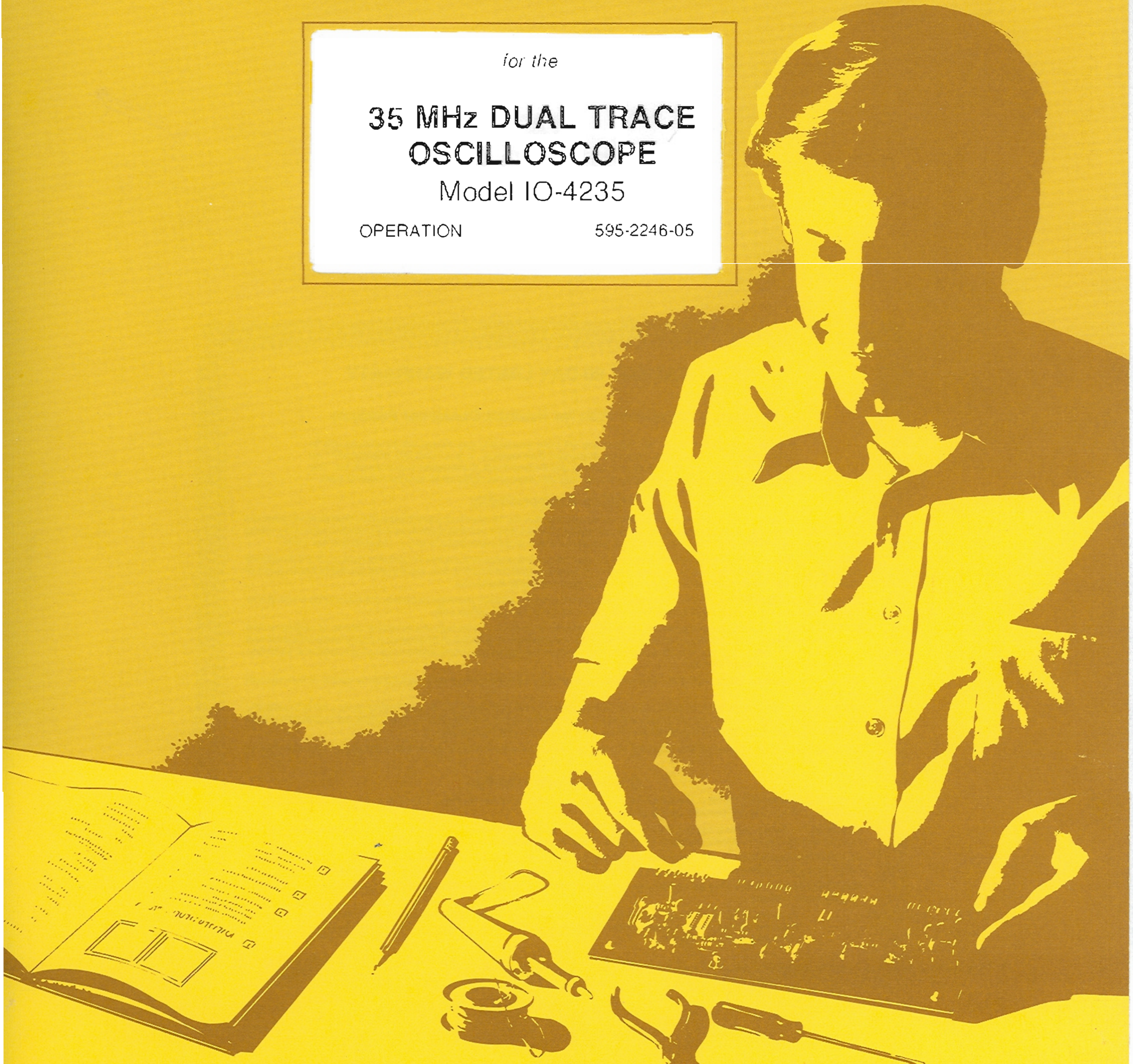
HEATHKIT® MANUAL

for the

35 MHz DUAL TRACE OSCILLOSCOPE

Model IO-4235

OPERATION 595-2246-05



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BENTON HARBOR, MICHIGAN 49022

TABLE OF CONTENTS

INTRODUCTION

This Oscilloscope is a laboratory-grade instrument that is ideal for the wide range of measurements typically found in electronics, development laboratories, and scientific research. Some of its outstanding features are:

- Dual trace
- Delayed sweep
- Wide 35 MHz bandwidth
- Fast 10 nS vertical rise time
- High brightness mesh CRT with internal graticule
- 2 mV/cm sensitivity
- Inverting input switches
- Algebraic add function
- Vertical delay lines
- TV coupling circuit for stable display of TV signals
- Single-sweep function
- Full X-Y operation with Z-axis control

The attenuator networks of each channel have 12 calibrated ranges, from 2 millivolts/centimeter to 10 volts/centimeter. Either or both inputs can be inverted by the Pull-to-Invert switches. This complements the ADD function, which displays the resultant waveform after both input signals have been algebraically added together.

The internal vertical delay lines insure that the horizontal sweep starts before the beginning of the vertical signal. Thus, the complete vertical waveform will be displayed. Since amplifier rise time is 10 nanoseconds, very fast rise time signals can be faithfully reproduced.

Calibrated time-base ranges from .2 seconds/centimeter to 50 nanoseconds/centimeter are readily switched in a 1-, 2-, 5-step sequence. Any sweep speed can be expanded 5 times when the X5 switch is pulled out. Delayed sweep is also available (a more sophisticated way of expanding the sweep speed). It allows you to first select the exact portion of the waveform that you want expanded and then it expands the waveform by a factor that you select.

The Trigger Select switch and Level control allow the time base to be precisely triggered at any point along the positive or negative slope of the trigger signal. Various trigger signals can be selected. Other Trigger Mode switches control the trigger input bandpass, cutting off unwanted low frequency trigger signals and triggering on only fast AC signals. Also, Auto and Norm switches are provided which can automatically display a baseline on the screen when there is no trigger signal.

A calibrated 1-volt peak-to-peak square wave signal is provided through a front panel connector. Also, rear panel switches match the power transformer to standard line voltages from 100 volts to 280 volts AC.

While the solid-state circuitry provides excellent sensitivity, stability and versatility; the rugged construction and dependable operation of this oscilloscope make it a versatile tool for the hobbyist, professional, or service technician.

SPECIFICATIONS

VERTICAL

Deflection Factor	
Sensitivity	2 mV/cm to 10 V/cm. 12 steps in a 1-2-5 sequence.
Variable	Continuous between steps to approximately 30 V/cm.
Accuracy	Within 3% (20°C to 30°C); 5% (10°C to 40°C), referred to 1 V/cm.
Vertical Response	
DC Coupling	DC to 35 MHz (−3dB).
AC Coupling	1 Hz to 35 MHz.
Rise Time	<10 nS.
Overshoot	Less than 3%.
Delay Line	Allows display of at least 20 nS of pre-triggered waveform.
Vertical Input	
Impedance	1 MΩ shunted by 30 pF.*
Maximum Input	400 volts peak combined AC and DC.
Connector	BNC.
Vertical Modes	Y1, Y2, Y1 and Y2 chopped, Y1 and Y2 alternate, algebraically add (±Y1) + (±Y2).

HORIZONTAL

Time Bases	
Ranges	.2 S/cm to 50 nS/cm.
Positions	21 steps in 1-2-5 sequence.
Variable	Continuous between ranges to approximately 600 mS/cm.
Accuracy	Within 3% (20° to 30°C); 5% (10°C to 40°C), referenced to 1 mS/cm.
Magnifier	X5 (accurate to within 5%, 20° to 30°C; 7%, 10°C to 40°C).

*Capacitance depends on probe used for calibration.

External Horizontal

Sensitivity	.1 V/cm (approximately).
Impedance	1 MΩ.
Polarity	Positive input causes right-hand deflection.
Frequency Response	DC to greater than 2 MHz (−3 dB).
Connector	BNC.

X − Y

Y Channel	Same as vertical.
X Channel	Same as vertical, except response is limited to 2 MHz and has no delay line.
Phase Shift	Less than 8° at 100 KHz.

TRIGGER

Source	Y1, Y2, EXT, Line.
Coupling	AC, DC, AC Fast, TV.*
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 >50 MHz	DC to >70 MHz	DC to >70 MHz
AC	15 Hz to >50 MHz	<1 Hz to >70 MHz	<1 Hz to >70 MHz
AC Fast	40 kHz to >50 MHz	30 kHz to >70 MHz	30 kHz to >70 MHz
TV*	40 Hz to 1.5 kHz	20 Hz to 3 kHz	20 Hz to 3 kHz

External Trigger

Sensitivity	100 mV at 50 MHz.
Input Impedance	1 MΩ shunted by 30 pF.

*The Oscilloscope triggers on alternate frames for steady display.

GENERAL

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.
AC Line Switch	Allows operation from a 100-140 VAC or 200-280 VAC power source.
Power Requirements	100-140 VAC or 200-280 VAC, 50/60 Hz, 85 watts (at 120 volts).
Dimensions	
Height	7.75" (19.7 cm).
Length (handle extended)	24" (61 cm).
Length (handle folded)	19.75" (50.2 cm).
Width	13.75" (34.9 cm).
Weight	30 lbs. (13.6 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 the United States, 120 VAC line voltage is most often used, while in other countries 240 VAC line voltage is more common. If your line voltage is consistently below 115 volts (or below 230 volts if you intend to operate the Oscilloscope on 240 volts), perform the following steps. Otherwise, proceed to "Control Functions." NOTE: Electrical regulations in some areas require a special line cord and/or plug for 240-volt operation. Replace them if necessary.

( ) Remove the back panel.

If your line voltage is consistently below 115 (or 230) volts:

( ) Shift the back panel NOR/LOW switch to the LOW position.

( ) Replace the back panel.

If you intend to operate your Oscilloscope on 240 volts:

( ) Remove the case.

( ) Shift the 120/240 slide switch to the 240 position. This switch is located on top of the rear subchassis, between the CRT and power transformer.

( ) Remove the 1-ampere slow-blow fuse and install the 1/2-ampere slow-blow fuse supplied with this instrument. The fuseholder is located inside the Oscilloscope near the 120/240 switch.

( ) Change the fuse label.

( ) Reinstall the case.

CONTROL FUNCTIONS

Refer to Pictorial 1-1 (Illustration Booklet, Page 1) as you read the following explanations of the major controls and switches.

1. INTENSITY — Clockwise rotation increases the brightness of the display. Adjust for nominal brightness in your room-lighting condition. Refocusing may be necessary when the intensity is changed. **CAUTION: Do not allow a bright spot to remain on the screen, it could damage the CRT.**

2. FOCUS — Varies the size of the beam striking the face of the CRT. Adjust for the sharpest display.

3. ON-OFF — Turns the Oscilloscope on and off.

4. POWER INDICATOR — Glows when AC power is turned on.

CHANNEL Y1 CONTROLS

5. Y1 POSITION — Positions the channel Y1 trace vertically on the screen.

6. DC BAL — This is not an operating control. Use it as directed in the "DC BALANCE" section (Page 11) of this Manual.

7. PULL TO INVERT — When pulled out, the Y1 trace will be inverted.

8. Y1 INPUT — This is the Y1 input connector. It is also the X input connector during XY operation.

9. VOLTS/CM — Each position of this attenuator switch is marked for the number of volts (peak-to-peak) required to produce a pattern one centimeter high on the graticule.

10. VARIABLE — This control is normally operated in its fully clockwise (CAL) position where the VOLTS/CM switch positions are calibrated. Vertical gain decreases as the control is turned counterclockwise, permitting you to adjust the vertical trace size.

11. AC-GND-DC (Input switch) — In the AC position, this switch blocks the DC level of the input signal so that only the AC component is displayed. In the GND position, the input is disconnected and the vertical amplifier input is grounded. Use this position when you wish to set the baseline (trace) at a desired position without disconnecting the input signal. In the DC position, both the DC and AC components of the input signal are displayed.

BOTH CHANNELS

12. VERTICAL DISPLAY — In the Y1 position, only channel Y1 is displayed on the screen. In the Y2 position, only channel Y2 is displayed. In the CHOP position, both Y1 and Y2 are displayed in the CHOP mode. In the ALT (alternate) position, Y1 and Y2 are displayed alternately at the end of each trace. In the ADD position, the algebraic summation of channels Y1 and Y2 is displayed.

CHANNEL Y2 CONTROLS

13. Y2 POSITION — Positions the channel Y2 trace vertically on the screen.

14. DC BAL — This is not an operating control. Use it as directed in the "DC BALANCE" section of this Manual.

15. PULL TO INVERT — When pulled out, the Y2 trace will be inverted.

16. VOLTS/CM — Each position of this attenuator switch is marked for the number of volts (peak-to-peak) required to produce a pattern one centimeter high on the graticule.

17. VARIABLE — This control is normally operated in its fully clockwise (CAL) position where the VOLTS/CM switch positions are calibrated. Vertical gain decreases as the control is turned counterclockwise, permitting the vertical trace size to be adjusted.

18. AC-GND-DC (Input Switch) — In the AC position, this switch blocks the DC level of the input signal so that only the AC component is displayed. In the GND position, the input is dis-

connected and the vertical amplifier input is grounded. Use this position when you wish to set the baseline (trace) at a desired position without disconnecting the input signal. In the DC position, both the DC and AC components of the input signal are displayed.

19. INPUT — This is the Y2 input connector. It is also the Y input connector during X-Y operation.

HORIZONTAL DISPLAY

20. A — Selects normal, single-time-base operation.

21. A INTEN BY B — Intensifies the trace during the time that the B time base is running.

22. B DELAYED — Selects the B time base.

23. X-Y — Selects the X-Y function when the TRIGGER SELECT switch is in one of the LINE positions.

24. EXT HORIZ — When this function is selected, the voltage at the EXTERNAL HORIZONTAL input connector will move the trace horizontally. The voltage of the Y1 or Y2 input (or both) will move the trace vertically.

TRIGGER MODE

25. AUTO — When selected, a base line will be automatically displayed in the absence of a trigger signal.

26. TRIG — Indicates when the Oscilloscope is being triggered.

27. NORMAL — When selected, a trace will appear only when the Oscilloscope is triggered.

28. SINGLE — The Oscilloscope will sweep only once when triggered and then wait until after it is RESET. Then on the next trigger signal it will sweep again.

29. RESET — Resets the single-sweep function.

TRIG COUPLING

30. DC — Allows triggering on a DC or very slow AC signal.

31. AC — Triggers on most normal signals, but blocks DC and very slow AC signals.

32. AC Fast — Rejects low frequency signals and triggers only on fast signals.

33. TV — Rejects high frequency trigger signals and triggers on alternate field trigger signals. This provides a stable display when you are viewing vertical TV field signals.

TIME BASE

34. DELAY TIME POSITION — Determines the starting point of the B time base. When in the A INTEN BY B mode, the control will position the intensified portion of the trace. When in the B DELAYED mode, the control determines the portion of the A sweep to be expanded.

35. HORIZONTAL POSITION, PULL FOR X5 — Positions the trace horizontally on the CRT. It also is the X position control in the X-Y mode. When pulled out, it expands the trace by a factor of five.

36. A AND B TIME/CM, PULL FOR DELAY TIME — Determines the time required for the beam to sweep. The clear knob (closest to the panel) sets the speed of the A time base; the middle knob selects the time for the B time base. The two knobs are normally locked together. However, if the center knob is pulled out and turned clockwise, then the A and B time bases will be at different settings. Then, when the two knobs are aligned again, they will automatically lock together.

37. VARIABLE — Provides a continuous adjustment of the A sweep time between time base ranges. When fully clockwise, the time base is calibrated.

38. HOLD OFF — Adjusts for a stable display if the input signal is an exact multiple of the time base repetition rate. Normally, it is in the full counterclockwise position. In the full clockwise position (which is the B ENDS A position), the A sweep will be stopped when the B sweep stops (in the A INTEN BY B or B DELAYED modes). This increases the writing speed and produces a brighter display, especially at low settings of the DELAY TIME POSITION control.

TRIGGER SELECT

39. TRIGGER SELECT — This control selects the source and polarity of the triggering signal:

Line (+/−)	—Trigger signal is a portion of the 60 Hz line frequency.
Y1 (+/−)	—Triggers on a signal from channel Y1 only.
Y2 (+/−)	—Triggers on a signal from channel Y2 only.
EXT (+/−)	—Triggers on a signal applied from an external source.

40. LEVEL — Adjusts the trigger circuits so the sweep can be started at any position on the input signal waveform. The sweep can be started on either a positive or negative slope, depending on the position of the TRIGGER SELECT switch.

EXTERNAL

41. EXTERNAL HORIZONTAL — With the EXT HORIZ switch pushed in, a positive voltage at this connector will cause a left-to-right deflection on the CRT.

42. EXTERNAL TRIGGER — An external signal can be applied through this connector to trigger to sweep circuits when the TRIGGER SELECT switch is in either EXT position.

CALIBRATE

43. CALIBRATE — This 1-volt (peak-to-peak) square wave signal (approximately 1000 Hz) can be used to periodically check vertical calibration. The rise time of this signal allows it to also be used for oscilloscope probe compensation.

REAR PANEL

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

45. CONTRAST — This is not an operating control. Use it as directed in the "Contrast" section on Page 43 when you want to change the brightness of the B time base display.

PRESETTING CONTROLS

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

INTENSITY	Center of rotation
FOCUS	Center of rotation
VERTICAL MODE	Y1
HORIZONTAL POSITION Pull for X5	Center of rotation and pushed in (X1)
HORIZONTAL DISPLAY	A
TRIGGER MODE	AUTO
TRIG COUPLING	AC
TIME/CM	.1 mS
VARIABLE	Fully clockwise (CAL)
HOLD OFF	Fully counterclockwise
TRIGGER SELECT	Y1, +(plus)
LEVEL	Center of rotation
Y1:	
POSITION	Center of rotation
PULL TO INVERT	IN
VOLTS/CM	50 mV
VARIABLE	Fully clockwise (CAL)
INPUT switch	GND
Y2:	
POSITION	Center of rotation
PULL TO INVERT	IN
VOLTS/CM	50 mV
VARIABLE	Fully clockwise (CAL)
INPUT switch	GND

Before the Oscilloscope can be used, it must be warmed up and have the beam in the cathode ray tube properly adjusted on the screen The following procedure will prepare the Oscilloscope 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 will burn the phosphors and leave a permanent image in the face of the CRT.

3. Turn the ON-OFF switch to the ON position. The power light will light.

4. Allow a moment or two for the instrument to warm up.

5. Slowly adjust the Y1 POSITION control and the HORIZONTAL POSITION control to center the trace on the screen.

6. Adjust the INTENSITY control to obtain a trace just bright enough for your room lighting conditions.

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

8. Adjust the HORIZONTAL POSITION control so the trace starts at the left edge of the graticule.

Your oscilloscope is now prepared for operation in the modes described in the "Operational Examples" section.

DC BALANCE (DC BAL)

The highly sensitive vertical amplifier input circuits in this Oscilloscope, as in other sensitive equipment, may exhibit an occasional unbalance caused by aging components and temperature effects. Even though the DC BAL (balance) control is not considered to be an operating control, you should check the DC balance periodically and readjust it when necessary. This is especially true when you use the more sensitive input ranges (20 mV to 2 mV). A small screwdriver is needed to make this adjustment through the small hole in the front panel.

To check the DC balance of either channel, set the Input Switch (AC-GND-DC) to ground (GND) and obtain a trace on the CRT. Turn the VOLTS/CM VARIABLE gain control from fully clockwise to fully counterclockwise. If the trace moves vertically, readjust the DC balance as follows:

1. Turn the VOLTS/CM switch to the 20 mV position.

2. Turn the VARIABLE gain control fully clockwise to the CAL position.

3. Center the trace on the screen.

4. Turn the VARIABLE gain control fully counterclockwise.

5. Adjust the DC BAL control to return the trace to the centerline.

6. Repeat steps 2 through 5 until the trace does not move when the VARIABLE gain control is turned.

7. Turn the VOLTS/CM switch to the 2 mV position and repeat steps 2 through 6.

NORMAL OPERATING CHARACTERISTICS

The following information is provided to help answer possible 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 Oscilloscope on, especially on the more sensitive voltage ranges. A short warm-up period (about 15 minutes) is recommended.
- If the HORIZONTAL DISPLAY switch is in the X-Y or EXT HORIZ position when you first turn the Oscilloscope on, the trace may not dim completely when you turn the INTENSITY control down. To overcome this, momentarily push in the A and AUTO pushbutton switches.
- Delayed sweep operation is useful only when the A and B Time/CM switches are at different settings. If the knobs are locked together in the A INTEN BY B OR B DELAYED modes, parts of the trace (or all of the trace) may disappear.
- The Trace may become slightly wider on the .2 volt and 2 millivolt/centimeter ranges. This is wideband noise generated by various components in the input circuits.
- When you are using the PULL TO INVERT switches, symmetrical signals may not appear to invert but they actually do. See "Operational Example 5" Page 15.
- In the AUTO 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 LEVEL control is near its center of rotation.
- In the SINGLE SWEEP mode, random noise may cause the highly sensitive sweep circuits to trigger. If this happens, readjust the LEVEL control slightly.

USING A 2-MILLIVOLT OSCILLOSCOPE

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

- Placement of the ground clip may be critical if the signal source ground carries an appreciable current. Voltage differences of several millivolts from one side of a chassis or ground foil to the other are common. Place the ground clip at the point that gives the least error. This is usually nearest the signal source. The ground clip may have to be moved when you measure different points.
- Stray 60 Hz pickup may be hard to eliminate, especially in high impedance circuits. Be sure to use shielded test cables. Shield the signal source if necessary.
- Wideband measurements in the millivolt and submillivolt regions are more difficult because of the inherent noise (shot noise and thermal noise) generated by electronic components. This may appear as a widening of the baseline or the baseline appearing out of focus. Noise on the baseline that appears as "hash" or "spikes" may be caused by the electromagnetic pickup of man-made noise such as ignition noise, appliance noise, 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 appear 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 operation.

EXAMPLE 1

Triggering the Sweep on the + or − Slope of a Waveform

Signal source: Sine wave generator of approximately 1 kHz.

Be sure all 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.

Set the switches as follows:

Y1:

INPUT	AC
A and B TIME/CM	.1 mS

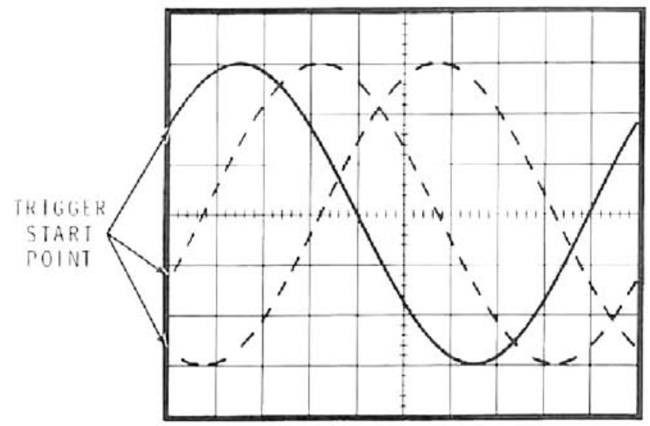
Connect the 1 kHz sine wave signal to the Y1 INPUT connector.

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

Refer to Pictorial 1-2 and readjust the trigger LEVEL control. Notice how the trigger starting point changes. When turned to the ends of the control, the trace will blank out momentarily and then begin to move (not locked in).

Set the Trigger LEVEL control for a stable display.

Set the TRIGGER SELECT switch to Y1 − (minus). The waveform should now trigger on the − slope and appear inverted.



PICTORIAL 1-2

EXAMPLE 2

Normal or Automatic Triggering

The AUTO mode (automatic triggering) provides a base or reference line without the presence of a vertical input signal. 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 waveform should show approximately 10 complete cycles.

Push in the NORM pushbutton. There should be no change.

Set the Y1 INPUT switch to GND. There should be no display.

Push in the AUTO pushbutton. The automatic base line will appear.

Place the Y1 INPUT switch back to AC. The trace should reappear.

Push in the NORM pushbutton. There should be no change.

Turn the trigger LEVEL control fully clockwise and notice that there is no trace. In the NORM position, a base line is not generated when the input signal is lost.

Push in the AUTO pushbutton. The trace will reappear but will be moving.

Set the trigger 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 INPUT switch to GND.

Push in the SINGLE pushbutton. The trace will disappear.

Push the RESET pushbutton.

Set the Y1 INPUT switch to AC. The trace will make one sweep.

Push in the RESET pushbutton. The trace will make one sweep. Notice that, in this mode, the trace only sweeps once after each reset and only after being triggered.

Push in the AUTO pushbutton.

Reset the A and B TIME BASE switches to .1mS/cm.

EXAMPLE 4

Dual-Trace Operation

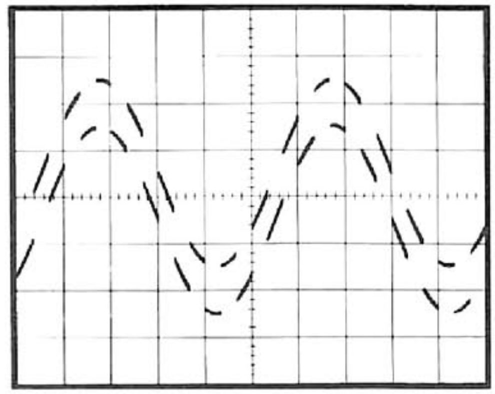
Connect a sine wave of approximately 1 kHz to both the Y1 and Y2 INPUT connectors.

Set the VERTICAL DISPLAY switch to CHOP.

Set the Y2 INPUT switch to AC.

Set the generator for a display that is 2 cm high and set the TRIGGER LEVEL control for a stable display.

Adjust the Y1 and Y2 POSITION controls so that the waveforms are separated as shown in Pictorial 1-3. NOTE: You can turn off either channel by positioning the VERTICAL DISPLAY switch to either Y1 or Y2.



PICTORIAL 1-3

Set the signal generator to approximately 10 kHz.

Set the A and B TIME/CM switches to 5 μS.

Adjust the VARIABLE TIME/CM control to obtain a stable dot pattern.

Adjust the Y1 and Y2 POSITION controls until the waveforms interweave and are together. This shows how the Oscilloscope draws the two pictures in the CHOP position. The tiny spaces remaining in the trace are caused by the chop blanking described in the "Theory of Operation" and "Circuit Description."

Readjust the POSITION controls to separate the waveforms again.

Set the VERTICAL DISPLAY switch to ALT. Note that now both waveforms are smooth.

Set the A and B TIME/CM switches to 20 mS.

Set the signal generator to approximately 100 Hz. Notice that this display draws one waveform and on the next (alternate) sweep, draws the other waveform.

Set the A and B TIME/CM switches to 5 mS. Notice how distracting the display is at these settings.

Set the VERTICAL DISPLAY switch to CHOP. The display is now much easier to look at. Therefore, the CHOP function is usually used on the lower 1/3 of the TIME/CM switch positions, and the ALT function is used for the upper 2/3 of the switch positions.

EXAMPLE 5

Pull to Invert Switches

Connect a sine wave of approximately 1 kHz to both the Y1 and Y2 INPUT connectors.

Set the VERTICAL DISPLAY switch to Y1.

Set the A and B TIME/CM switches to .5 mS.

Set the TRIGGER SELECT switch to Y1, +.

Pull the Y1 PULL TO INVERT switch. The trace may not look inverted because the trigger is still set for a positive slope. However, the signal is inverted.

Set the VERTICAL DISPLAY switch to ALT.

Push in the Y1 PULL TO INVERT switch. (Be sure the two waveforms are far enough apart not to interfere with each other.) Now the other channel (Y2) shifts 180°. It is not inverting.

Set the TRIGGER SELECT switch to Y2, +.

Push in and pull out the Y1 PULL TO INVERT switch. Now you can see the Y1 signal being inverted because the Oscilloscope is triggering on channel Y2 and is not affected by inverting channel Y1.

Be sure both PULL TO INVERT switches are pushed in.

Set the VERTICAL DISPLAY switch to ADD. Now the signal is twice as high as either the Y1 or the Y2 signal. This is the algebraic summation of the two waveforms.

Pull out the Y2 PULL TO INVERT switch. Now the display is a straight line. The Oscilloscope is subtracting channel Y2 from channel Y1 and the result is zero.*

This function is useful in making differential measurements. If the Y1 and Y2 channels were connected across a resistor, then the differential measurement will directly measure the voltage across the resistor.

Adjust either the Y1 or Y2 VARIABLE VOLTS/CM control and notice how the display changes. This is because the gains of each channel are now different and therefore cannot result in zero.

NOTE: It may be impossible to get a zero result at high frequencies or fast rise times due to the natural characteristics of the Oscilloscope.

EXAMPLE 6

Channels Y1 and Y2

Both channels operate exactly the same. If you wish, re-perform Examples 1 through 5 using the opposite channel rather than the one called for.

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

APPLICATIONS

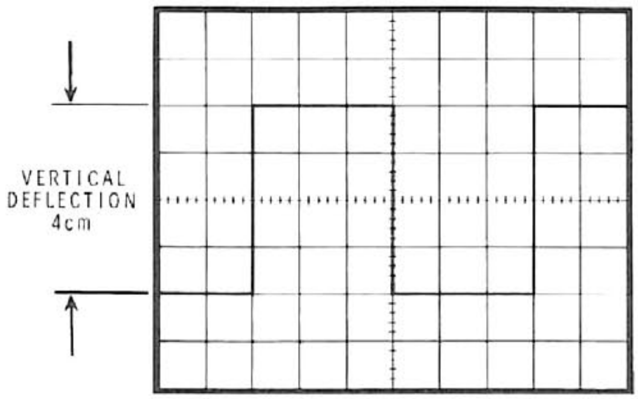
Peak-to-Peak Voltage Measurements

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

Example:

As shown in Pictorial 1-4, the display amplitude is four divisions. If the VOLTS/CM switch is at .2 V, then:

peak-to-peak voltage = 4 divisions × 0.2 volts/division = 0.8 volts



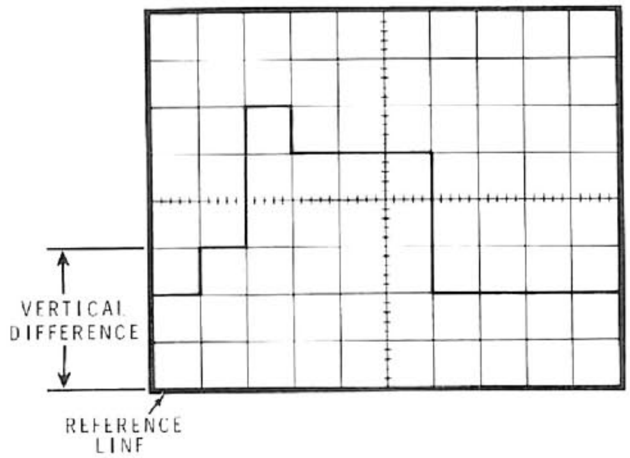
PICTORIAL 1-4

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 1-5.

2. Set the AC-GND-DC switch to DC. (Pull to INVERT switch in). If the waveform is above the reference line, the voltage is positive. If the waveform is below the reference line, the voltage is negative.



PICTORIAL 1-5

3. Measure the vertical difference (number of vertical divisions) between the reference line and the desired point on the waveform, multiply it by the VOLTS/CM switch setting.

Example:

The vertical difference is 3 divisions and the VOLTS/CM switch is set at 50 mV. The indicated voltage stop is:

3 divisions × 50 mV/division = 150 mV above ground.

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. Set the VERTICAL DISPLAY switch to CHOP or ALT and position both automatic base line traces on the horizontal centerline of the graticule.

2. 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.

3. Set the channel VOLTS/CM switches and VARIABLE controls so that the displays are equal and about four divisions high.

4. Set the A and B TIME/CM switches to a sweep rate that displays one cycle of the reference waveform.

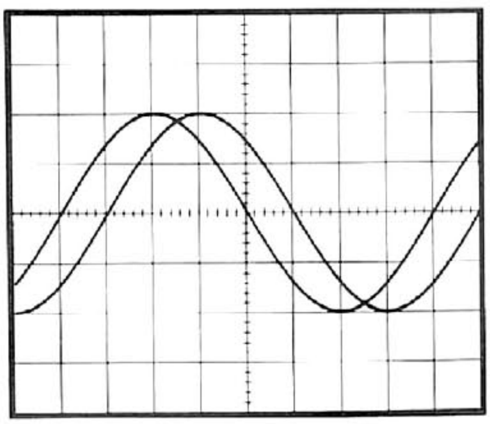
5. Turn the time/cm VARIABLE control until one cycle of the reference signal occupies exactly eight divisions between the first and ninth graticule lines. Each division of the graticule now represents 45° of the cycle (360° divided by 8 divisions = 45°/division).

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

Example:

The horizontal difference is 1.0 divisions as shown in Pictorial 1-6. Therefore:

Phase difference = 1.0 divisions × 45°/divisions = 45°



PICTORIAL 1-6

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. Frequency is the reciprocal of the time duration of one cycle.

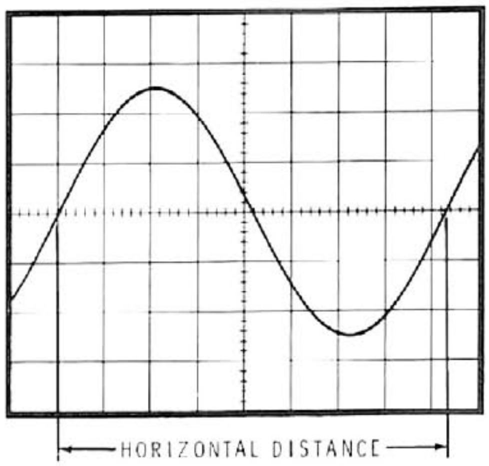
Example:

As shown in Pictorial 1-7, the horizontal distance measured is 8.3 divisions. The TIME/CM switch is set to 2 mS. Therefore:

Time Duration = 8.3 divisions × 2 mS/divisions = 16.6 mS.

and

Frequency = 1/time duration = 1/16.6 mS = 60 Hz



PICTORIAL 1-7

Delayed Sweep Operation

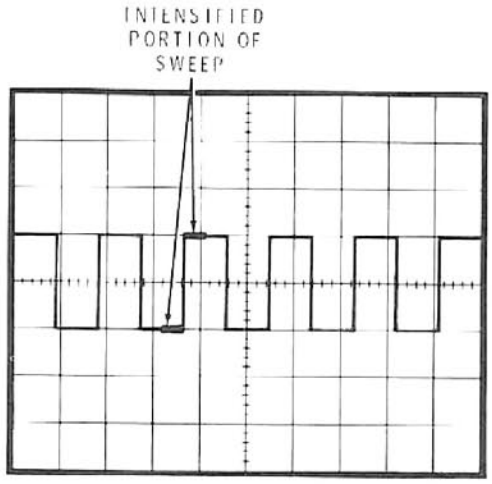
This mode of operation allows you to look at an expanded portion of a waveform after you select the portion of the waveform that you want to see.

Example:

Push in the A HORIZONTAL DISPLAY switch.

Connect the front panel CALIBRATE signal to one of the INPUT connectors. Turn the A TIME/CM switch to .5 mS and the B TIME/CM switch to 50 μS.

Push in the A INTEN BY B switch. Adjust the INTENSITY control so you can see the 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 1-8.



PICTORIAL 1-8

Push the B DELAYED switch. The intensified portion of the waveform is now expanded. Adjust the INTENSITY control as necessary.

Set the B TIME/CM switch to 10 μS.

Turn the DELAY TIME POSITION control so that a leading edge is displayed again. NOTE: This control is now more sensitive and you may have to turn up the INTENSITY control.

Push in the A INTEN BY B switch. Readjust the INTENSITY and DELAY TIME POSITION controls as necessary.

NOTE: The greater the difference between the A and B TIME/CM controls, the more "jitter" will be seen in the waveform. This is normal. When there is a 9-step difference between the two timebases (1000 to 1 difference in sweep speeds) and a stable generator is used, the jitter should be less than 1 cm and typically 1/2 cm. Under these conditions, the intensity will also be dim, and again this is normal.

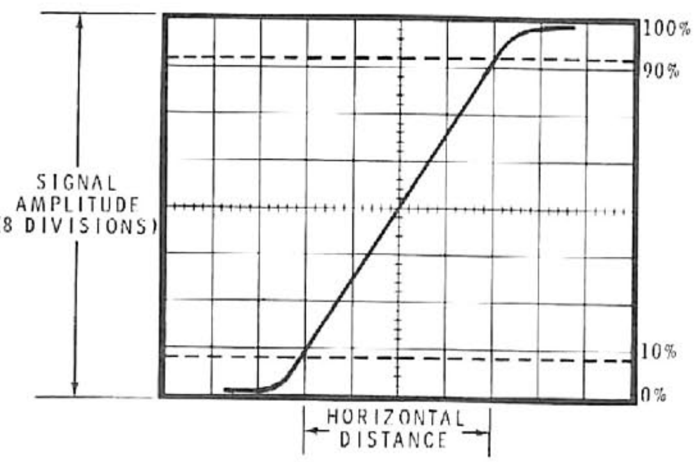
Risetime Measurements

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

To measure risetime:

1. Adjust the VOLTS/CM and VARIABLE controls for a display that is exactly 8 divisions high.

2. Adjust the POSITION control so that the display bottom just touches the 0% graticule line and the display top just touches the 100% graticule line. See Pictorial 1-9.



PICTORIAL 1-9

3. Measure the horizontal distance between the 10% and 90% points on the waveform.

4. Then: Risetime = horizontal distance × TIME/CM setting.

Example:

The horizontal distance between the 10% and 90% points on the waveform is 4 divisions and the TIME/CM switch is set at 1 μS.

Risetime= 4 divisions × 1 μS/division = 4 μS.

NOTE: When measuring very fast risetimes (less than 20 nS) the VARIABLE VOLTS/CM control should be in its CAL position. This guarantees a fixed Oscilloscope risetime. The fixed risetime and unknown risetime are related as follows:

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

OR

$$Tr \text{ unknown (in nS)} = \sqrt{Tr^2 \text{ display} - 10 \text{ nS}^2}$$

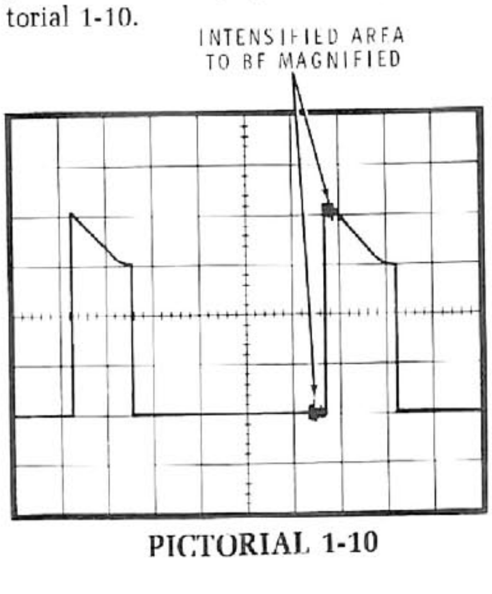
where Tr is the Oscilloscope risetime (typically 10 nS)

Delayed Sweep Magnification

The B DELAYED mode can provide a higher "apparent sweep rate magnification" than that provided by the ×5 switch.

To determine the apparent magnification factor:

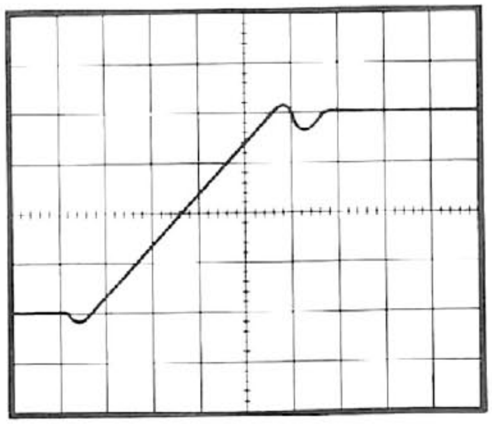
1. Push in the A INTEN BY B HORIZONTAL DISPLAY switch.
2. Use the DELAY TIME POSITION control and move the left edge of the intensified area to the portion of the display to be magnified. See Pictorial 1-10.



PICTORIAL 1-10

3. Set the B TIME/CM switch to cover only the portion of the A sweep that you want magnified.
4. Push in the B DELAYED switch. (See Pictorial 1-11) The portion of the A sweep that you selected is now magnified. The displayed sweep rate is determined by the B TIME/CM switch. To calculate the apparent magnification factor, use the following formula.

$$\text{Apparent magnification} = \frac{\text{A TIME/CM switch setting}}{\text{B TIME/CM switch setting}}$$



PICTORIAL 1-11

Differential Measurements

Make sure the Y1 and Y2 VOLTS/CM switches are in the same positions.

Set the VERTICAL DISPLAY switch to ADD.

Pull out the Y2 (or Y1) PULL TO INVERT switch. The resulting display is now Y1-Y2 (or Y2-Y1). Read the display directly by multiplying the vertical height (in cm) by the setting of **either** VOLTS/CM switch.

X-Y Mode Operation

With the X-Y switch pushed in and the TRIGGER SELECT in LINE + or −, Y1 signals produce a horizontal deflection (X) while the Y2 signals produce a vertical deflection. The HORIZONTAL POSITION control will operate the X deflection, and the Y1 position control is disconnected from the circuits. The VOLTS/CM switch, VARIABLE control, and PULL TO INVERT switch operate as previously described.

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

External Horizontal Operation

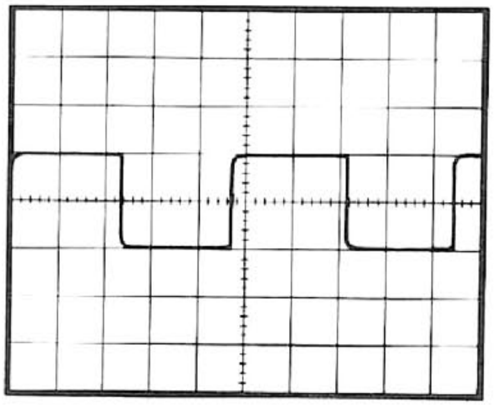
This mode is similar to that of X-Y. While using the external horizontal input does result in the loss of gain control in the X direction, it has the advantage of supplying two independent vertical channels (Y1, Y2, CHOP, ADD). Only one vertical channel is available in the X-Y mode.

X10 Probe Compensation

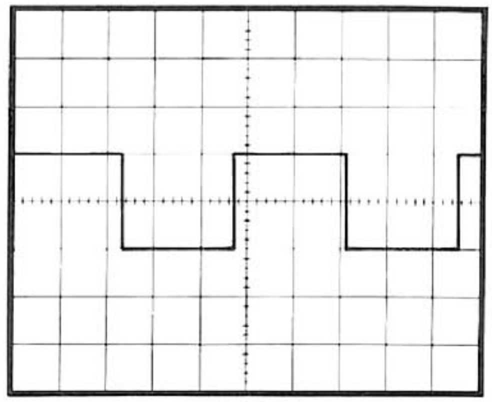
Set the VOLTS/CM switch to 50 mV and the TIME/CM switch to .2 mS.

Connect the probe tip to the front panel CALIBRATE signal.

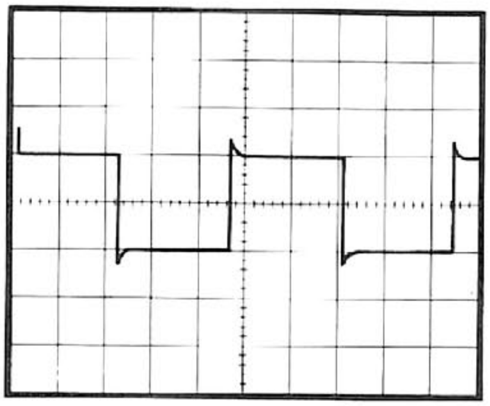
Adjust the ×10 probe for "correct" compensation as shown in Pictorial 1-12.



INCORRECT



CORRECT



INCORRECT

PICTORIAL 1-12

THEORY OF OPERATION

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

The dual-trace capability of this Oscilloscope allows two different signals to be displayed on a conventional CRT (cathode ray tube) that has only one set of vertical deflection plates. Two identical vertical preamplifier circuits, 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 two preamplifier circuits to pass to the vertical deflection amplifier. The vertical signal, a composite of both 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 both input signals as one "time-shared" signal.

The input signal connected to a channel input connector is coupled into the high impedance attenuator where the circuits select AC signals, DC signals, or grounds the amplifier input. The high impedance attenuator has two positions, a divide-by-one and a divide-by-one hundred. Attenuation is determined by the setting of the Volts/CM switch. The six most sensitive ranges on this switch correspond to the divide-by-one attenuator and the six least sensitive positions refer to the divide-by-one hundred section. The output of this attenuator is coupled into an impedance translator.

The impedance translator changes the impedance from one megohm down to the very low impedance level needed to drive the low impedance attenuator. This attenuator has six positions and each position is used twice. First, with the divide-by-one position of the high impedance attenuator, and the second time with the divide-by-one hundred position of the high impedance attenuator. The output of this low impedance attenuator circuit is applied to the main vertical preamplifier section which differentially amplifies the signal to a useful level.

The vertical preamplifier amplifies the signal to a 200 millivolt level to operate the trigger circuits. The preamplifier also inverts the signal when the Pull-to-Invert switch is in the out position and then outputs the signal to two places, the trigger amplifier and the switch circuit. The Pull-to-Invert switch effectively turns the CRT trace for that channel upside down.

The switch circuit passes the Y1 or Y2 amplifier signals (or both) into the deflection amplifier. The Vertical Display switch control circuitry determines whether the switch will select channel Y1, channel Y2, chopped dual-trace operation, alternate dual-trace operation, or if it will add the two signals together for an algebraic summation of Channels Y1 and Y2. The output of this switch goes into the first stage of the vertical deflection amplifier. From there, it passes through the delay line to the output amplifier section 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 insures that the entire vertical 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, 60 Hz line voltage, or an external trigger feeds into the trigger select circuitry. This circuitry selects one of the trigger signals and then connects it to the trigger input filter. The filter selects either an AC signal or a DC signal, rejects low frequencies in the AC Fast position, or rejects high frequencies in the TV 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 spot from the left-hand side to the right-hand side of the screen at a constant rate.

When the 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 in the A Intensified by B Mode, a sample of the sweep output voltage from the A sweep generator feeds into the B comparator and then to the B time base 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 2-1 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 Times/CM switch.) When the Oscilloscope is in the B Delayed position, the horizontal deflection amplifier is now 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 whose rate is that of the B Time/CM switch. The trace starts at some time after the main trigger, which is determined by the setting of the A sweep generator and the setting of the Delayed Time Position control.

When the X-Y switch is in, 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 connector. The Vertical Display switch control circuitry automatically selects Y2 to be applied to the vertical deflection plates. When the Horizontal Display control is in the External Horizontal position, the voltage connected to the External Horizontal connector can then be impressed upon the horizontal deflection amplifier again, giving horizontal movement of the spot. In this mode, the Vertical Display switch can be set in the Chop position which allows two channels to be simultaneously displayed vertically and external signals to be displayed horizontally.

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 Vertical Display switch is in the Chop position, the tube is momentarily blanked each time the channels are switched. This is to mask any switching transients which are produced by the high speed switch.

The high voltage for the CRT is generated by a Class C RF oscillator. There are basically two output voltages, a minus 1590 volts to feed the CRT gun and approximately 9000 volts which operate the post deflection anode. Therefore, there is about 10,000 volts across the CRT, which accounts for its high brightness. Regulated power supply circuits insure overall accuracy and control the electron beam size and intensity.

CIRCUIT DESCRIPTION

Refer to the Block Diagram (Illustration Booklet, Page 2) and the Schematic Diagram (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.
301-399	Parts on the vertical preamplifier circuit board.
401-499	Parts on the vertical deflection circuit board.
501-599	Parts on the A time base circuit board.
601-699	Parts on the B time base circuit board.
701-899	Parts on the horizontal circuit board.
901-999	Parts on the blanking 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 are designated by a −1 suffix, while those in the Channel Y2 vertical preamplifier are designated by a −2 suffix. (For example: The Channel Y1 AC coupling capacitor is C301-1, while the Channel Y2 AC coupling capacitor is C301-2.) Components without a suffix do not relate to a specific channel. Since both channels are identical, only Channel Y1 is described in this "Circuit Description."

INPUT CIRCUIT

When the Y1 Input switch (AC-GND-DC) is in the DC position, a signal at the Y1 input connector is coupled directly through switches SW301-1 and SW302-1A to the main vertical attenuator. In the AC position, the input signal passes through capacitor C301-1.

The attenuator is made up of two sections; divide-by-one and divide-by-one hundred. The divide-by-one section is used in the six most sensitive ranges while the divide-by-one hundred section is used in the six least sensitive ranges. When the divide-by-one section is in use, capacitor C302-1 sets the input capacitance of the Oscilloscope. When the other section is in use, capacitor C303-1 sets the input capacitance and C304-1 adjusts the attenuation of the capacitive divider (C304-1 and C305-1) so it is equal to that of the divide-by-one hundred resistive divider (R305-1 and R306-1). The resistors attenuate the low frequencies and the capacitors attenuate the high frequencies.

The output of the attenuator is applied through SW302-1B and R320-1 to R308-1. This resistor sets the input impedance of the Oscilloscope and also acts as part of the divide-by-one hundred attenuator. The signal is then coupled through current-limiting resistor R309-1 (bypassed by C306-1) and applied to the input FET, Q301-1A.

The input circuit is protected against high voltage. If the voltage of the gate of Q301-1A is greater than 9 volts, D301-1 will conduct and shunt the current to the +9-volt supply. R309-1 limits the current going through diode D301-1. If a large negative voltage appears, Diode D302-1 will conduct and shunt the current to the −15 volt supply. C306-1 couples high frequency signals into the amplifier. Q301-1A and Q301-1B are wired as voltage followers with the gate of Q301-1B grounded. Therefore, the ouput is the difference between ground and the input voltage. These two voltage followers are driven by two current sources Q302-1A and Q302-1B. Current source Q302-1A is variable. This lets you change the current through Q301-1A so its gate-to-source voltage is exactly that of Q301B, resulting in zero volts across the output of the follower. This is how the vertical amplifier is balanced.

Resistors R311-1, R312-1, R314-1, R315-1 and R313-1 set the current through the two current sources. The outputs of voltage followers Q301-1A and Q301-1B are fed into a pair of emitter followers, Q302-1C and Q302-1D. This lowers the output impedance enough to drive the low-impedance attenuator circuit. The two emitter followers are supplied current through R316-1 and R317-1 and current source Q303-1. Resistors R311-1, R312-1 and R318-1 set the current in the current source.

Transistors Q302, A, B, C and D are part of a monolithic transistor array. Since these transistors were manufactured at the same time, and are in the same case, their temperature compensation is excellent. The output of emitter followers Q302-1, C and D is coupled into voltage divider R319-1, which is a thick film resistor network. Switch SW302-1D selects which tap on this network will feed into the FET follower made up of Q304-1A and Q304-1B. This low impedance attenuator gives attenuation settings to divide by one, two, five, ten, twenty and fifty. The purpose of R322-1, R323-1, R324-1 and R325-1 is to make up the variable attenuator network. In a fully clockwise position, R323-1 has an infinite resistance and the circuit offers no attenuation. However, when R323-1 is in the uncalibrated position, and as it is turned counterclockwise, its resistance decreases and this reduces the voltage that appears at Q304-1A and Q304-1B. Resistors R326-1 and R327-1 supply current to the FET followers.

The remaining low value resistors (R301-1, R302-1, R307-1, and R320-1), primarily in the high impedance attenuator circuit keep the inductance of the wires from causing the oscilloscope to ring on fast risetime signals and are also used to shape the amplifier bandwidth. The network on the bottom of the low impedance attenuator, made up of R321-1 and C311-1, also provide frequency compensation. Capacitors C307-1, C308-1, and C312-1 are all bypass capacitors. Inductors L301-1 through L305-1 compensate for the inductance in the thick film resistors and associated wires and foils.

The differential signal from Q304-1A and Q304-1B is coupled through R328-1 and R329-1 and applied to transistors Q305-1 and Q306-1. These two transistors convert the voltage difference between their bases into a current difference between their collectors which is impressed across resistors R339-1 and

R341-1. The other end of these resistors connects to the collectors of Q307-1 and Q308-1, respectively, where the current gain of the circuits is changed to voltage.

The total current drawn through Q307-1 and Q308-1 is constant. Therefore, the voltage across R342-1 is constant. This presents a constant voltage at the emitters of Q307-1 and Q308-1, which produces a constant voltage at the bases of Q307-1 and Q308-1. In this configuration, the gain of the stage is roughly the resistance of R339-1 divided by the resistance of R336-1. For example, assume that the values of R336-1 and R337-1 are both 50 ohms, and the values of R339-1 and R341-1 are both 500 ohms. Also, assume that the voltage difference between inputs A and B is exactly 1 volt. This means that there is one volt difference between the emitters of Q305-1 and Q306-1. This, in turn, makes the current through Q305-1, 5 milliamperes more than it was before and the current through Q306-1, 5 milliamperes less than it was before. This difference of 10 milliamperes has to flow through R339-1 and R341-1. Since one end of each of the resistors is at a constant voltage, the difference of voltage on the other side of the two resistors is 1,000 ohms × 10 milliamperes = 10 volts. You can see in this example that the gain of this amplifier is 10. The output from this amplifier goes into a double-pole double throw switch, which inverts the signals when the pull-to-invert switch knob on the front panel is actuated. R334-1, R335-1 and R338-1 apply a small amount of differential current into the collectors of Q305-1 and Q306-1. This allows the output of the amplifier to be adjusted for zero volts, with zero volts going into it, to insure that the base line will not shift when the pul-to-invert switch is activated.

As shown in Pictorial 2-2 (Illustration Booklet, Page 4), differential amplifier Q309-1, Q310-1, Q317 and Q318 is very similar to the previous amplifier. R351-1 supplies a constant current to Q309-1 and Q310-1. R355-1 changes the impedance between the emitters of Q309-1 and Q310-1 so the current output can be adjusted for a given voltage input. Therefore, this control adjusts the gain of the stage. In the case shown, both diodes D303-1 and D306-1 are forward biased and have no effect on the circuit. The output from transistors Q317 and Q318 are connected to the differential emitter follower consisting of transistors Q319 and Q320. Resistors R398 and R399 supply the emitter current for these transistors.

The emitter followers isolate the preamplifier from the deflection amplifier and provide a low driving impedance. Resistors R347-1 and R352-1 (as shown on the large schematic) provide thermal compensation for transistors Q309-1 and Q310-1. Resistors R345-1, R346-1 and R350-1 make up a network to supply a small amount of differential current to the bases of Q317 and Q318. This is used to position the trace on the CRT.

The trigger amplifier is connected to the emitters of Q309-1 and Q310-1. It consists of Q312, Q313, Q314, Q315 and Q316, and operates very similar to the amplifiers already mentioned. Diode D310-1 acts as thermal compensation for the current source supplying Q312-1 and Q313-1. R365-1 sets the DC level on the collector of Q314-1, which adjusts the output of the trigger amplifier to zero. Q316-1 is an emitter follower.

VERTICAL SWITCHING

Both vertical preamplifiers share the final preamp stage, Q317 – Q320. This is accomplished with two high-speed diode switch networks (D303-1 thru D306-1 and D303-2 thru D306-2) that are actuated by the display control circuits. Normally, when one diode switch is turned on, the other is turned off so that only one signal can be coupled to the vertical deflection amplifier. Two-channel operation is accomplished by turning each switch network on and off at a rapid rate or on alternate display sweeps. When both switches are turned on at the same time, the signals are mixed (algebraically added).

Refer to Pictorial 2-3 (Illustration Booklet, Page 4) as you read the following explanation.

As we mentioned before in the explanation of how the amplifier circuit works, the voltage at the collector of a variable current source transistor remains fairly constant. In this stage, the voltage on the collector of Q309-1 is approximately 2.5 volts. If Channel Y1 is turned on (by Q323) and Channel Y2 is turned off (by Q324), the voltage at the anodes of D304-1 and D305-1 is near 0 volts. This reverse biases diodes D304-1 and D305-1 so they do not draw current. Therefore, all the current from Q309-1 and Q310-1 goes through diodes D303-1 and D306-1 to amplifier Q317 and Q318. The voltage at the anodes of D304-2 and D305-2 is at 5 volts. This forward biases diodes D304-2 and D305-2. Since the voltage at the anodes of D303-2 and D306-2 is about 3.1 volts, and the voltages at the cathode of

D303-2 and D306-2 is 4.4 volts, those two diodes are reverse biased and none of the signals from the Y2 amplifier are connected to amplifier Q317 and Q318. When Channel Y1 is switched off, and Channel Y2 is switched on, the reverse is true. The voltage at the anodes of D304-1 and D305-1 is 5 volts and the voltage setting at the anodes of D304-2 and D305-2 is near zero volts.

When the Verticle Mode switch is in the ADD position, the voltage at the anodes of D304-1, D305-1, D304-2 and D305-2 are all zero volts. This reverse biases all these diodes and forward biases diodes D303-1, D306-1, D303-2, and D306-2. Then both channels feed into the output amplifier of Q317 and Q318. Therefore, the output is the sum of Y1 and Y2 inputs. Since both the Y1 and Y2 circuits now feed into Q317 and Q318, there is twice the normal current flowing into the junction at the bases of transistors Q317 and Q318. In order for this to keep from upsetting the bias of the circuits, R387 and R388 are switched in by transistor switch circuit Q321 and Q322. This draws off half of the current, and as far as Q317 and Q318 are concerned, they are only being fed by one of the vertical amplifiers. When in the Add mode, R391 of the switching circuit is near zero volts. This turns Q322 off and Q321 on, and, therefore, draws any excess current away from Q317 and Q318. When the circuit is not in the Add mode, transistor Q322 is turned on, which turns Q321 off and therefore disconnects any effects of R387 and R388 from Q317 and Q318.

DISPLAY CONTROL

The Vertical Display switch selects Channel Y1, Channel Y2, CHOP, ALT, or the ADD function. In the X-Y mode, the switch may be in any position, as it is effectively disconnected from the other circuits.

When the Oscilloscope is not in the X-Y position, the logic level at Pins 12 and 13 of U304D is a logic 1. This makes output Pin 11 a logic zero and, when in the Y1 position, this zero is transferred into the set terminal of U303. This makes the Q a logic 1 and $\overline{Q}$ a logic zero. The one level from the Q output is fed into Pin 1 of NAND gate U304A. Since the other input is at a logic 1, due to R382, the output will be at a logic zero. This turns on transistor Q324 and puts its collector voltage near 5 volts. The zero output from the $\overline{Q}$ output of U303 is fed into Pin 5 of U304B, making its output a 1 level. This turns off Q323 and its collector voltage goes to zero volts. Then, from the operation of the diode switch, the Channel Y1 has been turned on and Channel Y2 turned off. When the Vertical Display switch is in the Y2 (Channel 2) position, U303 is in the reset condition. This means the output of the Q terminal is at its logic zero and the $\overline{Q}$ output is a logic one. This time the reverse happens. Q323 is turned on and Q324 is turned off.

When the Vertical Display switch is in the CHOP position, Pins 9 and 10 of U304C are at logic zero. The output of U304C is a logic 1, which turns on the chopper circuits in the time base section and a combination of the chop signal and the alternate signal then come onto the vertical board from the horizontal board on the line marked TOGGLE. Each time there is a negative-going transition at Pin 1 of U303, the flip-flop changes state and, therefore, alternately switches Channel Y1 and Y2.

When the Vertical Display switch is in the ALT (alternate) position, Pins 9 and 10 of U304C are at logic 1. This makes its output (Pin 8) a logic zero which turns the chopper off. The only signal coming back from the horizontal time base now is the alternate signal at the end of a sweep. This negative-going transition will cause the flip-flop to alternately turn Channels Y1 and Y2 on and off after each sweep.

When the Display switch is in the Add position, Pins 2 and 4 of U304 A and B are at zero level. This makes Pins 3 and 6 a 1 level, which turns off Q323 and Q324, which turns on both channels. Also, when the mode switch is in the Add position, transistors Q322 and Q321 switch in R387 and R388 which draws away the surplus current mentioned previously.

If the Oscilloscope is put in the X-Y position, the cathode of D308 and Pins 12 and 13 of U304D are at logic zero. This puts the logic zero level on the reset line of U303 and causes it to be in the Channel Y2 mode. The output of U304D pin 11 is now at a 1 level and effectively disconnects the Display switch. Therefore, when the X-Y button is pushed (on the horizontal board) the Vertical Display switch is completely disconnected and it may remain in any position.

+21 and −21 volts comes onto the vert preamp board, is filtered by C326 and C327, and is regulated by U301 and U302. R376, R377 and R378 set the output voltage to plus and minus 15 volts and C328 and C329 provide additional filtering. Transistors Q325 and Q326 increase the current capability of the regulator and resistors R373-1 and -2 and capacitors C324 and C334 also provide filtering. Resistor R374-1 and -2 and D311-1 and -2 make up a 9-volt regulated supply, used to power the input FET followers.

VERTICAL DEFLECTION

The output of the vertical preamplifier circuits connects to the bases of Q401 and Q402; and R404, R405, and R406 supply emitter current to these transistors. Resistors R403 and R407 provide thermal compensation and R402 and R408 are the actual load resistors of this circuit and provide approximately 200 ohms output impedance to feed the delay line. R401 and C401 together make a decoupling network to transistors Q401 and Q402. The RC networks consisting of R409, C403, C404, R411, R412 and C405 compensate the amplifier at several different frequencies to obtain good transient response characteristics.

The output of the delay line connects across R414, which terminates the delay line correctly. The signal then feeds into the bases of Q403 and Q404. Resistors R418 and R421 supply current to the emitters and R419 is a current source to operate the amplifier. Resistors R417 and R422 are the load resistors for this amplifier, and R416 and C406 together make a decoupling network to supply current to the transistors. The RC network across the emitters, consisting of R423 and C407, are again frequency compensating devices. The output is coupled into the bases of Q405 and Q406. R427 and R428 are wired in series to make a current source. C408, R431, C409 and R432 make another network to adjust the amplifier for optimum transient response. The bases of Q407 and Q408 are held at approximately 36 volts by diode D401. This also fixes the emitter voltage of Q407 and Q408 to approximately .6 volt below the base levels. Therefore, Q405 and Q406 are voltage-to-current converters and feed into the common base amplifiers consisting of Q407 and Q408. This arrangement is called a cascode amplifier and obtains maximum bandwidth from the transistors used. The ferrite beads and R433 and R434 limit oscillations in the output amplifier. R437 supplies current to operate the Zener diode, D401. The load resistors consist of a series combination of R438, R439, R441, R442, R443, R444, R445 and R446. Coils L401 and L402 together make up the shunt peaking network.

The output is then coupled through R447 and R448 to the vertical deflection plates in the CRT. C413 is a power supply filter capacitor.

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, if no trigger signal is present, the auto-baseline circuit allows the sweep generator to function and provide an automatic baseline.

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 $> -.9$ V.

TTL — logic 0, or low, is $<.8$.
logic 1, or high, is > 2.0.

TRIGGER

A trigger signal (Line, Y1, Y2 or Ext) is selected by Trigger Select switch SW502A, is applied through the Trigger Coupling circuits, and then is coupled through the plus or minus (+ or −) selector (SW502B) to the trigger amplifier circuits. External trigger signals are first amplified by the external trigger amplifier before they are applied to the Trigger Select switch. This amplifier consists of source follower Q711, constant current source Q712 and emitter follower Q710. R775 sets the input impedance, R776 and D709 form over-voltage input protection, and C731 forms a high frequency path around R776. External trigger zero control R779 sets the bias voltage so that the emitter of Q710 is at zero volts.

The trigger coupling switches allow you to select one of four coupling modes: DC, AC, through C512 and C513; AC Fast, through C514 (passes only signals of 5000 hertz or greater); and TV. Capacitors C512, C513, C515 and R701 form a low frequency divider that passes only AC signals under 1000 hertz.

The signal at part B of the Trigger Select switch is compared with the voltage on level control R502 by the trigger amplifier. The signal is amplified and then shaped by U701. Transistor Q703 is a constant current source for differential amplifier transistors Q701 and Q702, control R716 (Trig Level) adjusts the current through the stage, and control R711 balances the output.

U701B then further amplifies the signal, U701A "squares it up" (R723 and R722 make it a Schmitt trigger), and U701C amplifies it again and applies it to U702B, U703A and the auto-baseline generator.

When the TV Trig Coupling switch is in, U703A is inhibited, and U702B divides the trigger signal by two and applies it to U702A of the sweep control circuits. When the TV switch is not in, the trigger signal is coupled through U703A to the sweep control circuits. The auto-baseline circuit consists of Q706, Q707 and Q708. When a trigger signal is present, Q706 and Q707 conduct and charge C711. This causes Q708 to conduct and turn on Q709, which turns on D702, the Trig LED. When there is no trigger signal; C711 discharges through R735, Q708 and R738; and causes Q708, Q709 and the LED to turn off.

SWEEP

As shown on the Schematic, the Auto switch is activated (pushed in). With trigger signals coming in, both pins 12 and 13 of U703C are at logic low. This means pin 14 is high and pin 6 of U703B is low. When the end of the sweep is sensed, U702A is reset by a high at pin 4 and then waits for another trigger signal at pin 6. When there are no trigger signals coming in, U703C pin 13 goes high (Q708 turns off) and drives pin 14 low.

Now with Low's on pins 9, 10 and 11 of U703B, pin 6 is high, which automatically keeps setting U702A and starting a new sweep at the end of the previous one. When the Norm switch is in, the Auto switch is out and puts a high on pin 9 of U703B. This keeps pin 6 low so that U702A will only start a sweep when a trigger signal comes in to pin 6.

Sweep control IC U702A changes state when a trigger signal is received at pin 6. This transition is translated to TTL levels by Q704 and Q705, and applied to transistor Q501.

A low from the translator turns off Q501 to allow the A Sweep Generator to generate a ramp. Resistors R501, R502, R503, R504, R505, R506, R507, R508, R509, are timing resistors and are selected by the Time Base Switch. Capacitors C501, C502, C503, and C504 are timing capacitors, also selected by this switch. U501 and the emitter follower Q502 monitor the generated ramp. Q502 provies the drive to output circuits connected to the sweep generator. Resistor R511 and control R524, the variable time base control, and D501, D502, and R512, form a boot-strap circuit that maintains a constant voltage across the timing resistors to insure a constant current through them, and therefore, produces a linear ramp. This circuit is connected between the emitter of Q502 and the +82-volts power supply. The ramp signal is connected to resistors R521 (sweep length control) R522 and R523.

When the amplitude of the ramp is of sufficient height as set by the sweep length control, U707A will change state. The pulse is coupled to pin 3 of U710A. Pin 14 of U710A will change state immediately. This pulse is coupled through U709, Sections C and B, to the blanking amplifier to blank the CRT. The output of U707A is also coupled to a delay monostable consisting of U706, Sections 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 U705.

U705 and capacitors C517, C518, C519, C521, C522, C523 along with resistors R766 and R765, the variable holdoff, form the trigger holdoff circuit that allows the sweep generating circuits to settle down before the sweep control IC recognizes the next trigger pulse. U705 produces a pulse as soon as it receives the pulse from the monostable, U706. The pulse is coupled through U706B, translator resistors R763, R764 and R746 to pin 13 of U704C, to pin 4 of Sweep control U702A.

Pin 4 is the reset pin for U702A. The outputs of U702A change state and turn on Q501 which discharges the timing capacitor and causes the retrace. The output of the translator at U706B is also connected to pin 10 of U703B. If the Trigger Mode switch is in the Auto position and there is not a trigger signal, U703B will produce a pulse to make control IC U702A change state as soon as the holdoff time is finished: which in turn tells Q501 to turn off and allows the sweep generator to start a new ramp. U707B also monitors the output of the ramp generator. If the voltage at the top of resistor R523 becomes large enough, U707B will change state. Its pulse is also coupled through U706B and U704C to pin 4 of control U702A, 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 mode, an ECL low at pin 11 of U704B occurs when the Single switch is pushed. This enables cross-coupled latch U704A and U704B. Pin 13 of U704C and pin 4 of U704A are normally low between sweeps. Pushing the Reset switch causes an ECL high to be coupled through noise filter C716, R752, C715, and R753 to pin 10 of U704B. This puts an ECL low on pin 6 of U704B, pin 12 of U704C, and pin 5 of U704A. This produces an ECL low on the reset side of U702A (pin 4) and allows it to sweep when a trigger signal is detected and the toggle input (U702A pin 6) is pulsed low. The "end of sweep" signal appears at U704A pin 4 as an ECL high, causing the latch to change state and put an ECL high on U702A pin 4. This prevents another sweep until the Reset switch is pushed again and the latch changes back to wait for another pulse.

The output, from Q502, of the sweep generator is coupled through R519 and switch SW702 B and C to the horizontal amplifier. The signal is also coupled from U501 pin 6 to the B time base trigger circuits, transistor Q604, Q605 and Q606. R638, the Delay Time Position control, sets the point at which the B trigger circuits will trigger. The output of Q606 is coupled through capacitor C613 to the input of U602C. U602C and U606D are cross-coupled gates. As soon as the pulse is supplied to pin 9, pin 8 goes to a 1 state and is coupled through U602B to ramp switch Q601. The low at Q601 causes it to turn off to allow the B sweep generator to generate a ramp. Transistor Q603 is connected as an FET diode and limits the discharge current when Q601 turns on to end the sweep.

Timing resistors R601 through R609 and timing capacitors C601 through C604 operate similar to those of the A sweep generator previously described. U601 and Q602 monitor the ramp. Diode D601 and D602 form a boot-strap circuit to maintain a constant voltage across the timing resistors. The output of the sweep generator is connected to sweep length control R634 and resistor R635. When the amplitude of the signal reaches the predetermined value, U602A changes state. The output from U602A is coupled through a delay circuit R636 and C614 and connected to pin 13 of U602D. This resets the flip-flop and the signal is coupled through U602B to Q601. This turns on Q601, which discharges the timing capacitor and ends the sweep. The output of the B sweep generator is connected to the horizontal amplifier through "B Cal" control R633 and switch SW703C. When the delayed sweep feature is not being used, the B sweep generator is locked out via switches SW702D and SW703D that are connected to pin 5 of U602B that keeps any of the pulses from reaching Q601.

U711 and U708 form a logic array to control the dual trace functions of the scope. Sections A and B of U711 are connected as an oscillator which operates at approximately 200 kHz. When in the Chop mode, this oscillator supplies the switching signals for the vertical channels. U708C provides the output for the chop signal to the blanking amplifier and U708A provides the output to the vertical board for the toggle function. U708B forms the gating action to the oscillator when in the Chop mode. The output of U708D is connected to the preset of U710A so that when the oscilloscope is in the external X or X-Y mode of operation, the blanking is held on. U710B is the blanking control for B sweep generator U709; sections A, B, C, and D; which multiplexes the A and B sweep generator blanking signals for the various modes of operation. Diodes D706, D705, D704 and D707 connect the blanking signals to blanking control U710 when the different modes of operation are selected.

HORIZONTAL AMPLIFIER

The horizontal amplifier has several inputs which can be selected from the front panel pushbuttons. These inputs are the A time base, A intensified by B, B Delayed, X-Y, and Ext Horiz modes of operation. In the X-Y mode, the trigger amplifier from Channel 2 is connected through X-Y Cal control R790 and switch SW704C. Capacitor C735 provides a high frequency path around R790. In the Ext Horiz mode, the horizontal amplifier is connected to the output of the external horizontal amplifier. Resistor R782 sets the input impedance for the external amplifier. Resistor R783, that is bypassed by capacitor C733 (in conjunction with diode D711 and the gate drain junction of Q713) form the input protection for the external horizontal amplifier. Transistor Q713 is connected as a source follower with Q714 as the current source for the stage. Resistor R785, the ext horizontal zero control, sets the current through the stage to produce zero volts at the source (used at the drain) of Q714.

The horizontal amplifier has two stages of gain as shown on the Schematic Diagram. The first stage consists of Q716, where the input signal and the horizontal position voltage are summed together. The signal is amplified by approximately 6 and then is coupled directly to the base of Q718. The second stage consists of Q718 through Q724 and performs both amplification and single-ended to differential conversion. Q718 and Q719 are the input stages for the second stage of gain. The gain of the second stage is controlled by Cal control R814 which is in series with R815. This network is in parallel with the emitter resistors R809 and R811 and produces a gain of approximately 30. When the "times five" feature is used, times five Cal control R821 and series resistor R819 are switched in parallel with the emitter network, thus increasing the gain of the stage by five.

The differential signal is then coupled from the collectors of Q718 and Q719 to emitter followers Q721 and Q722. Q721 and Q722 in turn drive the output devices Q723 and Q724 respectively. The output of the second amplifier drives the CRT plates from the collectors of Q723 and Q724. Negative feedback is used in both sides of the differential amplifier with high frequency compensation across each feedback resistor. Trimmer capacitor C738 in series with capacitor C739 forms a high frequency path around feedback resistor R824, and trimmer cap C741 in series with capacitor C742 forms a high frequency path around feedback resistor R829. Diodes D712, D713, D714 and D715 prevent the output transistors from going into saturation and cutoff in the times five mode of operation.

The gain of the second stage is set by the ratio of the feedback resistor to the emitter resistor of Q718 and Q719. The plate adjust control, R816 at the collectors of Q718 and Q719, adjusts the voltage at the output of the amplifier for optimum CRT performance. Transistor Q717, and its associated components, provides a constant voltage source for the input of transistor Q719. Coils L701 and L702 in the collectors of the outputs provide shunt peaking to improve the high frequency response of the amplifier.

CALIBRATOR

Sections C and D of U711 are connected as an oscillator that oscillates at approximately 1000 hertz. The output of the oscillator is coupled by resistor R792 to the base of transistor Q715. Resistor string R793, R794 and R795 is a voltage divider between the +15-volt supply and ground, and along with transistor Q715, provide a 1-volt peak-to-peak signal at the junction of resistor R795 and R794.

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 and EXT Horizontal operation, the trace is left on to the level specified by the Intensity control. When in the A intensified by B mode, the trace has normal brightness during the A sweep, but is intensified when the B sweep is running. Since the control grid and cathode voltage of the CRT is about 1500 volts below ground (−1500 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 (Q905 and Q906) that is capacitor coupled by C911 to a demodulator, D907 and D908. This demodulator is referenced to the −1590-volt supply and its output is coupled to the CRT control grid by R936 and R937.

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 greater than 90 volts **more negative** than the cathode.

2. As the 90-volt difference between the grid and cathode is reduced, the CRT is unblanked and the beam intensity is increased.

The blanking amplifier (Q901-Q904) 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 (emitter of Q903), 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 C912 and R937.

The blanking amplifier has a common base input stage, Q901. Here, the input blanking pulses and the Intensity control voltage are summed in its emitter. Transistors Q902, Q903, and Q904 are current and voltage amplifiers whose gain is determined by the ratio of feedback resistor R916 and the appropriate input resistor: R903, R904, R906, R909, R911, or R912. Capacitor C903 is for high frequency compensation.

The blanking amplifier is coupled to the emitter of Q905 by R918 and R925. Q905 and Q906 form an emitter-coupled oscillator. Capacitor C907 and emitter resistor R925 determine the frequency of oscillation, which is approximately 200 kHz. Diode D906 protects Q906 from negative spikes during turn-on when C911 charges. D905 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 R933 and R934, and C908 filters this voltage.

As shown in Pictorial 2-1 (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 rotated, 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 of the second section, which in turn 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 pusle from the output of the first section of the blanking amplifier is also coupled directly to the grid by capacitor C912. Capacitor C912 forms the fast path around the oscillator section. This unblanks the CRT immediately and then the oscillator can follow and hold the tube on to 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.

As shown in Part 'A' by 'B' of the Pictorial, in the A INTEN BY B mode, both the A and B sweep signals and their separate blanking signals are shown. Only the A ramp is used but both blanking signals are summed by Q901; they appear as the "A" + "B" unblank signal. The B portion of the trace is intensified as shown at the bottom of the Pictorial. In the B DELAYED mode, the B ramp is used for the sweep. The B ramp is delayed and starts at a selected time (Td) after the A ramp starts.

Circuits on the horizontal board (U709) route the 'B' blanking signals to the 'A' blanking output during the B DELAYED mode. This corrects for brightness lost because the tube is blanked during the 'A' ramp and only turned on during the 'B' ramp. This creates a lower on-to-off ratio and a dimmer trace. Using the B Ends A control also increases this lost brightness by decreasing the off time of the tube.

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.

POWER SUPPLY

LOW VOLTAGE POWER SUPPLY

Line voltage enters the scope through fuse F1 and switch SW1 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. Another secondary tap supplies the high voltages for the high voltage oscillator, the deflection circuits, and other CRT bias circuits. Diodes D104 and D101 together make a full-wave rectifier and filtering is supplied by capacitor C103A. R105 couples voltage to the high voltage oscillator circuits and C102 filters the voltage to reduce the 120 hertz ripple. R101 adjusts the voltage to the geometry control grid of the CRT. C101 is a simple bypass capacitor. The voltage from C103A is applied through R106 to C103B for further filtering. This voltage (approximately 130 volts) powers the horizontal deflection amplifier circuits. Then R107 further reduces this voltage to power the blanking circuit. Another rectifier and filter circuit (D102, D103, C103C, C106, R108, and C104) supplies voltage to regulator transistor Q101 to produce constant voltage for the vertical deflection circuits. R111 supplies current to zener diodes D113 and D114. They set the voltage at the base of Q101 to approximately 92 volts. Since the emitter follows the base, its output is about six tenths below the voltage at the cathode of D113. This produces a regulated voltage for the vertical deflection circuits. R109 limits the dissipation of transistor Q101 and C105 keeps the circuit stable.

The next secondary on the transformer is connected to diodes D105, D106, D107 and D108. This makes a positive and negative full-wave rectifier system.

The AC output of the secondary voltage powers the pilot light (through P104 pin 2) and is also applied to R112 and C113 to supply voltage for the line trigger signal. The RC network filters the 60 cycle signal for more reliable line triggering. The rectifier output (from D105-D108) is filtered by C107 and C114 and C108 and C109. These voltages are applied to regulators U101 and U102. Resistors R113, R114 and R115 make up a bias arrangement to set the regulators to track at +15 and −15 volts. C111 and C112 provide output filtering and prevent oscillation.

The third secondary connects to diodes D109, D110, D111, and D112. The output is filtered by C115, C116, C117, C118, and applied to U103 and U104. U103 maintains a 5-volt regulated output, and R116 and R117 set the regulation voltage of U104 to minus 5.2-volts DC. C119 and C121 further filter the voltage coming out of the +5-volt and −5-volt regulators and suppress any oscillations.

HIGH VOLTAGE POWER SUPPLY

The previously mentioned voltage from R105 on the low voltage power supply board is connected to L201 on the high voltage power supply. L201 is a filter to keep "trash" from feeding from the high voltage oscillator into the rest of the Oscilloscope. R201 is a resistor which supplies current to regulator diode D202. The zener voltage of this diode is 30 volts and is used to operate regulator integrated circuit U201. Q1 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, Q2, C202, R218, R204, and C203 make a class C high voltage oscillator circuit. The purpose of R204 is to start the oscillator initially and maintain DC bias. C203 acts as a resonator circuit for the primary of the transformer, and C202 maintains a bias on Q2 while the oscillator is operating. RF voltage at the secondary of this oscillator, which is about 40 kHz, feeds to the packaged tripler on top of the transformer and is multiplied up to an 8500-volt level. The voltage coming out of the other secondary is rectified through D201 and filtered by C204, R205 and C205. This voltage is about −1590 volts and runs the CRT gun circuits. The CRT cathode, which is at −1500 volts, is directly hooked into the resistor divider string consisting of resistors R213, R214, R215, R216 and Focus control R2. This resistor string has two purposes. First, it supplies the bias voltages required for the CRT focus grid and secondly it supplies current to voltage regulator U201.

U201 is a standard operational amplifier connected as an inverting amplifier. Resistors R208 and R212 divide the 30 volts down to approximately 10 volts which is applied to the positive terminal, pin 3. R209 supplies current to D203, which is a 5-volt reference diode. This assures that the voltage at the junction of R209 and R211 is five volts above the voltage of U201, pin 3. Having a very high gain, the operational amplifier will try to make the voltages at pins 2 and 3 equal. Since the voltage at the resistor junction is 5 volts above the voltage at pin 3, the voltage across R211 is 5 volts. This will set a certain reference current into the node at pin 2.

The −1500 volts is connected to the top of the previously mentioned resistor string (R213, R214, R215, and R216). If this 1500 volts is constant, a constant current will flow through the resistor string. Remember, the operational amplifier will attempt to keep the voltages at pins 2 and 3 equal. In order for U201 to keep its input equal, the current through the resistor string has to be equal and opposite to the current in R211. Therefore, control R211 sets the voltage at the −1500-volt level.

The output voltage of the operational amplifier varies typically between 0 and 30 volts. This drives Q201, which translates this voltage up to approximately 90 to 125 volts and then drives pass transistor Q1. R207 limits the base current into Q201 and R206 sets the gain of that stage. The collector current of Q201 is supplied by R202 and connects directly to the base of Q1. The emitter voltage at Q1 is about .6 volt below the base, and that is the voltage that runs the high voltage oscillator circuit. If the −1500 volts should drop (to say, −1400 volts), there is less current at U201 pin 2. In order for U201 to maintain balance, its output voltage has to drop. When this drops, it feeds less current to Q201, which increases the collector voltage of Q201 and the base voltage of Q1. Therefore, the emitter voltage of Q1 goes up, which supplies more voltage to the oscillator circuit itself. This will supply enough extra voltage to the input of the oscillator such that the output of the oscillator will then put −1500 volts at the top of the resistor string and again balance the circuit.

CALIBRATION

This section of the Manual is divided into two parts: "Initial Calibration" and "Touch-Up Adjustments." The "Initial Calibration" must always be performed after the Oscilloscope has been serviced or parts have been replaced. The "Touch-Up Adjustments" must always be performed after the "Initial Calibration" and any time you doubt the accuracy of your Oscilloscope.

INITIAL CALIBRATION

The following equipment is needed to calibrate your Oscilloscope:

- VTVM.
- Heathkit Oscilloscope Calibrator — OR — A Square Wave Generator capable of producing 1 kHz to 1 MHz signals, with up to 5 volts output rise time <4 ns and overshoot <1%.
- Sine wave generator capable of 100 kHz.
- A 1000 Hz Square Wave Voltage Calibrator (1 to 10 volt output) is also recommended, but not necessary; accurate in amplitude to 1% at 1 volt; accurate in frequency to 1%.

Controls and adjustments associated with channel Y1 are identified as Y1, CH1, or a "−1" following the circuit component number, such as R301-1. Channel Y2 controls and adjustments are identified as Y2, CH2, or a "−2" following the circuit component number. Use the plastic alignment tool supplied with this kit to reach and make the adjustments. Some adjustments require a tool with a narrow blade. Use the "calibration tool" prepared for those.

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 proceeding.

LINE VOLTAGE

Turn off the Oscilloscope and disconnect the line cord plug from the AC power source.

Remove the six rear panel screws and slide the Oscilloscope out of the cabinet. Be careful not to touch any of the circuitry when you move the Oscilloscope around for various adjustments. **Dangerous voltages are present.**

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 the thermal drift of the sensitive vertical preamplifier circuits.

1. Measure the line voltage.
2. If the line voltage is below 115 (or 235) volts AC, set the rear panel NOR-LOW switch to LOW. Otherwise, leave it in the NOR position.
3. Connect the line cord plug to the AC power source.
4. Turn the ON-OFF switch clockwise to turn on the Oscilloscope. The power indicator lamp should light.
5. Allow the Oscilloscope to warm up for 30 minutes before you proceed.

WARNING: When the line cord is connected to an AC outlet, AC voltage 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 this voltage or an electrical shock will result. See Pictorial 3-1 (Illustration Booklet, Page 5).

HIGH VOLTAGE

Refer to Pictorial 3-1 to locate the high voltage circuit board.

Adjust your voltmeter to measure −1500 volts DC.

Connect the negative voltmeter lead to the Oscilloscope chassis.

Refer to Pictorial 3-2 (Illustration Booklet, Page 5), measure TP1, and then adjust the HIGH VOLTAGE ADJ control for −1500 volts DC.

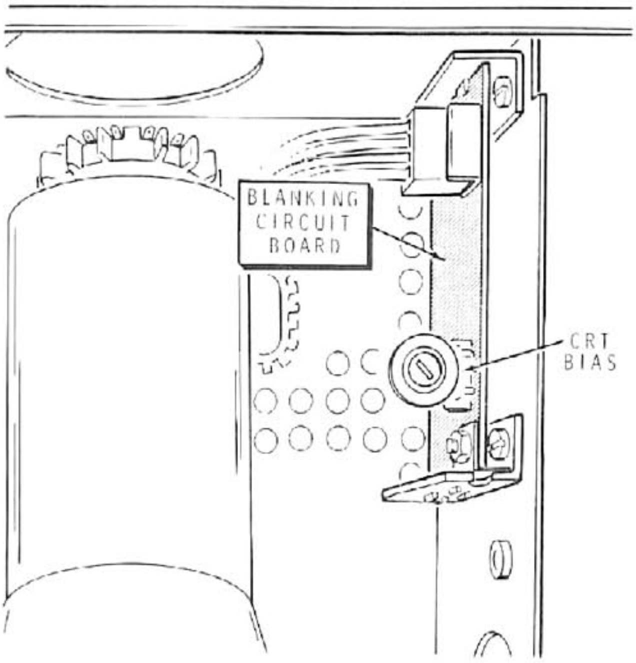
BEAM ADJUSTMENTS

Refer to Pictorial 3-1 (Illustration Booklet, Page 5) to locate the remaining seven circuit boards.

Momentarily refer to Pictorial 3-6 (Illustration Booklet, Page 6) and adjust trimmer capacitors C738 and C741 as shown in the inset drawing.

Set the indicated front panel controls as follows:

VERTICAL SECTION	
Y1:	
INPUT switch (AC-GND-DC)	GND
VOLTS/CM	.1 V
VARIABLE	Fully clockwise (CAL)
POSITION	Center of rotation
PULL TO INVERT	IN
Y2:	
INPUT switch (AC-GND-DC)	GND
VOLTS/CM	.1 V
VARIABLE	Fully clockwise (CAL)
POSITION	Center of rotation
PULL TO INVERT	IN
VERTICAL DISPLAY	Y1
HORIZONTAL SECTION	
HORIZONTAL DISPLAY	A
DELAY TIME POSITION	Any position
HORIZONTAL POSITION	Center of rotation and pushed in
A TIME/CM	.1 ms
B TIME/CM	.1 ms
VARIABLE	Fully clockwise (CAL)
HOLD OFF	Fully counterclockwise
TRIGGER SECTION	
TRIGGER MODE	AUTO
TRIG COUPLING	AC
TRIGGER SELECT	EXT +
LEVEL	Fully clockwise
BEAM SECTION	
INTENSITY	Fully clockwise
FOCUS	Center of rotation
ON-OFF	ON



PICTORIAL 3-4

After a few moments, a trace should appear on the CRT. If it does not appear, refer to Pictorial 3-4 and adjust the CRT BIAS control counterclockwise until a trace appears.

Turn the INTENSITY control counterclockwise to the 8 o'clock position.

Refer to Pictorial 3-4 and adjust the CRT BIAS control until the trace just turns off.

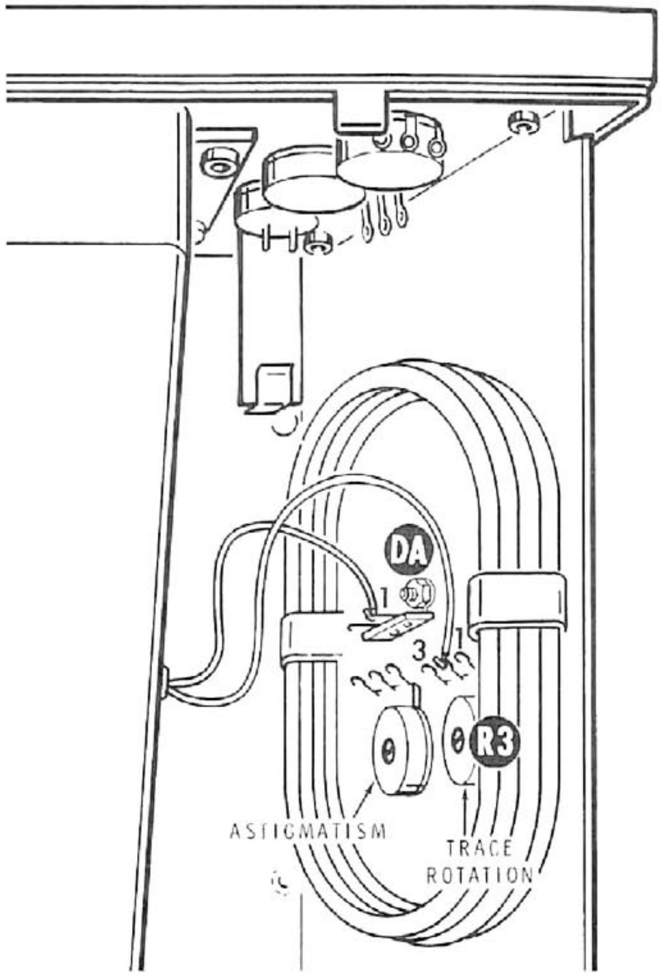
Adjust the INTENSITY control until the brightness of the display is like you want it.

Push in the X-Y pushbutton.

Adjust the Y2 POSITION and HORIZONTAL POSITION controls to center the dot on the screen.

Alternately adjust the FOCUS and ASTIGMATISM controls (see Pictorial 3-5) to obtain as small and round a dot as possible.

Adjust the HORIZONTAL POSITION control until the heat sinks of Q723 and Q724 (on the horizontal circuit board; see Pictorial 3-6, Illustration Booklet, Page 6) are both at the same voltage. Then adjust the horizontal circuit board PLATE ADJ control until the heat sinks both measure 60 volts.



PICTORIAL 3-5

Push in the A pushbutton and adjust the INTENSITY, Y1 POSITION and HORIZONTAL POSITION controls for a trace centered on the screen.

Set the A and B TIME/CM switches to 1 ms.

Adjust the TRACE ROTATION control (see Pictorial 3-5) until the trace is parallel with the horizontal graticule lines. If the control does not have enough adjustment, turn the Oscilloscope off and perform the following step that pertains to your situation.

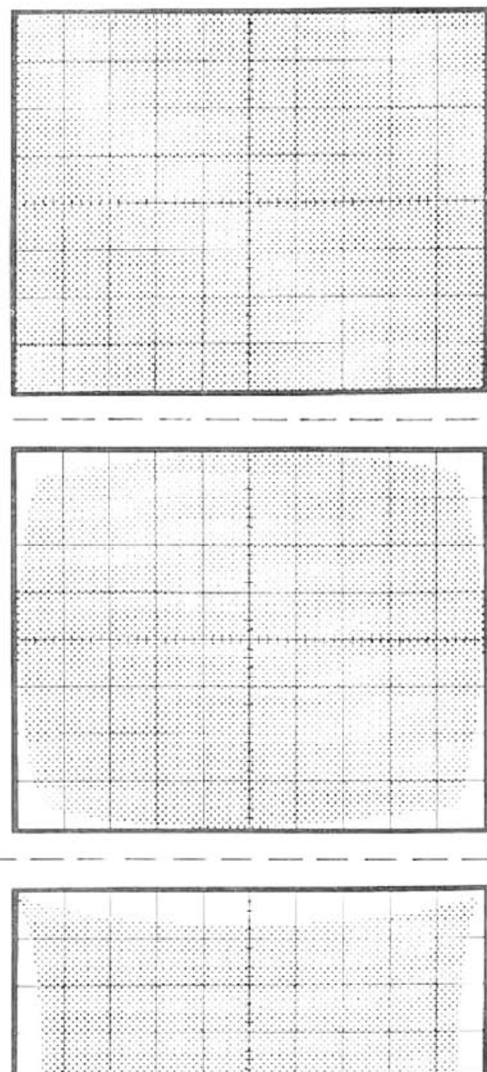
— If the control is fully clockwise: Remove the trace rotation wire from terminal strip DA lug 1 and solder it to control R3 lug 3 (an orange wire is also at this lug).

— If the control is fully counterclockwise: Remove the trace rotation wire from terminal strip DA lug 1 and solder it to control R3 lug 1 (a gray wire is also at this lug).

GEOMETRY ADJUSTMENT

Set the Y1 INPUT switch to AC. Connect an approximate 100 kHz sine wave to the Y1 INPUT connector and adjust its amplitude for a display that is 8 cm high.

Refer to Pictorial 3-6 and adjust the A time base circuit board SWEEP LENGTH control and the front panel HORIZONTAL POSITION control until the display is 10 cm long as shown in Pictorial 3-7 Part A.

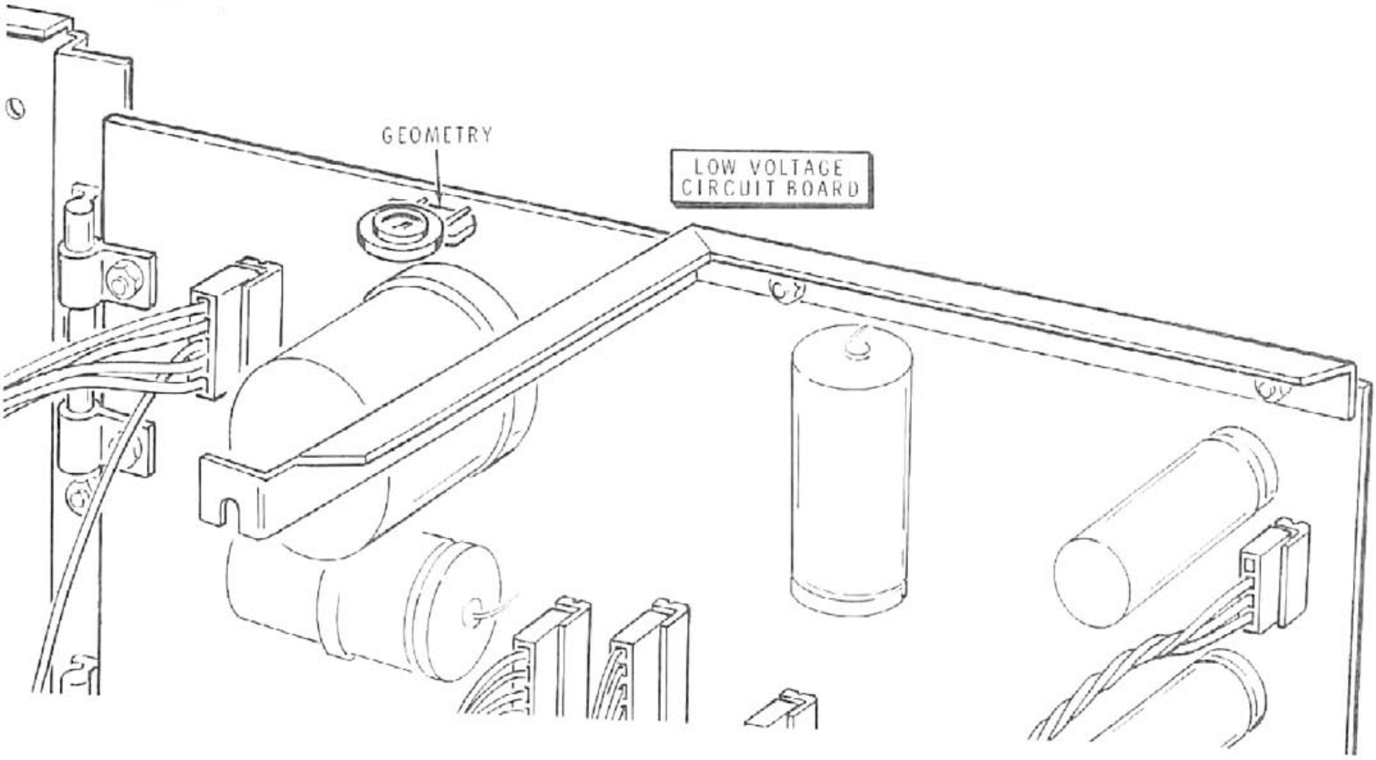


CORRECT — PART A

WRONG — PART B

WRONG — PART C

PICTORIAL 3-7



PICTORIAL 3-8

Refer to Pictorial 3-8 and adjust the low voltage circuit board GEOMETRY control until the display is as shown in Part A (**edges as straight as possible**) of Pictorial 3-7, and not as shown in Parts B and C of the Pictorial. (Readjust the controls in the previous step if necessary. Correct adjustment may occur when the GEOMETRY control is fully counterclockwise.)

Disconnect the sine wave from the Y1 INPUT connector.

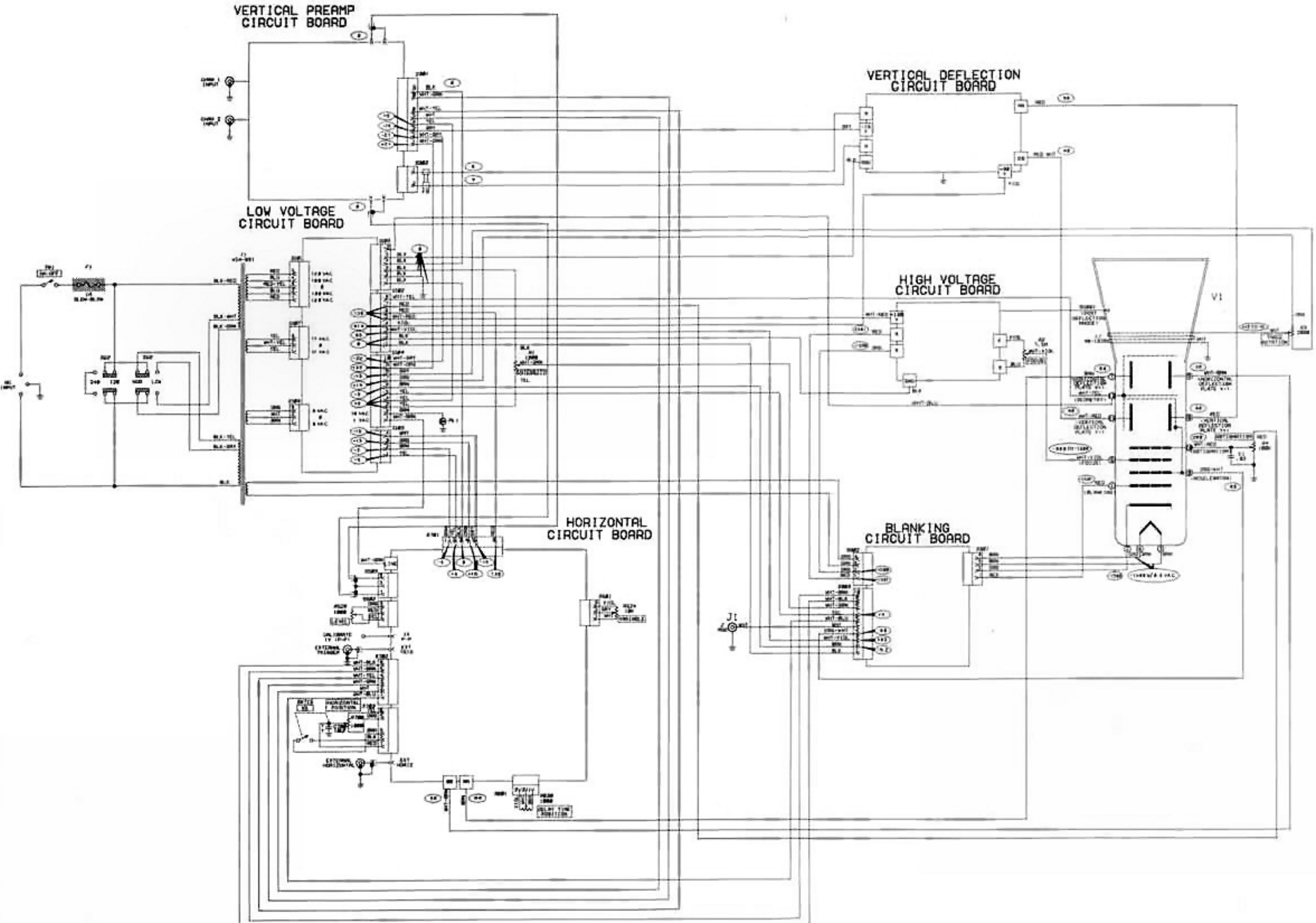
VERTICAL AMPLIFIER

Position the Y1 INPUT switch to GND.

NOTE: The preamplifier circuits are very sensitive and air currents may cause the trace to drift. Therefore, perform the following adjustments in an area where the air is still.

Channel Y1: Perform the following numbered steps (1-14). Adjust only the controls marked Y1 or associated with channel Y1.

1. Adjust the POSITION control to place the trace on the horizontal centerline.
2. Turn the VARIABLE control fully counterclockwise and note the position of the trace.
3. Turn the VARIABLE control fully clockwise (CAL) and adjust the DC BAL control (through the front panel) until the trace is in the same position as the previous step.
4. Repeat steps 2 and 3 until no more improvement can be made.
5. Turn the VOLTS/CM switch to 2 mV and repeat steps 2, 3, and 4.
6. Center the trace on the screen and then pull the PULL TO INVERT switch out and note the new position of the trace. If necessary, use the POSITION control to bring the trace back on the screen.
7. Push the PULL TO INVERT switch in, refer to Pictorial 3-9 (Illustration Booklet, Page 7), and adjust the OFFSET BAL control (on the vert preamp circuit board) to center the trace between the two positions.
8. Repeat steps 6 and 7 until the trace does not move when you operate the PULL TO INVERT switch. Leave the switch in its in position.
9. Adjust your voltmeter to measure +15 volts DC.



SCHEMATIC OF THE HEATHKIT®
35 MHz DUAL TRACE OSCILLOSCOPE
MODEL IO-4235/SO-4235

NOTES:

1. ALL CAPACITOR VALUES ARE IN µF UNLESS OTHERWISE SPECIFIED.
2. ALL RESISTORS ARE 1/4 WATT, 5% UNLESS MARKED OTHERWISE. RESISTOR VALUES ARE IN OHMS (K=1,000; M=1,000,000).
3. ▭ INDICATES A LETTERED WIRE CONNECTION ON A CIRCUIT BOARD.
4. ⏚ INDICATES CHASSIS GROUND.
5. ▽ INDICATES CIRCUIT BOARD GROUND.
6. ⊖ INDICATES A PART MOUNTED ON THE CHASSIS, ALTHOUGH ITS LOCATION IN THE SCHEMATIC SUGGESTS ANOTHER LOCATION.
7. CIRCUIT COMPONENT NUMBERS ARE 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.
   301-399 PARTS ON THE VERT PREAMP CIRCUIT BOARD.
   401-499 PARTS ON THE VERTICAL DEFLECTION CIRCUIT BOARD.
   501-599 PARTS ON THE A TIME BASE CIRCUIT BOARD.
   601-699 PARTS ON THE B TIME BASE CIRCUIT BOARD.
   701-899 PARTS ON THE HORIZONTAL CIRCUIT BOARD.
   901-999 PARTS ON THE BLANKING CIRCUIT BOARD.

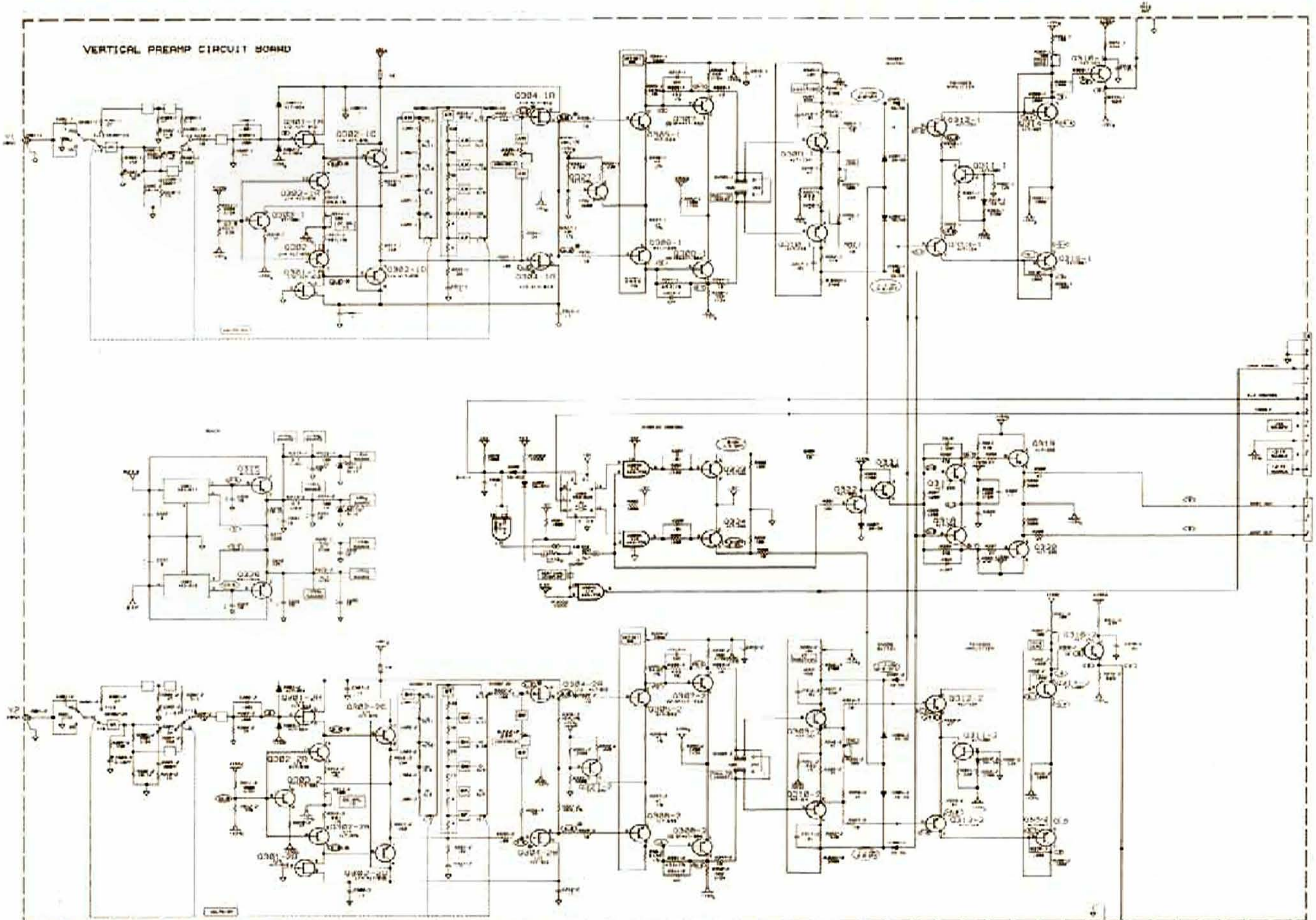
8. ⬭ INDICATES A DC VOLTAGE MEASURED FROM THE POINT INDICATED TO GROUND WITH THE VERTICAL AMPLIFIERS BALANCED AND THE HORIZONTAL POSITION CONTROL CENTERED. VOLTAGE MAY VARY ±20%. OTHER SWITCHES ARE SET AS FOLLOWS:

   VERTICAL DISPLAY - Y1
   HORIZONTAL DISPLAY - EXT HORIZ
   TRIGGER MODE - NORM
   TRIG COUPLING - AC
   TRIGGER SELECT - LINE.

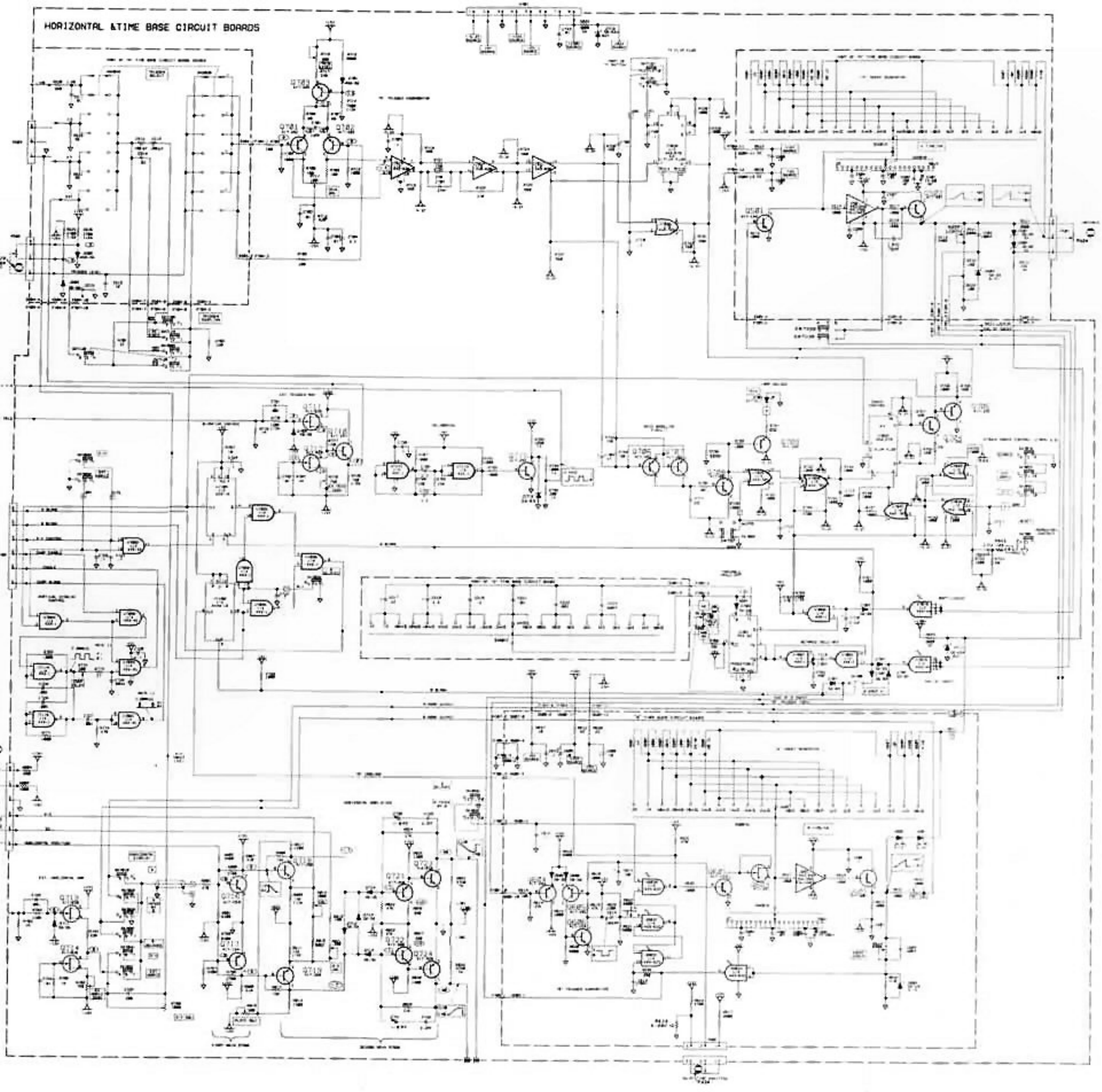
9. ALL WAVEFORMS ARE MEASURED FROM THE POINT INDICATED TO GROUND. THE FRONT PANEL CONTROLS ARE SET AS FOLLOWS:

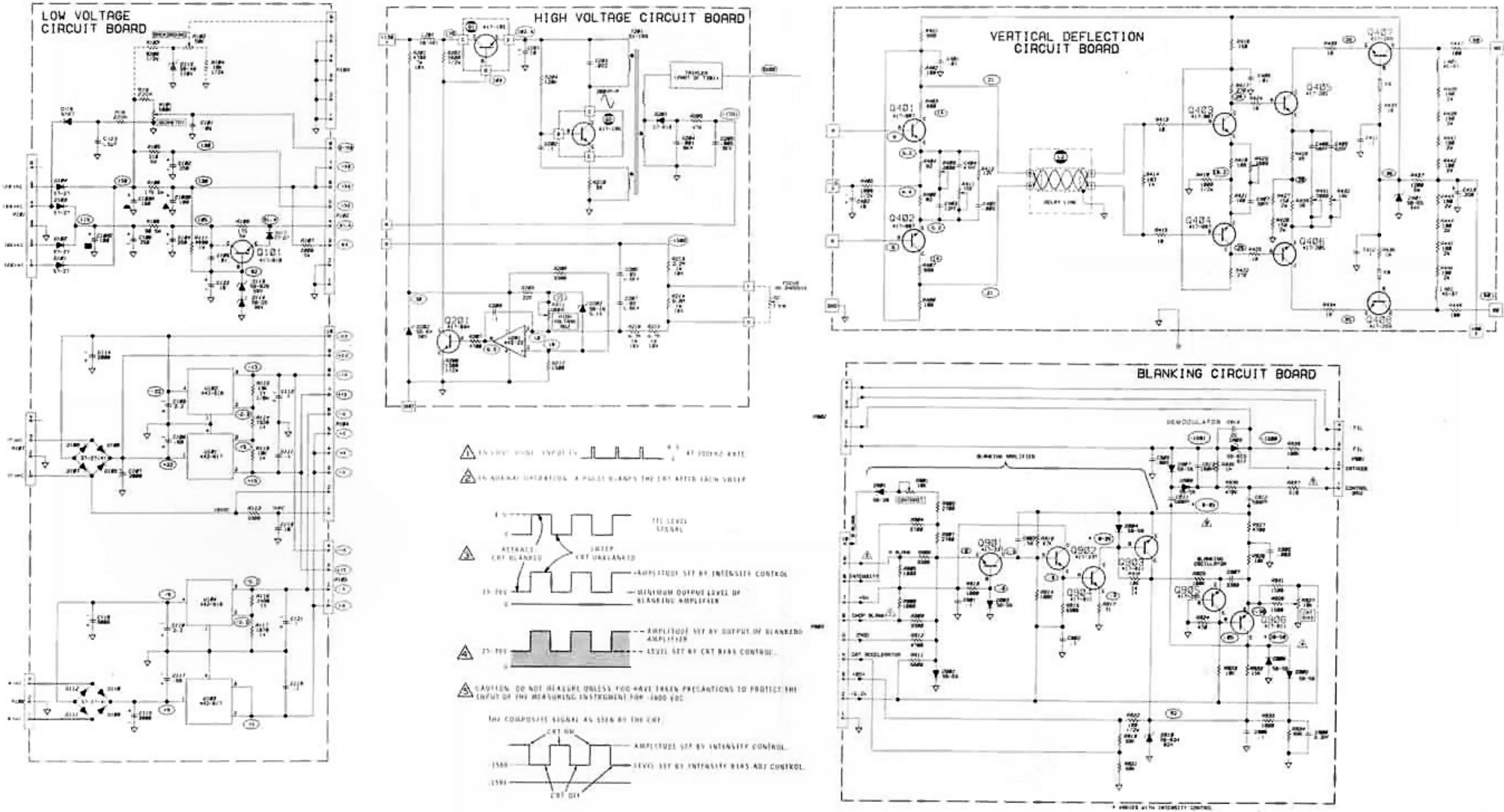
   HORIZONTAL POSITION - FOR TRACE TO START AT LEFT EDGE OF SCREEN
   HORIZONTAL DISPLAY - A INTEN BY B
   TRIGGER MODE - AUTO
   TRIGGER COUPLING - AC
   TRIGGER SELECT - Y1

10. TRANSISTOR TRANSISTOR LOGIC (TTL) LEVELS ARE AS FOLLOWS: A LOGIC 0, OR LOW, IS <0.8 VOLTS. A LOGIC 1, OR HIGH, IS >2.0 VOLTS BUT <3.5 VOLTS. A LOGIC 0 CONTROLS SET/RESETS.
11. ECL LEVELS ARE AS FOLLOWS: A LOGIC 0, OR LOW, IS -1.6 VOLTS. A LOGIC 1, OR HIGH, IS -.9 VOLT. A LOGIC 1 CONTROLS SET/RESETS.
12. ONLY IN CHOP MODE.



*STAGES MUST BALANCE, BUT LEVELS MAY VARY.


HORIZONTAL &TIME BASE CIRCUIT BOARDS


LOW VOLTAGE CIRCUIT BOARD
HIGH VOLTAGE CIRCUIT BOARD
VERTICAL DEFLECTION CIRCUIT BOARD
BLANKING CIRCUIT BOARD
BLANKING AMPLIFIER
DEMODULATOR
DELAY LINE
Q101
Q201
Q401
Q402
Q403
Q404
Q405
Q406
Q407
Q408
Q901
Q902
Q903
Q904
Q905
Q906
IN NORMAL OPERATION, A PULSE BLANKS THE CRT AFTER EACH SWEEP
TTL LEVEL SIGNAL
RETRACE CRT BLANKED
SWEEP CRT UNBLANKED
AMPLITUDE SET BY INTENSITY CONTROL
MINIMUM OUTPUT LEVEL OF BLANKING AMPLIFIER
AMPLITUDE SET BY OUTPUT OF BLANKING AMPLIFIER
LEVEL SET BY CRT BIAS CONTROL
CAUTION: DO NOT MEASURE UNLESS YOU HAVE TAKEN PRECAUTIONS TO PROTECT THE INPUT OF THE MEASURING INSTRUMENT FOR -1600 VDC
THE COMPOSITE SIGNAL AS SEEN BY THE CRT
CRT ON
AMPLITUDE SET BY INTENSITY CONTROL
LEVEL SET BY INTENSITY BIAS ADJ CONTROL
CRT OFF

CUSTOMER SERVICE

REPLACEMENT PARTS

Please provide complete information when you request replacements from either the factory or Heath/Zenith Computers and Electronics 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/ZENITH COMPUTER AND ELECTRONICS CENTERS

For your convenience, "over the counter" replacement parts are available from the Heath/Zenith Computer and Electronics 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/Zenith Computer and Electronics 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.

Heath/Zenith Computer and Electronics 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 Heath/Zenith Computers and Electronics 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

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