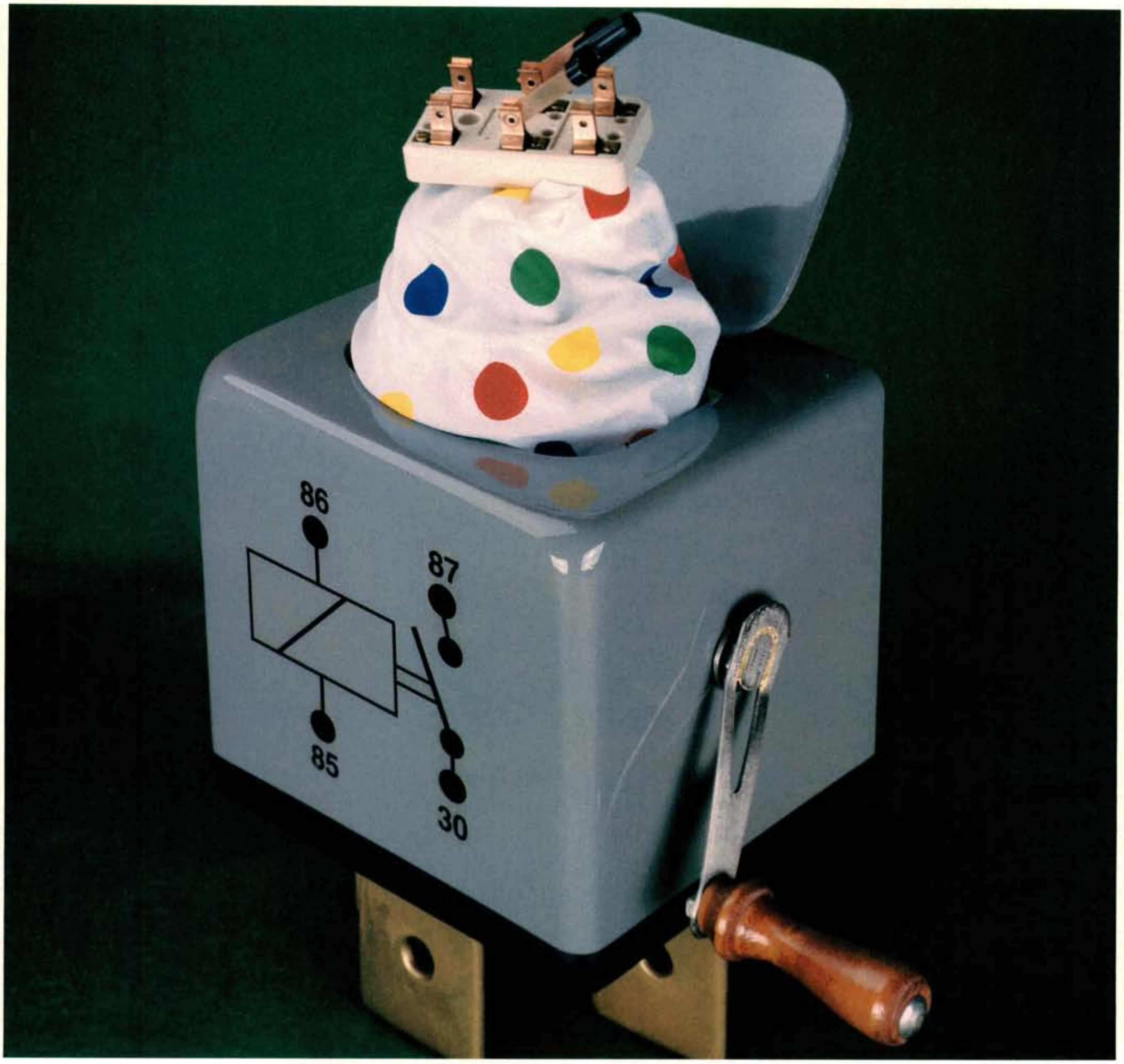


Switch-In-A-Box

Relays have grown in importance in automotive electrical systems. But our switch-in-the-box used to be a rare item. Years ago, many cars had only one relay—a horn relay. It seems that the horn switch was taking quite a beating carrying current for the horn. So some enterprising engineer added a relay to the circuit. When the horn switch was closed, it activated the relay. Current then passed through heavy duty contacts in the relay to blow the horn.

To troubleshoot relay circuits in the old days, a jumper wire was used to jump across the relay contacts to see if the horn worked. If the horn still didn't work, it was replaced. If it worked with the jumper wire, then voltage and ground were applied to the relay winding to see if it worked.

No click? New relay.

This troubleshooting technique worked just fine with horns. But our new computerized cars require us to use caution when testing relay circuits. Our jumper wire can get us into serious trouble when an ECU becomes the switching device operating the relay.

If we slip and apply ground or battery voltage to the wrong terminal of the relay socket, and the terminal is connected to the ECU, we can overload the ECU circuit and damage it. As we all know, car computers are very expensive. We humbly offer the following rule of thumb:

NEVER USE A JUMPER WIRE TO TROUBLESHOOT ANY RELAY CIRCUIT WHEN A COMPUTER IS INVOLVED IN THE CIRCUIT.

If you thought that the old horn switch needed help with loads, ECU circuits are even more fragile.

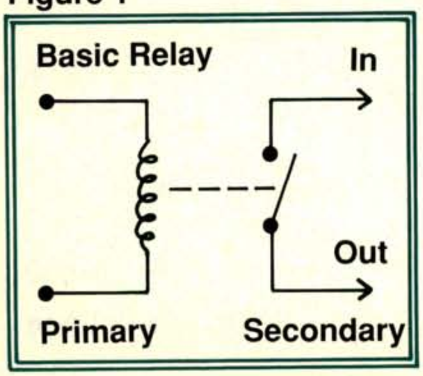
Wimpy, wimpy. That's why relays have gotten even more important. The ECU does the thinking—the relays do the dirty work.

Now that we've decided that relays are here to stay, let's discuss ways to troubleshoot them safely. With a little practice, it's easy.

Switch-in-a-Box

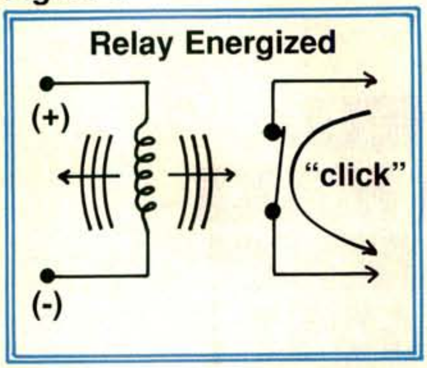
We'll start with a basic schematic symbol for a relay. As you can see, a relay has two distinctly different parts: The Primary and the Secondary Circuits.

Figure 1



• **The Primary Circuit** consists of the relay winding, commonly called the relay "coil." When current passes through the relay winding, an electromagnetic field builds up around the winding in the primary circuit. See **Figure 2**.

Figure 2

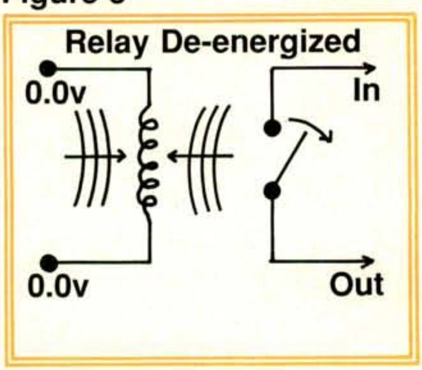


• **The Secondary Circuit** of the relay contains the relay contacts. These are the heavy duty current carriers mentioned earlier. The contacts in the Secondary are pulled closed by the electromagnetic force of the Primary Circuit.

When the relay contacts close, a click is heard as the contacts come together completing the circuit. Input connects to output, and the circuit is complete.

When the relay is de-energized (powered down), the flow of current through the Primary winding stops, and the electromagnetic field collapses. The contacts in the Secondary return to their normally open position. This turns the circuit OFF. See **Figure 3**.

Figure 3

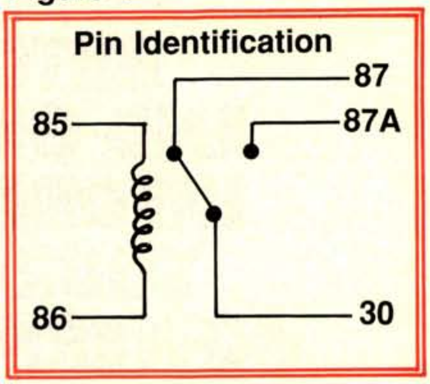


Standard Relay Terminal Identification

Many automotive relays use a standard relay terminal pin numbering system. See **Figure 4**.

Basic Relay Terminals

Figure 4



Terminals 85 and 86 are the two ends of the relay winding, or coil (Primary Circuit). Terminal 30 sits at one end of the Secondary Circuit. Many vehicles use terminal 30 to indicate constant battery voltage, although terminal 30 can also be connected to a switched voltage or ground. It all depends on the requirements of the circuit.

On a four terminal relay, our final terminal is marked 87. He sits directly across the box from old number 30, and takes the handoff when the contacts between the two close. A single four terminal has only one output.

Five terminal relays can control a single output, or alternately switch back and forth between two different consumers. The fifth terminal is numbered 87A (think of 87 Alternate). In a five terminal relay, terminal 30 is always connected to one of the two output terminals (87 or 87A). Instead of switching ON or OFF, the "swing arm" attached to terminal 30 toggles between 87 and 87A. Before the relay is energized, there is continuity between 30 and 87A. When the Secondary Circuit energizes, terminals 30 and 87 are connected.

This type of relay allows for a variety of applications using one relay. Circuits can be ON until switched OFF by hooking the load wire to terminal 87A. Or they can be OFF until switched ON by connecting the load to terminal 87.

A five terminal relay can be used in place of a four terminal relay, however. Use terminal 87 as you would on a four terminal relay, and leave 87A open.

Computer Control of Relays

Computers can control a relay in one of two ways:

- **Switch-to-Voltage**—The computer can switch voltage to a constantly grounded relay winding to energize the Primary Circuit.

- **Or Switch-to-Ground**—The computer can switch ground to a relay winding which is constantly connected to voltage.

Both are shown in **Figure 5**.

Figure 5

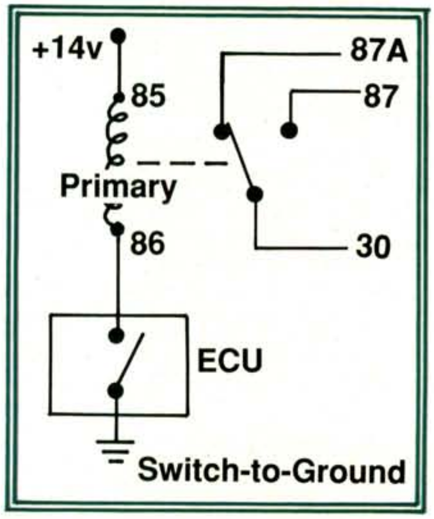
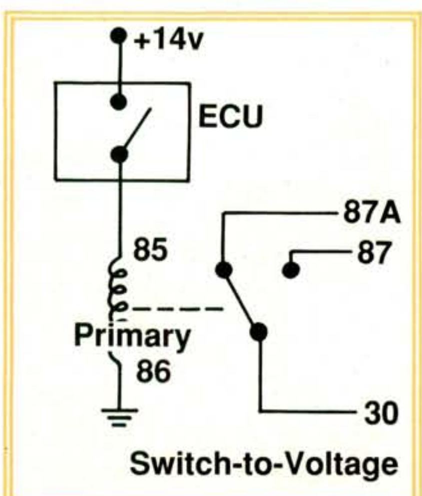


Figure 5



Troubleshooting Switch-to-Voltage Relay Circuits

Figure 6 shows a Switch-to-Voltage relay circuit. The DVOM is grounded and the red test lead measures the voltage at different relay terminals. We're using a DVOM because it won't harm the ECU circuit. The DVOM won't pass as much current as a jumper wire. Besides, careful evaluation of the DVOM readings will give us clues about problems in the circuit.

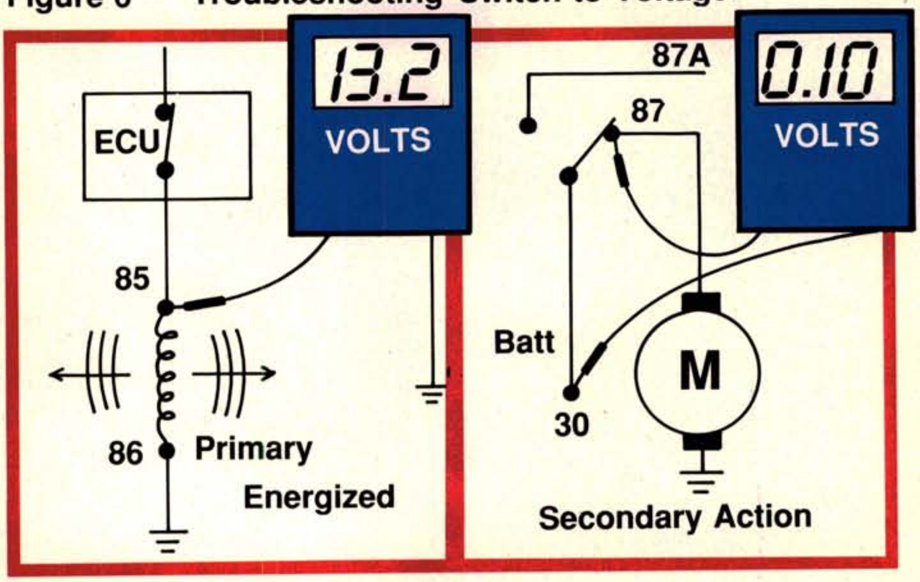
• **Testing the Primary Circuit**—Since terminal 86 is grounded all the time in a Switch-to-Voltage circuit, the switching action takes place on the 85 terminal. When voltage appears at the 85 terminal, the winding is energized. The ECU closes its internal switch to supply voltage to 85. About 0.8 volt is dropped across the ECU's internal switch, leaving about 13.2 volts to energize the relay winding.

If the voltage never appears at 85, the ECU may not be closing its switch because of an ECU failure, or there may be a loss of supply voltage to the ECU. Another possibility is that an input from a sensor never reaches the ECU to tell it to energize terminal 85.

If the ECU is supplying voltage, we still need a good ground at 86 to complete the circuit. Look for a voltage drop on the ground side of less that 0.1 volt to ensure that a good ground exists. High resistance in the ground circuit will result in a voltage drop greater than 0.1 volt. A reading above 0.3 volt indicates that the ground circuit needs to be cleaned, since corrosion has degraded the ground. Such a problem will only get worse with time.

• **Testing the Secondary Circuit**—The swinging contact in a five terminal relay connects terminals 30 and 87 when the Primary Circuit energizes. If the connection between 30 and 87 is a good one, the measured voltage drop should be less than 0.2 volt. If the contacts are open, the reading will be source voltage, about 14 volts. A reading of 0.0 volts might indicate an exceptionally clean set of contacts. But be careful. It could also mean that we haven't got any source voltage at 30.

Figure 6 **Troubleshooting Switch-to-Voltage**



Troubleshooting Switch-to-Ground Relay Circuits

Figure 7 shows a Switch-to-Ground relay circuit. The DVOM is grounded, and the red test lead measures the voltage just as it did with the Switch-to-Voltage tests.

•**Testing the Primary Circuit**—In the Switch-to-Ground circuits, 85 is now the terminal connected to voltage at all times. (In this circuit as opposed to the Switch-to-Voltage circuit, roles are reversed for terminals 85 and 86.) Now all the switching action takes place on terminal 86.

When the ECU switch closes, it connects 86 to ground to energize the relay winding. Until the ECU switch closes to ground terminal 86, you'll have 12 to 14 volts on both 85 and 86. Then when the ECU grounds 86, the voltage drop, measured at 86 should be about 0.6-0.8 volt.

If the voltage never drops at 86, the ECU may not be closing its switch because of an internal failure. Maybe the main ground to the ECU is bad. Also consider that a necessary sensor input to the ECU may be missing. In other words, the ECU never closes its switch because it is never told to do so.

Here are some things to check in a Switch-to-Ground circuit:

• Make sure that source voltage to the 85 terminal remains high when the coil is energized (look for about 14 volts).

• If voltage at 85 drops when 86 is grounded, there may be high resistance in the line feeding terminal 85. In fact, high resistance may cause voltage at 85 to drop so low that the relay won't energize.

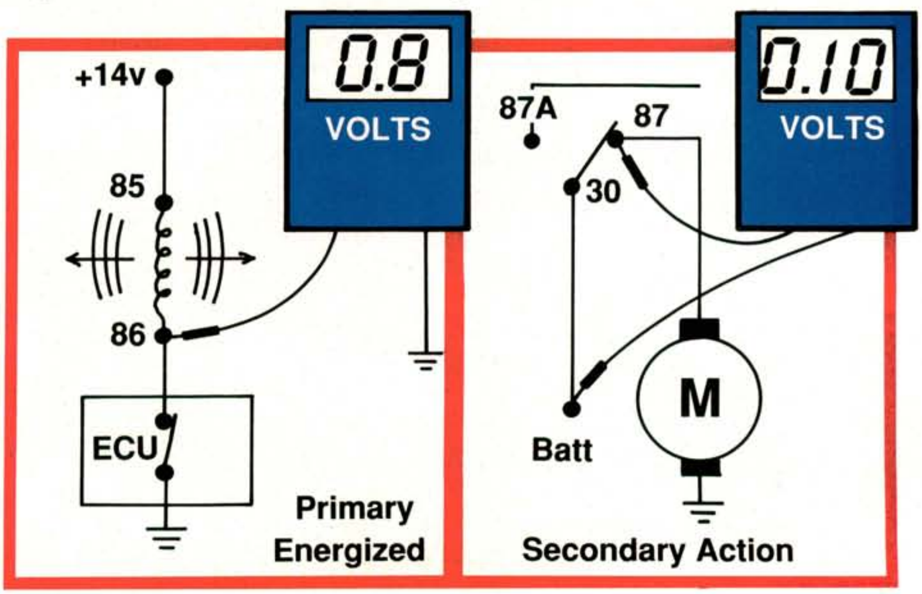
• **Testing the Secondary Circuit**—In Switch-to-Ground circuits, tests of the Secondary Circuit are similar to those for the Primary Circuit. The swinging contact in our five terminal relay connects 30 and 87 to complete the circuit to load. The DVOM measures the voltage drop of the closed contacts. A normal reading should be less that 0.2 volt.

If the reading is 0.0 volt, it could mean that we have an exceptionally clean set of contacts. But once again, make sure that a 0.0 volt reading isn't being caused by a lack of source voltage at terminal 30.

Testing the Relay Winding

This procedure applies to both Switch-to-Ground and Switch-to-Voltage circuits, and goes as follows:

Figure 7 Troubleshooting Switch-to-Ground



If all the values at the relay plug are correct, and the relay still won't energize, turn off the power, and test the resistance of the relay coil. If the winding is open, the ohmmeter will indicate an open on the highest ohmmeter range, usually an "OL" indication or a flashing "1." Replace a relay with an open winding.

Shorted Relay Windings Can Blow A Computer

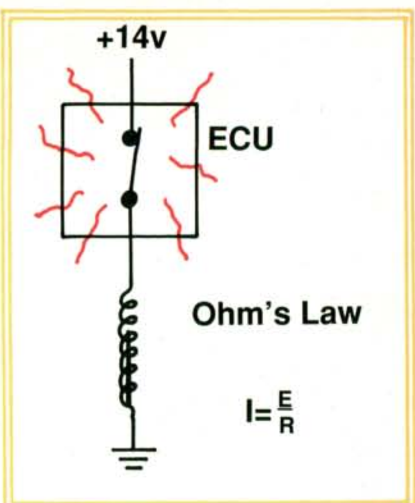
Figure 8 shows a Switch-to-Voltage circuit. The relay winding should normally have a resistance of about 40 ohms. But in this case, the windings are shorted, and resistance is much lower than 40 ohms.

Ohm's Law says: When circuit resistance decreases, circuit current must increase.

Our shorted windings allow too much current to pass through the circuit to the ECU. Like our old horn switch, the ECU switch overloads and burns.

Figure 8

If resistance decreases— current must increase

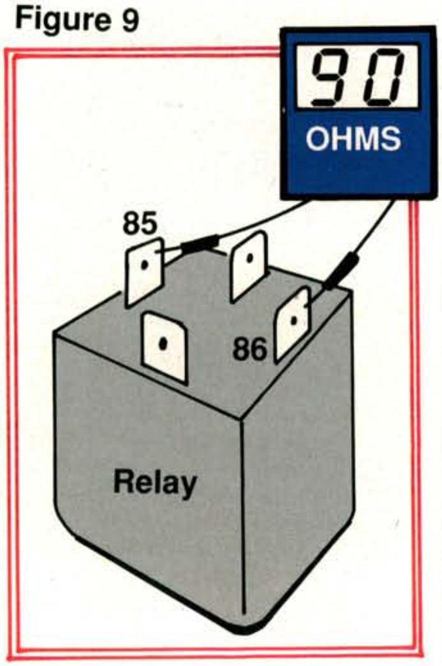


Measure Relay Winding Resistance With A DVOM

To determine the resistance of the relay winding, place a DVOM's test leads across the winding as shown in **Figure 9**. This test is done with the relay disconnected from the circuit. Measure between terminals 85 and 86, using the ohmmeter's 200 ohm range.

If the resistance of the winding is less than 75 percent of the normal reading, change the relay. In fact, when an ECU fails, it's a good idea to change the relay in the affected circuit. There's a chance that the problem in the relay winding isn't showing up until it gets warm. Then it kills the new ECU just as surely as it killed the old one.

Figure 9

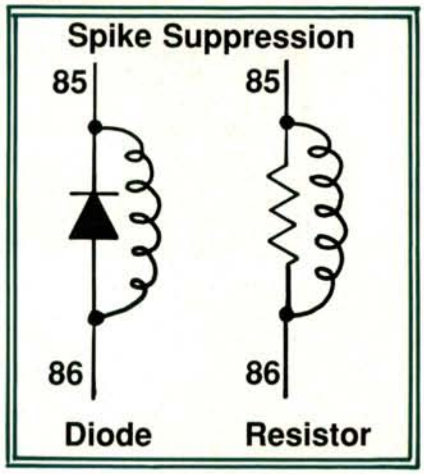


Spike Suppression Diodes

We've mentioned spike suppression diodes many times before in these pages. And they are very important in relay circuits. Every time the electromagnetic field around the holding coil collapses, a voltage spike is created. That spike can damage the ECU.

To suppress this tiny bolt of lightning, a small diode or resistor is connected across the relay winding as shown in **Figure 10**. (If neither is shown on the relay schematic, the spike suppressor is probably located inside the ECU.)

Figure 10



This brings us to another rule of relays:

IF YOU REPLACE A BAD RELAY, AND THAT RELAY HAD A SPIKE SUPPRESSOR, MAKE SURE THE REPLACEMENT RELAY HAS A SPIKE SUPPRESSOR.

Some relays don't have internal spike suppressors. Even if the new relay meets all the other requirements as a replacement (correct size, current rating, etc.), if it doesn't have a spike suppressor, it will probably damage the ECU.

Well, there you have it. Testing and troubleshooting the switch-in-a-box isn't all that difficult if you follow a few simple rules.

—By Vince Fischelli