



Relay Race

Part Three

The green flag is out for the third lap of our “Relay Race” series. So far, we’ve built a solid understanding of how relays work as well as explaining their roles in typical automotive circuitry. We’re ready to consider three unusual relay problems. These problems appear rather puzzling at first glance but are actually quite easy to troubleshoot once you understand them.

Our standing approach to diagnosing circuits is to determine separately what happens to *current* as well as what happens to *voltage* in the same circuit. We must treat each separately to get a complete picture of what is happening in the circuit when it’s working and what is not happening when it’s not. It also helps to diagnose and solve problems using current and voltage readings. We’ll begin by tracing current through a relay coil circuit.

Figure 1 shows a simple relay circuit controlling a cooling fan motor. The top of the relay coil, Pin 86, is permanently connected to B+ through Fuse F6. The ground side of the relay coil, Pin 85, is connected to ground through control switch S2, grounded at G104.

Relay contacts are almost always drawn in the OFF position in schematic diagrams. In most cases and in the examples we will use, this also means the relay contacts are in the OPEN position. When visualizing how the circuit works, close the relay contacts in your mind’s eye to turn the circuit ON. Notice the relay in **Figure 1** does not use a spike suppressor across the relay coil. Why? I’ll hide the answer somewhere in this article.

Let’s talk in terms of electron flow, from negative to positive. When S2 is CLOSED, coil current (I_{coil}) flows from the battery negative terminal, through G101, through G104, through the switch, through the relay coil winding, through the fuse and back to the positive terminal of the battery. Current through the relay coil energizes the relay, creating an electromagnet that pulls the relay contacts CLOSED. This connects relay Pins 30 and 87, thus applying B+ to the top of the DC motor. Since the DC motor is permanently grounded through G107, the battery can send a current (I_{motor}) through the cooling fan motor, through the relay contacts, through fuse F3 and back to B+. The fan then turns ON at full rpm. At least that’s how the circuit is supposed to work. But strange things can happen in electrical circuits, can’t they?

Buzzing Relay Problems

A fairly common problem is something I'll call a "buzzing relay." The relay buzzes and vibrates when the relay control switch is CLOSED. While the relay is buzzing, the cooling fan motor controlled by the relay in **Figure 1** does not operate. Replacing the relay and the cooling fan will not correct this problem. Time for some troubleshooting.

Before we discuss the troubleshooting steps, let's look at what has gone wrong with the circuit to make the relay buzz and vibrate. Simply put, a relay will buzz and vibrate when the total relay current, comprised of the relay coil current and the relay contact (load) current, must simultaneously flow through the same bad or corroded connection.

Figure 2 shows a resistance problem in the circuit. The specific cause in this case is corrosion at the negative battery cable. The resistance symbol in the cable could also represent corrosion at the negative battery terminal or at the battery ground connection G101. Any one of the three points along the negative cable could cause the problem if it were corroded, because all three must pass total relay current. Resistance in a circuit limits current flow through the circuit and produces a voltage drop, reducing the effective voltage applied to the relay coil. Resistance at any point along the negative cable or at the connections at either end of the cable limits the current available to the relay coil as well as to every other circuit.

Here's what happens to relay operation when there is high resistance along the negative battery cable:

- S2 CLOSES to turn the relay on. Up to this instant, we have full charging system/battery voltage to the switch. When the switch is closed voltage is applied to the relay coil.
- Current through S2 energizes the relay, but coil current causes a voltage drop across the resistance in the ground cable. This means the voltage available to the relay coil is immediately lower than normal. It also means the current through the relay coil is lower than it should be, but (at least in this example) still enough to hold the contacts closed.
- Once the relay contacts CLOSE, current begins to flow through the load side of the circuit, through the relay contacts and the fan motor. This increased current, unfortunately, increases the voltage drop in the bad or corroded connection. All of a sudden, the voltage left across the relay coil is not enough to keep the coil energized. The relay de-energizes and the relay contacts OPEN.

- With the relay contacts OPEN, the current through the high resistance connection falls back down, as does the voltage drop across it. Now there is enough voltage to re-energize the coil, so it clicks and the relay contacts CLOSE again.
- But now with the contacts CLOSED, the current raises the voltage drop below the coil threshold, and the relay contacts OPEN again.
- And so on. Fast enough to sound like a buzz.

This process continues and repeats rapidly as long as S2 stays CLOSED. The result is the relay contacts snap CLOSED and OPEN over and over. It sounds as if the relay is buzzing because the moveable contacts vibrate back and forth at a rapid rate. The buzzing is usually audible if you are close enough to the relay, and you can feel it vibrating if you touch the relay housing.

The same thing can happen if the resistance is on the positive side of the circuit, as shown in **Figure 3**. The resistance can be at the positive terminal of the battery, in the positive cable or in the common connection at the fuse box, providing B+ to the relay coil and cooling fan motor. Resistance on the positive side of the relay coil circuit reduces coil current just as it does when the resistance is on the ground side.

We can sum up a buzzing and vibrating relay with a simple statement: When relay coil current and relay contact current flow through the same bad connection at the same time, the relay can buzz and vibrate, and the load controlled by the relay contacts may not operate.

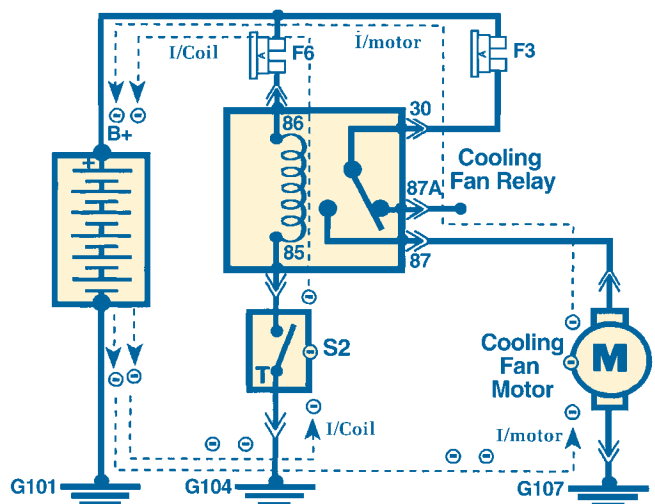


Figure 1

Relay Race

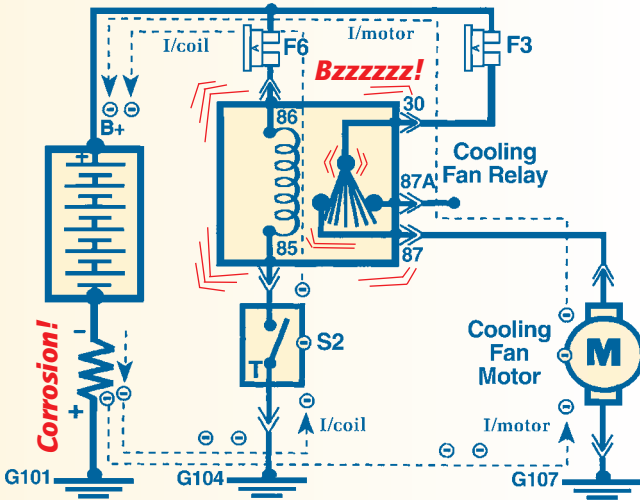


Figure 2: High resistance on the ground side.

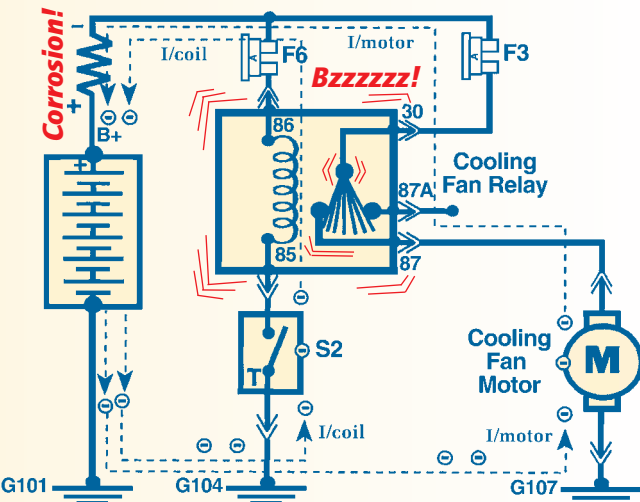


Figure 3: High resistance on the positive.

Squelching The Buzz

Remove the resistance in the relay coil circuit, and the relay circuit will resume normal operation because normal relay coil current can flow again. Replacing the relay or replacing the load on the relay contacts cannot fix this problem, as most parts-changers can probably tell you from experience.

How much resistance will cause this problem? About half the resistance of the relay coil. If the relay coil resistance is 80 ohms, it takes about 40 ohms in the shared relay coil circuit to start the relay buzz (provided the relay contact load current is several amps).

This does not mean you should use resistance checks to find the problem. Simply measure the voltage at Pin 86 — the B+ voltage side of the coil. A good voltage side circuit will read a steady B+ value when the relay is energized. If the resistance is on the B+ voltage side of the relay coil, the DMM reading will jump around, and it will be difficult to get a steady reading. You then know the excessive resistance and the bad connection are on the B+ voltage side of the relay coil.

If the DMM reading on the B+ voltage side is steady, measure the voltage at Pin 85 — the ground side of the coil. A good ground circuit will read a constant low voltage value of about 0.10 volt or less. If the resistance is on the ground side of the relay coil, the DMM reading also jumps around, and it will be difficult to get a stable reading. You then know the excessive resistance or the bad connection is on the ground side of the relay coil.

Next!

Temperamental Relays

Ever see a relay that sometimes clicks and sometimes does not? Sometimes the relay contacts CLOSE and sometimes they don't. Intermittent problems like these can be diagnosed just as easily as when the relay always fails to click and CLOSE the contacts.

Can you guess the cause of these temperamental relay problems? Changing the relay won't solve the problem because it is not a relay defect. It's a circuit problem that you can find with the proper troubleshooting techniques.

Figure 4 illustrates the cause of the problem. There is excessive resistance on the ground side of the relay coil between relay pin 85 and G104. It could be a bad connector at pin 85, a high resistance in the ground wire or a corroded ground G104. The resistance caused by the corrosion limits current through the relay coil when the control switch is CLOSED, just as any resistance limits current in a circuit.

If the resistance is high enough, the coil current will be too low to energize the relay, and the con-

tacts will not close. Some current flows through the relay coil, but the weak electromagnetic field pulling on the contacts can't quite close them. If the relay gets enough bumps and vibration from the movement of the vehicle, that may help the relay coil's weak magnetic field move the relay contacts to the CLOSED position. Once the contacts close, they remain closed until the relay is powered down.

Soothing The Temperamental Relay

Since there is a voltage drop on the ground side of the relay coil, the voltage on pin 85 is higher than 0.10 volt (usually several volts higher), indicating a bad ground. It is possible for the voltage drop to be on the voltage side, similarly reducing the current through the coil. This would make the voltage at pin 86 lower than it should be (several volts lower actually). A simple voltage check at pins 86 and 85 can reveal which side of the relay coil has the voltage drop. It doesn't matter whether the relay has closed the contacts or not. 'Intermittent relays' frequently (and incorrectly) get the blame for temperamental relay circuits like these. The voltage readings at pins 86 and 85 will be incorrect and identify which side of the relay coil circuit has a resistance problem. They are very easy to spot once you know what to look for.

Defective Relay Contacts

A third pesky relay problem can be caused by a voltage drop through the relay contacts. This voltage drop is due to relay contacts pitted and corroded after repeated opening and closing. This is a problem that occurs when relay contacts that must handle large currents have been in service for a long while. It can also happen to a relay that has been buzzing or functioning intermittently. **Figure 5** illustrates the condition of resistance in the CLOSED relay contacts. This condition produces a poor electrical connection between the contacts and has nothing to do with whether the relay will energize or not. The relay coil circuit is not affected by the condition of the relay contacts.

Corroded relay contacts affect the amount of current (in amps) that can pass through to the load controlled by the relay contacts. Defective contacts are a resistance in the circuit, which limits current to the load. Lower current to the load means the load will operate poorly (if at all). Defective contacts also drop some of the voltage, leaving lower operating voltage for the load.

This is one case where a new relay *will* fix the problem. But how can you tell whether the relay contacts are starting to go bad before the load is adversely affected?

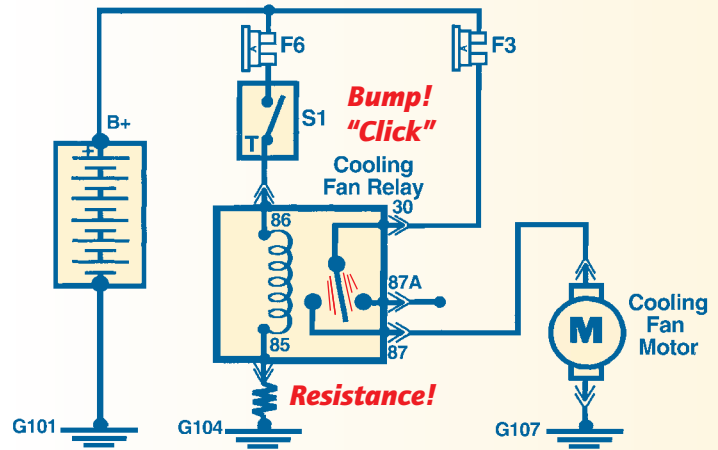


Figure 4

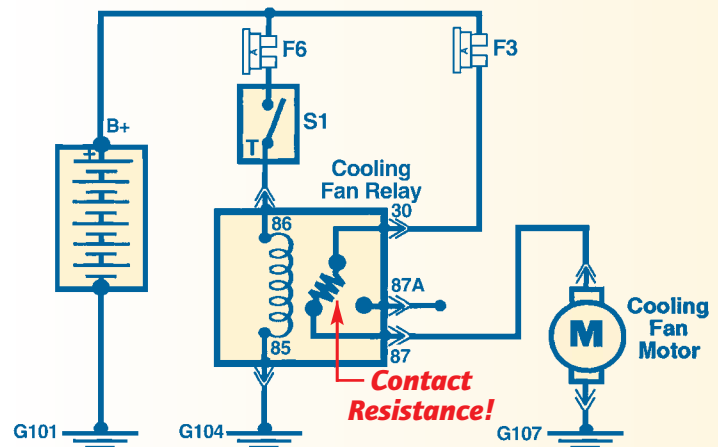


Figure 5

Relay Race

Graphing Bad Vibes

We rigged a radiator fan motor and its control relay in series with a dual-filament ignition ballast resistor, crosswired into series with itself, to simulate a poor ground connection between both components' ground terminals and the negative post of the battery. After flummocking around a bit to get just the right combination of relay, radiator fan current draw and ground circuit resistance, we found a combo that resonated at about 500 Hz, as you can see from the time scale on the screen captures. We monitored both voltage at relay and fan motor and current through the fan motor. None of our scopes or current probes can graph the small current through the relay coil, but its voltage trace indicates a similar pattern.

When the circuit closes to energize the relay, battery voltage is applied to the relay coil; and current flows, building the electromagnetic field and closing the relay's electrical load contacts. With the contacts closed, there's battery voltage available to the radiator fan motor, and the fan 'tries' to start.

But with the resistance we put in the ground side of the circuit, the available voltage begins to drop as soon as the fan motor starts demanding additional current. Almost at once, there's not enough voltage available to the relay coil or the electric motor to keep either party at work. The voltage drop caused by the ground circuit resistance equivalently reduces the voltage available to the relay and the fan motor. The relay springs are now stronger than the resistance-reduced magnetic force the first rush of current generated, so the relay contacts click open, chopping current to the fan motor.

But now, with the fan motor load removed from the circuit, battery voltage is available to the relay coil again, so current flows through the relay coil again, snapping the contacts closed again. And so on. 500 times a minute. If you're a musician, you already know our relay was singing a note or two above middle C.

The current graph shows the corresponding ampere pattern, bobbling up and down just as you'd expect. A surprising aspect of this vibrating relay syndrome is that when the malady occurs, the circuit consumes almost as much current as it

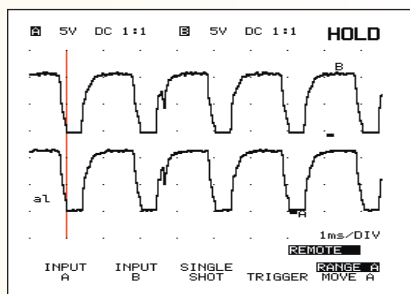
would if the fan ran normally. The energy, of course, goes entirely into jiggling the fan, humming the relay contact arm and frying the resistance on the ground side of the circuit. It does no useful work for the power consumed.

Of course, the fan motor meanwhile hardly twitches more than a fraction of a degree because there's not enough current applied long enough to overcome the friction and inertia of the armature and fan. The fix? As the article explains, clean out the high resistance on the ground side of the circuit, and all spins well in fantown.

— Editors

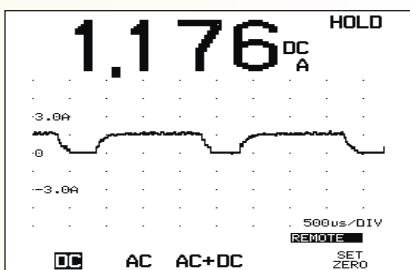
Voltage Patterns

The voltage pattern corresponds almost exactly between the relay coil and the radiator fan motor. Once the relay completes the circuit to the fan motor, the voltage available to the relay coil falls too low to hold the contacts closed. Once they pop open, the relay load circuit opens; and the circuit voltage goes back to the battery's potential, resuming the cycle.



Amperage Pattern

The current through both the relay coil and fan motor circuits follows the same pattern, cycling on and off as the relay contacts chirp at 500 Hz. Oddly enough, while the entire circuit consumes about the same amount of electricity as if the fan were running, the fan merely twitches in place. Almost all the power goes to heat the resistance between the loads and battery negative.



Troubleshooting Relay Contacts

There are two ways to check the electrical condition of the relay contacts. The first method is to energize the relay so the contacts CLOSE and the load draws current. Next measure the voltage at pin 30 and pin 87. The difference should be less than 0.30 volt, which is the voltage dropped (or blocked) by the relay contacts. The lower the voltage dropped by the relay contacts the better. More than a 0.30 volt drop indicates the contacts are either too small for the current they must handle or they are beginning to develop pitting caused by arcing when they OPEN.

A second way to check the electrical condition of the relay contacts is to energize the relay and measure the voltage drop through the relay contacts by attaching the red DMM test lead at pin 30 and the black DMM test lead at pin 87. Energize the relay and the voltage used by the contacts will appear on the DMM. It should be less than 0.30 volt.

One final point to remember. If the voltage drop at the relay contacts is too high and a new relay doesn't drop any lower voltage across the relay contacts, it's a sure sign that the load controlled by the relay is drawing too much current. But that's another problem for another time. ■

—By Vince Fischelli

The Answer: The reason the relay in Figure 1 does not have a spike suppression diode or resistor is that the relay coil is not controlled by a solid-state driver. Only with the advent of solid-state electronics in the early 1980's did it become necessary to control and suppress voltage spikes in automotive circuits. In B.C. (Before Computer) days, spike suppression was not necessary because there were no delicate solid-state driver circuits to protect. If you missed the answer, go back and re-run laps one and two of this relay race.