Return To Sender

Normally when we toss a letter into the mailbox, the last thing we want is to see it again, undeliverable and unopened. But when we diagnose electrical problems, the negative, or return side of the circuit is a critically important, and often forgotten component of each and every electrical circuit. When it comes to the ground side, return postage must be guaranteed.

Think about it for a moment. We've all poked around with a test light or voltmeter over the years looking for the voltage supply to a consumer. But since our tester provides its own path to ground, we sometimes forget that the electrical consumer's return circuit to the battery may be loose or damaged. If there is no "Return to Sender," there is no complete circuit, and our electrical force is undeliverable.

The Positive Side Gets All the Attention

We see lines and drawings all over the place in an electrical schematic showing the positive side. We read from top to bottom, and the positive stuff is usually at the top, getting top billing. But the ground side? Usually all we get to see of the ground side is that little upside down antenna-looking symbol at the bottom, or end of the circuit. At least it LOOKS like the end of the circuit. Maybe wiring diagrams should be drawn in circles instead of straight lines. That way we'd remember that our little ground symbol means "back to the battery."

And that's why the ground circuit is so often forgotten and ignored. But without a good return path for current, all the fancy wiring on the supply side won't do you a bit of good.

Conventional Versus Electron Theories

Thinking of the ground side as the return side implies that we're using Conventional Theory in this article. We are. Even though the chief wizards of science have shown that electrons flow from negative to positive (Electron Theory), many if not most of us are more accustomed to thinking in terms of current which flows from positive to negative (Conventional Theory). That's because automotive and electronics people don't always see eye to eye about which theory is the one we should adopt as automotive technicians.

But rather than get into a long and hairy discussion, let's move away from that point for a moment and make one simple observation:

An electrical circuit must be a complete circuit to operate properly, and that includes the ground side.

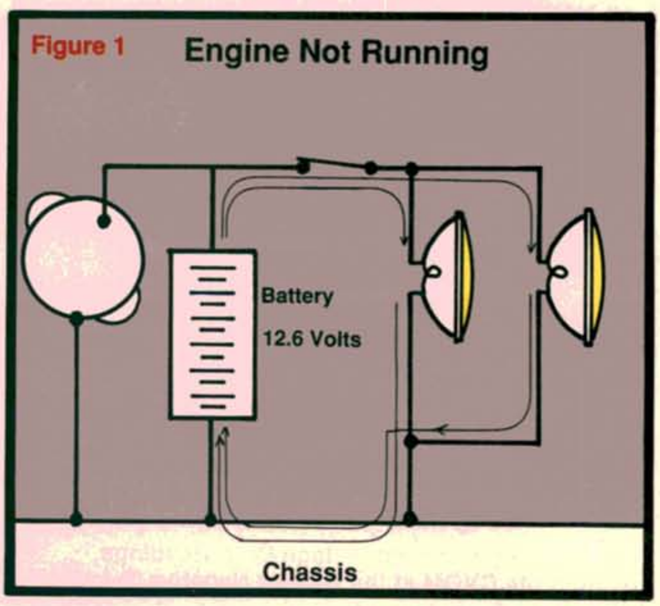
A Simple Headlight Circuit

Let's start by showing a common circuit. **Figure 1** shows a circuit you've all worked on before. It shows two lamps in parallel, and represents a common headlight circuit.

When the headlamp switch is closed, the circle is completed, the lamps light, and we can see where we're going. It's obvious that current will flow through the lamp filaments at this time.

Our engine is not running at this time, so there is no charging voltage. The battery voltage is the only force available to push current through the circuit.

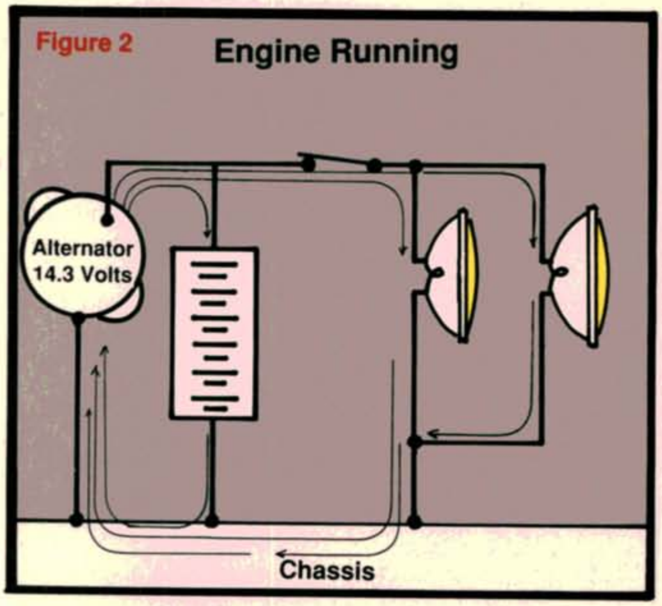
Current Flows to Lamps When Headlamp Switch is Closed



Same Circuit With the Engine Running

Figure 2 shows the same circuit. Only this time, the engine is running, and the alternator is generating a charging voltage greater than battery voltage. Now the alternator becomes the force driving current through the headlamps. This slightly higher voltage pushes more current through the lamp filaments, making the headlamps even brighter.

Current Flows to Lamps When Headlamp Switch is Closed



The higher charging voltage also overcomes the battery's voltage and forces charging current through the battery. The alternator is running the headlamps and also has enough left over to charge the battery.

Concentrating on the Ground Side

Let's swing over to the ground side for a while. Our illustration shows current flow with the engine running. In **Figure 3**, Lamp 2 has a resistance in the wire to its ground side. There is more resistance in the circuit, so less current flows through Lamp 2 and back to the alternator. The result? Lamp 2 is dimmer than Lamp 1.

If the resistance occurred on the voltage side of the circuit, you would have the same results—a dim Lamp number 2. But we're concerned with the ground side in this article, so let's not get sidetracked. (Pretty soon you'll start to get the idea that the ground side is the forgotten half of a complete circle, and every bit as important as the supply side.)

Lamp 2 has resistance on the ground side. We measure a 4.0 volt drop across the ground side of the lamp (switch closed, current flowing to the lamps). Since the alternator voltage is 14.0 volts, that leaves only 10 volts for Lamp 2.

A ground side voltage drop appears across the ground side of Lamp 2 so it is dimmer. Notice the DVOM on the ground side of Lamp 1 which has no ground side resistance. It reads only 0.10 volt, and as a result the lamp is bright.

SAE specifications call for ground circuits to have a voltage drop of 0.10 volt or less. That's good for any car or truck, domestic or import.

Where Do You Ground the DVOM?

Okay, just where do you ground the DVOM? This is very important, since the same bad grounds which can affect different consumers in the car, can also affect the DVOM's reading if you hook the negative DVOM to a bad ground connection.

Look at **Figure 9**. We have resistance in the ground circuit to the headlamps. For the moment, let's assume that the ground wires from the head lamps both go to a metal eyelet, and that that eyelet is connected to the chassis by a bolt screwed into the car's inner fender.

The battery is on the other side of the car, so for convenience, we decide to use the same bolt used to ground the headlights to ground the DVOM. We get a reading of 0.05 volt when we check the voltage drop at the ground side of the lamp. So why are the headlights still dim?

Because the DVOM's negative lead is not connected to a good ground.

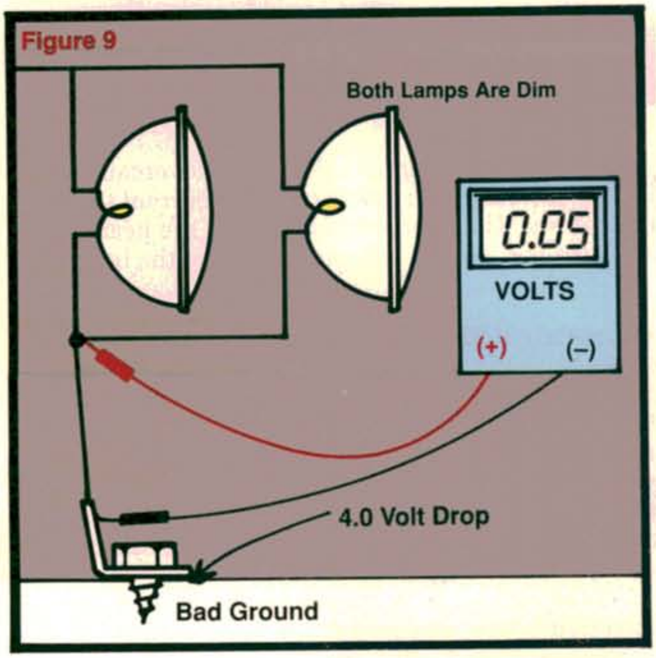
Remember this!

When diagnosing possible ground circuit problems ALWAYS ground the DVOM to the negative terminal of the car battery. Even if you've done a voltage drop test on the main and chassis ground connections, and they passed with flying colors, there are any number of other sub ground locations which may be loose or corroded.

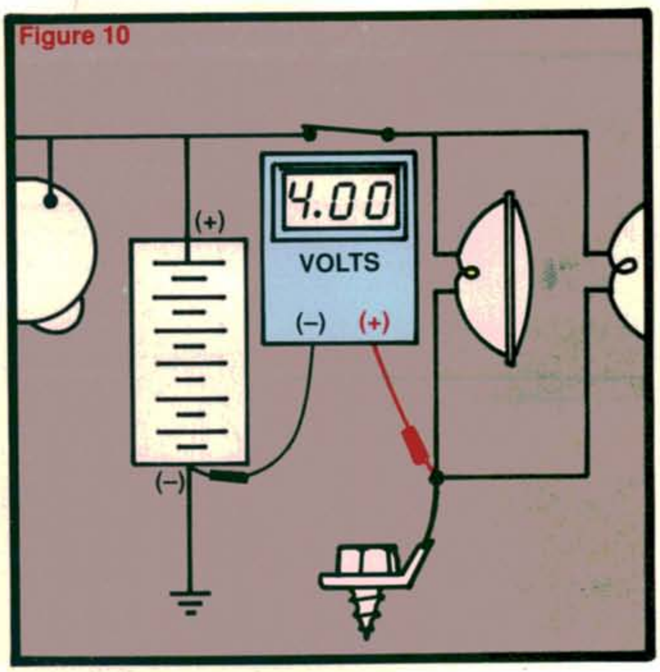
(The negative terminal of the battery gives us a reference point for all voltage drop tests—and on most cars, it's easy to reach. Yes, we know about Audis with batteries under the rear seats, BMWs with batteries in the trunk, and so forth. If you intend to use a ground point away from the battery terminal, you may still end up going back to the battery to test that particular connection, to be sure it doesn't have a voltage drop of its own.)

Let's look at the same voltage drop test with our DVOM connected to the negative battery terminal instead of being connected to that rusted and maybe loose bolt at the inner fender. Same test, but this time we show a 4.0 volt voltage drop (see **Figure 10**).

Now we know for sure why the headlamp is dim. The difference between the two readings tells us the sub ground at the inner fender is bad.



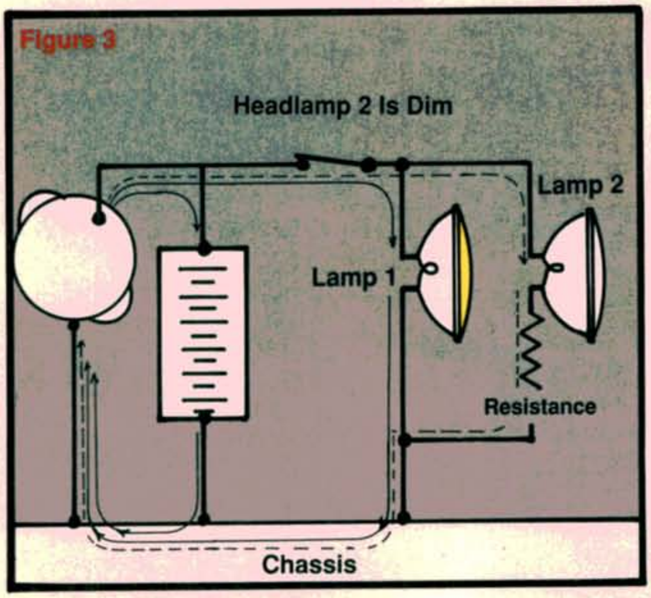
DVOM Indicates a Low Voltage Drop, but Reading is Inaccurate Because DVOM Itself is Connected to a Bad Ground



For the Most Accurate Voltage Drop Readings, Ground the DVOM at the Battery Negative Terminal

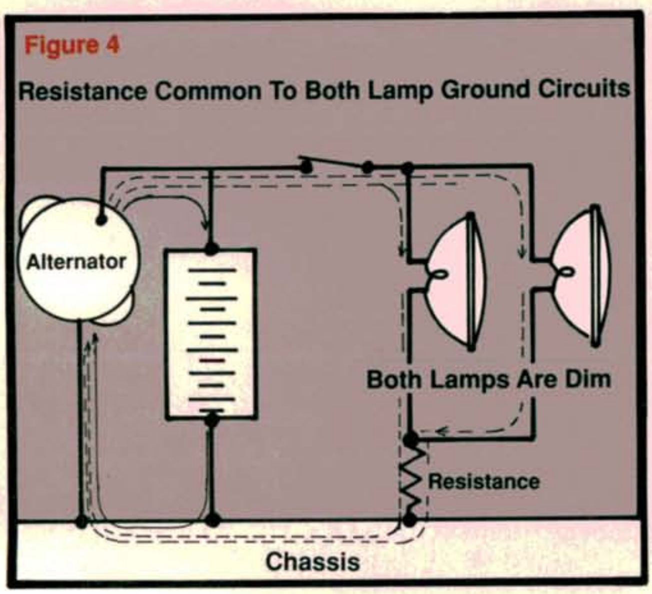
If we remove the resistance from the ground side of Lamp 2, and plug it into the ground circuit to Lamp 1, then the roles of the two lamps will be reversed. Now Lamp 1 will be dim, and Lamp 2 will shine brightly again.

Resistance In Ground Circuit To Lamp 2



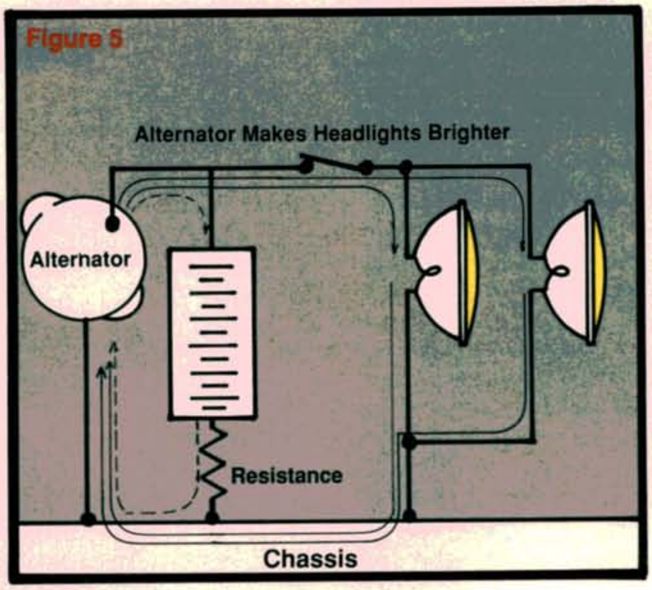
Finding the Resistance

Look at **Figure 4**. In this illustration, the resistance occurs at a ground side connector common to both lamps. This time both headlamps are dim. The main battery ground and alternator ground are both good, so other consumers, as well as normal alternator charging, are not affected.



Let's move our resistance one more time. Look at **Figure 5**. When the engine is off, the headlamps will be very dim, because the resistance is now located in the main cable between the battery and the ground circuit.

Resistance In Negative Battery Cable



Our resistance is not so great, however, that we can't start the car, and rev the engine. Let's also assume that our alternator has self-excitation. (That means it uses some of the current it generates to power itself, even if resistance in the circuit lowers battery current. Our alternator has a chance to charge, even with some resistance in the battery ground cable.)

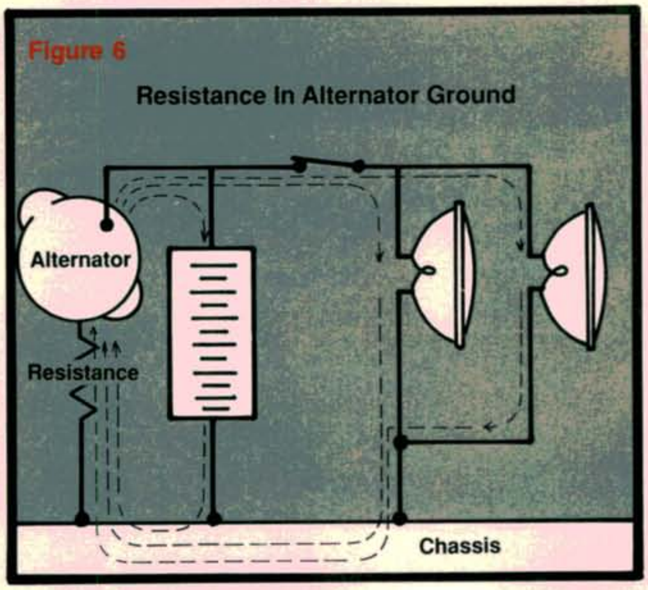
With the engine running, the headlights will get brighter as the alternator charges. The resistance in the main cable will reduce battery charging, however, and may ultimately lead to a dead battery.

A Look at a Bad Alternator Ground

Let's go back to our original schematic, and place some resistance in the ground circuit for the alternator. Look at **Figure 6**. This will reduce or eliminate charging depending on the amount of resistance present. The headlights may not brighten when we rev the engine. In fact, with the engine running, and other electrical consumers drawing on the battery to supply their needs as well, the headlights will get dimmer and dimmer as the battery goes dead.

The headlights will probably get brighter when you shut the engine off, since they become the only ones fighting for whatever current the battery has to offer in its weakened state.

A bad alternator ground means a low or no-charge and a dead battery. But how often do we check alternator ground?

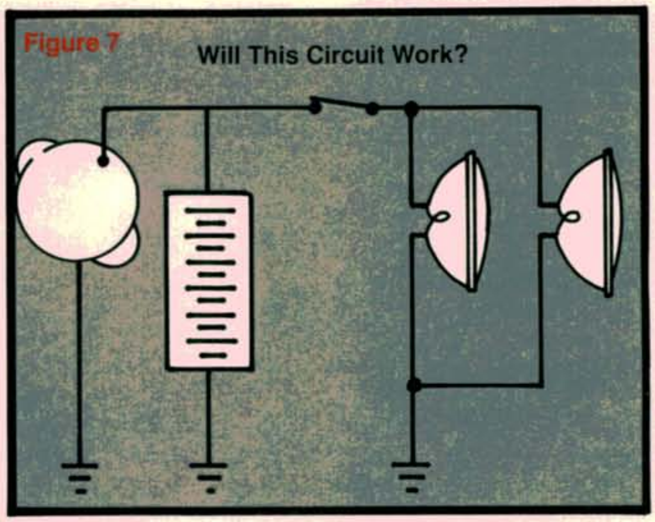


Upside Down Antennas

Look at **Figure 7**. Remember those funny little upside down antennas we mentioned earlier? Let's eliminate the chassis drawing from our schematic. Instead we'll replace it with an upside down antenna where each circuit goes to ground. If we close the headlamp switch, will the circuit still work? You bet.

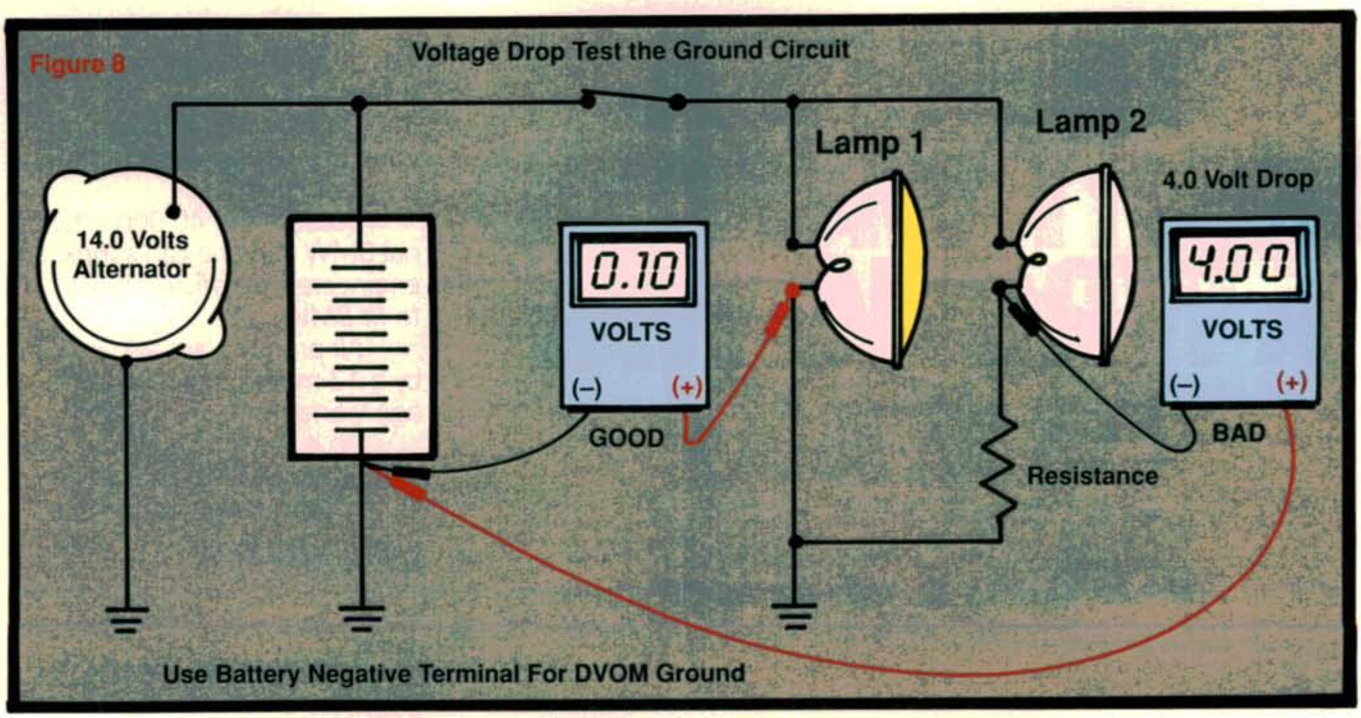
Each symbol shows how a given circuit is connected to the metal body or frame of the vehicle, completing the electrical circuit.

We'll use our ground symbols in the remaining illustrations.



Using Voltage Drop Tests to Check the Ground Side

You knew we had to go back to voltage drops before this was all over. A voltage drop test is the best way to check for a bad connection on BOTH sides of the electrical system. Look at **Figure 8**.



Problems Caused by Bad Grounds

Common problems with ground circuits are strange to hear about.
• Bad engine grounds have been known to cause shift lever linkages to act as ground circuits, welding these levers to the frame.
• Other reports tell of ball joints wearing out quickly. When removed, disassembled, and inspected, they show signs of arcing and pitting for the same reason.
• Premature automatic transmission failures are also attributable to poor grounds.
• Any metal part of the vehicle forced to work as a ground can exhibit these problems.

Basic Ground Side Tests

Case Study Number One

I once saw four separate alternators put on the same car. Each passed a bench test but would only put out about half a volt over battery voltage when installed in the vehicle. The battery tested out okay after being recharged. There was good voltage to the alternator. The alternator belt was tightened and then tightened again until it was pulled tighter than a guitar string.

Finally, in desperation, a wiring schematic was pulled from the shelf and studied. As things turned out, the alternator ground was provided by a wire and eyelet bolted to the front of the engine block, down low and out of sight.

The bolt was removed and cleaned, as were the eyelet and the threaded hole in the block. After two hours of frustration, the original alternator put out 14.5 volts.

Case Study Number Two

A customer with an Audi brought her car to a garage with a list of complaints, many of them related to intermittent electrical problems. She also brought new battery cables, purchased at the local parts store, and asked to have them installed.

Most of the Audi's electrical problems were caused by a corroded chassis ground. Originally, the chassis ground was provided by a crimped eyelet on the main battery ground cable which was bolted to the battery tray. Over time, the eyelet had been eaten away so badly, that it was pretty well destroyed, and separated from the old main cable as the technician removed it. As a result, he didn't even notice it was there.

The new cables had no separate wire for chassis ground, and in his hurry, the young technician forgot to install a separate chassis ground. After all, he never saw the old one come off!

The result was a great embarrassment when none of the consumers depending on that chassis ground would work. He ended up taking the customer home because he couldn't complete the job.

At about 3 AM he awoke from a fitful sleep, sat up in bed, slapped his forehead in disgust, and mumbled the word "dummy."

Maybe these voltage drop tests on the ground side will save you the same frustrations some day.

Checking the Engine Ground

To test the main engine ground, put your DVOM on the 2 volt range. Connect the DVOM leads between the battery negative terminal and the engine block. Now crank the engine to measure the voltage drop of the engine ground. Once again, the voltage drop should not exceed 0.1 volt for the ground to be considered good.

This is the first electrical test you should run on any car with electrical problems.

Check the Chassis Ground

Leave the DVOM on the 2 volt scale. Connect the leads between the battery negative terminal and a bare metal contact on the chassis. Turn on the ignition, but don't start the car. Then turn on all normal accessory loads—high beams, A/C high blower, windshield wipers, radio, and so forth. Look for no more than 0.1 volt if the chassis (accessory) ground is good.

If the main chassis ground checks out, but one or more of the consumers is dim (a lamp) or slow (a blower motor), check the wiring diagram to find any secondary ground locations or connections in the circuit to that consumer. Then use the voltage drop to check that sub circuit ground.

Checking the main chassis ground is the second test you should run on any car with electrical problems.

Check Computer Grounds

Use the same voltage drop tests to check the ECU grounds. The ECU ground is important not only for the ECU to think clearly, but also for the proper operation of ECU inputs and outputs.

Be careful here. Some electronic devices will have several ground leads going to a single ground terminal. Others may have separate grounds running to separate ground locations. A schematic is needed on many vehicles to help you find where to take your voltage drop readings.

Checking Individual Circuit Grounds

If one accessory on the car causes strange things to happen in other circuits when it's turned ON, grab a schematic and find out which components rely on which grounds to operate properly. This is especially important when engineers try to save some wire by grounding components in parallel through a single ground.

Some of you may be familiar with something called "stealing ground." If one consumer works properly until another consumer on the same circuit is switched on, look for a bad common ground. The added current flow from the extra consumer is more than the ground circuit can handle.

Tales From the Ground Side

You've probably noticed that the tests run to diagnose faulty grounds are the same tests used to check out the more glamorous supply side of the circuit. The ground side has always been the forgotten half of the circle every circuit must make both to and from the battery. And since the ground side is the one most often exposed to moisture and corrosives, it only seems logical that we start to include it in our troubleshooting thought process.

Drop us a line if you have a "Tale from the Ground Side." And don't forget to put a return address on the envelope, just in case.

—By Vince Fischelli