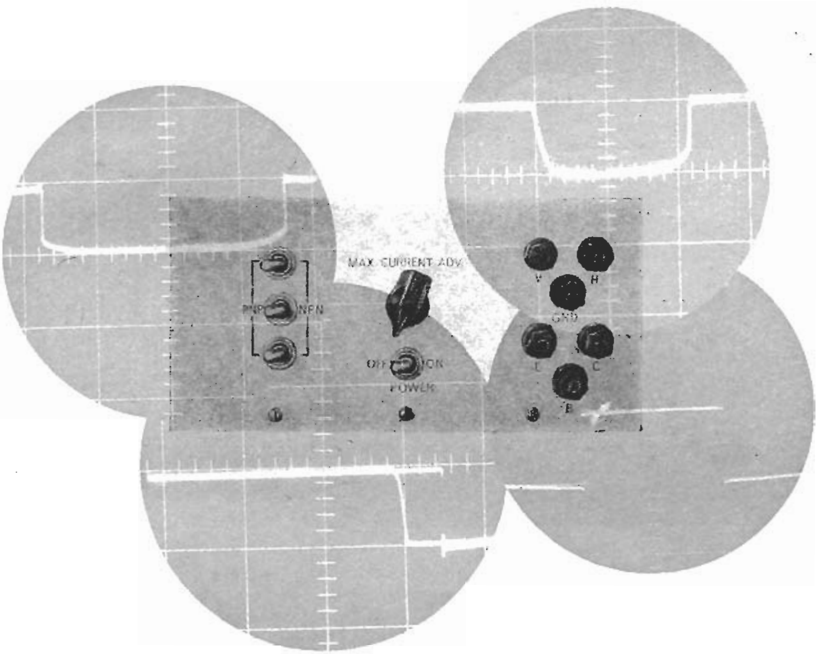

BREAKDOWN REVERSE VOLTAGE TRANSISTOR AND DIODE TESTER

NONDESTRUCTIVE "ONE-SHOT" SCOPE TECHNIQUE USED TO REVEAL SEVERAL CHARACTERISTICS AT ONCE

By CHARLES D. RAKES

FOR EACH different transistor parameter, there is a test procedure that can be set up and followed in order to predict a transistor's ability to live up to its specifications. While there are many different specifications for a transistor, not all of them must be up to par in any one application. For most applications, it is usually sufficient to know that a transistor will work in a given circuit, without being too concerned about the transistor's capabilities in excess of the circuit's requirements. Quite often you can take advantage of the commercially accepted tolerance of ratings by going through a batch of less expensive transistors and selecting those that will work in your circuit.

For example, if a transistor is rated to withstand a reverse voltage across the collector and base elements of, say, 100 volts, you wouldn't care whether or not the transistor breaks down at 75 volts when the most voltage it will see in a

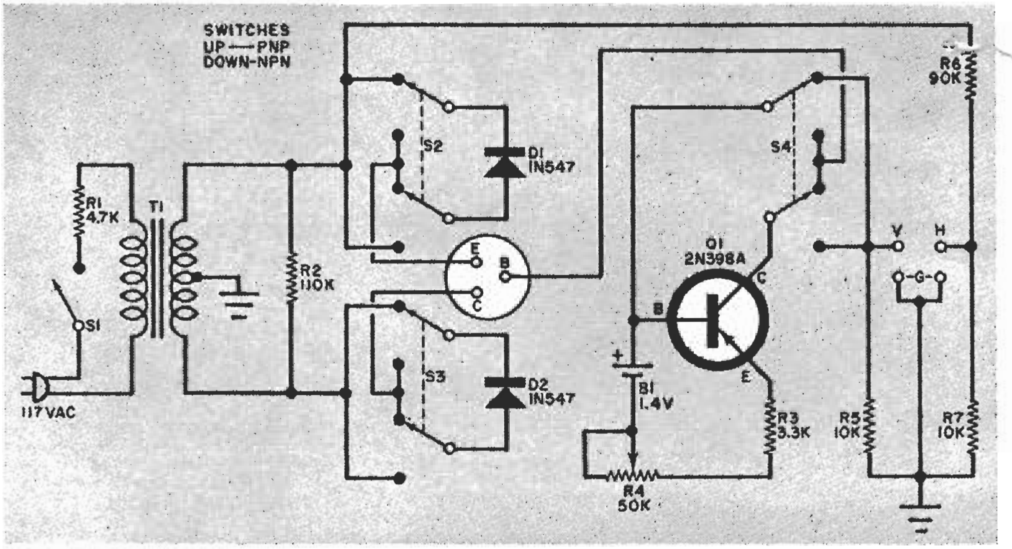

Fig. 1. Reverse voltage is applied alternately across the emitter-base junction and the collector-base junction of the transistor under test by the combined action of diodes D1 and D2 on the a.c. voltage from the transformer. Transistor Q1 acts as a current limiter. Potentiometer R4 can be adjusted to limit maximum current flow to a predetermined value. Zener diodes and other diodes as well as neon lamps can be checked out with this adapter. Output voltages are fed to an oscilloscope for interpretation.

given circuit does not exceed 9 volts. But you wouldn't want to put this transistor into a 90-volt circuit. By the same token, if the transistor checked out at 120 volts, there's no reason why you couldn't insert this component into a 110-volt circuit.

Many fine, inexpensive transistor testers are available that can predict gain and leakage, but none of them can tell you anything about the figure for reverse breakdown voltage. One way to check reverse breakdown voltage is to gradually apply an increasing amount of voltage until the transistor breaks down. Once you do that, you will know what the breakdown voltage is, and you will also have to junk the transistor. It's like testing a fuse to find out how much current it will take to make it pop. There is no trick to a destructive-type test and there *is* a point of no return that most of us would object to. The way to avoid destruction of solid-state components even in the presence of potentials in excess of the breakdown voltage is to limit the amount of current to prevent thermal runaway.

If you have an oscilloscope, you can take a page out of a transistor manufacturer's notebook; and if you build the simple, low-cost circuit presented here, you can perform a non-destructive test to check both emitter-to-base reverse breakdown voltage, and collector-to-base reverse breakdown voltage. With this circuit, you will also be able to determine emitter cutoff current and collector cutoff current. All four of these parameters can be ascertained from a single scope trace, in a "one-shot" type of test. The procedure is rapid and lends itself to mass production techniques.

As a sort of bonus feature, this same

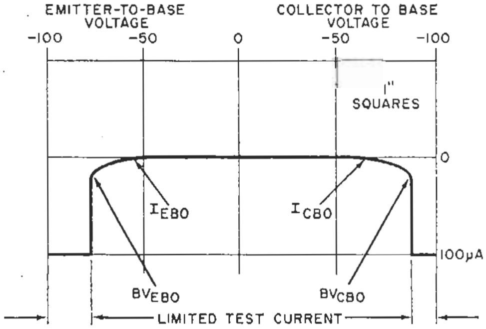

Fig. 2. Trace obtained when testing a good transistor can be analyzed as follows: left portion of curve shows what happens when reverse voltage is applied across emitter-base junction; right side indicates collector-base junction characteristics. Trace also shows cutoff and reverse current.

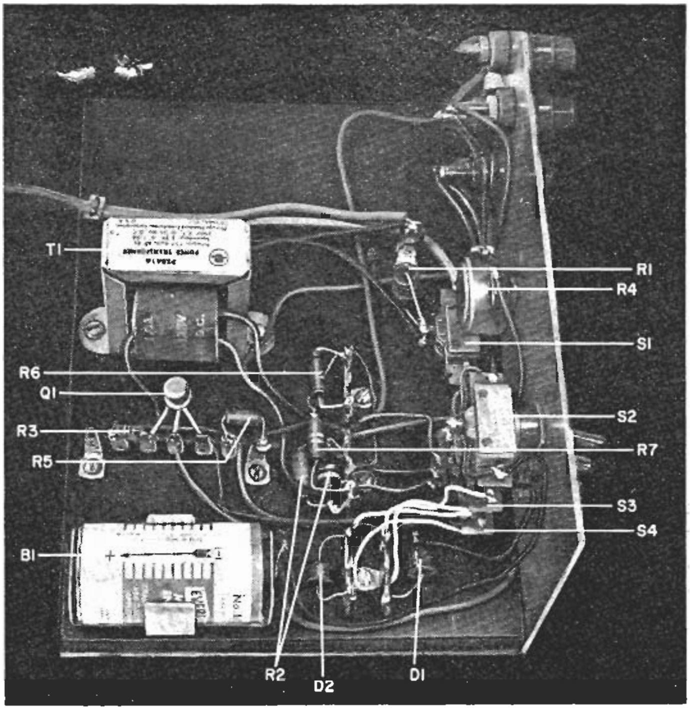

Fig. 3. Layout of components is not critical. Two resistors are shown connected in parallel to obtain proper value for R2. A 3-gang d.p.d.t. switch can be used instead of separate switches for S2, S3, and S4. Observe polarity of B1, D1 and D2.

PARTS LIST

B1—1.4-volt mercury battery
D1, D2—1N547 diode
Q1—2N398A transistor
R1—4700-ohm, 2-watt resistor
R2—110,000-ohm, 4-watt resistor—see text
R3—3300-ohm, ½-watt resistor
R4—50,000-ohm potentiometer
R5—10,000-ohm, ½-watt resistor
R6—90,000-ohm, ½-watt resistor
R7—10,000-ohm, ½-watt resistor
S1—S.p.s.t. switch
S2, S3, S4—D.p.d.t. switch
T1—Power transformer: primary, 117 volts; secondary, 250 volts with center tap (Stancor PS8416, or similar)
Misc.—Terminal strips, binding posts, chassis, hardware, etc.

test procedure will let you determine the zener voltage of zener diodes, the reverse breakdown voltage for low-peak-inverse-voltage diodes, and both the firing and holding voltages of neon lamps.

How It Works. With this test circuit, units under test are subjected to a maximum reverse voltage of about 100 volts. The "maximum-current" range is adjustable from approximately 20 μA to 500 μA. The amount of maximum current that can be safely passed through the transistor under test depends upon the power that can be safely dissipated in the tested unit. If a large number of units are to be checked, the voltage and current limits can be grease-penciled on the oscilloscope screen for a quick go-no-go selection.

As shown in Fig. 1, switches *S2, S3,* and *S4* are in the *PNP* position, and the anodes of diodes *D1* and *D2* are connected to the emitter and collector test jacks respectively. The base test jack is returned to ground through current sampling resistor *R5*.

The voltage developed across *R5* is fed to the vertical input of the scope through test jacks marked *V* and *G*. The scope's horizontal sweep is controlled by the voltage that appears across the 10 to 1 voltage divider resistors *R6* and *R7* and which is fed out through the terminals marked *H* and *G*.

Emitter-To-Base Reverse Voltage. When the top of *T1* goes negative with respect to ground, *D1* conducts, and sends the emitter voltage (with respect to base) of the transistor under test in the nega-

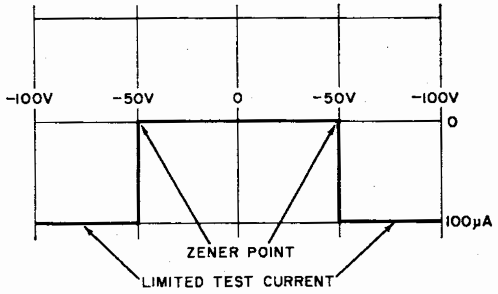

Fig. 4. Typical scope trace of good zener diode is shown here. Right half reveals same information as left half, and is actually redundant. Single-sided patterns can be just as easily obtained. See text.

tive direction and causes a downward deflection of the scope's trace when this voltage breaks through the emitter base junction. Keep in mind that this potential across the emitter and base is reverse voltage. Also, the voltage at the top end of *R6* and *R7* at this time is negative with respect to ground. As the voltage swings in the negative direction, the scope's spot travels from the center of the screen towards the left to display a horizontal trace.

The action of the scope's trace can be understood by an examination of Fig. 2. Note that as the negative horizontal voltage increases the reverse voltage across the emitter and base is also increasing, and at about 75 volts the curve drops sharply—this is the point of voltage breakdown.

During the time that the emitter-to-base-junction is subjected to this reverse voltage, *D2* blocks the collector current of the transistor under test and leaves the collector in an essentially open-circuited condition. This open-circuit condition satisfies one of the requirements for determining the specification for reverse voltage breakdown.

REVERSE VOLTAGE AND CURRENT CUTOFF PARAMETERS

BV_{CBO}: Collector-to-base d.c. breakdown reverse voltage with the emitter circuit open. Collector current (I_C) should be specified.

BV_{EBO}: Emitter-to-base d.c. breakdown reverse voltage with the collector circuit open. Emitter current (I_E) should be specified.

I_{CBO}: Collector d.c. current cutoff when the collector junction is reverse-biased with the emitter circuit open. Collector base voltage (V_{CB}) should be specified.

I_{EBO}: Emitter d.c. current cutoff when the emitter junction is reverse-biased with the collector circuit open. Emitter base voltage (V_{EB}) should be specified.

During the time that the applied voltage is in excess of the breakdown voltage, current is limited to prevent destruction of the component under test by the action of circuit *Q1*, *R3*, *R4*, and *B1*. Potentiometer *R4* can be adjusted to increase or decrease the maximum current.

As the voltage across the secondary of *T1* swings back to zero, the spot on the screen retraces its path, and returns to its central point on the zero reference line.

Collector-To-Base Reverse Voltage. When the polarity of the a.c. voltage across *T1* reverses, a positive voltage appears across *R6* and *R7* and pulls the spot horizontally from the center of the screen to the right. The positive voltage on the cathode of *D1* also blocks the emitter current of the transistor under test, effectively opening the emitter circuit. The negative voltage on the anode of *D2* now completes the collector-to-base circuit through *Q1*. The trace on the right side of the scope indicates the collector-to-base reverse voltage breakdown. Here again the requirement for the third element in a transistor to be open-circuited when checking for reverse voltage breakdown is satisfied.

The same action takes place for an *npn* type of transistor except that the polarity of the reverse voltage is reversed and the deflection of the trace will be upward. Of course, switches *S2, S3*, and *S4* are simultaneously flipped to the *NPN* position.

While the vertical deflection of the scope's beam is a function of the voltage drop across *R5*, the extent of this voltage drop depends upon the current through *R5*, the collector-to-base of *Q1* and the transistor under test. If the vertical input of the scope is calibrated for 1 volt per inch, a 1-inch high trace represents 100 μA of current ($100\ \mu A \times 10{,}000\ \Omega = 1$ volt).

The tilt on the left side of the trace (Fig. 2) shows emitter-to-base reverse current while the tilt on the right side shows collector-to-base reverse current. In this idealized trace, reverse current becomes evident at about −60 to −70 volts, and increases gradually until the breakdown voltage point is reached. The breakdown point is also commonly referred to as the zener point.

(Note that the 0 to −50 volts per inch along the horizontal scale represents the inverse voltage across the transistor under test when the scope's horizontal input sensitivity (through the test circuit) is calibrated at 50 volts per inch. The voltage across the horizontal input has a linear relationship and is in step with the inverse voltage applied to the test transistor.)

Construction. Parts placement and layout is not critical. In Fig. 3, the test circuit is shown breadboarded on an 8½″ x 6″ piece of ¾″ plywood. The front panel is an 8½″ x 4½″ piece of 16-gauge aluminum. More compact construction can be obtained by using a 6″ x 5″ x 4″ aluminum utility box. Ground only those points shown in the schematic (Fig. 1). Use spaghetti to insulate *Q1*'s leads.

A 2N398A transistor was chosen for *Q1* because of its high collector-to-base reverse breakdown voltage rating. The transistor used in the project is rated at −105 volts, but actually checked out at −150 volts.

Although individual switches are used for *S2*, *S3* and *S4*, you can substitute a suitable two-position rotary switch or stacked slide switch. The binding posts for the test transistor's connections and for the connections to the oscilloscope can be of any design. You may find it more convenient to add another ground post, or eliminate the terminals altogether and connect the leads that go to the scope directly to the circuit.

All parts used in the tester are standard. If you have any difficulty in locating a 110,000-ohm, 4-watt resistor for *R2*, you can connect two 220,000-ohm, 2-watt resistors in parallel.

Zener Diode Test. The curve shown for the zener diode (Fig. 4) can be obtained by connecting a jumper between the emitter and collector terminals (*E* and *C*) of the test circuit, and connecting the zener diode between one of these terminals and the base terminal (*B*). The cathode lead of the diode goes to ground, and the switches are in the *PNP* position. If you reverse the diode's connections, and flip the switches over to the *NPN* position, the trace will go upward instead of downward. The test can be made either way.

If you do not use the jumper and connect only one side of the diode either to the emitter or the collector terminal, the left half or the right half of the trace will be obtained. Both halves of the trace contain the same information.

Neon Lamp Test. If a good neon lamp is connected between the base and collector test points, the curve shown in Fig. 5 will be displayed. Reading this curve is more or less self-explanatory. Here *S2*, *S3*, and *S4* were set to the *PNP* position.

The accuracy of the test readings depends upon how accurately you calibrate the oscilloscope. Once the oscilloscope is correctly calibrated, no further scope adjustments are required.

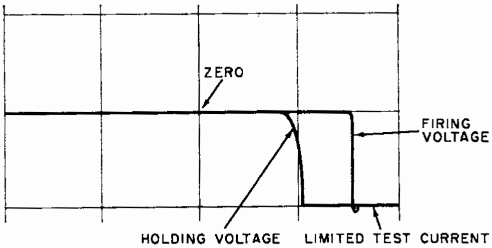

Fig. 5. Firing and holding voltage of a neon lamp can be predicted. If the scope's horizontal sweep is calibrated at 50 volts per inch, the neon lamp depicted here ignites at about 75 volts and stays lit until the potential drops to about 50 volts.

Scope Calibration. To adjust vertical sensitivity, apply a 1-volt peak-to-peak a.c. signal directly to the scope's vertical input, and adjust the vertical gain for a 1″-high pattern. This is all there is to the vertical calibration for a deflection of 100 microamperes per inch.

Horizontal sensitivity can be calibrated by applying a 5-volt peak-to-peak a.c. signal directly to the horizontal input terminals and adjusting the horizontal gain for a 1″-long trace. Because of the 10-to-1 voltage divider network in the test circuit, actual horizontal sensitivity will be 50 volts per inch. -30-