An In-Circuit Transistor Tester

A low-cost bench/portable instrument for testing bipolar transistors in- and out-of-circuit

By Jules H. Gilder

Even if you have good electronic troubleshooting skills and can zero in on a defective circuit section, you are still faced with confirming your suspicion that a transistor is bad. To do this, you will likely have to remove the device from a crowded area and test it with either a transistor tester or an ohmmeter. If your guess proves wrong, you will have to solder the device to the printed-circuit board land, risking excessive-heat damage to the transistor and possibly to the pc foil . . . then repeat the process with another suspect.

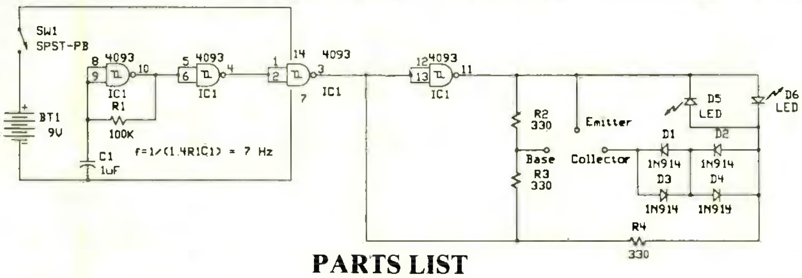
A much better way to troubleshoot transistorized circuits is provided by an *in-circuit* transistor tester, which eliminates the foregoing problems and saves a lot of time and frustration. You can build the one to be described for about $25 or less, including the enclosure. It is worth its weight in gold.

Our In-Circuit Transistor Tester's test clips make it easy to connect it directly to the leads of any bipolar transistor, even if the transistor is on a densely packed pc-board assembly. Using a pair of light-emitting diodes, one each for npn and pnp transistors, the Tester indicates when a suspect transistor is good or bad and simultaneously identifies it by type. If either LED lights, the transistor is good. On the other hand, if the two LEDs alternately flash or do not flash at all during a test, the transistor is bad.

About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the In-Circuit Transistor Tester. Its simple, straightforward design makes use of a single CMOS NAND-gate Schmitt trigger integrated circuit, identified as *IC1*. This 4093 IC is a bistable device that does not respond directly to an input signal. Rather, its snap action response, known as "hysteresis," creates a dead band that is useful for cleaning up slow and noisy digital signals.

The dead band is the result of the fact that a Schmitt trigger's input



PARTS LIST

BT1—9-volt battery
C1—1-μF, 25-volt electrolytic capacitor
D1 thru D4—1N914 switching diode
D5,D6—Miniature red light-emitting diode
IC1—4093 CMOS quad 2-input NAND Schmitt trigger
R1—100,000-ohm, ⅛-watt, 10% tolerance resistor
R2,R3,R4—330-ohm, ⅛-watt, 10% tolerance resistor
SW1—Momentary-action, normally-open spst pushbutton switch
Misc.—Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable soldering or Wire Wrap hardware (see text); suitable enclosure (see text); 14-pin DIP socket for IC1 (optional); snap connector for BT1; three ball-type or miniature alligator-clip test connectors (see text); three small rubber grommets; double-sided foam tape; adhesive-backed clear plastic laminate (see text); test cable and hookup wire; solder; etc.

Note: A complete kit of parts (less 9-volt battery, IC socket, plastic laminate and grommets) is available for $19.95 from: Redlig Systems, Inc., 2068 79 St., Brooklyn, NY 11214.

Fig. 1. Complete schematic diagram of In-Circuit Transistor Tester.

voltage must rise above a certain level, known as the high trip point, before the output voltage can change. Similarly, the input voltage must drop below a certain level, which is lower than the high trip point, before the output can change once again. Any change that occurs within the dead band itself has no effect on the output.

Built-in hysteresis makes it possible to design and build an astable oscillator with just a single gate, as shown for the gate at the left, capacitor *C1* and resistor *R1* in Fig. 1. Frequency of oscillation is calculated using the formula $f = 1/(1.4RC)$. With the component values shown in the schematic diagram and specified in the Parts List for *R1* and *C1*, oscillator frequency is approximately 7 Hz.

All remaining gates in *IC1* are used simply for inversion and buffering. The first of these gates following the oscillator isolates the latter from the rest of the circuit to prevent frequency drift as a result of loading. The remaining two gates are used to produce the complementary outputs needed to enable testing of both npn and pnp transistors.

Note that both inputs of each of the four gates that make up *IC1* are tied together. This is done because only the Schmitt trigger inversion—not the normal NAND—function is required in this project. Although a 4584 hex inverter Schmitt trigger could have been used to accomplish the same results, a 4093 (with the circuit modifications shown) is much more readily available from consumer sources.

The complementary outputs produced by the final two gates in *IC1* are connected to light-emitting diodes *D5* and *D6* through current-limiting resistor *R4*. Only one current-limiting resistor is needed in this arrangement because only one of the LEDs will normally be on at any given time.

The LEDs are connected in a reverse condition that is often referred to as anti-parallel. That is, the anode of one is connected to the cathode of the other and the remaining two leads are tied together. With this arrangement, when a logic high voltage appears at pin 11 of *IC1* and the voltage at pin 3 is at a logic low voltage, *D5* is held in reverse bias while *D6* conducts and the LED lights. With no transistor connected to the circuit, the outputs at pins 3 and 11 of *IC1* change at a frequency of about 7 Hz, allowing the LEDs to blink on and off alternately.

In addition to being connected to the LEDs, the complementary outputs at pins 3 and 11 of *IC1* are applied to the resistor network composed of *R2* and *R3*. The junction of these two resistors is brought out as a test point and is connected to the base of the transistor under test. The emitter of the transistor connects directly to pin 11 of *IC1*, while the collector connects to the *D1* through *D4* parallel diode arrangement and *D5* and *D6* anti-parallel LED arrangement.

An important purpose is served by the strange diode arrangement. When a transistor under test has an internal short circuit between its collector-base or base-emitter junctions, the good half of the transistor acts like an ordinary diode and will normally conduct and indicate a "good" transistor. When either *D1* and *D2* or *D3* and *D4* are conducting, a drop of about 1.2 volts appears across the operating pair. This voltage adds to the voltage dropped across the transistor being tested. If the transistor is good, the drop will be about 0.1 volt, and the total drop across the LEDs will be 1.3 volts for the half cycle that the transistor is conducting.

On the other hand, if the transistor being tested has a base-emitter or base-collector short, the 1.2-volt drop across the diodes adds to another 0.6-volt drop across the bad transistor to produce a drop of 1.8 volts. This is enough to turn on the LED. Therefore, internal short circuits will cause both LEDs to alternately flash.

Construction

Because the circuitry for this project is very simple, just about any wiring technique can be used to build the project. For example, you can etch and drill your own printed-circuit board using the actual-size etching-and-drilling guide shown in Fig. 2 (or purchase a complete kit of parts that contains a ready-to-wire board from the source given in the Note at the end of the Parts List). Alternatively, you can assemble the circuit on perforated board with holes on 0.1-inch centers using suitable soldering or Wire Wrap hardware. The following describes pc construction.

With the pc board component side up and oriented as shown in Fig. 3, start populating it by installing and soldering into place a 14-pin DIP IC socket in the IC1 location. Be careful to avoid creating solder bridges between the closely spaced copper pads on the bottom of the board. (Note: A socket is optional but highly recommended should the 4093 IC ever have to be replaced. If you do not use a socket for this IC, do *not* install the 4093 itself at this stage of construction.)

Next, install diodes *D1* through *D4* on the lower left of the board, taking care to properly orient each. Then flip over the board and solder all leads to the copper pads.

Install and solder into place the resistors, once again clipping off excess lead lengths. Making sure to properly polarize the electrolytic capacitor as shown, plug its leads into the specified holes in the board.

Prepare three 18-inch lengths of miniature test-lead wire by stripping from both ends of each 1/4 inch of insulation. Tightly twist together the

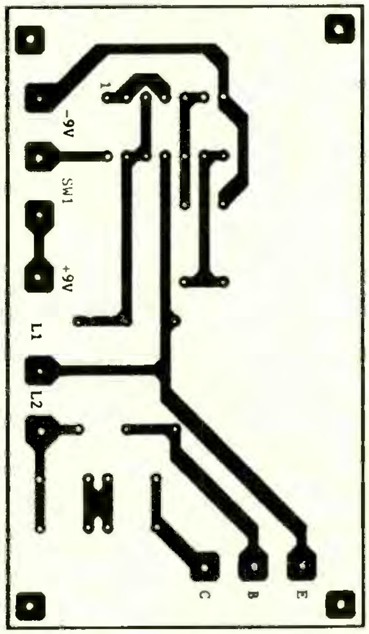


Fig. 2. Actual-size etching-and-drilling guide for fabricating printed-circuit boards.

fine wires at both ends of each wire and sparingly tin with solder. Plug one end of these wires into the holes labeled E, B and C in the upper-left of the board and solder into place.

Prepare four 6-inch lengths of hookup wire as you did for the test-lead wires and plug these into the holes labeled L1, L2 and SW1. Crimp the anode lead of one LED to the cathode lead of the other and then crimp together the remaining two LED leads. Solder the crimped con-

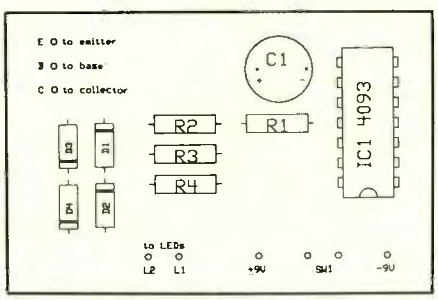


Fig. 3. Wiring guide for pc board. Use this layout as a general guide to component placement if you build circuit on perforated board.

nections, making sure to use soldering heat judiciously, and heat sink the LEDs to prevent heat damage.

Connect and solder the LED connections to the free ends of the L1 and L2 wires. Then connect and solder the free ends of the SW1 wires to the lugs of the normally-open spst pushbutton switch.

Tightly twist together the fine wires of both conductors of the 9-volt battery snap connector and sparingly tin with solder. Plug the red-insulated wire into the hole labeled +9V and the black-insulated wire into the hole labeled −9V.

You can use any suitably sized project box as an enclosure for the project. An ideal enclosure to use is a project box that has an aluminum front panel and measures 5 inches long by 2.5 inches wide by 1.5 inches deep. Only the front panel requires machining to prepare it for housing the project.

If possible, make a same-size photocopy of the actual-size artwork shown in Fig. 4 to use as a machining template for the project's front panel. Trim the photocopy to the outline border and tape it to the front panel. Using a center punch or sharp nail, gently detent the metal panel in the locations indicated by the six dots to prepare it for drilling the holes for the LEDs, switch and exits for the test leads.

Remove the template and use a 17/64-inch bit to drill the hole for the switch and test leads. Then use a 7/64-inch bit to drill the holes for the LEDs. Deburr all holes to remove sharp edges.

You can use either the actual artwork shown in Fig. 4 or a photocopy of it as a finished front panel for the project. The latter is recommended, since you will avoid any possibility of print on the opposite surface of the paper from "bleeding" through when the artwork is mounted to the panel.

Trim the artwork to about 1/4 inch wider and longer than shown. Then

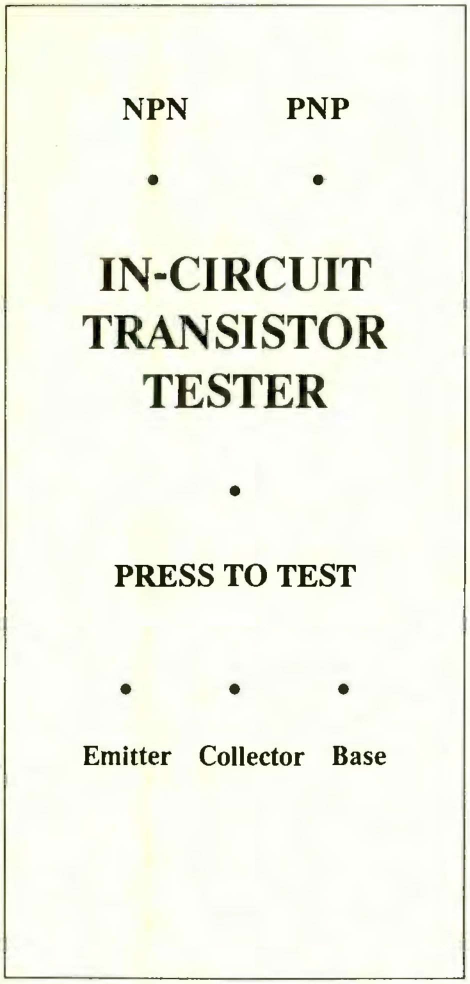


Fig. 4. Actual-size front-panel artwork. Use this or a same-size photocopy also as a machining template for front panel of project box.

face it with clear adhesive-backed plastic laminate (available from photographic, art-supply and most stationery stores) to protect it from damage as you use the project. Work carefully to avoid wrinkling the artwork as you lay on it the plastic laminate. After the laminate is completely down on the artwork, place the assembly laminate side up and solidly burnish it to the paper. Then trim the artwork to the exact dimensions of the metal front panel plate.

Coat the rear surface of the artwork and outer surface of the front panel with rubber cement and allow both to dry until they are tacky to the touch. Then very carefully place the artwork on the panel, starting from one corner. Once again, burnish the artwork to the panel.

Working *very* carefully with a sharp hobby knife, cut the artwork away from all holes. Work on the *artwork* side of the panel as you do this and be as neat as you possibly can. Gently work small rubber grommets into the EMITTER, COLLECTOR and BASE holes in the front panel from the artwork side to avoid lifting the artwork. Then mount the pushbutton switch in its hole in the center of the panel.

Tie a strain-relieving knot in each of the test-lead wires about 5 inches from the circuit-board end. Pass the free ends of these wires through the appropriate grommet-lined holes in the panel. Refer to both Fig. 3 and Fig. 4 to identify the test leads and the holes they are to exit the box.

You have a choice of either ball-type connectors like those shown in the lead photo or ordinary miniature alligator clips with insulated boots for terminating the test leads. The ball-type connectors are preferable because they provide more positive electrical contact and a more solid mechanical grip and present very little bare metal to short against points in a circuit that should not enter into a test.

Checkout & Use

Snap a fresh 9-volt battery onto the connector. Touch the common lead of a dc voltmeter, set to indicate at least 10 volts, to the pin 7 connector and the "hot" lead to the pin 14 connector of *IC1*'s socket. Press the switch's pushbutton and note the reading on the meter. If you do not obtain a reading of approximately 9 volts, release the switch and carefully check all components for proper orientations (diodes, LEDs and electrolytic capacitor) and all soldering for bridges and poor connections. Correct the problem before proceeding.

Once you obtain the proper 9-volt dc reading between pins 14 and 7 of the IC socket, release the switch's pushbutton and install the 4093 in the IC socket. Make sure you orient the IC as shown and take care to avoid having any pins overhang the socket or fold under between socket and IC body as you push the 4093 home. Exercise the usual precautions for MOS devices when handling the IC. If you are soldering the IC directly on the board, us a soldering iron with a grounded tip.

With the IC installed, press and hold down the switch's pushbutton and observe the activity of the LEDs. If everything is working properly, the two LEDs will alternately flash on and off. If both LEDs flash in step with each other, the two are not properly connected in anti-parallel with each other. In this event, power down the circuit and transpose the leads of one LED. If neither LED flashes, you have an error in construction and must recheck your wiring to correct the problem.

Having obtained proper flashing, release the switch's pushbutton and connect to the test leads a good transistor (you can use either a pnp or an npn transistor). Once again, press and hold the switch's pushbutton and note which LED lights. Mount this LED in the appropriate hole in the front panel of the enclosure. That is, if you are using an npn transistor for this test, the LED that lights goes into the NPN hole in the panel. The other LED then goes in the remaining LED hole. If the LEDs tend to fall out of their holes, secure them in place with either clear nail enamel or fast-set epoxy cement.

Cut a piece of double-sided foam tape to the approximate length and width of the the circuit-board assembly and another to the approximate length and depth of the 9-volt battery. Peel the protective backing from one side of the larger piece of foam tape and affix the tape to the

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bottom of the board. Peel the protective paper from the other side of the tape and mount the board assembly in the enclosure flush with one end of the box. Then mount the battery to the other end of the box with the other piece of foam tape.

Place the front panel on the box and secure it in place with the four screws that were provided.

Using the In-Circuit Transistor Tester is almost self-explanatory. You simply determine the base, emitter and collector leads of the transistor to be tested, clip the test-lead connectors to them accordingly and press the PRESS TO TEST pushbutton while observing the LEDs. If the transistor is good, either the NPN or the PNP LED will light, simultaneously identifying the type of transistor under test and verifying that it is good. If both LEDs or neither LED lights, the transistor is almost certainly bad, regardless of type, and should be replaced. **ME**