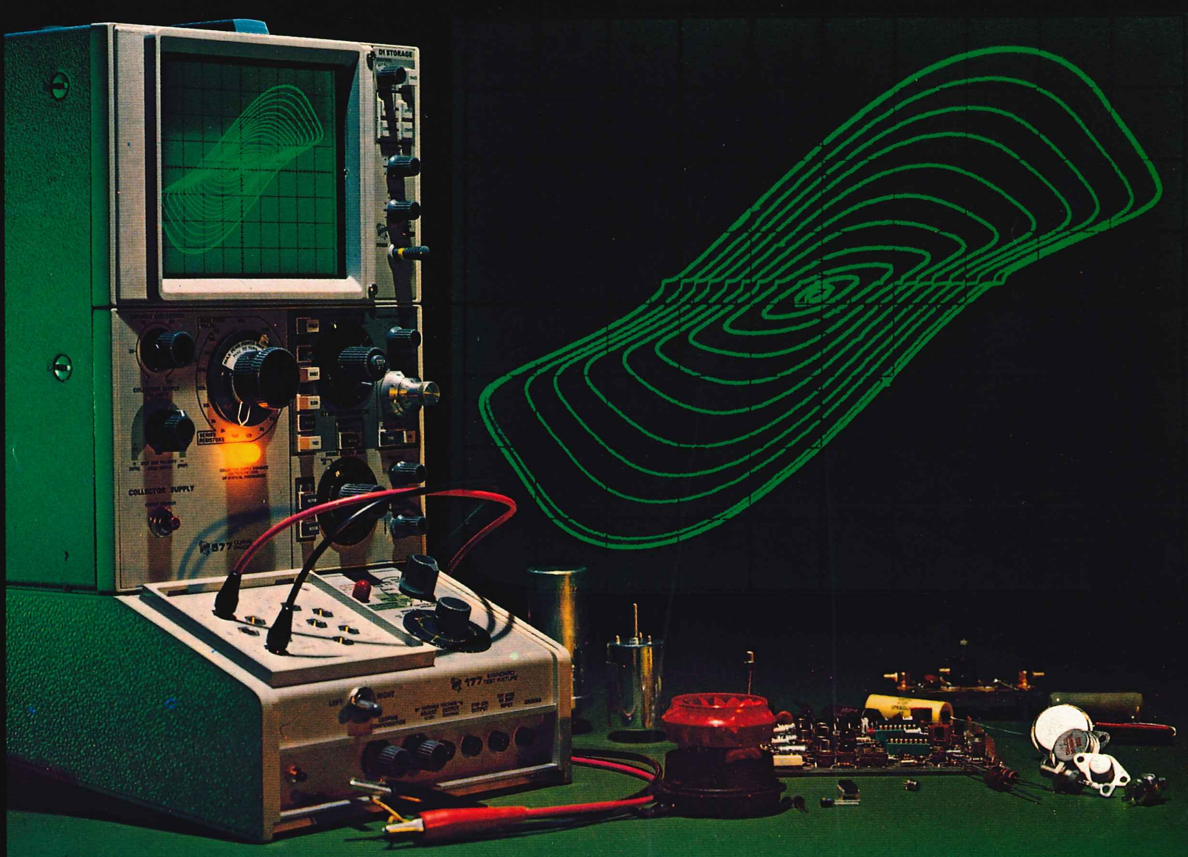
electronic products

Magazine
August 20, 1973

Getting your money's worth from a curve tracer



Getting your money's worth from a curve tracer

The versatile curve tracer can test most components quickly and easily over a wide range of voltage and current.

by Jack Millay
Tektronix

The curve tracer is rarely used to its full capability because most users don't realize that the same measurement methods that work so well with semiconductors work equally well with other components. The parameters of switches, relays, connectors, incandescent bulbs, photo-isolators, gas discharge devices and, to some extent, capacitors, resistors and small motors can all be measured with a curve tracer. It can also be used for in-circuit testing of p-c boards.

Testing passive components on a curve tracer is a matter of measuring dynamic resistance ($\Delta V/\Delta I$). Today's curve tracers can make dynamic resistance measurements from less than 0.001 ohm to over 1×10^{12} ohms. This large resistance range covers the resistance of circuit board runs and connector, relay, and switch contacts at its low end and can still measure the extremely high resistances of adjacent p-c wiring or open switch contacts at the high end. The high voltage ranges of the tracer's collector supply allow resistance measurements up to 1500 v, which is particularly useful when checking insulation, resistance and breakdown voltage.

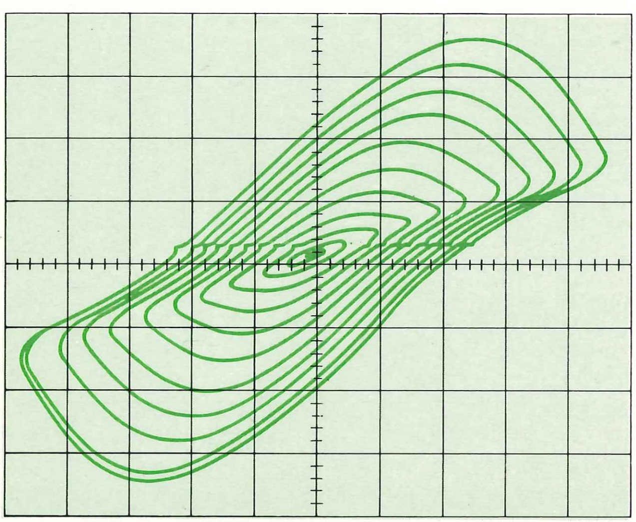


Fig. 1. A curve tracer with storage gives an immediate display of a motor's characteristic for many increments of applied voltage.

Curve tracers measure resistance over a specified group of voltage and current levels, important because all resistances are nonlinear if viewed over a large enough range of currents. Sometimes this nonlinearity is of no concern and the measurement can be done with either a curve tracer or an ohmmeter. But the ohmmeter fails when a resistance nonlinearity at a particular current and voltage is of critical importance, since the ohmmeter provides only one point on a resistance curve.

Resistances of relay, switch and connector contacts are often nonlinear in both the open and closed condition. A closed contact that is satisfactory in a high current, wet circuit may be completely unsatisfactory in a low current, dry circuit. This is because most contact materials develop a layer on the contact surface. The resistance of this layer is higher than that of the contact material and can act as an insulator in a dry circuit.

Measuring the contact resistance of dry circuits is done quickly with a curve tracer. Simply set the contact across the C and E terminals of the tracer's test fixture and gradually raise V and I to plot dynamic resistance.

It's important to remember that contacts that must have low resistance should be evaluated under dry circuit conditions first (low V and I) to prevent rupturing the film on the contact surface.

Low resistance measurements using the curve tracer's test fixture require special precautions. In an ordinary test fixture, each contact has a finite resistance and

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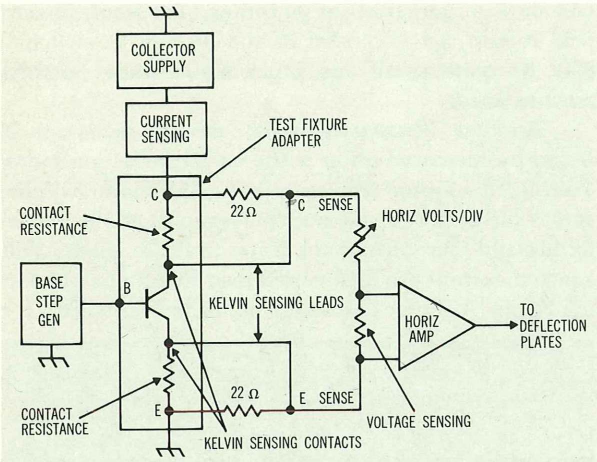


Fig. 2. Kelvin sensing is a must for low resistance measurements. It provides a direct low-current path to the horizontal amplifier, allowing voltage to be measured correctly.

a voltage drop will be developed across it during any test. This drop is of little consequence in low current measurements. But, fixture contact resistance can be an important consideration in high current (low resistance) measurements since the voltage across the fixture contact resistance can swamp out the component's voltage.

To avoid this, specify Kelvin connectors or Kelvin sensing (see Fig. 2). This method provides a path for voltage measurement through a separate set of contacts through which very little current flows.

Most curve tracers can resolve a voltage drop across the device under test of less than 5 mv, whether at high or low currents. The minimum dynamic resistance that can be displayed varies from 5k ohms at 1 μa to 0.5 milliohm at 10 amps.

For high resistances (related to leakage and breakdowns), measurements can be made at voltage levels up to 1.5 kv on most curve tracers. Some allow leakage-current measurements lower than 1 na. Maximum values of dynamic resistance that can be measured vary from 1×10^{11} ohms at 100 v to more than 1.5×10^{12} ohms at 1.5 kv. Measurement of switch and relay contacts covers both the low (closed) and high (open) resistance condition, and the wide dynamic range of the curve tracer easily adapts to both measurements.

Testing switch and relay contacts

The curve tracer can be used to evaluate the insulation resistance, leakage current, and voltage breakdown of switch and relay contacts in the open position. Humidity has an effect on these characteristics and must be taken into consideration.

An easy way to investigate humidity effects at the bench is to use a glass jar with feed through terminals on the lid. Components under test are suspended from the lid's terminal and are connected to the collector and emitter terminals of the tracer. Adding a little water to the bottom of the jar will increase the humidity until it is close to 100%. Using this method requires feedthroughs with high resistance under humid conditions.

The two switches in Fig. 3, each with a different insulation material, are being tested for leakage resistance under humidity. The current scale is 200 na per division and the voltage scale is 100 v per division. By using a stored display, the leakage resistance of both switches can be compared. This is also important when evaluating switches from different vendors.

The stored CRT display shows that one switch's insulation resistance (the bottom horizontal trace) is unaffected by humidity, while the other's insulation resistance has dropped from a normally high value to about 500 megohms (the diagonal trace). The spiked

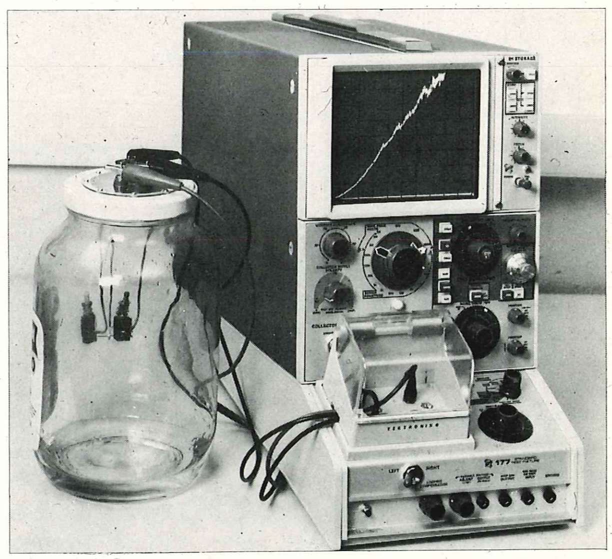


Fig. 3. A curve tracer and a jar are used to check pushbutton switch insulation resistance under humidity. The curve tracer indicates that one switch has infinite resistance (horizontal trace) and the other (diagonal) has 500 Megohms.

areas on the low resistance trace are due to momentary arcing and healing of the switch's insulation.

Contact resistance of closed contacts is investigated in much the same way as described in the section on low resistance measurement. Because most relay or switch contacts have a wiping action, closed contact resistance may change with successive operations. To observe this change, the switch or relay must be cycled on and off and the resistance change observed. A curve tracer with a storage CRT can display the resistance curve of many closures at one time.

For relay contact testing, the relay's coil can be activated manually using the tracer's step generator offset voltage or for automatic testing, the stepping mode can be used. But not all relays can be driven directly by the step generator. Relays whose coils require more voltage or current can be driven by a transistor controlled by the step generator (Fig. 4).

The relay coil rate of actuation can be varied by using different step rates and various amplitudes. On

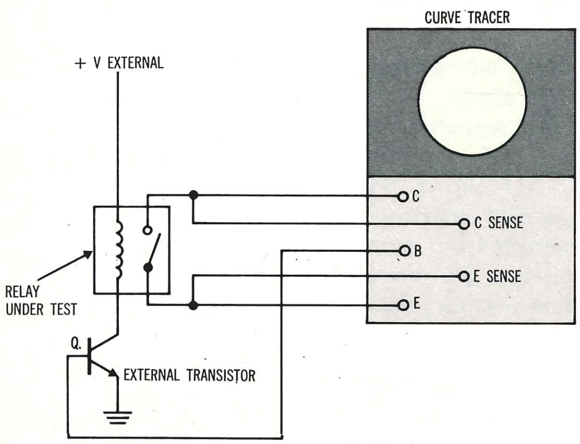


Fig. 4. A curve tracer with storage can be used to evaluate contact resistance vs operating life with this fixture. Certain types of relays cannot be driven directly by the tracer but require an external transistor.

Tek's Model 577-177, these rates can be as fast as 60 Hz or as low as 1 Hz.

Life testing of relay contacts can be run using the storage feature of the 577-155. Any gradual changes in contact resistance or poor closures (bounce) will be shown on the stored display, but outright contact misses will not be recorded.

Relay coil characteristics are equally as important as the contact characteristics. Here again, the curve tracer with storage capability can be used to measure coil resistance, pull-in voltage, pull-in current, drop-out voltage and current. Movement of the relay armature in the magnetic field of a coil generates a forward emf on closing and a back emf on dropout. The overall relay current-voltage locus can be used to obtain all relay coil parameters off the CRT face.

The coil of the relay under test is connected between the collector and the emitter terminals of the fixture. The collector supply is put in the dc mode and then varied manually to make the relay pull in and then drop out. This method will only work with curve tracers that have the dc collector mode.

The stored pattern of a relay tested in this manner is shown in Fig. 5. The inverse slope of the diagonal line ($\triangle V/\triangle I$) is the coil resistance. Pull-in current and voltage values can be read off the display at the junction of the dynamic coil resistance line and the upper spike. Drop-out current and voltage parameters can be read off at the bottom junction. Relays with larger coil inductance will show larger spikes at pull-in and drop-out. In some reed relays, the excursion of the display at switching may be quite small and other curve tracer methods must be used.

Another electromechanical device that can be tested by the curve tracer is the 60 Hz induction motor. Testing this motor requires placing the motor winding across the collector and emitter terminals of the tracer's fixture and then putting the tester in the ac mode. Voltage and current are then varied over the motor's operating range. A motor characteristic, as shown in Fig. 1, is

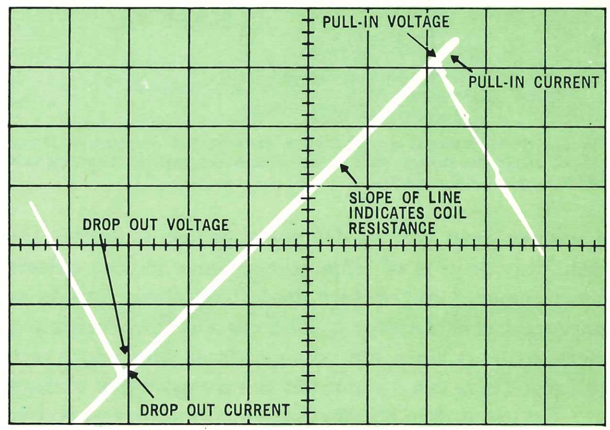


Fig. 5. Relay pull-in and drop-out voltages, and coil resistance can be evaluated from this stored curve tracer display. The two large spikes are caused by the relay's back emf.

for many increments of applied voltage. This is a better method than testing the motor with ammeters, voltmeters, Variacs™, etc., and then plotting the results.

Testing LED's and lights

One of the more unusual uses of the curve tracer is testing light emitting and optically coupled devices. Light emitting diodes and incandescent lights can be evaluated for current versus voltage and light output. This is done by putting either of these devices across the collector and emitter terminals of the curve tracer, then stepping through the various V and I ranges and checking the light output/step with a light meter.

Cold and hot restance of incandescent lamps can be displayed conveniently using a curve tracer with CRT storage. This is important for gaging the in-rush current, which is a function of cold resistance. To measure these parameters, use the ac collector mode and gradually increase collector sweep voltage until lamp operating voltage is reached. Slopes of the cold and hot resistance can easily be picked off the typical display of Fig. 6 (this is only possible with storage).

Firing voltage, breakdown voltage and leakage currents of neon bulbs can be measured with the same techniques used for LED's and incandescent bulbs, but

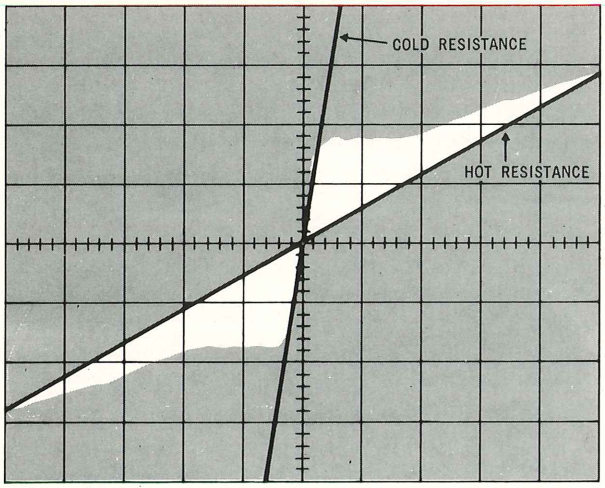


Fig. 6. Hot and cold resistance of an incandescent bulb can be read directly off this stored trace of current vs voltage.

with two precautions. When measuring firing or breakdown voltages, select a high value of series resistor since neons have negative resistance in the breakdown region and will draw excessive current without a resistor. Keep in mind that the amount of ambient light also affects the neon bulb's parameters.

Optically coupled isolators (a LED and a phototransistor) are especially easy to evaluate because no direct measurement of light output is necessary. Connect the anode of the LED to the step generator terminal B and the cathode to E. Then connect the isolator's collector and emitter to the C and E connections of the curve tracer. The resulting display will be similar to a family of bipolar transistor collector characteristics, except that the "beta" will be poor.

To check isolation or leakage in the off state, simply connect all the phototransistor leads to the C terminal of the tracer's test fixture. Tie the LED leads together, connect them to the E terminal, and check the leakage resistance or breakdown voltage between the C and E terminals, the same as in the relay leakage resistance test described.

Capacitance from a curve tracer?

AC dynamic resistance measurements on a curve tracer can bring about looping of the CRT trace. Looping is caused by the combined stray capacitance of the device under test, the test fixture and the adapter. Since the current across the stray capacitance leads its voltage by 90°, a Lissajou pattern is formed instead of the normal in-phase line pattern.

Ordinarily this looping effect is cancelled out by the looping compensation control on the curve tracer's test fixture, but this effect can be used to measure capacitance. With a diode adapter in the test fixture, set the horizontal volts/div control to collector volts range, set the collector supply polarity switch to ac and adjust the vertical sensitivity to display a loop on the screen (Fig. 7). Then adjust the looping compensation to close the loop. (This cancels out all stray capacitance.)

Place a reference capacitor in the diode adapter and measure the vertical loop opening. Calculate the current/pf for the reference capacitor. Then replace the reference with an unknown and measure the loop opening (changing the vertical scale, if necessary). The unknown capacitance is directly proportional to the ratio of the vertical loop openings. This test method is adequate for capacitance values up to 1000 pf and can resolve values as low as 1 pf.

A slightly modified method is available for measuring capacitors with values greater than 1000 pf. With these values of capacitance, voltage rating must be considered in order not to damage the unit. Polarized capacitors (electrolytics, tantalytics) can be tested with the modified method with caution, by limiting the curve tracer's voltage excursion in the reverse direction to a known safe value.

(A)

(B)

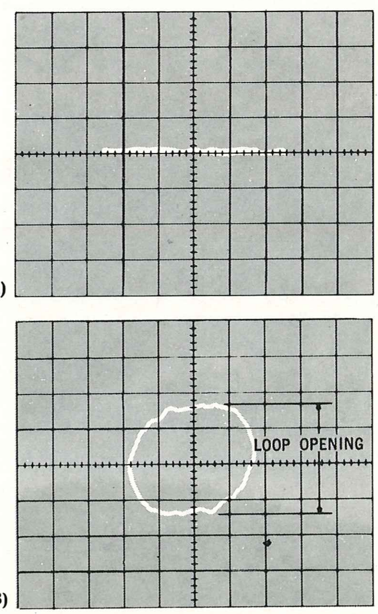


Fig. 7. Looping caused by stray capacitance (A) is normally cancelled out by the tracer's looping compensation (B). It can be used to measure capacitance from 1 to 1000 pf directly.

Checking power supplies

Power supply load current can be measured by using the curve tracer without putting a current measuring device in series with the supply. Connect the tracer's collector supply to the dc supply's output and the emitter terminal of the fixture to the ground of the supply. The polarity of the supply being tested must be connected to

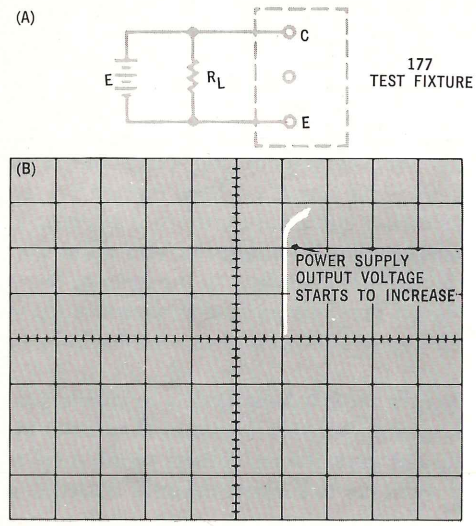


Fig. 8. The curve tracer can be used to measure the load current of a series regulator, A. In B, the current is measured at the point where the display voltage just starts to increase the load current.

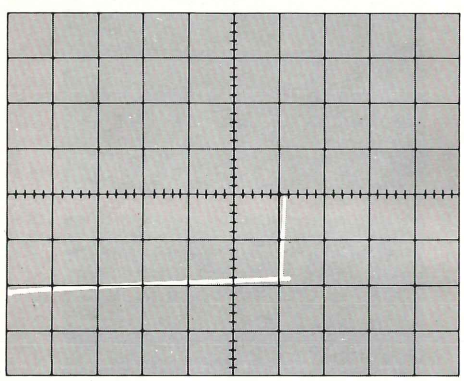


Fig. 9. The power supply of Fig. 8A can be tested for short circuit current by reversing the tracer's collector voltage. The current value at the intersection of the V/I locus and the I axis, is short circuit current.

the same polarity voltage on the collector supply. Select a collector supply voltage range that is higher than the supply being tested. Adjust the horizontal volts/div control (sensitivity) so the supply output voltage can be observed on the CRT with the supply under evaluation turned on.

Start with a high value of series resistance (in the curve tracer) and the variable collector voltage control turned down. Gradually increase the collector voltage until the supply voltage as observed on the CRT starts to increase. If the voltage does not increase, turn the variable collector voltage control down, select a lower series resistance value and repeat the procedure until there is an increase in supply voltage. At the point where the observed voltage just starts to increase, the collector supply current (observed on the vertical axis of the CRT) is equal to the current being supplied by the power supply under test (see Fig. 8). Be careful not to increase the collector voltage excessively, because devices powered by the supply under test may be damaged. This procedure can be used with all series regulated supplies, but cannot be used with shunt regulators.

Supplies with short circuit protection can be evaluated for short circuit current by using a similar technique. Use a collector supply polarity opposite to the supply under test. Starting with a high value of series resistance, alternately increase the collector voltage and lowering the series resistance as before. When the power supply voltage shown on the CRT reaches zero volts, the collector supply current (vertical axis on the CRT) is equal to the short circuit current of the supply (see Fig. 9).

If there is a load current from the power supply under test to a higher voltage, the measured current will be higher by the amount of the extra load current. If there is a load current from the power supply under test to a voltage of the opposite polarity, the measured current will be lower by the amount of that load. This method is especially useful when designing short circuit proof supplies because the supplies can be tested without destroying the series regulator if the supply shut-down circuit doesn't work.

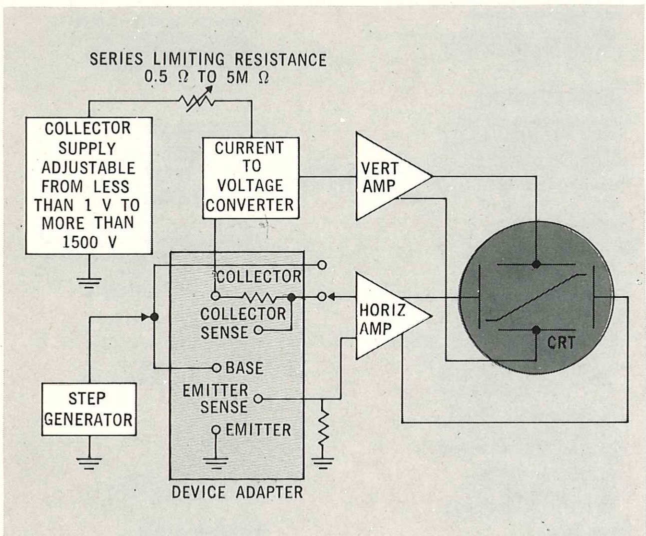
The curve tracer is ideally suited for in-circuit troubleshooting and measurements. Being able to display dynamic resistance over a range of voltage of both polarities on a single display is especially useful when the circuit contains active devices. There is no need to unsolder circuit components and perhaps ruin the circuit board.

Although conventional ohmmeters are satisfactory for the measurement of pure resistance, they are inadequate whenever resistance of the device changes with th applied voltage. Volt-ohmmeters can subject the circuit to currents as high as 300 ma and voltages as high as 33 v. These high currents can damage small semiconductor junctions in the forward direction, and the high voltage can break down emitter-base junctions in the reverse direction. Curve tracer voltage and currents can easily be limited to prevent these problems.

A curve tracer with a split screen storage display such as Tek's 577-177-D1, is very useful when comparing the performance of a suspected malfunctioning device in-circuit to one that is working correctly. Simply store the curve data from the suspected device on one half of the screen and display the curve of a properly functioning device on the other half of the display. ⊕

INSIDE THE CURVE TRACER

The curve tracer displays current as a function of voltage, unlike the conventional oscilloscope that displays voltage vs time.



At first glance, the curve tracer resembles a conventional oscilloscope. In addition to the usual scope's CRT and deflection sensitivity controls, the curve tracer contains two or more versatile power supplies to drive the device under test. Perhaps the biggest difference is that an oscilloscope displays current as a function of voltage. For instance, Tektronix's Model 577-177 displays currents from 1 na to 2 amps/div and voltages from 5 mv to 200 v/div.

The collector supply of the tracer is the primary source of signal and power; the step generator is the secondary source. Voltage ranges are continuously variable from a few millivolts to more than a kilovolt. The supply's output voltage may be a sinewave at line frequency, an unfiltered full-wave rectified voltage of either polarity at twice line frequency, or a filtered dc voltage of either polarity. The current ranges from 10 amps on the lower voltage ranges to 40 milliamps on the higher ranges.

The series limiting resistors shown protect the component or circuit under test. Changing the supply voltage range automatically changes the limiting resistor to maintain the desired current level.

The step generator is a regulated current or voltage power supply. It provides discrete steps of current or voltage synchronized with the collector supply and can provide a calibrated dc current or voltage adjustable from zero to its rated output. The stepped voltages and currents are used extensively in transistor and FET testing to create families of semiconductor characteristics.

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