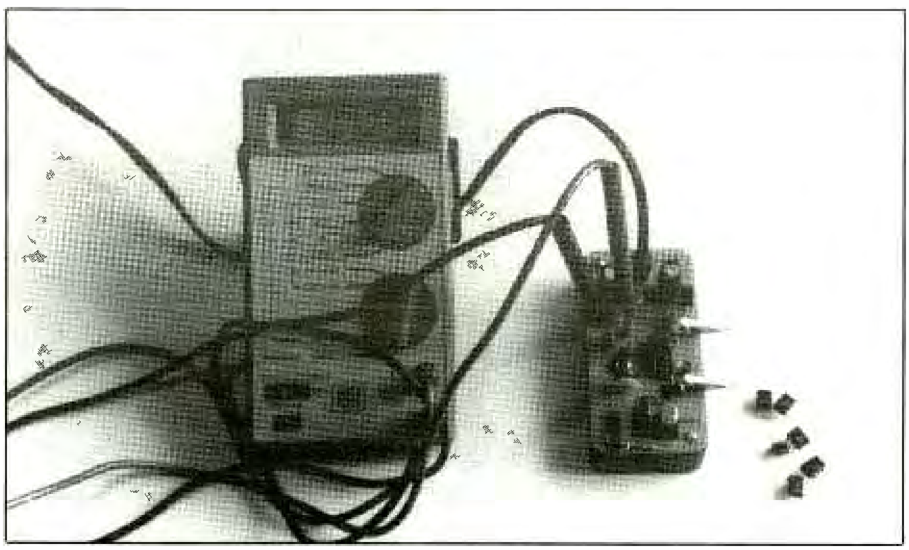
The Optical Isolator

(Conclusion)

Last month, in the first part of this series, we introduced you to the various types of optical isolators available to experimenters and hobbyists, their technical characteristics and some typical applications for these devices. In this concluding part, we present construction details for building an inexpensive and versatile tester that can be used in conjunction with a dual-channel oscilloscope and a digital multimeter to test all types of optical isolators in dual-inline packages, low-voltage zener diodes and 9-volt batteries.

Building an Opto Tester

By Ralph Tenny



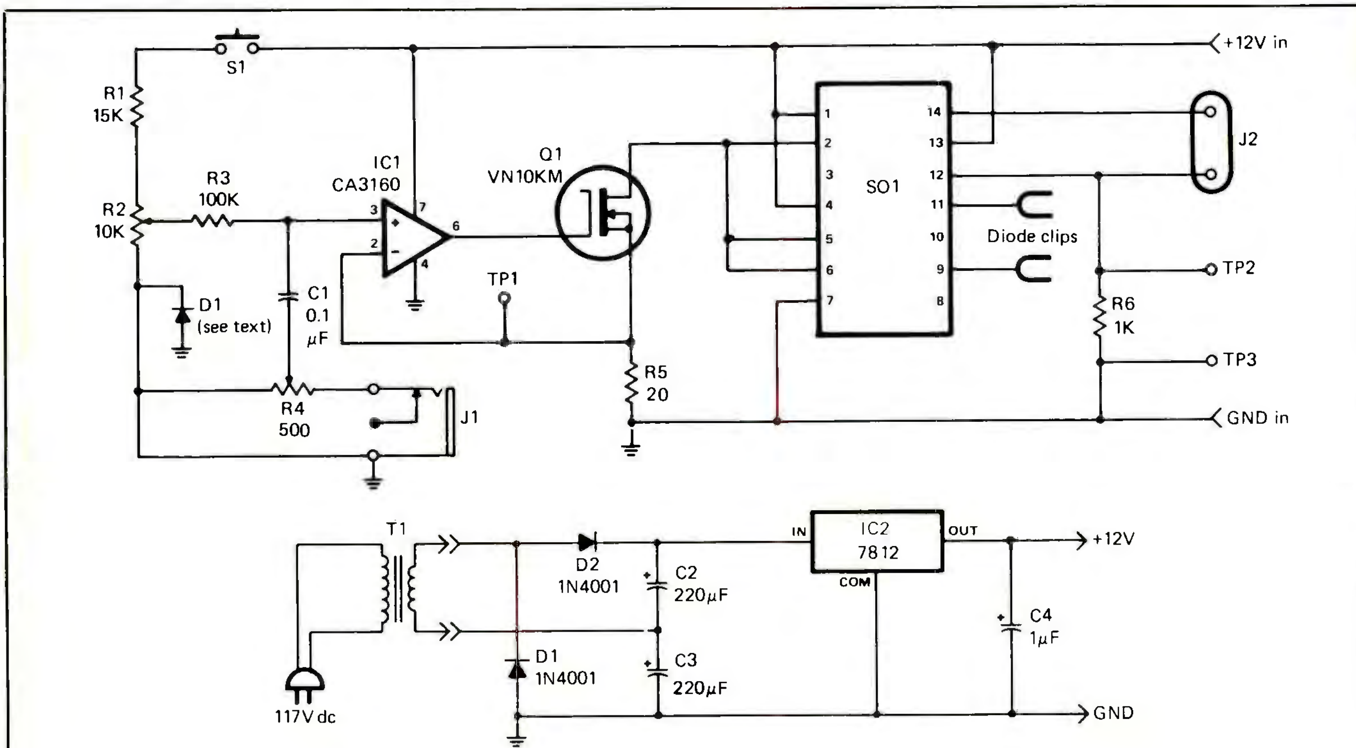
When designing with and using optical isolators, careful attention must be paid to their current transfer ratios (CTRs). Failure to take into account the CTR can result in electrical stress that can damage an optical isolator enough to change its CTR. It's also often important to match optical isolators—even if all are stamped with the identical part or type number—to obtain uniform performance. The only way to be sure you're using your devices properly and that a selected device is indeed operating at all is to test each one as you use it.

The Opto Tester described here is a handy accessory to test and match all types of optical isolators. In conjunction with an ordinary voltmeter and an oscilloscope it allows you to test optical isolators of unknown quality to determine if they are working and how well they are working. The latter is particularly important if you need optical isolators that must respond to a given signal. It lets you sort through a group of devices until you have as many with the same or nearly the same characteristics as are needed for a given application. As a bonus, the Opto Tester can also be used to test low-voltage zener diodes and 9-volt transistor batteries.

About the Circuit

The entire schematic diagram of the Opto Tester, including its ac power supply, is shown in Fig. 1. The Opto Tester's current source is made up of *IC1* and *Q1*. Because operational amplifier *IC1* continuously forces the voltage between its two inputs at pins 2 and 3 to be equal, external circuitry must be brought into play for an output other than 0 volt to be obtained.

Pin 3 is *IC1*'s noninverting (+) in-



PARTS LIST

Semiconductors
D1,D2—1N4001 rectifier diode
D3—Small-signal diode
IC1—CA3160 (RCA) or TLC-271 (Radio Shack Cat. No. 276-1748)—see text
IC1—7812 + 12-volt regulator
Q1—VN10KM enhancement-mode FET (Siliconix)

Capacitors
C1—0.1 µF film
C2,C3—220-µF, 25-volt electrolytic
C4—1-µF tantalum

Resistors (¼-watt)
R1—15,000 ohms, 5%
R3—10,000 ohms, 5%
R5—20 ohms, 1%
R6—1,000 ohms, 1%
R2—10,000-ohm, 15-turn potentiometer
R4—500-ohm potentiometer

Miscellaneous
J1—Miniature phone jack
J2—See text
S1—Spst normally open pushbutton switch
SO1—14-pin side-wipe IC socket (Radio Shack Cat. No. 276-1999—see text)
T1—Power transformer (Digi-Key Cat. No. T200-ND or similar)
TP1,TP2,TP3—Pc-mount pin jack—see text
Printed-circuit board or perforated board and suitable soldering or Wire Wrap hardware; suitable enclosure (Radio Shack Cat. No. 274-1565 or similar); component platform adapters (Radio Shack Cat. No. 276-1980); socket for IC1; plug to match jack on end of T1's power cord (see text); small alligator clips or other suitable connectors for Diode Test Clips (see text); solder posts; machine hardware; hookup wire; solder; etc.

Fig. 1. Schematic diagram of the Opto Tester.

put, which means that if a voltage more positive than that is on the pin 2 inverting (−) input is applied to this pin, the output at pin 6 will be positive as well. Conversely, if a voltage more positive than that on pin 3 is applied to pin 2, the output at pin 6 will be a negative voltage.

When power is applied to the circuit and *S1* is open, *R1*, *R2*, *R3* and pin 3 of *IC1* will all be 0 volt. This would cause the output of the op amp to go negative if it were powered from a dual-polarity power supply. However, since *IC1* in this project has no negative power supply line referenced to circuit ground, its output can't swing to a negative voltage. Therefore, pin 6 will go only to 0 volt with a positive voltage applied to pin 2, pulling the gate and source of *Q1* and pin 2 of *IC1* also to 0 volt.

Closing *S1* puts pin 3 of *IC1* at some positive voltage determined by the setting of *R2*. This drives the gate of *Q1* positive and causes the transistor to conduct until the voltage at pin 2 of *IC1* is equal to that on pin 3. If the potential on pin 3 of *IC1* is 0.2 volt, the current through *R5* is 0.2

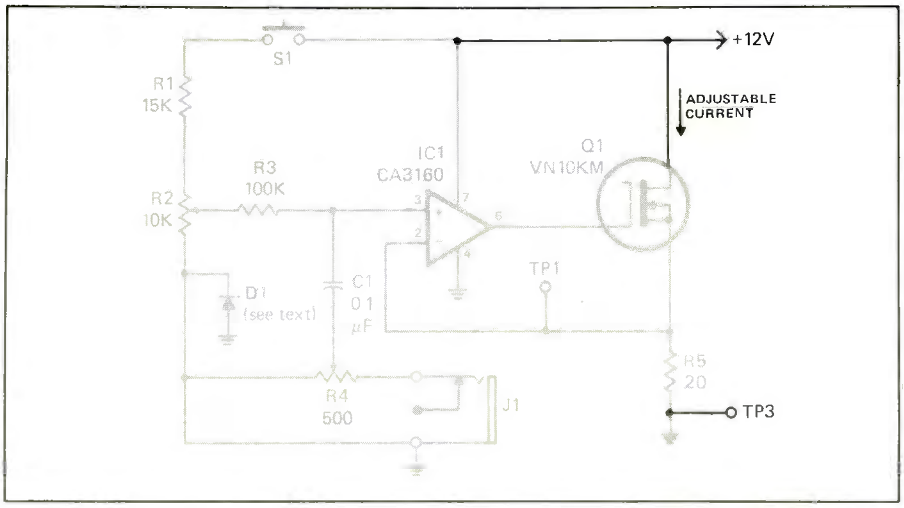


Fig. 2. Simplified schematic diagram illustrates adjustable current source.

volt/20 ohms, or 10 mA. The same current flows from the +12-volt power supply through the sink lead of *IC1*, as illustrated in the simplified schematic in Fig. 2.

With *R4*, *C1* and *J1* in the circuit, it's possible for the Opto Tester to dynamically test optical couplers for rise time and data rate (see Fig 3). A signal from a square-wave or pulse generator is injected into the test circuit through *J1*. The level of this signal is set as needed with trimmer control *R4* and is then coupled through *C1* to pin 3 of *IC1*.

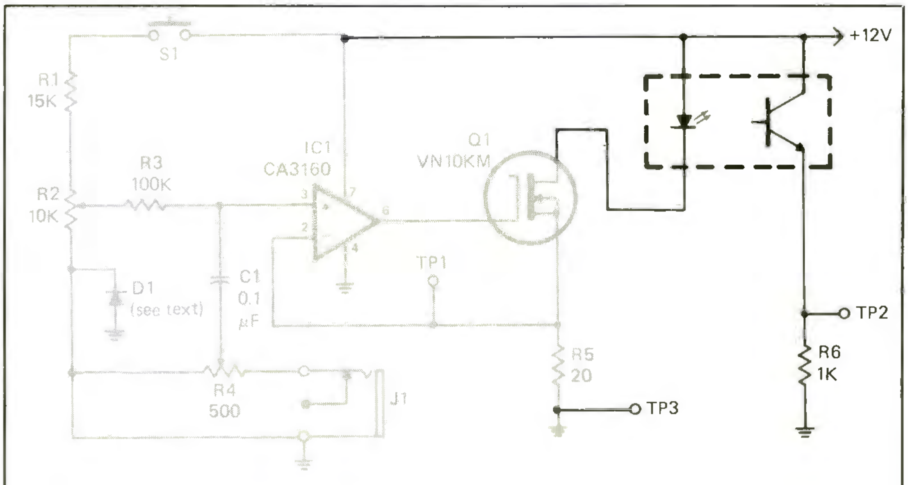
Input protection for *IC1* is provided by *D1*, which clamps the negative-going edge of the square-wave input test signal from the generator to a safe level. The base of the optical coupler's internal transistor can be connected to its emitter through a 22,000- to 100,000-ohm resistor via *J2* to improve response time of the optical coupler, though this is done at the expense of the CTR with some devices.

The input and output waveforms are monitored with an oscilloscope during dynamic testing. The input waveform is monitored between *TP1* and *TP2*, the output waveform between *TP2* and *TP3*.

It's possible to use the Opto Tester's adjustable current source for testing low-voltage zener diodes and batteries when adapters are used. Zener diodes are not perfect regulators, and some are less perfect than others. In the curve shown in Fig. 4, note that at lower currents the zener diode's "regulated" voltage can change quite a bit, while at higher currents the response settles out to a more linear voltage slope. With the Opto Tester, you can display the operating curve of zener diodes to determine if they are working and how well.

The wiring of the two test adapters is shown in Fig. 5. With Adapter 1 plugged into test socket *SO1* via the pins indicated, the Diode Test Clips shown in Fig. 1 become active. Figure 6 shows the Opto Tester circuit with the zener diode connected via the clips. This arrangement allows a particular bias current to be set by monitoring the voltage between *TP1* and *TP3* with a voltmeter and then applying a varying current to measure zener impedance.

When testing a zener diode, the slope of its waveform can be expressed as a change in voltage for a given change in current, such as millivolts per milliampere. For example, if a given zener diode's slope is 2.5 millivolts per milliampere, output impedance is 0.0025 volt/0.001 ampere, or 2.5 ohms. As a point of re-



R2 Voltages for Various Drive Currents

R3 (mV)	Current (mA)	R3 (V)	Current (mA)
20	0.001	0.2	0.010
40	0.002	0.3	0.015
60	0.003	0.4	0.020
80	0.004	0.5	0.025
100	0.005	0.6	0.030

Fig. 3. Equivalent Opto Tester circuit for dynamic testing of opto isolators.

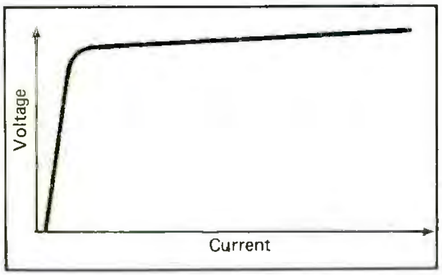


Fig. 4. Voltage-versus-current response curve of a typical zener diode.

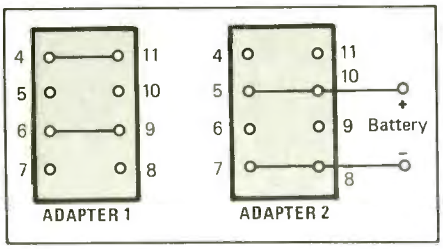


Fig. 5. Test adapters required for using Opto Tester to test zener diodes (Adapter 1) and batteries (Adapter 2).

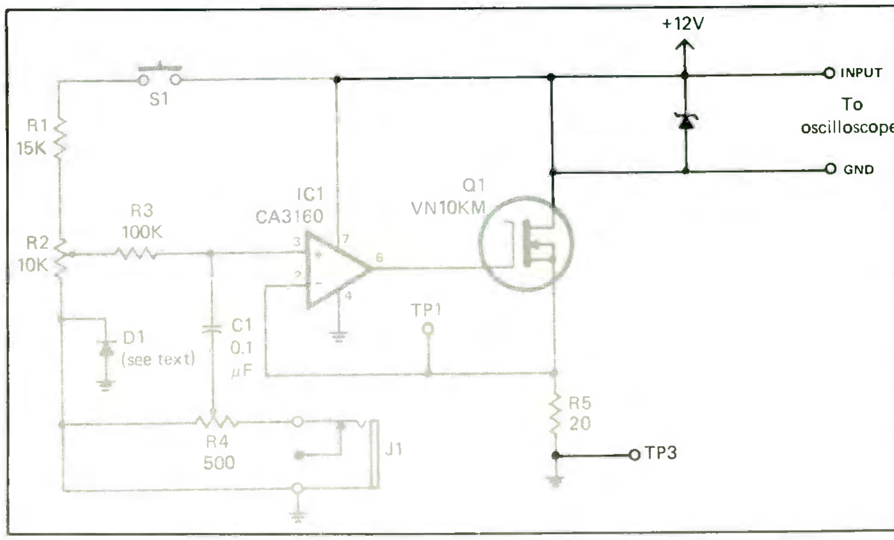


Fig. 6. Equivalent circuit with zener diode connected to Opto Tester.

ference, keep in mind that the ideal zener regulator has zero ohm of impedance.

Adapter 2 in Fig. 5 allows the output impedance of a battery to be tested. This test is conducted in a manner similar to that for the zener diode with one exception. The Fig. 7 test circuit shows that the negative terminal of the battery being tested goes to the Opto Tester's ground. This allows the output variation from the battery to be measured between *TP3* and the battery's + terminal.

The Opto Tester's power supply (Fig. 1) is driven from the 117-volt ac line through a plug-in ac wall transformer that delivers between 9 and 12 volts ac at not less than 200 mA. A higher-voltage transformer can be used if a full-wave bridge rectifier is used in place of the full-wave doubler shown. Just reconfigure the power supply as a standard bridge circuit and use a large value of capacitance (say, 220 microfarads or more) for a filter at the output from the bridge rectifier. In either case, *C4* should be a tantalum capacitor to improve the transient response of regulator *IC2*.

Construction

As shown in the lead photo and Figs. 8 and 9, this is a simple project to build. It's very compact and has very few components. Therefore, it can easily be assembled on a small piece of perforated board. Cut the board to fit (and replace) the top of the small project box specified in the Parts List. Use suitable soldering (or Wire Wrap) hardware to mount the components and a socket for *IC1*.

There's nothing critical about circuit layout. Just arrange the components in any way that lets you plug them into the board without crowding. Figure 8 shows the top of the board on which the prototype was assembled and a suggested layout. Simply plug in the components and wire them according to Fig. 1.

The socket recommended for *SO1* in the Parts List is a side-wipe type that assures good reliability. The Radio Shack part number was for this type of socket at the time this was written. If Radio Shack has changed suppliers in the meantime, you may not get the recommended type of socket and will, therefore, have to shop around to locate the preferred type.

Two different op amps are specified in the Parts List for *IC1*. The preferred op amp is the RCA CA3160. The Radio Shack part number is for a TLC-271, which has a more limited frequency response that will limit the frequency range possible during dynamic testing of optical isolators. If you should use the TLC-271, make sure to tie pin 8 to pin 7 during wiring.

For *TP1*, *TP2* and *TP3*, you have a choice of solder posts, small pin jacks or any other convenient devices. For the Diode Test Clips shown in Fig. 1, you can use small alligator clips, small pin jacks or any suitable test clips at the ends of flexible test-lead wire connected into the circuit at the appropriate points.

When wiring the circuit according to Fig. 1, use broad copper strips or heavy-duty solid wire for the V+ and ground buses between the power supply and circuit proper to assure good low-impedance connections. Figure 9 shows the underside of the wired board using self-stick copper strips and printed-circuit patterns.

Mount on the board or one of the walls or the box a jack that matches

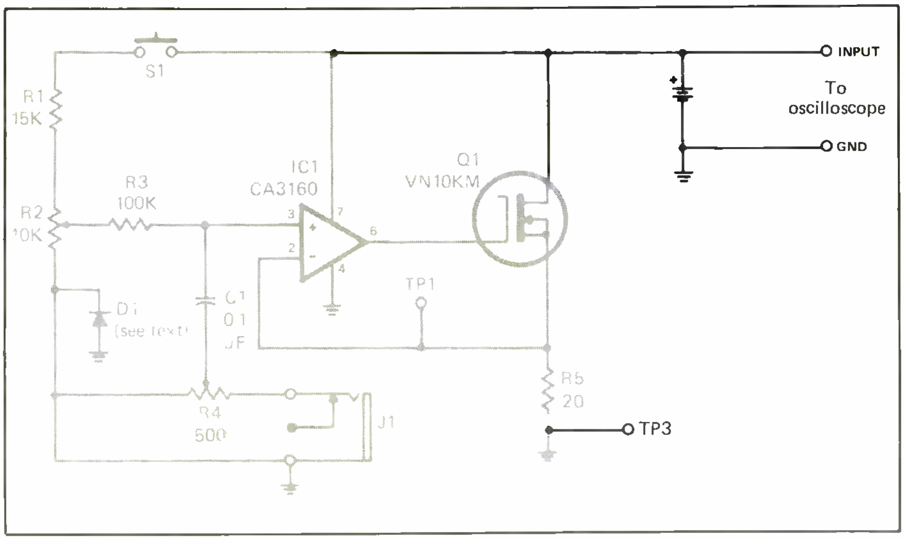


Fig. 7. Equivalent circuit set up for testing 9-volt batteries.

the connector on the end of the plug-in transformer's cord. Alternatively, cut off the transformer cord's connector, route the cord through a hole in the box and permanently wire it into the circuit. Pushbutton switch *S1* mounts either on the board or on one of the walls of the box. However, jacks *J1* and *J2* should mount on one of the walls of the box and on the board, respectively.

Finally, wire the test adapter as shown in Fig. 5, using component platform adapters that directly plug into *SO1* on the Opto Tester. Use solid bare hookup wire to make the pin-bridging connections, and for Adapter 2 connect and solder the red and black wires of a 9-volt battery snap connector to the battery + and − posts, respectively; as indicated.

Use Tips

The main function of this project, of course, is to test optical isolators. Since these are 6-pin DIP devices and *SO1* is a 14-pin socket, it's important that you insert the optical isolator in the socket properly, as indicated by the numbers in the parentheses shown in Fig. 10.

With an optical isolator plugged into *SO1* and a voltmeter (preferably digital for best resolution) connected between *TP1* and *TP3*, the Opto Tester is ready to test the CTR of the optical isolator. When using the tester in this manner, press (close) *S1* and adjust the drive current as you monitor the voltage across *R5*. Set this voltage by adjusting *R2* (the Table that accompanies Fig. 3 shows the voltages across *R2* for various drive currents). Each volt measured across *R5* is equal to 1 mA. (Note: All actual tests are made with *S2* in the closed position.)

An alternate test is to close *S1* and adjust *R2* until a 1-volt drop is measured across *R5*. Then check the voltage drop across *R3*. Optical isolators that have the same drive current range are well-matched.

When conducting a dynamic test, care must be exercised in setting it up to avoid erroneous results. Connect the two channels of the oscilloscope and plug a signal generator into *J1*, as detailed above, to obtain displays of the input and output waveforms. Then set up a large enough dc drive current to give a reasonable output current.

Slowly increase the setting of *R4* to add an ac component to the drive current until the output waveform begins to distort on the bottom of the

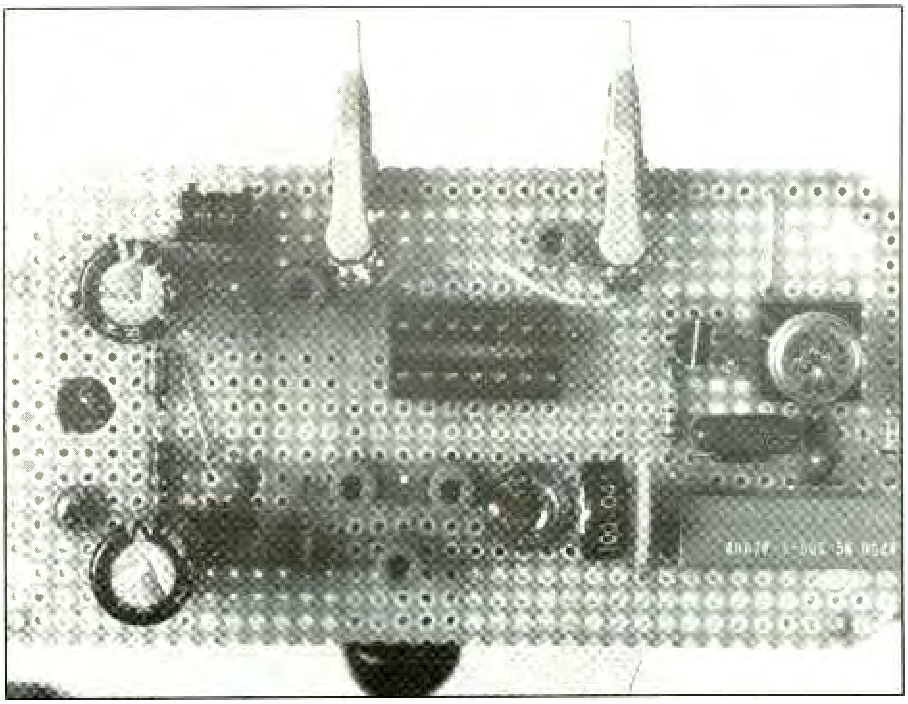


Fig. 8. Project is simple enough to assemble on small perforated board. Note how small alligator clips (Diode Test Clips) overhang one side of board.

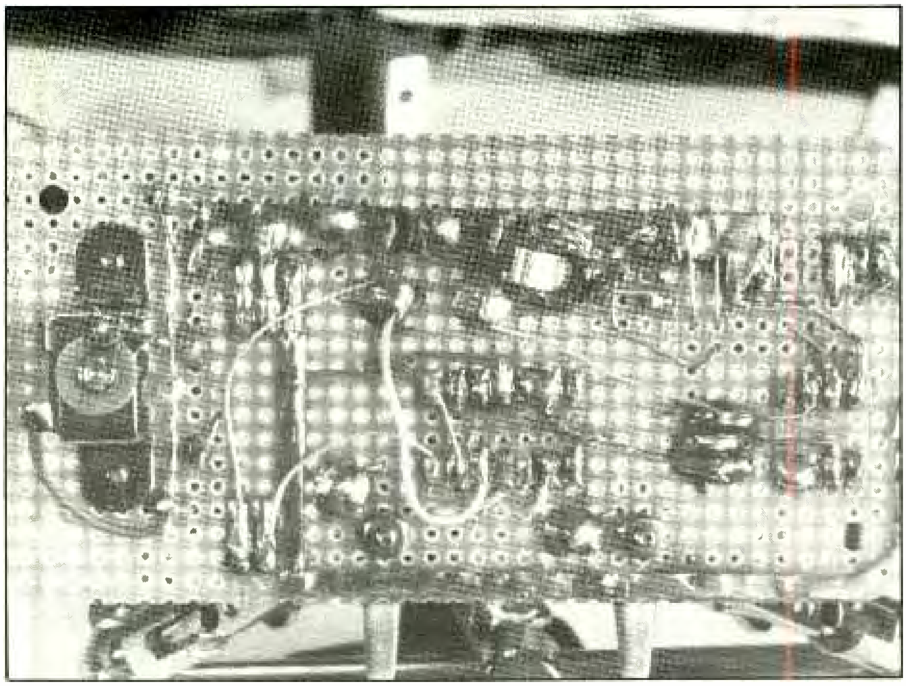


Fig. 9. Wiring and soldering details of underside of board shown in Fig. 8. Note the wide copper foil conductors used for power distribution and self-stick pc-type patterns used for component mounting.

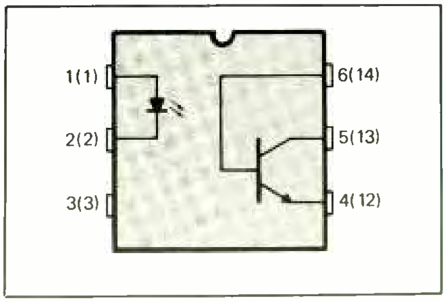


Fig. 10. Details of typical general-purpose optical isolator. Numbers in parentheses indicate SO1 pins into which the device plug.

trace. This excessive drive current will force the output current to turn off. Reduce the drive current to at least 15% below where the distortion began and then make your measurements.

Interpret the waveforms obtained as follows: for an input of 0.4 volt peak-to-peak across the 20 ohms of *R5*, the drive current is 0.4 volt/20 ohms, or 20 mA peak-to-peak. On the output waveform, 1.9 volts peak-to-peak across the 1,000 ohms of *R6* becomes 1.9 volts/1,000 ohms, or 1.9 mA. Now, CTR is 1.9 volts/20 ohms, or 9.5%.

The dynamic test has a more important purpose. Using a square-wave test signal from the generator, you can adjust the test frequency until the leading edge of the output waveform just begins to slow up. The amount of delay will be visible between the displayed input and output waveforms and can be interpreted in microsecond increments by interpreting the settings of the scope's front panel calibrating controls. This delay can be an important consideration when choosing an optical isolator for a given application, allowing you to choose a device with a faster response when needed.

When checking low-voltage zener diodes, use Adapter 1 in Fig. 5 and the Diode Test Clips on the Opto Tester. Connect a voltmeter to *TP1* and *TP2* and an oscilloscope across the diode. The meter serves as an indicator as you set the bias current for the test. The oscilloscope is used to set the variable drive current and to measure the resulting changing voltage across the zener diode.

An oscilloscope can't measure the ac drive and output voltages simultaneously. Therefore, it must be set to ac input coupling and its test leads must be connected to *TP1* and *TP3* to measure the ac drive. Then the scope leads are connected directly across the zener diode under test and the varying voltage across the zener diode is recorded.

Compute the diode's impedance as detailed above. A typical test of a 1N758 zener diode using a 20-mA bias current and a 30-mA peak-to-peak drive current from a signal generator plugged into *J1* might change the output by 75 mV peak-to-peak, and impedance might then be 0.075 volt/0.03 ampere = 2.5 ohms.

A battery test is simple and is performed in a manner similar to that used for the zener diode. Simply plug Adapter 2 (Fig. 5) into *SO1* on the Opto Tester and clip the snap connector onto the battery being tested. Then adjust the bias and peak-to-peak drive currents and view the waveform displayed on the oscilloscope's screen. A typical test using a 6.8-mA dc bias current and a 10-mA peak-to-peak drive current might yield an output variation of 0.028 volt from the battery. This gives an impedance of 0.028 volt/0.01 ampere, or 2.8 ohms.

From the foregoing it's easy to see that the Opto Tester fills a real need in your test equipment lineup if you use optical isolators. With it and your present digital multimeter and dual-channel osclloscope, you have a complete instrument that will assure you that all your optical isolators are working properly and are essentially matched before you put them into operation in your own circuit designs or replace faulty devices in other circuits. **ME**