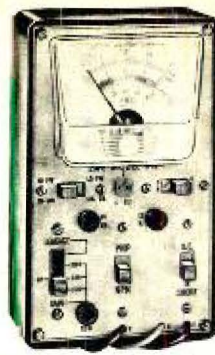
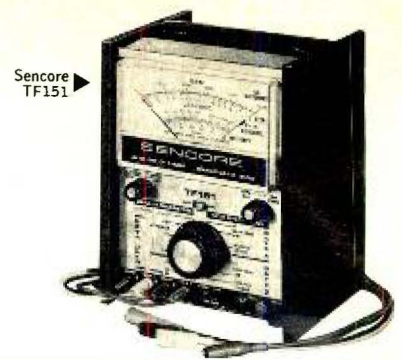




Eico 443 ▶



EMC 212 ▶



Sencore TF151 ▶

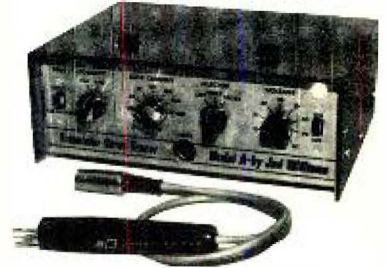
TRANSISTOR TESTERS for



B&K 162 ▶



▶ Leader LTC-902



Williams A ▶

THERE is certainly no mystique involved in testing transistors any more. Technicians and engineers know you can check for good or bad transistors with a simple ohmmeter, if the internal voltage or current is not too high. Lately, makers of volt-ohm-milliammeters have reduced ohmmeter voltages, and several have special low-power resistance ranges, so that they won't damage transistor or diode junctions.

But you might want to know if two transistors have the same *beta*, for use in push-pull. Or, you might want to pick one with low leakage for some critical circuit. There are a good many reasons you might need a quantitative evaluation.

That's when you need a transistor tester. There is a wide range of choices. Our recent survey for the accompanying chart turned up over twenty different models for the service technician; at least six are new this year. We know of two more that will be introduced soon.

The testers available fall into five categories: (1) inexpensive type, (2) general type, (3) automatic type, (4) lab type, and (5) curve tracer (use with scope).

Low Cost and Quick

Even within this category, instruments vary considerably. The simplest model tests only I_{CEO} (collector-to-emitter leakage current with base open) and makes a *beta* test of sorts. The diagram of Fig. 1A shows the basic test setup that is used.

For this *p-n-p* transistor, negative voltage goes to collector and positive to emitter. That reverse-biases the collector and emitter junction. Any current that flows is I_{CEO} leakage. A small-signal transistor should hardly wiggle a 0-3 mA meter at all. A power transistor could show normal I_{CEO} up to quarter-scale. More than that means the transistor is defective—with excessive leakage or shorted. No reading means the transistor may be open.

To see if the transistor amplifies, you close the Gain switch. A resistor applies negative voltage to forward-bias the base-emitter junction. If the transistor is okay, collector current jumps upward. The meter should read considerably more than it did with the base open. If not, the transistor is faulty.

This kind of evaluation is "go/no-go" testing. You make no accurate gain measurement. Also, the test voltage for leakage may be much less (or more) than what's needed by the transistor you want to test. That creates some inaccuracies. Yet, at low cost, these testers are acceptable. Two models that work this way are the *Heath IT-27* and the *RCA WC-506A*.

The *EMC 212* makes a simple I_{CEO} test and a check of d.c. *beta*. Then you can plug a transistor into the socket and test its performance as an oscillator. If it works, the signal generated can then be employed for signal-injection troubleshooting.

The *Simpson 650* permits reasonably accurate d.c. *beta* readings. The 650 is an adapter that fits on the *Simpson 260* v.o.m. Precision resistors, plus switches and adjustment pots, calibrate the tester for *beta* readings up to 250. The only leakage reading is I_{CEO} .

Testing I_{CEO} instead of I_{CBO} (collector-to-base leakage with emitter open) would be okay except that I_{CBO} usually tells more about how well most transistors will operate. Acceptable I_{CEO} and "relative gain" readings may camouflage a transistor that won't function well because of too much I_{CBO} . Some testers omit the I_{CEO} reading; their designers consider I_{CBO} the more important test.

More Time, Accuracy, Cost

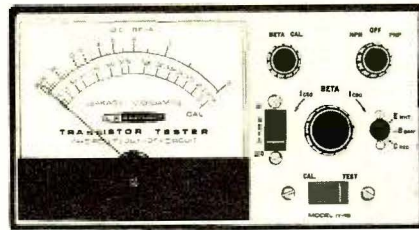
Several instruments test for both I_{CBO} and I_{CEO} , and measure *beta* with somewhat more accuracy. We've labeled these "general"-type models. Some do other tests, too.

The *Heath Model IT-18*, for example, measures both kinds of leakage. The test for I_{CBO} of an *n-p-n* transistor is shown in Fig. 1B. (For a *p-n-p* the battery and meter are reversed.) The base-collector junction is reverse-biased. Any current that flows is leakage. A few microamps is all that's allowable. As a rule of thumb: for r.f. transistors, no more than 5 μ A; low-power transistors, no more than 50 μ A; power-output transistors, up to 1 mA.

The d.c. *beta* test in general-type instruments is simple, but it's calibrated so you get a better idea of how well a transistor can amplify. The test arrangement in Fig. 1C is typical, although some may have several additional ranges and scales.



Hickok 890A



Heath IT-18

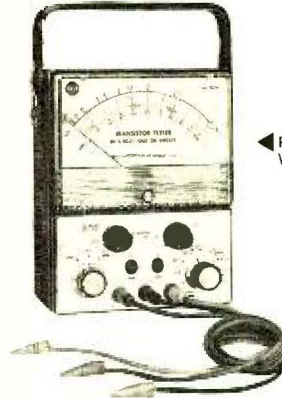


Lectrotech TT-250

SERVICING

By FOREST H. BELT

A survey of what is available to the service technician for checking leakage currents, amplification, and displaying characteristic curves of transistors, FET's, and diodes.



RCA WT-501A



Simpson 650

There are two steps. First, you push switch S1 to the Cal (calibrate) position. That puts the meter into the collector circuit across R2 and applies bias to the base through R1 and R3. You adjust bias with the knob of R3 until the meter reads a specific amount of collector current. For example, suppose this calibration I_C is 5 mA.

As the second step you push S1 back to the Read position (labeled Beta on some instruments). R1 becomes part of the collector circuit. The meter switches to the base circuit.

The meter measures how much base current is flowing. If the scale is marked in microamps, you can figure out *beta*. Roughly speaking, *beta* is the ratio of collector current to base current. Suppose that, with 5 mA of collector current, a particular transistor shows base current of 25 μ A (0.025 mA). Collector current of 5 mA divided by base current of 0.025 mA equals *beta* of 200.

To make it easier, the meter scale is marked in *beta*. This approximation of true a.c. *beta* is dependable only if the test voltages fit the particular transistor and its operating conditions.

Some instruments provide extra test ranges. The Heath IT-18 has two. So does the Lectrotech TT-250. The RCA WT-501A has five different operating levels for measuring *beta*; that improves the accuracy of the reading.

The Leader LTC-902 tests I_{CEO} and two ranges of d.c. *beta*. It also generates a high-harmonic 1-kHz tone for signal injection. An internal amplifier, with gain of 90 dB, makes a good a.f. signal tracer. As in several instruments, metering functions are accessible separately: 0-50 mA and 0-20 volts, in this model. This and virtually all other units measure diode leakage.

Several instruments measure *beta* the a.c. way. The Sencore TF17 and TF151, the B&K 162, and the Eico 685 are examples in the general category. Several models in other categories also measure a.c. *beta*.

It's interesting to note that the B&K, Eico, and Sencore instruments also measure transconductance (G_M) of field-effect transistors (FET's). That's similar in many ways to a.c. *beta*. G_M of a FET is a ratio worked out by dividing signal current in the drain circuit by signal voltage at the gate. The result is in *mhos* (reciprocal of ohms), or more accurately in micromhos (μ mhos).

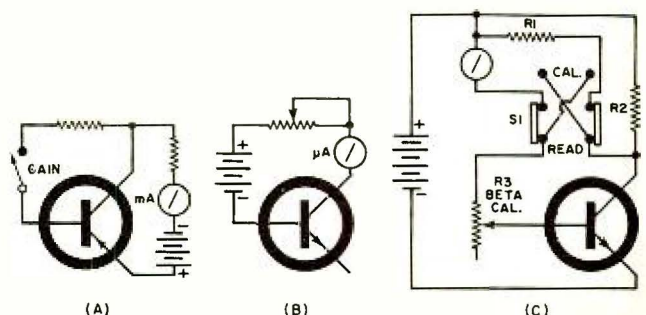
You find a.c. *beta* in bipolar transistors by dividing collector signal current by base signal current. If you did it the complicated way, you'd figure out currents from voltages across resistors in the collector and base circuits (no ordinary instrument measures *signal currents* directly). Then you'd calculate *beta*. With a tester, you set up switches and controls and the meter shows you a.c. *beta* already calculated.

These B&K, Eico, and Sencore models are the "upper class" of general-type transistor testers. They all check leakage in both bipolar and field-effect transistors. The Sencore units measure only I_{CBO} in bipolars, but measure both I_{GSS} (gate-to-source leakage with drain shorted to source) and I_{DSS} (zero-bias drain current) in FET's.

The B&K 162 performs a whole gamut of bipolar and FET measurements. In addition to I_{CBO} and I_{CEO} tests, it measures collector-to-emitter leakage with the base shorted to emitter (I_{CES}). This reading should be lower than the I_{CEO} reading, but not as low as the I_{CBO} reading. The 162 also checks both I_{GSS} and I_{DSS} in FET's.

The Eico 685 makes all three leakage tests for bipolars and both leakage tests on FET's. In addition, there is a pinchoff test for FET's. You apply 5 volts between drain and source, then turn up a control that applies pinchoff

Fig. 1. (A) Basic test circuit for I_{CEO} (collector-to-emitter leakage current with base open), and—by closing the switch—a gain evaluation. (B) Test for I_{CBO} (collector-to-base leakage current with emitter open). Reverse bias is used. Note that "n-p-n" transistor is shown here while "p-n-p" is shown in (A). (C) The simple test for d.c. *beta* requires two steps.



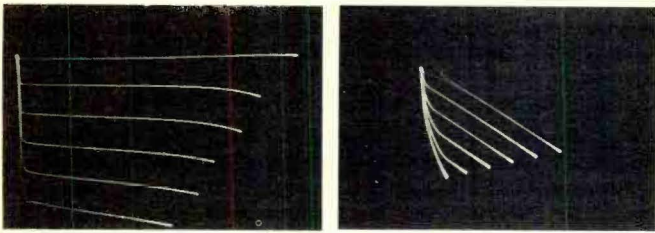


Fig. 2. Collector-voltage/current characteristics of transistor under different biases are displayed simultaneously on scope screen by curve tracer. (Left) Normal family of curves for an n-p-n transistor. (Right) A "signature pattern" of a transistor that is being checked out in a circuit.

to the gate. When current stops, the voltage control knob tells you the pinchoff value. (You use the same variable voltage to determine where a zener diode breaks over or an SCR fires.)

Another general unit is the *Sencore* FT155. It's special in that it tests only FET's. The unit makes all the FET tests the other *Sencore* units make, plus gate-2 tests on dual-gate FET's.

Automatic Testing

A couple of operations to test a transistor—or three or four, if you count leakage tests—isn't much work. But the new *Hy-Tronix* tester, made by a division of *Vanguard Tool Mfg. Co.*, takes even that chore out of in-circuit testing. There are five colored lights on the meter scale.

The in-circuit test is quick. You flip the function switch for Visual or Sound indication, Xstr test. Then you make connections to the foil side of the printed board with a special probe. If the transistor is good, the two top lights or the two bottom lights start blinking. A label between the two blinking lights tell you the polarity of the transistor.

If there's a short or excess leakage, different lights start blinking. Labels between whichever lights blink will tell you which elements in the transistor are shorted.

If you set the Function switch for Sound, and the transistor is okay, a Sonalert beeper sounds off each time the "Good NPN" or "Good PNP" lights flash. If the transistor is bad, you hear nothing. The idea is that you can go through a bunch of transistors on a printed board without looking up from your work.

Out-of-circuit tests are similar to those by other testers. You measure I_{CEO} or I_{CBO} . You can check *beta* with base current at 20 μA , 200 μA , or 2 mA, depending on whether the transistor is an r.f. type, low-power type, or a high-power type. The lights aren't involved.

"Lab" Testers

These instruments are for testing individual transistors, usually out-of-circuit. We've tagged them "lab types" because they provide operating conditions that closely approach optimum for each transistor—at least for some of the tests.

Simplest is the *Heath* IM-36. There are knobs for collector voltage, collector current, base voltage, base current, and leakage voltage. If you're testing transistors that need more voltage or current than the instrument supplies, you can connect an external voltage supply to binding posts on the panel. With the right combination of switch and control settings, you can test leakage between any two elements and measure d.c. *beta* under many different voltage and current conditions.

Similar advantages are obtained with the *Hickok* Model 890A. Test voltage and current for the collector are variable over a small range. You can test I_{CBO} and measure a.c. *beta* with a 1-kHz oscillator (more realistic than a 60-Hz a.c. *beta* test). You can test transistors in circuit or out.

The *Hickok* Model 870 is the most elaborate and versatile tester on the chart, and the most expensive. It has a roll

chart with data on over 1000 transistors. If your cross-reference books are up to date, you can test new types too.

The 870 lets you test *beta* by a.c. or d.c. methods. The a.c. *beta* measurement is at 1 kHz, and transistor operating voltage and current are variable. You can test I_{CBO} with a variable test voltage. You can run operating curves to determine saturation point, and check just about any other transistor parameter you care about. The instrument has voltages to suit almost any transistor—low power or high, ordinary or switching type.

Curve Tracers

These are fairly new to the transistor-testing scene, at least insofar as inexpensive instruments for the service technician are concerned. Only two curve tracers are available as this is written, but others are expected shortly.

There is some controversy about their usefulness for servicing. True, they are more elaborate than is necessary to spot a shorted or open transistor. But, for that matter, so are most transistor testers. Detractors object because you have to use an oscilloscope with the curve tracer—two pieces of equipment instead of one.

Many technicians insist transistors don't "get weak" like tubes do; they're either good or bad. Evidence proves otherwise for some kinds of transistors in some applications. Heat changes operating curves; so does age in some instances. You can spot such variances only if you see whole operating curves.

A curve tracer and scope display a "family" of operating curves for the transistor being tested—see Fig. 2 (left). Each curve is the I_C - V_C characteristic of the transistor. It is made by "sweeping" the collector voltage while keeping a certain value of base current (bias).

The *family* of curves is developed by staircase changes of bias. Each change of bias makes another curve. A different family can be displayed if you change the average (center) collector voltage. In an elaborate curve tracer, then, you can pick whatever collector "center" voltage and whatever set of bias stairsteps suit a particular transistor.

The *Eico* 443 lets you measure *beta*, I_{CEO} , inverse breakdown voltage, and several other parameters. You must know the calibration of your scope, but the 443 has calibration voltages built in. A collector-current switch lets you display two families of three curves each: one family for signal transistors and another for power types.

The *Williams* Model A provides for testing at eight different collector "center" voltages. The increment between stairsteps of base current is also variable. You can set the switch to make the curves 10 μA , 20 μA , 50 μA , 100 μA , 200 μA , 500 μA , or 1 mA apart. You can learn to read *beta*, spot leakage, test for breakdown levels, and so on. You must calibrate your scope, but that isn't too hard to do; most scopes have their own calibration system built right in.

Once a typical family of curves is available for every transistor type, the instrument will be more useful. It can also be used for SCR's, zener diodes, FET's, and ordinary diodes. But you must become familiar with what patterns are normal.

One TV manufacturer, *Sylvania*, has begun adding in-circuit "signature patterns" to service data for transistors in TV receivers. An example is shown in Fig. 2 (right). Once setmakers or service-lit publishers add transistor curve data to schematics, the curve tracer can be a more valuable aid. You just go through the set (with power off) touching the special three-prong probe to each transistor at the foil connections. Compare the curves you get with the pattern specified for *that* transistor in *that* circuit, and you can spot any significant variations.

The special transistor-testing probe we've mentioned is a product originated by *B&K*. The Model FP-3 probe has three tips or prods of needle-point steel. Each prod is independently mounted in a spring-loaded ball-socket. And

they're made in unequal lengths. The longest is for the collector connection, the middle length for emitter, and the shortest for base.

Here's how you use the probe. Locate the E, C, and B connections on the foil side of the printed board. Push the needle tip of the collector prod into the C connection. Then, keeping pressure so that the tip doesn't slip off, rotate the body of the probe until the emitter tip is over the E

connection; push downward until it makes contact. Keeping that pressure applied, again move the probe body around until the base tip is over its connection. Push downward some more and all three connections are made—even through resin protection—and with one hand.

You can use the probe with just about any tester listed in the chart. It is included with the *B&K* 162 and the *Williams* curve tracer. ▲

TRANSISTOR TESTERS

MFR.	MODEL	BIPOLAR TESTS				FET TESTS			IN-CKT.	OUT-CKT.	WHAT ELSE IT TESTS	PRICE \$(K-KIT)	COMMENTS
		I_{CBO}	I_{CEO}	I_{CES}	BETA	I_{DSS}	I_{OSS}	G_m					
B & K	162	0-1A	0-1A	0-1A	a.c. 1-5000	0-1A	0-1A	0-50,000	yes	yes	diode, SCR, UJT, triac	100	
EICO	680	0-0.5A	0-0.5A	—	d.c. 2-300	—	—	—	yes	yes	diode	35(K) 55	Can be used as v.o.m.
	685	0-5mA	0-5mA	0-5mA	a.c. 2-10,000	0-5mA	0-50mA	0-50,000	yes	yes	diode, zener, SCR, UJT, triac	100(K) 150	Can be used as v.o.m.
EMC	212	0-80mA	—	—	d.c. 0-200	—	—	—	yes	yes	diode	15(K) 22	Voltmeter 0-12V, millimeter 0-80mA; tests oscillation
HEATH	IM36	0-15 μ A	0-15 μ A	—	d.c. 0-400	—	—	—	—	yes	diode	62(K) 93	Portable case
	IT-18	0-15mA	0-5mA	—	d.c. 0-1000	—	—	—	yes	yes	diode	25(K)	
	IT-27	—	0-3mA	—	d.c. relative	—	—	—	—	yes	diode	7(K)	
HICKOK	870	0-10mA	yes	—	a.c. 1-600 d.c. 0-300	—	—	—	—	yes	—	425	Tests a.c. beta at 1000 Hz; roll chart built-in
	890A	0-50 μ A	—	—	a.c. 0-200	—	—	—	yes	yes	—	235	Measures B-E input res. & imp.; portable; a.c. beta tested at 1000 Hz
HY-TRONIX	900	0-100mA	0-100mA	—	d.c. 0-500	—	—	—	yes	yes	diode	287	Audible & light display; Model 103 probe \$15 extra
LEADER	LTC-902	—	0-50mA	—	d.c. 0-200	—	—	—	yes	yes	diode	100	Works also as injector & tracer
LECTROTECH	TT-250	0-5mA	—	—	d.c. 0-500	—	—	—	yes	yes	—	90	
RCA	WT-501A	0-100 μ A	0-1A	—	d.c. 1-1000	—	—	—	yes	yes	diode	67	
	WC-506A	—	relative	—	d.c. relative	—	—	—	—	yes	diode	18	
SENCORE	TF17	0-5mA	yes	—	a.c. 1-500	0-5mA	0-50mA	0-50,000	yes	yes	diode, zener, var. cap. diode	110	
	TF151	0-5mA	yes	—	a.c. 1-500	0-5mA	0-50mA	0-50,000	yes	yes	diode, zener, var. cap. diode	130	
	TR115	—	0-50mA	—	d.c. relative	—	—	—	—	yes	—	25	
	FT155	—	—	—	—	0-200 μ A	0-50mA	0-50,000	—	yes	—	95	
SIMPSON	650	—	0-100 μ A	—	d.c. 0-250	—	—	—	—	yes	—	44	Attaches to Model 260 v.o.m.

CURVE TRACERS

MFR.	MODEL	I_{CBO}	I_{CEO}	I_{CES}	BETA	OTHER TESTS	NO. OF CURVES DISPLAYED	COLLECTOR VOLTAGES	WHAT ELSE IT TESTS	PRICE \$(K-KIT)	COMMENTS
EICO	443	—	yes	—	yes	$V_{CE(SAT)}$, BV_{CEO}	3	10V @ 12mA 10V @ 1A	diode, zener, SCR, FET	100(K) 150	Has own scope calibrator
WILLIAMS	A	yes	yes	—	yes	BV_{CEO} , $V_{CE(SAT)}$	6	cont. variable 0-30V	diode, zener, SCR, FET	135	