be quite low because of the low display rate and because the x5 magnifier must be used to display the VITS 17 lines after occurrence of the vertical sync. pulse. Therefore, a scope hood or paper tube wrapped around the CRT bezel is recommended for viewing the screen.

6.16.4 The following procedure is to be followed for a test set up for VITS:

a. Set SWEET TIME/CM control to .1 msec and VARIABLE to CAL.

b. Set MAG switch to x1.

c. Connect Low-Capacitance Probe, (be sure it has been adjusted for a square wave), from the Model 459 to TV video output. When the probe is connected, the TV set picture should not be affected. If the picture is affected, try to isolate the probe further by inserting a 10kΩ resistor, parallel with a 1.5 pF capacitor, in series with the probe tip.

d. Connect a 0.005 μF capacitor from TV vertical sync. or composite sync. to EXT. TRIG. INPUT of Model 459. The composite sync. is located at the sync. separator. The vertical sync. can be picked up from the vertical output transformer at the input of the convergence circuit. A signal of 5 to 100 volts is usable when applied to the EXT. TRIG. INPUT.

e. Set TRIGGER MODE Switches to +, AC, NORM., EXT.

f. Adjust TRIGGER LEVEL control to sync. on equalizing pulses as shown in Figure 6-13 and observe VITS on right side of screen.

g. Set MAG switch to x5 position and adjust position controls to center VITS waveform on screen.

NOTE: In some TV sets, it will be necessary to disable the TV vertical blanking to properly sync. on the VITS.

6.17 ALIGNING AM RECEIVERS

6.17.1 As with all superheterodyne receivers, whether TV, FM or AM, the overall shape and width of the passband is determined by the tuning of the I-F (Intermediate Frequency) portion of the system. The principles applied in aligning AM sets are similar to those for TV and FM. The differences are mainly the much lower frequencies and narrower bandwidths involved in a broadcast AM receiver.

6.17.2 The sweep-generator/marker-generator method, in conjunction with a good oscilloscope like the Model 459, is the fastest and most effective method to use. The only simple alternative is alignment using a tunable signal generator and output indicator, combined with either

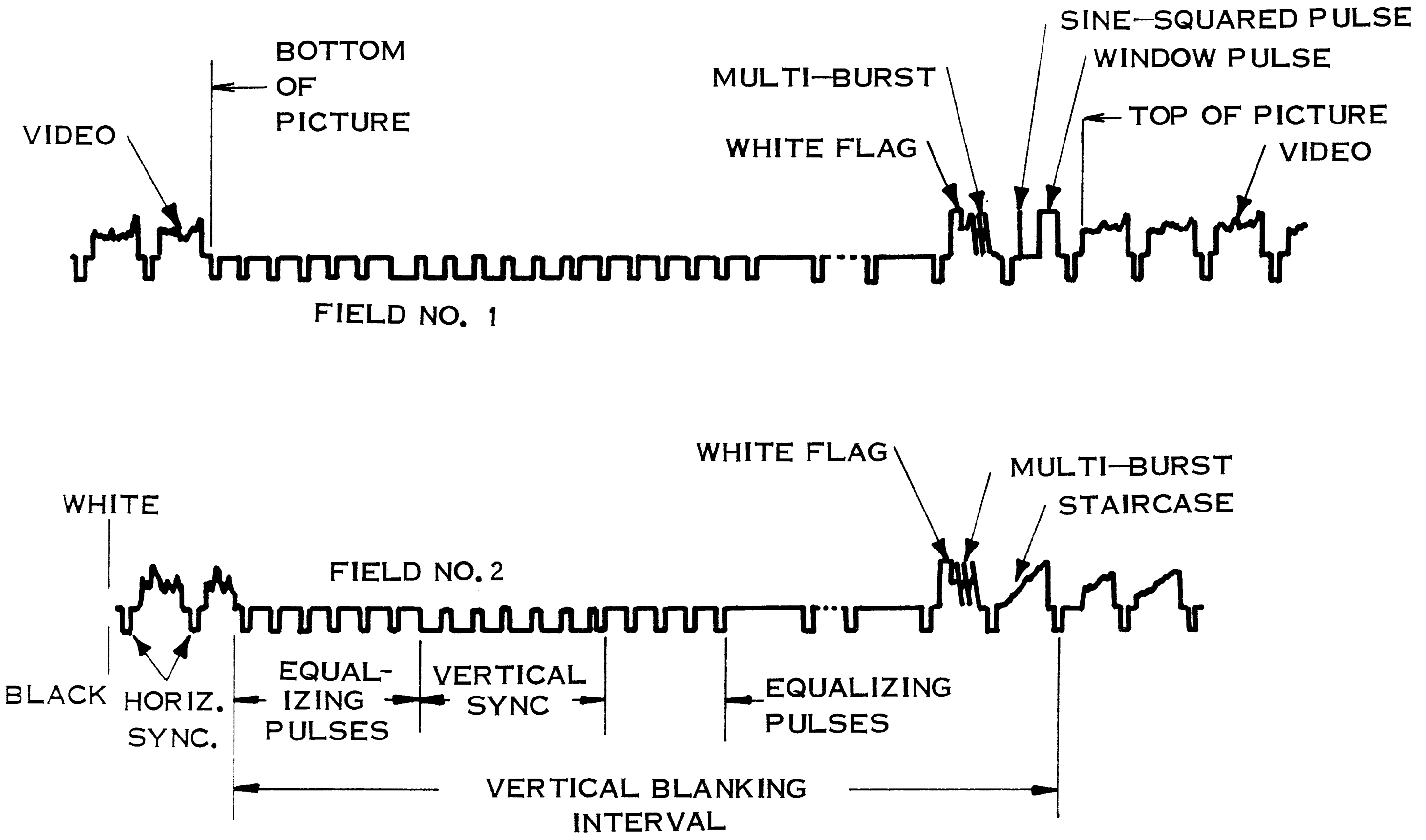


Figure 6-13. Vertical Blanking Interval Showing VITS Signal

mental calculations or a point-by-point plotting of frequency response. With the sweep-generator/ marker-generator method, not only is the present situation immediately apparent, but you can instantly see the effects of whatever adjustment you make.

6.17.3 As with TV alignment, the set manufacturer's data is highly valuable in supplying critical frequencies and where the most useful test points are located on the chassis. Do not merely "peak up" the I-F amplifier response. Undue emphasis on gain alone, or on bandwidth alone cannot give optimum performance for either speech or music reception. Also, the center frequency of the I-F passband must be properly adjusted; otherwise it might be impossible to get the RF (front end) circuits to function over the full dial-calibrated frequency range of the set.

6.18 ALIGNING FM RECEIVERS

The sweep-generator/marker-generator method, vital to rapid TV servicing, has been a longtime favorite in FM servicing too. The major practical distinction from TV alignment is that both tuner and I-F selectivity are notably less for FM. Otherwise, follow the guidelines of paragraphs 6.6 through 6.7 above. To the critical ear, the potential of FM for high-fidelity transmission is severely undermined by improper set alignment.

NOTE: Refer to the set manufacturers data for recommended frequency setting and test points. With the common acceptance of FM multiplex stereo and the new 4-channel systems, the importance of proper FM alignment has become even greater than before.

SECTION VII

MAINTENANCE

7.1 GENERAL

WARNING

The Model 459 uses high internal voltages which constitute a SHOCK HAZARD (refer to page iv). For service or repair beyond the instructions contained in this manual, send the Instrument to a Simpson Authorized Service Center. These Centers are listed on the last pages of this manual.

The Simpson Model 459 is carefully designed and constructed with high quality components. By using reasonable care and following the instructions in this manual, the Instrument can be expected to provide a long and useful service life.

7.2 WARRANTY

The Simpson Electric Company warranty policy is printed on the inside back cover of this manual. Read it carefully prior to requesting a warranty repair.

NOTE: For assistance of any kind, including help with the Instrument under warranty, contact your nearest Authorized Service Center for instructions. If you wish to contact the factory directly, give full details of the difficulty and include the instrument model number, serial number and date of purchase. Service data or shipping instructions will be sent to you promptly. There will be no charge for repair of the Instrument under warranty beyond one-way transportation charges. If an estimate of charges for non-warranty or other service work is required, a maximum charge estimate will be quoted. This charge will not be exceeded without your prior approval.

7.3 SHIPPING

Pack the Instrument carefully, and ship prepaid to the proper destination. Insure the shipment.

7.4 CHANGING AC LINE VOLTAGE REQUIREMENTS

WARNING

Remove all input power and connections to the Model 459 prior to removing the case, changing the line voltage connections to the power transformer or replacing the fuse.

The procedure for changing the AC line voltage provision of the Model 459 is as follows:

a. Remove case housing. The ornamental aluminum trim strip around the front edge of the case and the trim cap must also be removed to free the case housing.

b. Interchange connections to the power transformer, as shown in Figure 7-1.

c. Mark Instrument legibly (on the front and back case) to indicate that the line voltage rating of the Instrument has been changed from its original marked value.

d. Be sure to change fuse appropriately (see paragraph 7.5 below).

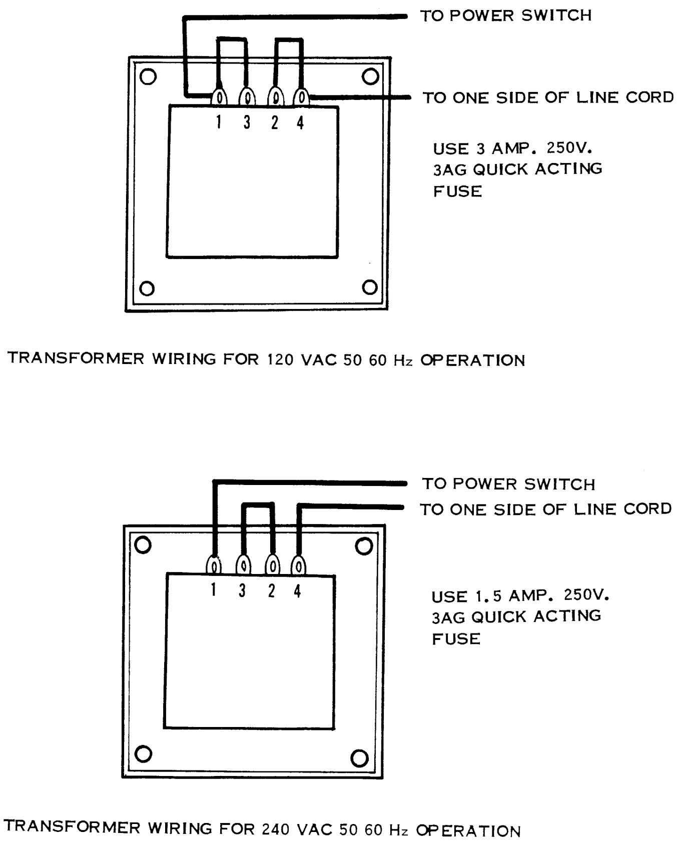


Figure 7-1. Connections for Different Primary Voltages

7.5 FUSE REPLACEMENT

The procedure for replacing the power line fuse is as follows:

a. Locate the fuse holder (see Figure 3-2). Fuse ratings are shown in Figure 7-1 and in Section 1, Table 1-1.

b. Replace defective fuse with one of equal rating.

7.6 PREVENTIVE MAINTENANCE

7.6.1 Daily Care

The Model 459 Oscilloscope is a reliable Instrument, and requires very little maintenance. Daily care of the Instrument basically consists of the following.

a. Turn off the power and disconnect any power and signal leads, etc. Immediately clean all spilled materials from the Instrument and wipe it dry. If the spillage is corrosive, remove the spillage and use a suitable chemical to neutralize the corrosive action. Then clean the Instrument and wipe it dry.

b. Whenever possible, avoid prolonged exposure or usage of the Instrument in areas which are subject to temperature and humidity extremes, vibration or mechanical shock, dust or corrosive fumes, or strong electrical or electromagnetic interferences.

7.6.2 Monthly Care

Verify Instrument calibration by performing operational checks using known, accurate, stable sources. If the need for re-calibration is indicated, contact your nearest Simpson Authorized Service Center (refer to list on last pages of this manual).

7.6.3 Annual Care

It is recommended that the Instrument be returned annually to your nearest Simpson Authorized Service Center or the factory for complete overall check, adjustment, and calibration.

7.6.4 Storage

When the Instrument is not in use, store it in an area free from temperature extremes, dust or corrosive fumes, and mechanical vibration or shock.

7.7 CIRCUIT ADJUSTMENTS

CAUTION

Prior to making any of the following component or circuit adjustments, review all of the warnings in paragraphs 4.2, 7.1 and 7.4, also the safety precautions in paragraph 4.2.

7.7.1 General

Adjustment of certain controls in the Model 459 might be required after long periods of use, or when components have been replaced for some apparent malfunction. The following is a list of checking and alignment procedures covering internal adjustments (refer to Figure 3-1 for proper identification of controls and indicators). Due to the complexity of the Model 459 circuitry, and the fact that high voltages are present, it is recommended that only experienced qualified personnel attempt alignment. Preferably, contact your nearest Simpson Authorized Service Center when realignment is required.

7.7.2 Procedure

Control Settings for Basic Alignment of Vertical Amplifier and Attenuator. See Figure 7-2.

a. Set both VARIABLE controls to CAL positions.

b. Set MAG to x1.

c. Set SWEEP TIME/CM to .5 ms/cm.

d. Set TRIGGER MODE switches to +, AC, AUTO and INT.

e. Set VERTICAL INPUT to GND.

f. Set VARIABLE VOLTS/CM to 0.01 v/cm.

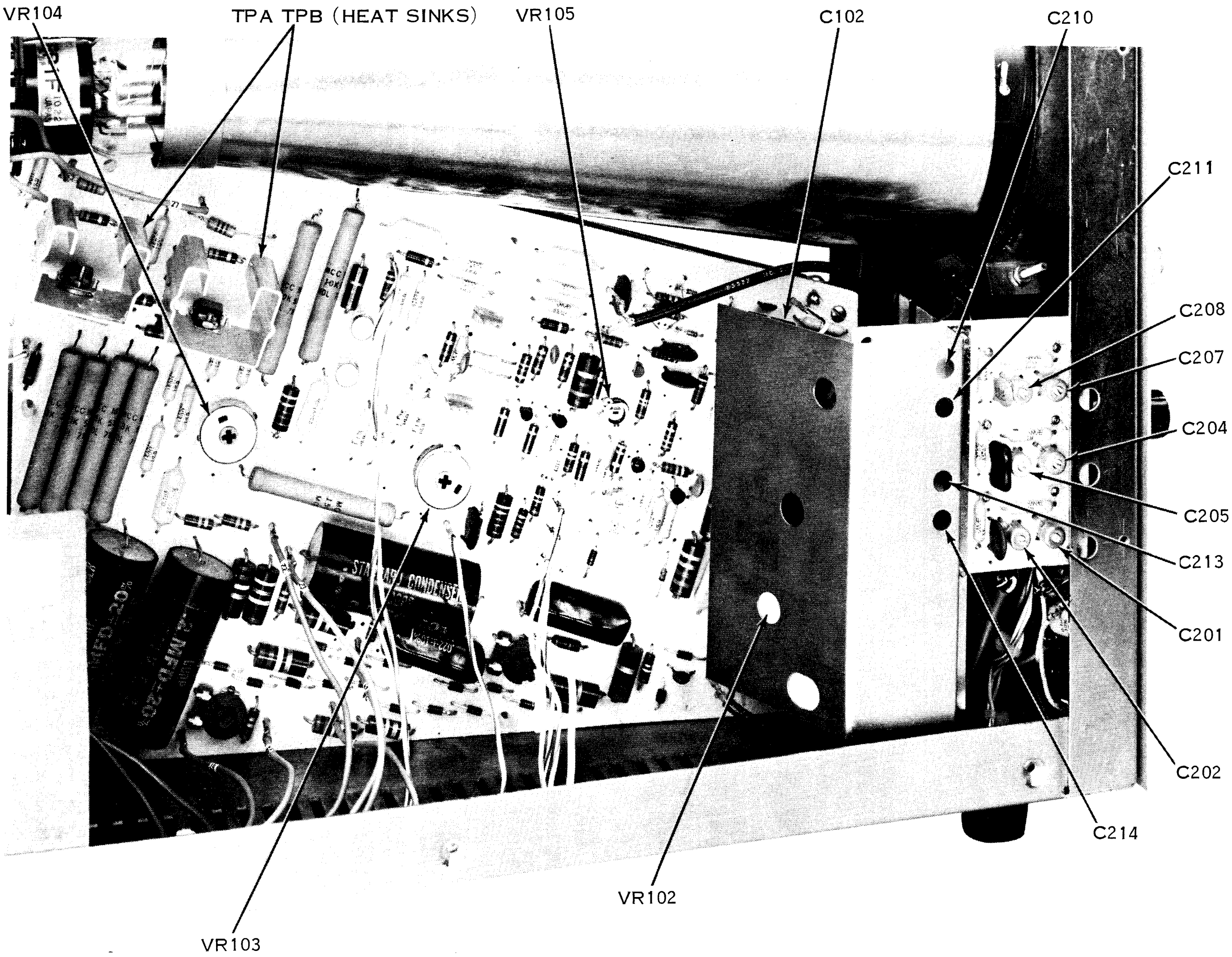


Figure 7-2. Vertical/HVPS PC Board and Vertical Attenuator

g. Rotate the vertical POSITION control knob to position trace at center of screen. Adjust INTENSITY, FOCUS and horizontal POSITION controls if necessary.

Turn POWER off and wait 10 seconds before attempting to touch CRT. For additional safety, short to ground (chassis) the CRT shield and any terminals close to where the hands go to make adjustments. Use a 260 type insulated lead.

h. Rotate the CRT if necessary to position the trace parallel with the horizontal center graticule. To rotate CRT, loosen screw holding band around front of tube. Also loosen two screws holding shield bracket at rear of CRT. Retighten during alignment to be sure it does not change.

7.7.3 Adjustment of Output Centering

In performing any adjustments within the Instrument, use insulated tools and extreme care not to touch portions of the circuit that operate at more than 30V.

Use Simpson 460 VOM with isolation probe No. 00182 to measure the voltages at TPA and TPB (heat sink of output transistors). Adjust VR103 using insulation tool until voltages are equal.

7.7.4 Adjustment of Output Level

Adjust VR104 using an insulated tool, until the voltages at the TPA and TPB are both 105V.

7.7.5 Adjustment of DC Input Balance

a. Set vertical POSITION control knob to mid-position.

b. Adjust VR11 (screw-driver adjustment on POSITION knob) using an insulated tool until trace lines up with the middle horizontal line of graticule.

c. Fine adjust VR11 to minimize vertical shift of trace caused by rotating VARIABLE knob and VOLTS/CM switch. Vertical POSITION control may be readjusted.

7.7.6 Adjustment of Vertical Amplifier Gain

a. Set vertical input to AC, VOLTS/CM to 0.01 and VARIABLE control to CAL. position. Apply a 1 kHz sine wave signal, with 80 mV p-p amplitude, to VERTICAL INPUT.

b. Adjust VR102 using an insulated tool until signal on scope has 8 cm deflection.

7.7.7 Input Capacitance Adjustment

a. Set VOLTS/CM to 0.01 V/cm and VARIABLE control to CAL.

b. Use precompensated x10 probe or compensate a x10 probe with scope which has 35 pF input capacitance.

c. Connect compensated x10 probe to scope under test and apply a 1 Kz square wave to probe. Set TIME/CM to .2 ms/cm. Amplitude shall be approximately 4 cm.

d. Adjust C102 using insulated tool, for optimum flat top and square corner within 0.1 cm.

7.7.8 Attenuator Compensation Adjustment

a. Use same x10 probe for measurements to follow. Do not readjust probe!

b. Adjust each vertical attenuator compensation capacitor for optimum flat top and square corners. Adjusting sequence is shown in Table 7-1.

7.7.9 Adjustment of Horizontal Sweep Width

Refer to Figure 7-3 and proceed as follows:

a. Set TRIGGER MODE switches to +, AC, FREE RUN INT.

b. Set SWEEP TIME/CM selector to .1 msec/cm and VARIABLE control to CAL positions.

c. Set MAG. switch to x1.

d. Set Vertical input switch to GND.

e. Turn POWER on.

f. Adjust vertical POSITION control to align trace with middle-horizontal graticule line.

WARNING

In performing any adjustments within the Instrument, use insulated tools plus extreme care not to put hands near portions of circuit that operate at more than 30V.

Table 7-1. Attenuator Compensation Adjustment Sequence

V/CM SETTING	Square Wave Output (V P-P)	ADJUST C– FOR OPTIMUM FLAT TOP	ADJUST C– FOR OPTIMUM SQUARE CORNER	DEFLECTION (APPROX. – CM)	PROBE SETTING
.02	1	C213	C214	5	x 10
.05	2	C210	C211	5	x 10
.1	5	C207	C208	5	x 10
.2	10	(1)	(1)	5	x 10
.5	20	(2)	(2)	5	x 10
1	50	C204	C205	5	x 10
2	100	(3)	(3)	5	x 10
5	100	(4)	(4)	2	x 10
10	100	C201	C202	1	x 10
20	100	Check the wave form only		.5	x 10
20	100	(5)	(5)	5	x 1
10	50	Check the wave form only		5	x 1
5	20	Check the wave form only		5	x 1
2	10	Check the wave form only		5	x 1
1	5	Check the wave form only		5	x 1
.5	2	Check the wave form only		5	x1
.2	1	Check the wave form only		5	x1
.1	.5	Check the wave form only		5	x 1
.05	.2	Check the wave form only		5	x 1
.02	.1	Check the wave form only		5	x 1
.01	.05	Check the wave form only		5	x 1

(1) If not ok, repeat both .02 and .1 V/CM adjustments.
(2) If not ok, repeat .02, .05, .1 and .2V/cm adjustments and checks.
(3) If not ok, repeat 1 V/cm adjustment.
(4) If not ok, repeat 1 and 2 V/cm adjustments and checks.
(5) If not ok, repeat 10V/cm (C202 adjustment only).

Any further vertical adjustments, such as high frequency peaking, the Model 459, should be sent to a qualified Simpson Service Center.

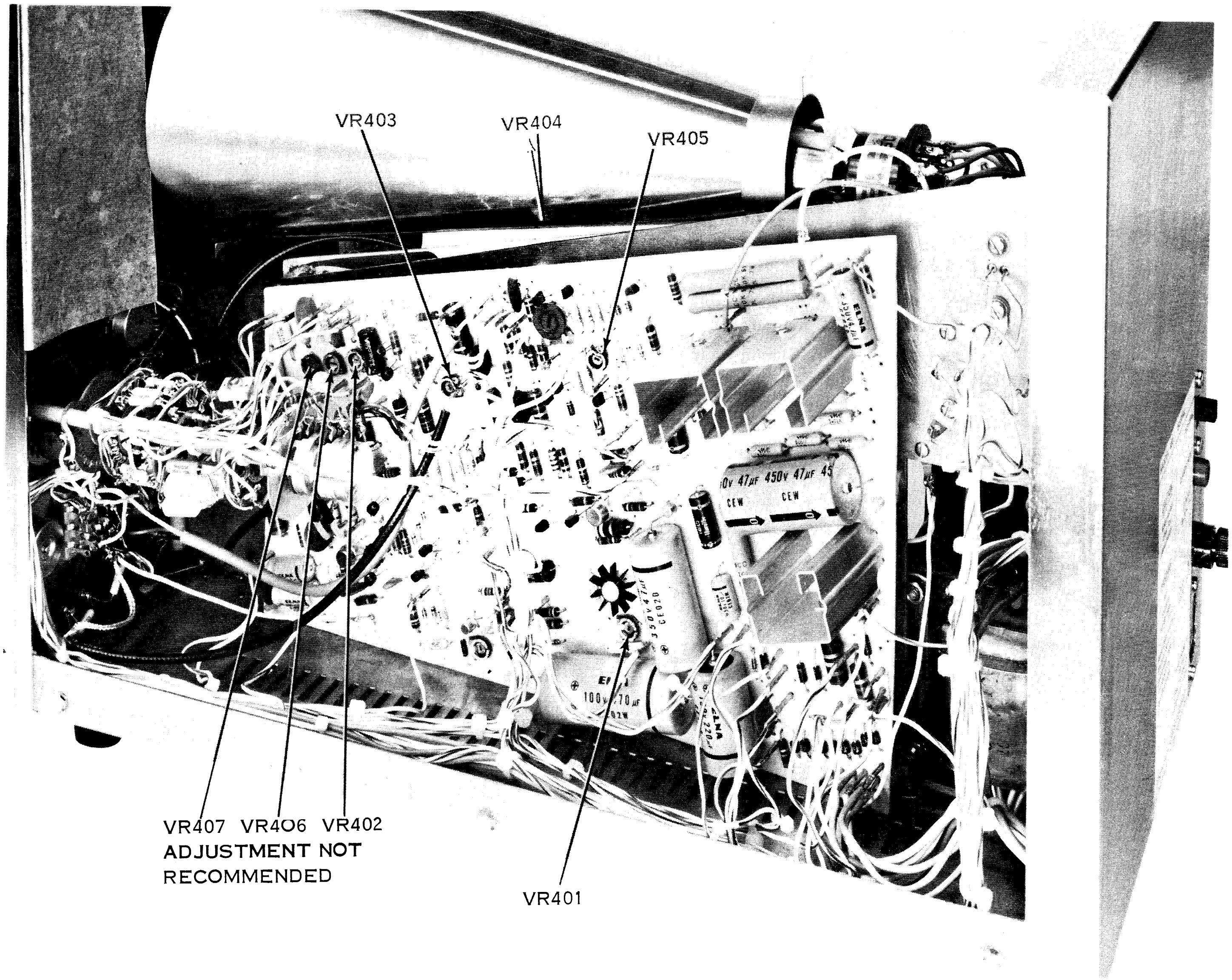


Figure 7-3. Horizontal/LVPS PC Board

g. Adjust VR401 using insulated tool, until horizontal trace covers more than 10 cm of the screen.

h. Adjust horizontal POSITION control, if necessary.

7.7.10 Adjustment of x1 Limit

a. Set vertical input switch to AC.

b. Set TRIGGER MODE switch to +, AC, AUTO, INT. positions.

c. Apply a 1 kHz square wave signal to VERTICAL INPUT.

d. Adjust VR405, using an insulated tool, until a full square wave cycle occupies 10 cm of screen horizontally.

7.7.11 Adjustment of x5 MAG Limit

a. Set MAG. to x5.

b. Set SWEEP TIME/CM selector to .5 msec/cm.

c. Adjust VR404 using an insulated tool, until a full square wave cycle occupies 10 cm of screen.

NOTE: Adjustments of VR407, VR406 and VR402 are not recommended.

7.7.12 Checking Horizontal Frequency Response

a. Apply a 1 kHz sine wave signal to EXT. HOR. INPUT. Adjust signal amplitude (not HOR. GAIN) until horizontal trace width is 10 cm exactly. Monitor the input signal amplitude.

b. Remove the 1 kHz input and substitute a 1 MHz sine wave signal, with the amplitude as monitored above to the EXT. HOR. INPUT. The length of the trace shall be 10, +1, −3 cm.

7.7.13 Adjustment of Calibration Output CAL. P-P

a. Adjust VR403 using an insulated tool for 5V p-p square wave output at 5V CAL. P-P output terminal. An adjustable DC power source and accurate DC volt meter may be used as a reference monitor. The DC voltage desired is applied to the input terminals of the Model 459 vertical amplifier (DC coupled). The exact deflection is noted then the square wave is applied to the same input and the same P-P deflection amplitude achieved.

b. Check that the .5V output is between .485V and .515V and the 50 mV output is between 48.5 mV and 51.5 mV. These two are non-adjustable.

7.7.14 Trigger Mode

a. Set TRIGGER MODE selectors to +, AC, AUTO and INT. respectively.

b. Set HOR. MAG. to x1. Set the TIME/CM for 2 μsec/cm.

c. Set vertical input to AC.

d. Apply a 500 kHz sine wave signal to VERTICAL INPUT.

e. Set VERTICAL V/CM to .1, and VARIABLE control to CAL. Adjust the signal level to obtain 4 cm p-p deflection. Reset step attenuator 3 positions CCW. Waveform shall appear synchronized on screen.

f. Set TRIGGER MODE to DC and change slope from + to −. If signal disappears from screen for either + or −, adjust VR105 until the signal appears synchronized on screen for both + and − TRIGGER MODE slopes.

g. Repeat above at 50 Hz, setting TIME/CM for 20 msec/cm.

7.7.15 Norm. Trigger Mode

a. Set TRIGGER MODE to NORM. Repeat paragraph 7.7.14.e. except obtain a 2 cm p-p deflection. Adjust TRIGGER LEVEL until the signal appears synchronized on the screen. No other adjustments shall be necessary.

b. Repeat Paragraph 7.7.14.e. except obtain a 5 cm p-p deflection at 15 MHz setting the TIME/CM for .2 μsec/cm.

7.7.16 Trigger Mode Free Run

a. Set AC/DC/GND switch to GND. Rotate TIME/CM selector and observe trace stays bright at all settings.

b. Set AC/DC/GND switch to AC. Apply a 500 kHz sine wave signal to VERTICAL INPUT. Set TIME/CM to 2 μsec/cm and observe free running, non-synchronized, waveform envelope.

7.7.17 Trigger Mode +, AC, AUTO and EXT.

Apply a 1V p-p 500 kHz sine wave signal to both the VERTICAL INPUT and EXT. TRIG. INPUT. A synchronized signal shall appear on the Model 459 screen.

7.7.18 Trigger Mode Line

a. Set TIME/CM to 5 ms/cm.

b. Apply a 60 Hz sine wave to the VERTICAL INPUT. A synchronized signal shall appear on the screen which is drifting slowly left or right, depending on whether the 60 Hz sine wave signal is slightly above or below the line frequency.

7.7.19 Z Axis Input Check Procedure

a. Set switch on rear panel (see Figure 3-2) to Z AXIS INPUT position.

b. Set vertical input switch to GND.

c. Set TRIGGER MODE switches to +, AC, AUTO EXT. positions.

d. Turn vertical POSITION control to bring trace to middle horizontal graticle line.

e. Adjust INTENSITY, FOCUS and ASTIGMATISM controls, if necessary.

f. Apply a 1 kHz square wave with 20V p-p amplitude to the Z INPUT jack on rear panel, and also to EXT. TRIG. INPUT, on front panel.

g. Set SWEEP TIME/CM to 1 ms/cm position. Trace shall be Z modulated and appear as a dashed line.