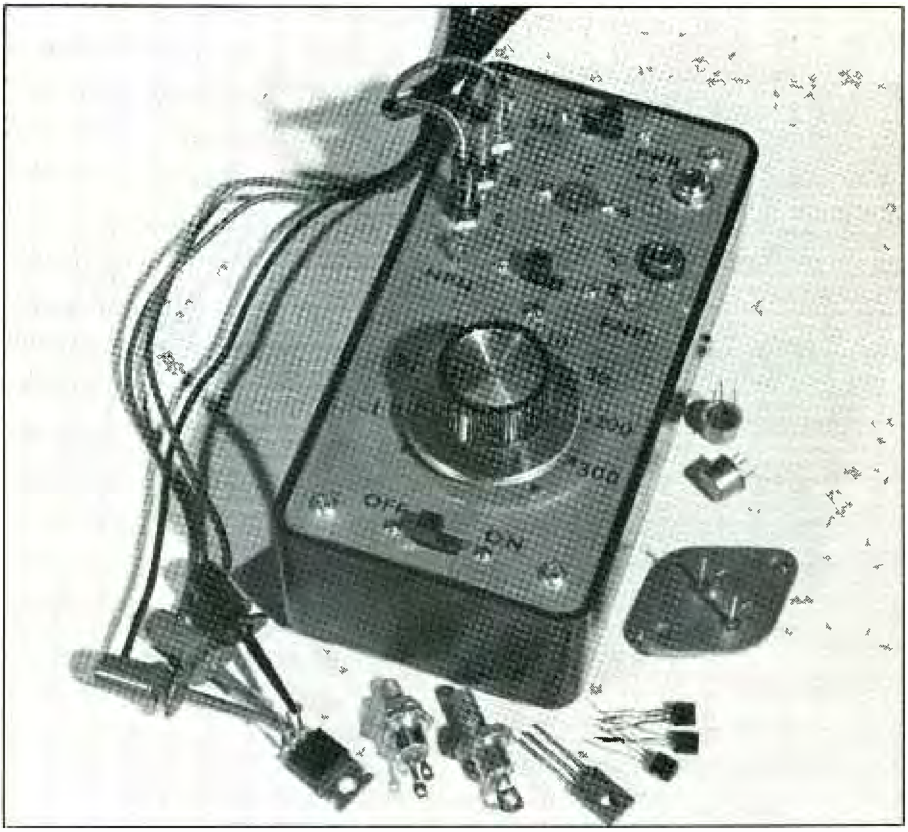
A Transistor/Diode/ SCR Tester

This simple project can be one of the most valuable you have on your testbench alongside your multimeter and oscilloscope

By Adolph A. Mangieri



If you're like most experimenters and professional service technicians, you probably have dozens or even hundreds of untested transistors and other discrete semiconductors. You could do some simple tests on these devices and the circuits in which they're used with an ohmmeter, but the results are often unsatisfactory. Having found yourself in this situation all too often, it's time you had a semiconductor tester like the transistor/diode/SCR tester to be described.

Our tester performs quick and reliable good/bad checks on a wide variety of discrete semiconductors. It provides a low-power signal test mode that virtually eliminates damage to even very-low-power devices. It also has a power mode that checks devices at higher currents. The low-power mode can be performed with either a battery or an ac-line-operated power supply. Because of the high-power demands of the power mode, the power supply here is strictly from the ac line. For maximum versatility, large-signal dc gain of transistors can be measured by plugging a common milliammeter into the tester.

About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the transistor/diode/SCR tester. Socket *SO1* provides the means for connecting low-power (milliwatt) transistors to the tester. Jacks *J3, J4* and *J5* parallel the connections to *SO1* and provide the means for connecting medium-power and high-power transistors to the tester.

The tester is powered by 9-volt transistor battery *B1* or a plug-in ac power supply that outputs 9 volts filtered dc at 300 milliamperes or more. Voltage regulator *IC1* supplies a stable 5 volts dc to the tester circuit.

Switch *S3* applies +5 volts dc to the V_{cc} bus when switched to check npn transistors and reverses the polarity supplied to the bus when switched to check pnp transistors. Jack *J2* permits insertion of a dc milliammeter that can be used to indicate collector current when measuring the dc gain of a transistor. If you wish, you can make the milliammeter a permanent part of the circuit, replacing *J2* with a switch that con-

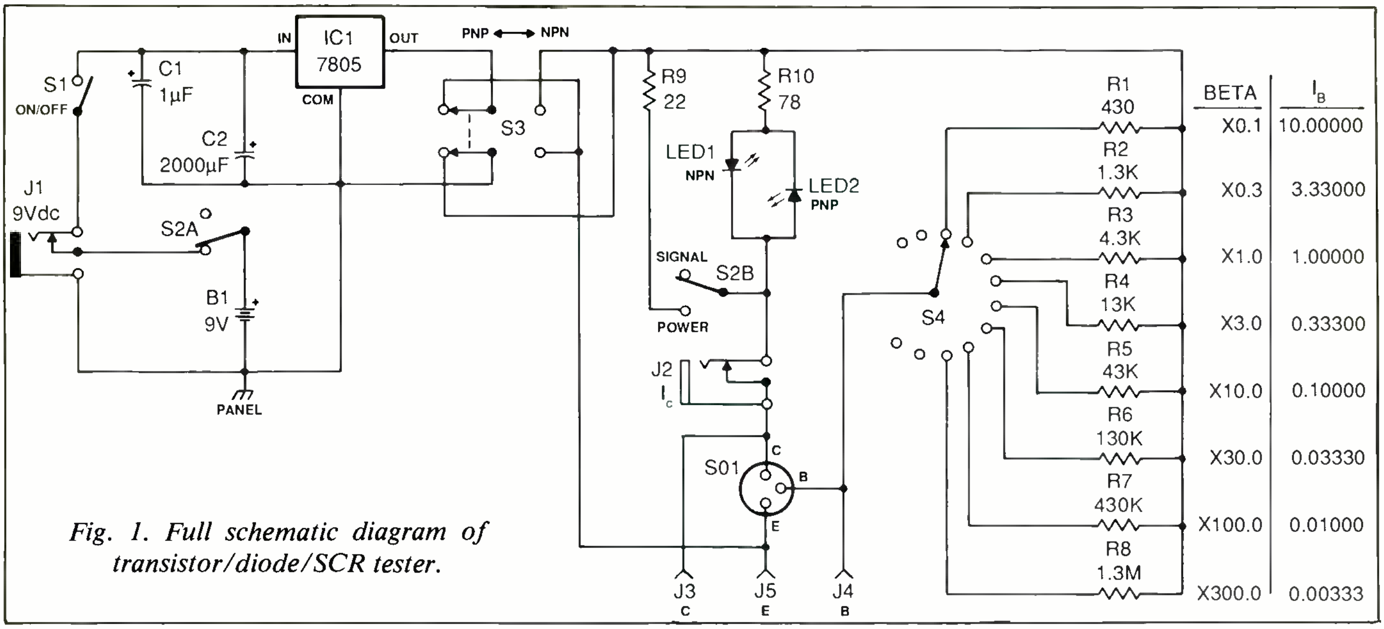


Fig. 1. Full schematic diagram of transistor/diode/SCR tester.

PARTS LIST

Semiconductors
IC1—7805 +5-volt regulator
LED1,LED2—Light-emitting diode
Capacitors
C1—1-µF, 35-volt tantalum electrolytic
C2—2,000-µF, 25-volt electrolytic (see text)
Resistors (½-watt, 5% tolerance)
R1—430 ohms
R2—1,300 ohms
R3—4,300 ohms
R4—13,000 ohms
R5—43,000 ohms
R6—130,000 ohms
R7—430,000 ohms
R8—1.3 megohms
R9—22 ohms (5-watt, 10% tolerance)
R10—78 ohms
Miscellaneous
B1—9-volt transistor battery
J1,J2—Miniature closed-circuit phone jack
J3,J4,J5—Insulated tip jack
S1—Spst slide or toggle switch
S2,S3—Dpdt switch
S4—Single-pole, 12-position nonshorting rotary switch
SO1—Chassis-mount transistor socket
Suitable project box with metal panel; snap connector and holder for B1; control knob for S4; labeling kit; machine hardware; hookup wire; solder; etc.

nects and disconnects the meter as desired.

Switch *S4* provides a means for selecting one of eight base currents ranging from 0.0033 to 10 milliamperes. Each setting of *S4* has a multiplier, as listed along the right side of the schematic in line with the given switch position. The multiplier is used to measure dc current-transfer ratio (beta or h_{FE}). For example, with *S4* set to ×100 and a measured collector current of 0.76 milliampere, gain is 100 × 0.76, or 76 milliamperes. The multipliers are the reciprocals of the base current. For instance, at a ×10 setting, base current is 1/10, or 0.1 milliamperes.

Switch *S2* allows you to select either the signal (SIG) test mode for low-power tests of devices or the power (PWR) mode for higher-current tests of medium- and high-power devices. In the SIG mode, the tester is powered by either battery *B1* or the ac adapter. In the PWR mode, the tester is powered by only the ac adapter plugged into *J1*.

In the SIG mode, the transistor collector-load circuit consists of *R9* connected in series with *LED1* and *LED2*. Only one LED lights; which one depends on the setting of *S3*. Maximum collector current in the SIG mode is about 28 milliamperes. Maximum collector potential in this mode is 5 volts minus the 2-volt drop across the LED, or 3 volts. Maximum power delivered to the transistor under test is about 20 milliwatts, which is well within the handling capabilities of virtually every low-power device now available.

Battery *B1* is deselected when *S2* is set to the PWR mode. Resistor *R9* is in parallel with resistor *R10* and the light-emitting diodes. The LED begins to light when a power semiconductor under test conducts 100 milliamperes or more. With the transistor switched fully on, maximum current is 220 milliamperes. Maximum collector potential is 5 volts with the transistor in cutoff. Maximum power delivered to the transistor is about 275 milliwatts.

Resistor *R9* limits maximum collector current in the SIG mode to 28 milliamperes, which may be a bit too much for a very few r-f/vhf/uhf transistors that have maximum current ratings of only 20 milliamperes. These are not likely to be damaged by the 28-milliampere maximum current with the value of *R9* specified. However, if you want to make certain that you're on the safe side, you can substitute a 150-ohm resistor for *R9* to limit maximum current to 20 milliamperes.

Construction

Assemble the tester on the metal front panel of a small project box, as shown in Fig. 2. Bolt *IC1* directly to the panel. Then mount *R9* and *R10* on a terminal strip and *R1* through *R8* via the lugs of *S4*. Mount the LEDs on the front panel in holes lined with small rubber grommets (friction fit), using fast-set clear epoxy cement or in standard LED panel clips. Insulate *J2* from the metal panel, and use insulated tip jacks for *J3, J4* and *J5*. Install a battery clip inside the project box for *B1*. Then use a dry-transfer lettering kit or a tape labeler to label the front panel (see Fig. 3).

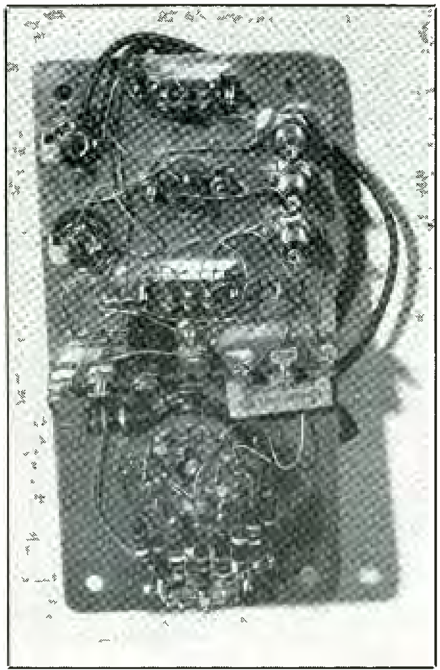


Fig. 2. Tester is assembled on metal panel of small project box.

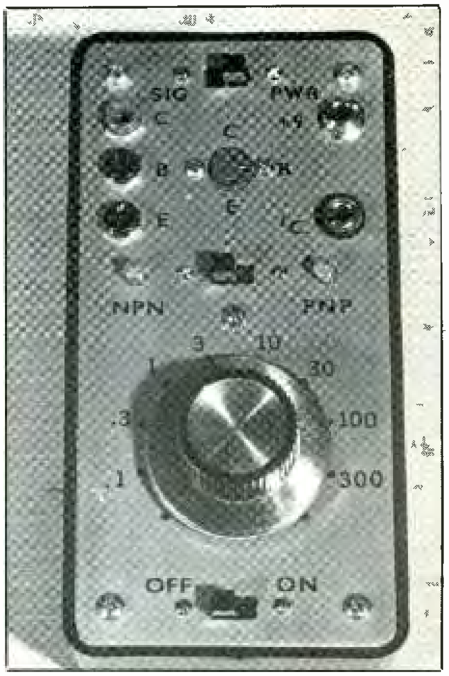


Fig. 3. Suggested front-panel layout, with appropriate panel labeling.

If you use an ac adapter that delivers between 9.5 and 12.5 filtered dc volts at 500 milliamperes, omit *C2* from the circuit. A power supply for a Timex/Sinclair TS1000 computer makes a satisfactory power supply if you have one handy. If you use a power supply rated at 6.5 to 7.5 unfiltered volts dc at 600 milliamperes, install *C2* as shown in Fig. 1.

To check your wiring, set *S2* to SIG and close *S1*. Verify with a dc voltmeter that +5 volts appears at the OUT terminal (pin 3) of *IC1*. Set *S3* to NPN and verify that +5 volts is on the V_{cc} bus (top rail that goes to all resistors in Fig. 1). Connect a jumper wire between *J3* and *J5* and verify that *LED1* lights. Now set *S3* to PNP and verify that *LED2* lights. Connect a milliammeter across *J3* and *J5*; the short-circuit current should be about 28 milliamperes. Connect the 9-volt dc power supply to *J1* and set *S2* to PWR; the short-circuit current should be about 220 milliamperes.

Set *S2* to SIG and *S3* to NPN. Now, using clip leads, connect any general-purpose low-power npn silicon transistor to the tester in the proper basing arrangement and connect a milliammeter in series with the base test lead. Rotate *S4* through each of its positions and verify the nominal base currents listed in Fig. 1. Keep in mind that measured base currents might be on the low side, the result of meter resistance.

Plug the 9-volt dc adapter into *J1*, set *S2* to SIG and *S3* to NPN, and plug a milliammeter into *J2*. Connect a voltmeter to the collector and emitter terminals to measure collector voltage. Set *S4* to an unused position for zero base current. The LED should now be off, collector current should be near zero, and collector potential should be about 3 volts. Advance *S4* in steps from ×0.1 upward while observing LED brightness and meter indications. In several positions of *S4*, the LED will be brightly lit, collector voltage will be very low and collector current will be maximum, all indicating that the transistor is operating in full saturation.

As you further advance the setting of *S4* clockwise, the LED will go to half brightness, collector voltage will rise and collector current will drop, indicating that the transistor is now operating in its linear region where dc gain measurements can be made. Transistor dc gain is equal to collector current in milliamperes multiplied by *S4*'s multiplier.

Set *S2* to PWR for higher current tests and repeat the above procedure. Notice now that the LED may go from full on to full off in one position of *S4*. This is because the LED doesn't begin to conduct until collector current reaches about 100 milliamperes.

Test Procedures

Each of the various semiconductor tests that can be made with the transistor/diode/SCR tester for different types of devices has its own special procedures. The following describes each procedure:

• *Diode Tests.* Test low-power diodes in the SIG mode to automatically limit current flow. Test rectifier diodes in either mode. Figure 4 shows the symbols and polarities of volt-

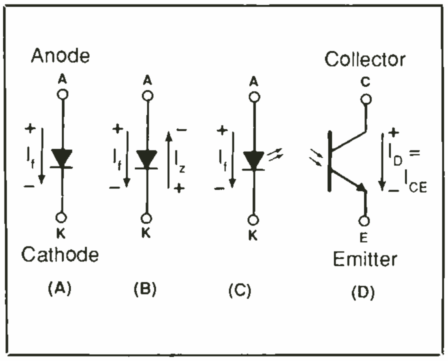


Fig. 4. Symbols and polarities: (A) rectifier diode; (B) zener diode; (C) light-emitting diode; (D) photo-diode.

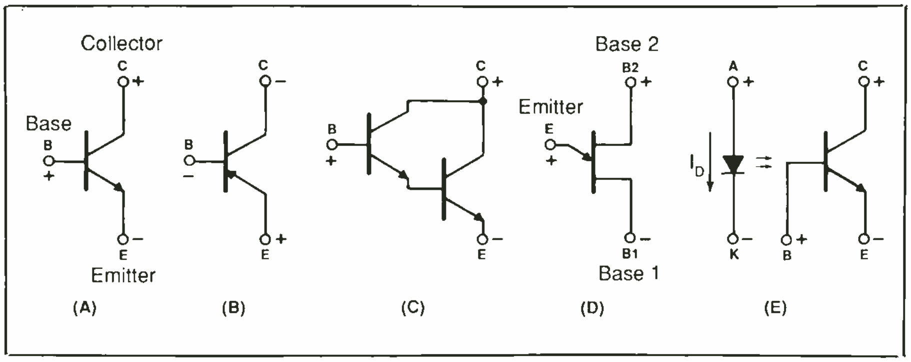


Fig. 5. Transistor symbols and polarities: (A) npn transistor; (B) pnp transistor; (C) npn Darlington transistor; (D) unijunction transistor (UJT); (E) dc-input optoisolator.

ages to use for rectifiers, zener diodes, LEDs and photodiodes.

When performing any diode test, set *S3* to NPN to make collector (C) jack *J3* positive and emitter (E) jack *J5* negative. With anode A connected to *J3* and cathode K connected to *J5*, a diode under test should conduct and *LED1* should light if the device is good. After doing this, reverse the connections and note that *LED1* is off, again assuming a good diode.

The zener diode is a special type of device that conducts like an ordinary diode in the forward direction and blocks the flow of current in the reverse direction until the breakover or "zener" voltage is exceeded. Limit tests on zener diodes to those rated at 6 volts or more and test these devices as you would any other rectifier diode. This tester does not check zener voltage.

To check an npn photodiode, set *S3* to NPN and connect emitter E to *J5* and collector C to *J3*. The device should be off (*LED2* off) with no illumination but should switch on (*LED1* on) when exposed to bright light. Reversing the connections should cause current to be blocked and *LED1* should be off. When subjected to light, a high-speed PIN photodiode may pass insufficient current to light *LED1*. In this case, plug a milliammeter set to its 1-milliampere range into *J2* and observe the magnitude of current flow.

Test light-emitting diodes only in the SIG mode to prevent excess current from burning them out. Set *S3* to NPN. The LED should light with anode A connected to *J3* and cathode K connected to *J5*.

Use the diode test to determine which lead of a diode is the anode and whether the device is a silicon or germanium type. Connect a dc voltmeter across *J3* and *J5*. With the diode conducting, the voltage dropped across a silicon type should be about 0.65 volt, while the voltage dropped across a germanium type should be about 0.35 volt.

• *Transistor Tests.* It is very difficult to zap a semiconductor in the SIG mode of the tester. However, keep in mind device current ratings and use a semiconductor cross-reference manual to keep tabs on device specifications as you use the tester. (General Electric's *Replacement Semiconductor Guide* lists transistors in order of decreasing current ratings. Other guides include those published by Archer and Radio Shack, NTE, Sylvania and RCA.) In the PWR mode, limit LED good/bad tests to devices rated at 200 milliamperes or more.

Shown in Fig. 5 are the symbols and polarities for npn and pnp transistors and for the npn Darlington transistor.

When performing an initial transistor test, use clip leads to connect the collector (C) and emitter (E) leads of the transistor to *J3* and *J5*, respectively and leave the base (B) of the device unconnected. Set *S3* to NPN or PNP, depending on the type of transistor being tested. Set *S4* to ×1 for 1 milliampere of base drive. With the base lead still unconnected, the transistor should be in cutoff and the LED should be off. Connecting the base lead to *J4* should cause the transistor to conduct and the LED to light. Use the PWR mode for low-gain, high-power transistors. Set *S4* to ×0.33 for 33 milliamperes of base drive or to ×0.1 for 10 milliamperes of base drive.

Dc base-transfer ratio, dc beta and h_{FE} variously refer to the large-signal gain of a transistor. Dc gain is the ratio of collector current to base current at a specified collector current and voltage. To measure gain, plug a milliammeter into *J4*. Then, beginning with *S4* set to ×300, rotate the switch counterclockwise and set collector current to any value up to 15 milliamperes in the SIG mode or up to 175 milliamperes in the PWR mode to ensure that the transistor doesn't saturate. Dc gain equals the measured current in milliamperes times *S4*'s multiplier. For low-power transistors in the 20-to-800-milliampere class, a good test current level is 0.5 to 10 milliamperes. For medium- and high-power transistors in the 1-to-30-ampere class, select a test current in the 30-to-150-milliampere range.

Base-emitter drops of silicon and germanium transistors are approximately 0.65 and 0.35 volt, respectively. Thus, the base current applied to a germanium transistor is about 10 percent greater than for a silicon transistor. Therefore, deduct 10 percent from the germanium transistor's dc gain measurement. A Darlington transistor has a base-emitter drop of about 1.2 volts, resulting in about 20 percent less base current; so use the ×300 setting of *S4* and add 20 percent to the gain figure. There is really no need to make these corrections if all you're checking for is nominal gain.

With a milliammeter plugged into *J2* and the base circuit of the transistor under test left open, the meter indicates collector-to-emitter current I_{ceo}, which is very small for silicon transistors but may be several milliamperes for germanium power transistors, enough to light the LED in the SIG mode. I_{ceo} is the result of amplification of internal collector-to-base leakage current I_{cbo}, which can be measured by connecting the collector lead to *J3* and base lead to *J5* and leaving the emitter lead unconnected.

Refer to Fig. 5(D) for the unijunction transistor (UJT) frequently used as a relaxation oscillator and a pulse driver for SCRs. There are two ways to check the UJT. For a UJT with the emitter arrow pointing toward the base as shown, set *S3* to NPN. Connect base 2 to *J3* (+) and base 1 to *J5* (−). Connect emitter E to *J4*. Then set *S4* to any unused position for zero current; *LED1* should be off. Setting *S4* to ×0.1 should cause *LED1* to light moderately.

A light-emitting diode and photosensitive npn transistor in a single DIP package make up the dc-input optoisolator, as shown in Fig. 5(E). To check this device, connect collector C to *J3* and emitter E to *J5*, leaving the base unconnected. Connect cathode K to *J5* and set *S3* to NPN and *S4* to ×1. With the diode's anode not connected, the transistor and *LED1* should be off.

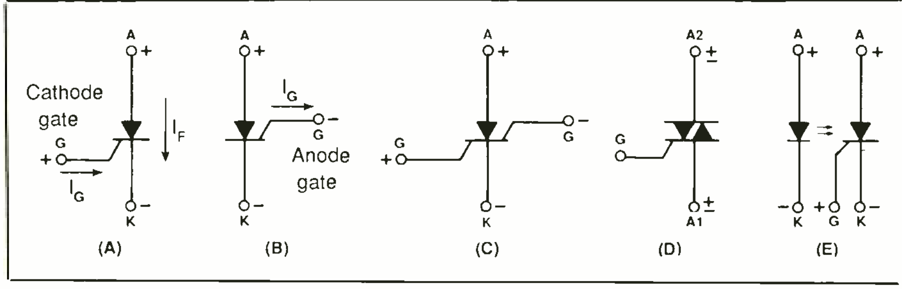


Fig. 6. Silicon controlled rectifier symbols and polarities: (A) silicon controlled rectifier (SCR); complementary SCR (CSCR); (B) silicon controlled switch (SCS); (C) triac; (D) SCR optoisolator.

Connecting the diode's anode to *J4* should cause *LED1* to light. If the LED does not light, set *S4* to ×0.33 or ×0.1. If the LED still doesn't turn on, test the diode and transistor as separate discrete devices.

An ac-input optoisolator has an additional LED connected in parallel but opposition with each other. This allows the input to conduct in both directions.

• *Silicon Controlled Rectifiers.* The SCR is an electronic switch that turns on when a low-level pulse is applied to its gate. Once triggered on, the SCR remains conducting until anode current falls below a relatively small holding current known as I_H.

Shown in Fig. 6 are the symbols for a few members of the SCR family. (A) is the symbol for the unidirectional SCR that turns on by making cathode-gate G positive with respect to cathode K, causing current to flow from anode to cathode. The light-activated SCR, or LASCR, is similar but is switched on by light striking the device. (B) is the symbol for the complementary SCR (CSCR) which has an anode gate and is switched on by making this gate negative with respect to the cathode. The programmable unijunction transistor (PUT) is similar to the CSCR. (C) is the symbol for the silicon controlled switch, or SCS, that has both anode and cathode gates. (D) is the symbol for the bidirectional triac that conducts in both directions and is controlled by a single gate. Finally, (E) is the symbol for the SCR optoisolator that provides electrical isolation between the controlling input and controlled output.

When testing SCR devices rated at less than 200 milliamperes, use the SIG mode. Check higher-current devices preferably in the PWR mode. Set *S3* to NPN to check the SCR. Set *S4* to ×0.1 for a 10-milliampere gate drive. Connect anode A to *J3* and cathode K to *J5*, but leave anode gate G unconnected.

Turning on the tester should not turn on the SCR or LED. If *LED1* is on, the SCR is either shorted or has turned on as a result of the sudden application of voltage and is known as the rate effect. Move *S3* to PNP and then back to NPN to turn off the SCR. With the SCR off, momentarily connect cathode gate G to *J4*, which should cause the SCR to switch on. If it doesn't, momentarily connect the gate to *J3* to turn it on. If a high-current SCR fails to trigger on in the SIG mode, use the PWR mode and momentarily short the cathode gate to the anode for turn-on.

PUT, CSCR and SCS devices are extremely sensitive to low-current devices and can turn on just by touching the gate leads. To check these devices via the anode gate, connect anode A to *J3*, cathode K to *J5* and anode gate G to *J4*. Set *S3* to

NPN. Then set *S4* to ×0.3 to connect a 1,300-ohm resistor from anode to anode gate to reduce the rate effect.

When you turn on the tester, *LED1* should be off. Momentarily jumper the anode gate to the cathode to trigger on the SCR and turn on *LED1*. To complete the test on an SCS via the cathode gate with the device switched off, momentarily jumper cathode gate G to *J4* or *J3* to trigger on the device.

You can obtain an estimate of gate turn-on current sensitivity for an SCR as follows. Set *S4* to ×300 for minimum gate drive and make connections to the SCR. With the SCR initially off, rotate *S4* counterclockwise until it switches on. If the SCR turns on at the ×10 setting, gate turn-on current is less than 0.1 milliampere (reciprocal of dial setting ×10).

Triacs are power devices that passe current in either direction when switched on. To test a triac, connect anode 2 to *J3* and anode 1 to *J5*, but leave gate G unconnected. The triac should not be on in either position of *S3*. However, it should switch on when the gate is momentarily touched to *J3* or *J5*. Depending on device holding current, the LED may go off when the gate is disconnected. If the triac remains on, open *S1* to turn it off and then reclose the switch.

The dc-input SCR optoisolator is analogous to the transistor optical isolator and is tested in a similar manner. Connect SCR anode A to *J3*, both cathodes K to *J5* and leave gate G unconnected. Set *S3* to NPN. The device should be off. Momentarily connecting diode anode A to *J3* should cause the device to turn on.

• *Other Tests.* For in-circuit tests, the project can show that a device is good if it passes the test. However, the device may or may not be bad if it fails the test. This depends on shunt current paths associated with the wired-in device being tested. To check a transistor, connect only the collector and emitter leads. The project's LED should be off or possibly only dimly lit. Connect the base lead and apply increasing base drive by rotating *S4* counterclockwise. The transistor is good if the LED lights in one or more positions.

To check electrolytic capacitors, set *S3* to NPN, connect the capacitor's – lead to *J5* and touch and hold the + lead to *J3*. For capacitors rated at 3 microfarads and larger, the LED should flash brightly at the start but fade in brilliance as the capacitor charges. No light whatever indicates an open capacitor, while a continuous unchanging light indicates a shorted capacitor.

Operating Notes

Unplug the ac line adapter from *J1* whenever you use the SIG mode so that only the project's battery is in the circuit. Battery drain on standby is a modest 5 milliamperes. With the LED brightly lit, current drain can increase up to 25 to 30 milliamperes. Therefore, to prolong battery life, avoid leaving the LED on continuously during testing. Either turn off the tester or make momentary connections to the base of a transistor or terminal of a diode under test. ME