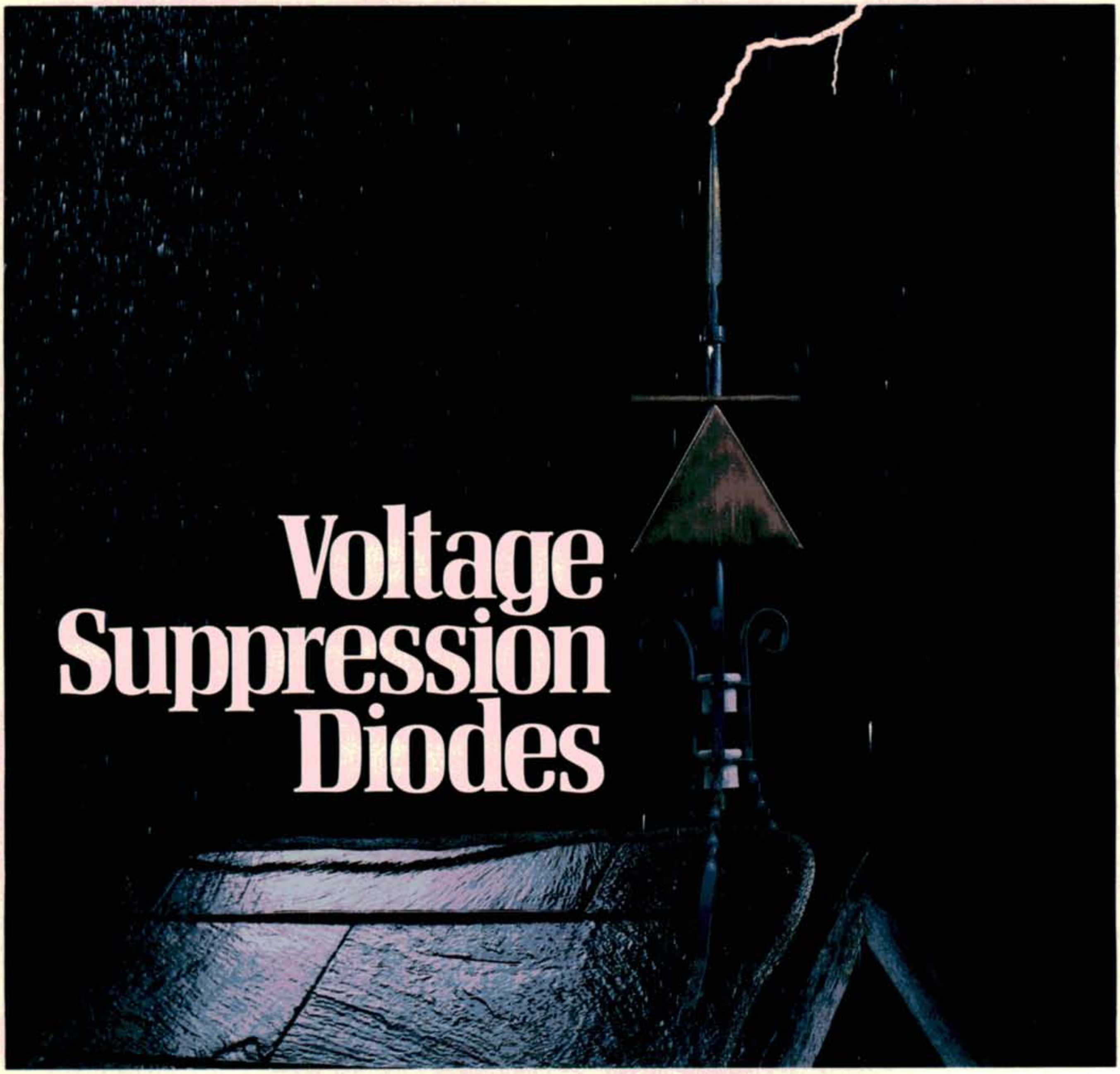

Voltage Suppression Diodes

To service the cars you see in your shop's stalls today, you need some basic electronics training. One area of basic electronics that's high on your "need-to-know" list is semiconductor diodes and diode function in automotive electronic circuits.

Diodes help make up the circuitry in practically all the computer boxes on today's cars. You may know these boxes as controllers, computers, ECUs, or ECMs. When one of these diodes fails, you diagnose the malfunctioning computer box and simply replace the box to fix the car.

But there are other diodes on the electronic car that are *external* to the computer box. What function do these diodes perform? What happens when they fail? How can you check these diodes? Let's learn about diodes and a very important diode application at the same time. This information may someday save you a lot of grief.

The Diode's Job

The main purpose of diodes in automotive electronic circuits is to suppress voltage spikes. These voltage spikes are created when the magnetic field around solenoids and relays collapses. The magnetic field—and the voltage spikes it creates—are a normal by-product of solenoid or relay operation.

If the voltage spike is not suppressed, it will knock out the circuits inside computer boxes and cause unnecessary computer failure. Unless you know how to locate the spike suppression diodes and check them, that customer's car will come back in a few days with the same problem. Who needs another comeback? Who wants to risk damaging the new computer box that he just installed?

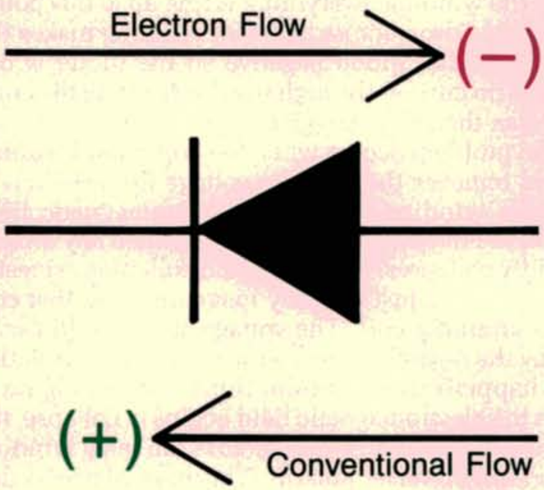

Figure 1

Most of us learned electricity via conventional current flow theory. Therefore, we say that current normally flows in the same direction as the diode's arrow.

The first thing we have to do is get familiar with some basic concepts about diodes. Figure 1 is the diode symbol as it appears on a schematic diagram. A diode only permits electrical current to flow through itself in one direction. If you use electron theory to explain electrical current, then electrons (tiny negatively charged particles) flow against the arrow in the diode symbol. Electrons never flow in the same direction as the diode arrow unless the diode is shorted.

If you use the conventional theory to explain current flow, then positive particles (positive ions) that make up conventional current, flow in the same direction the arrow is pointing in the diode symbol. Positive ions never flow against the arrow unless the diode is shorted.

How do we sum this up? Here, all you have to remember is that a diode is like a one-way check valve. A DIODE ONLY PERMITS ELECTRICAL CURRENT TO FLOW IN ONE DIRECTION.

Diode On, Diode Off

The diode symbol in Figure 2 can be thought of as an arrow sticking in a wall. The backside of the arrow head can be referred to as the backside of the diode. The polarity of the voltage on the backside of the diode tells you whether the diode is conducting current or not conducting current.

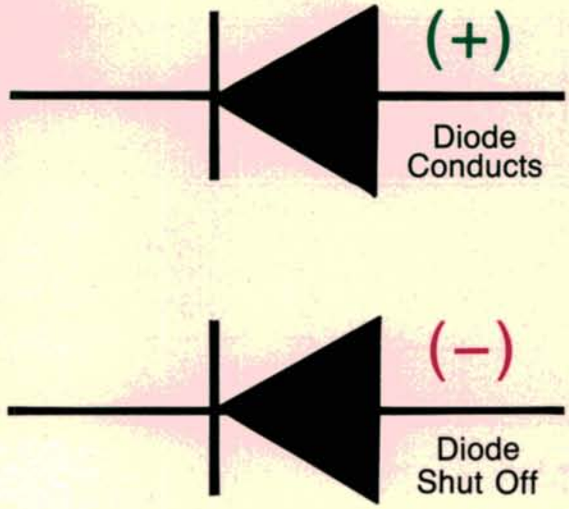

Figure 2

When the diode is on, it conducts current through itself in the direction the arrow is pointing.

When the diode is passing current in one direction, the diode is on. This is shown in the top diode of Figure 2. The backside of the diode is connected to the positive polarity voltage. The backside of the diode is more positive than the frontside, so current passes through the diode. Depending upon how you want to define current when the diode is on, electrons flow against the arrow or positive ions flow with the arrow.

When the diode is not passing current in one direction, the diode is off. This is shown in the bottom diode of Figure 2. The backside of the diode is connected to the negative polarity voltage. The backside of the diode is more negative than the frontside and current cannot pass through the diode. There is no current passing through the diode when the diode is off.

Suppression Diode Placement

Diodes for voltage spike suppression are placed across a solenoid or relay winding as shown in Figure 3. When the diode is placed across the relay winding (parallel to the winding), no current flows through the diode when the relay is energized.

The top of the relay winding is connected to an automotive computer output circuit. The bottom of the relay winding is connected to ground. Across the relay winding is a semiconductor diode. Because the backside of the diode is connected to ground—the negative side of the car battery—the diode is off. The relay contacts are A and B. Pin A is connected to the battery's positive terminal to supply voltage to pin B when the relay is energized and the contacts close. A high current device such as a fuel pump can be connected to pin B.

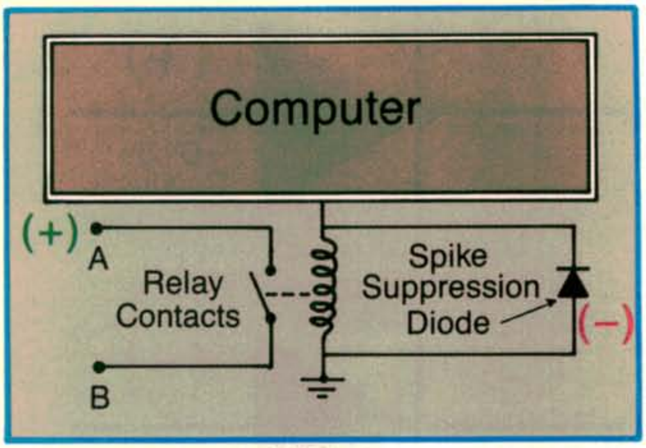

Figure 3

The computer controls the relatively low-current relay winding. The relay winding controls the relatively heavier current flowing through the relay contacts.

It is a common technique in automotive electronics to use a low power computer circuit to control a high power load circuit such as an electric fuel pump. The fuel pump needs more current to operate than the low power computer output circuit can deliver by itself. So the computer energizes a relay to close the relay contacts. This connects the battery voltage at pin A to pin B and the fuel pump operates. Figure 4 shows how the circuit works.

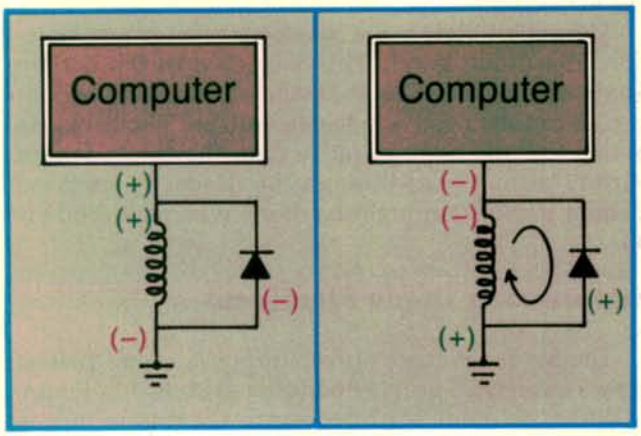

Figure 4

This is a closer look at the relay winding part of Figure 3. When the computer energizes the relay and the magnetic field builds up, the diode is off. When the computer shuts off the relay and the field collapses, the collapsing magnetic field turns on the diode.

In the first part of Figure 4, the computer supplies 12 volts on the top of the relay winding. Since the relay winding is grounded, current flows through the relay winding and the relay is energized. The relay contacts close, the battery voltage at pin A (refer back to Figure 3) connects to pin B and the fuel pump runs.

At this point, what we are interested in is the magnetic field that develops *around* the relay winding while current is flowing *through* the relay winding. A voltage drop across the relay winding makes the top of the relay winding positive with respect to the bottom of the winding. Everything is fine up to this point. The voltage drop across the relay winding makes the backside of the diode negative so the diode is off. There is no current through the diode while the computer has the relay energized.

The problem occurs when the computer is turned off and removes the positive voltage from the top of the relay winding. Since the electromagnetic field around the relay winding is not sustained any longer, it rapidly collapses. When the field collapses, it creates a voltage spike just like any magnetic field that collapses around a coil. The voltage spike could easily destroy the output circuit in the computer. But notice what happens in the second illustration of Figure 4.

As the electromagnetic field begins to collapse, the polarity of the voltage drop across the relay winding immediately reverses polarity. This reversal occurs due to some laws of electromagnetic physics. This makes the backside of the diode momentarily positive so the collapsing field turns the diode on. The diode then conducts the spike voltage through itself and actually absorbs it. After the electromagnetic field is dissipated, the diode is off again. The diode waits for the next computer turn-off cycle to occur.

Spike Diode Opens Up

If the spike-suppression diode opens up, the collapsing electromagnetic field generates a harmful voltage spike. How harmful? You're familiar with electrically operated fuel injection nozzles, aren't you? When the computer turns off such an injector, the injector windings can generate voltage spikes as high as 120 volts or more!

An open diode allows the voltage spike to travel into the computer box and burn up the computer output circuit. It may take one spike, it may take several spikes before the computer circuit fails. At any rate, buy another computer box!

Spike Diode Shorts Out

As soon as the computer puts 12 volts at the top of the relay winding, the shorted diode conducts electron current from ground. With a short to ground on the computer output circuit, the circuit burns out. Buy another computer box!

You can grow computer boxes in your garden. Or, you can spend a lot of money on replacement computer boxes. You might get yourself to the point where you would also have to install computer boxes with zippers for quick and easy replacement. Methinks it's easier to learn how to check the spike suppression diodes to find the ones that are open or shorted.

How To Check Spike Diodes

To check spike suppression diodes, use the same procedure you use on any diode. That is, use an ohmmeter to test the front-to-back resistance of the diode. The ohmmeter must have enough internal test voltage to turn the diode junction on. If the ohmmeter test voltage is too low to turn the diode on, it cannot be used to check the diode's resistance. Most analog ohmmeters have enough test voltage for testing diodes. Many digital ohmmeters cannot turn on a diode that's in parallel with a relay winding—even though the meter's equipped with a "diode test" position. So save those old VOMs (volt-ohmmeters)!

It takes about 0.3 volt to turn on a germanium diode. Most glass diodes are germanium. It takes about 0.6 volt to turn on a silicon (black epoxy) diode. This is well within the test voltage range of any old style analog ohmmeter.

Testing The Diode

Figure 5A illustrates how you hook up the test leads to test diode resistance. The diode should have at least one lead disconnected from the circuit. Be sure to zero the analog ohmmeter by shorting or touching the test leads together on the R x 1 scale—the lowest scale—and adjusting the reading for zero ohms. The ohmmeter is now calibrated for accurate resistance readings.

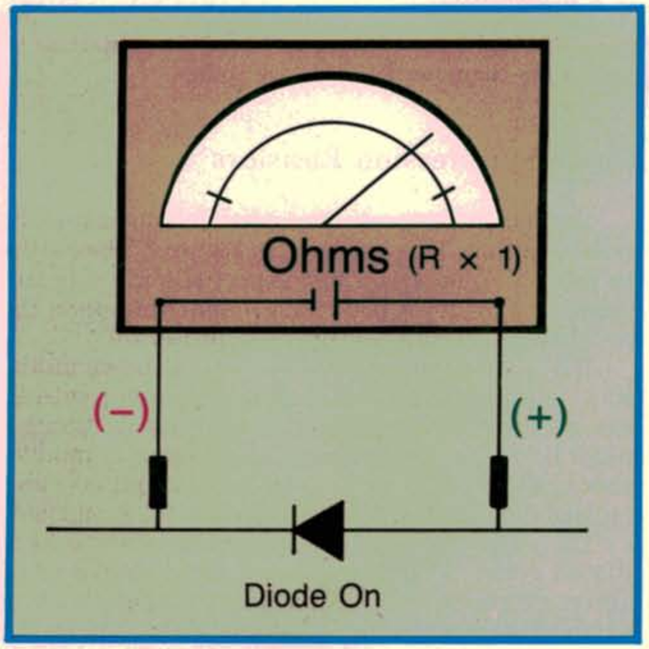

Figure 5A

With the analog ohmmeter connected as shown, a good diode will give you a reading of about 5 to 10 ohms.

In Figure 5A, the test leads are connected so that they place the positive terminal of the ohmmeter test battery on the backside of the diode. This turns the diode on and the ohmmeter reads a low resistance of about 5 to 10 ohms. Next, simply reverse the ohmmeter test leads (Figure 5B). This places the negative terminal of the ohmmeter test battery on the backside of the diode. The diode is turned off and the ohmmeter reads a high resistance of several thousand ohms.

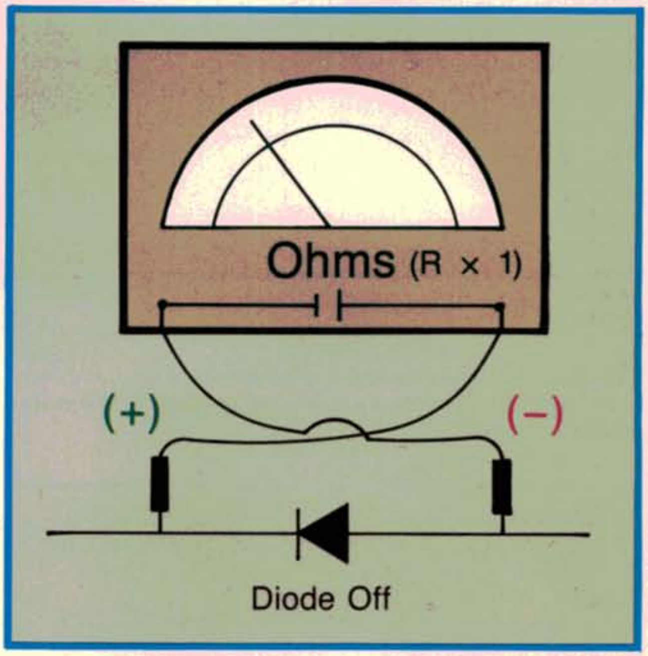

Figure 5B

With the ohmmeter connected as shown, the diode should be off and the meter should read several thousand ohms.

If the ohmmeter reads low in both directions, the diode is shorted. If it reads high in both directions, the diode is open. You can practice testing diodes to train yourself. Buy a package of miscellaneous diodes at your local Radio Shack store and use your own analog ohmmeter. The practice will make you an expert in testing diodes with an ohmmeter.

Sometimes it is too much trouble to disconnect one side of the diode, especially when the diode is sealed inside the relay. Figure 6A shows you what to do. This requires some practice, but it works. Disconnect the wiring harness so the relay winding with its spike suppression diode is removed from the computer box. Place the ohmmeter across the relay winding as shown in Figure 6A. The positive test lead of the ohmmeter is at the top of the relay winding where the positive voltage would normally appear to energize the relay. The negative test lead goes to ground. This turns the diode off and ohmmeter test current flows through the relay winding alone. So you are only checking the resistance of the relay winding in this test. The reading will vary according to the relay winding resistance, but it will usually be around 30-40 ohms. Or, check the manufacturer's specs.

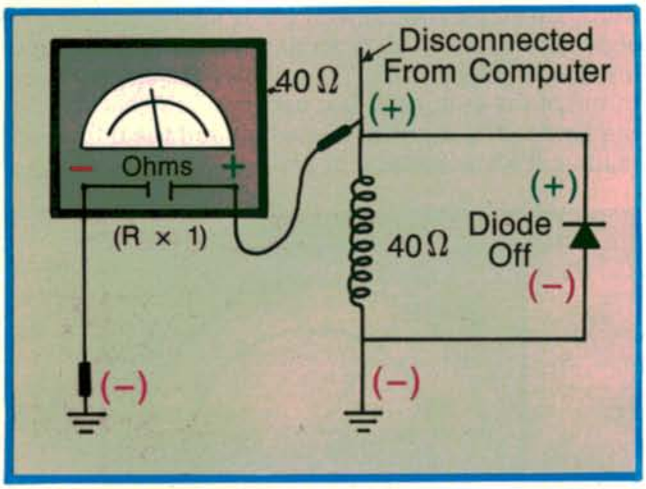

Figure 6A

With the relay/diode assembly disconnected from the computer and the ohmmeter connected as shown, the meter should read about 30 to 40 ohms.

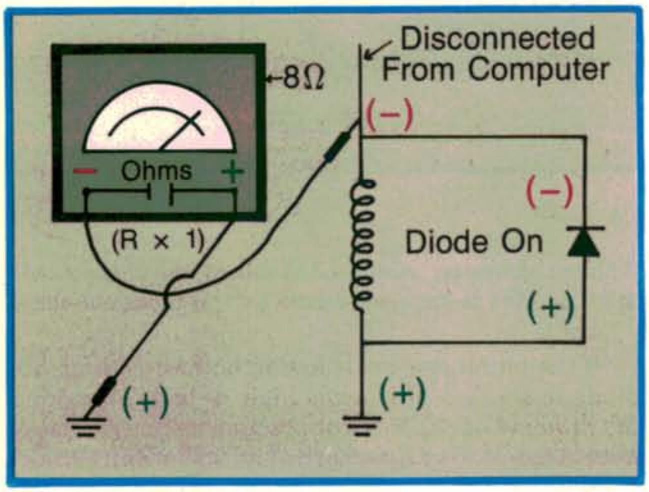

Figure 6B

With the relay/diode assembly disconnected from the computer and the ohmmeter connected as shown, the meter should read about 8 ohms.

Now reverse the ohmmeter test leads as shown in Figure 6B. Here the negative ohmmeter test lead is at the top and the positive ohmmeter test lead is grounded. This turns the diode on. The ohmmeter test current flows through both the relay winding and the diode (if the diode is good) at the same time. In this test, the relay winding and the diode resistance are in parallel. The reading should be about 8 ohms (40 ohms in parallel with 10 ohms of the diode).

How did I get 8 ohms? To calculate the total resistance of two resistances in parallel, use a simple formula called the product over the sum. In other words, 40 times 10 divided by 40 plus 10. ($40 \times 10 \div 40 + 10 = 400 \div 50 = 8$)

If the diode is open, the reading is 40 ohms both ways. If the diode is shorted, the reading is about 1-2 ohms both ways. With a little practice, you can tell if the diode is good or bad without disconnecting one side of the diode. If the coil's resistance (in parallel with the diode) is not known you can check an electrical shop manual for the vehicle. Or, you can check a similar circuit on the car or another car to determine what both readings should be. Then compare with the bad or suspect car. Once you determine what these readings are on a good circuit, record them on the electrical schematic for future reference.

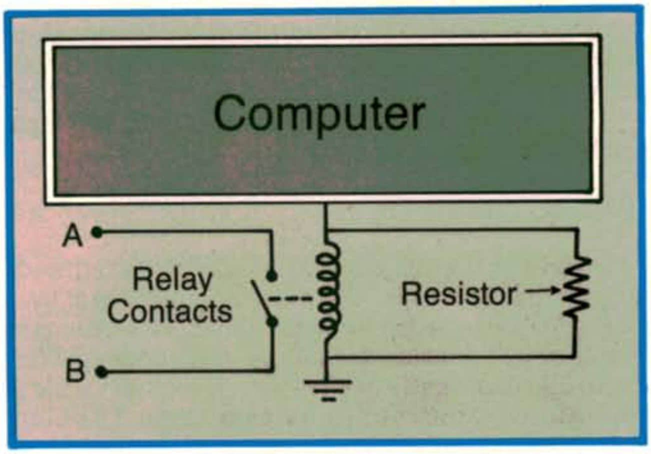

Figure 7

On some applications, a resistor is connected across the relay. The resistor acts like a spike suppression diode to protect the computer from voltage spikes.

Spike Suppression Resistors

Some manufacturers use a small resistor across the relay winding. This is shown in Figure 7. The testing technique is the same. Just expect slightly different ohmmeter readings both ways, depending upon the resistance value of the suppression resistor.

If a spike suppression diode is not shown on the schematic around a relay winding or solenoid, you can assume the spike suppression diode is inside the computer box. That makes some circuits easy to troubleshoot. Replace the bad computer box and you also replace the possibly defective diode at the same time.

On some cars, a spike suppression diode is even placed across a field winding of an alternator or an air conditioning clutch. This tells you there is a sensitive electronic circuit connected. Watch out for the spike diodes.

This is all you need to know to find bad spike suppression diodes. Don't let a bad diode eat your electronic (lunch) box!

—By Vince Fischelli