Hidden Danger: Replacement Relays

If it plugs in, it's right, right? Not hardly.

By Vince Fischelli

In a recent training session on troubleshooting relay circuits held in a fleet repair shop, I asked the foreman to bring a couple of standard replacement relays to class for discussion. After examining the two he brought in, I noticed they had the same pin-out and could easily be plugged into the same socket. So I got thinking about a common relay problem most technicians don't understand. After I passed the relays around the class for everyone's inspection, I asked if they would use either relay as a replacement in any vehicle circuit. Without hesitation, they all said they would, completely oblivious to the hidden danger. As long as the relay fit the socket, they'd plug it in. That's asking for trouble.

Coil Draw

Figure 1 shows the schematics of the two relays the shop foreman brought to class. Take a moment to compare them. Do you see the potential problem?

The relay pins are marked the same — 85, 86, 87, 87A, and 30 — as you can see in Figure 2. The relay on the left is a Potter & Brumfield 12V relay. It has a coil resistance of 90 ohms as measured with a digital ohmmeter. The relay on the right is a Tyco 24V relay. It has a measured coil resistance of 320 ohms.

That alone should be a factor in choosing one relay over the other. The 12V unit with the lower coil resistance of 90 ohms will draw 150 mA at 14 volts. The 24V unit with the higher coil resistance of 320 ohms will draw 44 mA at 14 volts and 75 mA at 24V. It is fairly likely a vehicle's computer driver transistor could handle either relay coil current, but the 90 ohm coil would stress the transistor more than the higher resistance coil because the lower resistance coil will draw more current.

It wouldn't be the first time someone plugged a 12V relay into a 24V circuit, or vice versa, and found that it worked . . . for a while. The hidden relay problem I'm concerned with here is more serious than the 12V or 24V coil issue.

Either relay could be plugged in, but one of the relays should NOT be used because it will damage the computer transistor driver circuit. Simply plugging in the wrong relay in the wrong situation and turning the circuit ON is enough to destroy the computer driver transistor that controls the relay. To ignore this could result in serious expense and embarrassment. Don't let it happen to you. Here's what you need to know.

Figure 1

Figure 2

Yikes, Spikes!

In Figure 3 we have redrawn both relay schematics. The pin numbering is still the same on both. Pins 85 and 86 connect to the relay coil. Pin 30 is the "swinging contact." Pin 87A is the "NC", normally closed (de-energized) contact. Pin 87 is the "NO" normally open (energized contact). Then, what's the difference between the two relays?

Relay #1 has a spike suppression *diode* while Relay #2 has a spike suppression *resistor*. So, it's not really a hidden problem after all — it's revealed in the schematics. The spike suppression diode in Relay #1 is polarity sensitive to the voltage wired to coil pins 85-86, and the spike suppression resistor is not. This is the crux of the hidden replacement relay problem.

When the computer turns ON, the driver transistor completes the circuit and current flows through the relay coil to CLOSE the contacts. When the relay is turned OFF, coil current stops and the energy released by the collapsing electromagnetic field surrounding the coil is dissipated through the diode to protect the computer's driver transistor from a voltage spike. If a diode were not across the relay coil, the released coil energy would pass through the driver transistor and destroy it.

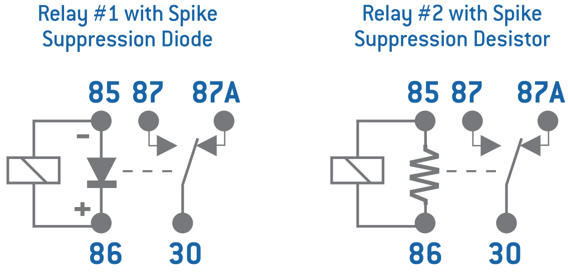


Figure 3: Relay Schematic Symbols

Relay Circuit "A" shows a little "+" (plus) sign at pin 86 and a little "-" (minus) sign at pin 85, indicating that polarity matters. Relay Circuit "B" does NOT have a plus and minus sign at pin 86 and pin 85 because it doesn't matter what polarity is connected to pins 85-86 when a spike suppression *resistor* is used. Current can flow in either direction through a resistor, so we say it is not polarity sensitive. When the relay is ON or energized, current flows through the coil and the resistor at the same time. When the relay is turned OFF, current through the coil stops and the energy released by the coil's electromagnetic field is dissipated through the resistor to protect the driver transistor from spike voltage damage.

For our purpose here, we're not going to get into a discussion of which way electrons *really* go (see sidebar). Suffice it to say that polarity matters if a relay has a spike suppression diode.

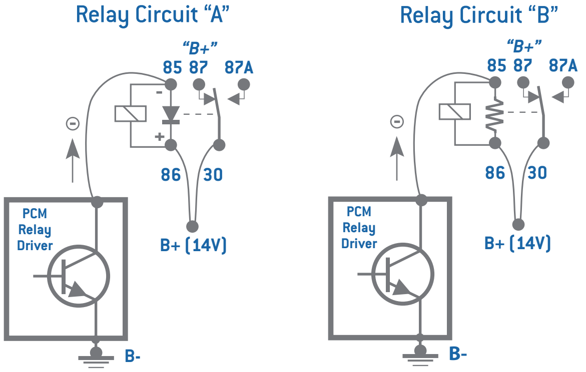


Figure 4: IN-Correct Relay Coil Connections

In Figure 4 there are two relay circuits side by side again. In circuit "C" a spike suppression resistor is used. Since the resistor is not sensitive to coil voltage polarity, pin 85 has been connected to B+. Pin 86 has been grounded by the computer's driver transistor. The relay contacts CLOSE when the driver transistor completes the circuit through the relay coil and B+ from pin 30 is connected to pin 87.

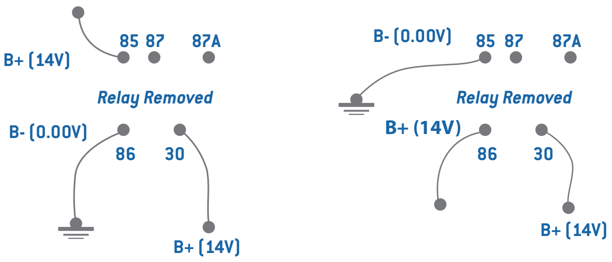
Poof!

Now, suppose a technician — let's call him Renaldo — is troubleshooting and finds that Relay Circuit "C" does not switch B+ to pin 87. "Hmmm, it could be a bad relay," muses Renaldo. "Let's plug in another one and see what happens," he thinks to himself.

"Hey Marty, hand me one of those black relays on the workbench," says Renaldo. Marty picks up a loose relay with a spike suppression diode and hands it to Renaldo, who without hesitation plugs it in, which results in Circuit "D." Notice in this relay pin 85 is marked "-," but is wired to B+, and the driver transistor grounds pin 86. That's the wrong polarity for the spike suppression diode in the replacement relay. When Renaldo turns the circuit ON, the computer turns ON. The driver transistor sends current through the relay coil, but at the same time current flows through the spike suppression diode. The diode will take more current than the driver transistor can handle and the result is that the driver transistor is burned up in seconds.

Of course, Renaldo doesn't realize he just blew the computer and created another problem. All Renaldo knows at this point is that the replacement relay didn't fix the problem.

What neither technician realizes is that Marty just happened to hand Renaldo a replacement relay with a spike suppression diode that fits the relay socket wired for a relay with a spike suppression resistor. When a circuit designer selects a relay for a circuit with a spike suppression resistor he may not always consider which side of the relay coil gets the B+ because it doesn't matter. It only matters when he selects a relay with a spike suppression diode. In that case, pin 86 had better be the positive (B+) side of the coil voltage.



Must only use relay with spike suppression resistor

Can use any relay with spike suppression resistor or diode

Figure 5: Testing Relay Coil Wiring

What should Renaldo have done first? Look at Figure 5. *Before the replacement relay is plugged in, Renaldo should have checked the voltage at pin 86 and 85 of the socket.* If the circuit is wired so that pin 86 is B+ and pin 85 is B- (0.00V), a relay with a spike suppression diode is safe to try. If the relay circuit is wired backwards so that pin 86 is B- (0.00V) and pin 85 is B+, use a replacement relay with a spike suppression resistor or the computer's driver transistor will be destroyed.

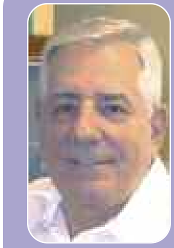
That is, unless the driver transistor circuit happens to be "short protected," which means that when the circuit senses higher than normal current demand, it shuts itself down in self-defense until the problem is corrected. Unfortunately, it will appear that the replacement relay is defective because it doesn't work, and keep in mind that not all computer transistor driver circuits are short protected.

Here's the bottom line: Before a replacement relay is plugged into a socket, measure the voltage at pin 86 and pin 85. If pin 86 is B+ and pin 85 is 0V, it is okay to plug in a relay with a spike suppression diode. But if pin 85 is B+, DO NOT plug in a relay unless it has a spike suppression resistor. Don't let the smoke out of a computer just because Marty handed you the wrong relay. ■

Ben Franklin and Conventional Theory

In reality, electrons flow from negative to positive. But early experimenters didn't know that — they didn't have a clue which way those tiny particles went, or even that they existed. They just observed electrical phenomena, and were trying to understand and explain them. Using the scientific principles of his day, Ben Franklin applied logical thinking to the question of which direction this mysterious force moved in. He surmised that, like water, this "corpuscle" would only flow from an area of excess (positive) to an area of deficiency (negative), and this idea was adopted.

"Standing on the shoulders of giants," we now know that Franklin's premises were not valid, which threw even his remarkable genius off the track. So, we're saddled with a false tradition, called "conventional theory," that is nevertheless followed in schematics to this day. For all practical purposes, however, it doesn't matter because this has no effect on how a circuit behaves. Never let this issue confuse you.



Vince Fischelli is a technical trainer specializing in electrical/electronics troubleshooting. After a great deal of training in the military, his auto service experience began at a electrical shop, then he started his own repair business where he specialized in the hard cases others couldn't solve. He was also the technical manager of GM's ECM remanufacturing facility in Dallas, and has written numerous books and electrical/electronics training programs. Check out his web site at *www.veejer.com*.