Operating Instructions

TUNNEL DIODE RISETIME TESTER

TEKTRONIX ®

Tektronix Inc.

070-254

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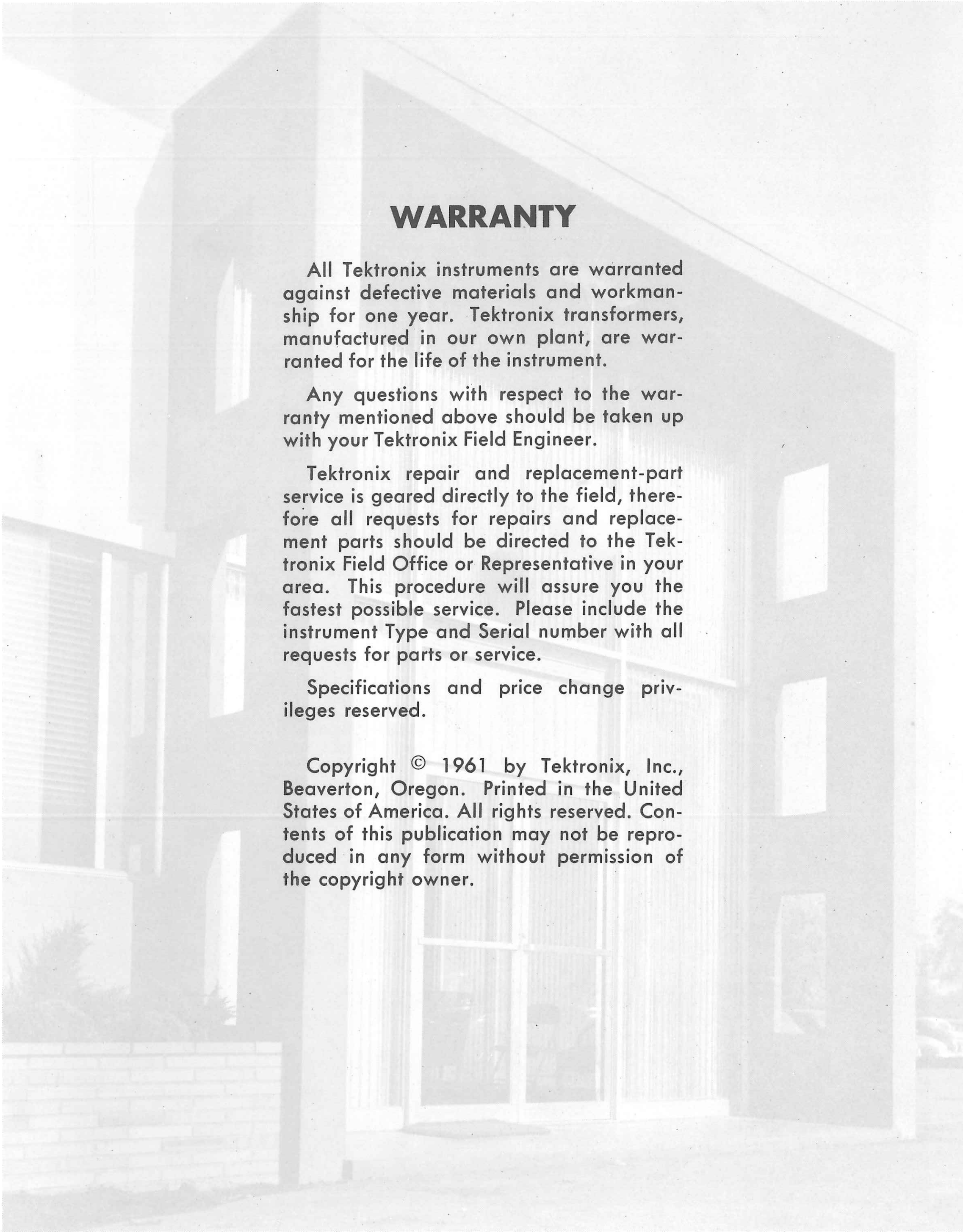

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All Tektronix instruments are warranted against defective materials and workmanship for one year. Tektronix transformers, manufactured in our own plant, are warranted for the life of the instrument.

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

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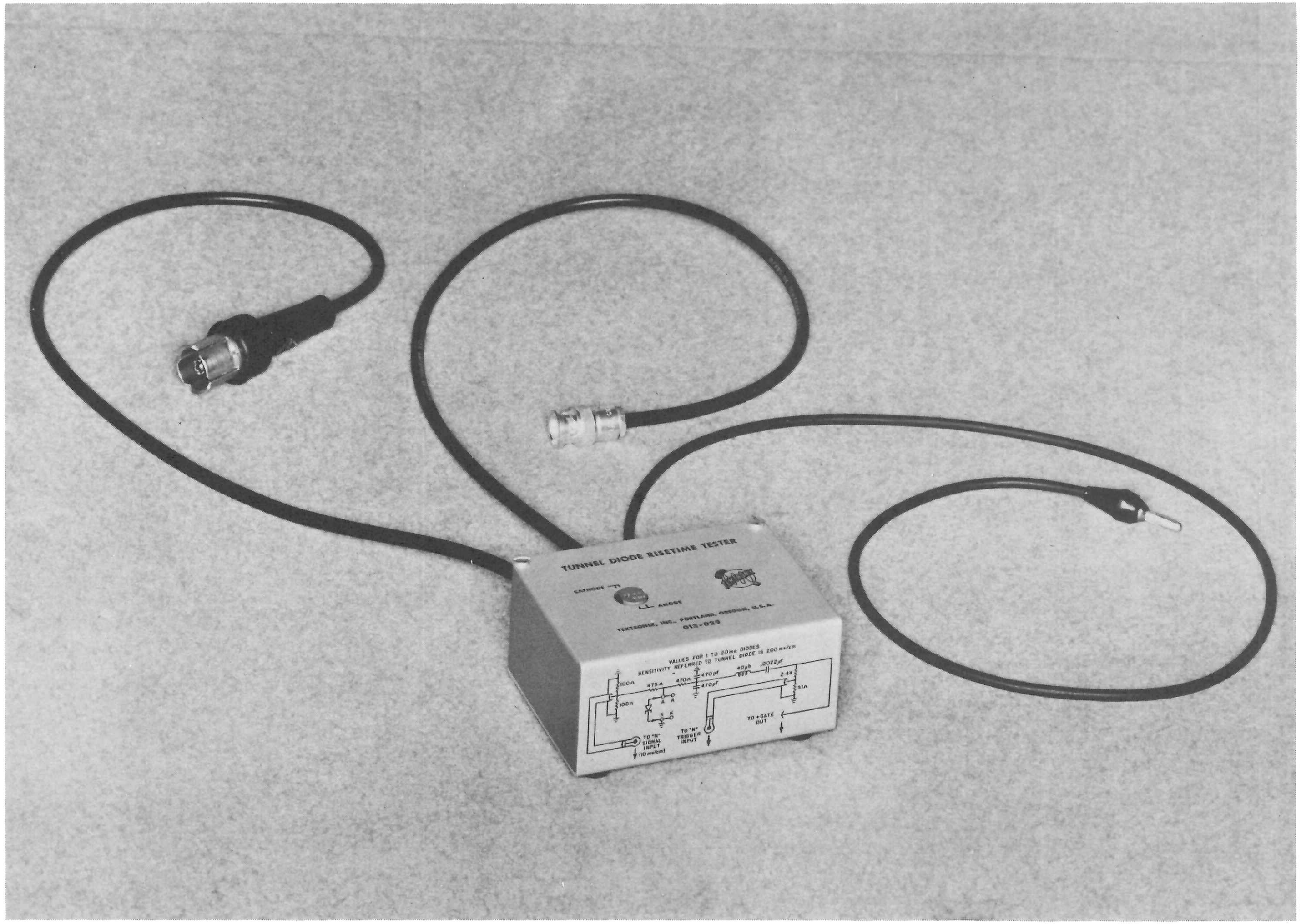

Fig. 1. The Tunnel Diode Risetime Tester.

TUNNEL DIODE RISETIME TESTER

The Tunnel Diode Risetime Tester, Fig. 1, is designed for use with the Tektronix Type N Sampling Plug-In Unit. It can be used to measure the switching times of 1-ma to 20-ma tunnel diodes directly and, in conjunction with an I-E characteristic-curve tracer such as the Tektronix Type 575 Transistor-Curve Tracer, can be used to calculate the tunnel diode capacity (C_d) and the peak-current-to-capacity (I_p/C_d) ratio.

For 1-ma to 20-ma diodes, the + GATE output of the main oscilloscope is used as the pulse input. Higher-current diodes can be tested by utilizing the Tektronix Type 105 Square-Wave Generator or the Type 110 Pulse Generator and Trigger Takeoff System as the input pulse source. (Certain precautions regarding the use of these instruments are included in the Operating Procedure.) The components in the tester may be changed to optimize operation over a narrower range, if desired.

CIRCUIT ACTION

A schematic diagram of the Tunnel Diode Risetime Tester is shown in Fig. 2. Operation of the unit is as follows:

The + GATE pulse (nominally about 30 volts in amplitude) from the oscilloscope is divided down by R1 and R2 to a suitable level for the Type N Unit TRIGGER INPUT. The + GATE pulse is also applied through C1 to L1 to form a current ramp through R3 and the tunnel diode under test. The start of the current ramp is delayed sufficiently by L1 to allow the Type N Unit sweep to get under way before the current through the diode reaches 1 ma. The current then builds up to a maximum of slightly over 20 ma in less than 200 nanoseconds. Thus, if the diode has a peak current between 1 and 20 ma, the diode switching signal can be displayed on the screen at some point during the 200-nanosecond time range of the Type N Unit. This switching signal is stepped down through a precision 20-to-1 divider, consisting of R4, R5, R6, and the 50-ohm cable, to provide a display sensitivity of 200 millivolts per centimeter (the basic sensitivity of the Type N Unit is 10 millivolts per centimeter).

The approximate initial rate of change of current through the tunnel diode is 50 microamperes per nanosecond, and the maximum is 100 microamperes per nanosecond. These values are low enough that a 1-ma gallium

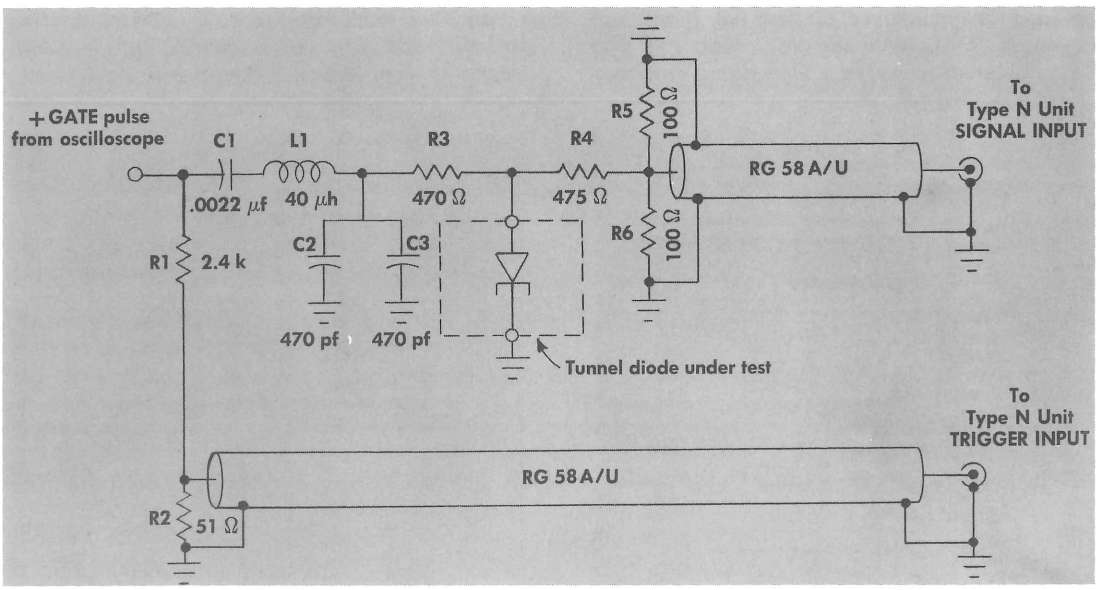

Fig. 2. Tunnel Diode Risetime Tester schematic diagram.

arsenide diode with a peak-current-to-capacity ratio of 5×10^8 volts per second or more is influenced less than 10% by the current sweep (a 20-ma gallium arsenide diode may be as poor as 5×10^7 volts per second). If it is necessary to consistently observe low-current diodes having low peak-current-to-capacity ratios, then it will be advantageous to raise the value of R3 to several thousand ohms (see Operating Procedure).

For most diodes, the capacitance of C2 and C3 is many times larger than the diode capacity, and the switching time of the diode is short compared to the time constant of R3 and C2 and C3. Thus, R3 in parallel with R4 (plus the 25 ohms of the output cable in parallel with R5 and R6) forms a load of about 240 ohms.

C1 protects the system in case an excessively long pulse is applied to the input.

DIODE ACTION

Referring to Fig. 3, note the 240-ohm load line through the origin. This is the initial condition of the system. As the positive gate is applied, the load line moves slowly upward, causing the diode operating point to move up the characteristic curve toward point 1. As the load line continues to rise, the diode can no longer satisfy both the static load line and the characteristic curve. The diode capacity then provides a dynamic load, permitting the operating point to move rapidly from point 1, down the negative resistance region to point 2, and then to point 3, where the static load line and the characteristic curve are again simultaneously satisfied. The traverse from point 1 to point 3 is normally rapid compared to the rate of change of the position of the load line, so, for practical purposes, the 240-ohm load line may be considered stationary during the switching time. (Correction for load-line shift can be made if accuracy warrants.)

Fig. 4 shows a typical tunnel diode switching waveform as it is displayed with the Tunnel Diode Risetime Tester. Points 1, 2, and 3 of this waveform correspond to points 1, 2, and 3 of Fig. 3. Thus the "switching time" of the diode can be determined by measuring the horizontal distance between points 1 and 3 in Fig. 4, and multiplying this distance by the setting of the NANOSEC/CM switch on the Type N Unit. (On the switching waveform, points 1 and 3 are at the points where the trace "breaks" from a steady slow rise to the switching portion of the trace.) A frequently used standard "risetime" definition would be the time between the 10% and 90% points of the vertical distance between points 1 and 3.

In determining C_d from the waveforms in Figs. 3 and 4, a simple analysis results if one neglects the effects of the spreading resistance, r_s, and the lead inductance, L_s, of Fig. 5. The socket leads may be regarded as a short length of near-240-ohm transmission line termi-

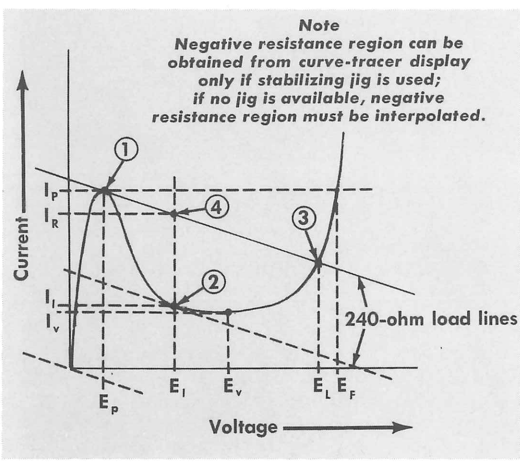

Fig. 3. Typical tunnel diode characteristic curve.

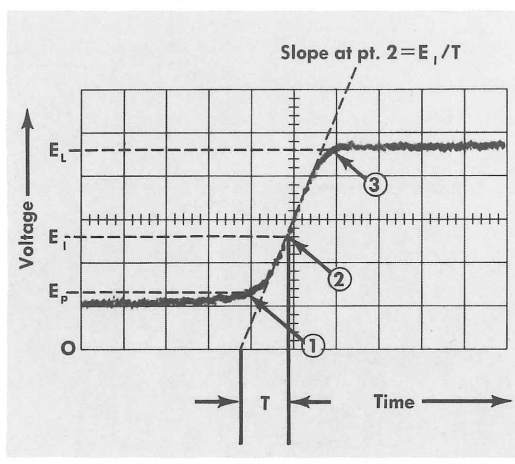

Fig. 4. Typical tunnel diode switching signal.

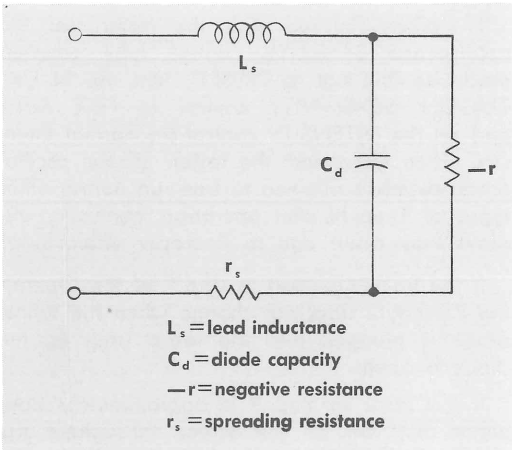

Fig. 5. Tunnel diode equivalent circuit.

nated in the 240-ohm R_L. These assumptions are reasonable since r_s is small compared to 240 ohms, and L_s/R_L is well under 0.6 nanosecond in the case of well-constructed tunnel diodes. Therefore, these approximations will give good results for diodes with switching times over 1 nanosecond (I_p/C_d of approximately 10^9 volts per second for gallium arsenide or 5×10^8 volts per second for germanium).

Based upon the foregoing assumptions, the maximum current flows into the diode capacity at the inflection point 2 (Fig. 4) since the rate of change of voltage is directly proportional to the current flowing into a capacity. From the static characteristics (Fig. 3), one can graphically determine the maximum current by constructing a load line parallel to R_L, but touching the curve in the negative resistance region at one point only. The peak current I_p less the current I_R, at point 4, is the current delivered to the load resistance. The difference between point 4 (I_R) and point 2 (I_I) is the maximum current delivered to the diode capacity. From $Q = CE$, one arrives at

$$C_d = (I_R - I_I)\, T/E_I$$

where T/E_I is the inverse rate of change of voltage at the point of inflection (point 2 in Fig. 4).

When R_L is much greater than the negative resistance, $-r$, of the diode (load line more nearly horizontal), certain simplifications are permissible. I_R approaches I_p rapidly, and I_I approaches I_v. Then one obtains simply

$$C_d = (I_p - I_v)\, T/E_I.$$

A switching-time figure of merit for tunnel diodes is I_p/C_d. A tunnel diode with negligible I_v ($I_p/I_v > 10$) operating with a large value of R_L ($R_L >> r$) will have a switching waveform with a relatively large percentage of the time between point 1 and point 3 at nearly the rate $E_I/T = I_p/C_d$. Since both I_v and C_d affect the switching speeds, it may be more convenient to specify a switching-speed test, rather than static tests, for diodes intended for use in large R_L circuits with maximum risetime as a design requirement. For a given switching speed, in the high R_L case, I_v can be a bit higher than usual, if C_d is properly lower than usual (or vice versa), without much effect on the operation of the circuit.

Three important conveniences of the switching-time type of tester are:

1. Static tests are usually unnecessary because (a) a normal switching waveform automatically assures normal values of E_p and E_L and the proper relation of I_p, I_v, and C_d, and (b) the variations in the value of I_p are detectable by the time-position of the switching waveform with respect to the sweep start.

2. Anomolous high-speed behavoir is usually detectable; for example, unusually large time jitter.

3. A tunnel diode with a fine crack, causing an open circuit, will usually not be re-welded, due to the limited energy available to the diode, when operated normally in the Risetime Tester; whereas static curve tracers have been observed to temporarily "repair" initially open diodes. Thus, testing the diode in the Risetime Tester first can detect flaws which might not appear had other tests been used.

OPERATING PROCEDURE

To display the tunnel diode switching waveform with the Tunnel Diode Risetime Tester, proceed as follows:

1. Set up the Type N for normal operation as described in the Type N Unit Instruction Manual.

2. Connect the GR connector of the tester to the SIGNAL INPUT connector of the Type N Unit, the BNC connector to the TRIGGER INPUT

connector of the Type N Unit, and the banana plug to the + GATE connector of the oscilloscope.

3. Set the Type N Unit NANOSEC/CM switch to 10, the SAMPLES/DISPLAY switch to 500, the DELAY control to MIN., and the TRIGGER SENSITIVITY control fully clockwise to FREE RUN.

4. Set the oscilloscope TIME/CM switch to 1 μSEC and the oscilloscope STABILITY control fully counterclockwise, but not to PRESET.

5. Adjust the VERTICAL POSITION control on the Type N Unit to position the trace at the bottom graticule line of the screen.

6. Set both the STABILITY and TRIGGERING LEVEL controls of the oscilloscope fully clockwise.

7. Turn the Type N Unit TRIGGER SENSITIVITY control counterclockwise until the Type N Unit stops free running and triggers on the + GATE pulses. (A curved trace extending from lower left to upper right will appear on the screen.)

8. Plug the tunnel diode into the tester socket, taking advantage of the dual lead connections if the tunnel diode has more than one anode or cathode lead.

9. Adjust the DELAY control as necessary to display a switching signal similar to that in Fig. 4 on the screen; the higher the peak-current rating of the diode, the more DELAY necessary to place the switching signal on the screen. The setting of the TRIGGER SENSITIVITY control may also be critical when operating at the extremes of the range of the tester (diodes with peak currents near 1 ma or 20 ma). If you are not able to display a switching signal, refer to the paragraphs following this procedure.

10. Set the NANOSEC/CM switch to allow convenient measurement of E_p, E_L, time from 10% to 90% of $E_L - E_p$, and E_l/T (see Fig. 4). These values can then be used to obtain the switching time, the diode capacity, and the peak-current-to-capacity ratio (see Diode Action). If desired, E_p, E_L, and E_l can be determined from the static characteristic curve (Fig. 3) and then translated to the switching waveform in Fig. 4. The sensitivity of the display is 200 millivolts per centimeter with the bottom graticule line representing zero volts.

11. When finished with the tester, set the oscilloscope STABILITY control fully counterclockwise (but not to PRESET), turn the N Unit TRIGGER SENSITIVITY control to FREE RUN, and set the INTENSITY control for normal intensity. Then disconnect the tester. (If the oscilloscope sweep is allowed to free run during other types of Type N Unit operation, confusing displays may result due to improper unblanking.)

If the trace obtained in step 7 of the Operating Procedure does not change when the tunnel diode is plugged into the tester (step 8), the diode is open.

If the trace in step 9 is approximately horizontal but low on the screen throughout the range of the DELAY control, the diode has not switched yet, is shorted, or is in the socket backwards. In this case, set the DELAY control fully counterclockwise and turn the TRIGGER SENSITIVITY control slightly counterclockwise. If the switching signal still cannot be obtained, then the diode is either in the socket backwards, is shorted, or has a peak current of more than 20 ma. If the diode is found to have a peak current of more than 20 ma, substitute a pulse generator of higher voltage than the + GATE pulse on the oscilloscope, such as the Type 105 Square-Wave Generator or the Type 110 Pulse Generator and Trigger Takeoff System. (Also, see the NOTE following this paragraph.) If you do use one of these alternate inputs, operate them at low enough pulse amplitudes and repetition rates to prevent damage to the tester components. When using pulses higher than about 100 volts in amplitude, an attenuator may be required in the trigger lead, or R1 may need to be increased, to present the proper size trigger pulse to the Type N Unit. If R1 is increased, a compensating capacitor may need to be placed across R2.

NOTE

In some of the Tektronix plug-in type oscilloscopes, the + GATE pulse may not be of sufficient amplitude to cause switching of a 20-ma diode in the tester. If you find this to be the case, you can raise the amplitude of the + GATE pulse to about 30 volts by modifying your oscilloscope as shown in Fig. 6 (assuming the + GATE Cathode Follower or associated components are not defective). This will not sensibly affect the operation of the oscilloscope, provided the replacement

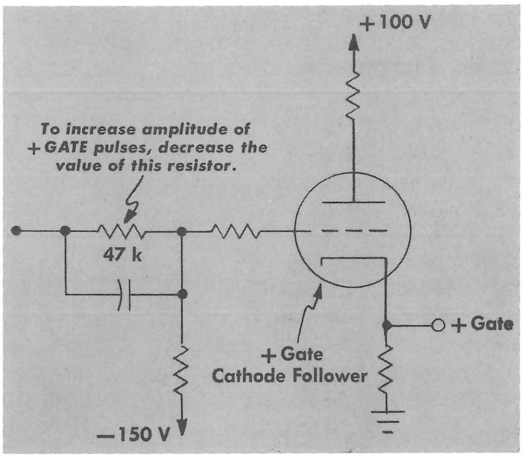

Fig. 6. Modification of + Gate Cathode Follower in oscilloscope to increase pulse amplitude to about 30 volts.

resistor is large enough to allow the + GATE output to return to zero with no external load. If too small a resistor is required (i.e., the + GATE output does not return to zero), the circuit preceding the + GATE Cathode Follower is probably defective.

If the trace in step 9 is approximately horizontal but high on the screen throughout the range of the DELAY control, the diode has already switched and less delay is needed. In this case, set the DELAY control fully clockwise, and turn the TRIGGER SENSITIVITY control slightly clockwise. If the switching signal still cannot be obtained, the diode has a peak current of less than 1 ma.

The 1-ma lower limit of the tester can be extended to about 0.5 ma by increasing the value of R3. Diodes with negative resistances approaching the load resistance (normally about 240 ohms in the Tunnel Diode Risetime Tester) stop operating as switches and become nonlinear amplifiers. Therefore, it is convenient to try to keep $R_L >> r$. Raising the value of R3 to 5000 ohms increases R_L to about 450 ohms. The minimum limit of the tester can be further reduced to about 0.25 ma by increasing R5; however, this results in an approximately direct loss in sensitivity. Operation below 0.25 ma is quite difficult due to loss of sensitivity and transient response problems. The transient response problems are the result of end-to-end capacity of R5 and mismatch of the socket lead "transmission lines."

PARTS LIST

Tektronix Part Number		Circuit Components		
301-242	R1	2.4 k	½ w	5%
301-510	R2	51 Ω	½ w	5%
301-471	R3	470 Ω	½ w	5%
318-076	R4	475 Ω	⅛ w	1%
318-040	R5	100 Ω	⅛ w	1%
318-040	R6	100 Ω	⅛ w	1%
283-028	C1	.0022 μf	50 v	Discap
281-525	C2	470 pf	500 v	Ceramic
281-525	C3	470 pf	500 v	Ceramic
108-116	L1	40 μh		

Electrical and Mechanical Components

136-062 .... Socket, 4-pin transistor
175-126 .... GR Cable Assembly
175-127 .... BNC Cable Assembly
175-128 .... Test Lead Assembly
333-627 .... Cover Panel
348-013 .... Feet, black rubber ½"
387-347 .... Circuit Board, unwired

ABBREVIATIONS

k	kilo	10^3
μ	micro	10^{-6}
p	pico	10^{-12}

HOW TO ORDER PARTS

Replacement parts may be purchased from or ordered through your local Tektronix Field Office. Most of the circuit components, however, can be purchased locally (be sure to obtain the exact value).

If you order parts from Tektronix, include all information stated in the Parts List and mention that the parts are required for the Tunnel Diode Risetime Tester.

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