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TEKTRONIX®

035-5028-00

SCR TURN-OFF TIME ADAPTER

INSTRUCTION MANUAL

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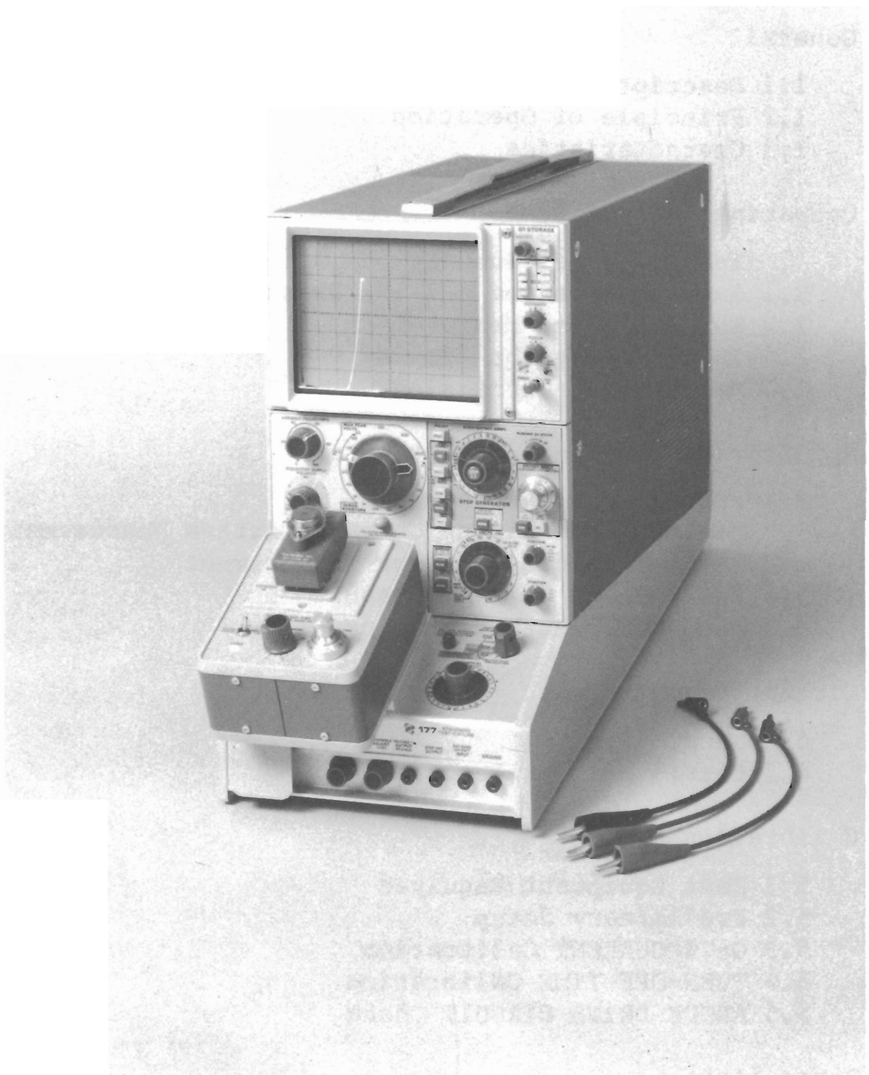


035-5028-00 TURN-OFF TIME ADAPTER (INSTALLED, WITH ACCESSORIES)

P/n 035-5028-00 SCR Turn-Off Time Adapter, installed on Type 177 Standard Test Fixture in Type 577/D1 Storage Curve Tracer, with TO-3 Adapter and SCR. Test-lead accessories shown alongside.

SCR TURN-OFF TIME ADAPTER

SECTION 1 - GENERAL

1.1 Description. The p/n 035-5028-00 SCR Turn-Off Time Adapter is designed for use with the 577/D1 or 577/D2 Curve Tracer and 177 standard test fixture to evaluate turn-off time characteristics of silicon controlled rectifiers (SCR's) over a range of forward currents up to 5 amperes.

Anode current for the device under test is supplied by the 577 Collector Sweep circuits. The 577 Step Generator is used as a power supply and timing source for the adapter, which supplies gate drive and anode commutation (turn-off) to the SCR under test.

The SCR Turn-Off Time Adapter plugs into the banana jacks on the sloping upper panel of the 177 standard test fixture. For SCR's designed for socket-mounting, the furnished TO-3 adapter or other passive adapters may be plugged into the banana jacks on the adapter panel. For stud-mount and other SCR types not fitting available adapters, a set of three clip-leads is furnished, for connection to the terminals of the device.

1.2 Principle of Operation. Turn-off time of the SCR under test is measured by turning on the SCR by application of gate drive during the positive-going portion of the Collector Sweep waveform, then removing gate drive and reversing the SCR anode current for a calibrated time (continuously adjustable from 5 to 105µs), after which forward voltage is again applied. If the SCR resumes conduction, its turn-off time exceeds the preset value. If the SCR remains "off", the device turn-off time is less than the preset value. The applied commutation interval is adjusted until the two are equal (for the peak anode current and the temperature at which the test was performed), and the duration of the commutation interval is read from the adapter dial. The SCR anode source voltage and current (hence, its on or off state) are indicated by the 577 CRT display.

1.3 Characteristics. Listed performance characteristics are applicable over the normal laboratory/shop temperature range of 10° to 40°C (50° to 105°F) if calibrated at 20° to 30°C. The system may be used outside this temperature range, but only with some loss of accuracy and current capabilities in the 577, 177 and the adapter.

Characteristic	Performance Requirement	Notes
ANODE		
Anode Source Voltage	0-6V, 0-25V	Half sine-wave
Anode Current (Maximum)		
0-6V Range	5A peak	Controlled and measured by 577/177
0-25V Range	2.5A peak*	
Current Measurement Accuracy	±(3% + 8mA)	8 mA peak looping error on 25V range.
Commutation Interval	5 to 105 µs	Continuously Variable
Calibration Accuracy	±(3% + 0.2µs)	SCR turn-off time is 0.3 to 5 µs longer. Correction table required at low anode currents.
Anode Voltage during Commutation Interval	-0.5 to -1V	
Rate of Reapplied Voltage	5V/µs maximum	
GATE		
Turn-on Current	0 to 80mA	Continuously Variable
Calibration Accuracy	±5% full-scale	
Duration	4 ms, approx.	
Off-state Leakage Withstand	Up to 50 mA	Z_o typically 1 to 3Ω during off state.
TEST RATE	2X Line Frequency	120 Hz for 60 Hz line.

Additional information on test conditions will be found in Section 3 (Paragraph 3.5) of this manual.

*Recurrent rating. Up to 5A may be drawn briefly, but will trip the 577 circuit breaker.

Turn-Off Time Measurement -- Index and Brief Summary

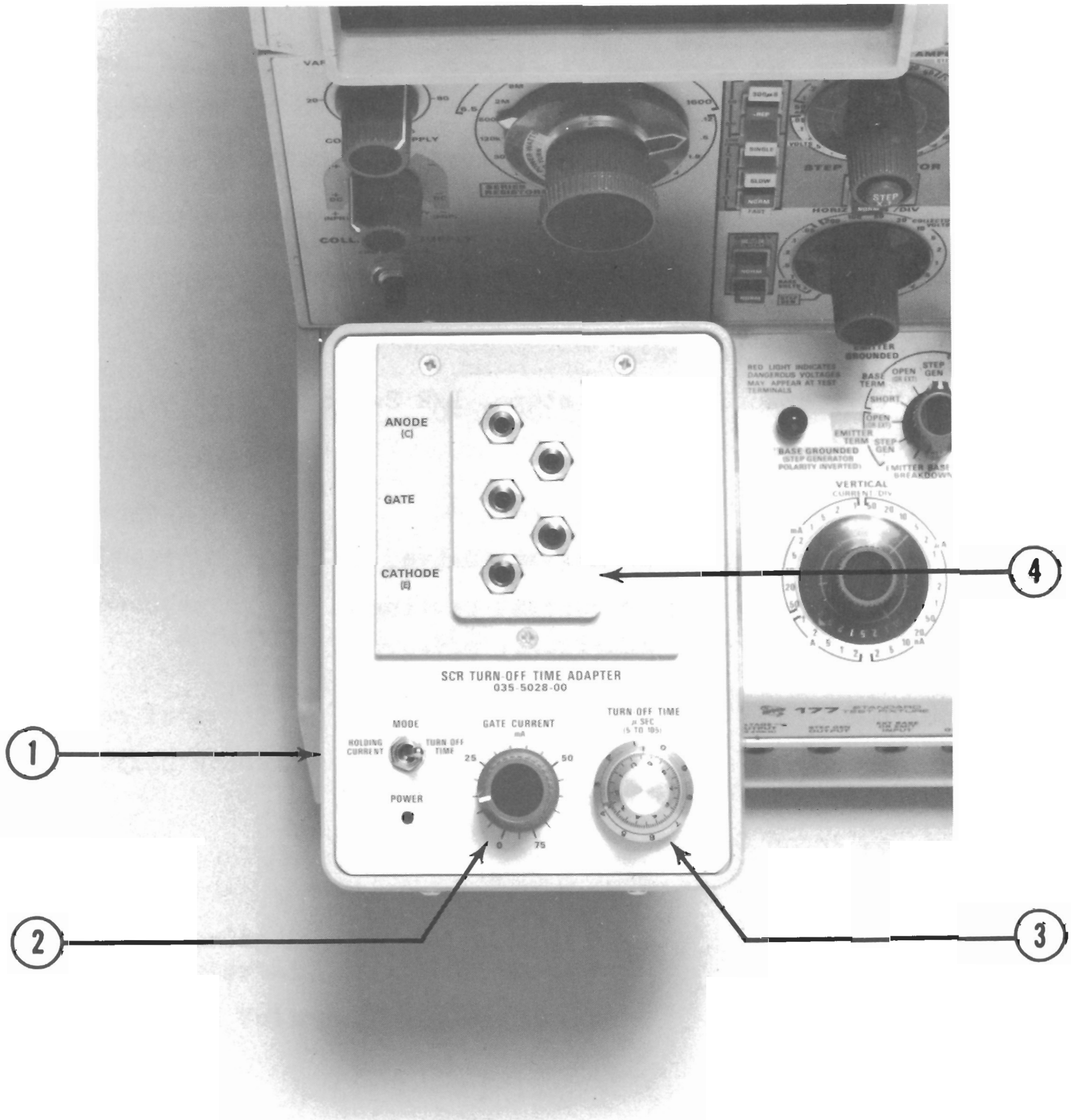


FIGURE 2-1 PANEL CONTROLS AND CONNECTORS.

(1) MODE Switch. Selects Holding Current (no turn-off pulse) or Turn-Off Time operating mode.

(2) GATE CURRENT Control. Adjusts gate current of SCR under test over a calibrated range of 5 to 80 mA, or to essentially 0mA.

(3) TURN-OFF TIME Control. Ten-turn control adjusts duration of the turn-off pulse from 5 to 105 µs. Outer dial reads tens of microseconds; inner dial reads microseconds. Reading shown, 9.4 µs.

(4) Fixture plate. Right-hand pair of jacks are wired in parallel with ANODE (Upper) and CATHODE (Lower) jacks of left-hand set.

2.1 Installation and 577/177 Presets.

2.1.1 177 Standard Test Fixture. Install the 177 Standard Test Fixture in the fixture compartment of the 577. Preset the 177 controls as follows:

*Terminal Selector:	Emitter Grounded, Step Gen
LEFT-RIGHT	Off (center position)
VERTICAL CURRENT/DIV	1A

2.1.2 577 Curve-Tracer Presets:

Collector Sweep Group

*COLLECTOR SUPPLY POLARITY	+
MAX PEAK VOLTS	6.5
SERIES RESISTORS	120
VARIABLE COLLECTOR %	0 (ccw)

Step Generator Group

Pushbuttons:

*STEP X .1	In
*300µs	Out
*REP	In
*FAST	In
*Polarity NORM	In
*ZERO	Out
*AID	In

Other Controls:

*STEP/OFFSET AMPL	2V
*OFFSET MULT	10.0 (cw)
NUMBER OF STEPS	1

Display Group

HORIZONTAL VOLTS/DIV	1
(Horizontal) POSITION	Centered, and In (MAG Off)
(Vertical) POSITION	Centered, and In (MAG Off)

Pushbuttons:

* Polarity NORM	In
* Filter NORM	In

* These controls must be in the indicated positions for correct operation of the Turn-Off Time Adapter. Others may be changed as required for specific measurements.

2.1 Installation and 577/177 Presets.

2.1.1 177 Standard Test Fixture.

Install the 177 Standard Test Fixture in the fixture compartment of the 577. Preset the 177 controls as follows:

*Terminal Selector:	Emitter Grounded, Step Gen
LEFT-RIGHT	Off (center position)
VERTICAL CURRENT/DIV	1A

2.1.2 577 Curve-Tracer Presets:

Collector Sweep Group

*COLLECTOR SUPPLY POLARITY	+
MAX PEAK VOLTS	6.5
SERIES RESISTORS	120
VARIABLE COLLECTOR %	0 (ccw)

Step Generator Group

Pushbuttons:

*STEP X .1	In
*300µs	Out
*REP	In
*FAST	In
*Polarity NORM	In
*ZERO	Out
*AID	In

Other Controls:

*STEP/OFFSET AMPL	2V
*OFFSET MULT	10.0 (cw)
NUMBER OF STEPS	1

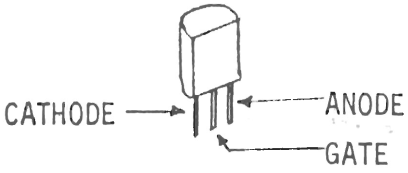
Display Group

HORIZONTAL VOLTS/DIV	1
(Horizontal) POSITION	Centered, and In (MAG Off)
(Vertical) POSITION	Centered, and In (MAG Off)

Pushbuttons:

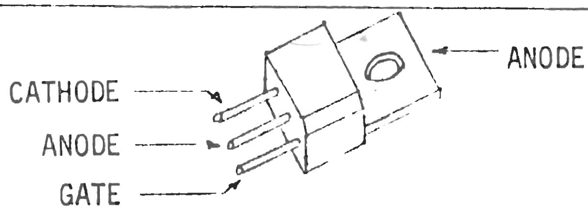
* Polarity NORM	In
* Filter NORM	In

* These controls must be in the indicated positions for correct operation of the Turn-Off Time Adapter. Others may be changed as required for specific measurements.

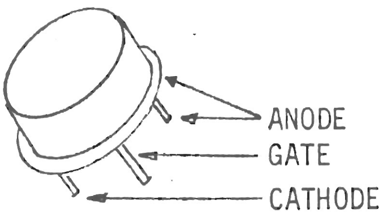


Case Style	Adapter
TO-92	013-0127-00

Adapters 013-0074-00 and 013-0163-00 may be used if leads are 0.5" or longer.

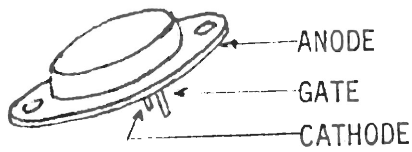


Case Style	Adapter
MU-27	013-0139-00
TO-126	013-0139-00
TO-127	013-0138-00

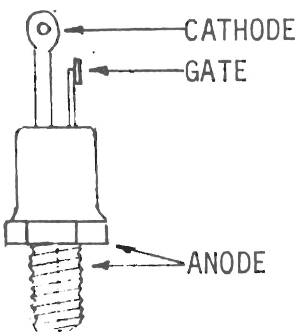


Case Style	Adapter
TO-5	013-0127-00
TO-39	013-0127-00
TO-8	013-0163-00

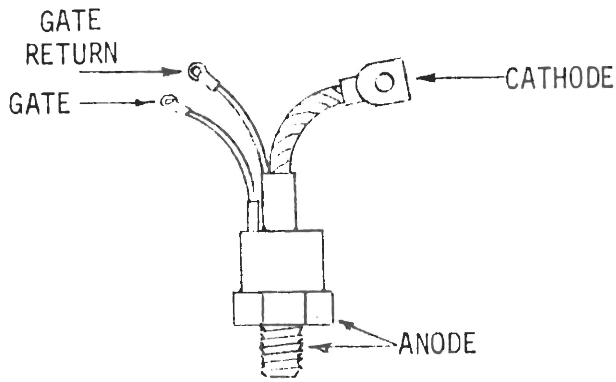
Adapter 013-0074-00 may also be used for any of the above case styles.



Case Style	Adapter
TO-3	013-0100-01
TO-66	013-0101-00



Case Style	Adapter
TO-48 &c	None*



Case Style	Adapter
TO-114 &c	None*

***Use clip leads.**

FIGURE 2-2 TYPICAL SCR TERMINAL CONNECTIONS.

2.1.3 SCR Turn-Off Time Adapter. If the transparent plastic terminal-cover assembly is installed on the 177, remove it by pressing toward you on the rear of its opaque base section and lifting it out of the test plate. It will not be required for the low-voltage tests performed with the Turn-Off Time Adapter. Also, remove any passive adapter mounted on the test plate of the 177.

Install the SCR Turn-Off Time Adapter by plugging its base into the banana jacks on the 177 test plate, turn on the 577 with the PULL-ON switch on the Display unit, and switch the 177 LEFT-RIGHT switch to Right.

If the 577 Step Generator and Offset controls have been correctly set, the green light on the Turn-Off Time Adapter panel will come on.

The Turn-Off Time Adapter is now ready to use. Set the Display unit and POSITION controls for a well-focussed spot at the lower left corner of the CRT graticule.

2.2 Turn-Off Time Measurement. The SCR turn-off time measurement is made in two steps. First, the latching and holding currents for the SCR under test are checked, to assure that the selected forward current for the turn-off time test are well in excess of the latching and holding values. Then, the turn-off time is measured.

2.2.1 Latching & Holding Current Check. Turn the LEFT-RIGHT switch on the 177 (below the installed Turn-Off Time Adapter) to the center (off) position, and connect the SCR to be tested to the Turn-Off Time Adapter, using a transistor adapter or the furnished clip-leads. Typical SCR lead-connections are shown in Figure 2-2.

Set the MODE switch on the Turn-Off Time Adapter to Holding Current, the GATE CURRENT control to 10mA, and the 577 Collector Sweep MAX PEAK VOLTS to 25. Set the SERIES RESISTOR selector (pull knob to disengage from the MAX PEAK VOLTS switch) to 120Ω, and the 177 VERTICAL CURRENT/DIV switch to 20 mA.

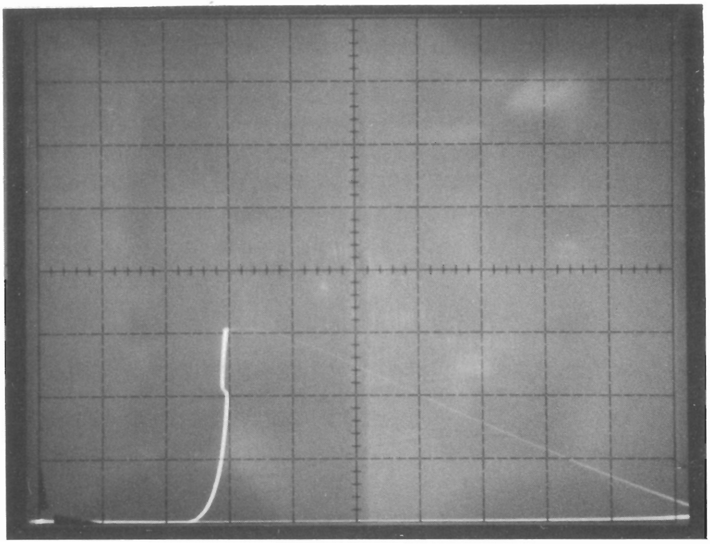


FIGURE 2-3a - SCR NOT LATCHED. Horizontal, 1V/div; Vertical, 20 mA/div. When gate drive is removed at peak of Collector Sweep, current drops immediately to zero and voltage rises to peak value (offscreen right).

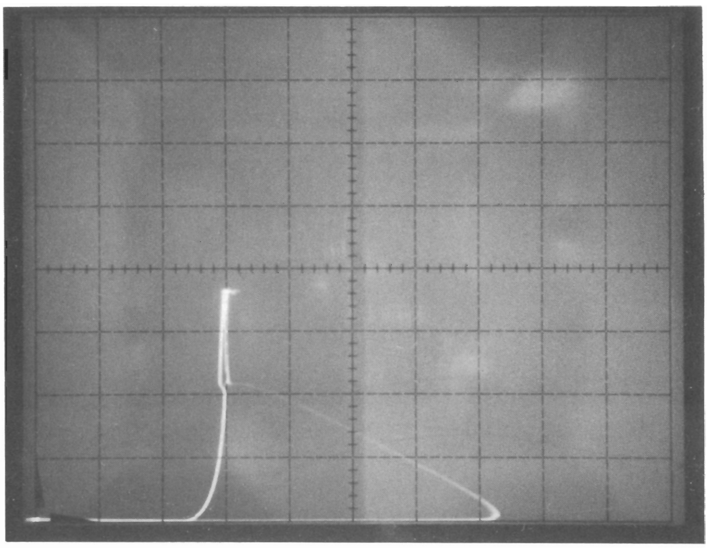


FIGURE 2-3b - SCR LATCHED. Conduction is maintained after gate drive is removed, until current drops to Holding Current level (44 mA), after which current drops quickly to zero and voltage rises.

FIGURE 2-3 HOLDING AND LATCHING CURRENTS - TYPE 2N3669.

Turn the LEFT-RIGHT switch to Right, and turn the VARIABLE COLLECTOR % knob clockwise until a display similar to that of Fig. 2-3a appears, having an extended baseline to the right of a current peak (if no current peak appears, increase the GATE CURRENT setting).*

Increase the VARIABLE COLLECTOR % further until the SCR latches, showing a definite retrace on the peak current line, and a shorter -- or brighter -- baseline (Fig. 2-3b).

The peak current at the lowest setting of the VARIABLE COLLECTOR % control at which the SCR latches is the latching current. At this point, displays like those of Fig. 2-3a and 2-3b may alternate, the peak currents being slightly different for the alternating peaks of the Collector Sweep.

The level at which the trace breaks away to the right of the current waveform and down to the baseline (Fig 2-3b) is the holding current**.

Turn-off time measurements may be taken at any current level above the setting at which the SCR latches reliably.

*At least 2.5V Collector Sweep must be applied before the gate drive is triggered.

**This figure may not correlate with the value specified for the SCR. A further discussion of holding current and measurements will be found in Sec. 3.3.

Turn the LEFT-RIGHT switch to Right, and turn the VARIABLE COLLECTOR % knob clockwise until a display similar to that of Fig. 2-3a appears, having an extended baseline to the right of a current peak (if no current peak appears, increase the GATE CURRENT setting).*

Increase the VARIABLE COLLECTOR % further until the SCR latches, showing a definite retrace on the peak current line, and a shorter -- or brighter -- baseline (Fig. 2-3b).

The peak current at the lowest setting of the VARIABLE COLLECTOR % control at which the SCR latches is the latching current. At **this point, displays like those of Fig. 2-3a and 2-3b may alternate**, the peak currents being slightly different for the alternating peaks of the Collector Sweep.

The level at which the trace breaks away to the right of the current waveform and down to the baseline (Fig 2-3b) is the holding current**.

Turn-off time measurements may be taken at any current level above the setting at which the SCR latches reliably.

*At least 2.5V Collector Sweep must be applied before the gate drive is triggered.

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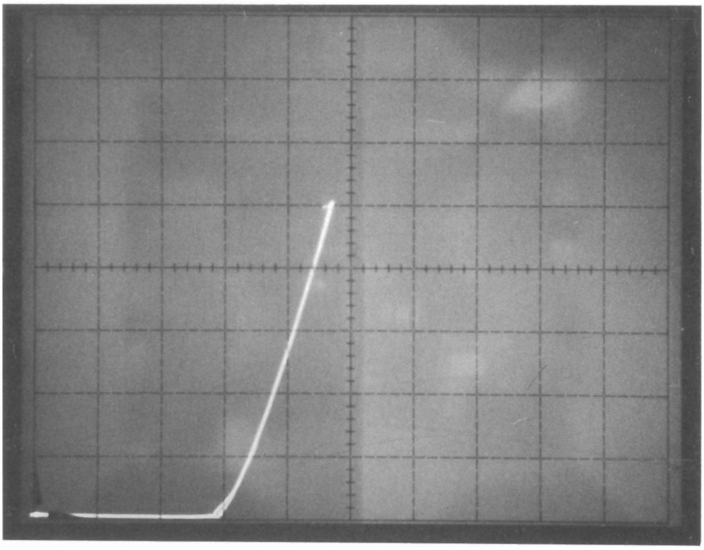


FIGURE 2-4a - TURNOFF NOT ACHIEVED. Vertical, 1A/div; Horizontal, 1V/div, Series Resistor 0.12Ω. SCR continues conducting through second half of Collector Sweep cycle; no baseline to the right of current peak.

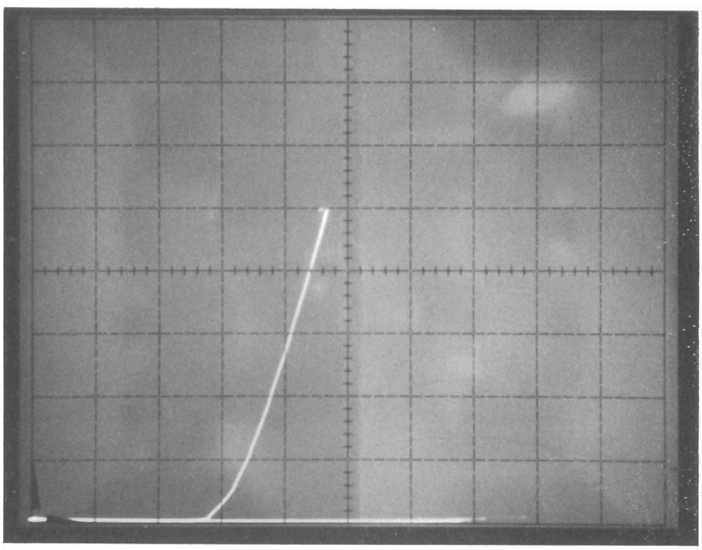


FIGURE 2-4b - TURNOFF ACHIEVED. Baseline to the right of current peak shows current has dropped to zero during second half of Collector Sweep cycle.

FIGURE 2-4 RECOGNIZING TURNOFF. SCR Type 2N3669.

2.2.2 Turn-Off Time. After observing latching and holding current (2.2.1 above), set the VERTICAL CURRENT/DIV to the highest level providing reasonable resolution of the peak current selected for the turn-off time test*, turn the VARIABLE COLLECTOR % control to zero (counterclockwise) and select a SERIES RESISTOR setting allowing the required peak current (See Table 2-1). Use the smallest resistor that will allow a reasonable turn-off indication in the display. The larger the series resistor, the easier it is to see the turn-off/no-turn-off difference, but use of a large resistor increases the actual SCR off-time and makes the SCR appear to be performing somewhat better than it actually does (See Sec 2.4 for details).

TABLE 2-1 SERIES RESISTORS - CURRENT AVAILABLE

MAX PEAK VOLTS Range	Series Resistor .12	.5	1.9	7.5	30	120	500
6.5	5A	3.4A	1.3A	0.4A	0.1A	.03A	6.5mA
25	-	-	2.5A**	2.3A	0.6A	.15A	40 mA

**Higher current may be drawn, but will trip the breaker after a few seconds.

Table 2-1 Approximate maximum currents available for various SERIES RESISTOR settings, for typical SCR's, at minimum line voltage. Actual available current will vary with SCR forward drop -- typically 0.2 to 1.0V under the test conditions applied.

Increase the VARIABLE COLLECTOR % setting until the desired current level is obtained. The display should resemble Fig. 2-4a.

Set the TURN-OFF TIME dial to 005 (counterclockwise), and set the MODE switch on the Turn-Off Time Adapter to Turn-Off Time.

*Do not use the 10-20-50mA or lower ranges. The metering resistors in these ranges significantly affect the total off-time of the SCR under test.

The display may immediately change from that of Fig. 2-4a (no baseline) to that of Fig. 2-4b (baseline extending to the right of the current peak). If so, turn the VARIABLE COLLECTOR % to zero, select a smaller series resistor, and repeat the test.

If, with the smallest series resistor that resolves turn-off, the SCR is still being turned off by the minimum commutating pulse width, its actual turn-off time is less than the minimum resolvable by the adapter under the current and temperature conditions of the test, and the exact value cannot be determined by this method.

If the display remains as in Fig. 2-4a, increase the TURN-OFF TIME dial setting just until the display switches to that of Fig. 2-4b, showing baseline to the right of the current peak (zero current during the second half of the collector sweep).

Read the TURN-OFF TIME dial for turn-off time in microseconds. The outer dial reads tens of microseconds (0-10); the inner dial reads microseconds (numbers) and tenths of microseconds (smallest divisions).

If the value read is 10µs or less, see Table 2-2, Sec 2.4 for corrections to apply (corrections become significant primarily at low currents, high SERIES RESISTOR settings, or low settings of the VERTICAL CURRENT/DIV control).

If at the maximum setting of the TURN-OFF TIME dial (105µs) the SCR has still not turned off, it may be running at more than its rated junction temperature: turn-off time can vary by more than 2:1 between room ambient and +125°C (typical rated junction temperature). Some "power-tab" devices -- case style MU-27 and similar -- operated without proper heat-sinks can be overdissipated at much less than their rated current level.

Except for very high current devices (over 500A rating), most SCR's in use today will turn off in 30µs or less at room temperature for currents in the 0.1 to 5A range.

2.3 Interpreting the Display. Active and passive elements in the Turn-Off Time Adapter affect the CRT display, requiring special interpretation. The major effects are outlined below.

2.3.1 Horizontal Deflection. The horizontal deflection in the display is of the Collector Sweep waveform applied to the adapter, and does not represent directly the voltage across the SCR under test. Voltage drop across protective and bias diodes and series resistance (0.25Ω) in the fixture are represented by the left-most 2.2 to 3.8V of the trace at various current levels while the fixture is operating normally. Typical horizontal displacement for various current levels of the fixture is shown in Fig 2-5.

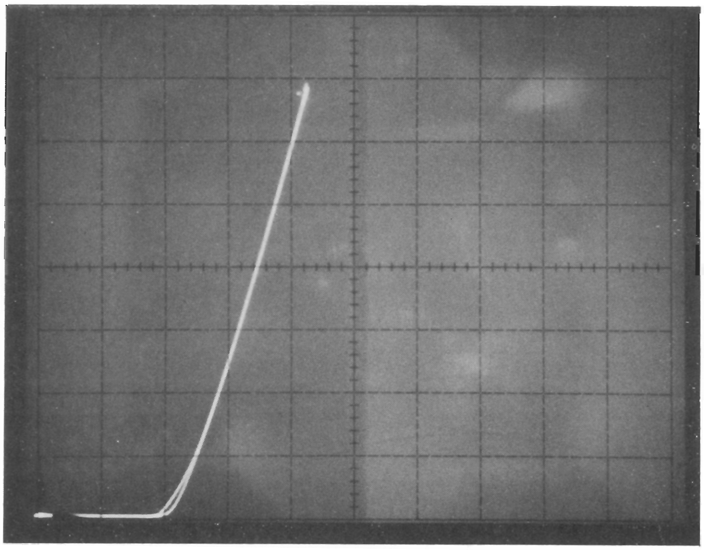


Figure 2-5 Forward voltage drop in Adapter.
Horizontal, 1V/div; Vertical, 1A/div.

Most of the excess horizontal deflection is due to the SCR anode current acting through the circuit impedances. At low (less than 1A) current levels an additional component due to gate current will be observable (Fig. 2-6), causing a slight additional horizontal offset in the display.

A procedure for measuring the actual voltage drop across the SCR without removing the Turn-Off Time Adapter will be found in Sec. 3.4.

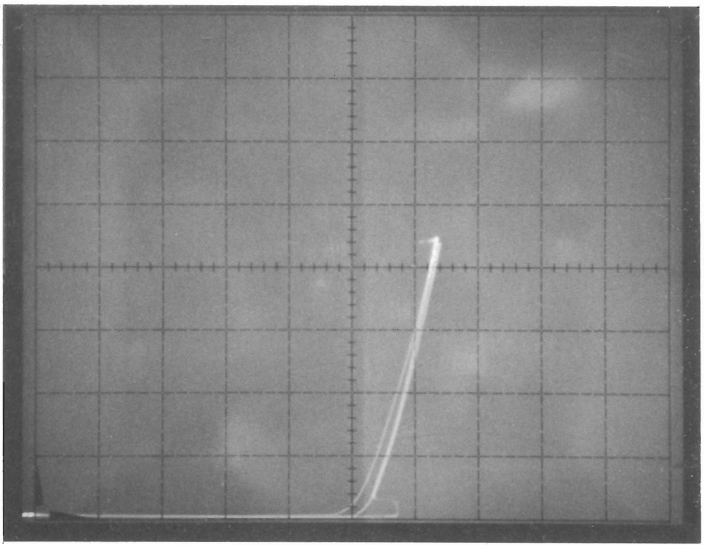


Figure 2-6 - Effect of gate current on Adapter forward voltage drop at low currents. Vertical, 100 mA/div; Horizontal, 0.5V/div; gate adjusted from min to max. (SCR Type 2N5060).

2.3.2 Vertical Deflection. Adapter components contribute two display effects which appear as anode current (vertical deflection).

The first of these is a resistance to ground (approx. 47kΩ) which causes a vertical deflection proportional to Collector Sweep voltage. This deflection, which appears as a slight upward slope of the baseline to the right of the +1V point on the sweep, amounts to about 120 µA at 6.5V or 0.5mA at 25V, and may be ignored for most measurements.

The second is a displacement current due to transient-limiting ("snubber") capacitors in the adapter, and is proportional to dV/dt of the Collector Sweep waveform, appearing as vertical looping in the display when the SCR under test is not conducting. With the 6.5V sweep, the peak value of trace displacement is about +2mA; with the 25V sweep, the peak value is about +7mA. Distortion and noise on the AC power line will vary these figures noticeably (Fig 2-7).

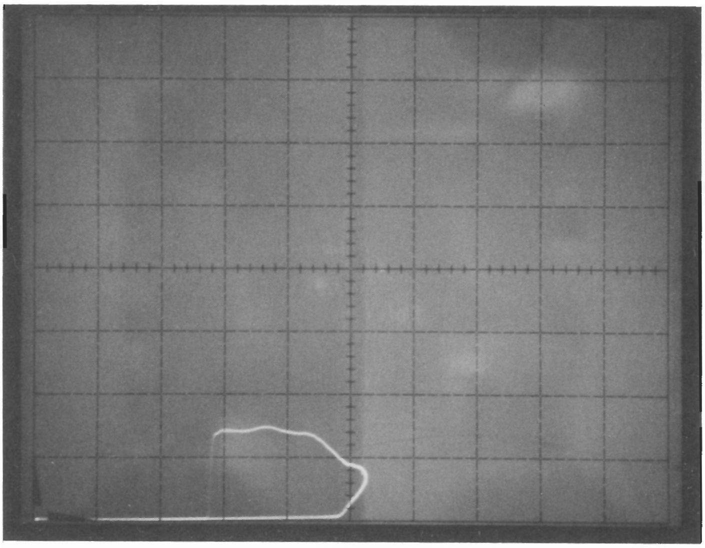


Figure 2-7 - Vertical looping due to displacement currents in dV/dt limiting circuits in Adapter. Horizontal, 5V/div; Vertical, 5mA/div. Adapter is diode-coupled, so negative excursion does not register. Power-line noise can create larger irregular excursions in this waveform.

Because the actual dV/dt while the SCR is conducting is very small, the displacement current does not significantly affect accuracy of current-level measurements during the turn-off time test.

However, the slope and looping effects do prevent use of the adapter for measurement of leakage current (forward blocking, reverse blocking voltage tests). The adapter should be removed for these tests.

2.3.2.1 Double Current Peak. A distorted Collector Sweep may have its peak voltage occur at some point other than halfway between zero-crossings. In the turn-off time test, this may result in an apparent change of peak current between the no-turn-off and turn-off displays (Fig. 2-8, next page).

The correct reading to use is the peak current value displayed after turn-off has been achieved. This is

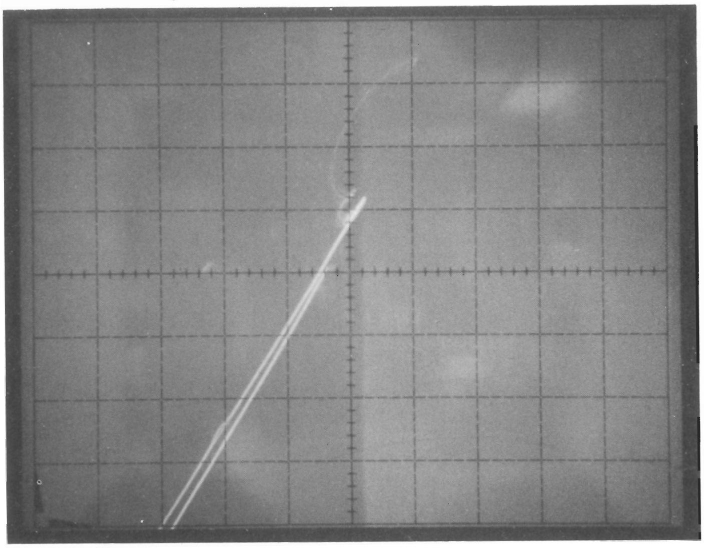


Figure 2-8a DOUBLE CURRENT PEAK. Top of 5-ampere peak, magnified (100 mA/div Vertical, 50 mV/div Horizontal), prior to SCR turn-off. The two peaks differ by about 120 mA, due to distortion of the Collector Sweep waveform (increase of voltage after 90° point).

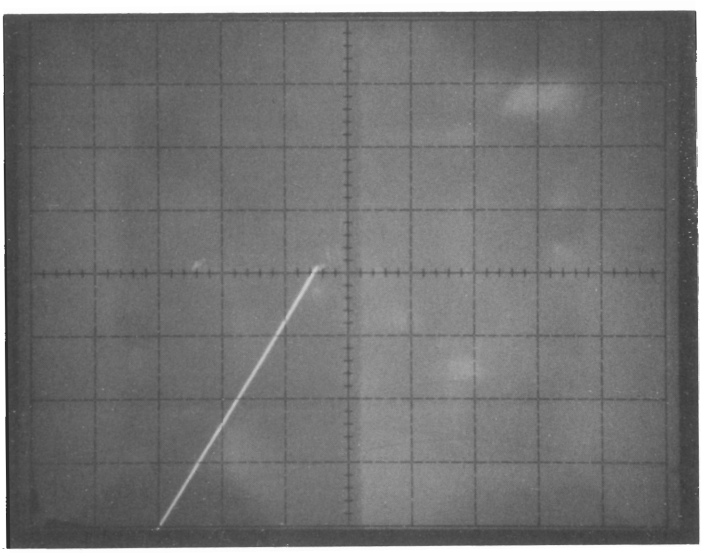


Figure 2-8b - AFTER TURN-OFF. After turn-off has been achieved, the value of peak current immediately prior to turn-off is displayed unambiguously. This is the true value for the test current level.

FIGURE 2-8 - DOUBLE CURRENT PEAK.

the true peak current being conducted immediately prior to turn-off. The second value, which disappears when turn-off is achieved, is the value conducted after an unsuccessful turn-off attempt, and is of no significance in the turn-off time test.

2.3.3 Transients. At high settings of the INTENSITY control, extreme voltage and current excursions may be noted in the display at the points where turn-off switching occurs. Because of the long (inductive) leads in the current- and voltage-measuring systems of the 577/177 and the quite limited bandpass of the deflection amplifiers, these should not be looked on as measured values, and should be ignored.

The maximum voltage transient (caused by the sudden reduction of current in the Collector Sweep transformer) on the 6.5V range is about 12V when the SERIES RESISTOR selector is at .12, but significantly less at other settings. With 25V Collector Sweep and the SERIES RESISTOR switch at 1.9, the transient peak could reach about +45V, but is clamped at +30V by a Zener diode in the Turn-Off Time Adapter, preventing damage to low-voltage SCR's.

2.4 Measurement Correction. Strictly defined, turn-off time is the time from the point where forward anode current passes through zero during commutation to the point where anode voltage passes through zero after commutation and thereafter continues to rise to essentially the applied voltage.

The p/n 035-5028-00 Turn-Off Time Adapter applies a commutation pulse of calibrated width to the SCR under test. Anode current of the SCR under test is reversed almost immediately (less than .05µs). After the commutation pulse, the anode voltage will start to rise, but will require a variable amount of time to reach 0V, depending on the Collector Sweep source voltage, the SERIES RESISTOR setting, and the resistance of the VERTICAL CURRENT/DIV measuring circuit. The excess time varies from less than 0.5 µs at settings allowing 1A measurements, to 5µs for a poor choice of settings for a measurement at the 100 mA level.

For comparison of SCR's all measured under the same conditions, no correction is necessary. However, for correlation with other measurements, a correction from Table 2-2 below should be added to the dial reading to find the "true" turn-off time.

TABLE 2-2 - TIMING CORRECTIONS

Peak Current	Series Resistor .12	.5	1.9	7.5	30	120	500	VERTICAL CURRENT/DIV
10 mA	-	-	5.5µs	8.5µs	16µs	30µs	45µs	2 mA/div
20 mA	1µs	1.25µs	1.75	3.5	10	18	25	10-20-50 mA/div Range
50 mA	1	1	1.6	3.2	6	10	12	
100 mA	0.8	0.9	1.5	3	4	5	-	
200 mA	0.4	0.5	0.8	1.5	2.5	3	-	.1-.2-.5 A/div Range
500 mA	0.4	0.4+	0.5	1	1.1	-	-	
1 A	0.4	0.4	0.45	0.5+	-	-	-	
2 A	0.3	0.3	0.4	0.4	-	-	-	1A/div
5 A	0.3	-	-	-	-	-	-	1A/div

Add the indicated time to the dial reading to obtain normal "turn-off time" reading. Measurements below 100mA current level are listed for reference only -- this is not a recommended operating region, and the corrections are only approximate.

To minimize corrections, always use the minimum value series resistor and maximum CURRENT/DIV setting that will allow resolution of the current level and turn-off.

A further discussion of turn-off time and factors affecting measured values will be found in Sec. 3.1 and 3.5 of this manual.

SECTION 3

APPLICATIONS AND MEASUREMENT NOTES

3.1 Principal SCR Parameters. The following is a list of principal SCR parameters, their typical ranges, and the ranges over which the 577/177 may be used to measure them, with and without the Turn-Off Time Adapter installed.

It should be noted that many of these parameters are in part defined by the methods -- and in some cases, fixtures -- used to measure them. The correlation among the results of various test methods and in-circuit performance and reliability of SCR's will be strongly influenced by circuit conditions and their effects on "minor" SCR characteristics, which may and may not be fully specified for a given SCR type.

A. VOLTAGE.

Maximum Off-State Voltage.

Forward Blocking Voltage V_{DRM}.
Reverse Blocking Voltage V_{RRM}.

Nominal peak working voltage.

Range 25V to over 3500V

Specified as the voltage at which leakage current reaches a specified value at a specific (ambient, case or junction) temperature. Gate-to-cathode resistance may also be specified. Current values range from 0.1 to 200 mA.

Measurement Notes:

Measurable with 577/177
0 to 1600V

577/177 have no temperature control or measurement facilities.

577/177 limited to 150 mA on 400V range, 40 mA on 1600V range.

Procedure:

577/177 Operators Manual, page 31.

B. CURRENT

Measurement Notes:

(1) Maximum Static On-State Current I_T.

Nominal forward rated current within the dissipation capabilities of the device.

Range 0.1 to over 4000 A.

Measurable with 577/177 to 10A peak*

Current rating is for a specified (ambient, case or junction) temperature.

577/177 have no temperature control or measurement facilities.

Value specified may be:
- (a) Continuous or rms current (rms over 360° full cycle).
- (b) Rms during 180° conduction half-cycle only.
- (c) Average during 180° conduction half-cycle only.

577/177 continuous current (+DC mode) limited to 40-50 mA without excessive ripple. No rms or average-calculating circuits.

Procedure: None.

The 577/177 are not generally suited for SCR maximum current evaluation. Use other equipment.

(2) Peak Surge Current I_{TSM}.

Peak anode current during a single half-cycle or other limited duration which will not damage the device.

Range, 1 A to 40,000 A.

Typically 5X to 20X the rated maximum steady-state current.

577/177 do not have single-collector sweep facilities**; typical required currents are beyond 577 capabilities.

Procedure: None.

Other specialized test equipment required.

*5A peak when Turn-Off Time Adapter is installed.

**The Pulsed and Single modes control only the base steps, not the collector sweep.

C. GATE TRIGGERING.

Maximum Gate Firing Characteristics	Measurement Notes:
Gate Current I_{GT} Gate Voltage V_{GT}	
Gate current required to turn on SCR; gate-to-cathode voltage at this current level.	
Typical values: I_{GT} 10 µA to 300 mA	Measurable with Turn-Off Time Adapter, 5-80 mA. With 577/177 only (preferred method), 50 nA to 2 A.
V_{GT} 0.6 to 5.0V	Not conveniently measured with Turn-Off Time Adapter installed. With 577/177 only, measurable from .05 to 5V or more.
Usually specified at relatively low anode voltage (6-12V) and current; also with gate trigger source impedance specified. Quite temperature-sensitive.	Procedure: Sec. 3.2 of this manual.

D. HOLDING CURRENT.

Maximum Holding Current I_H	
After triggering and latching, the minimum anode current required to maintain conduction, below which the SCR reverts spontaneously to the blocking mode.	
Typical values 10 µA to 0.5 A	Measurable with Turn-Off Time Adapter 5 mA to over 0.5A; with 577/177 only, µA to A.
Usually specified as performance in a specific test fixture. Results are highly circuit-dependent.	
Generally increases with a reduction in temperature, with a coefficient of about -1%/°C between 25°C and -40°C.	Procedure: 577/177 Operators Manual pp 31-32; this manual, Sec 2.2.1 and 3.3.

E. FORWARD VOLTAGE DROP

Measurement Notes:

Maximum On-State Voltage V_T

Anode-to-cathode voltage drop during peak forward current conduction.

Typical values 0.6 to 3.5V

Usually specified at a pulsed peak current 2X to 10X rated current.

Turn-Off Time Adapter limited to 5A max; 577/177 limited to 10A max.

Procedure:

With Turn-Off Time Adapter, this manual, Sec. 3.4

577/177 only: 577/177 Operators Manual, p 31.

F. SWITCHING TIME

(1) Turn-On Time t_{gt}

Time after triggering required for SCR anode current to reach 90% of maximum.

Range, 0.1 µs to 15 µs

Measured from 10% on the gate trigger waveform to 90% on the anode current waveform.

Cannot be measured with 577/177.

Often specified with gate trigger current 100 to 10,000 times the minimum specified for the device -- e.g., 30-ampere trigger for devices specified to trigger at 15 mA input.

Procedure: None.

Wideband oscilloscope and specialized test fixture required.

(2) Turn-Off Time t_q

Time at zero or reverse anode current for SCR to revert to blocking state after heavy forward conduction.

Range, 0.5 µs to 300 µs.

Changes significantly with temperature (2:1 or greater) and current (1.4:1 or greater). Usually specified at maximum rated temperature and current.

See Section 3.5 for a discussion of factors affecting actual and measured turn-off times.

Measurement Notes:

Measurable with Turn-Off Time Adapter 5-105 µs.

Maximum current available 5 A using Turn-Off Time Adapter.

No temperature control or measurement facilities in 577/177.

Procedure: Sec 2 and Sec 3.5 of this manual.

G. REAPPLIED DV/DT.

Maximum Rate of Rise of Reapplied Voltage.

Maximum rate of change of forward anode voltage after circuit-commutated turn-off which may be applied without self-triggering the SCR to the on-state.

Range, 1V/µs to 400V/µs

Phenomenon is chiefly due to anode-to-gate capacitance, producing a trigger current $I_T = C \times (dV/dt)$. Quite critical in circuit-commutated turn-off applications.

Not measurable by 577/177.

Turn-Off Time Adapter has built-in 5V/µs limit.

Procedure: None.

Special test equipment required.

3.2 Maximum Gate Firing Characteristics Measurement.

The Turn-Off Time Adapter is not used for this measurement. Remove the Turn-Off Time Adapter, set the 177 LEFT-RIGHT selector to its center (off) position, and connect the SCR under test to the COLLECTOR (anode), BASE (gate) and EMITTER (cathode) terminals of the fixture plate or passive adapter.

Set the front-panel controls of the 577 and 177 as follows:

Collector Sweep Group (Same as for Turn-Off Time tests):

VARIABLE COLLECTOR %	0
MAX PEAK VOLTS	6.5*
SERIES RESISTANCE	7.5*
COLLECTOR SUPPLY POLARITY	+

Step Generator Group

Pushbuttons:

PULSED	300µs	Out
STEP FAMILY	REP	In
STEP RATE	FAST	In
POLARITY	NORM	In
OFFSET	ZERO	Out
	AID	In
STEP X .1		In

Other Controls:

STEP/OFFSET AMPL	0.2V
NUMBER OF STEPS	1 (ccw)
OFFSET MULTI	0 (ccw)

Display Group

POLARITY	NORM	In
FILTER	NORM	In
HORIZ VOLTS/DIV		Base Volts, 0.1

177 Test Fixture:

Terminal Selector Emitter Grounded, Base Term Open (Ext)
VERTICAL CURRENT/DIV 0.2A.

Consult the SCR specification for the base-circuit resistance R_L to be used in the Gate Trigger measurement. If no R_L is specified, use 100Ω.

Install a half-watt composition or film resistor of the required R_L value between the STEP GEN OUTPUT and the EXT BASE OR EMIT INPUT jacks on the lower panel of the 177 (These jacks are on 3/4" centers. The resistor may be mounted on a GR 274-MB or equivalent double-plug for convenient installation).

*Check SCR specification. If specified anode current and voltage for Gate Trigger tests are significantly different from 7V, 1A, use the display to set the required voltage before setting the HORIZ VOLTS/DIV for Base Volts reading.

Set the VARIABLE COLLECTOR % (if not already preset to another value) to 100% and the LEFT-RIGHT switch to the position for the SCR under test.

A display of two dots should appear at the lower left corner of the graticule. Position the left-hand dot to the 0 voltage, 0 current reference point.

Slowly increase the OFFSET MULT control until the SCR fires (Fig 3-2). Just before the firing point is reached, the right hand dot may divide (SCR gate impedance shift). If the SCR does not trigger at the maximum OFFSET MULT setting, return it to 0 and repeat the procedure at 0.5V STEP/OFFSET AMPL, and a lower Horizontal sensitivity (0.2 or 0.5V/div).

Back off the OFFSET MULT until the right-hand dot does not quite trigger the SCR. The highest voltage reached without firing the SCR is the Gate Trigger Voltage V_{GT}.*

The firing current is found by calculation from the voltage drop across the series resistor R_L. The voltage drop is the applied offset plus one step, minus the measured gate voltage V_{GT}. The calculation is:

$$I_{GT} = \frac{\text{(STEP/OFFSET AMPL)} \times \text{(OFFSET MULT + 1)} - V_{GT}}{R_L}$$

For the Type 2N3669 in Fig. 3-2, R_L was 100Ω, STEP/OFFSET AMPL was 0.2V, the OFFSET MULT setting was at 7.24, and the observed firing voltage was 6.2V (somewhat to the right of the right-hand dot position in the photo). The drop across R_L was thus 1.03V and the firing current was 10.3 mA.

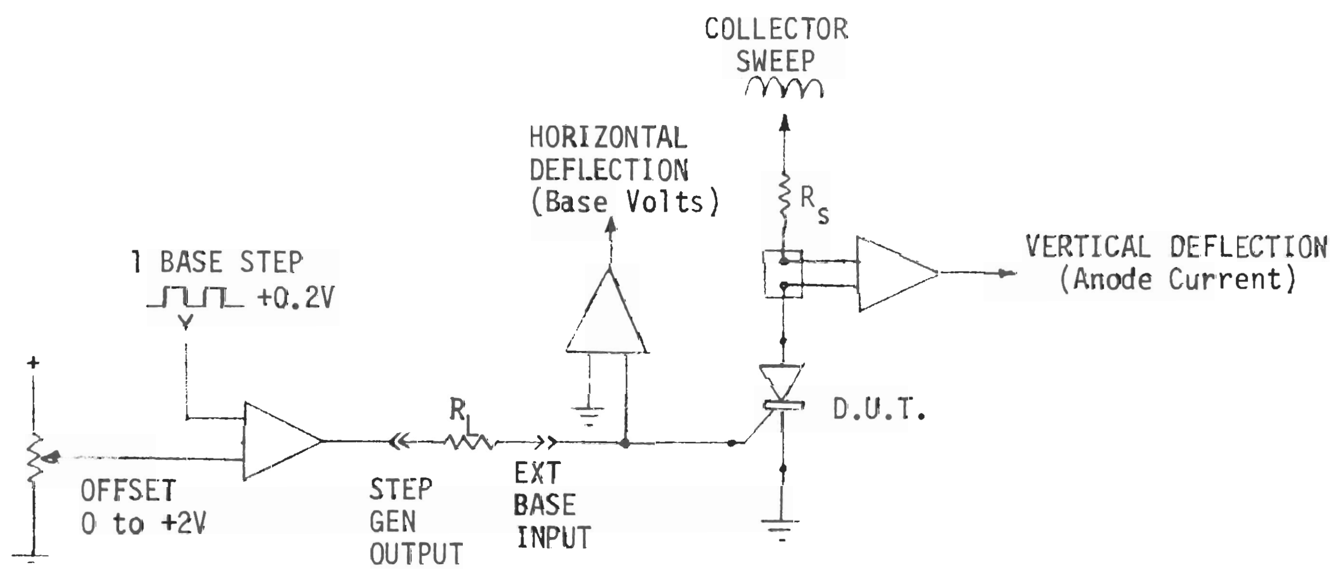


FIGURE 3-1 TEST SETUP FOR V_{GT} AND I_{GT}.

*So defined because the gate impedance and voltage increase sharply when the SCR is actually triggered, making measurement difficult.

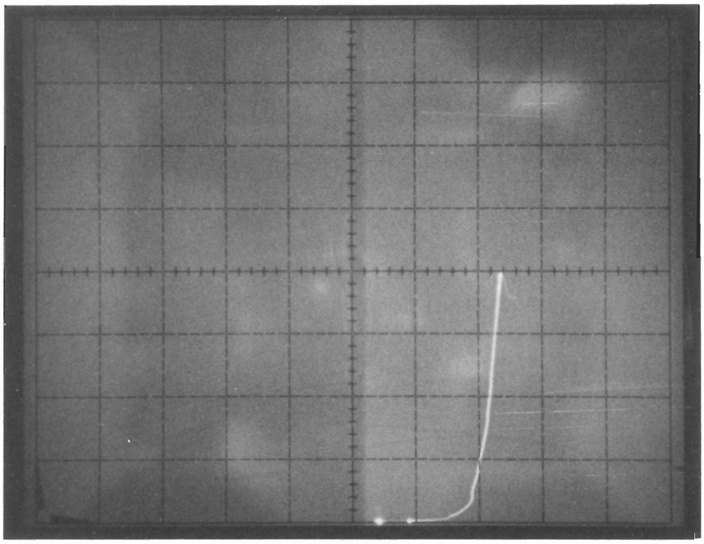


FIGURE 3-2 GATE FIRING VOLTAGE. Vertical, anode current, 0.2A/div; Horizontal, gate voltage, 0.1V/div. SCR has fired. Maximum position of the right-hand dot prior to firing, +6.2 div (+0.62V). SCR Type 2N3669.

3.3 Maximum Holding Current Measurement.

Holding current is conventionally measured in a specialized test circuit in which a high-impedance (2 kΩ to 50 kΩ) current-source furnishes anode current to the SCR under test after an initial trigger and high-current pulse which latches the device.

SCR holding currents are significantly affected by gate drive, the AC impedance of the external anode source, and the rate of decrease of anode current. In addition, low-power types and others not designed for high dV/dt anode ratings may be quite sensitive to the external gate circuit impedance. Table 3-1 below shows the effect of anode circuit impedance on holding current for the 200V 8A 2N3669; Table 3-2 shows the effect of gate circuit external impedance on the 30V 0.8A 2N5060.

	Anode Circuit External Impedance*					
	.12Ω	.5Ω	1.9Ω	7.5Ω	30Ω	120Ω
Holding Current	14mA	13mA	12mA	12mA	11mA	11mA

*SERIES RESISTOR values in 577. Actual impedances are somewhat higher.

TABLE 3-1 Effect of anode circuit external impedance on measured holding current, for 2N3669 SCR. Peak current was 190 mA; dI/dt at turnoff point was about 70A/sec. Because of increasing SCR anode impedance near turnoff, the actual dI/dt was higher for the low values of circuit impedance.

	Gate Trigger Source Impedance					
	0Ω	400Ω	3kΩ	15kΩ	35kΩ	Open
Holding Current	12mA	2 mA	0.4mA	0.1mA	50µA	10µA

TABLE 3-2 Effect of gate trigger source impedance on holding current, for Type 2N5060 SCR. The device specification calls for "open circuit" gate for holding-current measurement; the 0Ω case would be typical for a transformer-triggered application. Specified holding current for the device is 5 mA. Peak anode currents were 5 to 50 mA in the above tests.

The SCR Turn-Off Time Adapter has essentially 0Ω gate trigger source impedance in the gate-off state, and a low anode-circuit AC impedance due to its dV/dt limiting circuits.

Both of these characteristics tend to increase holding current over the values measured in the circuits called out in device specifications. In the case of the 2N5060, the difference is a factor of 1000.

Holding current can be measured using the Turn-Off Time Adapter as outlined in Sec. 2.2.1 of this manual, if a near-worst-case value is desired. The procedure outlined below provides more flexibility for evaluating SCR's for use in circuits designed to enhance the holding current characteristic.

PROCEDURE

Preliminary. Remove Turn-Off Time Adapter if installed; set LEFT-RIGHT switch to its center (off) position.

Presets.

Collector Sweep Group:

POLARITY	+
VARIABLE COLLECTOR %	0
MAX PEAK VOLTS	6.5
SERIES RESISTOR	120

Step Generator Group:

Pushbuttons:

PULSED	300μs	In
STEP FAMILY	REP	In
STEP RATE	FAST	In
POLARITY	NORM	In
OFFSET	ZERO	In
STEPS X .1		In

Other Controls:

STEP/OFFSET AMPL	1mA
NUMBER OF STEPS	1 (ccw)

Display Group:

DISPLAY INVERT	NORM	In
DISPLAY FILTER	NORM	In
HORIZ VOLTS/DIV		0.2
POSITION (Both)		Centered, In (Mag off)

177 Controls:

Terminal Selector	Emitter Grounded, Step Gen
VERTICAL CURRENT/DIV	20 mA

Base Circuit Resistance. Determine what gate-circuit external resistance is required for the holding-current test -- either from the device specification or from analysis of the circuit in which it is used.

If the value is 100Ω or greater, install this value of resistance between the STEP GEN OUTPUT and GROUND jacks on the 177 lower panel. If the value is less than 100Ω, set up the 577 and 177 as for the Maximum Gate Firing Characteristics Measurement (Sec. 3.2) with voltage drive from the Step Generator, and series resistance to the external base/gate input.

Connect the SCR under test to one set of COLLECTOR (anode), BASE (gate) and EMITTER (cathode) jacks on the 177 test plate, via clip-leads or a passive adapter, and turn the LEFT-RIGHT switch to the corresponding position.

Increase the VARIABLE COLLECTOR % control to maximum (6.5V). A display similar to that of Figure 3-3 should appear. If only a baseline appears, increase the STEP/OFFSET AMPL as required to fire the SCR.

If the SCR fails to latch (just a dot or short current-segment showing) it may be necessary to reduce the SERIES RESISTOR setting to 30Ω and set the VERTICAL CURRENT/DIV to a higher value.

The holding current breakaway should now appear at a point near the base of the current peak. (A dot to the right or left of the current peak -- as seen in Figure 3-3 -- is not significant, being due to amplifier reaction to a 3-screen-diameter step from offscreen right to mid-screen).

Increase Vertical sensitivity (or use the Vertical X10 MAG) as required to resolve holding current (Fig. 3-4).

Anode current, gate and anode circuit impedances and gate drive may now be varied to evaluate their effects on holding current.

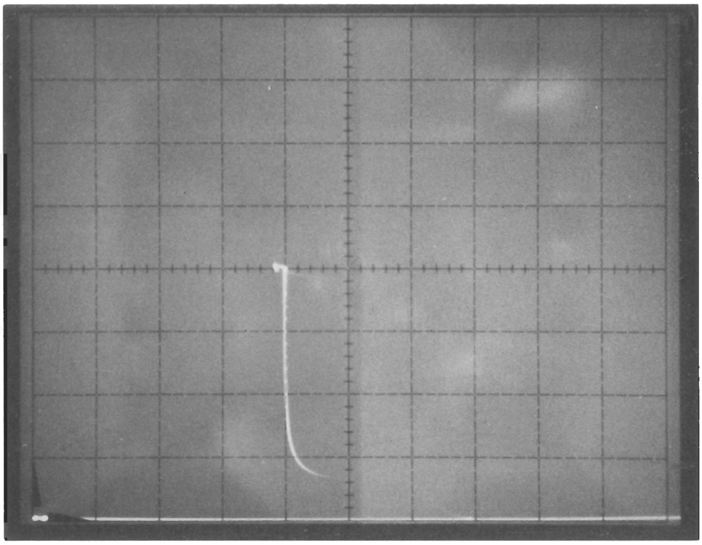


FIGURE 3-3 SCR Latched. Type 2N4103: Vertical, 20 mA/div; Horizontal 0.2V/div; 30Ω anode resistor; 100Ω gate resistance. STEP/OFFSET AMPL at 20 mA.

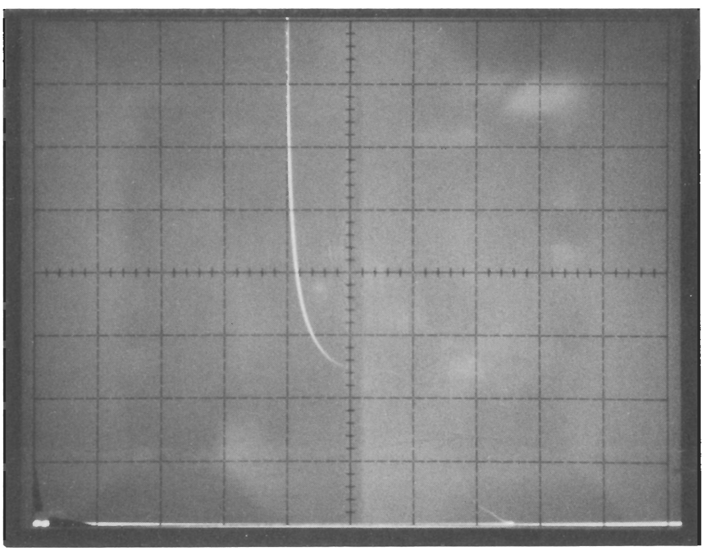


FIGURE 3-4 Holding Current. As in Fig. 3-3, but Vertical sensitivity increased to 5 mA/div. Holding current is 12.5 mA. Same device drops out at 20 to 30mA in the Turn-Off Time Adapter.

3.4 SCR Forward Voltage Measurement.

NOTE: The preferred method of measuring SCR forward voltage drop is shown in the 577/177 Operators' Manual, page 31. The following is a convenient check of forward drop which may be performed without removing the Turn-Off Time Adapter.

Preliminary: This procedure assumes that the equipment has been set up for turn-off time measurement (Sec. 2.1), and a turn-off or holding-current display has been obtained.

Procedure: To measure the actual voltage drop across the SCR at a given current level, position the trace horizontally until the desired vertical current level occurs at a convenient horizontal division line (Fig 3.5a).

Now, short out the SCR with a strap from anode to cathode (not to ground. The cathode is at about +1.2V in the Turn-Off Time Adapter). Observe the amount of leftward shift of the trace at the selected current level (Fig 3-5b). The amount of shift (horizontal divisions x HORIZ VOLTS/DIV setting) is the amount of the original deflection due to drop across the SCR itself.

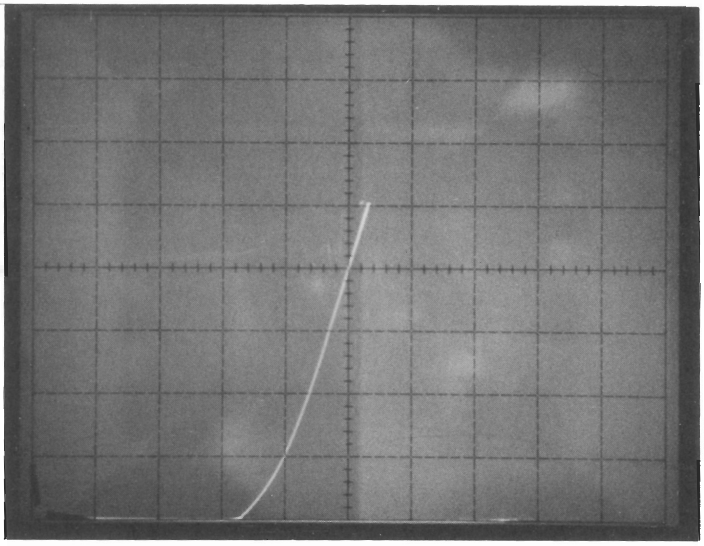


FIGURE 3-5a Waveform positioned horizontally to put the 4-ampere level at a convenient horizontal division line. Horizontal sensitivity, 1V/div.

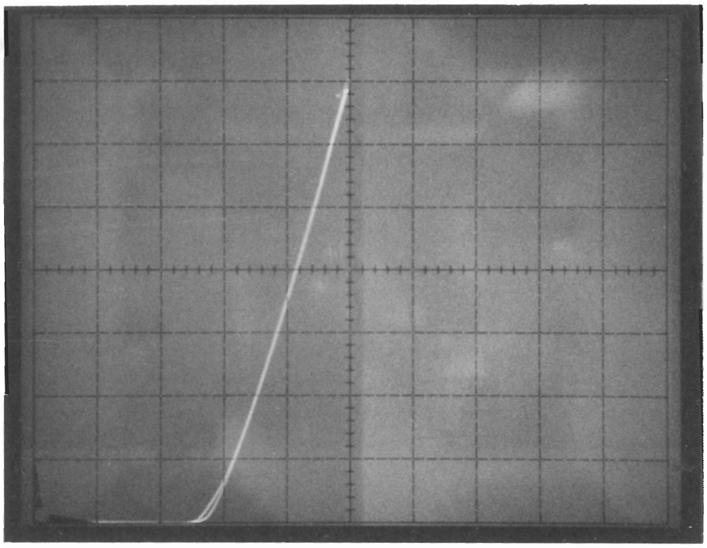


FIGURE 3-5b SCR shorted anode-to-cathode; horizontal shift at the 4-ampere level was -0.85 divisions. Actual drop across SCR in Fig. 3-5a was 0.85 x 1V = 0.85V at 4 A.

3.5 Turn-Off Time Measurement.

Factors Affecting Turn-Off Time. The turn-off time for a given SCR type will be specified in terms of a specific test circuit and test procedure.

There are 9 circuit parameters which affect the actual or apparent turn-off time of a device under test, and an additional parameter (lead length) which significantly affects several of the others. All ten parameters differ for various test circuits; for some SCR types, response to two testers of the same nominal design and layout may differ significantly.

Factors affecting turn-off time are keyed to Figure 3-6. Those marked with a (+) indicate that an increase in the parameter value will increase turn-off time; those with a (-) indicate the opposite effect. An "X" between the "Conventional Circuit" and "035-5028-00" columns indicates a significant difference between the two test circuits in their effect on turn-off time.

		Parameter	Conventional Circuit*		P/n 035-5028-00 Adapter
①	(+)	Junction Temperature	Uncontrolled		Uncontrolled
②	(+)	Forward Current	0.5 to 65A	X	0.1 to 5A
③	(+)	Rate of turnoff of Forward Current	Unknown**	X	-25A/µs (test leads) to -100A/µs (TO-3 adapter) after 5A forward.
④	(-)	Peak Reverse Current	24A to 80A**	X	5A (test leads) to 10A (TO-3 adapter)
⑤	(-)	Peak Reverse Voltage	up to -24V	X	-0.5 to -1V
⑥	(+)	Rate of change of Reapplied Blocking Voltage	.005 to 1000V/µs***	X	0.1 to 5V/µs
⑦	(+)	Maximum Reapplied Blocking Voltage	24V		0 to 12 or 0 to 30V
⑧	(+)	Gate Circuit Impedance	Open	X	1 to 3Ω typically
⑨	(+)	Gate Circuit (+) Bias	0	X	-0.5 to -1V

*Specifically, the circuit shown on page 590 (Figure 20.25) of the G-E SCR Manual, 5th Edition, 1972.

**Highly dependent on layout and lead lengths.

***Varies with forward current and turn-off time controls.

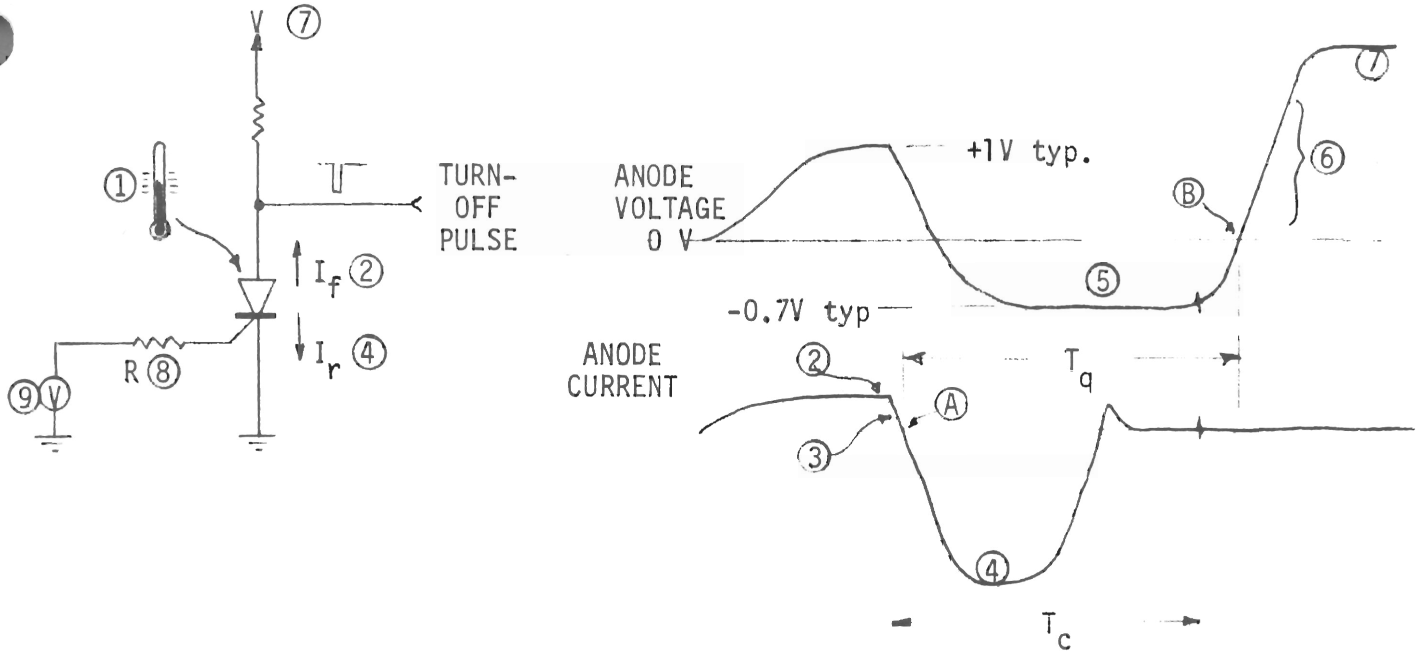


FIGURE 3-6 CIRCUIT PARAMETERS AFFECTING TURN-OFF TIME. Circled numbers refer to table on previous page. Turn-off time is defined as the time between points Ⓐ (forward current reaches zero) and Ⓑ (reverse voltage reaches zero). Calibrated dial on the Turn-Off Time Adapter reads interval marked T_c, somewhat less than T_q, depending on the rate-of-rise of reapplied blocking voltage. The difference in time between the start of T_c and the start of T_q is exaggerated in the sketch.

The test equipment used for factory production testing of SCR's is quite elaborate, and maintains control over all 9 (10) parameters. The equipment, however, is quite large and cumbersome, and not suited for field use.

Because equipment and fixtures designed for field use cannot exactly duplicate the factory equipment by which device specifications are verified, it is not possible to test exactly to "factory specs" in the field. However, because the original test conditions for turn-off time are generally more stringent than those applied by field test equipment, it may be safely assumed that any SCR measuring excessive turn-off time at 25°C in the Turn-Off Time Adapter will also not meet its original specification, usually specified for the maximum rated ambient, case or junction temperature (+65° to +125°C).

Extrapolation for Higher Currents.

Prediction of turn-off times for currents higher than those available with the Turn-Off Time Adapter may be done by extrapolation, for devices rated up to about 40 amperes forward current.

Procedure:

Measure turn-off times (if greater than 5 µs) at 1A, 3A and 5A forward currents. Make the measurements at 3A and 5A as quickly as possible after the 1A measurement, to minimize heating effects.

Multiply the difference between the 1A and 3A turn-off time readings by 2, and add to the 1A value. If the result is very close to the 5A value, the extrapolation will probably be valid.

Subtract the 1A turn-off time from the measured 5A figure, and multiply the difference by (n-1)/4, where n is the desired current level. Add the result to the 1A turn-off time to obtain the probable turn-off time for the desired current n.

EXAMPLE:

Data: Turn-off time at 1 A is 10 µs (t_1)
at 3 A 11.8 (t_3)
at 5 A 13.5 (t_5)

Problem: What is the probable turn-off time at 20 A?

Solution:

$$t_3 - t_1 = 11.8 - 10 = 1.8\ \mu s$$
$$\times 2 = 3.6\ \mu s$$
$$t_1 + 3.6 = 13.6\ \mu s$$
$$t_5 = 13.5\ \mu s$$ (very close -- OK)

$$t_5 - t_1 = 13.5 - 10 = 3.5$$
$$n = 20$$
$$n - 1 = 19$$
$$10\mu s + (3.5 \times 19/4) = \underline{26.6\ \mu s}$$, probable turn-off time at 20 A.

If the discrepancy between the $t_3 - t_1$ and the $t_5 - t_3$ differences is very great, further extrapolation will be increasingly inaccurate*. The method works best for values of n well below the rated maximum current for the device under test.

*More sophisticated techniques fitting the observed data to logarithmic or exponential curves can be used for accurate extrapolation, but the differences between test-fixture and in-circuit environments makes the exercise one of chiefly academic interest.

SECTION 4

CIRCUIT DESCRIPTION

Index

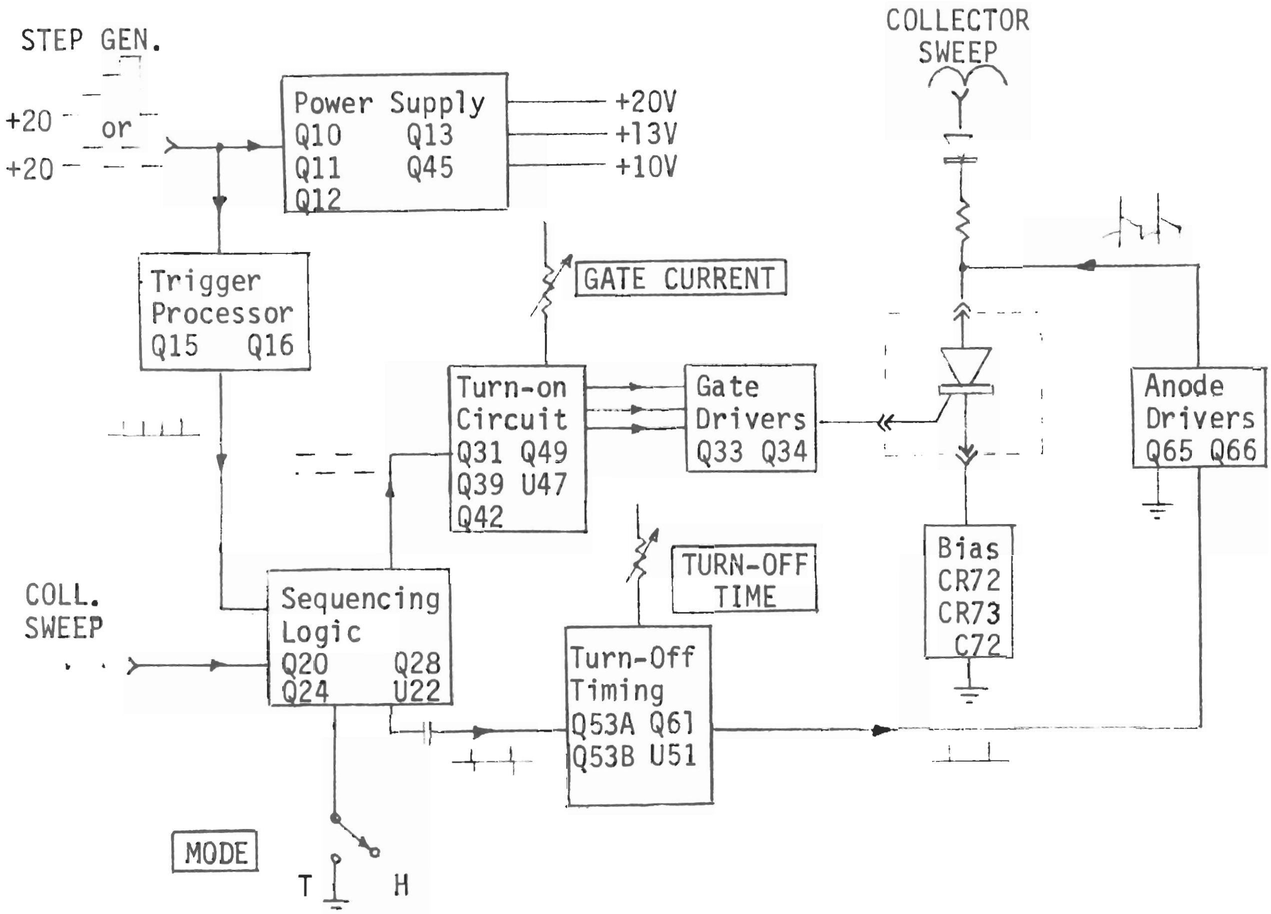


FIGURE 4-1 BLOCK DIAGRAM, SCR TURN-OFF TIME ADAPTER. For complete schematic diagram, see Section 7 of this Manual.

CIRCUIT DESCRIPTION

4.1 General (Refer to Block Diagram, Fig. 4-1, page 4-2.)

The p/n 035-5028-00 SCR Turn-Off Time Adapter measures turn-off time of the SCR under test by applying gate current and turning on the SCR during the first half of the Collector Sweep waveform, then removing gate current at the peak of the Collector Sweep and reversing the anode current and voltage for a calibrated length of time, after which forward anode voltage is reapplied. The curve-tracer display reveals whether the SCR resumed conduction or not.

Power and timing signals for the active circuits of the adapter are furnished by the curve-tracer Step Generator and Offset circuits. The Collector Sweep provides forward current for the device under test and a steering signal to the Sequencing Logic circuit.

The Step Generator output of the curve tracer may be a square-wave (when NUMBER OF STEPS is set to 1) or a stair-step waveform (when the NUMBER OF STEPS control is as 2 to 10). The Trigger Processor acts as an edge-detector to convert either input waveform into a series of positive-going pulses, one for each transition of either polarity.

The Sequencing Logic circuit combines the output of the Trigger Processor and Collector Sweep to provide an "on" signal to the Turn-On circuit when the Collector Sweep is at zero, lasting until the Collector Sweep reaches its peak value.

The Turn-On circuit provides a calibrated gate-current, set by the GATE CURRENT control on the panel, to the SCR under test, by way of the Gate Driver transistors Q33-Q34.

At the peak of the Collector Sweep, the next pulse from the Trigger Processor causes the Sequencing Logic to terminate the "on" signal to the Turn-On circuit, which now acts via the Gate Drivers to clamp the SCR gate to ground (Because forward SCR current has charged up C72 in the Bias circuit to above +1V, grounding the gate effectively applies a negative gate bias to the SCR under test).

If the MODE switch is set to Turn-Off Time, the termination of the "on" signal to the Turn-On circuit is followed -- after approximately 50µs delay -- by a trigger to the Turn-Off Timing circuit.

The timing circuit generates a turn-off pulse of 5 to 105µs duration, as set by the front-panel TURN-OFF TIME control. This pulse activates the Anode Driver Q65-66, which turn on quickly, diverting the SCR anode current supply to ground.

Because of the positive charge on Bias circuit capacitor C72, the Anode Drivers pull the SCR anode negative with respect to its cathode, and a reverse current is drawn, typically up to 10 amperes, until the stored charge Q_{RR} in the SCR junction has been withdrawn.

At the end of the Turn-Off Timing pulse, the Anode Drivers are turned off and the SCR anode voltage is allowed to rise.

The Collector Sweep waveform is still at or near its peak value at the end of the Turn-Off pulse. If the SCR has been turned off, the anode circuit will rise to the peak Collector Sweep voltage. If not, the SCR will resume conduction as its anode-to-cathode voltage goes positive, and the curve-tracer display for the second half of the Collector Sweep will retrace that of the first half.

When the MODE switch is set to Holding Current, the operation of the Turn-On circuit is the same, but no Turn-Off trigger is generated, and the display will reveal the current levels at which the SCR under test will spontaneously revert to the "off" state without gate drive.

4.2 Detail Circuit Description. Refer to the complete adapter schematic diagram in Section 7 of this manual, as well as the simplified diagrams in this section, to follow the descriptions below.

4.2.1 Trigger Processor. The Step Generator output from the Curve Tracer may consist of either a series of positive-going steps, or alternating positive and negative transitions, depending on the NUMBER OF STEPS control. Either waveform is converted into a series of positive-going pulses by the PNP transistors Q15 and Q16.

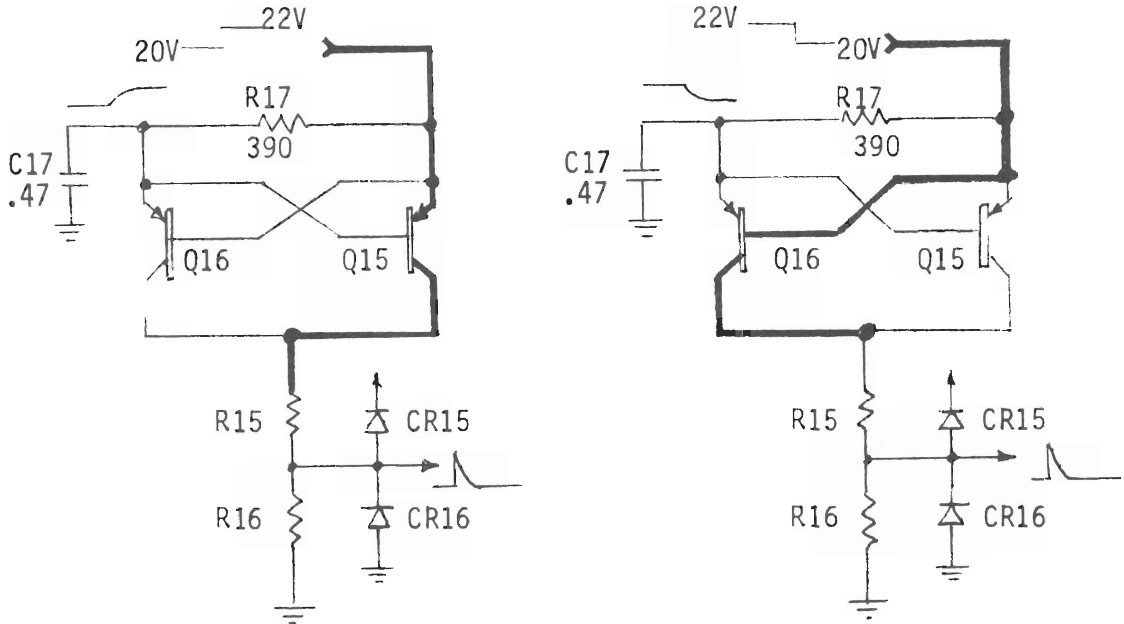


FIGURE 4-2 TRIGGER PROCESSOR (Simplified). Heavy lines show the signal paths for each polarity of input step. The R17 C17 time-constant is 183 microseconds (nominal).

Without step inputs, both transistors are off, emitters and bases being at the same voltage. If the input signal steps positive, the momentary voltage developed across R17 before charging C17 turns on Q15 by drawing its emitter positive, and pulling the output collector positive (Fig. 4-2, left).

If the waveform is negative-going, the momentary voltage across R17 turns on Q16 by pulling its base negative with respect to its emitter, which is held by C17, thus producing an inverted (positive-going) pulse at the Q16 collector.

For either direction of input transition, the charge on C17 changes to match the new input level, on the R17 C17 time-constant, and the circuit returns to its quiescent state with both transistors off. This action sets the width of the output pulse.

Both emitters are at +20V (or higher with several steps), and the output collectors pulse to almost the same voltage. Divider R15-R16 and clamp diode CR15 set the output pulse to +10.6V maximum, protecting the CMOS gates in the following stage. Clamp diode CR16 protects the CMOS stage in case the Step Generator or Offset is inadvertently set to the wrong polarity.

Additional capacitors C15 and C16 (not shown on simplified diagram) suppress transients on the Step Generator and trigger buses when the SCR under test is switched off, to prevent re-triggering of the Turn-On circuits.

4.2.2 Sequencing Logic. The Sequencing Logic circuit controls the timing of the turn-on and turn-off events during the Collector Sweep cycle.

In the quiescent state, the trigger bus from the Trigger Processor is low (0V) and the Collector Sweep waveform is also low, producing a high (+9V) at the collector of Q20 and a low at the collector of Q24. Nand gate U22A thus has both inputs low; U22D has one high and one low. The outputs of both U22A and U22D are therefore high, establishing the initial conditions for operation of the cross-coupled R-S nand flip-flop U22B-U22C*. The high at the output of U22A also keeps Q28 turned on via R25 -- assuming that the MODE switch S28 is closed.

When a Step Generator transition occurs (with the Curve Tracer STEP RATE set to Fast, steps occur both at the zero and peak amplitude points on the Collector Sweep), U22D momentarily has both inputs high, producing a momentary low at its output, and at the U22 input to the nand-gate R-S flip-flop. This transition latches the flip-flop with the U22C output (pin 10) high and the U22B (pin 4) output low. The U22B input to the flip-flop has remained high because of the continued low at pin 1 of U22A, forcing a high state at pin 3.

The low at the U22B output and the high at the U22C output release the Q34 clamp on the SCR gate bus, and enable the Turn-On circuit current generator (4.2.3, below), turning on the SCR under test.

*NOTE: The quad 2-input nand gate U22 is a Fairchild Type 34011 CMOS unit, similar to the 4011 or 4011A type, but having the higher and symmetrical output current capabilities of the "4000B" Series CMOS devices. The 4011 and 4011A types do not have sufficient output current capability for operation in this circuit, and should not be used.

The Collector Sweep waveform rises to a maximum over a period of about 4.2 ms (5 ms when operated from 50 Hz power). When an amplitude of about +2.5V is reached, Q20 is turned on and Q24 is turned off. Because the trigger bus from Q15-Q16 is again at a low level, the outputs of U22D and U22A do not change at this point.

When the Collector Sweep is at its peak, another Step Generator transition occurs, producing a positive trigger to U22D and U22A. U22D is not affected, as its pin 12 input is low, but U22A (with pin 1 high) produces a momentary low at pin 3.

This low from U22A turns off Q28, and resets the R-S flip-flop U22B-U22C, producing a low at U22C pin 10 (disables gate current generator) and a high at U22B pin 4 (turns on gate clamp circuit).

The turn-off of Q28 produces a positive Q28 collector transition, which is differentiated by C27 and R28//R29 to produce a positive spike on the trigger line to the Turn-Off Timing circuit. However, the timer responds only to negative-going triggers, and does not respond to this initial spike.

At the end of the momentary low from U22A (about 50 µs from the time that the Gate Turn-On circuits were switched off), Q28 is turned on again, producing a fast negative-going transition to the Turn-Off Timing circuit, which now starts the commutation (turn-off) cycle.

The timing of these events is shown in the timing diagram, Figure 4-3, page 4-8.

The collector circuit of Q28 is set by R27 and R26 to +3.2V when Q28 is off (.05 to .1V when Q28 is on). The differentiated output via C27 is set to a DC level of +5V by R29 and R28, so the triggering pulse to U51 starts at +5V and reaches about +2V.

4.2.2.1 Holding Current Mode. When the MODE switch S28 is set to Holding Current, the emitter of Q28 is open, and no output pulse is generated. The diodes CR27 and CR28 prevent the base of Q28 from being pulled more positive than its collector and generating an unwanted output in this mode.

4.2.2.2 Other Components. Diode CR22 in the Q20 base circuit protects Q20 against inadvertent inversion of the Collector Sweep polarity. Capacitors C21 (Q20) and C24 (Q24) suppress transients in the Collector Sweep which occur during turn-off and reapplication of SCR anode voltage, to prevent re-triggering the gate drive circuits.

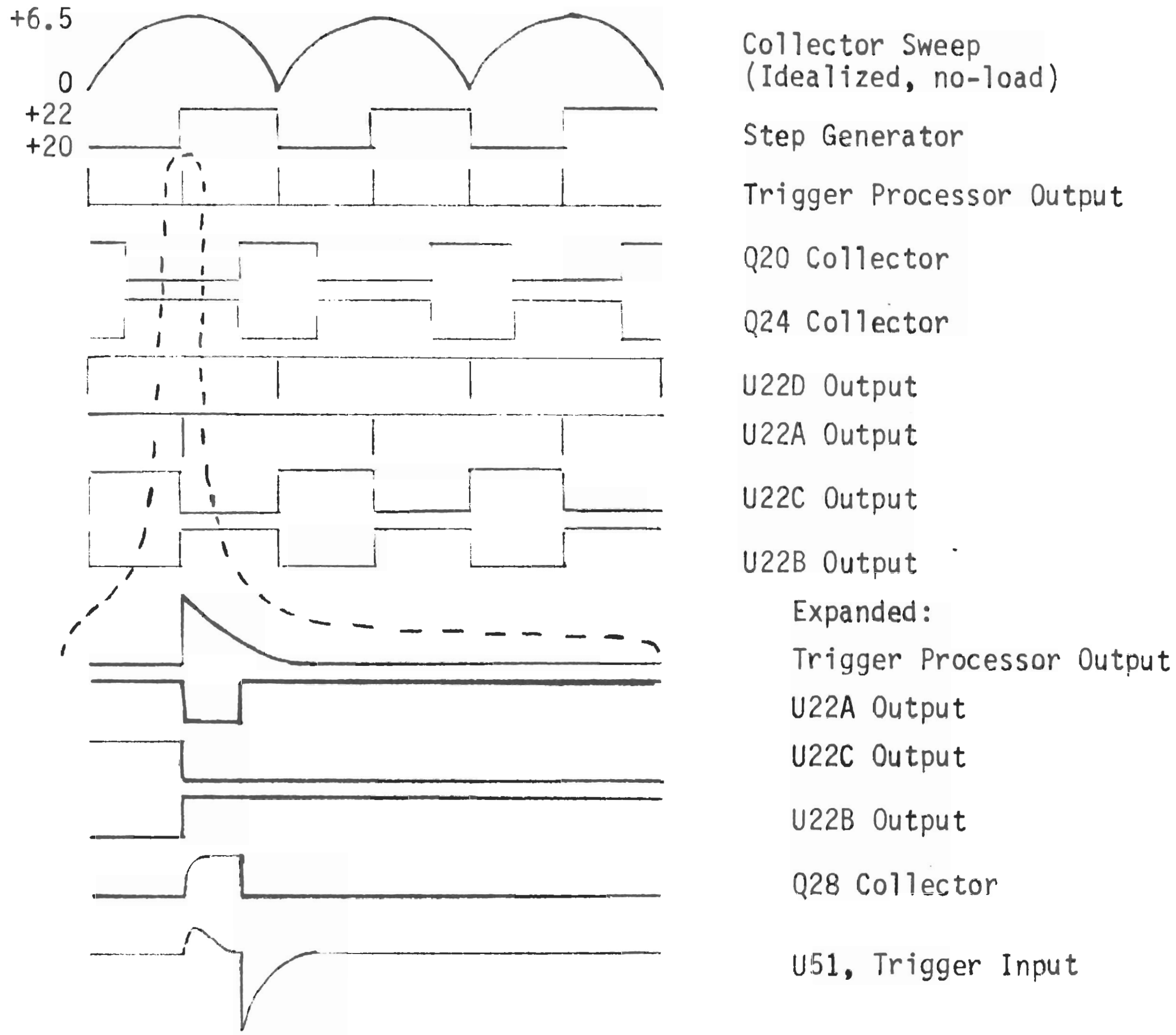


FIGURE 4-3 TIMING DIAGRAM. Lower set of waveforms is a time-expanded view of events within dotted lines above, plus the Q28 waveforms.

4.2.3 Turn-On Circuit and Gate Drivers. The Turn-On circuit consists of precision voltage generators U47B/Q49 and U47A/Q33, control transistor Q42, and shut-down FET Q39. Transistor Q34 and its driver Q31 pull the gate bus to ground when gate drive is turned off.

Operational amplifier U47B and NPN transistor Q49 operate as a single operational amplifier in the unity-gain follower mode, with maximum current capability in the positive direction. They set the positive end of the current-setting resistor R47 to precisely the voltage set by GATE CURRENT control R46, between +10V and the voltage set by U47A/Q33.

Operational amplifier U47A and PNP transistor Q33, with maximum current capability in the negative direction, set the voltage at the negative end of R47, to the value established by the divider R41-R44-R43.

In the quiescent state, Q42 is off, and its collector is at +10V, setting R47 and R46 (GATE CURRENT control) both at +10V and the net current through R47 and Q33 to 0.

When Q42 is turned on by the Sequencing Logic circuit, its collector drops to less than +0.1V, and the (+)input of U47A --and thus the emitter of Q33 -- moves to approximately +6V (adjustable over the range +5.85 to 6.15V by R41), setting the negative end of R47. The positive end of R47 is then settable from +6V (no current)* to +10V (80 mA) by the GATE CURRENT control.

The current in R47 is the emitter current of Q33, which -- less 0.25 to 0.4% of the emitter current which is base current -- becomes the collector current, and thus the drive to the gate of the SCR under test.

When the control transistor Q42 is on, Q31 is turned off, and driver Q34 appears as an open circuit. When the drive to Q42 is low (Q42 off), the drive via R31 to Q31 is high, turning on Q34 and maintaining a very low (1 to 3Ω typical) output impedance to ground on the gate bus. Diode CR34 prevents Q34 from saturating, and the negative feedback to Q31 while CR34 is conducting maintains the low impedance. This diode also limits the dissipation in Q31, which would exceed its rated limits without feedback.

4.2.3.1 Shut Down Circuit. FET Q39 in the base circuit of Q42 is a P-channel junction FET. Periodic switching of the R-S flip-flop U22B-U22C charges capacitor C39

*The actual current when the GATE CURRENT control is set to "0" may range from 0 to about 100μA, depending on input offsets of the operational amplifiers.

via diode CR39 to about +9V, and keeps Q39 turned off. When the Collector Sweep is turned below about +2.5V or the Step Generator is mis-set, drive to the Sequencing Logic is lost. If the flip-flop U22B-U22C stops switching with the pin 10 output high and the pin 4 output low, C39 discharges on the R39 C39 time-constant (about 700 ms) until Q39 turns on and Q42 is turned off.

The operation of this shut-down circuit prevents application of gate drive to the SCR under test except under conditions allowing proper operation of the Sequencing Logic circuit, eliminating a possible cause of misleading displays.

Jumper switch S39 is used during calibration to override the shut-down circuit to permit measurement of gate current with DC-calibrated equipment. During normal operation, S39 is always set to the "Y" position as shown on the schematic diagram.

4.2.4 Turn-Off Timing. Integrated circuit U51 is a Type 555 Timer, which accepts a negative-going trigger to produce a positive-going output pulse, the width of which is controlled by external R and C components.

Normally, the timer uses a simple external RC combination, and discharges the timing capacitor via a special Discharge terminal (pin 7). For accurate timing calibration and operation for intervals of less than 10 µs (the normal 555 timing limit), a linear timing ramp is required, and the saturating-type discharge circuit (very slow to release after a trigger) is replaced by a diode (CR52) from the output circuit to the timing capacitor C52.

Transistors Q53A-Q53B are a PNP-NPN matched complementary pair in one case, providing a temperature-compensated voltage-setting circuit for the negative end of timing resistance R56-R57-R58. The emitter of Q53B is at essentially the base voltage of Q53A, 8.0V. The timing current is set by the TURN-OFF TIME control R58, over the range 0.19 mA (105 µs) to 4 mA (5 µs).

When U51 is triggered, the output steps to very close to the supply voltage, +10V. The timing current from the collector of Q53B generates a linear increase of voltage with time across C52 by the formula Q = CE = It, or

$$\frac{E}{t} = \frac{I}{C} .$$

At 0.19 mA, the rate of rise is 5.76×10^4 V/s, or .0576 V/µs. At 4 mA, the rate of rise is 1.2 V/µs.

The voltage across the timing capacitor is monitored by the Threshold input (pin 6) of the Timer. When the voltage has risen to the preset value, the output pulse is terminated and the negative-going output of the pulse discharges the timing capacitor via CR52, to about +0.6V.

The threshold voltage is set internally to 2/3 of the supply voltage (10V), or +6.67V, but may be varied by input to the V_c terminal, pin 5. Pin 5 appears as a source of 6.67V behind 3.3 kΩ, and so can be varied over the range 5.95 to 7.03V by the 100 µs Cal⊘ control circuit. At the nominal setting of this adjustment (6.65V at pin 5), .0576 V/µs requires 105 µs to rise from +0.6V to the threshold when the TURN-OFF TIME dial is set to maximum.

At minimum (5 µs) timing, the internal signal transit time in the integrated circuit tends to delay termination of the pulse, producing an excessive width. Resistor R52 provides a correction voltage proportional to timing current (at 4 mA, the voltage to pin 6 is 400 mV above the capacitor voltage), which compensates for the internal delay, and provides good dial tracking from 5 to 105 µs widths. The 5 µs Cal⊘ adjustment sets absolute calibration for this end of the dial.

Emitter-follower Q61 provides low-impedance output to the Anode Drivers Q65-Q66, drawing energy from C62 to provide the current (approximately 475 mA) required for the base circuits of these transistors. The voltage on C62 is drawn down by about 5V during a 100-µs-wide turn-off pulse, and recovers to +20V on a 1.5 ms time-constant when Q61 is off.

4.2.5 Anode Drivers. The Anode Driver transistors Q65-Q66 are wired essentially in parallel, and perform two functions: (a) During the turn-off interval, they divert all current from the Collector Sweep circuit away from the SCR under test, reverse the SCR anode voltage, and draw reverse current through the SCR to clear out the stored charge, and (b) by means of added capacitors from collector to base, they function as Miller integrators to limit the rate of rise of reapplied anode voltage to the SCR under test, to 5 V/µs (less when series resistance in the Collector Sweep is set to a high value).

Figure 4-4 on page 4-12 shows the Anode Driver circuit in simplified form.

While forward current is applied to the SCR under test, Q65 and Q66 are turned off. After gate drive to the SCR under test has been removed, the timer turns on Q61, which provides about 475 mA current via R65 and R66, of which about 36 mA is "stolen" by R64 and R67, and the rest is supplied as base drive to Q65 and Q66.

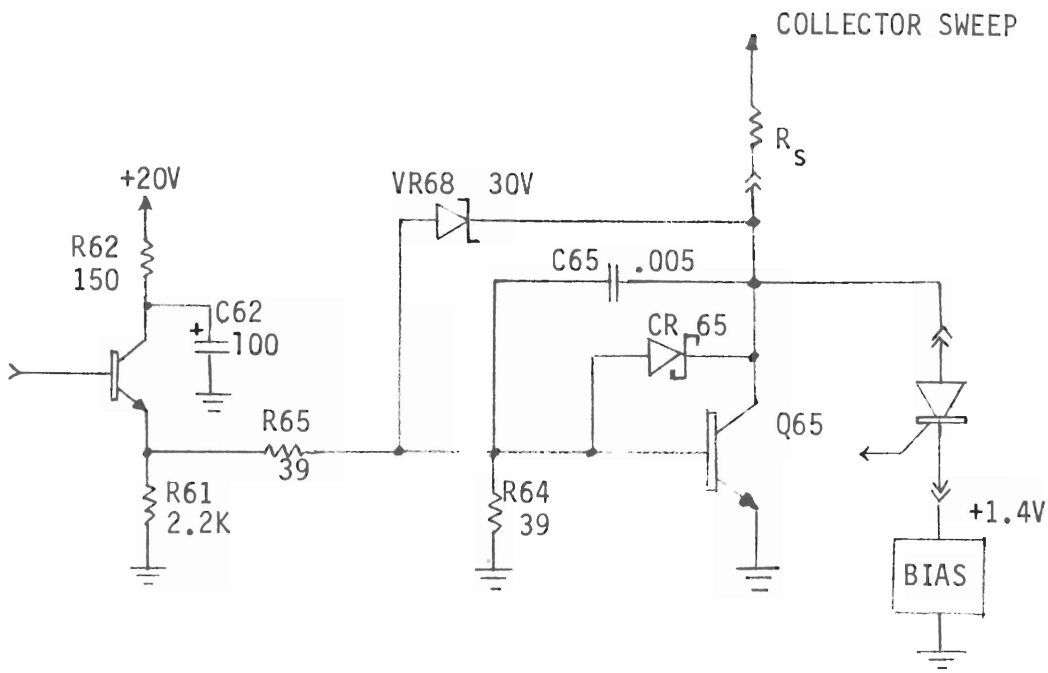


FIGURE 4-4 SIMPLIFIED ANODE DRIVER CIRCUIT. Circuit numbers shown are for Q65; Q66 circuit is essentially the same, except VR68 is common to both. Q65 and Q66 function in parallel.

Diodes CR65 and CR66 are high-current Schottky barrier diodes, characterized by very low (0.2 to 0.3V) forward drop when conducting heavily. These diodes come into conduction and limit the base drive to Q65 and Q66 before the transistors reach saturation, allowing Q65 and Q66 to be turned off again after the turn-off pulse, without excessive delay.

When Q65 and Q66 are turned on, each acts as a Miller integrator, with about 200 mA input current and .005 µF feedback capacitance, allowing a run-down at the rate of about 40V/µs. When base drive is removed, the integrating components are essentially R64 (R67) and C65 (C66): the rate of change of voltage at the collectors is limited to the value that provides no more than about 20 mA current through R64 (R67) via C65 (C66), developing 700 to 800 mV drop across the resistor. Any increase of current goes to the transistor base, turning it on and slowing the rate of rise.

Zener diode VR68, coupled to each of the output transistor bases (via CR64 and CR67, omitted in the simplified diagram), sets an absolute output voltage limit of about +30V -- necessary because of the Collector Sweep transformer reaction to a sudden drop of current, producing a peak "flyback" voltage up to +45V on the 25V range without limiting.

Resistors R64 and R67, in addition to setting the voltage recovery rate, absorb the leakage (up to 10 mA) of the Schottky diodes, preventing the Anode Drivers from being turned on and appearing in the display as SCR anode current after a successful turn-off.

Inductor L68 in the feedback circuit (not shown in the simplified diagram) minimizes circuit ringing introduced by interaction between the Anode Driver transistors and the Collector Sweep transformer when very low series resistor values are used. Additional damping in the circuit is provided by R70-71, C70-71 and C74.

Diode CR70 protects the adapter circuits in the event the Collector Sweep polarity in the Curve Tracer has been set to negative.

4.2.6 Bias Circuit. Diodes CR72 and CR73 with capacitor C72 (1000 µF) use the SCR forward anode current to provide 1 to 1.4V positive bias at the SCR cathode, so that the anode may be drawn negative with respect to the cathode during the turn-off pulse. Typically, the anode is switched to +0.65V, or about 750 mV below the cathode potential reached during measurements at 5A peak forward current.

The 1000µF value can supply 750 microcoulombs (ampere-microseconds) in drawing down from 1.4 to .65 V. The typical current drawn from the reversed SCR is 5 to 10A, which is supported for the first 1 to 3 µs by stored charge (about 20 µC at 5A) in CR72 and CR73, and thereafter by C72. The 750 to 770 µC thus available covers typical stored charge for 5A forward current for SCR's rated to 100 µs and greater turn-off times.

4.2.7 Power Supply. Three voltage levels are derived in the adapter power circuits from the Curve Tracer Step Generator and Offset circuit which -- if panel controls are correctly set for Turn-Off Time Adapter operation -- provides +20V at 200 mA, with a 2V squarewave (if NUMBER OF STEPS is set at 1) or a staircase of up to an additional 20V, superimposed on it.

Diode CR10 protects adapter circuits against inadvertent reversal of the Step and Offset polarity. Inductor L10 and capacitor C10 smooth out the square-wave or staircase transitions to minimize circuit interference, and the smoothed "+20V" bus (actual voltage may range from +20 to +40V) is distributed to non-critical circuits requiring maximum power.

Zener diode VR11 and transistor Q11 furnish the regulated +10V supply. Field-effect transistor Q10 operated at zero-bias provides a constant current to VR11, essentially independent of the voltage on the +20V bus.

Transistors Q12 and Q13 and Zener diodes VR12 and VR13 provide control over the power to DS13, the panel POWER indicator. Transistor Q12 is turned off if the +20V bus is at 10V or below, so Q13 and DS13 are turned off. As the +20V bus exceeds +15V, Q12 starts turning on Q13 and DS13, until at +20V, DS13 is at full brightness. If the +20V supply rises further, the drive to Q13 is limited by VR13, limiting the DS13 current to 20 mA, assuring long bulb life.

Transistor Q45 provides a nominal +13V to operational amplifiers U47A-U47B, which require somewhat more than a +10V supply to handle +10V input and output levels. The actual voltage on the +13V bus is +10.6V plus 28% of the difference between the +10V and +20V supplies, and can reach about +19V if the Curve Tracer NUMBER OF STEPS control is set to maximum. The +19V level is within the safe operating range for U47, which is rated for up to 36V power-suuply difference (+V - (-V)).

SECTION 5

CALIBRATION

CALIBRATION

5.1 TEST EQUIPMENT REQUIRED:

(a) Tektronix Type 577/D1 or 577/D2 Curve Tracer with Type 177 Standard Test Fixture (preferably, those with which the Adapter is to be used).

(b) Test Oscilloscope: Dual-Trace vertical amplifier, 25 MHz or greater bandwidth, DC-coupled, with provision for composite Vertical signal triggering in Alternate mode. Tektronix Type 465 or equiv.

(c) Time-Mark Generator: 5, 10 and 100 µs time-marks at .05% or better accuracy. Tektronix Type TG501 (in TM503 Power Module) or equivalent.

(d) Digital Voltmeter: Accuracy 0.5% or better at 4.00V. Tektronix Type DM 501 or DM 502 Digital Multimeter (in TM503 Power Module) or equivalent.

(e) Accessories: One 10X passive attenuator probe for Oscilloscope.
One 42", 50Ω coaxial cable, BNC/BNC.
One 50Ω feed-through termination, BNC/BNC.

PROCEDURE

5.2 PRELIMINARY SETUP:

(a) TURN-OFF TIME ADAPTER:

GATE CURRENT Control Knob: Check that the index dot on the knob skirt aligns with the 0 line on the panel when the control is at the counterclockwise stop.

TURN-OFF TIME Control Dial: Check that the outer ring of the dial is at 0 and the inner dial is at 5 when the control is at the counterclockwise stop.

ACCESS TO ADJUSTMENTS: Remove the left half (only) of the wraparound cover of the adapter to expose the test-points and adjustments. Leave the right half of the wraparound in place and its screws tight to support the panel during calibration.

(b) 577 and 177:

INSTALLATION: Install the 177 Standard Test Fixture in the 577, and preset the 577 and 177 controls as shown in Sections 2.1.1 and 2.1.2 of this manual. Remove any passive adapters or leads from the Turn-Off Time Adapter and install the Turn-Off Time Adapter on the 177 Fixture.

TURN-ON: Turn on the 577, and set the 177 LEFT/RIGHT switch to Right. The green POWER light on the Turn-Off Time Adapter should come on.

5.3 GATE CURRENT Calibration.

Connect the digital voltmeter to test-points TP33 (-) AND TP49 (+), and set the range selector for best resolution of a 4V measurement.

Set the S39 jumper (located on the circuit board just below the GATE CURRENT potentiometer) to the Z position (center and left pins).

Rotate the GATE CURRENT control fully clockwise, and check for a reading of 4.00V. If the reading is other than 4.00V, adjust R41 for a reading of 4.000V.

Check intermediate knob settings as follows:

Knob Setting	Meter Reading	Tolerance
75	3.75V	±0.187
50	2.50V	±0.125
25	1.25V	±0.062

Disconnect the voltmeter from the two test-points, and move the S39 jumper back to the Y position (center and right-hand pins).

5.4 TURN-OFF TIME CALIBRATION.

Set the 577 VARIABLE COLLECTOR % control to 100 (6.5V Peak)

Connect the 10X probe to one Vertical input of the Test Oscilloscope, and set its VOLTS/DIV for 5V/div (net, including probe), direct-coupled. Connect the probe tip to TP61 on the Turn-Off Time Adapter.

Set the other Vertical channel of the Test Oscilloscope to 0.5V/div, and attach the 50Ω feed-through termination and coaxial cable to its input, connecting the other end of the cable to the Time Mark Generator MARKERS output.

Set the Test Oscilloscope Vertical Mode to Alternate and its Time Base Triggering Source to Normal (composite Ch 1 & Ch 2 trigger), with the TIME/DIV set to 10 μs.

Set the MODE switch on the Turn-Off Time Adapter to Turn-Off Time. With the Test Oscilloscope Triggering Slope set to positive (+), adjust Triggering Slope for a stable Alternate display of both waveforms.

Set the TURN-OFF TIME dial to 100 μs (turn clockwise until outer dial and inner dial are both at 0). Set the Time Mark Generator for 100 μs markers, and check that the displayed TP61 pulse is exactly 100 μs long. If it is not, adjust R50 for 100 μs pulse duration.

Now, turn the TURN-OFF TIME dial counterclockwise to the 5 µs stop. Set the Time Mark Generator for 5 µs markers, and set the Test Oscilloscope for 0.5 µs/div. Check that the duration of the TP61 pulse is just 5 µs. If it is not, adjust R57 for 5.0 µs pulse duration.

Recheck the 100µs and 5 µs settings for control interaction if adjustments have been made.

Now set the Time Mark Generator for 10 µs markers, and check the calibration of the TURN-OFF TIME dial each 10 µs from 10 through 90 µs (tolerance, ±3%). Use the Oscilloscope MAGNIFIER as required for adequate resolution.

5.5 ANODE DRIVE CIRCUIT Check.

Move the Test Oscilloscope probe to the ANODE jack on the Turn-Off Time Adapter panel, and set the Test Oscilloscope to display that channel only.

Set TURN-OFF TIME to 105 µs (fully clockwise), the 577 SERIES RESISTORS control to .12, the Test Oscilloscope Triggering Slope to negative (-), and its VOLTS/DIV to 1V (net, including probe). With the Test Oscilloscope TIME/DIV at 20 µs, adjust Triggering Level for a stable display triggered on the negative-going slope of the turn-off pulse.

Check the negative portion of the displayed pulse for a level no higher than +1V, with essentially constant level for the 105 µs duration.

Now change the Test Oscilloscope to 10V/div (net, including probe), set the 577 VARIABLE COLLECTOR % to 40 and MAX PEAK VOLTS to 25 (the SERIES RESISTORS pointer will track to 1.9).

Increase the VARIABLE COLLECTOR % setting while observing the positive-going trailing edge of the turn-off pulse. The excursion at the end of the pulse should limit at approximately +30V (maximum, +35V).

Return the 577 MAX PEAK VOLTS to 6.5.

Disconnect the test equipment and reinstall the left-hand wraparound cover on the Turn-Off Time Adapter.

This completes the calibration of the adapter.

REPLACEABLE PARTS

PARTS ORDERING INFORMATION

Replacement parts are available from or through your local Tektronix, Inc. Field Office or representative.

Changes to Tektronix instruments are sometimes made to accommodate improved components as they become available, and to give you the benefit of the latest circuit improvements developed in our engineering department. It is therefore important, when ordering parts, to include the following information in your order: Part number, instrument type or number, serial number, and modification number if applicable.

If a part you have ordered has been replaced with a new or improved part, your local Tektronix, Inc. Field Office or representative will contact you concerning any change in part number.

Change information, if any, is located at the rear of this manual.

SPECIAL NOTES AND SYMBOLS

X000 Part first added at this serial number

00X Part removed after this serial number

FIGURE AND INDEX NUMBERS

Items in this section are referenced by figure and index numbers to the illustrations.

INDENTATION SYSTEM

This mechanical parts list is indented to indicate item relationships. Following is an example of the indentation system used in the description column.

1 2 3 4 5 Name & Description

Assembly and/or Component
Attaching parts for Assembly and/or Component
\- - - * - - -
  Detail Part of Assembly and/or Component
  Attaching parts for Detail Part
\- - - * - - -
    Parts of Detail Part
    Attaching parts for Parts of Detail Part
\- - - * - - -

Attaching Parts always appear in the same indentation as the item it mounts, while the detail parts are indented to the right. Indented items are part of, and included with, the next higher indentation. The separation symbol - - - * - - - indicates the end of attaching parts.

Attaching parts must be purchased separately, unless otherwise specified.

ITEM NAME

In the Parts List, an Item Name is separated from the description by a colon (:). Because of space limitations, an Item Name may sometimes appear as incomplete. For further Item Name identification, the U.S. Federal Cataloging Handbook H6-1 can be utilized where possible.

ABBREVIATIONS

"	INCH	ELCTRN	ELECTRON	IN	INCH	SE	SINGLE END
#	NUMBER SIZE	ELEC	ELECTRICAL	INCAND	INCANDESCENT	SECT	SECTION
ACTR	ACTUATOR	ELCTLT	ELECTROLYTIC	INSUL	INSULATOR	SEMICOND	SEMICONDUCTOR
ADPTR	ADAPTER	ELEM	ELEMENT	INTL	INTERNAL	SHLD	SHIELD
ALIGN	ALIGNMENT	EPL	ELECTRICAL PARTS LIST	LPHLDR	LAMPHOLDER	SHLDR	SHOULDERED
AL	ALUMINUM	EQPT	EQUIPMENT	MACH	MACHINE	SKT	SOCKET
ASSEM	ASSEMBLED	EXT	EXTERNAL	MECH	MECHANICAL	SL	SLIDE
ASSY	ASSEMBLY	FIL	FILLISTER HEAD	MTG	MOUNTING	SLFLKG	SELF-LOCKING
ATTEN	ATTENUATOR	FLEX	FLEXIBLE	NIP	NIPPLE	SLVG	SLEEVING
AWG	AMERICAN WIRE GAGE	FLH	FLAT HEAD	NON WIRE	NOT WIRE WOUND	SPR	SPRING
BD	BOARD	FLTR	FILTER	OBD	ORDER BY DESCRIPTION	SQ	SQUARE
BRKT	BRACKET	FR	FRAME or FRONT	OD	OUTSIDE DIAMETER	SST	STAINLESS STEEL
BRS	BRASS	FSTNR	FASTENER	OVH	OVAL HEAD	STL	STEEL
BRZ	BRONZE	FT	FOOT	PH BRZ	PHOSPHOR BRONZE	SW	SWITCH
BSHG	BUSHING	FXD	FIXED	PL	PLAIN or PLATE	T	TUBE
CAB	CABINET	GSKT	GASKET	PLSTC	PLASTIC	TERM	TERMINAL
CAP	CAPACITOR	HDL	HANDLE	PN	PART NUMBER	THD	THREAD
CER	CERAMIC	HEX	HEXAGON	PNH	PAN HEAD	THK	THICK
CHAS	CHASSIS	HEX HD	HEXAGONAL HEAD	PWR	POWER	TNSN	TENSION
CKT	CIRCUIT	HEX SOC	HEXAGONAL SOCKET	RCPT	RECEPTACLE	TPG	TAPPING
COMP	COMPOSITION	HLCPS	HELICAL COMPRESSION	RES	RESISTOR	TRH	TRUSS HEAD
CONN	CONNECTOR	HLEXT	HELICAL EXTENSION	RGD	RIGID	V	VOLTAGE
COV	COVER	HV	HIGH VOLTAGE	RLF	RELIEF	VAR	VARIABLE
CPLG	COUPLING	IC	INTEGRATED CIRCUIT	RTNR	RETAINER	W/	WITH
CRT	CATHODE RAY TUBE	ID	INSIDE DIAMETER	SCH	SOCKET HEAD	WSHR	WASHER
DEG	DEGREE	IDENT	IDENTIFICATION	SCOPE	OSCILLOSCOPE	XFMR	TRANSFORMER
DWR	DRAWER	IMPLR	IMPELLER	SCR	SCREW	XSTR	TRANSISTOR

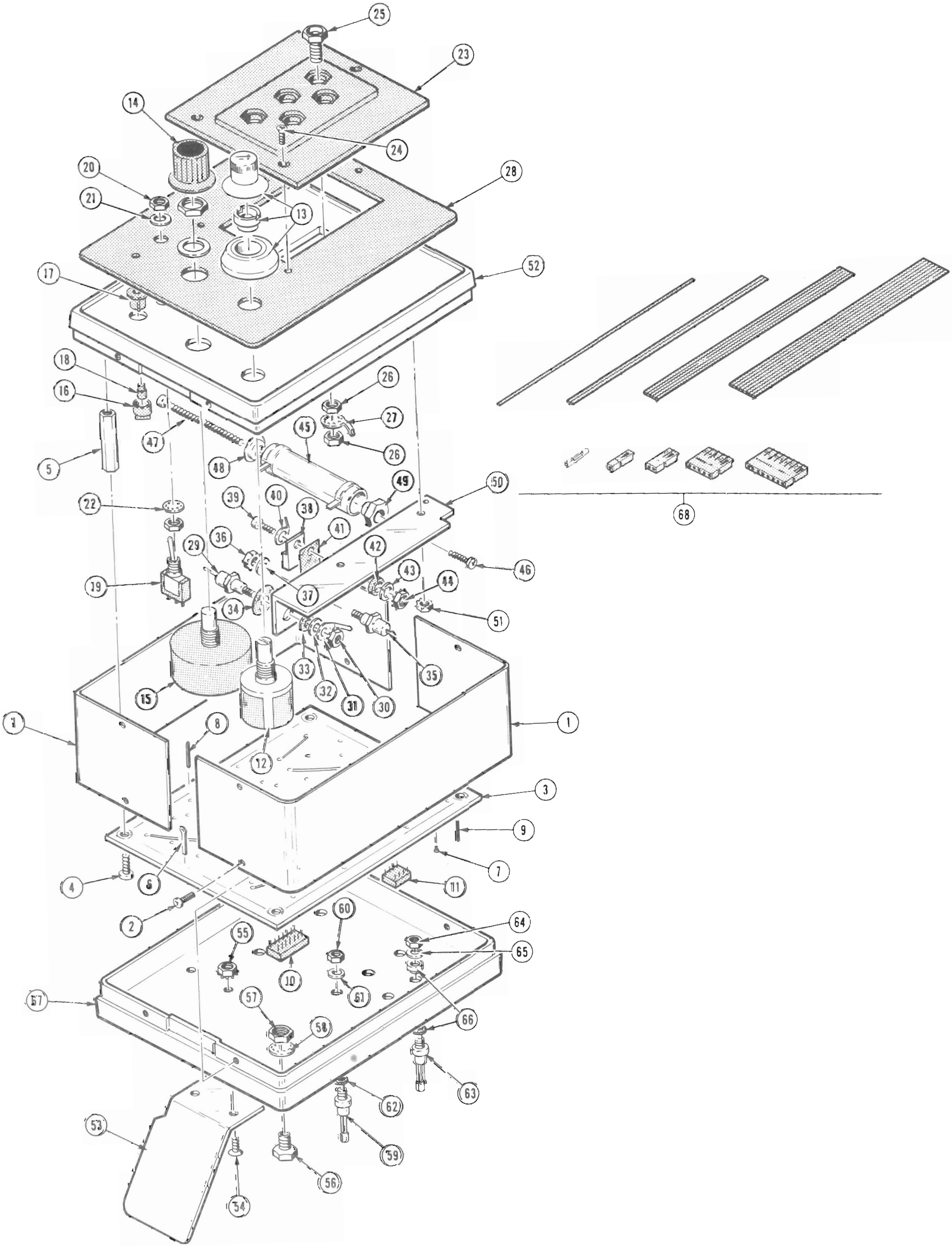
CROSS INDEX—MFR. CODE NUMBER TO MANUFACTURER

Mfr. Code	Manufacturer	Address	City, State, Zip
00853	SANGAMO ELECTRIC CO., S. CAROLINA DIV.	P O BOX 128	PICKENS, SC 29671
01121	ALLEN-BRADLEY COMPANY	1201 2ND STREET SOUTH	MILWAUKEE, WI 53204
01295	TEXAS INSTRUMENTS, INC., SEMICONDUCTOR GROUP	P O BOX 5012, 13500 N CENTRAL EXPRESSWAY	DALLAS, TX 75222
02735	RCA CORPORATION, SOLID STATE DIVISION	ROUTE 202	SOMERVILLE, NY 08876
04222	AVX CERAMICS, DIVISION OF AVX CORP.	P O BOX 867, 19TH AVE. SOUTH	MURTLE BEACH, SC 29577
04713	MOTOROLA, INC., SEMICONDUCTOR PROD. DIV.	5005 E MCDOWELL RD,PO BOX 20923	PHOENIX, AZ 85036
05129	KILO ENGINEERING COMPANY	2015 D	LA VERNE, CA 91750
07263	FAIRCHILD SEMICONDUCTOR, A DIV. OF FAIRCHILD CAMERA AND INSTRUMENT CORP.	464 ELLIS STREET	MOUNTAIN VIEW, CA 94042
07910	TELEDYNE SEMICONDUCTOR	12515 CHADRON AVE.	HAWTHORNE, CA 90250
09353	C AND K COMPONENTS, INC.	103 MORSE STREET	WATERTOWN, MA 02172
12327	FREEWAY CORPORATION	9301 ALLEN DRIVE	CLEVELAND, OH 44125
18324	SIGNETICS CORP.	811 E. ARQUES	SUNNYVALE, CA 94086
22526	BERG ELECTRONICS, INC.	YOUK EXPRESSWAY	NEW CUMBERLAND, PA 17070
32997	BOURNS, INC., TRIMPOT PRODUCTS DIV.	1200 COLUMBIA AVE.	RIVERSIDE, CA 92507
56289	SPRAGUE ELECTRIC CO.		NORTH ADAMS, MA 01247
63743	WARD LEONARD ELECTRIC CO., INC.	31 SOUTH ST.	MOUNT VERNON, NY 10550
71400	BUSSMAN MFG., DIVISION OF MCGRAW-EDISON CO.	2536 W. UNIVERSITY ST.	ST. LOUIS, MO 63107
71744	CHICAGO MINIATURE LAMP WORKS	4433 RAVENSWOOD AVE.	CHICAGO, IL 60640
72982	ERIE TECHNOLOGICAL PRODUCTS, INC.	644 W. 12TH ST.	ERIE, PA 16512
73138	BECKMAN INSTRUMENTS, INC., HELIPOT DIV.	2500 HARBOR BLVD.	FULLERTON, CA 92634
73743	FISCHER SPECIAL MFG. CO.	446 MORGAN ST.	CINCINNATI, OH 45206
73803	TEXAS INSTRUMENTS, INC., METALLURGICAL MATERIALS DIV.	34 FOREST STREET	ATTLEBORO, MA 02703
74921	ITEN FIBRE CO., THE	4001 BENEFIT AVE., P O BOX 9	ASHTABULA, OH 44004
74970	JOHNSON, E. F., CO.	299 10TH AVE. S. W.	WASECA, MN 56093
77250	PHEOLL MANUFACTURING CO., DIVISION OF ALLIED PRODUCTS CORP.	5700 W. ROOSEVELT RD.	CHICAGO, IL 60650
78189	ILLINOIS TOOL WORKS, INC. SHAKEPROOF DIVISION	ST. CHARLES ROAD	ELGIN, IL 60120
79807	WROUGHT WASHER MFG. CO.	2100 S. O BAY ST.	MILWAUKEE, WI 53207
80009	TEKTRONIX, INC.	P O BOX 500	BEAVERTON, OR 97077
81483	INTERNATIONAL RECTIFIER CORP.	9220 SUNSET BLVD.	LOS ANGELES, CA 90069
83003	VARO, INC.	P O BOX 411, 2203 WALNUT STREET	GARLAND, TX 75040
83385	CENTRAL SCREW CO.	2530 CRESCENT DR.	BROADVIEW, IL 60153
91637	DALE ELECTRONICS, INC.	P. O. BOX 609	COLUMBUS, NE 68601

Ckt No.	Tektronix Part No.	Serial/Model No. Eff	Dscont	Name & Description	Mfr Code	Mfr Part Number
A1	670-4884-00			CKT BOARD ASSY:SCR TURN-OFF TIME	80009	670-4884-00
C10	290-0325-00			CAP.,FXD,ELCTLT:330UF,+75-10%,50V	56289	601D337G050FL4
C11	283-0111-00			CAP.,FXD,CER DI:0.1UF,20%,50V	72982	8121-N088Z5U104M
C12	290-0215-00			CAP.,FXD,ELCTLT:100UF,+75-10%,25V	56289	30D107G025DD9
C15	283-0341-00			CAP.,FXD,CER DI:0.047UF,10%,100V	72982	8131N127X7R0473K
C16	281-0543-00			CAP.,FXD,CER DI:270PF,10%,500V	72982	301055X5P271K
C17	283-0203-00			CAP.,FXD,CER DI:0.47UF,20%,50V	72982	8131N075 E474M
C21	281-0525-00			CAP.,FXD,CER DI:470PF,+/-94PF,500V	04222	7001-1364
C24	281-0543-00			CAP.,FXD,CER DI:270PF,10%,500V	72982	301055X5P271K
C27	281-0524-00			CAP.,FXD,CER DI:150PF,+/-30PF,500V	04222	7001-1381
C39	283-0341-00			CAP.,FXD,CER DI:0.047UF,10%,100V	72982	8131N127X7R0473K
C51	283-0003-00			CAP.,FXD,CER DI:0.01UF,+80-20%,150V	72982	855-558Z5U-103Z
C52	283-0655-00			CAP.,FXD,MICA D:0.0033UF,1%,500V	00853	D195F332F0
C55	283-0059-00			CAP.,FXD,CER DI:1UF,+80-20%,25V	72982	8141N038E105Z
C62	290-0259-00			CAP.,FXD,ELCTLT:100UF,50VDC	56289	D36258
C65	283-0110-00			CAP.,FXD,CER DI:0.005UF,+80-20%,150V	56289	19C242B
C66	283-0110-00			CAP.,FXD,CER DI:0.005UF,+80-20%,150V	56289	19C242B
C70	283-0203-00			CAP.,FXD,CER DI:0.47UF,20%,50V	72982	8131N075 E474M
C71	283-0198-00			CAP.,FXD,CER DI:0.22UF,20%,50V	72982	8131N075 E224M
C72	290-0650-00			CAP.,FXD,ELCTLT:1000UF,20%,10V	56289	109D108X0010T2
C74	283-0119-00			CAP.,FXD,CER DI:2200PF,5%,200V	72982	855-535B222J
CR10	152-0107-00			SEMICOND DEVICE:SILICON,400V,400MA	80009	152-0107-00
CR15	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	1N4152
CR16	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	1N4152
CR22	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	1N4152
CR27	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	1N4152
CR28	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	1N4152
CR33	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	1N4152
CR34	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	1N4152
CR39	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	1N4152
CR49	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	1N4152
CR52	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	1N4152
CR64	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	1N4152
CR65	152-0670-00			SEMICOND DEVICE:SILICON,35V,3A	83003	SKS002
CR66	152-0670-00			SEMICOND DEVICE:SILICON,35V,3A	83003	SKS002
CR67	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	1N4152
CR70	152-0274-00			SEMICOND DEVICE:SILICON,100V,10A	80009	152-0274-00
CR72	152-0274-00			SEMICOND DEVICE:SILICON,100V,10A	80009	152-0274-00
CR73	152-0274-00			SEMICOND DEVICE:SILICON,100V,10A	80009	152-0274-00
DS13	150-0109-00			LAMP,INCAND:18V,26MA	71744	CM7220
L10	108-0224-00			COIL,RF:FIXED:,3.9MH	80009	108-0224-00
L68	276-0541-00			SHLD BEAD,ELEK:	80009	276-0541-00
Q10	151-1004-00			TRANSISTOR:SILICON,JFE,N-CHANNEL	80009	151-1004-00
Q11	151-0136-00			TRANSISTOR:SILICON,NPN	02735	35495
Q12	151-0342-00			TRANSISTOR:SILICON,PNP	80009	151-0342-00
Q13	151-0136-00			TRANSISTOR:SILICON,NPN	02735	35495
Q15	151-0342-00			TRANSISTOR:SILICON,PNP	80009	151-0342-00
Q16	151-0342-00			TRANSISTOR:SILICON,PNP	80009	151-0342-00
Q20	151-0341-00			TRANSISTOR:SILICON,NPN	07263	S040065
Q24	151-0341-00			TRANSISTOR:SILICON,NPN	07263	S040065
Q28	151-0341-00			TRANSISTOR:SILICON,NPN	07263	S040065

Ckt No.	Tektronix Part No.	Serial/Model No. Eff	Dscont	Name & Description	Mfr Code	Mfr Part Number
Q31	151-0341-00			TRANSISTOR:SILICON,NPN	07263	S040065
Q33	151-0134-00			TRANSISTOR:SILICON,PNP	80009	151-0134-00
Q34	151-0136-00			TRANSISTOR:SILICON,NPN	02735	35495
Q39	151-1045-00			TRANSISTOR:SILICON,JFE,P-CHANNEL	80009	151-1045-00
Q42	151-0341-00			TRANSISTOR:SILICON,NPN	07263	S040065
Q45	151-0341-00			TRANSISTOR:SILICON,NPN	07263	S040065
Q49	151-0183-00			TRANSISTOR:SILICON,NPN	80009	151-0183-00
Q53	151-0361-00			TRANSISTOR:SILICON,NPN,DUAL	56289	TD702
Q61	151-0136-00			TRANSISTOR:SILICON,NPN	02735	35495
Q65	151-0426-00			TRANSISTOR:SILICON,NPN	80009	151-0426-00
Q66	151-0426-00			TRANSISTOR:SILICON,NPN	80009	151-0426-00
R10	315-0332-00			RES.,FXD,CMPSN:3.3K OHM,5%,0.25W	01121	CB3325
R11	315-0132-00			RES.,FXD,CMPSN:1.3K OHM,5%,0.25W	01121	CB1325
R12	315-0512-00			RES.,FXD,CMPSN:5.1K OHM,5%,0.25W	01121	CB5125
R13	315-0221-00			RES.,FXD,CMPSN:220 OHM,5%,0.25W	01121	CB2215
R15	315-0223-00			RES.,FXD,CMPSN:22K OHM,5%,0.25W	01121	CB2235
R16	315-0273-00			RES.,FXD,CMPSN:27K OHM,5%,0.25W	01121	CB2735
R17	315-0391-00			RES.,FXD,CMPSN:390 OHM,5%,0.25W	01121	CB3915
R20	315-0473-00			RES.,FXD,CMPSN:47K OHM,5%,0.25W	01121	CB4735
R21	315-0103-00			RES.,FXD,CMPSN:10K OHM,5%,0.25W	01121	CB1035
R22	315-0273-00			RES.,FXD,CMPSN:27K OHM,5%,0.25W	01121	CB2735
R23	315-0273-00			RES.,FXD,CMPSN:27K OHM,5%,0.25W	01121	CB2735
R24	315-0104-00			RES.,FXD,CMPSN:100K OHM,5%,0.25W	01121	CB1045
R25	315-0183-00			RES.,FXD,CMPSN:18K OHM,5%,0.25W	01121	CB1835
R26	315-0563-00			RES.,FXD,CMPSN:56K OHM,5%,0.25W	01121	CB5635
R27	315-0124-00			RES.,FXD,CMPSN:120K OHM,5%,0.25W	01121	CB1245
R28	315-0103-00			RES.,FXD,CMPSN:10K OHM,5%,0.25W	01121	CB1035
R29	315-0103-00			RES.,FXD,CMPSN:10K OHM,5%,0.25W	01121	CB1035
R31	315-0183-00			RES.,FXD,CMPSN:18K OHM,5%,0.25W	01121	CB1835
R32	315-0561-00			RES.,FXD,CMPSN:560 OHM,5%,0.25W	01121	CB5615
R39	315-0155-00			RES.,FXD,CMPSN:1.5M OHM,5%,0.25W	01121	CB1555
R41	311-1563-00			RES.,VAR,NONWIR:1K OHM,20%,0.50W	73138	91A-10000M
R42	315-0183-00			RES.,FXD,CMPSN:18K OHM,5%,0.25W	01121	CB1835
R43	321-0261-00			RES.,FXD,FILM:5.11K OHM,1%,0.125W	91637	MFF1816G51100F
R44	321-0240-00			RES.,FXD,FILM:3.09K OHM,1%,0.125W	91637	MFF1816G30900F
R46	311-0543-01			RES.,VAR,WW:4K OHM,2.75W	73138	5311-401-0
R47	323-0626-00			RES.,FXD,FILM:50 OHM,1%,0.5W	91637	MFF1226G50R00F
R48	321-0268-00			RES.,FXD,FILM:6.04K OHM,1%,0.125W	91637	MFF1816G60400F
R49	304-0680-00			RES.,FXD,CMPSN:68 OHM,10%,1W	01121	GB6801
R50	311-1556-00			RES.,VAR,NONWIR:50K OHM,20%,0.50W	73138	91A-50001M
R51	315-0273-00			RES.,FXD,CMPSN:27K OHM,5%,0.25W	01121	CB2735
R52	315-0101-00			RES.,FXD,CMPSN:100 OHM,5%,0.25W	01121	CB1015
R53	321-0239-00			RES.,FXD,FILM:3.01K OHM,1%,0.125W	91637	MFF1816G30100F
R54	321-0297-00			RES.,FXD,FILM:12.1K OHM,1%,0.125W	91637	MFF1816G12101F
R55	315-0472-00			RES.,FXD,CMPSN:4.7K OHM,5%,0.25W	01121	CB4725
R56	321-0162-00			RES.,FXD,FILM:475 OHM,1%,0.125W	91637	MFF1816G475R0F
R57	311-1568-00			RES.,VAR,NONWIR:50 OHM,20%,0.50W	73138	91A-50R00M
R58	311-1729-00			RES.,VAR,WW:10K OHM,5%,2W	32997	3540S-561-103
R60	315-0470-00			RES.,FXD,CMPSN:47 OHM,5%,0.25W	01121	CB4705
R61	315-0222-00			RES.,FXD,CMPSN:2.2K OHM,5%,0.25W	01121	CB2225
R62	315-0151-00			RES.,FXD,CMPSN:150 OHM,5%,0.25W	01121	CB1515
R64	315-0390-00			RES.,FXD,CMPSN:39 OHM,5%,0.25W	01121	CB3905

Ckt No.	Tektronix Part No.	Serial/Model No. Eff	Dscont	Name & Description	Mfr Code	Mfr Part Number
R65	315-0390-00			RES.,FXD,CMPSN:39 OHM,5%,0.25W	01121	CB3905
R66	315-0390-00			RES.,FXD,CMPSN:39 OHM,5%,0.25W	01121	CB3905
R67	315-0390-00			RES.,FXD,CMPSN:39 OHM,5%,0.25W	01121	CB3905
R70	308-0691-00			RES.,FXD,WW:0.3 OHM,5%,25W	91637	HL2502Z6R000J
R71	308-0365-00			RES.,FXD,WW:1.5 OHM,5%,3W	56289	242EX1R500JQ151
S28	260-0613-00			SWITCH,TOGGLE:SPDT,115V	09353	7101N
U22	156-0350-01			MICROCIRCUIT,DI:QUAD 2-INPUT NAND GATE	80009	156-0350-01
U47	156-0158-00			MICROCIRCUIT,LI:DUAL OPERATIONAL AMPLIFIER	80009	156-0158-00
U51	156-0402-00			MICROCIRCUIT,DI:TIMER	18324	NE555V
VR11	152-0055-00			SEMICOND DEVICE:ZENER,0.4W,11V,5%	04713	1N962B
VR12	152-0395-00			SEMICOND DEVICE:ZENER,0.4W,4.3V,5%	04713	1N749A
VR13	152-0226-00			SEMICOND DEVICE:ZENER,0.4W,5.1V,5%	81483	69-6584
VR68	152-0282-00			SEMICOND DEVICE:ZENER,0.4W,30V,5%	04713	1N972B



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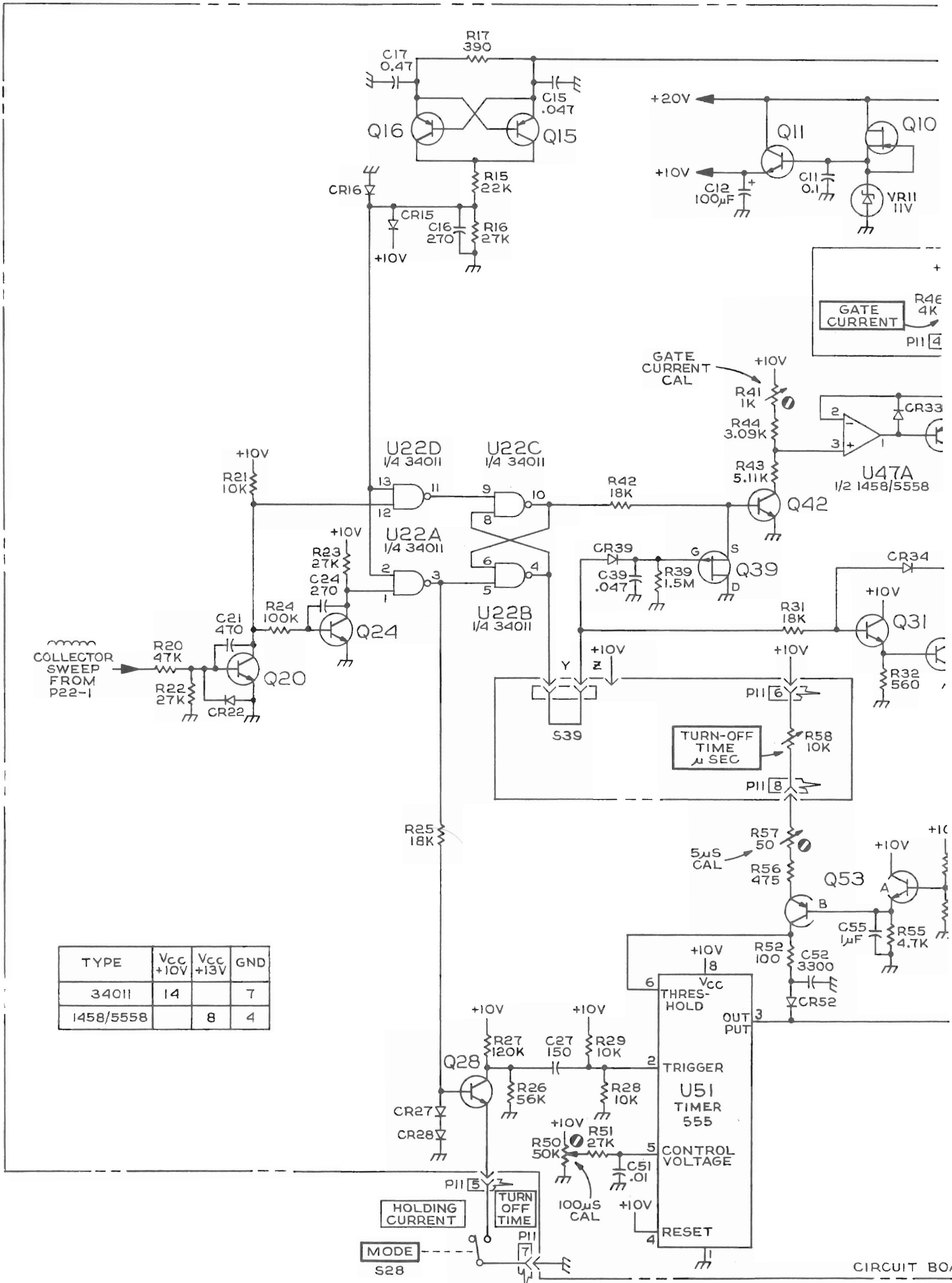
035-5028-00

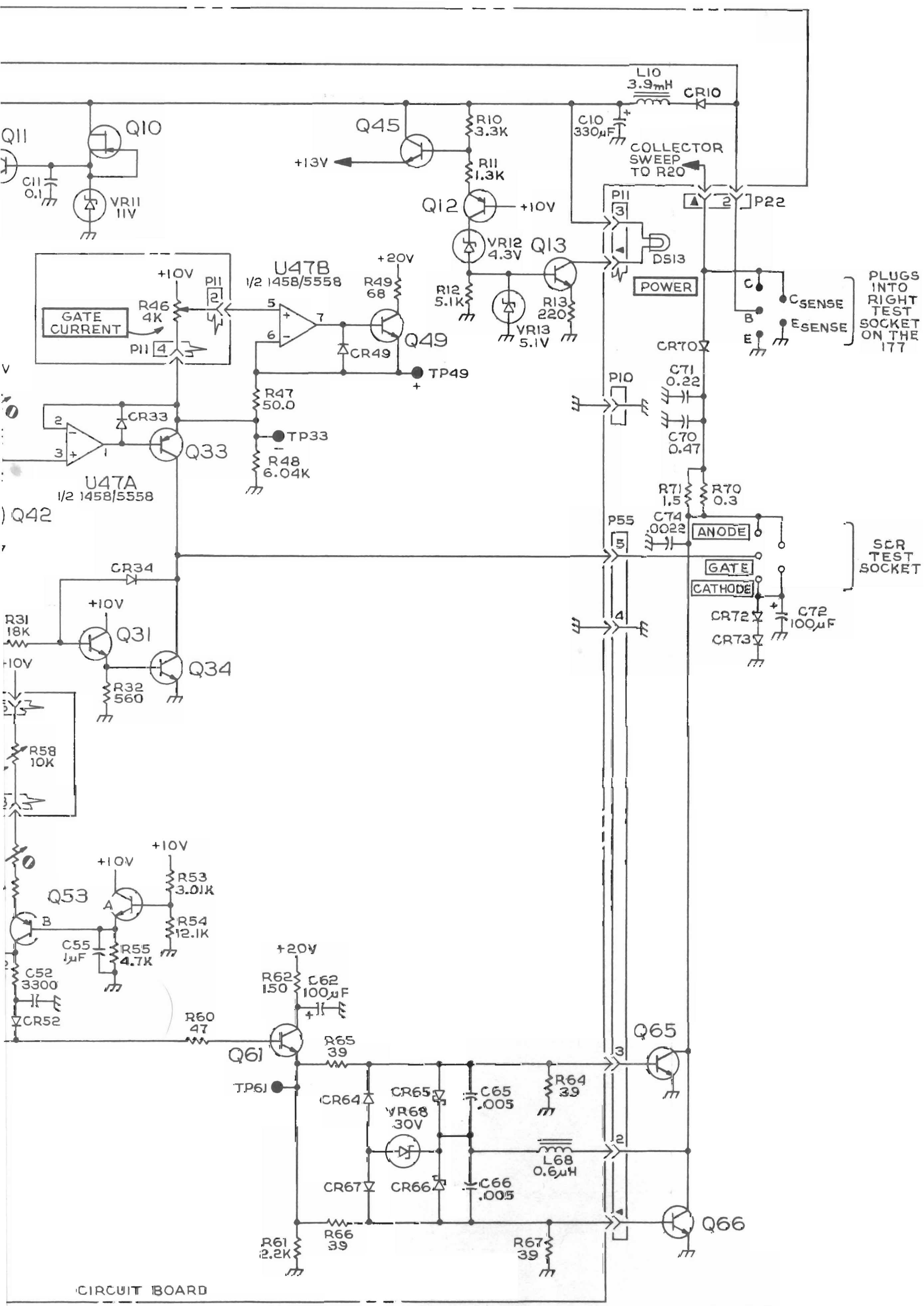
Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Dscont	Qty	1 2 3 4 5 Name & Description	Mfr Code	Mfr Part Number
	035-5028-00			1	TEST FIXTURE:SCR TURN-OFF TIME ADAPTER	80009	035-5028-00
-1	380-0498-00			2	. HSG HALF,WRAPAR:	80009	380-0498-00
					(ATTACHING PARTS)		
-2	211-0007-00			8	. SCREW,MACHINE:4-40 X 0.188 INCH,PNH STL	83385	OBD
					- - - * - - -		
-3	----- -----			1	. CKT BOARD ASSY:SCR TURN-OFF TIME(SEE A1 EPL)		
					(ATTACHING PARTS)		
-4	211-0504-00			4	. SCREW,MACHINE:6-32 X 0.25 INCH,PNH STL	83385	OBD
-5	129-0278-00			4	. SPACER,POST:6-32 X 0.25 X 1.11 INCHES	80009	129-0278-00
					- - - * - - -		
	----- -----			-	. . CKT BOARD ASSEMBLY INCLUDES:		
-6	214-0579-00			4	. . TERM.,TEST PT:0.40 INCH LONG	80009	214-0579-00
-7	136-0252-04			57	. . SOCKET,PIN TERM:0.188 INCH LON	22526	75060
-8	131-0608-00			16	. . CONTACT,ELEC:0.365 INCH LONG	22526	47357
-9	131-0787-00			3	. . CONTACT,ELEC:0.64 INCH LONG	22526	47359
-10	136-0269-02			1	. . SOCKET,PLUG-IN:14 CONTACT,LOW CLEARANCE	01295	C931402
-11	136-0514-00			2	. . SOCKET,PLUG-IN:8 CONTACT	73803	C9308-02
-12	----- -----			1	. RESISTOR,VAR:(SEE R58 EPL)		
					(ATTACHING PARTS)		
-13	331-0139-00			1	. DIAL,CONTROL:W/O BRAKE	05129	461S41
					- - - * - - -		
-14	366-1026-00			1	. KNOB:ROUND	80009	366-1026-00
-15	----- -----			1	. RESISTOR,VAR:(SEE R46 EPL)		
-16	200-0935-00			1	. BASE,LAMPHOLDER:0.29 OD X 0.19 CASE	80009	200-0935-00
-17	352-0157-00			1	. LAMPHOLDER:WHITE PLASTIC	80009	352-0157-00
-18	378-0602-00			1	. LENS,LIGHT:GREEN	80009	378-0602-00
-19	----- -----			1	. SWITCH,TOGGLE:(SEE S28 EPL)		
					(ATTACHING PARTS)		
-20	210-0562-00			1	. NUT,PLAIN,HEX.:0.25-40 X 0.312 INCH,BBS	73743	2X20224-402
-21	210-0940-00			2	. WASHER,FLAT:0.25 ID X 0.375 INCH OD,STL	79807	OBD
-22	210-0011-00			1	. WASHER,LOCK:INTL,0.062 IDX 0.253 OD,STL	78189	1214-00-00-0541C
					- - - * - - -		
-23	386-1551-02			1	. PL,MTG,TEST ADA:PLASTIC	80009	386-1551-02
					(ATTACHING PARTS)		
-24	211-0101-00			3	. SCREW,MACHINE:4-40 X 0.25" 100 DEG,FLH STL	83385	OBD
					- - - * - - -		
-25	131-0031-00			5	. JACK,TIP:0.635 INCH LONG W/LUG	74970	16-104-2AND13351
					(ATTACHING PARTS)		
-26	210-0455-00			10	. NUT,PLAIN,HEX.:0.25-28 X 0.375 INCH,BRASS	73743	3089-402
-27	210-0223-00			5	. TERMINAL,LUG:0.25 INCH DIA,SE	78189	2101-14-03-2520N
					- - - * - - -		
-28	333-2275-00			1	. PANEL,FRONT:	80009	333-2275-00
-29	----- -----			2	. SEMICOND DVC,DI:(SEE CR72 AND CR70 EPL)		
					(ATTACHING PARTS)		
-30	210-0410-00			2	. NUT,PLAIN,HEX.:10-32 X 0.312 INCH,BRS	73743	2X20003-402
-31	210-0206-00			2	. TERMINAL,LUG:SE #10	78189	2103-10-00-2520N
-32	210-0805-00			2	. WASHER,FLAT:0.204 ID X 0.438 INCH OD,STL	12327	OBD
-33	210-0813-00			2	. WSHR,SHOULDERED:# 10 FIBER	74921	OBD
-34	210-0909-00			2	. WASHER,NONMETAL:0.196 ID X 0.625" OD,MICA	71400	OBD
					- - - * - - -		
-35	----- -----			1	. SEMICOND DVC,DI:(SEE CR73 EPL)		
					(ATTACHING PARTS)		
-36	210-0410-00			1	. NUT,PLAIN,HEX.:10-32 X 0.312 INCH,BRS	73743	2X20003-402
-37	210-0206-00			1	. TERMINAL,LUG:SE #10	78189	2103-10-00-2520N
					- - - * - - -		
-38	----- -----			2	. TRANSISTOR:(SEE Q65 AND Q66 EPL)		
					(ATTACHING PARTS)		
-39	211-0510-00			2	. SCREW,MACHINE:6-32 X 0.312 INCH,PNH STL	83385	OBD
-40	210-0202-00			2	. TERMINAL,LUG:SE #6	78189	2104-06-00-2520N
-41	342-0163-00			2	. INSULATOR,PLATE:XSTR,0.675 X 0.625 X 0.001"	80009	342-0163-00
-42	210-0935-00			2	. WASHER,NONMETAL:FIBER,0.14 IDX 0.375"OD	74921	OBD
-43	210-0803-00			2	. WASHER,FLAT:0.15 ID X 0.375 INCH OD,STL	12327	OBD
-44	210-0457-00			2	. NUT,PLAIN,EXT W:6-32 X 0.312 INCH,STL	83385	OBD
					- - - * - - -		

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Dscont	Qty	1 2 3 4 5 Name & Description	Mfr Code	Mfr Part Number
1-45	----- -----			1	. RES.,FXD,WW:(SEE R70 EPL)		
					(ATTACHING PARTS)		
-46	212-0001-00			1	. SCREW,MACHINE:8-32 X 0.250 INCH,PNH STL	77250	OBD
-47	212-0037-00			1	. SCREW,MACHINE:8-32 X 1.75 INCH FILH,STL	83385	OBD
-48	210-0808-00			1	. EYELET,METALLIC:CENTERING	63743	2515113-3TP-909
-49	210-0462-00			1	. INSERT,SCR THD:SHOULDERED,0.719 INCH LONG	80009	210-0462-00
					- - - * - - -		
-50	386-3707-00			1	. PLATE,MOUNTING:	80009	386-3707-00
					(ATTACHING PARTS)		
-51	210-0457-00			2	. NUT,PLAIN,EXT W:6-32 X 0.312 INCH,STL	83385	OBD
					- - - * - - -		
-52	200-0277-15			1	. CAB.,TEST FXTR:TOP	80009	200-0277-15
-53	200-2062-00			1	. GUARD,SWITCH:	80009	200-2062-00
					(ATTACHING PARTS)		
-54	212-0070-00			2	. SCREW,MACHINE:8-32 X 0.312"100 DEG,FLH STL	83385	OBD
-55	210-0458-00			2	. NUT,PLAIN,EXT W:8-32 X 0.344 INCH,STL	83385	OBD
					- - - * - - -		
-56	131-0031-00			1	. JACK,TIP:0.635 INCH LONG W/LUG	74970	16-104-2AND13351
					(ATTACHING PARTS)		
-57	210-0455-00			1	. NUT,PLAIN,HEX.:0.25-28 X 0.375 INCH,BRASS	73743	3089-402
-58	210-0011-00			1	. WASHER,LOCK:INTL,0.062 IDX 0.253 OD,STL	78189	1214-00-00-0541C
					- - - * - - -		
-59	134-0108-00			2	. PLUG,TIP:	80009	134-0108-00
					(ATTACHING PARTS)		
-60	210-0407-00			2	. NUT,PLAIN,HEX.:6-32 X 0.25 INCH,BRS	73743	3038-0228-402
-61	210-0803-00			2	. WASHER,FLAT:0.15 ID X 0.375 INCH OD,STL	12327	OBD
-62	210-0935-00			2	. WASHER,NONMETAL:FIBER,0.14 IDX 0.375"OD	74921	OBD
					- - - * - - -		
-63	134-0108-00			5	. PLUG,TIP:	80009	134-0108-00
					(ATTACHING PARTS)		
-64	210-0407-00			5	. NUT,PLAIN,HEX.:6-32 X 0.25 INCH,BRS	73743	3038-0228-402
-65	210-0803-00			5	. WASHER,FLAT:0.15 ID X 0.375 INCH OD,STL	12327	OBD
-66	210-0935-00			10	. WASHER,NONMETAL:FIBER,0.14 IDX 0.375"OD	74921	OBD
					- - - * - - -		
-67	200-0277-14			1	. CAB.,TEST FXTR:BOTTOM	80009	200-0277-14
-68	198-3535-00			1	. WIRE SET,ELEC:COMPLETE	80009	198-3535-00
					ACCESSORIES		
	013-0099-02			1	ADAPTER,TEST:JUNCTION FET TRANSISTORS	80009	013-0099-02
	013-0101-00			1	ADAPTER,TEST:TO-66 TRANSISTOR	80009	013-0101-00
	013-0110-00			1	ADAPTER,TEST:DO-4,DO-5 DIODES	80009	013-0110-00
	013-0138-01			1	ADAPTER,TEST:W/KELVIN SENSING	80009	013-0138-01
	013-0163-00			1	ADAPTER,TEST:POWER TRANSISTOR	80009	013-0163-00
	650-0073-00			1	TEST LEAD ASSY:RED	80009	650-0073-00
	650-0074-00			1	TEST LEAD ASSY:BLACK	80009	650-0074-00



TYPE	Vcc +10V	Vcc +13V	GND
34011	14		7
1458/5558		8	4

035-5028-00



SCR TURN-OFF TIME ADAPTER

MANUAL CHANGE INFORMATION

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages.

A single change may affect several sections. Since the change information sheets are carried in the manual until all changes are permanently entered, some duplication may occur. If no such change pages appear following this page, your manual is correct as printed.

SERVICE NOTE

Because of the universal parts procurement problem, some electrical parts in your instrument may be different from those described in the Replaceable Electrical Parts List. The parts used will in no way alter or compromise the performance or reliability of this instrument. They are installed when necessary to ensure prompt delivery to the customer. Order replacement parts from the Replaceable Electrical Parts List.

CALIBRATION TEST EQUIPMENT REPLACEMENT

Calibration Test Equipment Chart

This chart compares TM 500 product performance to that of older Tektronix equipment. Only those characteristics where significant specification differences occur, are listed. In some cases the new instrument may not be a total functional replacement. Additional support instrumentation may be needed or a change in calibration procedure may be necessary.

Comparison of Main Characteristics

DM 501 replaces 7D13		
PG 501 replaces 107	PG 501 - Risetime less than 3.5 ns into 50 Ω.	107 - Risetime less than 3.0 ns into 50 Ω.
108	PG 501 - 5 V output pulse; 3.5 ns Risetime.	108 - 10 V output pulse; 1 ns Risetime.
111	PG 501 - Risetime less than 3.5 ns; 8 ns Pretrigger pulse delay.	111 - Risetime 0.5 ns; 30 to 250 ns Pretrigger Pulse delay.
114	PG 501 - ±5 V output.	114 - ±10 V output. Short proof output.
115	PG 501 - Does not have Paired, Burst, Gated, or Delayed pulse mode; ±5 V dc Offset. Has ±5 V output.	115 - Paired, Burst, Gated, and Delayed pulse mode; ±10 V output. Short-proof output.
PG 502 replaces 107		
108	PG 502 - 5 V output	108 - 10 V output.
111	PG 502 - Risetime less than 1 ns; 10 ns Pretrigger pulse delay.	111 - Risetime 0.5 ns; 30 to 250 ns Pretrigger pulse delay.
114	PG 502 - ±5 V output	114 - ±10 V output. Short proof output.
115	PG 502 - Does not have Paired, Burst, Gated, Delayed & Undelayed pulse mode; Has ±5 V output.	115 - Paired, Burst, Gated, Delayed & Un-delayed pulse mode; ±10 V output. Short-proof output.
2101	PG 502 - Does not have Paired or Delayed pulse. Has ±5 V output.	2101 - Paired and Delayed pulse; 10 V output.
PG 506 replaces 106	PG 506 - Positive-going trigger output signal at least 1 V; High Amplitude output, 60 V.	106 - Positive and Negative-going trigger output signal, 50 ns and 1 V; High Amplitude output, 100 V.
067-0502-01	PG 506 - Does not have chopped feature.	0502-01 - Comparator output can be alternately chopped to a reference voltage.
SG 503 replaces 190, 190A, 190B	SG 503 - Amplitude range 5 mV to 5.5 V p-p.	190B - Amplitude range 40 mV to 10 V p-p.
191	SG 503 - Frequency range 250 kHz to 250 MHz.	191 - Frequency range 350 kHz to 100 MHz.
067-0532-01	SG 503 - Frequency range 250 kHz to 250 MHz.	0532-01 - Frequency range 65 MHz to 500 MHz.
TG 501 replaces 180, 180A	TG 501 - Marker outputs, 5 sec to 1 ns. Sinewave available at 5, 2, and 1 ns. Trigger output - slaved to marker output from 5 sec through 100 ns. One time-mark can be generated at a time.	180A - Marker outputs, 5 sec to 1 μs. Sinewave available at 20, 10, and 2 ns. Trigger pulses 1, 10, 100 Hz; 1, 10, and 100 kHz. Multiple time-marks can be generated simultaneously.
181	TG 501 - Marker outputs, 5 sec to 1 ns. Sinewave available at 5, 2, and 1 ns.	181 - Marker outputs, 1, 10, 100, 1000, and 10,000 μs, plus 10 ns sinewave.
184	TG 501 - Marker outputs, 5 sec to 1 ns. Sinewave available at 5, 2, and 1 ns. Trigger output - slaved to marker output from 5 sec through 100 ns. One time-mark can be generated at a time.	184 - Marker outputs, 5 sec to 2 ns. Sinewave available at 50, 20, 10, 5, and 2 ns. Separate trigger pulses of 1 and .1 sec; 10, 1, and .1 ms; 10 and 1 μs. Marker amplifier provides positive or negative time marks of 25 V min. Marker intervals of 1 and .1 sec; 10, 1, and .1 ms; 10 and 1 μs.
2901	TG 501 - Marker outputs, 5 sec to 1 ns. Sinewave available at 5, 2, and 1 ns. Trigger output - slaved to marker output from 5 sec through 100 ns. One time-mark can be generated at a time.	2901 - Marker outputs, 5 sec to 0.1 μs. Sinewave available to 50, 10, and 5 ns. Separate trigger pulses, from 5 sec to 0.1 μs. Multiple time-marks can be generated simultaneously.

NOTE: All TM 500 generator outputs are short-proof. All TM 500 plug-in instruments require TM 500-Series Power Module.


ANODE
(C)
GATE
SCR TURN-OFF TIME ADAPTER
035-5028-00
MODE
HOLDING
CURRENT
TURN-OFF
TIME
POWER
GATE CURRENT
mA
25
50
0
75
TURN-OFF TIME
µ SEC
(5 TO 105)
10/19/2007