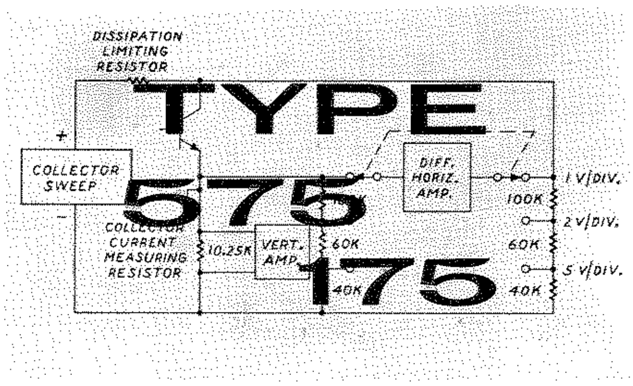
S/N - 11765

INSTRUCTION MANUAL



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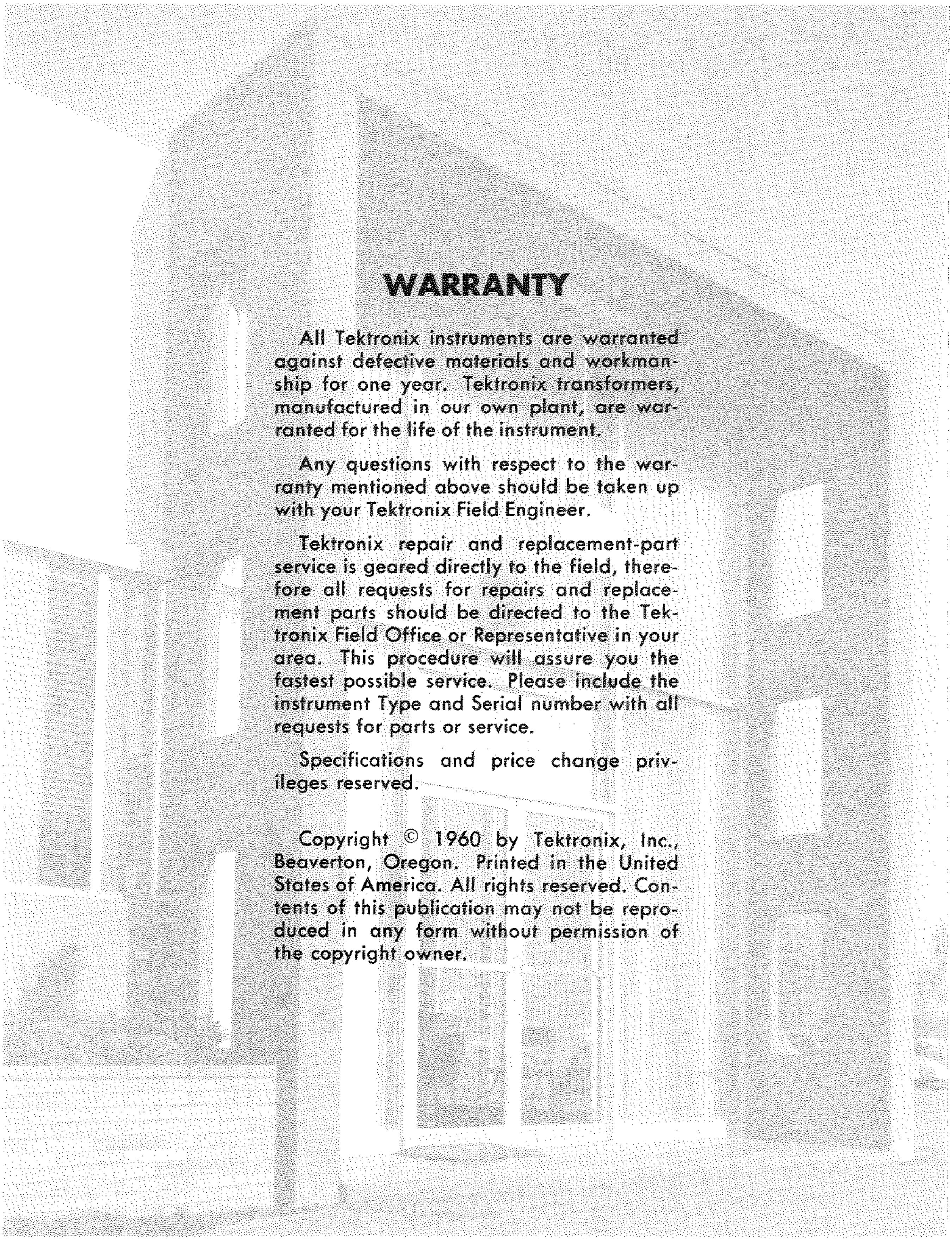

WARRANTY

All Tektronix instruments are warranted against defective materials and workmanship for one year. Tektronix transformers, manufactured in our own plant, are warranted for the life of the instrument.

Any questions with respect to the warranty mentioned above should be taken up with your Tektronix Field Engineer.

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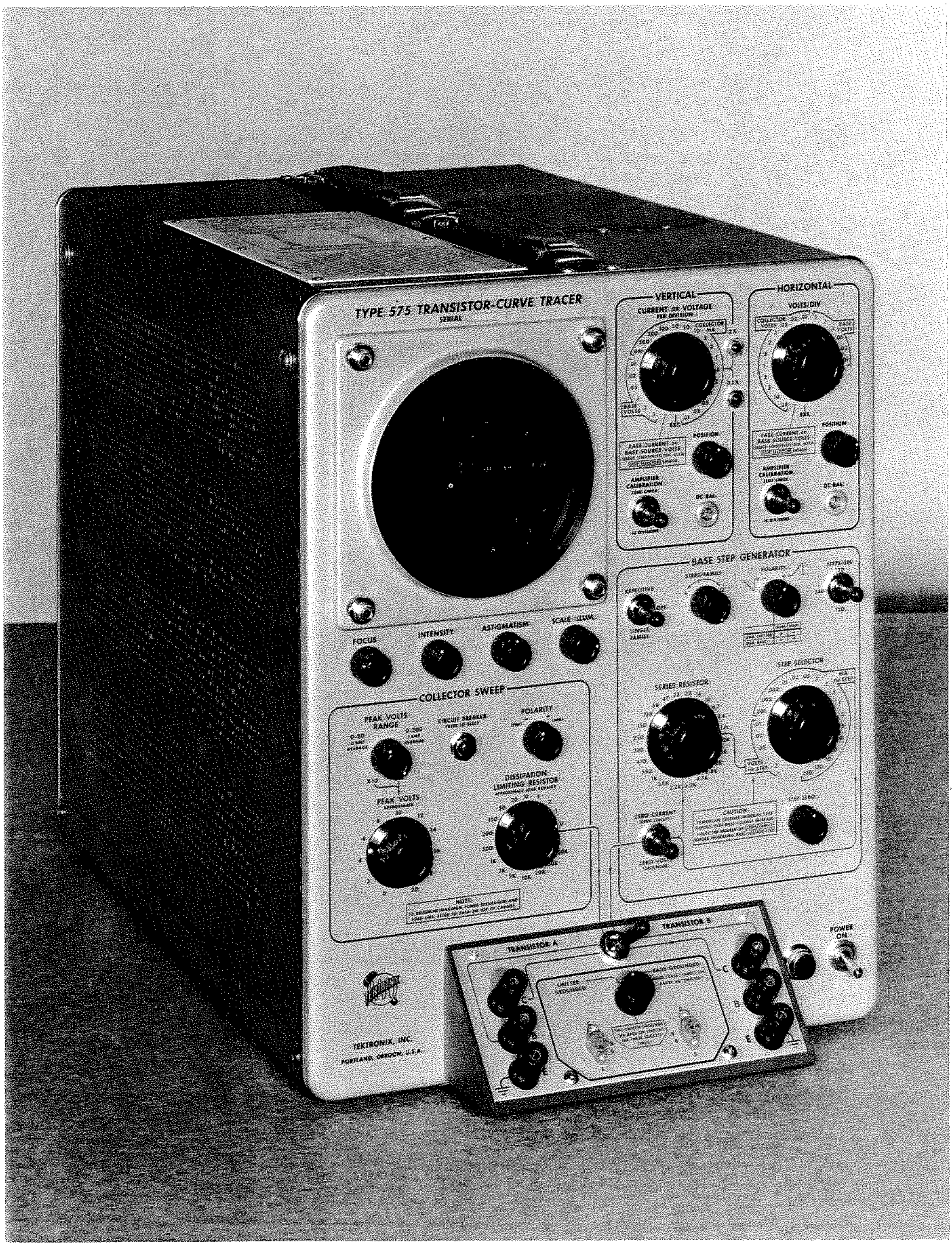
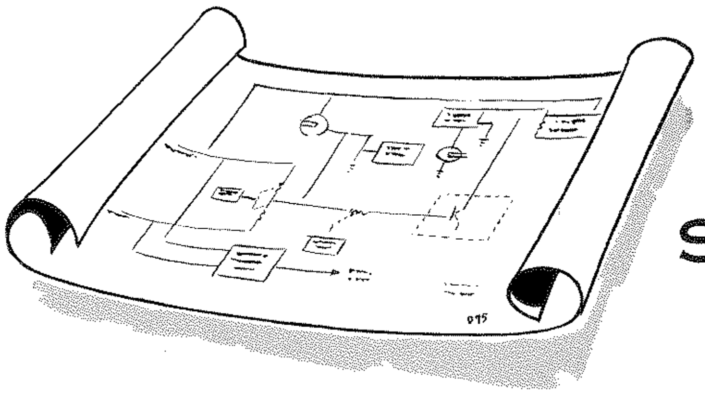

TYPE 575 TRANSISTOR-CURVE TRACER
SERIAL
VERTICAL
HORIZONTAL
POSITION
BASE STEP GENERATOR
FOCUS
INTENSITY
ASTIGMATISM
SCALE ILLUM.
COLLECTOR SWEEP
PEAK VOLTS RANGE
POLARITY
PEAK VOLTS
DISSIPATION LIMITING RESISTOR
SERIES RESISTOR
STEP SELECTOR
TRANSISTOR A
TRANSISTOR B
POWER ON
TEKTRONIX, INC.
PORTLAND, OREGON, U.S.A.



SECTION 1

SPECIFICATIONS

General Description

The Type 575 Transistor Curve Tracer displays the dynamic characteristic curves of both junction and point-contact transistors on the screen of a 5-inch cathode-ray tube. Several different transistor characteristic curves may be displayed, including the collector family in the common-base and common-emitter configuration. Regulated current or voltage steps are applied to the input of the transistor under test. A rectified sine wave of controllable amplitude is used for the collector sweep. The family of characteristic curves is accurately plotted as either a repetitive or single-family display.

Tolerances and accuracies as stated in Specifications section and the Recalibration Procedure of this manual apply only to Type 575 instruments above serial number 8030.

Operating Specifications

Collector Sweep

0-200 volts minimum peak with 1-ampere current curves.

0-20 volts minimum peak with 20-amperes current curves.

Base Step Generator

Generates 4-12 current- or voltage-steps per family of curves at 120- or 240-steps per second (2- or 4-times power-line frequency) for either repetitive or single-family displays.

17 current-step ranges from 1 μa/step to 200 ma/step $\pm 3\%$.

5 voltage-stetp ranges from .01 volt/step to .2 volt/step $\pm 3\%$, with output impedance adjustable from 1 ohm to 22 thousand ohms $\pm 10\%$, plus 0.1 ohm (wiring and switch contact resistance).

Vertical Display

Plots collector current from 0.01 ma/div. to 1000 ma./div. $\pm 3\%$ in 16 calibrated steps. Pushbuttons provide multiplying each current step by 2 or dividing by 10, increasing the current range from 0.001 ma./div. to 2000 ma./div. $\pm 3\%$.

Plots base voltage from .01 volt/div. to .5 volt/div. $\pm 3\%$ in 6 calibrated steps.

Plots base current or base source volts with sensitivity read from step selector switch $\pm 3\%$.

Horizontal Display

Plot collector voltage from .01 volt/div. to 20 volt/div. $\pm 3\%$ in 11 calibrated steps.

Plots base voltage from .01 volt/div. to .5 volt/idv. $\pm 3\%$ in 6 calibrated steps.

Plots base current or base source volts with sensitivity read from step collector switch $\pm 3\%$.

Other Features

Comparison switch permits rapid manual switching between two transistors for comparison tests.

Regulated power supplies and negative-feedback amplifiers assure the accuracy of the calibration and the stability of the display.

Cathode-ray tube is a Tektronix T52P. Accelerating potential is approximately 4 kv. P1 phosphor is supplied unless another phosphor is requested. P2, P7, or P11 phosphors are available at no extra charge.

Differential inputs to both vertical and horizontal amplifiers are available at the rear of the instrument, or at the Type 175 adaptor socket on instruments after S/N 3659. The sensitivity of each channel is .1 volt/div. and the bandpass is approximately 300 kc. The rejection of a common-mode signal is better than 100:1 with a peak-to-peak signal of 10 volts or less.

Mechanical Characteristics

Ventilation—Filtered- forced-air circulation maintains safe operating temperature.

Construction—Aluminum-alloy chassis and three-piece cabinet.

Finish—Photoetched, anodized front panel, with blue vinyl finished cabinet.

Dimensions—24" long, 13" wide, 16¾' 'high.

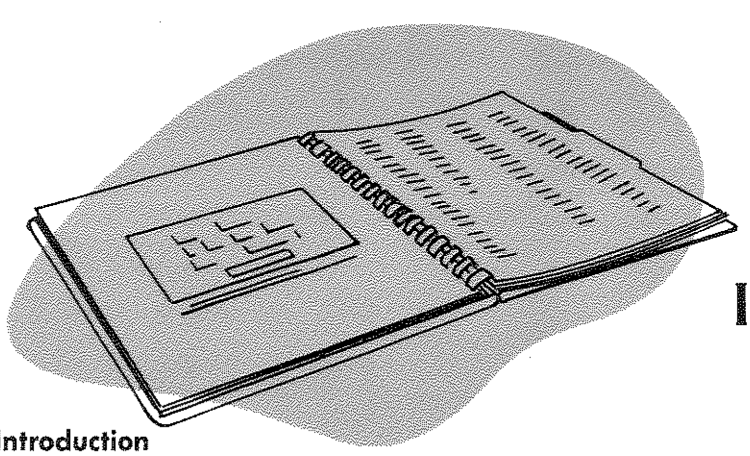
Weight—Approximately 70 lbs.

Power Requirements—105-125 or 210-250 volts, 50-60 cycles; 410 watts maximum at 117 v, 60 cycles, depending upon the type of transistor being tested, 200 watts standby.

Accessories

2—Transistor adapters, long, 013-010.
2—Transistor adapters, short, 013-012.
1—3 to 2-wire adapter, 103-013.
2—2N1381 Transistors, 151-039.
1—3-conductor power cord, 161-010.
1—Green filter, 378-514.
2—Instruction Manuals.

NOTES



SECTION 2

OPERATING INSTRUCTIONS

Introduction

The Type 575 is an extremely versatile instrument that can be used to make several tests on a transistor. Its full utility can only be realized, however, when the operator understands the function of each of the front-panel controls.

The front-panel layout, shown in Fig. 2-1, is quite simple and logical, and can be divided into five main blocks. These blocks contain the controls for the Vertical Amplifier, the Horizontal Amplifier, the Collector Sweep, the Base (or Emitter) Step Generator and Amplifier, and the Transistor Test Panel. The location of each section, as a functional part of the instrument, is shown in Fig. 2-2.

Notice the front panel is in two colors...red and blue. Those parts of the panel etched in red refer to the Collector voltages and currents, and those parts etched in blue refer to the Base voltages and currents. However, when testing a transistor in the common-base configuration, the emitter is stepped with voltage or current; in this case, the blue printing on the front panel refers to the Emitter rather than the Base.

Vertical Block

The Vertical block contains a 24-position Vertical Selector switch which selects the type of signal, and in some cases

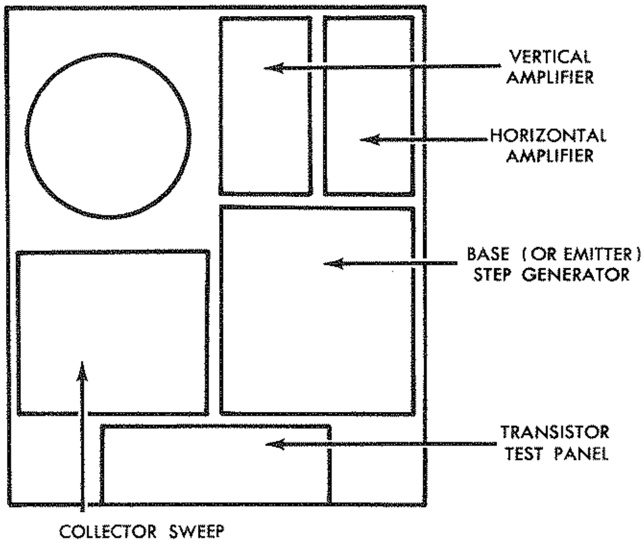


Fig. 2-1. Type 575 front-panel layout. Each section corresponds to a block in the block diagram.

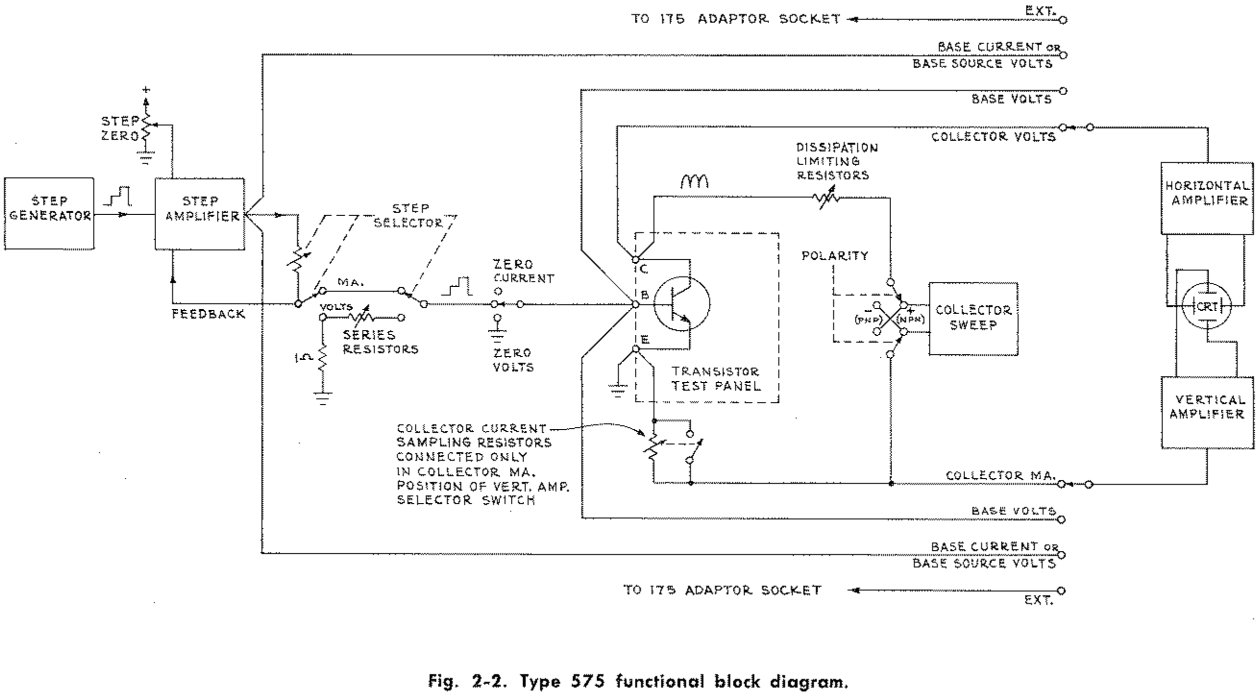


Fig. 2-2. Type 575 functional block diagram.

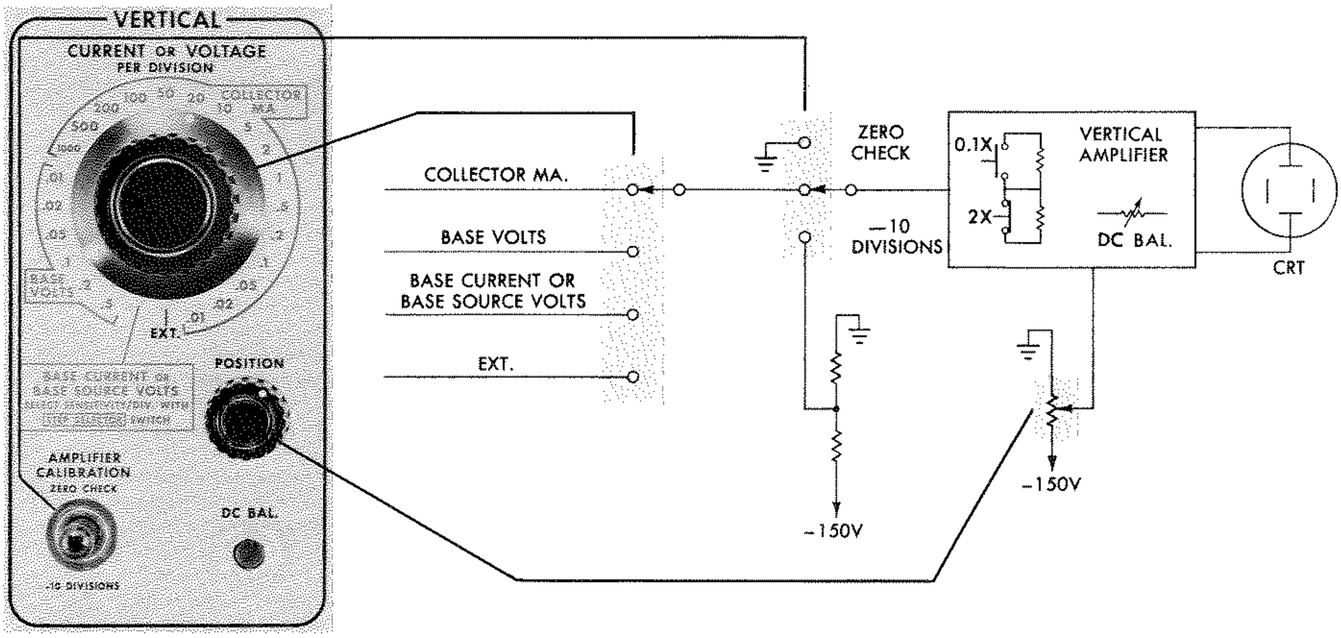


Fig. 2-3. Function of front-panel vertical-block controls.

the amplitude of the signal, fed to the Vertical Amplifier. When the switch is in any of the COLLECTOR MA positions, the collector current of the transistor appears as the Y axis signal, provided the transistor is being tested in the common-emitter (EMITTER-GROUNDED) configuration. The 2X and the 0.1X pushbutton switches provide increased current measurement ranges by multiplying each current step by 2 or dividing by 10.

When testing a transistor in the common-base (BASE GROUNDED) configuration, all of the Base-indicated nomenclature should be read as EMITTER, as explained in the note on the Transistor Test Panel.

When the Vertical Selector switch is in the BASE CURRENT OR BASE SOURCE VOLTS position, either the base current or the base source-voltage is monitored as the Y signal depending on the setting of the STEP SELECTOR switch in the Step Generator section. (In the common-base configuration, this would be either the emitter current or the emitter source-voltage).

In the EXT. position of the Vertical Selector switch, the Y signal must be obtained from an external test point, rather than from the Transistor Test Panel. Two external-input connectors are provided on the rear panel of the instrument, one for normal polarity and one for inverted polarity signals. Or, if preferred, both connectors may be employed for differential input. For instruments with S/N 3660 and up these connections are obtainable through the Type 175 adaptor socket.

The POSITION control is just what the name implies; it positions the trace or display vertically on the crt. The DC BAL. control is adjusted to maintain a state of dc balance between both sides of the Vertical Amplifier. This prevents the display from shifting vertically as the input sensitivity of the amplifier is changed in either the COLLECTOR MA or BASE VOLTS (or EMITTER VOLTS) range.

The AMPLIFIER CALIBRATION switch is used to check the gain setting (calibration) of the Vertical Amplifier. In the ZERO CHECK position both grids of the Input Amplifier are grounded to establish a zero reference on the crt. In the —10 DIVISIONS position, one grid is connected through a divider to a —150-volt supply. If the Amplifier is in proper calibration, the trace will be deflected exactly ten divisions below the zero reference.

Horizontal Block

The controls in the Horizontal block are similar to those in the Vertical block. A 19-position Horizontal Selector switch selects the type of signal, and in some cases the amplitude of the signal fed to the Horizontal Amplifier. When in any of the COLLECTOR VOLTS positions, the voltage applied to the collector of the transistor is the X-axis signal. When in any of the BASE VOLTS positions, the voltage applied to the base of the transistor is the X signal. In the BASE CURRENT OR BASE SOURCE VOLTS position, either the base current or the base source-voltage, depending on the setting of the STEP SELECTOR switch in the Step Generator block, is monitored as the X signal. As explained in conjunction with the Vertical block, the BASE-indicated nomenclature is used when testing transistors in the common-emitter configuration. When the common-base configuration is used, the word 'BASE' on the front-panel should be read as 'EMITTER'.

When the Horizontal Selector switch is in the EXT. position, the function is exactly the same as that explained for the Vertical Selector switch. In addition, the function of the POSITION, DC BAL. and AMPLIFIER CALIBRATION switches is exactly the same as that explained for the Vertical block.

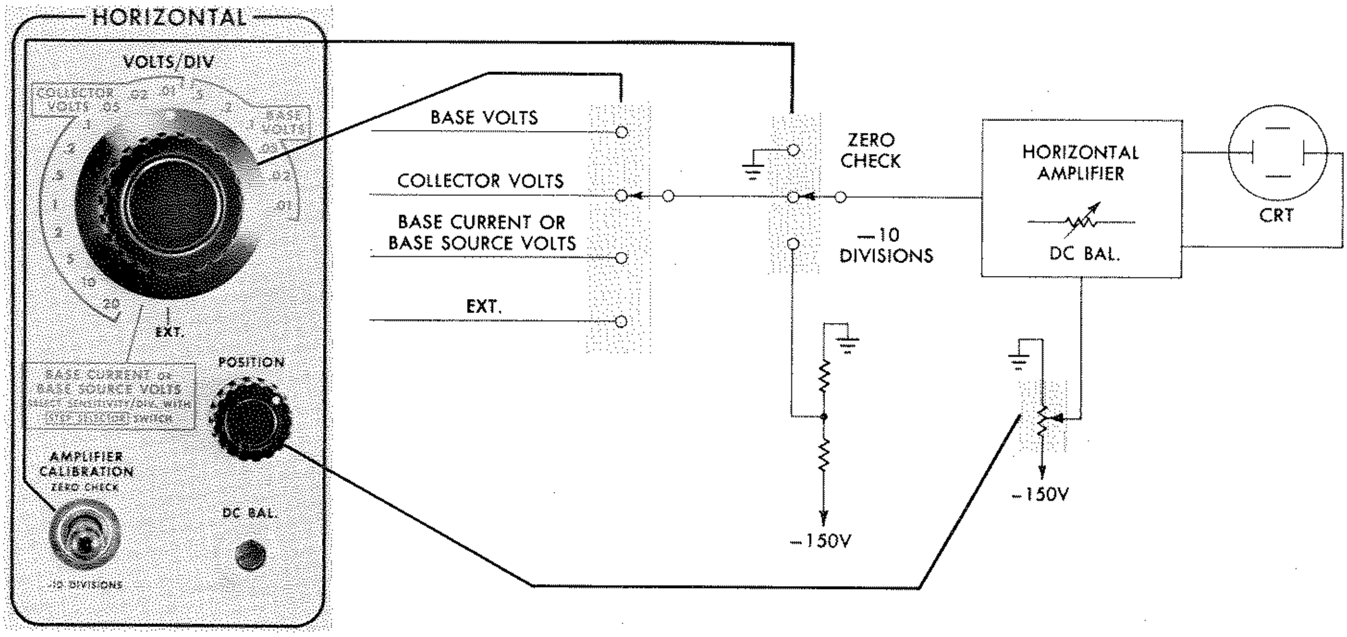


Fig. 2-4. Function of front-panel horizontal-block controls.

Collector Sweep Block

The PEAK VOLTS RANGE switch selects one of two peak voltage ranges for sweeping the collector of the transistor. In the 0-20 position, the peak voltage can be varied between zero and 20 volts by means of the PEAK VOLTS control; in the 0-200 position, the voltage is variable between zero and 200 volts. The POLARITY switch determines whether positive-going or negative-going sweeps are applied to the collector. The DISSIPATION LIMITING RESISTOR switch connects one of the indicated resistance values in series with the collector to limit the collector dissipation and thereby protect the transistor from excessive power dissipation. The value of resistance selected also becomes part of the transistor load, as explained under "Transistor Load Resistance" on the top-panel chart.

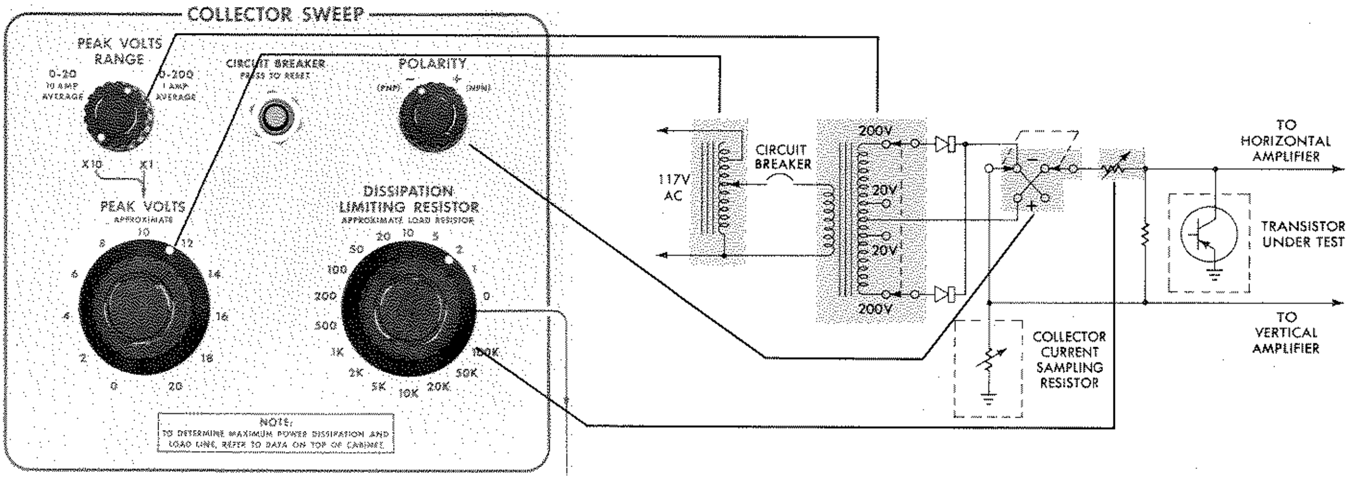


Fig. 2-5. Function of collector-sweep controls.

Step Generator Block

The Step Generator block contains a STEP SELECTOR switch which determines the type (current or voltage) and the amplitude of the steps applied to the base or the emitter of the transistor. The SERIES RESISTOR switch connects the selected value of resistance in series with the Step Generator when voltage steps are used. The value of resistance selected may be used to simulate the driving impedance of the circuit into which the transistor may be used. (In the 1Ω position of the SERIES RESISTOR switch, no resistance is added to the circuit; in this case the driving impedance is the 1-ohm internal impedance of the Step Generator.)

A POLARITY switch provides for stepping the input in either the positive or negative direction. The number of steps per family is adjustable from 4 to 12 (actually from 5 to 13 counting the zero step) by means of the STEPS/FAMILY control. With the STEPS/SEC switch, either 120 or 240 steps per second can be selected. In the upper 120 position, the current or voltage steps occur when the collector voltage is zero; in the lower 120 position of the switch, the steps occur when the collector voltage is maximum. In the 240 position, the steps occur both at zero and at maximum (of the collector voltage); this accounts for the double repetition rate in this position.

A switch is provided on the Step Generator block for selecting either a REPETITIVE or a SINGLE FAMILY display. The REPETITIVE position provides a continuous display for testing a transistor at or below its rated values. The SINGLE FAMILY position will provide a single display each time the spring-loaded switch is depressed. The low duty cycle, in this position of the switch, will permit the operator to test a transistor beyond its ratings without damage.

Another switch is provided for grounding the transistor input for a ZERO VOLTAGE check, or for opening the transistor input for a ZERO CURRENT check. The STEP ZERO control adjusts the starting point of the current or voltage steps.

Transistor Test Panel

The Transistor Test Panel has provisions for two transistors at the same time. The two sockets accept low-power transistors with short leads. The binding posts, located on either side of the small sockets, accept two types of plug-in adapters; one type of adapter is for power transistors with rigid leads, the other type is for transistors with long, flexible leads. For transistors that will not fit either type of adapter, direct connections with test leads may be made to the binding posts. For power transistors that fall into the latter category, it may be advisable to devise a heat sink to protect the transistor.

By means of a comparison switch, either transistor (TRANSISTOR A or TRANSISTOR B) can be connected into the test circuit. A Configuration switch reverses the base and emitter connections *for the transistor sockets only*. In the EMITTER GROUNDED position, the transistor is tested in the common-emitter configuration and the front-panel labels are read directly. In the BASE GROUNDED position, the transistor is tested in the common-base configuration and the BASE labels on the front panel are read as EMITTER.

If it is desired to test a transistor in the common-base configuration, when using the binding posts (with or without the adapters), the base lead must be plugged into the grounded connector marked E and the emitter lead must be plugged into the connector marked B.

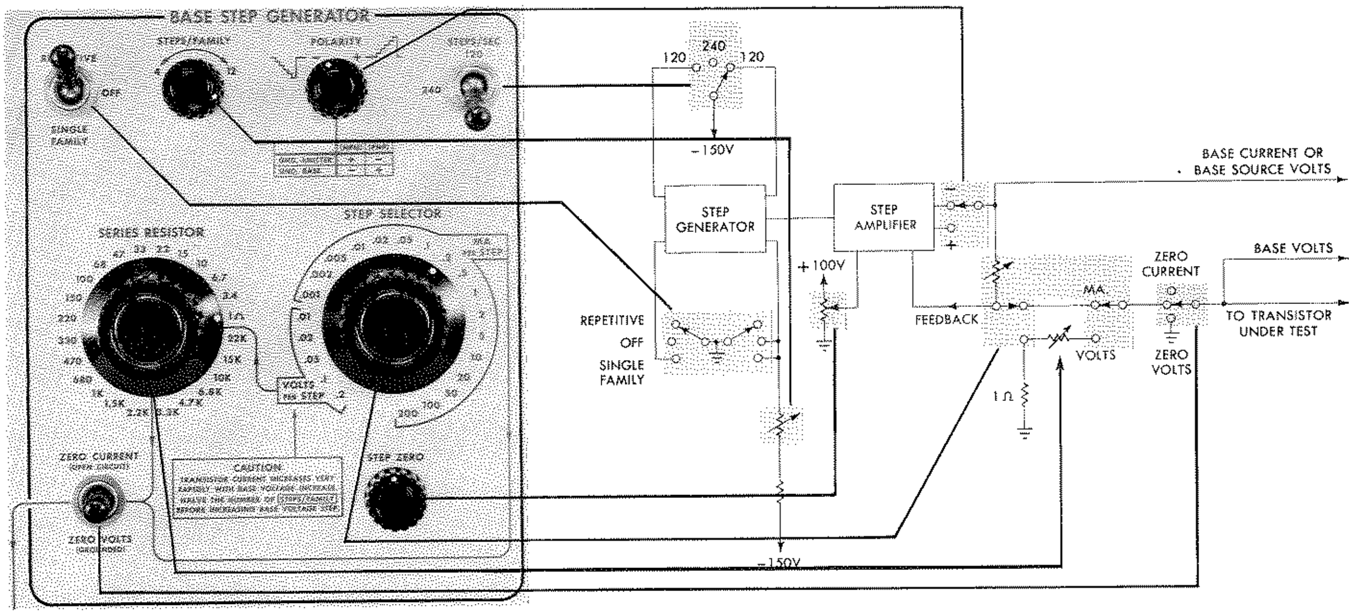


Fig. 2-6. Function of base-step generator controls.

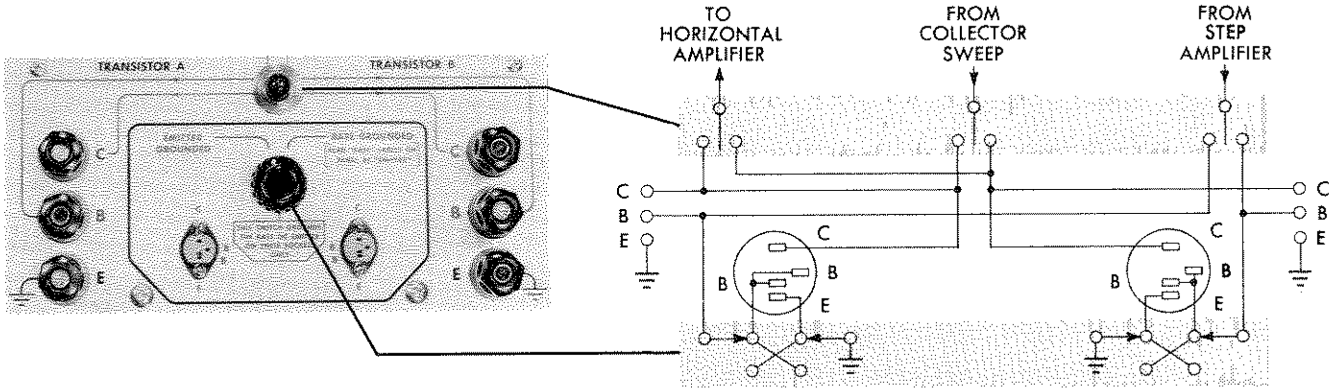


Fig. 2-7. Function of test-panel controls.

Setting Up The Front-Panel Controls

In displaying transistor curves on the Type 575 we are concerned with two considerations...properly displaying the curves we wish to interpret, and protecting the transistor under test from damage.

If we know quite a bit about the transistor...that is, if we know such factors as the collector dissipation rating, collector current and emitter current ratings, collector-to-base and collector-to-emitter voltage ratings...then we can set up the front-panel of the instrument without danger of damaging the transistor. However, if all we know is whether the transistor is an NPN or a PNP, more care must be exercised when setting up the front-panel controls.

The General Procedure that follows is an outline of the steps involved in setting up the front-panel controls to obtain a collector family of curves. Following the General Procedure is a step by step procedure for setting up the controls for a transistor of unknown characteristics, to obtain a collector family, and then a procedure for obtaining a collector family for a transistor of known characteristics.

General Procedure

Indicator Unit

1. The INTENSITY control is turned to mid-scale; this will prevent damage to the crt phosphor when the power is turned on.
2. The POWER switch is turned ON, so that the instrument can be warming up while it is being set up for use.

Test Panel

3. The Configuration switch is set to the EMITTER GROUNDED position (if a common-emitter configuration is desired).
4. The Comparison switch (TRANSISTOR A-TRANSISTOR B) is set to the center position; this prevents the application of any voltage or current to the transistor socket.

Collector Sweep Block

5. The POLARITY switch is set to the proper polarity for an NPN or a PNP transistor.
6. The DISSIPATION LIMITING RESISTOR switch is set to the proper value to prevent excessive collector dissipation.
7. The PEAK VOLTS RANGE and the PEAK VOLTS switches are set for the proper amplitude of collector sweep voltage.

Base Step Generator Block

8. The Display switch is set to REPETITIVE so that we may view a continuous display.
9. The STEPS/FAMILY control is adjusted for the number of curves we wish to display.
10. The POLARITY switch is set to — if the transistor under test is a PNP (since we are in the grounded-emitter configuration), or to + if an NPN transistor (again in the grounded-emitter configuration).
11. The STEPS/SEC. switch is set for the desired step rate of the Base Step Generator (either 120 or 240 steps/second).
12. The STEP SELECTOR is set for the current per step or voltage per step that we wish to apply to the base.

12.(a) If voltage steps are applied to the base of the transistor under test, the proper value of SERIES RESISTOR must be switched into the circuit to limit the base current.

Conclusion

13. The VERTICAL sensitivity for the collector current is set by adjusting the COLLECTOR MA/DIVISION switch.
14. The HORIZONTAL sensitivity for the collector voltage is set by adjusting the COLLECTOR VOLTS/DIV. switch.
15. The transistor to be tested is placed in the socket or binding post (either A or B) and the Comparison switch set to either TRANSISTOR A or TRANSISTOR B (depending on which socket or binding post is used). This connects the transistor into the test circuit.
16. The INTENSITY, FOCUS and ASTIGMATISM controls are adjusted for a display of suitable brightness and clarity.
17. The calibration of the horizontal and vertical amplifiers is checked.
18. The display is properly positioned for interpretation.

Testing a Transistor of Unknown Characteristics

To obtain a collector family for a transistor of unknown characteristics, the following control settings will afford maximum protection. We are assuming that the type of transistor is known (NPN or PNP), and that it is to be tested in the grounded-emitter configuration.

Test Panel

Configuration Switch	EMITTER GROUNDED
Comparison Switch	Centered

Collector Sweep Block

PEAK RANGE VOLTS	0-20
PEAK VOLTS	0
POLARITY	Set according to type of transistor being tested.
DISSIPATING LIMITING RESISTOR	100 K

Base Step Generator Block

Display Switch	REPETITIVE
STEPS/FAMILY	4 (full left)
POLARITY	Set according to type of transistor being tested.
STEPS/SEC.	Any setting
STEP SELECTOR	.001 MA per STEP, or .01 VOLTS per STEP
SERIES RESISTOR	22 K

SERIES RESISTOR switch is not connected in the circuit when STEP SELECTOR switch is in MA per STEP range.

Indicator Unit

VERTICAL	
COLLECTOR MA	.01
HORIZONTAL	
COLLECTOR VOLTS	.01

Place the transistor to be tested in either the socket or binding post on the left side of the Test Panel, and place the Comparison switch in the TRANSISTOR A position. Adjust the INTENSITY and POSITION controls for a crt indication near the upper right corner of the graticule for PNP or lower left corner for NPN. At this time each of the controls mentioned in the front-panel set-up can be adjust, one position at a time, until a suitable display is obtained on the crt. As soon as an indication of a collector family of curves becomes apparent on the crt, it will probably be necessary to reposition the display to properly interpret the values of voltage and current.

Testing a Transistor of Known Characteristics

To demonstrate the front-panel set-up for a transistor of known characteristics, we have selected a 2N407 PNP transistor. Note: The test transistors furnished with your instrument are a similar type.

Test Panel

Comparison Switch	Centered
Configuration Switch	EMITTER GROUNDED

2. Collector Sweep Block

The PEAK VOLTS RANGE and the PEAK VOLTS controls are set for the peak voltage with which we wish to sweep the collector. If we wish this to be 10 volts, the controls are set as follows:

PEAK VOLTS RANGE	0-20
PEAK VOLTS	10
POLARITY	PNP—

The value of the DISSIPATION LIMITING RESISTOR depends on the maximum collector disspation and the collector sweep voltage. The transistor manual states that the maximum collector disspation, for 25° C ambient temperature, is 150 mw. Consulting the RESISTOR SELECTION GRAPH on the instrument, the proper value of resistance, for a collector dissipation of 150 mw and a peak collector voltage of 10 volts, is 200 ohms.

Therefore:

DISSIPATION LIMITING RESISTOR	200

The remainder of the controls are set for the conditions under which we wish to test the transistor.

Base Step Generator Block

Display Switch	REPETITIVE
STEPS/FAMILY	4
POLARITY	—
STEPS/SEC.	240
STEPS SELECTOR	.02 MA per STEP

Indicator Unit

VERTICAL	
COLLECTOR MA	.5
HORIZONTAL	
COLLECTOR VOLTS	1

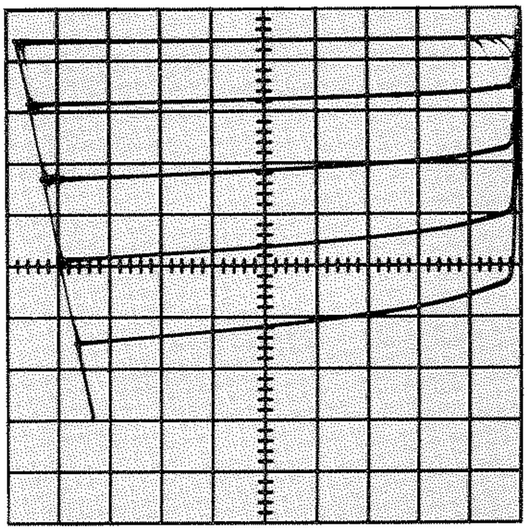


Fig. 2-8. Collector family of curves for a Type 2N407 transistor.

Insert a test transistor into the socket on the left side of the Test Panel, and place the Comparison Switch in the TRANSistor A position. Adjust the INTENSITY, FOCUS and ASTIGMATISM controls for a display of suitable brightness and clarity. The display should then be similar to the collector family shown in Fig. 2-8.

How To Check The Calibration of The Display

Before quantative information is taken from the display, a check should be made to see that the calibration of the vertical and horizontal scales is correct. The stability of the amplifiers is such that the instrument will remain in calibration over long periods of time if there are no component failures. The display must also be properly positioned.

NOTE: When you check the calibration of this instrument, calibrate it, or take information from the display, be sure your eye is at the same level as the line at which you are looking in order to avoid errors due to parallax.

Hold the VERTICAL AMPLIFIER CALIBRATION switch in the ZERO CHECK position and set the horizontal line even with the top line of the 10-division graticule. Next, hold this switch in the —10 DIVISIONS position. The horizontal line should be within 1½ minor divisions of the bottom line of the graticule if the calibration is within tolerance.

Now hold the HORIZONTAL AMPLIFIER CALIBRATION switch in the ZERO CHECK position and set the vertical line even with the extreme right vertical line of the graticule. Next, hold this switch in the —10 DIVISIONS position. The vertical line should move to within 1½ minor divisions of the extreme left vertical line of the graticule.

Since current steps are being fed into the base of the transistor under test, it is sometimes desirable to adjust the STEP ZERO control (BASE STEP GENERATOR) to a point where the first horizontal trace occurs when the base current is zero. To do this, it is necessary to have an open-circuit or zero base-current reference line. Hold the ZERO CURRENT-ZERO VOLTS switch in the ZERO CURRENT position and note precisely where the horizontal trace intersects the vertical center line of the graticule. Now release the ZERO CURRENT switch and adjust the STEP ZERO control so that the top line of the display intersects the vertical center line of the graticule at the same place.

Applying Voltage Steps to the Transistor Input

The control settings used in this display are the same as for the previous display except for the following:

SERIES RESISTOR	1 ohm
STEP SELECTOR	.02 VOLTS PER STEP
VERTICAL COLLECTOR MA	.05 MA PER DIVISION

If a complete and accurate display is desired, the display should be properly positioned by the method outlined in the next two paragraphs.

Hold the amplifier calibration switch (VERTICAL BLOCK) in the ZERO CHECK position and move the trace to the top line of the rectangular graticule. This operation sets the zero collector-current reference. Now depress the ZERO CURRENT-ZERO VOLTS switch (BASE STEP GENERATOR) in order to ground the transistor base. The vertical displacement of the horizontal trace from the zero-current reference indicates the collector current at zero bias with a calibration of .05 ma. per major division.

The STEP ZERO control (BASE STEP GENERATOR) must now be set so that the uppermost curve (zero bias) in the family of curves coincides with the position of the single curve just displayed. The family of curves now on the crt screen is that of collector current versus collector voltage with 20-millivolt steps applied to the transistor base.

Special precautions should be taken when voltage steps are fed to the input of the transistor under test. Since the input resistance of a transistor is quite nonlinear over its operating range, it is important that the number of voltage steps used does not cause excessive base current to flow. There are two controls which influence the maximum base current for a selected value of voltage-step amplitude. One is the STEPS/FAMILY control, which should be set to 4 for an initial test set-up. The other is the SERIES RESISTOR switch, which allows you to insert a protective current-limiting resistor in the transistor input lead. Excessive series resistance will seriously alter the characteristic curves displayed, therefore its effect should be taken into consideration before interpreting curves where voltage steps are being fed into the transistor input.

The SERIES RESISTOR may also be used to simulate driving impedances. When series resistance is used, it may not be possible to make the top curve of the display coincide with the zero-bias curve.

Characteristics of the Base Step Generator

The largest current steps the base generator can supply are 200 ma. each. Since up to 12 steps are available, the maximum current this supply will deliver is therefore 2.4 amperes. Because of necessary restrictions on the size of the power source for the internal transistors used to deliver the current steps, the input characteristics of the power transistor under test must be such that the base to emitter voltage does not exceed 5 volts when the base current is 2.4 amperes.

The minimum source resistance of the step generator in the VOLTS/STEP range of the STEP SELECTOR switch is one ohm (SERIES RESISTOR set at 1 ohm). This is a constant minimum source resistance irrespective of the size of the voltage steps. The source resistance increases as resistance is switched in series by the SERIES RESISTOR switch.

When power transistors are driven into the high base-current region, their input resistance is often low enough to cause the input steps to become non-uniform in size. Under these conditions, it is best to check the uniformity of the voltage steps by displaying the base voltage on either the vertical or horizontal axis. A quick check of generator loading may be made by changing the setting of the SERIES RESISTOR switch from 1 ohm to 3.4 ohms while collector characteristics are being displayed. A radical shift in the position of the trace displaying the highest collector current would indicate a low input resistance and the possiblity of non-uniform voltage input steps in the 1 ohm position.

Functions of Controls and Switches

All descriptions given below presume that the transistor under test is in the grounded-emitter configuration and that the power-line frequency is 60 CPS.

Collector Sweep Block

PEAK VOLTS RANGE. Selects appropriate power source to give collector sweep voltage and current range indicated. Operates in conjunction with PEAK VOLTS control.

PEAK VOLTS APPROXIMATE. Variable autotransformer in the primary of the collector sweep transformer. Operates in conjunction with PEAK VOLTS RANGE.

CIRCUIT BREAKER. Protects the collector sweep circuit from excessive overload currents.

POLARITY. Selects the polarity of the collector sweep to be applied to the transistor under test.

DISSIPATION LIMITING RESISTOR. Selects a protective series resistor for the collector circuit of the transistor under test. This resistance may be used as the collector load resistor to simulate operating conditions of the transistor under test. Refer to chart on top panel.

Base Step Generator Block

REPETITIVE-OFF-SINGLE-FAMILY. In the REPETITIVE position, the Base Step Generator produces stair-step waveforms. A characteristic curve is plotted during each horizontal portion of the stair-step waveform. In the OFF position, the BASE STEP GENERATOR is disabled. The SINGLE FAMILY position is a spring-return position which permits the generation of one stair-step waveform each time the switch handle is depressed.

STEPS/FAMILY. Determines the number of steps in each family of curves.

POLARITY. Selects the polarity of the stair-step waveform to be applied to the transistor under test.

STEPS/SEC. Selects the steps-per-second rate of the Base Step Generator as well as determining whether the steps occur at the beginning or at the end of each curve.

SERIES RESISTOR. This switch functions only when the STEP SELECTOR switch is in the VOLTS PER STEP position. It permits the simulation of the source impedance of the circuit in which the transistor under test is to be used. The SERIES RESISTOR may also be used as a protective device to limit the current that might otherwise be inadvertently applied to the transistor base.

STEP SELECTOR. Selects the magnitude of either voltage or current-per-step to be applied to the transistor under test.

STEP ZERO. The STEP ZERO control permits adjustment of the Step Generator to start on the zero-current or zero-volts curve of the display.

ZERO CURRENT—ZERO VOLTS. In the ZERO CURRENT position, the connection to the base of the transistor under test is broken. The curve displayed shows the open-base characteristic of the transistor. In the ZERO VOLTS position, the base is grounded to permit examination of the zero-bias characteristics.

Vertical Block

CURRENT OR VOLTAGE PER DIVISION. COLLECTOR MA. Selects the collector-current of the transistor under test for the vertical display. Different switch positions within this range change the calibration of the vertical display by changing the value of an internal current-sampling resistance.

2X. Pushbutton switch multiplies each current step by 2.

0.1X. Pushbutton switch divides each current step by 10.

BASE VOLTS. Selects the base voltage of the transistor under test for the vertical display. The sensitivity is determined by the resistance of an attenuator in the vertical amplifier.

BASE CURRENT OR BASE SOURCE VOLTS. Base current is displayed vertically when the STEP SELECTOR switch (BASE STEP GENERATOR) is in the MA PER STEP range. The calibration of the vertical display is that indicated by the STEP SELECTOR switch except that it is also in milliamperes per major division as well as milliamperes per step.

The base-source voltage is displayed vertically when the STEP SELECTOR switch is in the VOLTS PER STEP range. The display is that of the voltage steps which are occuring ahead of the SERIES RESISTOR. The calibration is indicated by the STEP SELECTOR switch except that it is also in volts per major division as well as volts per step.

EXT. This switch position permits the vertical dc amplifier to be driven by an external signal applied through connectors on the back panel of the instrument, or on instruments after S/N 3659 through the pins of the Type 175 adaptor socket. The external signal may be either single-ended or push-pull.

POSITION. This control permits the display to be moved vertically over the entire face of the crt without introducing distortion into the display.

AMPLIFIER CALIBRATION. A three-position switch with two spring-return positions used to check the ZERO position and the calibration of the vertical amplifier.

DC BAL. This control is adjusted to permit changing of the amplifier sensitivity without changing the position of the display.

Horizontal Block

VOLTS/DIV. BASE VOLTS. Selects the base voltage of the transistor under test for the horizontal display. The sensitivity is determined by the resistance of an attenuator.

COLLECTOR VOLTS. Selects the voltage on the collector of the transistor under test for the horizontal display. The various switch positions in this range either change the gain of the horizontal amplifier or introduce attenuation of the collector voltage signal applied to the input of the horizontal amplifier.

BASE CURRENT OR BASE SOURCE VOLTS. The description of this switch position is the same as that given in the VERTICAL BLOCK under the same heading, except that the display is horizontal instead of vertical.

EXT. The description of this switch position is the same as that given in the VERTICAL BLOCK under the same heading, except that the display is horizontal instead of vertical.

POSITION. This control permits the display to be moved horizontally over the entire face of the CRT without introducing distortion into the display.

AMPLIFIER CALIBRATION. A three-position switch with two spring-return positions used to check the ZERO position and the calibration of the horizontal amplifier.

DC BAL. This control adjusts the tube-current balance in the direct-coupled horizontal amplifier to permit changing of the amplifier sensitivity without changing the position of the display.

Test Panel

TRANSISTOR A, TRANSISTOR B. A three-position switch which, in either outside position, connects the two binding posts and the transistor socket indicated to the appropriate circuitry within the instrument. In the center (off) position, it disconnects all power from the transistor, sockets and binding posts.

EMITTER GROUNDED, BASE GROUNDED. A reversing switch in the base and emitter leads of the transistor sockets. It permits small transistors to be rapidly switched between the grounded-emitter and grounded-base configurations. This switch does not reverse binding post connections.

Interpreting Type 575 Curves

The following displays are devoted to some typical transistor displays and their meaning. While no attempt is made to explain transistor terminology and parameters, it is hoped that these diagrams and curves will help the operator to arrive at the desired answer in less time, and perhaps better understand the operation of the instrument in so doing.

The transistor used in most of the following tests is the 2N407 PNP junction transistor. The curves are not necessarily typical of the average 2N407 as a number of different transistors were used in order to best demonstrate certain characteristics. Other curves shown include those for the point contact transistor, Zener diode, gaseous voltage-regulator tube NE2, tetrode transistor, photodiode and phototransistor.

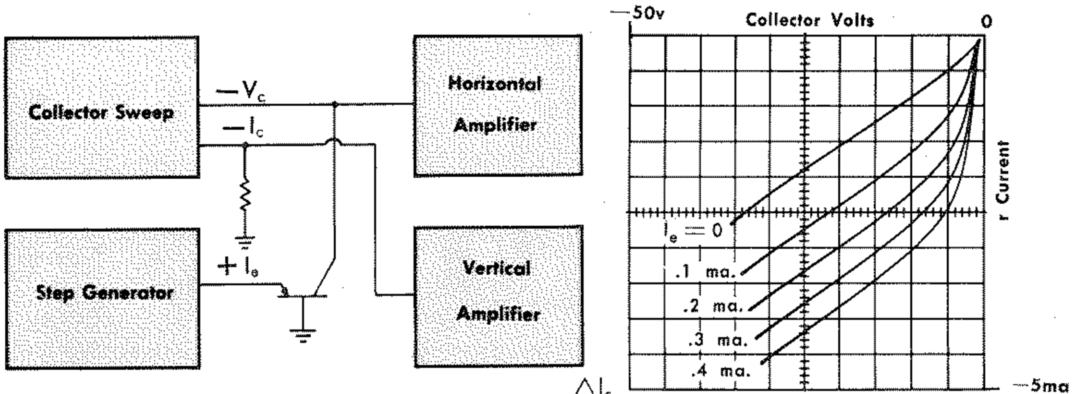
An attempt has been made to portray all of the voltages and currents that appear in transistor specifications; i.e., V_{ce}, V_{be}, V_{cb}, BV_{ce}, BV_{ceo}, I_{co}, I_{cbo}, I_{eo}, etc. Also, since some manufacturers employ the hybrid h parameters while others use the r parameters (as in low-frequency equivalent T circuit), measurements of both types have been included.

Note: The measurements obtained on the Type 575 are valid for low-frequency operation only; other equipment is required for high-frequency testing.

The effects of temperature on transistor operation are very important; this can be noted in the top two curves on page 2-7. The temperature effects can be portrayed with the aid of a thermocouple or heat box, or by means of an oil bath and heating element.

Collector Family

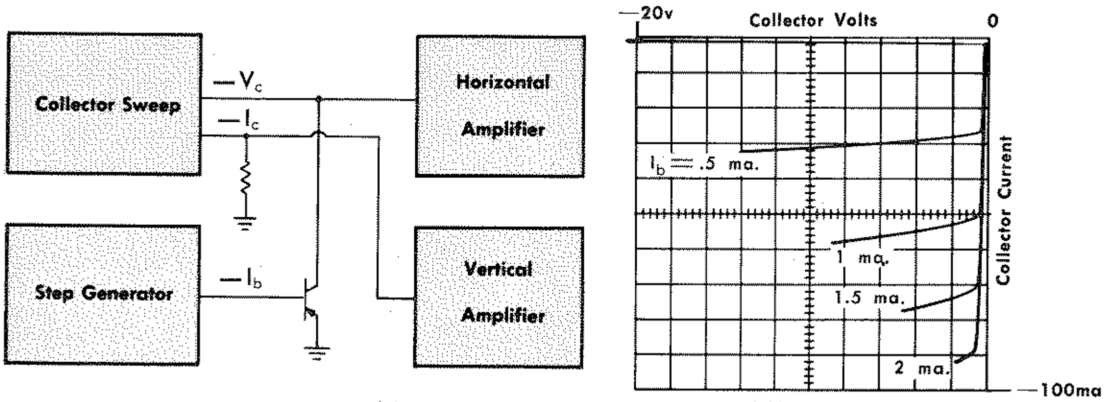
X-Bell point-contact transistor



Note: Alpha (α) $= \frac{\Delta I_c}{\Delta I_e}$ is greater than 1.

Collector Family

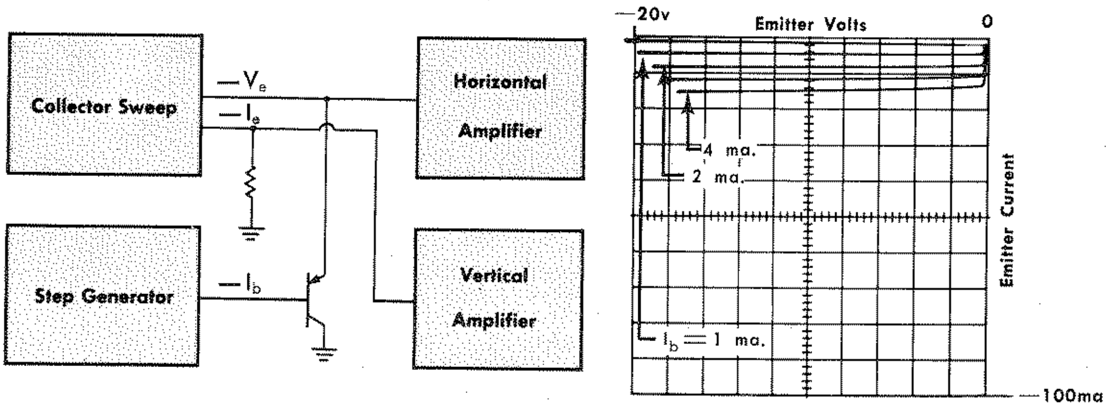
2N407 PNP junction transistor



Beta (β) $= \frac{\Delta I_c}{\Delta I_b} = h_{fe}, h_{FE}.$ $r_{22e} = r_e + r_c = \frac{\Delta V_c}{\Delta I_c}$

Inverted Collector Family

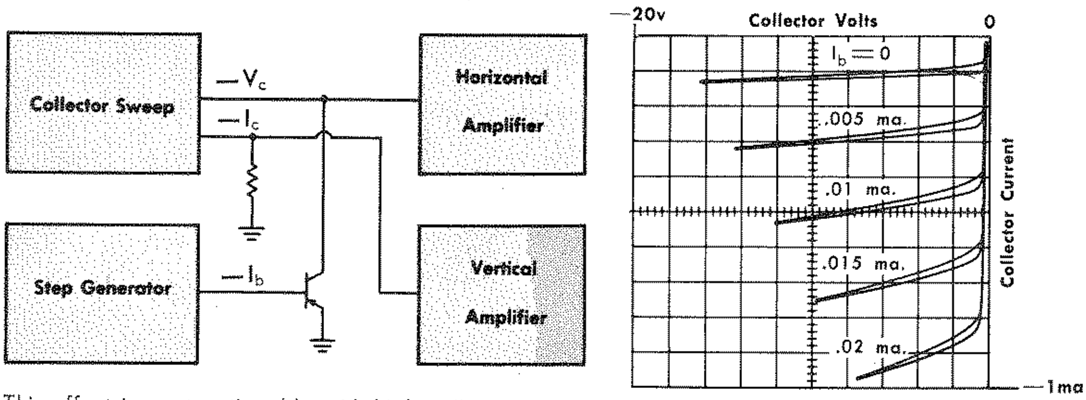
2N407 PNP junction transistor



Reverse current transfer ratio $= h_{fc}, h_{FC}.$

Collector Family . . . Effect of collector to base capacity

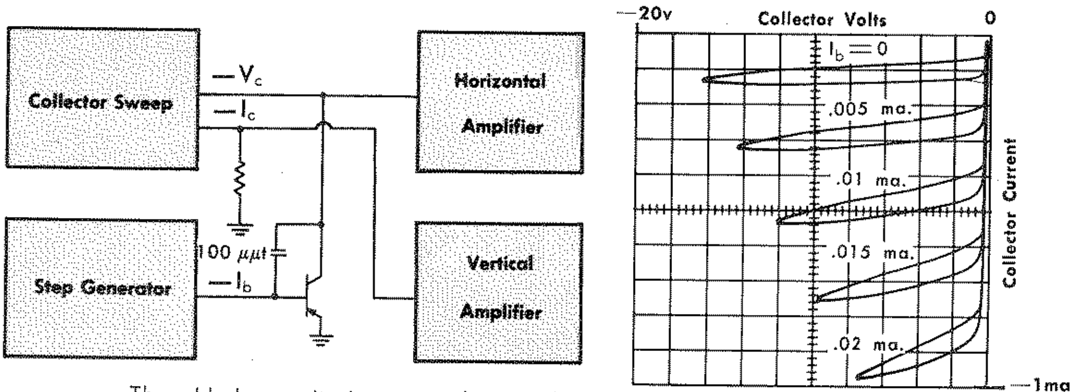
2N407 PNP junction transistor



This effect is most noticeable with high collector voltage and low collector current.

Collector Family . . . External capacity added

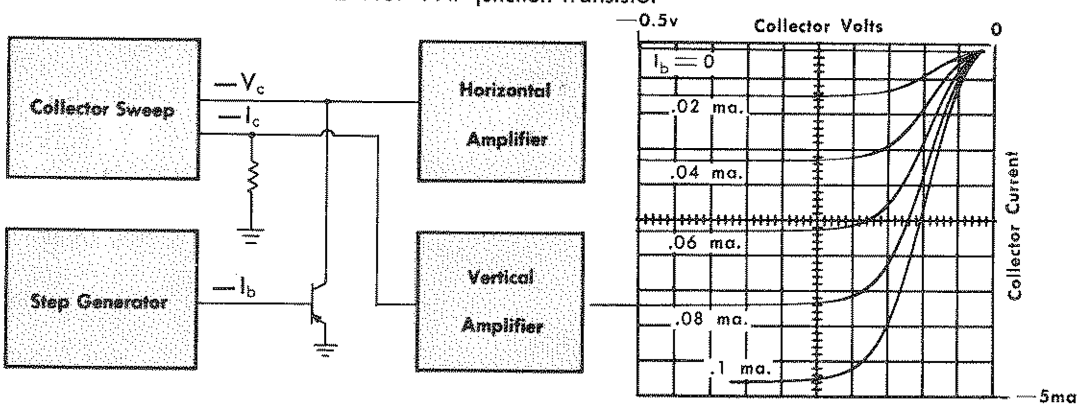
2N407 PNP junction transistor



The added capacity increases the modulation of the base current;
this effect is amplified by the transistor.

Collector Family . . . Saturation region

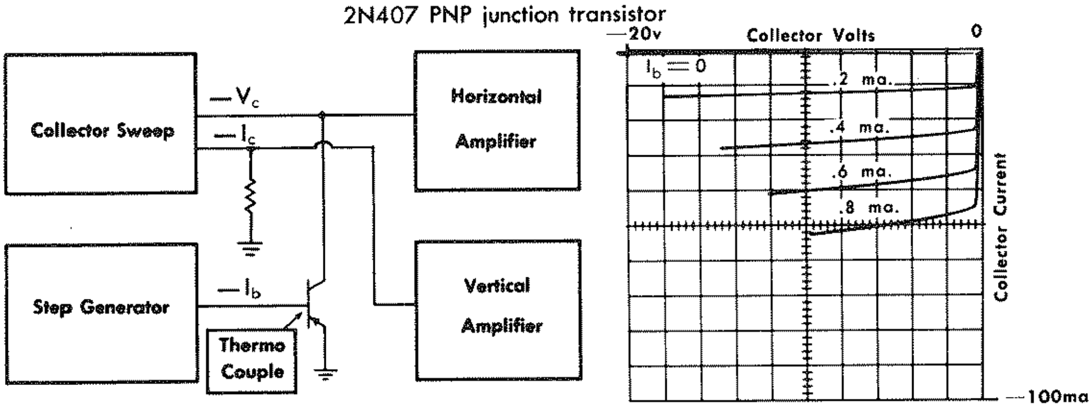
2N407 PNP junction transistor



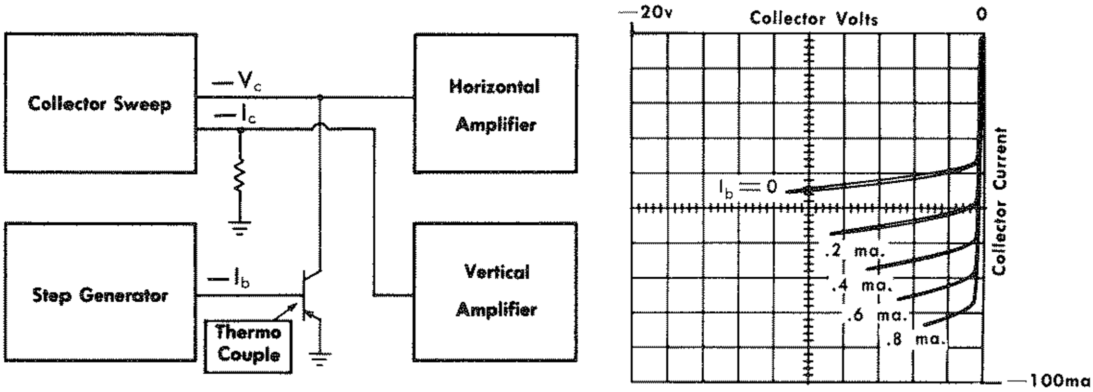
Saturation voltage V_{CE} (SAT), at specified I_b and I_c.
Saturation resistance R_{SC} = slope of I_c-V_c curve at specified I_c.

Collector Family . . . Room temperature (75° F.)

2N407 PNP junction transistor



Above transistor at temperature of 150° F.

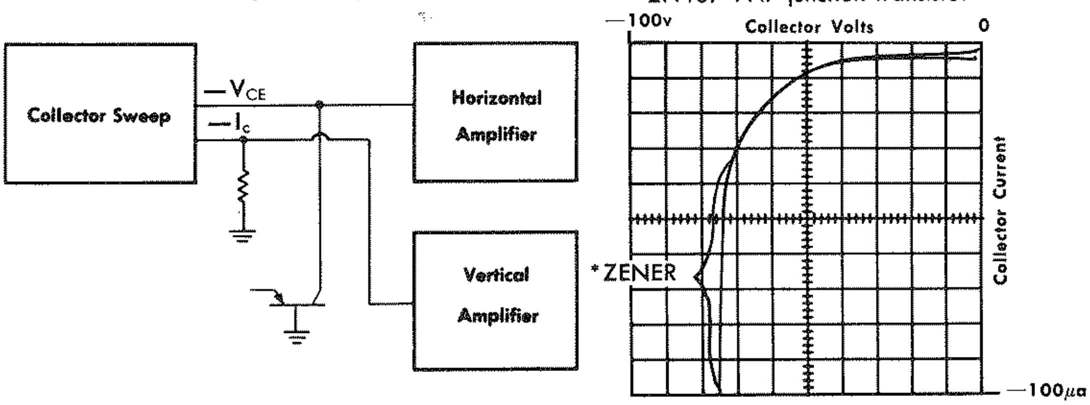


Note increase in leakage current and Beta.

Breakdown Voltage, collector to base (emitter open) BV_{CBO}

Collector Cutoff Current I_{CO}, I_{CBO}

2N407 PNP junction transistor



For BV_{CBO} the I_c should be specified; For I_{CBO} the voltage should be specified. Note the Zener * region.

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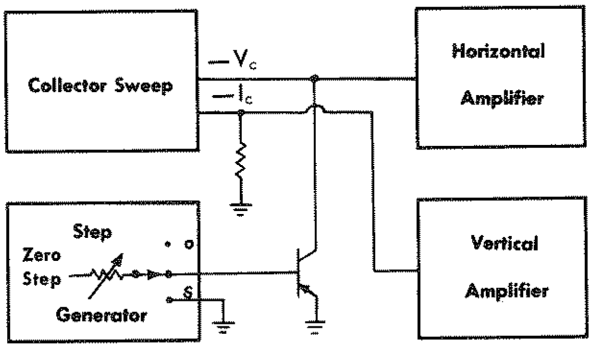
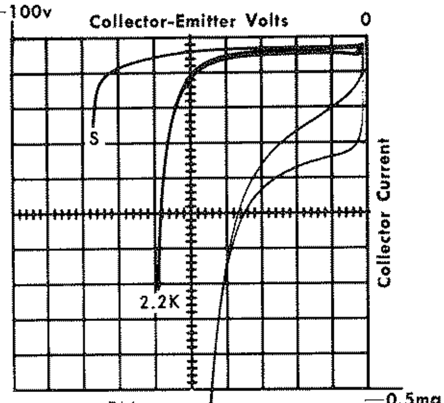
Breakdown Voltage, collector to emitter
BV_{CE}, BV_{CEO}, BV_{CER}, BV_{CES}



Collector Current I_{CE}, I_{CEO}, I_{CES}
2N407 PNP junction transistor



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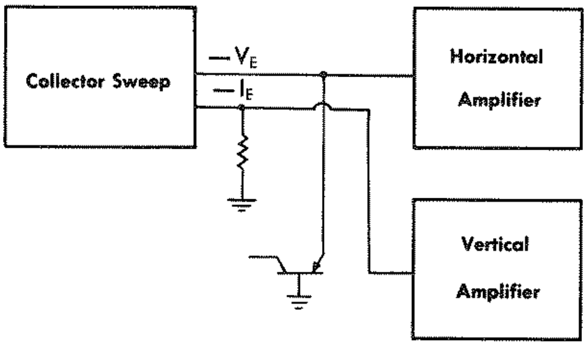
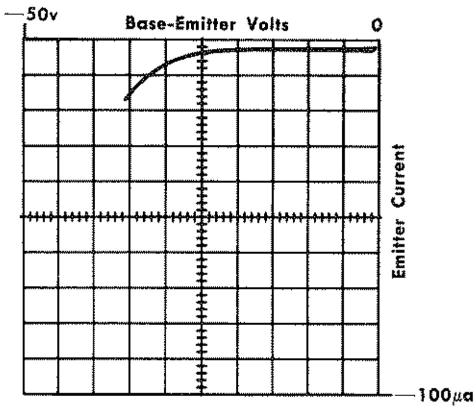
The current should be specified when measuring BV_{CE};
the resistance should be specified when measuring BV_{CER}.

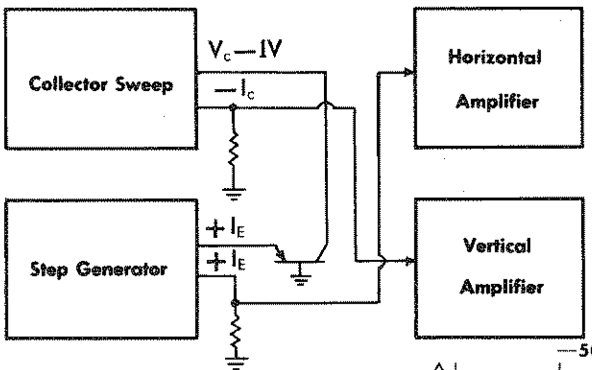
Breakdown Voltage, base to emitter (collector open) BV_{BEO}

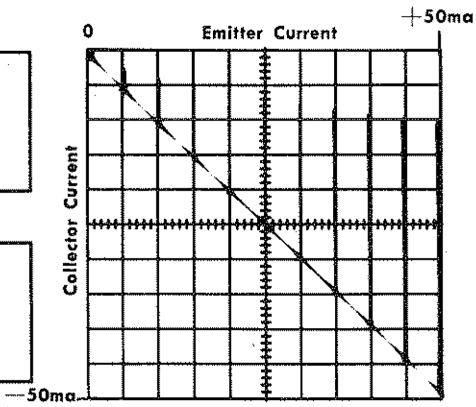


Emitter Current I_{EO}, I_{EBO}.



Alpha Curve, α, h_{21b}, h_{fb}, h_{FB}
2N407 PNP junction transistor



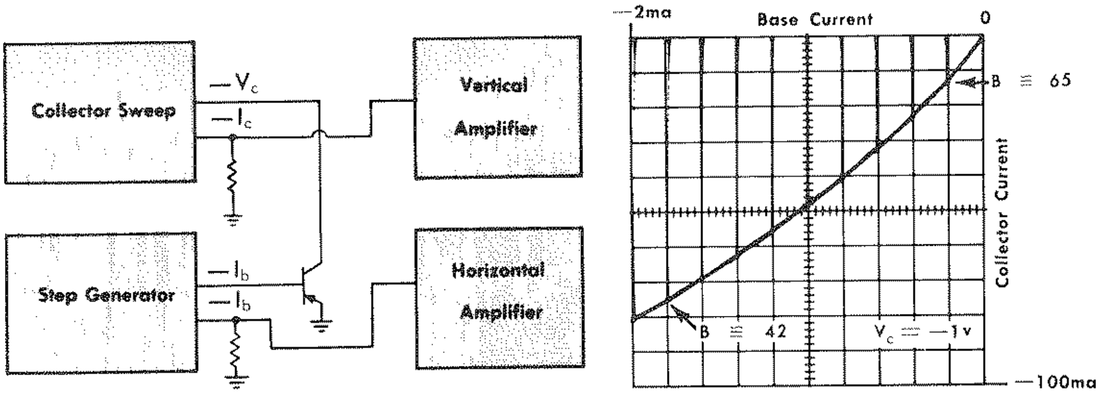


$\alpha \cong .98$

$$h_{fb} = \frac{\Delta I_c}{\Delta I_e};\ h_{FB} = \frac{I_C}{I_E}$$

Forward Current Transfer Ratio, Beta, β, h_{21e}, h_{fe}, h_{FE}

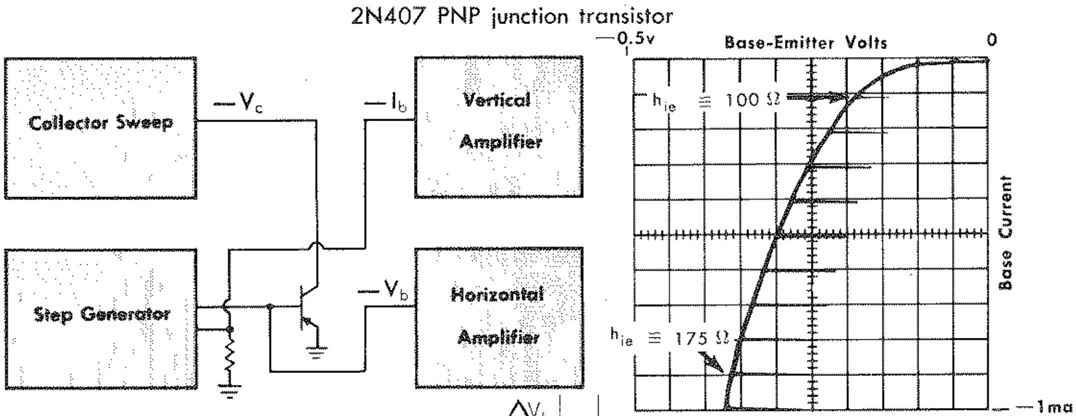
2N407 PNP junction transistor



Note Beta, $h_{fe} = \frac{\Delta I_c}{\Delta I_b}$, decreases at higher currents.

Input Impedance, h_{11e}, h_{ie}

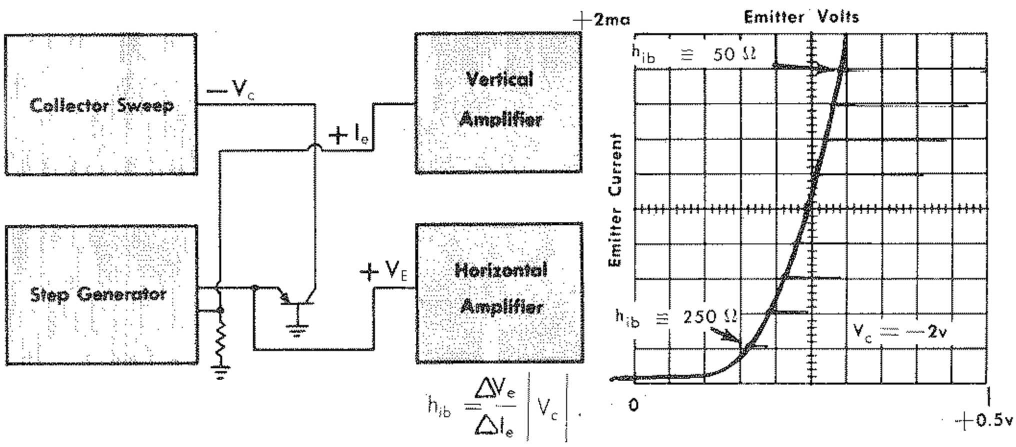
2N407 PNP junction transistor



$$h_{ie} = \frac{\Delta V_b}{\Delta I_b} \bigg| V_c \bigg| .$$

Input Impedance, h_{11b}, h_{ib}

2N407 PNP junction transistor



$$h_{ib} = \frac{\Delta V_e}{\Delta I_e} \bigg| V_c \bigg| .$$

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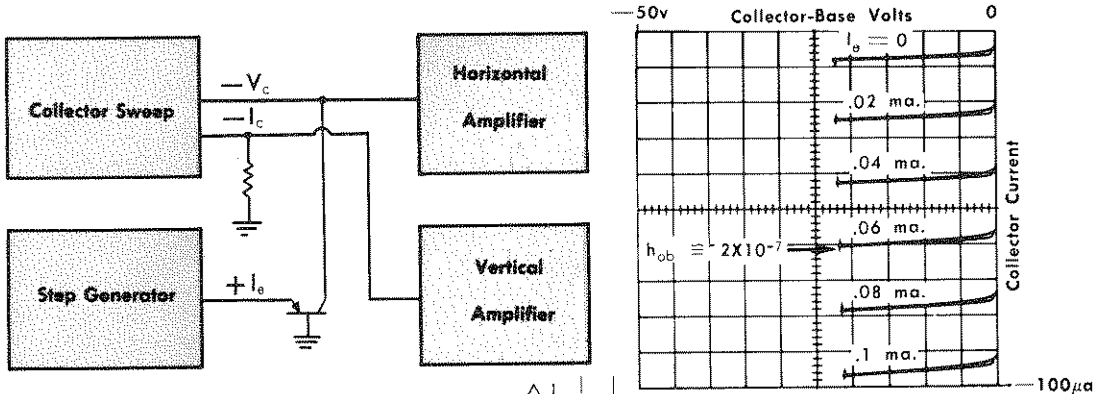
Output Admittance, h_{22b}, h_{ob}

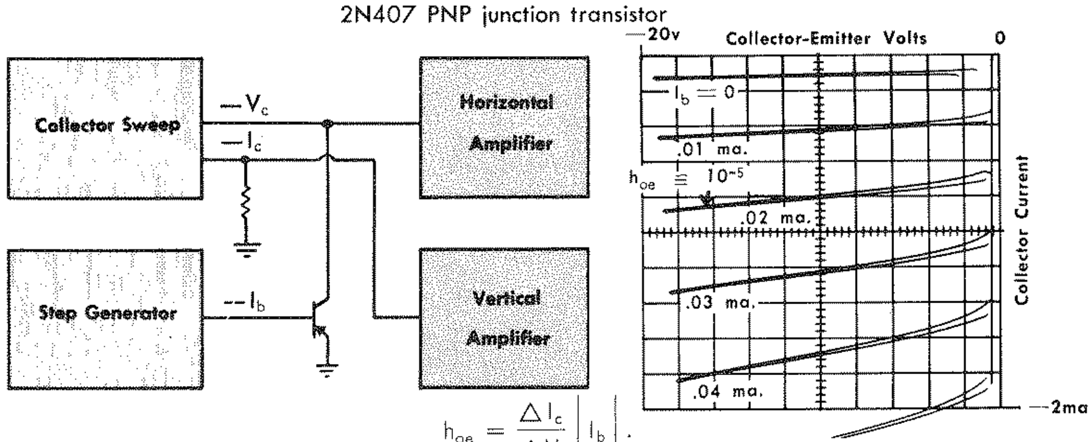
2N407 PNP junction transistor



$$h_{ob} = \frac{\Delta I_c}{\Delta V_c}\bigg|_{I_e}.$$

Output Admittance, h_{22e}, h_{oe}

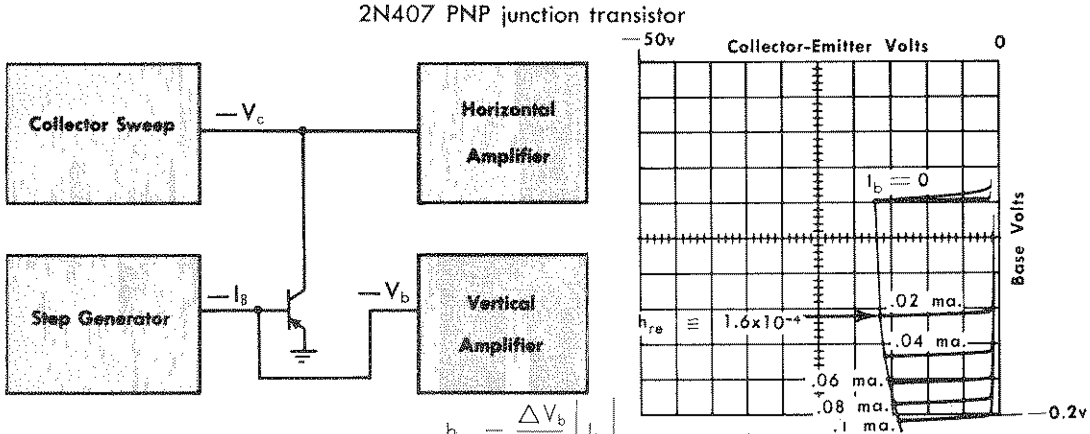
2N407 PNP junction transistor



$$h_{oe} = \frac{\Delta I_c}{\Delta V_c}\bigg|_{I_b}.$$

Voltage Feedback Ratio, h_{12e}, h_{re}

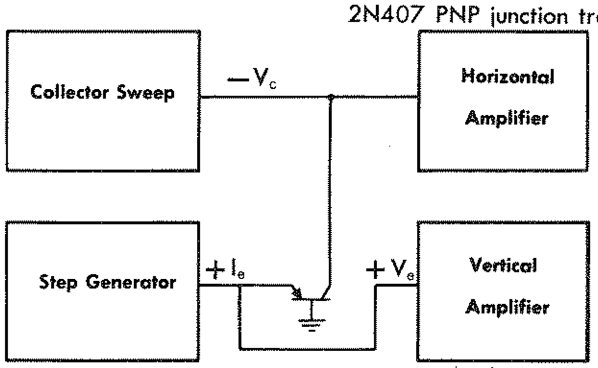
2N407 PNP junction transistor

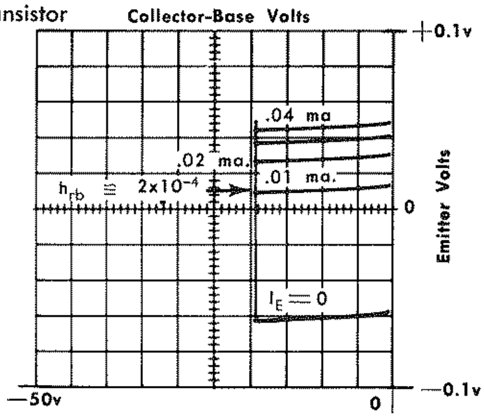


$$h_{re} = \frac{\Delta V_b}{\Delta V_c}\bigg|_{I_b}.$$

Voltage Feedback Ratio, h_{12b}, h_{rb}

2N407 PNP junction transistor

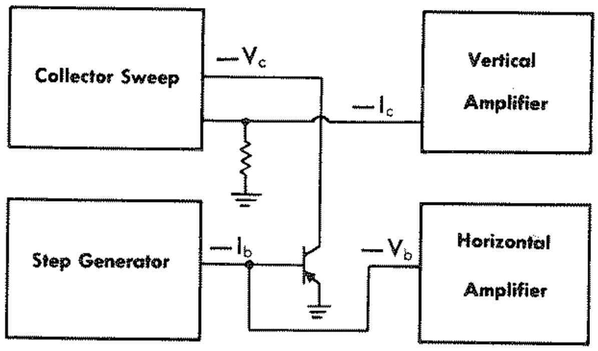


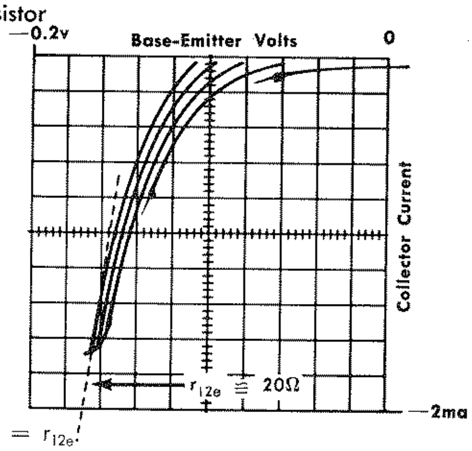


$$h_{rb} = \frac{\Delta V_e}{\Delta V_c}\Big| I_e \Big|$$

Reverse Transfer Resistance, r_{12e}

2N407 PNP junction transistor

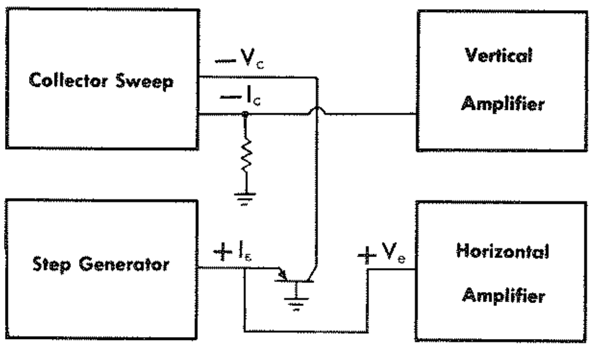


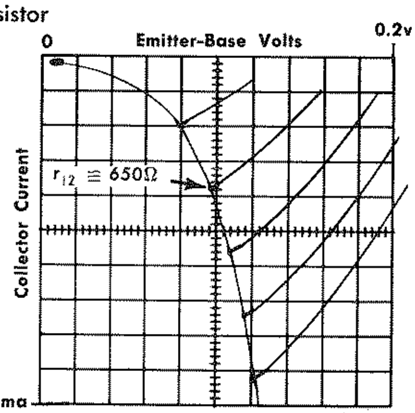


$$r_{12e} = \frac{\Delta V_b}{\Delta I_c}\Big| I_b \Big| = r_e.\ \text{Slope} = r_{12e}.$$

Reverse Transfer Resistance, r_{12b}

2N407 PNP junction transistor

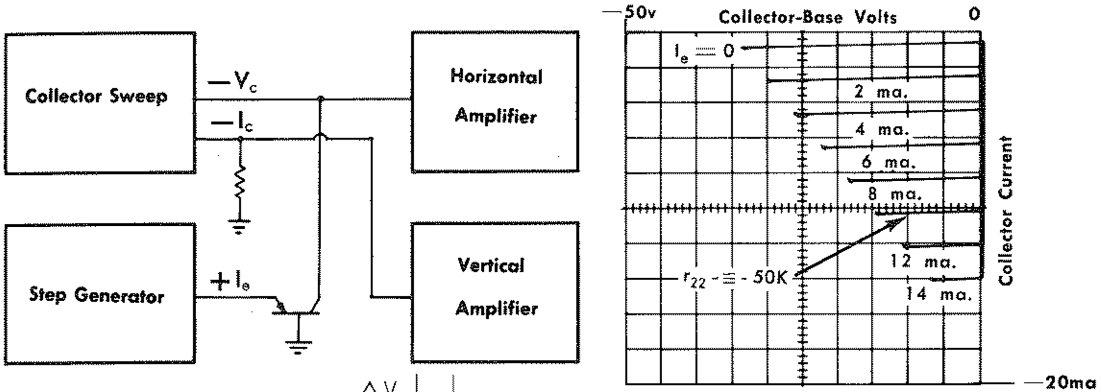




$$r_{12b} = \frac{\Delta V_e}{\Delta I_c}\Big| I_e \Big| = r_b.\ \text{Slope} = r_{12}.$$

Output Resistance (input open-circuited to ac).

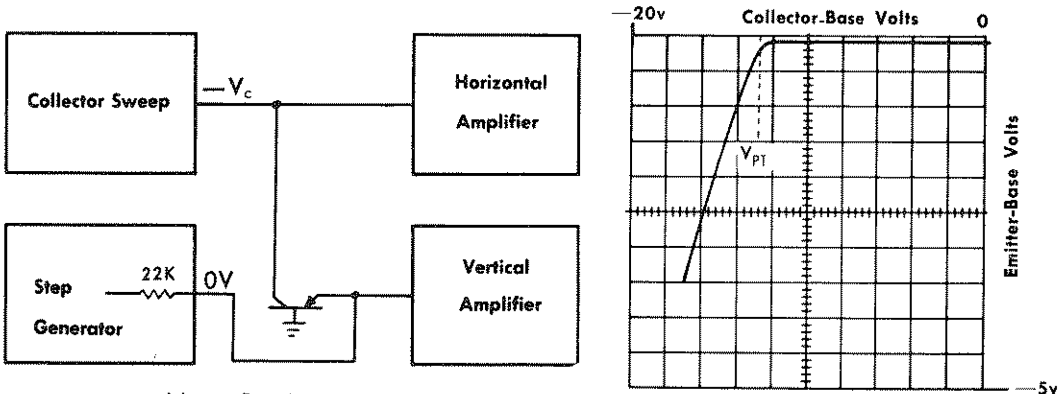
2N407 PNP junction transistor



$$r_{22} = \frac{\Delta V_c}{\Delta I_c}\bigg|_{I_e} = r_b + r_c. \quad \text{Slope} = r_{22}.$$

Punch-Through Voltage (V_{PT}) and Floating Potential.

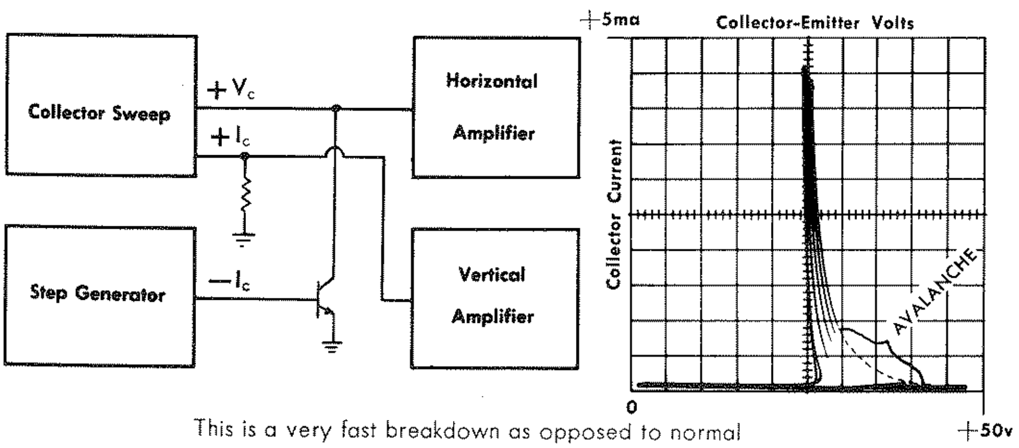
X-Philco surface-barrier transistor.



Note: Punch-through rarely occurs before BV_{CE}. V_{EB} is the floating potential

Back-Biased NPN in Avalanche Mode

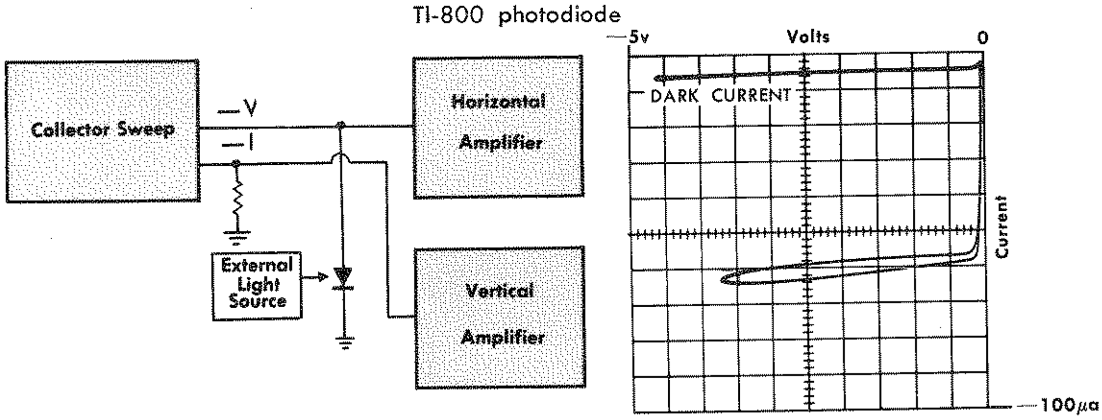
2N212 NPN junction transistor



This is a very fast breakdown as opposed to normal Zener breakdown.

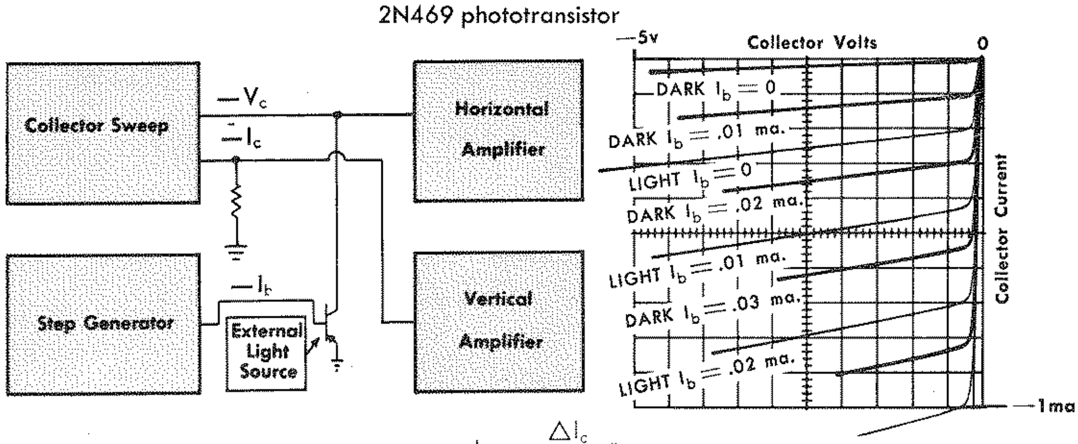
Photodiode, with and without light

TI-800 photodiode



Phototransistor, with and without light

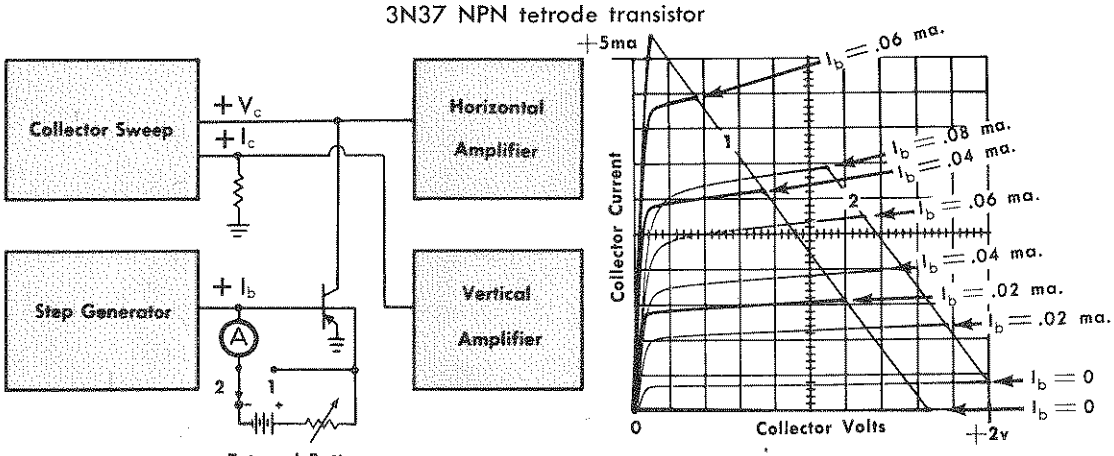
2N469 phototransistor



$$h_{fe} = \frac{\Delta I_c}{\Delta I_b}, r_{22}$$

Tetrode NPN: Effect of Interbase Bias

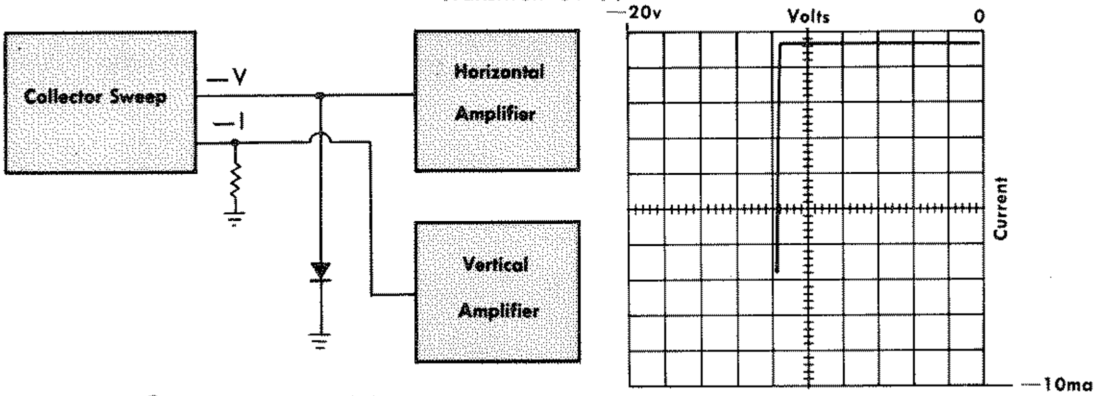
3N37 NPN tetrode transistor



Note the reduction in Beta with interbase bias.

Zener or Reference Diode, Reverse Biased

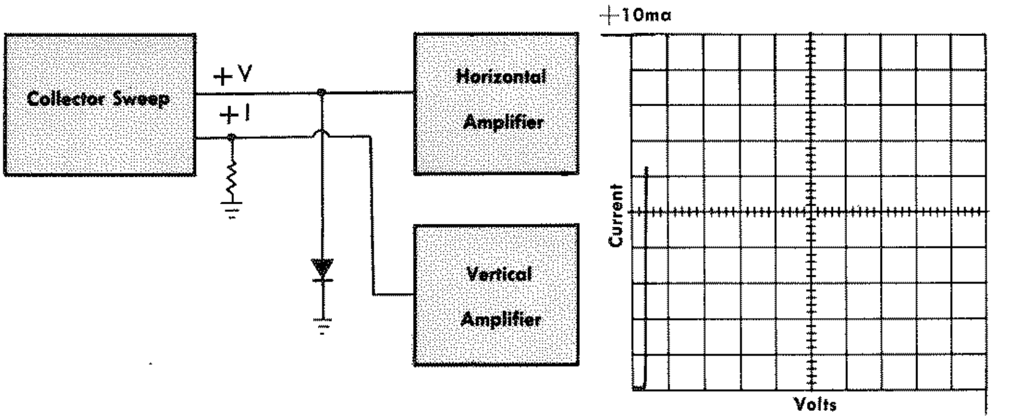
Transitron SV-11



Operating potential (Zener region), Dynamic impedance (slope)

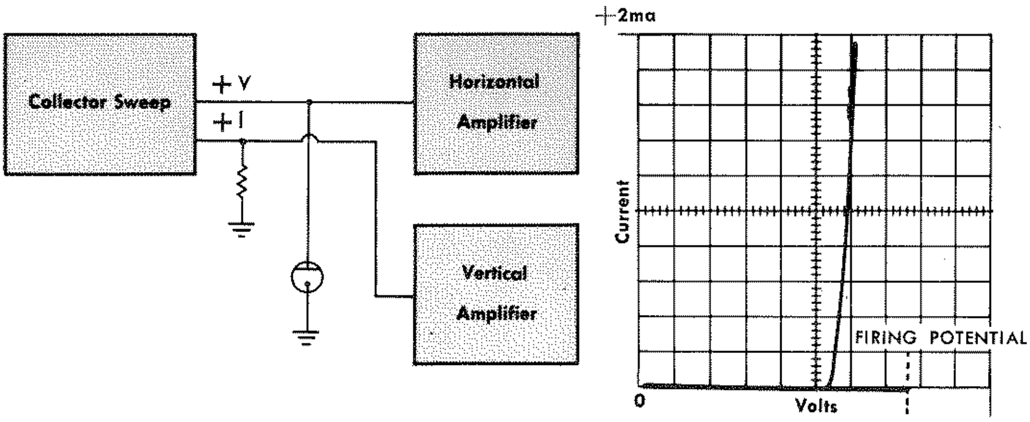
Zener or Reference Diode, Forward Biased

Transitron SV-11



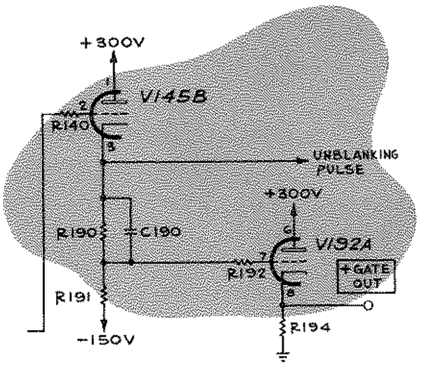
The forward and reverse curves can also be plotted for semiconductor diodes and metallic rectifiers.

Voltage Regulator Tube NE-2



Firing potential, operating potential and dynamic impedance

NOTES



SECTION 3

CIRCUIT DESCRIPTION

Block Diagram

The Block Diagram shows the relationship of the Collector Sweep, the Step Generator, the Step Amplifier, and the CRT Deflection Amplifiers to the transistor under test. The Step Generator is driven by the 60-cycle line voltage and the waveform from the Step Amplifier is applied to the input of the transistor under test. The Collector Sweep Generator supplies the full-wave rectified pulses that are applied to the collector of the transistor. Notice that the pulsations occur at twice the line frequency. The crt deflection amplifiers are shown connected for a display of the transistor I_c - V_c characteristic curves.

The three possible time relationships between waveforms of the Collector Sweep and the Step Generator are shown in Fig. 3-1. In waveform (b), each voltage step begins at a time when the Collector Sweep voltage is zero. In waveform (c), each step begins at a time when the Collector Sweep voltage is at its maximum value. In waveform (d), steps begin both at times when the Collector Sweep voltage is at its maximum value and when it is at its minimum value.

Collector Sweep

The Collector Sweep circuit rectifies the 60-cycle line voltage (full-wave circuit) to produce 120 sweeps per second for the collector of the transistor under test.

The primary voltage of T702 is variable from 0 to 140 volts rms by the variable autotransformer T701 (PEAK VOLTS control). The secondary of T702 provides output voltages up to 20 volts and 200 volts, peak, depending on the setting of the PEAK VOLTS control and the PEAK VOLTS RANGE switch SW706. The collector-supply primary is protected by a circuit breaker, set to trip within 30 seconds at 1.2 ampere rms current but to hold on a rms current of 1 ampere. The turns ratio of the transformer for the 20-v range is such that a maximum peak current of 15 amperes is available with 1 ampere rms in the primary. Because the current pulses for transistors are not sinusoidal nor of constant amplitude, and their duty cycle is dependent upon the characteristics of the device being tested, it is difficult to say what maximum collector-current curves can be plotted. Generally, a family of collector-current curves can be plotted to 20 amperes or more

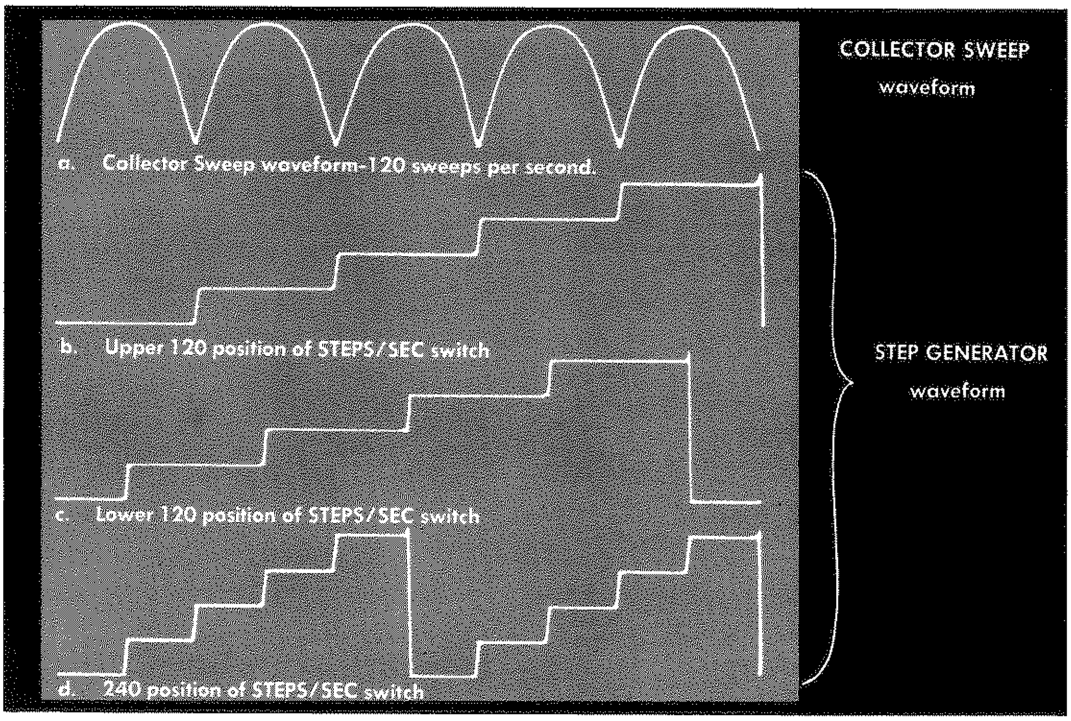


Fig. 3-1. The time relationship between waveforms of the Collector Sweep circuit and the Step Generator.

when the transistors have a beta of 8 or greater. When checking diodes, you will notice that the waveform of current pulses is such that a curve of approximately 15 amperes maximum is drawn.

By means of the PEAK VOLTS RANGE switch, each set of rectifier diodes is connected in parallel for the 0-20 volt range, or in series for the 0-200 volt range. The polarity of the output sweeps is determined by the POLARITY switch SW708. The DISSIPATION LIMITING RESISTOR switch SW710 connects the desired value of resistance in series with the collector to protect the transistor.

To compensate for the stray-circuit-capacitance charging current through the Current Sampling Resistor, a sample of the collector sweep voltage is applied through the cathode-follower V733 to the top of the Current Sampling Resistor. Capacitors C706 and C735 are used to balance the circuit capacitances.

Step Generator

The circuit diagram of the Step Generator may be considered in two sections: the pulse-generator section (left side) which develops rectangular pulses from the sine-wave input, and the staircase-generator section which uses these pulses to develop a staircase waveform. V171 is the "heart" of the Step Generator and its operation will be described first.

Staircase Generator

The staircase waveform is generated by increasing the charge on a capacitor by equal steps and then discharging the capacitor after the desired number of steps has been generated. A simplified example is shown in Fig. 3-2. When the switch is closed the voltage will rise at the normal RC charging rate as in curve A. If the switch is closed in a series of short, equal intervals, a staircase waveform like that of waveform B is produced. It is a very poor staircase waveform because the steps become progressively smaller as the voltage across the capacitor increases. To achieve a series of equal-amplitude steps, the capacitor charging current, and hence the voltage across the resistor, must be kept constant.

The diagram of Fig. 3-3 shows a method of achieving this end. It is called the Miller integrator. With the switch in position 1, the plate of the pentode is at +100 volts, the quiescent output voltage, and the charge on C177 is 101.5 volts.

When the switch is moved to position 3, C177 charges through R1 and the grid of V171 tends to become more negative. But since a negative signal on the control grid reduces the plate current, the plate voltage increases, raising the voltage at the top of C177. The coupling of this positive change at the top of C177 to the control grid almost completely cancels the negative-going tendency of the control grid. Since the dc gain of the pentode stage is very high, the plate-voltage change is always very large compared to the voltage change that occurs on the grid.

When the switch is moved to position 1, the charging process stops and the tube returns to its initial condition, discharging C177 to 101.5 volts.

Waveform A of Fig. 3-3 is the output waveform which results from moving the switch from position 2 to position 3 at a regular rate. Note that this staircase waveform has steps which are of equal amplitude, since C177 is charged at the same rate whenever the switch is in position 3. Waveform B is the corresponding grid waveform.

The circuit of Figure 3-4 is a modification of the one in Fig. 3-3, the only changes being the addition of a cathode follower between the plate of the pentode and the top of C177 and an additional switch position which permits the coupling of negative-going pulses to the bottom of C177.

With the switch in position 1, the plate of the pentode is again at +100 volts; however, the output terminal (top of C177) will be about ground potential.

With the switch in position 4, and with no input pulses fed into diodes V172A and V172B, the output voltage is constant since the electrical path through C177 is incomplete. When

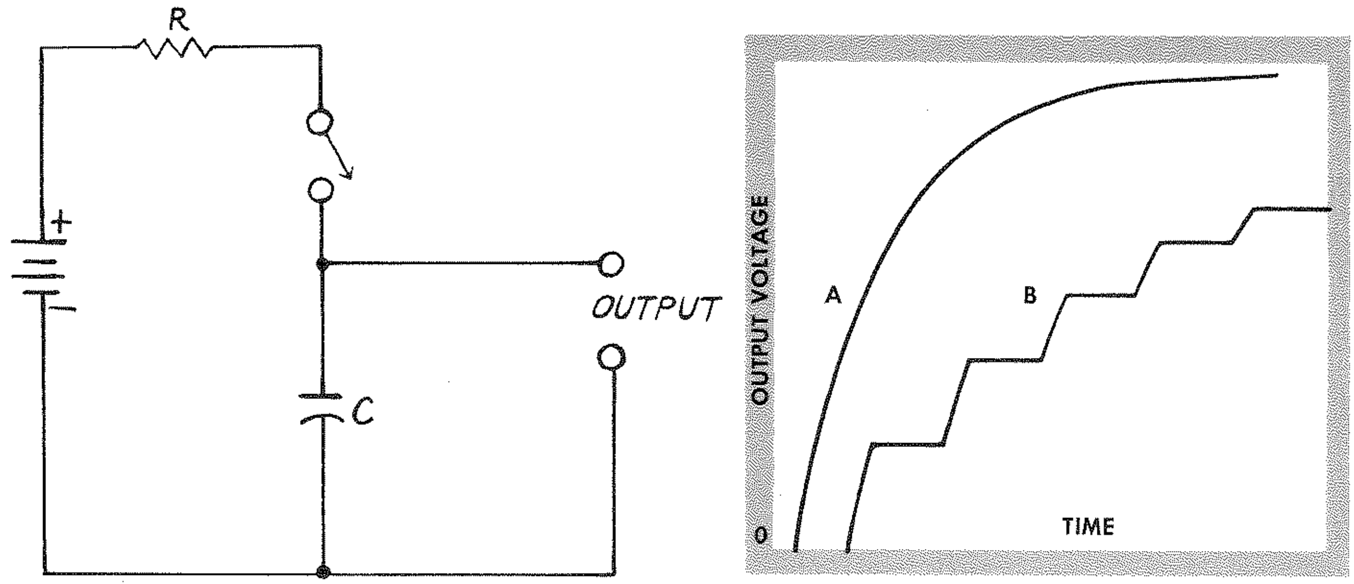


Fig. 3-2. Basic circuit (a) for generating a step waveform (waveform B in (b).

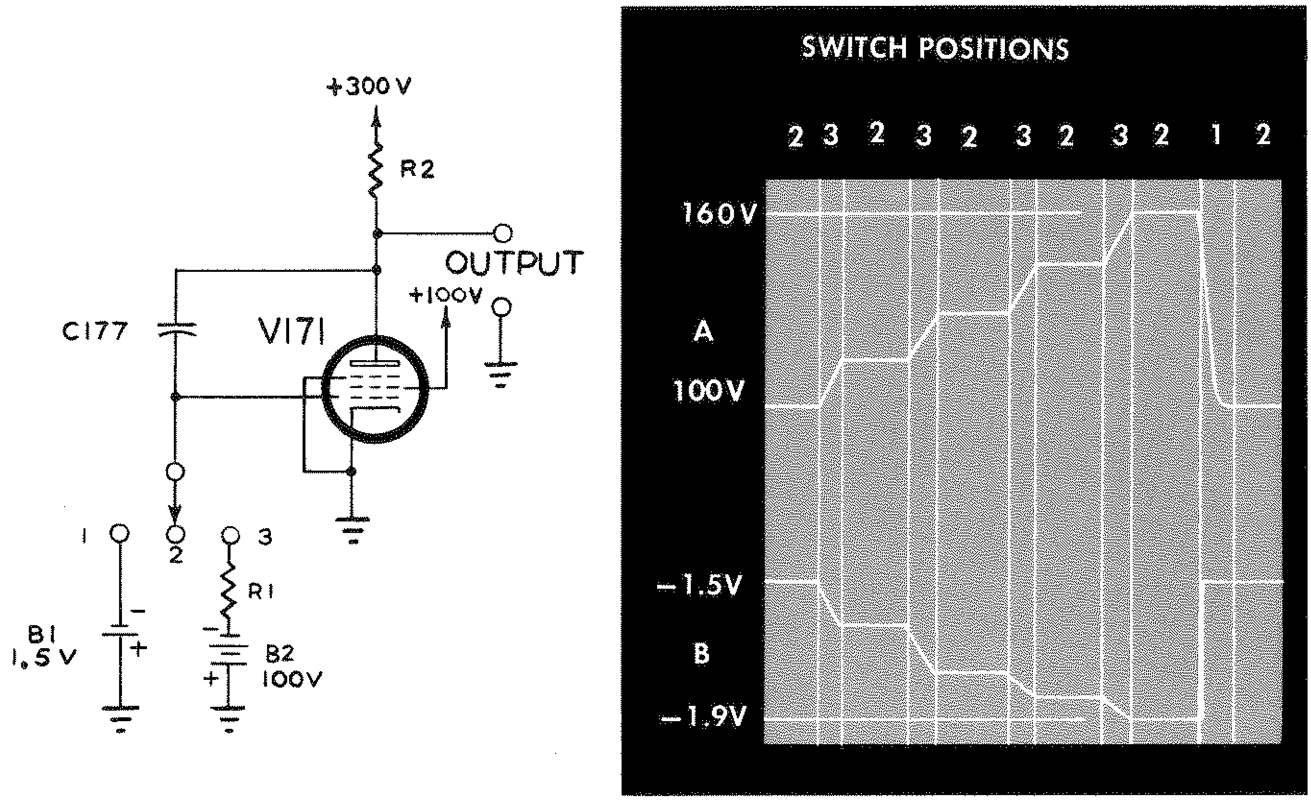


Fig. 3-3. The basic Miller Integrator circuit and the resulting plate and grid waveforms for linear step operation.

a negative pulse is fed to the cathode of V172A, C142 transfers a quantity of its charge to C177. As the negative input pulse returns to its base level, V172A stops conducting. V172B, however, begins to conduct heavily to restore the charge on C142.

Because the Miller integrator keeps the voltage at the bottom of C177 nearly constant, the same quantity of charge is transferred to C177 with each pulse. The voltage steps occuring at the output are equal, because the voltage across a capacitor is directly proportional to its charge.

The changing charge on C142 is an important part of the generation of steps. On waveform C, point "a" (between negative pulses) shows the left end of C142 to be +150 volts. Waveform B shows that at the same time, the junction of diodes V172A and V172B is near ground. The charge on C142, then, must be about 150 volts. As a negative pulse begins, the left end of C142 is driven negatively toward +50 volts. As the right end of C142 tries to follow, V172A provides a current path for C177 and its charge is increased as shown on waveform A. Since the capacity of C177 is about 7 times as large as that of C142, the increase in voltage across C177, 15 volts is equal to 1/7 of the decrease in voltage across C142. Because the Miller integrator keeps the bottom of C177 at a constant voltage, the 15-volt step occurs at the output and not at the grid of V171.

Repetitive Triggering

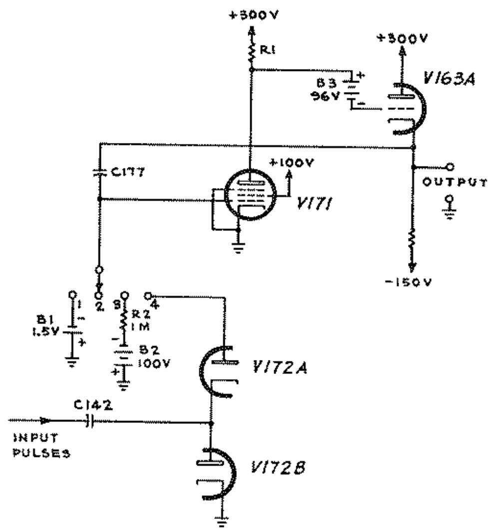
The circuit of Fig. 3-5 is used to show the operation of the Schmitt Trigger and the Hold-Off Cathode Follower. Their action provides a repetitive display, since they cause C177 to be discharged and then permit the formation of steps to proceed again in the same manner as described previously.

For our purposes, we think of the Schmitt Trigger as a voltage-activated switch. In its operation, the entire current through R156 in the cathode circuit is shifted from one section of V155 to the other. When one side of V155 conducts the other side is cut off.

Typical conditions for conduction are as follows: when the grid voltage of V155A is above —42 volts, V155A conducts; when the grid voltage of V155A is below —58 volts, V155B conducts. When the grid voltage of V155A is within the range from —42 to —58 volts, either tube section may conduct, but not both sections. The output of the trigger circuit is at the plate of V155B. The voltage at this plate switches between zero (V155B cut off) and a negative voltage (V155B conducting).

When V155B is conducting, the diodes V152A and V152B are cut off because their plate voltages are more negative than their cathodes. This condition permits the staircase generator to generate a stairstep waveform as described previously. As the output stairstep waveform rises, the cathode voltage of V143B follows. When the cathode voltage (and the grid voltage of V155A) reaches —42 volts, the Schmitt trigger will switch to its other stable state; that is, V155A will be conducting and V155B will be cutoff.

When V155B is not conducting, its plate voltage will be at ground potential, permitting diodes V152A and V152B to conduct. As V152B conducts, the grid of V171 is clamped at ground potential causing the plate voltage to fall rapidly.



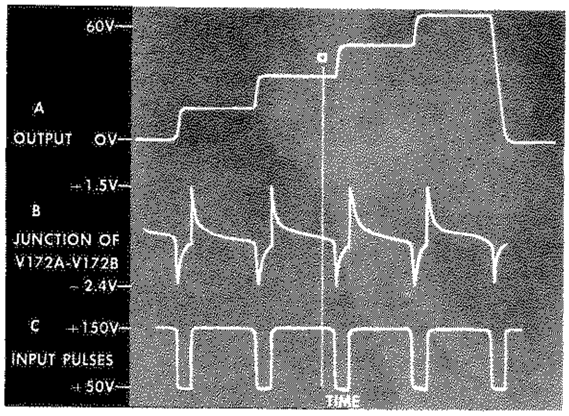


Fig. 3-4. Modification of Fig. 3-3.

As the plate voltage of V171 falls, the cathode voltage of V163A also falls, discharging C177. The cathode of V163A is prevented from going below ground potential by conduction of V152A. Because the Miller tube grid is clamped at ground potential by V152B, its plate voltage will quickly reach an equilibrium condition.

As the cathode voltage of V163A falls, so do the voltages at the cathode of V143B and the grid of V155A. If they go more negative than —58 volts, V155A will be cutoff, V155B will conduct, V152B will no longer clamp the grid of the Miller tube, and the stepping process will be resumed.

Note that the cathode circuit of V143B consists of a resistor shunted by a capacitor. If V143B is driven below cutoff, the rate of fall of the cathode voltage will be limited by the discharge rate of C186 through R186. This time-delay circuit affects only relatively fast negative-going signals; positive-going signals are not delayed. C180 emphasizes rapid changes in the output signal at the grid of V143B, and tends to compensate for the loading effect of C186 in the positive direction.

The time delay in the negative direction is necessary to allow C177 to be discharged to the point where the output voltage of the Step Amplifier has fallen to the base level before the Schmitt trigger reverts and permits the stepping process to be resumed.

Single-Family Triggering

On the circuit diagram of the Step Generator, notice the section of switch SW145 which is shown near C143B. In the OFF position of SW145, a voltage divider formed by R184 and R186 fixes the grid voltage of V155A to keep it in conduction. As a result, V155B is cutoff, disabling the Staircase Generator.

The display of a single family of curves requires that the Schmitt trigger change to its other conduction state long enough for the desired number of steps to be generated, then revert to the OFF position condition. To start the generation of one stairstep waveform, the top of C146 is grounded by depressing SW145 to the SINGLE FAMILY position. This drops the grid of V155A about 50 volts, causing the trigger circuit to change to its other state (V155B conducting).

When V155B conducts, V171 is no longer clamped and the staircase generator is ready to generate a series of voltage steps. When the desired number of steps has been generated, V143B acts in the usual way to bring V155A into conduction again.

Pulse Generator

The circuit diagram of the step Generator shows the split-load phase inverters, V104A and V124A, driven by sine waves at the power-line frequency. The single angle between these signals is adjusted to 90 degrees by the RC networks R102/C102 and R122/C122. The resulting waveforms, A and B, are shown in Fig. 3-6; the voltages are approximate. The output of each phase inverter is rectified to produce a pulsating dc waveform (C) (D) at a frequency of 120 cps. The rectified outputs of the phase inverters are fed into two pentodes (V104B and V124B) having a common plate-

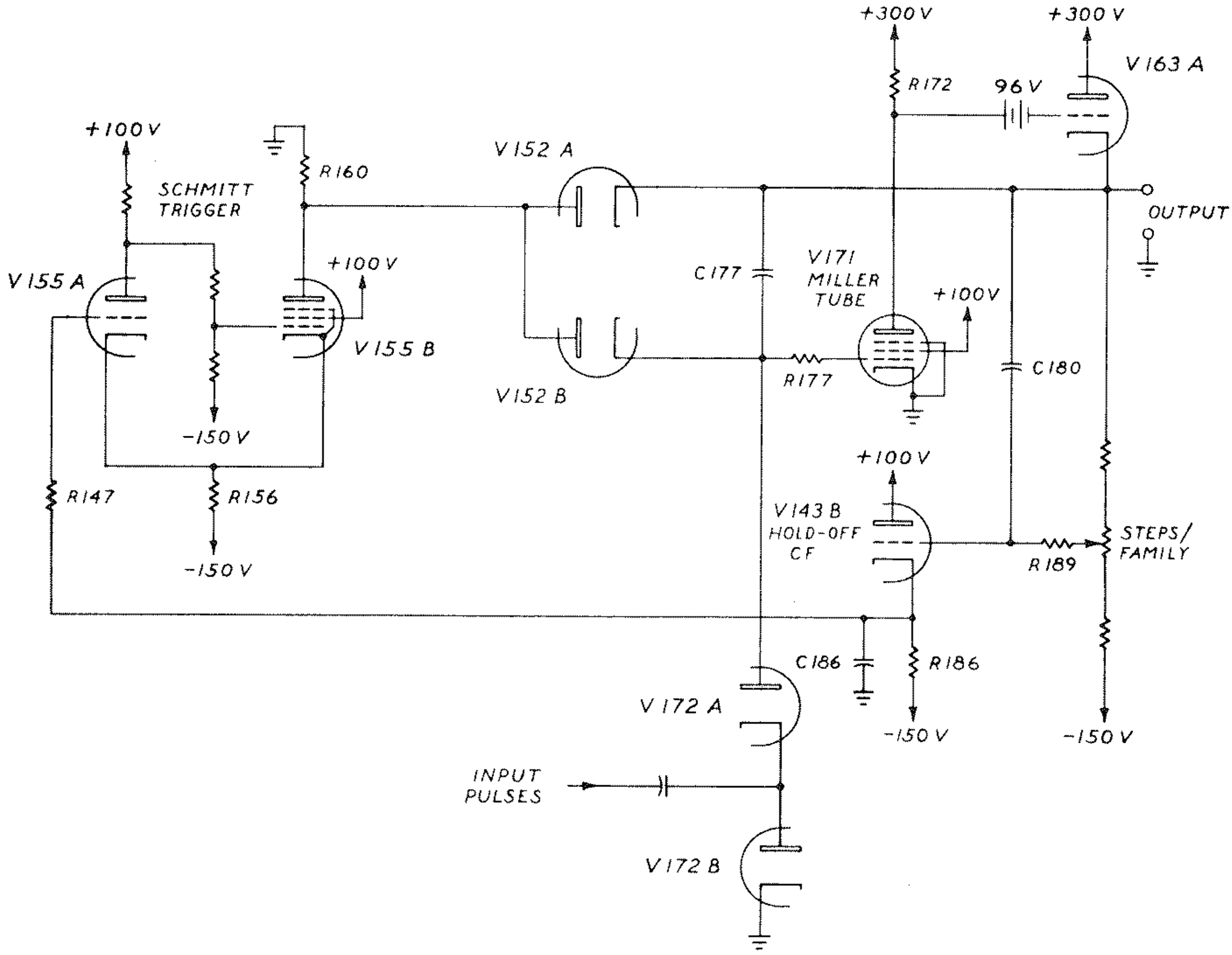


Fig. 3-5. The complete stairstep generator.

load resistor. The voltage at the common plate swings between the plate-supply voltage and ground because the voltage at the input grids drive the tubes from below cutoff to saturation. The frequency of these pulses is 240 per second (or 4 times power-line frequency). The first negative-going pulse is extra wide because the pulse generator is disabled by the clamping action of V163B during the time V155B is cut off. A cathode follower (V143A) provides a low-impedance output.

The upper limit of the pulses appearing at the cathode of V143A, determined by the setting of the VOLTS/STEP ADJ, is 150 volts. The lower limit, determined by R142/R143 is 50 volts.

Each negative-going pulse applied to the left side of C142 causes C142 to partially discharge into C177. C142 recharges through diode V172B as the input pulse returns to 150 volts. The voltage across C177 increases 15 volts with each transfer of charge. The action of the Miller integrating circuit causes this voltage increase to appear at the top of C177. The voltage at the bottom of C177 remains almost constant.

Between pulses, C177 has no discharge path and the voltage at the output of the Step Generator remains constant.

After the trigger has reverted to its initial state (V155B conducting), V163B and V152B no longer conduct and another staircase waveform is generated in response to the pulses applied to the left of C142.

Fig. 3-7 illustrates the sequence of events occuring in the generation of a staircase waveform. Voltages shown are approximate.

Step Amplifier

The voltage gain of the Step Amplifier is less than one, but the current gain is several thousand. The functions of the Step Amplifier are as follows:

1. It permits selection of the size of the output steps (current or voltage).

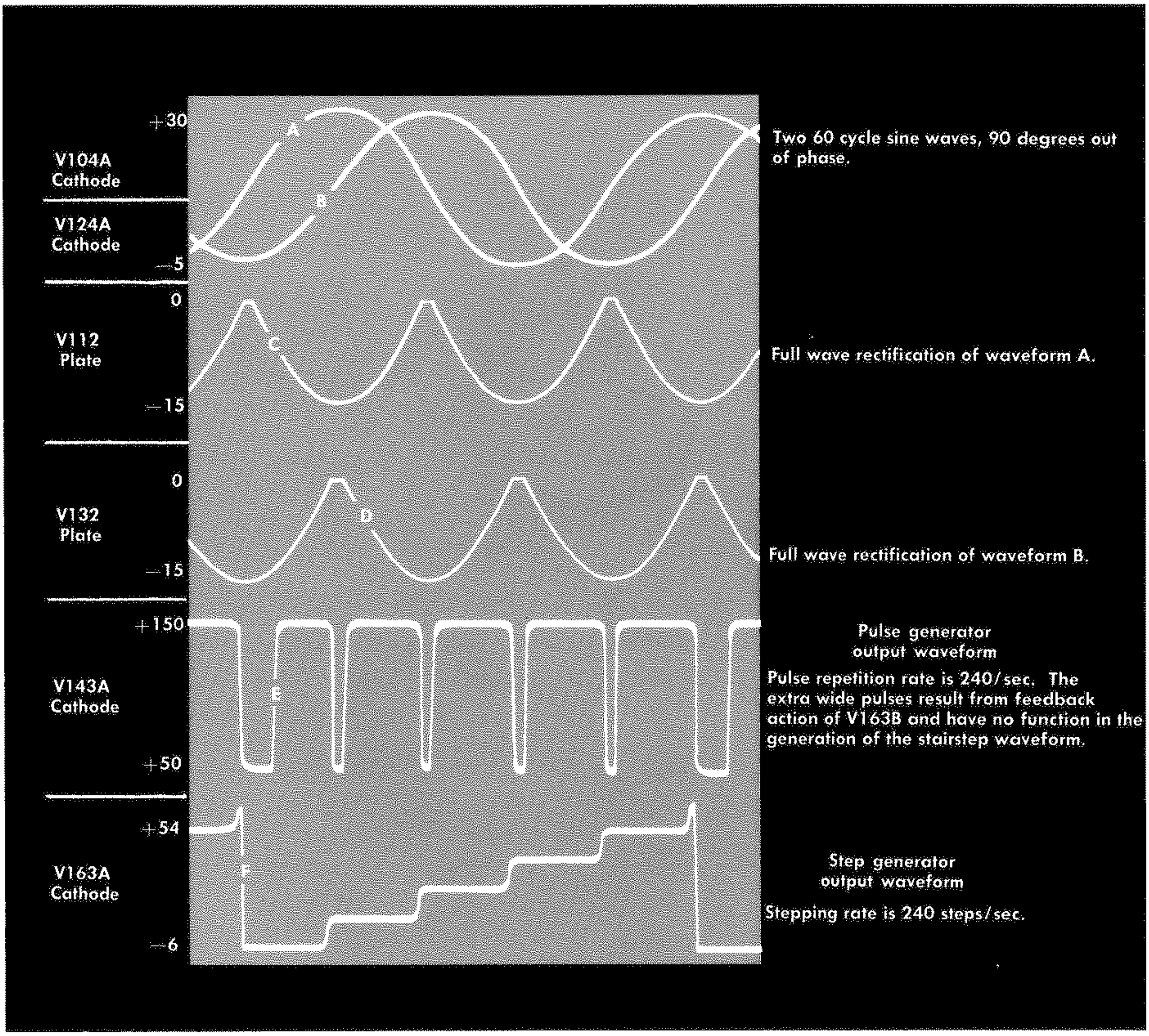


Fig. 3-6. Time relationships between the Step Generator output waveform at key points in the pulse generator section.

2. It regulates the size of the output steps (within limits) to the value chosen by means of the STEP SELECTOR switch.

3. It provides either a positive-going or a negative-going output waveform.

Figure 3-8 illustrates the role of the Step Amplifier in providing either *voltage* or *current* steps to the input of PNP transistor.

The two positions shown on SW246, the STEP SELECTOR switch, correspond to the volts-per-step and ma-per-step ranges.

The Step Amplifier consists of three functional units; a current-regulated power supply, a power-transistor output stage, and an amplifier with a voltage gain of about one.

Output Stage

A transistorized power output stage is used to deliver the output current of the Step Amplifier because of the relatively large regulated currents which must sometimes be applied to the input of the transistor under test. Since the Step Amplifier must furnish high current of either polarity, a floating power supply is used in the output stage.

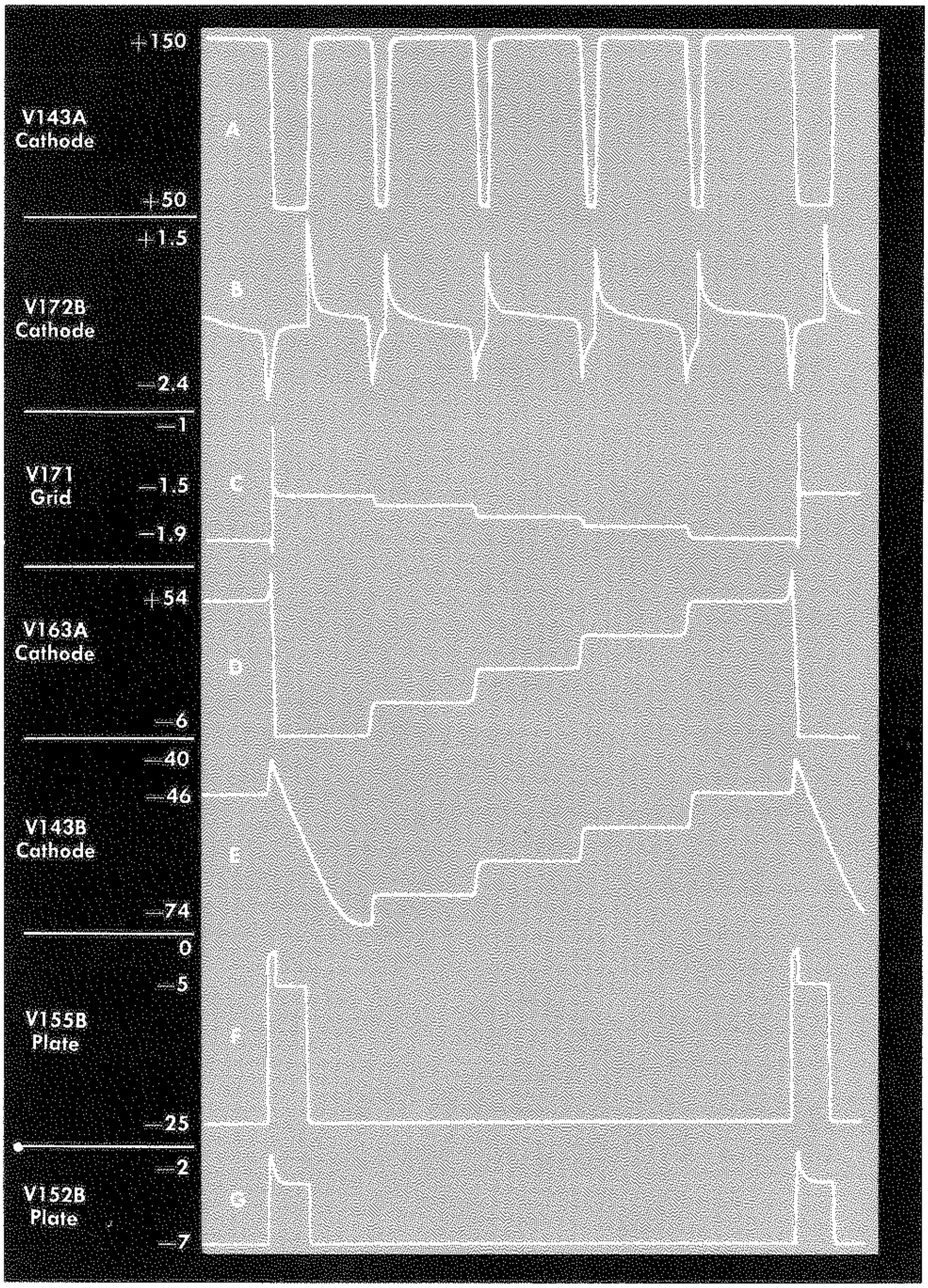


Fig. 3-7. Time relationships between the Step Generator output waveforms (D) and waveforms at key points in the step generator section.

Fig. 3-9 (a) is a diagram of a transistor operating as an emitter follower. Fig. 3-9 (b) is the vacuum-tube equivalent of the same circuit. Note that in both cases the output signal is *in phase with* the input signal. The average value of the output voltage may be set to zero by proper biasing of the input.

Fig. 3-10 shows how an *out-of-phase* signal centered around ground can be obtained with the same general configuration. Note that only the ground point has been moved. The transistor is no longer operating as an emitter follower, but as an ordinary voltage amplifier. The 100-ohm resistor is now the collector load resistor.

The approximate positive and negative limits of the no-load output voltage of Fig. 3-10 can be determined by considering the transistor as a switch which is either opened or closed. When the switch is closed (emitter and collector shorted), the output voltage must be +15 volts. When the

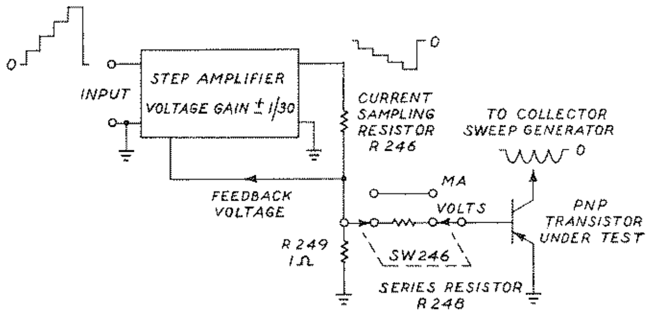


Fig. 3-8. The Step Amplifier furnishes either current or voltage steps to the input of the transistor under test.

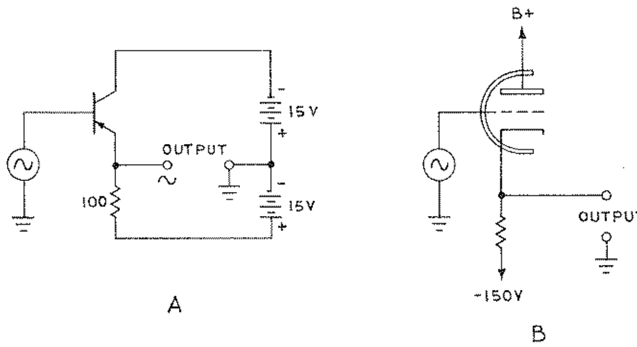


Fig. 3-9. The emitter-follower (a) operates the same as the cathode-follower (b).

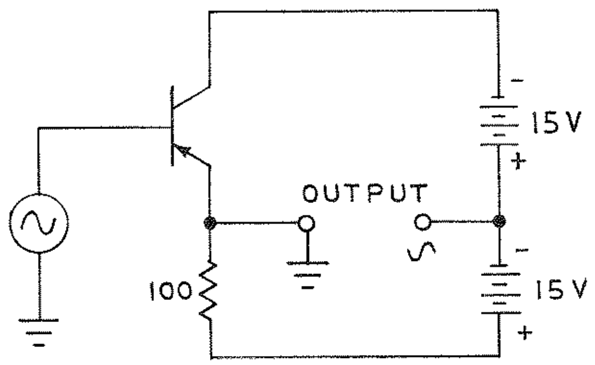


Fig. 3-10. By switching the output connections, the emitter-follower of Fig. 3-9 (a) becomes a collector-loaded amplifier.

switch is open (no current through the collector), the no-load output voltage must be —15 volts.

The circuits of Fig. 3-9 (a) and Fig. 3-10 have maximum-current limitations which are different. The circuit of Fig. 3-9 (a) can supply much more current in the *negative* direction, (making the ungrounded end of the load resistance negative) than it can supply in the positive direction (through the 100-ohm resistor).

By the same method, it can be shown that the circuit of Fig. 3-10 can supply much more current in the *positive* direction than in the negative direction.

Since the path of the higher current through the load in both circuits was always through the upper battery, the upper battery must be able to deliver more current than that which is required of the lower one.

The drawing of Fig. 3-11 shows the electron-current flow through the circuit components as the Step Generator drives a load resistance in the negative direction. The lower battery supplies only the current which flows through the 100-ohm resistor. The upper battery must supply current to the load as well.

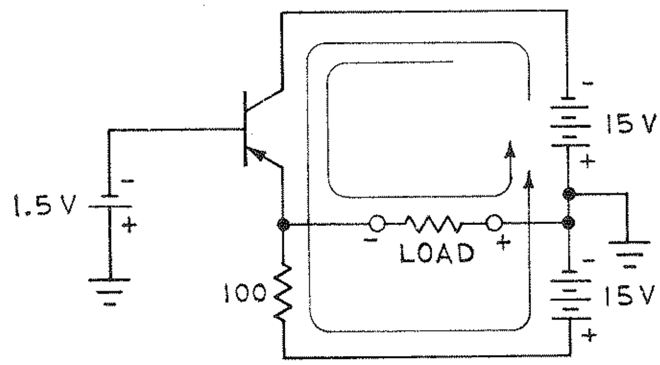


Fig. 3-11. Electron flow through the transistor V253 circuit when negative-going steps are required.

Figure 3-12 is a simplified diagram of the output circuit of the Step Amplifier. Note that the load resistance across the output circuit is always the current-sampling resistor in series with either a 1-ohm resistor (voltage steps) or the input of the transistor under test (current steps). The feedback paths go directly to vacuum-tube grids and do not load the output circuit.

The maximum current the Step Amplifier will deliver to an external load is 2.4 amperes of either polarity (ma-per-

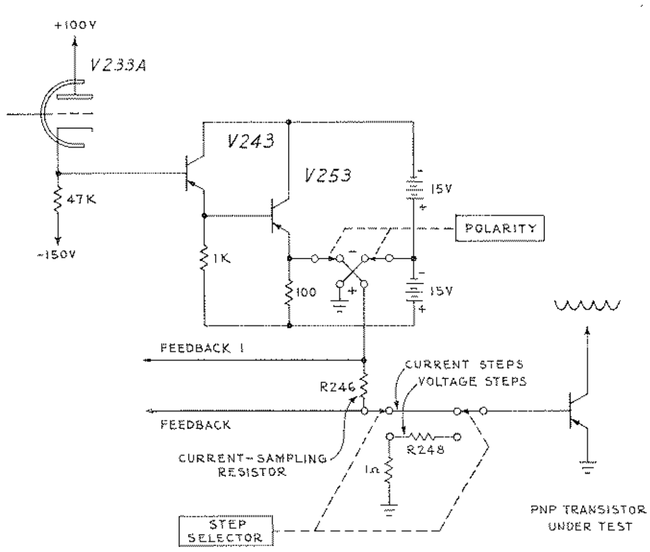


Fig. 3-12. Simplified diagram of the output circuit of the Step Amplifier.

step positions of the STEP SELECTOR switch). However, the characteristics of the external load must be such that the voltage drop across the external load resistance is no more than 5 volts when the current through it is 2.4 amperes. At lower currents, however, the 5-volt figure may be exceeded.

The simplified diagrams of Fig. 3-13 and 3-14 show the operation of the entire Step Amplifier when delivering current steps to the input of the transistor under test. Current regulation is accomplished by maintaining a constant voltage drop across R246 for each step of the input voltage from the Step Generator. That is, each time the input voltage is stepped 15 volts, the voltage drop across R246 should change 1/30 of 15 volts, or 0.5 volt, and remain at the new voltage for the duration of the step. This will provide steps of constant current proportional to the input voltage steps.

It would be a simple matter to maintain a constant voltage across R246, proportional to the input steps, if the voltage at the lower end of R246, (that is, the voltage at the input to the resistor under test) were constant. In other words, if we fix the voltage at the lower end of R246 at some potential, say ground, the voltage across R246 would remain constant for the duration of each of the input steps, and would change only when the input voltage steps from one level to the next.

However, the lower end of R246 is connected to the input of the transistor under test and not to a fixed reference. When the collector sweep voltage is applied to the collector of the transistor the voltage at the input of the transistor will change and the voltage at the lower end of R246 will change. In order to maintain a constant voltage, the voltage at the upper end of R246 must change the same amount and in the same direction as the voltage at the lower end. To accomplish this action the +1 Amplifier and the feedback loops couple any voltage change at the lower end of R246 to the difference amplifier V214-V224 which in turn, through the cathode-follower V233A and the output amplifier V243- V253, produces the same voltage change at the top of R246. Fig. 3-13 shows the circuit configuration when the POLARITY switch is set for a negative output. The operation of the circuit will be explained in two parts; first, to show how the voltage at the top of R246 changes in proportion to the input steps, and second, to show how the voltage at the top of R246 changes as a result of any voltage change at the bottom of R246.

Assume the input voltage changes from 0 to +15 volts (1 step). This tends to make the voltage at the grid of V214 go in the positive direction, and the plate voltage to go in the negative direction. The voltage at both the grid and cathode of the cathode-follower V233A goes in the negative direction, following the plate of V214. Q243 is an emitter-follower, so its emitter goes in the negative direction carrying with it the base of Q253. Since Q253 is also connected as an emitter-follower, for negative-polarity operation, its emitter and hence the voltage at the top of R246 goes in the negative direction.

A positive step at the input will therefore produce a negative step at the top of R246. This negative step also appears at the lower end of R203, since this point is connected to the top of R246. This means that as the top of R202 goes positive the lower end of R203 goes negative. The amplifier and feedback network therefore acts as a "teeter-totter" circuit that pivots about the junction of R202-R203; the grid of V214 is at virtual ground, or zero, potential.

Since the top of R203 is at ground potential, the change in voltage across R246, due to an input step, is equal to the change in voltage across R203. R202 and R203 make up a

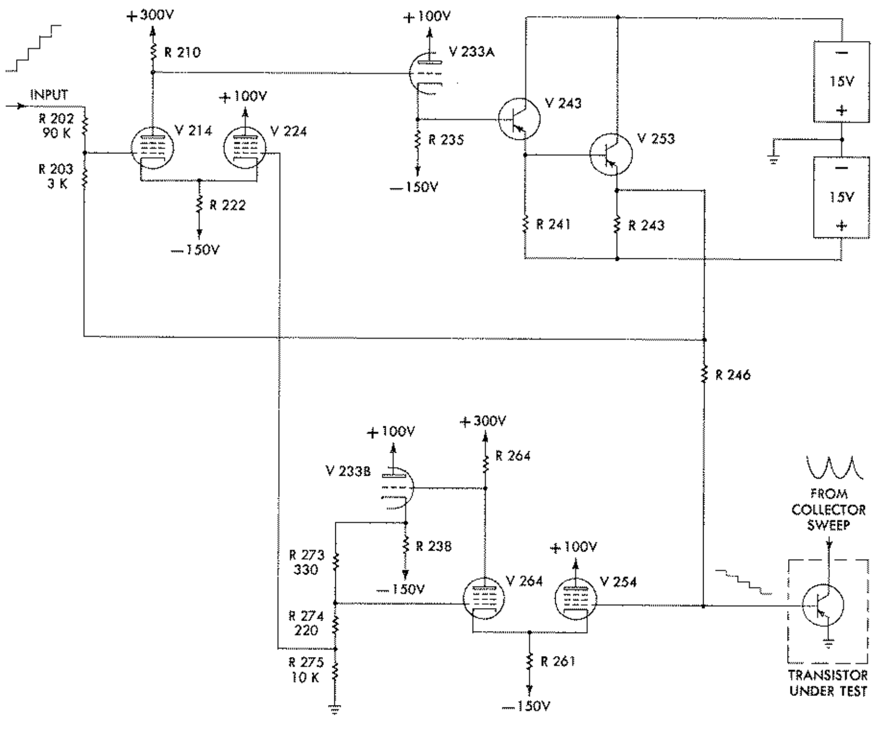


Fig. 3-13. Simplified diagram of the Step Amplifier for negative-going current steps.

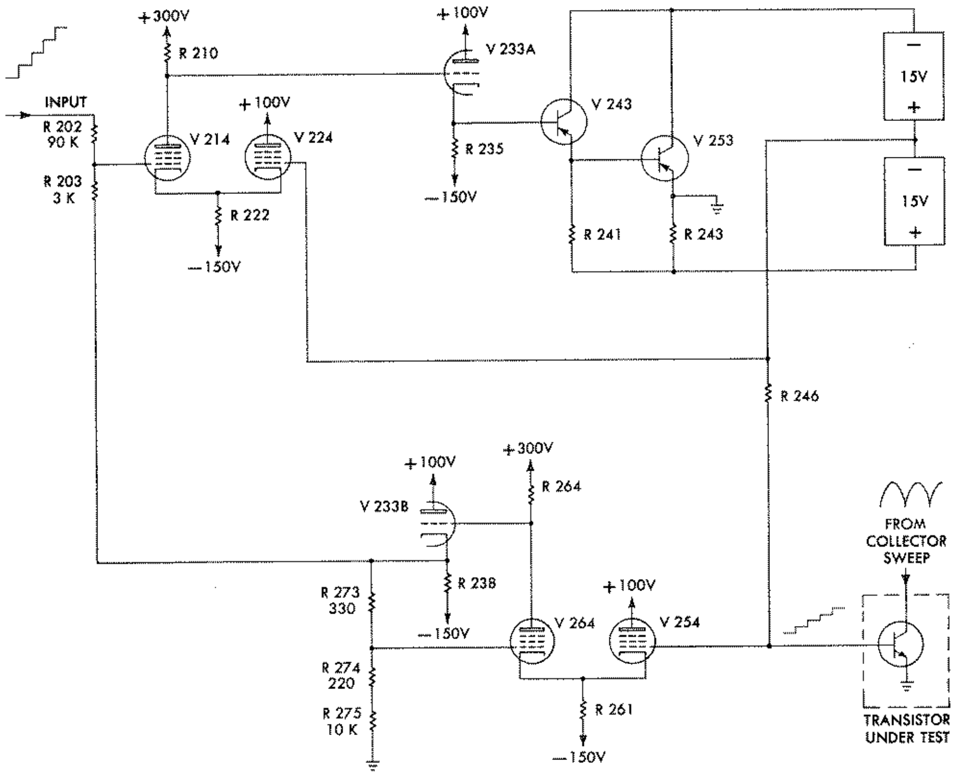


Fig. 3-14. Simplified diagram of the Step Amplifier for positive-going current steps.

30 to 1 divider; a 15-volt step in the positive direction at the top of R202 will therefore produce a 0.5-volt step in the negative direction across R246.

If the voltage at the lower end of R246 changes, the voltage at the top of R246 must change the same amount and in the same direction. This will insure that the voltage drop across R246 is proportional only to the input step voltage.

The +1 Amplifier is a feedback amplifier whose gain is just slightly greater than unity. The input impedance of this circuit is very high, so that it does not load the input of the transistor under test.

Let us assume that the voltage at the lower end of R246, and hence at the grid of V254, goes in the positive direction. This will cause the cathodes of V254 and V264 to go in the positive direction. The voltage at the plate of V264 will then go up carrying with it the voltage at the grid and cathode of V233B. Because the gain of the circuit is slightly greater than unity the change in voltage at the cathode of V233B will be slightly greater than that at the lower end of R246, but will be of the same polarity.

The output of V233B is applied to a divider consisting of R273, R274 and R275. One tap on the divider couples almost all of the output voltage back to the grid of V264. This causes the grid of V264 to move in the same direction as its cathode, and hence reduces the gain of the stage to just slightly greater than unity. The gain of the +1 Amplifier is therefore relatively independent of tube characteristics and is determined almost entirely by the ratio of R273 to R274 + R275.

The resistance values in the divider are chosen so that the change in voltage at the top of R275 is the same as that at the grid of V254 (the lower end of R246). This positive-going voltage at the top of R275 is then applied to the grid of V224, and the cathodes of V224 and V214 go in the positive direction. This causes the voltage at the plate of V214 to go up, and since there is no polarity shift in V233A or the emitter-followers, the voltage at the top of R246 will go up. Thus, the voltage at the top of R246 follows any voltage change that may occur at its lower terminal. This prevents any change in the voltage at the input of the transistor under test from affecting the current through R246, and provides for steps of constant current into the input of the transistor.

If voltage steps are desired, R249 (not shown on Fig. 3-13) is connected between R246 and ground. The current steps through R246 and R249 then produce voltage steps across R249 which are coupled through the series resistor R248 (not shown) to the input of the transistor under test.

When negative steps are required, the voltage steps at the top of R246 must be reversed in polarity from those at the input (positive-going steps are always applied to the input of the Step Amplifier). The 180-degree shift in signal polarity is accomplished in V214, since this stage is a plate-loaded amplifier. And, since V233A is a cathode-follower and the transistors are connected as emitter-followers, the polarity shift in V214 satisfies the circuit requirements.

When positive-going steps are required at the top of R246, however, the output of V214 must be reversed in polarity. This is accomplished by reversing the output and ground terminals in the Q253 circuit. Q253 is connected in the common emitter configuration, as shown in Fig. 3-14, and the load resistor R243 is connected into the collecter circuit. With this configuration V253 is a collector-loaded amplifier and will produce a 180-degree shift in the signal polarity. This will put voltage steps at the top of R246 in phase with input steps (positive-going steps).

To compensate for the additional shift in signal polarity, the grids of the difference amplifier V214-V224 must be switched insofar as the feedback loops are concerned. That is, the grid of V224 is now connected to the top of R246 and the grid of V214 is connected through R203 to the divider at the output of the +1 Amplifier. Notice, in Fig. 3-14, that the grid circuit of V214 is connected to the top of the divider at the output of the +1 Amplifier, while in Fig. 3-13 the grid circuit of V224 is connected to a tap on the divider.

Since the gain of the +1 Amplifier is just slightly greater than 1, the voltage at the cathode of V233B is slightly greater than that at the grid of V254. The voltage applied to the difference amplifier from the +1 Amplifier must be equal to the amount of correction needed to keep the voltage across R246 constant. The resistance values in the divider at the output of the +1 Amplifier are such that the voltage drop across R275 is the same as the voltage at the grid of V254. This satisfies the requirements of the circuit, in Fig. 3-13, where the feedback is applied directly to the grid of V224. In Fig. 3-14, the feedback is applied to the grid of V214 through R203, and, since there is a voltage drop across R203, the voltage at the output of the +1 Amplifier must exceed the required feedback voltage by an amount equal to this drop. For positive-polarity signals, therefore, the voltage at the output of the +1 Amplifier must exceed the voltage at the grid of V254 by an amount equal to the drop across R203.

CRT Deflection Amplifiers

The diagram of the Vertical and Horizontal Amplifiers include a simplified diagram of most of the switching related to these amplifiers. The purpose of the simplified diagram is to help you understand the relationships between the Vertical and Horizontal Amplifiers and other parts of this instrument. Accordingly, this discussion will include switching information.

The circuits of the Vertical and Horizontal Amplifiers are quite similar. Both consist of three difference amplifiers in cascade. A difference amplifier, or cathode-coupled phase inverter, rejects any signal applied to both input grids, responding only to a voltage difference between the input grids. The gain of the difference amplifiers in the Type 575 is stabilized by negative-feedback paths from the plates of the output amplifier to the opposite cathodes of the input stage.

The ranges of the VERTICAL and HORIZONTAL switches are shown in capital letters. Only a few of the positions in the COLLECTOR MA, BASE VOLTS, and COLLECTOR VOLTS ranges are shown. In the following paragraphs, the signal paths to the Vertical and Horizontal Amplifiers will be traced for each range of the corresponding switch.

Collector MA Display

Collector current is displayed on the vertical axis only. The collector current is proportional to the voltage drop across a current-sampling resistance. This voltage is fed directly to the control grid of V454, the other input to the vertical amplifier being grounded. One volt must be developed across the current-sampling resistance to cause a full-scale vertical deflection of ten major divisions. In all switch positions within the COLLECTOR MA range, the Vertical Amplifier works at a reduced constant gain. This reduced gain, one-tenth of maximum, is accomplished by inserting a resistance of about 10K ohms, R447 in parallel with R432B, between the cathodes of the input stage. R432B is located on the detailed switching diagram.

Base Volts

In the BASE VOLTS position of the VERTICAL switch, the control grid of V454 is grounded and a signal from the base of the transistor under test is fed to the control grid of V444. The sensitivity of the Vertical Amplifier is varied by changing the resistance between the cathodes of V454 and V444.

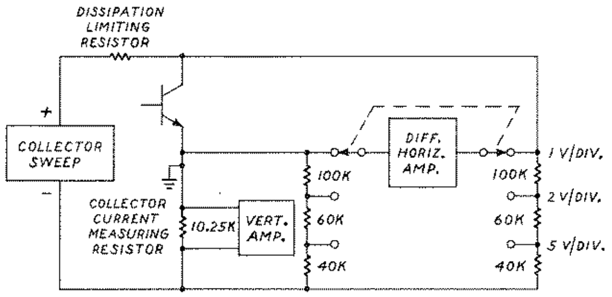


Fig. 3-15. With this configuration an accurate display of collector current (Vert. Amp.) and collector voltage (Horiz. Amp.) is obtained.

Collector Volts Display

The diagram of Fig. 3-15 shows the method used to solve the problem of presenting an accurate display of both collector current and collector voltage at the same time. Discussion of this diagram does not necessarily apply to corresponding parts of the Type 575. Note that two attenuators are used and that the horizontal display of collector voltage is obtained by using the common-mode rejection feature of the Horizontal Amplifier. As shown in Fig. 3-15, the Horizontal Amplifier amplifies only the voltage difference existing between its input grids.

Also note that the true current-sampling resistance is made up of the 10.25-K resistor and the attenuator in parallel with it.

Low-Voltage Power Supply

Plate and filament power for the Type 575 is furnished by a single power transformer T601. The primary windings may be connected in parallel for 105- to 125-volt operation, or in series for 210- to 250-volt operation.

The three regulated supplies furnish voltages of —150-volts, +100 volts and +300 volts. The +300-volt supply also has an unregulated output of about +400 volts for the oscillator tube in the high-voltage supply for the crt.

Reference voltage for the —150-volt, full-wave power supply is established by a voltage-regulator tube V649. This tube, which has a constant voltage drop of about 85 volts, is connected between the —150-volt bus and the grid circuit of V644A, one-half of a difference amplifier. The grid potential for the other half of the difference amplifier, V644B, is obtained from a divider consisting of R662, R664 and R666. The —150-V ADJ, R664, determines the percentage of total voltage appearing at the grid of V644B and thus determines the total voltage across the divider. When this control is properly set, the output voltage is exactly —150-volts.

The operation of the circuit can be explained by assuming the output voltage tends to change. For example, assume the loading on the supply tends to make the output voltage go more negative. The voltage at the grid of V644A will go negative the same amount as the output, since the voltage across the voltage-regulator tube is always constant. The voltage at the grid of V644B will go negative only a proportionate amount, however, since this grid obtains its voltage from the divider, an error voltage will then exist between the two grids of the difference amplifier, which will be in a direction to make less current go through the left side and more current through the right side.

The voltage at both the plate of V644B and the grid of V657 will then go in the negative direction, which will cause the voltage at the plate of V657 to go in the positive direction. The change in voltage at the plate of V657, which will be in a direction to compensate for the change in the output voltage, is coupled through the rectifier to the output and forces the output voltage back to its established value of —150 volts.

C644 and C655 improve the ac response of the feedback loop, thereby increasing the response of the circuit to sudden changes in output voltage.

The +100-volt supply uses silicon rectifiers in a full-wave bridge circuit. Reference voltage for this supply is obtained from the regulated —150-volt supply. The voltage divider R636-R638 establishes a voltage of essentially zero at the grid of V624. (The actual voltage at this grid is equal to the bias required by the tube). If the loading should tend to change the output voltage, an error signal will exist at the grid of V624. The error signal will be amplified and inverted in polarity, and will appear at the grids of the parallel cathode-followers V627A and V627B. The cathodes will follow the grids and will force the output voltage back to its established value of +100 volts. C630 improves the response of this circuit to sudden changes in output voltage.

A small sample of the unregulated bus ripple will appear at the screen grid of V624 through R624. The ripple signal appearing at the screen (which acts as an injector grid) will produce a ripple component at the grids of V627 which will be opposite in polarity to the ripple appearing at the plates of V627. This tends to cancel the ripple at the cathodes, thereby reducing the ripple on the 100-volt bus. The same circuit also improves the regulation of the supply in the presence of line-voltage variations.

The operation of the regulator circuit in the +300-volt supply is the same as that in the +100-volt supply.

CRT Circuit

A 30-kc Hartley oscillator circuit furnishes energy for the two half-wave power supplies that provide accelerating potentials for the crt. The main components of the oscillator circuit are V810 and the primary of T801 tuned by C809.

V812 supplies about +2400 volts for the post-deflection accelerating helix. V822 supplies about —1850 volts to a divider to provide the grid and cathode potentials. The other end of the divider is connected to the regulated +300-volt bus. The —1700 V ADJ control R816 determines the total resistance in the divider and hence the total voltage across the divider. When this control is properly set, the voltage at the test point will be exactly —1700 volts.

The accelerating potentials are kept constant by regulating the supplies by comparing a sample of the negative high voltage to the regulated —150-volt supply. This sample of the negative high voltage is obtained from a tap on the divider (the junction of R816 and R818) and is applied to the grid of an amplifier V804A. The cathode of this tube is connected to the —150-volt regulated supply. If the negative supply tends to drift, an error signal appears at the grid of V804A. The error signal is amplified by V804A and V804B, and produces a change in the screen voltage at the oscillator tube. This varies the amplitude of the oscillator output in a direction to compensate for the change in output voltage.

The positive high-voltage supply is regulated indirectly, as the output of both supplies is proportional to the oscillator output.