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Heathkit

HEATHKIT® MANUAL

for the

60 MHz TRIPLE TRACE OSCILLOSCOPE

Model IO-4360A

OPERATION 595-3240

HEATH COMPANY • BENTON HARBOR, MICHIGAN

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TABLE OF CONTENTS

INTRODUCTION

This Operation Manual is an extension of the Assembly Manual you used to assemble your Heathkit Triple-Trace Oscilloscope, Model IO-4360A. In this Manual you will find all the necessary instructions to calibrate, operate, and if necessary, to service your Scope. As in the Assembly Manual, be sure to follow the instructions carefully. In directed steps, be sure to read and understand the entire step before you perform the operation.

You will find this book to be a handy reference as you start to use your Oscilloscope, and should the need arise, a valuable aid in locating and correcting any problem that might occur in the future. Of special interest is the detail in which the Circuit Description, along with the Block Diagram and the Schematic, will lead you through the complex circuits in a clear and concise manner.

Note that a copy of your Warranty and information on Customer Service are located inside the front and rear covers of your Manual.

SPECIFICATIONS

VERTICAL

Display Modes	Y1, Y2, Add (Y1 + Y2), Add-Invert (Y1 − Y2), Dual, Triple, Alt/Chop.

CHANNELS Y1 AND Y2

Deflection Factor	
Sensitivity	2 mV/cm to 10 V/cm. 12 steps in a 1-2-5 sequence.
Variablity	Continuous between steps to approximately 30 V/cm.
Accuracy	Within 3% (20°C to 30°C); 5% (10°C to 40°C), referred to 5 mV/cm.
Vertical Response	
DC Coupling	5 mV to 10 volts/cm, DC to 60 MHz; 2 mV, DC to 50 MHz.
AC Coupling	5 mV to 10 volts/cm, 10 Hz to 60 MHz; 2 mV, 10 Hz to 50 MHz.
Rise Time	7 ns or less.
Overshoot	Less than 5%.
Delay Line	Allows display of at least 20 ns of pretriggered waveform.
Vertical Input	
Impedance	1 MΩ shunted by 40 pF.*
Maximum Input	400 volts peak combined AC and DC.
Connector	BNC.

*Capacitance depends on probe used for calibration.

CHANNEL Y3

Deflection Factor	
Sensitivity	200 mV/cm for divide-by-one, 2 V/cm for divide-by-ten.
Accuracy	Within 3% (20°C to 30°C); 5% (10°C to 40°C), referred to 200 mV/cm.
Response	DC to 25 MHz.
Rise Time	14 ns or less.
Overshoot	5% or less.
Impedance	1 MΩ shunted by 50 pF.*
Maximum Input	400 volts peak combined AC and DC.
Connector	BNC (single input for Y3 and Ext. Trigger).

HORIZONTAL

Time Bases	
Ranges	100 ms/cm to .1 μs/cm.
Positions	19 steps in 1-2-5 sequence.
Variable	Continuous between ranges to approximately 300 ms/cm.
Accuracy	Within 3% (20°C to 30°C); 5% (10°C to 40°C), referred to 1 ms/cm.
Magnifier	X 10 (accurate to within 5%, 20°C to 30°C; 7%, 10°C to 40°C).
X – Y	
Y Channel (Y2)	Same as vertical.
X Channel (Y1)	Same as vertical, except that response is limited to 2 MHz and has no delay line.
Phase Shift	Less than 3° at 100 kHz.

TRIGGER

Source	Y1, Y2, EXT, Line.
Coupling	AC, DC, AC-HF, AC-LF, TV-V**, TV-H**.
Modes	Automatic baseline, Normal, Single Sweep.
Hold Off	Variable, including a "B ends A" position.

Sensitivity/Bandwidth:

MODE	0.5 cm	1 cm	1.5 cm
DC	DC to >60 MHz	DC to >90 MHz	DC to >90 MHz
AC	6 Hz to >60 MHz	2 Hz to >90 MHz	2 Hz to >90 MHz
AC-HF	1 kHz to >60 MHz	1 kHz to >90 MHz	1 kHz to >90 MHz
AC-LF	2 Hz to 2 kHz	1 Hz to 2 kHz	1 Hz to 2 kHz
TV-V	(4 cm, TV vertical sync pulses)		
TV-H	(4 cm, TV horizontal sync pulses)		

*Capacitance depends on probe used for calibration.

**The oscilloscope triggers on alternate frames for steady display.

External Trigger

Sensitivity	500 mV at 60 MHz.
Input Impedance	1 MΩ shunted by 50 pF.

GENERAL

1-volt P-P CAL Accuracy	≤3%.
CRT Acceleration Potential	10 kV regulated.
CRT Type	8 × 10 cm mesh with internal graticule.
CRT Phosphor	P31.
Z Axis	
Full on to full off	0 to 5 volts. Positive voltage decreases intensity.
Input impedance	5000 Ω.
Maximum Input	50 volts peak.
Power Supplies	Fully regulated, (except +130 VDC).
AC Line Switch	Allows operation from a 108-132 VAC or 216-264 VAC power source.
Power Requirements	108-132 VAC or 216-264 VAC, 50/60 Hz, 75 watts (at 120 VAC).
Dimensions	
Height	6″ (15.2 cm).
Length (handle extended)	22″ (56 cm).
Length (handle folded)	18″ (46 cm).
Width	11.5″ (29 cm).
Weight	23 lbs. (10.4 kg).
Operating Temperature	10°C to 40°C.

OPERATION

This section of the Manual explains the function of each control, switch, and connector; gives a preset for each control and switch; provides several operational examples; and gives some applications.

ALTERNATE PRIMARY VOLTAGES

In some countries, such as the United States, 120 VAC line voltage is most often used, while in other countries 240 VAC is more common. However, in any country, you may encounter voltages that are below the national standard (below 115 volts for 120-volt countries, or below 230 volts for 240-volt countries). Refer to the following sets of steps if you wish to change operation voltage settings for your Scope (to 115, 120, 230, or 240 VAC, as your application requires).

- Make sure your Oscilloscope power cord is not plugged in to the power outlet. Then remove the cabinet top.

For operation at low voltages (115 or 230 VAC):

- Remove the NOR/LOW switch from the rear panel.
- Shift the NOR/LOW switch to the LOW position.
- Replace the NOR/LOW switch and its plastic cover.
- If necessary, refer to the next group of steps and set your 120/240 slide switch.
- Replace the cabinet top.

Use the following steps to set your primary operating voltage for either the 120 or 240 VAC range:

- If necessary, remove the cabinet top.
- Remove the 120/240 slide switch from the rear panel.
- Set the 120/240 slide switch to the proper setting for the voltage available in your area.
- Remove the fuse (located below the 120/240 switch) in your Oscilloscope, and replace it with the correct value. For 120 VAC operation you should have a 1-ampere slow-blow; for 240 VAC operation, you should have a 1/2-ampere slow-blow.
- Replace the 120/240 switch and its plastic cover in the back panel.
- Change the fuse label data to show the proper size fuse.
- Reinstall the cabinet top.

CONTROL FUNCTIONS

Refer to Pictorial 11-1 (Illustration Booklet, Page 1) as you read the following explanations of the major controls and switches. In discussing the controls, we will use these abbreviations: **pressed** refers to a pushbutton set to the "in" position, **released** refers to the pushbutton set to the "out" position, **CCW** means counterclockwise, and **CW** means clockwise.

1. INTENSITY (also OFF) — Turn this control fully CCW to turn the Scope off, turn it CW from there to turn the Scope on. Turning it further CW brightens the trace(s). Adjust for the brightness you need in your lighting conditions. Changing the brightness may affect the FOCUS slightly. **CAUTION: Do not allow a bright spot to remain on the screen; it could damage the CRT.**

2. FOCUS — Use this control to adjust the size of the CRT electron beam for the sharpest display. See also ASTIG.

3. POWER indicator — This LED lights whenever the Scope is on.

4. ASTIG — Use this astigmatism control to adjust the shape of the CRT electron beam for the sharpest display. See also FOCUS.

5. CAL 1V(P-P) — Use this 1-volt peak-to-peak, square wave signal (approximately 1000 Hz) to check vertical calibration. The rise time of this signal also allows you to use it for oscilloscope probe compensation.

6. TRACE ROTATION — Use this control to make the horizontal trace parallel to the horizontal graticule lines.

7. GND — Use this connector for a ground to the Scope's chassis.

CHANNEL Y1 AND Y2 CONTROLS

8. Y1(Y2) POS — Use these controls to position the Y1 or Y2 trace vertically on the screen.

9. Y1(Y2) INPUT (connector) — These are the inputs for the Y1 and Y2 signals. In addition, Y1 serves as the X input and Y2 serves as the Y input for XY operation.

10. VOLTS/CM — Each position of this attenuator switch is marked with a number. This number indicates the peak-to-peak input voltage that will deflect the trace one square (one centimeter) on the screen's graticule, if the VARIABLE control is in the CAL detent position.

11. VARIABLE — If you set this control fully CW to the CAL detent position, the VOLTS/CM control will be calibrated. Turn VARIABLE in the CCW direction to decrease the sensitivity of the vertical deflection amplifiers.

12. AC-GND-DC (switch) — Set this switch to the AC position to accept only the AC (no DC) on the input. Set the switch to the DC position to accept both the AC and DC components. Set the switch to GND to ground the amplifier's input to position the baseline accurately.

13. Y2 INVERT — Press this button to reverse the polarity of the signal displayed as Y2. Note, however that the trigger sensing for Y2 is taken **after** the INVERT button. This means that there will be no apparent change if you are triggering from Y2 and press INVERT (you must be triggering from Y1, line, or external to see Y2 invert).

DISPLAY MODE CONTROLS

NOTE: The five buttons (Y1 through TRIPLE) are connected together mechanically so that pressing one will move any other to the released position. Only one button will be pressed at any time.

14. Y1 — Press this button to display only input Y1.

15. Y2 — Press this button to display only input Y2.

16. ADD — Press this button to display the algebraic sum of inputs Y1 and Y2.

17. DUAL — Press this button to display the inputs to Y1 and Y2 simultaneously.

18. TRIPLE — Press this button to display the inputs to Y1, Y2, and Y3 simultaneously.

19. ALT/CHOP — This button is used for Dual and Triple displays. With the button pressed, the Scope displays the inputs by chopping (switching back and forth between traces during the sweep — good for low sweep rates). With the button released, the Scope alternates (showing one trace on one sweep, another trace on the next sweep — good for higher sweep rates).

CHANNEL Y3 CONTROLS

20. Y3 POS — Use this control to position the Y3 trace vertically on the screen.

21. EXT INPUT-Y3 (connector) — Use this connector to accept the Y3 input or an external trigger signal.

22. EXT ÷10 — Press this button to attenuate the Y3 or external trigger input signals by a factor of ten.

HORIZONTAL DISPLAY CONTROLS

NOTE: These buttons work one at a time, just like the Display Mode buttons.

23. A — Pressing this selects normal, single time-base operation.

24. A-B — Pressing this intensifies the trace during the time that time-base B is running.

25. B — Pressing this displays only the portion of the trace that is included during time-base B.

TRIGGER MODE

26. TRIG (LED) — This LED lights each time the scope is triggered.

NOTE: These buttons work one at a time, just like the Display Mode buttons.

27. AUTO — Press this button and a base line will automatically be displayed when no trigger signal is detected.

28. NORM — Press this button, and a trace will appear only when the Scope trigger is detected.

29. SINGLE — Use this button for single sweep. Press the button briefly to arm the Scope. The READY LED will light to show that the Scope is armed. As soon as a trigger is detected, a single trace is made and the READY LED goes out. To re-arm the Scope, press the SINGLE button again.

30. READY — This LED lights when the Scope is ready for single-sweep operation. After the single sweep is made, the LED goes out until the SINGLE button is pushed again.

TRIGGER COUPLING

NOTE: These buttons work one at a time, just like the Display Mode buttons.

31. DC — Press this button to allow triggering on all signals, down to DC.

32. AC — Press this button to allow triggering on most normal AC signals. This blocks DC and very slow AC signals.

33. AC-HF — Press this button to reject lower frequency AC signals.

34. AC-LF — Press this button to reject higher frequency AC signals.

35. TV-V — Press this button to reject high frequency sync signals in a composite video signal.

36. TV-H — Press this button to reject low frequency sync signals in a composite video signal.

TIME BASE CONTROLS

37. DELAY TIME POS — This ten-turn control determines the starting point of the B time base. When the A-B or the B buttons are pressed, the control determines where on the A ramp the time-base B trace will begin.

38. HORIZ POS, PULL FOR X10 — Use this control to move the trace horizontally so that it is properly placed on the screen (the inner knob is for coarse adjustment, the outer knob is for fine adjustment). Pull the center knob out to expand the speed of the trace by a factor of ten.

39. A AND B TIME/CM, PULL FOR DELAY TIME — This control sets how fast the trace sweeps the screen. The clear knob closest to the panel selects the A time base. The inner knob sets time base B and normally tracks the clear knob. To set time-base B independent of A, pull this inner knob outward slightly and turn it CW for a faster sweep rate. The A-B button (#24) causes the B time-base to be shown more brightly on the display, and the DELAY TIME POS moves the B section along the A time-base to the desired position. When the two knobs are set to the same sweep rate, they will again lock and track together.

40. VARIABLE TIME — Use this control for continuous adjustment between the A time-base ranges.

41. VARIABLE HOLDOFF — Adjust this for a stable display if the input signal is an exact multiple of the time base repitition rate. Normally, it is in the full CW position. In the CCW position (B ENDS A), the end of the B sweep stops the A sweep at the same spot on the screen (for the A-B or B display). This increases the writing speed and produces a brighter display, especially at faster sweep rates.

TRIGGER SELECT

42. TRIGGER SELECT — This control selects the source and slope (+ or −) of the triggering signal:

    LINE (±) — Trigger signal is derived from the AC power source.
    Y1 (±) — Trigger signal is from Y1 channel.
    Y2 (±) — Trigger signal is from Y2 channel.
    EXT (±) — Trigger signal is from an external source applied to the EXT INPUT – Y3 connector.

43. LEVEL — This control adjusts the level (along the selected slope) at which the actual trigger point occurs.

REAR PANEL

44. Z-AXIS INPUT — A positive-going voltage will decrease the display intensity. The normal operating range is 0 to 5 VDC.

PRESETTING CONTROLS

Preset the following switches and controls before you begin the "Operational Examples" (Page 11-7). Refer again to Pictorial 11-1 to verify which control or switch is being referred to.

1. Set the front panel controls and switches as follows:

INTENSITY	CCW (Off)
FOCUS	Center of rotation
DISPLAY MODE	Y1 pressed
Y1 POS	Center of rotation
(Y1) VOLTS/CM	50 mV
(Y1) VARIABLE	CW (CAL)
(Y1) AC-GND-DC	GND
Y2 POS	Center of rotation
(Y2) VOLTS/CM	50 mV
(Y2) VARIABLE	CW (CAL)
(Y2) AC-GND-DC	GND
Y2 INVERT	Released
HORIZ POS	Center of rotation
(PULL FOR X10)	In
A AND B TIME/CM	.1 mS
PULL FOR DELAY TIME	In (knobs locked together)
TIME BASE	A pressed
TRIGGER MODE	AUTO pressed
TRIGGER COUPLING	AC pressed
TRIGGER SELECT	Y1, +
LEVEL	Center of rotation
VARIABLE TIME	CW (CAL)
VARIABLE HOLDOFF	CW (NORMAL)

Before you can use the Scope, it must be warmed up and you must have the trace properly adjusted on the screen. The following part of the procedure will prepare the Scope for operation in any mode, and may be used at any time to check the basic instrument operation.

2. Connect the line cord to an AC power source.

CAUTION: Do not permit a bright dot to remain on the face of the cathode ray tube for a prolonged period of time; a dot can burn the phosphors and leave a permanent image on the face of the CRT.

3. Turn the INTENSITY control to the mid-position. The POWER LED will light.

4. Allow time for the instrument to warm up (see "Normal Operating Characteristics," Page 11-6).

5. Slowly adjust the Y1 POS and HORIZ POS controls to center the trace on the screen.

6. Adjust the INTENSITY control to obtain a trace just bright enough for comfortable use.

7. Adjust the FOCUS control for the finest and sharpest trace.

8. Adjust the HORIZ POS control so that the trace starts at the left edge of the graticule.

Your Oscilloscope is now prepared for operation in the modes described in "Operational Examples" (Page 11-7).

NORMAL OPERATING CHARACTERISTICS

The following information is provided to help answer some questions you may have about the operation of your Oscilloscope.

- It may require several minutes for the trace to stabilize when you first turn the Scope on, especially on the more sensitive ranges. The trace intensity may also shift slightly at first. A short warm-up period (about 15 minutes) is recommended before you make sensitive measurements.
- Delayed sweep operation is useful only when the A and B Time/cm switches are at different settings (with B time shorter than A). If the knobs are locked together in the A-B or B modes, part of the trace may disappear.
- The trace may become slightly wider on the 2 millivolt/cm range. This is wideband noise generated by various components in the input circuits.
- When you use the Y2 INVERT switch, symmetrical signals may not appear to invert, although they actually do. Refer back to the Y2 INVERT control discussion under "Control Functions" in the "Operation" section.
- In the AUTO trigger position, with no input signal applied, the trace may blink. This is due to random noise in the sensitive vertical circuits.
- Random noise on the input signal may cause false triggering, especially on the most sensitive voltage ranges when the trigger LEVEL control is near its center of rotation.
- In the SINGLE sweep mode, random noise can cause the highly sensitive sweep circuits to trigger. If this happens, readjust the trigger LEVEL control slightly.

USING A 2-MILLIVOLT OSCILLOSCOPE

When you use an Oscilloscope as sensitive as this one, you must use special care to make reliable measurements. Keep the following points in mind when you measure very low level signals.

- **Where** you place the ground clip may be critical, if the signal source ground carries an appreciable current. Voltage differences of several millivolts are common from one side of a chassis or ground foil to the other. Place the ground clip at the point that gives the least error. This usually means nearest to the signal source. You may have to move the clip when you measure at different points.
- It may be hard to eliminate the pickup of stray 60 Hz signals, especially in high-impedance circuits. Be sure to use shielded test cables. Shield the signal source if necessary.
- Wideband measurements in the millivolt and microvolt regions are more difficult because of the inherent noise (shot noise and thermal noise) generated by electronic components. This may cause the baseline to appear wider or out of focus. Noise on the baseline that appears as "hash" or "spikes" may be caused by the electromagnetic pickup of external noises such as those generated by lightening, ignition, appliance noises, etc. Noise of any kind may cause erratic triggering.
- Radio frequency interference may be picked up in strong RF signal areas. This type of interference may come from a commercial broadcasting station or from nearby equipment.
- Thermal drift may also appear if the test clip is connected across a junction of two dissimilar metals or across a semiconductor. This will apear as a baseline drift when the junction changes temperature.

OPERATIONAL EXAMPLES

This section of the Manual gives several examples of how to use the Oscilloscope in its different modes of operation. These examples will help you become familiar with the controls, especially the sweep and triggering controls, and with dual-trace or triple-trace operation.

EXAMPLE 1

Sweep Triggering on a Waveform's + or − Slope

Use a sine wave generator signal source, at approximately 1000 Hz.

Be sure all Scope controls and switches are in the positions described in "Presetting Controls." Do not change any of these settings unless you are directed to do so in a step.

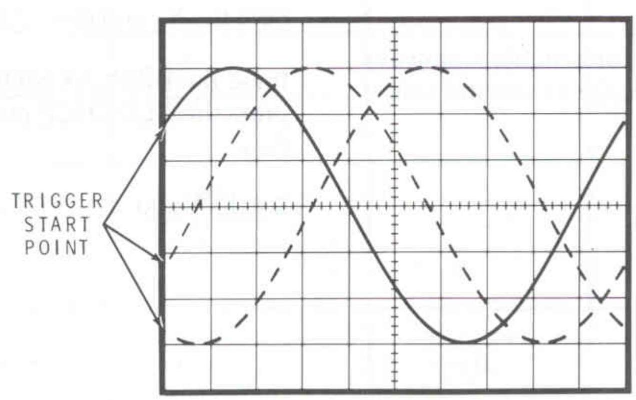
Connect the 1000 Hz sine wave signal to the Y1 INPUT connector.

Adjust the generator for a 6 cm display and the TRIG LEVEL control for a stable display.

Refer to Pictorial 11-2 and change the TRIG LEVEL control. Notice how the trigger starting point moves up or down on the graticule. When this LEVEL control is turned to either end of its rotation, the trace will blank out momentarily and then begin to move (not locked in).

Reset the TRIG LEVEL control for a stable display.

Change the TRIG SELECT switch from Y1(+) to Y1(−). The trigger should now occur on the opposite slope of the waveform.



PICTORIAL 11-2

EXAMPLE 2

Normal or Automatic Triggering

The AUTO mode (automatic triggering) provides a base or reference line when the Scope is not triggered. This line is used as a reference point, especially for DC measurements.

Change the A AND B TIME/CM switch to 1 ms/CM. The display should be approximately 10 complete cycles.

Press the TRIGGER MODE, NORM pushbutton. The display should remain.

Set the (Y1) AC-GND-DC switch to GND. The display should disappear.

Press the TRIGGER MODE, AUTO pushbutton. The base line will appear.

Return the (Y1) AC-GND-DC switch back to AC. The display trace should reappear.

Press the NORM pushbutton. The display should remain.

Turn the TRIG LEVEL control CCW and notice that the display disappears. In the NORM position, there is no baseline when the Scope is not triggered.

Press the AUTO pushbutton. The display will reappear, but will not be locked in.

Set the TRIG LEVEL control for a stable sine-wave display that starts 1 cm above the horizontal center line.

EXAMPLE 3

Single Sweep Mode

Set the A AND B TIME/CM switches to 10 mS/CM.

Set the (Y1) AC-GND-DC switch to GND, removing the input signal.

Press the TRIGGER MODE, SINGLE pushbutton. The base-line will disappear, and the READY light will turn on.

Change the (Y1) AC-GND-DC switch back to AC, returning the input signal. The Scope will be triggered, and will make one sweep. The READY light will go off.

Press the SINGLE pushbutton again. It will reset, then trigger again and generate one trace, each time you reset it by pressing it again.

Press the TRIGGER MODE, AUTO pushbutton again.

Reset the A AND B TIME/CM switches to .1 mS/CM.

EXAMPLE 4

Dual Trace Operation

Connect a sine wave (approximately 50 kHz) to both the Y1 and the Y2 INPUT connectors.

Press the DISPLAY MODE, DUAL pushbutton, and press the ALT/CHOP pushbutton to the CHOP position.

Set the Y1 AC-GND-DC switch to AC.

Set the generator for a Y1 display that is 2 cm high and set the TRIG SELECT, LEVEL control for a stable display.

Set the Y2 AC-GND-DC switch to AC.

Set the A AND B TIME switch to 5 μS.

Adjust the Y1 and Y2 POS controls so the waveforms are separated slightly. NOTE: You can select either channel alone (to see it clearly while you move it) by pressing the Display Mode Y1 or Y2 pushbutton.

Look closely at the screen, and you will notice that, in the CHOP mode, the two waveforms are actually composed in a single sweep that alternates, drawing part of one waveform, then jumping to draw the other, etc.

Reset the ALT/CHOP pushbutton to the released (ALT) position. Set the signal generator to a frequency below 50 Hz if possible, or whatever low frequency you can achieve. Change the A AND B TIME switch to 20 mS.

Now notice that (in the ALT mode) the two waveforms are drawn during alternate sweeps (one complete wave on one sweep, the other wave on the next sweep).

By comparing the ALT and CHOP performance at different sweep speeds, you will find that Chopping is usually the best method of display for the lower speed sweeps, while Alternating is more effective for middle and higher speed sweeps.

EXAMPLE 5

Y2 Invert Button

Connect a sine wave of approximately 1000 Hz to both the Y1 and Y2 INPUT connectors.

Press the Y2 Display Mode pushbutton.

Set the A AND B TIME/CM switch to .5 mS.

Set the TRIG SELECT switch to Y2 +.

Press the Y2 INVERT pushbutton. The trace will not appear to invert, since the Trigger still selects a positive slope on the curve. However, the signal actually is inverted.

Press the DUAL pushbutton.

Release the ALT/CHOP pushbutton to ALT.

Set the TRIG SELECT switch to Y1 +.

Press and release the Y2 INVERT pushbutton a few times as you watch the Y2 signal being inverted on the screen. You can see the inversion this time, since the triggering takes place from the Y1 signal.

Leave the Y2 INVERT pushbutton in the released (noninverting) position.

Press the ADD pushbutton. Now the display is twice as high as it was before. Y1 and Y2 have been algebraically added to produce this curve.

Press Y2 INVERT. This inverts Y2, and produces a flat* curve, since Y2 and Y1 cancel each other out.

This function is useful in making differential measurements. If You connect Y1 and Y2 across a resistor, the differential measurement (using Y2 INVERT) will measure the direct voltage drop across that resistor.

Adjust either the Y1 or Y2 VOLTS/CM, VARIABLE control and notice how the diplay changes. This is because the gains of each channel are now different, and their algebraic difference is no longer zero.

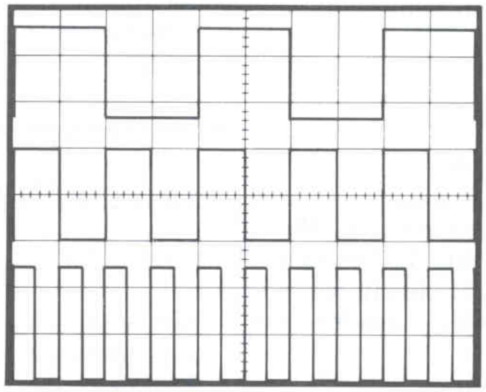
NOTE: It may not be possible to get a zero at high frequencies, or fast rise times, due to circuit limitations.

EXAMPLE 6

Channels Y1 and Y2

Both channels operate exactly the same (except for the Y2 INVERT pushbutton). If you wish, you may reperform Examples 1 through 4, using the channel that was not called for in each case.

*Due to the aging of components, the calibration may have drifted slightly. Adjust the appropriate VARIABLE VOLTS/CM control to achieve the straight line.



PICTORIAL 11-3

EXAMPLE 7

Three Channel Operation

For this example, you will need three different inputs. While you may select any reasonable signals for this, one typical application in digital electronics might be to check the delay of a digital signal through semiconductor devices. Pictorial 11-3 shows a square wave, processed through two divide-by-two devices.

Press the DISPLAY MODE, TRIPLE trace button.

Connect the lowest frequency (reference) input to the EXT INPUT – Y3. Connect either remaining input to Y2 INPUT and the last input to Y1 INPUT.

Set the TRIG SELECT switch to EXT +. You may wish to press the TRIGGER COUPLING, EXT ÷10 button to get space enough for all three traces, if the input voltages are at TTL levels or higher.

Set the VOLTS/CM switches to allow the Y1 and Y2 waveforms to fit comfortably on the screen (make each waveform about 2 cm high). Use the Y1 POS, Y2 POS, and Y3 POS controls to place the three waveforms as you want them on the screen.

Adjust the A AND B TIME/CM control to give the number of cycles you want on the display.

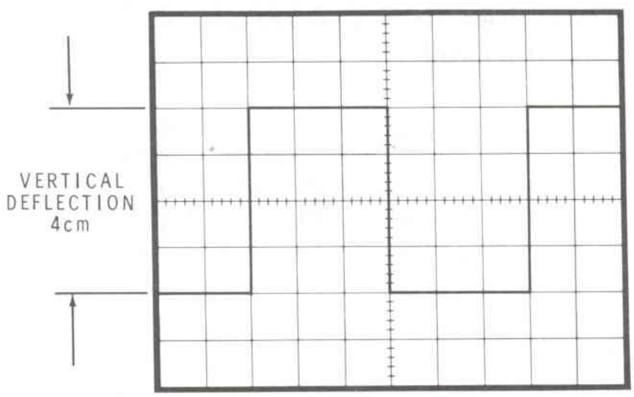
APPLICATIONS

PEAK-TO-PEAK VOLTAGE MEASUREMENTS

To measure the peak-to-peak voltage of a signal, first make sure the VOLTS/CM VARIABLE control is turned fully CW to the CAL position. Then multiply the vertical deflection (number of vertical divisions from the bottom of the curve to the top) by the setting of the VOLTS/CM switch.

Example:

As shown in Pictorial 11-4, the display amplitude is four centimeters. If the VOLTS/CM switch is at .2 V, then 0.2 V/cm times 4 cm equals 0.8 volts peak-to-peak.

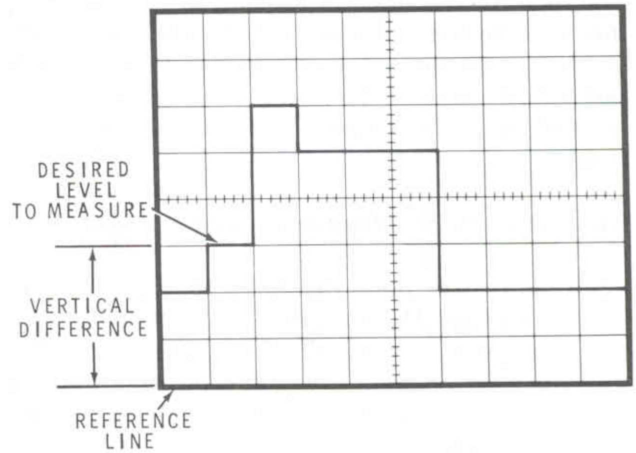


PICTORIAL 11-4

INSTANTANEOUS VOLTAGE MEASUREMENTS

To measure the voltage at any point on a waveform with respect to ground:

1. Set the AC-GND-DC switch to GND and adjust the trace to some reference line. See Pictorial 11-5.



PICTORIAL 11-5

2. Set the AC-GND-DC switch to DC. If you are using the Y2 input, make sure the Y2 INVERT pushbutton is released. If the waveform is above the reference line, the voltage is positive. If the waverform is below, then the voltage is negative.

3. Measure the vertical difference (number of vertical divisions) between the reference line and the desired point on the waveform. Then multiply by the VOLTS/CM setting for that input.

Example:

In Pictorial 11-5, the vertical difference to the selected part of the waveform is 3 divisions and the VOLTS/CM switch is set at 50 mV. The indicated voltage step is 3 divisions times 50 mV/division, or 150 mV.

DUAL-TRACE PHASE DIFFERENCE MEASUREMENTS

The dual-trace method of measuring the phase difference between two signals of the same frequency is more accurate and easier to use than the X-Y method. It can also be used up to the frequency limit of the vertical system. To make the measurement:

1. Press the Display Mode DUAL pushbutton.

2. Release or press the ALT CHOP pushbutton to either ALT or CHOP, as dictated by the frequencies you will be measuring (see "Operation Example #4"), and position the two baselines on the horizontal centerline of the graticule.

3. Connect the reference signal to the channel Y1 INPUT connector and the comparison signal to the channel Y2 INPUT connector. Use coaxial cables or probes that have equal time delay.

4. Set the channel VOLTS/CM switches and the VARIABLE controls so that the displays are equal in height, and occupy about the full screen (eight divisions) vertically.

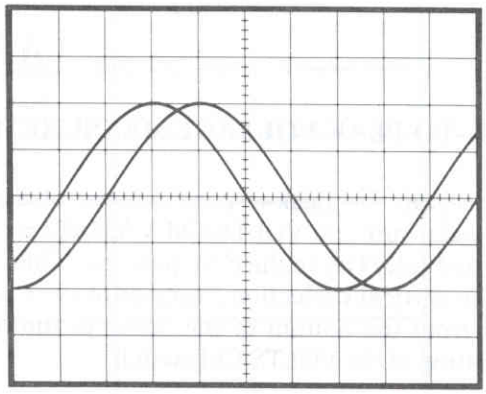
5. Set the A AND B TIME/CM switches to a sweep speed that displays one cycle of the reference waveform.

6. Turn the Time/Cm VARIABLE control until one cycle of the reference signal occupies exactly eight divisions between the first and ninth graticule lines. Each division of the graticule now represents 45° of the cycle (360° divided by 8 divisions is 45° per division).

7. Measure the horizontal difference between corresponding points on the waveforms. Then, multiply the measured distance (in divisions) by 45° division.

Example:

The horizontal difference in Pictorial 11-6 is 1.0 division. The phase difference is 1.0 division × 45°/division which is 45°.



PICTORIAL 11-6

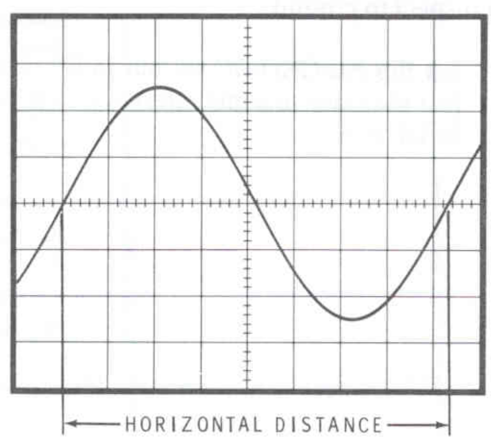
The phase difference of a third waveform can also be found using channel Y3.

TIME DURATION AND FREQUENCY MEASUREMENTS

To find the time duration between two points on a waveform, multiply the horizontal distance (in divisions) between the two points by the setting of the TIME/CM switch (VARIABLE TIME must be kept in the CAL position). Frequency is the reciprocal of one cycle's time duration.

Example:

As shown in Pictorial 11-7, the horizontal distance measured is 8.3 divisions. The TIME/CM switch is set to 2 ms. So the time duration will be 8.3 divisions × 2 ms/division, or 16.6 ms. Frequency is 1/time duration, or 1/16.6 ms, which turns out to be 60 Hz.



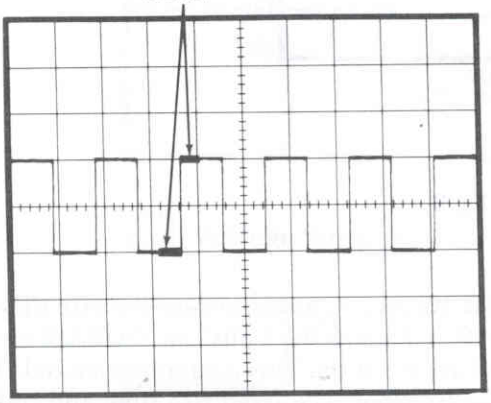
PICTORIAL 11-7

DELAYED SWEEP OPERATION

This mode of operation allows you to select a portion of a waveform and then expand just that portion for a closer look.

Example:

Refer to Pictorial 11-8.



PICTORIAL 11-8

1. Press the Time Base A pushbutton.

2. Connect the CAL 1V (P-P) signal from the center of the Scope's front panel to one of the INPUT connectors. Turn the A knob of the A AND B TIME/CM switch to .5 ms and turn the B knob to 50 µs.

3. Press the Time Base A-B pushbutton. Adjust the INTENSITY control so that you can see an intensified portion (about 1 cm long) of the trace. Turn the DELAY TIME POSITION control and watch the intensified portion move. Leave it so that the intensified portion is on a leading edge of the waveform as shown in Pictorial 11-8.

4. Press the Time Base B pushbutton. The display now shows the portion of the waveform that was intensified before. Adjust the INTENSITY as needed to get a bright trace.

5. Set the B section of the A AND B TIME/CM switch to 10 µs.

6. Turn the DELAY TIME POS control so that a leading edge is displayed again. NOTE: This control is more sensitive now; also, you may have to turn up the INTENSITY.

7. Press the Time Base A pushbutton. Readjust the INTENSITY control as necessary.

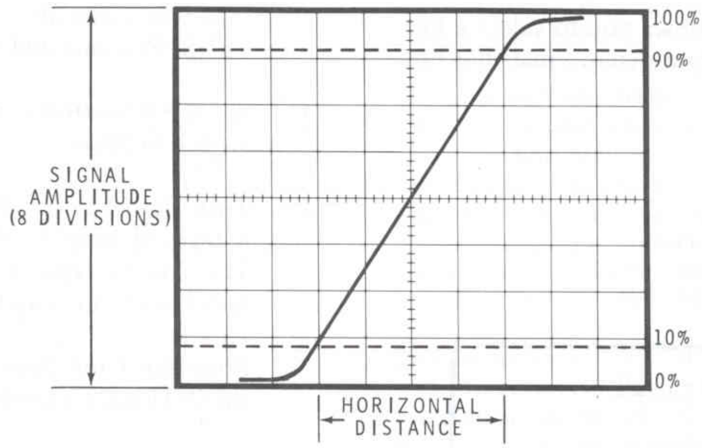
NOTE: The greater the difference between the settings of the A and B TIME/CM switches, the more "jitter" you will see in the waveform. When there is a nine-step difference between the two timebases (1000 to 1 differences in sweep speeds) and a stable generator is used, the jitter should be less than 1 cm, and will typically be about 0.5 cm. Also, the display will lose intensity. When you turn the VARIABLE HOLDOFF control to the B ENDS A position, the display intensity will increase.

RISE TIME MEASUREMENTS

Rise time measurements are made the same as time duration measurements, except that these measurements are made between the 10% and 90% points of the waveform's amplitude.

To measure rise time:

1. Adjust the VOLTS/CM, VARIABLE, and Y POS controls for a display that is exactly 8 divisions high, and is just touching the top and bottom lines of the graticule.



PICTORIAL 11-9

2. This position allows you to easily find the 90% and 10% points. Refer to Pictorial 11-9 and note the dotted lines. These lines indicate points located just 1 small division above the seventh graticule line and 1 small division below the first graticule line.

3. Measure the **horizontal** distance between these two crossing points.

4. The rise time is the horizontal distance × the TIME/CM setting.

Example:

In Pictorial 11-9, the horizontal distance between 10% and 90% points is 4 cm. The TIME/CM switch is set at 1 µs. So the rise time is 4 cm times 1 µs/cm, or 4 µs.

NOTE: When you measure very fast rise times (less than 20 ns), place the Volts/Cm VARIABLE control in its CAL position. This guarantees a fixed Oscilloscope rise time. The fixed rise time and unknown rise time are related as follows:

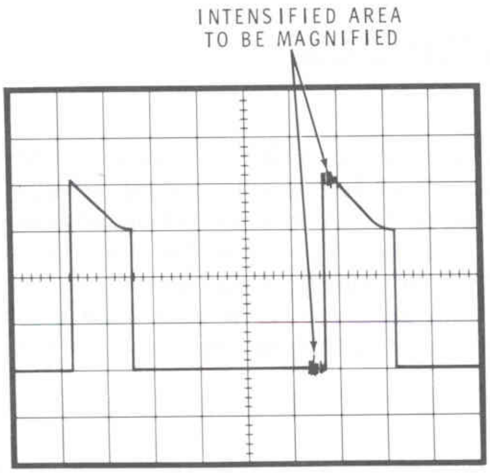
$$Tr^2\ \text{display} = Tr^2\ \text{scope} + Tr^2\ \text{unknown}$$

OR

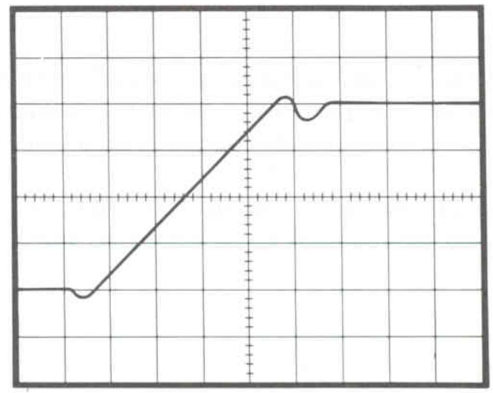
$$Tr\ \text{unknown (in ns)} = \sqrt{(Tr^2\ \text{display} - 6\ \text{ns}^2)}^*$$

(since 6 ns is the typical rise time of the Scope)

*NOTE: When the VOLTS/CM switch is at 2 mV, use 7 ns.



PICTORIAL 11-10



PICTORIAL 11-11

DELAYED SWEEP MAGNIFICATION

The B delayed Time Base mode can provide a higher "apparent sweep rate magnification" than provided by the HORIZ POS PULL FOR X10 switch.

To determine the apparent magnification factor:

1. Press the Time Base A-B pushbutton.
2. Use the DELAY TIME POS control to move the left edge of the intensified area to the portion of the display that you want to have magnified. See Pictorial 11-10.
3. Set the B section of the A AND B TIME/CM switch to cover only the portion of the A sweep that you want magnified.
4. Press the Time Base B pushbutton. The portion of the A sweep that you selected is now magnified (see Pictorial 11-11). The displayed sweep rate is determined by the B section of A AND B TIME/CM. To calculate the apparent magnification factor, use the following formula:

$$\text{Mag} = \frac{\text{A sec. TIME/CM setting}}{\text{B sec. TIME/CM setting}}$$

5. Press TIME BASE A pushbutton to return the Scope to normal operation.

DIFFERENTIAL MEASUREMENTS

Make sure the Y1 and Y2 VOLTS/CM switches are in the same positions. Press the Display Mode ADD pushbutton. Press the Y2 INVERT pushbutton.

The resulting display is now Y1 minus Y2. Read the difference directly by multiplying the vertical height (in cm) times the setting of the VOLTS/CM switch when the VARIABLE control is in the CAL position.

X-Y MODE OPERATION

When the TIME/CM switch is turned fully CW to the X-Y position, the Y1 input signal produces a horizontal deflection (X-axis) and the Y2 input signal produces a vertical deflection (Y-axis). The VOLTS/CM switch, VARIABLE control, and INVERT pushbutton operate as previously described.

Use the X-Y mode of operation to get trapezoidal and Lissajous patterns that are useful in studying modulation characteristics or phase and frequency comparisons. This mode is also useful for displaying graphics and patterns that result when the Oscilloscope is connected to a curve tracer.

THEORY OF OPERATION

Refer to the Block Diagram (Illustration Booklet, Page 2) as you read the following paragraphs.

The triple trace capability of this Oscilloscope allows three different signals to be displayed on a conventional CRT (cathode ray tube) with only one set of vertical deflection plates. Two identical vertical preamplifier circuits, a third similar vertical preamplifier circuit, a switching circuit, and a vertical deflection amplifier make this possible. Each vertical preamplifier circuit attenuates its input signal by a known factor, amplifies it to a usable level, and provides the necessary positioning bias.

The switching circuit, which is automatically controlled by the display control circuit, alternately allows the output signals from the three preamplifier circuits to pass to the vertical deflection amplifier. The vertical signal, a composite of the three input signals, is amplified further by the vertical deflection amplifier before it is applied to the vertical deflection plates of the CRT. The signal at the vertical deflection plates (which produces the display on the CRT screen) thus represents up to three input signals as one "time shared" signal.

The input signal connected to a channel Y1 or Y2 input is coupled into a high impedance attenuator where the circuits select AC signals or DC signals, or else ground the amplifier input. The high impedance attenuator has three positions, a divide-by-one, a divide-by-ten, and a divide-by-one hundred.

Attenuation is determined by the settings of the Volts/CM switch. The five most sensitive settings on this switch correspond to the divide-by-one attenuator, the next three settings correspond to the divide-by-ten attenuator, and the four least sensitive settings correspond to the divide-by-one-hundred attenuator. The channel Y3 input is coupled directly to its own high impedance attenuator; the attenuator has two positions, divide-by-one and divide-by-ten.

The outputs of these attenuators go to impedance translators. The impedance translator changes the impedance from one megohm down to the very low impedance level needed to drive a low impedance attenuator.

In the low impedance attenuator, the first two positions of the Y1, Y2 attenuator switches provide no attenuation. The next nine positions provide sequenced attenuation of 1, 2, and 4 for the divide-by-one, divide-by-ten, and divide-by-one-hundred attenuation. The last position provides an attenuation of twenty for the divide-by-one hundred attenuator. Channel Y3 has a fixed attenuator.

The output of the low impedance attenuator circuitry is differentially amplified to a useful level in the subsequent amplifier stages, beginning with the first gain stage.

The first gain stage amplifies the pre-scaled input signal to a 5-millivolt level to operate the trigger circuits. In the Y2 circuitry, it also inverts the signal when the Y2 Invert pushbutton is pressed, and then outputs the signal to the switch circuit. The Y2 Invert pushbutton effectively turns the CRT trace for that channel upside down.

The second gain stage/switch circuit passes the Y1, Y2, or Y3 amplifier signals to the third gain stage and its following (deflection amplifier) stages. The Display Mode pushbuttons determine whether the switch will select channel Y1, channel Y2, chopped dual-trace or triple-trace display, alternate dual- or triple- trace display, or add Y1 and Y2 signals. The output of this gain/switch setup goes into the third gain stage. From there, it passes through the delay line to the deflection amplifier section (fourth and fifth gain stages and output stage), and then drives the vertical deflection plates on the CRT.

The delay lines delay the vertical signals slightly so the sweep starts before the vertical signal is displayed. This is done so that the entire waveform will be presented.

The horizontal portion of the trace displayed on the CRT screen is produced by the sweep and trigger circuits. Either a sample from the Y1 trigger amplifier, Y2 trigger amplifier, line frequency, or external trigger — Y3 signal feeds into the trigger select circuitry. This circuitry selects one of the trigger signals and sends it to the trigger input filter. The filter selects an AC signal, a DC signal, rejects low frequencies in the AC-HF position, rejects high frequencies in the AC-LF position, rejects horizontal sync pulses in the TV-V position, or rejects vertical sync pulses in the TV-H position.

The output of the trigger input filter is then compared against the setting of the Level control by the trigger comparator. The output of the trigger comparator is then applied to the A sweep generator which produces the sawtooth waveform necessary to sweep the electron beam at a constant rate from the left-hand side to the right-hand side of the screen.

When the A sweep generator is triggered, a signal goes out on the "A unblank" line and into the summing junction of the blanking circuits. This unblanks the CRT and allows the spot to appear. The output of the sweep generator then is coupled through the A switch and into the horizontal deflection amplifier to the horizontal deflection plates.

When the Scope is in the A-B mode, a sample of the sweep output voltage from the A sweep generator feeds into the B comparator and then to the B sweep generator. The Delayed Time Position control is compared with the voltage at the output of the A sweep generator. When the two are equal, the B generator starts to generate a single ramp (see Pictorial 12-1, Illustration Booklet, Page 3). At the same time, the B unblanked voltage feeds into the summing junction of the blanking circuits which further unblanks the CRT and allows the spot to become brighter.

Therefore, the Delay Time Position control selects the precise point at which this intensified portion starts to appear. (The length of the intensified portion is then determined by the setting of the B Time/CM switch.) When the Oscilloscope is in the B delayed position, the horizontal deflection amplifier is connected to the output of the B sweep generator, and the tube only unblanks during the operation of the B sweep generator. This results in a trace on the CRT with the rate of the B Time/CM switch. The trace starts at some time after the main trigger (determined by the setting of the A sweep generator and the setting of the Delayed Time Position control).

When the Time/cm switch is in the X-Y position, the output of the Y1 vertical trigger amplifier is connected to the horizontal deflection amplifier. This provides an X (or horizontal) movement of the spot which is proportional to the voltage going into the Y1 input. The Display Mode control circuitry automatically selects Y2 to be applied to the vertical deflection plates.

The intensity of the spot on the CRT is proportional to the currents coming into the summing junction of the blanking circuit amplifier. The Intensity control also feeds into this point, which provides a DC reference. An external signal can be added through the Z-Axis modulation connector, and this also sums into the blanking circuits. Therefore, the brightness of the spot on the CRT is proportional to the currents going into the Z-Axis modulation connector, the A unblanking signal, the B unblanking signal, and the Intensity control. Also, during the time that the display mode is in the Chop position, the tube is momentarily blanked each time the channels are switched. This is to mask any switching transients produced by the high speed switch.

The voltage for the CRT is generated by a Class C RF oscillator. There are basically two output voltages, a −1341 volts to feed the CRT gun and approximately 8500 volts which operate the post deflection anode. With these, there is a potential of about 10,000 volts across the CRT, which accounts for its high brightness. Regulated power supply circuits give overall accuracy and control the electron beam size and intensity.

CIRCUIT DESCRIPTION

Refer to the Block Diagram (Illustration Booklet, Page 2) and the Schematic Diagrams (fold-in) as you read this "Circuit Description."

Components are numbered in the following groups:

1-99	Parts on the chassis.
101-199	Parts on the low voltage circuit board.
201-299	Parts on the high voltage circuit board.
301-359	Parts on the vertical deflection circuit board.
361-399	Parts on the control board.
401-699	Parts on the vertical preamplifier circuit board.
701-999	Parts on the horizontal circuit board.

VERTICAL

The vertical preamplifier consists of two identical circuits: one for Channel Y1 and the other for channel Y2. Components in the channel Y1 vertical preamplifier circuit have component numbers in the 400 numbering series; those in the Y2 vertical amplifier use the corresponding number in the 500 numbering series. (For example, the AC coupling capacitor in channel Y1 is C401, while the same capacitor in channel Y2 is C501.) There are also some vertical preamp components that do not belong to a specific channel. They have the 600 series numbers. Since the channels are identical, only channel Y1 is described in this "Circuit Description."

INPUT CIRCUIT

When the Y1 input switch (AC-GND-DC) SW401 is in the DC position, a signal at the Y1 input connector, J401, goes directly from the switch through R401 and R403 to wafer B of attenuator switch SW402 (Volts/CM). With SW401 in the AC position, the signal passes through capacitor C401 and resistors R405, R401, and R403. Resistor R402 provides a DC equalizing path for C401. When the switch is in the GND position, the switch grounds the input to the high impedance attenuator through resistor R405.

The high impedance attenuator is made up of three sections: divide-by-one, divide-by-ten, and divide-by-one-hundred. The divide-by-one uses the first five positions of the attenuator (Volts/CM) switch, the divide-by-ten uses the next three, and the divide-by-one-hundred uses the remaining four. When the divide-by-one positions are used, capacitor C402 determines the input capacitance of the scope. When the divide-by-ten positions are used, C403 determines the input capacitance. Capacitor C404 adjusts the attenuation of the capacitive divider (C404 and C405) so it is equal to that of the divide-by-ten resistive divider (R407 and R408).

In the divide-by-one-hundred positions, capacitor C406 determines the input capacitance, capacitor C407 matches the capacitive divider (C407 and C408) to the resistive divider (R411 and R412). The resistors in each section attenuate the low frequencies and the capacitors attenuate the high frequencies.

The output of the high impedance attenuator is applied through attenuator switch section SW402C to resistors R416, R417, R493, and capacitor C411. Resistors R416 and R417 determine the input resistance of the Scope and are part of the resistive section of each attenuator. Resistors R401, R403, R404, R406, R409, R413, R405, R492, and R493, are coupling resistors, and act as damping resistors to the LC circuits which come from fixed and stray capacitance, and foil and component lead inductance. The signal is then applied to input FET Q401 and to pin 3 of op amp U401.

The input to FET Q401 is protected against high voltage by its gate-to-drain junction and diode D401. If the input voltage goes higher than 6 volts, the gate-to-drain junction becomes forward biased, and clamps the input at approximately 0.7 volts above Q401's drain voltage. If the input goes low, diode D401 will clamp the voltage at approximately 0.7 volts more negative than the voltage at the emitter of Q403. Q401 is connected as a follower. Q403 is the current source for Q401. The output of Q401 is coupled to a second follower, Q402. The output of Q402 is then connected to the low impedance attenuator. The output is also coupled to a bootstrap circuit consisting of R429, Q404, D402, and R425 that keeps the voltage constant at the drain of FET Q401, which in conjunction with the constant current being supplied by Q403, keeps Q401 at a constant power level to prevent distorting applied signals.

The output is also coupled to pin 2 of op amp U401 by R423 and DC adjust control R422. The output (pin 6) of op amp U401 is coupled to the gate of FET Q401 by resistor R421. Op amp U401 controls the bias of the FET, always adjusting that bias to keep the input and output voltages equal. The step balance control, R414 and R415, and resistors R418 and R499 sum in a current to pin 2 of the op amp to adjust the voltage at the low impedance attenuator. This is done to eliminate trace shift when changing attenuator positions. Capacitor C436 and R434 provide high frequency compensation for the FET.

The low impedance attenuator consists of resistors R435 and R488. R488 is a thick-film resistor network that provides a divide-by-two, divide-by-four, divide-by-ten, and divide-by-twenty function. For the first two positions of the attenuator, R435 couples the signal through SW402D to the first gain stage. In each of the next nine positions, the divide-by-two, divide-by-four, and divide-by-ten functions are selected one time for each high attenuator section. The last position of the high attenuator selects the divide-by-twenty function. The resulting voltage division produces a divide-by-one, divide-by-two, divide-by-four sequence. The remaining resistor in R488 is connected to the base of transistors Q405 (A and C).

Transistor Q405 is an array consisting of four transistors, A, B, C, and D.

From switch SW402D, pin 9, the signal goes to the base of transistors Q405 (B and D) in the first gain stage. The first gain stage is a "times 1," "times 2.5" (×1, ×2.5) switch-selected gain stage, controlled by SW402E. This stage is a differential cascode with a voltage gain of approximately 5 in the ×1 and 12.5 in the ×2.5 positions. Control R436, the variable attenuator, and R437 shunt out the input signal as the control is rotated from its CAL position to provide variable attentuation for the channel.

The gain of the amp is selected by turning on the desired pair of transistors. The ×2.5 pair are used only in the first attenuator position. The ×1 pair is used for all other positions of the attenuator. Transistors Q406 and Q407 are the common-base amps in this stage, and resistors R449 and R451 and their bypass capacitors (C419 and C421) provide thermal stability. Capacitors C417 and C418 provide high frequency compensation in the ×2.5 mode. Control R439 adjusts the gain of the stage when it is in the ×2.5 mode. Due to offset bias currents being different between the pairs of transistors, control R441 and FET Q416 are used to balance the stage when the gain is changed.

Capacitors C422 and C423 provide high frequency compensation for the ×1 stage. Position control R453 and resistors R452 and R454 provide additional bias currents. When the position control is rotated, the currents being summed in each half of the stage are changed, resulting in a voltage change at the collectors of Q406 and Q407. Gain control R463 and limiting resistor R462 are in parallel with collector load resistors R459 and R461. When the control is rotated, the voltage gain of the first stage and the vertical amp is changed.

Channel Y2 contains the invert function. There are two sets of common-base amplifiers in this stage (transistor pairs Q506 and Q507, and Q509 and Q508), and they are controlled by invert switch SW601G. When the switch is pressed, transistors Q508 and Q509 are turned on, inverting the output signal of the stage. Invert balance control R589 provides current to correct for any unbalance that may occur when inverting.

The channel Y3 input and the first half of the first differential gain stage are on the horizontal board. Resistors R649 and R651 terminate the cables carrying the input signal from the horizontal board. The rest of the amp works like the Y1 channel.

The signal from the first gain stage is applied to a differential cascode amplifier composed of transistor array (six transistors) Q411A through Q411F. This is the second gain stage and has a current gain of approximately 5. The input comes to the bases of transistors F and B. The other transistors are connected in common base pairs, A and D, and C and E. They provide the output and also do the channel switching (see below). RC networks in the emitter circuit of the input transistors provide high frequency compensation. The trigger pick-off signals are also provided by the emitters of this stage.

VERTICAL SWITCHING

Three vertical preamplifiers (Q411, Q511, and Q611) share the third, or final, preamplifier stage. This is allowed since the output of the second stage (Q411 A, D, C, and E) can be switched on or off by the channel switching logic.

Each channel uses two pairs of switching transistors. One pair (A and D) has the collectors tied together. Differential signals are summed there, resulting in a zero output signal. This action in effect, turns the channel off when the transistors are turned on. The other two (C and E), when turned on, allow the signal currents to pass. This couples the output signal from the second stage on to the next gain stage.

Normally when one channel is on, the other two channels are off. Then, only the signal from one channel at a time is coupled to the output preamp. However, you can get multichannel operation in either of two ways. First, turn the different channels on and off, one at a time, at a very rapid rate during each sweep (Chop). Second, you can display one channel for one sweep, then change channels for the next sweep (Alt). Another mode of display is the Add mode, where the Y1 channel and the Y2 channel are both on; their signals are added algebraically to give a single sweep which represents the sum of the two.

THIRD GAIN STAGE

The signals from the vertical switching (second gain stage) are applied to the input of the third gain stage. The third gain stage is a shunt-feedback amplifier. Transistors Q601 and Q602 and feedback resistors R603 and R604 make up this stage. The load consists of R606, R605, the delay line, and resistors R301 and R302 on the deflection board. Resistors R601, R602, R694, and R693 add in additional bias currents for the stage. The third stage converts the signal currents from the second gain stage to voltage signals at the collectors of Q601 and Q602.

To find the voltage gain of these stages, divide the value of the feedback resistor by the value of the second stage emitter resistor; the voltage gain from the input of the second gain stage to the output of the third is approximately 6.5. Capacitors C601 and C602 provide high frequency compensation.

TRIGGER AMPLIFIER

The trigger amplifier provides a differential to single-ended conversion with a voltage gain of approximately 8.8. Transistors Q412, Q413, Q414, and Q415 make up the series-shunt feedback amp. Zero control R477 adjusts the bias currents in the amp, and in that way controls the voltage at the collector of Q415. Resistor R487 matches the output impedance of the amplifier to coaxial cable coupling to the trigger circuits on the horizontal board. Capacitors C427 and C432 provide high frequency compensation.

DISPLAY CONTROL

Display Mode switch SW601 selects channel Y1, channel Y2, Add, Dual, Triple, and Alt/Chop functions. When you select the X-Y mode with the Time/CM switch, the Display Mode switches are disconnected from the control circuitry. When the scope is not in the X-Y mode of operation: (1) the X-Y control line is in a high state, (2) all vertical mode switches are enabled, and (3) the output of IC U601 gate A is low. When you push switch Y1 in, pin 7 of JK flip-flop IC U602A is forced low. With pin 7 low, output pins 11 and 10 go high and low respectively. The high at pin 11 is coupled to the ON pair of common-base transistors Q411 C and E of the second gain stage. The low at pin 10 is coupled to the OFF pair of transistors A and D. Resistors R616 and R617 couple the signal to the transistors from the logic circuitry. Transistor follower Q603 and resistors R612, R613, R625, and R626 establish the bias to turn the common-base amplifiers on when the logic outputs for the ON pair (C and E) go high.

The channel is turned off when the OFF line goes high, turning on the "off transistor" pair (A and D). At the same time the Y1 pushbutton is pressed, pin 8 of JK flip-flop U603A goes low, presetting its Q-not output high to turn off channel Y2.

Channel Y3 JK flip-flop U603B is always preset, keeping channel Y3 turned off as long as the Triple pushbutton is not pressed. When the Y2 button is pressed, a low is applied through U604 D to JK flip-flop U602A; at the same time, a low is applied through U604B to pin 7 of JK flip-flop U603A, and channel Y2 is turned on.

When the Add pushbutton is pressed, a low is applied to pin 7 of JK flip-flop U602A, and through U604B to pin 7 of JK flip-flop U603A. This turns both channels Y1 and Y2 on.

When the Dual pushbutton is pressed, flip-flops U602A and U603A are connected so that they perform a divide-by-two function. If the Alt/Chop pushbutton is released (Alt position), the toggle signal changes state at the end of each sweep; this signal is applied to all three flip-flop clock pins. When the trace starts, the toggle goes high; at this time, channel Y1 is on and channel Y2 is off. At the end of the sweep, the toggle line goes low and the Y1 flip-flop changes state, turning Y1 off. Also, Y2 flip-flop changes state, turning Y2 on. On each successive sweep, Y1 and Y2 change state. The Q output of channel Y1's flip-flop is connected to the J input of channel Y2's flip-flop, to make sure the proper sequence is followed.

When the Triple pushbutton is pressed, pin 3 of channel Y3's JK flip-flop U603B is set high via U604C. This allows U603B to toggle channel Y3 along with Y2 and Y1. The sequence of channel use is, Y1, Y2, and Y3. The gates U604A, U601C, and U601D make sure that this is the sequence the channels follow.

When the Chop mode is used, U605 makes sure that there is a minimum width pulse present to the clock inputs of each flip-flop to get correct operation of the control logic.

When the Scope is used in the X-Y mode of operation, the X-Y control line goes low and forces the output of U601A high. All of the Display Mode pushbutton operations are inhibited. The Reset pins of the Y1 and Y3 flip-flops are forced low via U604D and C. This turns Y1 and Y3 off. At the same time U603A pin 7 goes low via U604B, turning Y2 on.

VERTICAL DEFLECTION AMPLIFIER

The deflection amp consists of three cascode gain stages that amplify the signal from the pre-amp. The output voltage must be large enough to drive the vertical deflection plates in the CRT.

The input signal is coupled to the first gain stage by the delay line. Since this delay line does not delay higher frequencies as much as the lower ones, a circuit must be added to supply more delay to the higher frequencies. The circuit consists of coils L301 through L304 and capacitors C301, C302, and C303. R301 and R302 are load resistors for the output stage of the pre-amp and also terminate the delay line.

The first gain stage has a voltage gain of approximately 2.5 and consists of transistors Q301, Q302, Q303, and Q304. Resistors R311 and R314 are the thermal balance resistors, and C305 and C306 provide the bypass for those resistors. Capacitors C312, C311, C309, C308, C307, and their associated resistors, provide the necessary fixed and adjustable high frequency compensation.

The second gain stage has a voltage gain of approximately 2 and consists of transistors Q305, Q306, Q307,and Q308. Resistors R323 and R324 provide the thermal balance and C313 and C314 provide the bypass. Capacitor C315 provides the high frequency compensation. Bias control R351 sets the voltage at the output of the deflection amplifier.

The third (output) stage has a voltage gain of approximately 30, and consists of transistors Q309, Q312, Q313, and Q314. R347 and R348 are for thermal balance, and C326 and C327 are the bypass capacitors. Capacitors C316, C317, C318, and C319 and their associated resistors provide fixed and adjustable high frequency response. Resistors and coils R341 and L313, and R342 and L314 are the load resistors and high frequency compensation for the stage. The remaining inductive-resistive networks (L307 and R337, and L308 and R338) provide the coupling to the CRT along with damping resistors R345 and R346.

TRIGGER, SWEEP, HORIZONTAL AMPLIFIER, AND CALIBRATOR CIRCUITS

On command from a trigger pulse, the sweep circuits generate a linear ramp signal to drive the horizontal deflection plates. They also generate pulses of proper amplitude to unblank the CRT to specified brightness levels. In the automatic triggering mode, the auto-baseline circuit allows the sweep generator to function and provide an automatic baseline, if no trigger signal is present.
NOTE: Some of the following circuits use both TTL and ECL integrated circuits. These circuits operate at different logic levels:

ECL: logic 0 (or low) is < -1.6 V.
logic 1 (or high) is > -0.9 V.

TTL: logic 0 (or low) is $< +0.8$ V.
logic 1 (or high) is $> +2.0$ V.

TRIGGER

A trigger signal (line, Y1, Y2, or Ext) is selected by Trig Select switch SW702, and is coupled through the trigger coupling circuits to the trigger amplifier circuits. External trigger signals are first routed through an impedance converter before they are applied to the Trig Select switch. This impedance converter consists of source follower Q701B, constant current source Q701A, and emitter follower Q702. R701 and R702 set the input impedance, R703 and D701 provide over-voltage protection, while C703 forms a high frequency path around R703.

External trigger zero control R705 sets the bias voltage so that the emitter of Q702 is at zero volts. R701, R702, C701, and C702 form a compensated high impedance divider. Q703 and Q704 are the common emitter section of a cascode amplifier which couples the external trigger/Y3 signals (both of which come from the same input connector) to the vertical preamp board for channel Y3. The common base section of the cascode amplifier uses Q606 and Q607 on the vertical preamp board.

The trigger coupling switches allow you to select one of six coupling modes: DC, AC (through C712), AC-HF (through C713-- passes only signals of 5000 Hz or greater), AC-LF (capacitors C714 and C785, and R723 form a low frequency divider that passes only AC signals under 5000 Hz), TV-V, and TV-H (see next paragraphs).

U716 and its associated circuitry form a sync separator to provide stable triggering on composite video signals. When the TV-V or TV-H pushbutton of SW703 is pressed, trigger signals are processed by the sync separator before they go to the trigger amplifier. In normal operation, the input to the sync separator will be a composite video signal. This signal consists of vertical and horizontal sync pulses along with the TV video information. The sync separator removes the video information and separates the vertical and horizontal sync pulses. These separated pulses can then by used by the trigger amplifier, to give a stable display.

U716D is arranged as a noninverting amplifier with a gain of 10. Amplifier U716C also receives an input signal, through R950, which is controlled by Trigger Select slope switch SW702. In the + slope position, SW702 applies −5 volts to R750, causing the output of U716C to clamp at +15 volts. This prevents U716C from passing any AC signals. Since C786 blocks DC signals, putting the slope switch (SW702) in the + position effectively turns off the inverting amplifier (U716C). If the slope switch is in the – position, the input to R750 is grounded. Since no current flows through R750 in this case, it does not affect U716C, which then functions as a normal inverting amplifier with a gain of 10.

U716B is used to sum the outputs of U716C and U716D. If U716C is turned off by SW702, the only input to U716B is from U716D. Since U716B is arranged as an inverting amplifier, the output of U716B will be an inverted version of the composite video signal from U716D. If U716C is turned on, U716B will sum the signals from U716D and U716C. However, since R964 is smaller than R963, the signal from U716D will be smaller than the signal from U716C. The resultant signal will then be the noninverted version of the composite video signal (at U716B's output). In this way switch SW702 controls whether an inverted or noninverted composite video signal appears at the output of U716B.

Since the sync detector that follows U716B only works with negative-going sync pulses, SW702 can be used to provide negative-going sync pulses, no matter which way the sync pulses are going on the input signal. If the input signal has negative-going sync pulses, the slope switch should be in the – position. Similarly, if the input signal has positive-going sync pulses, the slope switch should be in the + position.

C787 couples the composite video signal to silicon diode D744, which clamps the negative-going sync pulses to –.7 volts. This signal is then applied to the positive input of U716A. The negative input of U716A is held at –.3 volts by germanium diode D745. U716A is used as a comparator whose output is high (+15 volts) whenever the composite video signal on pin 3 is more positive than –.3 volts. Only the horizontal and vertical pulses (which are clamped at –.6 volts) can make pin 3 more negative than –.3 volts. Therefore, whenever a horizontal or vertical sync pulse occurs, the output of U716A goes low (–15 volts). This makes the output of U716A a series of negative pulses synchronized to the horizontal or vertical sync pulses (with all video information removed).

Separation of these horizontal sync pulses into vertical and horizontal trigger information is performed by C789 and R969, C709, C788, R968, C796, and R972. Capacitor C789 and R969 form a high-pass filter that passes only the horizontal sync pulses to SW703, where they can be selected as the trigger source (TV-H). The low-pass filter formed by C788, R968, C796, and R972 removes the horizontal sync pulses. The vertical blanking pulse passes through the filter, since it is at a much lower frequency than the horizontal sync pulses. C709 passes the vertical sync pulses to SW703, where they can be selected as a trigger source (for TV-V).

From the trigger coupling switches, the trigger signal is applied to the high input impedance FET follower formed by Q705 and Q706. R725 sets the current through the FET to give a signal voltage (center value) of –.7 volts on the emitter of Q706. This signal is amplified, with the voltage on Trig Select Level control R728, by the cascode amplifier formed by common emitter transistors Q707 and Q708, and common-base transistors Q711 and Q712. Q709 supplies current for this amplifier; this current is adjusted to give a center voltage of –1.35 volts on the collectors of Q711 and Q712 (ECL center voltage). This stage has a gain of approximately 10 and also serves as a translation from analog levels to ECL logic levels. The line receiver, U701, amplifies and shapes (squares up) the trigger signal through R751 and R747: U701C drives both the trigger logic and the auto baseline generator.

When one of the TV pushbuttons is pressed, U702D is inhibited, and U703B divides the trigger signal by 2 and applies it to U703A of the sweep control circuits. When both pushbuttons are out, the trigger signal is coupled through U702D to the sweep control circuits. The auto baseline circuit consists of Q713, Q714, and Q715. When a trigger signal is present, Q713 and Q714 conduct and turn Q716 on, which turns on Trig LED D707. When there is no trigger signal; C719 discharges through R758, Q715, and R761, and causes Q714 and Q715 and the LED to turn off.

SWEEP

Consider the circuit as shown in the Schematic, with the Trigger Mode Auto pushbutton pressed in. With trigger signals coming in, both pins 12 and 13 of U704C are at logic low. This means pin 14 is high and pin 6 of U704B is low. When the end of the sweep is sensed, U703A is reset by a high at pin 4 by U706 via U707, U708, and U705, and then waits for another trigger signal at pin 6. When there are no trigger signals coming in, U704C pin 13 goes high (Q715 turns off) and drives pin 14 low. At the end of a sweep, pin 10 of U704B is driven low by the output of U707A, pin 3. With low's on U704B input pins 9, 10, and 11, output pin 6 is high, which automatically keeps setting U703A and starting a new sweep at the end of the previous one.

When the Trigger Mode Norm pushbutton is pressed, the Auto button is out and puts an ECL high on pin 9 of U704B. This keeps pin 6 low so that U703A will only start a sweep when a trigger signal comes in to pin 6.

Sweep control U703A changes state when a trigger signal is received at pin 6. This transition is translated to TTL levels by Q717 and Q718, and applied to transistor Q719.

A low from the translator turns off Q719 to allow the A sweep generator to generate a ramp. Resistors R803, R804, R805, R806, R807, R808, and R809 are timing resistors and are selected by a Time Base switch. Capacitors C723, C724, C725, and C726 are timing capacitors, also selected by this switch. Q721 is a FET follower to monitor the ramp increase and Q722 is an emitter follower that drives the bootstrap circuit and the "B" time delay trigger amplifier.

Q761 provides the drive to circuits connected to the sweep generator. Resistor R802 and Variable Time control R801, plus D708, D709, and R997, form a bootstrap circuit that maintains a constant voltage across the timing resistors to give a constant current through them, charging timing capacitors C723, C724, C725, and C726, which produces a linear ramp. This circuit is connected between the emitter of Q722 and the +90 volt power supply. The ramp signal is connected to resistors R812 (sweep length control), R813, and R814.

When the ramp voltage reaches the level set by the sweep length control, U706A will change state. The pulse is coupled to pin 3 of U709A. Pin 14 of U709A will change state immediately. This pulse is coupled through U711C and B, to the blanking amplifier to blank the CRT. The output of U706A is also coupled to a delay monostable consisting of U707 C and D. The circuit delays the control pulse long enough for the blanking circuits to start blanking the tube; then it couples the pulse to U708.

U708 and capacitors C731 through C737, along with resistors R821 and R822 (the Variable Holdoff) form the trigger holdoff circuit that allows the sweep generating circuits to settle down before the sweep control IC (U703A) recognizes the next trigger pulse. U708 produces a pulse as soon as it receives the pulse from monostable (U707 C and D).

The pulse is coupled through U707A, translator resistors R818, R819, and R771 to pin 13 of U705C, to pin 4 of sweep control U703A.

Pin 4 is the reset pin for U703A. The outputs of U703A change state and turn on Q719, which discharges the timing capacitor and causes the retrace. The output of the translator at U707A is also connected to pin 10 of U704B. If the Trigger Mode pushbuttons are in the Auto position and there is no trigger signal, U704B will produce a pulse to make control IC U703A change state as soon as the holdoff time is finished; this in turn tells Q719 to turn off and allows the sweep generator to start a new ramp.

U706B monitors the output of the ramp generator. If the voltage at the top of resistor R814 becomes large enough, U706B will change state. Its pulse is also coupled through U707A and U705C to pin 4 of control U703A, telling it to end the ramp. This circuit bypasses the holdoff circuit and acts as an anti-lockup circuit to reset the ramp generator, both in case of a missed pulse and during initial turn-on of the Oscilloscope.

In the single-sweep operation an ECL low at pin 11 of U705B occurs when the Trigger Mode Single switch is pushed. This enables cross-coupled latch U705A and U705B. Pin 13 of U705C and pin 4 of U705A are normally low between sweeps. Pushing the Single pushbutton to reset it, causes an ECL high to be coupled through noise filter C722, R793, and R794 to pin 10 of U705B. This puts an ECL low on pin 6 of U705B, pin 12 of U705C, and pin 5 of U705A. This produces an ECL low on the reset side of U703A (pin 4) and allows it to sweep when a trigger signal is detected and the toggle input (U703A pin 6) is pulsed low. The "end of sweep" signal appears at U705A pin 4 as an ECL high, causing the latch to change state and put an ECL high on U703A pin 4. This prevents another sweep until the pushbutton is pushed to reset it again, and the latch changes back to wait for another pulse.

While the single-sweep function is in the ready (armed) state, U705B pin 7 is high and pin 6 is low. This reverse biases the base-emitter junction of Q763, turning it off to allow Ready light D757 to light through pull-up resistor R979. After a sweep, the levels on pin 6 and 7 are reversed, turning on Q763 and pulling down the anode of D757 to turn it off. During Auto and Normal operation, the cathode of D757 is opened from ground by SW703, assuring that it cannot light.

The output of the sweep generator, from Q761, is coupled through R797 and switch SW703 to the horizontal amplifier. The signal is also coupled from the emitter of Q722 to the B time base trigger circuits, transistors Q725, Q726, and Q727. R851, the Delay Time Position control, sets the point at which the B trigger circuits will trigger. The output of Q727 is coupled through capacitor C752 to the input of U715B. U715A and U715B are cross-coupled gates. As soon as the pulse is supplied to pin 5, pin 6 goes high and is coupled through U715C to ramp switch Q728. The low at Q728 causes it to turn off, allowing the B sweep generator to generate a ramp. Transistor Q729 is connected as an FET diode and limits the discharge current when Q728 turns on to end the sweep.

Timing resistors R871 through R877 and timing capacitors C754 through C757 operate similarly to those of the A sweep generator previously described. Q731 and Q732 monitor the ramp. Diodes D723 and D724 form a bootstrap circuit to maintain a constant voltage across the timing resistors. The output of the sweep generator is connected to sweep length control R867 and resistor R863. When the amplitude of the signal reaches the predetermined value, U715D changes state. The output from U715D is coupled through a delay circuit, R860 and C753, and connected to pin 1 of U715A. This resets the flip-flop and the signal is coupled through U715C to Q728. This turns on Q728, which discharges the timing capacitor and ends the sweep.

The output of the B sweep generator is connected to the horizontal amplifier through the circuit board B Cal control R868 and switch SW703. When the delayed sweep feature is not being used, the B sweep generator is locked out by switch SW703, connected to pin 10 of U715C and keeps any of the pulses from reaching Q728.

U712 and U713 form a logic array to control the dual-trace functions of the Scope. Sections C and D of U712 are connected as an oscillator which operates at approximately 500 kHz. In the Chop mode, this oscillator supplies the switching signals for the vertical channels. U713C provides the output for the chop signal to the blanking amplifier, and U713D provides the output to the vertical board for the toggle function. Pin 13 of SW701 is connected to the preset of U709A so that when the Oscilloscope is in the X-Y mode of operation, the CRT is turned on. U709B is the blanking control for B sweep generator. U711 A, B, C, and D multiplex the A and B sweep generator blanking signals for the various modes of operation. Diodes D713, D714, D715, and D716 connect the blanking signals to blanking control U709 when the different modes of operation are selected.

HORIZONTAL AMPLIFIER

The horizontal amplifier has several inputs which can be selected from the front panel. They are the A time base, A-B, B delayed time base, and X-Y. In the X-Y mode, the trigger amplifier from channel Y2 is connected through circuit board X-Y Cal control R888 and switch SW701 pin 34 to pin 35.

In the A and A-B modes, the A ramp signal from Q761 is routed through SW703 (pins 5 and 8, to pins 6 and 9) and SW701 (pin 36 to 35) to Q739. In the B mode the B ramp signal from Q762 is routed through SW703 (pin 14 to pin 15) and SW701 (pin 36 to pin 35).

The horizontal amplifier consists of two stages, an input stage and an output stage. The input stage is a cascode amplifier with two sets of common-emitter transistors and two sets of common-base transistors. The two common emitter stages each have their own current source, to provide for either X1 operation or X10 and X-Y operation.

When the Horizontal Position, Pull For X10 knob is pushed in, there is a logic 1 (5 volts) applied to pin 1 of U713A. This produces a high at pin 3, and turns off Q736 and current source Q737. This keeps transistors Q741 and Q742 turned off (the X10 amplifier pair). The high from pin 3 of U713A is also connected to pins 12 and 13 of U714D, forcing pin 11 to be low. A low at pin 11 turns on transistor Q734 and current source Q735. This turns on the X1 gain stage amplifiers, Q738 and U739.

When the X10 operation is chosen (Pull For X10 knob pulled), switch SW706 closes. Q736 and current source Q737 are turned on, turning on the X10 amplifier stage, Q741 and Q742 of the amplifier. Transistors Q734 and Q735 and X1 amplifiers Q738 and Q739 are turned off.

During X-Y operation the signal on U713A pin 2 turns on the X10 section and is also applied to U714C. This turns on Q733 which limits the Horizontal Position control R884 in horizontal operation. Q758 is turned off by the low on U713A pin 2, and Q759 turns off removing the − 0.7-volt supply from R884 and R885. This further limits the position controls. Diodes D732 through D735 prevent the input transistors from being reverse biased at the extremes of the position control. The signals from the common emitter section then go to common base transistors Q743, Q744, Q745, and Q746. These transistors, along with diodes D737 and D738, form a current limiter to limit the signal currents to the output stage when X10 operation is selected.

Q747 and Q748 are the input transistors for the output stage, which is a shunt feedback amplifier. The gain of this amplifier is set by the ratio of R926 to R943, and R931 to R944, and is approximately 40. Q749 and Q751 are emitter followers that drive output transistors Q755, Q756, Q754, and Q757. Q752 and Q753 are translaters to couple the signals to Q754 and Q757. The bias adjust control R932, with R927 and R928, sums the currents into the output stage and sets the output voltage to the optimum value required by the CRT.

CALIBRATOR

Sections A and B of U714 are connected as an oscillator with a frequency of approximately 1000 Hz. The output of the oscillator is coupled by resistor R827 to the base of transistor Q723. Q724 is a constant current source for D719, a 5-volt zener. The 5 volts at D719 is divided by R832 and R833 to produce 1 volt. As Q723 is turned on and off by U714, the 5 volts to D719 is alternately shorted to ground and allowed to return to 5 volts. This produces the 1-volt square wave at R833, which is available at the front panel as Cal 1V (P-P).

POWER SUPPLY

LOW VOLTAGE POWER SUPPLY

Line voltage enters the Scope through fuse F1 and switch SW1 and goes to the primary of transformer T1. Switch SW2 puts the primary coils on T1 either in parallel for 120-volt operation or in series for 240-volt operation. SW3 selects whether the high or low voltage tap on the primary is used. The 6.3-volt secondary of transformer T1 powers the CRT filament. Other secondary windings supply the high voltages for the high voltage oscillator, the deflection circuits, and other CRT bias circuits. Diodes D102 and D103 together make a full-wave rectifier, and capacitor C107 supplies the filtering.

R102 adjusts the voltage to the geometry control grid of the CRT. C111 is a simple bypass capacitor. The voltage from C107 is applied through R104 to C112 for further filtering. This voltage (approximately 130 volts) powers the horizontal deflection amplifier circuits, and the high voltage oscillator circuits. Another rectifier and filter circuit (D104, D105, C109, R105, and C108) supplies voltage to regulator transistor Q105 to produce constant voltage for the vertical deflection circuits.

Q101, Q102, Q105, Q103, and Q104 make a 90-volt regulator for the vertical deflection circuits. Resistors R116 and R117 form the divider that sets the output voltage. R115 and Q106 provide the short circuit shutdown circuit. D107 and R118 provide the reference for the regulator.

The next secondary on the transformer is connected to diodes D108, D109, D111, and D112. This makes a positive and negative full-wave rectifier system.

The AC output of this secondary voltage is applied to R122, C114, R123, C115 and R124, C116, and C117 to supply voltage for the line trigger signal. The RC networks filter the 60 Hz signal for more reliable line triggering. The rectifier output (from D108 through D112) is filtered by C123, C124, C125, and C127. These voltages are applied to regulators U101 and U103. Resistors R126 and R125 set the bias for +15-volt regulator U101. Resistors R129, R131, R128, R127, and op amp U102 make up a bias arrangement to force −15-volt regulator U103 to track the +15-volt regulator. C126 and C128 provide output filtering and prevent oscillation.

Another secondary connects to diodes D113, D114, D115, and D116. The output is filtered by C157, C134, C158, and C135, and applied to U104 and U105. C136 and C137 further filter the voltage coming from the +5-volt and −5-volt regulators and suppress any oscillations. Resistors R132 and R133 set the bias for the −5-volt regulator. R175 and C138, and R174 and C139 are decoupling RC networks for the + and − 5 volts used on the low voltage board. The capacitors around the rectifier diodes are used to minimize noise being radiated from the line cord.

HIGH VOLTAGE POWER SUPPLY

The previously mentioned voltage from the +130-volt supply on the low voltage power supply board is connected to R216 of the high voltage power supply. R216 and C201 form an RC filter to keep noise from feeding from the high voltage oscillator into the rest of the Oscilloscope. R215 supplies +15 volts to operate regulator U201. Q201 is a simple series-pass transistor that sets the voltage at the primary of high voltage transformer T201. The output voltage of T201 is proportional to the voltage at this point.

T201, Q202, C203, R203, R202, and C204 make a class C high voltage oscillator circuit. The purpose of R202 is to start the oscillator initially and maintain DC bias. C204 acts as a resonator circuit for the primary of the transformer, and C203 maintains a bias on Q202 while the oscillator is operating. RF voltage at the secondary of this oscillator, which is about 40 kHz, is fed to the packaged tripler on top of the transformer and is multiplied up to 8500 volts.

The voltage from the other secondary is rectified through D201 and filtered by C205, R204, and C206. This voltage is about −1341 volts, and supplies the CRT gun circuits. The CRT cathode, which is at −1250 volts, is hooked directly into the resistor divider string consisting of resistors, R211, R212, R213, R214, Focus control R365, R217, and High Volts Adj control R209. This resistor string supplies the bias voltages required for the CRT and voltage regulator U201.

U201 is an operation amplifier connected as an inverting amplifier. A 7.5-volt reference voltage is provided by resistors R207 and R208 to pin 3. Resistor R209 is connected to the +15-volt supply and then to pin 2 through R217. Pin 2 is also connected to the rest of the divider resistors coming from the −1250-volt supply. The current through this resistor-divider network causes a voltage drop across R209 and R217 at pin 2 that is equal to the reference voltage at pin 3. If the High-Voltage control is rotated or the −1250 volts changes, the voltage at pin 2 will change. U201 will cause the −1250 volts to change to keep the voltage at pin 2 equal to the voltage at pin 3.

The output voltage of the operational amplifier varies typically between 0 and 15 volts. This drives Q203, which translates this voltage up to approximately 90 to 125 volts to drive pass transistor Q201. R206 limits the base current into Q203. The collector current of Q203 is supplied by R201 and connects directly to the base of Q201. The emitter voltage at Q201 is about .6 volt below the base, and that is the voltage that runs the high voltage oscillator circuit. If the −1250 volts should drop (for example, to −1150 volts), there would be more voltage at U201 pin 2.

In order for U201 to maintain balance, its output voltage would have to drop. This in turn would feed less current to Q203, which would increase the collector voltage of Q203 and the base of Q201. Therefore, the emitter voltage of Q201 would go up, which would supply more voltage to the oscillator circuit itself. This would supply enough extra voltage to the input of the oscillator to again put −1250 volts at the top of the resistor string, and balance the circuit.

BLANKING CIRCUITS

The purpose of the CRT blanking circuits is to control the intensity of the trace. The trace has to be turned off after each sweep (for retrace) and has to turn on to a specified level (controlled by the Intensity control) during each sweep. During X-Y operation, the trace is always left on, to the level specified by the Intensity control. When in the A-B mode, the trace has normal brightness during the A sweep, but is intensified during the B portion of the sweep.

Since the control grid and cathode voltage of the CRT is about 1250 volts below ground (−1250 VDC), and the other Oscilloscope circuits are near ground, the blanking circuits have to translate the DC voltage coming from the blanking amplifier to the control grid. This is done by amplitude modulating an oscillator (Q112 and Q113) that is capacitor-coupled by C153 to a demodulator, D127 and D128. This demodulator is referenced to the −1341-volt supply, and its output is coupled to the CRT control grid by R169 and R172.

The amplitude of the oscillator output follows the DC output of the blanking amplifier on a one-to-one basis. The output of the demodulator follows the peak value of the oscillator waveform. This means, then, that the DC output of the blanking amplifier is translated to the CRT grid on a one-to-one basis.

An oscillator signal of larger amplitude (as adjusted by the Intensity or CRT Bias controls) will produce a more positive DC voltage on the CRT grid which will make a brighter trace. A retrace pulse will reduce the amplitude of the oscillator signal, and the resulting reduced DC voltage will turn off the CRT during "retrace" or "holdoff."

To fully understand the blanking circuits, keep the following two ideas in mind.

1. The CRT is fully blanked when the control grid is 91 volts more negative than the cathode.
2. As the 91-volt difference between the grid and cathode is reduced, the CRT unblanks and the beam intensity increases.

The blanking amplifier (Q107 through Q111) provides the necessary gain to amplify the input blanking pulses and the voltage from the Intensity control. The Intensity control controls the output DC level of the amplifier (collectors of Q109 and Q111), and the input blanking pulses reduce this DC level for the duration of each pulse. The leading and trailing edges of the amplified blanking pulses are capacitor-coupled to the grid of the CRT by C152 and R172.

The blanking amplifier has a common-base input stage, Q107. Here, the input blanking pulses and the Intensity control voltage are summed in its emitter. Transistors Q108, Q109, and Q111 are current and voltage amplifiers whose gain is determined by the ratio between feedback resistor R151 and the appropriate input resistor: R135, R137, R138, R139, R142, R143, or R141. Capacitor C144 is for high frequency compensation.

The blanking amplifier is coupled to the emitter of Q113 by R155 and R156. Q113 and Q112 form an emitter-coupled oscillator. Capacitor C147 and emitter resistor R158 determine the frequency of oscillation, which is approximately 200 kHz. Diode D125 protects Q113 from negative spikes during turn-on when C153 charges. D126 is referenced to a maximum voltage that the oscillator is limited to and clamps the output of the oscillator if it tries to exceed this voltage. The reference voltage is set by resistors R167 and R168, and C151 filters this voltage.

As shown in Pictorial 12-1 (Illustration Booklet, Page 3) column A, if a sweep is started, a blanking signal from the horizontal board is applied to the input and/or if the Intensity control is changed, the output of the first section of the blanking amplifier will be an unblanking pulse with a maximum amplitude determined by the position of the Intensity control. This, in turn, controls the amplitude of the oscillator for the second section, which will change the value of the DC voltage at the output of the demodulator. This will unblank the CRT or change the intensity of the trace.

The unblanking pulse from the output of the first section of the blanking amplifier is also coupled directly to the grid by capacitor C152 and resistor R172. Capacitor C152 supplies the fast path around the oscillator section. This unblanks the CRT immediately, then the oscillator can follow and hold the screen on at the level set by the Intensity control, until a blanking pulse is applied to the input. Then the output of the first section of the blanking amplifier will go low, and this will decrease the level of the oscillator output and blank the CRT.

On Pictorial 12-1 (Illustration Booklet, Page 3), the "A-B" column shows both the A and B sweep signals and their separate blanking signals. Only the A ramp is used, but both blanking signals are summed by Q107 and displayed (from the Q111 collector) in the fifth display of the "A-B" column. The B portion of the trace is intensified as shown at the bottom of the Pictorial. In the B mode (column 3 of the Pictorial), the B ramp is used for the sweep. The B ramp is delayed and starts at a selected time after the A ramp starts.

Circuits on the horizontal board route the B blanking signals to drive the A blanking output during the B mode. This corrects for brightness that is lost when the tube is blanked during the A ramp and only turned on during the B ramp. This blanking creates a lower on-to-off ratio and a dimmer trace. Using the B Ends A control also counteracts the loss of brightness by decreasing the turn-around time of the A trace.

Two other signals are available to the input of the blanking amplifier, and are summed the same way as the A and B blanking signals. These are the chop blank input and the external Z-axis input.

CALIBRATION

This section of the Manual is divided into two parts: "Initial Calibration" and "Touch-Up Calibration." Perform the "Initial Calibration" after you complete the Oscilloscope, or after parts have been replaced. Perform the "Touch-Up Calibration" after the "Initial Calibration" and also whenever you doubt the accuracy of your Oscilloscope. Always allow the Scope time to warm up and stabilize before you do the calibration procedure. NOTE: In this section of the Manual, the names that are on the front panel (controls and their positions) are printed in ALL CAPITAL LETTERS; names on the circuit boards and other names not printed on the front panel are printed with Initial Capital Letters.

INITIAL CALIBRATION

You need the following equipment to calibrate your Oscilloscope:

- A volt-ohmmeter (VTVM or DMM).
- An oscilloscope calibrator or a square wave generator capable of producing 1000 Hz to 1 MHz signals, with up to 5 volts output, a rise time of 1 ns or better, and overshoot of less than 1%.
- A sine wave generator capable of 100 kHz.
- A 1000 Hz square wave voltage calibrator (with adjustable output of up to 10 volts) is also recommended, but not necessary. It should be accurate in amplitude to 1% at 1 volt and accurate in frequency to 1%.

Controls and adjustments associated with channel Y1 are identified as Y1 or CH1, or by component numbers in the 400 series, such as R402. Those identified with channel Y2 are identified as Y2 or CH2, or by component numbers in the 500 series. Use the plastic alignment tool supplied with this kit to reach and make the adjustments.

If you do not obtain the proper results in the following steps, turn the Oscilloscope off, refer to the "Troubleshooting" section of the Manual, and correct any difficulties before you proceed.

NOTE: Pictorials 14-1 through 14-5 have been placed in the Illustration Booklet on Pages 4, 5 and 6, because they are referred to from many different pages in this Manual section. This will free you from having to turn pages in this Manual to find the appropriate Pictorials while you read.

illustration Book from the operators manual.

LINE VOLTAGE

WARNING: Observe the safety precautions that pertain to your particular voltmeter when you measure the power line voltage in the following step.

NOTE: With the cabinet removed from the Oscilloscope, some signal drift will occur. This is due to thermal drift of the very sensitive vertical preamplifier; removing the cover, places it in an unstable temperature environment.

1. Measure the line voltage available at your power outlet.

2. If the line voltage is below 115 VAC (or 235 VAC, whichever is applicable) set the rear panel NOR-LOW switch to LOW. Otherwise, leave it in the NOR position. (More detailed instructions on how to do this are available under "Operation," on Page 11-1.)

3. Connect the Oscilloscopes, line cord plug to the power source.

WARNING: When the line cord is connected to AC power, this AC power will be present at several places on the chassis and on the control circuit board. When the Oscilloscope is turned on, high voltage DC will also be present. Be careful that you do not contact these voltages, or you may receive an electrical shock. See Pictorial 14-1 (Illustration Booklet, Page 4).

4. Turn the INTENSITY-OFF switch clockwise to midposition. The power indicator should light. You may or may not see a display on the CRT. If you do have a display, turn the FOCUS control fully counterclockwise so the display does not burn the phosphor on the CRT screen.

5. Allow the Oscilloscope to warm up for 30 minutes before you proceed.

HIGH VOLTAGE ADJUSTMENTS

Refer to Pictorial 14-1 to locate the high voltage circuit board.

Set your voltmeter to measure −1500 volts DC.

Connect the negative voltmeter lead to the Oscilloscope chassis.

Refer to the inset of Pictorial 14-2 (Illustration Booklet, Page 5) and measure the voltage at pin 4 of the CRT. Adjust High Volt Adj (R209) control to give a reading of −1250 volts.

NOTE: If your voltmeter will not measure −1500 volts, you may use the following procedure, with a 10 M Ω input voltmeter and the 10 M Ω resistor supplied with your kit.

1. Turn the Oscilloscope off.

2. Solder one end of the resistor to pin 4 of the CRT socket, shown in Pictorial 14-2 (inset).

3. Turn on the Oscilloscope power.

4. Measure at the other end of the resistor for −625 volts, adjusting control R209 to get the desired voltage.

5. Turn the Oscilloscope power off.

6. Remove the 10 MΩ test resistor.

VERTICAL PREAMP INITIAL (DC) SETUP

Refer again to Pictorial 14-1, to see where the circuit boards are. Make all voltage measurements with the meter common lead connected to the chassis. Refer to Pictorial 14-4 (vertical preamp board) for the test points mentioned in the following steps.

1. Set the front panel controls as indicated below:

(Y1) AC-GND-DC	GND
Y1 VOLTS/CM	5 mV
(VOLTS/CM) VARIABLE	CAL
Y1 POS	Midposition
(Y2) AC-GND-DC	GND
Y2 VOLTS/CM	5 mV
(VOLTS/CM) VARIABLE	CAL
DISPLAY MODE pushbutton	Y1
Y2 POS	Midposition
Time Base pushbuttons	A
Trigger Mode	AUTO
TIME/CM	1 mS
VARIABLE TIME	CAL
Trigger Coupling	AC

2. Turn on the Oscilloscope power (if it is not already on).

3. Measure the voltage at pin 9 of switch SW402D (TP1) on the vertical preamp board and adjust Y1 Step Bal control R414 to give zero volts.

4. Measure the voltage at pin 9 of switch SW502D (TP2) of the vertical preamp board and adjust Y2 Step Bal control R514 to give zero volts.

5. Alternately measure the voltages at TP3 and TP4 (the indicated ends of R693 and R694), and adjust the Y1 POS control (front panel) until they are equal. Then adjust Y1 Trig Zero R477 for a voltmeter reading of zero volts at TP5 (R487).

6. Change the DISPLAY MODE pushbuttons to Y2. Alternately measure the voltages at TP3 and TP4, and adjust the Y2 POS control (front panel) until they are equal. Then adjust Y-2 Trig Zero R577 for a voltmeter reading of zero volts DC at TP6 (R587).

7. Measure the voltages at pins 11 and 13 of the CRT socket (inset on Pictorial 14-2). Adjust front panel Y2 POS control to equalize the two voltages. Adjust R351 on the vertical deflection board (Pictorial 14-11, Illustration Booklet, Page 5) for a reading of +47 VDC on both pins.

Refer to horizontal board Pictorial 14-5 for the following steps.

8. Change the TIME/CM control to the X-Y position. Refer to Pictorial 14-5 and measure the voltage at the emitter of Q722. Adjust the A Zero control, R795 to give a reading of zero volts DC.

9. Measure the voltage at the emitter (E) of Q732. Adjust B ZERO control R864 for zero volts DC.

10. Alternately measure the voltages at the collectors (tabs) of Q754 and Q757. Use Y1 POS (front panel) to adjust the voltages until they are equal. Then adjust Horiz Bias R932 control to give a reading of 60-volts DC on each collector.

11. Measure the voltage at the emitter of Q706 and adjust Trig Zero control R725 to give a reading of −0.65-volts DC.

12. Measure the voltage at the emitter of Q702 and adjust Ext Zero control R705 to give a reading of zero volts DC.

13. Turn off the Oscilloscope power.

Refer to Pictorial 14-14 (Illustration Booklet, Page 8) for the following steps.

( ) Making sure the lettered side is positioned outward as shown, carefully install the preamplifier shield on the outside of the vertical preamplifier assembly. Be sure the front tabs of the shield are under the two wire loops, the two .02 μF ceramic capacitors (C401 and C501), and the two 5.1 Ω resistors are positioned as shown. Be sure that capacitor C401 does not cover any of the shield (alignment) holes.

( ) Loosely mount the center of the shield onto the inner preamplifier shield with three 4-40 × 1/4″ screws at DE, DF, and DG.

( ) Loosely mount the top and bottom edges of the shield onto the top and bottom cover with four 4-40 × 1/4″ screws. Then tighten all seven shield mounting screws.

( ) Bend the two wire loops at the front of the shield down onto the shield surface; then solder both loops to the shield.

( ) Carefully check to make sure that none of the wires or component leads are shorting to the preamplifier shield.

BEAM ADJUSTMENTS

Beam adjustment controls that are not found on the front panel are on the low voltage power supply, Pictorial 14-3 (Illustration Booklet, Page 5).

Reset the front panel controls as follows:

Vertical Section (Y1)	
AC-GND-DC	GND
VOLTS/CM	.1 V
VARIABLE	CAL
Y1 POS	Midposition
Vertical Section (Y2)	
AC-GND-DC	GND
VOLTS/CM	.1 V
VARIABLE	CAL
Y2 POS	Midposition
Y2 INVERT	Out
DISPLAY MODE	Y1
Horizontal Section	
Time Base	A
HORIZ POS	Midposition and pushed in
A TIME/CM	.1 mS
VARIABLE TIME	CAL
VARIABLE HOLDOFF	NORM
Trigger Section	
Trigger Mode	AUTO
Trigger Coupling	AC
TRIG SELECT	EXT +
LEVEL	Fully CW
Beam Section	
INTENSITY	Midposition
FOCUS	Midposition

A trace should appear on the CRT. If there is none, refer to Pictorial 14-3 and turn Bias Adj control R166 CCW until a trace appears.

Adjust the HORIZ POS control to start the trace on the left edge of the graticule.

Turn the INTENSITY control fully CCW, without turning the Oscilloscope off.

Readjust Bias Adj R166 until the trace is just turned off. Then turn the INTENSITY control slightly CW until a faint trace appears again on the CRT.

Check the ends of the trace for equal brightness. If they are not equal, adjust Level Adj control R164 in either direction to get them equal. NOTE: Each time you adjust R164, you will have to readjust Bias Adj R166 back to the original display level. Continue adjusting these two controls until you have a faint trace that has equal brightness at either end.

Adjust the INTENSITY control until you have the display brightness you desire.

Change the TIME/CM switch to the X-Y position.

Adjust the Y1 POS and Y2 POS controls to center the dot on the screen. Then adjust the FOCUS and ASTIG controls to give as small and round a dot as possible. It may be easier to see how round the dot is if the Intensity is not too bright.

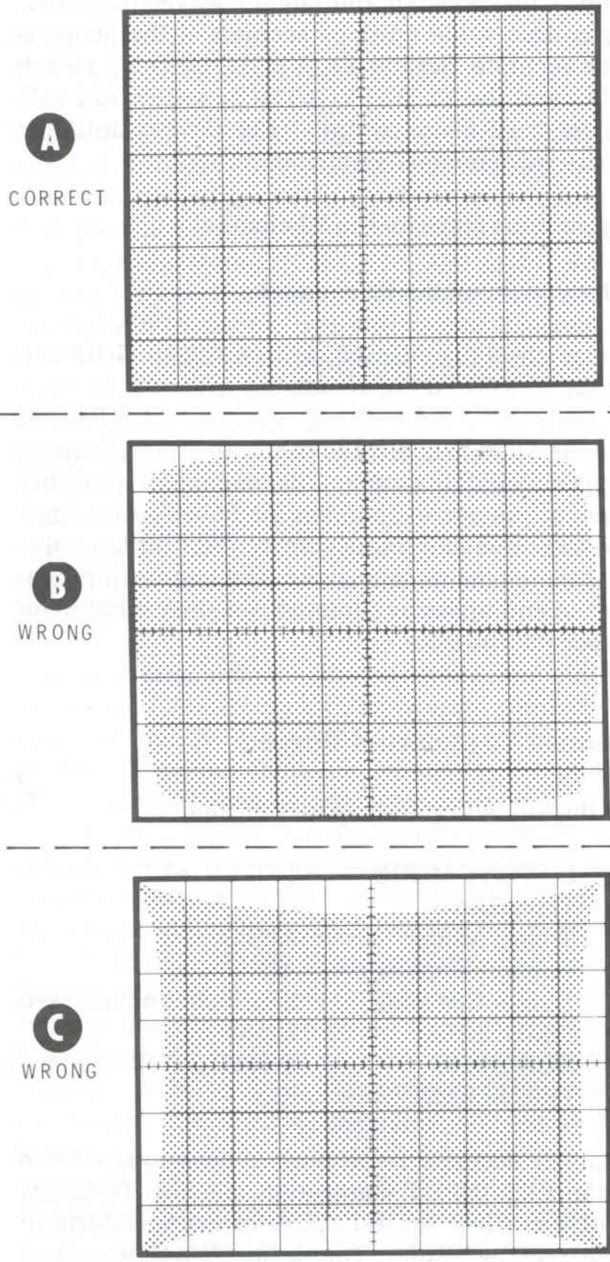
Change the TIME/CM switch to the 1 μS position.

Adjust the INTENSITY, Y1 POS, and HORIZ POS controls to give a trace centered on the screen. Adjust the TRACE ROTATION control to make the trace parallel with the horizontal graticule lines. NOTE: If the control does not turn far enough to level the trace, turn the Scope off, locate the control board at the front of the scope, and reverse the two wires plugged into J364 and J365.

GEOMETRY ADJUSTMENT

Set the (Y1) AC-GND-DC switch to AC. Connect a sine wave of approximately 1000 Hz to the Y1 input. Adjust its amplitude (or the VOLTS/CM switch and VARIABLE control) to give a display that is 8 cm high (equal to the height of the graticule). Use the Y1 POS control to center this display vertically within the graticule. Adjust A Length control R812 (horizontal board, Pictorial 14-5) and the front panel HORIZ POS control until the display is just 10 cm long (again, fitting it exactly within the graticule), as shown in part A of Pictorial 14-6.

Adjust Geometry Adj control R102 (low voltage board, Pictorial 14-3) until your display looks like Pictorial 14-6, part A. Do not leave the display bowed as in part B, or concave as in part C. If this adjustment changes the overall height or width of the display, readjust as you did in the previous paragraph. NOTE: Correct adjustment may occur when Geometry Adj is turned fully clockwise; this is normal.



PICTORIAL 14-6

Disconnect the sine wave input.

CONTRAST

1. Set the indicated front panel controls as follows:

DISPLAY MODE	Y1
A TIME/CM	1 ms
B TIME/CM	.1 ms
Time Base	A-B

2. Adjust the Contrast Adj control on the low voltage board (Pictorial 14-3) until the intensified portion of the trace is easy to see. NOTE: If you cannot see an intensified (brighter) portion, turn the INTENSITY control CCW until you can.

DC GAIN AND STEP BALANCE ADJUSTMENT

Channels Y1 and Y2

NOTE: you will go through this procedure twice. The first time you will adjust the Y1 channel; at that time, use the instructions as written, ignoring the material in brackets [ ]. The second time you will adjust the Y2 channel; use the controls, titles, and names included in the brackets for Y2. Set the following controls as indicated:

Y1 [Y2]AC-GND-DC	GND
Y1 [Y2]VOLTS/CM	50 mV
Y1 [Y2]VARIABLE	CAL
DISPLAY MODE	Y1 [Y2]
Time Base	A
Trigger Mode	AUTO
Trigger Coupling	AC
TIME/CM (A)	2 ms
HORIZ POS	In (PULL FOR × 10 is "off")
TRIG SELECT	Y1 + [Y2 +]

Adjust the INTENSITY, FOCUS, and ASTIG controls, if necessary, for a nice sharp trace. NOTE: The circuit board adjustment points in this section are shown on Pictorial 14-4, the vertical preamp.

Change the Y1 [Y2] AC-GND-DC switch to DC, then connect a 100 Hz (10 ms) square wave to the Y1 [Y2] input. Adjust the output of your generator to give a display that is about 6 cm (divisions) in height. Adjust the trigger LEVEL control for a stable display.

Adjust DC Adj R422 [R522] on the vertical preamp board, Pictorial 14-4, to make the horizontal portions of the square wave parallel to the horizontal graticule lines. For now, ignore the shape of the corners of the square wave.

Set the Y1 [Y2] VOLTS/CM control to 5 mV. Connect an accurate 20 mV square wave to the Y1 [Y2] input. Adjust the TIME/CM control to display several cycles of the waveform. NOTE: The vertical accuracy of this channel of your Scope will depend on the voltage accuracy of the square wave; a desirable accuracy is 1% or better.

Adjust Y1 [Y2] Gain (R463) [R563] until the square wave is exactly 4 divisions high from top to bottom.

Change the Y1 [Y2] AC-GND-DC switch to GND. Switch the Y1 [Y2] VOLTS/CM switch back and forth between 10 mV/CM and 5 mV/CM. You will probably notice a shift in the vertical position of the trace while doing this. Continue to switch back and forth, and adjust Step Bal R414 [R514] until switching the VOLTS/CM switch does not move the trace.

Use the Y1 [Y2] POS control to center the trace. Switch the VOLTS/CM control to 2 mV and adjust 2 mV Bal R441 [R541] control to bring the trace to the center of the graticule.

Reduce the level of the square wave to 10 mV. Again, this value must be accurate if the Scope is to be accurate. Set the Y1 [Y2] AC-GND-DC switch to DC, and the Y1 [Y2] VOLTS/CM switch to 2 mV. Adjust 2mV Gain control R439 [R539] until the square wave is exactly 5 divisions high.

Repeat these steps for the Y2 channel.

After you finish the Y2 channel:

Return the (Y2) AC-GND-DC switch to GND and set the Y2 VOLTS/CM switch to 5 mV.

Use the Y2 POS control to center the trace. Depress the Y2 INVERT switch. The trace will probably move off center. Adjust the Y2 POS control until you can press and release the INVERT button without causing the trace to move. The trace will probably not end up being centered. Use Invert Bal R589 to recenter the trace.

Channel Y3 (External Trigger)

Set the following controls as indicated:

DISPLAY MODE	TRIPLE, ALT
Time Base	A
Trigger Mode	AUTO
Trigger Coupling	AC
Trigger Coupling	EXT ÷ 10 is not pressed
TIME/CM (A)	2 mS
HORIZ POS	In (PULL FOR × 10 is "off")
TRIG SELECT	EXT +

Apply an accurate 1-volt peak-to-peak square wave to the EXT INPUT connection. Set the TIME/CM switch to allow several cycles of the waveform to appear on the display. Then adjust Y-3 Gain control R663 (Pictorial 14-4, vertical preamp board) until the waveform is exactly 5 cm from top to bottom.

HORIZONTAL AMPLIFIER

Set the following controls as indicated:

Channel Y1	
AC-GND-DC	GND
VARIABLE	CAL
Channel Y2	
AC-GND-DC	GND
VARIABLE	CAL
DISPLAY MODE	Y1
TRIGGER SELECT	Y1 +
LEVEL	Center of rotation

Refer to (horizontal board) Pictorial 14-5 to locate the following test or adjustment points.

You will need a voltmeter that measures −1.35 volts.

Measure the voltages at U701 pins 9 and 10. Adjust the front panel TRIGGER SELECT LEVEL control until the readings are equal. Then adjust Trig Bias control R736 to get −1.35 volts at either pin. If the other pin is not also −1.35 volts, readjust the LEVEL and Trig Bias controls until they are equal at −1.35 volts.

A Sweep Time

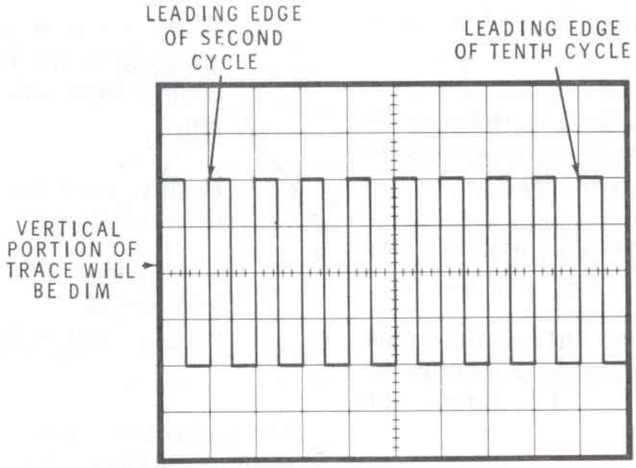
Connect an accurate 1 kHz (1 mS) square wave to the Y1 INPUT connector. Set the following front panel controls as indicated:

Y1 AC-GND-DC	AC
VOLTS/CM, and VARIABLE	As necessary to produce a display about 4 cm high.
DISPLAY MODE	Y1
Time Base	A
Trigger Mode	AUTO
Trigger Coupling	AC
TIME/CM (A)	1 ms
VARIABLE TIME	CAL
TRIG SELECT	Y1 +
LEVEL	As necessary to produce a stable display.

Use horizontal board Pictorial 14-5 to locate the following controls. If necessary, adjust A Length control R812 to give a trace that is at least 10 cm (the width of the graticule) long.

Adjust ×1 Cal control R907 and the HORIZ POS control on the front panel to give exactly 8 cycles in 8 divisions of the graticule as shown in Pictorial 14-7. Use the leading edge of the second and tenth cycles for this adjustment.

Readjust A Length R812 again, if necessary, to maintain at least a 10 cm long display.

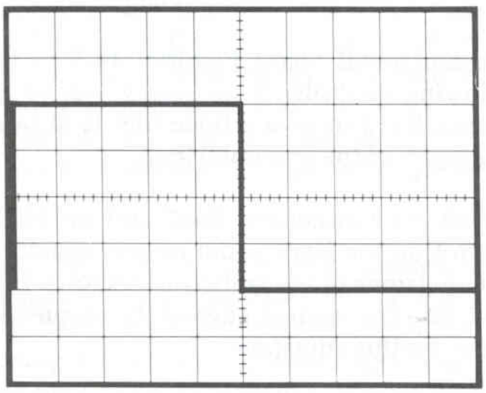


PICTORIAL 14-7

Pull out the HORIZ POS, PULL FOR ×10 control on the front panel. Then adjust ×10 Cal control R913 to give exactly 1 cycle in 10 cm as shown in Pictorial 14-8. When you make this adjustment, place the leading edge of the first cycle on the left-hand graticule line and the leading edge of the second cycle on the right-hand graticule line.

Push in the HORIZ POS, PULL FOR ×10 control.

Disconnect the square wave generator.



PICTORIAL 14-8

A Sweep Length

Use the Y1 POS and the HORIZ POS controls to center the trace on the screen. Then use the following 11 steps to adjust the length of the trace. Refer to Pictorial 14-5 horizontal board to see the adjustment controls.

1. Use A Length control R812, if necessary, to adjust the length of the sweep to exactly 10 cm (10 divisions of the graticule).

2. Use the HORIZ POS control to move the trace 2 cm to the left.

3. Readjust A Length control R812 until the right end of the trace has moved back 2 cm to the right edge of the graticule. The trace length is now 12 cm long.

4. **Position the left end of the trace on the left vertical graticule line.**

5. Set the following controls as indicated:

Time Base	A-B
TIME/CM (A)	.1 ms
TIME/CM (B)	2 µs
DELAY TIME POS	Fully CCW

6. Adjust Delay Min control R849 to place the left edge of the intensified portion of the trace 0.6 cm in from the left edge of the screen.

7. Turn the DELAY TIME POS control fully CW. This will move the intensified portion of the trace to the right.

8. Adjust Delay Max control R853 to place the left edge (beginning) of the intensified portion of the trace on the 10 cm mark of the graticule.

9. Use the HORIZ POS control to move the trace .6 cm to the left; then go back to Delay Max R853 control and use it to reposition the intensified portion of the trace at the 10 cm mark.

10. Move the DELAY TIME POS to the CCW end, the intensified portion of the trace should be at the 0 cm mark. If it is not, adjust the Delay Min (R849) to place it there. Then move the DELAY TIME POS to the CW end; the intensified portion of the trace should be at the 10 cm mark. If it is not, adjust the Delay Max (R853) to place it there.

11. Repeat step 9, until the trace moves exactly between the 0 and 10 cm marks on the graticule as you turn the DELAY TIME POS control from one end of its rotation to the other.

12. Finally, reset the A AND B TIME/CM controls as follows:

A TIME/CM	1 µs
B TIME/CM	.1 µs
DELAY TIME POS	Fully CCW

The intensified trace should be visible. If it is not, readjust the Delay Min (R849) control slightly until it is. This completes the A sweep length adjustments.

B Sweep Time

Reconnect the 1000 Hz square wave to the Y1 input and set the front panel controls as follows:

Y1 AC-GND-DC	AC
VOLTS/CM, and VARIABLE	As necessary to produce a display about 4 cm high.
DISPLAY MODE	Y1
Time Base	B
Trigger Mode	AUTO
Trigger Coupling	AC
TIME/CM (A AND B)	1 ms
VARIABLE TIME	CAL
TRIG SELECT	Y1, +
LEVEL	As necessary to produce a stable display.

Adjust B Length control R867 to produce a trace at least 10 cm long. Adjust B Cal R868, as you did before with the A sweep, to give exactly 8 cycles of the square wave in exactly 8 cm.

When you are done, disconnect the input and set the Y1 AC-GND- DC switch to GND.

B Sweep Length

1. Position the trace with the HORIZ POS control to start at the left vertical graticule.
2. Adjust B Length control R867 to set the length of the sweep at 10 cm (the width of the graticule).
3. Use the HORIZ POS control to move the entire trace to the left one cm.
4. Adjust B Length control R867 again, to change the trace length until the right end of the trace has moved back to the right edge of the graticule. The trace will now be 11 cm long.

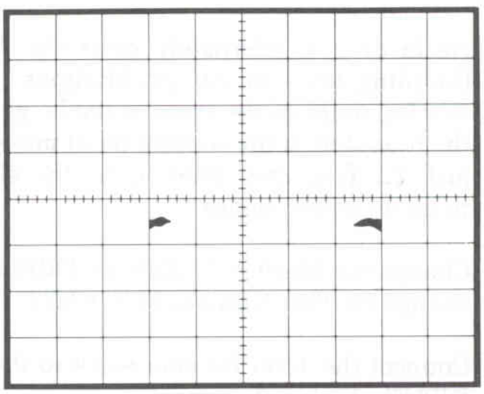
Fast Sweep Time

Continue on the horizontal board (Pictorial 14-5) for these steps. Push in the Time Base A pushbutton, set the A and B TIME/CM controls to 1 μs, and connect a 1 MHz square wave (1 μs) to the Y1 input. Set the Y1 AC-GND-DC switch to AC, and adjust the trigger LEVEL control for a stable display.

1. Set A Trim capacitor C726 to give 8 cycles in 8 cm as you did before.
2. Push in the Time Base B pushbutton, set the A TIME/CM switch to 2 μs. Pull out the B TIME/CM switch and set it to 1 μs.
3. Set B Trim capacitor C757 to give 8 cycles in 8 cm.

X-Y Calibration

1. Set the Y1 VOLTS/CM switch to .2 V and turn the TIME/CM switch to X-Y. Press the TIME BASE A pushbutton.
2. Use the Y1 control to position the trace approximately in the center of the screen.
3. Change the square wave generator frequency to approximately 1000 Hz, with a 1-volt peak-to-peak (± 1%) signal to the Y1 input.
4. Adjust the X-Y calibration control (R888, on the horizontal board, Pictorial 14-5) to place the dots exactly 5 cm apart as shown in Pictorial 14-9. Use the Y1 control also, if you wish, to position the dots for easier measuring.
5. Disconnect the generator.



PICTORIAL 14-9

Trigger Adjustment

Unless you are told otherwise, the controls mentioned in the following steps are either on the front panel or on the vertical preamp board (Pictorial 14-4, Illustration Booklet Page 5).

1. Set the following controls as indicated:

DISPLAY MODE	Y1
Time Base	A
TIME/CM	.1 ms
Trigger Mode	AUTO
Trigger Coupling	AC
TRIG SELECT	Y1 +

2. Center the trace on the graticule with the Y1 POS control.

3. Connect a 1000 Hz sine wave to the Y1 input, and adjust the front panel controls to give a stable display, with the sweep starting at the center horizontal line on the graticule.

4. Alternately press the Trigger Coupling DC and AC pushbuttons. If the starting point of the trace stays the same (does not move) in both the DC and AC modes, go on to Step 5. If the starting point moves as you change from DC to AC, adjust Y1 Zero Trig (R477) until the starting point no longer moves.

5. Change the DISPLAY MODE to Y2 and change the TRIGGER SELECT to Y2 +. Center the trace with the Y2 POS control.

6. Connect a 1000 Hz sine wave to the Y2 input.

7. As in Step 4, alternately press the Trigger Coupling DC and AC pushbuttons. If the starting point of the trace is stable, go on to the next step. If the starting point moves, adjust Y2 Trig Zero R557 until the starting point no longer moves.

8. Change the DISPLAY MODE to TRIPLE, and change the TRIGGER SELECT to EXT +.

9. Connect the 1000 Hz sine wave to the EXT INPUT – Y3 input.

10. As in Steps 4 and 7, press the DC and AC buttons to see if the beginning of the trace moves. If it does, adjust Ext Zero R705 (horizontal circuit board, Pictorial 14-5) until the beginning of the trace no longer moves.

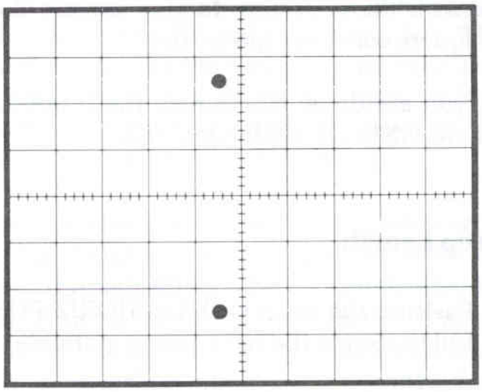
Chop Delay

1. Set the following controls as indicated:

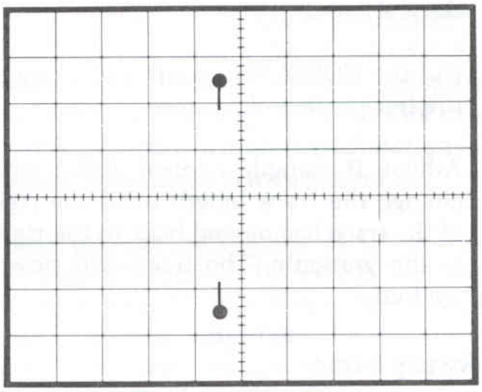
Y1 AC-GND-DC	GND
(Y2) AC-GND-DC	GND
DISPLAY MODE	DUAL, CHOP
A TIME/CM	100 mS
TRIG LEVEL	Fully CW
VARIABLE TIME	Fully CCW

2. Adjust the Y1 and [Y2] POS controls to give two dots as shown in Pictorial 14-10, part A.

A



B



PICTORIAL 14-10

3. The display should look like part A of the Pictorial, with only the two dots moving across the screen. If your display has lines from the dots, adjust Chop Delay R838 on the horizontal board (see Pictorial 14-5) to correct the display. NOTE: This is a very broad control and you may end up with it turned to either extreme, or you may find that the display is correct regardless of where you set the control.

SQUARE WAVE COMPENSATION

Use a square wave generator that is capable of producing 10 volts peak-to-peak at 1000 Hz for the following.

1. Set the following controls as indicated.

Y1 AC-GND-DC	DC
Y2 AC-GND-DC	DC
Y1 VOLTS/DIV	20 mV
Y2 VOLTS/DIV	20 mV
DISPLAY MODE	Y1
A TIME/CM	.2 mS
VARIABLE TIME	CAL
TRIG SELECT	Y1+

2. Apply a 1000 Hz square wave to the Y1 input.

3. Adjust the generator to make the waveform 5 cm high. Then examine the corners and top of the square wave, and memorize how they look. You will need to know this for the next step.

4. Change the Y1 VOLTS/CM setting to .2 V and readjust the generator, to give a display 5 cm high.

5. Adjust C404 (vertical preamp board, Pictorial 14-4) to make the corners and top of the square wave in this display look (as close as possible) like they did in Step 3, above.

6. Change the Y1 VOLTS/CM switch to 2 V, and readjust the generator. Then adjust trimmer C407 to make the corners and top of the square wave match (as closely as possible) the display as it was in Step 3 above.

7. Start again, this time with the input applied to Y2. Set the DISPLAY MODE for Y2, the TRIGGER SELECT to Y2 +. Adjust the generator to produce a display that is 5 cm high.

8. Again, memorize the shape of the corners and top of the square wave in the display.

9. Change the Scope to .2 V and readjust the generator to give a 5 cm display. Compare this display to the one in Step 8, and adjust C504 to make the corners and top of the square wave look just like you saw in Step 8.

10. In the same manner, change the Scope to 2 V and readjust the generator to give a 5 cm display. Compare this display with the one in Step 8, and adjust C507 to make the square wave look just like you saw in Step 8.

11. Start again, this time with the input applied to EXT INPUT – Y3. Set the DISPLAY MODE for TRIPLE and the TRIGGER SELECT to EXT +, and apply enough of a signal to generate a display that is 5 cm high.

12. Again, memorize the shape of the corners and top in the display.

13. Push in the Trigger Coupling EXT ÷ 10 pushbutton and readjust the generator to give a 5 cm display. Compare this display with the one in Step 12 and adjust C701 (horizontal board, Pictorial 14-5) to make the corners and top of the square wave look just like those you saw in Step 12.

PROBE COMPENSATION

If you do not have probes, or do not intend to use probes with your scope, do the following steps. If you do have and intend to use probes, skip the next 11 steps and go on to the following group of instructions.

1. If you will not use probes, set the DISPLAY MODE pushbuttons for Y1.

2. Apply a fast rise, 1 MHz (1 μs) square wave to the Y1 input and set the TRIGGER SELECT switch to Y1 −.

3. Set the VOLTS/CM switch to 20 mV and adjust the generator to give a display that is 5 cm high.

4. Look carefully at the overshoot at the leading edge of the square wave. Memorize this shape for the following steps.

5. Change the Y1 VOLTS/CM switch to .1 V and readjust the generator to give a 5 cm display. Compare this display to the one in step 4, and adjust C403 to make the overshoot of the waveform just like what you saw in Step 4.

6. Change the Y1 VOLTS/CM switch to 1 V and readjust the generator to give a 5 cm display. Compare this display to the one in step 4, and adjust C406 to make the overshoot of the waveform just like what you saw in Step 4.

7. Start again, with the signal generator connected to the Y2 Input. Set the DISPLAY MODE for Y2 and the TRIGGER SELECT to Y2.

8. Set the Y2 VOLTS/CM switch to 20 mV, and set the generator to give a display that is 5 cm high.

9. Look carefully at the square wave. Memorize this shape for the following steps.

10. Change the Y2 VOLTS/CM switch to .1 V and adjust C503 to make the display look as much as possible like what you saw in Step 9.

11. Change the Y2 VOLTS/CM switch to 1 V and adjust C506 to make the display look as much as possible like what you saw in Step 9.

NOTE: Perform the following steps if you intend to use a probe with your scope. Use Pictorial 14-13. Change the DISPLAY MODE and TRIG SELECT to the channel you will use.

1. Set the VOLTS/CM controls on both Y1 and Y2 to 20 mV.

2. Attach the probe's BNC connector to the Y1 input. If the probe has ×1 and ×10 settings, begin with the ×10 setting.

3. Connect a 1-volt, 1000 Hz, square wave signal to the probe, and adjust the Scope for a stable display.

4. Use a nonmetallic screwdriver to adjust the compensation screw on the probe to make the waveform corners as square as possible.

5. Move the probe to the Y2 input and adjust the Scope for a stable display.

6. Adjust trimmer C502 to make the square wave corners look as square as possible. If it is not possible to make the corners square, set C502 (vertical preamp board, Pictorial 14-4) to its minimum (with the solder blob away from the flat side), and readjust the compensation screw on the probe to make the corners square.

NOTE: Do the next step only if you changed the probe compensation in Step 6.

7. If you just changed the probe compensation, move the probe back to Y1, and adjust the Scope for a stable display. Adjust trimmer capacitor C402 to make the square wave corners as square as possible. Then return the probe to Y2 and adjust the Scope for a stable display.

Do the following steps whether you had to do Step 7 or not.

8. Set both VOLT/CM switches to .2 V, and increase the amplitude of the square wave generator to produce a display 5 divisions high.

9. Adjust C503 to make the square wave corners as square as possible.

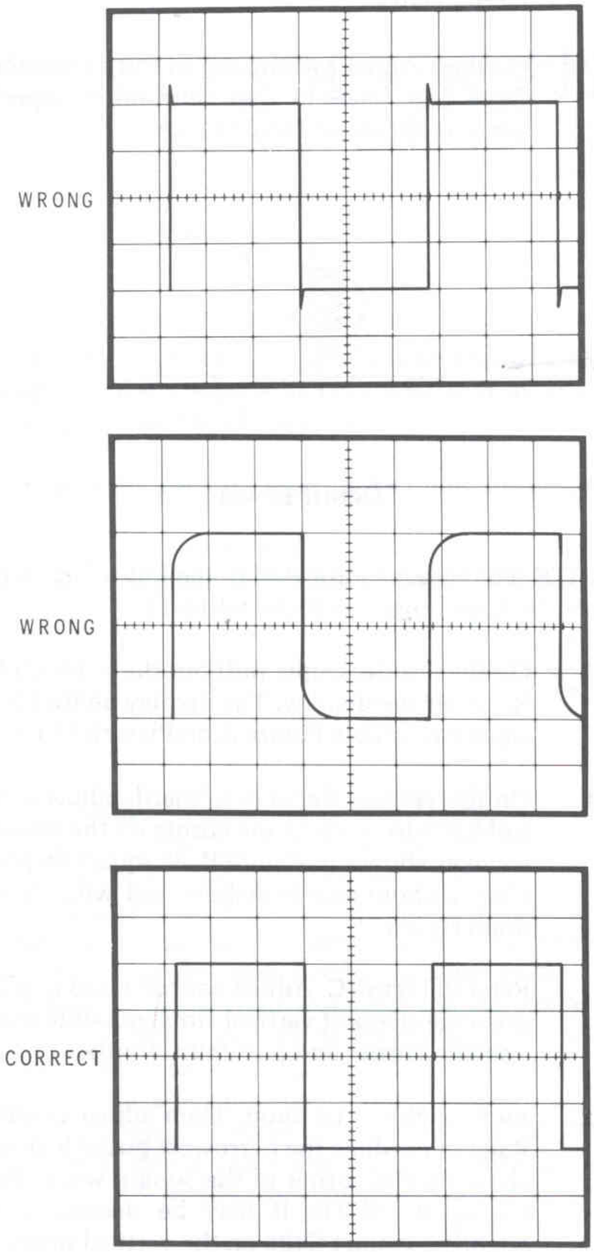
10. Move the probe to the Y1 input and adjust the Scope for a stable display. Adjust trimmer C403 to make the corners as square as possible.

NOTE: In the following step, if you do not have a generator capable of a 100-volt output, set the VOLTS/CM switch to 1V, and adjust the square wave generator output to produce a 1 division square wave.

11. Set both VOLT/CM switches to 2 V. and adjust the square wave generator output to produce a display 5 divisions high.

12. Adjust trimmer C406 (for Y1) to make the corners as square as possible.

13. Move the probe to the Y2 input and repeat the process, adjusting C506 for the squarest corners you can get.



PICTORIAL 14-13

SQUARE WAVE COMPENSATION
(Cont'd.)

1. Set the front panel controls as follows for both Y1 and Y2:

AC-GND-DC	AC
VOLTS/CM	20 mV
VARIABLE	CAL
DISPLAY MODE	Y1
Time Base	A
TIME/CM	2 μs
VARIABLE TIME	CAL
Trigger Coupling	AC
TRIG SELECT	Y1 +

2. Set the square wave generator to produce a 500 kHz (2 µs) output and connect it to the Y1 input. Adjust the generator output and the trigger LEVEL to give a stable display that is 5 cm high.

3. Adjust vertical control R497 (vertical preamp board, Pictorial 14-4) until the top of the square waves are as flat as possible.

4. Connect the generator to the Y2 input, press the TRIGGER MODE Y2 pushbutton, and set the TRIG SELECT switch to Y2 +. Adjust the LEVEL control for a stable display.

5. Adjust vertical control R597 (also in Pictorial 14-4) until the top of the square waves are as flat as possible.

6. Connect the generator to the Y1 input again. Set the DISPLAY MODE pushbutton to Y1, and the TRIG SELECT to Y1 −. Change the TIME/CM switch to .1 µS and set the signal generator to produce 1 MHz (1 µs). Adjust the input for a 5 cm. display.

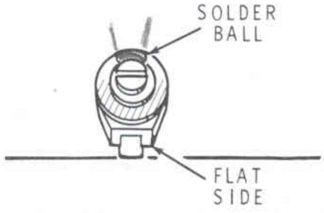
NOTE: The following adjustments on the vertical deflection board will optimize the response of the Scope to the square wave. Each different adjustment is directed primarily at a different part of the waveform, but also affects the other controls. Due to this, you will find that repeating the following steps once or twice will improve your Scope's performance.

While you are performing the following steps, you will find it helpful to use the ×10 feature (HORIZ POS, PULL FOR ×10). Pulling this control out will speed up the sweep rate to 10 nS and allow you to examine the leading edge of the square wave more effectively. Switch back and forth between the ×1 and ×10 positions while performing the following adjustments.

Continue to refer to Pictorial 14-4 for the locations of the vertical preamp controls, and also to Pictorial 14-11 for the locations of the vertical deflection circuit board controls. The waveforms referred to in the following steps are shown in Pictorial 14-12 (Illustration Booklet, Page 7).

7. Use a plastic alignment tool and, on the vertical deflection circuit board, turn controls R309, R335, and R336 to the centers of their rotation. Turn control R308 fully counterclockwise.

8. On the vertical preamp board, turn trimmers C426 and C526 to their minimum capacitance as shown in Detail 14-4A.



Detail 14-4A

NOTE: The Figures indicated in the following steps refer to those shown on Pictorial 14-12.

9. On the Oscilloscope, pull out the ×10 knob. Recenter the display. The display on the CRT should resemble Figure A on Pictorial 14-12.

10. On the vertical deflection board, adjust control R335 to produce the corner on the square wave as shown in Figure B, as square as possible without any overshoot and with minimum ripple.

11. Refer to Figure C. Adjust control R336 to produce the steepest vertical slope possible with a square corner and minimum ripple.

12. Push in the ×10 knob. Then adjust control R309 to produce the narrowest possible overshoot on the corner of the square wave. See Figure D. NOTE: It may be necessary to slightly readjust C426 on the vertical preamp to produce the desired overshoot.

13. Turn control R308 to adjust the square wave top corner, making the top of the trace as flat as possible. See Figure E. There may be a dip after the overshoot; make the trace as flat as possible after the dip.

14. Readjust R335 to make the overshoot on the leading edge exactly the same height as the first ripple. See Figure F. Readjust C426 to reduce the overshoot if that is necessary to keep the peaks equal while keeping the trace as flat as possible.

NOTES:

A. Refer to Figure G as you perform Steps 15 and 16.

B. In the next two steps, it may be necessary to readjust R335 to keep the trace and the two peaks flat and equal as you adjust the designated controls.

15. Readjust control R336 so the notch between the overshoot and first ripple is as deep as possible, making sure to maintain the same relative height.

16. Readjust control R309 to again make the notch as deep as possible while keeping the heights the same.

17. On the vertical preamp, adjust trimmer C426 to produce exactly 1-1/2 small graticule divisions (0.3 cm) of vertical overshoot on the leading edge of the trace as shown in Figure H.

18. Readjust first control R335 for a minimum ripple and the narrowest possible overshoot, and then R336 for the same thing; turn this control clockwise until you just see an increase in the ripple, and then turn it counterclockwise slightly. See Figure J.

19. Readjust C426 to produce 1-1/2" small divisions (.3 cm) of overshoot.

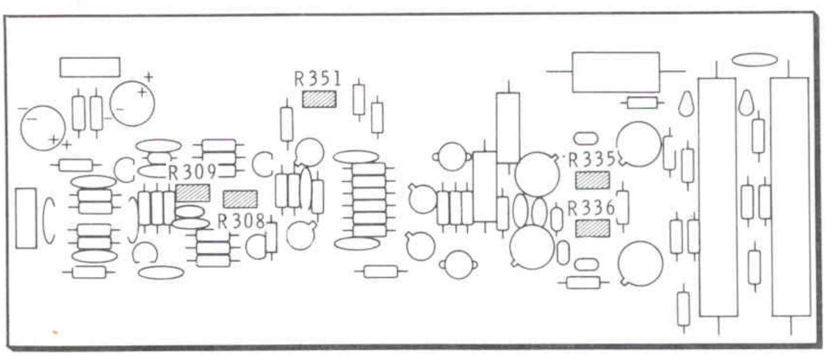
20. Disconnect the generator from the Y1 input and connect it to the Y2 input. Set the TRIGGER SELECT switch to Y2 –. Set the Y2 AC-GND-DC switch to DC. Then make sure the display is stable.

21. On the vertical preamp, adjust trimmer C526 for 1-1/2 small vertical divisions (.3 cm) of overshoot, as you did in Step 19. See Figure J.

NOTE: If you cannot set the Y2 display to look like Figure J, you must make readjustments as follows.

22. If necessary, readjust R335, R336, R308, and R309 slightly to make the Y2 display look like Figure J. Once this is done, you must go back to Y1. Connect the input to Y1 and readjust C426 to get Y1 to look like Figure J again. If necessary, continue to fine-tune the controls until you get the desired display for both Y1 and Y2.

This completes the initial calibration instructions. Return to your Assembly Manual and complete the "Final Assembly" of your kit.



PICTORIAL 14-11 (repeat)
Vertical Deflection Board

TOUCH-UP CALIBRATION

This section of the Manual deals with the touch-up adjustments that keep your Scope accurate. Any time that you perform the "Initial Calibration," operate the Oscilloscope for at least 48 hours, and then perform all of the following touch-up adjustments. However, any other time that you doubt the accuracy of a particular circuit within your calibrated Oscilloscope, you may make the appropriate touch-up adjustment for that circuit only.

Allow the Oscilloscope to warm up for at least one hour with the cover on and with the Oscilloscope setting in its normal operating position. Do not stand it on the rear feet to make the touch-up adjustments.

If you have replaced components in the Oscilloscope, you must perform the "Initial Calibration" before you make touch-up adjustments.

Contrast — Perform the "Contrast" calibration steps on Page 14-5. This adjustment will not affect other adjustments.

Touch-Up Vertical Amp Gain Adjustment — Carefully Perform the "DC Gain and Step Balance Adjustment" steps beginning on Page 14-5. NOTE: The vertical calibration is affected when the High Voltage, and Geometry are readjusted.

Touch-Up Sweep Time (time base calibration) — Carefully perform the "Horizontal Amplifier" steps beginning on Page 14-7. NOTE: The sweep calibration is affected when the High Voltage, Geometry, and Horizontal Amplifier are readjusted.

Touch-Up Sweep Length Adjustment — The sweep length controls can be readjusted as desired (usually for a 12 cm trace for the A sweep and an 11 cm trace for the B, See Pages 14-8 and 14-9) without affecting other adjustments.

Touch-Up X-Y Adjustment — Carefully perform the "X-Y Calibration" steps on Page 14-9. NOTE: The X-Y calibration is affected when the Y1 Vertical Amplifier, High Voltage, and Horizontal Gain are readjusted.

Touch-Up Trigger Adjustment — Carefully perform the "Trigger Adjustment" calibration steps on Page 14-10. This adjustment is not affected by other adjustments.

IN CASE OF DIFFICULTY

The first part of this section of the Manual, titled "Visual Checks," tells you what to do about any difficulties that occur right after your unit is assembled.

If the "Visual Checks" fail to clear up the problems, or if difficulties occur after your unit has been in use for some time, refer to the "Troubleshooting Charts."

NOTE: Refer to the "Circuit Board X-Ray Views" for the physical location of parts.

VISUAL CHECKS

1. Recheck the wiring. Trace each lead with a colored pencil on the Pictorial as you check it. It is frequently helpful to have a friend check your work. Someone who is not familiar with the unit may notice something consistently overlooked by the kit builder.

2. About 90% of the kits that are returned to the Heath Company for service do not function properly due to poor connections and soldering. Therefore, you can eliminate many troubles by reheating all connections to make sure they are soldered as described in the "Soldering" instructions in your Assembly Manual.

3. Closely examine each circuit board foil in a good light to see that no solder bridges exist between adjacent connections. Remove any solder bridges by holding a clean, hot soldering iron tip between the two points that are bridged until the excess solder flows down onto the tip. Compare your foil pattern with the "Circuit Board X-Ray Views."

4. Check to be sure each transistor is in the proper location (correct part number and/or type number). Make sure each transistor lead is connected to the proper point.

5. Check to be sure the correct diode is installed at each diode location. Make sure each diode band is positioned above the diode band printed on the circuit board.

6. Check each capacitor value. Make sure that a capacitor of the correct value is installed at each capacitor location. Check electrolytic capacitors to be sure their positive (+) and negative (−) leads are at the correct positions.

7. Check each resistor value carefully. Be sure in each step that the proper part has been wired into the circuit, as shown in the Pictorial Diagrams. It would be easy, for example, to install a 1200 Ω (brn-red-red) resistor where a 220 Ω (red-red-brn) resistor should have been installed.

8. Be sure all the wires and leads connected to the circuit boards have been trimmed as close as possible to the circuit board foils.

9. Check for bits of solder, wire ends, or other foreign matter which may be lodged in the wiring.

If you still have not located the trouble after the "Visual Checks" are completed, and if a voltmeter is available, check the voltage readings at the locations indicated on the Schematic Diagram. Read the "Precautions for Troubleshooting" before you make any measurements. NOTE: All voltage readings were taken with a high-input impedance voltmeter.

Regulated voltages should not vary more than 5% from those indicated on the Schematic. Other voltages may vary as much as ± 20%.

NOTE: In an extreme case where you are unable to resolve a difficulty, refer to the "Customer Service" information inside the rear cover of this Manual. The Warranty is located inside the front cover.

PRECAUTIONS FOR TROUBLESHOOTING

WARNING: The full AC line voltage, and high voltage DC, are present at several points in the Oscilloscope. Be careful to avoid electrical shock when working on the Oscilloscope. See Pictorial 14-1 (Illustration Booklet, Page 4).

Be careful when you test transistors and integrated circuits. Although they have almost unlimited life when used properly, they are much more vulnerable to damage from excessive voltage and current than other circuit components.

Be careful not to short any terminals to ground when you make voltage measurements. If the probe should slip, for example, and short out a bias or voltage supply point, it might damage one or more components.

Do not remove any components or circuit boards while the Oscilloscope is turned on.

When you make repairs to the Oscilloscope, make sure you eliminate the cause as well as the effect of the trouble. If, for example, you should find a damaged resistor, be sure you find out what caused the resistor to be damaged (a wiring error in a kit, or some other failed component). If the cause is not eliminated, the replacement resistor may soon be damaged just as the first one was.

Refer to the "Circuit Board X-Ray Views," "Component Charts," and the "Schematic Diagram" to locate the various components.

Use a high impedance voltmeter to make the specified measurements in this section.

If you suspect that a transistor is defective, first measure the base-to-emitter voltage. This voltage is normally between 0.6 and 0.8 volts. If the voltage is above this range, the transistor is open. If the voltage is 0 volts, the transistor may be shorted, or an external short may exist (in another component or on the circuit board).

If you have trouble locating the problem, read the "Circuit Description," beginning on Page 13-1, to help you determine where to look for the trouble.

NOTE: in an extreme case where you are unable to resolve a difficulty, refer to the "Customer Service" information inside the rear cover of the Manual. Your Warranty is located inside the front cover.

TROUBLESHOOTING CHARTS

The troubleshooting is divided into four sections: power supplies, vertical, horizontal, and blanking. The problem has to be in one of these four sections. If you know what section your problem is in, proceed to that section and perform those steps. If you do not know what section has the problem, start at "Power Supplies" and go through the troubleshooting until you locate the problem. This troubleshooting section is intended to be used only as a guide, and cannot cover every possible fault or component.

NOTE: All voltages are DC, measured to chassis ground, and may vary by ±20%, unless otherwise stated.

POWER SUPPLIES

±5 V Supply

MEASURE	READING	IF NOT, CHECK	COMMENTS
U104 IN lead	Approx. +8 V	D114-D116, C134	Unplug S104 and check transformer secondary for approximately 6 VAC between pins 1 and 2, and 2 and 3.
U105 IN lead	Approx. −8 V	D113-D115, C135	
U104 OUT lead	+5 V	U104, C136	Unplug P101, P108, and P109 to unload supplies, if necessary.
U105 OUT lead	−5 V	U105, R132, R133, C137	

± 15 V Supply

MEASURE	READING	IF NOT, CHECK	COMMENTS
U101 IN lead	Approx. + 18 V	D109-D112, C123	Check transformer secondary for approximately 13 VAC. between pins 1 and 2, and 2 and 3 of S103.
U103 IN lead	Approx. − 18 V	D108-D111 C124	
U101 OUT lead	+ 15 V	U101, R126, R125, C126, D118	Unplug P109, P108, P110, and P101 to unload the supplies, if necessary.
U103 OUT lead	− 15 V	U103, D117, U102, C128, D119, R127, R128, R129, R131	

Horizontal Deflection Supply

MEASURE	READING	IF NOT, CHECK	COMMENTS
C102 + lead	137 VDC	D102, D103 C107	Check transformer secondary for approximately 100 VAC at pins 4 and 5 of S102.
C112 + lead	130 VDC	C112, R104	Unplug P107 to unload the supply, if necessary.

Vertical Deflection Supply

MEASURE	READING	IF NOT, CHECK	COMMENTS
C109 + lead	110 V	D114, D105, C109	Check transformer secondary for approximately 78 VAC at pins 2 and 3 of S102, if necessary.
D106 Cathode (banded end)	105 V	R105, C108	
C113 + lead	90 VDC ±3%	Entire regulator circuit.	Unplug P101 and P110, and remove R176, to unload the supply, if necessary.

High Voltage Supply

MEASURE	READING	IF NOT, CHECK	COMMENTS
Q201 collector	130 VDC	Supply voltage to high voltage board.	
Q202 collector	70 to 120 VDC	Entire circuit if oscillator is not working.	To confirm that the regulator circuits are operating.

VERTICAL

Vertical Preamp

Press the Display Mode Y1 button. Measure the difference between P602, pin 2 and pin 4. Try to make these two pins equal by adjusting Y1 Pos on the front panel.

Repeat the step, this time with the Y2 button pressed, using the Y2 Pos control.

If you did get the two pins equal in each case, go on to the next section, "Vertical Deflection."

If you could not get the voltages to balance in either step, or both steps, go back to check the appropriate feeds for the channel(s) that you cannot balance (Q406 and Q407, and Q506 and Q507). Check these by measuring between the collectors (of Q406 and Q407, for example) and adjusting Step Bal (R414 or R514) until they are equal. If you can do this, troubleshoot between the transistors and P602; if not, look in the circuit prior to the transistors. If previous voltages balance but this point is out of balance, the problem is in this area. Becuase of DC coupling, you may have to isolate circuits. Do this by removing resistors, or lifting the bases of the transistors of the following stage's input. Remember that the collector voltages of the Q405, Q411, Q511, and Q611 arrays will not change appreciably, because they are current amplifiers.

To check channel Y3, press the Triple pushbutton and rotate the Y3 Pos control. If the third channel trace does not move, check Q604 and Q607. If you do not locate the problem, measure the voltage at the emitter of Q702. Adjust Trig Zero (R725) to give 0 V. Check Q701 and Q702 if the Trig Zero control doesn't work.

Vertical Deflection

MEASURE	READING	IF NOT, CHECK	COMMENTS
CRT socket pins 9 and 11	Each voltage should change as you turn the channel Pos control. Voltages should not track together.	Delay line.	Use ohmmeter to check continuity at delay line connectors.
CRT socket pins 9 and 11	Adjust channel Position control to balance reading.		If the voltages balance, proceed to "Horizontal."

HORIZONTAL

Horizontal Amplifier

Set the Time/CM switch to the X-Y position.

MEASURE	READING	IF NOT, CHECK	COMMENTS
Q755 collector Q756 collector	Should vary between 0 and 120 V, as the Y1 Pos control is rotated.	Troubleshoot the entire amp, starting at the input.	

To troubleshoot, check the emitter, base and collector voltages of transistors Q738 through Q757, and compare them to the voltages on the schematic. Start at Q738 and work toward the outputs. The Bias Adj control adjusts the current in the output stage and thereby changes the voltage at the outputs. Q733 shorts the base of Q738 to ground when the Scope is in the X-Y mode.

Trigger Amp

MEASURE	READING	IF NOT, CHECK	COMMENTS
U702 pin 15	Push the DC pushbutton and rotate the Trigger Select Level control back and forth. Voltage should change (logic shift) with each rotation.		If test is OK, proceed to "Ext Trig Amp." Otherwise, proceed to next step.
Q711 collector and Q712 collector	Adjust horizontal circuit board Trig Bias and front panel Trig Select Level controls for −1.2 V.	Q707, Q708 Q709, Q711 Q712, U701	If amplifier will not adjust, remove U701 and try again.
U701 pin 15	Rotate Trig Select Level. The voltage should change between −1.9 and −1.7 V.	U701	
Pin 15 of 703	Push in TV-H pushbutton and rotate Trig Select Level. The voltage should change every four rotations.	U703A, U702	

Auto Base Line

Set the Trigger Select switch to Ext +.

Connect a trigger signal to the Ext Input-Y3 connector.

Center the Trigger Select Level control.

If the Trig indicator lights, but you still do not have an automatic base line (with no trigger signal applied), check U704.

If the Trig indicator does not light, perform the following checks.

MEASURE	READING	IF NOT, CHECK	COMMENTS
Q715 base	−0.9 V	Q713, Q714	
Q716 base	−4 V	D707, Q716	
U704 pin 14	−0.9 V with Auto pushbutton pressed in.	U704	
U704 pin 14	−1.8 V with Norm pushbutton pressed in.	U704	
Q718 emitter	If "High" (greater than 3 V), do the following steps. If "Low" (less than 1 V), go to "Low" (next chart).		
Q719 collector	"Low"	Q719	
Q761 emitter	"Low"	Q721, Q722, Q761	
U706 pin 6	"High"	U706	
U707 pin 12	"High"	D713-D716, U707A & B, B Ends A Switch	
U707 pin 8	"High"	U708, U707	
U708 pin 6	"High"	U708A, R821 "A" Time/CM Switch	
U707 pin 3	"Low"	U707, U706, C729, D717	
U705 pins 4 and 13	"ECL Low" (−1.6 V or lower)	R818, R819	
U704 pin 10	"ECL Low"	R818, R819, R771	
U703 pin 4	"ECL Low"	U704, U705, U703	
U703 pin 5	"ECL High" (−0.9 V or higher)	U704, U702, U703	
U703 pin 2	"ECL High"	U703, Q717, Q718	
U703 pin 3	"ECL Low"	U703, Q717, Q718	

Low

MEASURE	READING	IF NOT, CHECK	COMMENTS
Q761 emitter	High (10-15 V)	Q721, Q722 Q761, 90-volt supply, A Time/ CM switch, R801	
U706 pins 6 and 8	Low	U706	
U707 pin 8	High	U708, U706, U707	
U703 pin 4	"ECL Low"	U703, U704, U705	
U703 pin 5	"ECL High"	U703, Q717, Q718	
U703 pin 2	"ECL High"	U703	

Single Sweep

Push in the Trigger Mode Single pushbutton.

MEASURE	READING	IF NOT, CHECK	COMMENTS
U705 pin 3	−1.6 V	U705	
U705 pin 6	−0.9 V	U705	

B Sweep Generator

Push in the Time Base A pushbutton. Set the A and B Time/CM switches to .2 mS.

MEASURE	READING	IF NOT, CHECK	COMMENTS
Q727 collector	3 volt pulse each.		B sweep circuits work similarly to the A sweep.
U715 pin 11	Greater than 2.8 V (with Q728 collector shorted to ground).	Q729, Q731, Q732, Q762	
U715 pin 3	Greater than 2.8 V after first pulse.	U715	
U715 pin 6	Less than .8 V after first pulse.	U715	

Blanking Control

MEASURE	READING	IF NOT, CHECK	COMMENTS
U709 pins 2 and 3	More than 2.8 V when triggered.	U709	Blanking signal from Q718 triggers U709, pin 1.
U708 pin 14	Less than 0.8 V when triggered.		
U709 pin 8	More than 2.8 V when triggered.	U709	Blanking signal from U715 pin 8 triggers U709 pin 6.

Chop/Alt

Make sure the Display Mode Chop/Alt pushbutton is in the Alt (released) position.

MEASURE	READING	IF NOT, CHECK	COMMENTS
Pin 8 of U712	More than 2.8 V	U712	Chop disable from the vertical pre-amp.

Change the display Mode Chop/Alt pushbutton to the Chop (pressed) position.

MEASURE	READING	IF NOT, CHECK	COMMENTS
U712 pin 8	Less than 0.8 V.	SW502, U601 (on vert pre-amp board)	U712C & D should oscillate.

BLANKING AMPLIFIER

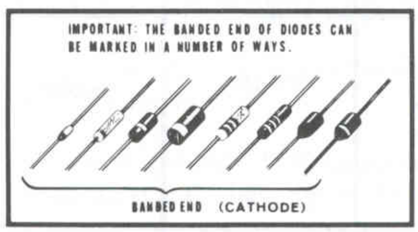
Set the Time/CM switch to X-Y.

MEASURE	READING	IF NOT, CHECK	COMMENTS
P107 pin 2	0.6 V	U709	
P107 pin 3	0.6 V	U709, U711	
P107 pin 4	0.6 V	U713	
Q111 collector	30 V, when Intensity control is fully CCW. Should increase to 80 as control moves CW.	Q107, Q108, Q109, Q111, D121, D122, D123	
Q113 collector	0 to 60 V as Bias Adj R166 is adjusted, and should vary 20 to 50 V as the Intensity control is turned. Set the voltage to 30 V with Intensity fully CCW.	Q112, Q113, D128, D128 (if CRT does not light), Q112, Q113, D125, D126 (if Q113 collector does not vary).	

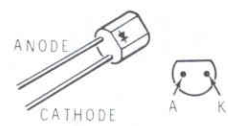
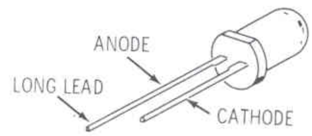
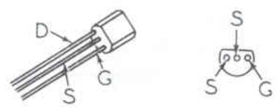
SEMICONDUCTOR IDENTIFICATION CHARTS

DIODES

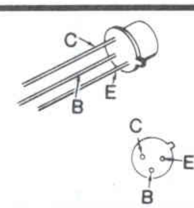
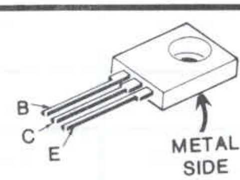
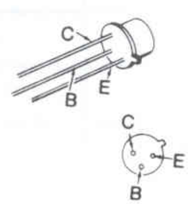
COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
D106	56-16	1N5231B	
D122–D128	56-24	1N458	
D117, D121	56-26	1N191	
D402, D502	56-31	PS18775	
D403, D503, D701–D706, D711, D718, D721, D722, D726, D727, D729, D731–D735, D739, D741–D744, D746	56-56	1N4149	
D404, D504	56-67	1N4740A	
D708, D723, D709, D724	56-71	1N825A	
D107, D719	56-85	5V Zener	
D713–D717, D745	56-602	Selected	
D712, D725	56-613	1N5230B	
D728	56-616	1N5232B	
D101–D105, D108–D116, D118, D119	57-27	1N2071	
D201	57-610	FM50	



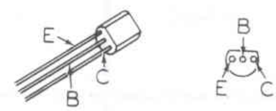
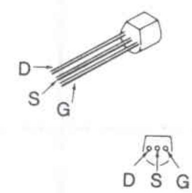
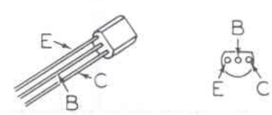
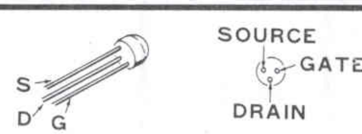
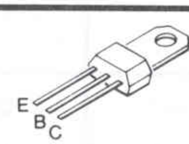
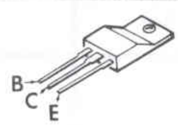
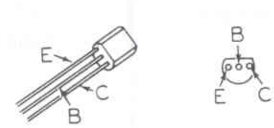
Diodes (Cont'd.)

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
D737, D738	56-670	MBD101	
D361, D707, D747	412-637	LED	
D401, D501	417-854	SF50077	

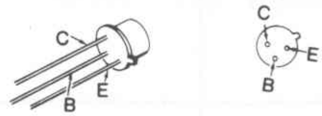
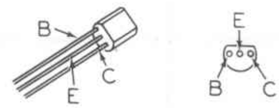
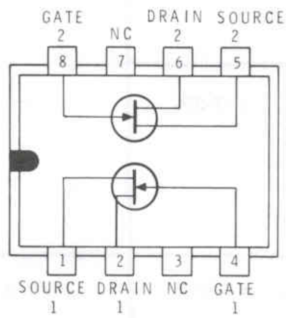
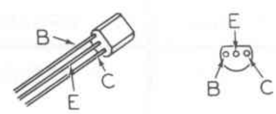
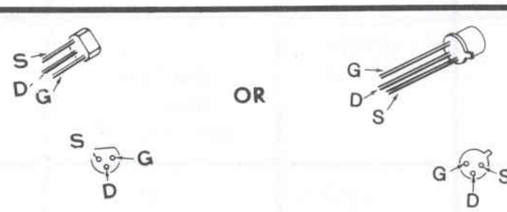
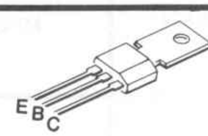
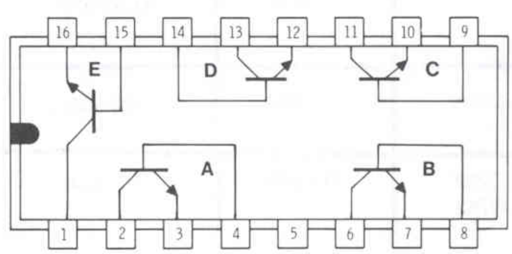
TRANSISTORS

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
Q601, Q602, Q715, Q717, Q719, Q727, Q728, Q733	417-154	2N2369	
Q201, Q202	417-195	MJE340	
Q307, Q308	417-205	2N3866	

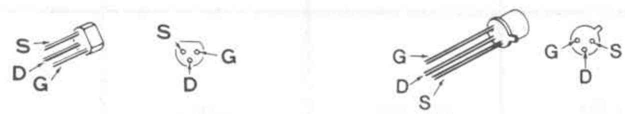
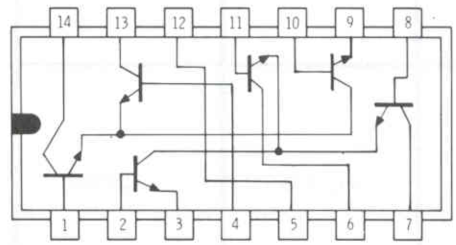
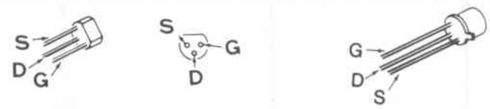
Transistors (Cont'd.)

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
Q716, Q718, Q722, Q732, Q734, Q736, Q758	417-235	2N4121	
Q108, Q702, Q711, Q712, Q713, Q714, Q724, Q726	417-260	2N4258A	
Q729	417-291	2N5458	
Q402, Q502, Q606, Q607 Q706–Q709 Q723, Q747, Q748, Q749, Q751	417-293	2N5770	
Q101, Q109, Q112	417-295	MPSL51	
Q603	417-801	MPSA20	
Q102, Q103, Q104, Q106, Q111, Q113	417-811	MPSL01	
Q401, Q501	417-828	Available Only From Heath Co. (selected E304)	
Q203	417-834	MPSU10	
Q105	417-856	MJE5979	
Q404, Q504, Q725	417-874	2N3906	
Q107, Q759, Q761, Q762, Q763	417-875	2N3904	

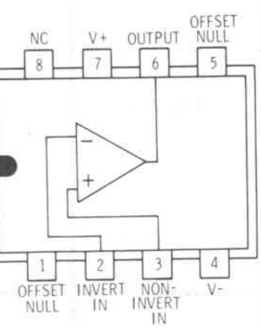
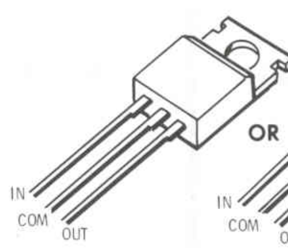
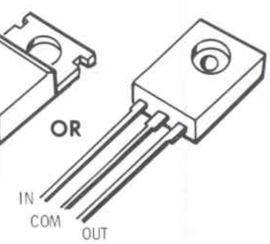
Transistors (Cont'd.)

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
Q305, Q306	417-893	2N5109	
Q403, Q406, Q407, Q503, Q506, Q507, Q508, Q509, Q703, Q704, Q735, Q737–Q739, Q741–Q744	417-887	MPSH10	
Q701, Q705, Q721, Q731	417-902	NDP5566 8-pin Dip	
Q301–Q304, Q412–Q415, Q512–Q515, Q745, Q746	417-917	MPSH81	
Q416, Q516	417-931	PN4858	
Q752, Q753, Q755, Q756	417-947	MDS-21	
Q754, Q757	417-948	MDS-60	
Q405, Q505	417-975	CA3127 16-pin Dip	

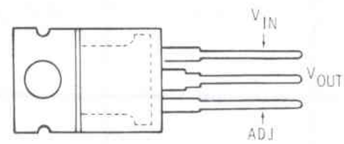
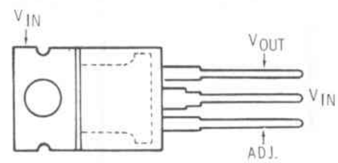
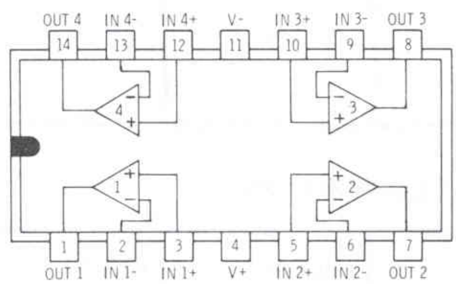
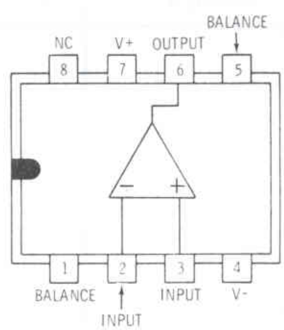
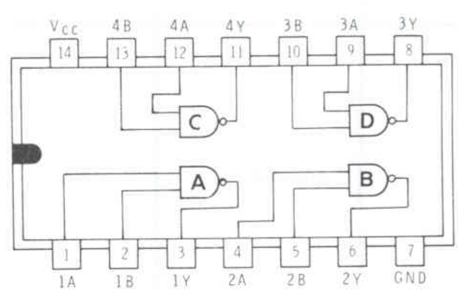
Transistors (Cont'd.)

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
Q309, Q312	417-976	MRF525	
Q411, Q511, Q611	417-978	CA3102 14-pin Dip	
Q313, Q314	417-982	MRF531	

INTEGRATED CIRCUITS

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
U102, U201	442-22	NS741V	
U104	442-603	78M05	 OR 

Integrated Circuits (Cont'd.)

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
U101	442-708	LM317	
U103, U105	442-709	LM337	
U716	442-742	LF347	
U401, U501	442-759	LF411N	
U707, U711, U712, U714	443-1	SN7400	

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Integrated Circuits (Cont'd)

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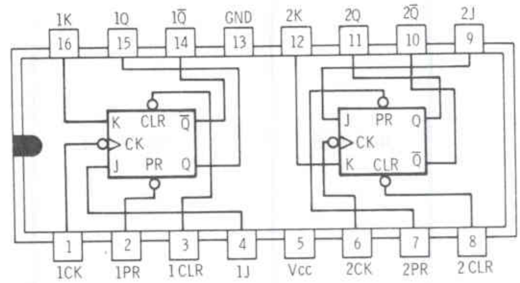
<tr><td>U709</td><td>443-16</td><td>SN7476</td><td>
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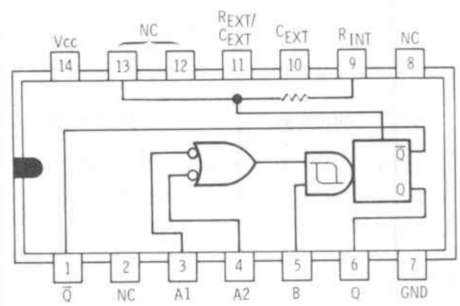
<tr><td>U605</td><td>443-22</td><td>SN7421</td><td>
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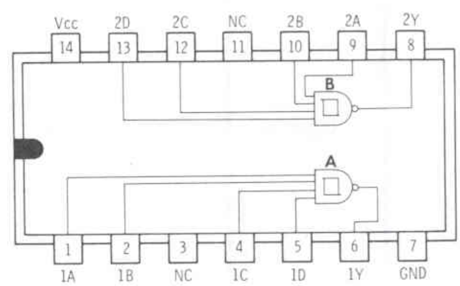
<tr><td>U706</td><td>443-44</td><td>SN7413</td><td>
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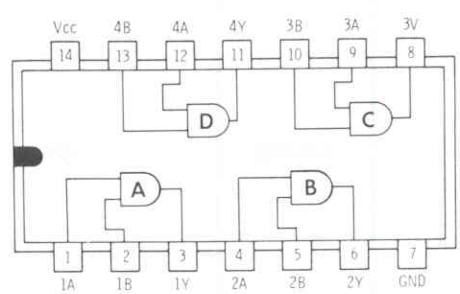
<tr><td>U713</td><td>443-45</td><td>SN7408</td><td>
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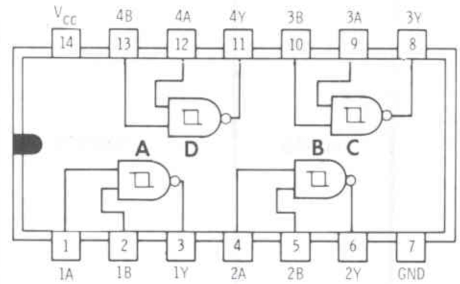
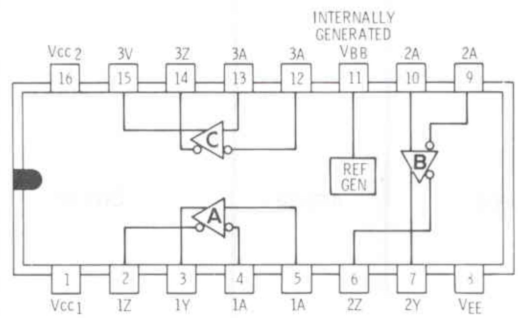
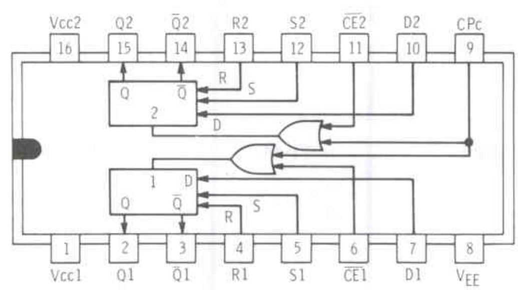
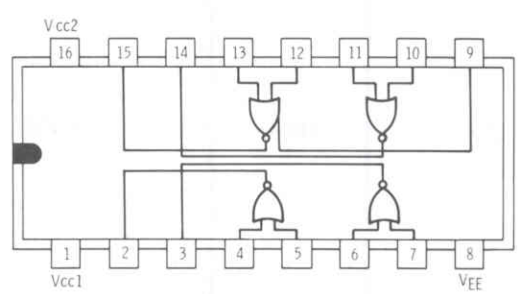
U715	443-625	SN74132	
U701	443-636	MC10116	
U703	443-679	MC10131	
U702	443-683	MC10102	

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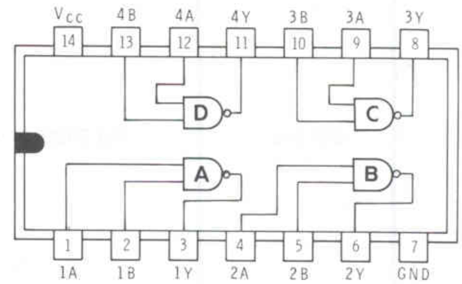
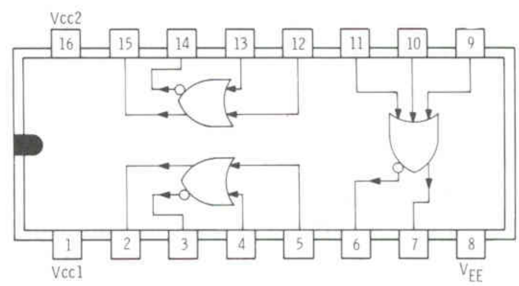
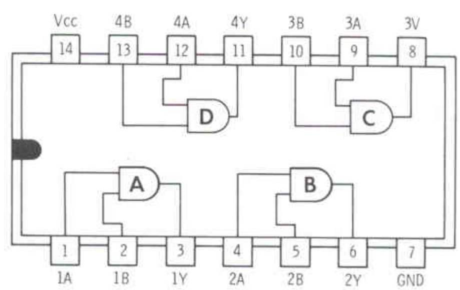
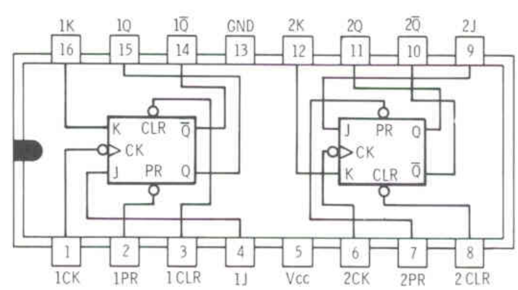
Integrated Circuits (Cont'd.)

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
U601	443-728	SN74LS00	
U704, U705	443-765	MC10105	
U604	443-780	SN74LS08	
U602, U603	443-829	SN74LS76	

Integrated Circuits (Cont'd.)

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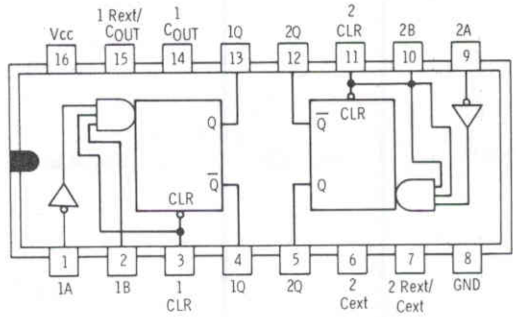
U708	443-942	74LS123	

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CUSTOMER SERVICE

REPLACEMENT PARTS

Please provide complete information when you request replacements from either the factory or Heath Electronic Centers. Be certain to include the **HEATH** part number exactly as it appears in the parts list.

ORDERING FROM THE FACTORY

Print all of the information requested on the parts order form furnished with this product and mail it to Heath. For telephone orders (parts only) dial 616 982-3571. If you are unable to locate an order form, write us a letter or card including:

- Heath part number.
- Model number.
- Date of purchase.
- Location purchased or invoice number.
- Nature of the defect.
- Your payment or authorization for COD shipment of parts not covered by warranty.

Mail letters to: Heath Company
Benton Harbor
MI 49022
Attn: Parts Replacement

Retain original parts until you receive replacements. Parts that should be returned to the factory will be listed on your packing slip.

OBTAINING REPLACEMENTS FROM HEATH ELECTRONIC CENTERS

For your convenience, "over the counter" replacement parts are available from the Heath Electronic Centers listed in your catalog. Be sure to bring in the original part and purchase invoice when you request a warranty replacement from a Heath Electronic Center.

TECHNICAL CONSULTATION

Need help with your kit? — Self-Service? — Construction? — Operation? — Call or write for assistance. you'll find our Technical Consultants eager to help with just about any technical problem except "customizing" for unique applications.

The effectiveness of our consultation service depends on the information you furnish. Be sure to tell us:

- The Model number and Series number from the blue and white label.
- The date of purchase.
- An exact description of the difficulty.
- Everything you have done in attempting to correct the problem.

Also include switch positions, connections to other units, operating procedures, voltage readings, and any other information you think might be helpful.

Please do not send parts for testing, unless this is specifically requested by our Consultants.

Hints: Telephone traffic is lightest at midweek — please be sure your Manual and notes are on hand when you call.

Heathkit Electronic Center facilities are also available for telephone or "walk-in" personal assistance.

REPAIR SERVICE

Service facilities are available, if they are needed, to repair your completed kit. (Kits that have been modified, soldered with paste flux or acid core solder, cannot be accepted for repair.)

If it is convenient, personally deliver your kit to a Heathkit Electronic Center. For warranty parts replacement, supply a copy of the invoice or sales slip.

If you prefer to ship your kit to the factory, attach a letter containing the following information directly to the unit:

- Your name and address.
- Date of purchase and invoice number.
- Copies of all correspondence relevant to the service of the kit.
- A brief description of the difficulty.
- Authorization to return your kit COD for the service and shipping charges. (This will reduce the possibility of delay.)

Check the equipment to see that all screws and parts are secured. (Do not include any wooden cabinets or color television picture tubes, as these are easily damaged in shipment. Do not include the kit Manual.) Place the equipment in a strong carton with at least THREE INCHES of *resilient* packing material (shredded paper, excelsior, etc.) on all sides. Use additional packing material where there are protrusions (control sticks, large knobs, etc.). If the unit weighs over 15 lbs., place this carton in another one with 3/4" of packing material between the two.

Seal the carton with reinforced gummed tape, tie it with a strong cord, and mark it "Fragile" on at least two sides. Remember, the carrier will not accept liability for shipping damage if the unit is insufficiently packed. Ship by prepaid express, United Parcel Service, or insured Parcel Post to:

Heath Company
Service Department
Benton Harbor, Michigan 49022

HEATH
ZENITH

HEATH COMPANY • BENTON HARBOR, MICHIGAN

THE WORLD'S FINEST ELECTRONIC EQUIPMENT IN KIT FORM

LITHO IN U.S.A.