LB-1081

A BASIC TESTER FOR TRANSISTORS

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Approved

Stuart Wm Seeley

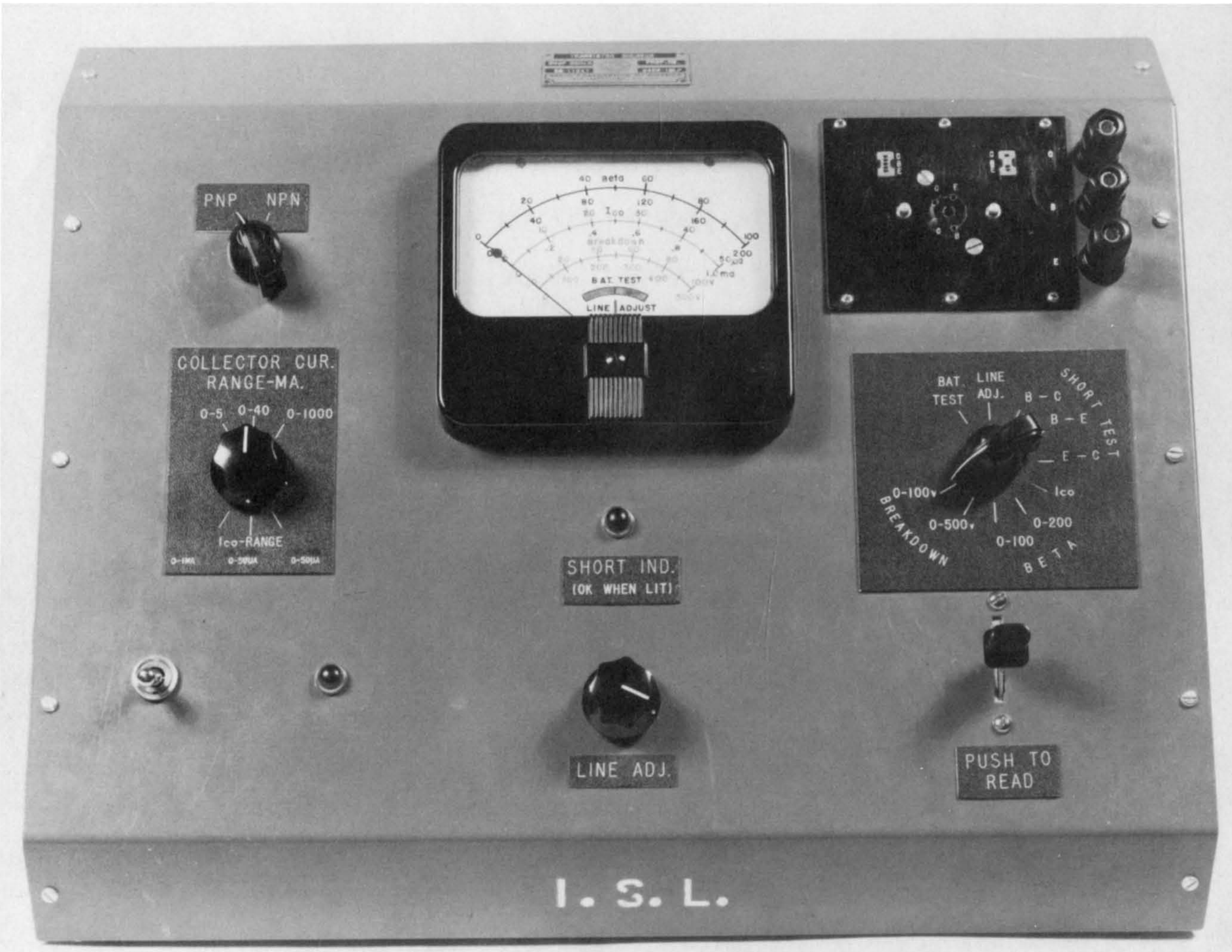

Fig. 1 - Front view of transistor tester.

The basic transistor tester described in this bulletin measures large-signal common-emitter current gain (*beta*), collector saturation-plus-leakage current (I_{co}), and collector-junction breakdown voltage, and directly indicates the value of these characteristics on a multiple scale meter. Inter-electrode shorts are indicated by a panel light. In purpose and in operation the instrument resembles a conventional tube tester. The design features simplicity of operation and avoidance of transistor overload. The tester accomodates both p-n-p and n-p-n types, in the collector-current range up to 2 amperes.

General Description

Transistors may be classified in accordance with their current or power-handling capability. Arbitrary classifications of "low", "medium" and "high" power levels, as listed in Table I, were chosen to establish ranges for the design of this tester. The current and power ranges indicated in Table I encompass the majority of widely used transistors. The appropriate range for a given transistor type is selected by means of the three-position *collector-current-range* switch located at the left center of the front panel of the tester, as shown in Fig. 1.

Table I

Arbitrary Transistor Classification

Power or Current Level	Maximum Collector Currents	Maximum Allowable Collector Dissipation
Low	10 ma	50 mw
Medium	100 ma	150 mw
High	2 amperes	6 watts

The tester performs a series of simple tests on the transistors, covering basic characteristics. The tests are selected in logical order by means of a ten-position *function-selector* switch (right center, Fig. 1). The various characteristics are indicated on a single meter having appropriate scales and calibration points.

Signal power is obtained from the 60-cycle power line. Collector energizing voltage is obtained from four serially-connected RCA VS-100 "A" batteries. As a a precaution against injuring the transistors, signal and energizing voltages are applied only when the operator depresses a *push-to-read* spring-returned switch (lower right, Fig. 1).

The circuit functions are described in the sequence in which the tests are normally performed.

Battery Test

Battery condition is checked in the *battery test* position of the function-selector switch. A 12-ohm resistor is shunted across the battery, and the current through this resistor is measured to determine if the battery is capable of supplying the peak collector current required for the high-current range. The meter has a "good-bad" type scale for battery condition indication. At the dividing point (scale center) a current of 0.7 ampere is indicated in the 12-ohm load. A battery giving this end-of-life indication can therefore be expected to deliver, on a short-time basis, a peak collector of approximately 1.3 amperes with a minimum of 0.5 volt between collector and emitter. This will adequately supply a transistor having a common-emitter current gain (beta) up to 80 in the high-current test range.

Line Voltage Adjustment

In the *line-adjust* position, the function-selector switch inserts the meter in series with the base lead of the transistor under test, as is shown in dotted outline in the simplified circuit of Fig. 2. The signal drive to the transistor is adjusted by means of the *line-adjust* control to produce a design value of base current. This "calibrates" the instrument for the common-emitter current gain (beta) measurement to be made later. The signal source resistance is much larger than the transistor input resistance; thus, readjustment of the drive is not required to accommodate differences in input re-

Table II

Information for Measuring Beta

Power Level	V_{in} (volts r-m-s)	R_s (ohms)	I_b		I_c		
					Calibration Equation*	For Beta = 100	
			av	Peak		av	Peak
Low	2.8	47,000	25 μa	78 μa	25 beta μa	2.5 ma	7.8 ma
Medium	5.6	11,700	200 μa	630 μa	200 beta μa	20.0 ma	63.0 ma
High	11.2	940	5 ma	15.8 ma	5 beta ma	0.5 amp.	1.58 amp.

*Full-scale meter reading for a required full-scale beta.

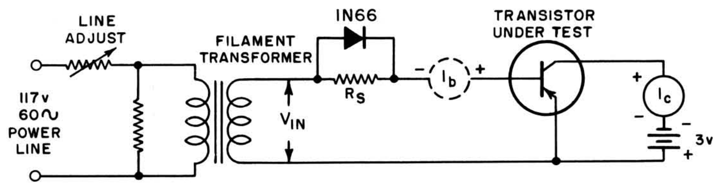

Fig. 2 - Beta measurement of junction transistor (illustrating polarity for a p-n-p unit).

sistance. The values of R_s and V_{in} are so selected (see Table II) that the same calibrate adjustment will accommodate the three power levels. The calibrate adjustment is required to compensate only for differences in the power-line voltage. It is essentially a line-voltage adjustment. Thus, when the tester is set to the "line-adjust" mark on the meter, Fig. 1, the meter indicated that the transistor base current has one of the values given under I_b in Table II, as determined by the setting of the *collector-current-range* switch.

Measurement of Interelectrode Shorts

Fig. 3 is a simplified schematic of the short-test setup for indicating a base-to-collector short in a p-n-p junction transistor. This circuitry is selected by the *B-C Short Test* setting of the function-selector switch. The collector junction under test is driven in a class B manner by the a-c signal, V_{in} of Table II. The 1N66 diode shunting R_s is poled so that it "closes" on reverse drive to the junction. The reverse current which flows is limited principally by the back impedance of the junction. A transistor "relay" in series with the junction senses increase in reverse current above a threshold value. The relay operates a pilot light (*Short Ind.*, Fig. 1) which is normally on. If the reverse current in the junction under test exceeds the threshold value

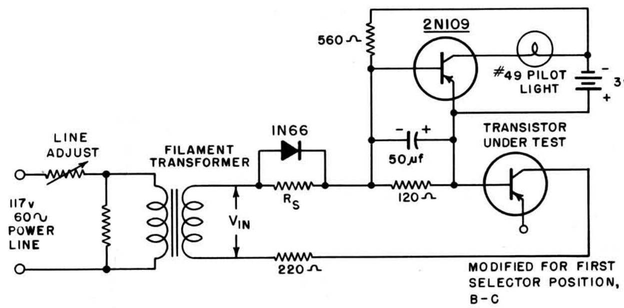

Fig. 3 - Checking collector junction for shorts (illustrating polarity for a p-n-p unit).

of 1.5 ma, the pilot light is extinguished, which indicates a shorted junction.

In the succeeding position of the function-selector switch (B-E), the emitter junction is checked for shorts in the manner just described. In the next position (E-C), the short-test circuit is inserted between emitter and collector, with the base directly connected to the emitter. This checks the transistor for a collector-to-emitter short. This setting also checks the transistor for punch-through breakdown within the limitation of the peak value of V_{in}; a means of measuring punch-through breakdown voltage at higher voltages is described later.

Measurement of I_{co}

The collector saturation-plus-leakage current, I_{co}, is measured by applying the battery voltage (nominally 12 v) between collector and base and metering the collector current. The emitter is open-circuited for this measurement. A series resistance of either 56 K for the low and medium power levels or 5.6 K for the high power level limits the current to a value that will not damage

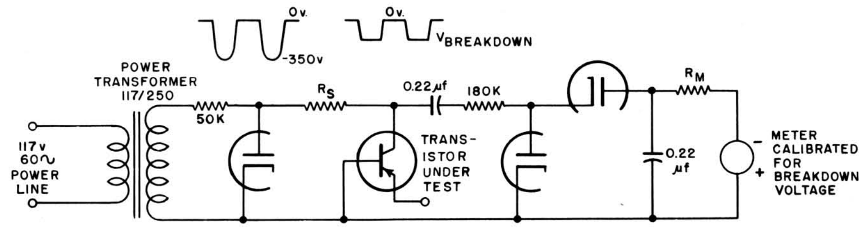

Fig. 4 - Measuring collector junction breakdown voltage (illustrating polarity for a p-n-p unit).

the meter when measuring transistors with excessively large leakage current.

Beta Measurement

Large-signal common-emitter current gain, beta, is measured by inserting a known, fixed current at the base and metering the resulting collector current. With reference to Fig. 2, the polarities shown are those for testing a p-n-p transistor. The transistor is driven in a class B manner from a constant-current source, which consists of a large resistor, R_s, in series with a filament transformer for supplying the drive voltage, V_{in}. The negative half-cycle of the input-voltage waveform provides the drive for the transistor; the positive half-cycle, as previously explained, is used in the determination of inter-electrode shorts. The series resistor is shunted by a 1N66 diode, poled in a manner that will not affect the class B drive of the transistor, but will provide a low-impedance path for the uncontrollable collector current, I_{co}. The low-resistance base path prevents I_{co}, which is retuned to the collector through the base circuit, from remodulating the emitter junction. The idling collector current is thereby held at I_{co}, which is trivial by comparison to the average collector current.

Beta is the ratio of the measured collector current to the base current. Since the base current has been previously adjusted to the design value appropriate to the power level of the transistor being tested, the meter is calibrated to read beta directly. The meter has two beta ranges, 0 to 200 and 0 to 100, which are selected by similarly marked function-selector settings. Table II lists the particular values encountered in the measurement of beta for the three arbitrary power levels.

The a-c drive used in the beta test corresponds to large-signal conditions, and the indication given is therefore most characteristic of large-signal operation. Since the purpose of the tester is to tell good transistors from defective ones, rather than to precisely measure their characteristics for a given application, the large-signal-type beta indication is a realistic criterion.

Two advantages are realized by operating the transistor class B. Both base and collector currents are rectified by the transistor and can be measured with a d-c meter, as previously described. Also, the collector is swept through its full useful current range without causing excessive collector dissipation. The collector dissipation is a function of beta; it is equal to the product of the average collector current and the collector energizing potential of 3 volts. Table II lists the collector current as a function of beta for the three power levels. For the low, medium, and high power levels the average collector dissipation is 7.5 mw, 60 mw, and 1.5 watts for units with betas of 100. The dissipation increases linearly with beta.

Measurement of Collector Junction Breakdown Voltage

For measurement of collector-junction breakdown voltage, a half-sinusoid of voltage (350 volts peak value) from a high-impedance source is applied to the collector junction. The circuit is shown in Fig. 4. The half cycle of voltage which is in a direction to forward-drive the collector junction is clipped by the diode in the source network.

For back-bias voltages in excess of the junction breakdown voltage the transistor presents a low-impedance load to the driving source. The excess back-bias voltage appears across the source resistance, consisting of R_s in series with 50 K. Thus, the voltage swing across the junction is limited between the values of zero and breakdown. An a-c voltmeter is connected across the collector junction to read the breakdown voltage. The voltmeter consists of a full-wave rectifier and a d-c meter. A d-c voltage directly proportional to the transistor breakdown voltage is developed across the rectifier output. This voltage is applied to the d-c meter, which is calibrated to read the actual breakdown voltage. The use of a full-wave rectifier avoids the necessity for pnp-npn polarity switching in this portion of the tester.

The meter has two scales, 0 to 500 and 0 to 100 volts which are selected by similarly marked function-selector settings. On the 0 to 500 volt scale the maximum obtainable reading is 350 volts, which is limited by the peak a-c driving voltage.

Table III

Generator Characteristics for Measuring Collector Junction Breakdown Voltage

Power level	Effective source resistance	Maximum possible power available from generator to a resistive load
Low Medium	270 K	27 mw
High	60 K	125 mw

The driving-source resistance is selected to be low compared to the back resistance of the collector junction, and yet sufficiently large to limit the breakdown current of the collector junction to a safe value. The compromise requires two values of source resistance, one for the low and medium power levels, and a second value for the high power levels. Table III lists the effective source resistances and the maximum possible power that the generator can deliver to a transistor, considered as a matched resistive load.

Collector-to-emitter punch-through voltage can be measured by connecting the emitter of the transistor under test to the transistor base. This connection can be made between the E and B binding posts at the upper right corner of the front panel (Fig. 1).

Switching

The integrated circuit is shown in Fig. 5. A rather elaborate switching system has been used to simplify operation and to avoid duplication of driving signals,

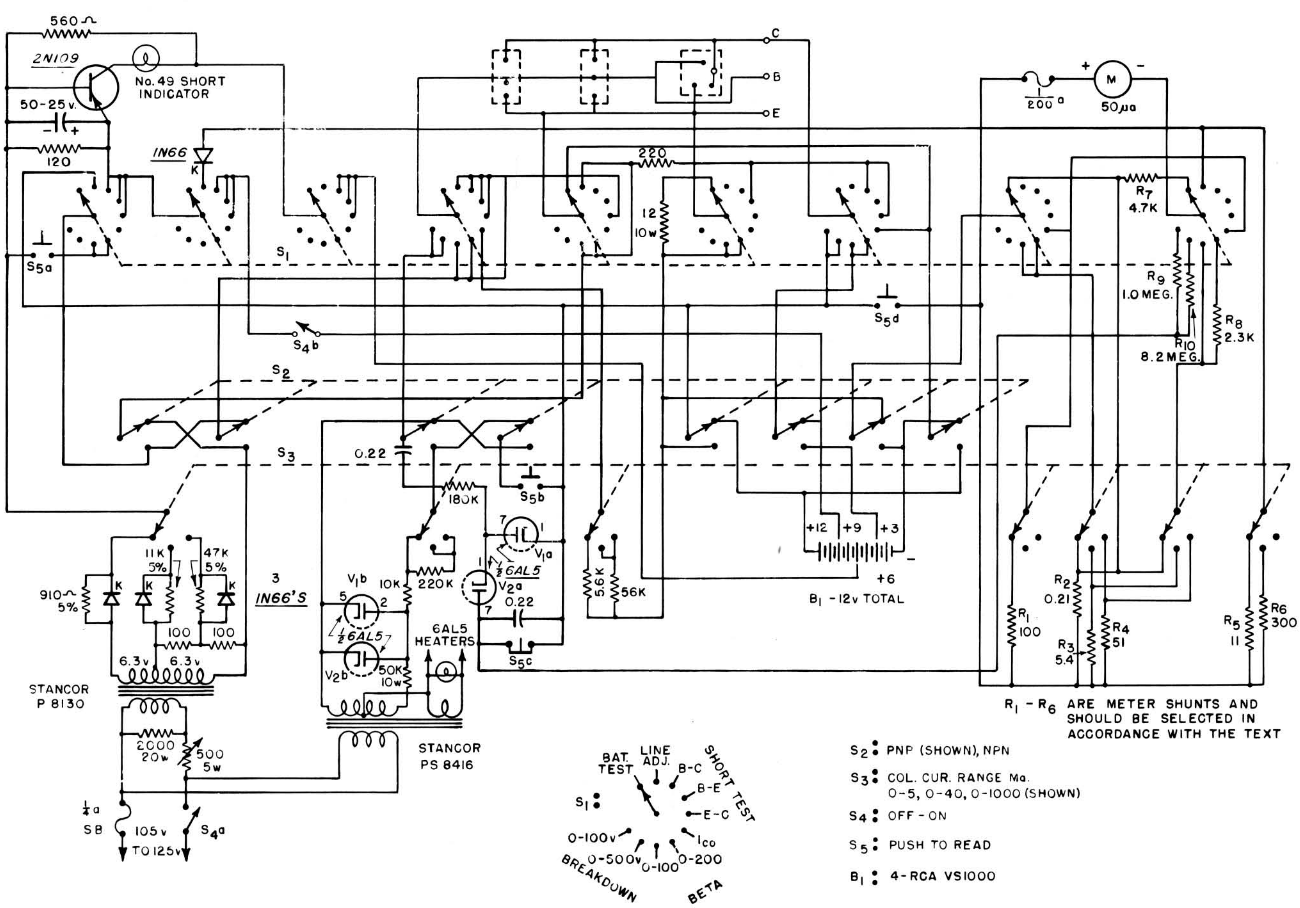

Fig. 5 - Circuit schematic diagram of the basic transistor tester.

energizing voltages, and meter shunts. All switches either can be obtained commercially or can be assembled from commercial stock parts.

The *function-selector* switch, S_1, selects the driving, metering and energizing circuits appropriate to the selected test. This is a 9-circuit, 10-position non-shorting rotary selector switch.

The correct values of drive signal, energizing voltages and meter shunt or multiplier are selected by the *collector-current-range* switch, S_3. This is a 7-circuit, 3-position non-shorting rotary selector switch.

The correct polarities of driving and energizing voltages and the correct meter polarity are set by the *PNP-NPN* polarity switch, S_2. This is an 8-circuit, 2-position non-shorting rotary selector switch.

Energizing and driving voltages are applied to the transistor only when the operator depresses a spring-return *push-to-read* switch, S_5. This switch is of the 4-circuit, 2-position type. Three of the switches are normally open, the fourth is normally closed.

Mechanical Details

The test set has been constructed in a 15 inch × 10 inch × 8 inch sloping panel cabinet. The layout of the front panel and the scale markings are evident from the photograph, Fig. 1. The switches, with associated shunts, multipliers, driving resistors and diodes, are mounted directly on the front panel. The remaining circuitry is on a 7 inch × 9 inch aluminum chassis, mounted on the floor of the cabinet. The batteries, four RCA VS100's, are secured to the back panel of the cabinet. This panel is hinged at its lower edge to facilitate battery replacement. Figs. 6 and 7 show internal construction details.

Meter Shunts, Multipliers, and Calibration

The test set uses a 4½-inch rectangular panel meter having a full-scale deflection sensitivity of 50 μa, and a resistance of approximately 2000 ohms. Numerous shunts and multipliers are required to adapt the meter for measuring the various currents and voltages involved in the various tests. These quantities range in value from 50 microamperes to 1 ampere and from 100 to 500 volts.

Inaccuracies in current division that might result from switch-contact resistance are avoided by using a two-circuit switch for the high-current shunts, required for the measurement of beta. The switch-contact resistance appears in series with the relatively high-resistance meter path rather than in the low-resistance shunt path. The same shunts are used for both beta ranges. For the higher ranges, a resistor is inserted in series with the meter to decrease its sensitivity. The approximate values of the shunts and the currents required for full-scale deflection of the meter are listed in Table IV. The shunts can be readily adjusted by supplying the tabulated values of current to the metering circuit and varying the shunt resistance to obtain full-scale deflection.

For the measurement of beta the driving-source resistors are selected so that one setting of the line voltage adjustment potentiometer provides calibration for the three current ranges. Reverse meter current,

Table IV

Full-scale Currents and Approximate Values of Shunts

Test	Power Level	Shunts	Full-Scale Currents
Line Adjust	Low	None	50 μa
	Medium	300 Ω	400 μa
	High	11 Ω	10 ma
Beta (0 to 100)	Low	51 Ω	2.5 ma
	Medium	5.4 Ω	20 ma
	High	0.21 Ω	500 ma
I_{CO}	Low	None	50 μa
	Medium	None	50 μa
	High	100 Ω	1 ma

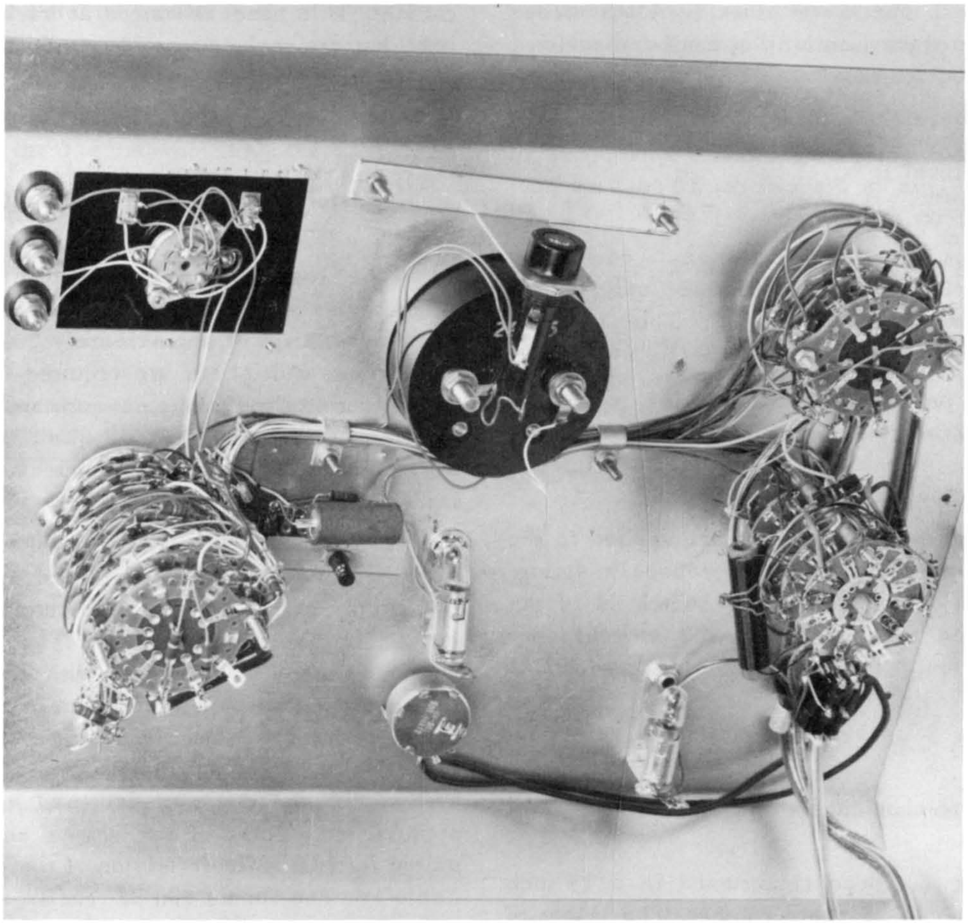

Fig. 6 - Photograph of wiring side of front panel.

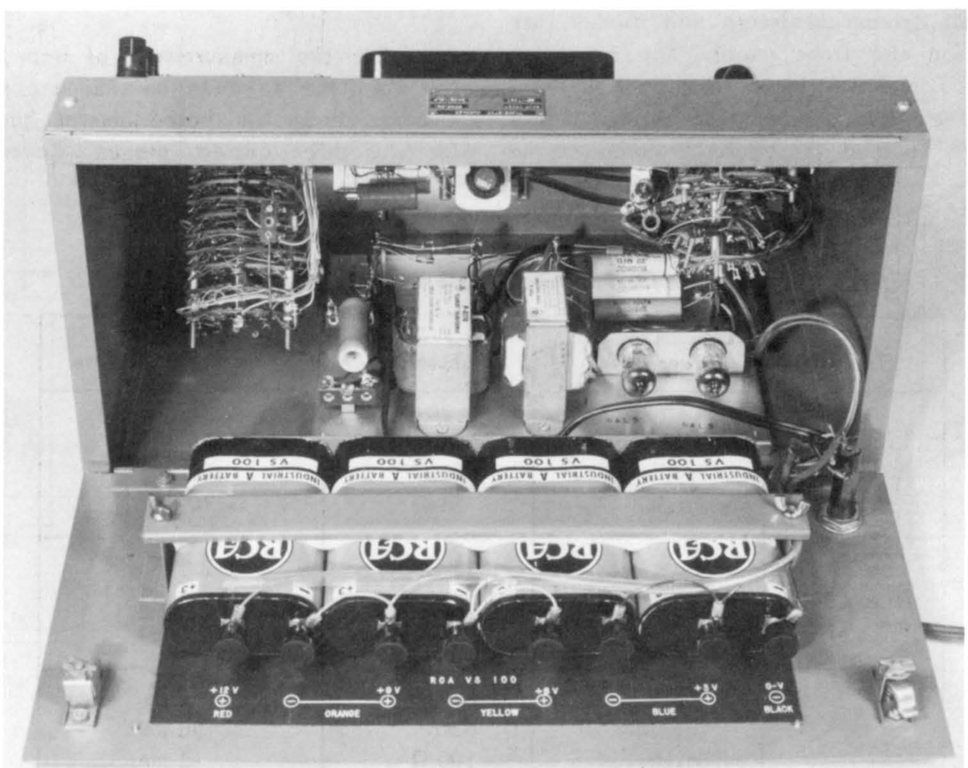

Fig. 7 - Interior view of tester with back panel open.

which might result if calibration were attempted with a defective transistor, is prevented by insetting a properly poled diode in the calibration set-up.

For the measurement of breakdown voltages, the meter circuit functions as a voltmeter. The multipliers must compensate both for the inefficiencies of the diodes and for the voltage drop across the 180K protective resistor. A protective resistor is included in the series path between the transistor and the voltmeter to limit the surge current, which results from the residual charge of the 0.22-μf capacitor. For the lower range the value of the protective resistance is comparable to the voltmeter input impedance. Therefore, the meter is approximately responsive to the full-wave average of the collector-voltage waveform. For the higher voltage range the meter loading is not as severe; the meter is responsive to nearly the peak-to-peak value of the collector voltage waveform. The difference in voltage sensitivities is reflected in the values of the multipliers, which are approximately 1M and 8.2 M for the 100 and 500 volt scales, respectively. The calibration of the voltmeter can be checked by measuring the breakdown voltage of a transistor with a calibrated oscilloscope or an auxiliary peak-reading voltmeter, and comparing this value to the reading of the test set. The calibration should be checked near full scale.

Robert C. Greene

Marvin Meth