INSTRUCTION MANUAL

Serial Number B020303

TYPE 576 CURVE-TRACER

Tektronix, Inc.

S.W. Millikan Way ● P. O. Box 500 ● Beaverton, Oregon 97005 ● Phone 644-0161 ● Cables: Tektronix

070-0905-00

269

CONTENTS

Abbreviations and symbols used in this manual are based on or taken directly from IEEE Standard 260 "Standard Symbols for Units", MIL-STD-12B and other standards of the electronics industry. Change information, if any, is located at the rear of this manual.

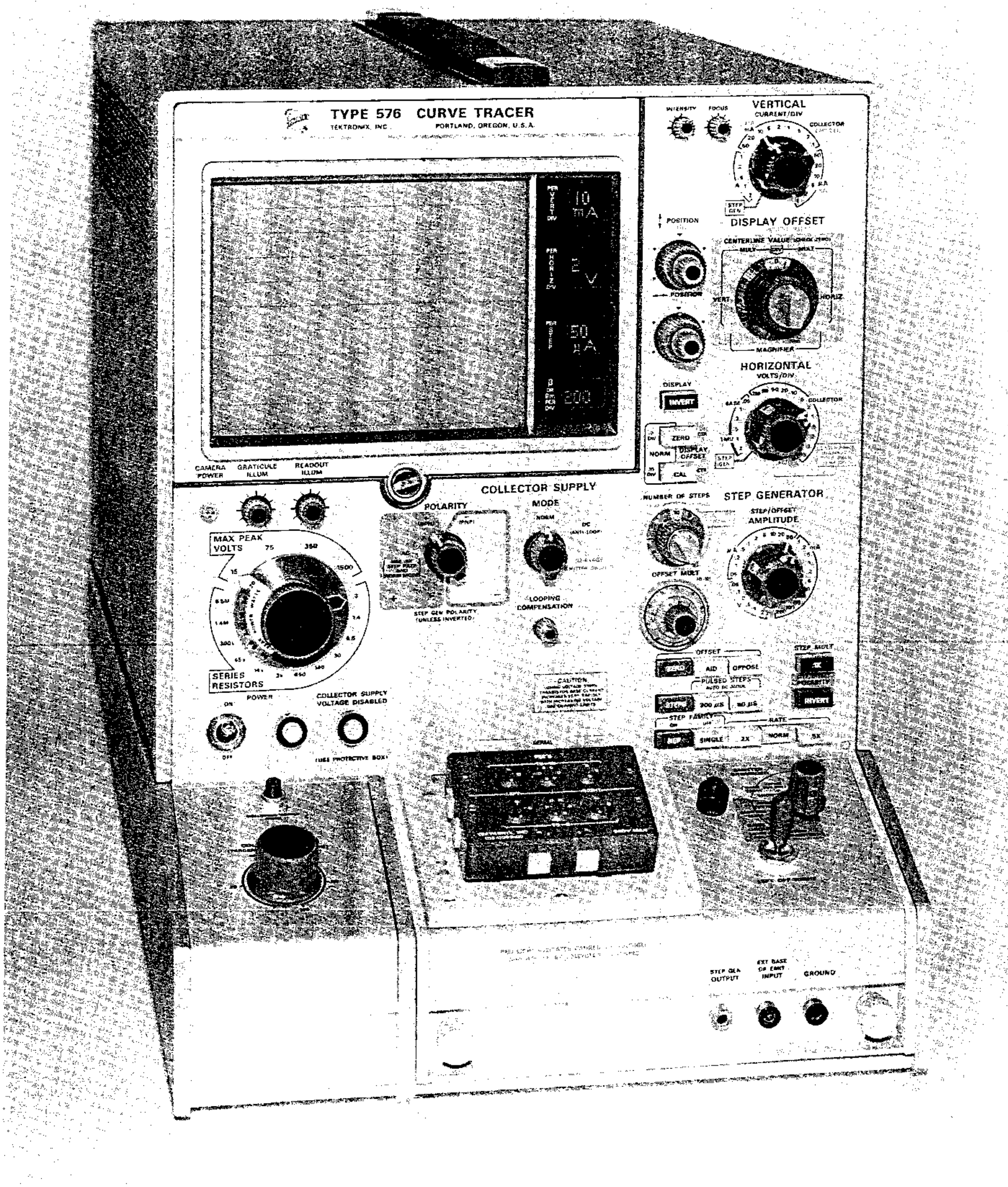


Fig. 1-1. Type 576 Curve Tracer.

OPERATORS SAFETY SUMMARY

The general safety information in this part of the summary is for both operating and servicing personnel. Specific warnings and cautions will be found throughout the manual where they apply, but may not appear in this summary.

TERMS

In This Manual

CAUTION statements identify conditions or practices that could result in damage to the equipment or other property.

WARNING statements identify conditions or practices that could result in personal injury or loss of life.

As Marked on Equipment

CAUTION indicates a personal injury hazard not immediately accessible as one reads the marking, or a hazard to property including the equipment itself.

DANGER indicates a personal injury hazard immediately accessible as one reads the marking.

SYMBOLS

In This Manual

⚠ This symbol indictes where applicable cautionary or other information is to be found.

As Marked on Equipment

⚡ DANGER — High voltage.

⏚ Protective ground (earth) terminal.

⚠ ATTENTION — refer to manual.

Power Source

This product is intended to operate from a power module connected to a power source that will not apply more than 250 volts rms between the supply conductors or between either supply conductor and ground. A protective ground connection by way of the grounding conductor in the power cord is essential for safe operation.

Grounding the Product

This product is grounded through the grounding conductor of the power module power cord. To avoid electrical shock, plug the power cord into a properly wired receptacle before connecting to the product input or output terminals. A protective ground connection by way of the grounding conductor in the power module power cord is essential for safe operation.

Danger Arising From Loss of Ground

Upon loss of the protective-ground connection, all accessible conductive parts (including knobs and controls that may appear to be insulating) can render an electric shock.

Use the Proper Fuse

To avoid fire hazard, use only the fuse of correct type, voltage rating and current rating as specified in the parts list for your product.

Refer fuse replacement to qualified service personnel.

Do Not Operate in Explosive Atmospheres

To avoid explosion, do not operate this product in an explosive atmosphere unless it has been specifically certified for such operation.

Do Not Operate Without Covers

To avoid personal injury, do not operate this product without covers or panels installed. Do not apply power to the plug-in via a plug-in extender.

SECTION 1
SPECIFICATION

Change information, if any, affecting this section will be found at the rear of the manual.

The Type 576 Curve Tracer is a dynamic semiconductor tester which allows display and measurement of characteristic curves of a variety of two and three terminal devices including bipolar transistors, field effect transistors, MOSFETs, silicon controlled rectifiers and unijunction transistors. A variety of possible measurements is available using either grounded emitter or grounded base configurations. The instrument has available either an AC or a DC collector supply voltage ranging from 0 to ±1500 volts. The step generator produces either current or voltage steps. Step generator outputs range from 5 nA in the current mode, and from 5 mV to 40 V in the voltage mode. The steps may also be produced as short duration pulses. Calibrated step offset allows offsetting the step generator output either positive or negative. The vertical display amplifier measures either collector current or leakage current with a maximum deflection factor of 1 nA/division when making a leakage measurement. The horizontal display amplifier allows measurement of both collector and base voltage.

The following electrical and environmental characteristics are valid for instruments operated at an ambient temperature of from 0° C to +50° C after an initial warmup period of 5 minutes, when previously calibrated at a temperature of +25° C, ±5° C. Section 5, Performance Check and Calibration Procedure, gives a procedure for checking and adjusting the Type 576 with respect to the following specification.

TABLE 1-1
ELECTRICAL CHARACTERISTICS

Collector Supply

Characteristic	Performance			
Sweep Modes	Normal mode: AC (at line frequency); positive-or negative-going full wave rectified AC. DC mode: positive or negative DC.			
DC Mode Ripple	No-load: 2% or less of voltage, or 0.1% or less of full range voltage.			
Voltages Accuracy	Peak open circuit voltages on all ranges within +35% and −5%.			
Ranges	15 V	75 V	350 V	1500 V
Maximum Peak Current (Normal Mode)	10 A	2 A	0.5 A	0.1 A
Peak Current (Step Generator in Pulsed Steps Mode)	At least 20 A	At least 4 A	At least 1 A	At least 0.2 A
Minimum Series Resistance	0.3 Ω	6.5 Ω	140 Ω	3 kΩ
Maximum Series Resistance	65 kΩ	1.4 MΩ	6.5 MΩ	6.5 MΩ
Series Resistance Available	0.3 Ω, 1.4 Ω, 6.5 Ω, 30 Ω, 140 Ω, 650 Ω, 3 kΩ, 14 kΩ, 65 kΩ, 300 kΩ, 1.4 MΩ and 6.5 MΩ, all within 5% or 0.1 Ω.			
Peak Power Watts Settings	0.1 W, 0.5 W, 2.2 W, 10 W, 50 W and 220 W, all within 25%.			
Safety Interlock	When MAX PEAK VOLTS switch is set to either 75, 350 or 1500, a protective box must be in place over test terminals and its lid closed before voltage can be applied. Amber light on indicates interlock is open. Red light on indicates voltage is being applied to test terminals.			
Looping Compensation	Cancels stray capacitance between collector test terminal and ground in Standard Test Fixture and all Standard Test Fixture Accessories.			
Step Generator				
Accuracy (Current or Voltage Steps, Including Offset)				
Incremental Accuracy	Within 5% between any two steps, without .1X STEP MULT button pressed; within 10% with .1X STEP MULT button pressed.			

Absolute Accuracy	Within 2% of total output, including any amount of offset, or 1% of AMPLITUDE switch setting, whichever is greater.
Step (Current or Voltage) Amplitudes	One times or 0.1 times (with .1X STEP MULT button pressed) the AMPLITUDE switch setting.
OFFSET MULT Range	Continuously variable from 0 to 10 times AMPLITUDE switch setting, either aiding or opposing the step generator polarity.
Current Mode	
AMPLITUDE Switch Range	200 mA to 50 nA, in 1-2-5 sequence.
Maximum Current (Steps and Aiding Offset)	20 times AMPLITUDE switch setting, except 10 times switch setting when switch is set to 200 mA, and 15 times switch setting when the switch is set to 100 mA.
Maximum Voltage (Steps and Aiding Offset)	At least 10 V.
Maximum Opposing Offset Current	10 times AMPLITUDE switch setting, or between 10 mA and 20 mA.
Maximum Opposing Voltage	Between 1 V and 3 V.
Ripple Plus Noise	0.5% or less of AMPLITUDE switch setting or 2 nA, peak to peak.
Voltage Mode	
AMPLITUDE Switch Range	2 V to 50 mV, in 1-2-5 sequence.
Maximum Voltage (Steps and Aiding Offset)	20 times AMPLITUDE switch setting.
Maximum Current (Steps and Aiding Offset)	At least 2 A at 10 V or less, derating linearly to 10 mA at 40 V.
Short Circuit Current Limiting (Steps and Aiding Offset)	20 mA, 100 mA, 500 mA and 2 A, all within +40% −0%, as selected by CURRENT LIMIT switch.
Maximum Opposing Offset Voltage	10 times AMPLITUDE switch setting.
Maximum Opposing Current	Limited between 10 mA and 20 mA
Ripple Plus Noise	0.5% or less of AMPLITUDE switch setting, or 2 mV, peak to peak.
Step Rates	(Front panel RATE button labels in parentheses.) 1 times (.5X), 2 times (NORM) and 4 times (2X) line frequency. Steps occur at zero collector voltage when .5X or NORM RATE buttons are pressed, and also at peak voltage when 2X RATE button is pressed. Steps occur at collector voltage peak when .5X and NORM RATE buttons are pressed together.
Pulsed Steps	Pulsed steps 80 µs or 300 µs wide within +20%, −5% produced whenever one of the PULSED STEPS buttons is pressed. Pulsed steps can be produced only at normal and .5 times normal rates. Collector Supply mode automatically becomes DC when either the 80 µs PULSED STEPS buttons are pressed unless POLARITY switch is set to AC. If both 80 µs and 300 µs PULSED STEPS buttons are pressed together, 300 µs pulsed steps are produced, but collector supply mode does not change.
Steps and Offset Polarity	Corresponds with collector supply polarity (positive going when POLARITY switch is set to AC) when the POLARITY INVERT button is released. Is opposite collector supply polarity (negative-going in AC) when either the POLARITY INVERT button is pressed or the Lead Selector switch is set to BASE GROUNDED. If Lead Selector switch is set to BASE GROUNDED, POLARITY INVERT button has no effect on steps and offset polarity.

Step Families	Repetitive families of characteristic curves generated with REP STEP FAMILY button pressed. Single family of characteristic curves generated each time SINGLE STEP FAMILY button is pressed.
Number of Steps	Ranges from 1 to 10 as selected by the NUMBER OF STEPS switch. For zero steps, press SINGLE STEP FAMILY button.

Display Amplifiers

Display Accuracies (%of Highest On-Screen Value)	Display magnified (DISPLAY OFFSET Selector switch set to either VERT X10 or HORIZ X10 and offset between			Display Unmagnified
	100 and 40 divisions	35 and 15 divisions	10 and 0 divisions	
Normal and DC Collector Supply Modes				
Vertical Collector Current	2%	3%	4%	3%
External Vertical (Through Interface)	2%	3%	4%	3%
Horizontal Collector Volts	2%	3%	4%	3%
Horizontal Base Volts	2%	3%	4%	3%
External Horizontal (Through Interface)	2%	3%	4%	3%
Leakage Collector Supply Mode				
Vertical Emitter Current (VERTICAL Switch set between 10 nA and 2 mA)	2% ±1 nA	3% ±1 nA	4% ±1 nA	3% ±1 nA
Vertical Emitter Current (VERTICAL Switch set to 5 nA, 2 nA or 1 nA)	Not Applicable			5% ±1 nA
Horizontal Collector or Base Volts VERTICAL Switch set to 1 μA or more	2%	3%	4%	3%
100 nA, 10 nA or 1 nA	Not Applicable			3% + 0.025 V for each vertical division of deflection on the CRT
500 nA, 50 nA or 5 nA	Not Applicable			3% plus 0.125 for each vertitical division of deflection on the CRT
200 nA, 20 nA or 2 nA	Not Applicable			3% plus 0.050 for each vertical division of deflection on the CRT
Step Generator Display				
Vertical Step Generator	3%	4%	5%	4%
Horizontal Step Generator	3%	4%	5%	4%

Deflection Factors Vertical Collector Current	1 μA/division to 2 A/division in 1-2-5 sequence.

Emitter Current	1 nA/division to 2 mA/division in 1-2-5 sequence.
Step Generator	1 step/division.
Horizontal Collector Volts	50 mV/division to 200 V/division in 1-2-5 sequence
Base Volts	50 mV/division to 2 V/division in 1-2-5 sequence.
Input Impedance	At least 100 MΩ with HORIZONTAL switch set to 50 mV, 100 mV and 200 mV BASE; 1 MΩ within 2% with switch set to .5 V, 1 V and
Step Generator	1 step/division

Displayed Noise Vertical	MAX PEAK VOLTS Switch			
	15	75	350	1500
COLLECTOR	0.2 µA	0.5 µA	1 µA	2 µA
EMITTER	0.1 nA	0.2 nA	0.5 nA	1 nA
Horizontal	1% or less, or 3 mV peak to peak.			

Calibration Check	With DISPLAY OFFSET Selector switch set to NORM (OFF), spot is deflected 10 divisions both vertically and horizontally within 1.5% whenever the CAL button is pressed. With DISPLAY OFFSET Selector switch set to X10 MAGNIFIER (either axis) the calibration spot is within 0.5% of zero spot (previously set to CRT graticule center) when CAL button is pressed.
Vertical and Horizontal Position Controls	Coarse positioning in 5 division increments within 0.1 division; continuous fine positioning over at least 5 divisions for each coarse position.
Display Offset	Vertical or Horizontal offset of display centerline value up to 10 divisions in 21 half division steps.

CRT and Readout

CRT Type	Electrostatic deflection.
Screen Size	Calibrated area of 10 divisions by 10 divisions; 12 usable divisions horizontally (1 division equals 1 cm).
Readouts	Automatic digitally lighted display. Readout is automatically blanked if readings would be outside the available ranges or would give erroneous display.
PER VERT DIV	1 nA to 20 A calculated from VERTICAL switch settings, DISPLAY OFFSET Selector switch settings, MODE switch settings (or X10 Vertical Interface Input).
PER HORIZ DIV	5 mV to 200 V calculated from HORIZONTAL switch setting and DISPLAY OFFSET Selector switch setting.
PER STEPS	5 nA to 2A and 5 mV to 20 V calculated from AMPLITUDE switch setting and .1X STEP MULT button position (or X10 Step Interface Input).
β or g_m PER DIV	1 µ to 500 k calculated from VERTICAL switch setting, DISPLAY OFFSET Selector switch setting, AMPLITUDE switch setting, .1X STEP MULT button position, X10 Vertical Interface Input and X10 Step Interface Input.

Power Requirements

Power Connection	This instrument is designed for operation from a power source with its neutral at or near ground (earth) potential. It is not intended for operation from two phases of a multi-phase system, or across the legs of a single-phase, three wire system.

	It is provided with a three-wire power cord with a three-terminal polarized plug for connection to the power source. The third wire is directly connected to the instrument frame, and is intended to ground the instrument to protect operating personnel, as recommended by national and international safety codes.

Line Voltage Ranges	230 VAC	115 VAC
Low	90 V to 110 V	180 V to 220 V
Medium	104 V to 126 V	208 V to 252 V
High	112 V to 136 V	224 V to 272 V
Line Frequency Range	48 to 66 Hz	
Maximum Power Consumption at 115 VAC, 60 Hz	305 W, 3.2 A	

Table 1-2
ENVIRONMENTAL CHARACTERISTICS

Characteristic	Information
Temperature	
Nonoperating	−40°C to +65°C
Useful Operation	0°C to +50°C
Specified Operation	+10°C to +40°C
Altitude	
Nonoperating	To 50,000 feet
Operating	To 10,000 feet
Vibration	
Operating	15 minutes along each axis at 0.015 inch with frequency varied from 10-50-10 c/s in 1-minute cycles. Three minutes at any resonant point or at 50 c/s.
Shock	
Nonoperating	30 g's, 1/2 sine, 11 ms duration, 1 shock per axis. Total of 6 shocks
Transportation	12 inch package drop. Qualified under the National Safe Transit Committee test procedure 1A.

TABLE 1-3
MECHANICAL CHARACTERISTICS

Characteristic	Description
Dimensions	
Height	15 inches
Width	11 1/2 inches
Depth	23 inches
Weight	69 lbs.
Finish	
Front Panel (Type 576 and Standard Test Fixture)	Anodized Aluminum
Cabinet	Blue vinyl painted aluminum
Trim and Rear Panel	Satin finished chrome

NOTES

SECTION 2
OPERATING INSTRUCTIONS

Change information, if any, affecting this section will be found at the rear of the manual.

General

This section of the instruction manual provides information necessary for operating the Type 576 and for using it to test various semiconductor devices. Included are setup procedures, a description of the Type 576 controls and connectors, a discussion of the theory of the instrument, a first time operation procedure, and general operating information. Also included is a section describing the use of the Type 576 for measuring the characteristics of various semiconductor devices.

INITIAL CONSIDERATIONS

Cooling

The Type 576 maintains a safe operating temperature when operated in an ambient temperature of 0° C (32° F) to 50° C (122° F). Adequate clearance on all sides of the instrument should be provided to assure free air flow and dissipation of heat away from the instrument. A thermal cutout in the instrument provides thermal protection by disconnecting the power to the instrument if the internal temperature exceeds a safe operating level. Power is automatically restored when the temperature returns to a safe level.

Operating Voltage and Frequency

The Type 576 can be operated from either a 115-volt or a 230-volt line voltage source. The LINE VOLTAGE SELECTOR assembly, located on the rear panel, allows conversion of the instrument so that it may be operated from one line voltage or the other. In addition, this assembly changes the connections of the power transformer primary to allow selection of one of three regulating ranges (see Table 2-1). The assembly also includes the two line fuses. When the instrument is converted from 115-volt to 230-volt operation or vice versa, the assembly selects the proper fuse to provide the correct protection for the instrument.

The Type 576 may be operated from either a 50 Hz or a 60 Hz line frequency. The 60 Hz-50 Hz switch located on the Type 576 rear panel, below the LINE VOLTAGE SELECTOR assembly, allows conversion of the instrument for operation with one frequency or the other.

Use the following procedure to convert this instrument between line voltages, regulating ranges or line frequencies:

1. Disconnect the instrument from the power source.

TABLE 2-1

Regulating Ranges

Range Selector Switch Position	Regulating Range 115 Volts Nominal	230 Volts Nominal
LO (switch bar in left holes)	90 to 110 volts	180 to 220 volts
M (switch bar in middle holes)	104 to 126 volts	208 to 252 volts
HI (switch bar in right holes)	112 to 136 volts	224 to 272 volts

2. Loosen the two captive screws which hold the cover onto the voltage selector assembly, then pull to remove the cover.

3. To convert from 115-volt to 230-volt line voltage or vice versa, pull out the Voltage Selector switch bar (see Fig. 2-1); turn it 180° and plug it back into the remaining holes. Change the line-cord power plug to match the power-source receptacle or use a 115-to-230-volt adapter.

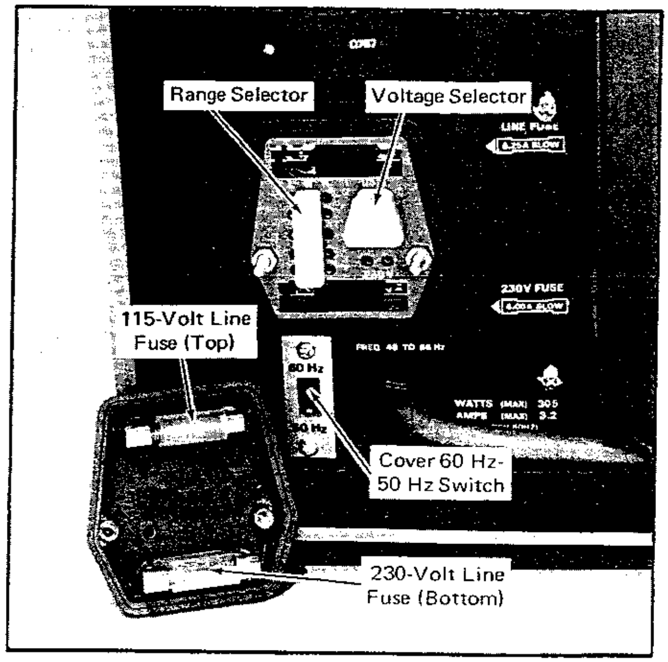


Fig. 2-1. Line Voltage Selector assembly and 60 Hz-50 Hz switch on the rear panel (shown with cover removed).

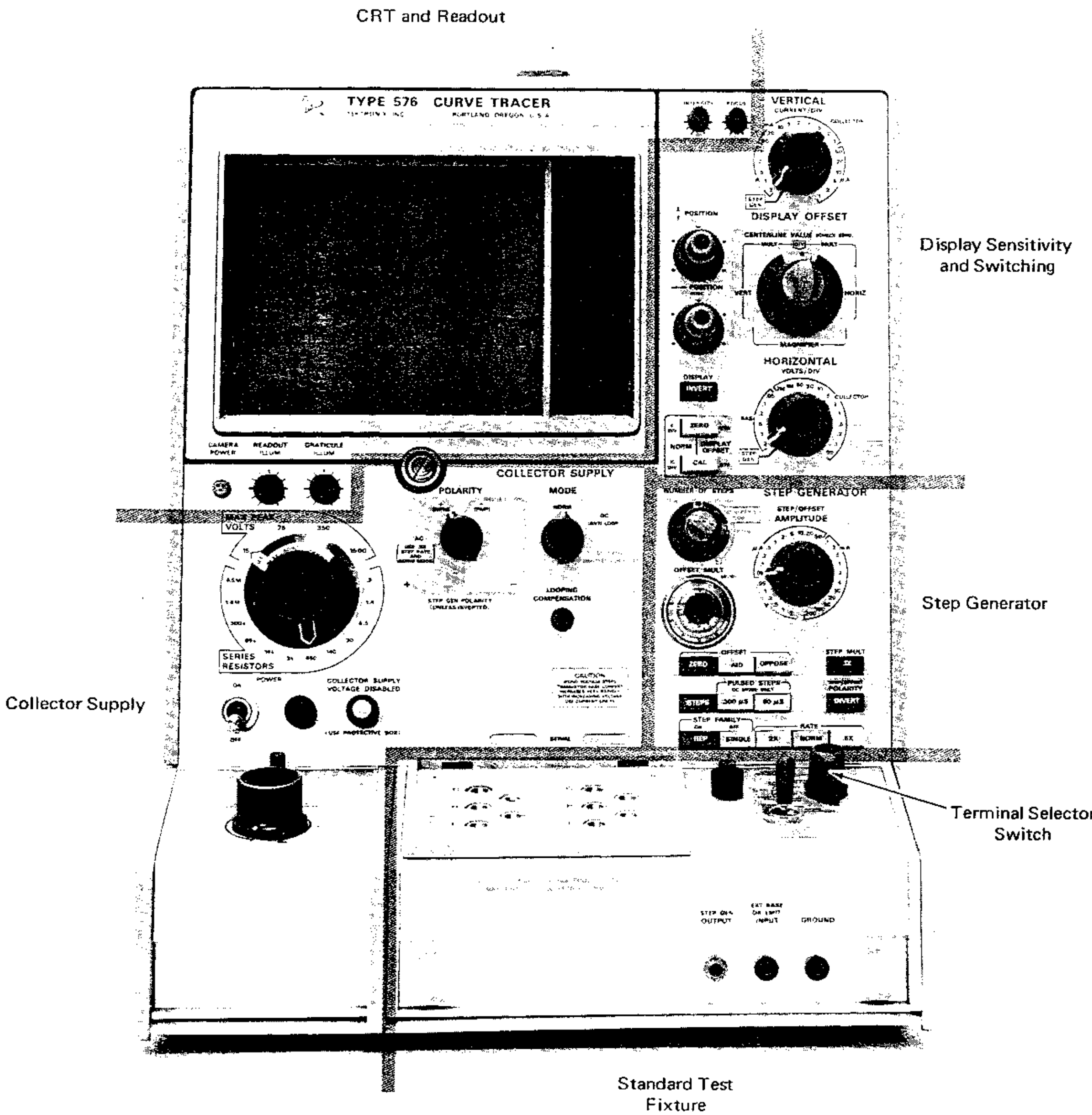


Fig. 2-2. Front-panel controls, connectors and readout.

4. To change regulating ranges, pull out the Range Selector switch bar (see Fig. 2-1) slide it to the desired position and plug it back in. Select a range which is centered about the average line voltage to which the instrument is to be connected (see Table 2-1).

5. Re-install the cover and tighten the two captive screws.

6. To convert from 60 Hz to 50 Hz line frequency (or vice versa), slide the 60 Hz-50 Hz switch (see Fig. 2-1) from its 60 Hz position to its 50 Hz position.

7. Before applying power to the instrument, check that the indicating tabs on the switch bars are protruding through the correct holes in the voltage selector assembly cover for the desired line voltage and regulating range.

CAUTION

The Type 576 should not be operated with the Voltage Selector switch, the Range Selector switch or the 60 Hz-50 Hz switch in the wrong position for the line voltage and frequency applied. Operation of the instrument with any one of these switches in the wrong position will cause incorrect operation and may damage the instrument.

CONTROLS, CONNECTORS AND READOUT

All controls and connectors required for normal operation of the Type 576 are located on the front and rear panels of the instrument and on the front panel of the standard test fisture (see Figs. 2-2 and 2-3). In addition, readout of some of the instrument functions has been provided on the front panel. Familiarity with the function and use of each of these controls, connectors and the readout is necessary for effective operation of the instrument. The functions are described in the following table.

CRT and Readout

Controls	
INTENSITY Control	Controls brightness of display.
FOCUS Control	Provides adjustment for optimum display definition.
READOUT ILLUM Control	Controls brightness of readout.
SCALE ILLUM Control	Controls graticule illumination.
Connector	
CAMERA POWER Connector	Provides +15 volts for operation of camera.

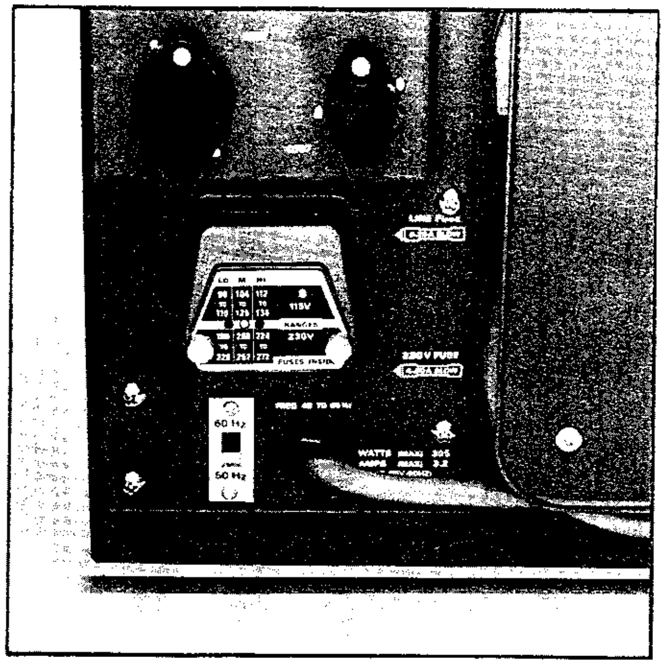


Fig. 2-3. Rear-panel controls.

Readouts

PER VERT DIV Readout	Readout indicates deflection factor of vertical display as viewed on CRT.
PER HORIZ DIV Readout	Readout indicates deflection factor of horizontal display as viewed on CRT.
PER STEP Readout	Readout indicates amplitude per step of Step Generator output.
β OR g_m PER DIV Readout	Readout indicates beta or transconductance per division of CRT display.

Display Sensitivity and Positioning

VERTICAL CURRENT/DIV Switch	Selects vertical deflection factor of display. COLLECTOR—Normal operation of instrument. Vertical display represents collector current. Use black units to determine vertical deflection factor. EMITTER—Operation of instrument with MODE switch set to LEAKAGE (EMITTER CURRENT). Vertical display represents emitter current. Use orange units to determine vertical deflection factor. STEP GEN—Steps indicating Step Generator output and displayed vertically. AMPLITUDE switch setting per division determines vertical deflection factor.

DISPLAY OFFSET Selector Switch	Allows selection of display offset or display offset and magnification. NORM (OFF)—Display offset is not operable. HORIZ X1—Allows horizontal display to be offset using calibrated CENTERLINE VALUE switch. VERT X1—Allows vertical display to be offset using calibrated CENTERLINE VALUE switch. HORIZ X10—Horizontal display magnified by 10 times. Allows horizontal display to be offset using calibrated CENTERLINE VALUE switch. VERT X10—Vertical display magnified by 10 times. Allows vertical display to be offset using calibrated CENTERLINE VALUE switch.
CENTERLINE VALUE Switch	(Clear plastic flange with numbers on it) Provides calibrated offset of display. X1 (VERT or HORIZ)—Number on CENTERLINE VALUE switch appearing in blue window represents number of divisions centerline of display is offset either vertically or horizontally from zero offset line. X10 (VERT or HORIZ)—Number on CENTERLINE VALUE switch appearing in blue window multiplied by 10 represents number of divisions centerline of display is offset either vertically or horizontally from zero offset line.
HORIZONTAL VOLTS/DIV Switch	Selects the horizontal deflection factor of display. COLLECTOR—Horizontal display represents collector voltage to ground. BASE—Horizontal display represents base voltage to ground. STEP GEN—Steps indicating Step Generator output are displayed horizontally. AMPLITUDE switch setting per division determines horizontal deflection factor.
ZERO Button	Provides a zero reference for the display. NORM—When DISPLAY OFFSET selector switch is set to NORM (OFF), ZERO button provides point on CRT of zero vertical and horizontal deflection for adjusting position controls. DISPLAY OFFSET—When DISPLAY OFFSET Selector switch is in one of four display offset positions, ZERO button provides reference point on CRT which must be positioned to vertical centerline (horizontal offset) or to horizontal centerline (vertical offset) to insure that the CENTERLINE VALUE switch setting applies to centerline. (Should always be checked with DISPLAY OFFSET Selector switch is set to MAGNIFIER.)
CAL Button	Provides signal which should cause 10 divisions of vertical and horizontal deflection for checking calibration of vertical and horizontal amplifiers. NORM—When DISPLAY OFFSET selector switch is set to NORM (OFF), CAL button provides point on CRT of 10 divisions of vertical and horizontal deflection. DISPLAY OFFSET—When DISPLAY OFFSET Selector switch is in one of four display offset positions, CAL button provides signal which should cause reference point on CRT to appear on vertical centerline (horizontal offset) or on horizontal centerline (vertical offset), assuming zero reference point was properly adjusted. (Check should be performed with DISPLAY OFFSET Selector switch set to MAGNIFIER.)
DISPLAY INVERT Button	Inverts display vertically and horizontally about center of CRT.
POSITION Switch (Horizontal)	Provides coarse positioning of horizontal display.
FINE POSITION Control (Horizontal)	Provides fine positioning of horizontal display.
POSITION Switch (Vertical)	Provides fine positioning of vertical display.
FINE POSITION Control (Vertical)	Provides fine positioning of vertical display.

COLLECTOR SUPPLY

Controls

MAX PEAK VOLTS Switch	Selects range of VARIABLE COLLECTOR SUPPLY control. Switch is located below PEAK POWER WATTS

	switch and range is indicated by white arrow. When switch is set to 75, 350 and 1500, protective box must be used with Standard Test Fixtures (see section on interlock system).
PEAK POWER WATTS Switch	Selects maximum peak power output allowed by Collector Supply, by selecting resistance in series with Collector Supply output. PEAK POWER WATTS is indicated by number on transparent switch flange appearing above white MAX PEAK VOLTS indicator. SERIES RESISTORS are indicated by blue indicator. PEAK POWER WATTS switch must be pulled out to set maximum peak power output. When PEAK POWER WATTS is set, series resistance is automatically changed to maintain desired maximum peak power output when MAX PEAK VOLTS switch setting is changed.
VARIABLE COLLECTOR SUPPLY Control	Allows varying of collector supply voltage within range set by MAX PEAK VOLTS switch.
POLARITY Switch	Selects polarity of Collector Supply voltage and Step Generator output. —(PNP)—Collector Supply voltage and Step Generator output are negative-going. +(NPN)—Collector Supply voltage and Step Generator output are positive-going. AC—Collector Supply voltage is both positive- and negative-going (sine wave); Step Generator output is positive-going. When switch is set to AC position, use .5X step rate and normal mode of operation.
MODE Switch	Selects mode of operation of Collector Supply. NORM—Normal Collector Supply output is obtained. DC (ANTILOOP)—Collector Supply output is DC voltage equal to peak value set by VARIABLE COLLECTOR SUPPLY control. LEAKAGE (EMITTER CURRENT)—Vertical sensitivity is increased 1000 times. Vertical amplifier measures emitter current. Collector Supply mode set for DC voltage output.
LOOPING COMPENSATION Control	Allows adjustment of looping compensation. Allows compensation of internal and adapter stray capacitance. Does not compensate for device capacitance.
COLLECTOR SUPPLY RESET Button	Resets Collector Supply if it has been disabled by internal circuit breaker. Collector Supply is turned off whenever maximum current rating of transformer primary of 1.2 Amperes is exceeded.
POWER ON-OFF Switch	Controls input power to instrument.

Lights

POWER Light	Lights when power is on.
COLLECTOR SUPPLY VOLTAGE DISABLED Light	Indicates Collector Supply voltage has been disabled. Lights when Collector Supply may present a potentially dangerous voltage at its output. Use of protective box is required to enable Collector Supply.

STEP GENERATOR

Controls

NUMBER OF STEPS Switch	Selects number of steps per family of Step Generator output.
CURRENT LIMIT Switch	Provides current limit of the Step Generator output when voltage steps are being produced.
STEP/OFFSET AMPLITUDE Switch	Selects amplitude per step of steps and offset of Step Generator output. Amplitudes within black arc represent current steps; within yellow arc, voltage steps. Note caution on front-panel when using voltage steps.
OFFSET Buttons	Allows offsetting of Step Generator output using OFFSET MULT control. ZERO—No offset available. AID—Allows zero step of Step Generator output to be offset as many as 10 steps above its zero offset level. OPPOSE—Allows zero step of Step Generator output to be offset as many as 10 steps below its zero offset level.
OFFSET MULT Control	Provides calibrated offset of from zero to ±10 times AMPLITUDE setting when OFFSET AID or OFFSET OPPOSE buttons are pressed.
STEPS Button	Provides steps of normal duration (step lasts for entire period of rate cycle).

PULSED STEPS Buttons — Allows Step Generator output to be applied to Device Under Test for only a portion of normal step duration. Pulsed steps occur at peak of Collector Supply output.
- 300 μs—Selects pulsed steps with duration of 300 μs. Collector Supply is automatically switched to DC mode.
- 80 μs—Selects pulsed steps with duration of 80 μs. Collector Supply is automatically switched to DC mode.
- 300 μs and 80 μs—When buttons are pressed together, selects pulsed steps with duration of 300 μs; however, Collector Supply is not automatically switched to DC mode.

STEP FAMILY Buttons — Allows steps to be generated in repetitive families or one family at a time.
- ON REP—Provides repetitive Step Generator output.
- OFF SINGLE—Provides one family of steps whenever button is pressed. Once button has been pressed, Step Generator is turned off until pressed again or until ON REP button is pressed.

RATE Buttons — Selects rate at which steps are generated.
- NORM—Provides normal Step Generator rate of 1X normal Collector Supply rate (120 steps per second for 60 Hz line frequency).
- 2X—Provides rate of two times normal rate.
- .5X—Provides rate of one half normal rate.
- 2X and .5X—Provides normal rate but with step transitions occurring at peak of Collector Supply sweep.

STEP/OFFSET POLARITY INVERT Button — Allows change of polarity of Step Generator output (from polarity set by POLARITY switch).

STEP MULT .1X Button — Provides 0.1 times multiplication of step amplitude, but does not effect offset.

Standard Test Fixture

Controls

Terminal Selector Switch — Selects the way in which Step Generator is applied to the Device Under Test. In all positions the Collector Supply output is connected to Collector terminal.

- EMITTER GROUNDED—Emitter of Device Under Test is connected to ground.
  - STEP GEN (NORM)—Step Generator is applied to base terminal of Device Under Test. Normal operating position.
  - OPEN (OR EXT)—Base terminal of Device Under Test open. External signal applied to EXT BASE OR EMIT INPUT connector, will be applied to base terminal.
  - SHORT—Base terminal of Device Under Test is shorted to emitter terminal.
- BASE GROUNDED—Base terminal of Device Under Test is connected to ground. Step Generator polarity is inverted.
  - OPEN (OR EXT)—Emitter terminal of Device Under Test is open. External signal applied to EXT BASE OR EMIT INPUT connector, will be applied to emitter terminal.
  - STEP GEN—Inverted Step Generator output is applied to emitter of Device Under Test.

LEFT-OFF-RIGHT Switch — Selects which device (choice of 2) is to be tested, left or right.

INTERLOCK Switch — Enables Collector Supply when Protective Box is in place and lid is closed.

Connectors

Adapter Connectors — Allows connection of various adapters to Standard Test Fixture. Connectors will accept standard size banana plugs if some other means of connecting Device Under Test to Standard Test Fixture is desired. C, B and E stand for collector, base and emitter, respectively. Unlabeled terminals allow Kelvin sensing of voltage for high current devices.

STEP GEN OUT Connector — Step Generator output signal appears at this connector.

EXT BASE OR EMIT INPUT Connector — Allows input of externally generated signal to either base terminal or emitter terminal of Device Under Test as determined by Terminal Selector Switch.

GROUND Connector	Provides external access to ground reference.

Light

Caution Light	Red light on, indicates Collector Supply is enabled and dangerous voltage may appear at collector terminals.

Rear Panel

Controls

Line Voltage Selector Switches	Switch assembly selects operating voltage and line voltage range. Also includes line fuses. Voltage Selector—Selects operating voltage (115 V or 230 V). Range Selector—Selects line voltage range (low, medium, high).
60 Hz-50 Hz Switch	Selects operating line frequency.

FRONT PANEL COLORS

The various colors on the front-panel of the Type 576 and Standard Test Fixture indicate relationships between controls and control functions. Table 2-2 shows the relationship which each color indicates.

Table 2-2

Colors and Controls

Color	Relationship
Green	Indicates controls which affect the Step Generator polarity.
Blue	Indicates controls and statements associated with display offset.
Orange	Indicates relationship of LEAKAGE (EMITTER CURRENT) mode with the VERTICAL and HORIZONTAL switches.
Yellow	Indicates controls and statements associated with the voltage mode of operation of the Step Generator.
Black (Buttons)	Indicates function controlled by a single button, which is released for most common applications.
Dark Grey (Buttons)	Indicates function controlled by several buttons, and the dark grey button is pressed for most common applications.

PRECAUTIONS

A number of the Type 576 front-panel controls could, through improper use, cause damage to the device under test. Fig. 2-4 indicates the area of the Type 576 front panel where these controls are located. Care should be exercised when using controls located in this area.

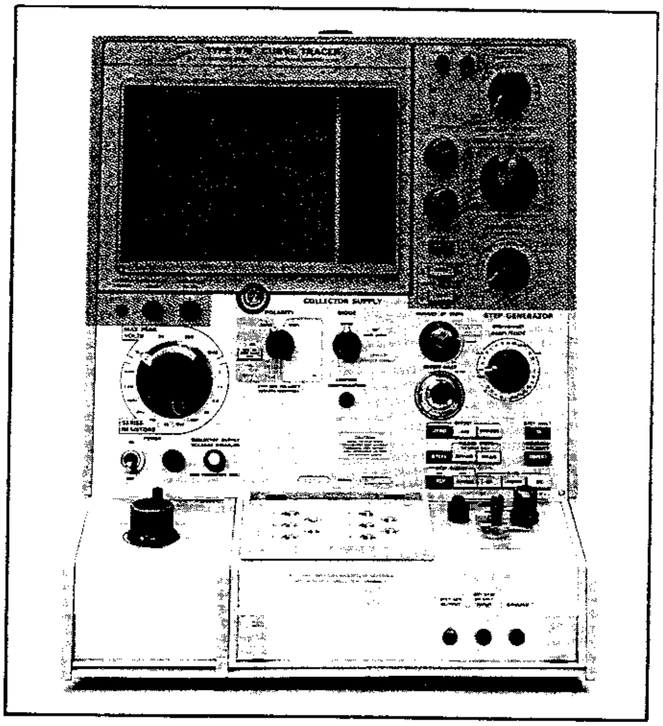


Fig. 2-4. Area of Type 576 front-panel with controls which could cause damage to a device under test if used improperly.

GENERAL DESCRIPTION OF INSTRUMENT OPERATION

The Type 576 is a dynamic semiconductor tester which displays and allows measurement of simiconductor characteristics obtained under simulated operating conditions. The Collector Supply and the Step Generator produces voltages and currents which are applied to the device under test. The display amplifiers measure the effects of these applied conditions on the device under test. The result is families of characteristics curves traced on a CRT.

The Collector Supply circuit normally produces a full-wave rectified sine wave which may be either positive- or negative going. The amplitude of the signal can be varied from 0 to 1500 volts as determined by the MAX PEAK VOLTS switch and the VARIABLE COLLECTOR SUPPLY VOLTS control. This Collector Supply output is applied to the collector (or equivalent) terminal of the device under test.

The Step Generator produces ascending steps of current or voltage at a normal rate of one step per cycle of the Collector Supply. The amount of current or voltage per

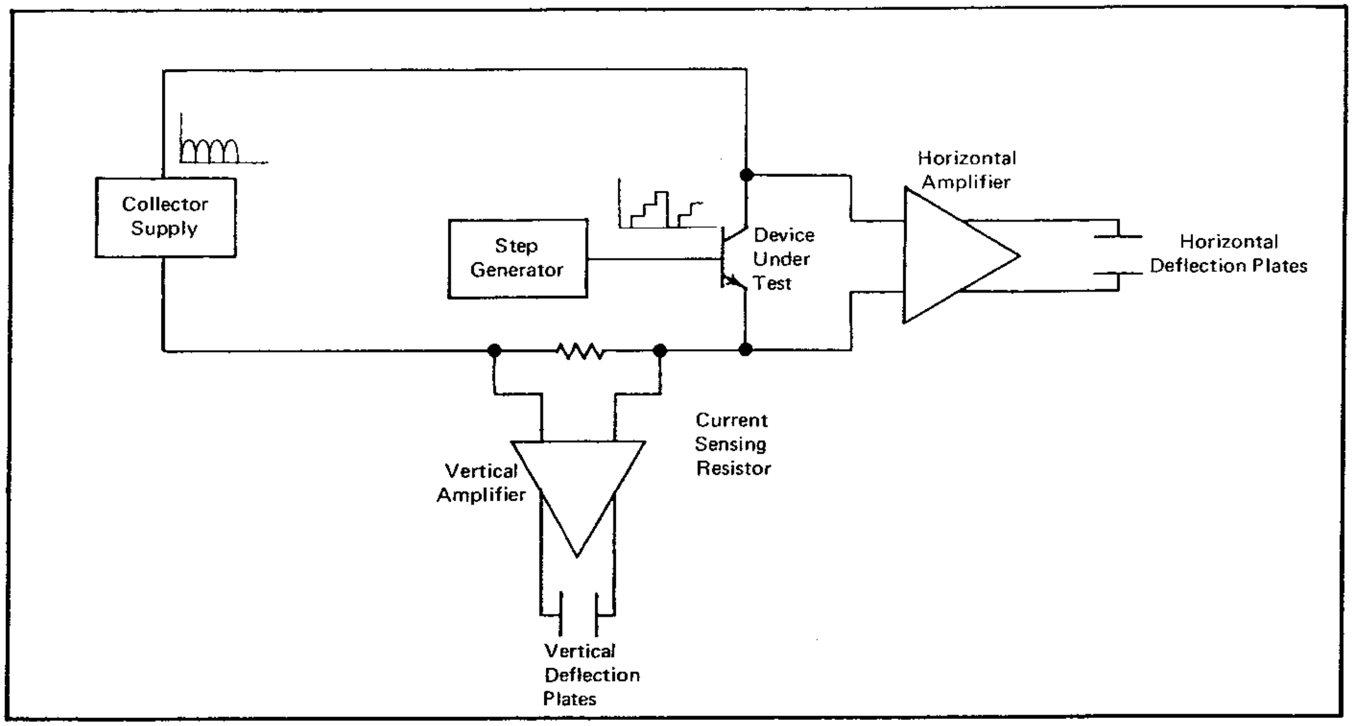


Fig. 2-5. Basic Block diagram showing typical connections of Collector Supply, Step Generator and Display Amplifiers to the device under test.

step is controlled by the AMPLITUDE switch and the total number of steps is controlled by the NUMBER OF STEPS switch. This Step Generator output may be applied to either the base or the emitter (or equivalent) terminals of the device under test.

The display amplifiers are connected to the device under test. These amplifiers measure the effects of the Collector Supply and of the Step Generator on the device under test, amplify the measurements and apply the resulting voltages to the deflection plates of the CRT. The sensitivities of these amplifiers are controlled by the VERTICAL CURRENT/DIV switch and the HORIZONTAL VOLTS/DIV switch.

Fig. 2-5 is a block diagram showing the connection of these circuits to the device under test for a typical measurement.

FIRST TIME OPERATION

When the Type 576 is received, it is calibrated and should be performing within the specification shown in Section 1. The following procedure allows the operator to become familiar with the front panel controls and their functions as well as how they may be used to display transistor or diode characteristics. This procedure may also be used as a general check of the instrument's performance. For a check of the instrument's operation with respect to the specification given in Section 1, the Performance Check and Calibration Procedure in Section 5 must be used.

1. Apply power to the Type 576.

2. Allow the instrument to warm up for a few minutes. Instrument should operate within specified tolerances 5 minutes after it has been turned on.

3. Set the Type 576 and Standard Test Fixture front-panel controls as follows:

READOUT ILLUM	Fully counterclockwise
GRATICULE ILLUM	Fully counterclockwise
INTENSITY	Fully counterclockwise
FOCUS	Centered
VERTICAL	1 mA
DISPLAY OFFSET Selector	NORM (OFF)
CENTERLINE VALUE	0
HORIZONTAL	1 V COLLECTOR
Vertical POSITION	Centered
Vertical FINE POSITION	Centered
Horizontal POSITION	Centered

Horizontal FINE POSITION	Centered
ZERO	Released
CAL	Released
DISPLAY INVERT	Released
MAX PEAK VOLTS	15
PEAK POWER WATTS	0.1
VARIABLE COLLECTOR SUPPLY	Fully Counterclockwise
POLARITY	AC
MODE	NORM
LOOPING COMPENSATION	As is
NUMBER OF STEPS	1
CURRENT LIMIT	20 mA
AMPLITUDE	0.5 µA
OFFSET	ZERO
STEPS	Pressed
PULSED STEPS	Released
STEP FAMILY	REP ON
RATE	NORM
POLARITY INVERT	Not pressed
STEP MULT .1X	Not pressed
Terminal Selector	BASE TERMINAL STEPS (NORM)
LEFT-OFF-RIGHT	OFF

CRT and Readout Controls

4. Turn the GRATICULE ILLUM control throughout its range. Note that the graticule lines become illuminated as the control is turned clockwise. Set the control for desired illumination.

5. Turn the READOUT ILLUM control throughout its range. Note that the fiber-optic readouts and the titles become illuminated as the control is turned clockwise. Set the control for the desired readout illumination. The readout should read for these initial control settings; 1 mA per vertical division, 1 V per horizontal division, 50 nA per step and 20 k β or gm per division.

6. Turn the INTENSITY control clockwise until a spot appears at the center of the CRT graticule. To avoid burning the CRT phosphor, adjust the INTENSITY control until the spot is easily visible, but not overly bright.

7. Turn the FOCUS control throughout its range. Adjust the FOCUS control for a sharp, well-defined spot.

Positioning Controls

8. Turn the vertical FINE POSITION control throughout its range. Note that the control has a range of at least ±2.5 divisions about the center horizontal line. Set the control so that the spot is centered vertically on the CRT graticule.

9. Repeat step 8 using the horizontal FINE POSITION control.

10. Turn the vertical coarse POSITION switch. Note that the spot moves 5 divisions vertically each time the switch is moved one position. (The most extreme positions of the switch represent 10 divisions of deflection, which in this case causes the spot to be off the CRT graticule.) Set the POSITION switch to the center position.

11. Repeat step 10 using the horizontal coarse POSITION switch.

12. Set the POLARITY switch to −(PNP). Note that the spot moves to the upper right corner of the CRT graticule.

13. Set the POLARITY switch to +(NPN). Note that the spot moves to the lower left corner of the CRT graticule.

Vertical and Horizontal Sensitivity

14. Install the diode adapter (Tektronix Part No. 013-0072-00) into the right-hand set of accessory connectors located on the Standard Test Fixture.

15. Install a 1 kΩ, 1/2 watt resistor in the diode adapter.

16. Set the LEFT-OFF-RIGHT switch to RIGHT and turn the VARIABLE COLLECTOR SUPPLY control until a trace appears diagonally across the CRT.

17. Turn the VERTICAL switch clockwise and note that as the vertical deflection factor decreases the slope of the line decreases (see Fig. 2-6). Turn the VERTICAL switch counterclockwise from the 1 mA position and note that the slope increases. Also note that the PER VERT DIV readout changes in accordance with the position of the VERTICAL switch. Reset the VERTICAL switch to 1 mA.

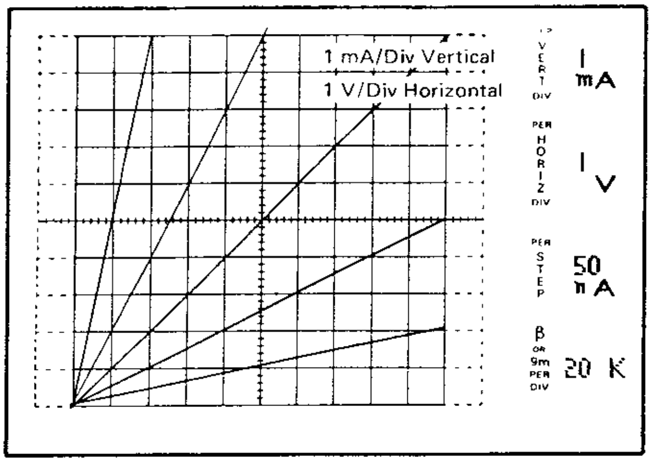


Fig. 2-6. Display of I vs. V for a 1 kΩ resistor using various settings of the VERTICAL and HORIZONTAL switches.

18. Repeat step 17 using the HORIZONTAL switch within the COLLECTOR range of the switch. The change in slope of the trace will be the inverse of what it was for the VERTICAL switch. Reset the HORIZONTAL switch to 1 V COLLECTOR.

19. Press the ZERO button. Note that the diagonal trace reduces to a spot in the lower left corner of the CRT graticule. This spot denotes the point of zero deflection of the vertical and horizontal amplifiers. Release the ZERO button.

20. Press the CAL button. Note that the diagonal trace reduces to a spot in the upper right corner of the CRT graticule. The position of this spot indicates 10 divisions of deflection both vertically and horizontally. Release the CAL button.

21. Press the DISPLAY INVERT button and turn the VARIABLE COLLECTOR SUPPLY control counterclockwise. Note that the display has been inverted and is now originating from the upper right corner of the CRT graticule. Release the DISPLAY INVERT button.

Collector Supply

22. Turn the MAX PEAK VOLTS switch throughout its range. Note that when the switch is in the 75, 350 and 1500 positions, the yellow light comes on.

23. While the yellow light is on, turn the VARIABLE COLLECTOR SUPPLY control fully clockwise. Note that the diagonal line obtained in step 16 does not appear. When the yellow light is on, the Collector Supply is disabled.

24. Set the following Type 576 controls:

MAX PEAK VOLTS	75
VARIABLE COLLECTOR SUPPLY	Fully counterclockwise
LEFT-OFF-RIGHT	OFF

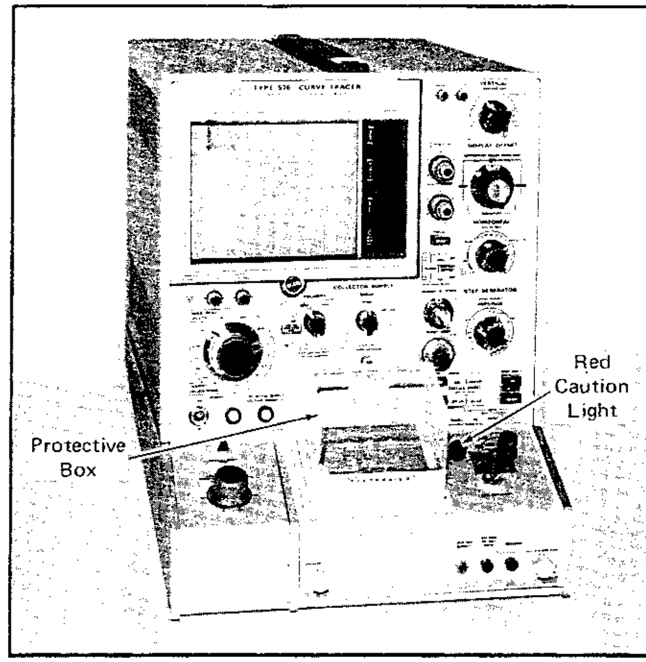


Fig. 2-7. Type 576 Standard Test Fixture with protective box installed for safe operation.

25. Install the protective box on the Standard Test Fixture as shown in Fig. 2-7.

26. Close the lid of the protective box and set the LEFT-OFF-RIGHT switch to RIGHT. Note that the yellow light turns off and the red light turns on.

WARNING

The red light indicates that dangerous voltages may appear at the collector terminals of the Standard Test Fixture.

27. Turn the VARIABLE COLLECTOR SUPPLY control clockwise. Note that the diagonal trace appears indicating that the Collector Supply has been enabled.

28. Set the following Type 576 controls to:

MAX PEAK VOLTS	15
VARIABLE COLLECTOR SUPPLY	Fully Counterclockwise

(The protective box may be removed if desired.)

29. Turn the VARIABLE COLLECTOR SUPPLY control until the diagonal trace reaches the center of the CRT graticule. Pull out on the PEAK POWER WATTS switch and set it to 220. Note that the diagonal trace lengthens as the switch is turned through its range. Also note that the SERIES RESISTORS decrease as the maximum peak power is increased.

30. Allow the MAX PEAK VOLTS switch and the PEAK POWER WATTS switch to become interlocked and switch to 75. Note that the maximum peak power value remains at 220 and that the SERIES RESISTORS values change.

31. Set the following Type 576 controls to:

MAX PEAK VOLTS	15
PEAK POWER WATTS	0.1
LEFT-OFF-RIGHT	OFF

32. Remove the resistor from the diode adapter and replace it with a silicon diode. Align the diode so that its cathode is connected to the emitter terminal.

33. Set the LEFT-OFF-RIGHT switch to RIGHT and turn the VARIABLE COLLECTOR SUPPLY control clockwise. Note the display of the forward voltage characteristic of the diode. (see Fig. 2-8).

34. Set the COLLECTOR SUPPLY POLARITY switch to −(PNP). Note the display of the reverse voltage characteristic of the diode (see Fig. 2-8).

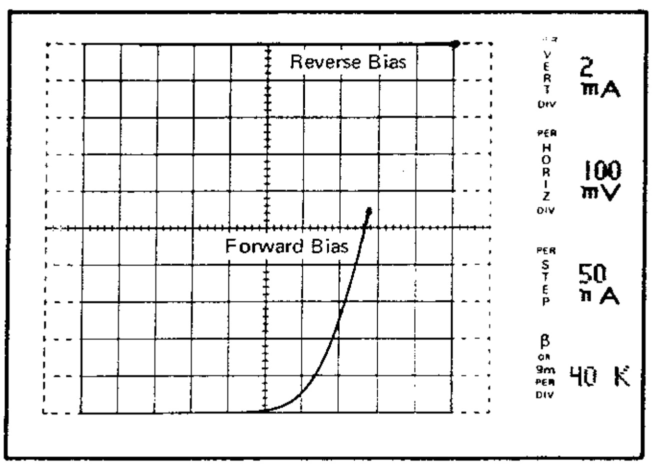


Fig. 2-8. Display of forward and reverse bias characteristics of a signal diode.

35. Set the following Type 576 controls to:

POLARITY	+ (NPN)
MODE	DC

Note that the display of the forward voltage diode characteristic has become a spot. The spot indicates the current conducted by the diode and the voltage across it.

36. Turn the VARIABLE COLLECTOR SUPPLY control counterclockwise. Note that the spot traces out of the diode characteristic.

37. Set the following Type 576 controls to:

VERTICAL	1 μA
HORIZONTAL	2 V COLLECTOR
Vertical POSITION	Display Centered
VARIABLE COLLECTOR SUPPLY	Fully Clockwise
MODE	NORM
LEFT-OFF-RIGHT	LEFT

38. Adjust the LOOPING COMPENSATION control for minimum trace width (see Fig. 2-9).

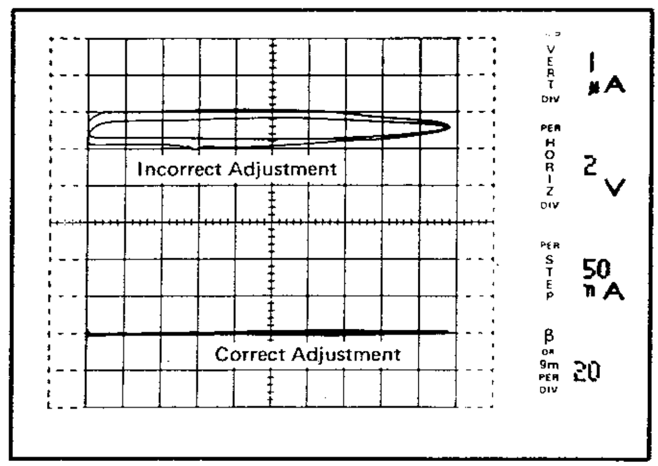


Fig. 2-9. Adjustment of LOOPING COMPENSATION control.

39. Set the following Type 576 controls to:

VERTICAL	5 mA
Vertical POSITION	Switch centered
VARIABLE COLLECTOR SUPPLY	Fully Counterclockwise
MODE	AC
LEFT-OFF-RIGHT	OFF

40. Remove the diode from the diode adapter and replace it with a 8 volt Zener diode. Align the diode so that its cathode is connected to the emitter terminal.

41. Set the LEFT-OFF-RIGHT switch to RIGHT and turn the VARIABLE COLLECTOR SUPPLY control clockwise. Note that the display shows both the forward and reverse characteristics of the Zener diode (see Fig. 2-10).

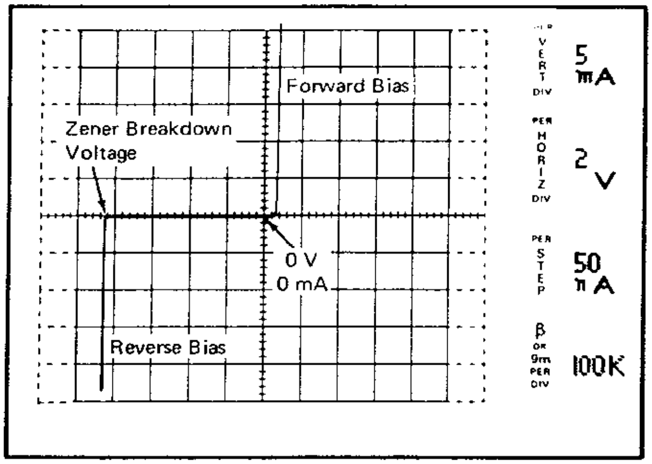


Fig. 2-10. Display of Zener diode I vs. V characteristic with POLARITY switch set to AC.

Display Offset and Magnifier

42. Set the following Type 576 controls to:

HORIZONTAL	2 V COLLECTOR
POLARITY	—(PNP)

Note the display of the reverse voltage characteristic of the Zener diode.

43. Position the display to the center of the CRT graticule with the vertical POSITION switch (see Fig. 2-11A).

44. Set the DISPLAY OFFSET Selector switch to HORIZ X10. Press the ZERO button and, using the horizontal FINE POSITION control, adjust the spot so that it is on the center vertical line of the CRT graticule. This spot position represents the zero offset position. Release the ZERO button and set the DISPLAY OFFSET Selector switch to HORIZ X1.

45. Turn the CENTERLINE VALUE switch from the 0 position clockwise, until the Zener breakdown portion of the display is within ±0.5 divisions of the center vertical line (see Fig. 2-11B). Note the number on the CENTERLINE VALUE switch which appears in the blue window below the word DIV. This number multiplied by the PER HORIZ DIV readout value gives the approximate value of the breakdown voltage of this Zener diode. For the diode in the example shown in Fig. 2-11, the approximate Zener breakdown voltage is 4 divisions times 2 V/division = 8 volts.

46. Set the DISPLAY OFFSET Selector switch to HORIZ X10. Note that PER HORIZ DIV readout value has changed to indicate the 10 times multiplication. By expanding the scale, a measurement can be made of that part of the characteristic which was not quite offset to the center vertical line of the CRT graticule (see Fig. 2-11C). This value when added to the approximate value (or subratcted

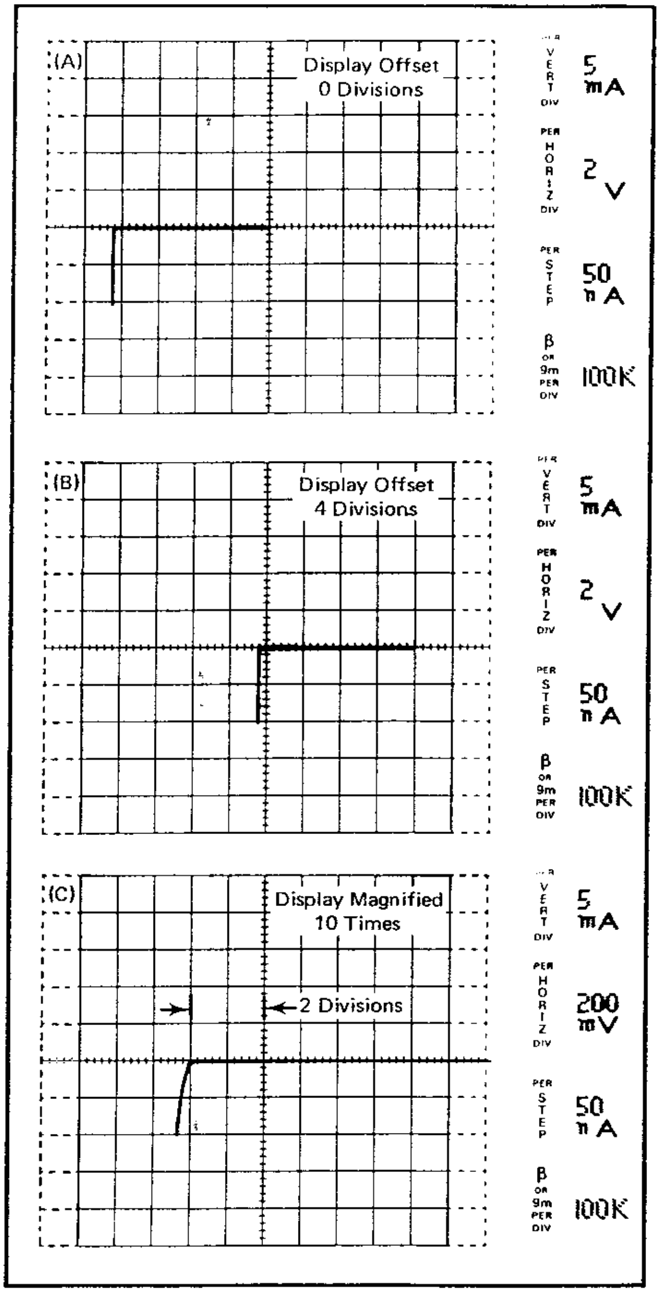


Fig. 2-11. Displays of measurement of Zener breakdown voltage using the DISPLAY OFFSET Selector and CENTERLINE VALUE switches, (A) DISPLAY OFFSET Selector switch set to HORIZ X1 and CENTERLINE VALUE switch set to 0; (B) CENTERLINE VALUE switch set to 4; (C) DISPLAY OFFSET Selector switch set to HORIZ X10.

if the approximate value was greater than the actual value) produces a more exact measurement of the breakdown voltage. In the example shown in Fig. 2-11, 400 mV should be added to the approximate estimate, yielding a value of 8.4 for the Zener voltage of the diode. The same process can also be carried out using vertical display offset and magnification.

Step Generator

47. Set the following Type 576 controls to:

DISPLAY OFFSET Selector	NORM (OFF)
CENTERLINE VALUE	0
Vertical POSITION	Switch centered
POLARITY	+(NPN)
VARIABLE COLLECTOR SUPPLY	Fully Counterclockwise
LEFT-OFF-RIGHT	OFF

48. Remove the diode adapter and replace it with the universal transistor adapter (Tektronix Part No. 013-0098-00).

49. Place an NPN silicon transistor into the right transistor test socket of the universal transistor adapter.

50. Set the LEFT-OFF-RIGHT switch to RIGHT and turn the VARIABLE COLLECTOR SUPPLY clockwise until the peak collector-emitter voltage is about 10 volts.

51. Turn the AMPLITUDE switch until a step appears on the CRT. Note that the greater the step amplitude, the greater the collector current (see Fig. 2-12). Set the AMPLITUDE for the minimum step amplitude which produces a noticeable step in the display.

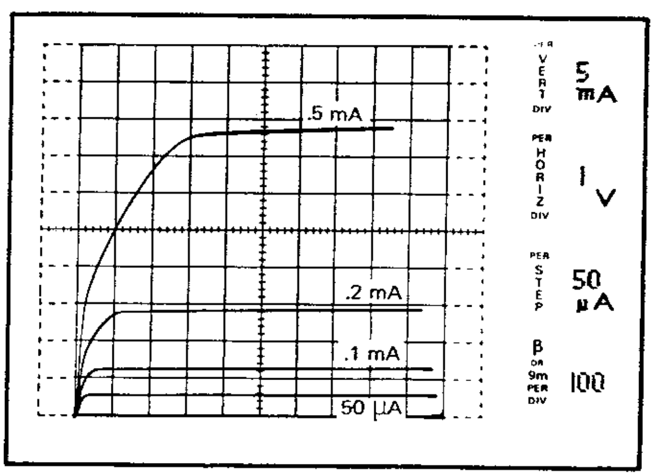


Fig. 2-12. Collector current vs. Collector-Emitter voltage for various settings of the AMPLITUDE switch.

52. Turn the NUMBER OF STEPS switch clockwise. Be sure the PEAK POWER WATTS switch is set within the power dissipation rating of the transistor being used. Note the display of collector current vs. collector-emitter voltage for ten different values of base current (see Fig. 2-13A).

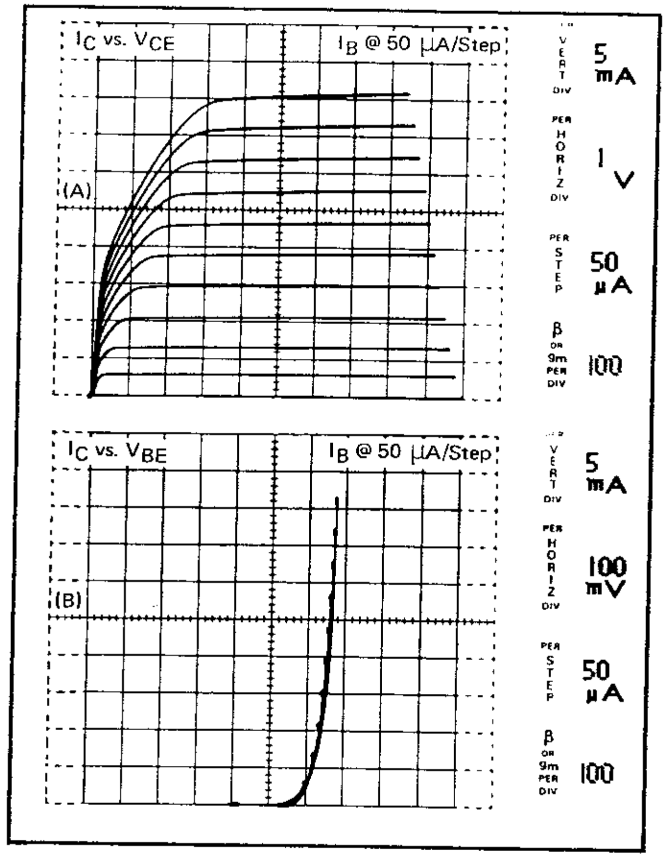


Fig. 2-13. (A) I_C vs. V_{CE} for 10 steps of base current at 50 µA per step; (B) I_C vs. V_{BE} for 10 steps of lease current at 50 µA per step.

53. Set the HORIZONTAL switch to .1 V BASE. Note the display of the collector current vs. base-emitter voltage for ten different values of base current (see Fig. 2-13B).

54. Set the VERTICAL switch to STEP GEN and the HORIZONTAL switch to 1 V COLLECTOR. Note the display of the base current, one step per vertical division, vs. the collector-emitter voltage (see Fig. 2-14A).

55. Set the HORIZONTAL switch to .1 V Base. Note the display of base current, one step per vertical division, vs. base-emitter voltage (see Fig. 2-14B).

56. Set the VERTICAL switch to 5 mA and the HORIZONTAL switch to STEP GEN. Note the display of collector current vs. base-current, one step per horizontal division (see Fig. 2-15).

57. Set the following Type 576 controls to:

HORIZONTAL	1 V COLLECTOR
RATE	.5X

Note that the step rate is slower than the normal rate.

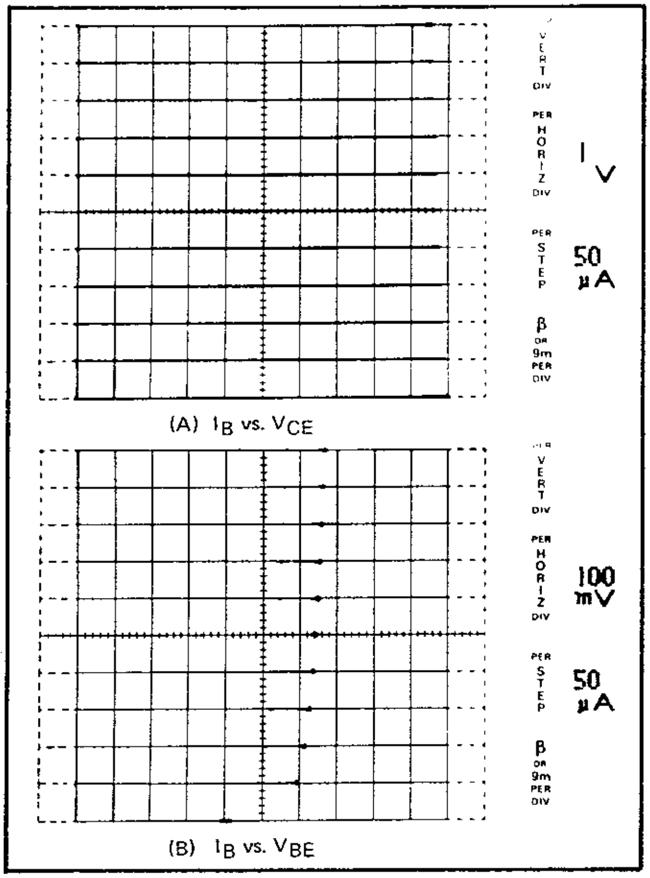


Fig. 2-14. (A) I_B vs. V_{CE}, I_b @ 50 µA per division; (B) I_B vs. V_{BE}, I_B @ 50 µA per division.

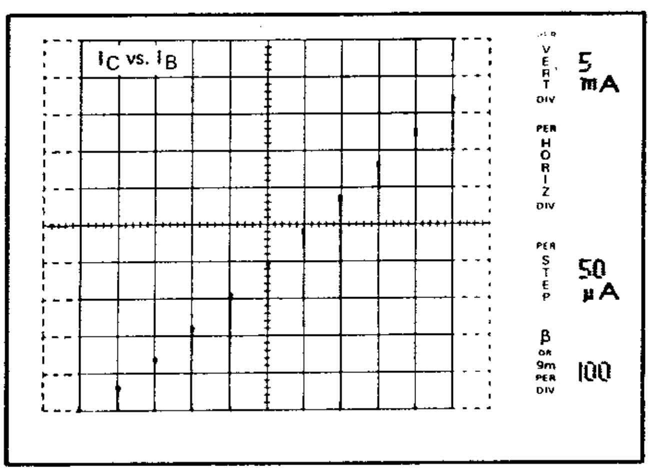


Fig. 2-15. I_C vs. I_B, I_B @ 50 µA per division.

58. Press the NORM RATE button and then the 2X RATE button. Note that the step rate is faster than the normal rate.

59. Press both the 2X RATE and .5X RATE buttons. Note that the step rate is normal, but that the steps occur at the peak of each collector sweep, rather than at the beginning of each collector sweep, as when the NORM RATE button is pushed.

60. Press the SINGLE STEP FAMILY button. Press it again. Note that each time the SINGLE button is pressed, a single family of characteristic curves is displayed and then the Step Generator turns off.

61. Set the following Type 576 controls to:

STEP FAMILY	REP ON
RATE	NORM
PULSED STEPS	300 µs

Note that the collector supply is in the DC mode and that each step is in the form of a pulse. (See Fig. 2-16A.) (Readjustment of the INTENSITY control may be necessary.)

62. Press the 80 µs button. Note that the duration of each pulsed step is reduced.

63. Press both the 300 µs and the 80 µs buttons. Note that the Collector Supply is in the normal mode and the steps are occurring at the peak of the collector sweep, with a duration as observed in step 61 (see Fig. 2-16B).

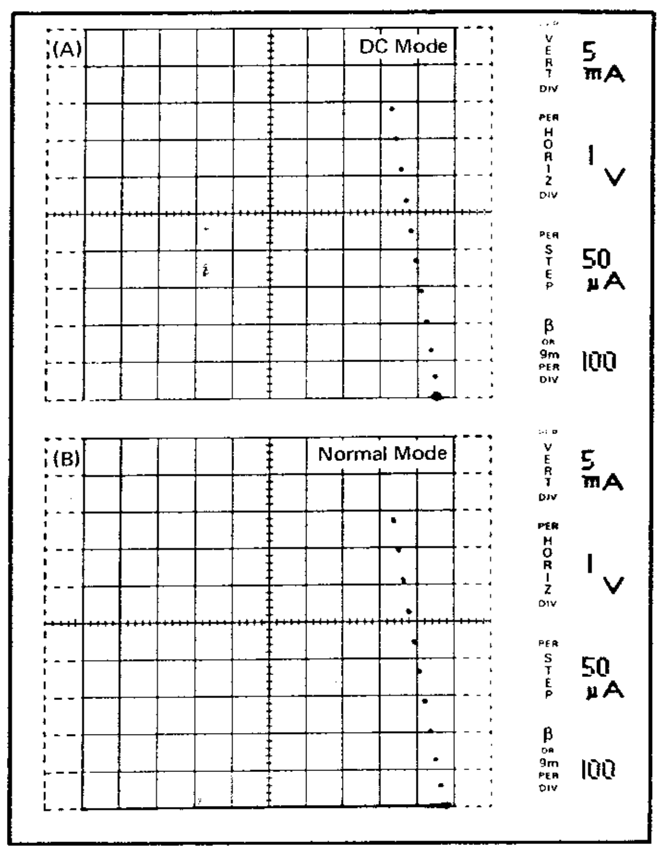


Fig. 2-16. 300 µs PULSED STEPS, (A) DC mode; (B) Normal mode.

64. Set the following Type 576 controls to:

INTENSITY	Visible Display
VERTICAL	.5 mA
VARIABLE COLLECTOR SUPPLY	Fully Counterclockwise
POLARITY	−(PNP)
STEPS	Pressed

65. Press the STEP/OFFSET POLARITY INVERT button and turn the VARIABLE COLLECTOR SUPPLY control slowly clockwise. Note the reverse voltage characteristics obtained by reversing the polarity of the collector sweep but keeping the Step Generator polarity the same. Note that as the reverse Collector Supply voltage is increased, Zener breakdown of the base-emitter junctions occurs (see Fig. 2-17).

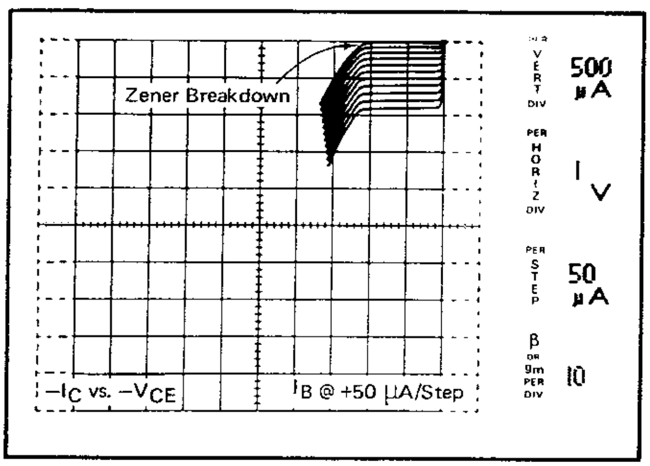


Fig. 2-17. Reverse voltage characteristic of transistor.

66. Release the INVERT button and press the OPPOSE OFFSET button.

67. Turn the OFFSET MULT control clockwise and note that a display similar to that seen in step 65 is obtained.

68. Set the following Type 576 controls to:

POLARITY	AC
OFFSET	ZERO
OFFSET MULT	0
RATE	.5X

Note a display similar to that viewed in step 65 except that the display for the positive collector sweep is also shown (see Fig. 2-13A).

69. Set the following Type 576 controls to:

VERTICAL	5 mA
POLARITY	+(NPN)
NUMBER OF STEPS	5
RATE	NORM

70. Note the β or g_m per division readout. By measuring the vertical divisions between two curves of the displayed family, the β of the device in that region can be determined. For example, there is approximately 0.9 division between the fourth and fifth steps shown in Fig. 2-18A. The β of the device when operated in this region is, therefore, approximately 0.9 (200) or 180. To make a more accurate measurement of β, the difference in both collector and base current between the fourth and fifth steps should be less.

71. Press the OFFSET AID button and set the OFFSET MULT control to 4. Note that the offset current has been added to the Step Generator output so that the zero step is now at the level of the fourth step displayed.

72. Press the STEP MULT .1X button. Note that the current per step is now 1/10 of the value set by the AMPLITUDE switch. Check the PER STEP readout for the new amplitude per step. (See Fig. 2-18B.)

73. Set the DISPLAY OFFSET Selector switch to VERT X1 and turn the CENTERLINE VALUE switch clockwise until the first step is within ±0.5 division of the center horizontal line.

74. Set the DISPLAY OFFSET Selector switch to VERT X10. Note that though the β per division is still 200 as it was in step 70, the change in collector and base current (ΔI_C and ΔI_B) is less between the fourth and the fifth step. This allows for a more accurate measurement of β at the level of the fourth step (see Fig. 2-18C). The β of the device at the fourth step now measures at about 0.8 (200) = 160.

75. Set the following Type 576 controls to:

VERTICAL	1 mA
DISPLAY OFFSET Selector	NORM (OFF)
AMPLITUDE	.05 V
NUMBER OF STEPS	1
OFFSET MULT	0
STEP MULT	Released

76. Turn the OFFSET MULT control until a step just begins to appear on the CRT. Note the multiplier value on the OFFSET MULT control. This number times the AMPLITUDE switch setting is the base-to-emitter turn on voltage of the transistor.

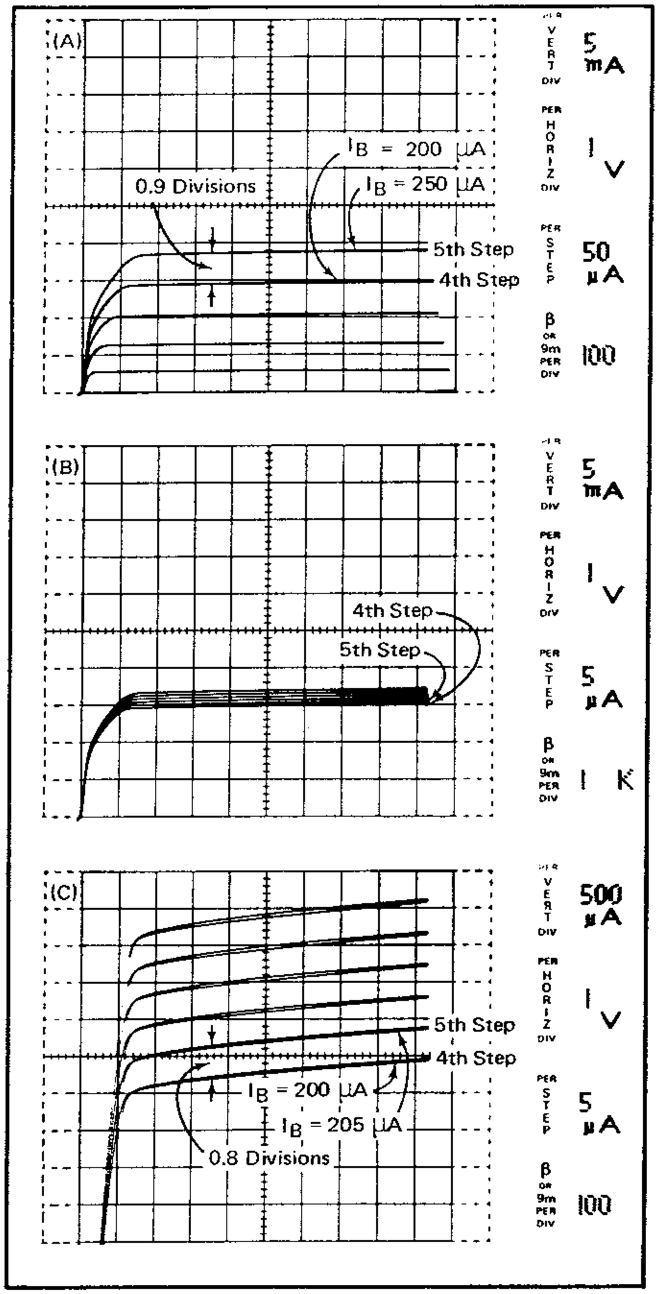


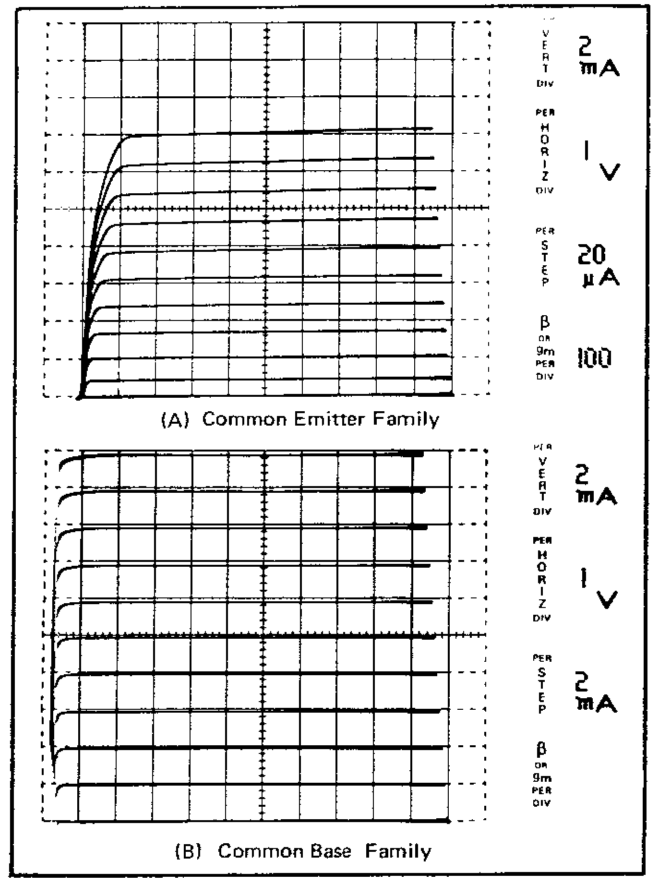
Fig. 2-18. Measurement of β of transistor, (A) Coarse measurement; (B) Offsetting of display and .1X multiplication of step amplitude; (C) 10X magnification of vertical display.

Standard Test Fixture

77. Set the following Type 576 controls to:

AMPLITUDE	20 µA
OFFSET	ZERO

78. Note the display of the characteristic curves with the emitter grounded and the current steps applied to the base (see Fig. 2-19A).



(A) Common Emitter Family

(B) Common Base Family

Fig. 2-19. (A) Terminal Selector switch set to BASE TERM STEP GEN (NORM); (B) Terminal Selector switch set to EMITTER TERM STEP GEN.

79. Set the LEFT-OFF-RIGHT switch to OFF and the STEP FAMILY button to OFF. Take a patch cord with banana plugs on each end and connect it between the STEP GEN OUTPUT connector and the EXT BASE OR EMIT INPUT connector.

80. Set the following Type 576 controls to:

STEP FAMILY	ON
LEFT-OFF-RIGHT	RIGHT
Terminal Selector	BASE TERM OPEN (OR EXT)

Note a display similar to that seen in step 78.

81. Set the following Type 576 controls to:

VERTICAL	1 nA EMITTER
MODE	LEAKAGE
VARIABLE COLLECTOR SUPPLY	Fully Counterclockwise
STEP FAMILY	OFF

Remove the patch cord.

82. Turn the VARIABLE COLLECTOR SUPPLY control clockwise and note the display of emitter leakage current with the base terminal open.

83. Set the Terminal Selector switch to SHORT and note the display of emitter leakage current with the base terminal shorted to ground.

84. Set the following Type 576 controls to:

VERTICAL	5 mA
AMPLITUDE	5 mA
Terminal Selector	EMITTER TERM STEP GEN
STEP FAMILY	ON

Turn the VARIABLE COLLECTOR SUPPLY control clockwise and note the display of collector current vs. collector-emitter voltage with current steps applied to the emitter of the transistor (see Fig. 2-19B).

85. Set the following Type 576 controls to:

STEP FAMILY	OFF
Terminal Selector	EMITTER TERM OPEN (OR EXT)

Reconnect the patch cord between the STEP GEN OUTPUT connector and the EXT BASE OR EMIT INPUT connector.

86. Set the STEP FAMILY button to ON and note a display similar to that seen in step 84.

This completes the first-time operation.

GENERAL OPERATING INFORMATION

CRT

The CRT in the Type 576 has a permanently etched internal graticule. The graticule is 10 divisions by 12 divisions, each division being 1 cm. Illumination of the graticule is controlled by the GRATICULE ILLUM control. Protective shields for the CRT and the fiber-optic readout display are fitted to the bezel. The bezel covers the CRT and the fiber-optic readout display. To remove, loosen the securing screw and pull out on the bottom of the bezel.

A blue filter has been provided to improve the contrast of the display when the ambient light is intense. This filter may be installed (or removed) by removing the bezel and sliding the filter between the CRT protective shield and the bezel frame.

Readout

The readout located to the right of the CRT is made up of the fiber-optic displays and their titles. The fiber-optic displays show numbers and units (5 mA, 2 V, etc.) the values of which are a function of front-panel control settings. The titles are words printed on the fiber-optic display shield attached to the bezel. These words indicate the characteristics of the CRT display to which each fiber-optic display is related (PER VERT DIV, PER STEP, etc.). Illumination of the titles and the fiber-optic diplays is controlled by the READOUT ILLUM control.

Intensity

The intensity of the display on the CRT is controlled by the INTENSITY control. This control should be adjusted so that the display is easily visible but not overly bright. It will probably require readjustment for different displays. Particular care should be exercised when a spot is being displayed. A high intensity spot may burn the CRT phosphor and cause permanent damage to the CRT.

Focus

The focus of the CRT display is controlled by the FOCUS control. This control should be adjusted for optimum display definition.

Positioning

The position of the display on the CRT graticule, both vertically and horizontally, is controlled by four sets of controls: the vertical and horizontal POSITION controls, the POLARITY switch, the DISPLAY OFFSET controls and the DISPLAY INVERT, ZERO and CAL buttons.

The position controls provide coarse and fine positioning of the display both vertically and horizontally. Each coarse POSITION switch provides 5-division increments of display positioning. Each FINE POSITION control has a continuous range of greater than 5 divisions. The position controls should not be used to position the zero reference off the CRT. The DISPLAY OFFSET controls may be used for this purpose. If the display is magnified either vertically or horizontally using the DISPLAY OFFSET Selector switch, the ranges of the position controls are increased 10 times.

The POLARITY switch positions the zero signal point of a display (located by pressing the ZERO button) to a position convenient for making measurements on an NPN device, a PNP device or when making an AC measurement (described under Collector Supply).

The DISPLAY OFFSET controls provide calibrated offset (or positioning) of the display either vertically or horizontally. These controls may be used either to make a measurement or to position particular portions of a display, which has been magnified, on the CRT graticule. The DISPLAY OFFSET Selector switch determines whether the display will be offset vertically or horizontally and the CENTERLINE VALUE switch provides the offset. Under unmagnified conditions, 10 divisions of offset are available. When the DISPLAY OFFSET Selector switch is set to one of its MAGNIFIER positions, 100 divisions of offset are available.

When making a measurement using the DISPLAY OFFSET controls, the CRT graticule becomes a window. When the CENTERLINE VALUE switch is set to 0, the vertical centerline (horizontal offset) or the horizontal centerline (vertical offset) of the window is at the zero signal portion of the display. As the CENTERLINE VALUE switch is turned counterclockwise, the window moves either vertically or horizontally along the display. For each position of the CENTERLINE VALUE switch, the number on the switch appearing in the blue window represents the number of divisions the vertical centerline or the horizontal centerline has been offset from the zero offset line. If the display has been magnified, the number in the blue window must be multiplied by 10.

The ZERO button provides a convenient means of positioning the zero reference point on the CRT graticule. Under normal operating conditions (DISPLAY OFFSET Selector switch set to NORM) when the ZERO button is pressed, a zero reference spot appears on the CRT graticule. This spot indicates the point on the CRT where zero signal is being measured by the vertical and horizontal display amplifiers. With the button pressed, the positioning controls may be used to position the spot to a point on the CRT graticule which makes measurements convenient. If the DISPLAY OFFSET Selector switch is set to VERT or HORIZ, the zero reference point indicates the horizontal or vertical graticule line, respectively, to which the CENTERLINE VALUE switch setting applies. To assure the accuracy of the CENTERLINE VALUE switch settings, the zero reference spot should be adjusted (using the positioning controls) to the appropriate centerline for the offset being used. For maximum accuracy of measurement, the position of this zero reference point should be adjusted with the DISPLAY OFFSET Selector switch in one of its MAGNIFIER positions.

The CAL button provides a means of checking the calibration of the display amplifiers. Under normal operating conditions (DISPLAY OFFSET Selector switch set to NORM) when the CAL button is pressed, a calibration reference spot appears on the CRT. This spot represents a signal applied to both the vertical and the horizontal display amplifiers which should cause 10 divisions deflection on the CRT graticule both vertically and horizontally. If the position of this spot is compared with the position of the spot obtained when the ZERO button is pressed, the accuracy of calibration of the display amplifiers can be determined. When the DISPLAY OFFSET Selector switch is set to either VERT or HORIZ, the calibration reference spot should appear on the vertical centerline (horizontal offset) or the horizontal centerline (vertical offset), assuming the zero reference point is properly adjusted. This calibration check should be made with the DISPLAY OFFSET Selector switch in either HORIZ X10 or VERT X10. Any departure of the calibration reference spot from the centerline, when this check is made, represents an error of 1% per division in the display offset.

The DISPLAY INVERT button provides a means of inverting the display on the CRT. When the DISPLAY INVERT button is pushed, the inputs to the display amplifiers are reversed, causing the display on the CRT to be inverted both vertically and horizontally about the center of the graticule.

If the position controls are centered, the zero and calibration references spots should appear in particular positions on the graticule depending on the positions of the POLARITY switch and the DISPLAY OFFSET Selector switch. Fig. 2-20 shows these positions of the spot for the various settings of the two switches. To determine the spot positions when the INVERT button is pressed, assume the graticule shown is inverted both vertically and horizontally.

Vertical Measurement and Deflection Factor

In the vertical dimension, the display on the CRT measures either collector current (I_C), emitter current (I_E) or the output of the Step Generator. The MODE switch and the VERTICAL switch determine which of these measurements are made.

The Vertical deflection factor of the display on the CRT is controlled by the VERTICAL switch, the DISPLAY OFFSET Selector switch and the MODE switch. The PER VERT DIV readout to the right of the CRT indicates the vertical deflection factor due to the combined effects of these three controls.

Under normal operating conditions, with the MODE switch set to NORM and the DISPLAY OFFSET Selector switch set to NORM (OFF), collector current is measured vertically and the VERTICAL switch determines the vertical sensitivity of the display.

When measuring collector current, the VERTICAL switch provides deflection factors (unmagnified) ranging from 1 µA/division to 2 A/division. The vertical deflection factor is indicated either by the PER VERT DIV readout or by the position of the VERTICAL switch, using the letters printed in black to determine units. The readout and the switch position should coincide.

When the MODE switch is set to LEAKAGE (EMITTER CURRENT) the CRT display measures emitter current vertically. In this case the vertical sensitivity of the display is increased by 1000 times for each position of the VERTICAL switch. The vertical deflection factor is indicated either by the PER VERT DIV readout or by the position of the VERTICAL switch, using the letters printed in orange to determine units. When the MODE switch is set to LEAKAGE the output of the Collector Supply is DC voltage, like that obtained when the MODE switch is set to DC (ANTI LOOP), rather than a voltage sweep. Also in the leakage mode a slight error (up to 1.25 V) is added to the horizontal display. The following Horizontal Measurement and Deflection Factor section shows how to determine the degree of this error.

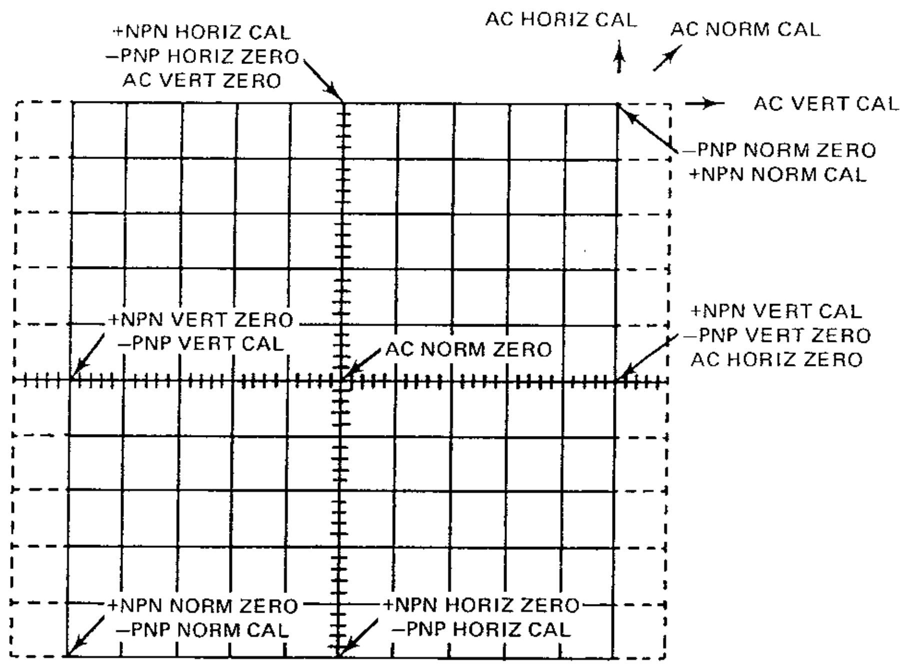


Fig. 2-20. Positions of spot on CRT graticule when ZERO or CAL buttons are pressed, for various positions of the POLARITY switch and the DISPLAY OFFSET Selection switch, assuming the position controls are centered.

When the VERTICAL switch is set to STEP GEN, steps indicating the Step Generator output are displayed vertically. The vertical display shows one step per division and the amplitude of each step, as shown by the PER STEP readout, determines the vertical deflection factor. It should be noted that if the HORIZONTAL switch is set to STEP GEN, the Step Generator output signal is not available for display vertically. In this case, setting the VERTICAL switch to STEP GEN causes zero vertical signal to be displayed.

The vertical sensitivity can be increased by 10 times for any of the previously mentioned measurements by setting the DISPLAY OFFSET Selector switch to VERT X10. The magnified vertical deflection factor can be determined either from the PER VERT DIV readout[1] or by dividing the setting of the VERTICAL switch by 10.

Horizontal Measurement and Deflection Factor

In the horizontal dimension, the display on the CRT measures either collector to emitter voltage (V_{CE}), collector to base voltage (V_{CB}), base to emitter voltage (V_{BE}), emitter to base voltage (V_{EB}) or the Step Generator output. The HORIZONTAL switch, the Terminal Selector switch and the parameter being measured vertically determine what is measured horizontally.

[1]**The PER VERT DIV readout does not indicate deflection factors less than 1 nA/division.**

The horizontal deflection factor of the display on the CRT is controlled by the HORIZONTAL switch and the DISPLAY OFFSET Selector switch. The PER HORIZ DIV readout to the right of the CRT idnicates the horizontal deflection factor due to the combined effects of these two controls.

Under normal operating conditions with collector current being measured vertically, the Terminal Selector switch set to EMITTER GROUNDED and the DISPLAY OFFSET Selector switch set to NORM (OFF), the display will measure V_{CE} or V_{BE} horizontally. To measure V_{CE}, the HORIZONTAL switch must be set within the COLLECTOR range which has deflection factors between 50 mV/division and 200 V/division. To measure V_{BE}, the HORIZONTAL switch must be set within BASE range which has deflection factors between 50 mV/division and 2 V/division. In both cases, the horizontal deflection factors are indicated by both the PER HORIZ DIV readout and the position of the HORIZONTAL switch. The two values should coincide

When the Terminal Selector switch is set to BASE GROUNDED the horizontal display measures collector to base voltage (V_{CB}) with the HORIZONTAL switch in the COLLECTOR range, or emitter to base voltage (V_{EB}) with the HORIZONTAL switch in the BASE range.

When emitter current is being measured by the vertical display, the only significant measurements made by the horizontal display are V_{CE} and V_{CB}. To make these measurements, the HORIZONTAL switch is set within the COLLECTOR range and the Terminal Selector switch is set to EMITTER GROUNDED or BASE GROUNDED.

With the VERTICAL switch set between 500 nA/division and 1 nA/division, an error occurs in the horizontal measurement. Table 2-3 indicates the degree of this error in voltage per division of vertical deflection for all the settings of the VERTICAL switch within this given range. Using this table and the following procedure, the actual V_{CE} or V_{CB} can be caluclated.

TABLE 2-3

Error in Horizontal Voltage Measurement Per Division of Vertical Deflection

VERTICAL Switch Setting[1]	Voltage Error Per Vertical Division
50 nA, 5 nA	125 mV
20 nA, 2 nA	50 mV
100 nA, 10 nA, 1 nA	25 mV

[1]**EMITTER current, DISPLAY OFFSET Selector switch set to NORM (OFF).**

1. Measure the vertical deflection of the display in divisions (see Fig. 2-21).

2. Measure the horizontal deflection of the display in volts.

3. Using Table 2-3, find the error factor for the setting of the VERTICAL switch and multiply it by the value determined in step 1.

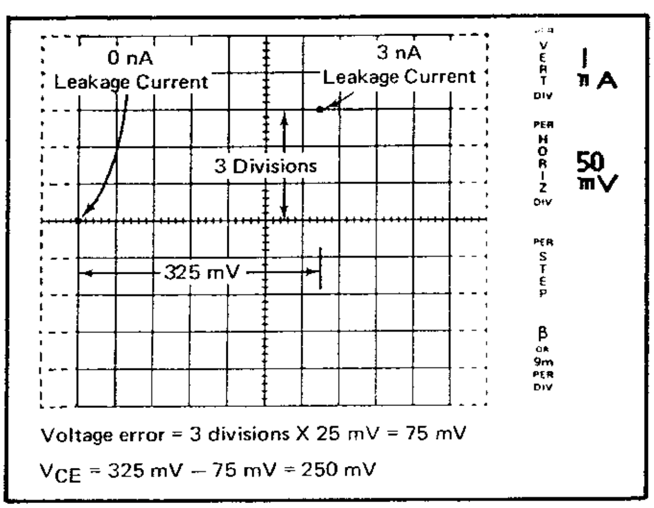


Fig. 2-21. Sample calculation of error in collector to emitter voltage incurred when measuring leakage of a transistor.

4. Subtract the voltage determined in step 3 from the voltage determined in step 2 to give the actual V_{CE} or V_{CB}.

When the HORIZONTAL switch is set to STEP GEN, steps indicating the Step Generator output are displayed horizontally. The horizontal display shows one step per division and the amplitude of each step, as shown by the PER STEP readout determines the horizontal deflection factor.

The horizontal deflection factor can be increased by 10 times for any of the previously mentioned measurements by setting the DISPLAY OFFSET Selector switch to HORIZ X10[2]. The magnified horizontal deflection can be determined either from the PER HORIZ DIV readout or by dividing the setting of the HORIZONTAL switch by 10.

Measurements

Table 2-4 shows the measurements which are being made vertically and horizontally by the display for the various positions of the VERTICAL switch, the HORIZONTAL switch and the Terminal Selector switch. Those switch position combinations not covered by the table are not considered useful.

Display Offset and Magnifier

The DISPLAY OFFSET Selector switch and the CENTERLINE VALUE switch provides a calibrated display offset of from 0 to 10 divisions (0 to 100 divisions when the display is magnified) and a 10 times display magnifier. The display offset and the display magnifier, when in operation, effect the display either vertically or horizontally, but never the whole display. Use of the calibrate display offset is discussed in the Positioning section. Use of the magnifier is discussed in both the Vertical and Horizontal Measurement and Deflection Factor sections.

Collector Supply

The Collector Supply provides operating voltage for the device under test. It is a variable voltage in the form of either a sine wave, or a full-wave rectified sine wave (see Fig. 2-22). This voltage is applied to the collector terminals of the Standard Test Fixture.

The MAX PEAK VOLTS switch and the VARIABLE COLLECTOR SUPPLY control determine the peak voltage output of the Collector Supply, which may be varied from 0 volts to 1500 volts. The MAX PEAK VOLTS switch provides four peak voltage ranges: 15 volts, 75 volts, 350 volts and 1500 volts. The VARIABLE COLLECTOR SUPPLY allows continuous voltage variation of the peak voltage within each peak voltage range.

The PEAK POWER WATTS switch, which interlocks with the MAX PEAK VOLTS switch, determines the maximum power output of the Collector Supply. Power output

[2]**The Horizontal display is not calibrated when the VERTICAL switch is set between 100 nA and 1 nA EMITTER.**

TABLE 2-4

Measurements Made by the Type 576 Display

Switch Settings			Measured by Display	
VERTICAL	HORIZONTAL	Terminal Selector	Vertically	Horizontally
COLLECTOR	COLLECTOR	EMITTER GROUNDED	I_C	V_{CE}
COLLECTOR	BASE	EMITTER GROUNDED	I_C	V_{CB}
COLLECTOR	STEP GEN	EMITTER GROUNDED	I_C	I_B or V_{BE}
COLLECTOR	COLLECTOR	BASE GROUNDED	I_C	V_{CB}
COLLECTOR	BASE	BASE GROUNDED	I_C	V_{EB}
COLLECTOR	STEP GEN	BASE GROUNDED	I_C	I_B or V_{EB}
EMITTER	COLLECTOR	EMITTER GROUNDED	I_E	V_{CE}[1]
EMITTER	COLLECTOR	BASE GROUNDED	I_E	V_{CB}[1]
STEP GEN	COLLECTOR	EMITTER GROUNDED	I_B or V_{BE}	V_{CE}
STEP GEN	BASE	EMITTER GROUNDED	I_B or V_{BE}	V_{BE}
STEP GEN	COLLECTOR	BASE GROUNDED	I_B or V_{BE}	V_{CB}
STEP GEN	BASE	BASE GROUNDED	I_B or V_{EB}	V_{EB}

[1]**Error in voltage must be calculated. See Horizontal Measurement in Deflection Factor section.**

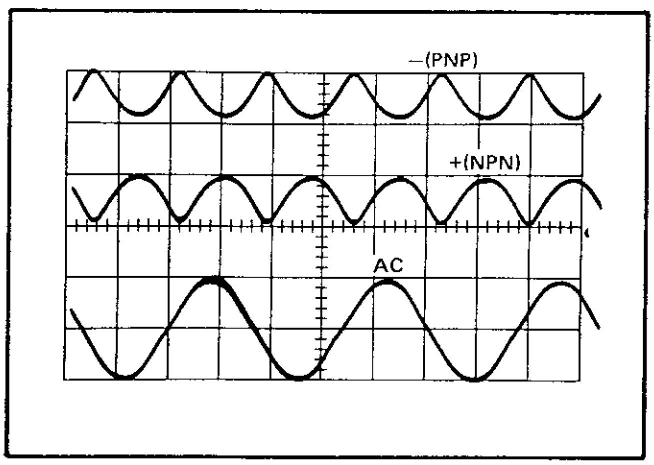


Fig. 2-22. Output of Collector Supply for three settings of POLARITY switch.

is controlled by placing a resistor, selected from the SERIES RESISTORS, in series with the Collector Supply output. The series resistance limits the amount of current which can be conducted by the Collector Supply. In setting the peak power output using the PEAK POWER WATTS switch, the proper series resistor is automatically selected. If the peak voltage range is changed while the MAX PEAK VOLTS and the PEAK POWER WATTS switches are interlocked, a new series resistor is chosen which will provide the same peak power output.

The Collector Supply POLARITY switch determines the polarity of the Collector Supply output and the Step Generator output. It also provides an initial display position on the CRT graticule as discussed in the section on positioning. When the POLARITY switch is set to +(NPN) the Collector Supply output is a positive-going full wave rectified sine wave and the Step Generator output is positive-going. When the switch is set to –(PNP) the Collector Supply output is a negative-going full wave rectified sine wave and the Step Generator output is also negative-going. The AC position of the POLARITY switch provides a Collector Supply output which is an unrectified sine wave, and the Step Generator output is positive-going. A negative-going Step Generator output can be obtained in this case by pressing the STEP/OFFSET POLARITY INVERT button. As noted on the front panel, when the AC position is being used, the MODE switch should be set to NORM and the Step Generator rate to .5X.

The MODE switch determines whether the Collector Supply output voltage will be a voltage sweep or a DC voltage. When the MODE switch is set to NORM the output is a repetitive voltage sweep varying from 0 volts to the peak voltage set by the MAX PEAK VOLTS switch and the VARIABLE COLLECTOR SUPPLY control. When the MODE switch is set to DC (ANTILOOP) or LEAKAGE (EMITTER CURRENT) the Collector Supply output is a DC voltage equal to the peak voltage set by the MAX PEAK VOLTS switch and the VARIABLE COLLECTOR SUPPLY control. This DC voltage may be either positive or negative. The DC mode is very useful when the normal display is exhibiting excessive looping.

Occasionally some of the characteristic curves displayed on the CRT consist of loops rather than well defined lines (see Fig. 2-23). This effect is known as looping and is most noticeable at very low or very high values or current. Looping is generally caused by stray capacitance within the Type 576, and device capacitance. It may also be caused by heating of the device under test. The LOOPING COMPENSATION control provides complete compensation for non heat-related looping due to the Type 576 and any standard device adapter which may be used. In general it does not compensate for any added capacitance introduced by the device under test. (Control has some effect in reducing stray capacitance in small diodes, and voltage-driven three terminal devices.) If uncompensated looping is hindering measurements, the MODE switch should be set to DC (ANTILOOP). If the collector sweep mode of operation (MODE switch set to NORM) is desired, an imaginary line lying inside the loop and equidistant from each side of the loop is the best approximation of the actual characteristic curve (see Fig. 2-23). Looping due to heating may be reduced by using the pulsed steps operation of the Type 576.

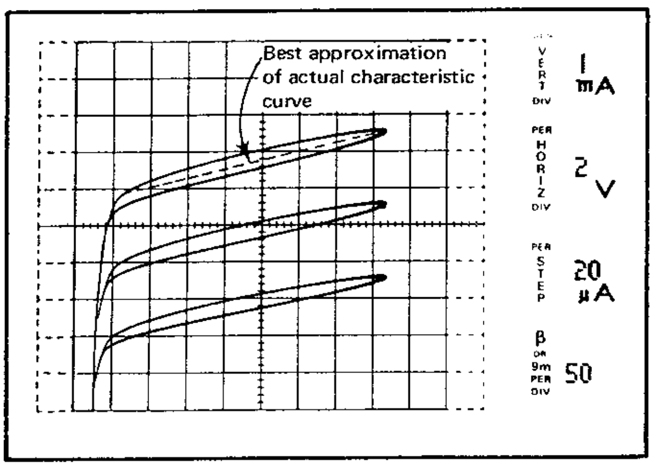


Fig. 2-23. Example of a display exhibiting looping.

Interlock System

Whenever the MAX PEAK VOLTS switch is in the 75, 350 or 1500 positions, the yellow COLLECTOR SUPPLY VOLTAGE DISABLED light comes on. This light indicates that the Collector Supply is disabled. In order to enable the Collector Supply under these circumstances, the Type 576 uses an interlock system. When the yellow light is on, the protective box must be installed over the accessories connectors (see Fig. 2-7). When the protective box is in place and the lid closed, the yellow light turns off and the red light turns on. The red light indicates that the Collector Supply is enabled and that a dangerous voltage may appear at the Collector terminals. For further information about the interlock system, see the Circuit Description.

Step Generator

The Step Generator provides current or voltage which may be applied to the base or the emitter of the device under test. The output of the Step Generator is families of ascending steps of current or voltage (see Fig. 2-24). When these steps together with the Collector Supply output are applied to the device under test, families of characteristic curves of the device are displayed on the CRT.

The NUMBER OF STEPS switch determines the number of steps per family and has a range of from 1 step to 10 steps. The AMPLITUDE switch determines the amplitude of each step and whether it is a current step or a voltage step. The ranges of step amplitudes available are from 50 nA/step to 200 mA/step for current steps and from 5 mV/step to 2 V/step for voltage steps. The STEP MULT .1X button, when pressed, divides the step amplitude by 10. When voltage steps are being applied to the base of a transistor, the base current increases very rapidly with increasing base voltage (note Caution on front-panel). To avoid damage to the transistor when using voltage steps, current limiting is provided through the CURRENT LIMIT switch.

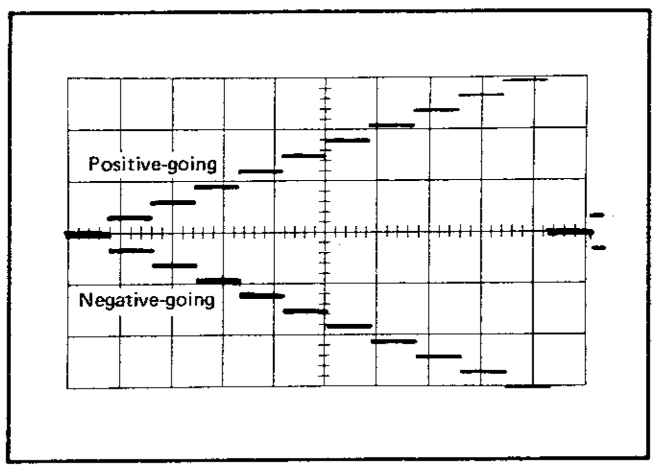


Fig. 2-24. Step Generator output in both polarities

The rate of generation of steps by the Step Generator is determined by the RATE buttons. When the NORM RATE button is pressed, steps are generated at a rate of 120 steps/second (assuming a 60 Hz line frequency), or one step per cycle of the Collector Supply, POLARITY switch set to +(NPN) or −(PNP). In this case each step occurs at the beginning of a Collector Supply cycle. When the .5X RATE button is pressed, the Step Generator rate is 60 steps/

second, or one step per 2 cycles of the Collector supply. Again, each step occurs at the beginning of a Collector Supply cycle. (This rate should be used when the POLARITY switch is set to AC.) Pressing the 2X RATE button produces a Step Generator rate of 240 steps/second, 2 steps per cycle of the Collector Supply. In this case steps occur at both the beginning and the peak of a Collector Supply cycle. If the 2X RATE and .5X RATE buttons are pressed together, the Step Generator rate is the normal rate of 120 steps/second except that the steps occur at the peak of each Collector Supply cycle rather than at the beginning as in normal rate operation.

The STEP FAMILY buttons determine whether step families are generated repetitively or one family at a time. Pressing the REP STEP FAMILY button turns the Step Generator on and provides repetitive families of steps. When the SINGLE STEP FAMILY button is pushed, one step family is generated and the Step Generator turns off. To get another step family, the SINGLE button must be pressed again.

The OFFSET buttons and the OFFSET MULT control allow current or voltage to be either added or subtracted from the Step Generator output. This causes the level at which the steps begin, to be shifted either in the direction of the ascending steps (aiding) offset, or in the opposite direction of the steps (opposing) offset. When the ZERO OFFSET button is pushed, the step family is generated at its nomal level where the zero step level is either 0 mA or 0 V and the OFFSET MULT control is inhibited. When the AID OFFSET button is pressed, current or voltage may be added to the Step Generator output using the STEP MULT control. The amount of current or voltage added to the Step Generator output when the AID button is pressed is equal to the setting of the STEP MULT control times the setting of the AMPLITUDE switch. The STEP MULT control has a continuous range of 0 to 10 times the setting of the AMPLITUDE switch. Pressing the OPPOSE OFFSET button allows either current or voltage to be subrtracted from the Step Generator output, the amount subtracted determined by the STEP MULT control. Table 2-5 shows the polarity of the offset current or voltage for the two polarities of the Step Generator output.

Opposing offset is most useful when generating voltage steps to test field effect transistors. When current steps are being generated, the maximum opposing voltage is limited to approximately 2 volts. This voltage limiting protects the base-emitter junction of a bi-polar transistor from reverse breakdown.

The STEP/OFFSET POLARITY INVERT button allows the Step Generator output (both steps and offset) to be inverted from the polarity at which it was set by the POLARITY switch. It has no effect when the Terminal Selector switch is set to BASE GROUNDED. Caution should be exercised when using this button to cause reverse current to flow between the base and emitter terminals. Voltage limiting occurs, when current steps are being generated, only when the OPPOSE OFFSET button is pressed.

TABLE 2-5

Polarity of Offset for Polarity of Step Generator Output

Step Generator Polarity	OFFSET Buttons	Offset	
		Current	Voltage
Positive going	AID	Positive	Positive
Positive going	OPPOSE	Negative	Negative
Negative going	AID	Negative	Negative
Negative going	OPPOSE	Positive	Positive

When one of the PULSED STEPS buttons is pressed, steps are generated in pulses having durations of either 300 µs or 80 µs (offset is unaffected). Pulsed operation is useful when testing a device at power levels which might damage the device if applied for a sustained length of time. Pulsed steps of a 300 µs duration occur when the 300µs PULSED STEPS button is pressed. When the 80 µs PULSED STEPS button is pressed, the duration of the pulsed steps is 80 µs. When either the 300 µs button or the 80 µs button is pressed, the Collector Supply mode is automatically set to DC. If the 300 µs and 80 µs buttons are pressed together, the Collector Supply remains in the normal mode and 300 µs pulsed steps are produced. In all the previously mentioned cases, the pulses occur at the peak of the Collector Supply sweep and therefore only the normal and .5 times normal Step Generator rates are available for use.

Standard Test Fixture

The Standard Test Fixture, which slides into the front of the Type 576, provides a means of connecting the Collector Supply output, the Step Generator output and the display amplifiers to the device to be tested.

The Terminal Selector switch, located on the Standard Test Fixture, determines the state of the base and the emitter terminals of the device under test. The switch has two ranges: EMITTER GROUNDED and BASE GROUNDED. In the EMITTER GROUNDED range, the emitter terminal is connected to ground and the Terminal Selector switch determines the state of the base terminal. With the switch set to STEP GEN (NORM), the Step Generator output is applied to the base terminal. In the OPEN (OR EXT) position, the base terminal is left open. In this case measurements may be made with the base terminal left open or with an externally generated signal applied to it through the

TEST SET-UP CHART TYPE 576

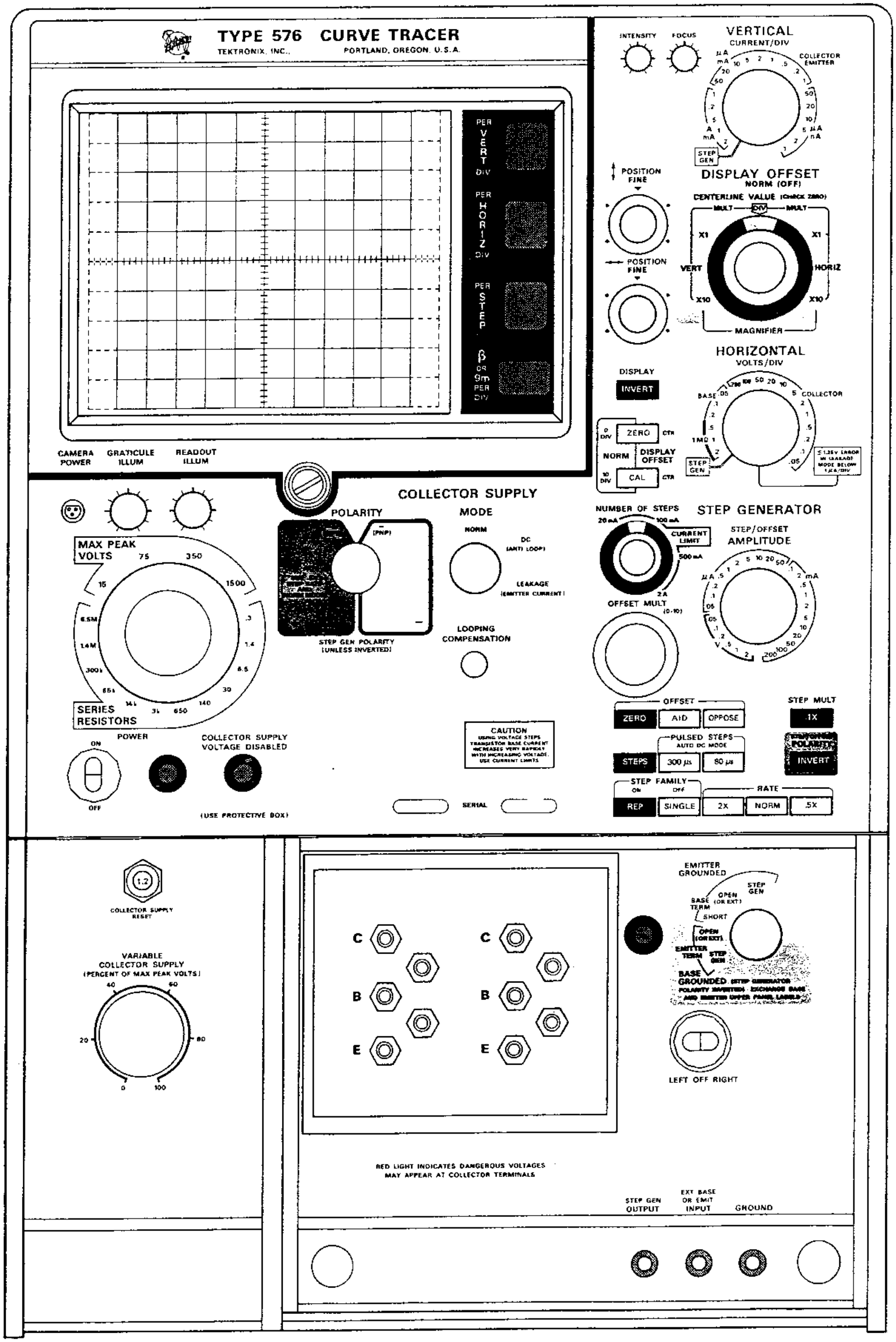


Fig. 2-25. Control setup chart for the Type 576 front-panel.

EXT BASE OR EMIT INPUT connector. When the Terminal Selector switch is set to BASE TERM SHORT, the base terminal is shorted to the emitter.

In the BASE GROUNDED range, the base terminal is connected to ground and the Terminal Selector switch determines the state of the emitter terminal. With the switch set to STEP GEN, the Step Generator output is inverted and applied to the emitter terminal. When the switch is set to OPEN (OR EXT) the emitter terminal is left open. In this case, measurements may be made with the emitter terminal left open or with an externally generated signal applied to it through the EXT BASE OR EMIT INPUT connector.

Tektronix Type 576 device testing accessories[3] may be plugged into the 10 Accessories connectors provided on the Standard Test Fixture. These accessories provide sockets into which semiconductors with various lead arrangements may be placed for testing. The 10 Accessories connectors allow the setting up of two devices at a time for comparison testing. The LEFT-OFF-RIGHT switch determines which device is under test. The 10 Accessories connectors also accept standard banana plugs so that a device may be connected to the Type 576 without using a specific device testing accessory.

[3]Some of these accessories are made of plastic and are susceptible to damage from excessive heat. If a device is likely to heat excessively a heat sink or the pulsed steps mode of operation should be used.

The unlabeled Accessories connectors allow Kelvin sensing of voltage under high current conditions. Kelvin sensing means that voltage measurements on the collector and the emitter teminals of a device under test are made through separate contacts to the device leads, utilizing Kelvin sensing.

The STEP GEN OUTPUT connector allows the Step Generator output to be used externally. The EXT BASE OR EMIT INPUT connector allows application of an externally generated signal to either the base or the emitter of the device under test. The external signal is applied to whichever terminal is chosen by the Terminal Selector switch. The GROUND connector provides a Type 576 ground reference for signals generated or used external in Type 576.

Polarities of the Collector Supply and Step Generator Output

Table 2-7 shows the polarities of the Collector Supply and the Step Generator output for various settings of the Collector Supply POLARITY switch and the Terminal Selector switch.

TABLE 2-7

Polarities of the Collector Supply and Step Generator Output

Switches		Polarities	
Collector Supply POLARITY	Terminal Selector	Collector Supply	Step Generator
−(PNP)	EMITTER GROUNDED	Negative going	Negative going[1]
−(PNP)	BASE GROUNDED	Negative going	Positive going
+(NPN)	EMITTER GROUNDED	Positive going	Positive going[1]
+(NPN)	BASE GROUNDED	Positive going	Negative going
AC	EMITTER GROUNDED	Positive and Negative going	Positive going[1]
AC	BASE GROUNDED	Positive and Negative going	Negative going

[1]May be inverted by pressing the POLARITY INVERT button.

NOTES

SECTION 3
CIRCUIT DESCRIPTION

Change information, if any, affecting this section will be found at the rear of this manual.

General

This discussion of the Type 576 internal operation is divided into two parts: Block diagram description and circuit description. The block diagram description discusses the functions of the major circuits within the instrument, using the overall block diagram. The circuit description provides a detailed description of all the major circuits and the signal switching within the instrument.

It is suggested that the block diagrams and schematics which have been included in this manual be referred to while reading this circuit description. Individual block diagrams and simplified schematics of most of the major circuits and signal switching accompany the text of this section. An overall block diagram of the instrument, showing all the major circuits and a simplified version of the signal switching, is provided in the diagrams section at the back of the manual. Also in the diagrams section are complete schematics of all the circuitry within the Type 576 which include component part numbers and values.

BLOCK DIAGRAM DESCRIPTION

The Type 576 is a dynamic semiconductor tester which displays and allows measurement of semiconductor characteristics obtained under simulated operating conditions. The collector supply circuit and the step generator produce operating voltages and currents which are applied to the device under test. The display amplifiers measure the effects of these applied conditions. The tests result in curves of transistor, diode, and other semiconductor device characteristics traced on the face of a CRT.

The collector supply circuit produces full-wave rectified sine waves which may be either positive-going or negative-going or unrectified sine waves, depending on the position of the POLARITY switch. The amplitude of the signal can be varied from 0 to 1500 volts as determined by the MAX PEAK VOLTS switch and the VARIABLE COLLECTOR SUPPLY control. The Collector Supply output is applied to the collector (or equivalent) terminal of the device under test.

The step generator produces ascending steps of current or voltage at a normal rate of one step for each half-sine wave of the collector supply. The amount of current or voltage per step is controlled by the AMPLITUDE switch and the total number of steps is controlled by the NUMBER OF STEPS switch. The Step Generator output may be applied to either the base or the emitter (or equivalent) terminals of the device under test.

The display amplifiers are connected to the device under test. These amplifiers measure the effects of the collector supply and the step generator on the device under test, amplify the measurements, and apply the resulting voltages to the deflection plates of the CRT. The sensitivities of these amplifiers are controlled by the VERTICAL CURRENT/DIV switch and the HORIZONTAL VOLTS/DIV switch.

CIRCUIT DESCRIPTION

The following discussion provides a detailed circuit description of all the major circuits within the Type 576 and the Standard Test Fixture. This description explains the operation of the various circuits within the instrument, and the voltages and waveforms which can be expected from them. Discussion of basic electronics and simple electronic circuits will be kept at a minimum.

Collector Supply

The collector supply circuit produces an unrectified sine wave or a full-wave rectified sine wave with a peak amplitude which may be varied from 0 to 1500 volts peak in four ranges. The initial voltage for the collector supply comes from variable autotransformer T300 (see Fig. 3-1) which has a source voltage of 115 volts AC. The output of T300 is connected to the primary of sweep transformer T301 and is controlled by the VARIABLE COLLECTOR SUPPLY VOLTS control and varies from 0 to 115 volts. The MAX PEAK VOLTS switch allows the choice of four collector sweep voltage ranges by choosing pairs of transformer taps from the secondary of T301. The voltage from these taps is rectified by one of two diode bridge rectifier assemblies: the 500 volt assembly for the 15, 75 and 350 volt ranges and the 2 kilovolt assembly for the 1500 volt range.

The 500 volt rectifier assembly is used either as a center tapped full-wave rectifier or a bridge rectifier depending on the connection of the current return input to the collector supply. The current return comes from the non-grounded side of the current sensing resistor. Since the voltage level of the current return input is dependent on the current flowing through the current sensing resistor, the collector supply can be considered to be floating. For the 15 volt or 75 volt ranges, the current return is connected to the center tap of the sweep transformer secondary. In this case only two diodes of the 500 volt rectifier assembly are used as a full-wave rectifier. For the 350 volt range, the current return goes to the bridge rather than the center tap of the transformer. In this case, the whole 500 volt rectifier

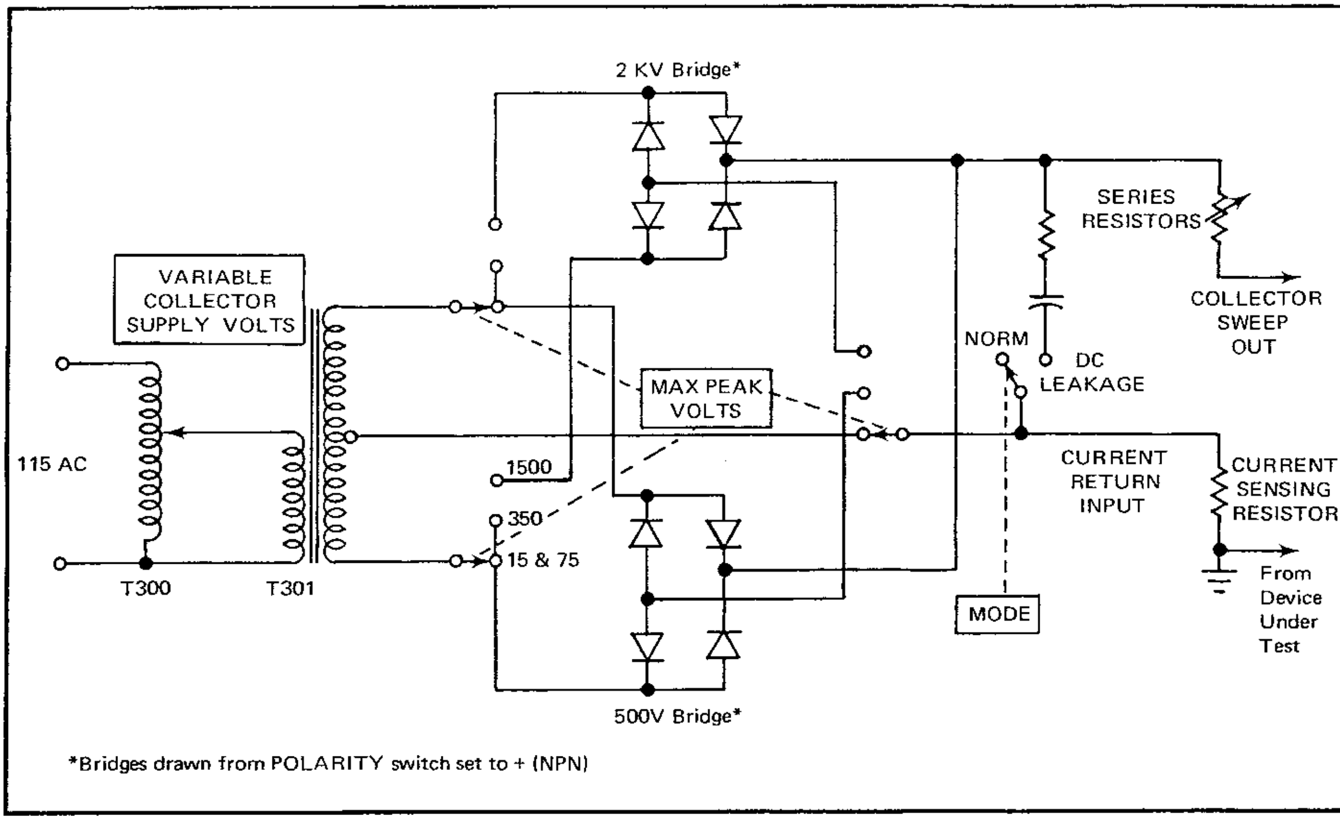


Fig. 3-1. Simplified schematic of collector supply circuit.

assembly is used for rectification. Operation in the 1500 volt range is similar to operation in the 350 volt range except that the 2 kilovolt bridge is used for rectification.

The POLARITY switch (see the Collector Supply schematic) allows the choice of three different sweep outputs from the collector supply by changing the output connections on the rectifier bridges. The possible outputs are positive-going +(NPN) or negative-going −(PNP) full-wave rectified sine waves or unrectified sine waves (AC). In all cases the peak amplitude of the collector sweep is controlled by the VARIABLE COLLECTOR SUPPLY control and the MAX PEAK VOLTS switch.

The MODE switch allows the choice of two different Collector Supply outputs: the normal collector sweep as has been previously mentioned and a DC collector voltage output. When the MODE switch is set to DC (ANTILOOP) or LEAKAGE (EMITTER CURRENT) the MAX PEAK VOLTS switch picks one of four resistor-capacitor combinations which is connected between the collector sweep output and the current return input. The purpose of these capacitors is to hold the collector sweep voltage at a constant DC level set by the VARIABLE COLLECTOR SUPPLY control. This holding is done by charging the capacitor up to maximum peak voltage as set by the VARIABLE COLLECTOR SUPPLY control and keeping them charged with the repetitive collector sweep. The result of charging these holding capacitors is a dot on the CRT rather than the normal sweep.

In series with the collector sweep are series resistors R345 through R355. The interconnected MAX PEAK VOLTS and PEAK POWER WATTS switches add these resistors in series according to the amount of peak collector current desired. The amount of this current is determined by the maximum power dissipation rating of the device under test.

Looping

There is a certain amount of non-discrete capacitance associated with the collector supply which causes an effect known as looping. Part of this undesired capacitance is stray capacitance, which provides an AC current path between the collector supply and chassis ground. The transformer and the guard box also exhibit some undesired capacitance between the guard box potential (common return point connected to guard box) and chassis ground. Fig. 3-2A shows that these two capacitances form a divider for AC current, the center of the divider being connected to the vertical amplifier.

During transitions of the collector sweep, some current will be transmitted by this undesired capacitance, bypassing the device under test. This current, however, is sensed by the vertical amplifier along with the collector current and causes the reading of collector current on the CRT to be incorrect. When the collector sweep rises, the undesired current will start positive and decrease to zero as the collector sweep reaches its peak. As the sweep falls, the stray current

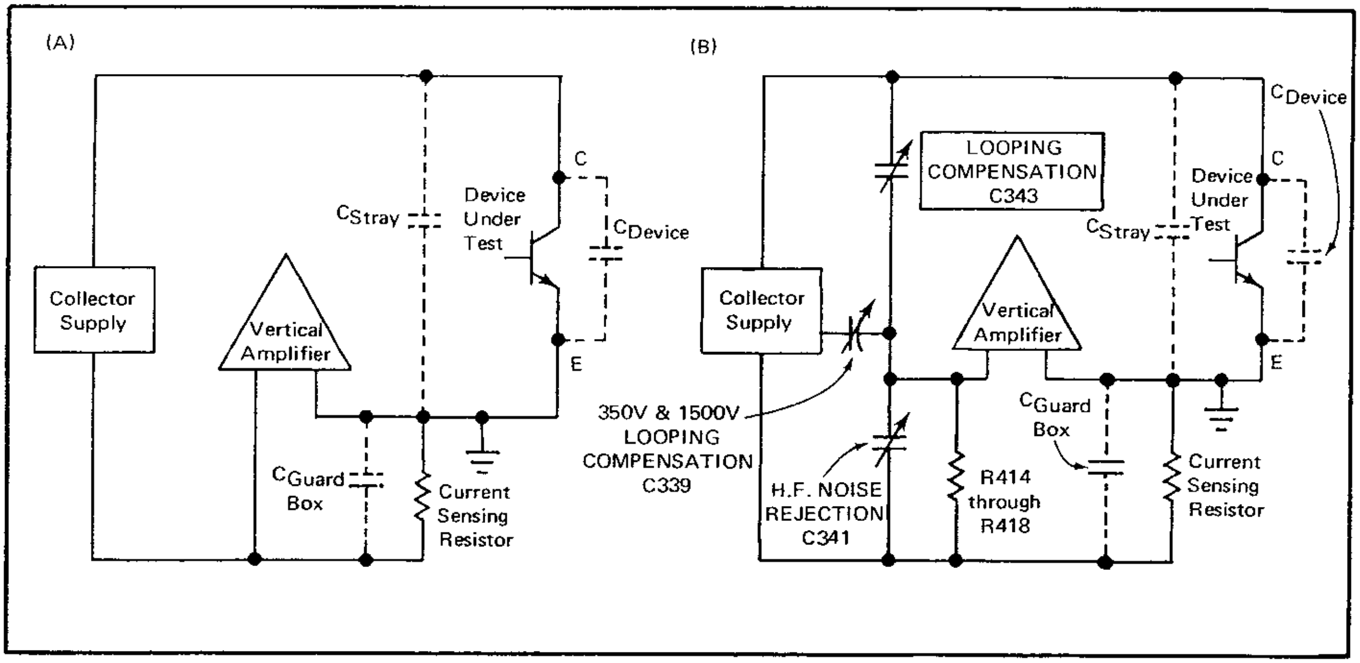


Fig. 3-2. (A) Undesired capacitance causing looping; (B) Looping compensation.

will go negative. The result on the CRT is a loop instead of a single line to represent the curve of I_C vs V_{CE}.

Looping Compensation

The LOOPING COMPENSATION adjustment, C343 (see Fig. 3-2B and the Collector Supply schematic), H.F. NOISE REJECTION adjustment C341 and R414 through R418 (see the Display Sensitivity Switching schematic) have been added to the circuitry as compensation for the stray and guard box capacitance previously discussed. In general, these adjustments will not compensate for device capacitance. This added capacitance forms a new capacitive divider which transmits AC current to the vertical amplifier in opposition to the current transmitted by the undesired capacitance. This opposing current, therefore, nulls the effect of the undesired capacitance which causes looping. In adjusting these added capacitors, C343 is adjusted to compensate for looping current transmitted from the collector sweep to ground, and C341 is adjusted to compensate for high frequency noise coming in on the line.

Another source of looping current is unbalance in the sweep transformer. As has been discussed in the collector supply circuit description, the sweep transformer is sometimes used in a full-wave rectifier arrangement. This method of transformer operation requires that the transformer be balanced about the center tap. LOOPING BALANCE adjustment C301 is adjusted to equalize the capacitance on both sides of the transformer center tap.

When the transformer is used in bridge operation, the voltage at one end is held essentially constant, and the transformer operates unbalanced. In this case, the transformer capacitance is added to the stray capacitance found between the Collector Supply and ground. 350 V and 1500 V LOOPING COMP adjustment C339 has been added between the transformer center tap and the junction of C343 and C341, for bridge operation of the Collector Supply to compensate for unbalanced operation of the transformer.

Interlock

The Type 576 has an interlock system designed to protect the user of the instrument from potentially dangerous voltages which may appear at the Collector terminals of the Standard Test Fixture. Fig. 3-3A shows a simplified schematic (see Collector Supply schematic for complete circuit) of this system.

Coil K323 enables or disables the Collector Supply output through K323-B, enabling it when the coil is energized. The coil is always energized when the MAX PEAK VOLTS switch is set to 15. When this switch is set to the 75, 350 or 1500 positions, one side of the coil is opened and the Collector Supply is disabled. The yellow COLLECTOR SUPPLY VOLTAGE DISABLED light is turned on through K323-A. In order to enable the Collector Supply under these conditions, the Protective Box must be put in place on the Standard Test Fixture and the lid closed. With the lid closed, High Voltage Interlock switch SW360 is closed and +12.5 volts is applied through the red DANGEROUS VOLTAGE light, B360, to coil K323, thus enabling the Collector Supply. With the coil now activated, the COLLECTOR SUPPLY VOLTAGE DISABLED light is turned off.

This interlock may be bypassed on the 75 or the 75 and 350 positions of the MAX PEAK VOLTS switch by reconnecting the wire connected to pin 1 of J300 to one of two alternate positions, labeled 75 and 350 in Fig. 3-3A. Changing the connection of this wire allows +12.5 volts to be applied to K323 through B360 regardless of the state of High Voltage Interlock switch SW360. The DANGEROUS VOLTAGE light is turned on in the 75, 350 and 1500 positions of the MAX PEAK VOLTS switch even if the interlock has been bypassed. If B360 were to burn out, the collector supply would be automatically disabled.

The interlock system may also be modified for use in all positions of the MAX PEAK VOLTS switch. This modification may be performed by removing the ground from the 15 V position of wafer 1R and connecting this position to the 75 V position of 1R. This wiring change makes it necessary to close SW360 (using the protective box) in order to activate K323 and enable the collector supply voltage.

These alternate connections are located on wafer 1F and 1R of the MAX PEAK VOLTS switch, inside the guard box on the left of the instrument. Fig. 3-3B shows a picture of this wafer and labels the alternate connections. The bypass modification is performed by soldering a jumper wire between terminals 1F19 and 1F20 (75 bypass) or between terminals 1F19 and 1F2 (75 and 350 bypass). To modify the interlock system for use on all maximum peak voltage ranges, unsolder the existing jumper wire connected between terminals 1R17 and 1R1, from 1R17 and resolder it to the buss wire connected to terminal 1R3. In unsoldering the jumper wire from terminal 1R17, be sure the white wire remains soldered to the terminal.

WARNING

The Type 576 is considered safe as shipped. Any modification of the interlock system in order to override its purpose of protecting operators from dangerous voltages, will make operation of the instrument potentially hazardous. Operators of the instrument should always be aware of the fact that when the red light is on dangerous voltages may appear at the Collector terminals.

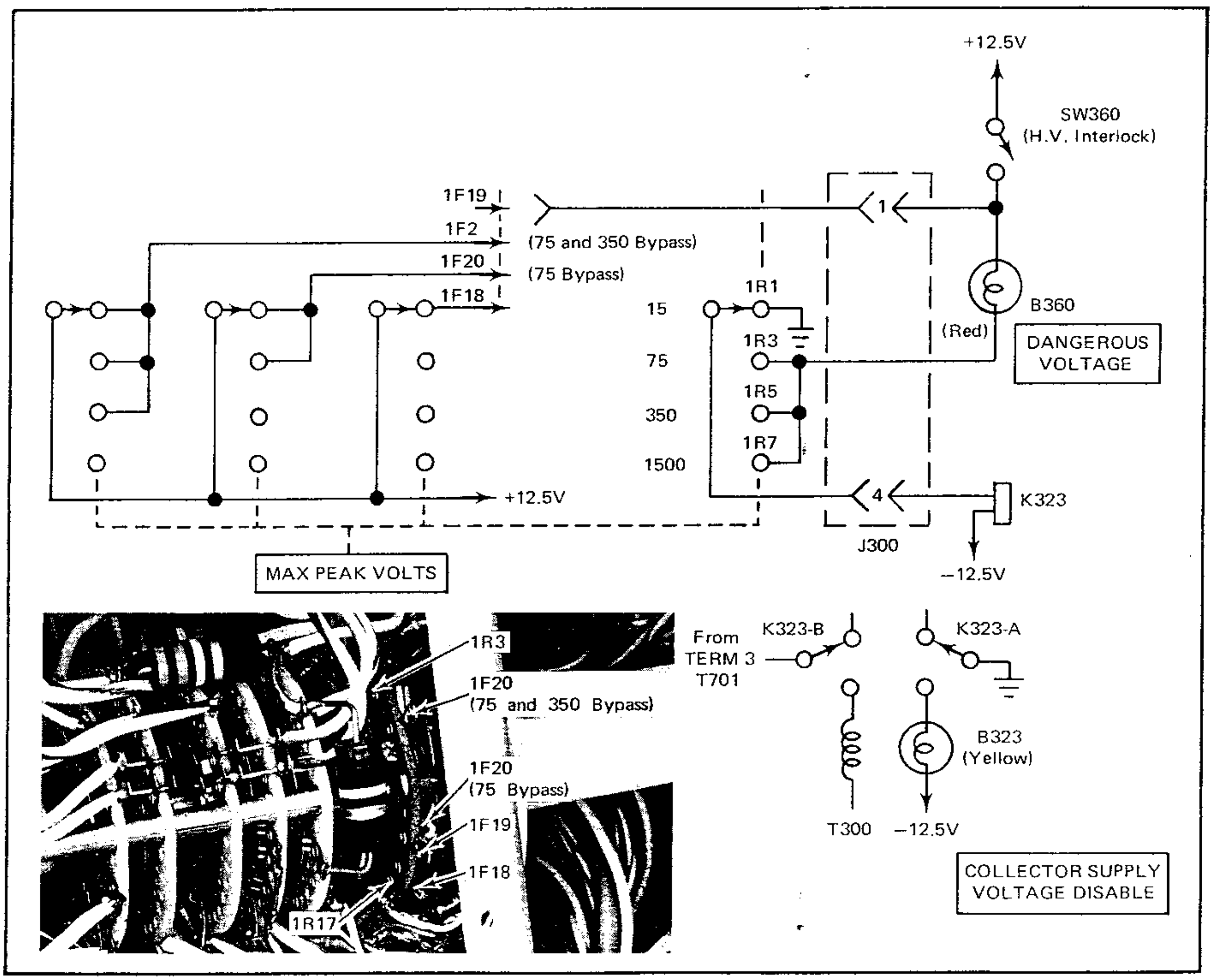


Fig. 3-3. (A) Simplified schematic of interlock circuit, (B) picture of wafer IF and IR of MAX PEAK VOLTS switch located inside guard box.

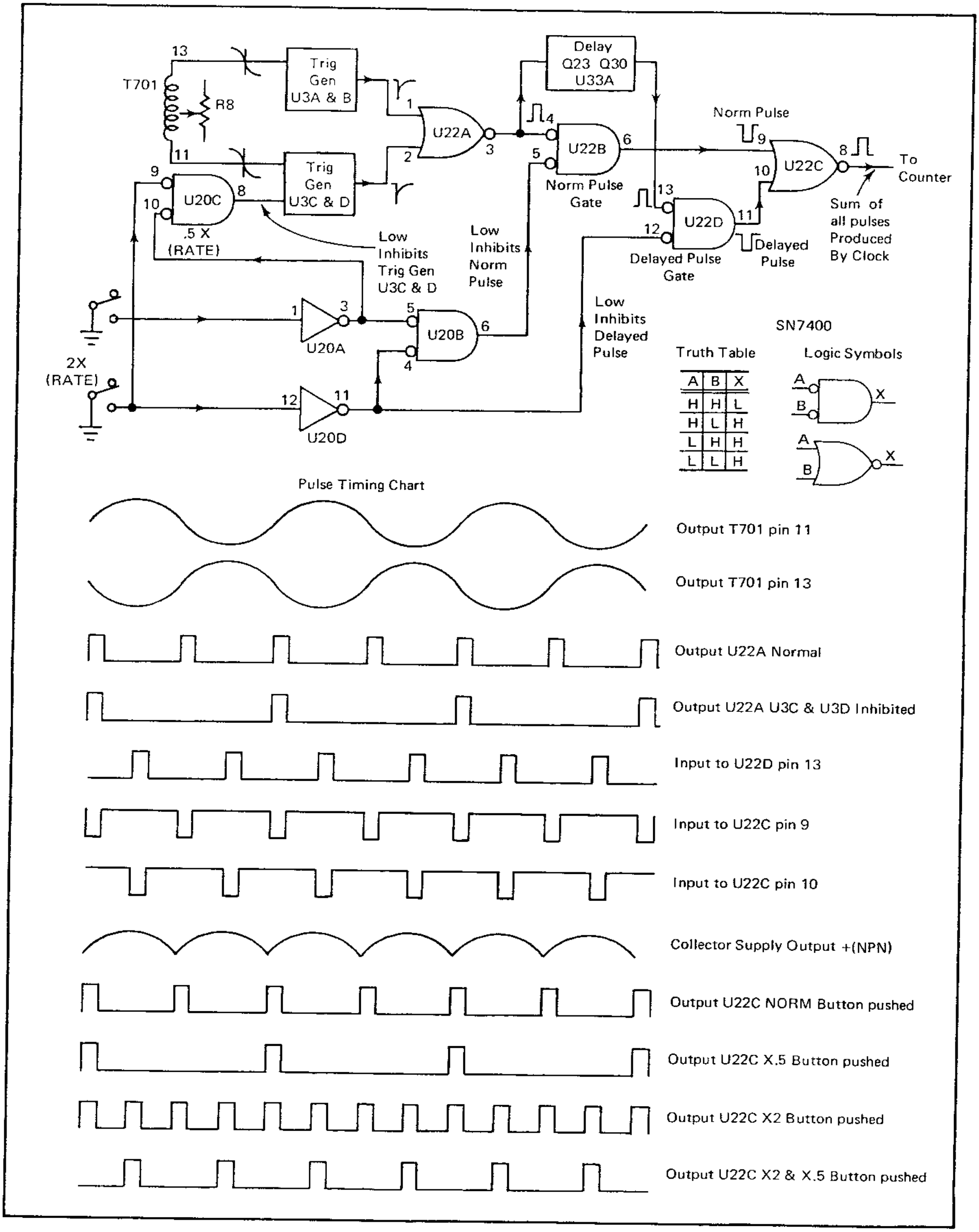


Fig. 3-4. Logic diagram, Pulse Timing chart for Step Generator Clock circuit.

Step Generator

The purpose of the step generator is to present a discrete level of current or voltage to the base or emitter (or equivalent terminals) of the device under test for each sweep, or change of direction of sweep, of the collector supply. These discrete levels are generated in the form of ascending steps which have a calibrated current or voltage separation.

The step generator circuit consists of four major sections: the clock, the counter, the digital-to-analog converter, and the pulsed steps operation section. The clock circuit produces negative-going clock pulses which determine the rate and phase, with respect to the collector supply, of the Step Generator output. The counter circuit counts these clock pulses and transforms each count into a digital code which controls the digital-to-analog converter. The digital-to-analog converter transforms the digital code into analog current which is summed at a current summing node and transmitted to the step amplifier. The pulsed steps operation circuit provides a variation of the Step Generator output where short duration pulsed steps rather than normal steps are generated.

Logic. The clock circuit, the counter circuit and a portion of the digital-to-analog circuit are digital circuits which make use of transistors and integrated circuits in digital configurations. The most convenient method of describing and understanding digital circuitry is through a logic description rather than a detailed circuit description. In order to make this description understandable by a wider range of readers, a simplified logic description, using high and low rather than true and false, has been utilized. A knowledge of basic logic symbols (NAND gates, NOR gates, flip-flops, etc.) and truth tables will help in understanding this description.

Simplified schematics of these circuits are shown in Figs. 3-4, 3-5 and 3-6. Also included in these figures are truth tables and some internal logic diagrams for the logic devices used. Pertinent logic level information for these logic devices is shown in blue on the Step Generator schematic. Familiarity with the logic symbols and related truth tables of these logic devices will greatly aid in understanding the following description.[1]

Clock. Sine waves produced at line frequency by transformer T701 provide the timing source for the clock (see the Step Generator schematic). Transformer T701, steering diodes D1-D2 and D10-D11, and trigger generators U3A-U3B and U3C-U3D operate together to produce low level pulses at the inputs of U22A. Using U3A-U3B as an example, each time the transformer voltage at the anode of D1 crosses zero going negative, D1 will turn off and D2 will turn on. When D2 is conducting, the voltage at the pin 1 input of U3A is held at a low voltage level. Since the other input to U3A, pin 2, is held at a high voltage level by voltage divider R4-R5, this low causes a high to appear at the output of U3A (see truth table for NOR gate shown in Fig. 3-4). This high is inverted by U3B and the resulting low is applied to the pin 1 input of U22A. This low output produced by the trigger generation continues until C5 charges to a high voltage level as determined by divider R4-R5. When the voltage at D1 crosses through zero going positive, D1 turns on and D2 turns off. With D2 off, both inputs to U3A are high, the output goes low and the output of U3B goes high. This is the quiescent state of the trigger generator. Trigger generator U3D-U3C operates the same as U3B-U3A except that the additional input at pin 9 of U3C allows the trigger generator to be inhibited when a low is applied to it.

Since Transformer T701 (see Fig. 3-4) is center tapped, the voltages at its outputs are equal and opposite. Since the two trigger generators are triggered by T701, they operate in opposite phase, producing alternate low level pulses at their outputs. Since T701 is in phase with the Collector Supply output, a pulse is generated by one of the trigger generators at the start of each collector sweep (assuming +NPN or −PNP polarity). ZERO CROSS adjustment R8 allows adjustment of trigger level of trigger generators.

With the NORM RATE button pressed, low pulses from the trigger generator are inverted to U22A and transmitted to norm pulse gate U22B. The pin 5 input to U22B is normally held high. A high at its other input, therefore, produces a low at its output. This low is applied to U22C, which produces a high level clock pulse to be applied to the counter circuit. With the NORM RATE button pressed, the rate of production of clock pulses (and therefore the step generator rate) is 120 pulses/second (assuming a 60 Hz line frequency) which is the normal collector supply rate.

High level output pulses from U22A are also applied to the base of Q23 (shown on the Step Generator schematic), the input to the delay circuit. This circuit generates clock pulses at the normal rate, but delayed (with respect to the start of each normal clock pulse) by a delay time equal to half the time duration between normal clock pulses. This delay circuit is triggered each time a high is produced at the output of U22A. This high turns on Q23, and pulls down on the base of Q30, turning it off. Since Q23 is pulling down on one side of C26, the other side begins charging. It continues to charge until a high enough voltage is reached to again turn on Q30. When Q30 turns on, a low level is produced at its collector, which is differentiated by C33 and R33 into a negative-going spike and applied to the input of inverter U33A. The result of this low at the input of U33A is a high at its output, and thus a high-level delayed pulse at the pin 13 input of U22D. The delay time of the half-step delay circuit is controlled by DELAY adjust-

[1]The schematics and block diagrams in this manual which involve digital logic are drawn in terms of negative logic. In negative logic, the true state is the more negative of the two logic levels and the false state is the more positive. The small circles on some of the input or output terminals of the logic symbols indicate a logic negation. Any terminal having a logic negation symbol on it will be at a false level when the related device is in its activated state. For further information see USA Standard Y32.14 1962.

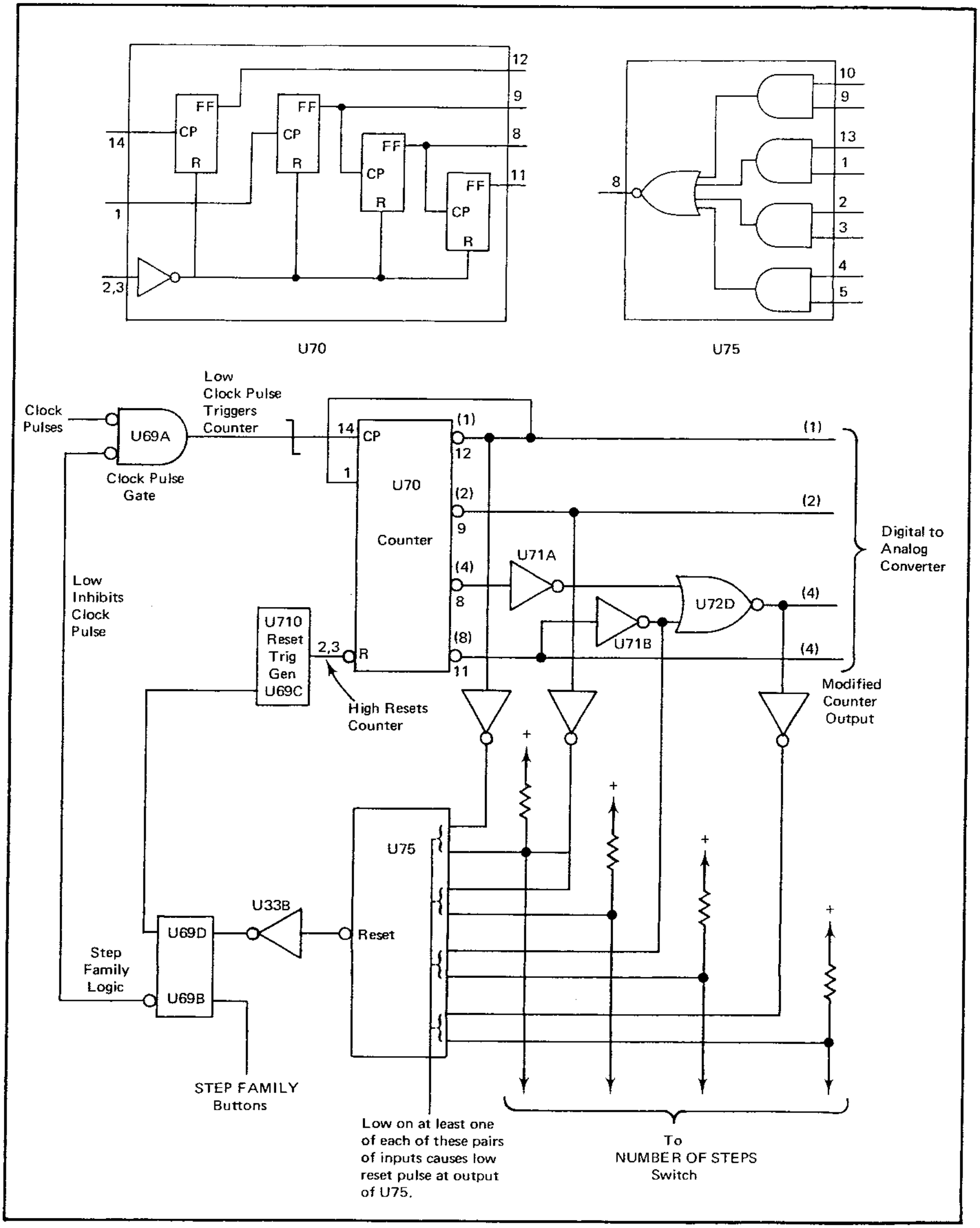


Fig. 3-5. Block diagram of counter and reset logic.

ment R24, which controls the charge time of C26. R24 is adjusted for a delay time equal to half the duration of a normal step (about 4167 μs). Delayed clock pulses, therefore, occur coincident with the peak of the Collector Supply output. SW27 lengthens the delay time of this circuit to 5000 μs when T701 is operated with a 50 Hz line frequency.

The clock circuit has two sources of clock pulses, the output of U22A and the output of the delay circuit. The various step generator rates are produced by inhibiting some of the clock pulses from these two sources from being summed by U22C. Three devices control the transmission of clock pulses through the circuit: Trig Gen Gate U20C, Norm Pulse Gate U22B and Delayed Pulse Gate U22D.

When the NORM RATE button is pressed, pin 9 of U3C is held high, enabling trigger generator U3D-U3C. A high is also applied to pin 5 of U22B, allowing the clock pulses from U22A to be transmitted to pin 9 of U22C. A low is applied to pin 12 of U22D, inhibiting the delayed clock pulse. When the .5X RATE button is pressed, the circuit operates as described for normal operation except that both inputs of U20C are held high, which holds pin 9 of U3C low and inhibits trigger generator U3C-U3D. The result is a step generator rate of half the normal rate, 60 steps/second (assuming a 60 Hz line frequency). Pressing the 2X RATE button causes normal operation of the circuit, except that a high is applied to pin 12 of U22D, allowing the delayed clock pulses to be applied to pin 10 of U22C. The step generator rate in this case is 240 steps/second. When both the 2X RATE and the .5X RATE buttons are pressed, the normal clock pulses are inhibited by a low at pin 5 of U22B and the delayed clock pulses are transmitted to U22C. In this case the Step Generator rate is normal, but the steps occur out of phase with the normal steps by the delay time of the delay circuit.

Counter. When the clock circuit generates a clock pulse, it is counted by the counter (see Fig. 3-5). The counter counts clock pulses until it reaches a preset number, then resets and begins counting again. Each time the counter counts, it changes a four-bit binary code which is applied to the digital-to-analog converter.

U70 is a divide-by-16 counter with the outputs of all four of its internal flip-flops utilized (see Fig. 3-5). A negative pulse at the pin 14 input of U70 causes a count to be recorded by the flip-flops. In recording a count, the flip-flops assume high or low states according to a 1-2-4-8 binary code. A high state represents the presents of either a 1, 2, 4 or 8. A low state represents a 0. Output terminals 12, 9, 8 and 11 of U70 represent 1, 2, 4 and 8 respectively. By connecting pin 8 and pin 11 of U70 to U72D through inverters, the 1-2-4-8 code of the U70 outputs is modified to a 1-2-4-4 code. The truth table in Table 3-1 shows the state of each modified counter output for successive counts counted by U70 up to 11. Whenever U70 is reset, it returns to the zero count state with lows on all the outputs.

TABLE 3-1

Normal and Modified Counter Output Codes

Count	Normal Code				Modified Code			
	Pins on U70				Pins on U70			U72D
	12	9	8	11	12	9	11	11
0	L	L	L	L	L	L	L	L
1	H	L	L	L	H	L	L	L
2	L	H	L	L	L	H	L	L
3	H	H	L	L	H	H	L	L
4	L	L	H	L	L	L	H	L
5	H	L	H	L	H	L	H	L
6	L	H	H	L	L	H	H	L
7	H	H	H	L	H	H	H	L
8	L	L	L	H	L	L	H	H
9	H	L	L	H	H	L	H	H
10	L	H	L	H	L	H	H	H
11	H	H	L	H	H	H	H	H

The counter may be reset after from 1 to 10 steps have been produced. The NUMBER OF STEPS switch determines on which clock pulse the counter is reset. This switch presets the inputs to U75, so that when the counter has counted the desired number of clock pulses, a high is generated at pins 2 and 3 of U70, resetting the counter. This high is obtained from a high at the output of reset trigger generator U75. U75 consists of four 2-input OR gates whose outputs are connected to a 4-input NAND gate. One input of each OR gate is connected through an inverter to an output of the modified counter. The other input is connected to a section of the NUMBER OF STEPS switch. When a low appears on one input of each OR gate of U75, all four inputs to the U75 NAND gate will be low and a high reset pulse is produced at the output. This condition of having at least one low on each OR gate of U75 is typically obtained by first setting lows on some of the OR gates through the NUMBER OF STEPS switch. The counter then counts until lows are produced by the modified counter output at the OR gates without preset lows. When no preset lows are applied to U75, the counter is reset when it reaches the eleventh step (1 + 2 + 4 + 4 = 11) when all modified counter outputs are low. It should be noted that the clock pulse which causes the counter to be reset is always one clock pulse more than the number selected by the NUMBER OF STEPS switch. The time duration from the point at which this extra clock pulse is counted by the counter to the point when the counter is reset is so short that the extra step never appears at the Step Generator output.

The high at the output of U75 is inverted by U33B (see the Step Generator Schematic) and again by U69C, producing a reset high at pin 2 and 3 of U70. U71D and C81 stretch the reset high to a long-enough duration to assure that the counter is reset.

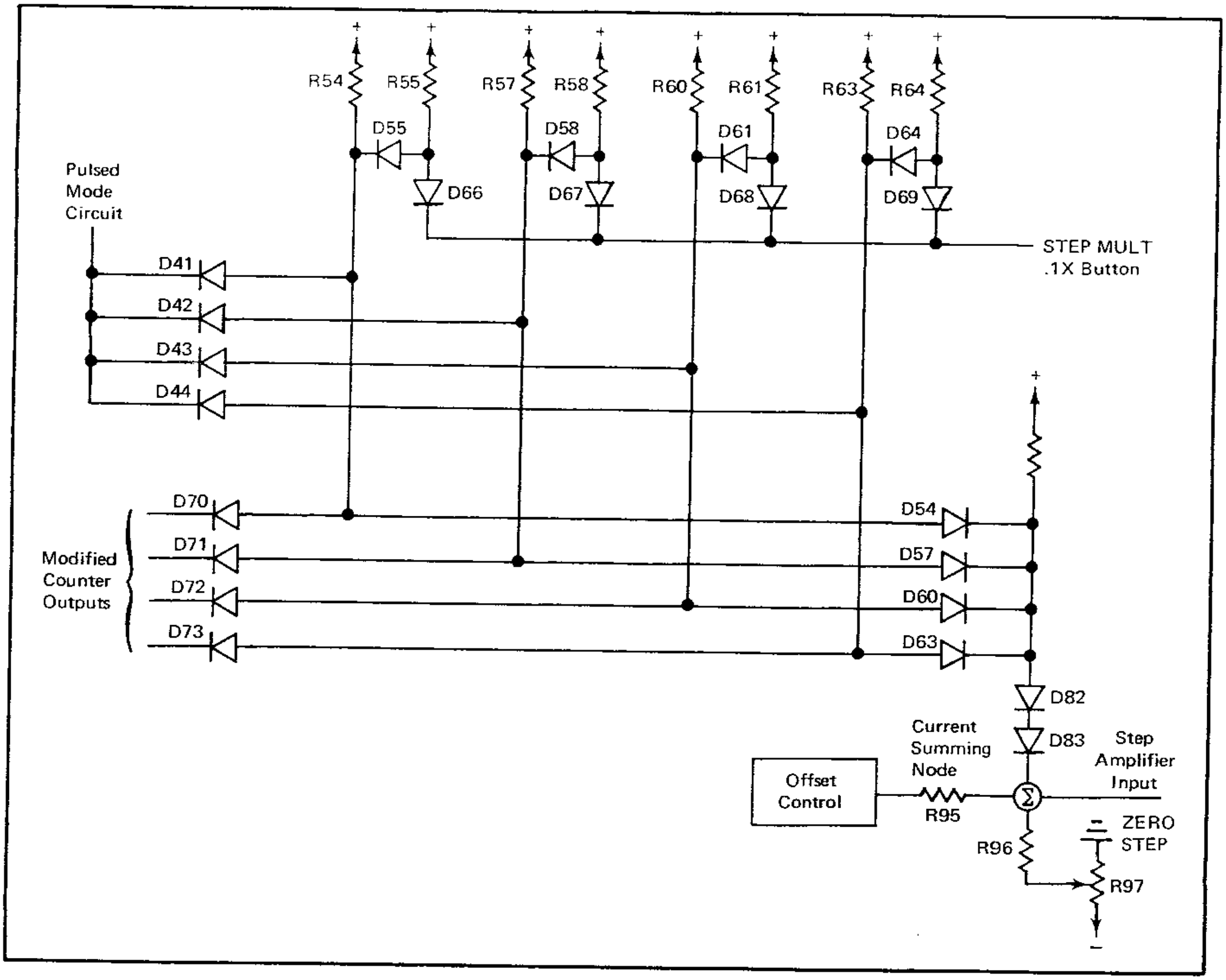


Fig. 3-6. Simplified schematic of Digital-To-Analog Converter.

The state of pin 2 of clock pulse enable U69A determines whether clock pulses are applied to the pin 14 input of U70. When the STEP FAMILY REP button is pressed, a low is applied to pin 5 of U69B, causing pin 2 of U69A to be held permanently high. In this state of U69A, all clock pulses applied to its pin 1 input are inverted, and become counter triggers. When the STEP FAMILY SINGLE button is pressed, a momentary low is applied to pin 5 of U69B which goes high as C78 charges. This momentary low enables U69A until one step family has been generated. When the reset high causes pin 4 of U69B to go high, a low is produced at the pin 2 input of U69A. This low inhibits clock pulses from being transmitted past U69A.

Digital-to-Analog Converter. The outputs of the modified counter are connected to the digital-to-analog converter. The purpose of this circuit is to convert the modified counter output code into analog current which is applied to the step amplifier input. The digital-to-analog converter consists of a set of current setting resistor pairs and four sets of current steering diodes.

The digital-to-analog converter conducts a constant amount of current, the amount of which is set by current setting resistor pairs R54-R55, R57-R58, R60-R61 and R63-R64 (see Fig. 3-6). Each resistor pair conducts a discrete amount of current which is a multiple of the modified counter code: one increment of current conducted by R54-R55, two increments by R57-R58, four by R60-R61 and four by R63-R64. Each successive increment of current causes one step to be generated at the Step Generator output.

The steering diodes determine where in the circuit current from these resistor pairs is conducted. Diodes D70, D71, D72 and D73 provide current paths between the modified counter outputs and the resistor pairs. Current is conducted by one of these diodes whenever its associated modified counter output is low.

Another set of current paths is provided by diodes D54, D57, D60 and D63. These diodes provide current paths between the current summing node (at the cathode of D83) and the current setting resistor pairs. It is these current paths which cause step current to be applied to the step amplifier input. Whenever a high appears at one of the modified counter outputs, its associated steering diode turns off and the current conducted by its associated resistor pair is applied to the step amplifier input.

The amount of current applied to the step amplifier input is a function of the modified counter output and may be determined by adding the currents conducted by each resistor pair associated with a modified counter output which is high. For example, if five counts have been recorded by the counter, highs appear at the cathodes of D70 and D72. The current applied to the step amplifier input is, therefore, one increment by R54-R55 plus four increments by R60-R61, totalling 5 increments. Thus five counts recorded by the counter results in five increments of analog current applied to the step amplifier input. The 1-2-4-4 modified counter code is designed so that the step current applied to the step amplifier input increases by one increment for each clock pulse counted by the counter (until the counter resets). ZERO STEP adjustment R97 controls the level of the zero step (with zero offset) by adjusting the quiescent current through D82 and D83.

Steering diodes D66, D67, D68 and D69 provide current paths for the currents conducted by R55, R58, R61 and R64, respectively, whenever the STEP MULT .1X button is pressed. (With the STEP MULT .1X button pressed D55, D58, D61 and D64 are reverse biased.) These new current paths reduce the amount current per increment which may be applied to the step amplifier input by a factor of 10. The result is that the normal step amplitude at the Step Generator output is reduced to one-tenth its normal value.

The fourth set of steering diodes, D41, D42, D43 and D44 is used only when the step generator is operating in the pulsed mode. In all other cases, their cathodes are held high and they have no effect on the current applied to the step amplifier input.

The current summing node sums current from R95 as well as the digital-to-analog converter. The zero step level may be offset either in the direction which steps are ascending or in the opposite direction of ascent as determined by the DC current conducted by R95. If offset in the direction of the steps is desired, the AID OFFSET button is pressed. This allows positive voltage to be applied to the base of Q90 using the OFFSET MULT control, which raises the emitter voltage of Q93 and causes current to be conducted through R95. When the OPPOSE OFFSET button is pressed, negative voltage is applied to the base of Q90 using the OFFSET MULT control, which causes current to be conducted through R95 in the opposite direction. OPPOSE OFFSET adjustment R85 and AID OFFSET adjustment R86 adjusts the offset level of the steps when the OPPOSE OFFSET and AID OFFSET buttons are pressed, respectively.

Pulsed Step Mode. When one of the PULSED STEPS buttons is pressed, the Step Generator output steps are reduced to short pulses. These pulsed steps are obtained by inhibiting the digital-to-analog converter for all but 300 μs or 80 μs of each step.

The digital-to-analog converter is inhibited by pressing either the 300 μs or the 80 μs PULSED STEPS button (see the Step Generator schematic). Pressing one of these buttons turns Q41 on and provides current paths for the resistor pairs through D41, D42, D43 and D44. The digital-to-analog converter is inhibited in this state because no step current is available to be applied to the step amplifier input, regardless of the condition of the modified counter output. The digital-to-analog converter remains inhibited until a negative-going trigger from the collector of Q30 reverse biases D39 and turns off Q41. With Q41 off, its collector goes high, turning on Q36 and reverse biasing steering diodes D41, D42, D43 and D44. The digital-to-analog converter is now enabled and free to produce a step in the manner described previously. The duration of the step is controlled by the charge time of C35. With Q36 on, its collector holds one side of C35 at about ground, allowing the other side to be charged through R39 (and R37 when the 300 μs button is pressed). C35 charges until D39 is forward biased and Q41 again turns on. With Q41 on, Q36 is turned off and the digital-to-analog converter is again inhibited by the steering diodes D41, D42, D43 and D44.

Since each pulsed step is triggered by a negative-going trigger from the delay circuit, the pulsed steps always appear at the peak of the Collector Supply output. When the step generator is operating in the pulsed step mode, the 2X RATE button is inhibited.

When Q41 is turned on, Q46 is turned off, which also turns off Q52. The emitter of Q52 is connected to the grid of the CRT, V897 (see the CRT Circuit schematic). When Q52 turns off, its emitter voltage goes negative, causing the intensity of the CRT display to be reduced. The display intensity remains reduced until Q41 turns off, allowing Q46 and Q52 to turn on. The CRT display in the pulsed step mode is, therefore, intensified only when a pulsed step occurs.

The Collector Supply schematic shows that when either the 300 μs or the 80 μs PULSED STEPS button is pressed, K320 is energized and the Collector Supply operates in its DC mode. It may also be seen, that if the 300 μs and 80 μs PULSED STEPS buttons are pressed together, 300 μs pulsed steps are generated and the collector supply operates in its normal mode (K320 is not energized).

Step Amplifier

The step amplifier transforms the output of the step generator into current or voltage steps of various amplitudes to be applied to the device under test. The AMPLITUDE switch, which is part of this circuit, determines the amplitude of the steps. The circuit consists of a current to voltage converter, an inverter and a differential output amplifier. The output amplifier has two modes of operation, one producing current steps and the other producing voltage steps.

The output of the Step Generator, which may be from one to ten current steps of 350 μA per step plus from one to ten steps of offset, is applied to the base of Q105A (see the Step Amplifier schematic). Q105A and B comprise a differential amplifier. As the base current of Q105A is decreased, the collector current of Q105B increases, raising the voltage at the base of Q110. Each current step at the base of Q105A, therefore, causes a positive voltage step at the base of Q110. These voltage steps are amplified and inverted by Q110, and part of the output is transmitted through R113, R112 and C112 creating negative feedback at the base of Q105A. R113 adjusts the feedback gain of current to voltage amplifier Q105 and Q110 for an output at the collector of Q110 of negative going steps with amplitudes of 1/2 volt/step.

Q117 and Q122 have been added to the current to voltage amplifier circuit to slow down the voltage transition from the level of the last step generated to the zero step level, in cases where this transition may cause damage to the device under test. When the preset number of steps has been produced at the Q110 output, a rapid transition occurs as the step returns to its starting point. This transition, when applied to the base of a transistor, rapidly turns it off. If a transistor is turned off in this manner when its collector is at a high level, a high inductive voltage kick will be produced in the collector supply transformer. Such an inductive voltage kick may be large enough to damage the transistor.

This circuit operates either when the 2X RATE button is pressed or when the 300 μs and 80 μs PULSED STEPS buttons are pressed together. In this case the emitter circuit of Q122 is opened, turning the transistor off. The source of FET Q117 is held at −11.3 volts by divider R116-D115-R108. When Q122 turns off, divider R119-R120-R121 sets the voltage at the gate of Q117 at −10.3 volts, turning the FET on. With Q117 on, its drain is held at about −11.3 volts, providing a constant voltage on the side of C114 connected to Q117. By holding one side of C114 at constant voltage and transmitting the output of Q110 across the other side, C114 becomes an integrator. The voltage transition of the Q110 output from the level of its last step to the starting level is, therefore, slowed down by integrator C114. When Q122 is turned on (normal or 0.5 times rate or DC mode), Q117 is held off by having about −34 volts at its gate. In this case, the current through R117 controls the voltage on Q117 side of C114, which moves up and down with changes in the output of Q110. C114, therefore, has little effect on the output of Q110 and causes no slowing of the voltage transition.

When relay K101A is in the − position, the output of Q110 is transmitted through inverter circuit Q130A and B and Q133 and inverted before it is applied to the output amplifier. The inverter is identical in operation to the current to voltage amplifier described previously. Since the input resistance (R125) and the feedback resistance (R137) are equal, the gain of the inverter is 1. INVERT ZERO adjustment R127 sets the voltage at the base of Q130A so that the initial level is the same for the non-inverted steps and the inverted steps.

The position of relay K101A is controlled by the COLLECTOR SUPPLY POLARITY switch, the STEP-OFFSET POLARITY INVERT button and the Terminal Selector switch in conjunction with the step generator polarity logic (see the Step Amplifier schematic). U33C and D, U72A, B and C form a coincidence gate. See Table 3-2 for a truth table of this gate. The output at pin 6 of U72B causes Q101 to turn on and off, thus switching relay K101A between + and −. If a high appears at the output of U72B, K101A switches to the − position and if a low appears, it remains in the + state. The inputs to U33C and D and to U72A and C are controlled by the voltage levels on connectors T and S as shown in Table 3-2. Setting the Terminal Selector switch to EMITTER TERM STEP GEN has the same effect on the voltage level of connector T as pressing the POLARITY INVERT button. If the POLARITY INVERT button is pressed, however, the Terminal Selector switch has no effect on the voltage level at connector T and vice versa.

TABLE 3-2

Step Generator Polarity Logic

COLLECTOR SUPPLY POLARITY	POLARITY INVERT	Connectors		Pin 6 U72B
		T	S	
AC	Pressed	H	L	H
AC	Not Pressed	H	H	L
+(NPN)	Pressed	H	L	H
+(NPN)	Not Pressed	H	H	L
−(PNP)	Pressed	L	L	L
−(PNP)	Not Pressed	L	H	H

Output Amplifier. The step output amplifier transforms the output steps of the current to voltage amplifier (or inverter) into current or voltage steps of various amplitudes as determined by the AMPLITUDE switch. It is basically a differential amplifier with separate feedback to each input. The negative input side of the amplifier controls the amplitude of the output steps. The positive input side of the amplifier provides either current regulation or a constant operating level. To obtain current steps (see Fig. 3-7A), the gain of the negative side of the differential amplifier is set for an output of 1 volt per step. This output is then transmitted through a variable resistance in series, Current Setting Resistors. With the constant voltage per step relationship across the current setting resistors, the current per step output can be varied by changing this resistance in series. To obtain voltage steps, the input resistance to the nega-

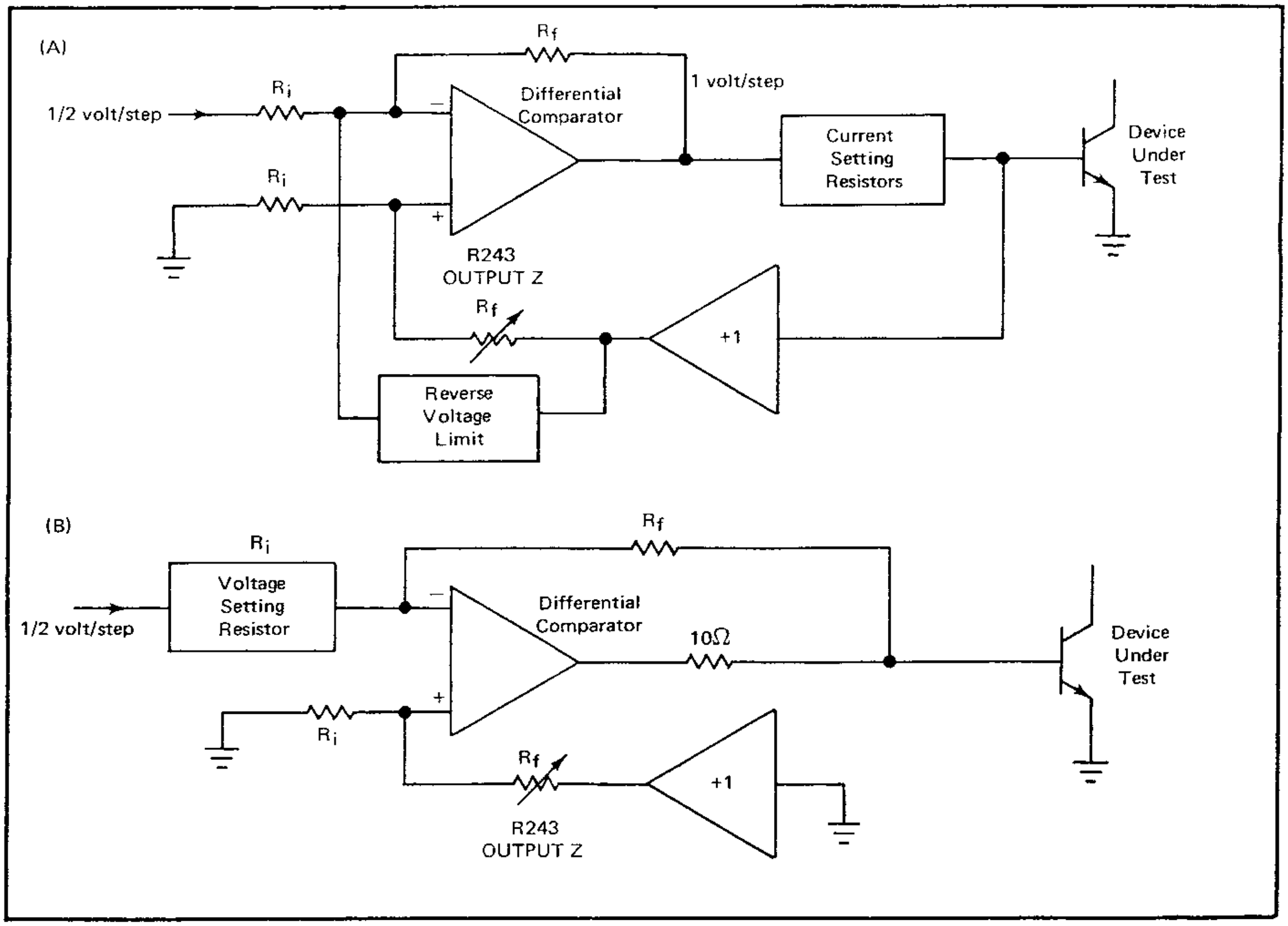


Fig. 3-7. Block diagram of Step Output Amplifier: (A) Current Mode, (B) Voltage Mode.

tive input, the voltage setting resistors, is changed, thus varying the feedback gain of that side of the differential amplifier. In this manner voltage steps of various amplitudes are obtained.

Current Mode. Input to the negative side of differential comparator Q150 (the base of Q150A) is always through VOLTAGE SETTING RESISTORS R141 through R145. In the current mode, this input resistance is set at 3.01 kΩ (R141) for all current positions of the AMPLITUDE switch. When 1/2 volt steps are applied to the base of Q150A through R141, they are inverted, applied to the base of Q164 and inverted again. The steps are then transmitted through emitter follower Q169 to the bases of Q172 and Q176. Depending on the position of relay contacts K102B and K102C, either Q172 and Q180 or Q176 and Q184 are turned on. If, for example, K102B and K102C are in the + positions signifying positive-going steps out, Q176 and Q184 are on the Q172 and Q180 are off. In this case the input to Q176 is negative-going steps. They are inverted by Q176 and the resulting positive-going steps are transmitted through emitter follower Q184 to the negative side of the floating 50-volt supply. Each time a positive step occurs at the negative side of the 50-volt supply, the supply is pushed up by the amount of the step. The positive side of the 50-volt supply is connected to both the feedback resistors and the input to the current setting resistors, so that each time the 50-volt supply is raised by a step, the voltage at this connecting point is also raised by the amount of the step. Due to the presence of the 50-volt supply, the voltage at the input to the current setting resistors is offset by 50 volts. To compensate for this offset, 50 volts of opposing offset is added to the input of the current setting resistors through relay K102A. If K102B and K102C are in their – positions, Q172 and Q180 are on and Q176 and Q184 are off. In this case negative-going steps are applied to the positive side of the 50-volt supply and negative-going steps appear at the input to the current setting resistors.

The output of the negative side of the differential amplifier at either K102B or K102C is fed back to the base of Q105A through feedback resistor R194. Since R194 is 6.04 kΩ and the input resistance, R141, is 3.01 kΩ, the feedback gain of this circuit is 2. For a half volt per step input, the resulting output of the negative side of the differential amplifier (as seen by the input to CURRENT SETTING RESISTORS R197 through R216) is steps of one volt per step, the zero level being at ground. (If offset has been added in the step generator circuit, the zero step level may range from 0 to 10 volts.)

The output end of the current setting resistors is connected through the device under test to ground. When voltage steps of 1 volt per step are applied between the input end of the current setting resistors and ground, current steps of variable amplitude flow through the device under test. The current amplitude of the steps is determined by AMPLITUDE switch SW195 (see Step Generator Switching schematic), which chooses various combinations of resistors R197 through R216.

In order to obtain calibrated current steps, the voltage across the current setting resistors must be held at 1 volt per step. The voltage at the output, however, may vary by the amount of the turn-on voltage of the device under test and alter the current per step output of the step generator. To compensate for this turn-on voltage, any variation from ground of voltage at the input to the device under test is transmitted through the +1 amplifier to the positive side of the differential amplifier. This starts a regulating process which causes the voltage at the input to the current setting resistors to move in the same direction as the turn-on voltage at the output, thus nullifying its effect.

The +1 amplifier is made up of paraphase amplifier Q229A and B, constant current sources Q233 and Q226, and emitter followers Q235 and Q241. In the current mode, any voltage at the input of the device under test is transmitted through R220 to the high impedance gate input to Q229B. If, for example, this variation is a rise in voltage at the gate input, it will be accompanied by a rise in voltage at the drain of Q229A, due to the paraphase operation of Q229A and B. Raising the voltage at the Q226A drain raises the base of emitter follower Q235, and thus the base of emitter follower Q241. As the emitter of Q241 follows its base up, it pulls the voltage at the gate of Q266A up so that it is equal to the voltage at the gate of Q266B. This rise in voltage at the gate of Q266A is then transmitted to the base of Q150B (positive side of the differential amplifier) through feedback resistors R243 and R244. The +1 amplifier, therefore, transmits any voltage variation from the input to the device under test to the input to the base of Q150B with no change in amplitude or polarity. In performing this task, the +1 amplifier provides the voltage variation with a high impedance input and a low impedance output. When the rise in voltage at the base of Q150B has been transmitted to the input to the current setting resistors, it compensates for voltage variations at the input to the device under test holding the voltage across the current setting resistors at 1 volt per step. AMP BAL R224 adjusts the DC balance of paraphase amplifier Q229, and also compensates for unbalance in Q150. OUTPUT Z adjustment R243 adjusts the output impedance of the step amplifier.

Relay K101B and Q248 or Q250 are used to limit the voltage which may be applied to a device under test in the reverse direction using opposing offset. If, for example, positive going steps are to be applied to the device under test, K101B is in the + position. If negative offset is applied to the device under test by pushing the OPPOSE button and turning the OFFSET MULT control clockwise, the step generator will attempt to conduct negative current at the input to the device under test. In doing this, the voltage at the input and thus the voltage at the Q229B gate input is driven down. When the voltage goes approximately 2 volts below ground, Q248 turns on. With Q248 on, the negative-going voltage steps at the base of Q150A are limited, thus limiting the output of the output amplifier (the input to the device under test) to about 2 volts. This amount of voltage should not damage a device under test.

Voltage Mode. Voltage steps are obtained from the output amplifier in a manner similar to that used to obtain current steps. For voltage steps, however, the VOLTAGE SETTING RESISTORS are changed to obtain the various voltage amplitudes, rather than the CURRENT SETTING RESISTORS (which are held constant in the voltage mode). Also since it is not desirable to regulate the voltage at the input to the CURRENT SETTING RESISTORS in the voltage mode, the feedback to the positive side of the differential amplifier through the +1 amplifier is disconnected and the input to the +1 amplifier is connected to ground. The base of Q150B is, therefore, held at essentially ground. Since the output of the +1 amplifier is at ground, reverse voltage limiting transistors Q248 and Q250 are disabled in the voltage mode.

In the voltage mode when steps of 1/2 volt per step are applied to the step output amplifier, they are transmitted through VOLTAGE SETTING RESISTANCE R141 through R145, the input resistance. By varying this input resistance with respect to constant feedback resistance R194, the feedback gain of the negative side of the differential amplifier is changed, thus varying the amplitude of the voltage steps. After being conducted through the voltage setting resistors, the steps are amplified and transmitted through the negative side of the differential amplifier in the same manner as described in the current mode section. When the voltage steps reach the CURRENT SETTING RESISTORS, they are transmitted through a nominal resistance (R215 and R216) of 5 Ω, for all voltage positions of the AMPLITUDE switch, before being applied to the device under test. Voltage steps of varying amplitudes, as determined by the AMPLITUDE switch, are then developed across the input impedance of the device under test. Feedback to the input to the differential amplifier occurs at the output of the current setting resistors, therefore, minimizing the effect of R215 and R216.

When using voltage steps, the current conducted at the step generator input to the device under test may increase quite rapidly and possibly damage the device under test (especially when testing transistors). As a means of limiting this current in the voltage mode, current limiting resistors R185, R186 and R187 are added to the output amplifier circuit by the AMPLITUDE switch. These resistors limit current at the Step Generator Output by limiting current

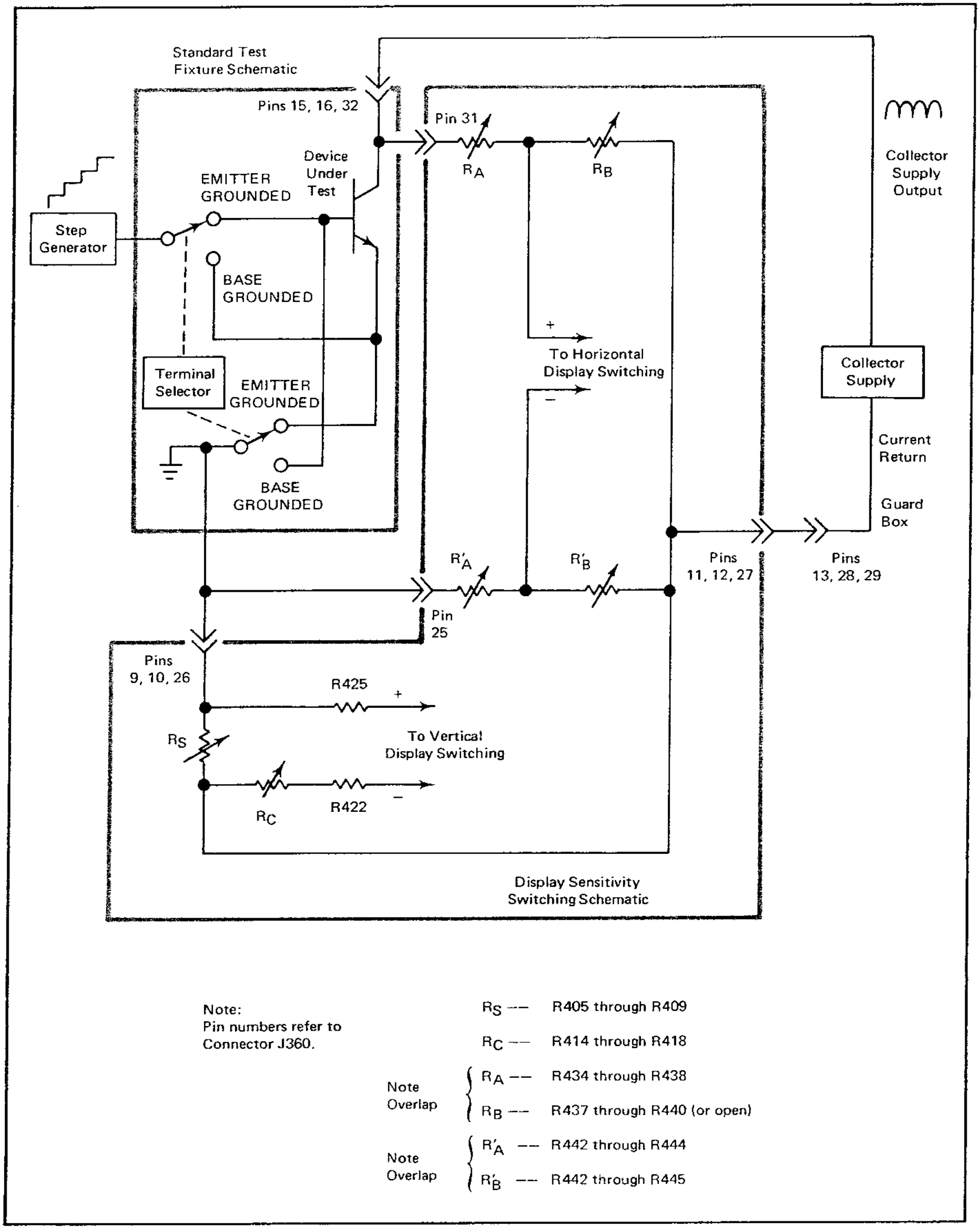


Fig. 3-8. Simplified schematic of Display Sensitivity Switching and Standard Test Fixture schematics for measurement of collector current (I_C) and collector-emitter voltage (V_{CE}) or collector-base voltage (V_{CB}).

through R165, R166 and R167. As the voltage steps increase through Q176 and Q184 or through Q172 and Q180, the current increases through the current limiting resistors. This current increase causes the voltage drop across the resistors to increase. If positive-going steps are being produced, this increase in voltage drop is transmitted through Q176 and Q169 to the junction of R166 and R167. As the voltage drop increases, the voltage at this junction point goes down. When the voltage reaches about −2.3 volts, D165 forward biases, clamping the voltage at the base of Q169. This prevents generation of further steps. When negative-going steps are being produced, the drop across the current limiting resistors is transmitted through three base-emitter junctions, Q180, Q172 and Q169, to the junction of R166 and R167. As voltage drop increases, the voltage at the collector of Q164 goes up. When this voltage reaches +12.5 volts, Q169 is saturated, and again no further steps can be generated. The CURRENT LIMIT switch determines the number of resistors to be included in the current limiting resistance, therefore determining the amount of current necessary to either turn on D165 or saturate Q169.

VERTICAL AND HORIZONTAL DISPLAY

Signal Sensing and Display Sensitivity

Once the Collector Supply and the Step Generator Output have been applied to the device under test, measurements of the voltages and currents seen at the terminals of the device under test may be displayed on the vertical and horizontal axes of the CRT. These measurements are made by first sensing the current or voltage through current sensing resistors or voltage dividers, then amplifying the measurement with the display amplifiers and applying the measurement to the deflection plates of the CRT. The positions of the HORIZONTAL, the MODE and the Terminal Selector switches determine which measurements are made.

Collector Current Sensing. If the MODE switch is set to either NORM or DC, collector current (I_C) is measured on the vertical axis of the CRT. Collector current is measured by placing a resistor between ground and the current return to the collector supply and measuring the voltage developed across this resistor (see Fig. 3-8 and Fig. 3-9). By varying

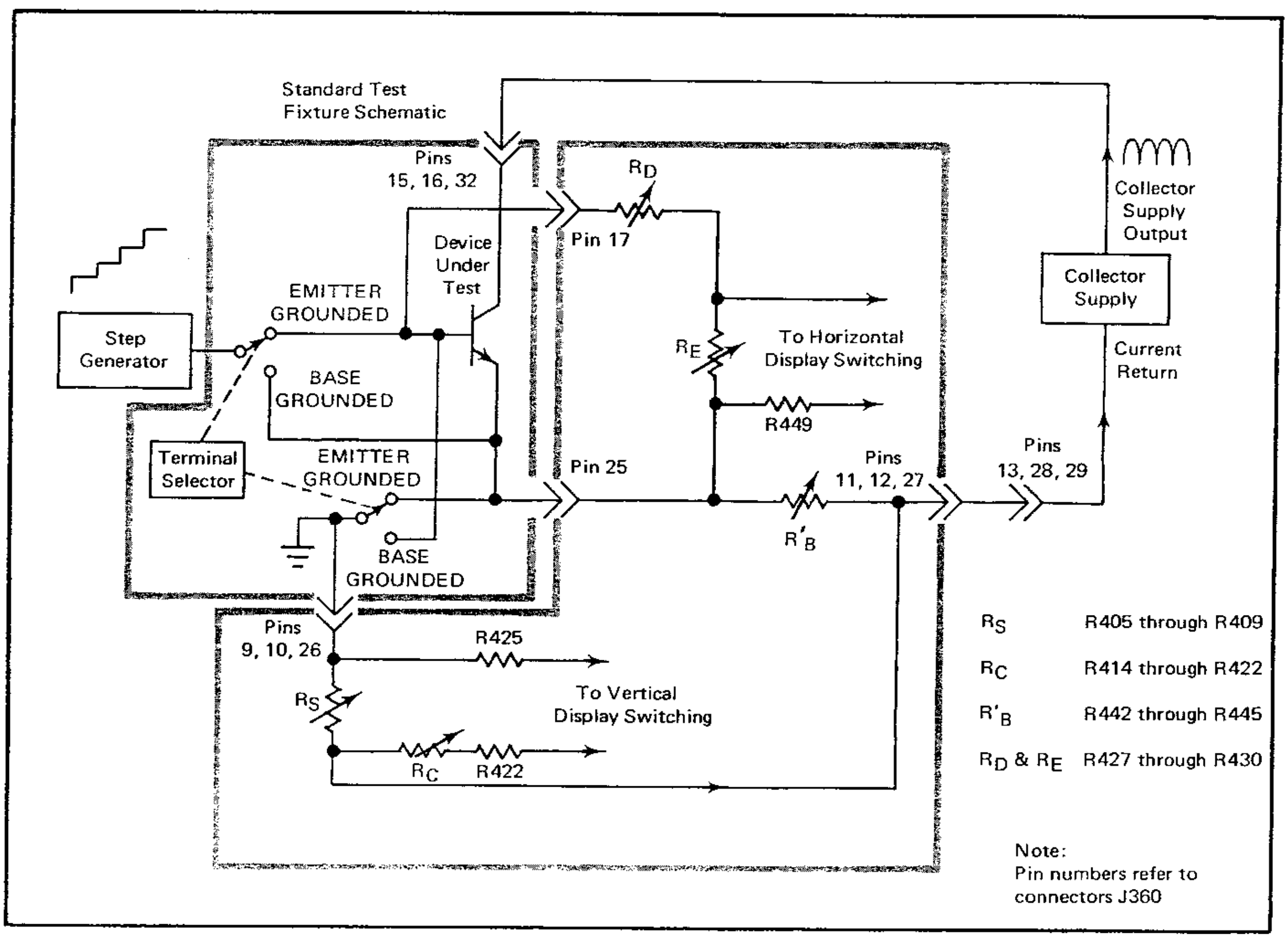


Fig. 3-9. Simplified schematic of Display Sensitivity Switching and Standard Test Fixture schematics for measurement of collector current (I_C) and base-emitter voltage (V_{BE}) on emitter-base voltage (V_{EB}).

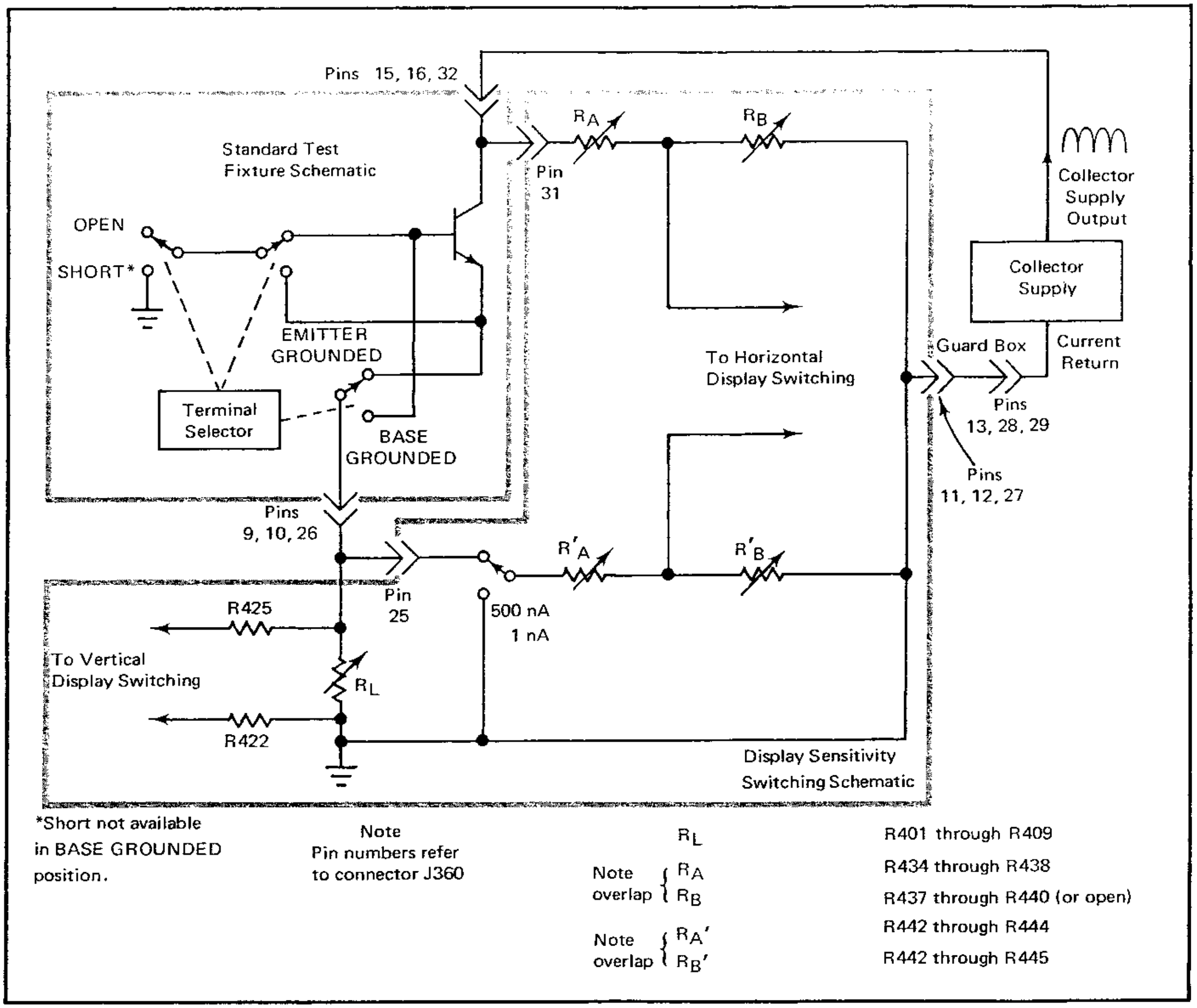


Fig. 3-10. Simplified schematic of Display Sensitivity switching and Standard Test Fixture schematics for measurement of emitter current (I_E) collector-base current (I_{CBO}) collector-emitter voltage (V_{CE}) or collector-base voltage (V_{CB}).

the value of this current sensing resistor (R_S), the deflection factor of the display on the CRT may be varied.

Leakage Current Sensing. If the MODE switch is set to LEAKAGE, emitter current (I_E) or collector-base current (I_{CBO}) is measured on the vertical axis of the CRT. Emitter current is measured by placing a current sensing resistance between the emitter terminal of the device under test and ground, and measuring the voltage developed across it (see Fig. 3-10). If emitter current is to be measured, the Terminal Selector switch must be set to GROUNDED EMITTER BASE TERM OPEN or BASE TERM SHORT. When the Terminal Selector switch is set to BASE GROUNDED EMITTER TERM OPEN, collector-base current is measured on the vertical axis. In this case the current sensing resistor is connected between the base terminal and ground. As when measuring collector current, the deflection factor of the display, when measuring emitter current and collector-base current, can be varied by varying the current sensing resistance. It should be noted that the deflection factor of the vertical display is always decreased 1000 times when the MODE switch is set to LEAKAGE and the collector supply operates in its DC mode.

Voltage Sensing Normal Mode. Either collector or base voltage may be measured on the horizontal axis of the CRT, depending on the position of the HORIZONTAL switch. When the HORIZONTAL switch is in its COLLECTOR range, voltage is measured between the collector and emitter terminals of the device under test, V_{CE} (Terminal Selector switch set to EMITTER GROUNDED), or between the collector and base terminals, V_{CB}, (Terminal Selector switch set at BASE GROUNDED). When the HORIZONTAL switch is in its BASE range, voltage is measured between the base and emitter terminals, V_{BE} (EMITTER GROUNDED), or between the emitter and base terminals,

V_{EB} (BASE GROUNDED). By use of a variable voltage divider across these terminals, the deflection factor of the horizontal display can be varied.

Voltage Sensing Leakage Mode. When the Mode switch is set to LEAKAGE, only the measurement of V_{CE} and V_{CB} are useful. In this situation a slight error in voltage measurement occurs whenever the VERTICAL switch is set within the 500 nA to 1 nA EMITTER range. In this range (see Fig. 3-10) the horizontal display is a measurement of collector voltage to ground, rather than collector to emitter or collector to base voltage. As discussed previously, when current measurements are made in the leakage mode, the current sensing resistor is between ground and the emitter or ground and the base terminal. Any measurement of voltage between the collector and ground, therefore, measures the voltage drop across the current sensing resistor and adds it to the desired measurement of V_{CE} or V_{CB}. The correct values of V_{CE} or V_{CB} can be determined by subtracting the voltage drop across the current sensing resistor from the total measurement shown on the horizontal axis of the CRT. See the Horizontal Measurement and Sensitivity section of the Operating Instructions for instructions on how to determine this error voltage.

Display of Step Generator. If either the VERTICAL or the HORIZONTAL switch is set to STEP GEN, the 1/2 volt steps at the input to the output amplifier section of the step amplifier (see Fig. 3-7) are applied to the inputs to the vertical display amplifier or the horizontal display amplifier (see Fig. 3-11). If both switches are set to STEP GEN, the 1/2 volt steps are applied to the Horizontal Display Amplifier only.

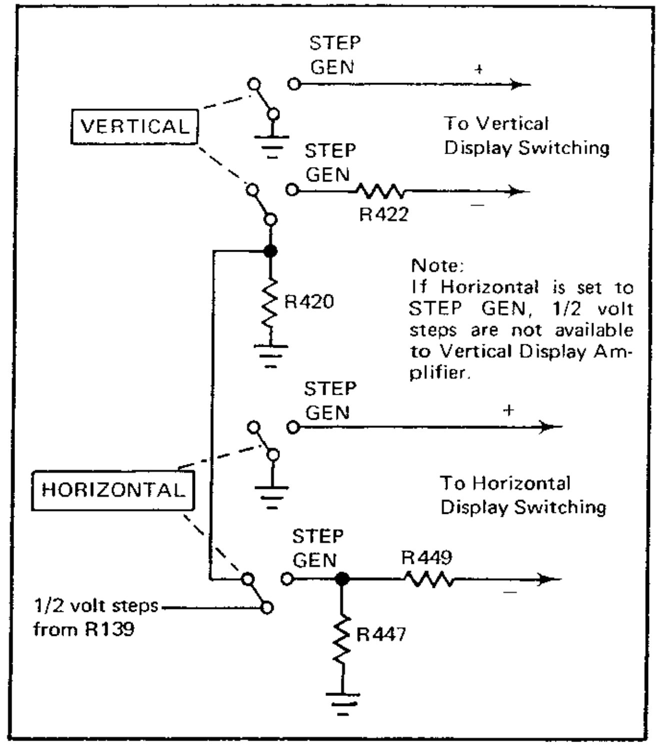


Fig. 3-11. Simplified schematic of Display Sensitivity Switching when VERTICAL and/or HORIZONTAL switches are set to STEP GEN.

Vertical and Horizontal Positioning

The positioning of the display on the CRT is determined by current applied to the low impedance inputs of the Display Amplifiers at the emitters of Q533A and B in the vertical display amplifier, and Q633A and B in the horizontal display amplifier (see discussion of Display Amplifiers). This current comes from many individual current sources which are controlled by the POSITION switches, the FINE POSITION controls, the POLARITY switch and the DISPLAY OFFSET controls (see the Display Positioning schematic).

The POSITION switches and the FINE POSITION controls allow both coarse and fine positioning of the display. The current for the coarse control comes from resistors R480 through R483 (vertical) and R490 through R493 (horizontal). These resistors are all connected to the −75 volt supply, making them current sources. Each of these current sources is connected between a pair of contacts. When one contact of a pair is closed, this current flows into one side of the display amplifier. If the other contact of the pair is closed, the current flows into the other side of the amplifier. The matrixes for the POSITION cam switches show that at all times one contact of each pair must be closed, but never both closed at once. This assures that the sum of the positioning current flowing into the amplifiers is always a constant. Each POSITION switch provides 20 divisions of positioning in five division steps. The FINE POSITION controls, R488 (vertical) and R498 (horizontal) operate in a similar manner to the coarse controls except that the adjustment is continuously variable.

The POLARITY switch provides automatic positioning of the display when switching between the AC, +(NPN) or −(PNP) positions of the switch. This positioning current is obtained in the same manner as the coarse positioning current. Current sources R474 and R475 (vertical) and R477 and R478 (horizontal) provide this positioning current.

The display may also be positioned by the calibrated CENTERLINE VALUE switch. This control effects the circuit only when the DISPLAY OFFSET Selector switch is switched to one of its VERT or HORIZ positions and affects only one display amplifier at a time. When the DISPLAY OFFSET Selector switch is set to NORM (OFF), current sources R468 and R469 (vertical) and R471 and R472 (horizontal) supply current to the display amplifiers. When, for example, the switch is set to VERT, R468 and R469 are disconnected from the circuit and an equal amount of current is supplied to the vertical display amplifier by current sources R450 through R464. These resistor-contact combinations are controlled by the CENTERLINE VALUE switch and operate identical to the POSITION switches. The CENTERLINE VALUE switch provides 10 divisions of calibrated positioning in half-division steps.

Display Switching

Once the desired voltages and currents have been sensed by the display sensitivity switching circuit, and once the desired positioning currents have been obtained from the display positioning circuit, the resulting voltage signals and positioning currents must be applied to the display amplifiers. Before being applied to the display amplifiers, however, these signals pass through the display switching circuit (see the Display Amplifiers and Display Positioning schematics).

Under normal operating conditions with neither the DISPLAY INVERT, the ZERO nor the CAL buttons pressed, these signals and currents pass directly to the display amplifiers. If the DISPLAY INVERT button is pressed, however, the signal and current input lines to both amplifiers are reversed. This causes the display on the CRT to be inverted, both vertically and horizontally.

The ZERO button, when pressed, disconnects the signal input lines from both pairs of high impedance inputs and shorts the input pairs together. This provides a zero reference for both display amplifiers. If the DISPLAY OFFSET controls are being used when the ZERO button is pressed, offset positioning current is caused to flow as if the CENTERLINE VALUE switch were set to 0 (see Display Positioning schematic and discussion of positioning).

The CAL button, when pressed, disconnects the signal input lines from both pairs of high impedance inputs and applies a substitute voltage across each input pair which should cause full graticule deflection (10 divisions by 10 divisions). This provides a means of checking the accuracy of calibration of the display amplifiers. The substitute voltage is determined by R501 through R513 and by D507. Since each display amplifier has three gains to check, three substitute voltages must be available. Relays K537C, K541C, K637C and K641C determine which voltages are applied to the high impedance input pairs for various settings of the VERTICAL and HORIZONTAL switches. If the DISPLAY OFFSET current controls are being used when the CAL button is pressed, offset current is caused to flow as if the CENTERLINE VALUE switch were set to 10.

Display Amplifiers

The vertical and horizontal display amplifiers are identical with a few minor exceptions. They are both differential amplifiers, each with two sets of differential inputs and one set of differential outputs. One set of differential inputs is high impedance and receives its inputs from the display sensitivity switching circuit. The other set of differential inputs is low impedance and their inputs are the differential positioning currents from the display positioning circuit. The differential outputs are connected to the deflection plates of the CRT and control the potential on the deflection plates.

The simplified schematic in Fig. 3-12 will help in understanding the operation of the display amplifiers. The display amplifiers control the voltage between the deflection plates of the CRT by controlling the currents through load resistors R_{L1} and R_{L2}. The currents I_{L1} and I_{L2} conducted by the load resistors are controlled by two means: differential current I_S and positioning currents I_{P1} and I_{P2}. The differential current flows through source coupling resistor R_S whenever there is a differential voltage signal applied to the high impedance gate inputs of FETS Q1A and Q1B. Positioning currents I_{P1} and I_{P2} are determined by the resistance between the emitter of Q2A and −75 volts and between Q2B and −75 volts, respectively.

The relationship between the load resistor currents and the other currents in the amplifier is as follows:

$$I_L = I_P - (I_D + I_S) \quad \text{(Equation 3-1)}$$

Equation 3-1 pertains to the currents which flow in one side of the amplifier. I_S is either positive or negative, depending on whether it adds to or subtracts from I_D. I_D represents the FET drain current. It originates from a constant current source and is the same in each side of the amplifier. This equation also shows that the load current is dependent on the interaction between the differential current (I_S) and the positioning current (I_P).

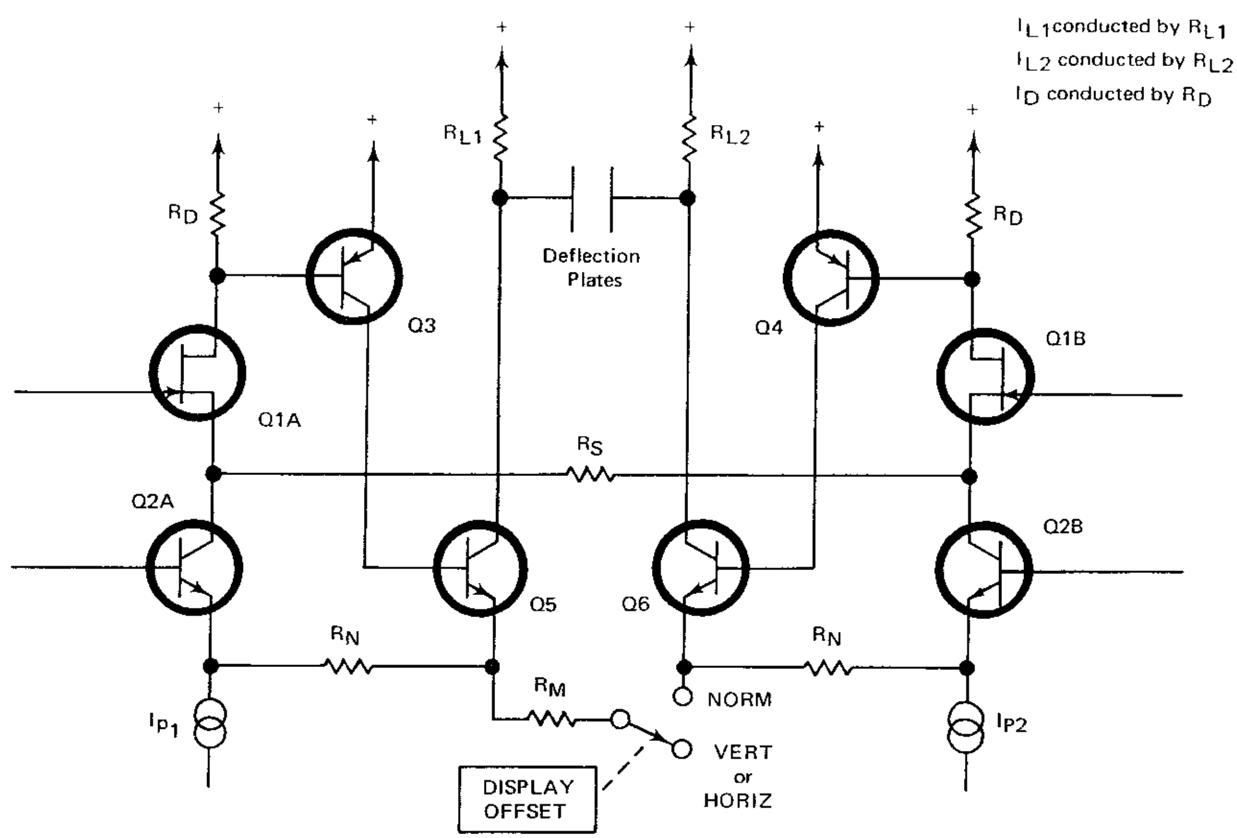
To understand the operation of this circuit, first assume that the amplifier is operating in a balanced condition where the two positioning currents are equal ($I_{P1} = I_{P2}$) and there is no voltage difference between the two high impedance inputs ($I_S = 0$). In this case, the load currents on each side of the amplifier are equal to I_{LO}. Equation 3-1, then, becomes:

$$I_{LO} = I_{L1} = I_{L2} = I_{P1} - I_D = I_{P2} - I_D \quad \text{(Equation 3-2)}$$

To illustrate the effect the high impedance inputs have on the load current, assume that a difference in voltage is applied across the gates of Q1A and Q1B, making the gate of Q1A more positive. This voltage differential causes differential current I_S to flow through source coupling resistance R_S. With this additional current (I_S) flowing through Q1A, less current is needed from Q2A to keep drain current I_D constant. The current conducted by Q2A is thus reduced to $I_D - I_S$. Since the positioning current I_{P1}, which supplies the current conducted by Q2A, is also constant, there is a surplus of positioning current created equal to I_S which must be conducted by Q5, and therefore R_{L1}. The load current is increased to $I_{L1} = I_{LO} + I_S$. On the other side of the amplifier, the current through Q2B is increased to $I_D + I_S$, which decreases the load current through Q6 and R_{L2} to $I_{L2} = I_{LO} - I_S$. For this example, it can be seen that whenever a differential voltage occurs between the two high impedance inputs, the load currents change, thus changing the voltage potential between the deflection plates of the CRT.

To illustrate the effect the positioning currents have on the load currents, assume that the voltages at the high

 Ⓐ



Substitutions from Display Amplifier Schematic

Vertical Amplifier	Simplified Schematic	Horizontal Amplifier
Q531A & B	Q1A & B	Q631A & B
Q533A & B	Q2A & B	Q633A & B
Q560	Q3	Q660
Q569	Q4	Q669
Q578	Q5	Q678
Q587	Q6	Q687

Fig. 3-12. Simplified schematic of display amplifier.

impedance inputs are equal ($I_S = 0$) and that the positioning currents are unequal ($I_{P1} \neq I_{P2}$). From Equation 3-1 the load currents are found to be:

$$I_{L1} = I_{P1} - I_D \quad \text{(Equation 3-3)}$$

$$I_{L2} = I_{P2} - I_D \quad \text{(Equation 3-4)}$$

By subtracting Equation 3-4 from Equation 3-3, it is shown that the difference in the two load currents exactly equal the difference in the two positioning currents.

$$I_{L1} - I_{L2} = I_{P1} - I_{P2} \quad \text{(Equation 3-5)}$$

Since the positioning currents are not unequal, the load currents (I_{L1} and I_{L2}) are unequal, which again changes the voltage potential between the deflection plates of the CRT.

These two examples have shown that the voltage between the deflection plates (and thus the position of the electron beam as it strikes the face of the CRT) is controlled by two means, the voltage applied to the high impedance inputs and the positioning currents applied to the low impedance inputs. Equation 3-1 shows this relationship.

It should be noted that it is transistors Q3 and Q4 which cause Q5 and Q6 to conduct more or less load current. As in previous examples, assume the normally constant drain current I_D conducted by Q1A is caused to increase either by increasing I_S or I_{P1}. This increase in I_D causes the source voltage of Q1A to go negative, causing Q3 to conduct more current. This in turn causes Q5 to conduct more current. The additional current conducted by Q5 reduces the current through Q2A and causes the drain current I_D to be reduced back to its normal constant value.

The gain of the display amplifiers is adjusted in two ways. The overall gain is controlled by varying the load resistance (R_{L1} and R_{L2}). Adjusting the load resistance affects the gain of the high impedance inputs, as well as that of the positioning current. R_{L1} and R_{L2} are adjusted so that the positioning inputs provide the proper deflection. Varying the source coupling resistance (R_S) sets the gain of the high impedance inputs only. R_S is adjusted to match the high impedance gain to the positioning inputs.

By switching R_M into the circuit, the overall display amplifier gain is increased by a factor of 10. Load currents I_{L1} and I_{L2} flow through resistors R_{N1} and R_{N2}. When R_M is in the circuit, any change in the current through R_{N1} and R_{N2} causes a voltage across R_M. This voltage across RM causes additional load current to be conducted by Q5 and Q6, load current which is not felt by the emitters of Q2A and Q2B. For a given change in current at the emitters of Q2A and Q2B, therefore, a greater change in load current through Q5 and Q6 occurs, causing additional gain of the display amplifier. The gain of the circuit under magnified conditions is controlled by adjusting R_M.

Vertical Display Amplifier

The Display Amplifiers schematic shows the complete schematic of the vertical display amplifier. The table in Fig. 3-12 relates the transistors and FETs in the simplified schematic with those in the actual schematic of this circuit.

The complete schematic shows that the high impedance inputs of the amplifier have three separate gains (R_S has three different values). As has been mentioned previously in the discussion of the signal sensing and display sensitivity, the deflection factor of the vertical display is partially determined before the measurement is applied to the high impedance inputs. The three gains of the vertical display amplifier allow the vertical display to have three different deflection factors for each voltage signal applied to the high impedance inputs in a 1-2-5 relationship. 1'S GAIN adjustment R541, 2'S GAIN adjustment R538 and 5'S GAIN adjustment R536 determine the three gains of the high impedance inputs. Relays K537A and K541A determine which resistors will control the gain for the various positions of the VERTICAL switch. VERT OUTPUT GAIN adjustment R592A and B determines the overall gain of the vertical display amplifier by allowing adjustment to the load resistors R_{L1} and R_{L2}.

The overall balance of the positioning currents of the vertical display amplifier is controlled by VERT CENT adjustment R581. In addition, 1'S BAL adjustment R550 and 2'S BAL adjustment R545 provide positioning current balance when the VERTICAL switch is set to a position with a one times or a two times multiplier, respectively. Relays K537B and K541B determine which resistors control the positioning current balance for various positions of the VERTICAL switch.

When the DISPLAY OFFSET Selector switch is set to VERT X10, R574 and VERT MAG GAIN adjustment R573 are added to the vertical display amplifier circuit. These resistors constitute R_M and increase the sensitivity of the vertical display 10 times. R580 is always in the circuit and gives the output stage an unmagnified gain of about 1.8.

Horizontal Display Amplifier

The Display Amplifiers schematic shows the complete schematic of the horizontal display amplifier. The table in Fig. 3-12 relates the transistors and FETs in the simplified schematic with those in the actual schematic of this circuit.

The horizontal display amplifier operates basically the same as the vertical display amplifier. 1'S GAIN adjustment R638, 2'S GAIN adjustment R636 and 5'S GAIN adjustment R641 control the three gains of the horizontal high impedance inputs. Relays K637A and K641A determine which resistors will control the gain for the various positions of the HORIZONTAL switch. HORIZ OUTPUT GAIN adjustment R692A and B controls the load resistance. ORTHOG adjustment R685 interacts with the vertical display amplifier and allows adjustment of the orthogonality of the display on the CRT. When the DISPLAY OFFSET Selector switch is set to HORIZ X10, R674 and HORIZ MAG GAIN adjustment R673 are added to the circuit and form R_M. R680, like R580, is always in the circuit and gives the output stage an unmagnified gain of about 1.8.

The overall balance of the position currents of the horizontal display amplifier is controlled by HORIZ CENT adjustment R681. In addition, 1'S BAL adjustment R650 and 5'S BAL adjustment R645 provide positioning current balance when the HORIZONTAL switch is set to a position with a one times or a five times multiplier, respectively. Relays K637B and K641B determine which resistors control the positioning current balance for various positions of the HORIZONTAL switch.

Readout

A display of the vertical and horizontal deflection factors, the step amplitude and the β or g_m per division (vertical deflection factor divided by step amplitude) is given to the right of the CRT. This display of numbers and units is obtained through the use of fiber-optic readout. Fiber-optic readout involves the use of plastic fibers of very small diameter, called light tubes, for transferring light from one place to another. The light tubes are designed so that the light incident at one end of the tube is transmitted through the tube to the other end. If the output end of the tube is viewed directly, the output light looks like a small dot. This transmission of light occurs even if the light tubes are bent at slight angles. In order to form a character, many light tubes are arranged so that their output ends, the dots of light, are in the configuration of the character to be formed. The input ends are then arranged so that they receive their incident light from the same light source. In some cases it may take two or more light sources to form one character. Whenever the proper light source (or sources) is illuminated, the desired character appears. It is the purpose of the readout circuitry, therefore, to light the readout lamps so the deflection factors they indicate correspond with the CRT display deflection factors determined by the positions of the VERTICAL and HORIZONTAL switches, the MODE switch, the DISPLAY OFFSET Selector switch, the AMPLITUDE switch and the .1X STEP MULT button.

The inputs for the readout logic come from logic lines whose logic levels are controlled by the switches shown on the Readout Switching and Interconnections schematic, or by externally provided logic levels. The form of the inputs is a high-low code. Normally all inputs are high and the code is determined by switching some of the logic lines to ground. Ground reference is generally provided directly as part of the switch. However, in the case of the vertical and horizontal switches, ground is provided through saturation transistors Q900 and Q943 respectively. If lows are applied to pins 7 and 20 of J363, these transistors are turned off. In this case ground reference for the affected logic lines must then be provided externally.

The readout logic (see Readout Logic schematic) primarily consists of integrated circuit decoders. These decoders receive inputs from the incoming logic lines in terms of the above-mentioned switch code. This input code is then translated into a high-low lamp code which appears on the output logic lines. Each of the output logic lines is connected to a readout lamp (see Readout Lamps schematics) and each lamp illuminates one character of one part of a character. A low on a readout lamp causes the lamp to light. The intensity of the readout is determined by the 0 to 4.5 volt supply.

The readout logic circuitry also generates a lamp code which produces a readout of beta or transconductance (g_m) per division. This β or g_m readout lamp code is obtained by dividing the vertical lamp code by the steps lamp code.

The decoders which control the horizontal deflection factor readout are U951 and U953. Inputs to these decoders are controlled by the HORIZONTAL switch, the DISPLAY OFFSET Selector switch or by externally applied inputs to J363. Outputs from these decoders go to the horizontal readout lamps. As an example of how a lamp code is generated, assume that the HORIZONTAL switch is set to .5 V COLLECTOR and the DISPLAY OFFSET Selector switch is set to NORM (OFF). Due to the closing of contacts by the HORIZONTAL cam switch (see the Readout Switching and Interconnections schematic), lows are applied to the inputs to U951 and U953 at connectors 13, T, and S of P950 (see Fig. 3-13). The other inputs to the horizontal decoders are held high. The output lamp code resulting from this input code is lows at lamp input connectors F, I, J, L, A, C, D and E. The resulting PER HORIZ DIV readout is 500 mV, which corresponds with the .5 V COLLECTOR position of the HORIZONTAL switch.

Decoders U956 and U960 control the vertical deflection factor readout. Inputs to these decoders are controlled by the VERTICAL switch, the DISPLAY OFFSET Selector switch, the MODE switch and externally applied inputs to J363. Outputs from these decoders go to the vertical readout lamps. The horizontal and vertical decoders are affected by these logic inputs, at pin U, pin Y and pin 12 of J363, whose logic levels may only be determined externally.

Decoders U965 and U970 control the step amplitude readout. Inputs to U965 and U970 are controlled by the AMPLITUDE switch, the STEP MULT .1X button and externally applied inputs to J361. Outputs from U965 and U970 go to the steps readout lamps.

The beta or g_m generator consists of U974, U975 and U976. The input code received by these decoders is a combination of logic levels coming in part from the vertical lamp code, and in part from the steps lamp code. The outputs from these decoders go to the beta readout lamps. Q960 and Q974 decode the logic levels appearing at pins 13 and 15 of U960 and pins 13 and 15 of U970. Q977 and Q979 provide a means of lighting the 1,4 lamp (connector BI) whenever the 2,5 lamp (connector AR) is off.

Power Supply

The Type 576 can be operated either from a 115-volt or a 230-volt line voltage source. The low voltage power supply (see Fig. 3-14) consists of a single transformer, T701, which has nine secondaries. This supply provides six regulated voltages: −75 volts, −12.5 volts, +5 volts, +12.5 volts, +15 volts and +100 volts. It also produces a regulated variable voltage of 0 to 4.5 volts, one unregulated voltage of +50 volts and an AC voltage to drive the POWER ON light and the GRATICULE ILLUM lights. The windings providing a source of clock pulses for the step generator and the CRT heater are among the nine secondaries of T701. All the regulated power supplies are completely short proof.

Input Circuit. When the POWER switch is switched to ON, line current flows from the input, P701 (see Power Supply schematic), through power switch SW701, fuse F701, Thermal Cutout TK701 and into the primary wind-

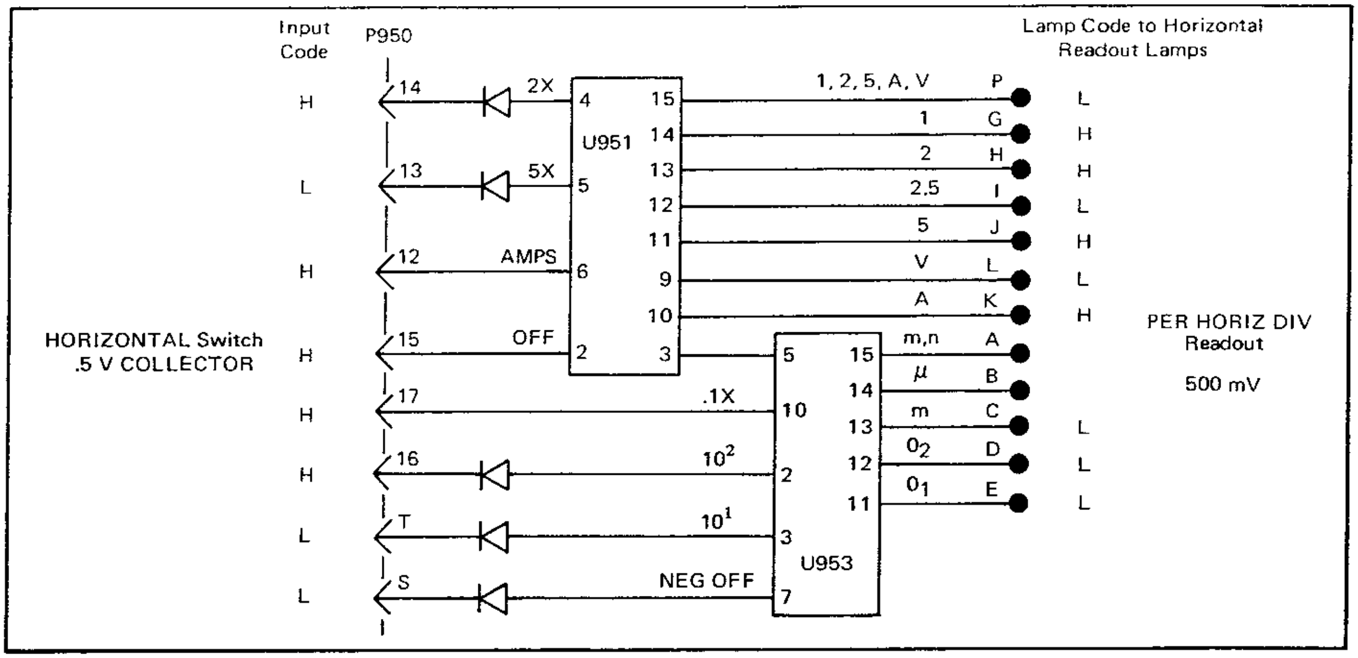


Fig. 3-13. Example of operation of Horizontal Readout decoders.

ings. For 115-volt operation the LINE SELECTOR switch connects the two primaries in parallel and for 230-volt operation connects them in series. For 230-volt operation, F703 is connected into the circuit. The RANGE SELECTOR plug determines how many turns of each primary winding are utilized to compensate for variations in line voltage.

−75-volt Supply. The −75-volt supply consists of diode bridge D706 A, B, C and D, filter capacitors C706 and C707, comparator Q716A and B, emitter follower Q729, short protection Q725 and Q727, and series regulator Q734.

9-volt Zener diode D708 sets the base voltage of comparator transistor Q716A while the quiescent voltage at the base of Q716B is set by −75 V adjustment R721. Any variation in the −75-volt supply voltage is compared by Q716A and B. The resulting rise or fall in voltage across R715 is transmitted by Q729 to the base of series regulator Q734. Any change in voltage of the −75-volt supply will be opposed by a change in current through the series regulator.

The output current of the −75 volt supply is limited to a value less than normal whenever the supply is shorted to a voltage between −75 V and chassis ground. The supply current of the −75 volt supply is controlled by the voltage across R735, which is dependent on the base voltage of Q734. This voltage is in turn dependent on the voltage across R730 and R731. As the −75 volt supply becomes more positive (due to shorting it to a more positive supply), the voltage at the base of Q734 is raised, causing more supply current to be conducted through R735. As the supply voltage becomes more positive, the voltage at the junction of R730 and R731 rises high enough to turn on Q727. When Q727 turns on, it begins pulling down on the base voltage of Q729 and down on the base voltage of Q734, thus limiting the supply current. The output current of the −75-volt supply comes less, the closer the supply voltage is to ground.

D732 prevents the supply from going more than 0.6 volt above chassis ground if the −75 volt supply is shorted to a positive voltage. D722 protects the −12.5 volt supply if it is shorted to the −75 volt supply. If the −12.5 volt supply is pulled negative, D722 turns on when the supply is about at −15 volts which disables comparator Q716A and B. The −75 volt supply then limits current until both supplies are at about −2.5 volts. If the +12.5 volt supply is shorted to the +100 volt supply, Q725 turns on. When Q725 is on, it limits current through R735 in the same manner as discussed previously for Q727. The result of shorting the +12.5 volt supply to a more positive voltage is to turn off the −75 volts supply. Since the −75 volt supply is the reference for the −12.5 volt, +12.5 volt, +100 volt, and CRT voltage supplies, when the −75 volt supply is turned off, the other power supplies are turned off.

−12.5-volt Supply. The −12.5 volt supply consists of diode bridge D737A, B, C and D, filter capacitor C738, comparator Q744A and B, emitter follower Q750, short protection Q748 and series regulator Q756. This circuit regulates the −12.5-volt supply in essentially the same manner as the −75-volt supply operates.

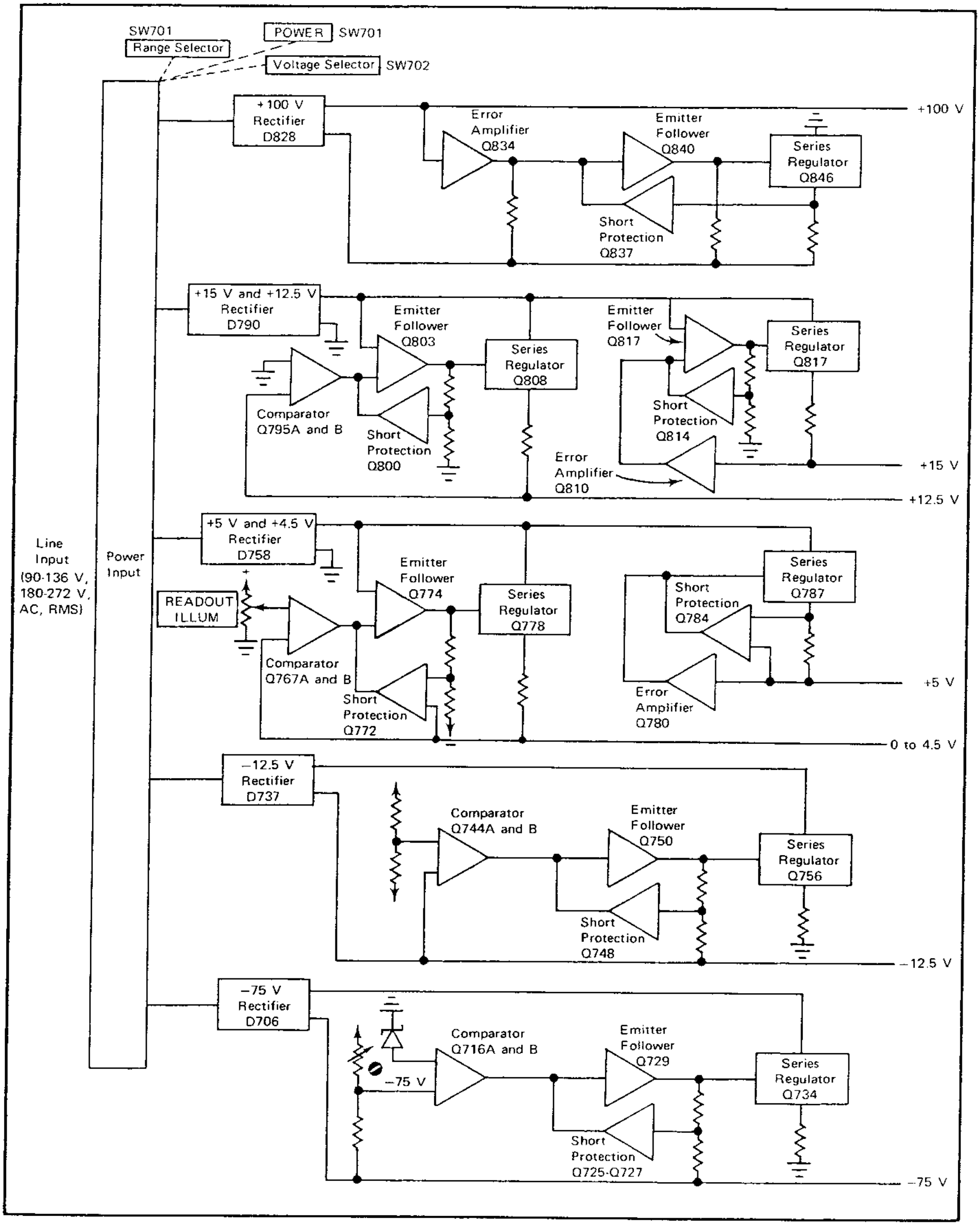


Fig. 3-14. Block diagram of L. V. Power Supply.

0 to +4.5-volt Variable Supply. The 0 to +4.5-volt variable supply consists of diode bridge D758A, B, C and D, filter capacitor C759, comparator Q767A and B, emitter follower Q774, short protection Q772 and series regulator Q778. This circuit operates in essentially the same manner as the −75-volt supply circuit. In this circuit, however, the reference voltage at the base of Q767A is variable from 0 volts to +4.5 volts by the READOUT ILLUM control, R760, and divider R762 and R763. The output current of the supply is limited by Q772.

+5-volt Supply. The +5-volt supply consists of error amplifier Q780, short protection Q784 and series regulator Q787. The supply shares diode bridge D758A, B, C and D and filter capacitors C758 and C759 with the +4.5-volt supply. Any variation in the +5-volt supply voltage is amplified by Q780, causing the base voltage of Q787 to vary in opposition to the variation of the supply. The current conducted through R788 by the supply is thus regulated, which in turn regulates the +5-volt supply. Q784 provides short protection by turning on whenever the current through R788 becomes excessive. When Q784 turns on, the base voltage of Q787 is pulled down, limiting the current through R788.

+12.5-volt Supply. The +12.5-volt supply consists of diode bridge D790A, B, C and D, filter capacitor C791, comparator Q795A and B, emitter follower Q803, short protection Q800, and series regulator Q808. This circuit operates in essentially the same manner as the −75-volt supply. Short protection of the +12.5-volt supply when it is shorted to a more positive voltage is provided by Q725 of the −75-volt supply. If the +12.5-volt supply voltage is pulled up, the base of Q725 is also pulled up, turning on Q725. With Q725 turned on, the base of Q729 is pulled down turning off the −75-volt supply, which will turn off the +12.5-volt supply.

+15-volt Supply, Camera Power. The +15-volt supply consists of error amplifier Q810, emitter follower Q817, short protection Q814 and series regulator Q819. The supply shares diode bridge D790 and filter capacitors C790 and C791 with the +12.5-volt supply. Any variation in the +15-volt supply voltage is amplified by Q810, causing an opposing variation in the voltage at the base of Q817. This opposing voltage variation is transmitted through the emitter of Q817 to the base of series regulator Q819 where it controls the current conducted by R819 and thus regulates the supply. When enough current is conducted by Q819 to turn on Q814, the voltage at the base of Q817 is pulled down, thus limiting the current through Q819.

+50-volt Supply. The +50-volt supply consists of diode bridge D821A, B, C and D, and filter capacitors C822 and C823. It is a floating unregulated supply used to power the step amplifier output.

+100-volt Supply. The +100-volt supply consists of diode bridge D828A, B, C and D, filter capacitor C829, error amplifier Q834, emitter follower Q840, short protection Q837 and series regulator Q846. Any variation in voltage by the +100-volt supply is amplified by Q834 and transmitted through Q840 to the base of Q846. Since any variation in the supply is inverted by Q834, the base voltage of Q846 will always move in opposition to a variation of the supply. The current conducted by R846, therefore, also is conducted so as to oppose any change in supply voltage. When enough current is conducted by Q846 to turn on Q837, the voltage at the base of Q840 is pulled down, thus limiting the current conducted by Q819.

CRT Voltage Supply

The CRT power supply produces two high voltages, −4 kV and +225 volts, for operation of the CRT and its related controls. In addition, the +225-volt supply is used by the display amplifiers. The source of power for the two supplies is a high frequency (about 28 kHz) Hartley oscillator which consists of Q851 and the two primaries of transformer T850. The collector of Q851 is connected through the collector primary, R850 and L850 to the +100-volt supply. When current flows through the collector primary, a magnetic field is built up in the transformer core. Due to this field, a reverse base current is caused to be conducted through Q851 by the base primary and Q851 is eventually turned off. With Q851 off, no current flows through the collector primary. The residual field in the transformer core now causes forward base current to be conducted through Q851, turning it on. As Q851 turns on, current again flows through the collector primary, thus beginning a new cycle. The frequency of the oscillator and thus the output current of the secondaries is controlled by the voltage on pin 2 of the base primary.

−4 kilovolt Supply. The −4 kV supply consists of half-wave rectifier D870, filter capacitors C870 and C871, and divider resistors R875 through R883. This supply is a half-wave rectified supply with D870 forward biasing on negative transistions of the voltage on the −4 kV secondary. The −4 kV supply voltage after being filtered by C870 and C871 is reduced by Zener diode D882 to provide the −3890 volt cathode voltage. The grid voltage is controlled by the divider made up of R882 and INTENSITY control R883. The voltage on the focus screen of the CRT is controlled by FOCUS control R880.

The −4 kV supply is regulated from a reference supply which is generated by the winding between terminals 6 and 5 of T850. This reference supply consists of half-wave rectifier D866 and D869, and filter capacitor C866. The regulator circuit consists of error amplifier Q859 and emitter follower Q855. Any variation in the reference supply voltage is transmitted to the base of Q859 through divider R860-R864. The variation is then amplified and inverted by Q859 and transmitted through Q855 to the base of Q851, where it regulates the drive of the oscillator. Any variation in current conducted by the −4 kV supply is conducted by R899, which causes the decoupled supply voltage at the emitter of Q859 to vary, thus compensating for current variation in the −4 kV supply.

The voltage on the display geometry screen is controlled by GEOMETRY adjustment R893. The voltage on the display astigmatism screen is controlled by ASTIGMATISM adjustment R891. Current for the trace rotation controlling coil is controlled by TRACE ROTATION adjustment R897.

+225-volt Supply. The +225-volt supply is generated from the same transformer winding as the −4 kV reference supply. It consists of half-wave rectifier D868 and D865, filter capacitors C869, C868 and Q868. Regulation of the +225-volt supply is supplied by the reference supply through divider R860 through R864, and through emitter followers Q866 and Q868.

NOTES