# DEVICE TESTING TECHNIQUES

TEKTRONIX
CURVE TRACERS

## INTRODUCING CURVE TRACER DEVICE TESTING TECHNIQUES

With just this book and a curve tracer, you can quickly learn how to test more than half a dozen different semiconductor devices. The detailed procedures provided include the steps to be followed, sample control settings, waveform photos, and enough theory to make it all understandable.

The procedures have been designed to be sufficiently general to be used for testing most individual device types in any of the included semiconductor families. However, each section also provides actual settings necessary for testing an example of one of the most common parts from a device family; this particular device is included in the special plastic box in the back of this book.

## HOW TO USE IT

Using this book is very straightforward. There is a separate, independent section consisting of three subsections for each device family.

The first subsection, the introduction, is a brief description of the device family in general, some of its important basic characteristics, and how this type of semiconductor is tested on a curve tracer. This introductory material applies to both the device family in general and to the sample part selected for this book.

The second subsection is a general set-up procedure that describes the initial control settings needed on the curve tracer and any adapters that are necessary for testing the devices in the family. General rules for selecting switch positions are provided where necessary, and specific settings to be used for the sample device are given in brackets. Any special curve tracer configurations or accessory components needed are also called out (some tests can be made only with a particular instrument type, such as the 577/178 combination required for testing linear IC's).

The third subsection provided for each device family consists of the actual procedures for making the various tests. These procedures take you step-by-step through one test at a time. Each individual test within a section has been written to start from the family general set-up procedure, so you can go directly to a test of particular interest, or make only certain selected tests if you like. Photos of typical displays used in making the measurements, as well as additional waveform photos that may aid you in obtaining the proper display, are included.

Again, general rules are provided, plus numeric values and settings in brackets for use with the sample device.

## THE SAMPLE DEVICES

The representative device, used as an example of each broad family, is enclosed in a compartment of the plastic box at the back of the book. For each test section, you'll find a corresponding compartment with the device inside.

Some of the procedures require a few other small parts, such as a resistor or two, to perform all the outlined tests. In those cases, the additional parts are also included in the same compartment with the semiconductor device.

For your convenience, a listing of both the Tektronix part number and the JEDEC Type number of the devices is also included in the box in case parts replacement is ever necessary. Parts can be ordered from Tektronix or purchased from an outside supplier.

## TO GET MORE HELP

We've tried to make these procedures as clear and self-explanatory as possible. If you have any difficulties, or need test procedures for a device-type not listed, please ask your Tektronix representative to put you in touch with a curve tracer specialist.

## INTRODUCTION

For most day-to-day applications, testing or characterizing bipolar transistors involves a combination of two-terminal and three-terminal measurements covering a wide range of both currents and voltages. Curve tracers are often associated with bipolar transistor measurements because they do this task so well. In many applications, even relatively untrained personnel can perform accurate inspections of small to moderate numbers of devices for either incoming inspection or quality control.

The TEKTRONIX 577-D1 (storage) or 577-D2 (non-storage) Curve Tracers can be used to make such common bipolar transistor characteristic measurements as breakdown voltages, dc current gains, resistance, and small signal amplification. This includes on and off voltage drops, saturation voltages, leakages, and so forth. For most applications, these types of measurements will encompass the total testing required. In some cases, though, where time and frequency-based measurements are required, the curve tracer will require supplementing with other Tektronix measuring equipment.

Most bipolar measurements are either plots of current flow versus applied voltage across a single voltage, or displays of the effect on one current path of changes in the parameters applied to another path. On the curve tracer, the collector supply is normally used to provide the larger voltages required (through 1000 V), and the display is set to show the resulting current.

When a second voltage or current must be applied, the curve tracer provides an extremely accurate and versatile source in its step generator. This supply can be configured to provide a series of discrete steps, or, using its offset provision, a steady value of either current or voltage. The two modes can be used simultaneously, yielding a step function superimposed upon a dc level.

**NOTE:** These procedures have been designed to be sufficiently general for testing most individual device types in the bipolar transistor family. However, this section also provides actual settings, check values, and part numbers necessary for testing a specific bipolar transistor [2N3904]. This information is given in brackets at appropriate points throughout the section.

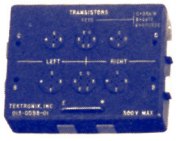
This section provides instructions for the specific tests listed below. These are preceded by general set-up instructions.

1) Collector-Emitter Breakdown Voltage $V_{(BR)CEO}$
2) Emitter-Base Breakdown Voltage $V_{(BR)EBO}$
3) Collector Cutoff Current $I_{CEV}$ or $I_{CEX}$
4) Collector-Base Breakdown Voltage $V_{(BR)CBO}$
5) DC Forward Current-Gain DC Beta or $h_{FE}$
6) Collector-Emitter Saturation Voltage $V_{CE(SAT)}$

## GENERAL SET-UP

### EQUIPMENT REQUIRED:

577-177-D2 or D1 (storage) Curve Tracer, socket adapter with appropriate pin configuration for transistor under test [Transistor Adapter, Tektronix part number 013-0098-01], transistor to be tested [2N3904], and specifications for that transistor.



### SET-UP:

1) Install 177 – If 177 Standard Test Fixture is not already installed in 577 Mainframe, do so first (with power off). See Figure 0-1.

2) Insert Socket Adapter – Place appropriate bipolar Socket Adapter in position provided on 177 test fixture. See Figure 0-1.

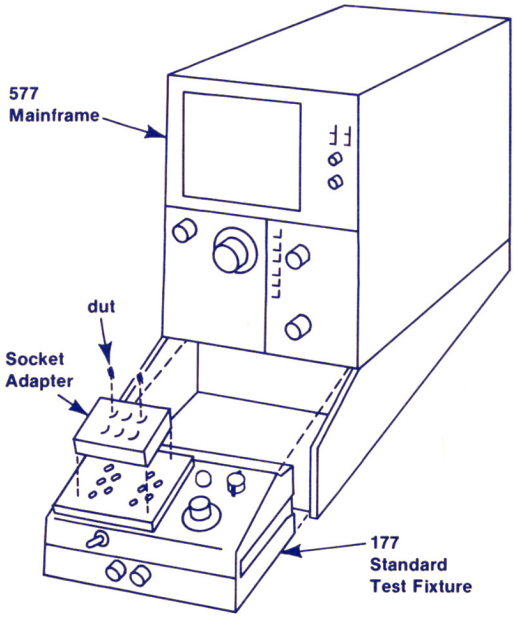
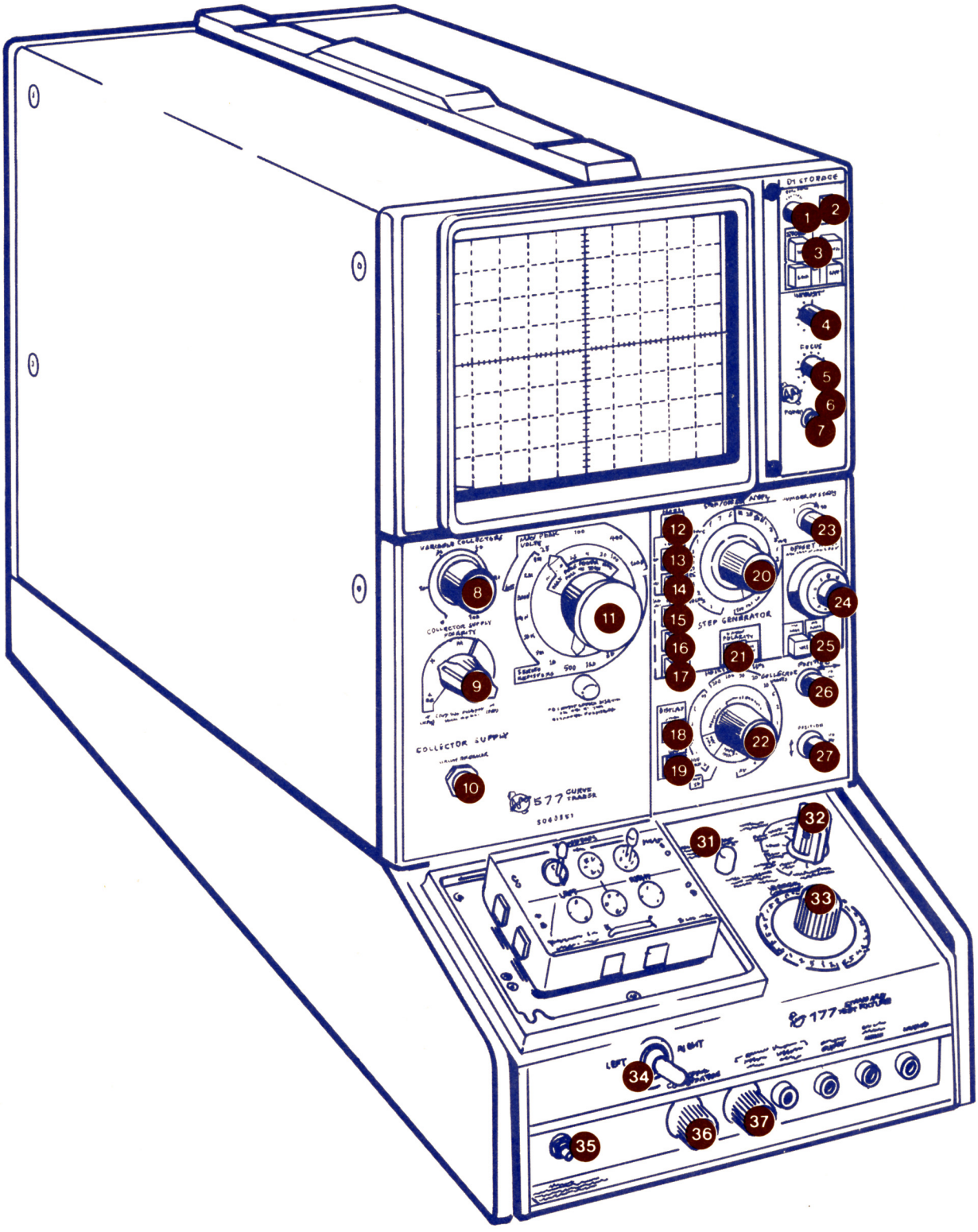



**Figure 0-1.** Installing standard test fixture.

## GENERAL SET-UP DIAGRAM



## GENERAL SET-UP continued

3) Set initial conditions— Referring to Bipolar set-up diagram (foldout), set controls as follows:
NOTE: This preliminary procedure has been designed to be applicable to all of the following tests. In each case, the detailed test procedure contains minor modifications to the settings of this procedure. Thus, it is possible to perform only one, some, or all of the tests, in any sequence.

On 577:

- MAX PEAK VOLTS to 25 (11)
- MAX PEAK POWER-WATTS to .15 (11)
- DISPLAY FILTER in (19)
- DISPLAY INVERT in (normal) (18)
- HORIZ VOLTS/DIV to 1 V (22)
- X10 HORIZ MAG in (off) (26)
- X10 VERT MAG in (off) (27)
- BRIGHTNESS to maximum (cw) (1)
- INTENSITY to minimum (ccw) (4)
- HORIZ POSITION to center (26)
- VERT POSITION to center (27)
- COLLECTOR POLARITY to + (9)
- VARIABLE SUPPLY COLLECTOR % to minimum (ccw) (8)
- Press STEP FAMILY-SINGLE in and release (single family) (14)
- NUMBER OF STEPS to minimum (ccw) (23)
- PULSED 300 μS out (off) (12)
- OFFSET ZERO in (offset off) (25)
- STEP/OFFSET Polarity in (normal) (21)

Ignore STEP/OFFSET AMPL, OFFSET AID, OFFSET MULTIPLEXER, STEP X.1.

On D1 (storage models):

- UPPER and LOWER STORE to out (non-store) (3)

On 177:

- FUNCTION to EMITTER GROUNDED, BASE TERM, STEP GEN (32)
- LEFT RIGHT selector to center (off) (34)

## GENERAL SET-UP continued

4) Obtain trace — Using controls on 577:

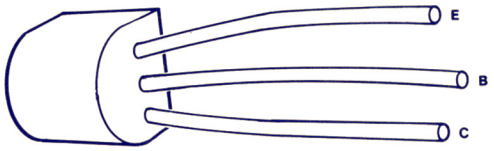
a) Pull POWER ON switch. Wait for warm-up. (7)

b) Find spot — Press BEAM FINDER button in, and advance INTENSITY control until spot is clearly visible. (6) (4)

c) Move spot — using VERT and HORIZ POSITION controls, move spot to bottom left corner of graticle (hold BEAM FINDER button in at first if necessary). (27) (26)

5) Insert device — Insert device to be tested in socket. See Figure 0-2.

Set-up procedure is now complete. Proceed to selected test.




EMITTER (E)
BASE (B)
COLLECTOR (C)

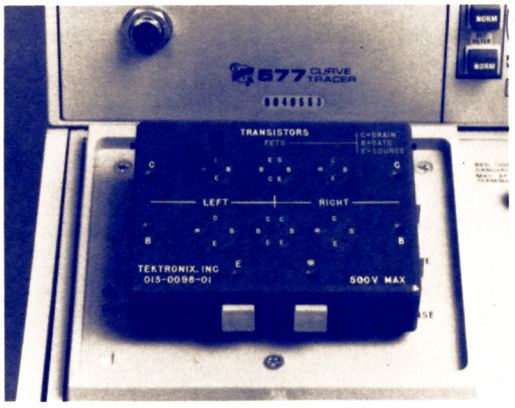



**Figure 0-2. Device inserted in socket.**

## TEST 1: COLLECTOR-EMITTER BREAKDOWN VOLTAGE $V_{(BR)CEO}$

Collector-emitter breakdown voltage is the limit at which excessive current begins to flow between the collector and the emitter with the base terminal open. Since it is a reverse current flow across a junction, the current exhibits a knee-shaped rise, increasing rather quickly once this limit is exceeded. The exact point taken as an indication of excessive current varies with the device to be tested, and must be obtained from the manufacturer's specification.

### WHAT THE DISPLAY SHOWS

The display shows applied collector-emitter voltage on the horizontal axis, and resulting current on the vertical.

Specifications are met when the specified voltage level can be applied without causing currents greater than the specified maximum.

### PROCEDURE:

1) Set controls— Beginning with general Bipolar transistor set-up, change controls as follows:

On 577:

- MAXIMUM PEAK VOLTS to smallest possible value above voltage required. (Note that, above 25 V, interlock switch must be pressed to activate device under test for each test.) [100 V] (11)
- HORIZ VOLTS/DIV to smallest value equal to or greater than 1/8 of maximum voltage to be tested [5 V] (22)
- COLLECTOR SUPPLY POLARITY to + for NPN, – for PNP [+] (9)
- VARIABLE COLLECTOR % to minimum (ccw) (8)

On 177:

- FUNCTION to EMITTER GROUNDED, BASE TERM,OPEN (32)
- VERTICAL CURRENT/DIV to smallest value at least 1/6 of specified maximum current flow [.2 mA] (33)

## TEST 1: COLLECTOR-EMITTER BREAKDOWN VOLTAGE $V_{(BR)CEO}$ continued

2) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Close protective cover or hold INTERLOCK BUTTON in if necessary. [yes]. *Slowly* increase VARIABLE COLLECTOR % supply until either specified current on vertical axis is exceeded or minimum specified voltage (on horizontal) is attained. [5 divs vertical, or 8 horizontal, corresponding to 1.0 mA and 40 V]. See Figure 1-1. 34 35 8

3) Compare to specifications — Check to see that specified voltage is reached before specified current is exceeded. See Figures 1-1, 1-2.

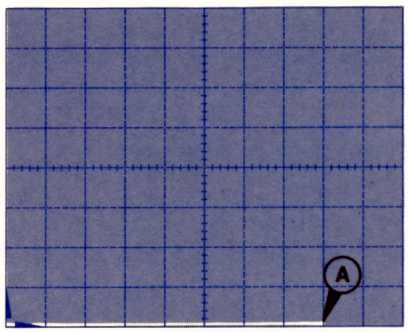



**Figure 1-1.** Typical display of collector-emitter breakdown voltage $V_{(BR)CEO}$ meeting specifications. [Point (A) shows attainment of minimum specified voltage 40 V.]

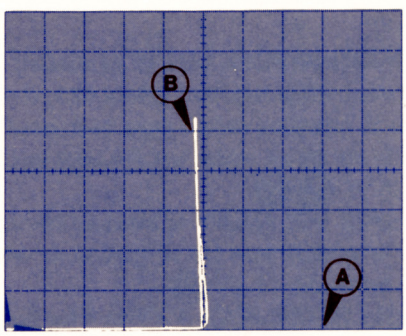



**Figure 1-2.** Typical display of collector-emitter breakdown voltage $V_{(BR)CEO}$ showing breakdown before specified voltage is attained. Note knee shaped rise. [Point (B) shows that specified current, 1 mA, is exceeded before specified voltage, point (A) is attained.]

## TEST 2: EMITTER-BASE BREAKDOWN VOLTAGE $V_{(BR)EBO}$

Emitter-base breakdown voltage is the limit at which excessive current begins to flow between the base and the emitter with the collector terminal open. Since it is a reverse current flow across a junction, the current exhibits a knee-shaped rise, increasing rather quickly once this limit is exceeded. The exact point taken as an indication of excessive current varies with the device to be tested, and must be obtained from the manufacturer's specification.

### WHAT THE DISPLAY SHOWS

The display shows applied base-emitter voltage on the horizontal axis, and resulting current on the vertical.

Specifications are met when the specified voltage level can be applied without causing currents above the specified maximum.

### PROCEDURE:

1) Set controls— Beginning with general Bipolar transistor set-up, change controls as follows:

   On 577:
   - MAXIMUM PEAK VOLTS to smallest value above voltage required. (Note that, above 25 V, interlock switch must be pressed to activate device under test for each test.) [25 V] 11 35
   - HORIZ VOLTS/DIV to smallest value equal to or greater than 1/8 of maximum voltage to be tested [1 V] 22
   - COLLECTOR POLARITY to + for NPN, - for PNP [+] 9
   - VARIABLE COLLECTOR % to minimum (ccw) 8

   On 177:
   - FUNCTION to EMITTER-BASE BREAKDOWN 32
   - VERTICAL CURRENT/DIV to smallest value at least 1/6 of specified maximum current flow [2 μA] 33

2) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. *Slowly* increase VARIABLE COLLECTOR % supply until either specified current is exceeded (vertical) or voltage (horizontal) is attained. [5 divs vertical, or 6 horizontal, corresponding to 10 μA and 6 V]. See Figure 2-1. 34 8

3) Compare to specifications — Check to see that specified voltage is reached before specified current is exceeded. See Figures 2-1, 2-2.

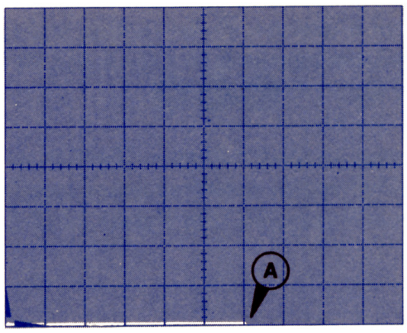



**Figure 2-1.** Typical display of emitter-base breakdown voltage $V_{(BR)EBO}$ meeting specifications. [Point (A) shows attainment of minimum specified voltage, 6 V.]

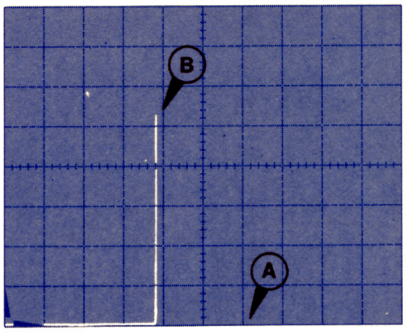



**Figure 2-2.** Typical display of emitter-base breakdown voltage $V_{(BR)EBO}$ showing breakdown before specified voltage is attained. Note knee-shaped rise. [Point (B) shows that specified current, 10 μA, is exceeded. Specified voltage point, 6 V, is attained.]

## TEST 3: COLLECTOR CUTOFF CURRENT $I_{CEV}$ or $I_{CEX}$

Collector cutoff current is the current that still flows through the collector terminal at a specified collector-emitter voltage when the base-emitter junction has been reverse biased to a specified value. It is normally less than either $I_{CEO}$ or $I_{CER}$ (base terminal open, or resistively connected to the emitter, respectively), because the reverse bias removes most thermal and avalanche carriers from the base.

Because of non-linearities and the effect of base-drive source impedance on this measurement, the base drive is often specified as a current instead of a voltage. The symbol $I_{CEV}$ is commonly used for the voltage method of specification, while $I_{CEX}$ is for values stated with current inputs. The low source impedance and voltage and current drive capability of the curve tracer permits both types of measurement with good results.

### WHAT THE DISPLAY SHOWS

The display shows applied collector-emitter voltage on the horizontal axis, and resulting current on the vertical.

Specifications are met when the current does not exceed the manufacturer's specified value of collector voltage, the measurement being performed with the specified level of base voltage.

### PROCEDURE:

1) Set controls— Beginning with general Bipolar transistor set-up, change controls as follows:

On 577:

- MAXIMUM PEAK VOLTS to smallest value above voltage required (Note that, above 25 V, interlock switch must be pressed to activate device under test for each test.) [100 V] 11
- HORIZ VOLTS/DIV to smallest value at least 1/8 of maximum voltage to be tested [5 V] 22
- COLLECTOR POLARITY to + DC for NPN, -DC for PNP [+DC] 9
- VARIABLE COLLECTOR % to minimum (ccw) 8
- NUMBER OF STEPS to minimum (ccw) 23
- STEP/OFFSET AMPL to smallest voltage value at least 1/10 of specified base voltage [0.5 V] 20
- OFFSET MULT to required multiplier to convert offset amplitude to required base drive [6.0] 24
- OFFSET ZERO out (offset on) 25
- OFFSET AID out (oppose) 25

## TEST 3: COLLECTOR CUTOFF CURRENT $I_{CEV}$ or $I_{CEX}$ continued

On 177:

- FUNCTION to EMITTER GROUNDED, BASE TERM, STEP GEN (32)
- VERTICAL CURRENT/DIV to smallest value at least 1/6 of specified maximum current flow. [10 nA] (33)

2) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Close protective cover, or press and hold INTERLOCK. *Slowly* increase VARIABLE COLLECTOR % supply until either specified current (vertical) is exceeded or specified voltage (horizontal) is attained. [5 divs vertical, or 6 horizontal, corresponding to 50nA and 30 V]. Refer to Figure 3-1. (34) (35) (8)

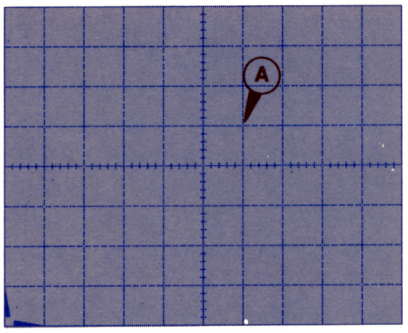



**Figure 3-1.** Typical display of collector cutoff current $I_{CEV}$ within specifications. [Point (A) shows attainment of the specified current, 50 nA, at the specified voltage, 30V.]

## TEST 3: COLLECTOR CUTOFF CURRENT $I_{CEV}$ OR $I_{CEX}$ continued

3) Compare to specifications — Check to see that specified voltage is reached before specified current is exceeded. See Figures 3-1, 3-2, 3-3.

Note the effect of DISPLAY FILTER when noise is a problem 19

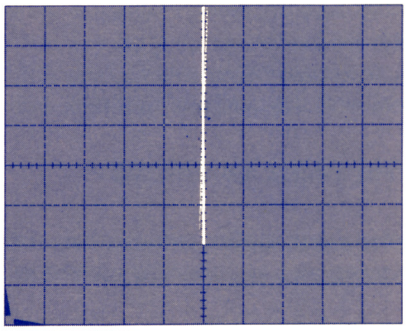


**Figure 3-2.** Typical display of collector cutoff current failing specification. At greater sensitivities, noise tends to elongate spot. See Figure 3-3 for effect of using DISPLAY FILTER on this trace. [ A value for current is difficult to read because noise tends to elongate spot at 25 V.]

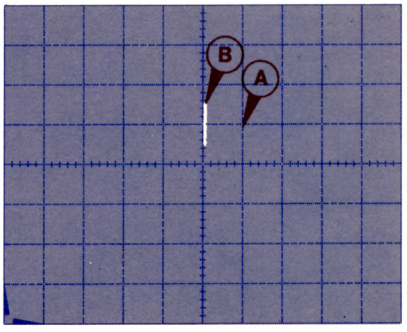



**Figure 3-3.** Display of excessive collector cutoff current $I_{CEV}$, but using DISPLAY FILTER for more accurate reading. [55 nA cutoff current at 25V point (B) exceeds the spedified values, point (A) .

## TEST 4: COLLECTOR-BASE BREAKDOWN VOLTAGE $V_{(BR)CBO}$

Collector-base breakdown voltage is the limit at which excessive current begins to flow between the collector and the base with the emitter terminal open. Since it is a reverse current flow across a junction, the current exhibits a knee-shaped rise, increasing rather quickly once this limit is exceeded. The exact point taken as an indication of excessive current varies with the device to be tested, and must be obtained from the manufacturer's specification.

### WHAT THE DISPLAY SHOWS

The display shows applied collector-base voltage on the horizontal axis, and resulting current on the vertical.

Specifications are met when the specified voltage level can be applied without causing currents greater than the specified maximum.

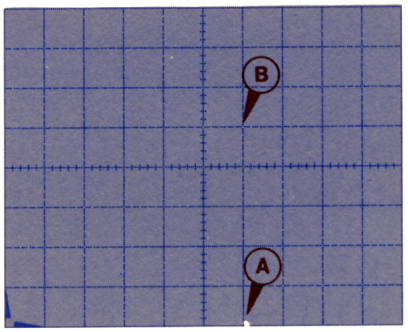



**Figure 4-1.** Typical display of collector-base breakdown voltage $V_{(BR)CBO}$ within specifications. [point (A) shows the attainment of specified voltage, 60 V, without exceeding the specified current. While this display shows the specifications being met at point (A), specifications are met at any point on the vertical division line from point (A) to point (B).]

### PROCEDURE:

1) Set controls— Beginning with general Bipolar transistor set-up, change controls as follows:

On 577:

- MAXIMUM PEAK VOLTS to smallest value above voltage required (Note that, above 25 V, interlock switch must be pressed to activate device under test for each test.) [100 V] 11
- HORIZ VOLTS/DIV to smallest value at least 1/8 of maximum voltage to be tested [10 V] 22
- COLLECTOR POLARITY to + DC for NPN, - DC for PNP [+ DC] 9
- VARIABLE COLLECTOR % to minimum (ccw) 8

On 177:

- FUNCTION to BASE GROUNDED, EMITTER TERM, OPEN 32
- VERTICAL CURRENT/DIV to largest value equal to or less than 1/6 of specified maximum current flow [2 μA] 33

## TEST 4: COLLECTOR-BASE BREAKDOWN VOLTAGE $V_{(BR)CBO}$ continued

2) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Press and hold INTERLOCK. *Slowly* increase VARIABLE COLLECTOR % supply until either specified current is exceeded (vertical) or voltage (horizontal) is attained. [5 divs vertical, or 6 horizontal, 10 μA and 60 V]. See Figures 4-1, 4-2, 4-3. 34 35 8

3) Compare to specifications — Check to see that specified voltage is reached before specified current is exceeded.

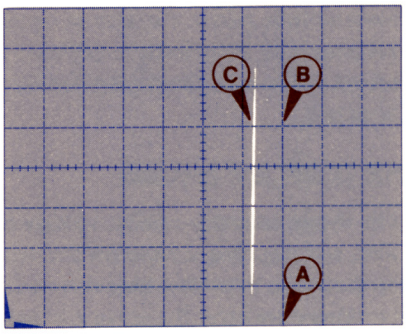



**Figure 4-2.** Display of collector-base breakdown $V_{(BR)CBO}$ failing specification.

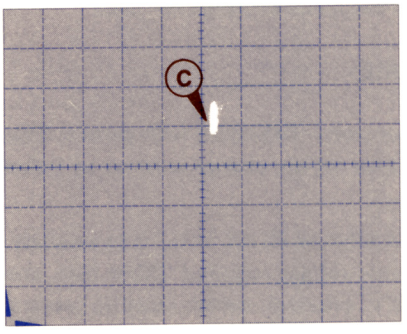



**Figure 4-3.** Same collector-base breakdown voltage $V_{(BR)CBO}$ display, but using DISPLAY FILTER for greater accuracy. See Point (C).

## TEST 5: DC FORWARD CURRENT-GAIN (DC BETA OR $h_{FE}$)

Dc forward current gain is the ratio of dc collector current to dc base current under specified operating conditions. Because of variance with temperature, collector voltage and collector current (or base current, which is related) values must be obtained at the conditions specified by the device manufacturer. Normally, a set of values at different operating point is tested.

### WHAT THE DISPLAY SHOWS

The display shows collector-emitter voltage on the horizontal axis, and resulting current on the vertical. With the step generator providing base drive and a normally operating transistor, the curve will appear displaced upward from the horizontal axis as the base drive causes a proportional collector current.

Specifications are met when, at either the specified base current or specified collector current, the value of the collector current divided by the base current falls within the specified range for beta.

### PROCEDURE:

1) Set controls— Beginning with general Bipolar transistor set-up, change controls as follows:

On 577:

- MAXIMUM PEAK VOLTS to smallest value above voltage required (Note that, above 25 V, interlock switch must be pressed to activate device under test for each test.) [25 V] 11
- HORIZ VOLTS/DIV to smallest value equal to or greater than 1/8 of maximum voltage to be tested [0.2V collector] 22
- COLLECTOR SUPPLY POLARITY to + for NPN, - for PNP [+] 9
- VARIABLE COLLECTOR % to minimum (ccw) 8
- NUMBER OF STEPS to minimum (ccw) 23
- STEP/OFFSET AMPL to largest current value less than or equal to specified base current, or, if none given, of collector current divided by stated $h_{FE}$ [0.1 mA ÷ 40 = 2.5 μA, therefore 2 μA] 20
- OFFSET ZERO out (offset on) 25
- OFFSET MULT to zero (ccw) 24
- OFFSET AID in (aid) 25

## TEST 5: DC FORWARD CURRENT-GAIN (DC BETA or $h_{FE}$ continued

On 177:

- FUNCTION to EMITTER GROUNDED, BASE TERM, STEP GEN (32)
- VERTICAL CURRENT/ DIV to smallest value at least ½ of specified collector current flow, or if none given, 1/6 of base current times specified $h_{FE}$ [20 μA] (33)

2) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Close protective cover, or press and hold INTERLOCK if necessary [NO]. *Slowly* increase VARIABLE COLLECTOR % supply until specified voltage (horizontal) is attained. [5 divs horizontal, or 1.0 V]. See figure 5-1. (34) (35) (8)

3) Adjust to parameters — If operating point is given in terms of collector current, advance OFFSET MULT (cw) until curve crosses the the horizontal line corresponding to the specified collector current [5 divs vertical, or 0.1 mA], then adjust VARIABLE COLLECTOR % supply until the curve crosses the vertical line corresponding to the specified voltage [5 divs horizontal, or 1.0 V]. See figure 5-2. (24) (8)

**Note on Temperature Effects:** If the displayed curve (Figure 5-2) appears to drift up or down the graticule, thermal effects may be altering device operation. On D1 (storage models), to see how serious this drift may be, store the curve by pressing UPPER and LOWER STORE buttons in (store), then press ERASE, and now observe the stored drift. See Figure 5-3. If this problem is serious enough, it is impossible to obtain an accurate measurement. It is possible, however, to minimize these thermal effects by using the pulsed, 300 μs, 2% duty cycle of the step generator instead of the offset multiplier. In this "pulsed mode" method, it is not always possible to match the exact specified value of collector and base current. (3) (2) (12)

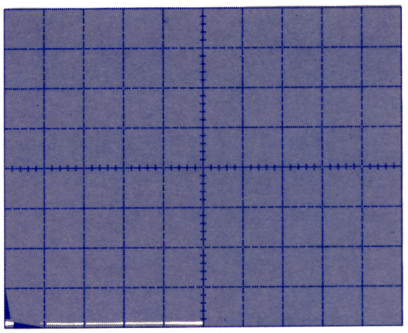


**Figure 5-1.** Display shows specified horizontal voltage.

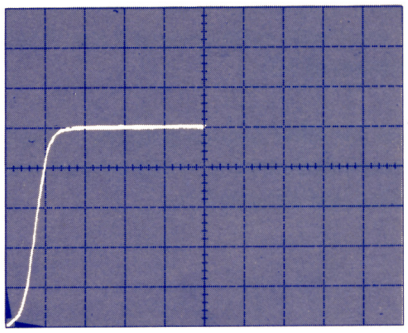


**Figure 5-2.** Typical display of dc forward current-gain (dc beta or $h_{FE}$) test.

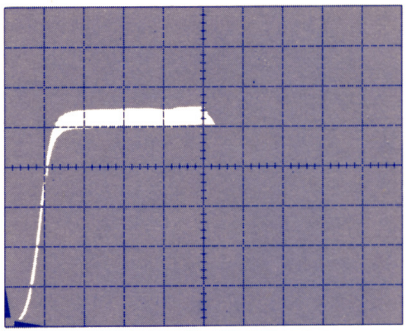


**Figure 5-3.** Typical display of dc forward current-gain showing thermal effects.

## TEST 5: DC FORWARD CURRENT-GAIN (DC BETA or $h_{FE}$ continued

4) Calculate beta ($h_{FE}$) — Divide indicated collector current by base current (base current is OFFSET MULT value times STEP/OFFSET AMPL).

$$h_{FE} = \frac{\text{VERT SENSITIVITY x divisions vertical}}{\text{OFFSET MULT x STEP/OFFSET AMPL}}$$

$$h_{FE} = \frac{[20\mu A] \times [5 \text{ divs}]}{[1.25] \times [2\mu A]}$$

$$h_{FE} = \frac{[100\mu A]}{[2.5\,\mu A]}$$

$$h_{FE} = 40$$

5) Compare to specified value — Compare calculated value with manufacturer's specification. [minimum of 40].

6) Repeat for other operating points — Repeat procedure as desired to check beta at other specified operating points.

## TEST 6: COLLECTOR-EMITTER SATURATION VOLTAGE $V_{CE(SAT)}$

Collector-emitter saturation voltage is the value of collector voltage below which an increase in specified base current cannot cause an increase in collector current. This measurement must be performed at specified collector and base current values. This is an important factor in the transistor's dissipation when used in the switching mode.

On the curve tracer, this measurement is made by examining a single operating curve or family of curves, and noting where the transition knee from the rising, collector voltage-controlled operation to the flat, base-controlled operation occurs.

### WHAT THE DISPLAY SHOWS

The display shows collector-emitter voltage on the horizontal axis, and resulting current on the vertical. With the step generator providing base drive and a normally operating transistor, the curve will first appear rising as the collector voltage controls the current, then flat as the base assumes control.

Specifications are met when, at the specified base current or specified collector current, the transition knee to base-controlled operation appears within the horizontal displacement corresponding to the collector voltage specified.

### PROCEDURE:

1) Set controls— Beginning with general Bipolar transistor set-up, change controls as follows:

   On 577:

   - MAXIMUM PEAK VOLTS to smallest value above voltage required (Note that, above 25 V, interlock switch must be pressed to activate device under test for each test.) [not required] [25V] (11)
   - HORIZ VOLTS/DIV to smallest value equal to or greater than maximum voltage to be tested (It may be necessary to pull X10 HORIZ MAG to obtain small enough value.) [not required] [0.2V] (22)
   - MAX PEAK POWER - WATTS to smallest possible value at least MAX PEAK VOLTS times desired current [2.3] (11)
   - COLLECTOR SUPPLY POLARITY to + for NPN, - for PNP [+] (9)
   - VARIABLE COLLECTOR % to minimum (ccw) (8)
   - STEP FAMILY REP in (on) (13)
   - STEP/OFFSET AMPL to smallest value less than or equal to specified base current [1 mA] (20)

## TEST 6: COLLECTOR-EMITTER SATURATION VOLTAGE $V_{CE}$ (SAT) continued

- OFFSET MULT to multiplier needed to convert STEP/OFFSET AMPL to specified base current (MULT = base current ÷ STEP/OFFSET AMPL). [1] 24 20
- OFFSET ZERO out (offset on) 25
- SLOW (1X LINE) in 15
- PULSED 300 μS in (2-% duty cycle) 12
- OFFSET AID in 25

On 177:

- FUNCTION to EMITTER GROUNDED, BASE TERM, STEP GEN 32
- VERTICAL CURRENT/DIV to smallest value at least 1/6 of specified collector current flow. [2mA] 33

2) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. If necessary, press and hold INTERLOCK [not required]. *Slowly* increase VARIABLE COLLECTOR % supply until specified collector current (vertical) is attained. [5divs vertical]. See figure 6-1. 34 35 8

3) Compare to specifications — Check that, at stated collector current (vertical), collector voltage (horizontal) is not more than manufacturer's specified value. [at 5 vertical divisions (10 mA), less than one horizontal division (0.2 V)].

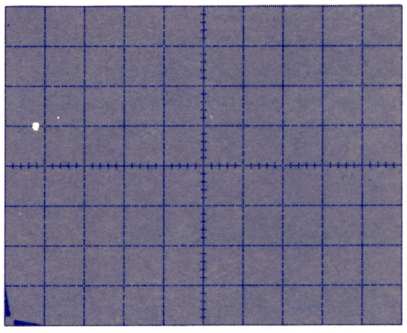


**Figure 6-1.** Typical collector-emitter saturation voltage $V_{CE}$ (SAT) display.

## INTRODUCTION

Junction Field Effect Transistors (JFET's) must be characterized using a wide range of both voltages and currents; measurement units often range from picoamps to amps and microvolts to tens of volts. The curve tracer, with its ability to present such a wide range of information in accurate, graphic form, is often a good choice for a testing system, especially when the number of transistors to be tested is too small to justify setting up a fully automated system, or when a few pieces must be characterized in great detail.

The TEKTRONIX 577-177 curve tracer (in either storage D1 or non-storage D2 model) provides the capabilities required for the common JFET tests. Test set-up is done through a simple combination of dial settings and front panel jumper connections.

**NOTE:** These procedures have been designed to be sufficiently general for testing most individual device types in the JFET family. However, this section also provides actual settings, check values, and part numbers necessary for testing a specific JFET (2N4302). This information is given in brackets at appropriate points throughout the section.

JFET's exhibit both current-controlled and voltage-controlled behavior. Most tests use the step generator in the 577. This generator can provide controlled levels of both of these parameters to provide either the independent variable or a steady bias level. The 577 collector supply is used for device bias, and for testing when higher levels of voltage are required. The 177 Standard Test Fixture provides the support for the special JFET socket adapter and also carries the device on-off selector switch (labeled LEFT-RIGHT) and the vertical sensitivity control for the display.

This section provides instructions for the specific tests listed below. These are preceded by general set-up instructions.

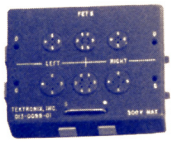
1) Zero Gate Voltage Drain Current $I_{DSS}$
2) Gate-Source Breakdown Voltage $V_{(BR)GSS}$
3) Reverse Gate Leakage $I_{GSS}$
4) Small Signal Transconductance $G_m$
5) Pinch-Off Voltage $V_p$

## GENERAL SET-UP

### EQUIPMENT REQUIRED:

577-177-D2 or D1 (storage) Curve Tracer, socket adapter*, [FET Adapter, Tektronix part number 013-0099-01], jumpers for socket pins, JFET to be tested [2N4302], and specifications for that JFET.

*Note: The standard bipolar transistor socket may be used if the JFET device leads are inserted to correspond to base-gate, collector-drain, emitter-source. Test directions must be interpreted correspondingly.



### SET-UP:

1) Install 177 – If 177 Standard Text Fixture is not already installed in 577 Mainframe, do so first (with power off).

2) Insert Socket Adapter – Place FET Socket Adapter in position provided on 177 test fixture. See Figure 0-1.

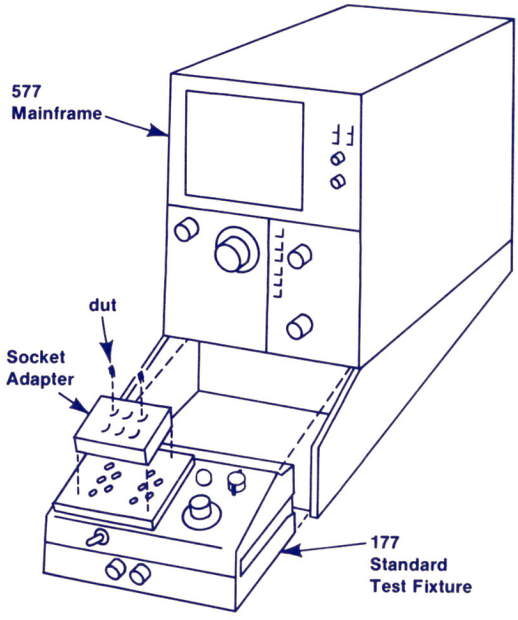
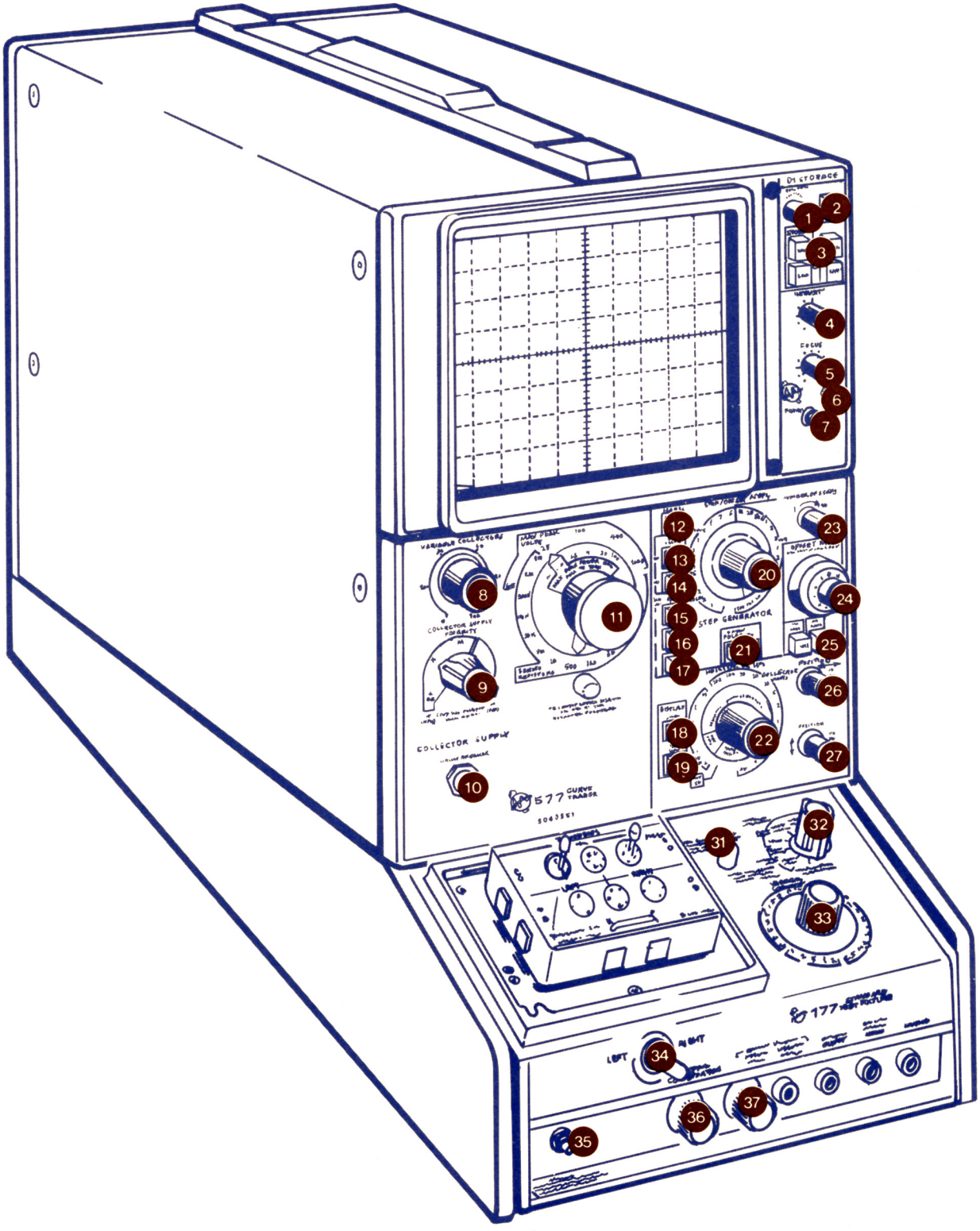



**Figure 0-1.** Installing test fixture.

## GENERAL SET-UP DIAGRAM



## GENERAL SET-UP continued

3) **Set initial conditions— Referring to JFET set-up diagram (foldout), set controls as follows:**
NOTE: This preliminary procedure has been designed to be applicable to all of the following tests. In each case, the detailed test procedure contains minor modifications to the settings of this procedure. Thus, it is possible to perform only one, some, or all of the tests, in any sequence.

On 577:

- MAX PEAK VOLTS to 25 (11)
- MAX PEAK POWER-WATTS to .15 (11)
- DISPLAY FILTER in (19)
- DISPLAY INVERT in (normal) (18)
- HORIZ VOLTS/DIV to 5 V (22)
- X10 HORIZ MAG to off (26)
- X10 VERT MAG to off (27)
- BRIGHTNESS control to maximum (cw) (1)
- INTENSITY control to minimum (ccw) (4)
- HORIZ POSITION to center (26)
- VERT POSITION to center (27)
- COLLECTOR SUPPLY POLARITY to + (9)
- VARIABLE COLLECTOR % to minimum (ccw) (8)
- Press STEP FAMILY-SINGLE in and release (single-family) (14)
- PULSED 300 $\mu$S out (12)
- OFFSET ZERO in (25)
- STEP/OFFSET Polarity in (normal) (21)

Ignore STEP/OFFSET AMP, OFFSET AID, NUMBER OF STEPS, OFFSET MULTIPLIER, STEP X.1. (20) (25) (23) (24) (20)

On D1 (storage models):

- UPPER and LOWER STORE out (normal) (3)

On 177:

- FUNCTION to EMITTER GROUNDED, BASE TERM, STEP GEN (32)
- LEFT-RIGHT selector to center (off) (34)

## GENERAL SET-UP cont.

4) Obtain trace — Using controls on 577:

   a) Pull POWER ON switch. Wait for warm-up. 7

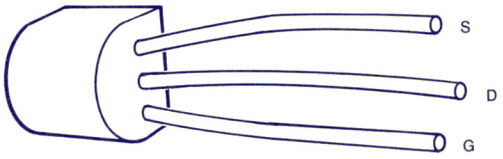
   b) (D1 storage only) Clear screen — Press UPPER and LOWER STORE buttons, and then UPPER and LOWER ERASE. Release STORE buttons. 3

   c) Find spot — Press BEAM FINDER button in, and advance INTENSITY control until spot is clearly visible. 6 4

   d) Position spot — Using VERTICAL and HORIZONTAL POSITION controls, move spot to lower left hand corner of graticule. Use BEAM FINDER to see present direction if spot is off-screen. 27 26 6

5) Insert device — Insert device to be tested in socket. See Figure 0-2.

Set-up procedure is now complete. Proceed to selected test.




**SOURCE**(S)
**DRAIN**(D)
**GATE**(G)

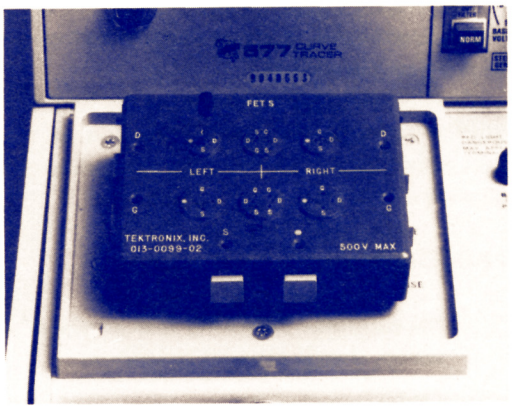



**Figure 0-2.** Device inserted in socket

## TEST 1: ZERO GATE VOLTAGE DRAIN CURRENT $I_{DSS}$

Zero gate voltage drain current is the measurement of current flow between drain and source with no applied gate signal. Drain-source voltage and permissible currents for this test are specified by the manufacturer for the particular JFET type under test.

On the curve tracer, the collector supply is used to provide the specified bias, the appropriate function switch position is used to short the gate to the source.

### WHAT THE DISPLAY SHOWS

The display shows applied drain-source voltage on the horizontal axis, and current flowing from source to drain on the vertical.

Specifications are met when, at the horizontal position corresponding to the given voltage, the trace falls within the vertical band corresponding to the allowable current.

### PROCEDURE:

1) Set controls— Beginning with general JFET set-up, change controls as follows:

On 577:

- HORIZ VOLTS/DIV to smallest value at least 1/8 of specified drain-source voltage [5 V] 22
- COLLECTOR SUPPLY POLARITY to + 9
- VARIABLE COLLECTOR % to minimum (ccw) 8

On 177:

- FUNCTION TO EMITTER-GROUNDED, BASE TERM, SHORT 32
- VERTICAL CURRENT/DIV to smallest possible value more than 1/6 of specified maximum current [5 mA] 33

## TEST 1: ZERO GATE VOLTAGE DRAIN CURRENT $I_{DSS}$ continued

2) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Increase VARIABLE COLLECTOR % supply until specified voltage is reached on horizontal. [4 divs, or 20 V] 34 8

3) Compare to specifications — Check to see if vertical displacement indicates specified current. [more than 1/5 divs or 1 mA, and less than 4 divs, or 20 mA]. If necessary, increase vertical sensitivity to read low currents. See Figure 1-1.

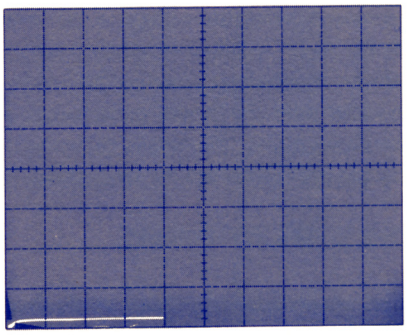


**Figure 1-1.** Display of zero gate voltage drain current $I_{DSS}$.

## TEST 2: GATE-SOURCE BREAKDOWN VOLTAGE $V_{(BR)GSS}$

Gate-source breakdown voltage is the limit at which excessive current begins to flow between the gate and the source, with the drain terminal shorted to the source. Since it is current flow across a junction, the current exhibits a knee-shaped rise, increasing rather quickly once this limit is exceeded. The exact point taken as an indication of excessive current varies with the device to be tested, and must be obtained from the manufacturer's specification.

On the curve tracer, this test is performed by grounding the drain and supplying reverse voltage to the gate. The source and drain are connected by an external jumper. Collector voltages up to 1600 V may be used.

### WHAT THE DISPLAY SHOWS

The display shows applied voltage on the horizontal axis, and resulting current on the vertical.

Specifications are met when the specified voltage level can be applied without causing currents above the given value.

### PROCEDURE:

1) Set controls— Beginning with general JFET set-up, change controls as follows:

On 577:

- MAXIMUM PEAK VOLTS to smallest value above voltage required. (Note that, above 25 V, interlock switch must be pressed for each test.) [100 V] 11
- HORIZ VOLTS/DIV to smallest value at least 1/8 of maximum voltage to be tested [5 V] 22
- COLLECTOR SUPPLY POLARITY to + DC 9
- VARIABLE COLLECTOR % to minimum (ccw) 8

On 177:

- FUNCTION to BASE-GROUNDED, EMITTER TERM, OPEN (source open) 32
- VERTICAL CURRENT SENSITIVITY/DIV to smallest value at least 1/6 of specified maximum current flow [200 nA] 33

## TEST 2: GATE-SOURCE BREAKDOWN VOLTAGE $V_{(BR)GSS}$ continued

2) Connect jumper — Using jumper, connect holes corresponding to source and drain positions on socket adapter. To insert wires, press square buttons on side of adapter, alongside each jumper receptacle.

3) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. *Slowly* increase VARIABLE COLLECTOR % supply until either specified current (vertical) or minimum voltage (horizontal) is attained. [5 divs vertical, or 6 horizontal]. 34 8

4) Compare to specifications — Check to see that specified voltage is reached before stated current is exceeded. See Figure 2-1. See note 2

Note 1: $I_{GSS}$ may be tested using this same set-up. If that test is desired, perform it next. See procedure on page 10.

Note 2: Be sure to remove jumper when finished with this test configuration.

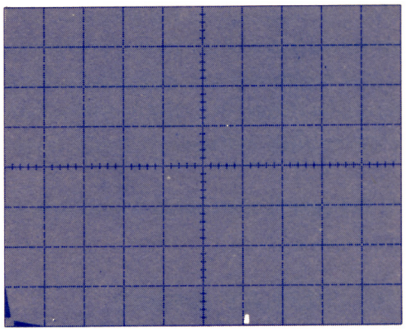


**Figure 2-1.** Display of gate-source breakdown voltage $V_{(BR)GSS}$.

## TEST 3: REVERSE GATE LEAKAGE $I_{GSS}$ JFET

Reverse gate leakage is the measure of how much current flows from the gate to the channel at moderate reverse bias levels. More specifically, it is the negative current flowing from gate to source with the drain shorted to the source, and measured at a specified voltage level.

On the curve tracer, this test is performed in a manner similar to the test for gate-source breakdown voltage, except that the applied voltage is brought only to a specified lower point, and the resulting current measured at that point.

Again, the gate is grounded, and reverse collector voltage is applied to the drain. The jumper shorts drain and source.

### WHAT THE DISPLAY SHOWS

The display shows applied voltage on the horizontal axis, and resulting current on the vertical.

Specifications are met when no more than the specified current flows at the rated test voltage.

### PROCEDURE:

1) Set controls— Beginning with general JFET set-up, change controls as follows:

On 577:

- HORIZ VOLTS/DIV to approximately 1/8 of maximum voltage to be tested [2 V] 22
- COLLECTOR SUPPLY POLARITY to + DC 9
- DISPLAY FILTER out (on) 19
- VARIABLE COLLECTOR % to minimum (ccw) 8

On 177:

- FUNCTION to BASE GROUNDED, EMITTER TERM, OPEN 32
- VERTICAL CURRENT/DIV to smallest possible value more than 1/8 of specified maximum current [2 nA] 33

## TEST 3: REVERSE GATE LEAKAGE $I_{GSS}$ continued

2) Connect jumper — Using jumper, connect holes corresponding to source and drain positions on socket adapter. To insert wire, press square buttons on side of adapter, alongside each jumper receptacle.

3) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Increase VARIABLE COLLECTOR % supply until specified voltage is reached on horizontal. [5 divs, or 10 V]. 34 8

4) If necessary, use X10 vertical magnifier push-button on 577 to obtain more vertical sensitivity. [2 nA setting/X10 in, providing 200 pA]. 27

5) Compare to specifications — Check to see if vertical displacement indicates specified current [within 1/2 div, or 10 nA at 2 nA/div, or with 5 divs at 200 pA/div]. See Figure 3-1. See Note 2.

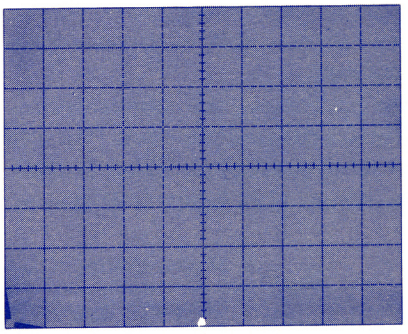


**Figure 3-1.** Display of reverse gate leakage $I_{GSS}$.

Note 1: $V_{(BR)GSS}$ can be tested using this same set-up. If that test is desired, and has not been performed, perform it next. See page 8.

Note 2: Be sure to remove jumper when finished with this test configuration.

## TEST 4: SMALL SIGNAL TRANSCONDUCTANCE ($G_m$)

Small signal transconductance is the change in output current caused by a small change in input voltage near a specified input point, usually zero volt. Although a current divided by voltage function, it is often loosely referred to as small-signal gain.

On the curve tracer, this measurement is performed by measuring the difference between two characteristic curves bracketing the specified point. The collector supply provides drain-source bias. The step generator and offset controls are set to provide two values (1 step) around the operating point. The change in the vertical display, multiplied by the current scale factor, is divided by the change in the gate bias, which is 1 times the step generator scale factor:

$$G_m = \frac{\#\text{ of divs change X } I_D/\text{div}}{1\text{ step X } V_{GS}/\text{step}}$$

### WHAT THE DISPLAY SHOWS

The horizontal axis of the display shows drain-source voltage. The vertical dimension indicates the current flowing through the drain. Using the step generator, two curves will be provided on each display, the first at only the offset gate-source voltage, and the second at a voltage equal to the original gate voltage plus one step from the step generator.

**PROCEDURE:**

1) Set controls— Beginning with general JFET set-up, change controls as follows:

On 577:

- HORIZ VOLTS/DIV to smallest value at least 1/8 of specified drain-source voltage [5 V] 22
- COLLECTOR SUPPLY POLARITY to + 9
- STEP FAMILY REP in (on) 13
- VARIABLE COLLECTOR % to minimum (ccw) 8
- STEP/OFFSET AMPL to approximately 1/40 of drain-source voltage [ .5 V] 20
- NUMBER OF STEPS to minimum (ccw) 23

On 177:

- FUNCTION to EMITTER GROUNDED, BASE TERM, STEP GEN 32
- VERTICAL CURRENT/DIV to initially approximate, in mA per division, 1/6 of specified drain-source voltage in volts [2 mA] 33

## TEST 4: SMALL TRANSCONDUCTANCE ($G_m$) continued

2) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Increase VARIABLE COLLECTOR % supply until specified voltage is reached on horizontal. [4 divs, or 20 V]. See Figure 4-1. 34 8

3) Readjust scale factors — Readjust VERTICAL CURRENT/DIV to provide display that comes closest to crossing center of screen. 33

4) Reposition trace— Using HORIZONTAL and VERTICAL POSITION controls, move point (A) (fig. 4-2) corresponding to specified drain source voltage to intersection of middle horizontal graticule line and any convenient vertical graticule line. 26 27

5) Calculate $G_m$ and compare to specifications — Using formula: $G_m$ = # of vertical divisions between traces X vertical scale factor ÷ step amplitude, calculate $G_m$. Compare to specified value. See Figure 4-2.

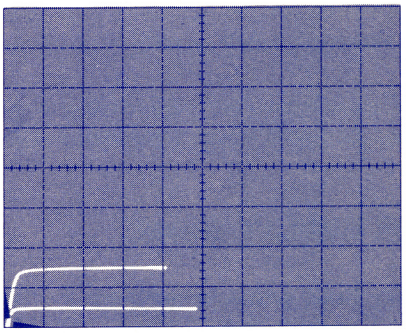


**Figure 4-1.** Display of small signal transconductance $G_m$.

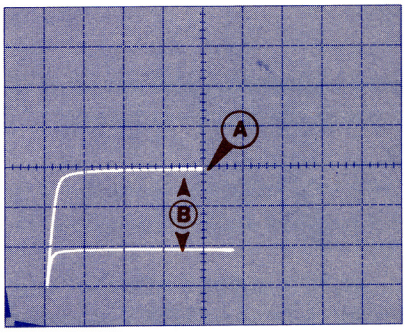



**Figure 4-2.** Small signal transconductance $G_m$ measurement. Point (B) is the area of interest.

## TEST 5: PINCH-OFF VOLTAGE ($V_p$)

Pinch-off voltage is the amount of gate potential needed to shut off current flow in the channel. The value of drain-source voltage required, and the level of current considered to be turn-off, are obtained from the device specifications.

On the curve tracer, this measurement is performed by increasing the opposing gate voltage with the step generator until the drain current falls below the stated value. The collector supply provides the device bias at the specified value.

### WHAT THE DISPLAY SHOWS

The display shows drain-source voltage on the horizontal axis, and resulting current on the vertical.

Specifications are met when current is reduced to the specified flow at or before the point at which rated voltage is applied by the step/offset generator.

**PROCEDURE:**

1) Set controls— Beginning with general JFET set-up, change the controls as follows:

On 577:

- HORIZ VOLTS/DIV to first value at least 1/8 of specified drain-source voltage [5 V] 22 [5 V]
- COLLECTOR SUPPLY POLARITY to + DC 9
- VARIABLE COLLECTOR % to minimum (ccw) 8
- STEP/OFFSET AMPL to first value at least equal to 1/5 of maximum specified pinch-off [1 V] 20
- OFFSET MULT to multiplier required to produce approximately 1.5 times specified maximum $V_p$ (i.e., MULT = 1.5 $V_p$/AMPL [6.0] 24
- OFFSET ZERO out (applied) 25
- OFFSET OPPOSE out (opposed) 25
- NUMBER OF STEPS to minimum (ccw) 23
- DISPLAY FILTER out (on) 19

On 177:

- FUNCTION to EMITTER GROUNDED, BASE TERM, STEP GEN 32
- VERTICAL CURRENT/DIV to specified drain-source current (If necessary, use X 10 vertical magnifier pushbutton on 577 to obtain smaller values.) [10 nA setting, X 10 in (off)]. 33

## TEST 5: PINCH-OFF VOLTAGE ($V_p$) cont.

2) Realign spot with origin — Using the HORIZ and VERT POSITION controls, align spot to lower left-hand corner of screen. 26 27

3) Use storage — Press UPPER and LOWER STORE buttons. Press ERASE to clear screen. 3 2

4) Apply power to device— Position LEFT-RIGHT switch on 177 to appropriate side. Increase VARIABLE COLLECTOR % until specified voltage is reached on horizontal [4 divs, or 20 V]. See Figure 5-1. 34 8

5) Apply offset — Turn OFFSET MULT control ccw until trace meets intersection of horizontal line corresponding to specified pinch-off current and vertical line representing stated drain-source voltage. [1 vertical and 4 horizontal divs, representing 10 nA and 20 V]. 24

6) Produce trace — Press ERASE to clear screen, then reduce VARIABLE COLLECTOR % to 0. 2 8

7) Calculate $V_p$ and compare to specifications — Using formula: $V_p$ = multiplier from OFFSET MULT X STEP/OFFSET AMPL, calculate $V_p$. Compare to specified value. See Figure 5-2. 24 20

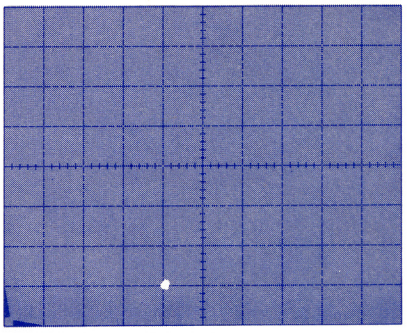


**Figure 5-1.** Display of pinch-off voltage $V_p$.

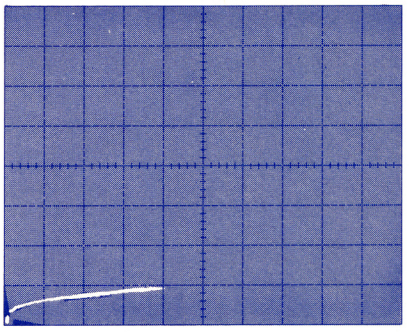


**Figure 5-2.** Display of pinch-off voltage $V_p$ in the storage mode.

## INTRODUCTION

Silicon Controlled Rectifiers (SCR's) are used extensively in power and pulse control circuitry. Because SCR's are non-linear devices, testing and characterization with a curve tracer is particularly helpful in visualizing the complex operating curves of those devices.

SCR's are, in theory, one-way bistable valves that allow a small control pulse applied to the gate terminal to turn on a large gain current. In reality, leakage effects and voltage drops must be taken into account, and the curve tracer's ability to measure both large and small currents becomes vital. The TEKTRONIX 577-177 Curve Tracer is an appropriate choice for testing low power SCR devices—for high power units, the 576-176 Curve Tracer Pulsed High-Current Fixture is necessary.

On the curve tracer, two different families of SCR characteristics are usually produced. The gate values are most often measured by applying the step generator output to that terminal, applying the collector supply to the anode, and viewing the gate voltage and current. Anode-cathode characteristics are measured by keeping gate voltage or current at a constant or known series of values while viewing anode current versus applied anode voltage.

**NOTE:** These procedures have been designed to be sufficiently general for testing most individual device types in the SCR family. However, this section also provides actual settings, check values, and part numbers necessary for testing a specific SCR (2N4441). This information is given in brackets at appropriate points throughout the section.

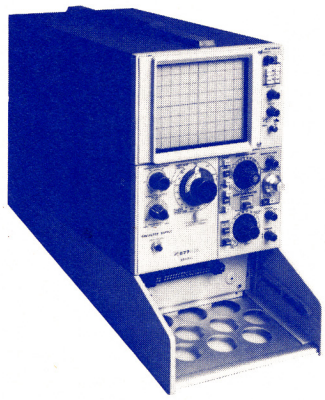
This section provides instructions for the specific tests listed below. These are preceded by general set-up instructions.

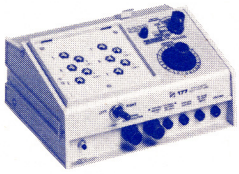
1) Peak Forward Blocking Voltage $V_{DRM}$
2) Peak Forward Blocking Current $I_{DRM}$
3) Peak Reverse Blocking Current $I_{RRM}$
4) Gate Trigger Current $I_{GT}$
5) Gate Trigger Voltage
6) Peak On-State Voltage $V_{TM}$
7) Holding Current $I_H$

## GENERAL SET-UP

**EQUIPMENT REQUIRED:**

577-177 D1 (storage) or D2 (non-storage) Curve Tracer, socket adapter [Large In-Line Adapter, Tektronix part number 013-0138-00], SCR to be tested [2N4441], and specifications for that SCR.






**SET-UP:**

1) Install 177 – If 177 Standard Test Fixture is not already installed in 577 Mainframe, do so first (with power off). See Figure 0-1.

2) Insert Socket Adapter – Place appropriate SCR Socket Adapter in position provided on 177 test fixture. See Figure 0-1.

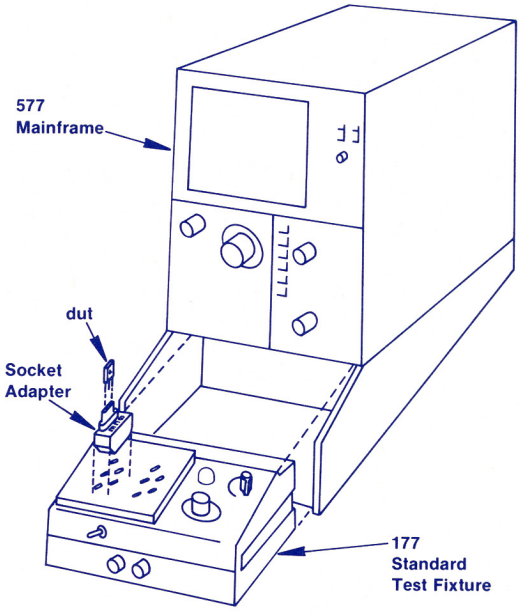
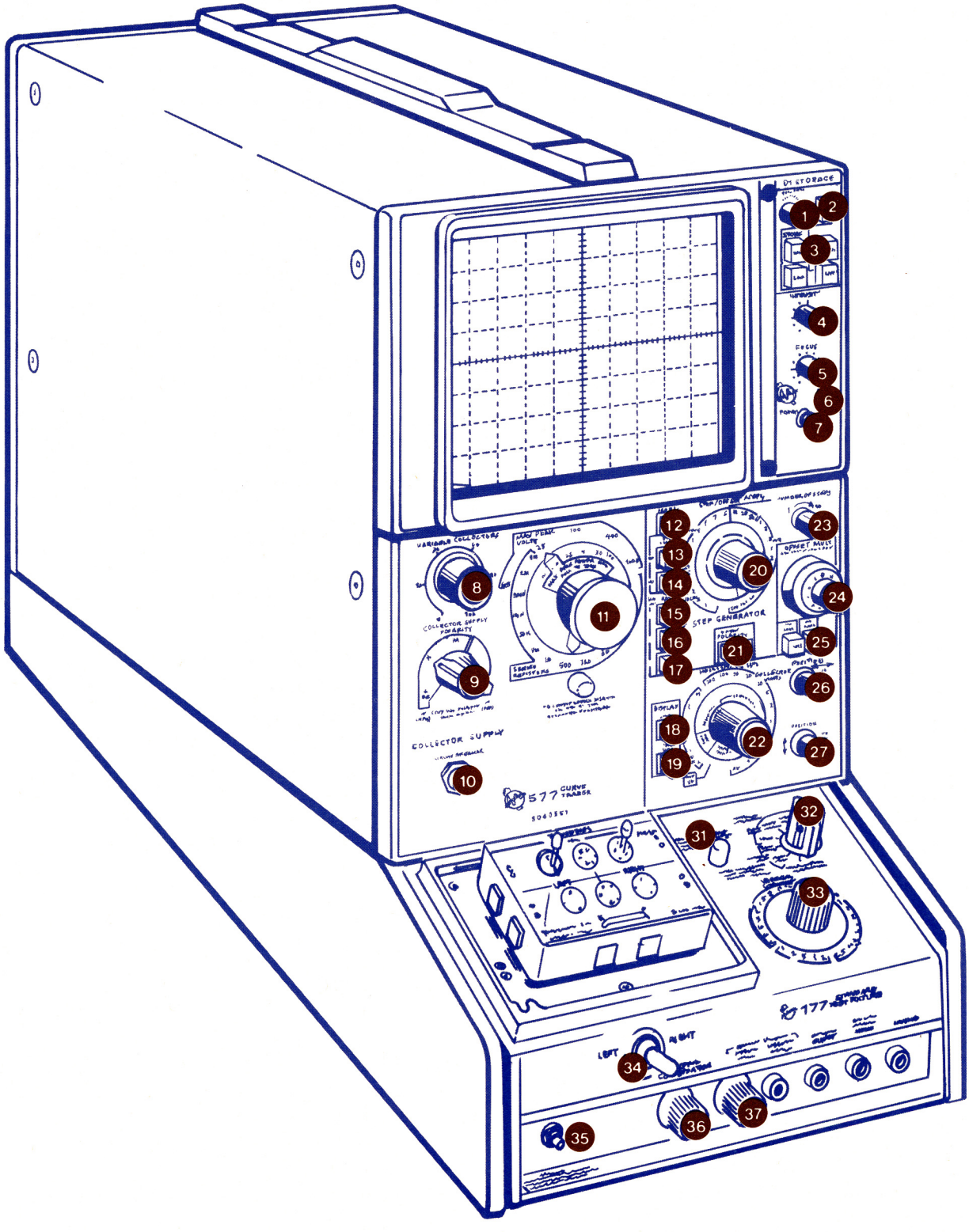



**Figure 0-1.** Installing standard test fixture.

## GENERAL SET-UP DIAGRAM



## GENERAL SET-UP continued

3) Set initial conditions— referring to SCR set-up diagram (foldout), set controls as follows:
NOTE: This preliminary procedure has been designed to be applicable to all of the following tests. In each case, the detailed test procedure contains minor modifications to the settings of this procedure. Thus, it is possible to perform only one, some, or all of the tests, in any sequence.

On 577:
- MAX PEAK VOLTS to 25 (11)
- MAX PEAK POWER-WATTS to .15 (11)
- DISPLAY FILTER in (19)
- DISPLAY INVERT in (normal) (18)
- HORIZ VOLTS/DIV to 5 V (22)
- X10 HORIZ MAG to off (26)
- X10 VERT MAG to off (27)
- BRIGHTNESS control to maximum (cw) (1)
- INTENSITY control to minimum (ccw) (4)
- HORIZ POSITION to center (26)
- VERT POSITION to center (27)
- COLLECTOR SUPPLY POLARITY to + (9)
- VARIABLE COLLECTOR % to minimum (ccw) (8)
- Press STEP FAMILY-SINGLE in and release (single family) (14)
- NORM 2X LINE in (16)
- PULSED 300 $\mu$S out (12)
- OFFSET ZERO in (25)
- OFFSET OPPOSE in (aiding) (25)
- STEP/OFFSET AMPL to 1 mA (20)
- OFFSET MULTIPLIER to 1
- STEP X.1 in (off) (20)
- STEP/OFFSET Polarity in (normal) (21)

On D1 (storage models):
- UPPER and LOWER STORE out (normal) (3)

On 177:
- FUNCTION to EMITTER GROUNDED, BASE TERM, STEP GEN (32)
- LEFT-RIGHT selector to center (off) (34)

## GENERAL SET-UP continued

4) Obtain trace — Using controls on 577:

a) Pull POWER ON switch. Wait for warm-up. 7

b) (D1 storage only) Clear Screen — Press UPPER and LOWER STORE buttons, and then UPPER and LOWER ERASE. Release STORE buttons. 3

c) Find spot — Press BEAM FINDER button in, and advance INTENSITY control until spot is clearly visible. 6 4

d) Center spot — Using VERTICAL and HORIZONTAL POSITION controls, center spot. Use BEAM FINDER to see present direction if spot is off-screen. 27 26 6

5) Insert device — Insert device to be tested in socket. See Figure 0-2.

Set-up procedure is now complete. Proceed to selected test.

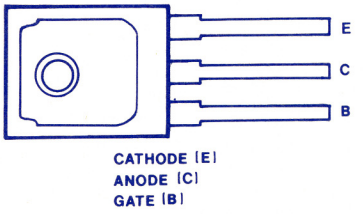




**Figure 0-2. Device installed in socket.**

## TEST 1: PEAK FORWARD BLOCKING VOLTAGE $V_{DRM}$

Peak forward blocking voltage is the upper limit to the forward voltage that can be safely applied to the SCR anode terminal and still not cause conduction with no gate signal applied. It is, therefore, a key measure of the SCR's off-state performance. However, since SCR's are not actual contactor switches, even in the off state, there is some leakage current because of thermal effects and impurities.

Consequently, the specifications include a maximum current value at which the forward blocking voltage is to be measured. Note that this parameter is a dc value, so that the measurement is valid only for gradually changing inputs.

On the curve tracer, the collector supply is used to supply the test voltage for this measurement. The gate terminal is left open.

### WHAT THE DISPLAY SHOWS

The horizontal axis of the display indicates applied voltage; the vertical shows resulting current into the anode.

Specifications are met when the horizontal displacement exceeds the rated value before the trace rises past the line corresponding to the specified current.

**PROCEDURE:**

1) Set controls— Beginning with general SCR set-up, change controls as follows:

On 577:

- MAXIMUM PEAK VOLTS to smallest value above that required for test. (Note that, above 25 V, interlock switch must be pressed to actuate each test.) [100 V] 11
- HORIZ VOLTS/DIV to smallest value at least 1/5 of maximum voltage to be tested [10 V] 22
- COLLECTOR SUPPLY POLARITY to + 9
- VARIABLE COLLECTOR % to minimum (ccw) 8

On 177:

- FUNCTION to EMITTER-GROUNDED, BASE TERM, OPEN (gate open) 32
- VERTICAL CURRENT/DIV to smallest value at least 1/4 of specified maximum current flow [.5 mA] 33

## TEST 1: PEAK FORWARD BLOCKING VOLTAGE $V_{DRM}$ continued

2) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. *Slowly* increase VARIABLE COLLECTOR % supply until either specified current (vertical) or voltage (horizontal) is attained. [4 divs vertical, or 5 horizontal]. 34 8

3) Compare to specifications — Check to see that specified voltage is reached before stated current is exceeded.

**Note 1:** This set-up is quite similar to that for $I_{DRM}$ and $I_{RRM}$. Perform all three sequentially for easiest procedure. See pages 8 and 10

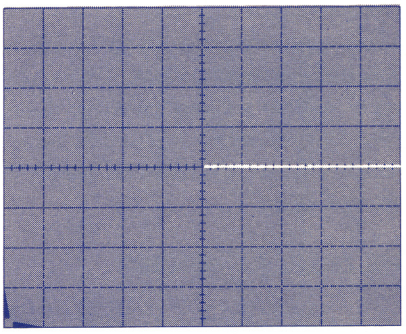


**Figure 1-1.** Display shows 50 V across device and no anode current. SCR is within specification. Figure 1-2 is example of SCR out of specification.

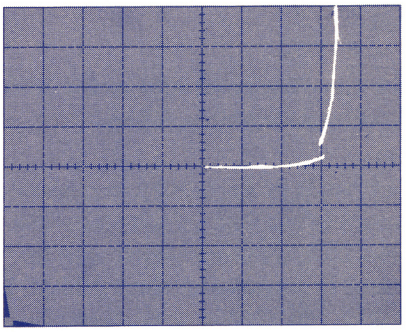


**Figure 1-2.** Display shows what SCR curve might look like if not within specifications. Trace shows that SCR has over 2 mA of current flowing with only 30 V across it.

## TEST 2: PEAK FORWARD BLOCKING CURRENT $I_{DRM}$

When no gate signal is applied and the SCR is in the blocking state, the amount of current that still flows through the anode is an important circuit design characteristic. Individual devices may vary from specified levels on this characteristic, so this test is a common one. Test set-up and procedure are similar to that of forward blocking voltage, except that the trace is read for a numerical value of current exactly at the specified blocking voltage.

Note that this parameter is also a dc value, so the measurement is valid only for gradually changing inputs.

On the curve tracer, the collector supply is again used to supply the test voltage for this measurement. The gate terminal is floated open.

### WHAT THE DISPLAY SHOWS

The horizontal axis of the display indicates applied voltage; the vertical shows resulting current into the anode.

Specifications are met when, at the horizontal displacement corresponding to the rated value of applied voltage, the trace is still below the line corresponding to the specified current.

### PROCEDURE:

1) Set controls— Beginning with general SCR set-up, change controls as follows:

On 577:

- MAXIMUM PEAK VOLTS to smallest value above that required for test (Note that, above 25 V, interlock switch must be pressed to actuate each test.) [100 V] 11
- HORIZ VOLTS/DIV to smallest value at least 1/5 of maximum voltage to be tested. [10 V] 22
- COLLECTOR SUPPLY POLARITY to + 9
- VARIABLE COLLECTOR % to minimum (ccw) 8

On 177:

- FUNCTION to EMITTER-GROUNDED, BASE TERM, OPEN (gate open) 32
- VERTICAL CURRENT/DIV to smallest value at least 1/4 of specified maximum current flow [.5 mA] 33

## TEST 2: PEAK FORWARD BLOCKING CURRENT $I_{DRM}$ continued

2) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. *Slowly* increase VARIABLE COLLECTOR % supply until specified voltage (horizontal) is attained. [5 divs horizontal]. 34 8

3) Compare to specifications — Check to see that, at specified voltage, stated current is not exceeded. [4 divs vertical, or 2.0 mA]. See Figure 2-1.

**Note 1:** This set-up is quite similar to that for $V_{DRM}$ and $I_{RRM}$. Perform all three sequentially for easiest procedure. See pages 6 and 10.

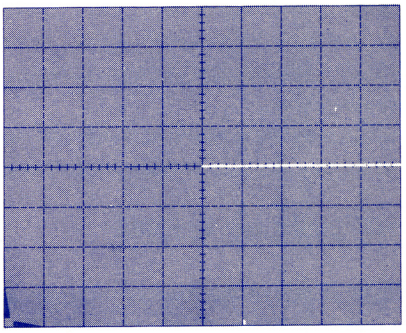


**Figure 2-1.** Display shows 50 V across device and no current through it. SCR is within specification. Figure 2-2 is example of SCR out of specifications.

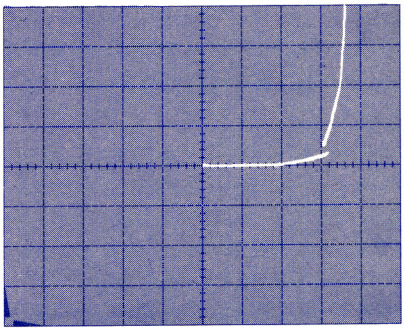


**Figure 2-2.** Display shows what SCR curve might look like if not within specifications. Trace shows that SCR has over 2 mA anode current flowing with only 30 V across it.

## TEST 3: PEAK REVERSE BLOCKING CURRENT $I_{RRM}$

Peak reverse blocking current is the current flowing through the SCR when connected to a reverse voltage equal in magnitude to the forward blocking voltage but opposite in direction. It is thus another measure of the off-state performance of the SCR. Like most SCR characteristics, this value may be rate-of-change sensitive, so all test signals should be dc or low frequency ac.

This measurement is made in a manner very similar to that of forward blocking current. The collector supply is again used to supply the test voltage for this measurement. The gate terminal is kept open.

### WHAT THE DISPLAY SHOWS

The horizontal axis of the display indicates applied voltage; the vertical shows resulting current flowing out of the anode.

Specifications are met when, at the horizontal displacement corresponding to the rated value of applied voltage, the trace is still below the line corresponding to the specified current.

### PROCEDURE:

1) Set controls— Beginning with general SCR set-up, change controls as follows:

On 577:

- MAXIMUM PEAK VOLTS to smallest value above that required for test (Note that, above 25 V, protective cover must be closed or interlock switch must be pressed to actuate each test ) [100 V] 11
- HORIZ VOLTS/DIV to smallest value at least 1/5 of maximum voltage to be tested. [10 V] 22
- COLLECTOR SUPPLY POLARITY to – 9
- DISPLAY INVERT out (inverted) 18
- VARIABLE COLLECTOR % to minimum (ccw) 8

On 177:

- FUNCTION to EMITTER-GROUNDED, BASE TERM, OPEN (gate open) 32
- VERTICAL CURRENT/DIV to smallest value at least 1/4 of specified maximum current flow [.5 mA] 33

## TEST 3: PEAK REVERSE BLOCKING CURRENT $I_{RRM}$ continued

2) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Close protective cover or press and hold INTERLOCK switch. *Slowly* increase VARIABLE COLLECTOR % supply until specified voltage (horizontal) is attained. [5 divs horizontal, representing 50 V]. See Figure 3-1 for display of device within specifications; see Figure 3-2 for device *not* within specifications. 34 35 8

3) Compare to specifications — Check to see that, at specified voltage, vertical displacement corresponding to stated reverse blocking current is not exceeded. [4 divs vertical, or 2 mA]. See Figures 3-1 and 3-2.

**Note 1:** This set-up is quite similar to that for $V_{DRM}$ and $I_{DRM}$. Perform all three sequentially for easiest procedure. See pages 6 and 8.

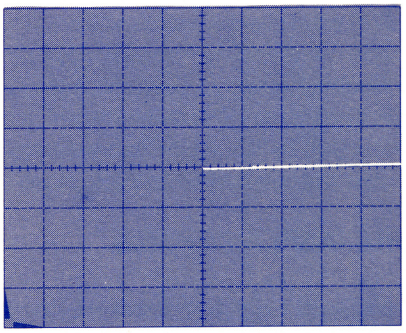


**Figure 3-1.** Display shows 50 V reverse blocking voltage and no anode current. Figure 3-2 shows SCR with over 2 mA of reverse leakage current.

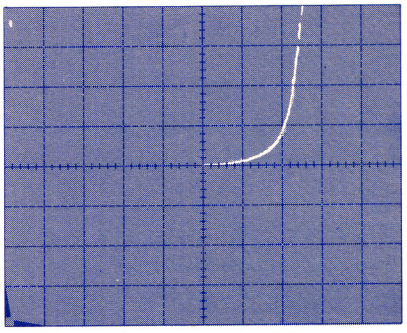


**Figure 3-2.** Display shows that SCR has over 2 mA of reverse leakage current flowing with approximately 25 V across it. Device does not meet specifications.

## TEST 4: GATE TRIGGER CURRENT $I_{GT}$

The SCR is a current-sensitive device, so one of the more important gate specifications is the amount of current required to turn on the SCR. This gate trigger current is normally specified at a low value of anode-to-cathode voltage; commonly for steady-state or slowly changing operating conditions.

On the curve tracer, this measurement is made by examining the anode current while slowly increasing the current supplied to the gate by the step/offset generator. When the SCR turns on, as evidenced by the jump in the anode current, the current into the gate is read and compared to specifications.

### WHAT THE DISPLAY SHOWS

The crt display is a conventional anode transfer characteristics plot, with applied voltage on the horizontal and resulting current on the vertical. The reading of the offset multiplier dial is just as important to the result, however.

Specifications are met when the curve shows the vertical jump in current corresponding to device turn on at or below the specified maximum gate current indicated on the offset controls.

### PROCEDURE:

1) Set controls— Beginning with general SCR set-up, change controls as follows:

On 577:

- MAXIMUM PEAK VOLTS to smallest value above that required for test. (Note that, above 25 V, interlock switch must be pressed to actuate each test.) [25 V] 11
- SERIES RESISTOR to value closest to that specified (only some values are available at higher voltages). [120 Ω] 11
- HORIZ VOLTS/DIV to smallest value at least 1/8 of maximum voltage to be applied. [1 V] 22
- COLLECTOR SUPPLY POLARITY to + 9
- VARIABLE COLLECTOR % to minimum (ccw) 8
- STEP/OFFSET to smallest value at least 1/10 of specified maximum gate current [5 mA] 20
- OFFSET MULT to 0 (ccw) 25
- OFFSET ZERO out (offset on) 25

On 177:

- FUNCTION to EMITTER-GROUNDED, BASE TERM, STEP GEN 32
- VERTICAL CURRENT/DIV to smallest value at least 1/6 of current that would flow resistively at specified anode voltage and load resistance if SCR were shorted. [10 mA] 33

## TEST 4: GATE TRIGGER CURRENT $I_{GT}$ continued

2) Position spot — Using VERT and HORIZ controls on 577, position spot to lower left corner of graticule. 27 26

3) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. *Slowly* increase VARIABLE COLLECTOR % supply until specified voltage (horizontal) is attained. [7 divs horizontal]. See Figure 4-1. 34 8

4) Apply gate current — Slowly increase OFFSET MULTIPLIER SETTING, while carefully watching display. When trace switches suddenly from mostly horizontal line to vertical curve, SCR has turned on. See Figure 4-2. Note value shown on OFFSET MULT dial at this point. 24

5) Calculate and compare to specifications — Gate current turn on is equal to STEP/OFFSET AMPL setting times OFFSET MULT setting. This should be less than or equal to specified maximum. [30 mA]. 20 24

**Note 1:** $V_{GT}$, gate trigger voltage, is measured in an almost identical procedure, but with the STEP/OFFSET AMPL set to a voltage value. See page 14.

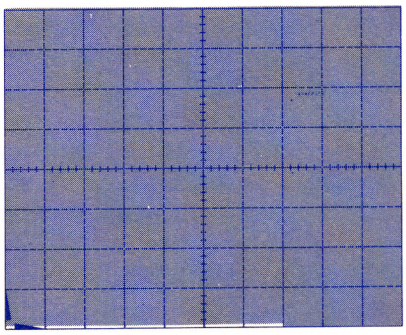


**Figure 4-1.** Display showing 7 V across SCR.

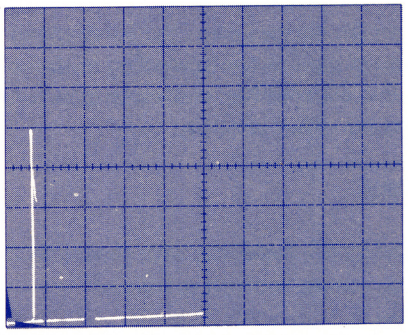


**Figure 4-2.** Display showing gate trigger current $I_{GT}$.

## TEST 5: GATE TRIGGER VOLTAGE $V_{GT}$

Many SCR trigger sources are voltage specified, so gate triggering characteristics are also commonly supplied in terms of voltage. The gate trigger voltage is the amount of applied gate-to-cathode voltage required to turn on the SCR. This characteristic is normally specified at a low value of anode to cathode voltage; commonly for steady-state or slowly changing operating conditions.

On the curve tracers, this measurement is made by examining the anode current while slowly increasing the voltage applied to the gate by the step/offset generator. When the SCR turns on, as evidenced by the jump in the anode current, the voltage applied to the gate is read and compared to specifications.

### WHAT THE DISPLAY SHOWS

The crt display is a conventional anode transfer characteristics plot, with applied voltage on the horizontal and resulting current on the vertical. The reading of the offset multiplier dial is just as important to the result, however.

Specifications are met when the curve shows the vertical jump in current corresponding to device turn on at or below the specified maximum gate voltage indicated on the offset controls.

### PROCEDURE:

1) Set controls— Beginning with general SCR set-up, change controls as follows:

On 577:

- MAXIMUM PEAK VOLTS to smallest value above that required for test. (Note that, above 25 V, interlock switch must be pressed to actuate each test.) [25 V] 11
- SERIES RESISTOR to value closest to that specified (only some values are available at higher voltages) [120 Ω] 11
- HORIZ VOLTS/DIV to smallest value at least 1/8 of maximum voltage to be applied [1 V] 22
- COLLECTOR SUPPLY POLARITY to + 9
- VARIABLE COLLECTOR % to minimum (ccw) 8
- STEP/OFFSET AMPL to smallest value at least 1/10 of specified maximum gate voltage. [.2 V] 20
- NUMBER OF STEPS to zero (ccw) 2
- OFFSET MULT to 0 (ccw) 24
- OFFSET ZERO out (offset on)

On 177:

- FUNCTION to EMITTER GROUNDED, BASE TERM, STEP GEN 32
- VERTICAL CURRENT/DIV to smallest value at least 1/6 of current that would flow at specified anode voltage and load resistance if SCR were shorted [10 mA] 33

## TEST 5: GATE TRIGGER VOLTAGE $V_{GT}$ continued

2) Position spot — Using VERT and HORIZ position controls on 577, position spot to lower left corner of graticule. 27 26

3) Apply power device — Position LEFT-RIGHT switch on 177 to appropriate side. *Slowly* increase VARIABLE COLLECTOR % supply until specified voltage (horizontal) is attained. [7 divs horizontal]. 34

4) Apply gate voltage — Slowly increase OFFSET MULTIPLIER SETTING while carefully watching display. When trace switches suddenly from mostly horizontal line to vertical curve, SCR has turned on. See Figure 5-1. Note value shown on OFFSET MULT dial at this point. 24

5) Calculate and compare to specifications — Gate voltage turn-on is equal to STEP/OFFSET AMPL setting times OFFSET MULT setting. This should be less than or equal to specified maximum. [1.5 V]. 20 24

**Note 1:** $I_{GT}$, gate trigger current, is measured in almost identical procedure, but with STEP/OFFSET AMPL set to current value. See page 13.

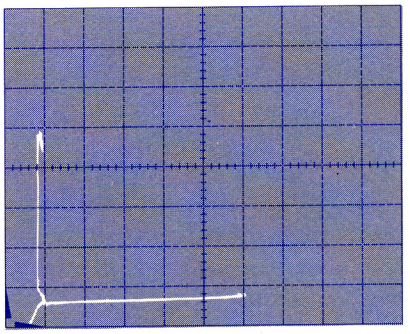


**Figure 5-1.** Display of gate trigger voltage $V_{GT}$ test.

## TEST 6: PEAK ON-STATE VOLTAGE $V_{TM}$

When an SCR turns on, the resistance of the device still causes an appreciable voltage drop. The maximum value for this voltage, under specified conditions, is the peak on-state voltage. The step generator is used to turn the SCR on. Specified current is applied to the SCR, and the voltage drop is measured.

### WHAT THE DISPLAY SHOWS

The horizontal axis of the display indicates anode-cathode voltage; the vertical shows the anode current.

Specifications are met when the specified current can be forced through the SCR without causing a voltage drop above the specified maximum.

### PROCEDURE:

1) Set controls— Beginning with general SCR set-up, change controls as follows:

On 577:

- MAXIMUM PEAK VOLTS to curve tracer's smallest value, 6.5 V, for maximum current. (11)
- SERIES RESISTOR to closest value less than that required to limit current to specified test value, R series = 6.5 V ÷ specified current [6.5 V ÷ 5 A, so set to 0.5 Ω], or smallest available. (11)
- HORIZ VOLTS/DIV to smallest value at least 1/8 of specified maximum voltage. [.2 V] (22)
- COLLECTOR SUPPLY POLARITY to +DC (9)
- VARIABLE COLLECTOR % to minimum (ccw) (8)
- STEP/OFFSET AMPL to smallest value less than or equal to the maximum gate trigger current ($I_{GT}$). [20 mA] (20)
- NUMBER OF STEPS to zero (ccw) (23)
- OFFSET MULT to 1 (24)
- OFFSET ZERO out (offset on) (25)

On 177:

- FUNCTION to EMITTER-GROUNDED, BASE TERM, STEP GEN (32)
- VERTICAL CURRENT/DIV to smallest value at least 1/8 of specified current. [1 A] (33)

## TEST 6: PEAK ON STATE VOLTAGE $V_{TM}$ continued

2) Position spot — Using VERT and HORIZ position controls on 577, position spot to lower left corner of graticule. 27 26

3) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. *Slowly* increase VARIABLE COLLECTOR % supply until specified current is attained. [5 divs vertical]. See Figure 6-1. 34 8

4) Compare voltage to specifications — Check to see that horizontal excursion of line at point of intersection with vertical displacement indicating rating current is less than or equal to specified maximum. [7.5 divs, or 1.5 V].

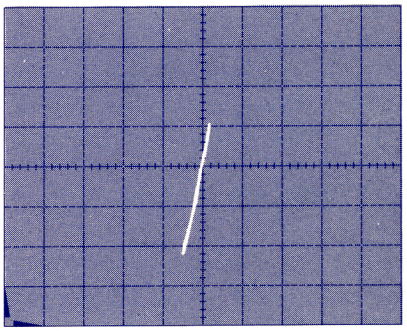


**Figure 6-1.** Peak on-state voltage $V_{TM}$. Upper end of elongated spot has just crossed 5A point.

## TEST 7: HOLDING CURRENT $I_H$

The holding current is the minimum current necessary to keep the SCR in the on-state once the gate signal has been removed. It is normally specified at a low value of anode-cathode voltage.

On the curve tracer, the holding current measurement is done by applying a gate signal until the device switches on and anode current flows. The gate signal is then removed. At this time, anode-current is reduced to the point at which anode current just stops flowing, and that value is noted.

### WHAT THE DISPLAY SHOWS

The horizontal axis of the display indicates applied anode-cathode voltage; the vertical shows resulting current flowing into the anode.

Specifications are met when anode-cathode voltage is reduced and anode current still flows at the specified maximum rated value or less.

### PROCEDURE:

1) Set controls— Beginning with general SCR set-up, change controls as follows:

On 577:

- MAXIMUM PEAK POWER-WATTS to 2.3 (11)
- HORIZ VOLTS/DIV to smallest value at least 1/8 of maximum voltage to be applied. [1 V] (22)
- COLLECTOR SUPPLY POLARITY to +DC (9)
- VARIABLE COLLECTOR % to minimum (ccw) (8)
- STEP/OFFSET AMPL to smallest value at least 1/2 of specified maximum gate trigger voltage. [1 V] (20)
- NUMBER OF STEPS to 0 (ccw) (23)
- OFFSET MULT to 0 (ccw) (25)
- OFFSET ZERO out (25)

On 177:

- FUNCTION to EMITTER-GROUNDED, BASE TERM, STEP GEN. (32)
- VERTICAL CURRENT/DIV to 10 mA (33)

## TEST 7: HOLDING CURRENT $I_H$ continued

2) Position spot — Using VERT and HORIZ POSITION controls, move spot to lower left corner of graticule. 27 26

3) Use STORAGE mode — Press and leave in UPPER and LOWER STORE and UPPER and LOWER ERASE buttons. Then, press ERASE button. 3 2

4) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. *Slowly* increase VARIABLE COLLECTOR % supply until specified voltage is attained. [7 divs horizontally]. 34 8

5) Apply gate voltage — Slowly increase OFFSET MULTIPLIER setting until anode current flows. See Figure 7-1. Press OFFSET ZERO in. Slowly decrease VARIABLE COLLECTOR % control until vertical trace switches down to bottom graticule line. Measured holding current is last point before upper section of trace disappears. See Figure 7-1. 24 25

6) Compare to specifications — Check that vertical displacement of measured holding current corresponds to value no more than maximum specified value. [4 divs, or 40 mA]

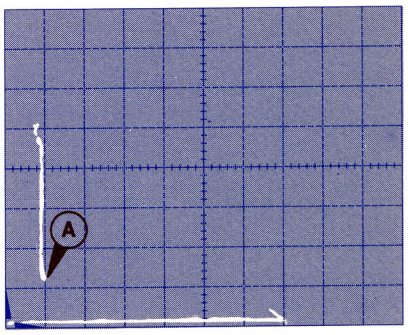



**Figure 7-1.** Display of SCR holding current $I_H$. Point (A) is the measured holding current.

## INTRODUCTION

Even though the unijunction transistor (UJT) is the simplest three-terminal junction device in terms of construction, its operation is sometimes harder to understand than that of more complex units. Physically, a UJT is simply a bar of n-doped silicon with a base terminal at each end, plus a junction near the middle connecting the channel to a p-doped emitter. In operation, though, the UJT provides a combination of amplification, negative resistance, and feedback at different points in its working region.

The graphic display provided by the curve tracer is particularly helpful, since several of the UJT's operating characteristics are composed of both regions of smooth variation and parts with sharp reversals. It would be difficult at best to establish many of these parameters through a series of single-point measurements.

Important UJT measurements that may be made directly on a TEKTRONIX 577-D1 (storage) or 577-D2 (non-storage) Curve Tracer include peak point voltage and current, saturation voltage, gate leakage, and terminal-to-terminal resistance. Intrinsic stand-off value may be easily calculated from measured values. Both current and voltage measurements may be made, down to quantities as small as 0.2 nA per division.

Most UJT measurements on the curve tracer are obtained by using the step generator to supply known current or voltages to base 2, applying the collector supply to the emitter, and grounding base 1. In this configuration, the horizontal axis of the display would normally represent emitter-base 1 voltage, and the vertical axis the corresponding current into the emitter terminal.

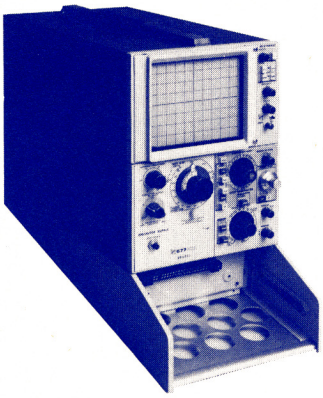
**NOTE:** These procedures have been designed to be sufficiently general for testing most individual device types in the UJT family. However, this section also provides actual settings, check values, and part numbers necessary for testing a specific UJT (2N4851). This information is given in brackets at appropriate points throughout the section.

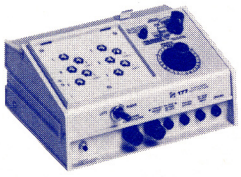
This section provides instructions for the specific tests listed below. These are preceded by general set-up instructions.

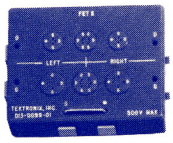
1) Emitter Saturation Voltage $V_{EB1}(SAT)$
2) Intrinsic Stand-Off Ratio n and Peak Voltage $V_P$
3) Emitter Reverse Current $I_{EBZO}$
4) Peak-Point Emitter Current $I_P$
5) Valley-Point Emitter Current $I_V$
6) Interbase Resistance $R_{BB}$

## GENERAL SET-UP

**EQUIPMENT REQUIRED:**
577-177 D1 (storage) or D2 (non-storage) Curve Tracer, socket adapter [FETS Adapter, Tektronix part number 013-0099-01], UJT to be tested [2N4851], and specifications for that UJT. For some measurements on some device types, an external power supply and connecting cables will also be required.



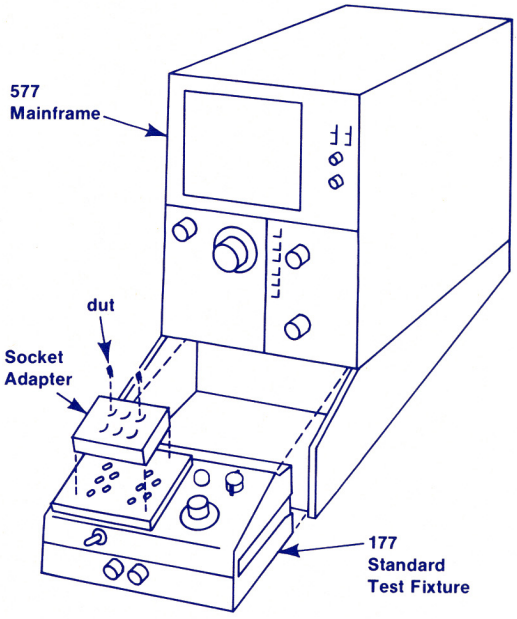




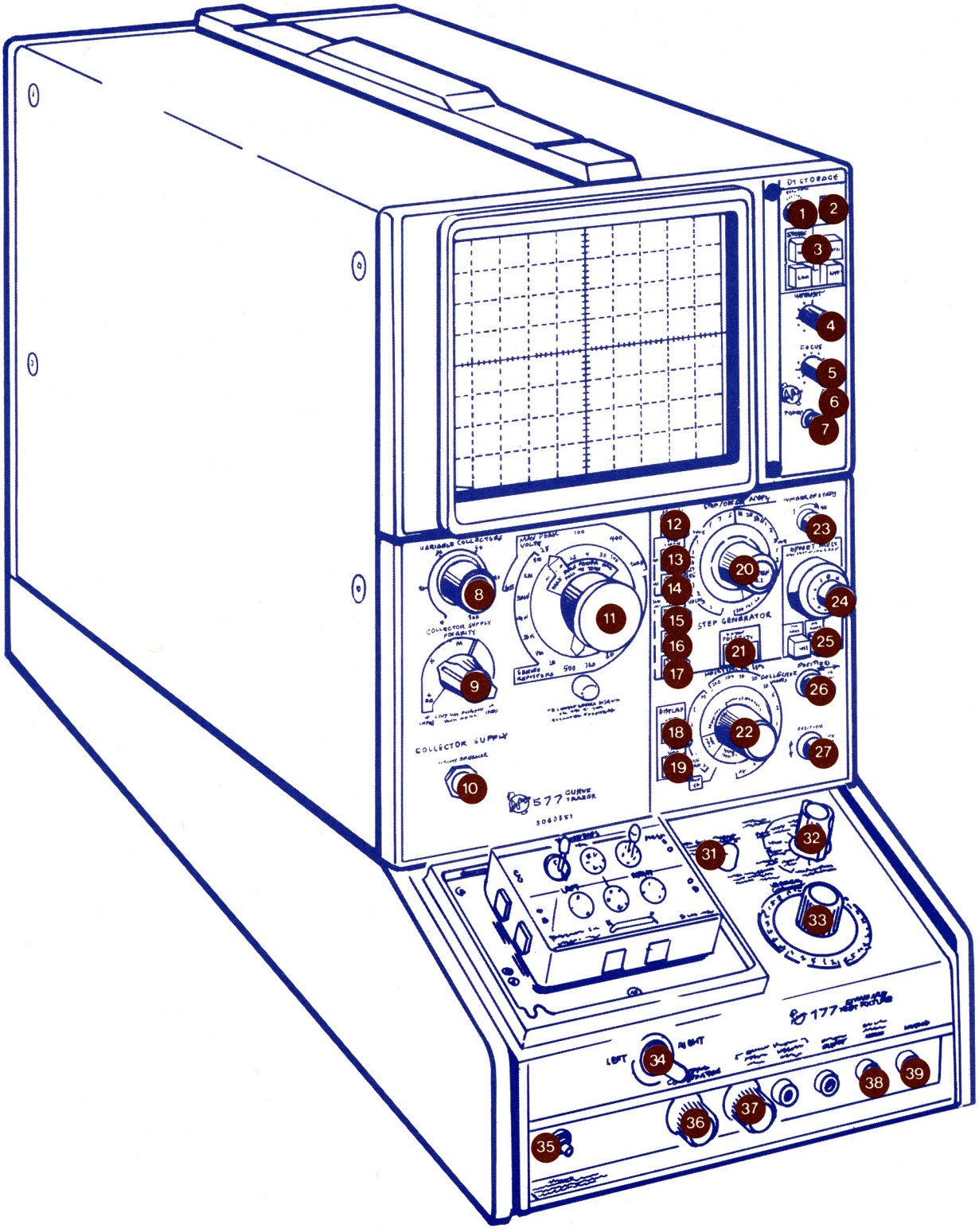
**SET-UP:**

1) Install 177 — If 177 fixture is not already installed in 577, do so first (with power off). See Figure 0-1.

2) Insert Socket Adapter — Place appropriate UJT Socket Adapter in position provided on 177 test fixture (see foldout).



## GENERAL SET-UP DIAGRAM



## GENERAL SET-UP continued

3) Set initial conditions— referring to UJT set-up diagram (foldout), set controls as follows:
NOTE: This preliminary procedure has been designed to be applicable to all of the following tests. In each case, the detailed test procedure contains minor modifications to the settings of this procedure. Thus, it is possible to perform only one, some, or all of the tests, in any sequence.

On 577:

- MAX PEAK VOLTS to 25 (11)
- MAX PEAK POWER-WATTS to .15 (11)
- DISPLAY FILTER in (19)
- DISPLAY INVERT in (normal) (18)
- HORIZ VOLTS/DIV to 5 V (22)
- X10 HORIZ MAG to off (in) (26)
- X10 VERT MAG to off (in) (27)
- BRIGHTNESS to maximum (cw) (1)
- INTENSITY to minimum (ccw) (4)
- HORIZ POSITION to center (26)
- VERT POSITION to center (27)
- COLLECTOR SUPPLY POLARITY to + DC (9)
- VARIABLE COLLECTOR % to minimum (ccw) (8)
- Press STEP FAMILY-SINGLE in and release (single-family) (14)
- NUMBER OF STEPS to minimum (ccw) (13)
- PULSED 300 $\mu$S in (12)
- OFFSET ZERO out (on) (25)
- OFFSET OPPOSE in (aiding) (25)
- STEP/OFFSET AMPL to 2 volts (20)
- OFFSET MULTIPLIER TO 5 (24)
- STEP X.1 in (off) (20)
- STEP/OFFSET Polarity in (normal) (21)

On D1 (storage models):

- UPPER and LOWER STORE out (non-store) (3)
- UPPER and LOWER ERASE in (ready to erase) (3)

On 177:

- FUNCTION to EMITTER GROUNDED, BASE TERM, STEP GEN (32)
- LEFT-RIGHT selector to center (off) (34)

## GENERAL SET-UP continued

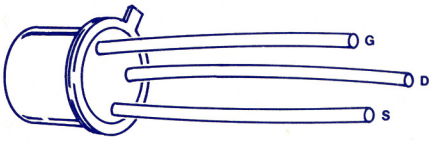
4) Obtain trace — Using controls on 577:

a) Pull POWER ON switch. Wait for warm-up. 7

b) Find spot — Press BEAM FINDER button in, and advance INTENSITY control until spot is clearly visible. 6 4

c) Position spot — Using VERTICAL and HORIZONTAL POSITION controls, position spot to bottom left corner of graticule. 27 26

5) Insert device — Insert device to be tested in socket. See Figure 0-2. Put UJT emitter in Drain position, base 2 lead in Gate position, base 1 lead in source position. Proceed to selected test.




BASE 2 (G)
EMITTER (D)
BASE 1 (S)

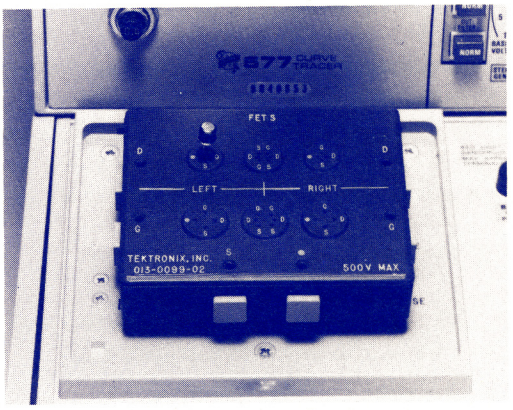



**Figure 0-2.** Device inserted in socket.

## TEST 1: EMITTER SATURATION VOLTAGE $V_{EB1}$ (SAT)

After sufficient voltage is supplied to the emitter to turn on the UJT junction, large further increases in emitter current occur with little change in input voltage. The value of the emitter-base 1 voltage where this occurs, given a specified interbase voltage, is the emitter saturation voltage. It is usually specified as a single value at a given level of emitter current. Often, a typical value will be given instead of absolute maximum and minimum.

On the curve tracer, this measurement is made by supplying the stated interbase voltage with the step generator/offset supply, and using the collector supply for the emitter.

### WHAT THE DISPLAY SHOWS

The display shows emitter current on the vertical axis and emitter voltage on the horizontal axis.

Specifications are met when, at the height corresponding to the stated current, the horizontal displacement corresponds to a voltage within the stated range.

### PROCEDURE:

1) Set controls— Beginning with general UJT set-up, change controls as follows:

On 577:

- MAX PEAK POWER-WATTS to smallest value at least equal to device specifications or package type [2.3] 11
- HORIZ VOLTS/DIV to smallest value at least 1/8 of maximum emitter voltage to be tested [0.5 V] 22
- VARIABLE COLLECTOR % to minimum (ccw) 8

On 177:

- VERT UNITS/DIV to smallest value more than 1/6 of specified current. [10 mA] 33
- OFFSET MULT to necessary value required to obtain exact specified interbase voltage ($V_{B2B1}$). $\left(\text{MULT} = \frac{V_{B2B1}}{2\text{ V}}\right)$ [5.0] 24

## TEST 1: EMITTER SATURATION VOLTAGE $V_{EB1}$(SAT) cont.

2) Use storage — For clearer, lasting display, press UPPER and LOWER STORE buttons. (If necessary, also press ERASE to clear screen.) 3 2

3) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Increase VARIABLE COLLECTOR % supply past point at which trace switches from almost horizontal (off screen) to more vertical (on screen). Continue until specified emitter current is reached on vertical. [5 divs, or 50 mA]. See Figure 1-1. 34 8

4) Compare to specifications — Check to see if horizontal displacement indicates voltage within specifications. [close to 5 divs, or 2.5 V].

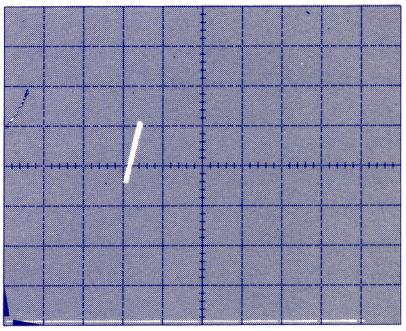


**Figure 1-1.** Display of emitter saturation voltage $V_{EB1}$ (SAT) with instrument in storage mode.

## TEST 2: INTRINSIC STANDOFF RATIO n, AND PEAK-POINT VOLTAGE $V_P$

Peak voltage, for a unijunction transistor, is the voltage necessary to forward bias the emitter-base 1 junction at a given value of interbase voltage. It is composed of the diode voltage of the junction itself, typically 0.2 to 0.7 volt, plus the voltage existing in the channel at the junction.

This potential at the junction point in the channel is caused by the voltage divider effect of the resistance of the channel material itself on the interbase supply voltage. The proportionality constant that indicates how much of the interbase voltage appears at the emitter junction is called the intrinsic standoff ratio, n, and is a property of the device. Since the middle of the channel is not accessible, standoff ratio is calculated from peak voltage measurements.

The peak point is the dividing point between the cutoff region and the negative resistance region of the UJT's emitter characteristics. As such, its defining values are among the important elements of design for UJT circuits.

On the curve tracer, the peak voltage measurement is made by supplying the stated interbase voltage with the step generator/offset supply, and using the collector supply for the emitter.

### WHAT THE DISPLAY SHOWS

The display shows emitter current on the vertical axis and emitter voltage on the horizontal axis. The resulting trace shows a quite definite voltage peak, which is then measured.

Specifications are met when the peak horizontal displacement corresponds to a voltage within the stated range.

**PROCEDURE:**

1) Set controls— Beginning with general UJT set-up, change controls as follows:

On 577:

- MAX PEAK POWER-WATTS to 0.6 (11)
- HORIZ VOLTS/DIV to smallest value at least 1/8 of maximum peak voltage to be tested (If specification is given in terms of intrinsic standoff ratio, then assume peak voltage to be interbase voltage times standoff ratio plus 0.5 volt.) $V_p = V_{B2B1} \times n + 0.5$ [1.0 V] (22)
- VARIABLE COLLECTOR % to minimum (ccw) (8)

On 177:

- VERT UNITS/DIV to 2 mA (33)
- OFFSET MULT to value necessary to obtain exact specified interbase voltage.

$\left(\text{MULT} = \frac{V_{B2B1}}{2\ V}\right)$ [5.0] (24)

## TEST 2: INTRINSIC STANDOFF RATIO n, AND PEAK-POINT VOLTAGE $V_P$ continued

2) Use storage — For clearer, lasting display, press UPPER and LOWER STORE buttons. (If necessary, also press ERASE to clear screen.) 3 2

3) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Increase VARIABLE COLLECTOR % supply until trace jumps from mostly horizontal to more vertical. See Figure 2-1. 34 8 33

4) Last point on mostly horizontal segment is peak-point. 8 2

5) Compare to specifications — Check to see if peak horizontal displacement indicates peak-point voltage within specification (given in terms of intrinsic standoff ratio). To calculate intrinsic standoff ratio, subtract 0.5 V from measured $V_p$ and divide by interbase voltage. [6.1 divs to 8.0 divs, for measured $V_p$ of 6.1 V to 8.0 V, corresponding to intrinsic standoff ratio of 0.56 to 0.75].

6) Measure exact diode voltage drop (optional) — If extremely precise standoff measurements are required, junction diode voltage drop may be easily measured. Turn VARIABLE COLLECTOR % to minimum, VERT UNITS/DIV to smallest value at least 1/6 of specified $I_F$ [2 $\mu$A], HORIZ VOLTS/DIV to 0.1 V, and FUNCTION switch to EMITTER GROUNDED, BASE TERM, OPEN. Press ERASE. Advance VARIABLE COLLECTOR % until vertical displacement equals specified $I_F$. Read corresponding diode voltage from horizontal scale factor. Recalculate applicable quantities using this number instead of 0.5 V for diode drop. See Figure 2-2. 8 22 32 2 33

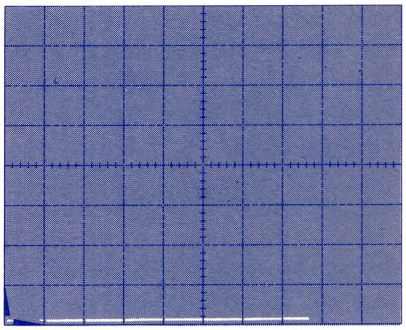


**Figure 2-1.** Display of peak-point voltage.

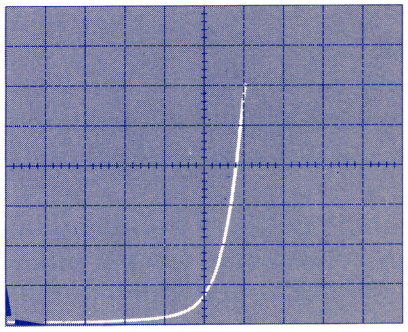


**Figure 2-2.** Display of $V_F$ (junction diode voltage) in expanded mode.

## TEST 3: EMITTER REVERSE CURRENT $I_{EB20}$

When the UJT's junction is reverse biased, a small reverse current continues to flow through the emitter to the channel due to imperfections and thermal effects. This current, measured at a specified voltage, is the emitter reverse current, $I_{EB20}$ (equivalently, it can be specified and measured as $I_{EB10}$).

On the curve tracer, this characteristic is measured by applying reverse collector voltage to the emitter while holding one base terminal open. The resulting curve shows emitter reverse current versus voltage.

### WHAT THE DISPLAY SHOWS

The display shows emitter reverse current on the vertical axis and emitter reverse voltage on the horizontal axis.

Specifications are met when the vertical displacement corresponding to maximum reverse current is not exceeded before the horizontal displacement corresponding to specified interbase voltage is reached.

### PROCEDURE:

1) Set controls— Beginning with general UJT set-up, change controls as follows:

On 577:

- HORIZ VOLTS/DIV to smallest value at least 1/8 of specified interbase voltage. [5 V]
- VARIABLE COLLECTOR % to minimum (ccw) 22
- MAX PEAK VOLTS to smallest value above voltage required for test. (Note that, above 25 V, protective cover must be closed or INTERLOCK button held for device-operating part of each test.) [100 V] 11 35
- DISPLAY INVERT NORM out (inverted) 18
- COLLECTOR SUPPLY POLARITY to –DC 9

On 177:

- FUNCTION to BASE GROUNDED, EMITTER TERM, OPEN. 32
- VERT UNITS/DIV to smallest possible value at least 1/6 of maximum specified reverse current. (If necessary, use X10 VERT MAG.) [200 nA] 33

## TEST 3: EMITTER REVERSE CURRENT $I_{EB20}$ continued

2) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Increase VARIABLE COLLECTOR % supply until horizontal displacement corresponds to specified voltage. [6.0 divs, or 30 V]. See Figures 3-1 and 3-2. 34 8

3) Increase sensitivity — If necessary, increase sensitivity of VERT UNITS/DIV, or pull X10 VERT MAG. At each setting, realign trace to bottom graticule line first by putting LEFT-RIGHT switch temporarily in center position, and adjusting VERT POSITION control. Press and release DISPLAY FILTER for clearer display. 33 27 34 19

4) Compare current to specifications — Check to see that vertical displacement corresponds to current within specified maximum. [5 divs, or 0.1 μA at original sensitivity].

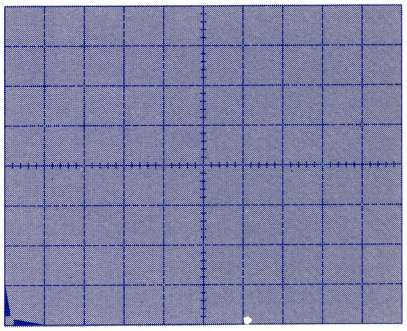


**Figure 3-1.** Display of emitter reverse current $I_{EB2O}$.

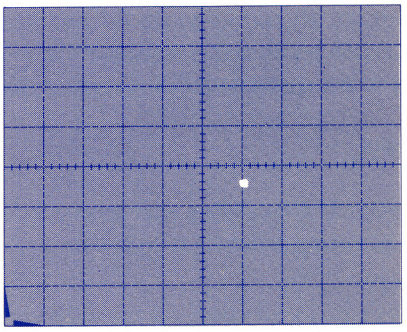


**Figure 3-2.** Display of actual amount of emitter reverse current at 500 pA/div. DISPLAY FILTER was used.

## TEST 4: PEAK-POINT EMITTER CURRENT $I_p$

At the UJT emitter peak-point, the junction is just about to turn on. A small but appreciably greater current than the reverse leakage begins to flow. This is the peak point current.

To make this measurement, an external moderate-voltage power supply must be used in conjunction with the curve tracer when the specified interbase voltage is above the range of the curve tracer's step generator supply.

The set-up uses the curve tracer collector supply as before to provide emitter voltage. The step generator, or, when required, the power supply, now provides the interbase voltage.

### WHAT THE DISPLAY SHOWS

The display shows emitter current on the vertical axis and emitter voltage on the horizontal axis. The resulting trace shows the UJT characteristic curve, with a definite peak horizontal excursion. The corresponding vertical displacement at this peak point is the peak-point emitter current.

Specifications are met when the vertical displacement at the peak point does not exceed the level corresponding to the stated peak-point current value.

### PROCEDURE:

1) Set controls— Beginning with general UJT set-up, change controls as follows:

On 577:

- MAX PEAK POWER-WATTS to 0.15 (11)
- MAX PEAK VOLTS to smallest value equal to or greater than interbase voltage. [25 V] (11)
- HORIZ VOLTS/DIV to smallest value at least 1/8 of peak voltage, $V_p$. (If not known, use specified value or interbase voltage times maximum specified intrinsic standoff ratio plus 0.5 V as $V_p$.)

  $V_p = V_{B2B1} \times n + 0.5$

  [25 V x 0.75 + 0.5 = 19 V] [5 V] (22)
- COLLECTOR SUPPLY POLARITY to +DC (9)
- VARIABLE COLLECTOR % to minimum (ccw) (8)
- DISPLAY INVERT in (normal) (18)

On 177:

- VERT UNITS/DIV to smallest possible value at least 1/6 of maximum specified peak-point current. (If necessary, use X10 VERT MAG.) [0.5 μA, no MAG] (33) (27)

## TEST 4: PEAK-POINT EMITTER CURRENT $I_p$ continued

2) Apply interbase voltage — If required interbase voltage is not above 20 V (if it is, see step 3), set FUNCTION switch to EMITTER GROUNDED, BASE TERM, STEP GEN. Set STEP/OFFSET AMPL to smallest value at least 1/10 of required voltage. Set OFFSET MULT dial to required multiplier to obtain specified voltage. 32 20 24

3) Connect external power supply if required (interbase voltage greater than 20 V) — Set FUNCTION switch to EMITTER GROUNDED, BASE TERM, OPEN. With supply off, connect external power supply to EXT BASE and GROUND terminals on front of 177. Set voltage to specified interbase voltage. [25 V]. 32 38 39

4) Use storage — For clearer, more lasting display, press UPPER and LOWER STORE buttons. (If necessary, also press ERASE to clear screen.) 3 2

5) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Slowly increase VARIABLE COLLECTOR % supply until trace shows excursion to right and then deflects upward before jumping off screen. 34 8 33

6) Find peak-point current — Find point where displacement is vertical, and then jumps. Last point before jump is peak-point current measurement point. See Figure 4-1.

7) Compare current to specifications — Check to see that vertical displacement at peak-point corresponds to current within specified maximum. [4 divs, or 2.0 μA].

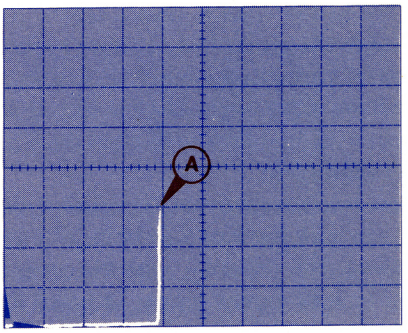



**Figure 4-1.** Display of peak-point emitter current $I_p$. Point (A) is the peak-point.

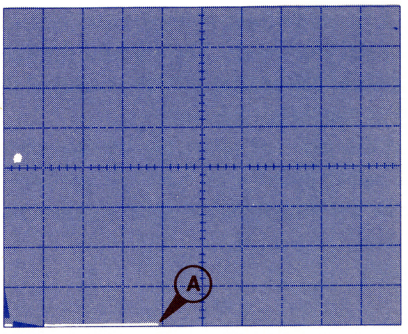



**Figure 4-2.** Compressed overview of current through junction just before switching. Point (A) is the same point expanded in Figure 4-1.

## TEST 5: VALLEY-POINT EMITTER CURRENT $I_v$

After the emitter voltage passes emitter peak-point, the junction turns on. An appreciably greater current than the peak-point current begins to flow. A negative resistance phenomenon comes into play, and the required emitter voltage for increasing current actually decreases for a while before increasing again. This minimum emitter voltage following the peak-point is called the valley point, and the current at this point is the valley-point current, $I_v$.

Since it is this current that is often used to force a certain circuit state, its amplitude must meet minimum and/or maximum specifications.

To make this measurement, an external moderate-voltage power supply must be used in conjunction with the curve tracer when the specified interbase voltage is above the range of the curve tracer's step generator supply.

The set-up, consequently, uses the curve tracer collector supply as before, to provide emitter voltage. The step generator, or external power supply, provides the interbase voltage. An external resistor also is frequently required.

### WHAT THE DISPLAY SHOWS

The display shows emitter current on the vertical axis and emitter voltage on the horizontal axis. The resulting trace shows the UJT characteristic curve, with a quite definite voltage peak followed by a visible local minimum. The vertical displacement at this local horizontal minimum called the valley point is the valley current.

Specifications are met when the vertical displacement at the valley point is at least the amount corresponding to the stated valley-point current value.

### PROCEDURE:

1) Set controls— Beginning with general UJT set-up, change controls as follows:

On 577:

- HORIZ VOLTS/DIV to smallest value at least 1/8 of valley-point voltage, $V_v$, if known. (If not known, use 0.15 times $V_p$. If that value is not known, calculate it as interbase voltage times maximum specified intrinsic standoff ratio plus 0.5 V.)

  $V_p = V_{B2B1} \times n + 0.5$

  $V_v \lesssim 0.15 \times V_p$

  [$V_p$ = 20 V x 0.75 + 0.5 = 15.5 V

  $V_v \leq 0.15 \times 15.5 = 2.3$ V] [0.5 V] (22)

- VARIABLE COLLECTOR % to minimum (ccw) (8)

On 177:

- FUNCTION to EMITTER GROUNDED, BASE TERM, STEP GEN (32)
- VERT UNITS/DIV to smallest possible value not less than minimum specified valley-point current. [2 mA]. (33)

## TEST 5: VALLEY-POINT EMITTER CURRENT $I_V$ continued

2) Connect external resistance — Remove base 2 lead from gate position of socket adapter, and place it in yellow dot socket position. Insert specified resistor [100 Ω] between yellow dot and gate external connection points on edge of socket adapter. Note that, to open hole for resistor lead insertion, press square button (on side of adapter) nearest hole. See Figure 5-1.

3) Apply interbase voltage — If required interbase voltage is not above 20 V (if it is, see step 4), set FUNCTION switch to EMITTER GROUNDED, BASE TERM, STEP GEN. Set STEP/OFFSET AMPL to smallest value at least 1/10 of required voltage [2V]. Set OFFSET MULT dial to required multiplier to obtain specified voltage [10.0] 32 20 24

4) Connect external power supply if required (interbase voltage greater than 20 V) — Set FUNCTION switch to EMITTER GROUNDED, BASE TERM, OPEN. With supply off, connect external power supply to EXT BASE and GROUND terminals on front of 177. Set voltage to specified interbase voltage. [25 V] 32 38 39

5) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Increase VARIABLE COLLECTOR % supply until trace shows excursion to right (off screen) and then jumps back to left. If necessary, readjust VERT UNITS/DIV to obtain more detail or greater coverage. See Figure 5-2. 34 8 33

6) Find valley-point current — Find point where trace jumps from almost horizontal to more vertical. Point just after jump is valley point.

7) Compare current to specifications — Check to see that vertical displacement at valley-point corresponds to current within specified minimum. [4 divs, or 2.0 mA].

8) Replace base-2 lead — Put base-2 lead back in gate position of adapter, and remove the resistor.

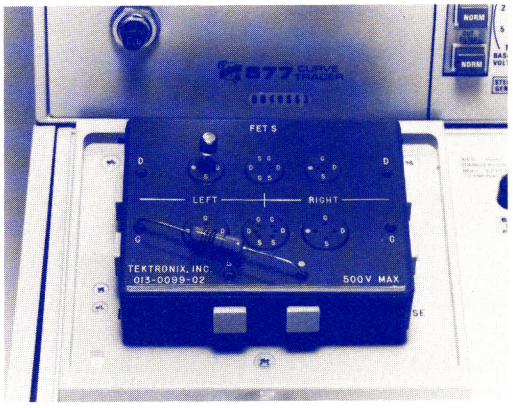



**Figure 5-1.** External resistor installed.

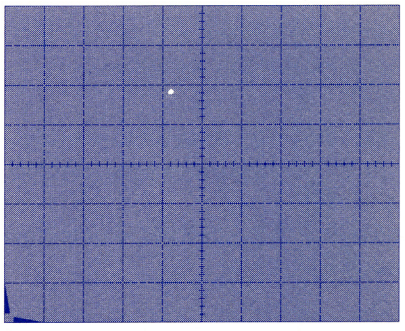


**Figure 5-2.** Display of valley-point current $I_V$.

## TEST 6: INTERBASE RESISTANCE

Without any emitter current, the channel of a UJT acts as a fairly linear resistive element. A value for this resistance is often stated at a single low value of interbase voltage, with no emitter current flowing.

On the curve tracer, this measurement is made by configuring the step generator supply to apply voltage between the bases, and displaying a graph of current versus voltage.

## WHAT THE DISPLAY SHOWS

The display shows interbase current on the vertical axis and emitter voltage on the horizontal axis. The slope of this curve is the resistance. A single value of resistance, at a specified point, is obtained by applying Ohm's law to the appropriate displayed quantities.

### PROCEDURE:

1) Set controls— Beginning with general UJT set-up, change controls as follows:

On 577:

- HORIZ VOLTS/DIV to smallest value at least 1/8 of voltage conditions specified [0.5 V] 22
- VARIABLE COLLECTOR % to minimum (ccw) 8

On 177:

- FUNCTION to EMITTER-BASE BREAKDOWN 32
- VERT UNITS/DIV to value closest to 1/8 times interbase voltage divided by minimum specified resistance. [0.125 × 3.0 ÷ 4.7K= 80μA, set to 0.1 mA] 33

## TEST 6: INTERBASE RESISTANCE continued

2) Use storage — For clearer, lasting display, press UPPER and LOWER STORE buttons. (If necessary, also press ERASE to clear screen.) 3 2

3) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Increase VARIABLE COLLECTOR % supply until horizontal displacement corresponds to specified voltage. [6.0 divs, or 3.0 V]. See Figure 6-1. 34 8

4) Compute resistance — Read current from vertical displacement and scale factor. Compute resistance, $R = \frac{E}{I}$.

5) Compare to specifications — Check to see that displayed and computed values are within specified range. [6.4 divs to 3.3 divs, corresponding to 4.7 KΩ to 9.1 KΩ].

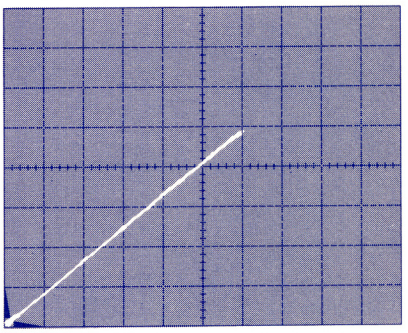


**Figure 6-1.** Display of interbase resistance $r_{BB}$.

## INTRODUCTION

In one sense, a programmable unijunction transistor (PUJT) is simply a unijunction transistor with external base resistors. Alternately, it can be thought of as a specialized relative of the SCR, which is how it obtained its SCR-like schematic symbol.

Curve tracer measurements of PUJT's are particularly useful because it is hard to envision the detailed operation of these devices from spec sheet values alone. The effects of external resistances and individual device variation on a complex curve are much easier to discover with a quick display than through laborious calculation from single-point measurements. The curve tracer can also be used to check devices against specifications for short-run incoming inspection or quality control.

Important PUJT measurements that can be made directly on a TEKTRONIX 577-D1 (storage) or 577-D2 (non-storage) Curve Tracer include peak current, offset voltage, gate leakage, forward voltage, and terminal-to-terminal resistance. Both current and voltage measurements can be made, down to quantities as small as 0.2 nA per division.

Most PUJT measurements on the curve tracer are obtained by using the step generator or an external supply to supply steady voltage through a resistor to the gate, applying the collector supply to the anode, and grounding the cathode. In this configuration, the horizontal axis of the display would normally represent anode-cathode voltage, and the vertical axis the corresponding current into the anode terminal.

**NOTE:** These procedures have been designed to be sufficiently general for testing most individual device types in the PUJT family. However, this section also provides actual settings, check values, and part numbers necessary for testing a specific PUJT (2N6027). This information is given in brackets at appropriate points throughout the section.

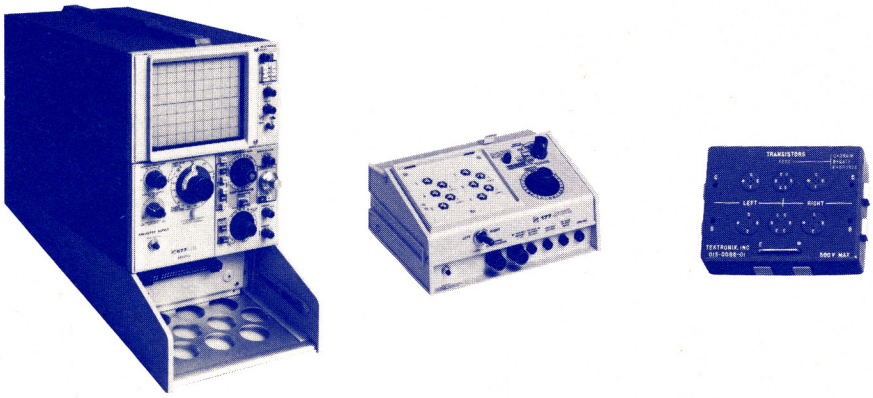
This section provides instructions for the specific tests listed below. These are preceded by a general set-up section.

1) Peak-Point Anode Current $I_p$
2) Valley-Point Anode Current $I_v$
3) Forward Voltage $V_f$
4) Offset Voltage $V_t$
5) Gate to Cathode Leakage Current $I_{GKS}$
6) Gate to Anode Leakage Current $I_{GAO}$

## GENERAL SET-UP

**EQUIPMENT REQUIRED:**

577-177 D1(storage) or D2 (non-storage), Curve Tracer, socket adapter [Transistor Adapter, Tektronix part number 013-0098-01], PUJT to be tested [2N6027], specifications for that transistor, jumper for connecting external-access points on socket adapter, appropriate gate resistors [200 Ω, 10 kΩ and 1 MΩ], external power supply.



**SET-UP**

1) Install 177 — If 177 fixture is not already installed in 577, do so first (with power off). See Figure 0-1.

2) Insert Socket Adapter — Place appropriate PUJT socket adapter in position provided on 177 test fixture.

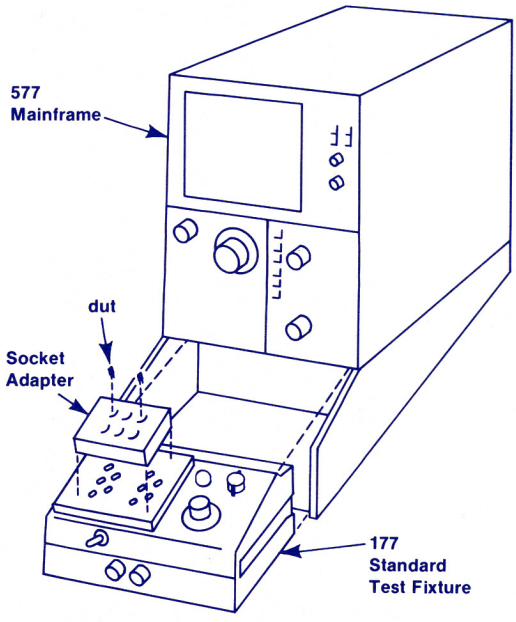
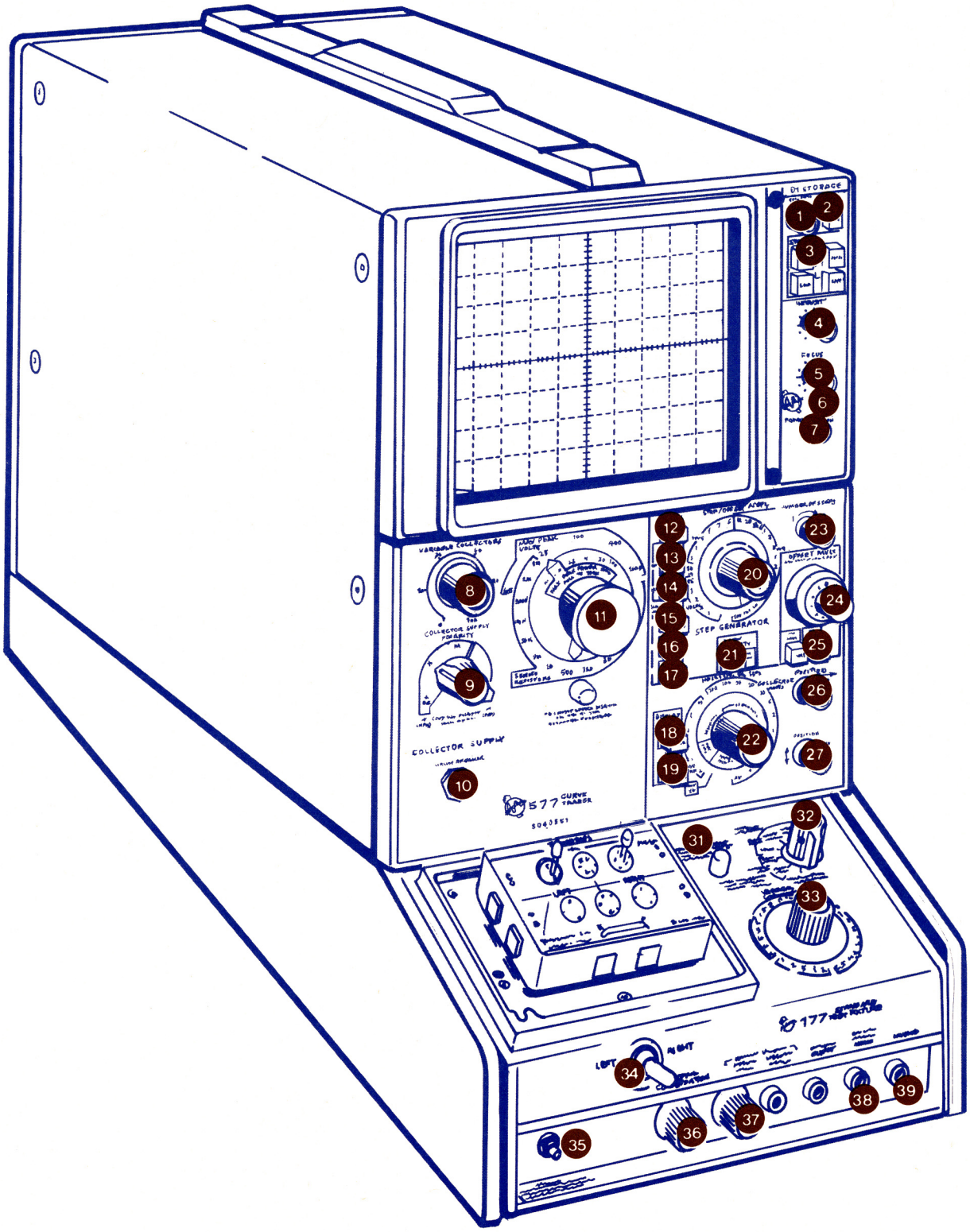



**Figure 0-1.** Installing standard test fixture.

## GENERAL SET-UP DIAGRAM



## GENERAL SET-UP continued

3) Set initial conditions— referring to PUJT set-up diagram (foldout), set controls as follows:
NOTE: This preliminary procedure has been designed to be applicable to all of the following tests. In each case, the detailed test procedure contains minor modifications to the settings of this procedure. Thus, it is possible to perform only one, some, or all of the tests, in any sequence.

On 577:

- MAX PEAK VOLTS to smallest value equal to or greater than largest anode voltage required [25 V] 11
- MAX PEAK POWER-WATTS to .15 11
- DISPLAY FILTER in 19
- DISPLAY INVERT in (normal) 18
- HORIZ VOLTS/DIV to 2 V 22
- X10 HORIZ MAG in (off) 26
- X10 VERT MAG in (off) 27
- BRIGHTNESS control to maximum (cw) 1
- INTENSITY control to minimum (ccw) 4
- HORIZ POSITION to center 26
- VERT POSITION to center 27
- COLLECTOR SUPPLY POLARITY to +DC 9
- VARIABLE COLLECTOR % to minimum (ccw) 8
- Press STEP FAMILY-SINGLE in and release (single-family) 13
- NUMBER OF STEPS to minimum (ccw) 23
- STEP RATE NORM in (normal rate) 16
- PULSED 300 $\mu$S in 12
- OFFSET ZERO out (on) 25
- OFFSET OPPOSE in (aiding) 25
- STEP/OFFSET POLARITY NORM in (normal) 21
- STEP/OFFSET AMPL to 2 V 20
- OFFSET MULTIPLIER to 5 24
- STEP X.1 in (off) 20

On D1 (storage models):

- UPPER and LOWER STORE out (non-store) 3
- UPPER and LOWER ERASE in (erase both when ERASE pushed) 3

On 177:

- FUNCTION to EMITTER GROUNDED, BASE TERM, STEP GEN 32
- LEFT-RIGHT selector to center (off) 34

## GENERAL SET-UP continued

4) Obtain trace — Using controls on 577:

a) Pull POWER ON switch. Wait for warm-up. 7

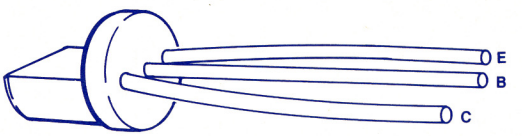
b) Find spot — Press BEAM FINDER button in, and advance INTENSITY control until spot is clearly visible. 6 4

c) Position spot — Using VERTICAL and HORIZONTAL POSITION controls, move spot to bottom left corner of graticule. 27 26

5) Insert-device — Insert device to be tested, PUJT Gate into yellow dot socket, PUJT anode in collector position, PUJT cathode in emitter position. See Figure 0-2.
Note: For tests 5 and 6 only, place PUJT GATE lead into base position of socket and omit step 6. Proceed to selected test.

6) Add gate resistor. Again referring to Figure 0-2, add specified gate resistor [1 MΩ] between yellow dot and base external-connection terminals on edge of socket adapter. To open hole for resistor lead insertion, press square button (on side of adapter) nearest hole.

Proceed to selected test.




CATHODE (E)
GATE (B)
ANODE (C)

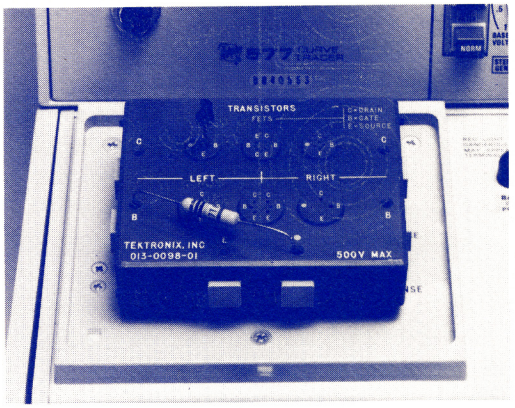



**Figure 0-2.** Device inserted in socket.

## TEST 1: PEAK-POINT ANODE CURRENT $I_p$

At the PUJT emitter peak-point, the anode junction is just about to turn on. A small but appreciably greater current than the reverse leakage begins to flow. This is the peak-point current.

To make this measurement, an external moderate-voltage power supply must be used in conjunction with the curve tracer when the specified gate voltage is above the range of the curve tracer's step generator supply.

The set-up, consequently, uses the curve tracer collector supply to provide emitter voltage. If gate voltage above 20 V is required, an external power supply is required to provide the gate voltage; below this figure, the step generator is employed.

### WHAT THE DISPLAY SHOWS

The display shows anode current on the vertical axis and emitter voltage on the horizontal axis. The resulting trace shows the PUJT characteristic curve, with a definite peak horizontal excursion. The corresponding vertical displacement at this peak point is the peak-point anode current.

Specifications are met when the vertical displacement at the peak point does not exceed the level corresponding to the specified peak-point current value.

### PROCEDURE:

1) Set controls— Beginning with general PUJT set-up, change controls as follows:

On 577:

- HORIZ VOLTS/DIV to smallest value at least 1/8 of specified gate voltage $V_s$ + 2 V [12 V, so set to 2 V]. 22
- VARIABLE COLLECTOR % to minimum (ccw) 8

On 177:

- VERT UNITS/DIV to smallest value more than 1/6 of specified maximum current [0.5 μA] 33
- STEP/OFFSET AMPL to largest possible value less than or equal to 1/16 of specified gate source voltage [2V] (If required value is above 20 V, see step 2.) 20
- OFFSET MULT to value necessary to obtain exact specified gate source voltage (MULT = specified ÷ AMPL) [5.0] 24

## TEST 1: PEAK-POINT ANODE CURRENT $I_p$ continued

2) Connect external power supply, if required— Set FUNCTION to EMITTER GROUNDED, BASE TERM, OPEN. Connect external power supply to EXT BASE and GROUND terminals on front of 177. Set voltage to specified gate source voltage (not necessary, below 20 V). 32 38 39

3) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Increase VARIABLE COLLECTOR % supply until trace shows definite peak excursion to right and then deflects upward. If necessary, readjust VERT UNITS/DIV to obtain more detail or greater coverage. 34 8 33

4) Use storage — For clearer, lasting display, press UPPER and LOWER STORE buttons. (If necessary, also press ERASE to clear screen.) 3 2

5) Find peak-point current — Find point at which vertical displacement reaches peak. This is peak-point. See Figure 1-1.

6) Compare current to specifications — Check to see that vertical displacement at peak-point corresponds to current within specified maximum. [4 divs, or 2.0 μA].

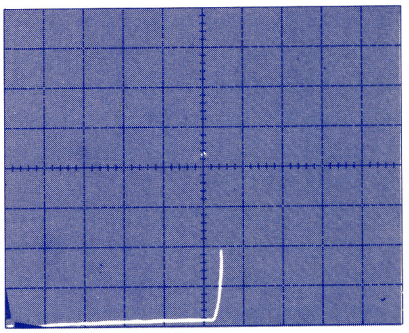


**Figure 1-1.** Display of peak-point anode current $I_p$.

## TEST 2: VALLEY-POINT ANODE CURRENT $I_V$

After the anode voltage passes the peak-point, the junction turns on. An appreciably greater current than the peak-point current begins to flow. Next, a negative resistance phenomenon comes into play, and the required anode voltage for increasing current actually decreases for a while before increasing again. This minimum anode voltage following the peak-point is called the valley point, and the current at this point is the valley-point current, $I_V$.

Since it is this current that is often used to force a certain circuit state, its amplitude must meet specifications for minimum, maximum, or both.

To make this measurement, an external moderate-voltage power supply must be used in conjunction with the curve tracer when the specified gate voltage is above the range of the curve tracer's step generator supply.

The set-up, consequently, uses the curve tracer collector supply as before, to provide the anode voltage. Gate voltage is supplied by the step/offset generator if the required voltage is within its range. If not, an external power supply provides the gate voltage.

### WHAT THE DISPLAY SHOWS

The display shows anode current on the vertical axis and anode voltage on the horizontal axis. The resulting trace shows the PUJT characteristic curve, with a quite definite voltage peak followed by a visible local minimum. The vertical displacement at this local horizontal minimum called the valley point, is the valley current.

Specifications are met when the vertical displacement at the valley point is within the range corresponding to the specified valley-point current value.

### PROCEDURE:

1) Set controls— Beginning with general PUJT set-up, change controls as follows:

On 577:

- HORIZ VOLTS/DIV initially to smallest value at least 1/8 of valley-point voltage, $V_V$, if known (If not known, use $V_p$. If that value is not known, approximate it as gate source voltage $V_s$ plus 2V.)
  $V_p \approx V_s + 2.0$
  $V_v < V_p$
  [$V_p \approx 10V + 2V \approx 12V$
  $V_v \leq 12V$] [Set to 2V] 22
- VARIABLE COLLECTOR % to minimum (ccw) 8

## TEST 2: VALLEY-POINT ANODE CURRENT $I_V$ continued

On 177:

- VERT UNITS/DIV to smallest possible value at least 100 times specified maximum emitter current [1 mA] 33
- STEP/OFFSET AMPL to largest possible value less than or equal to 1/16 of specified gate source voltage $V_S$ [2 V]. (If required gate voltage is greater than 20 V, see step 2.) 20
- OFFSET MULT to value necessary to obtain exact specified gate source voltage (MULT = specified ÷ AMPL) [5.0] 24

2) Connect external power supply, if required— Set FUNCTION switch to EMITTER GROUNDED, BASE TERM, OPEN. Connect external power supply to EXT BASE and GROUND terminals on front of 177. Set voltage to specified gate source voltage [not required]. 32 38 39

3) Apply power to device— Position LEFT-RIGHT switch on 177 to appropriate side. 34

4) Use storage— For clearer, more lasting display, press UPPER and LOWER STORE buttons. (If necessary, also press ERASE to clear screen.) 3 2

## TEST 2: VALLEY-POINT ANODE CURRENT $I_V$ continued

5) Correct sensitivity— Valley-point anode current measurement requires very fine adjustment of controls. Thus, correct sensitivity must be approached in steps as follows:

a) Rotate VARIABLE COLLECTOR % control cw to maximum. If spot moves beyond middle of screen vertically, reduce VARIABLE COLLECTOR % until spot returns to center graticule line. See Figure 2-1. 8

b) Then rotate VERT UNITS/DIV control cw for greater sensitivity until spot moves up off screen. Slowly decrease VARIABLE COLLECTOR % until spot returns to center horizontal graticule line. If spot disappears while rotating VARIABLE COLLECTOR % ccw, repeat from step a. 33 8

c) Repeat part b until VERTICAL control is at smallest value at least 1/6 of specified valley current. [10 μA]. 33

d) Turn VARIABLE COLLECTOR % lightly until spot is at center horizontal graticule line. See Figure 2-2. 8

e) Set HORIZ VOLTS/DIV to most sensitive position (0.05 V plus X10 HORIZ MAG out for 50 mV). Spot may disappear. 22 26

f) Rotate HORIZ position control ccw slowly until spot appears at center vertical graticule line. See Figure 2-3. 26

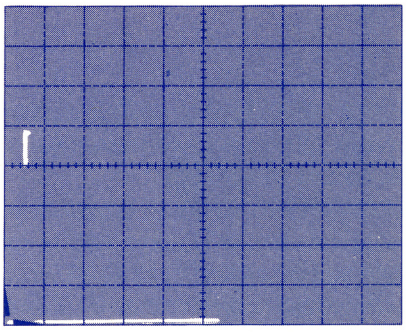


**Figure 2-1.** Returning spot to center of screen.

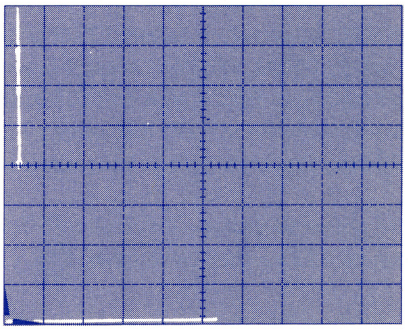


**Figure 2-2.** Moving spot back to horizontal center of screen.

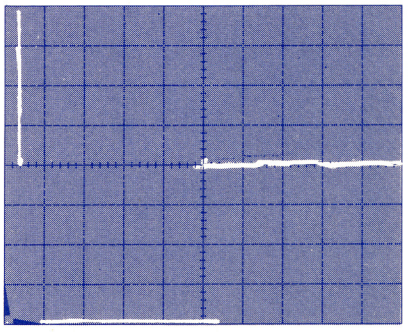


**Figure 2-3.** Returning spot to center of screen.

## TEST 2: VALLEY-POINT ANODE CURRENT $I_V$ continued

g) Return VARIABLE COLLECTOR % control to 0. Press ERASE to clear screen. 8

h) Rotate VARIABLE COLLECTOR % control cw to maximum then ccw to 0. Wait for a moment until spot returns and produces a trace. See Figure 2-4. 8

6) Find valley-point current — Find point at which curve makes horizontal bulge to left near center of screen. Extreme point of this bulge is valley point.

7) Compare current to specifications — Check to see that vertical displacement at valley-point corresponds to current within specified range. [5 divs, or 50 μA maximum].

8) Repeat with alternate values of gate resistance (optional) — Repeat peak procedure, using other specified gate resistors, and checking appropriate maximum or minimum current. [with $R_G$= 10.0 k, to 70 μA minimum; with $R_G$= 200 ohms, 1.5 mA minimum].

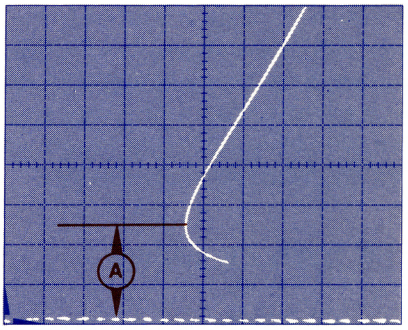



**Figure 2-4.** Display of valley-point anode current $I_V$. Point A is area of measurement.

## TEST 3: FORWARD VOLTAGE $V_F$

After sufficient voltage is supplied to the anode to turn on the PUJT junction, further large increases in anode current occur with little change in input voltage. The value of the anode-cathode voltage at which this occurs, given a specified current, is the forward voltage $V_F$. Although it does vary with current, this voltage is usually specified as a single value at a given current level. Often, a typical value will be given, instead of absolute maximum and minimum.

On the curve tracer, this measurement is made by supplying the stated anode voltage with the collector supply, and using the step/offset supply for the gate.

### WHAT THE DISPLAY SHOWS

The display shows anode current on the vertical axis and anode voltage on the horizontal axis.

Specifications are met when, at the height corresponding to the stated current, the horizontal displacement corresponds to a voltage within the specified range.

### PROCEDURE:

1) Set controls— Beginning with general PUJT set-up, change controls as follows:

On 577:

- HORIZ VOLTS/DIV to smallest value at least 1/8 of sum of gate source voltage $V_S$ + maximum offset voltage specified [10 + 1.6 V, set to 2 V]. 22
- MAX PEAK POWER — WATTS to .6 11
- VARIABLE COLLECTOR % to minimum (ccw) 8

On 177:

- VERTICAL CURRENT/ DIV to smallest value at least 1/5 of specified collector current 10 mA 33

## TEST 3: FORWARD VOLTAGE $V_F$ continued

2) Connect external power supply, if required — If gate source voltage $V_S$ is greater than 20 V, external power supply is required. In that case, FUNCTION to EMITTER GROUNDED, BASE TERM, OPEN. With supply off, connect it to EXT BASE and GROUND terminals on front of 177. Set voltage to specified gate source voltage $V_S$ [not required, under 20 V]. 32 38 39

3) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Increase VARIABLE COLLECTOR % supply until specified anode current is reached on vertical. [5 divs, or 50 mA]. See Figure 5-1. 34 8

4) Increase horizontal sensitivity — If possible, turn HORIZ VOLTS/DIV cw to increase sensitivity, but keep intersection of specified vertical graticule line and trace on screen. See Figure 5-2. 22

5) Compare to specifications — Check to see if horizontal displacement indicates voltage within specifications. [less than 1.5 V].

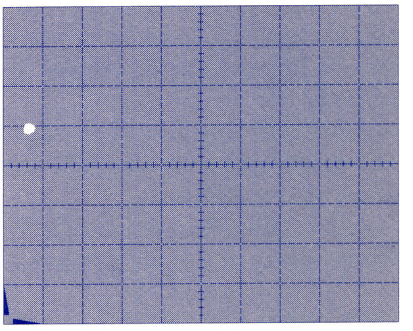


**Figure 5-1.** Display of forward voltage $V_F$

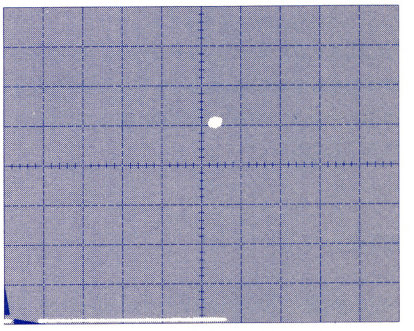


**Figure 5-2.** Display of forward voltage $V_F$ at greater horizontal sensitivity.

## TEST 4: OFFSET VOLTAGE $V_T$

Offset voltage, for a PUJT, is the voltage necessary to forward bias the anode junction at a given value of thejunc-gate voltage and resistance. It is a diode voltage, typically 0.2 to 2.0 volts. The offset voltage is $V_S$, the gate source voltage, minus $V_p$, the anode peak voltage. Its measurement, therefore, consists of finding $V_p$, and subtracting it from a known $V_S$.

The anode peak voltage, $V_P$, is also useful to know because it is the dividing point between the cutoff region and the negative resistance region of the PUJT emitter characteristics. As such, its defining values are among the important design elements for PUJT circuits.

On the curve tracer, the peak voltage measurement is made by supplying the stated gate voltage with the step generator/offset supply or a higher-voltage external supply, and using the collector supply to power the anode.

### WHAT THE DISPLAY SHOWS

The display shows anode current on the vertical axis and anode voltage on the horizontal axis. The resulting trace shows a quite definite voltage peak, which is then measured to find $V_P$.

Specifications are met when the difference between $V_S$, the gate source voltage, and $V_P$, the peak horizontal displacement, corresponds to a voltage within the specified range.

### PROCEDURE:

1) Set controls— Beginning with general PUJT set-up, change controls as follows:

On 577:

- HORIZ VOLTS/DIV to smallest value at least 1/8 of maximum peak voltage to be tested (If specification is not given, assume peak voltage to be near gate source voltage plus 2 volts. ($V_p \approx V_S + 2$ V.) [12 V sum, so set to 2 V] 22
- VARIABLE COLLECTOR % to minimum (ccw) 8

On 177:

- VERT UNITS/DIV to smallest value more than 1/6 of current specified for forward voltage $I_F$ [10 mA] 33
- STEP/OFFSET AMPL to largest possible value less than or equal to 1/16 of specified gate source voltage $V_S$ [2 V] (If required voltage is greater than 20 V, see Step 2.) 20
- OFFSET MULT to value necessary to obtain exact specified gate source voltage (MULT = specified ÷ AMPL) [5.0] 24

## TEST 4: OFFSET VOLTAGE $V_T$ continued

2) Connect external power supply, if required — Set FUNCTION to EMITTER GROUNDED, BASE TERM, OPEN. Connect external power supply to EXT BASE and GROUND terminals on front of 177. Set voltage to specified gate source voltage $V_S$ [not required.] 32 38 39

3) Use storage — For cleaner, more lasting displays, press UPPER and LOWER STORE buttons. (If necessary, also press ERASE to clear screen). 3 2

4) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Increase VARIABLE COLLECTOR % supply until trace switches from mostly horizontal to fairly vertical. 34 8

5) Find peak point — Find extreme point at right at which trace switches from mostly horizontal to mostly vertical. This is peak-point. See Figure 6-1.

6) Calculate offset — Read peak voltage from horizontal displacement at peak point and multiply times HORIZ VOLTS/DIV setting. Subtract gate source voltage $V_S$ to obtain offset voltage $V_T$. $V_T = V_P - V_S$. 22

7) Compare to specifications — Check to see that derived value is within range stated in specifications. [0.2 to 1.6 V]. Alternately calculate necessary peak voltage range, $V_p$, and compare displacement to that required.

$V_p = V_T + V_S$

[$10.2 < V_p < 11.6$, therefore peak point is between 5.1 and 5.8 horizontal divs].

8) Repeat with alternate values of gate resistance (optional) — Repeat procedure using other specified gate resistors, and checking appropriate ranges. [for $R_G = 10\ k\Omega$, $0.2 < V_T < 0.6$, $10.2 < V_p < 10.6$, betwen 5.1 and 5.3 horizontal divs].

9) Remove gate resistor — Replace gate lead in base terminal of adapter, and remove gate resistor.

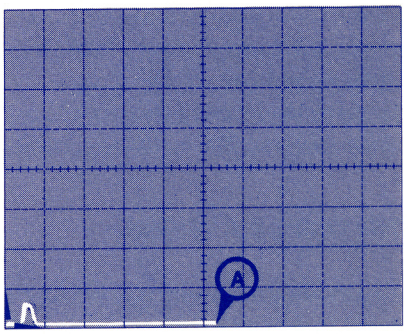



**Figure 6-1.** Display of offset voltage $V_t$. Point (A) is peak- point.

## TEST 5: GATE-TO-CATHODE LEAKAGE CURRENT $I_{GKS}$

When the PUJT junction is reverse biased, a small reverse current continues to flow through the junction because of imperfections and thermal effects. This current, measured from gate to cathode and anode at a specified voltage, is the gate-to-cathode leakage current $I_{GKS}$.

On the curve tracer, this characteristic is measured by applying reverse collector voltage to the anode and cathode while grounding the gate. The resulting curve shows gate reverse current versus voltage.

### WHAT THE DISPLAY SHOWS

The display shows gate reverse current on the vertical axis and gate reverse voltage on the horizontal axis.

Specifications are met when the vertical displacement corresponding to maximum reverse current is not exceeded before the horizontal displacement corresponding to the specified gate-cathode voltage is reached.

### PROCEDURE

1) Set controls— Beginning with general PUJT set-up, change controls as follows:

On 577:

- FUNCTION to BASE GROUNDED, EMITTER TERM, OPEN (32)
- HORIZ VOLTS/DIV to smallest value at least 1/8 of specified gate-cathode voltage [5 V] (22)
- MAX PEAK VOLTS to smallest value above voltage to be tested. (Note that, above 25 V, protective cover must be closed or INTERLOCK switch held in for device-operating part of each test.) [100 V] (11)
- VARIABLE COLLECTOR % to minimum (ccw) (8)
- COLLECTOR SUPPLY POLARITY TO – DC (9)
- DISPLAY INVERT NORM out (inverted) (18)
- DISPLAY FILTER out (on) (19)

On 177:

- VERT UNITS/DIV to smallest possible value at least 1/6 of maximum specified reverse current. (If necessary, use X10 VERT MAG.) [10 nA] (33)

## TEST 5: GATE-TO-CATHODE LEAKAGE CURRENT $I_{GKS}$ continued

2) Connect anode and cathode — Using jumper, connect C and E external connection points on socket adapter. Refer to Figure 3-1.

3) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Increase VARIABLE COLLECTOR % supply until horizontal displacement corresponds to specified voltage. [8.0 divs, or 40 V]. See Figure 3-2. 34 8

4) Compare current to specifications — Check to see that vertical displacement corresponds to current within specified maximum. [5 divs, or 50 nA].

5) Remove jumper — Remove jumper from socket adapter.

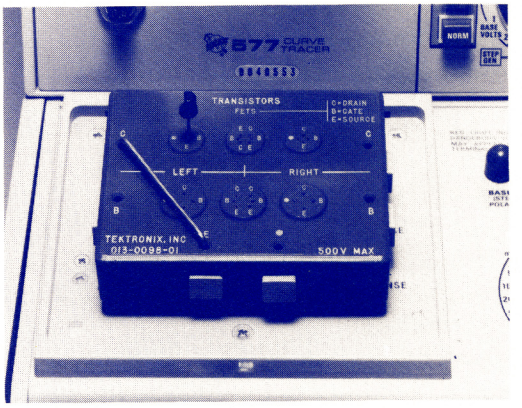



**Figure 3-1.** Jumper in place.

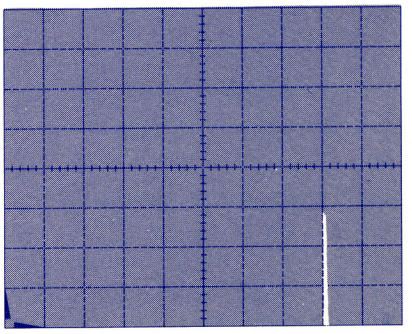


**Figure 3-2.** Display of gate-to-cathode leakage current $I_{GKS}$.

## TEST 6: GATE-TO-ANODE LEAKAGE CURRENT $I_{GAO}$

Another important leakage current (when the PUJT junction is reverse biased) is the one that continues to flow through the gate to the anode. This current, measured at a specified voltage and with the cathode open, is the gate-to-anode leakage current, $I_{GAO}$.

On the curve tracer, this characteristic is measured by applying reverse collector voltage to the anode, grounding the gate, and holding the cathode terminal open. The resulting curve shows anode reverse current versus voltage.

### WHAT THE DISPLAY SHOWS

The display shows anode reverse current on the vertical axis and anode-to-gate reverse voltage on the horizontal axis.

Specifications are met when the vertical displacement corresponding to maximum reverse current is not exceeded before the horizontal displacement corresponding to the specified anode-gate voltage is reached.

**PROCEDURE:**

1) Set controls— Beginning with general PUJT set-up, change controls as follows:

On 577:

- FUNCTION to BASE GROUNDED, EMITTER TERM, OPEN 32
- HORIZ VOLTS/DIV to smallest value at least 1/8 of specified interbase voltage [5 V] 22
- MAX PEAK VOLTS to 100 11
- VARIABLE COLLECTOR % to minimum (ccw) 8
- COLLECTOR SUPPLY POLARITY to [ – ] 9
- DISPLAY INVERT NORM out (inverted) 18
- DISPLAY FILTER out (on) 19

On 177:

- VERT UNITS/DIV to smallest possible value at least 1/6 of maximum specified reverse current. (If necessary, use X10 VERT MAG.) [2 nA] 32 27

## TEST 6: GATE-TO-ANODE LEAKAGE CURRENT $I_{GAO}$ continued

2) Apply power to device — Position LEFT-RIGHT switch on 177 to appropriate side. Increase VARIABLE COLLECTOR % supply until horizontal displacement corresponds to specified voltage. [8.0 divs, or 40 V]. See Figure 4-1. 34 8

3) Compare current to specifications — Check to see that vertical displacement corresponds to current within specified maximum. [5 divs, or 10 nA].

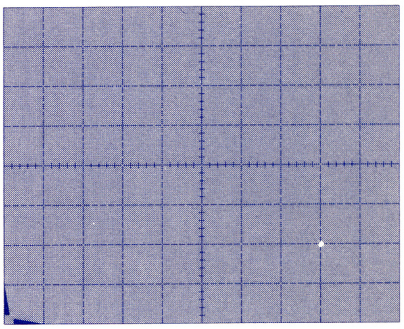


**Figure 4-1.** Display of gate-to-anode leakage current $I_{GAO}$.

## INTRODUCTION

Testing integrated circuit operational amplifiers with a curve tracer is a relatively easy operation, one well suited for short-run incoming inspection or circuit design and characterization. The TEKTRONIX 577-D1 Storage Curve Tracer with its 178 Linear IC Test Fixture provides facilities for most common op amp tests (timing and rate tests, however, do require the use of additional Tektronix test equipment).

In testing op amps, the 178 Linear IC Test Fixture acts as the interface unit, supplying appropriate voltages, currents, and loads as set by the operator. An easy-to-use function switch automatically configures the 178 for each test, a series of controls sets power supply voltages and sweep signal input frequency and amplitude; a multi-position switch allows selection of load and source resistance. The 178 also contains the display vertical sensitivity control.

The 577-D1 Mainframe furnishes the display, display controls, and supporting circuits such as primary power supplies.

Op amps are connected to the 178 using a special slide-in circuits card plus a plug-in socket adapter. The standard circuit card supplied with the 178 sets the system to work with op amps; socket adapters provide the proper mounting configuration. Other circuit cards and adapters are available for various IC types and packages.

In most op amp tests on the curve tracer, the op amp under test is inserted in a feedback loop that derives its control voltage from the differential between op amp output and a zero reference. Typically, the test will measure the additional signal required to counteract some op amp internal characteristic and keep the output at zero.

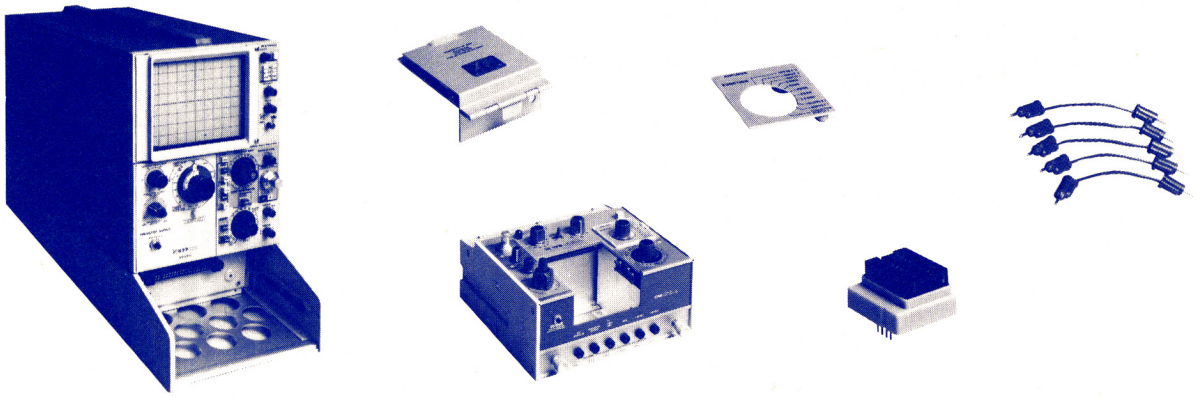
**NOTE:** These procedures have been designed to be sufficiently general for testing most individual device types in the op amp family. However, this section provides actual settings, check values, and part numbers necessary for testing a 741-type op amp. This information is given in brackets at appropriate points throughout the section.

This section provides instructions for the specific tests listed below. These are preceded by general set-up instructions.

1) Input Offset Voltage
2) Input Bias Current
3) Input Offset Current
4) Common-Mode Rejection Ratio (cmrr)
5) Gain
6) Output Voltage Swing
7) Positive Supply Voltage Rejection Ratio
8) Negative Supply Voltage Rejection Ratio
9) Dual Power Supply Voltage Rejection Ratio

## GENERAL SET-UP

**EQUIPMENT REQUIRED:**
577-178-D1 (storage) Linear IC Curve Tracer, Standard Op Amp Card, 5 to 8 patch cords, op amp to be tested [741-type, in 8-pin package], specifications for that op amp, corresponding socket adapter [14-Lead Dual-In-Line Package, Tektronix part number 136-0443-00; or 16-Lead Dual-In-Line Package, Tektronix part number 136-0442-00], and appropriate nomenclature panel [Tektronix part number 333-1770-00].



**SET-UP:**

1) Install 178 — If 178 Fixture is not already installed in 577, do so first (with power off). See Figure 0-1.

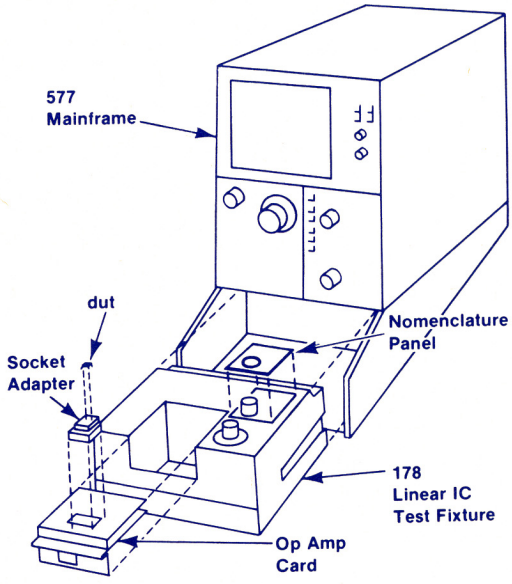
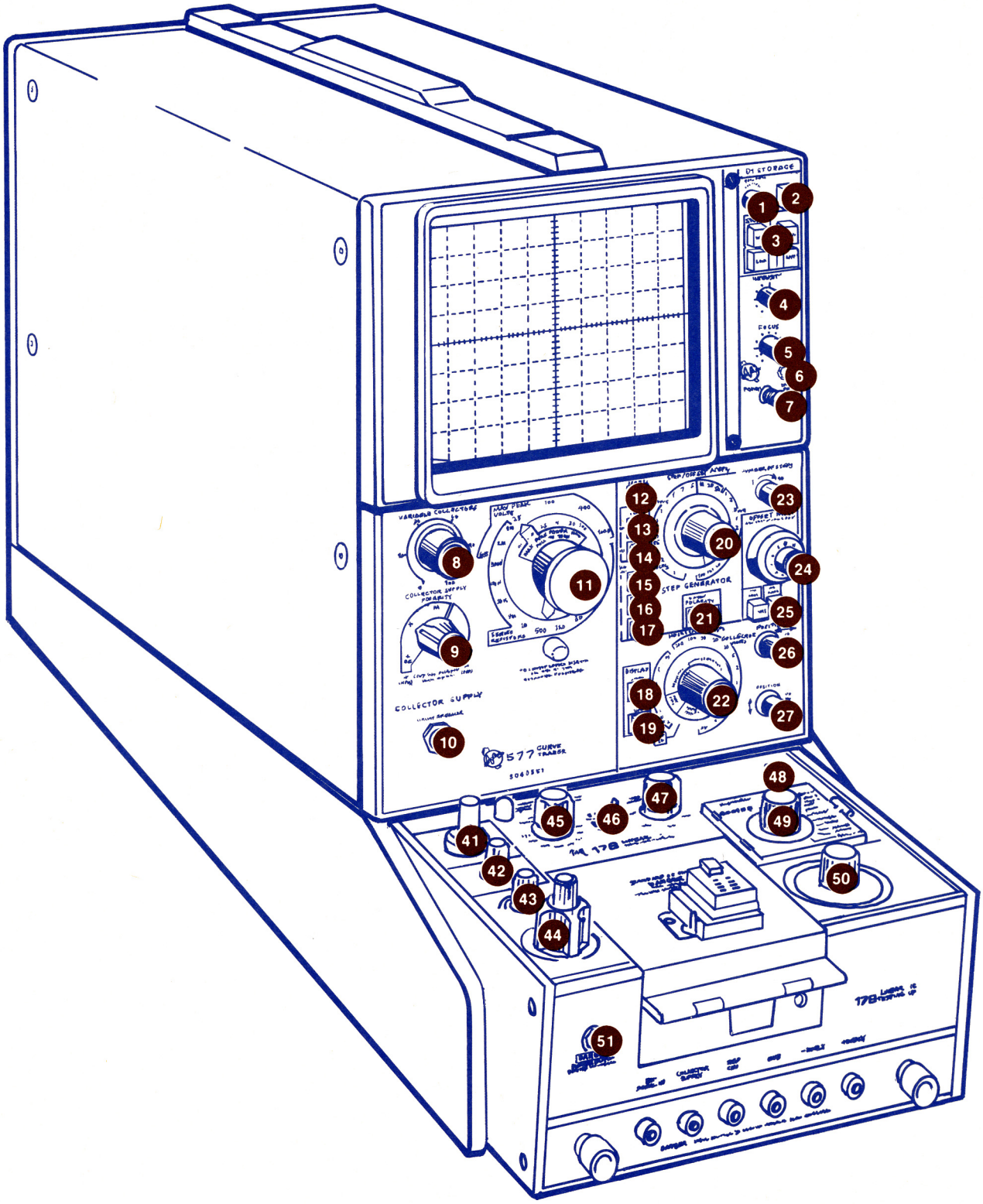



**Figure 0-1** Installing linear IC test fixture.

## GENERAL SET-UP DIAGRAM



## GENERAL SET-UP continued

2) Install AMPLIFIER nomenclature panel on FUNCTION SWITCH. If panel is not in place around FUNCTION switch, install it now. See Figure 0-2. 49

3) Prepare device card — Remove device card from 178. See Figure 0-1.

Make following connections as necessary:

a) Connect jumpers — using Op Amp symbol drawn on card and basing diagram from specifications for device to be tested, connect jumpers between socket pin pc board connectors and corresponding function. At least V+, V−, +IN, −IN, and OUT must be connected. (See Figure 0-3 for connections for 741-type devices.) A
NOTE: 8-pin or 14-pin DIP devices may be used with 16-pin DIP adapter, but pin numbers shown on card for second side of device must be mentally replaced with new pin numbers.

b) Set current limits—there are separate current limit controls for V+ and V− supplies on card. See Figure 0-3. B Adjustment range is approximately 10 mA (ccw) to 150 mA (cw). Set to center. Alternately set to appropriate value for device to be tested. (For procedure for more exact setting, see 577-178-D1 Linear IC Curve Tracer manual, p. 2-10.)

c) Set feedback — Set switch on device card to NORM. See Figure 0-3 C

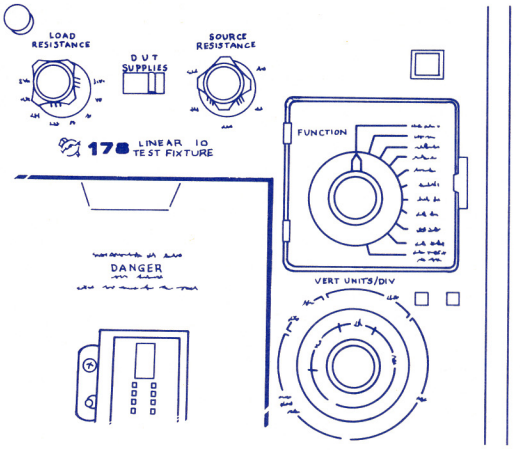



**Figure 0-2** Installing nomenclature panel.

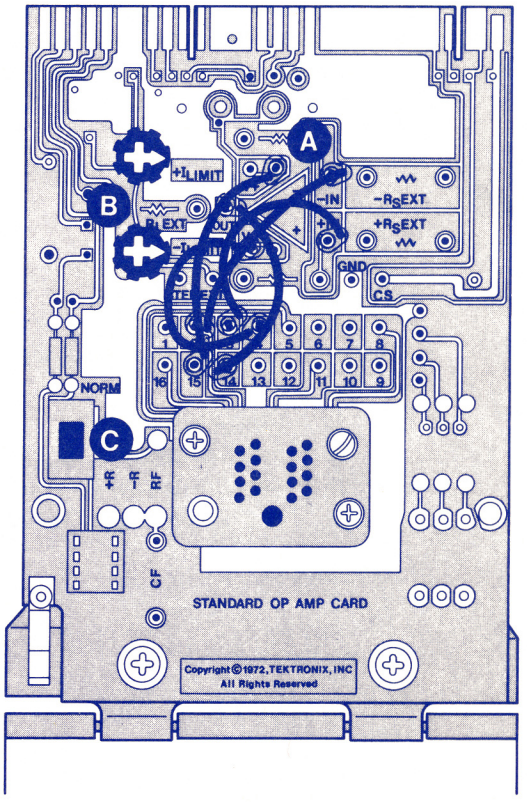



**Figure 0-3** Standard op amp card.

## GENERAL SET-UP continued

Reinstall device card in 178. See Figure 0-4.

d) Install adapter — Install device adapter into socket on device card. See Figure 0-5.

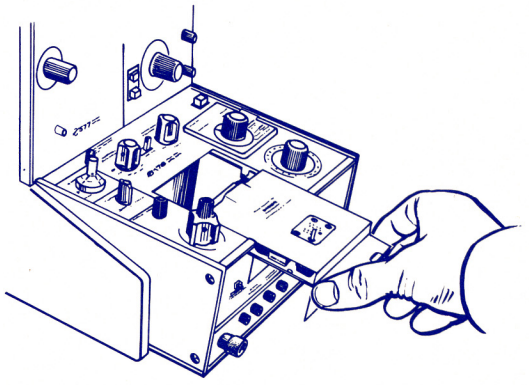


**Figure 0-4** Reinstalling device card in 178.

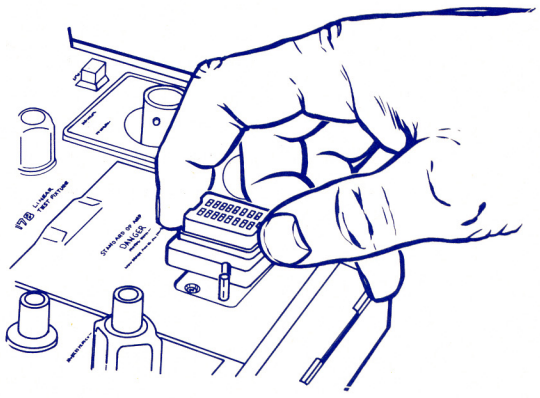


**Figure 0-5** Installing device card adapter in socket.

## GENERAL SET-UP continued

4) Set unused controls off — Referring to op amp set-up diagram (foldout), set:

- COLLECTOR SUPPLY POLARITY to + 9
- VARIABLE COLLECTOR % to minimum (ccw) 8
- Press STEP FAMILY-SINGLE in and release 14
- PULSE 300 μS out 12
- STEP X.1 in 20

Ignore STEP/OFFSET AMPL, OFFSET AID, NUMBER OF STEPS, OFFSET MULTIPLIER. 20 25 23 24

5) Set initial conditions — referring to Op Amp set-up diagram (foldout), set controls as follows:

NOTE: This preliminary procedure has been designed to be applicable to all of the following tests. In each case, the detailed test procedure contains minor modifications to the settings of this procedure. Thus, it is possible to perform only one, some or all of the tests, in any sequence.

On 577:

- MAX PEAK VOLTS to 25 11
- MAX PEAK POWER-WATTS to 0.6 11
- DISPLAY FILTER in 19
- DISPLAY INVERT in (normal) 18
- STEP RATE NORM in 16
- HORIZ VOLTS/DIV to 5 V 22
- X10 HORIZ MAG to off 26
- X10 VERT MAG to off 27
- BRIGHTNESS control to maximum (cw) 1
- INTENSITY control to minimum (ccw) 4
- HORIZ POSITION to center 26
- VERT POSITION to center 27

On 178:

- DUT SUPPLIES to OFF 46
- LOAD RESISTANCE to 2 kΩ 45
- SOURCE RESISTANCE to 50 kΩ 47
- +SUPPLY to 15 V (or rated voltage for device) 41
- −SUPPLY to TRACK +SUPPLY 42
- SWEEP AMPLITUDE to minimum (ccw) 43
- SWEEP FREQUENCY to 0.1 Hz 44
- FUNCTION to OFFSET V 49
- VERT UNITS/DIV to 50 mV 50

## GENERAL SET-UP continued

6) Obtain trace — Using controls on 577:

a) Pull POWER ON switch. Wait for warm up. 7

b) Clear screen — Press the UPPER and LOWER STORE buttons and then UPPER and LOWER ERASE. Release STORE buttons. 3

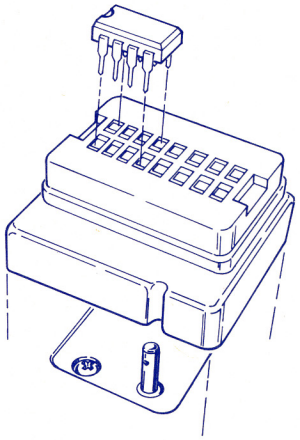
c) Find spot — Press BEAM FINDER button in, and advance INTENSITY control until spot is clearly visible. 6 4

d) Center spot — Using VERTICAL and HORIZONTAL POSITION controls, center spot. Use BEAM FINDER to see present direction if spot is off-screen. 27 26 6

7) Insert device — Insert device to be tested in socket. See Figure 0-6.

Set-up procedure is now complete.

Proceed to selected test.



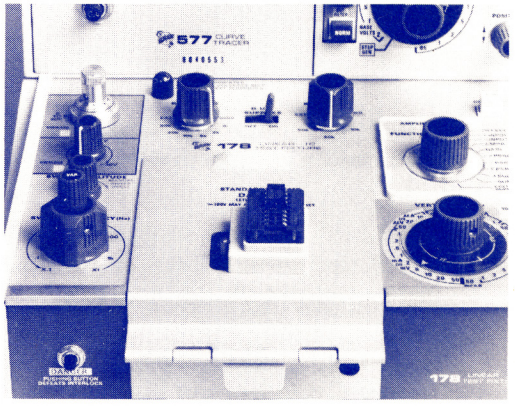


**Figure 0-6** Device inserted in socket.

## TEST 1: INPUT OFFSET VOLTAGE

Input offset voltage is the amount of dc voltage input needed to keep the op amp output at zero with no applied signal voltage.

In this test, the op amp being tested is made part of a feedback loop together with another amplifier supplied in the curve tracer. The curve trace sweep generator attempts to drive the op amp output over its working range, but the feedback loop supplies a voltage input to the op amp that, when amplified, cancels out this driving voltage.

This input voltage, which keeps the op amp output at zero, is therefore the input offset voltage.

### WHAT THE DISPLAY SHOWS

The display shows input offset voltage, measured between the op amp's inverting input and non-inverting input, on the vertical axis, and the voltage applied by the sweep generator to the op amp output on the horizontal axis. Specifications are met when the trace stays within the vertical band specified, over the defined horizontal range.

### PROCEDURE:

1) Set controls — Beginning with general Op Amp set-up, change controls as follows:

On 577:

- HORIZ VOLTS/DIV to smallest value at least 1/4 of specified testing domain excursion from zero [+10 V range, 5 V] 22

On 178:

- FUNCTION to OFFSET 49
- SOURCE RESISTANCE to specification value [10 kΩ] 47
- VERT UNITS/DIV to smallest value at least 1/3 of specified maximum offset voltage [2 mV] 50
- DUT SUPPLIES to ON 46

## TEST 1: INPUT OFFSET VOLTAGE continued

2) Zero display — Press DISPLAY ZERO and hold in while centering display with VERT and HORIZ POSITION controls of 577. 48 27 26

3) Measure trace — Advance SWEEP AMPLITUDE on 178 to obtain full range of specified input offset voltage. Press UPPER and LOWER STORE buttons on 577 to obtain clear, lasting trace. (If necessary, press UPPER and LOWER ERASE first to clear screen.) Check to see that vertical displacement is within specified value [3 divisions, equal to 6 mV] over op amp's specified output range [+10 V, 2 divisions each way from center]. See Figure 1-1. 43 3

4) Turn off device — Switch DUT SUPPLIES to OFF. 46

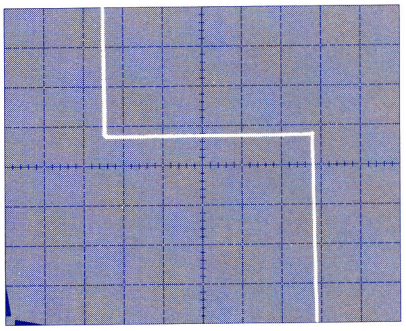


**Figure 1-1.** Input offset voltage.

## TEST 2: INPUT BIAS CURRENT

Input bias current is the amount of dc current flowing into the op amp inputs, tested over the full input voltage range. Alternately, it may be specified only with a zero voltage input.

This test is done twice, once for the inverting and once for the non-inverting input. In each run-through, current into the selected terminal is measured as the sweep generator drives the common mode input voltage over the full input range. A feedback loop keeps the output at zero by supplying the appropriate voltage to the input opposite to the one being tested.

## WHAT THE DISPLAY SHOWS

The display shows current into the selected input on the vertical axis graphed against common-mode input voltage on the horizontal. Specifications are met when the trace stays between specified limits on the vertical over the specified horizontal domain.

**PROCEDURE:**

Following steps are performed twice, once for each of two positions of FUNCTION switch.

1) Set controls — Beginning with general Op Amp set-up, change controls as follows:

On 577:

- HORIZ VOLTS/DIV to smallest value at least 1/4 specified common mode voltage excursion from zero [±10 V, 5 V setting] 22
- FUNCTION to +INPUT I (first time) through entire test; then to −INPUT I (second time) through entire test 49
- SOURCE RESISTANCE to specification value [50 Ω] 47
- VERT UNITS/DIV to smallest value at least 1/3 of specified maximum input bias [0.2 μA] 50
- DUT SUPPLIES to ON 46
- SWEEP AMPLITUDE to maximum (cw) 43

## TEST 2: INPUT BIAS CURRENT continued

2) Zero display — Press DISPLAY ZERO and hold in while centering display with VERT and HORIZ POSITION controls of 577. 48 27 26

3) Measure Trace — Press UPPER and LOWER STORE buttons on 577 to obtain clear trace. If necessary, press UPPER and LOWER ERASE to clear screen. Check to see that vertical displacement is within specified value [2.5 divs, equal to 0.5 μA] over op amp's specified input common-mode range. Refer to Figures 2-1 and 2-2. 3 2

**NOTE:** The 577-D1 storage display will not automatically erase the display when the FUNCTION is switched from +INPUT to −INPUT. Do not erase it manually either if you wish to measure input offset current (see test 3). 49

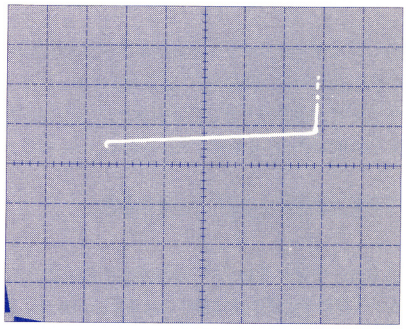


**Figure 2-1.** +Input bias current.

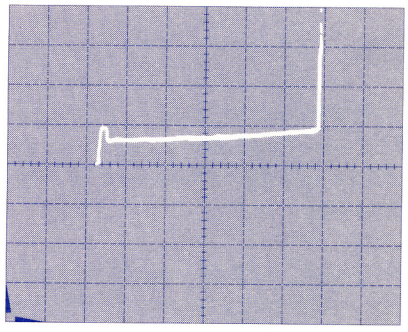


**Figure 2-2.** −Input bias current. Display was produced by following procedure for +input bias current, however, FUNCTION switch was set to −input bias current.

## TEST 3: INPUT OFFSET CURRENT

Input offset current is the amount of differential current flowing into the op amp input required to keep the output at zero with no applied differential voltage.

This specification is checked by examining the results of the positive and negative input bias current tests. The difference between the two values is the input offset current.

### WHAT THE DISPLAY SHOWS

This test uses the D1 storage feature to retain the traces of the positive and negative input bias currents on screen. Thus, input bias current is shown on the vertical axis and common-mode input voltage on the horizontal. The difference in displacement between these two curves is the input offset current.

**PROCEDURE:**

1) Perform bias current tests — Perform positive and negative input bias current tests (see test 2 procedures) without erasing display between tests.

2) Read display — Check that difference between vertical displacements is within specified limits [1.0 division, equal to 0.2 μA] over full stated horizontal domain [+2 divisions from center] as specified. See Figure 3-1.

3) Measure offset current (optional) — To obtain numeric value for offset current, display resolution must be increased.

   a) Set FUNCTION to +INPUT. Decrease value of VERT UNITS/DIV and then move trace down by turning VERTICAL POSITION control ccw with DISPLAY ZERO held in, until trace starts on bottom graticule line and makes sharp excursion to right crossing center vertical graticule line in top half of screen (see Figure 3-2). If necessary, release X10 VERT MAG to increase display resolution. 49 50 48 27

   b) Press UPPER and LOWER STORE to save display. Then switch FUNCTION to −INPUT. Measure vertical separation between traces at intersection with center vertical graticule line. This amount, multiplied by VERT UNITS/DIV, and X10 if used, is zero-point input off-set current. 3 49 27

4) Turn off device — Switch DUT SUPPLIES to OFF. 46

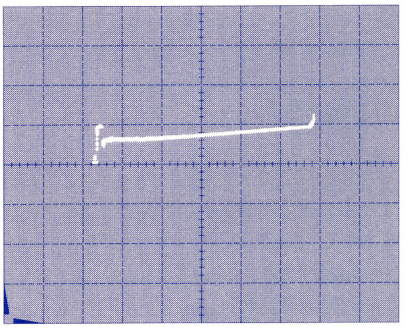


**Figure 3-1.** + and − input bias current on one display. Typical input offset current is very low and little to no trace separation is noticeable on the display.

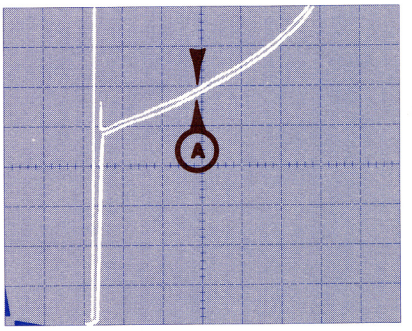



**Figure 3-2** + and − input bias current at increased vertical sensitivity can be displayed at the same time. Trace separation at center of display along vertical graticule line is amount of input offset incurrent. Point (A) is the area of measurement.

## TEST 4: COMMON-MODE REJECTION RATIO

Common-mode rejection ratio (cmrr) is the ratio of two different modes of signals required to obtain the same output. More specifically, it is the amount of signal applied together to both op amp inputs simultaneously, compared to the size of the signal that produces the same output if applied between the inputs differentially. The signal amplitude is normally measured in volts and fractions, while the ratio is expressed in decibels (dB).

In this test, the sweep generator output is applied to both op amp inputs, driving both in common mode over the set range. At the same time, the feedback loop keeps the op amp output at zero by supplying the required differential input to provide an equal and opposite op amp output as would be produced by the common mode input alone. Thus, at each point, the differential input voltage required to produce a given output is compared to the common mode voltage that produces the equal, but opposite, result.

### WHAT THE DISPLAY SHOWS

The vertical axis shows the differential voltage applied to the op amp inputs; the horizontal direction shows the applied common mode voltage. To obtain the cmrr, divide the horizontal deflection, including scale factors, by the vertical deflection, using the common-mode range specified. Specifications are met when this ratio, expressed in dB, falls within the stated value [70 dB over −10 V to +10 V].

**PROCEDURE:**

1) Set controls — Beginning with general Op Amp set-up, change controls as follows:

On 577:

- HORIZ VOLTS/DIV to smallest value at least 1/4 of specified common mode voltage excursion from zero [5 V] 22

On 178:

- FUNCTION to CMRR 49
- SOURCE RESISTANCE to 10 kΩ 47
- VERT UNITS/DIV to smallest value at least 1/3 of input required to produce defined output swing at specified CMRR [0.5 mV] 50
- SWEEP AMPLITUDE to minimum (ccw) 43

## TEST 4: COMMON-MODE REJECTION RATIO continued

2) Turn on device — Switch DUT SUPPLIES to ON. 46

3) Zero display — Press DISPLAY ZERO and hold in while centering display with VERT and HORIZ POSITION controls of 577. 48 27 26

4) Apply input — Advance SWEEP AMPLITUDE to obtain specified common-mode swing on horizontal axis. [2 divs each way from center]. 43

5) Measure trace — Press UPPER and LOWER STORE buttons on 577 to obtain clear, lasting trace. (If necessary, press UPPER and LOWER ERASE first to clear screen). Refer to Figure 4-1. 3 2

6) Calculate cmrr.

$$CMRR = \frac{\Delta \text{ Horiz}}{\Delta \text{ Vert}}$$

In decibels, gain $= 20 \log_{10} \frac{\Delta H}{\Delta V}$ dB.

Compare to specification value.

7) Check that horizontal range between sharp knees in curve is at least equal to specified input common mode range.

8) Turn off device — Switch DUT SUPPLIES to OFF. 46

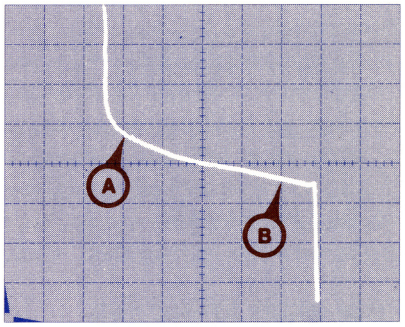



**Figure 4-1.** Common mode rejection ratio. Total voltage swing between measurement points (A) and (B) is 20 V. Cmrr is calculated by dividing horizontal change by vertical change, then multiplying by 20 $\log_{10}$ to convert to dB.

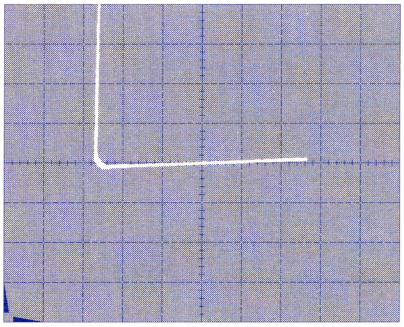


**Figure 4-2.** CMRR, same measurement with different display.

## TEST 5: GAIN

Gain is the ratio of op amp output voltage swing to input voltage change, measured over a specified range. While a curve tracer is particularly useful for verifying that the gain figure measured is applicable over the complete normal operating range of the intended use, gain is normally specified as a measurement based on two points.

In this test, the op amp being tested is made part of a feedback loop together with another amplifier supplied internally in the curve tracer. The sweep generator attempts to drive the op amp output over its working range, but the feedback loop supplies a voltage input to the op amp which, when amplified by the op amp, cancels out this voltage.

The op amp's offset voltage is cancelled out by a sample-hold circuit. The remaining input voltage supplied to the op amp being tested is therefore the amount required to, when amplified, supply a voltage equal to and opposite from that provided by the sweep generator.

## WHAT THE DISPLAY SHOWS

The display shows the output voltage on the horizontal, and a voltage equal to the opposite of the op amp input on the vertical. Specifications are met when the change in the vertical displacement is within the limits called for by the gain ratio. This measurement is normally taken between two defined output voltage points [less than 1 mV, or better than 1:200,000 at −10 to +10 V].

**PROCEDURE:**

1) Set controls — Beginning with general Op Amp set-up, change controls as follows:

On 577:

- HORIZ VOLTS/DIV to smallest value at least 1/4 of specified output voltage excursion from zero [5 V] 22

On 178:

- FUNCTION to GAIN 49
- LOAD RESISTANCE to value closest to specified amount [2 kΩ] 45
- VERT UNITS/DIV to smallest value at least 1/3 of input required to produce defined output swing at specified gain [1 mV] 50

## TEST 5: GAIN continued

2) Turn on device — Switch DUT SUPPLIES to ON. 46

3) Zero display — Press ZERO DISPLAY and hold in while centering display with VERT and HORIZ POSITION controls of 577. 48 27 26

4) Apply input — Advance SWEEP AMPLITUDE on 178 to obtain desired output swing on horizontal axis [2 divisions each way from center]. 43

5) Check gain against limits — Press UPPER and LOWER STORE buttons on 577 to obtain a clear, lasting trace. If necessary, press UPPER and LOWER ERASE first to clear screen. Check to see that vertical displacement is within specified value [1 div, or 1 mV] at specified points [+ and −2 divs from center], and that gain does not vary excessively over op amp's working output range. Refer to Figure 5-1. 3 2

**Optional Step**

6) Display actual gain — Switch VERT UNITS/DIV to smaller values until display almost fills screen vertically in region between horizontal points corresponding to specified domain. As necessary, press DISPLAY ZERO to center trace on screen. Press UPPER and LOWER ERASE to clear screen, UPPER and LOWER STORE to save display. Refer to Figure 5-2. 50 48 3 2

7) Calculate gain — Gain is ratio of horizontal to vertical displacement, including scale factors. In decibels, it is 20 times log of ratio:

$$\text{Gain} = \frac{\Delta \text{ Horiz}}{\Delta \text{ Vert}}$$

$$\text{Gain}_{dB} = 20 \log \frac{\Delta H}{\Delta V} \text{ dB.}$$

8) Turn off device — Switch DUT SUPPLIES to OFF. 46

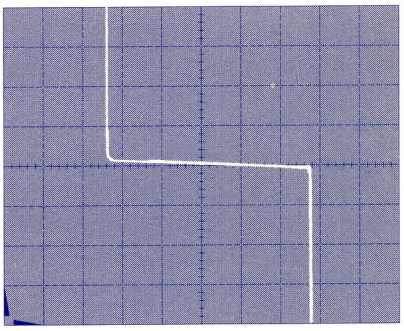


**Figure 5-1.** Gain curve with a 2-kΩ load, 1 mV/div vertical sensitivity.

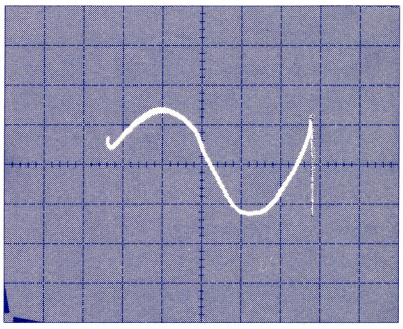


**Figure 5-2.** Gain curve with a 2-kΩ load, 50 μV/div vertical sensitivity.

## TEST 6: OUTPUT VOLTAGE SWING

The output voltage swing test assures that the op amp will produce its rated output voltage when operating into specified loads.

In this test, the op amp being tested is made part of a feedback loop together with another amplifier supplied in the curve tracer. The sweep generator attempts to drive the op amp output over its working range, but the feedback loop supplies a voltage input to the op amp which, when amplified, cancels out this voltage.

The op amp offset voltage is cancelled out by a sample-hold circuit. The output range over which the op amp continues to operate satisfactorily is the output voltage swing.

## WHAT THE DISPLAY SHOWS

The display shows the output voltage on the horizontal, and a voltage equal to the opposite of the op amp input on the vertical. Specifications are met when the usable gain slope is close enough to monotonic for the intended use and extends at least to the specified points on the horizontal (see Test 5 for explanation of gain measurements).

**PROCEDURE:**

It may be necessary to perform this test several times, once for each specified load resistance.

1) Set controls — Beginning with general Op Amp set-up, change controls as follows:

On 577:

- HORIZ VOLTS/DIV to smallest value at least 1/4 of specified domain excursion from zero [5 V] 22

On 178:

- FUNCTION to GAIN 49
- SOURCE RESISTANCE to 50 47
- VERT UNITS/DIV to smallest value at least 1/3 of input required to produce defined output swing at specified gain [1 mV] 50
- LOAD RESISTANCE to specified value [2 k, 10 k] 45

## TEST 6: OUTPUT VOLTAGE SWING continued

2) Turn on device — Switch DUT SUPPLIES to ON. 46

3) Zero display — Press ZERO DISPLAY and hold in while centering display with VERT and HORIZ POSITION controls of 577. 48 27 26

4) Apply input — Advance SWEEP AMPLITUDE on 178 to obtain desired output swing on horizontal axis.

5) Measure trace — Press UPPER and LOWER STORE buttons on 577 to obtain clear, lasting trace. If necessary, press UPPER and LOWER ERASE first to clear screen. Check to see that middle of the gain curve extends for sufficient horizontal length before making sharp turns to vertical off-screen directions near ends. [2 divs each way from center, equal to ±10 V at 2 k, and 2.4 divs, or ±12 V at 10 k]. Refer to Figures 6-1 and 6-2. 3 2

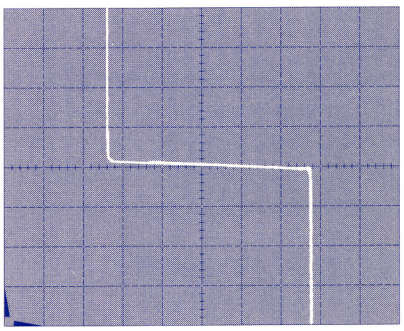


**Figure 6-1.** Output voltage swing with 2-kΩ load.

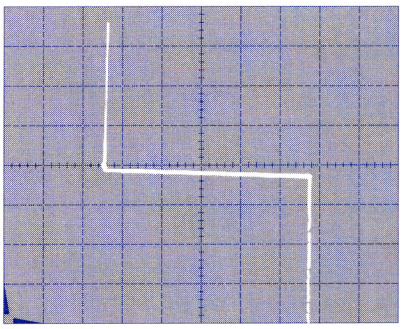


**Figure 6-2** Output voltage swing with 10-kΩ load.

Power supply voltage rejection ratios measure the effect of variations in the power supply voltage compared to the effects of changes in the input signal.

More specifically, rejection ratios are the amount of variations in the power supply voltage measured at the specified terminal divided by the size of the signal that produces the same output if applied between the op amp inputs differentially. The signal amplitude is normally measured in volts and fractions; the ratio is expressed in $\mu$V/V or decibels.

In these tests, the sweep generator is used to vary the voltage on the indicated power supply terminals:

Test 7 — Positive Power Supply Voltage Rejection Ratio (to the positive power input, driving it more positive).

Test 8 — Negative Power Supply Voltage Rejection Ratio (to the negative power input, driving it more negative).

Test 9 — Dual Power Supply Voltage Rejection Ratio (between the positive and negative power supply terminals, driving the voltages farther apart).

At the same time that the voltages on these terminals ar being varied, a feedback loop keeps the op amp output at zero by supplying the required differential input to provide an op amp output equal to and opposite from the output that would be produced by the power supply voltage variations, acting alone. This differential input signal is then compared with the corresponding power supply voltage variation applied.

## WHAT THE DISPLAY SHOWS

The vertical axis shows the differential voltage applied to the op amp inputs; the horizontal direction shows the variation applied to the power supply voltage under test (positive for Test 7, negative for Test 8, and the positive part for Test 9, although both positive nad negative actually vary in Test 9). To obtain the appropriate PSRR, divide the horizontal deflection, including scale factors, by the vertical deflection, using the power supply voltage range specified. Specifications are met when this ratio, expressed in $\mu$V/V or dB, falls within the stated value [150 $\mu$V/V].

**PROCEDURE:**

1) Set controls — Beginning with general Op Amp set-up, change controls as follows:

On 577:

- HORIZ VOLTS/DIV to smallest value at least 1/4 of specified supply excursion from its reference [5 V] 22

On 178:

- FUNCTION to +PSRR for Test 7 49
- FUNCTION to −PSRR for Test 8 49
- FUNCTION to ±PSRR for Test 9 49
- SOURCE RESISTANCE to 10 k 47
- VERT UNITS/DIV to smallest value at least 1/3 of input needed to produce defined output swing at specified PSRR [0.5 mV] 50
- SWEEP AMPLITUDE to minimum (ccw) 43

## TEST 7, 8 and 9: POWER SUPPLY REJECTION RATIO continued

2) Turn on device — Switch DUT SUPPLIES to ON. 46

3) Zero display — Press ZERO DISPLAY and hold in while centering display with VERT and HORIZ POSITION controls of 577. 48 27 26

4) Apply input — Advance SWEEP AMPLITUDE to obtain specified power supply swing on horizontal axis. 43

5) Measure trace — Press UPPER and LOWER STORE buttons on 577 to obtain clear, lasting trace. (If necessary, press UPPER and LOWER ERASE first to clear screen.) Refer to Figures 7-1, 8-1, and 9-1. 3 2

6) Calculate PSRR —

$$PSRR = \frac{\Delta \text{ Horiz}}{\Delta \text{ Vert}}$$

In dB: $PSRR = 20 \log_{10} \frac{\Delta H}{\Delta V}$ dB.

7) Compare to specifications value.

8) Turn off device — Switch DUT SUPPLIES to OFF. 46

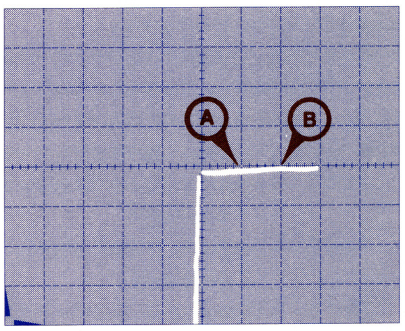



**Figure 7-1.** +Power supply voltage rejection ratio. Points (A) and (B) are voltage levels, 5 V and 10 V respectively. Change of 5 V in positive supply is comparable to approximately 0.2 mV of signal between its inputs. Ratio of 10 V (±5 V) to 0.2 mV equals 50,000.

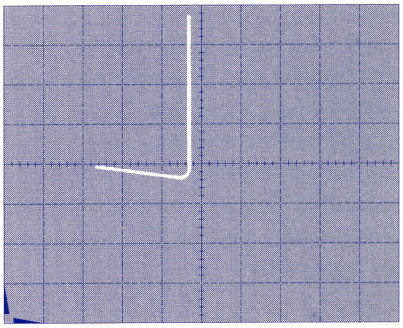


**Figure 8-1.** −Power supply voltage rejection ratio.

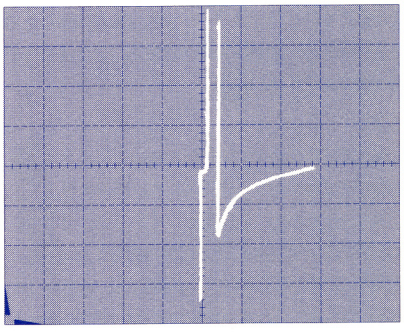


**Figure 9-1.** Dual power supply voltage rejection ratio.

## INTRODUCTION

The increasing use of on-board three-terminal regulators has also created a need for a fast and easy means of testing these devices. The TEKTRONIX 577-D1 Storage Curve Tracer and 178 Linear IC Test Fixture with its Three-Terminal Regulator Test Unit is often the solution, particularly for short-run incoming inspection, circuit design, or device characterization.

The regulator test unit comes in two similar models, one wired for negative regulator devices and one for positive units. Each slides into the 178 Linear IC Test Fixture, which is itself a slide-in module for the 577 Curve Tracer. A snap-on escutcheon plate for the 178 function switch customizes the Curve Tracer function switch to either negative or positive regulator test units. The device under test (abbreviated DUT) is placed in an appropriate mating socket adapter that connects it to the regulator test unit.

Functionally, the 577 Mainframe supplies the display and its controls, primary power supply, and a sweep generator that can act as a variable source or load. The 178 Linear IC Test Fixture further regulates the supply voltages and provides the function selector switch, which sets up the internal circuits for the appropriate tests. The Regulator Test Unit has its own specialized power supply range switch and output voltage comparison standard.

In most tests, the sweep generator on the 577 Mainframe is used to vary either the regulator load or supply, and the effect is viewed by comparing the output voltage with the comparison standard.

**NOTE:** These procedures have been designed to be sufficiently general for testing most individual devices in the 3-terminal regulator family. However, this section also provides actual settings, check values, and part numbers necessary for testing a specific regulator (7805 C). This information is given in brackets at appropriate points throughout the section.

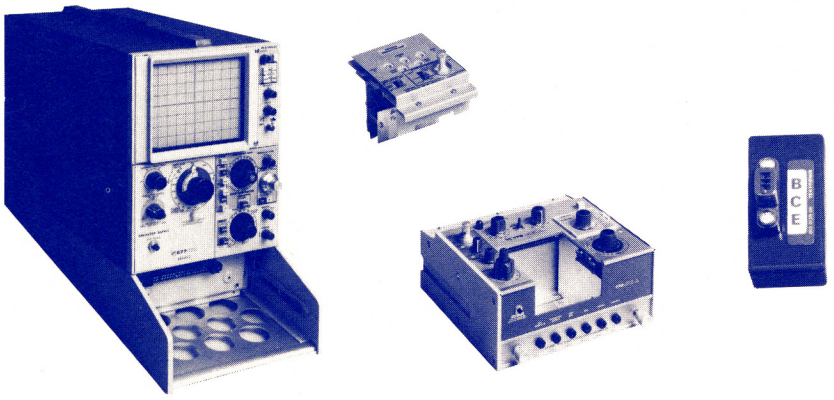
This section provides instructions for the specific tests listed below. These are preceded by general set-up instructions.

1) Load regulation
2) Line Regulation
3) Quiescent or common current

## GENERAL SET-UP

**EQUIPMENT REQUIRED:**

577-178-D1 Linear IC Curve Tracer with storage, Three-Terminal Regulator Test Unit, socket adapter [Small In-Line Adapter, Tektronix part number 013-0139-00], regulator to be tested [7805 C], and specifications for that regulator.




**SET-UP:**

1) Prepare device adapter if necessary — Using Figure 0-1, prepare test adapter. Label adapters wired for positive regulators. (CBE)

2) Install 178 — If 178 fixture is not already installed in 577, do so first (with power off). See Figure 0-2.

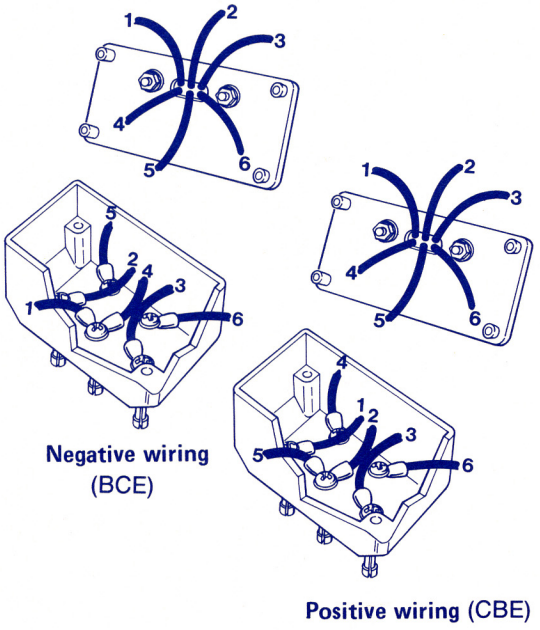



**Figure 0-1.** Modifying device adapter for positive voltage regulator. (CBE)

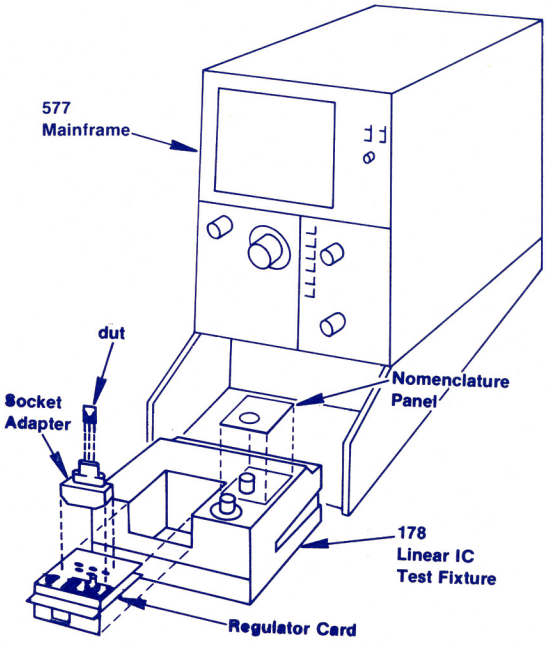
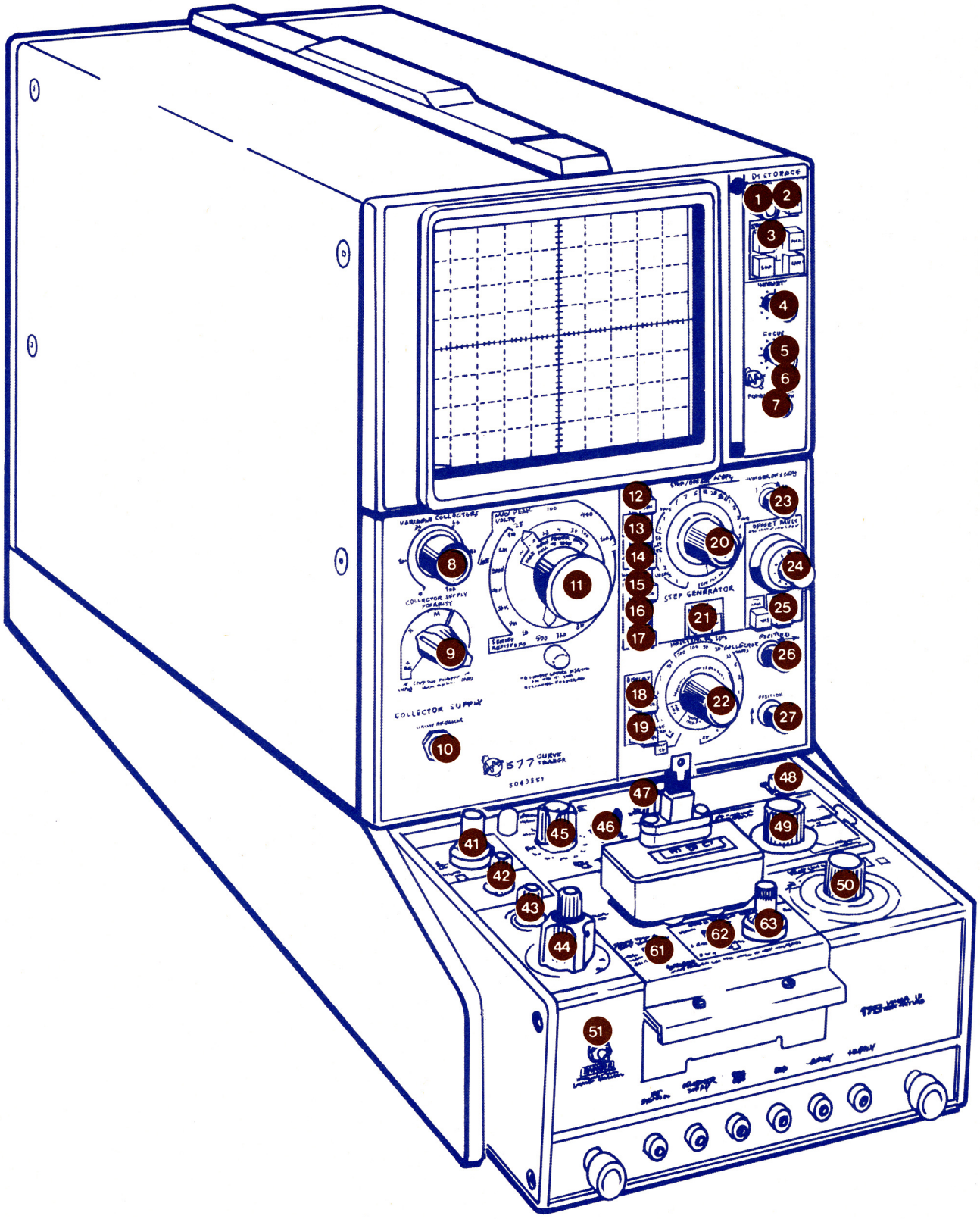



**Figure 0-2.** Installing 178 into 577 Mainframe.

## GENERAL SET-UP DIAGRAM



## GENERAL SET-UP continued

3) Install compensating capacitor if required — If compensating capacitor is required by regulator to be tested, install between two points on regulator circuit board as marked. See Figure 0-3.

4) Insert regulator test unit — Lower unit vertically into front of 178, then slide toward rear. See Figure 0-4.

5) Set initial conditions— referring to 3—Term Reg set-up diagram (foldout), set controls as follows:
NOTE: This preliminary procedure has been designed to be applicable to all of the following tests. In each case, the detailed test procedure contains minor modifications to the settings of this procedure. Thus, it is possible to perform only one, some, or all of the tests, in any sequence.

On 577:

- MAX PEAK VOLTS to 25 if maximum input voltage will be less than 15 V, 100 if more. (Note that INTERLOCK DEFEAT button must be held in during device-operation part of each test if 100-V setting is used). [25 V] 11
- MAX PEAK POWER-WATTS to 100 11
- DISPLAY FILTER in (off) 19
- DISPLAY INVERT in (normal) 18
- HORIZ VOLTS/DIV to 5 V 22
- X10 HORIZ MAG in (off) 26
- X10 VERT MAG in (off) 27
- BRIGHTNESS control to maximum (cw) 1
- UPPER and LOWER STORE out (non-store) 3
- UPPER and LOWER ERASE in (ready to erase) 3
- INTENSITY control to minimum (ccw) 4
- HORIZ POSITION to center 26
- VERT POSITION to center 27
- COLLECTORS SUPPLY POLARITY to + 9 (not +DC) for positive regulators, — for negative regulators [+]
- VARIABLE COLLECTOR % to maximum (cw) 8
- Press STEP FAMILY-SINGLE in and release (single-family) 14
- PULSED 300 $\mu$S in 12
- OFFSET ZERO in 25

Ignore STEP/OFFSET AMPL, OFFSET AID, NUMBER OF STEPS, OFFSET MULTIPLIER, STEP X.1. 20 25 23 24 20

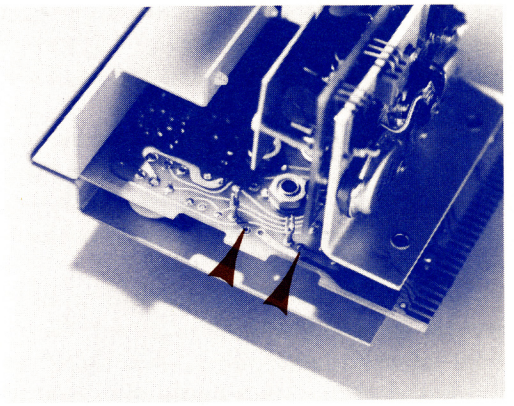


**Figure 0-3.** Installing compensating capacitor on regulator board. Note arrows.

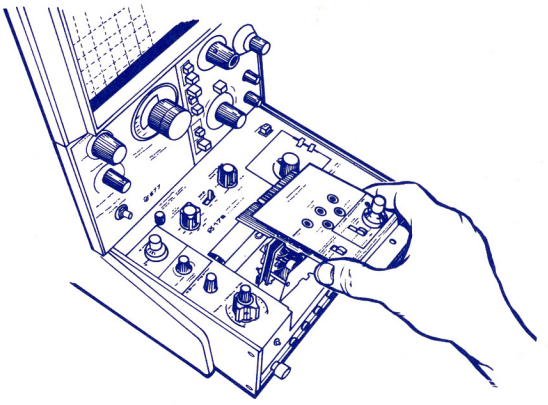


**Figure 0-4.** Installing regulator test unit into 178.

## GENERAL SET-UP continued

On 178:

- Install function plate. See Figure 0-5.
- DUT SUPPLIES to off 46
- + SUPPLY to either: a) specified input voltage to regulator, if this is less than 30 V, or b) if greater than 30 V, to 1/2 of required input volts (switch on regulator test unit will be set double this voltage). In either case, maximum usable voltage is limited to approximately two-thirds of collector supply voltage setting on 577. 41
- + SUPPLY to [10 V] 41
- – SUPPLY to required voltage only if different in magnitude from + SUPPLY (again, possibly using voltage doubling switch); to TRACK + SUPPLY if same in magnitude but opposite in polarity. 42
- SWEEP AMPLITUDE to minimum (ccw) 43
- SWEEP FREQUENCY to .1Hz 44
- FUNCTION to LOAD REGULATION 49
- VERT UNITS/DIV to 50 mV 50

Ignore LOAD RESISTANCE, SOURCE RESISTANCE. 45 47

On regulator test unit:

- SUPPLY RANGE to 0 to 30 V if required input voltage to DUT is under 30 V, 0 to 60 V if required voltage is 30 to 60 V. (Note: Make certain that +SUPPLY controls on 178 are set to appropriate value. Details are provided in that section). [0 to 30 V] 61
- OUTPUT VOLTAGE COMPARISON SWITCH to 0 to 10 V MANUAL, unless regulator output is above 10 V (In latter case, to 0 to 100 V MANUAL.) 62
- OUTPUT VOLTAGE COMPARISON DIAL to nominal regulator output voltage [5 V] 63

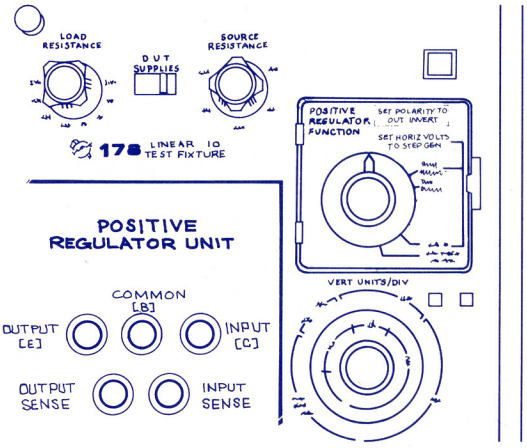



**Figure 0-5.** Installing function plate.

## GENERAL SET-UP continued

6) Obtain trace — Using controls on 577:

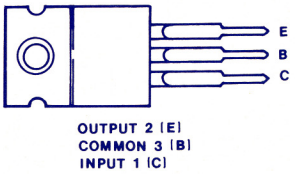
a) Pull POWER ON switch. Wait for warm up. 7

b) Find spot — Press BEAM FINDER button in and advance INTENSITY control until spot is clearly visible. 6 4

c) Center spot — Press and hold display zero button. Using VERTICAL and HORIZONTAL POSITION controls, center spot. Use BEAM FINDER to see direction from center if spot is off-screen. 48 26 27 6

7) Insert device — Insert socket adapter in regulator test unit. Insert device to be tested in socket. See Figure 0-6

Proceed to selected test.



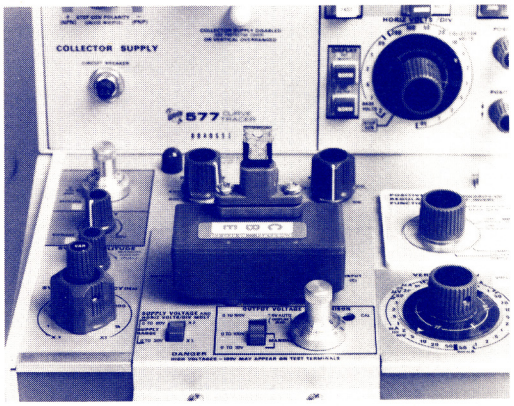




**Figure 0-6.** Device inserted in socket.

## TEST 1: LOAD REGULATION

Load regulation is the change in regulator output voltage over the specified range of load current, with provision made to keep chip temperature constant.

This test is done on the curve tracer using the step generator as a current sink or variable load. The step generator pulse mode is employed to provide a load that is active for only a small part of the duty cycle, thus keeping chip dissipation low and possible temperature rise small.

### WHAT THE DISPLAY SHOWS

The display shows output voltage deviation from the comparison voltage on the vertical axis, and load current on the horizontal. Specifications are met when the trace stays between the stated limits on the vertical over the entire horizontal range of interest.

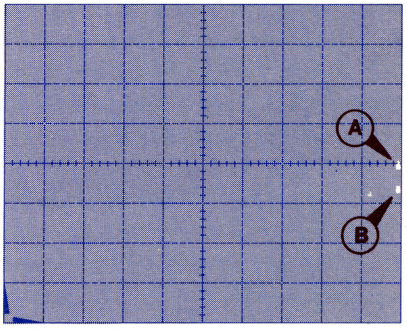



**Figure 1-1.** Load Regulation Test. Point (A) is obtained by pressing DISPLAY ZERO and adjusting positioning controls. Point (B) is obtained when DISPLAY ZERO is not pressed.

### PROCEDURE:

1) Set controls— Beginning with general 3-Term Reg set-up, change the controls as follows:

   On 577:
   - STEP/OFFSET POLARITY NORM out (invert) 21
   - STEP/OFFSET AMPL to smallest value at least 1/8 of maximum rated regulator current. [200 mA] 20
   - Press and release STEP X.1 button. (Note that lighted display area will indicate correct step settings.) 20
   - NUMBER OF STEPS to 1 (ccw) 23
   - HORIZ VOLTS/DIV to STEP GEN 22

2) Obtain zero trace — Using controls on 178:

   a) DUT SUPPLIES switch to on. 46

   b) While holding DISPLAY ZERO button, use VERT and HORIZ POSITION to move spot half way up graticule on right edge for positive regulators, or left edge for negative ones. See Figure 1-1. 48 27 26

3) Set comparison voltage — Adjust OUTPUT VOLTAGE COMPARISON dial to again position spot half way up graticule. If spot is off-screen, press BEAM FINDER to compress display and show spot direction from center. Value on OUTPUT VOLTAGE COMPARISON dial is regulator no-load output voltage. [5 V]. 63 6

## TEST 1: LOAD REGULATION continued

4) Obtain trace over full range — Press STEP FAMILY REP button in. Turn NUMBER OF STEPS fully clockwise (providing approximately 95 steps). See Figure 1-2. 13 23

5) Position for easy reading of display — Reset VERT UNITS/DIV so trace crosses bottom graticule line at point near maximum rated load current on horizontal axis. [7.5 divisions representing 1.5 A]. See Figure 1-3. Then use OUTPUT VOLTAGE COMPARISON dial to make fine adjustment so trace crosses bottom graticule line exactly at rated load current point. 50 63

6) Measure trace — Press UPPER and LOWER STORE buttons on 577 to obtain clear trace. (If necessary, press ERASE button to clear screen.) Using VERT UNITS/ DIV as scale factor, measure indicated change in output voltage on vertical axis over specified load current range on horizontal. Compare to specification value. [100 mV max]. 3 2 50

OPTIONAL STEPS

7) Measure low current end with more precision — After storing display in step 6, decrease INTENSITY control, but leave UPPER and LOWER STORE buttons in. Reset OFFSET AMPL to about 1/4 of its present value. Advance INTENSITY control on 577 to provide second trace on screen. See Figure 1-4. Use this second trace to measure output voltage variation over low end of regulator load range (using 50 mA STEP/OFFSET AMPL setting, for example each dot represents 5 mA load current). 4 3 20 50 63

8) For greater resolution, decrease VERT UNITS/DIV while adjusting OUTPUT VOLTAGE COMPARISON to keep trace on screen.

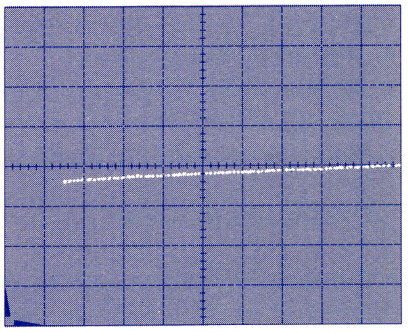


**Figure 1-2.** Load Regulation Test. Trace was obtained by resetting the OUTPUT VOLTAGE COMPARISON control so that trace aligns with center graticule line.

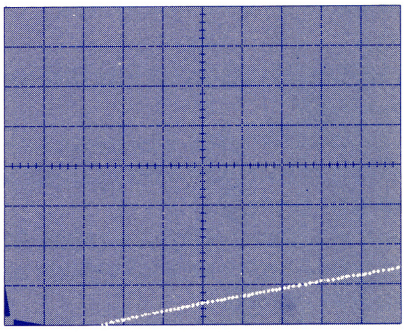


**Figure 1-3.** Display of load regulation.

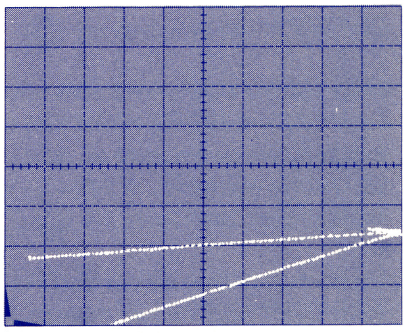


**Figure 1-4.** Load Regulation Test. Trace (1) is same display as obtained in step 5, Figure 1-3. Trace (2) is display of regulator output variation over low end of load range.

## TEST 1: LOAD REGULATION continued

9) Set OFFSET AMPL to approximately 1/15 of maximum rated output current [100 mA]. Set VERT UNITS/DIV to 50 mV and press ERASE button. Horizontal divisions from 2.5 to 7.5 represent central part of regulator range [250 mA to 750 mA]. Measure change in vertical displacement over this length to obtain load regulation for this range. For greater resolution, decrease VERT UNITS/DIV (adjust OUTPUT VOLTAGE COMPARISON if necessary to keep trace on screen). Compare to specified value [25 mV max]. 20 50 2 63

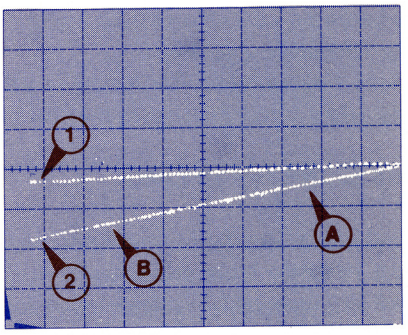



**Figure 1-5.** Load Regulation Test. Trace (1) is what display will look like at 50 mV/div. Trace (2) is obtained by decreasing vert units/div to 10 mV. Display shows central part of regulator range. Point (A) is 250 mA and point (B) is 750 mA.

## TEST 2: LINE REGULATION

Line regulation is the change in regulator output over a specified range of input voltage, with provisions made to keep the chip temperature constant.

The curve tracer provides the necessary test conditions by adding a swept voltage to the input voltage supply while providing a constant, short duty-cycle load for the output.

## WHAT THE DISPLAY SHOWS

The vertical axis of the display represents regulator output voltage deviation from the comparison voltage; the horizontal axis represents regulator input voltage.

Specifications are met when the trace stays between stated limits on the vertical axis over the entire horizontal range of interest.

### PROCEDURE:

1) Set controls— Beginning with general 3-Term Reg set-up, change controls as follows:

   On 577:
   - VARIABLE COLLECTOR % to minimum (ccw) 8
   - STEP/OFFSET POLARITY NORM out (invert) 21
   - Press STEP X.1 in (off) 20
   - STEP/OFFSET AMPL to value closest to 1/5 of load current given in device specification [100 mA] 20
   - NUMBER OF STEPS to 1 (ccw) 23
   - HORIZ VOLTS/DIV to smallest value at least 1/8 of maximum specified input voltage. [5] 22

   On 178:
   - + SUPPLY to maximum value of input range to be tested. [25 V] (For + SUPPLY voltages greater than 15 V, set MAX PEAK VOLTS control to 100 V.) 41 11
   - SWEEP FREQUENCY to 0.1 Hz 44
   - SWEEP AMPLITUDE to 0 43
   - FUNCTION to LINE REGULATION 49
   - VERT UNITS/DIV to approximately 1/5 of specified output voltage variation. [10 mV] 50

2) Obtain zero trace — Slide DUT SUPPLIES switch to on. Press and hold DISPLAY ZERO button and, using POSITION controls on 577, position spot half way up graticule on left edge for positive regulators, right edge for negative ones). 46 48 26 27

## TEST 2: LINE REGULATION continued

3) Set comparison voltage — Press and hold red INTERLOCK DEFEAT button to supply power to DUT. Set VARIABLE COLLECTOR % to approximately 25. Set OUTPUT VOLTAGE COMPARISON dial to position spot half way up graticule vertical axis. See Figure 2-1. Rotate VARIABLE COLLECTOR % to move spot toward center of screen and obtain well defined round spot. Notice when +SUPPLY overload light on the 178 test fixture extinguishes and stop at that point. Rotating VARIABLE COLLECTOR % even 1 degree farther may prevent display from appearing in step 5. See Figure 2-2. Value on the OUTPUT VOLTAGE COMPARISON dial is regulator no-load output voltage. 51 8 41 63

4) Set load — Press STEP FAMILY REP button in. Adjust NUMBER OF STEPS to provide 6 dots (five steps). 13 23

5) Adjust scale factors — Adjust VERT UNITS/DIV for greater dot separation, but do not allow sixth dot to move off screen at bottom. If necessary, re-adjust OUTPUT VOLTAGE COMPARISON control to keep top dot at center of graticule. (See Figure 2-3.) Advance SWEEP AMPLITUDE to provide specified input voltage sweep (shown on the horizontal) required. [1.4 to 5 divs, or 7 to 25 V]. Bottom trace (see Figure 2-4) approximately represents load [500 mA] for this test. 50 63 43

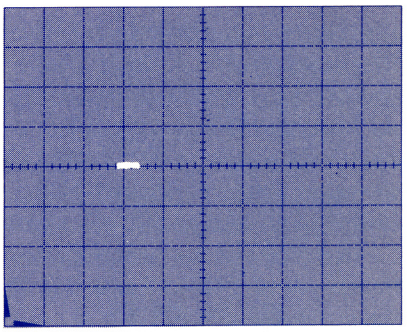


**Figure 2-1.** Trace was obtained by setting VARIABLE COLLECTOR % control to approximately 25.

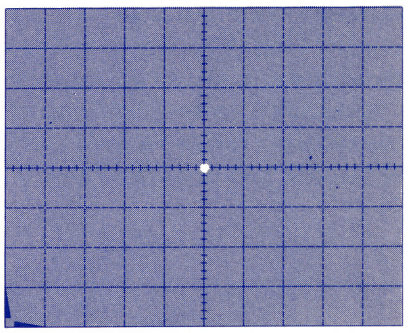


**Figure 2-2.** A well defined spot brought to center of screen by the OUTPUT VOLTAGE COMPARISON control.

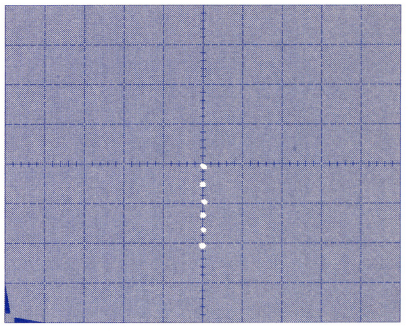


**Figure 2-3.** VERT UNITS/DIV was changed to 5 mV.

## TEST 2: LINE REGULATION continued

6) Measure trace — Press UPPER and LOWER STORE buttons on 577 to obtain clear trace. (If necessary, press ERASE button to clear screen.) Then turn INTENSITY down. Looking at bottom trace and using VERT UNITS/DIV as scale factor, measure indicated change in output voltage on vertical axis over specified input voltage range on horizontal. Compare to specification value. [100 mV over 7 to 25 V]. See Figure 2-4. 3 2 4 50

7) Measure low voltage end with more precision — After storing display in step 6, decrease INTENSITY, but leave UPPER and LOWER STORE buttons in. Reset HORIZ VOLTS/DIV to approximately 1/4 of previous value. [1 V]. Advance INTENSITY control on 577 to provide second trace on screen. Use second trace (with its expanded horizontal deflection factor) to measure output voltage variation over low end of regulator load range. See Figure 2-5. 4 3 22

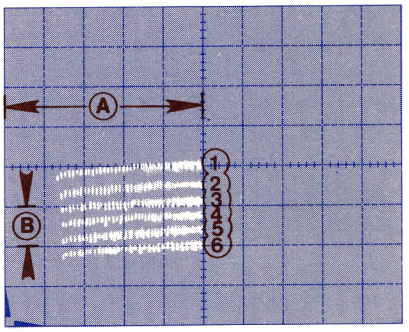



**Figure 2-4.** Input voltage change horizontally versus output voltage change vertically at 5 different load settings. Point (A) is 25 V input voltage swing. Traces (1) thru (6) are 0.0 ma, 100 ma, 200 ma, 300 ma, 400 ma and 500 ma. Point (B) indicates 5 mV/div sensitivity.

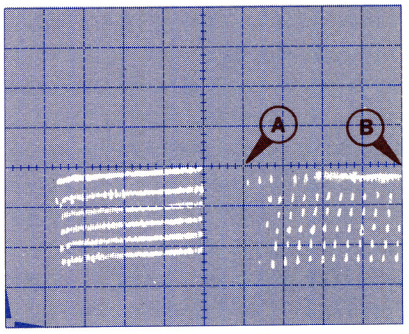



**Figure 2-5.** Display to right of center vertical graticule line obtained by setting HORIZ VOLTS/DIV to 1 V. Curves show output variation over low end of regulator load range. Points (A) & (B) are 6 Volts and 10 Volts.

## TEST 2: LINE REGULATION continued

8) Measure central input voltage range — Turn down INTENSITY and press LOWER and UPPER ERASE. Reset + SUPPLY to upper end of central region. [12 V]. Set HORIZ VOLTS/DIV to approximately 1/5 of this value [2V, COLLECTOR VOLTS] and SWEEP FREQUENCY VARIABLE counterclockwise to approximately midrange (approximately 0.05 Hz). Turn up INTENSITY and allow full sweep to be stored, then turn INTENSITY back down. Using bottom curve on display, read line regulation vertically between horizontal end points of region of interest. [8 V (4 major divs from left) and 12 V (6 major divs from left)]. Compare with specifications. [50 mV]. See Figure 2-6. 4 3 41

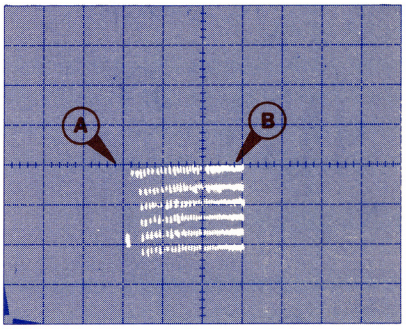



**Figure 2-6.** Central input voltage range. Points (A) & (B) are 8 volts and 12 volts.

## TEST 3: QUIESCENT OR COMMON CURRENT

Quiescent current is the current used by the regulator for its internal functioning and then routed out through the third (ground) terminal.

The curve tracer provides a display of steady-state quiescent current, plus two tests of quiescent current changes, the first with constant load and line (input) voltage change, and the second with constant input voltage and changes in the load. Changes in input voltage are provided by the sweep generator on the 178 Linear IC Test Fixture; load changes are produced by using the 577 step generator in the current-sinking mode.

### WHAT THE DISPLAY SHOWS

The vertical direction of the display represents the common terminal current; the horizontal axis shows load current.

Specifications are met when the trace stays between the stated vertical limits over the full operating range of interest indicated on the horizontal axis.

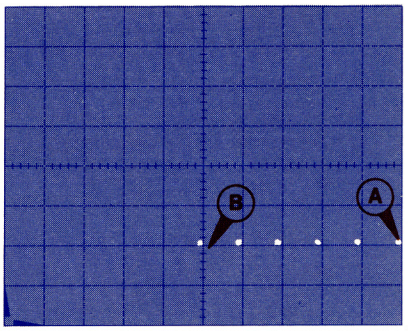



**Figure 3-1.** Quiescent current shown in display. Zero current is at center of screen. Display shows approximately 4 mA of quiescent or common current. Point (A) is 0.0 mA output load. Point (B) is 500 mA output load.

**PROCEDURE:**

1) Set controls— Beginning with general 3-Term Reg set-up, change controls as follows:

   On 577:
   - STEP/OFFSET POLARITY NORM out (invert) 21
   - STEP X.1 in 20
   - STEP/OFFSET AMPL to approximately 1/5 of specified load current for this test. [100 mA] 20
   - HORIZ VOLTS/DIV to STEP GEN 22

   On 178:
   - FUNCTION to I COMMON 49
   - VERT UNITS/DIV to approximately 1/4 of maximum specified quiescent current. [2 mA] 50

2) Obtain zero trace — Slide DUT SUPPLIES switch to on. Press and hold DISPLAY ZERO button and, using POSITION controls on 577, position spot half way up graticule on right edge (for positive regulators, left edge for negative ones.) 46 48 26 27

3) Check steady-state quiescent current — Press STEP FAMILY REP button. Turn NUMBER OF STEPS control clockwise until five steps (six spots) are displayed. Vertical displacement from center line of sixth horizontal dot from right, which represents approximately specified load [500 mA], is quiescent current. Compare to specification. [8.0 mA]. See Figure 3-1. 13 23

## TEST 3: QUIESCENT OR COMMON CURRENT continued

4) Set to display quiescent current with line change — Reset VARIABLE COLLECTOR % to 0, MAX PEAK VOLTS to 100, + SUPPLY to upper limit of specified input voltage range [25 V], VERT UNITS/DIV to approximately 2 times specification value for quiescent current change [2 mA], and pull X10 VERT MAG. Press and hold interlock defeat button and increase VARIABLE COLLECTOR % until + SUPPLY OVERLOAD lamp extinguishes. Using vertical POSITION control, position sixth spot to bottom graticule line. See Figure 3-2. 8 11 27 27 41

5) Store and measure trace — Press UPPER and LOWER STORE buttons, and then decrease + SUPPLY dial on 178 to lower end of input voltage range being tested. [7 V]. Then decrease display intensity. Vertical height of sixth line (fifth step) represents change in quiescent current (include X10 magnification factor). Compare with specifications. [1.3 mA or 6.5 divs]. See Figure 3-3. 3 41

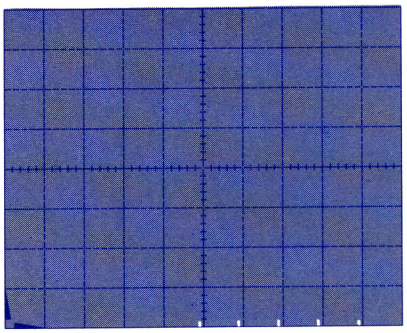


**Figure 3-2.** Sixth dot at bottom center graticule line representing 500 mA output current load.

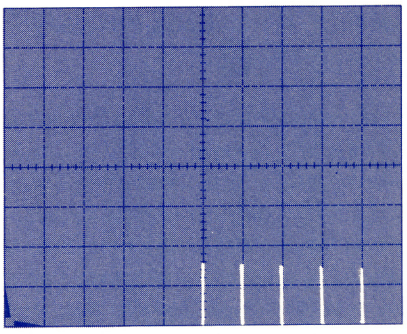


**Figure 3-3.** Display showing quiescent current with input line voltage change. Bottom end of sixth vertical trace equals 25 V; top end equals 7 V. Specifications are met when sixth vertical trace is no higher than 6.5 divs. (VERT UNITS/DIV = 0.2 mA; with X10 VERT MAG, 0.2 ma x 6.5 div=1.3 mA as specified.

## TEST 3: QUIESCENT OR COMMON CURRENT continued

6) Set to display quiescent current with load change — Reset controls as follows:

- DUT SUPPLIES to off (46)
- MAX PEAK VOLTS to at least twice specified input voltage [25 V] (11)
- VARIABLE COLLECTOR % to 100 (8)
- STEP/OFFSET AMPL to approximately 1/5 of maximum load current specified for this test [200 mA] (20)
- + SUPPLY to rated input voltage [10 V] (41)
- VERT UNITS/DIV to 1 mA. (50)
- X10 VERT MAG out (27)
- Switch DUT SUPPLIES to ON, then adjust display to center screen using vertical POSITION control (46) (27)
- NUMBER OF STEPS to 6 (7 spots) (23)
- Press STEP X.1 to release to out position. See Figure 3-4. (20)

7) Store and measure trace — Press UPPER and LOWER STORE buttons on 577 to obtain clear trace. (If necessary, also press UPPER and LOWER ERASE buttons to clear screen.) Then, turn down display INTENSITY control. Measure change in vertical displacement (taking into account X10 magnification) over horizontal range of interest. [5 mA to 1 A]. Compare with specified value. [0.5 mA, or 5 vertical divs]. See Figure 3-4. (3) (2) (4)

OPTIONAL STEP

8) Measure low current end with more precision — After storing display in step 8, decrease INTENSITY, but leave UPPER and LOWER STORE buttons in. Reset STEP/OFFSET AMPL to approximately 1/20 of present value. Advance INTENSITY control on 577 to provide second trace on screen. Use this second trace to measure output voltage variation over low end of regulator load range. See Figure 3-5. (4) (3) (20)

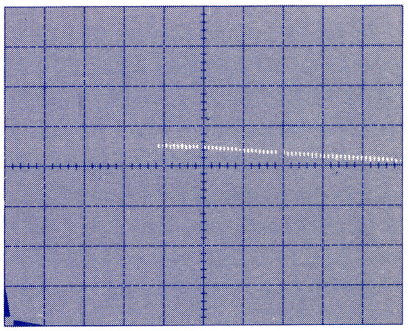


**Figure 3-4.** Change in common current as output load is changed. Each horizontal division along the trace equals 200 mA (20 ma/dot).

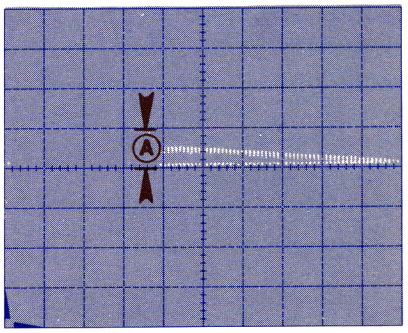



**Figure 3-5.** Display of quiescent current. Upper trace is same as shown in Figure 3-4. Lower trace shows output voltage variation over low end of regulator load range. Each horizontal division along trace equals 10 mA (1 mA/dot). Point (A) is 100 μA/div.