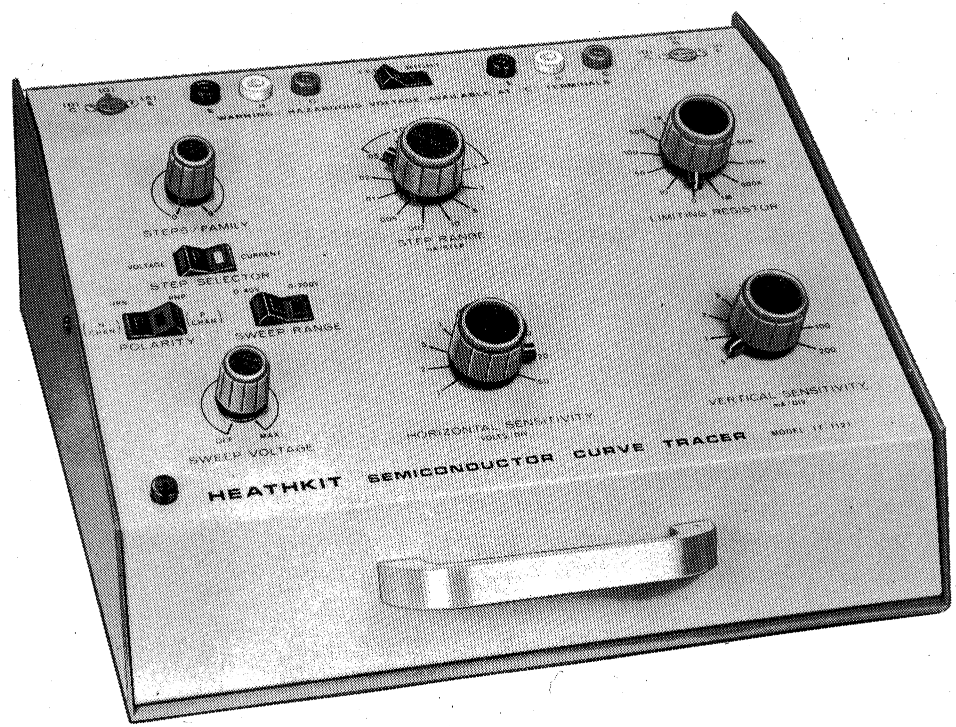
Assembly
and
Operation
of the

HEATHKIT

SEMICONDUCTOR CURVE TRACER

MODEL IT-1121



HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

PE1ABR

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INTRODUCTION

The Model IT-1121 Heathkit Semiconductor Curve Tracer is a versatile and sophisticated instrument. It accurately measures the operating parameters of virtually all types of discrete semiconductors — gain (beta), leakage, breakdown voltage, saturation, forward conduction voltage, output admittance, linearity, capacitance effects, temperature effects, etc. The Curve Tracer also can be used to select devices for specific design applications; for sorting, inspecting, and testing semiconductors; and for troubleshooting.

Any oscilloscope with horizontal sensitivity of .5 volt/division and vertical sensitivity of 1 volt/division can be used with the Curve Tracer. Connecting the Curve Tracer to the oscilloscope is easy with the plug-in cables supplied, and a calibration switch permits fast and accurate oscilloscope calibration.

The following features make the Curve Tracer very versatile:

- Accurate current steps from 2 μA/step to 10 mA/step in a 1, 2, 5 sequence — the steps are variable from 0 to 9.
- Accurate voltage steps from .05 volt/step to 1 volt/step in a 1, 2, 5 sequence — the steps are variable from 0 to 9.
- Two-range sweep supply — 0 to 40 volts at currents up to 1 ampere, and 0 to 200 volts at currents up to 200 milliamperes.
- Monitored sweep voltage can be displayed from .1 volt/division to 50 volts/division in a 1, 2, 5 sequence.
- Monitored sweep current — from .5 mA/division to 200 mA/division in a 1, 2, 5 sequence.
- Switch selectable NPN (N channel) or PNP (P channel) testing.
- Eleven current limiting resistors from 10 Ω to 1 MΩ to protect the device being tested.
- Many internal protection devices to protect the Curve Tracer and components being tested from improper operation.

Low profile styling and the sloped front panel permit the Curve Tracer to set in front of most oscilloscopes without blocking the CRT. A convenient handle provides portability, and extra leads (included) allow you to test large devices or make in-circuit tests. The versatility, accuracy, and reliability of this test instrument make it a valuable addition to your work bench for years to come.

Refer to the "Kit Builders Guide" for complete information on unpacking, parts identification, tools, wiring, soldering, and step-by-step assembly procedures.

HEATHKIT®

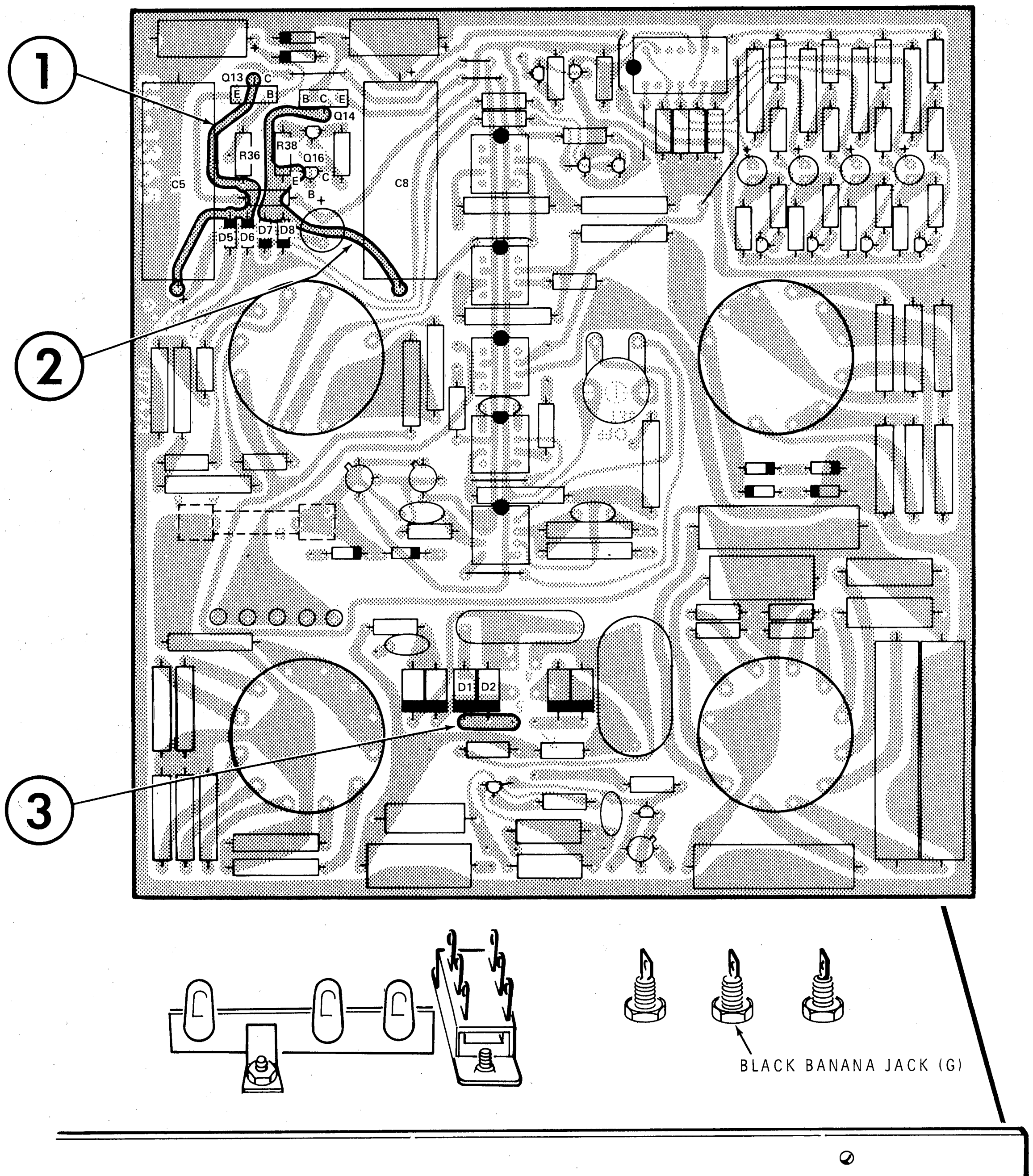


Figure A

TESTS AND ADJUSTMENTS

INITIAL CHECKS

The purpose of this section of the Manual is to make sure your Curve Tracer operates properly and will not be damaged as the result of a wiring error. A transistor or integrated circuit, for example, could be destroyed instantly by a short circuit that causes excessive current.

( ) Inspect the Curve Tracer for improperly soldered connections, or connections that may have been missed and not soldered. Also check for solder bridged across two or more circuit board foils, which would cause a short circuit.

( ) Examine the chassis-mounted parts to make sure they are properly mounted and connected.

( ) Be sure no bare wires are touching any components or the chassis.

NOTE: If a VTVM is available, make the following "Resistance Checks." If a meter is not available, proceed to "Oscilloscopes."

RESISTANCE CHECKS

These resistance checks are to make sure there are no short circuits in any of the three power supply branches. DO NOT plug in the line cord until you are instructed to do so.

( ) Set your ohmmeter on the RX100 scale.

( ) Connect the common lead of your ohmmeter to the black banana jack (G) shown in Figure A.

NOTE: The resistances in the following steps are the minimum desired. If the resistance readings are significantly less, the reason (such as a short circuit caused by a solder bridge between foils) must be determined and corrected before you proceed. As some ohmmeters use the "common" lead as the positive lead, try reversing your ohmmeter leads if you do not get the designated resistance readings.

( ) Refer to Figure A and touch the ohmmeter probe to the foil at point (1). The meter reading should be 10 kΩ or more.

( ) Touch the ohmmeter probe to the foil at point (3). The meter reading should be 100 kΩ or more.

( ) Touch the ohmmeter probe to the black banana jack (G) and the ohmmeter common lead to point (2). The meter reading should be 10 kΩ or more.

( ) Disconnect the meter.

CAUTION: High voltage are exposed in the Curve Tracer when the line cord is plugged into an AC outlet. Refer to the "Chassis Photographs" on Page 100 for the location of these high voltage areas.

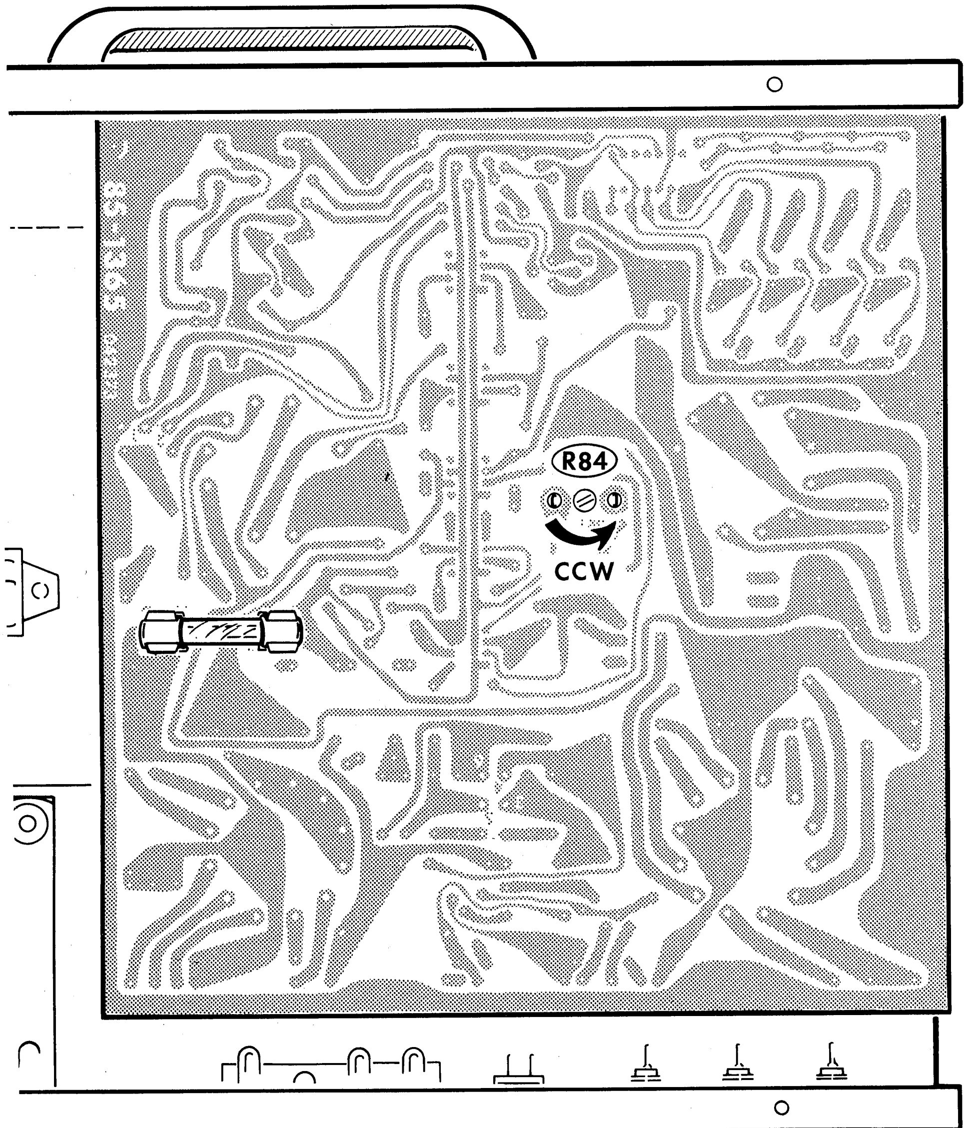


Figure 1-7

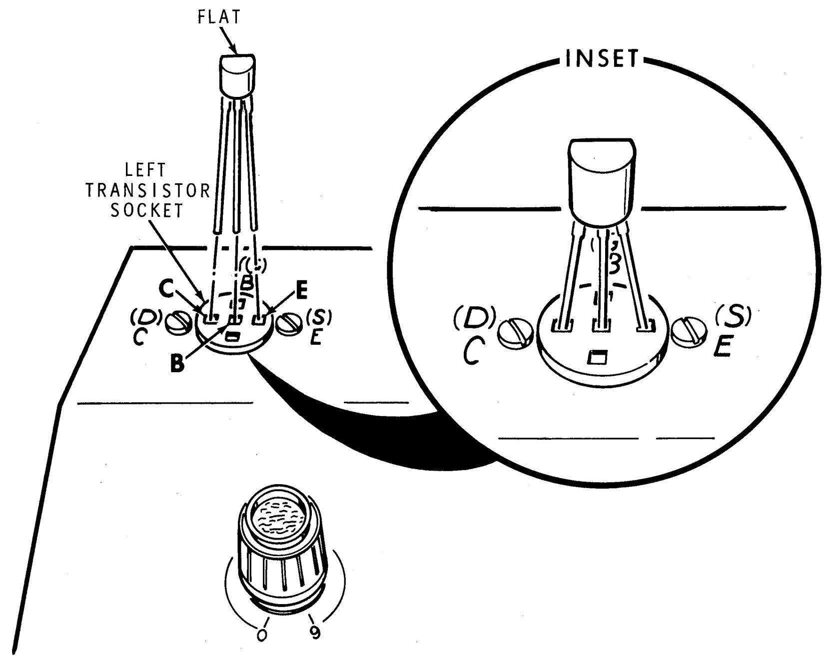


Figure 1-8

OSCILLOSCOPES

This section of the Manual contains special considerations for "Heath Oscilloscopes" and all kinds of "AC-coupled oscilloscopes." Therefore, if you intend to use a DC oscilloscope other than a Heath one with your Curve Tracer, you may proceed to "Oscilloscope Calibration."

HEATH OSCILLOSCOPES

NOTES:

1. In the following material, X means horizontal and Y means vertical.
2. The IO-10, IO-12, IO-17, IO-18, and IO-21 will produce backward traces. That is, an NPN transistor display will be from right to left instead of from left to right, etc.

IO-10 – Use the X and Y input channels.

IO-12 – This oscilloscope is AC coupled. Read "AC-Coupled Oscilloscopes."

IO-14 – This oscilloscope may not have enough horizontal gain for proper calibration. If necessary, when you perform the "Oscilloscope Calibration," calibrate the horizontal dots on every division. Note that, in this case, all the horizontal sensitivity readings will be off by a factor of two. (Example: When the Curve Tracer is set for 1 V/division, the oscilloscope will display 2 V/division.)

IO-17 – This oscilloscope is AC coupled. Read "AC-Coupled Oscilloscopes."

IO-18 – This oscilloscope is AC coupled. Read "AC-Coupled Oscilloscopes."

IO-21 – This oscilloscope is AC coupled. Read "AC-Coupled Oscilloscopes."

IO-102 – The horizontal input of this oscilloscope is AC coupled. To obtain DC coupling for use with the Curve Tracer, place a jumper wire from the horizontal input to TP (Test Point) on the horizontal amplifier circuit board inside the IO-102. However, for normal oscilloscope operation, remove this jumper wire, as it interferes with the internal sweep. Note also that the horizontal portion of the trace should not extend over 10 cm or the input may be overloaded and produce distortion.

IO-103 – No special considerations.

IO-104 – Use the X10 position of the TIME/CM switch. If this does not provide enough gain, pull out X5 MAG knob. Do not use the X1 switch position. In some cases, you may not be able to position the dot all the way into the upper right-hand corner of the screen.

IO-105 – Use the X-Y mode.

AC-COUPLED OSCILLOSCOPES

Oscilloscopes that are AC coupled on one or both inputs (vertical and/or horizontal) are usable with the Curve Tracer but have certain limitations. Calibration of the oscilloscope will be more difficult as the dots will "smear" somewhat (see Figure 1-3 on Page 53). However, this can be reduced by using only two or three dots.

When you position the dot on the oscilloscope screen, before you apply any sweep voltage, position the dot one or two divisions toward the center of the screen. When the sweep voltage is applied, the display will expand in both directions from the dot. (That is, both ways horizontally if that input is AC coupled, and both ways vertically if that input is AC coupled.) To get better looking displays, use only 2 to 5 steps/family instead of all 9.

The following show the difference between displays of DC-coupled and AC-coupled oscilloscopes.

DC COUPLED

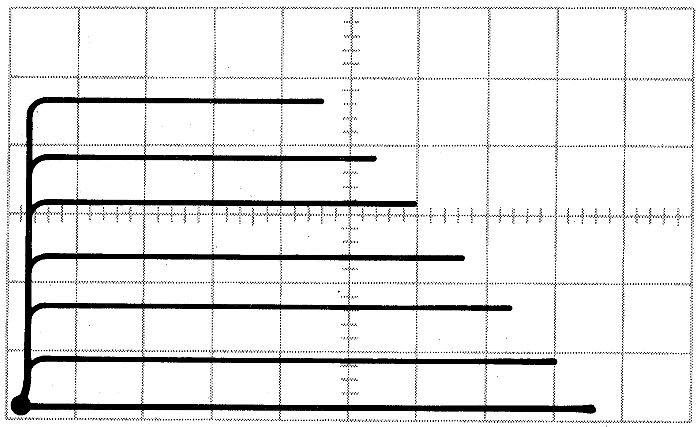


Figure 1-1

AC COUPLED

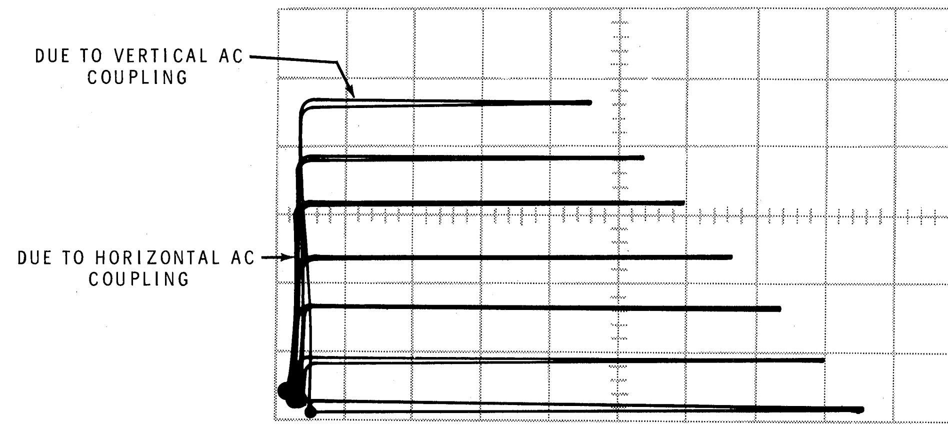


Figure 1-2

DC COUPLED

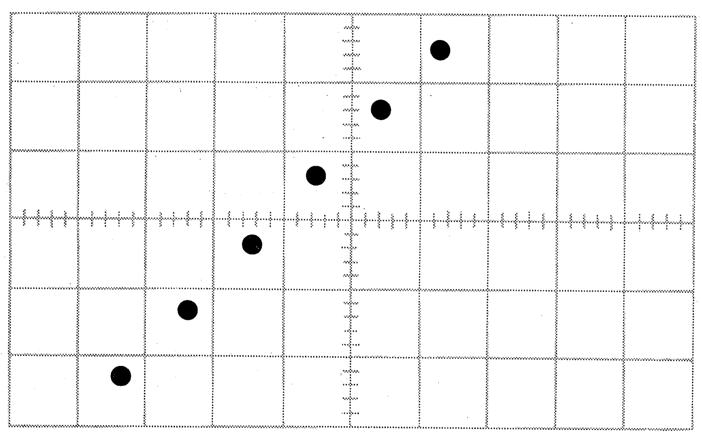


Figure 1-3

AC COUPLED

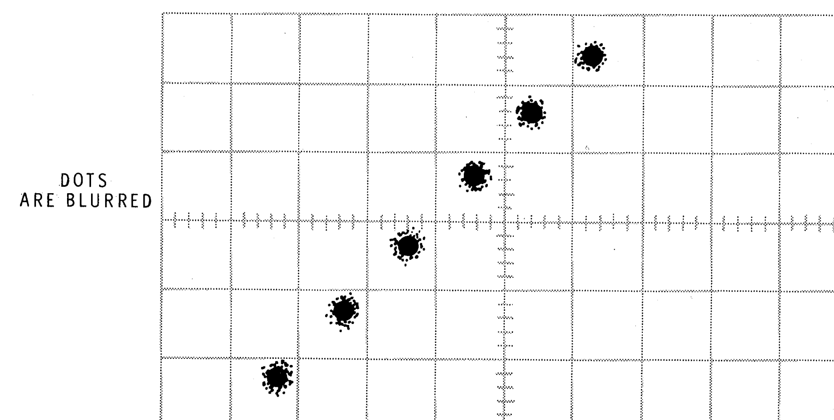


Figure 1-4

OSCILLOSCOPE CALIBRATION

Turn on your oscilloscope and set the controls as follows:

( ) Set the oscilloscope for approximately .5V/division horizontal, and 1 V/division vertical. (If you have a dual trace oscilloscope, place it in the X-Y mode.)

( ) If the vertical and horizontal inputs are switchable, place them in their DC positions.

( ) Use the vertical and horizontal position controls and move the dot to the lower left-hand area of the screen.

( ) Keep the trace intensity low to protect the screen from being burned by the dot.

Refer to Figure 2-1 (fold-out from Page 48) for the following steps.

Set the Curve Tracer controls as follows:

SWEEP VOLTAGE — Fully counterclockwise and OFF.

HORIZONTAL SENSITIVITY — 1.

VERTICAL SENSITIVITY — 10.

POLARITY — NPN.

SWEEP RANGE — 0-40V.

STEP SELECTOR — CURRENT.

STEPS/FAMILY — Fully counterclockwise.

STEP RANGE — 1.

LIMITING RESISTOR — 100.

LEFT-RIGHT — LEFT.

LOOP — Center of rotation.

NORM-CAL — CAL.

( ) Refer to Figure 1-5 (fold-out from Page 48) and connect the H, G, and V outputs of the Curve Tracer to the horizontal, ground, and vertical inputs of the oscilloscope. Use one black lead and two red leads with banana plugs on both ends as shown in the Figure.

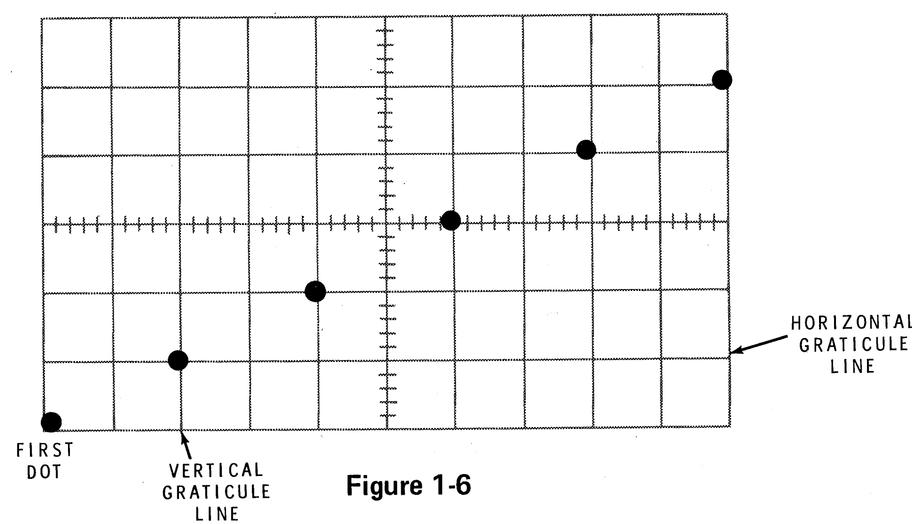


Figure 1-6

NOTE: In the following steps, if the Curve Tracer does not operate as described, immediately unplug the line cord and refer to the "In Case of Difficulty" section of the Manual on Page 88. Then correct the problem before proceeding with the "Initial Tests."

CAUTION: High voltages are exposed in the Curve Tracer when the line cord is plugged into an AC outlet. Refer to the "Chassis Photographs" on Page 100 for the location of these high voltage areas.

( ) Plug the line cord plug into an AC outlet of the proper voltage (120 or 240 VAC, depending upon the wiring of the power transformer).

( ) Turn on the Curve Tracer (until the SWEEP VOLTAGE control just clicks) and slowly turns the STEPS/FAMILY control clockwise until four to six dots appear in a diagonal row and fill the oscilloscope screen, as shown. See Figure 1-6. NOTE: Adjust the HORIZONTAL and VERTICAL SENSITIVITY controls on the oscilloscope if the dots are too widely spaced.

( ) Use the oscilloscope horizontal and vertical positioning controls to place the first dot on the line in the lower left-hand corner as shown.

( ) Adjust the vertical sensitivity and vertical position of the oscilloscope so each dot appears on the next higher horizontal graticule line as shown.

( ) Adjust the horizontal sensitivity and horizontal position so the dots appear on every other vertical graticule line as shown.

( ) Make sure the first dot is still in the position shown.

The oscilloscope is now calibrated. DO NOT readjust the oscilloscope vertical and horizontal sensitivity controls.

( ) Position the NORM-CAL switch to the NORM position. A single dot should appear within 1/2 division of the first dot of the calibration dots.

NOTE: Condensed calibration instructions are on the rear panel of the Curve Tracer for future reference.

OFFSET ADJUSTMENT

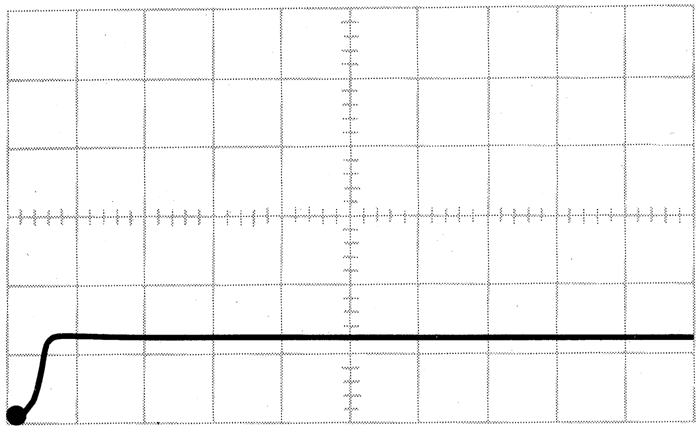


Figure 1-9

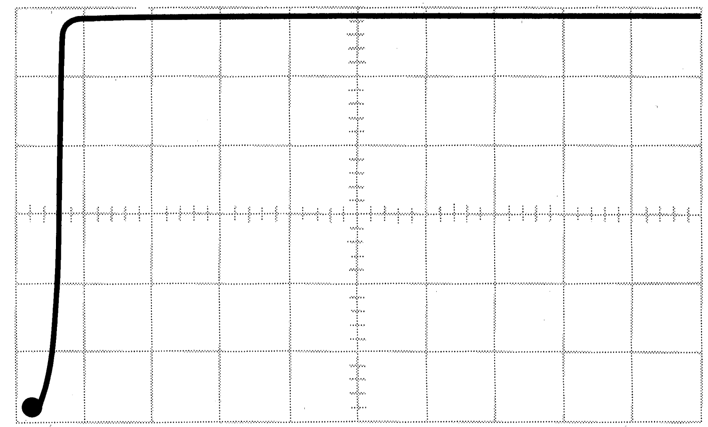


Figure 1-10

( ) Refer to Figure 1-7 (fold-out from Page 52) and turn circuit board control R84 fully counterclocksise.

( ) Refer to Figure 1-8 (fold-out from Page 52) and install the extra MPSA20 transistor in the left transistor socket as shown. Be sure the flat of the transistor is toward the rear of the cabinet.

( ) Adjust the STEPS/FAMILY control fully counterclockwise.

( ) Adjust the STEP RANGE control to .05.

( ) Adjust the SWEEP VOLTAGE control to produce a line across the bottom of the screen as shown in Figure 1-9.

( ) Turn the VERTICAL SENSITIVITY control counterclockwise until the display is near the top of the screen as shown in Figure 1-10.

( ) Adjust circuit board control R84 until the base line just becomes straight and flat. See Figure 1-11. NOTE: If you turn the control any farther than this, the base line may be distorted when you make very sensitive tests on PNP transistors and P channel FET's.

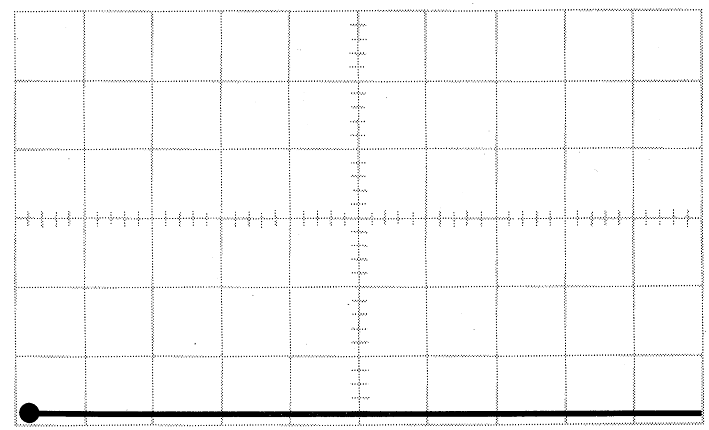


Figure 1-11

( ) Turn the VERTICAL SENSITIVITY control to .5 and make the above adjustment again.

TRANSISTOR TESTS

Again use the extra transistor (MPSA20, #417-801) that was supplied with your kit.

Set the Curve Tracer controls as follows: (See Figure 2-1 on fold-out from Page 48).

SWEEP VOLTAGE – Fully counterclockwise and OFF.

HORIZONTAL SENSITIVITY – 1.

VERTICAL SENSITIVITY – 5.

POLARITY – NPN.

SWEEP RANGE – 0-40V.

STEP SELECTOR – CURRENT.

STEPS/FAMILY – Fully counterclockwise.

STEP RANGE – .01.

LIMITING RESISTOR – 100.

LEFT-RIGHT – LEFT.

NORM-CAL – NORM.

( ) Turn the SWEEP VOLTAGE control only far enough clockwise to turn the Curve Tracer on.

NOTE: The following steps assume your oscilloscope is DC coupled. If your oscilloscope is AC coupled, you may have to make oscilloscope adjustments not listed in the steps. However, do not change the oscilloscope vertical and horizontal sensitivity controls. If necessary, again refer to "AC-Coupled Oscilloscopes" on Page 52.

( ) Position the dot in the lower left-hand corner of the graticule. See Figure 1-12.

( ) Turn the SWEEP VOLTAGE control clockwise until a line appears across the bottom of the display. Then turn the control counterclockwise until only a dot remains.

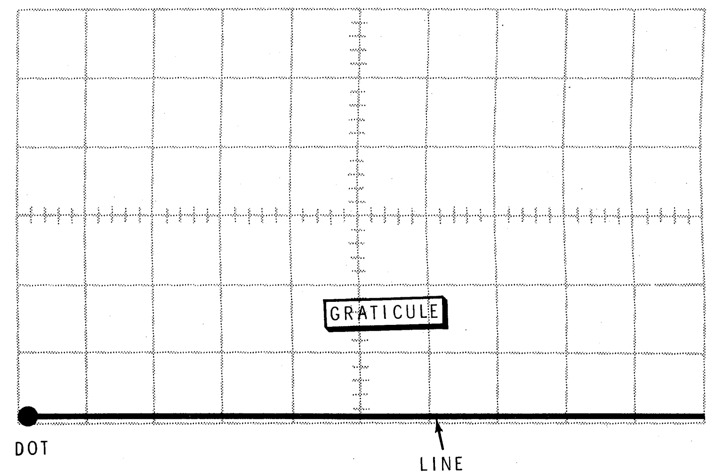


Figure 1-12

( ) Again turn the SWEEP VOLTAGE control clockwise until the bottom horizontal line is across the full length of the graticule.

( ) Turn the STEPS/FAMILY control fully clockwise. A set of nine curves plus the base line should appear. If some of the curves are off the screen, set the VERTICAL SENSITIVITY control to 10 mA/division. If they appear crowded at the bottom, set the switch to 2 mA/division.

( ) Slowly turn the STEPS/FAMILY control counterclockwise. Note that one by one, from the top down, the steps disappear until only the base line is left. Now adjust the control until three steps plus the base line appear. See Figure 1-13.

( ) If the display does not fill the screen, turn the VERTICAL SENSITIVITY switch of the Curve Tracer one step counterclockwise.

( ) Turn the LIMITING RESISTOR switch from 100 (ohms) to 50 (ohms). Note that the upper curves have increased slightly horizontally.

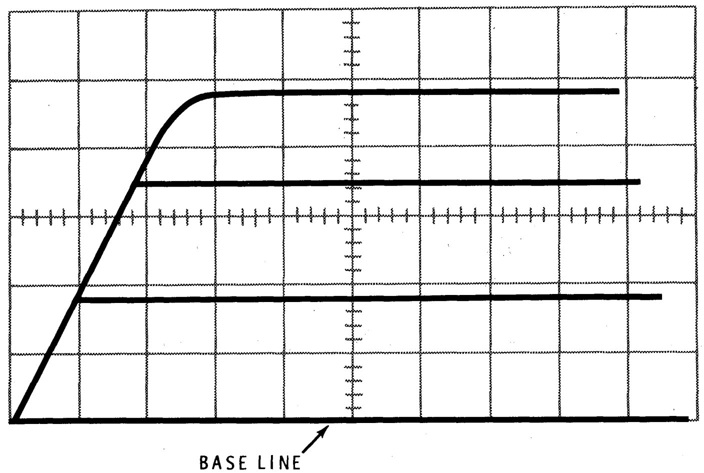


Figure 1-13

( ) Turn the same switch to 500 (ohms). Note that the upper curves have shortened. (One or two may have disappeared entirely.) Then return the switch to 100 (ohms).

( ) Turn the HORIZONTAL SENSITIVITY switch to 2 volts/division. Note that the curves have all shortened by a factor of two.

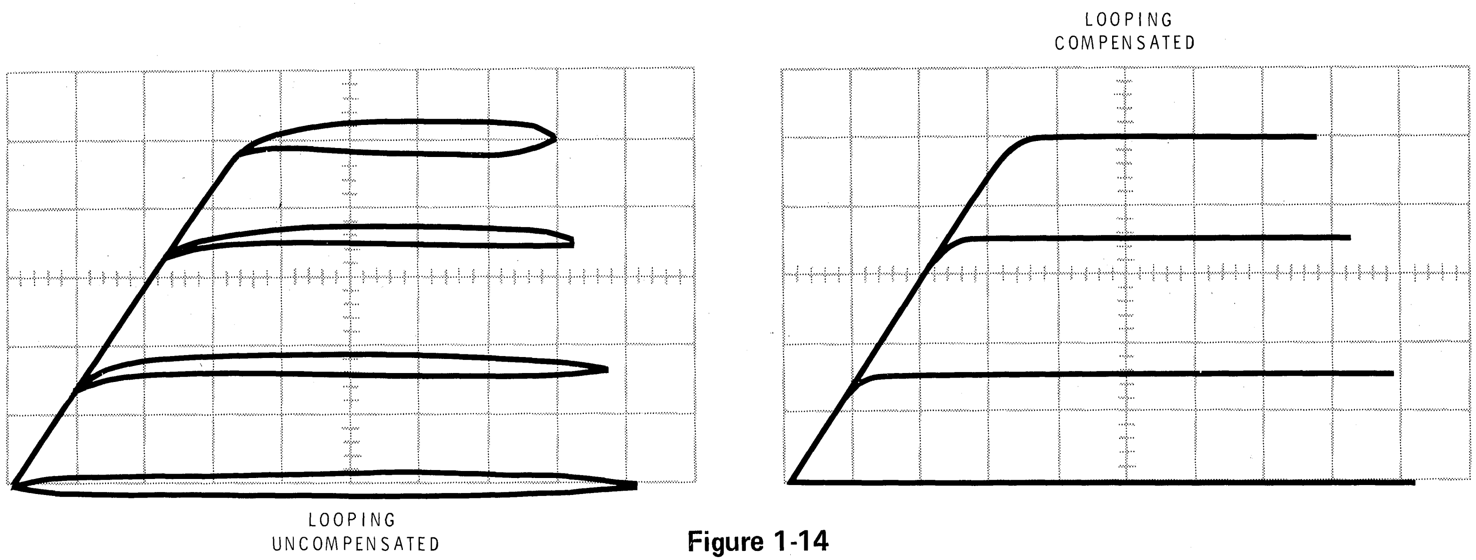


Figure 1-14

( ) Turn the HORIZONTAL SENSITIVITY switch to .5 volts/division. Note that the curves are now twice as long as they originally were and that they may extend off the CRT. Return the HORIZONTAL SENSITIVITY switch to 1.

( ) Turn the VERTICAL SENSITIVTY control to the .5 mA/division range. (Remember where the switch was set.) One or two curves may go off the screen.

( ) Adjust the LOOP control so the curves have a minimum of looping. See Figure 1-14. Then return the VERTICAL SENSITIVITY switch to its original position.

( ) Turn the STEP RANGE switch to .02 mA/division and note that the steps have doubled in value. (Some steps may go off the screen.)

( ) Turn the STEP RANGE switch to .005 mA/division and note that the steps are one half their original value. Then return the switch to .01 mA/division.

( ) Turn the SWEEP VOLTAGE control fully counterclockwise but not OFF.

( ) Switch the SWEEP RANGE switch to 0-200 V. CAUTION: On this range dangerous voltage can be available at the "C" output.

( ) Slowly turn the SWEEP VOLTAGE control clockwise until you obtain the same curves as before. (DO NOT turn the control further. The transistor is only rated to 40 volts.) Note that the curves have a less polished appearance.

( ) Turn the control back counterclockwise and set the SWEEP RANGE switch to 0-40 V.

OBSERVATION: Use the 0-200 V range only when voltages greater than 40 are required. The 40 V range provides cleaner and more precise displays, and the exposed operating voltages are safer.

( ) Position the dot in the upper right-hand corner of the screen. See Figure 1-15.

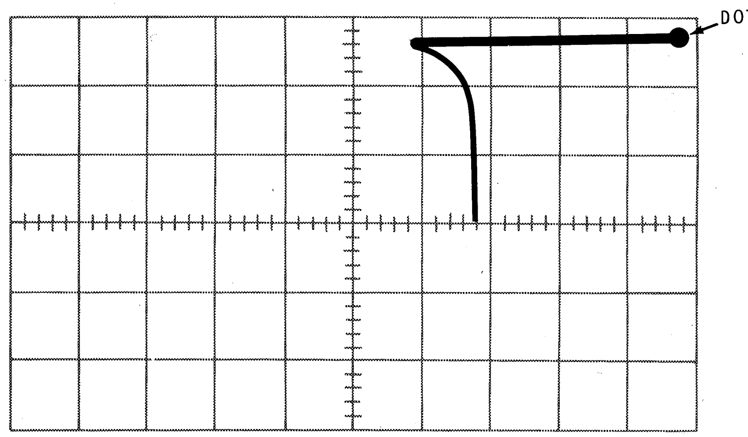


Figure 1-15

( ) Set the LIMITING RESISTOR to 1000.

( ) Set the HORIZONTAL SENSITIVITY switch to 2 volts/division.

( ) Change the POLARITY switch to PNP.

( ) Turn the STEPS/FAMILY control fully counterclockwise.

( ) Turn the SWEEP VOLTAGE control clockwise until a line appears as in Figure 1-15. This is reverse breakdown of the C to E junction.

( ) Turn the SWEEP VOLTAGE control fully counterclockwise and OFF.

This completes the "Tests and Adjustments."

FINAL ASSEMBLY

Refer to Pictorial 4-1 for the following steps.

( ) Unplug the line cord, disconnect all leads, and remove the test transistor.

( ) Carefully turn the Curve Tracer upside down. Then lower the cabinet shell into position and secure it with six #6 x 3/8" sheet metal screws and two 8-32 x 3/8" screws.

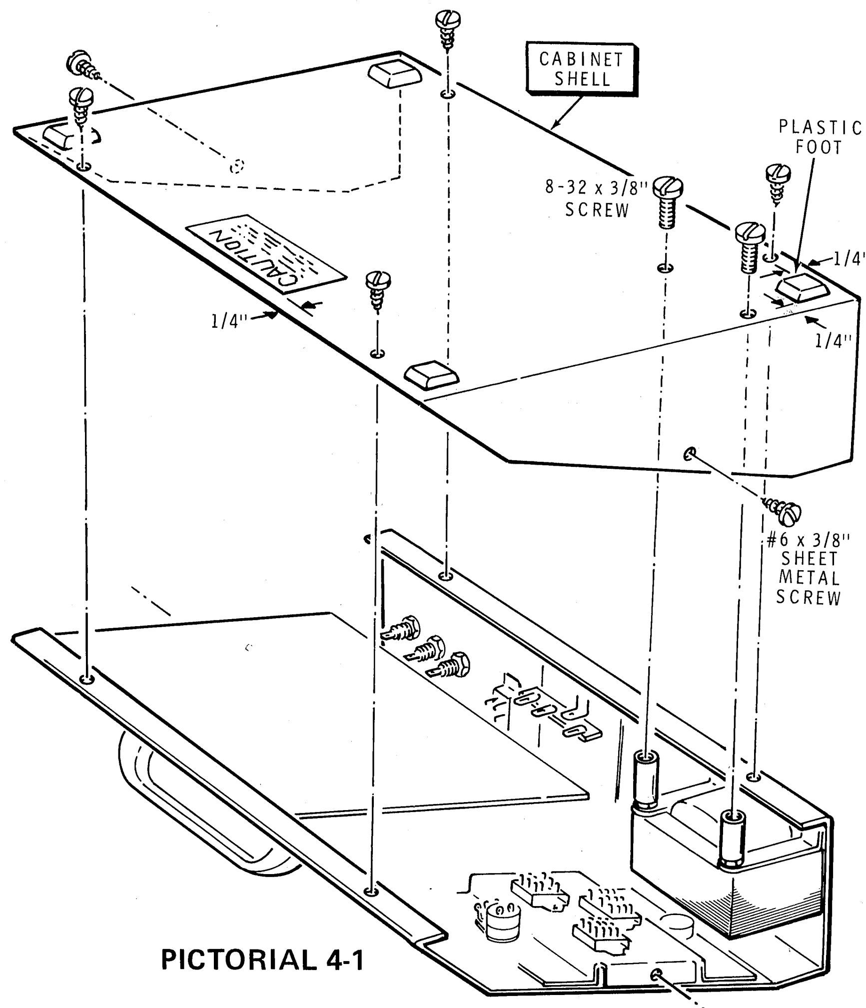
( ) Remove the protective backing from the CAUTION label and apply it to the cabinet shell as shown.

( ) Remove the protective backing from a plastic foot and press it in a corner 1/4" from the edges of the cabinet shell.

( ) In a similar manner, install plastic feet at the three remaining corners.

( ) Turn the Curve Tracer right side up.

This completes the "Final Assembly" of your kit.



PICTORIAL 4-1

OPERATION

CONTROL FUNCTIONS

Refer to Figure 2-1 (fold-out from Page 48) as you read the description of each control function.

1. PILOT LAMP (PL1) – Indicates when the Curve Tracer is plugged in and turned on.

2. SWEEP VOLTAGE (R6, SW1) – Combination ON–OFF switch and SWEEP VOLTAGE control. Turns the unit on and off, and sets the value of the sweep voltage at "C" terminals.

3. HORIZONTAL SENSITIVITY (SW6) – While the oscilloscope monitors the sweep voltage on the device under test, this switch selects one of the nine voltage ranges for a proper display.

4. VERTICAL SENSITIVITY (SW7) – Selects one of nine current ranges so the oscilloscope can monitor the current (produced by the sweep voltage) passing through the test device.

5. POLARITY (SW3) – Selects either NPN or PNP (N-channel or P-channel).

	Sweep Voltage	Current Steps	Voltage Steps
NPN	positive	positive	negative
PNP	negative	negative	positive

6. SWEEP RANGE (SW2) – Selects sweep voltage of either 0-40 V (at up to 1 ampere maximum) or 0-200 V (at up to 200 milliamperes maximum). Always use the lower range unless more voltage is needed.

7. STEP SELECTOR (SW9) – Selects either VOLTAGE or CURRENT steps, and the polarity of the signal supplied to the B output terminals.

8. STEPS/FAMILY (R47) – Adjusts the number of steps from zero to nine.

9. STEP RANGE (SW8) – Selects either current steps or voltage steps, depending on the setting of the STEP SELECTOR switch. Provides 12 values of current steps or 5 values of voltage steps.

10. LIMITING RESISTOR (SW4) – Selects one of 11 resistors plus zero ohms. These current limiting resistors protect the device under test. Use the highest value that gives a consistent display.

11. LEFT TRANSISTOR SOCKET – For testing small transistors out of circuit. Active when the LEFT-RIGHT switch is at LEFT.

12. LEFT BANANA JACKS – Use these jacks with the supplied cables to test large semiconductors in and out of circuit. Active when the LEFT-RIGHT switch is at LEFT.

13. LEFT-RIGHT (SW5) — Selects either the left or right socket and jacks.

14. RIGHT BANANA JACKS — Use with the supplied cables to test large semiconductors in or out of circuit. Active when the LEFT-RIGHT switch is at RIGHT.

15. RIGHT TRANSISTOR SOCKET — For testing small transistor out of circuit. Active when the LEFT-RIGHT switch is at RIGHT.

16. H, G, V TERMINALS — Provide output connections to an oscilloscope.

H connects to the horizontal input.
G connects to ground.
V connects to the vertical input.

17. LOOP (R5) — Compensates for circuit capacitance to minimize looping in the display.

18. NORM-CAL (SW10) — In the CAL position, dots resulting from a precision staircase waveform are applied to the oscilloscope for calibration. The NORM position provides normal operation.

CURVE TRACER CHARACTERISTICS

Because of the great versatility of this Curve Tracer, in a few instances the display may be other than ideal. These can be caused by the limitations of the device being tested, interaction between the tested device and the Curve Tracer, and, in some cases, the Curve Tracer itself.

Refer to Figure 2-2 as you read the following information.

A. A coil-like loop may occur here with sweep voltages higher than 30 volts. Higher limiting resistance will minimize this effect.

B. Looping (double line) may occur with low sweep currents (.5 mA/div) and high sweep voltages (above 30 volts). Use the LOOP control to minimize this effect.

C. This hump may occur with certain transistors. Use a higher value of limiting resistance to minimize the hump.

D. A faint line at higher sweep voltages (above 30 volts) is more noticeable with less steps and can be minimized by adding more limiting resistance.

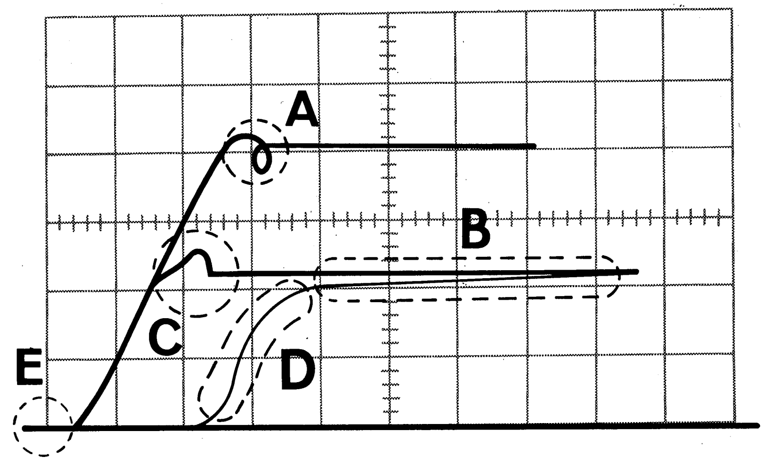


Figure 2-2

E. Some reverse voltage sweep will appear here on the .1 volts range for the low sweep range, and on the .1 volt/div through the 5 volt/div on the 200 volt sweep range.

APPLICATIONS

GENERAL INFORMATION

PRECAUTIONS

To protect the device being tested, always observe the following precautions.

- Keep the SWEEP VOLTAGE below the collector breakdown level except during the short time of a collector voltage breakdown test. Although the limiting resistors prevent destruction of the transistor, high internal temperatures from long periods of operation may cause the transistor to fail.

- Limit the testing of power transistors without heat sinks to a few seconds – just long enough to make an accurate reading. Excessive temperatures in the test device may result from longer periods of operation. Start and stop the tests by using the LEFT-RIGHT switch.

- Before you make a test, be sure the following controls are set as follows:

SWEEP VOLTAGE	Fully counterclockwise
SWEEP RANGE	0-40 V
LIMITING RESISTOR	5 k or higher
STEP RANGE	.02 mA/Step or less

Return the controls to these positions after each test. This will insure that no device will be accidentally destroyed.

- Completely remove power from the unit under test. The Curve Tracer supplies the complete test signal. Any additional signal or DC current may make the test inaccurate and could damage the unit.

TESTING BIPOLAR TRANSISTORS

The most common use of the Curve Tracer is to test NPN and PNP transistors. The family of curves of an NPN transistor is in a positive direction. That is, zero volts is at the left and zero current is at the bottom of the display. The curves sweep upward and to the right as collector voltage and current increases, and the sweep voltage is positive.

The curves of a PNP transistor, however, are in the negative direction. Zero volts is at the right and zero current is at the top of the display. The curves sweep downward and to the left as collector voltage and current increase, and the sweep voltage is negative.

Any test of an NPN transistor can be performed on a PNP and vice versa. The displays are merely inverted.

Transistors can be tested for:

- Current gain (DC and AC beta)
- Collector-to-emitter breakdown
- Collector-to-base breakdown
- Output admittance
- Saturation voltage
- Saturation resistance
- Cutoff current
- Leakage current
- Linearity and distortion
- Temperature effects
- Identifying germanium or silicon
- Matching
- Sorting and substitution

TRANSISTOR IDENTIFICATION

To test a transistor you need to know three things.

1. The basing configuration (E, B, C, or S, G, D). Figure 2-3 shows some of the more common configurations. If the transistor type number is available, the basing configuration can be found in the manufacturer's handbook. Also, a schematic may provide this information.

2. The type (NPN or PNP). This information can come from the circuit, schematic, manufacturer's handbook, or from the Curve Tracer as described on **Page 66**.

3. The power class. See Figure 2-3. (Signal, intermediate power, or power.)

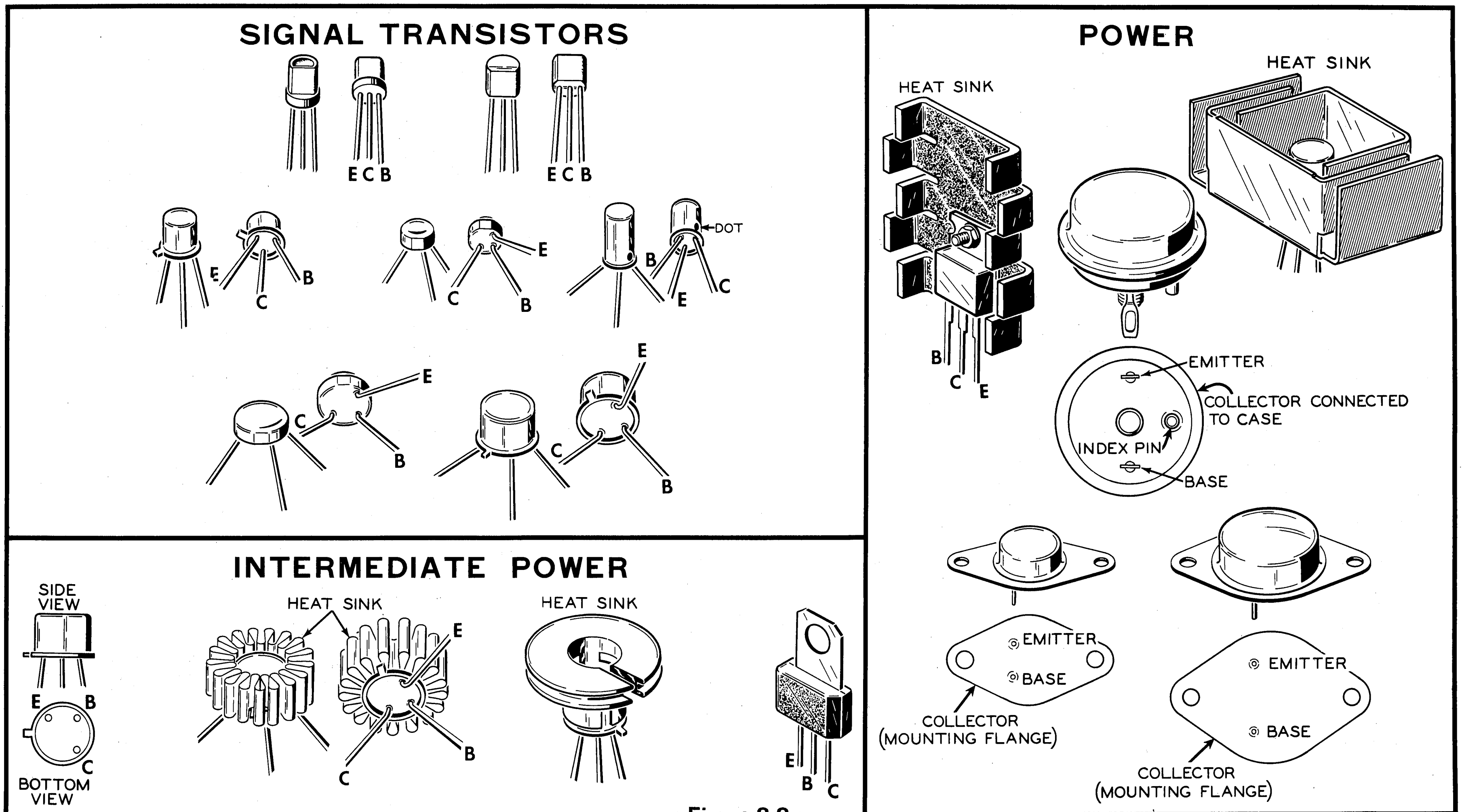


Figure 2-3

INITIAL DISPLAY

To obtain an initial display, set the Curve Tracer controls as shown below. Note that the switches marked with an asterisk are always in these positions for transistor tests. Refer to Table 1 and make other control settings according to the power rating of the transistor. Also, if the oscilloscope is not connected and calibrated, see "Oscilloscope Calibration" on Page 54.

SWEEP VOLTAGE	– Fully counterclockwise and off.
HORIZONTAL SENSITIVITY	– See Table 1.
VERTICAL SENSITIVITY	– See Table 1.
POLARITY	– Set for type of transistor.
SWEEP RANGE	– 0-40 V.
STEPS/FAMILY	– Fully clockwise.
*STEP SELECTOR	– Current.
STEP RANGE	– See Table 1.
LIMITING RESISTOR	– See Table 1.
LEFT-RIGHT	– Left.
LOOP	– Fully clockwise.
*NORM-CAL	– Norm.

	Base Step	HORIZONTAL SENSITIVITY	VERTICAL SENSITIVITY	LIMITING RESISTOR	SWEEP RANGE
SIGNAL	.002	1 V/div.	.5 mA/div.	5 k	0-40 V
INTERMEDIATE POWER	.02	1 V/div.	5 mA/div.	500	0-40 V
POWER	.2	1 V/div.	50 mA/div.	50	0-40 V

TABLE 1

( ) Turn the SWEEP VOLTAGE control clockwise only far enough to turn the unit on.

( ) Connect the transistor to be tested to the right socket, or to the E, B, C terminals with test leads.

( ) Set the LEFT-RIGHT switch to RIGHT.

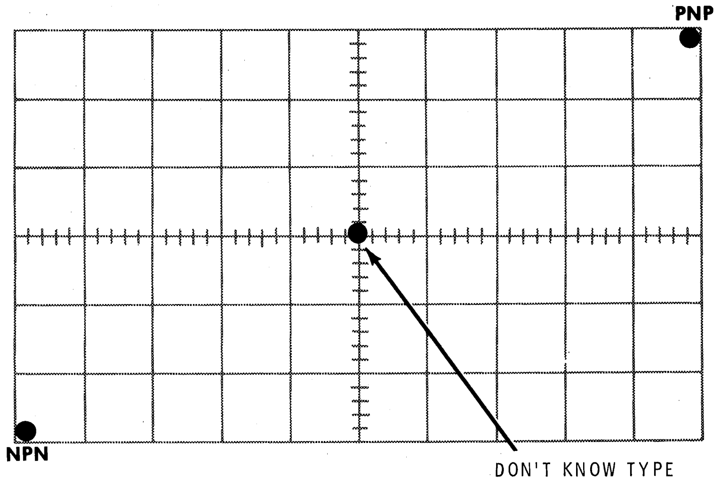


Figure 2-4

( ) If the transistor is an NPN, place the dot in the lower left-hand corner of the screen. If it is a PNP, place it in the upper right-hand corner of the screen. If you don't know if it is NPN or PNP, place the dot in the middle of the screen as shown in Figure 2-4.

NOTE: Perform the following numbered steps only if you don't know if the transistor is an NPN or PNP.

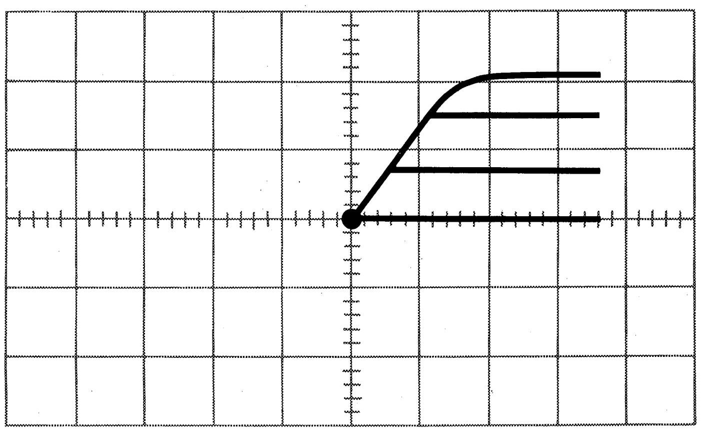


Figure 2-5

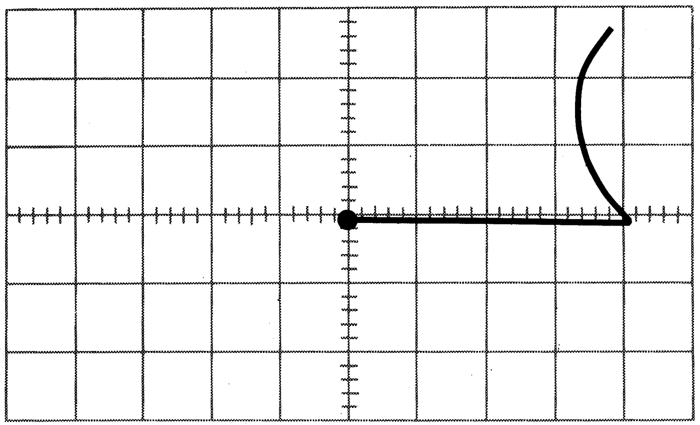


Figure 2-6

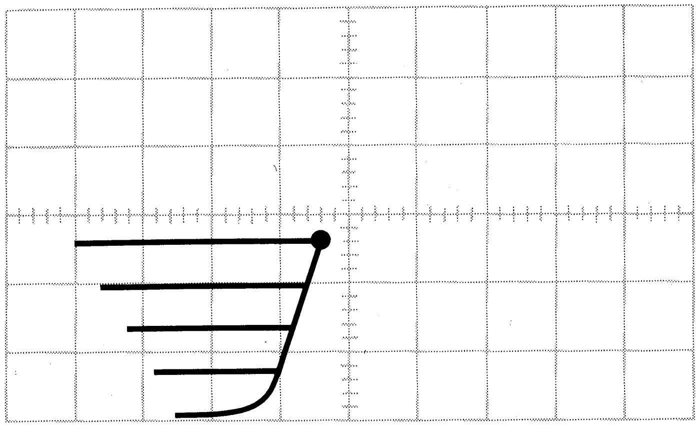


Figure 2-7

1. Slowly turn up the SWEEP VOLTAGE control. If the transistor is an NPN, curves will appear as shown in Figure 2-5. If it is a PNP, no curves will appear and breakdown, as shown in Figure 2-6, may appear. If this happens, switch the Polarity control to PNP. Then curves as shown in Figure 2-7 should appear.

2. Refer again to Figure 2-4, turn the SWEEP VOLTAGE control fully counterclockwise, and place the dot in the appropriate corner of the screen for NPN or PNP.

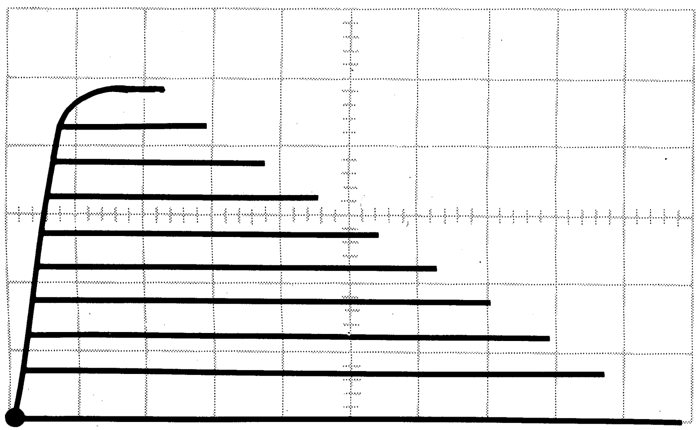


Figure 2-8

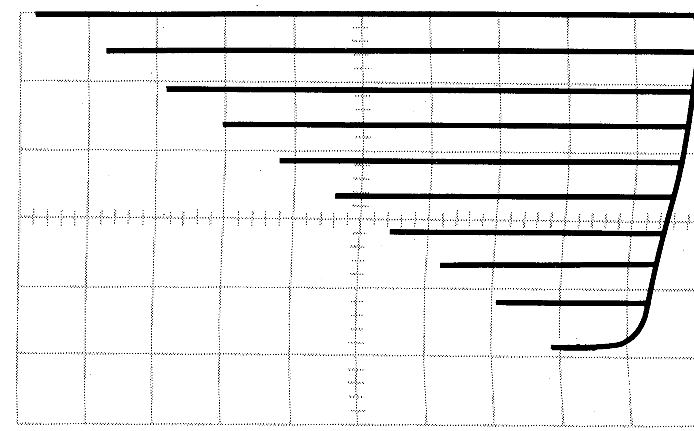


Figure 2-9

Figures 2-8 and 2-9 show typical displays of NPN and PNP transistors. They are identical — only inverted.

NOTE: If some curves go off the screen, switch the VERTICAL SENSITIVITY control to the next higher range (clockwise). Also, you may have to lower the LIMITING RESISTOR value. If the curves are to close together, select a more sensitive current range.

Table 2 gives ranges of operating parameters for transistors with different power ratings. Use Table 1 as a starting point to ensure that the device will be operated within its specifications. Always be cautious when you use ranges listed in Table 2 so that the device ratings are not exceeded.

	BASE CURRENT RANGE	COLLECTOR CURRENT RANGE	VOLTAGE RANGE
SIGNAL (Audio, RF, IF, etc.)	.002 through .1 mA/step	.5 through 5 mA/div.	STAY BELOW DEVICE BREAKDOWN
INTERMEDIATE POWER (Audio, Switching)	.02 through 1 mA/step	2 mA through 50 mA/div.	STAY BELOW DEVICE BREAKDOWN
POWER (Audio, Output, Regulator)	.2 through 10 mA/step	20 mA through 200 mA/div.	STAY BELOW DEVICE BREAKDOWN

TABLE 2

MEASUREMENTS

In-Circuit Tests — Many times these can only be made by comparing results with those known to be proper. If no curves can be obtained at all, remove the device from the circuit and then test the device.

Matching Transistors — It is often desirable to match transistors for gain, linearity, saturation, output admittance, etc. Use the LEFT-RIGHT switch to compare the curves. Matched devices have identical curves.

Sorting Transistors — To sort transistors, use the oscilloscope controls and place the CRT dot (with no input signal) in the center of the screen. Then NPN transistors will produce curves in the upper right-hand quadrant of the screen and PNP transistors will produce curves in the lower left-hand quadrant of the screen as you flip the NPN-PNP switch back and forth.

Integrated Circuits — Integrated circuits are often several transistors, diodes, etc. packaged together. These IC's may be tested if the internal devices can be identified and isolated to specific terminals of the IC. Note, however, that other circuit elements may produce loops in the curves, or other variations, of the display.

The following are examples of typical measurements and the control settings under which they were performed. Many of these use the extra MPSA20 (#417-801) transistor supplied with your kit; the control settings may vary widely for other devices.

NOTES:

1. All of these tests, unless they are described otherwise, were made with the NORM-CAL switch in the NORM position, the LOOP control adjusted for minimum looping, the LEFT-RIGHT switch in the LEFT position, and the SWEEP VOLTAGE control adjusted clockwise for a proper display.

2. If a transistor is open, only the base line will appear on the display. If the transistor is shorted, there will be a vertical line as in Figure 3-2 but there will be no base line.

Proceed to the heading of the test you are interested in.

SATURATION VOLTAGE [$V_{CE\ (sat)}$]

MPSA20:

HORIZONTAL SENSITIVITY	.1 volts/Div.
VERTICAL SENSITIVITY	2 mA/Div.
POLARITY	NPN
STEPS/FAMILY	5 steps
STEP RANGE	.01 mA/Step
LIMITING RESISTOR	0

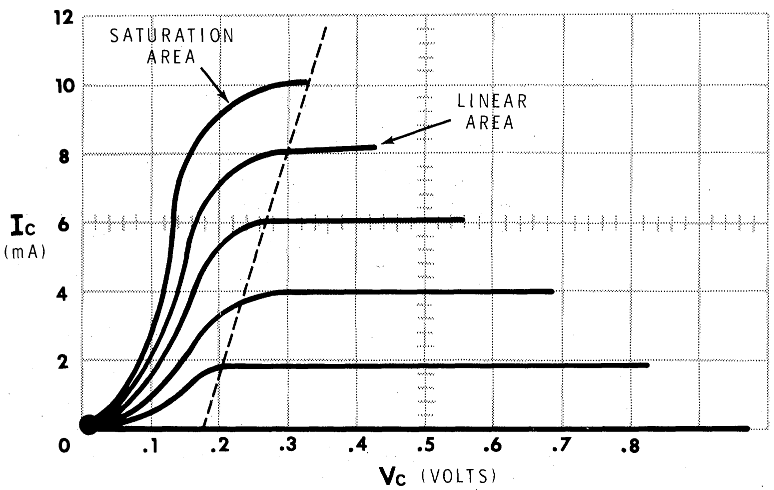


Figure 3-1

The collector saturation region of a transistor is that portion of the family of curves in the area of low collector voltage and current below the knee of each curve. The knee of each curve occurs at approximately the same collector voltage (from .18 to .32 in Figure 3-1). Collector voltage above the knee has little effect on collector current; the base current controls collector current in this area.

MPSA20: $V_{CE\ (sat)}$ = 0.25 VDC (MAX) @ I_c = 10 mA and I_B = 1 mA.

HORIZONTAL SENSITIVITY	.1 Volts/Div.
VERTICAL SENSITIVITY	2 mA/Div.
POLARITY	NPN
STEPS/FAMILY	1 Step
STEP RANGE	1 mA/Step
LIMITING RESISTOR	0

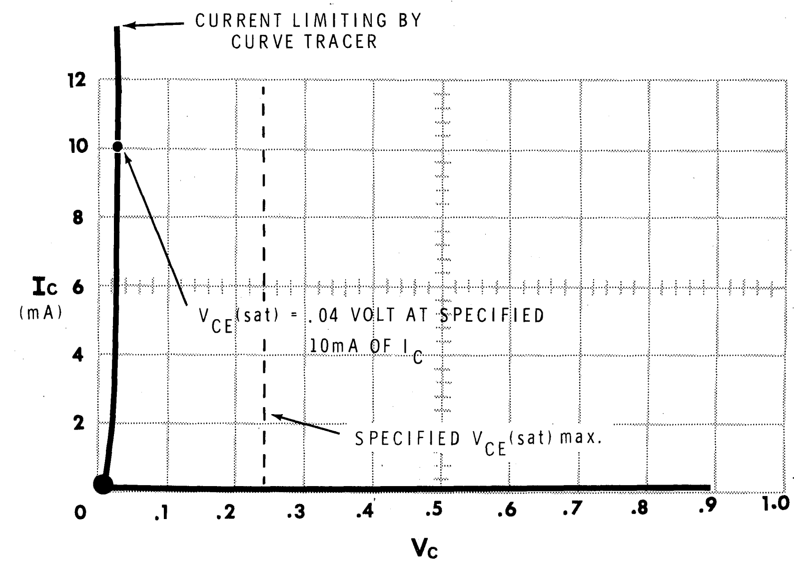


Figure 3-2

Transistor data sheets specify $V_{CE(sat)}$ as a maximum voltage at a given base current and collector current. In Figure 3-2 this value is .04 volt.

Saturation resistance, $r_{CE\,(sat)}$, can be calculated, if desired, by the formula $r_{CE\,(sat)} = \frac{V_C}{I_C}$ for a given value of base current in the saturation region. In Figure 3-2, $r_{CE\,(sat)} = \frac{.04\ V}{10\ mA} = \frac{40\ mV}{10\ mA} = 4\ \Omega$.

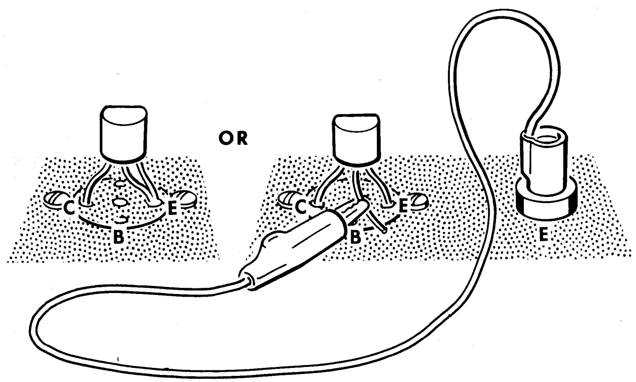
LEAKAGE CURRENT (I_{CEO}) and (I_{CES})

HORIZONTAL SENSITIVITY	5 Volts/Div.
VERTICAL SENSITIVITY	.5 mA/Div.
POLARITY	NPN
STEPS/FAMILY	0
STEP RANGE	Any position
LIMITING RESISTOR	5 k

I_{CEO} is the collector to emitter leakage current that flows when the base is open (not connected). I_{CES} is the collector to emitter leakage current that flows when the base is shorted to the emitter.

I_{CEO} – Do not connect the transistor base lead to the Curve Tracer.

I_{CES} – Connect both the transistor base lead and emitter lead to the E connector of the transistor socket. See below.



The leakage current is proportional to the collector-to-emitter voltage and becomes greatest as the breakdown voltage is approached. For a good transistor, I_{CEO} is always greater than I_{CES}.

NOTE: Silicon transistors typically have leakage currents in the nanoampere region and will not display any leakage on the Curve Tracer. Germanium transistors are much more likely to show measurable leakage.

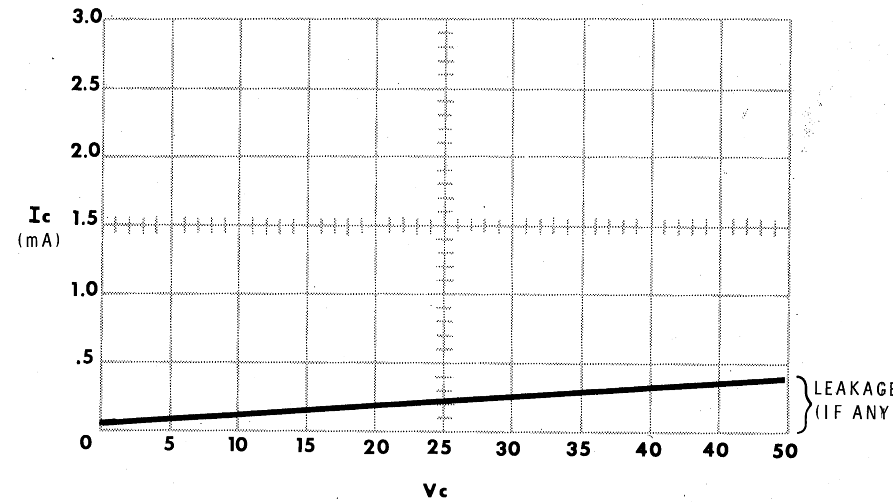


Figure 3-3

BREAKDOWN VOLTAGE

MPSA20: Minimum 40 volts at 1 mA of I_c

HORIZONTAL SENSITIVITY	5 volts/Div.
VERTICAL SENSITIVITY	2 mA/Div.
POLARITY	NPN
STEPS/FAMILY	5 Steps
STEP RANGE	.005 mA/Step
LIMITING RESISTOR	5 k

The breakdown voltage is where the collector current becomes independent of the base current and rises sharply until limited by the Curve Tracer. If it were not for this limiting, the transistor would be destroyed. Keep the test short so the transistor is not damaged by too much heat. Increase the sweep voltage until the collector breakdown point is reached.

Most transistors can be tested for breakdown because of the high voltage capability (200 volts) of the Curve Tracer.

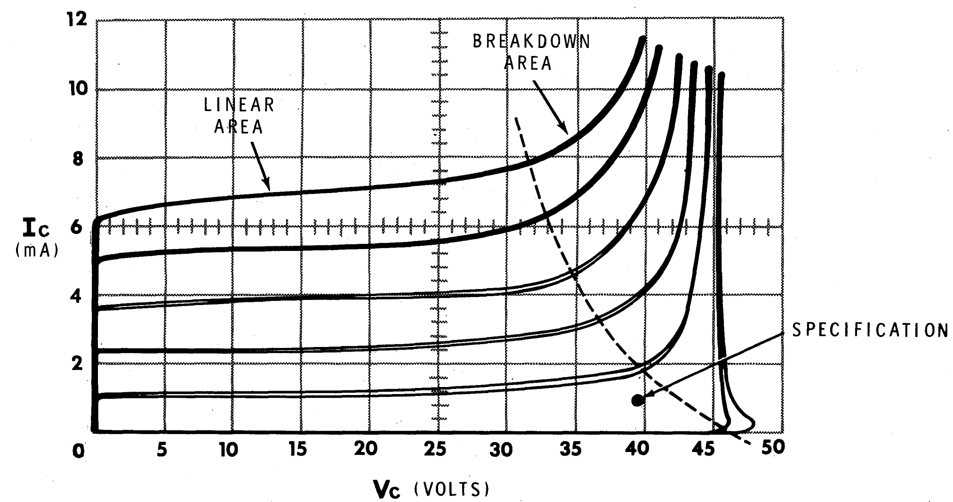


Figure 3-4

OUTPUT ADMITTANCE (h_{oe})

MPSA20:

HORIZONTAL SENSITIVITY	5 volts/Div.
VERTICAL SENSITIVITY	2 mA/Div.
POLARITY	NPN
STEPS/FAMILY	5 Steps
STEP RANGE	.005 mA/Step
LIMITING RESISTOR	5 k

The output admittance of a transistor is the change in collector current (ΔI_c) that results from a specific change in collector voltage (ΔV_c) at a constant base current. Admittance is measured in μmhos and its "h" parameter in the common emitter configuration is $h_{oe} = \frac{\Delta I_c}{\Delta V_c} = \frac{\Delta I_c}{\Delta V_c} = \frac{.8 \text{ mA}}{25 \text{ V}} = 32\ \mu\text{mhos}$.

The output impedance of the transistor (collector resistance) is the reciprocal of its output admittance and is measured in ohms. To calculate it, transpose the current and voltage values used to determine the admittance.

$$\text{Output impedance} = \frac{\Delta V_c}{\Delta I_c} = \frac{25}{.8 \text{ mA}} = 31{,}250 \text{ ohms.}$$

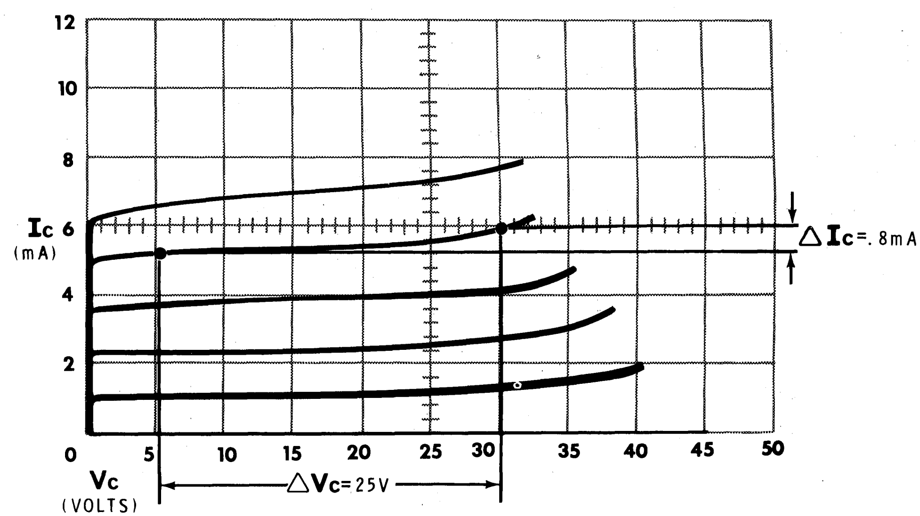


Figure 3-5

DC BETA (h_{FE})

MPSA20: 40-400, I_c = 5 mA, V_c = 10V

HORIZONTAL SENSITIVITY	1 Volt/Div.
VERTICAL SENSITIVITY	5 mA/Div.
POLARITY	NPN
STEPS/FAMILY	3 Steps
STEP RANGE	.05 mA/Step
LIMITING RESISTOR	100

Beta (β) is the ratio of collector current to base current and is equal to current gain. That is, for a given base current, a proportionally larger collector current is produced. DC beta is dependent upon what collector voltage and current points are picked. Even at specific values, DC beta can vary greatly in the same type device.

DC Beta is found by the formula:

$$\text{DC beta} = \frac{I_C}{I_B}$$

Therefore, the above example produces a beta of:

$$\beta = \frac{I_C}{I_B} \quad \beta = \frac{20\text{ mA}}{.1\text{ mA}} \quad \beta = 200$$

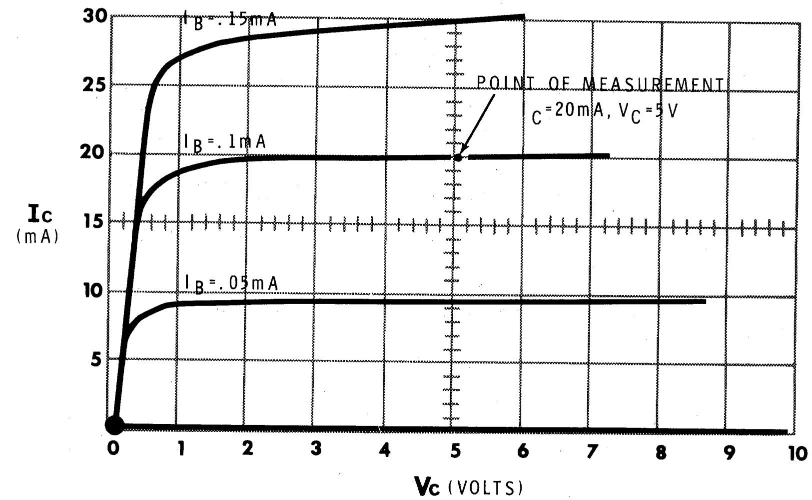


Figure 3-6

DC beta is indicated by capital FE in the term "h_{FE}," while AC beta is indicated by lower case fe in the term "h_{fe}."

AC BETA (h_{fe})

MPSA20:

HORIZONTAL SENSITIVITY	1 Volt/Div.
VERTICAL SENSITIVITY	5 mA/Div.
POLARITY	NPN
STEPS/FAMILY	3 Steps
STEP RANGE	.05 mA/Step
LIMITING RESISTOR	100

AC beta, or gain, is the ratio of change in collector current to the change in base current. This measurement is more useful because it is taken under actual operating conditions and performance can be more precisely predicted.

If the transistor data sheet is available, beta should be measured at the approximate collector current and voltage specified. If not, the STEP RANGE is usually adjusted for a display of the most evenly and widely spaced curves.

Gain is usually higher in the normal operating region of the transistor and is lower at collector currents above or below this region.

Calculate AC beta as follows:

1. Measure the difference in collector current (ΔI_c) between two curves at the same collector voltage.

2. Note the change in base current (ΔI_b) from the STEP RANGE switch. (.05 mA in this case.)

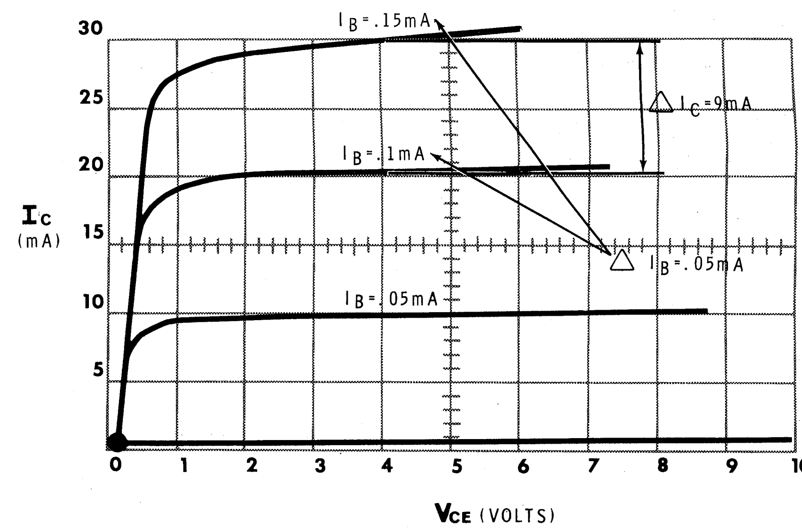


Figure 3-7

3. Then AC beta = $\dfrac{\Delta I_c}{\Delta I_b}$ at V_{CE} of 4 volts

$$\beta = \frac{9 \text{ mA}}{.05 \text{ mA}}$$

$$\beta = 180$$

LINEARITY AND GENERAL DISPLAY-LOW I_C

MPSA20:

HORIZONTAL SENSITIVITY	2 Volts/Div.
VERTICAL SENSITIVITY	2 mA/Div.
POLARITY	NPN
STEPS/FAMILY	9 Steps
STEP RANGE	.005 mA/Step
LIMITING RESISTOR	1 k

Linearity is a measure of the transistor's ability to amplify, in exact proportion, a signal that appears at its base.

The step generator in the Curve Tracer produces precise steps. Therefore, if the device being tested is perfect, the spacing between curves will be constant — similar to the curves in Figure 3-8. These curves can be used to check both gain and linearity. Linearity is usually better with a low collector current.

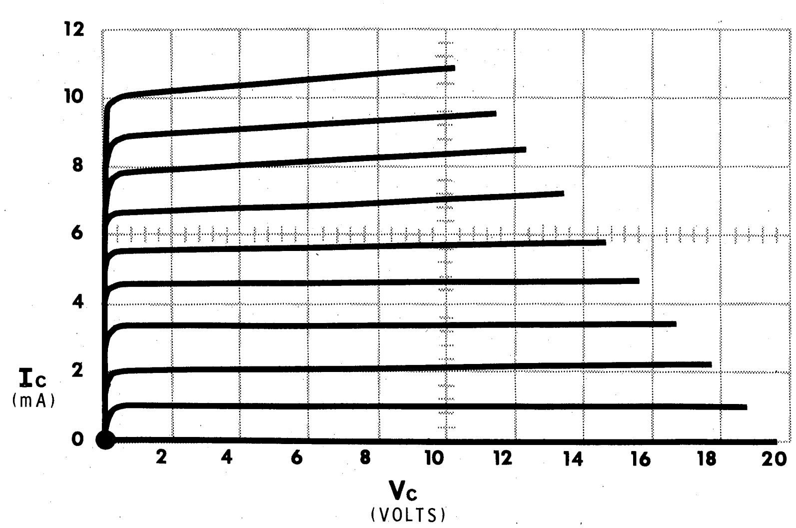


Figure 3-8

LINEARITY AND GENERAL DISPLAY—HIGH I_C

MPSA20: To maximum of 100 mA of I_c

HORIZONTAL SENSITIVITY	1 Volt/Div.
VERTICAL SENSITIVITY	20 mA/Div.
POLARITY	NPN
STEPS/FAMILY	5 Steps
STEP RANGE	.1 mA/Step
LIMITING RESISTOR	50

Nonlinearity increases with an increase in collector current. (Note the closer spacing of the upper curves.)

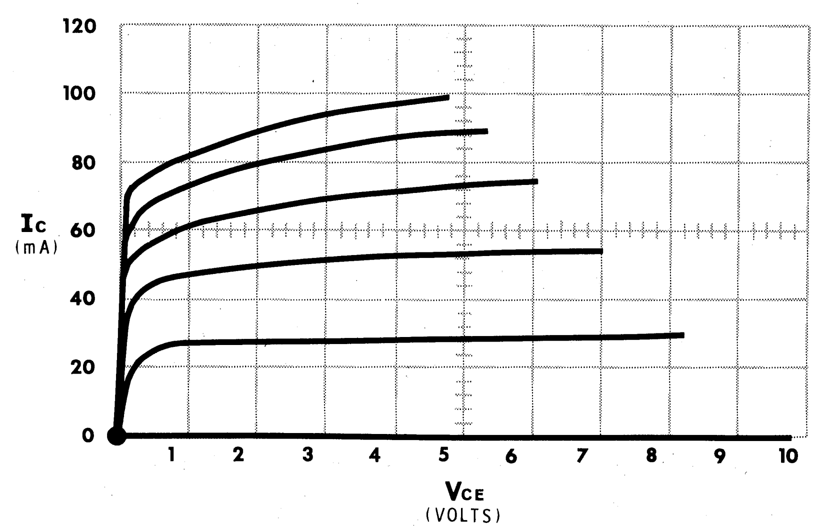


Figure 3-9

NONLINEARITY

MPSA20:

HORIZONTAL SENSITIVITY	1 Volt/Div.
VERTICAL SENSITIVITY	5 mA/Div.
POLARITY	NPN
STEPS/FAMILY	3 Steps
STEP RANGE	.05 mA/Step
LIMITING RESISTOR	100

Transistor gain is not necessarily constant, but is dependent on the point of measurement. If the transistor is operated in a nonlinear region, the gain is nonlinear and distortion is produced. This may be desirable or undesirable, depending on the application of the transistor.

To measure nonlinearity:

1. Plot an imaginary line along the ends of the curves. This is the "test load line."
2. Plot an "operating load line" in parallel with the test load line but intersecting the zero IC line at the desired operating V_{CE} for the transistor.
3. Measure and compare the changes in collector current (ΔI_c) between the curves on the operating load line. If the changes are the same, the transistor is linear at this point. If they are different, it is nonlinear at this point. In the above example there is some nonlinearity, and thus distortion at this point, because Δ 9 mA does not equal Δ 11 mA. As can be seen, an input signal of ±.05 mA will produce an output signal of +9 mA and −11 mA.

Nonlinearity should be measured along a load line rather than at a specific V_{CE} because it more nearly duplicates operating conditions. The transistor will operate with a load, not at a fixed V_{CE}. The load causes operation along the load line, since a change in collector current produces a change in collector voltage and vice versa.

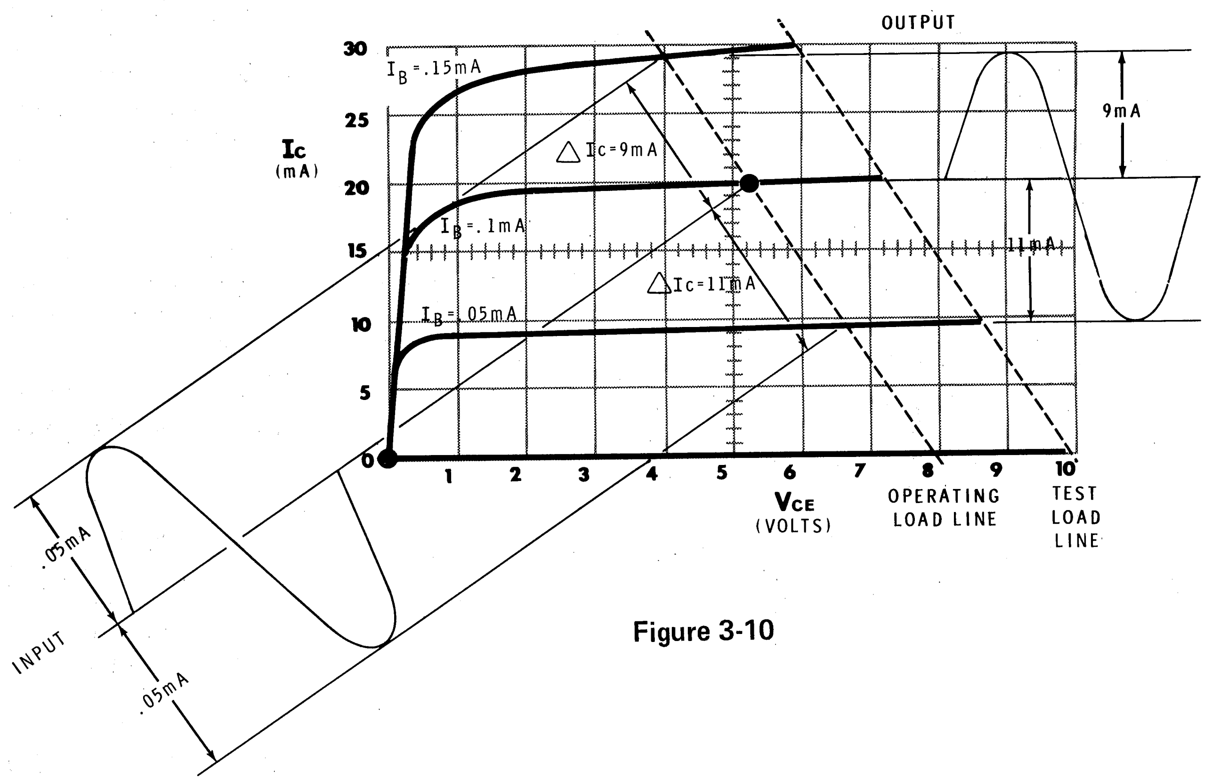


Figure 3-10

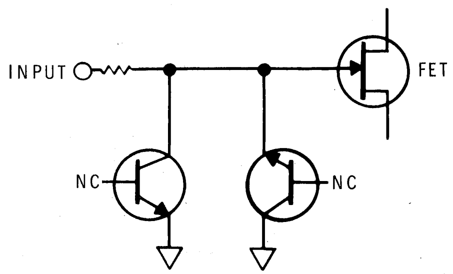
REVERSE C TO E BREAKDOWN

MPSA20:

HORIZONTAL SENSITIVITY	1 Volt/Div.
VERTICAL SENSITIVITY	2 mA/Div.
POLARITY	PNP
STEPS/FAMILY	Counterclockwise
STEP RANGE	.002 mA/Step
LIMITING RESISTOR	500

This breakdown occurs when the reverse collector-to-emitter voltage becomes great enough to suddenly cause excessive collector current to flow.

Figure 3-11 is a typical display. However, other proper displays may have different slopes after the breakdown point. The collector-to-emitter breakdown of bipolar transistors is sometimes used in an input circuit to protect an FET from large signals, as shown.



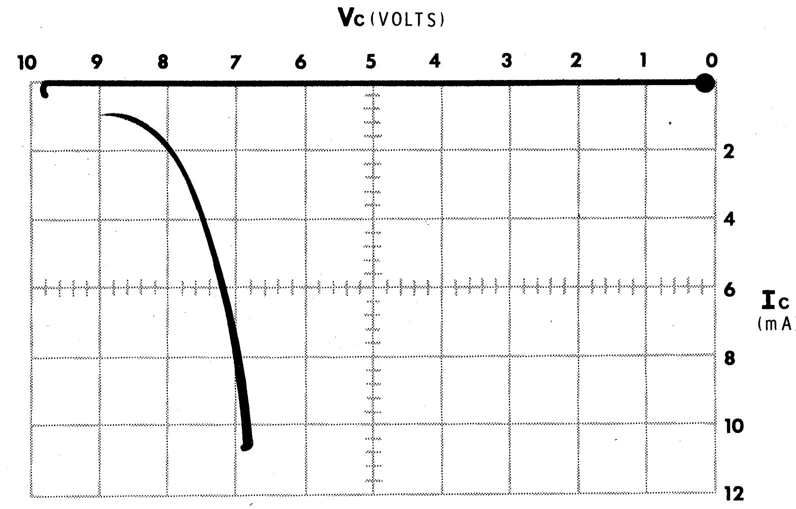


Figure 3-11

THERMAL HEATING

MPSA20:

HORIZONTAL SENSITIVITY	5 Volts/Div.	
VERTICAL SENSITIVITY	50 mA/Div.	
POLARITY	NPN	
STEPS/FAMILY	4 Steps	
STEP RANGE	2 mA/Step	.2 mA/Step
LIMITING RESISTOR	50	

Looping can be caused by collector capacitance and inductance, in certain cases by the Curve Tracer itself (see "Curve Tracer Characteristics"), and by thermal heating. If current causes heat that cannot be adequately dissipated, then looping is produced. In the forward sweep, heat is produced. This heat increases or decreases current flow (depending the temperature coefficient of the device). Therefore, on the return sweep, a different amount of current flows because of the time lag required for cooling to occur. This difference appears as looping.

CAUTION: Do not make a transistor produce excessive looping. This is not normal and may damage or destroy the device.

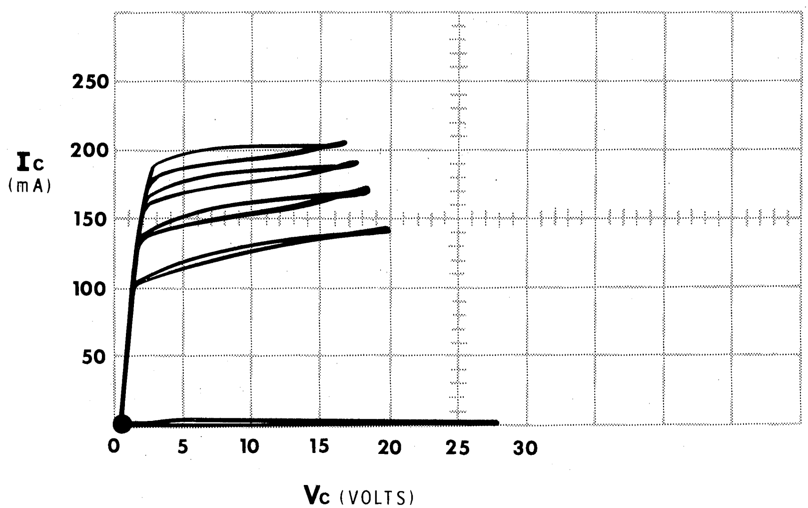


Figure 3-12

THERMAL RUNAWAY

MPSA20:

This test will damage or destroy the device.

HORIZONTAL SENSITIVITY	5 Volts/Div.
VERTICAL SENSITIVITY	50 mA/Div.
POLARITY	NPN
STEPS/FAMILY	4 Steps
STEP RANGE	.5 mA/Step
LIMITING RESISTOR	50

High current produces excessive heat and causes "thermal runaway." The curves will roll towards the top of the screen until the device is permanently damaged or destroyed.

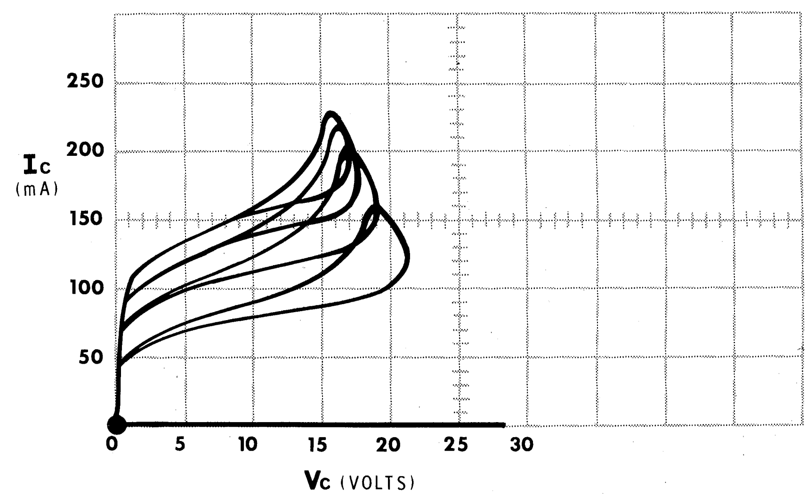
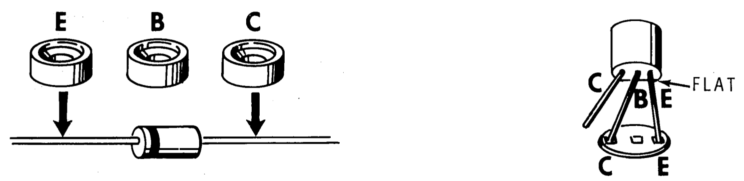


Figure 3-13

DIODE FORWARD CONDUCTION



MPSA20: Base to Emitter. Install the E and B leads of the transistor in the E and C socket holes as shown.

HORIZONTAL SENSITIVITY	.1 Volt/Div.
VERTICAL SENSITIVITY	.5 mA/Div.
POLARITY	NPN
STEPS/FAMILY	Counterclockwise (has no effect)
STEP RANGE	.002 mA/Steps
LIMITING RESISTOR	1 k

Diodes conduct easily in one direction and do not conduct in the reverse direction. To test a diode, apply the sweep voltage across the device. The step voltage and current are not used, and the STEPS/FAMILY control is not used.

For diodes, only one curve is displayed. From this you can measure forward voltage drop and diode resistance. No current flows until the sweep voltage exceeds the junction barrier. This voltage drop is about 0.3 volt for germanium diodes and 0.6 volt for silicon diodes. Then, above this point, current increases rapidly as the voltage is increased.

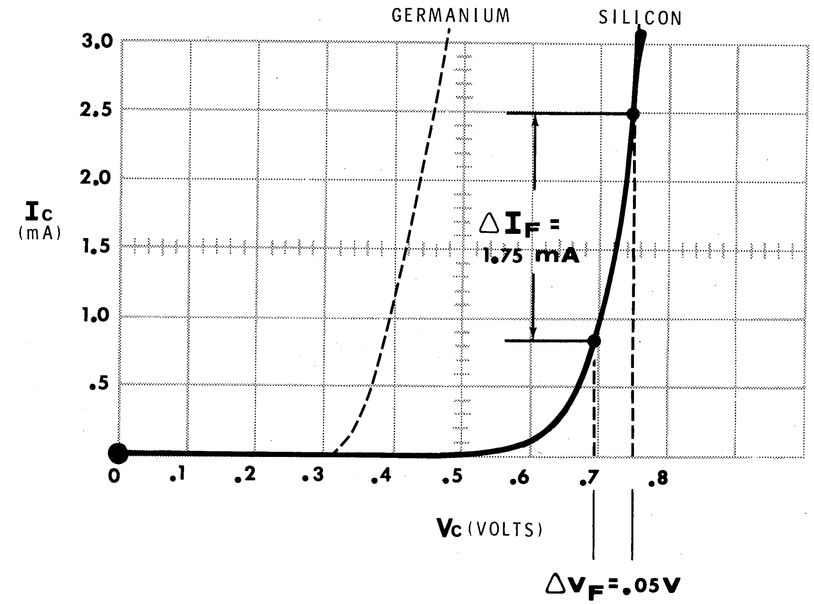


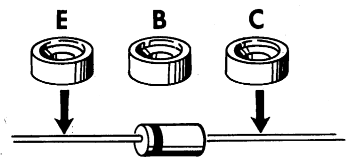
Figure 3-14

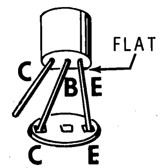
The dynamic resistance of a diode equals the change in forward voltage (V_F) divided by the change in forward current (I_F).

$$R_D = \frac{\Delta V_F}{\Delta I_F} = \frac{.05V}{1.75\ mA} = 28.57\ \Omega$$

When you test a conventional diode, connect it as shown.

DIODE REVERSE BREAKDOWN





MPSA20: Base to Emitter. Install the E and B leads of the transistor in the E and C socket holes as shown.

HORIZONTAL SENSITIVITY	1 volt/Div.
VERTICAL SENSITIVITY	.5 mA/Div.
POLARITY	PNP
STEPS/FAMILY	Counterclockwise (has no effect)
STEP RANGE	.002 mA/Step
LIMITING RESISTOR	1 k

Diode reverse breakdown is the voltage point where the diode begins to conduct current independent of voltage.

Position the dot in the upper right-hand corner.

When you test a conventional diode, connect it as shown. Be sure to use a sufficiently high limiting resistor so the diode is not damaged by excessive current. Germanium diodes may show leakage. (See upper left-hand corner of the Figure.)

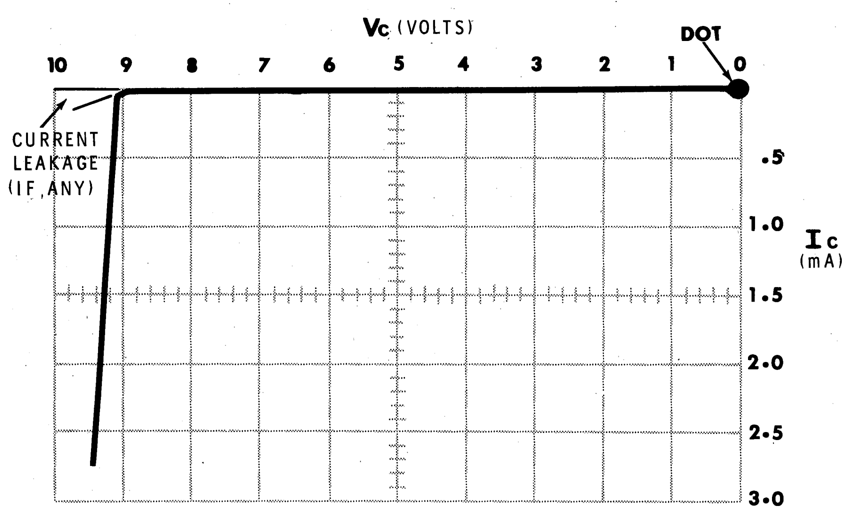


Figure 3-15

ZENER DIODES

HORIZONTAL SENSITIVITY	5 volts/Div.
VERTICAL SENSITIVITY	.5 mA/Div.
POLARITY	PNP
STEPS/FAMILY	Counterclockwise (has no effect)
STEP RANGE	.002 mA/Step
LIMITING RESISTOR	10 k

Zener diodes are like conventional diodes except that they are designed to operate in the reverse breakdown mode. The knee is the point where this breakdown begins. The sharper the knee, the better the zener is. Some zeners may have some leakage current before breakdown. This leakage can be measured as shown.

The dynamic impedance (the ratio of a change of voltage to a change of current in the breakdown region) can be determined by picking two points and calculating this ratio. The better zeners have a lower dynamic impedance.

$$Z \text{ (dynamic impedance)} = \frac{\Delta V_C}{\Delta I_C} = \frac{2.5\text{V}}{1.5\text{ mA}} = 1667\ \Omega.$$

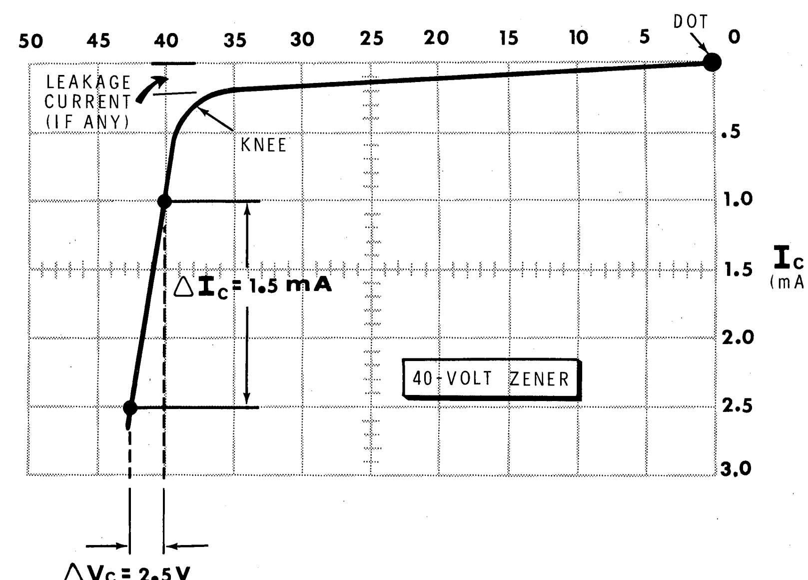


Figure 3-16

CURVE TRACER LIMITS

High-Voltage Transistor, To 200 Volt Limit

HORIZONTAL SENSITIVITY	20 Volts/Div.
VERTICAL SENSITIVITY	2 mA/Div.
POLARITY	NPN
SWEEP RANGE	0-200 V
STEPS/FAMILY	4 Steps
STEP RANGE	.02 mA/Step
LIMITING RESISTOR	10 k

NOTES:

1. Do not exceed the specifications of the device.
2. Be sure to set the SWEEP RANGE switch back to 0-40 V after you finish any high voltage tests.
3. Use as high a limiting resistance as practical.

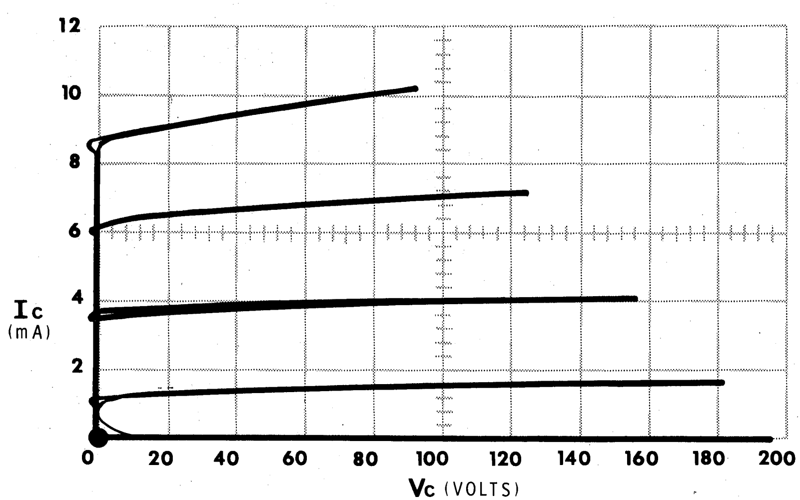


Figure 3-17

Power Transistor, To 1-Ampere Limit

HORIZONTAL SENSITIVITY	50 Volts/Div.
VERTICAL SENSITIVITY	200 mA/Div.
POLARITY	NPN
STEPS/FAMILY	8 Steps
STEP RANGE	2 mA/Step
LIMITING RESISTOR	10

The Curve Tracer limits the current above 1000 mA. This may produce distortion (crowding of the curves) at the top of the waveform.

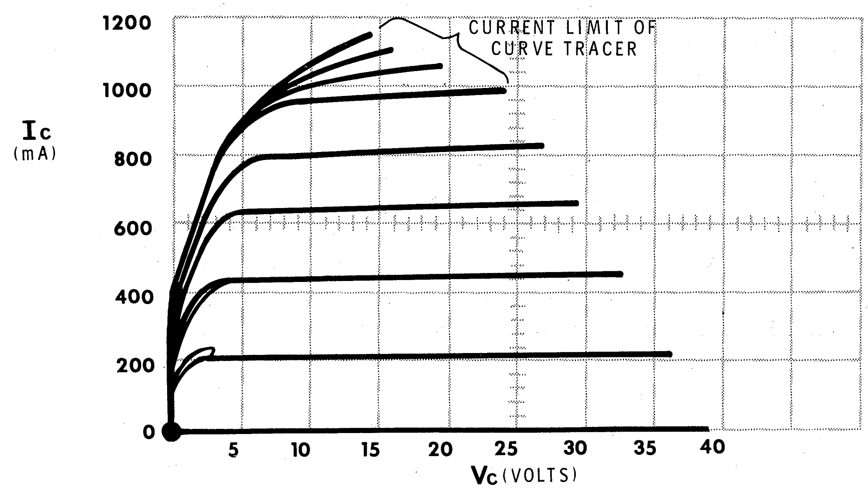


Figure 3-18

GENERAL FET DISPLAY

HORIZONTAL SENSITIVITY	1 Volt/Div.
VERTICAL SENSITIVITY	1 mA/Div.
POLARITY	N Chan.
STEPS/FAMILY	Fully Clockwise
STEP RANGE	.1 Volt/Step
LIMITING RESISTOR	1 k

Testing FET's (including MOS FET's) is similar to testing bipolar transistors (NPN's and PNP's). However, instead of a graph of collector current versus collector voltage at various base currents, FET curves are a graph of drain current versus drain voltage at various gate voltages.

To test an FET, the STEP RANGE switch is placed in a "VOLTS/STEP" position so the Curve Tracer will supply constant voltage steps rather than constant current steps. Also, the polarity of the step voltage is reversed in relation to the sweep voltage. The zero base current step of a bipolar transistor usually produces no collector current. However, in an FET, the zero gate voltage produces the highest drain current. Then each reverse bias voltage step results in less drain current. Therefore, what is the base line in regular transistors is the top line in Figure 3-19.

Some MOS FET's can be damaged by static electricity carried by the person handling the device. Therefore, discharge any static charge by touching ground with one hand before and while handling the MOS FET with the other hand.

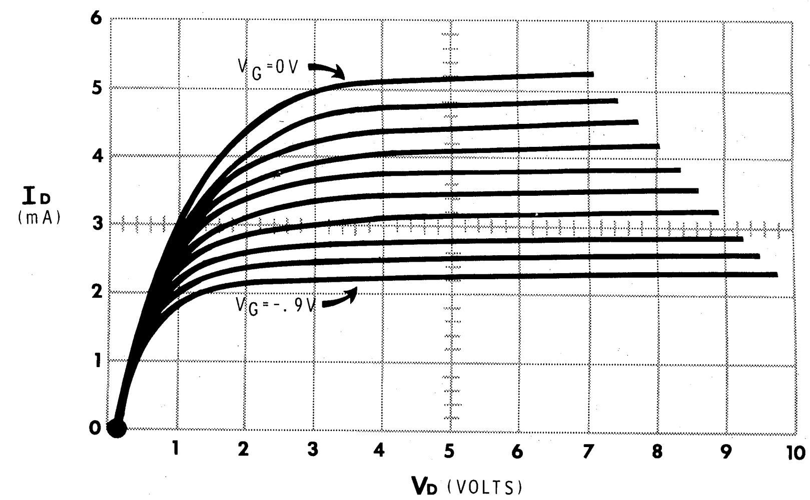


Figure 3-19

To test the few enhancement mode FET's, disconnect the gate lead from the Curve Tracer and connect a DC bias supply to provide forward bias voltage. Be sure the common of the supply is connected to the circuit ground of the Curve Tracer. (Connect a test lead between the supply and S jack of the Curve Tracer.)

When you test dual-gate MOS FET's, either ground or bias the gate not being tested-do not leave it open circuited.

FET PINCHOFF AND TRANSCONDUCTANCE

HORIZONTAL SENSITIVITY	1 Volt/Div.
VERTICAL SENSITIVITY	1 mA/Div.
POLARITY	N Chan.
STEPS/FAMILY	5 Steps
STEP RANGE	.5 Volt/Step
LIMITING RESISTOR	1 k

If the reverse bias voltage steps are of a high enough value, drain current stops and "pinchoff" is attained. The approximate value of pinchoff is found by noting which step produces no drain current (I_D). In the example, the 5th step (all higher steps will fall in the same place as the 5th step) produces no drain current. Thus pinchoff occurs between -2.0 volts (4th step) and -2.5 volts (5th step).

The gain of an FET is the gate-to-drain forward transconductance (gm). This is the ratio of change in drain current to the change in gate voltage at a given drain voltage. Transconductance is measured in µmhos.

To calculate gm:

1. Note the difference in drain current between two curves (ΔI_D) at the same drain voltage (V_D).
2. Note the change in gate voltage (ΔV_G) from the STEP RANGE switch.
3. Then gm - $\frac{\Delta I_D}{\Delta V_G}$

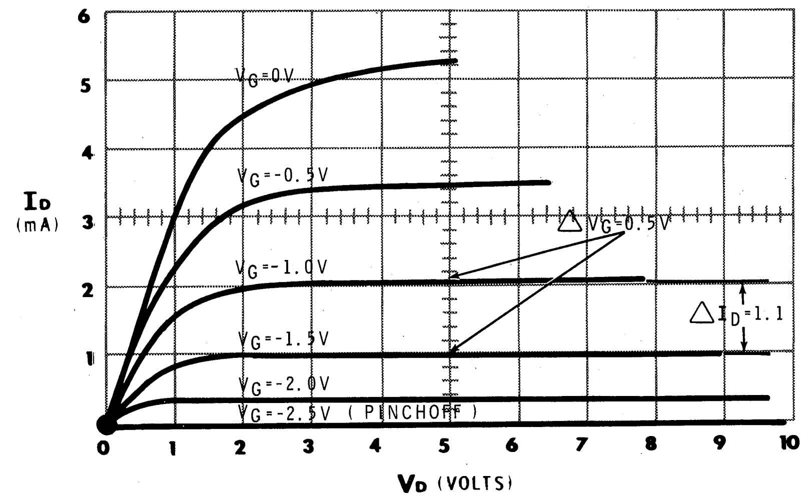


Figure 3-20

$$gm = \frac{1.1\ mA}{.5\ V} = \frac{1100\ \mu A}{.5} = 2200\ \mu mhos \text{ at } V_D \text{ of 5 volts.}$$

NOTE: Like beta, gm depends on the point of measurement. As you can see by the nonlinearity of the curves in Figure 3-20, gm is not a constant.

FET BREAKDOWN (Figure 3-21)

HORIZONTAL SENSITIVITY	10 Volts/Div.
VERTICAL SENSITIVITY	1 mA/Div.
POLARITY	N Chan.
SWEEP RANGE	0-200 V
STEPS/FAMILY	4 Steps
STEP RANGE	.2 Volt/Step
LIMITING RESISTOR	10 k

As the sweep voltage is increased, a point is reached where the FET breaks down. At this point drain current becomes independent of gate voltage and rises sharply until limited by the Curve Tracer. If it were not for this limiting, the FET would be destroyed. Keep the test short so the transistor is not damaged by too much heat.

NOTE: FET's are more easily damaged by high voltage than are bipolar transistors.

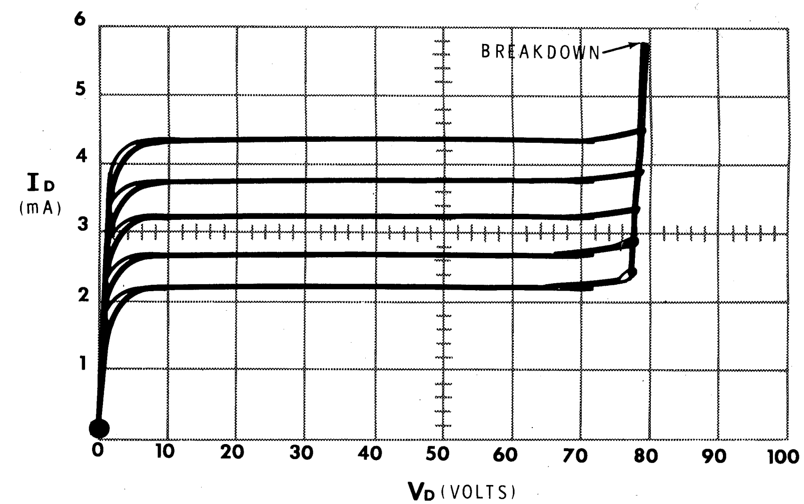


Figure 3-21

TUNNEL DIODE (Figure 3-22)

HORIZONTAL SENSITIVITY	.1 Volt/Div.
VERTICAL SENSITIVITY	2 mA/Div.
POLARITY	NPN
STEPS/FAMILY	Fully counterclockwise
STEP RANGE	-------
LIMITING RESISTOR	1 k

Tunnel diodes are p-n junction devices with a negative resistance or "tunnel" region. The "tunnel" makes it possible to use the diode as an amplifier, oscillator, or pulse generator. The diode conducts very easily in one direction (at a much lower voltage than conventional signal diodes), but the tunnel is in the direction of the higher resistance. These diodes are normally operated at very low voltage and current levels.

NOTE: Carefully select the limiting resistor so the diode does not oscillate.

Connect the diode to a transistor socket: Cathode to the emitter connector, and anode to the collector connector. A trace will not normally be displayed in the negative resistance region.

The following characteristics can be measured directly from the display.

I_p – peak current, start of tunnel region

V_p – peak voltage, start of tunnel region

I_v – valley current, end of tunnel region

V_v – valley voltage, end of tunnel region

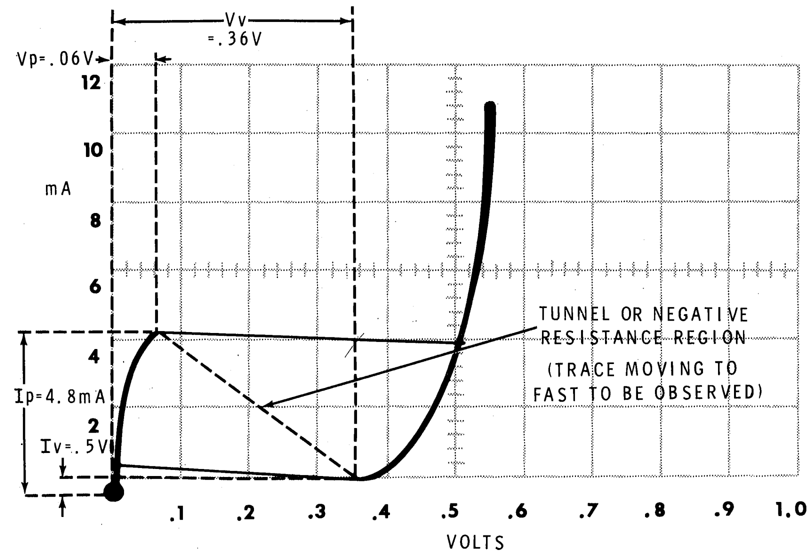


Figure 3-22

The average negative resistance can be calculated from these values.

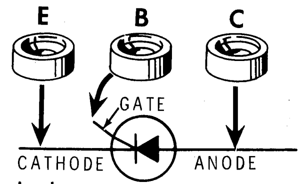
$$\text{Average negative resistance} = \frac{V_V - V_P}{I_P - I_V} = \frac{.36\text{ V} - .06\text{ V}}{4.8\text{ mA} - .5\text{ mA}} = \frac{.3\text{ V}}{4.3\text{ mA}} = 69.8\ \Omega.$$

SCR

An SCR (silicon controlled Rectifier or Thyristor) is a four layer p-n-p-n device with three terminals; cathode, anode, and gate. In the "on" state, the SCR behaves much like a diode. However, unlike a diode, the SCR also has an "off" state and does not conduct in either direction.

If the forward blocking voltage is exceeded, the SCR will turn on. The SCR will then stay on until the anode to cathode current drops below a certain value (called the holding current).

Forward Blocking Voltage And Holding Current



HORIZONTAL SENSITIVITY	20 Volts/Div.
VERTICAL SENSITIVITY	5 mA/Div.
POLARITY	NPN
STEPS/FAMILY	Fully counterclockwise
STEP RANGE	.002 mA/Step
LIMITING RESISTOR	10 k

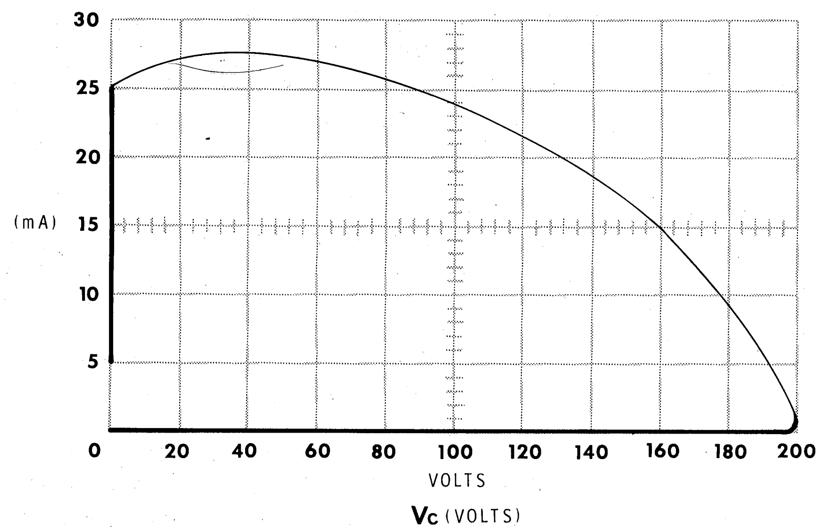


Figure 3-23

For the example in Figure 23, the forward blocking voltage is 200 volts and the holding current is 5 mA.

Reverse Blocking Voltage And Leakage Current

The procedure is the same as for testing a reverse biased diode. Be sure you are in the PNP mode and the STEPS/FAMILY control is fully counterclockwise.

Gate Trigger Current

The gate current needed to turn on the SCR depends on the anode-to-cathode voltage. The following example shows how to determine this current.

HORIZONTAL SENSITIVITY	5 Volts/Div.
VERTICAL SENSITIVITY	200 mA/Div.
POLARITY	NPN
STEPS/FAMILY	1 Step
STEP RANGE	.002 mA/Step
LIMITING RESISTOR	50

NOTE: To set the STEPS/FAMILY control for 1 step, position the NORM-CAL switch to the CAL position and adjust the STEPS/FAMILY control until two dots appear. Then reposition the switch back to the NORM position.

Turn the STEP RANGE switch clockwise until a vertical line appears as in Figure 3-24. The trigger current is then between the step range just selected and the previous step. If the 10 mA/step position is reached and no vertical line appears, turn the STEPS/FAMILY control slowly clockwise. When the line appears, use the NORM-CAL switch to determine how many steps were required and multiply the number by 10 mA.

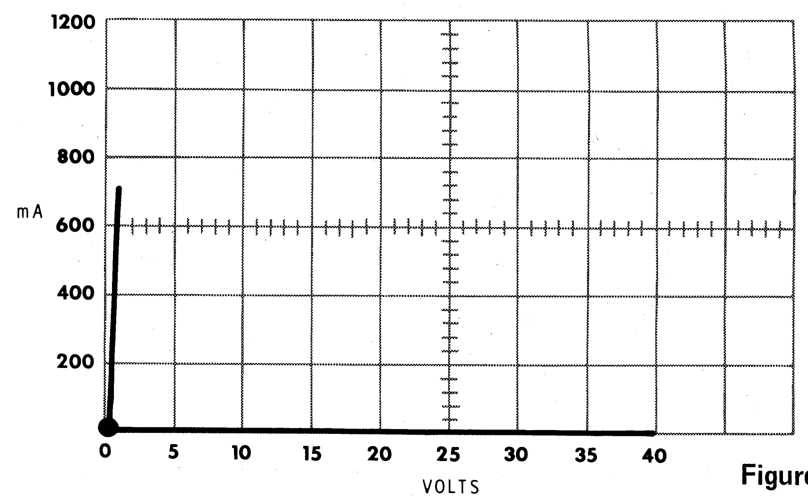
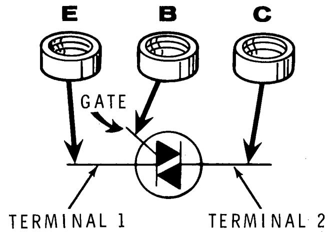
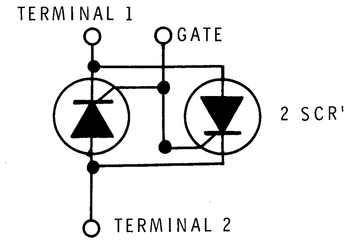


Figure 3-24

Forward Conduction

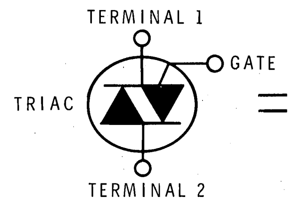
HORIZONTAL SENSITIVITY	.2 Volt/Div.
VERTICAL SENSITIVITY	50 mA/Div.
POLARITY	NPN
STEPS/FAMILY	1 Step
STEP RANGE	.05 mA/Step
LIMITING RESISTOR	0





The forward voltage drop of an SCR is similar to that of a forward biased diode and the voltage depends on the selected current.

With two volts applied, the forward voltage drop of the SCR in Figure 3-25 is approximately 0.9 volt at a current of 250 mA. From these values the instantaneous watts dissipated in the device can be determined. W = VI = .9V X 250 mA = .225 watts.



TRIAC

Triacs may be tested the same as SCR's except that the forward tests should be performed in both directions and there will be no reverse blocking voltage measurement. This is because a triac is the same as two SCR's in parallel, but oriented in opposite directions.

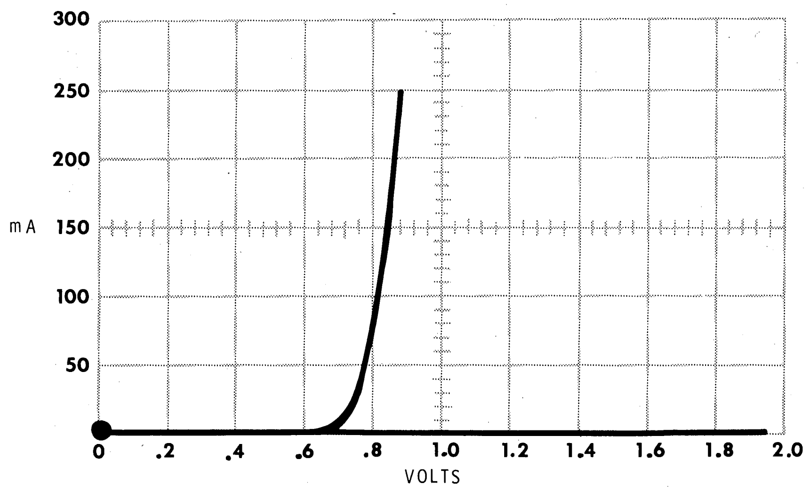


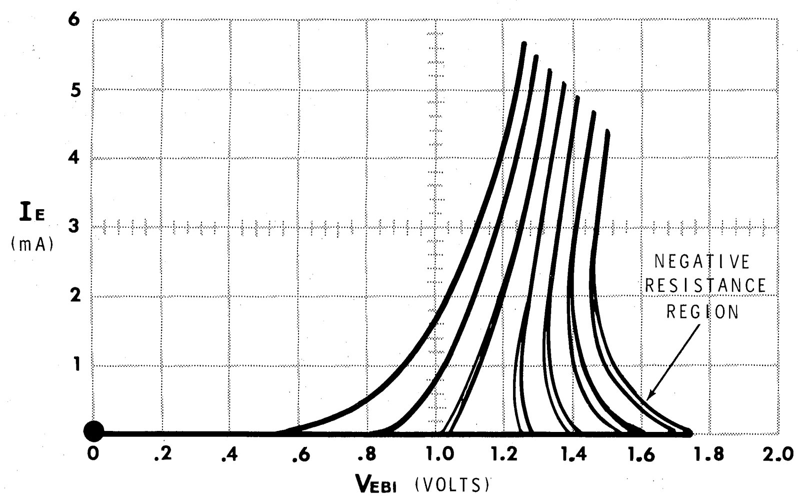
Figure 3-25

UJT

HORIZONTAL SENSITIVITY	.2 Volt/Div.
VERTICAL SENSITIVITY	1 mA/Div.
POLARITY	NPN
STEPS/FAMILY	6 Steps
STEP RANGE	.5 mA/Step
LIMITING RESISTOR	100

A unijunction transistor (UJT) is a single junction device with three terminals. Conduction between base 1 and base 2 is purely resistive until an emitter current is applied. A small trigger current applied to the emitter causes a negative resistance condition. The value of trigger voltage is dependent upon the voltage between base 1 and base 2.

When tested, the step current is applied from base 2 to base 1. This step current causes a step voltage across B_2 and B_1. The sweep voltage is applied to the emitter of the UJT. For each increase in B_2 B_1 voltage, more emitter trigger voltage is required. See Figure 3-26.



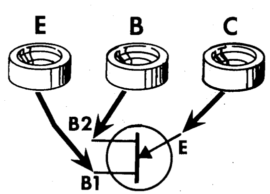
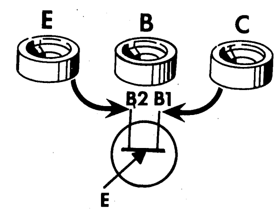


Figure 3-26

UJT (R_{BB})

HORIZONTAL SENSITIVITY	1 Volt/Div.
VERTICAL SENSITIVITY	1 mA/Div.
POLARITY	NPN
STEPS/FAMILY	0
STEP RANGE	Not used
LIMITING RESISTOR	1 k

Interbase resistance (R_{BB}) can be displayed by connecting base 1 and base 2 to the collector and emitter jacks of the Curve Tracer and leaving the emitter lead open circuited. This displays a linear trace of forward current (I_F) versus interbase voltage (V_{BB}). $R_{BB} = V_{BB}/I_F = \frac{9V}{3\ mA} = 3\ k\Omega$



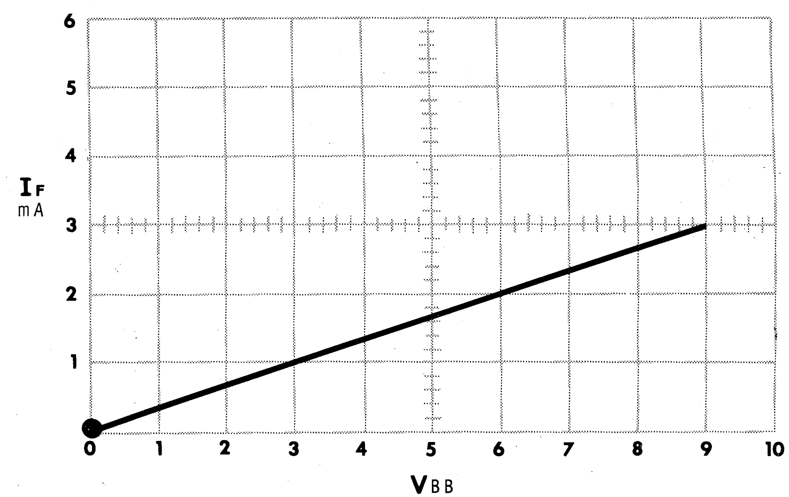


Figure 3-27

IN CASE OF DIFFICULTY

Begin your search for any trouble that occurs after assembly by carefully following the steps listed below in the "Visual Tests." After the "Visual Tests" are completed, refer to the "Troubleshooting Chart."

NOTE: Refer to the "Circuit Board X-Ray Views" on Page 97 for the physical location of parts on the circuit boards.

VISUAL TESTS

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

2. About 90% of the kits that are returned to the Heath Company for repair do not function properly due to poor connections and soldering. Therefore, many troubles can be eliminated by reheating all connections to make sure they are soldered as described in the "Soldering" section of the "Kit Builders Guide." Be sure there are no solder bridges.

3. Check to be sure that all transistors and diodes are in their proper locations. Make sure each lead is connected to the proper point.

4. Check to be sure that each IC is properly installed in its socket, and the pins are not bent out or under the IC. Also be sure the IC's are installed in their correct positions.

5. Check the values of the parts. Be sure in each step that the proper part has been wired into the circuit, as shown in the Pictorial Diagrams. It would be easy, for example, to install a 510 Ω (green-brown-brown) resistor where a 150 Ω (brown-green-brown) resistor should have been installed.

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

7. Look between the circuit board and the chassis to be sure all leads have been cut off.

8. A review of the "Circuit Description" may also help you to determine where the trouble is.

If the trouble is still not located after the "Visual Tests" are completed, and a voltmeter is available, check voltage readings against those shown on the "Schematic Diagram" (fold-out from Page 103). Read the "Precautions for Troubleshooting" below before taking any measurements. NOTE: All voltage readings are taken with a high-impedance voltmeter. Voltages may vary as much as ±20%.

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

PRECAUTIONS FOR TROUBLESHOOTING

1. Be cautious when testing IC and transistor circuits. Although they have almost unlimited life when used properly, they are much more vulnerable to damage from excessive voltage or current than tubes.

2. Be sure you do not short any terminals to ground when making voltage measurements. If the probe should slip, for example, and short across components or voltage sources, it is very likely to cause damage to one or more IC's, transistors, or diodes.

3. High voltages are exposed in the Curve Tracer when the line cord is plugged into an AC outlet. Refer to the "Chassis Photographs" on Page 100 for the location of these high voltage areas.

TROUBLESHOOTING CHART

The following chart lists the "Condition" and the "Possible Cause" for a number of malfunctions. If a particular part or parts are mentioned (transistor Q201, for example, or resistor (R104) as a possible cause, check these parts to see if they are incorrectly installed or wired. Also check to see if an improper part was installed at that location. It is also possible on rare occasions for a part to be faulty.

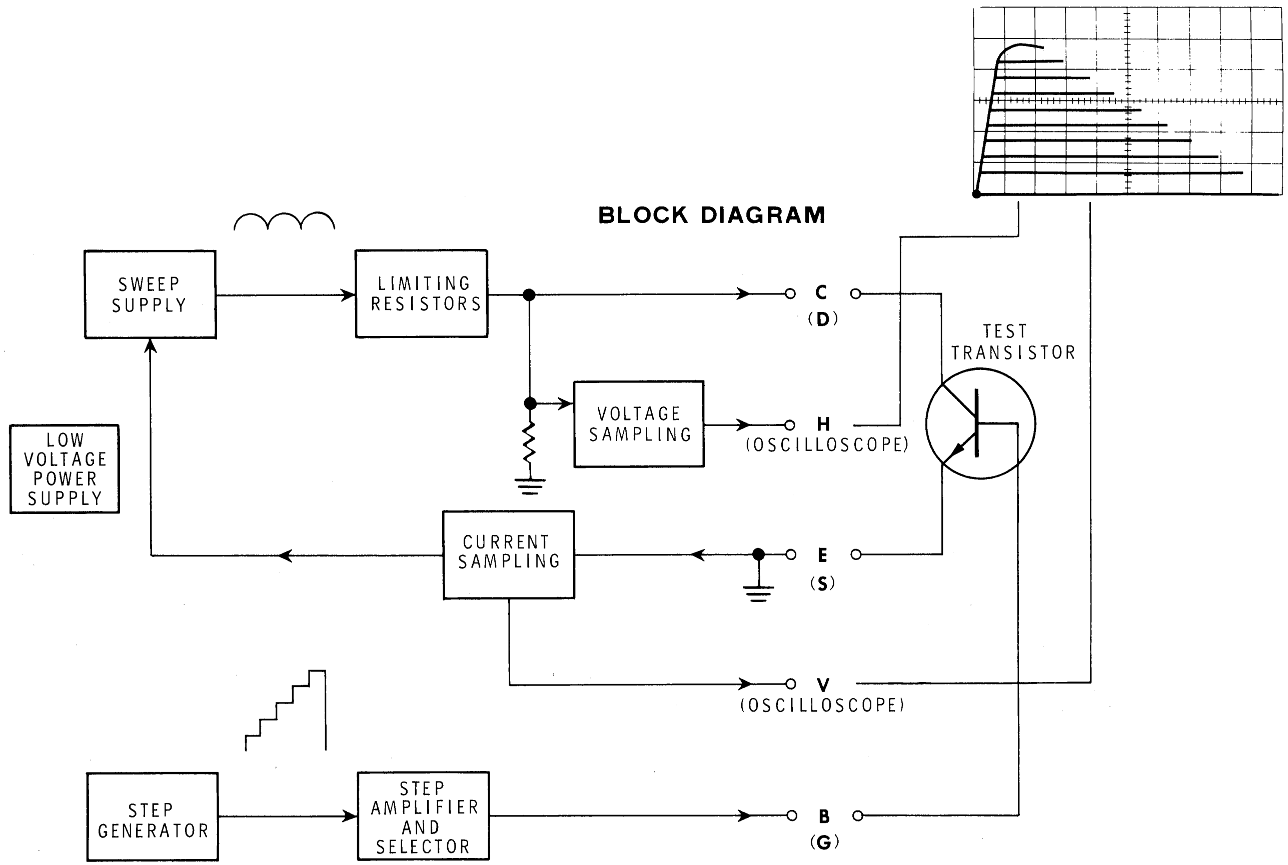
CONDITION	POSSIBLE CAUSE
No horizontal or vertical deflection.	1. Sweep Range and Polarity switches not firmly in their proper position. 2. Transistors Q1, Q2, Q3, Q4. 3. Switch S1.
Dot on oscilloscope deflects off scale when Signal Tracer is turned on.	1. IC1, IC2. 2. ±15.5 volt power supply. 3. Oscilloscope sensitivity too high.
In CAL position, diagonal dots not obtained.	1. Steps/Family control at too far counterclockwise. 2. Oscilloscope not set to proper sensitivity. 3. IC3, IC6. 4. Q5, Q6, or Q13, Q14. 5. ±15.5 volt power supply.
No horizontal deflection.	1. Check oscilloscope's horizontal control settings. 2. Check for proper range of Horizontal Sensitivity switch (on Curve Tracer). 3. Check value of limiting resistor (may be too high). 4. Horizontal Sensitivity switch. 5. IC1 (interchange with IC2).

CONDITION	POSSIBLE CAUSE
No vertical deflection.	1. Check oscilloscope's vertical control settings. 2. Check for proper range of Vertical Sensitivity switch (on Curve Tracer). 3. Check for proper position of Step Range switch. 4. Check Steps/Family control (turn clockwise). 5. Check value of limiting resistor (may be too high). 6. Vertical Sensitivity switch. 7. IC2 (substitute with IC1). 8. Output fuse of step amplifier. 9. Left-right socket selector switch.
Some base steps missing.	1. Check setting of Steps/Family control 2. Base fuse. 3. Q11, Q12.
Display curves have excessive looping.	1. Oscilloscope is on AC input. 2. Device under test is too hot. 3. May be normal if tested "in circuit."
Pilot lamp does not light.	1. Line Fuse. 2. No AC power to Curve Tracer. 3. Pilot lamp.

SPECIFICATIONS

Sweep Voltage Ranges	0-40 volts at 1 ampere maximum. 0-200 volts at 200 milliamperes maximum.
Sweep Voltage Sampling	.1, .2, .5, 1, 2, 5, 10, 20, and 50 volts/division ±3%.
Sweep Current Sampling	.5, 1, 2, 5, 10, 20, 50, 100, and 200 milliamperes/division ±3%.
Sweep Dissipation Resistors	0, 10, 50, 100, 500, 1000, 5000, 10 k, 50 k, 100 k, 500 k, 1 M ±10%.
Step Currents Available	.002, .005, .01, .02, .05, .1, .2, .5, 1, 2, 5, and 10 milliamperes/step, ±3%, ±250 nanoamperes offset current maximum.
Step Voltages Available	.05, .1, .2, .5, and 1 volt/step, ±3%, ±5mV maximum offset voltage.
Polarity Available	PNP and NPN (P Channel – N Channel).
Calibration Source	9 volts ±2% in 1 volt steps.
Oscilloscope Requirements	Vertical sensitivity of 1 volt/cm. Horizontal sensitivity of 0.5 volt/cm. Bandwidth to 20 kHz or greater. (DC-coupled oscilloscope is recommended.)

(Continued on next page)



BLOCK DIAGRAM

Operating Temperature Range	10°C to 40°C. Temperature variation, referenced at 25°C, will have a maximum effect of ±1% on all other specifications.
Line Voltage	110 to 130 or 220 to 260 VAC.
Dimensions	11-1/4" W x 10" D x 4-1/2" H.
Weight	Approximately 8-1/2 lbs.

The Heath Company reserves the right to discontinue products and to change specifications at any time without incurring any obligation to incorporate new features in products previously sold.

CIRCUIT DESCRIPTION

Refer to the Schematic Diagram (fold-out from Page 103) and the Block Diagram (fold-out from Page 92) while you read this "Circuit Description."

The Block Diagram shows the basic parts of the Curve Tracer. The sweep supply applies pulsating DC through the current limiting resistors to the collector (or drain) of the transistor under test, and also through the voltage sampling circuitry to the horizontal input of an oscilloscope. The current that flows through the transistor under test is sampled and applied to the vertical input of an oscilloscope. The base (or gate) is stepped with constant current (or voltage) from the step generator and amplifier. The effect of this staircase waveform on the output parameters of the device under test is monitored by the oscilloscope.

SWEEP SUPPLY

The sweep supply produces a floating, pulsating DC (0-40 volts at 1 ampere, or 0-200 volts at 200 milliamperes) that is both current limited and voltage adjustable.

Resistor R1 is a current limiting resistor for lamp PL1, and resistors R2 and R3 provide loading for the high voltage winding of transformer T1. Diodes D1, D2, D3, and D4 rectify the AC and produce two positive voltages. Either voltage can be selected by the Sweep Range switch, SW2. Capacitors C2 and C3 are noise filters.

Due to circuit capacitance that affects the positive supply, at times "looping" can be seen on the oscilloscope screen. This looping is caused by stray capacitance coupled to ground through the sweep circuitry and wiring, and the secondary sweep windings of transformer T1. To minimize this looping, stray capacitance is injected into the circuit from a supply of the opposite polarity (D15, D16, and R4) through loop control R5 and capacitor C1.

The voltage selected by the Sweep Range switch is applied to Sweep Voltage control R6 and the collectors of transistors Q1, Q2, and Q3. The Sweep Voltage control sets the amount of voltage that is applied to the base of these transistors and, therefore, controls the amplitude of the output signal on the emitter of Q1. The other two sections of switch SW2 switch select proper load resistors (R12 and R13) and current sensing resistors (R8 and R9). As the current through the current sensing resistors reaches its rated limit, the voltage across these resistors turns on transistor Q4, which places a less positive voltage at the base of transistor Q3. This turns off Q3, Q2, and Q1 to limit the current.

The Polarity switch selects either a positive or negative voltage, depending on the type of device being tested.

LIMITING RESISTORS

Limiting Resistor switch SW4 selects the proper resistance (zero ohms through 1 megohm) to protect the device being tested from excessive current.

VOLTAGE SAMPLING

Resistors R26 through R33 form a divider network to monitor the voltage at C (D). This voltage from the divider is applied to IC1, amplified by five, and applied to the horizontal output to an oscilloscope.

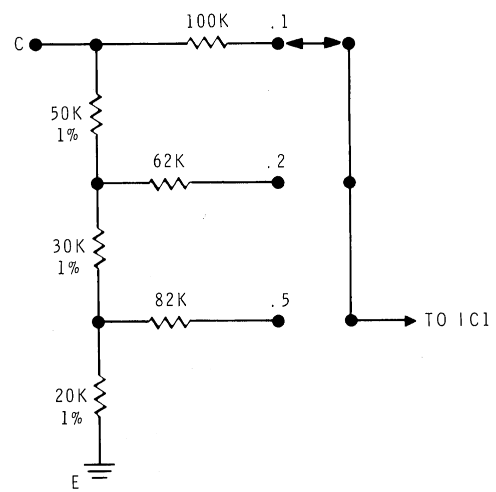


Figure 4-1

Figure 4-1 is a partial schematic showing the divider network in the .1, .2, and .5 V/div. positions. The 100 kΩ, 62 kΩ, and 82 kΩ resistors provide input protection and equalization of input impedance for minimum DC shift between ranges.

IC1 is used as a noninverting amplifier. The output of the IC is then five times greater than the input because of the voltage divider, R34 and R35.

CURRENT SAMPLING

The current that flows through the device under test also flows through the selected sensing resistance and back to the power supply. The voltage drop across the sensing resistors is inverted and amplified by IC2, and applied to the "V" (vertical) output connector to an oscilloscope. Diodes D9 through D12 protect the sensing resistors from excessive voltage. IC2 has a gain of 10 because of the 10:1 ratio between resistors R104 and R106.

LOW VOLTAGE POWER SUPPLY

For the positive supply, the AC from the low voltage winding of the transformer is rectified by diodes D5 and D6. Capacitor C5 then filters the pulsating DC. Resistor R36 limits the current to the zener diode, D15, which is again filtered by capacitor C6. The emitter of transistor Q13 follows the constant voltage that is at its base. Resistor R37 drops the 15 volts to 5 volts and capacitor C7 filters this voltage.

The negative supply is similar to the positive supply. However, instead of using a simple current limiting resistor to protect the zener diode, a constant current source is used; R38, R39, Q15, and Q16. This insures constant current through the zener diode in spite of changes in line voltage. This zener is the precision voltage reference for the step generator switching transistors.

STEP GENERATOR

The step generator produces a precision staircase waveform. Each time the sweep supply goes to zero volts, the step generator switches to the next higher step. The available steps are zero through nine.

Each time the line voltage passes through zero, transistor Q5 or Q6 generates a sync pulse (120 pulses per second). These pulses are applied to decade counter IC6 which counts these pulses and converts them to BCD (bindary coded decimal) on four output lines (A, B, C, and D). These pulses are capacitor coupled to the four switching transistors; Q7, Q8, Q9, and Q10. As these transistors turn on and off, they switch precision amounts of current into the minus (—) summing junction of IC3. See Figure 4-2. IC3 changes these current steps into voltage steps.

STEP	OUTPUT OF IC6				TRANSISTORS					
	A	B	C	D	Q7	Q9	Q10	Q8	UNITS OF CURRENT	TOTAL UNITS OF CURRENT
0	0	0	0	0	OFF	OFF	OFF	OFF	0 + 0 + 0 + 0	0
1	1	0	0	0	ON	"	"	"	1 + 0 + 0 + 0	1
2	0	1	0	0	OFF	ON	"	"	0 + 2 + 0 + 0	2
3	1	1	0	0	ON	ON	"	"	1 + 2 + 0 + 0	3
4	0	0	1	0	OFF	OFF	ON	"	0 + 0 + 4 + 0	4
5	1	0	1	0	ON	"	ON	"	1 + 0 + 4 + 0	5
6	0	1	1	0	OFF	ON	ON	"	0 + 2 + 4 + 0	6
7	1	1	1	0	ON	ON	ON	"	1 + 2 + 4 + 0	7
8	0	0	0	1	OFF	OFF	OFF	ON	0 + 0 + 0 + 8	8
9	1	0	0	1	ON	"	"	ON	1 + 0 + 0 + 8	9

NOTE: Q7 switches 1 unit of current, Q9 switches 2 units of current, Q10 switches 4 units of current, and Q8 switches 8 units of current.

Figure 4-2

The decade counter, IC6, automatically resets itself after the ninth step. To reset sooner, a sampling of the staircase is taken from resistors R48 through R52, connected to the Steps/Family control, and then through transistor Q17 to Q18. Normally, Q17 and Q18 are turned on and hold the reset line of IC6 low. However, by adjusting the Steps/Family control, the base of Q17 becomes less positive and transistors Q17 and Q18 turn off and reset IC6 to the 0 step, which turns Q17 and Q18 back on. Thus the Step-Family control will reset the counter after any desired step.

The gain of IC3 is switchable to produce gains of .05, .1, .2, .5, and 1. With the Cal/Norm switch in the Cal position, the 1 volt/step waveform is coupled to the "V" and "H" outputs for oscilloscope calibration. In normal operation, the waveform is applied to SW3 and then to SW9 where the waveform may be switched into the plus (+) or minus (-) input of IC5.

IC5 supplies a voltage gain of +1 or -1, depending on the positions of switches SW3 and S9. Transistors Q11 and Q12 provide current gain and apply the signal through the selected resistor (R86 through R94) to the base of the transistor under test.

For constant current steps, the output from transistors Q11 and Q12 is coupled through the feedback resistor, R83, to IC5 to produce a gain of one. The output from transistors Q11 and Q12 is also coupled through the selected resistor (R86 through R94) to the base of the transistor under test. IC4, a voltage follower, monitors the offset voltage of the test transistor and adds this offset voltage to the voltage at IC5. Because IC5, and Q11 and Q12 have a gain of one, the offset voltage appears on both sides of the resistor selected by the Step Range switch, and the current per step is solely a function of the precision resistor selected and the voltage per step selected.

IC4 has a very high input impedance (many megohms) and therefore does not load the circuit. Resistor R95 protects IC4 from overload, and diodes D13 and D14 clamp the output voltage to less than ±17 volts in case a device under test fails and the sweep voltage at "C" shorts to "B". Also, fuse F1 will open if an excessive amount of current flows through the diodes.

When voltage steps are required, switch SW9 switches feedback resistor R83 to the base of the transistor under test, grounds IC4 so that no error signal is produced, and inverts the waveform from what it was in the current/step position. Resistor R91 is switched in for all five of the volt/step positions to protect the circuitry in case there is a base to ground short circuit. The switching of the feedback resistor at IC3 determines whether the steps are .05, .1, .2, .5, or 1 volt per step.

CIRCUIT BOARD X-RAY VIEWS

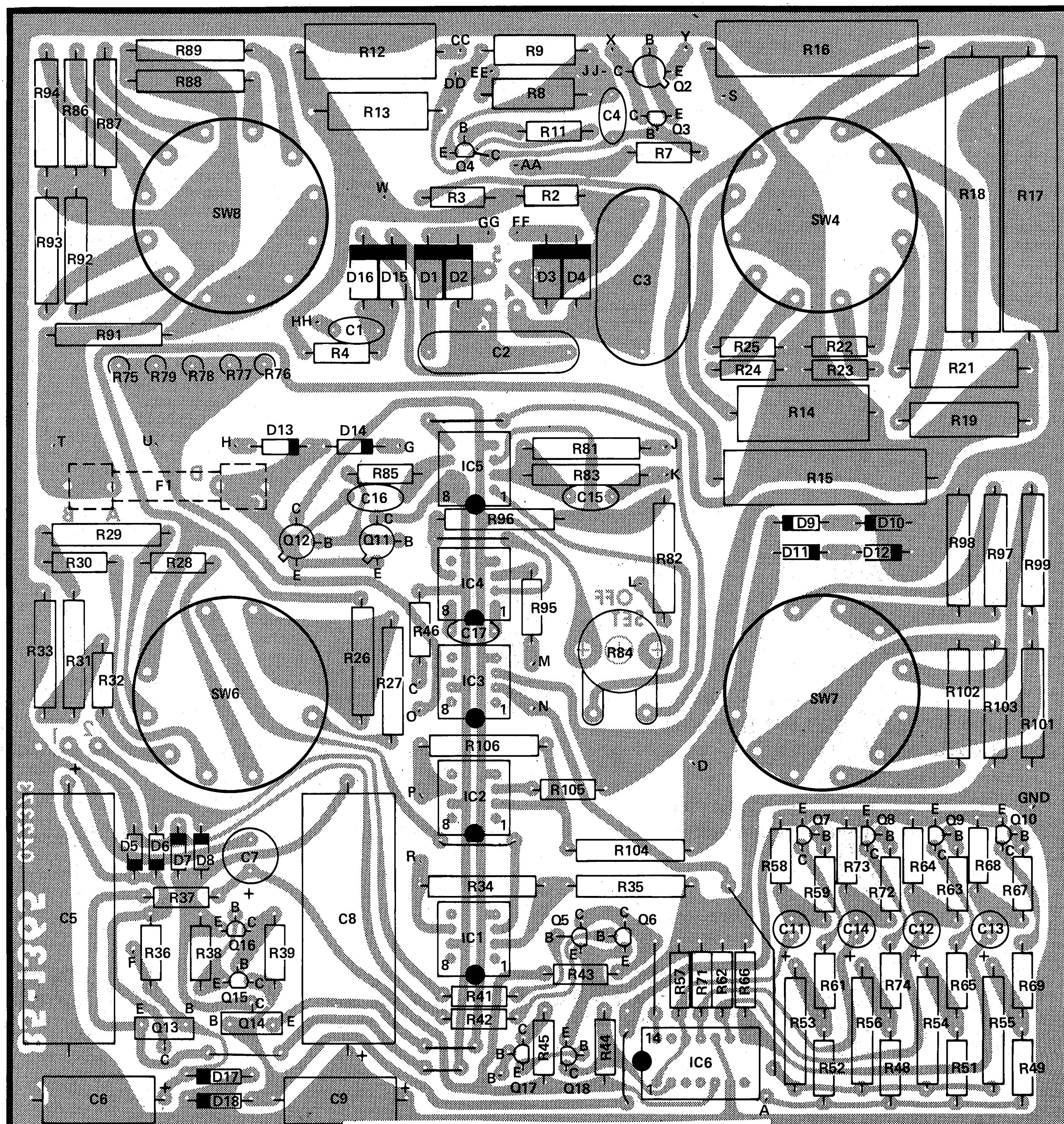
NOTE: To find the PART NUMBER of a component for the purpose of ordering a replacement:

A. Find the circuit component number (R15, C3, etc.) on the X-Ray View or "Chassis Photograph."

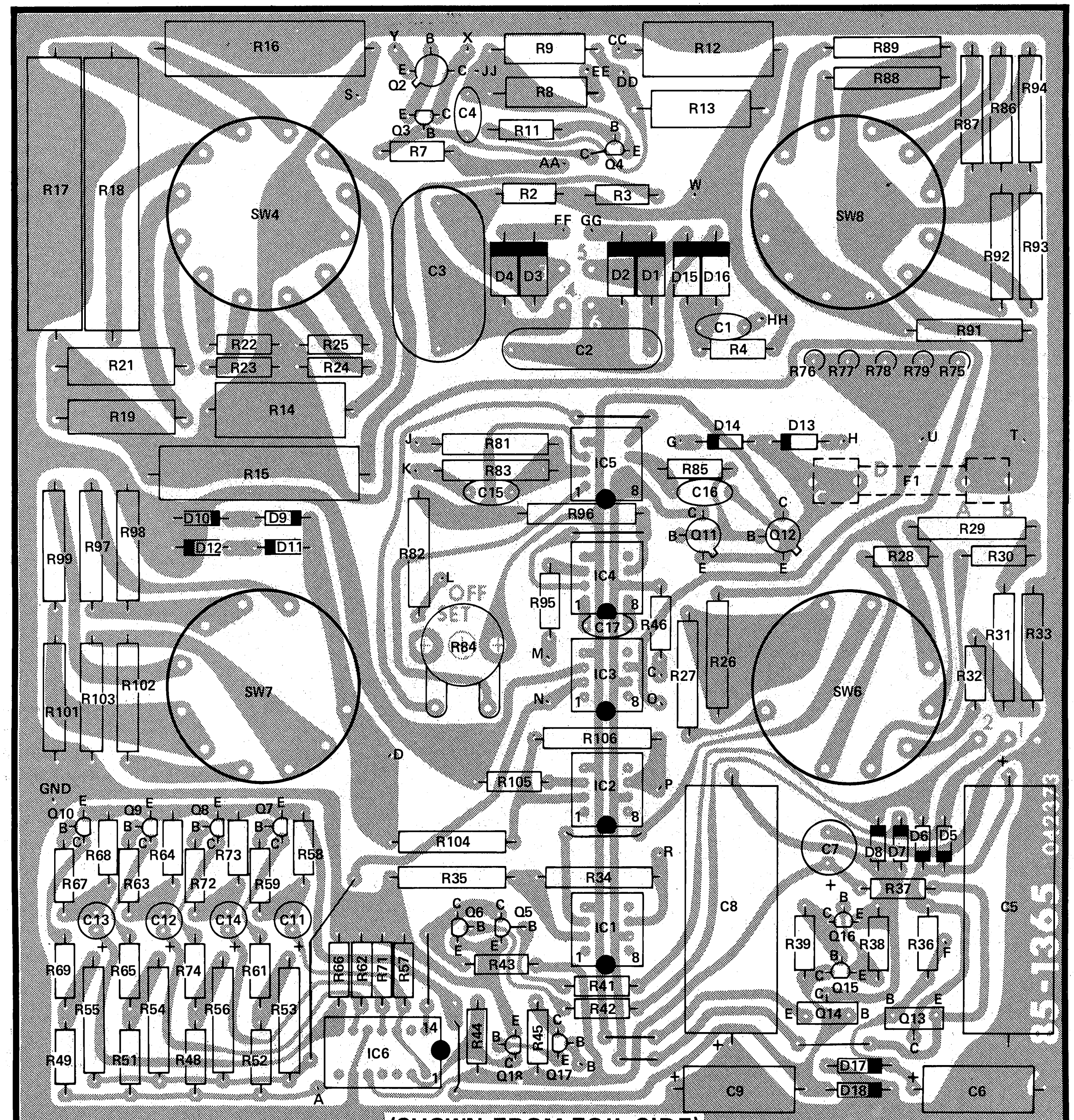
B. Locate this same number in the "Circuit Component Number" column of the "Parts List."

C. Adjacent to the circuit component number, you will find the PART NUMBER and DESCRIPTION which must be supplied when you order a replacement part.

HEATHKIT®



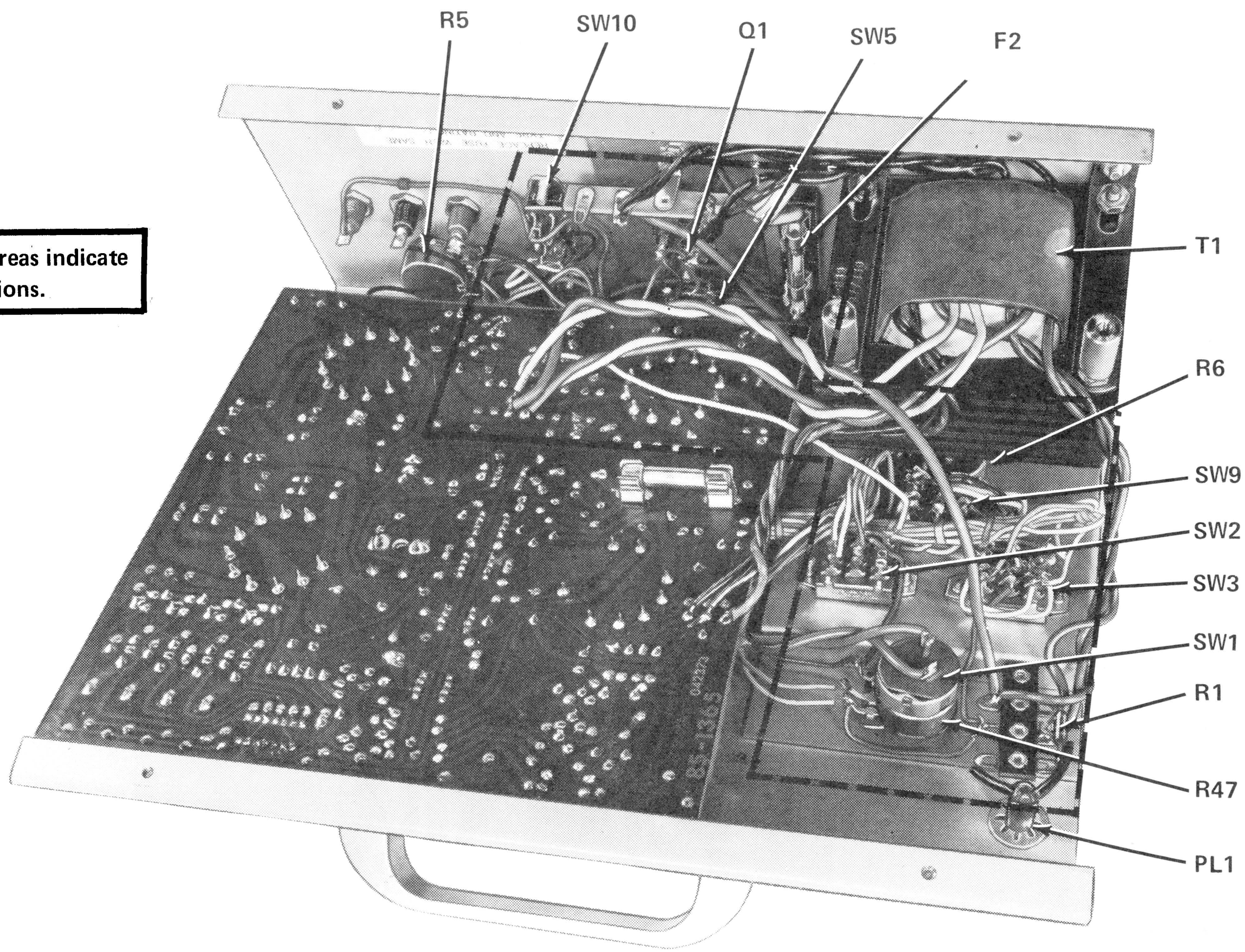
(SHOWN FROM COMPONENT SIDE)



(SHOWN FROM FOIL SIDE)

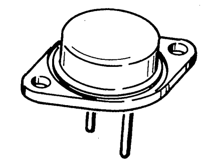
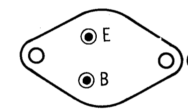
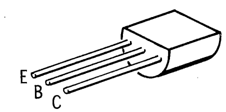
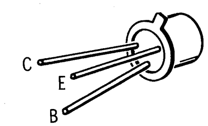
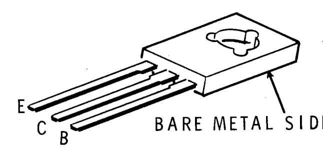
CHASSIS PHOTOGRAPHS

WARNING: Boxed-in areas indicate hazardous voltage locations.

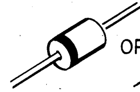
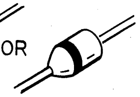
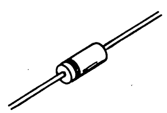
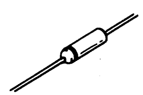


IDENTIFICATION CHARTS

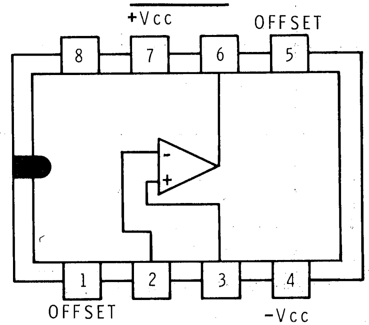
TRANSISTORS

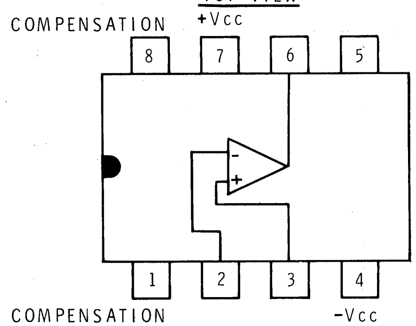
COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED BY	IDENTIFICATION
Q1	417-239	TA7420	 
Q3, Q4	417-294	MPSA42	
Q5, Q6, Q7, Q8 Q9, Q10, Q15 Q16, Q17, Q18	417-801	MPSA20	
Q2	417-232	FT123	
Q11	417-269	SGC5282	
Q12	417-270	SGC5283	
Q13	417-818	MJE181	
Q14	417-819	MJE171	

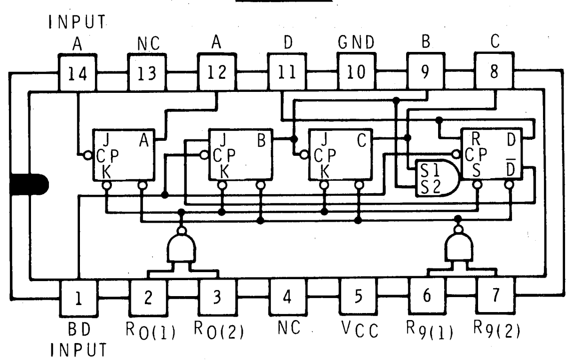
DIODES

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED BY	IDENTIFICATION
D1, D2, D3, D4, D15, D16	57-27	1N2071	 OR 
D5, D6, D7, D8, D9, D10, D11, D12, D13, D14	57-65	1N4002	
D17, D18	56-36	VR-16.1G	

INTEGRATED CIRCUITS

<table>
<tr><th>COMPONENT NUMBER</th><th>HEATH PART NUMBER</th><th>MAY BE REPLACED BY</th><th>IDENTIFICATION</th></tr>
<tr><td>IC1, IC2
IC3, IC5</td><td>442-22</td><td>N5741V</td><td>TOP VIEW


OPERATIONAL AMPLIFIER</td></tr>
<tr><td>IC4</td><td>442-39</td><td>LM301AN</td><td>TOP VIEW


OPERATIONAL AMPLIFIER</td></tr>
<tr><td>IC6</td><td>443-7</td><td>SN7490N</td><td>TOP VIEW


HIGH SPEED BCD DECADE COUNTER</td></tr>
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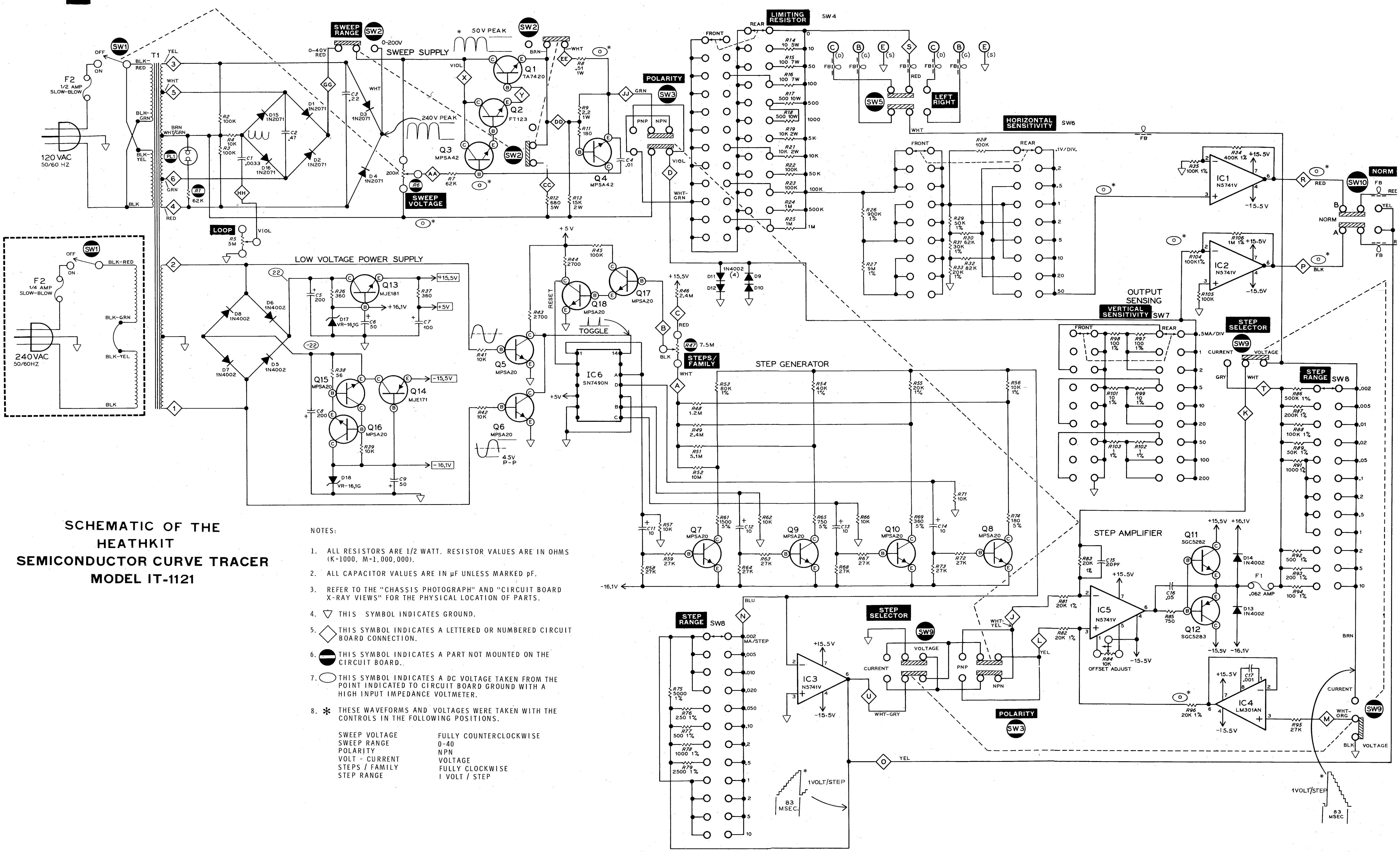


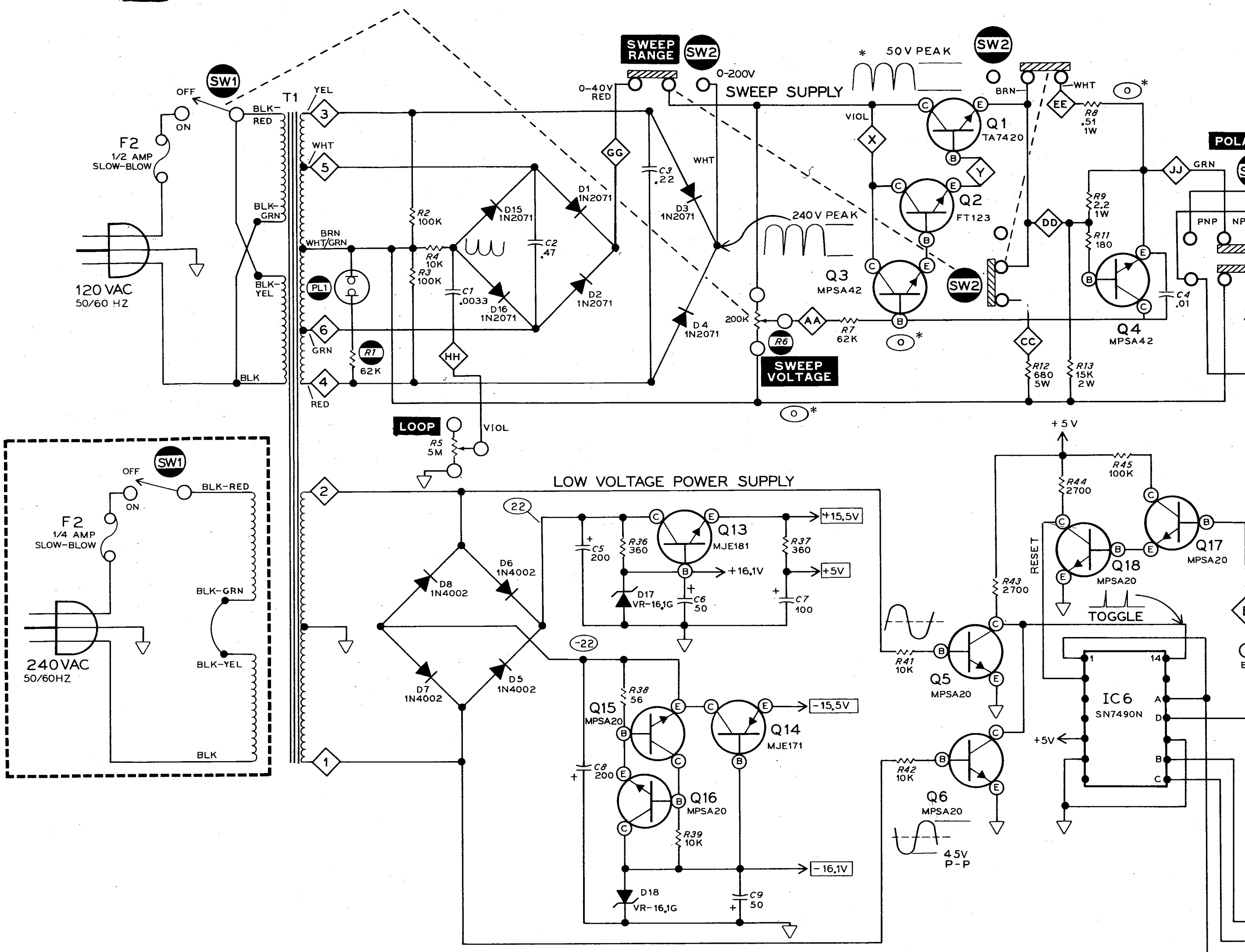
SCHEMATIC OF THE HEATHKIT SEMICONDUCTOR CURVE TRACER MODEL IT-1121

NOTES:

1. ALL RESISTORS ARE 1/2 WATT. RESISTOR VALUES ARE IN OHMS (K=1000, M=1,000,000).
2. ALL CAPACITOR VALUES ARE IN µF UNLESS MARKED pF.
3. REFER TO THE "CHASSIS PHOTOGRAPH" AND "CIRCUIT BOARD X-RAY VIEWS" FOR THE PHYSICAL LOCATION OF PARTS.
4. ▽ THIS SYMBOL INDICATES GROUND.
5. ◇ THIS SYMBOL INDICATES A LETTERED OR NUMBERED CIRCUIT BOARD CONNECTION.
6. THIS SYMBOL INDICATES A PART NOT MOUNTED ON THE CIRCUIT BOARD.
7. THIS SYMBOL INDICATES A DC VOLTAGE TAKEN FROM THE POINT INDICATED TO CIRCUIT BOARD GROUND WITH A HIGH INPUT IMPEDANCE VOLTMETER.
8. * THESE WAVEFORMS AND VOLTAGES WERE TAKEN WITH THE CONTROLS IN THE FOLLOWING POSITIONS.

SWEEP VOLTAGE	FULLY COUNTERCLOCKWISE
SWEEP RANGE	0-40
POLARITY	NPN
VOLT - CURRENT	VOLTAGE
STEPS / FAMILY	FULLY CLOCKWISE
STEP RANGE	1 VOLT / STEP

PE1ABR



SCHEMATIC OF THE HEATHKIT SEMICONDUCTOR CURVE TRACER MODEL IT-1121

NOTES:

1. ALL RESISTORS ARE 1/2 WATT. RESISTOR VALUES ARE IN OHMS (K=1000, M=1,000,000).
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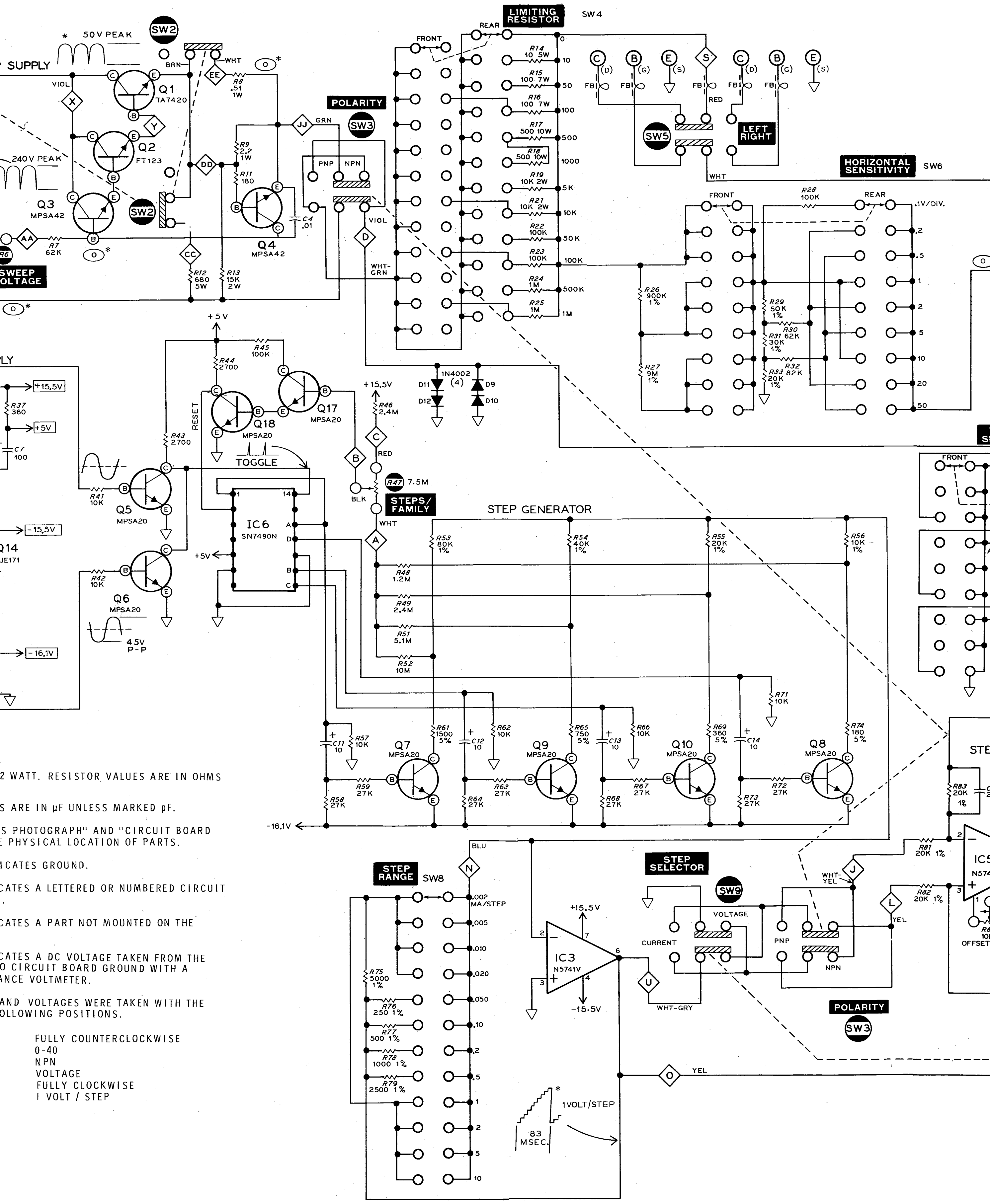
SWEEP VOLTAGE	FULLY COUNTERCLOCKWISE
SWEEP RANGE	0-40
POLARITY	NPN
VOLT - CURRENT	VOLTAGE
STEPS / FAMILY	FULLY CLOCKWISE
STEP RANGE	I VOLT / STEP



2 WATT. RESISTOR VALUES ARE IN OHMS

S ARE IN µF UNLESS MARKED pF.

S PHOTOGRAPH" AND "CIRCUIT BOARD
E PHYSICAL LOCATION OF PARTS.

ICATES GROUND.

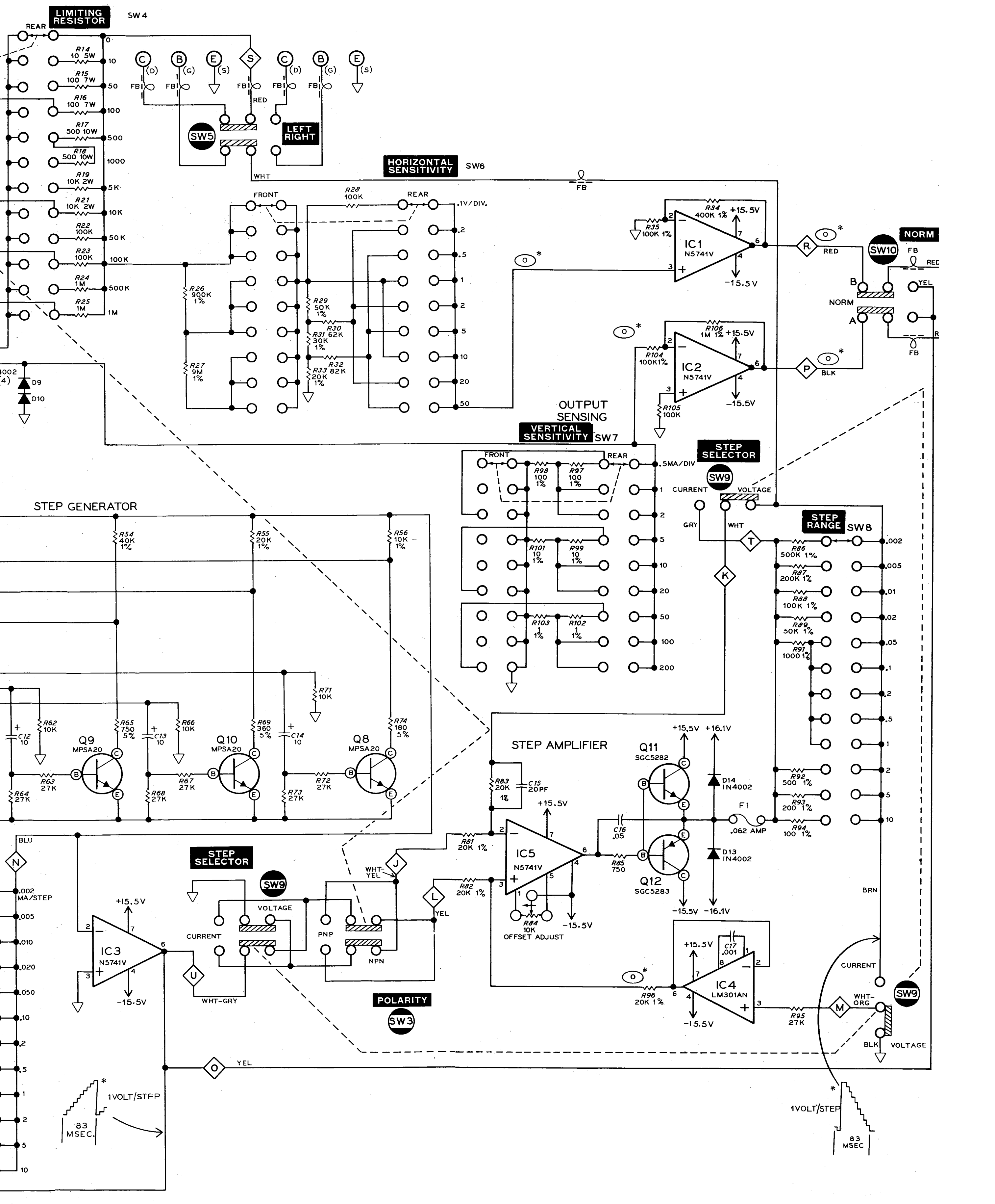
CATES A LETTERED OR NUMBERED CIRCUIT
.

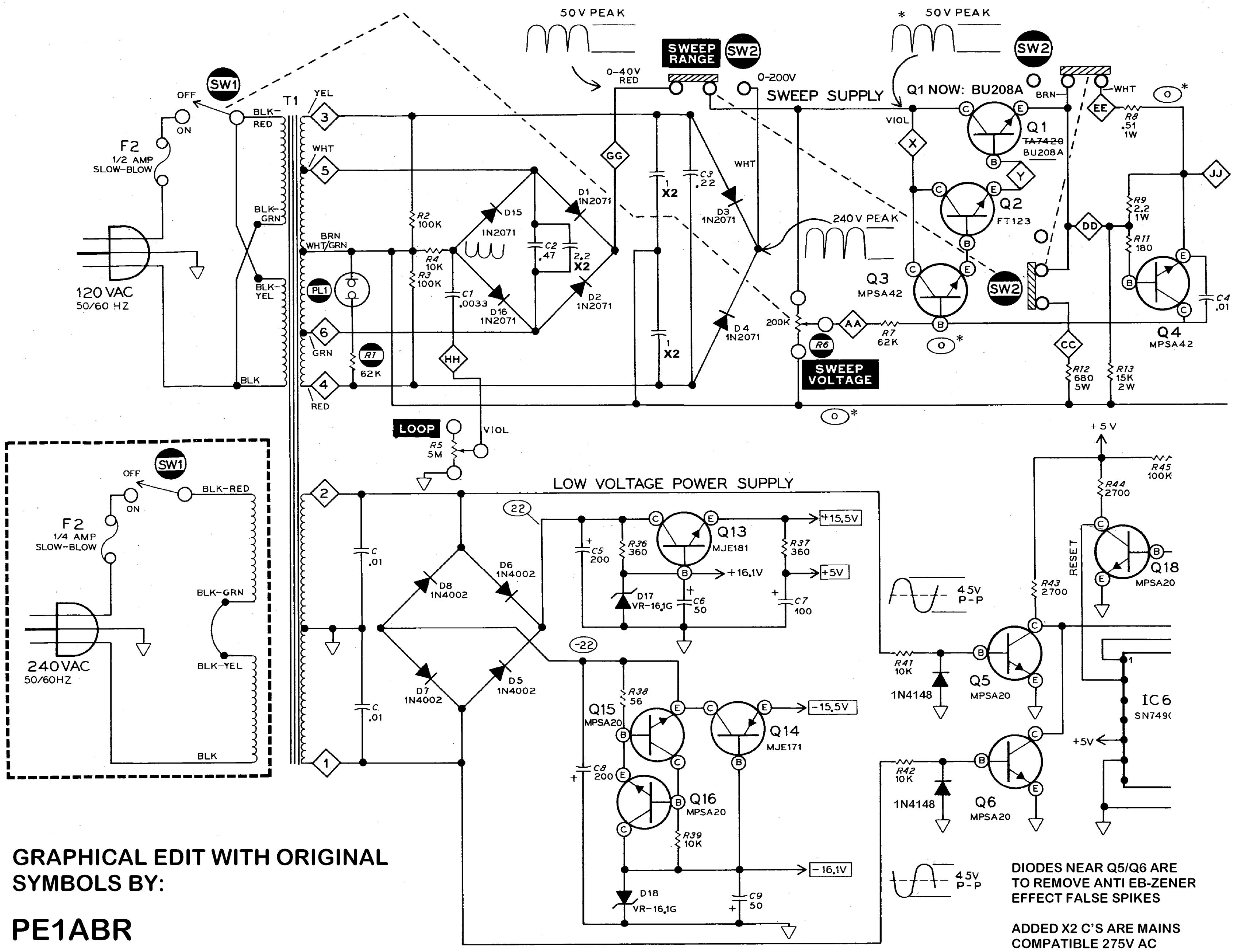
CATES A PART NOT MOUNTED ON THE

CATES A DC VOLTAGE TAKEN FROM THE
O CIRCUIT BOARD GROUND WITH A
ANCE VOLTMETER.

AND VOLTAGES WERE TAKEN WITH THE
OLLOWING POSITIONS.

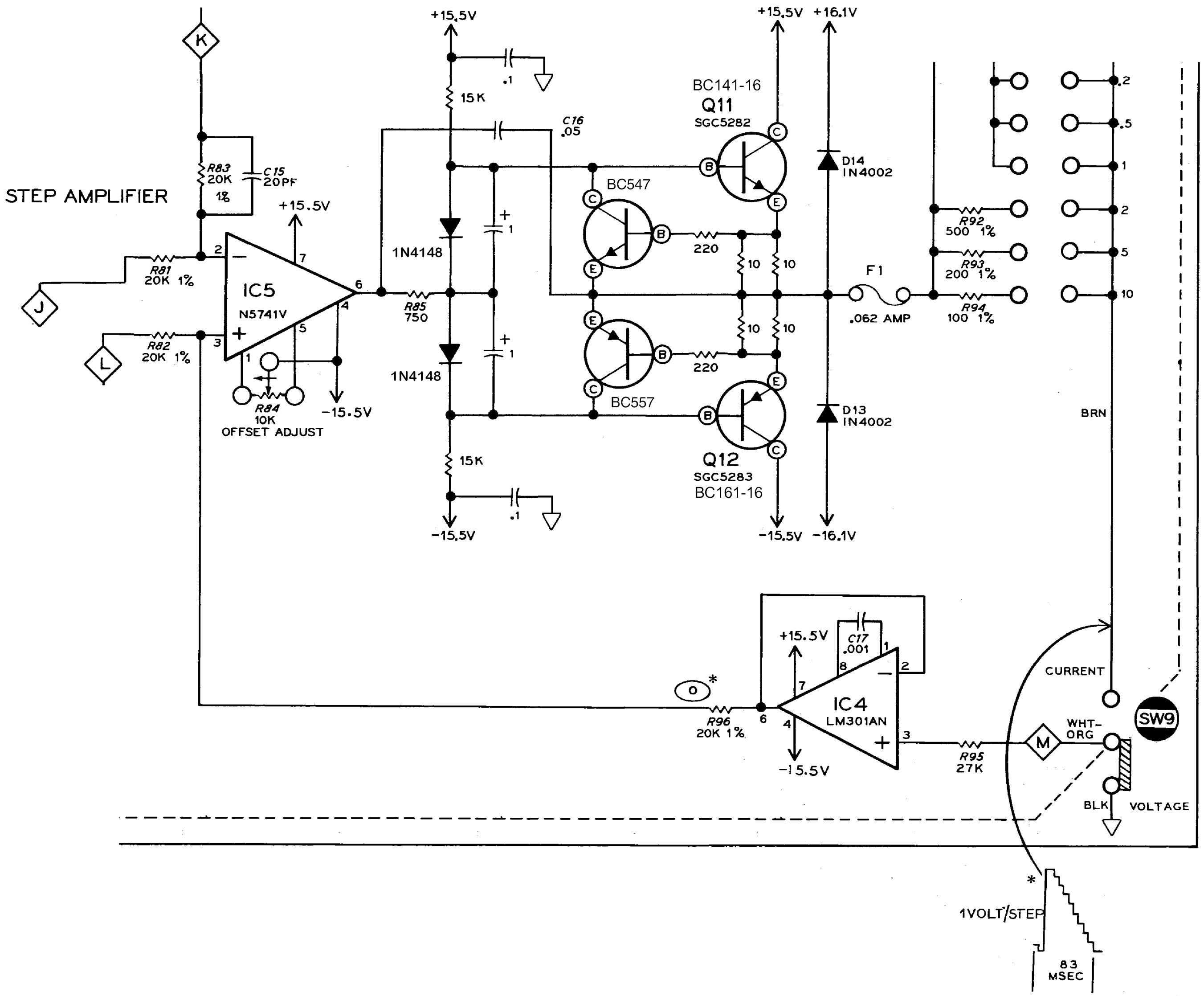
FULLY COUNTERCLOCKWISE
0-40
NPN
VOLTAGE
FULLY CLOCKWISE
I VOLT / STEP


LIMITING RESISTOR
SW4
REAR
R14 10 5W
R15 100 7W
R16 100 7W
R17 500 10W
R18 500 10W
R19 10K 2W
R21 10K 2W
R22 100K
R23 100K
R24 1M
R25 1M
SW5
LEFT RIGHT
RED
WHT
HORIZONTAL SENSITIVITY
SW6
FRONT
REAR
R28 100K
.1V/DIV.
R26 900K 1%
R27 9M 1%
R29 50K 1%
R30
R31 62K 30K 1%
R32
R33 82K 20K 1%
D9
D10
R34 400K 1%
R35 100K 1%
IC1 N5741V
+15.5V
-15.5V
RED
NORM
SW10
FB
YEL
R106 1M 1%
R104 100K1%
IC2 N5741V
R105 100K
BLK
OUTPUT SENSING
VERTICAL SENSITIVITY
SW7
.5MA/DIV
R98 100 1%
R97 100 1%
R101 10 1%
R99 10 1%
R103 1 1%
R102 1 1%
STEP SELECTOR
SW9
CURRENT
VOLTAGE
GRY
WHT
STEP RANGE
SW8
R86 500K 1%
R87 200K 1%
R88 100K 1%
R89 50K 1%
R91 1000 1%
R92 500 1%
R93 200 1%
R94 100 1%
STEP GENERATOR
R54 40K 1%
R55 20K 1%
R56 10K 1%
R71 10K
R62 10K
C12 10
Q9 MPSA20
R65 750 5%
C13 10
R66 10K
Q10 MPSA20
R69 360 5%
C14 10
Q8 MPSA20
R74 180 5%
R63 27K
R64 27K
R67 27K
R68 27K
R72 27K
R73 27K
STEP AMPLIFIER
R83 20K 1%
C15 20PF
Q11 SGC5282
Q12 SGC5283
D14 1N4002
D13 1N4002
F1 .062 AMP
C16 .05
R85 750
R81 20K 1%
R82 20K 1%
IC5 N5741V
R84 10K OFFSET ADJUST
+16.1V
-16.1V
BLU
.002 MA/STEP
STEP SELECTOR
SW9
IC3 N5741V
WHT-GRY
POLARITY
SW3
PNP
NPN
WHT-YEL
YEL
IC4 LM301AN
C17 .001
R96 20K 1%
R95 27K
WHT-ORG
CURRENT
BLK
VOLTAGE
BRN
1 VOLT/STEP
83 MSEC.



GRAPHICAL EDIT WITH ORIGINAL SYMBOLS BY:

PE1ABR



IN MY CASE THE TRANSISTORS Q11 AND Q12 WERE BLOWN FASTER THAN THE FUSE.

I MADE THE OUTPUT SHORT CIRCUIT PROOF. THE OUTPUT DRIVERS ARE WORKING MORE LINEAIR THAN BEFORE, TO AVOID OSCILLATION THERE ARE 100 nF C's ADDED OVER THE POSITIVE AND NEGATIVE SUPPLY NEAR IC5.

THE 63 mA FUSEHOLDER IS NOW IN A HOLE IN A CORNER ON THE BACK.

GRAPHICAL EDIT WITH ORIGINAL SYMBOLS BY:

PE1ABR

60 Hz SINGLE PULSE = HALVE SINE = 8.33 msec
50 Hz SINGLE PULSE = HALVE SINE = 10 msec

83 msec IS FOR 60 Hz, FOR 50 Hz THIS IS 100 msec