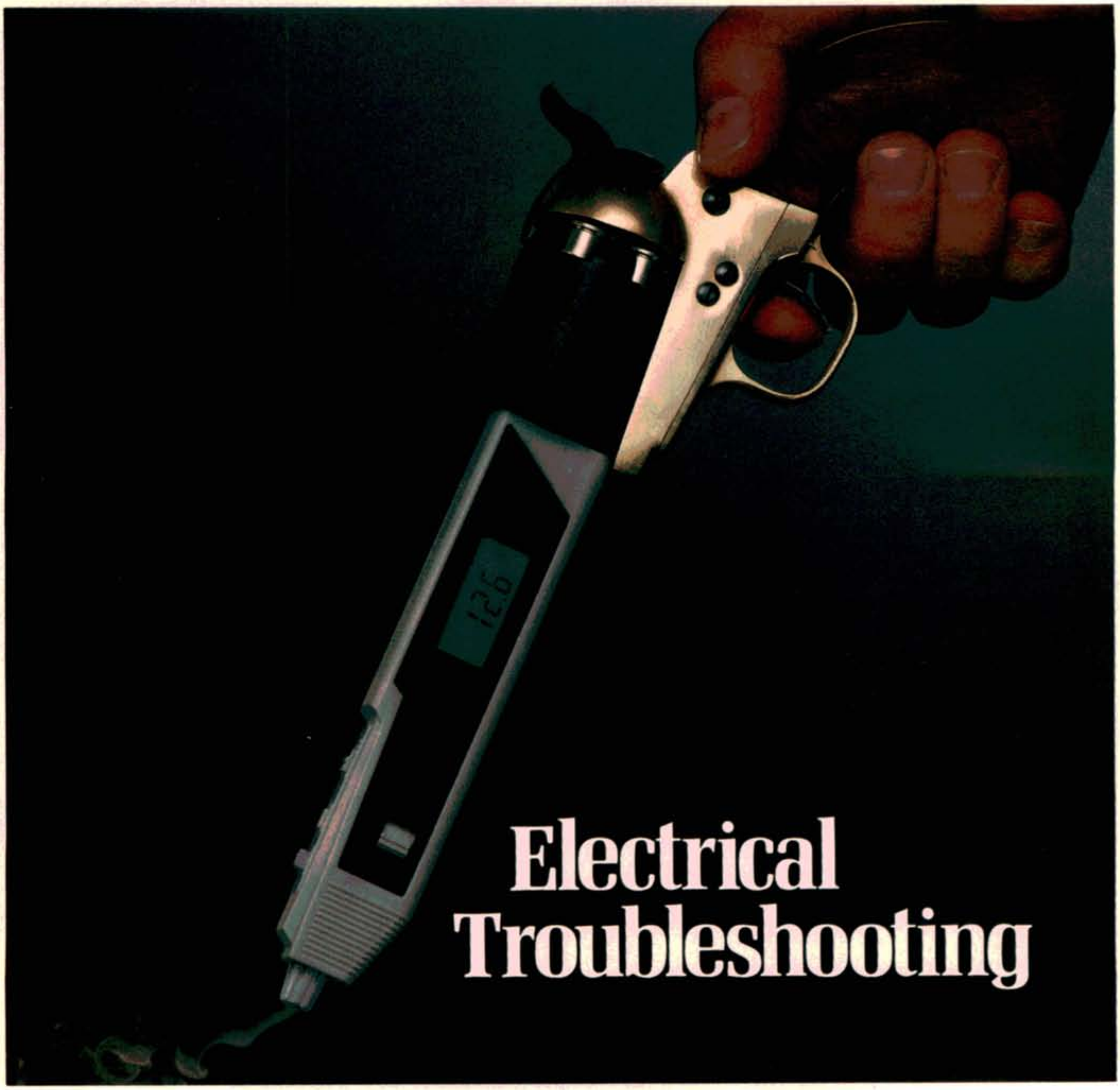


Electrical Troubleshooting

It's high noon at Shade Tree Gulch. The two technicians face each other on the main street. Of course, one wears a white hat and the other a black hat. People are ducking for cover while trying to keep a view of the action. The two technicians begin to walk toward each other. Each one's looking for an advantage to get the "drop" on the other one.

"Drop?" What do you mean by *drop*? Funny you should ask that question! This article happens to be all about a major "drop" that all technicians ought to know. It's called *voltage* drop. But before we get back to the excitement at Shade Tree Gulch, let's take a closer look at voltage drops.

The presence of a voltage drop in the electrical or electronic system of a vehicle absorbs operating voltage and keeps that voltage from getting to the load circuit. Since the load circuit gets less operating voltage, less current flows through the load. Therefore, the load doesn't work as well as it should. In some cases, the voltage drop is severe enough to completely shut down the load circuit. If you cowboys have ever seen a starter motor (the load) that couldn't turn fast enough to crank the engine due to corroded battery connections (the voltage drop), then you know what I'm talking about, kimo sabé!

Digital Accuracy Needed

Voltage drops reveal the location of hard-to-find electrical problems because the circuit resistance that produces the voltage drop usually cannot be measured with an ohmmeter. You must use a digital volt-ohmmeter, or DVOM, to locate voltage drops. (Some people call these meters DMMs, or digital multimeters.) Forget the old analog voltmeter with the swinging needle. It isn't accurate enough in the low voltage range (usually tenths of a volt) needed to measure voltage drops.

An additional advantage of voltage drop measurement is that it will detect a problem before the problem begins to affect vehicle performance. Obviously, this will save a lot of time. Checking voltage drops is also an effective way to find intermittent problems. Even if the intermittent problem is not affecting vehicle performance at the time you are checking voltage drops, a higher-than-normal voltage drop often indicates the cause of the intermittent condition.

Gringo Grounds

Down in Shade Tree Gulch, they got a saying that goes "First time the mule kicks you, blame the mule. The second time that mule kicks you, blame yourself—you're supposed to know better by then!"

These accessory/body grounds are like unfriendly mules. You may not think they're dangerous 'til one kicks you. But after the first one kicks you, you know how to handle them next time—you handle 'em the way "Varmint" Vince Fischelli tells you to! Trouble is, some fellers are so dense, a mule can kick them pretty often 'til they feel it. They don't feel a thing—and they don't fix a thing, either! They send all their electrical problems down to your corral.

So how many ways can a bad accessory ground kick you? Count 'em, pardner:

- **flaring or flickering headlights**
- **erratic or sluggish turn signals**
- **undercharging or overcharging**
- **poor EFI performance**
- **damaged transmission shift cables**
- **any number of combinations of erratic and/or intermittent electrical problems.**

Figure 1a

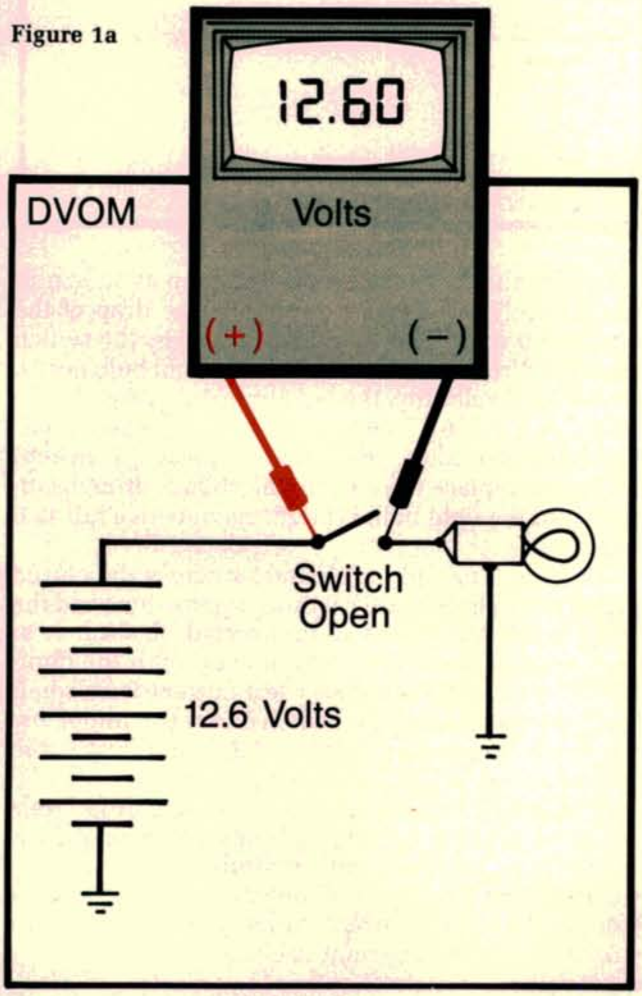
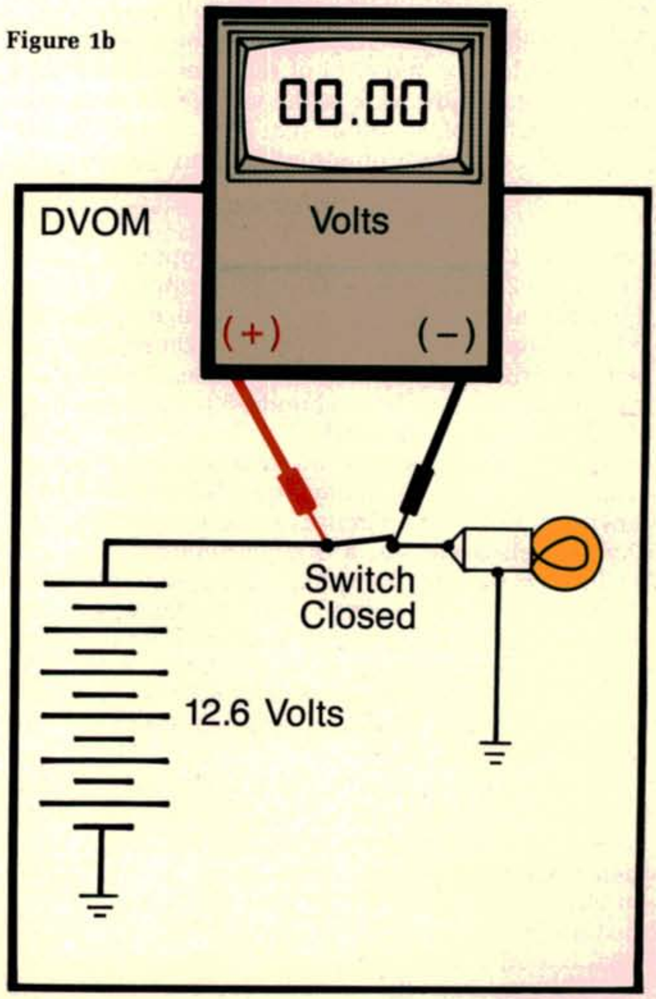


Figure 1b



Ohm's Law Revisited

Now before you get your spurs caught in mesquite brush and get pulled off your horse, you need to see the voltage drop principle again. To explain this principle, we'll use the old faithful companion of the automotive technician, Ohm's Law. (Any similarity to Tonto is strictly in your own mind!)

In its basic form, Ohm's Law says that E = I × R. The voltage drop is equal to the current times the resistance. Voltage drops have two ingredients, current and resistance. One without the other means there is no voltage drop.

E = Amps × Resistance

- So, E = 1 × 0 = 0 voltage drop.
- Or, E = 100 × 0 = 0 voltage drop.

You can see that it doesn't matter how much current flows through a circuit or wire. If there is no resistance, there is no voltage drop. But when resistance is present, look what happens to the voltage drop.

E = Amps × Resistance

- So, E = 1 amp × 1 ohm = 1.0 volt dropped.

See what happened? Only one amp of current flowing through only one ohm of resistance produced a one volt drop. Now look at the voltage drop that occurs when a typical automotive level of current, 200 amps, flows through only *tenths* of an ohm.

E = Amps × Resistance

- So, E = 200 × 0.01 = 2.0 volts dropped.
- Or, E = 200 × 0.02 = 4.0 volts dropped.

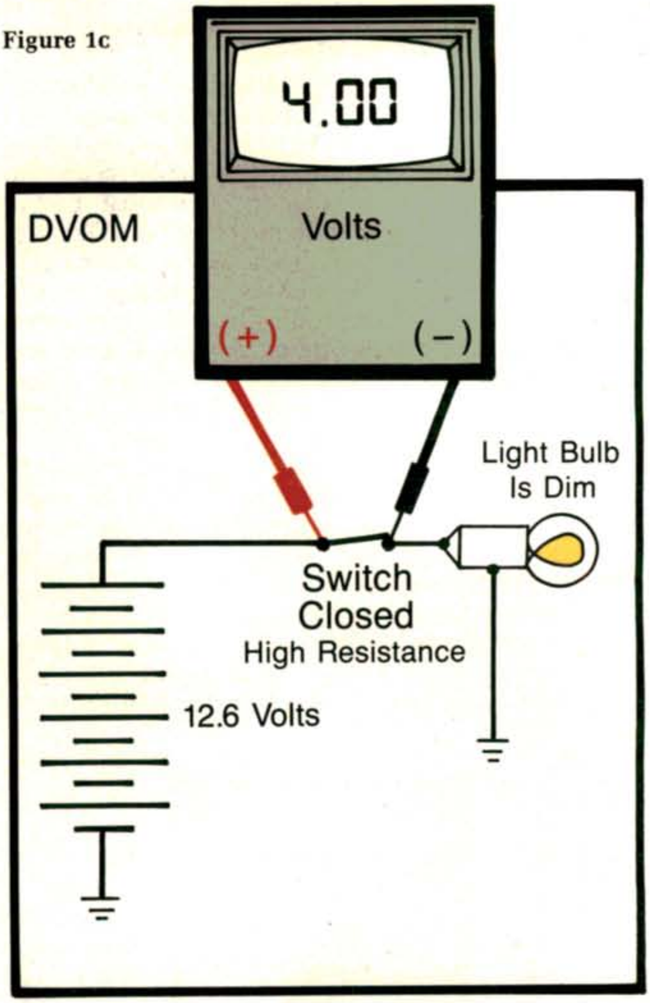
It doesn't take much resistance to produce significant voltage drops in automotive circuits because high currents flow through very small resistances. These small resistances, usually about a hundredth of an ohm (0.01 ohm), cannot be measured accurately with an ohmmeter. It's also critical that you understand that voltage drops only appear when the *normal* circuit current is flowing through the circuit. So in these cases, the ohmmeter is useless as a troubleshooting tool.

To help you see the voltage drop principle more clearly, we can use a simple switch such as the one shown in Figure 1a. In Figure 1a, the DVOM is placed across an open switch and reads 12.60 volts. The voltage drop across the open switch is the same as battery voltage. Also, no voltage reaches the light bulb, so the bulb is off. This is a normal circuit condition.

In Figure 1b, the DVOM reads the voltage drop of the switch when the switch is closed. If the switch has no resistance to current passing through its contacts, then there is no voltage drop—as shown by DVOM number 2. The full 12.6 volts from the battery reaches the light bulb and the bulb burns brightly. This is the ideal circuit condition.

Now suppose the switch contacts had some

Figure 1c



resistance that produced a 4.0 volt drop as shown in Figure 1c. The DVOM reads the voltage drop of the switch, 4.0 volts. The 4.0 volts dropped by the switch takes away from the 12.6 volts that the light bulb needs. With the 4.0 volt drop, the light bulb only gets 8.6 volts (12.6 − 4.0 = 8.6). At 8.6 volts, the light bulb is dim. To repair the circuit, you have to replace the switch. When you replace the switch, the voltage drop disappears and the light bulb is bright again with a full 12.6 volts.

If you connected an ohmmeter across the closed switch contacts, it could easily read zero ohms and the defective switch would go undetected. Resistance to the switch contacts may not show up with the ohmmeter because the ohmmeter test current is so small that it passes through the switch contacts without any resistance. Remember that a voltage drop test is the only sure way to find a defective switch.

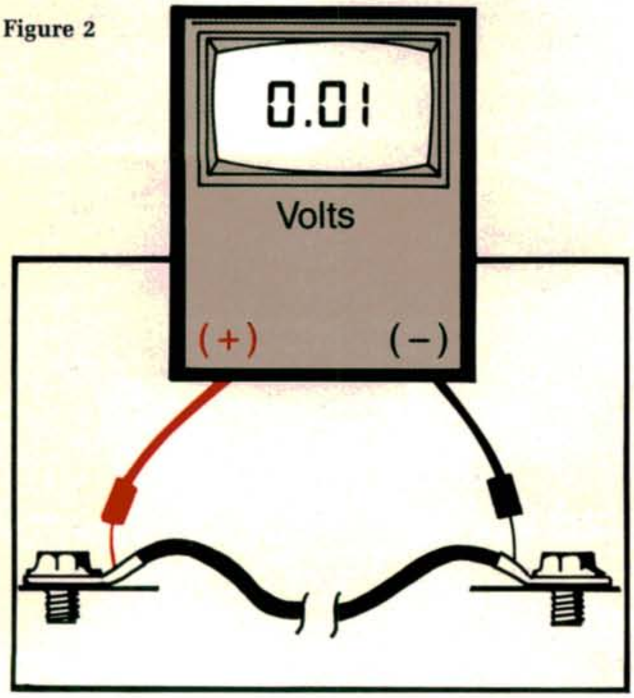
The recommended maximum voltage drop levels are given by the Society of Automotive Engineers (SAE). The maximum voltage drops are:

- 0.0 volt for small wire connections;
- 0.1 volt for high current connections;
- 0.2 volt for high current cables;
- 0.3 volt for switch or solenoid contacts.

Since the switch in Figure 1c had a 4.0 volt drop, clearly it is defective. It should not have exceeded 0.3 volt.

To check the voltage drop of cables, use the technique shown in Figure 2. Place the DVOM leads across the cable from end to end. As long as normal circuit current is flowing through the cable and the voltage drop doesn't exceed 0.2 volt, the cable is good. If the voltage drop is greater than 0.2 volt, the cable is showing signs of deterioration. It's developing resistance to current flow and this resistance will worsen as time goes on, resulting in vehicle system failure.

Figure 2

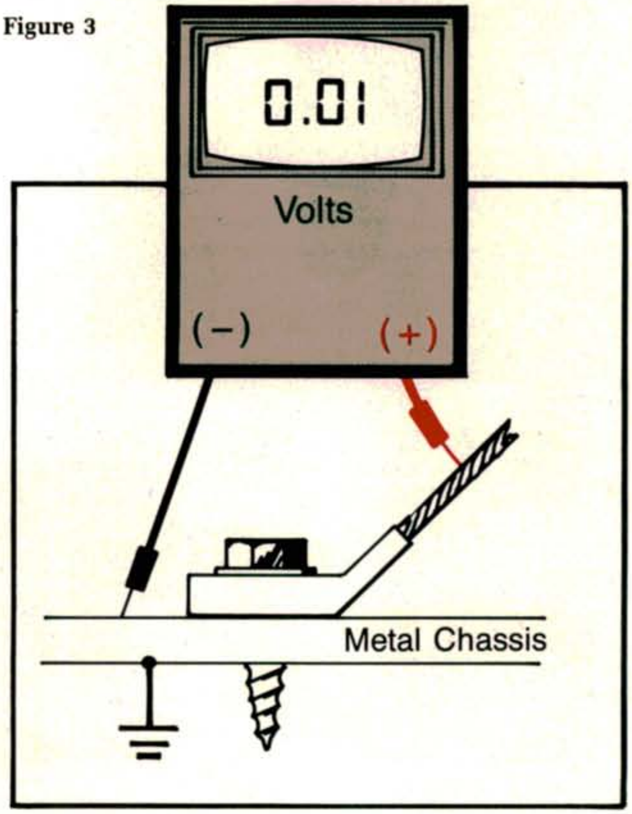


Shooting Down Bad Grounds

Use the same technique to measure the voltage drop of ground connections, as shown in Figure 3. Connect the DVOM between the cable strands and the metal chassis. It's best to use a DVOM lead with a fine point to pierce the cable insulation in order to make contact with the cable's metal strands. A voltage drop greater than 0.1 volt indicates a faulty ground connection.

Suppose the voltage drop is 0.3 volt on a vehicle that has an intermittent problem. The problem is not showing up at the time you're working on the vehicle. That higher-than-normal voltage drop could indicate a defective ground connection that's causing the intermittent problem. Take the connection apart, clean all contacting metal surfaces, and reassemble the connection. The voltage drop should fall to a normal level—provided the problem is not where the cable is crimped into the ground lug. This way, you can detect intermittent problems even when they aren't occurring.

Figure 3



Which Side of the Horse Are You On?

Voltage drops can be applied to every part of the electrical and electronic system. Your skill in using voltage drop measurement to find problems will grow each time you use it.

There are two major parts to every electrical circuit: the positive voltage side of the circuit and the negative voltage side of the circuit. For the benefit of you cowboys, it's just like your horse. That horse has a right side and a left side.

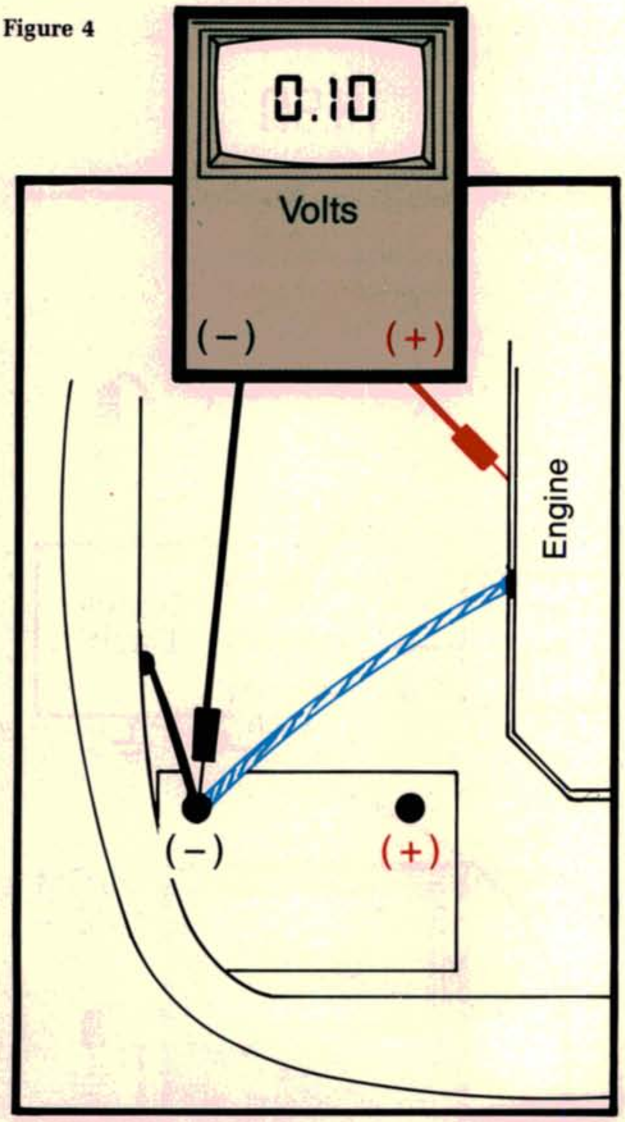
The positive side of the circuit begins at the positive battery terminal and ends at the positive side of the load. (The load in Figure 1 is the light bulb.) Therefore, the switch in Figure 1 is is in the positive side of the circuit. The negative side of the circuit begins at the negative terminal of the battery and ends at the ground side of the light bulb. Each side of the circuit has its own voltage drop depending upon circuit conditions. You can use these voltage drops to determine if either side of the circuit has a problem. Let's go through a series of typical voltage drop tests.

Check Ground Side First

Okay pardner, the vehicle has an electrical or electronic problem in it? The very first voltage drop tests you must make on any problem car are on the two battery grounds. These grounds are common to every car and are in the negative side of the circuit.

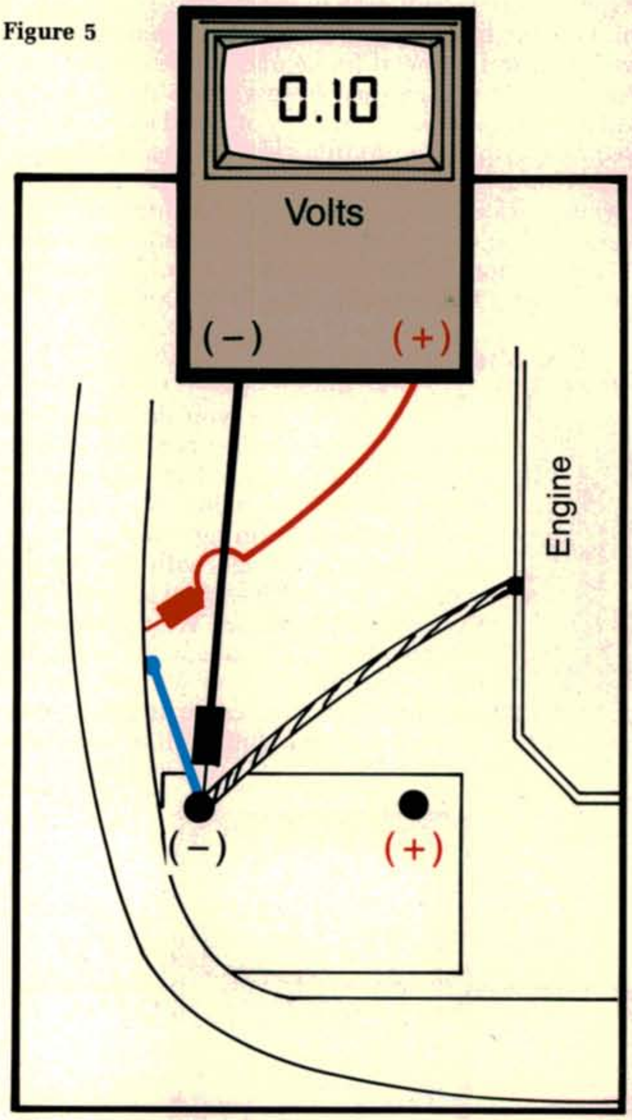
The first ground connection is the engine ground shown in Figure 4. Here's just one example of how voltage drop measurement can save you time.

Figure 4



Instead of visually following the engine ground cable and inspecting the cable and its connections, just check its voltage drop. Besides, in many cases you can't see the corrosion inside a connection that's causing the voltage drop! Connect the DVOM test leads as shown in Figure 4 and crank the engine. The voltage drop should not exceed 0.2 volt on most

Figure 5



vehicles. If the cable is very long, the voltage drop may be about 0.3 volt but should pose no problem.

As long as the voltage drop is normal, you don't have to waste time with a visual inspection of the cable and connections at both ends. If the voltage drop is higher than normal, clean the connections. If that doesn't fix it, replace the engine ground cable.

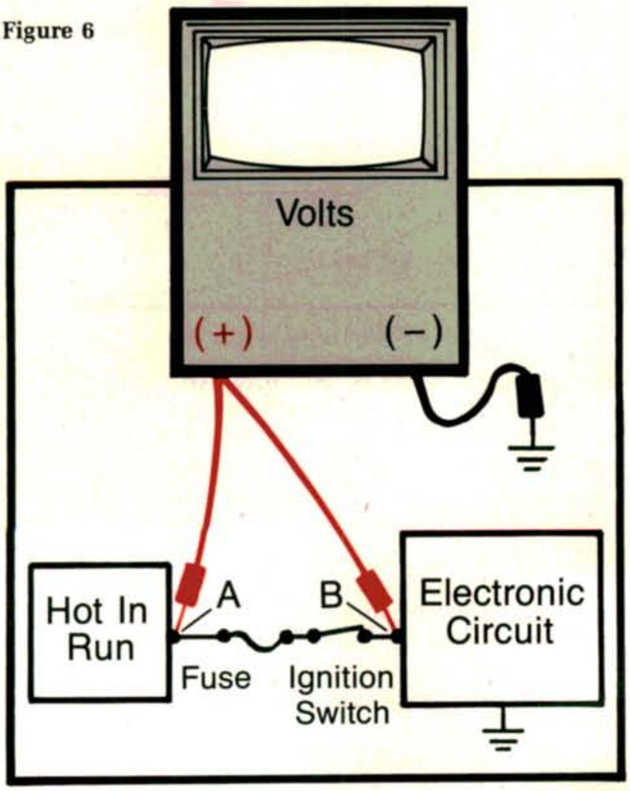
The second ground connection is the accessory ground shown in Figure 5. Turn on the ignition switch but don't start the engine. Next turn on all accessories, including the headlights, the wipers, radio, blower motor on high speed, etc. Check the accessory cable voltage drop as shown in Figure 5. The voltage drop should not exceed 0.1 volt. If it does, clean the connections at both ends of the accessory cable and retest it. If cleaning doesn't eliminate the voltage drop, replace the accessory cable.

Once you have determined that these two ground connections are good, then you have determined that the metal frame of the vehicle is a good connection or good current path back to the negative terminal of the battery. In other words, the battery is properly grounded to the metal frame and to the engine. Experience has shown that these voltage drop checks will reveal the cause of a variety of weird and unusual electrical symptoms. At first glance, these symptoms seem confusing to those technicians who do not or have not used the voltage drop measurement technique. If you're interested in eliminating the causes of these symptoms, you will always check the voltage drops across these two ground connections first.

Positive, Pardner

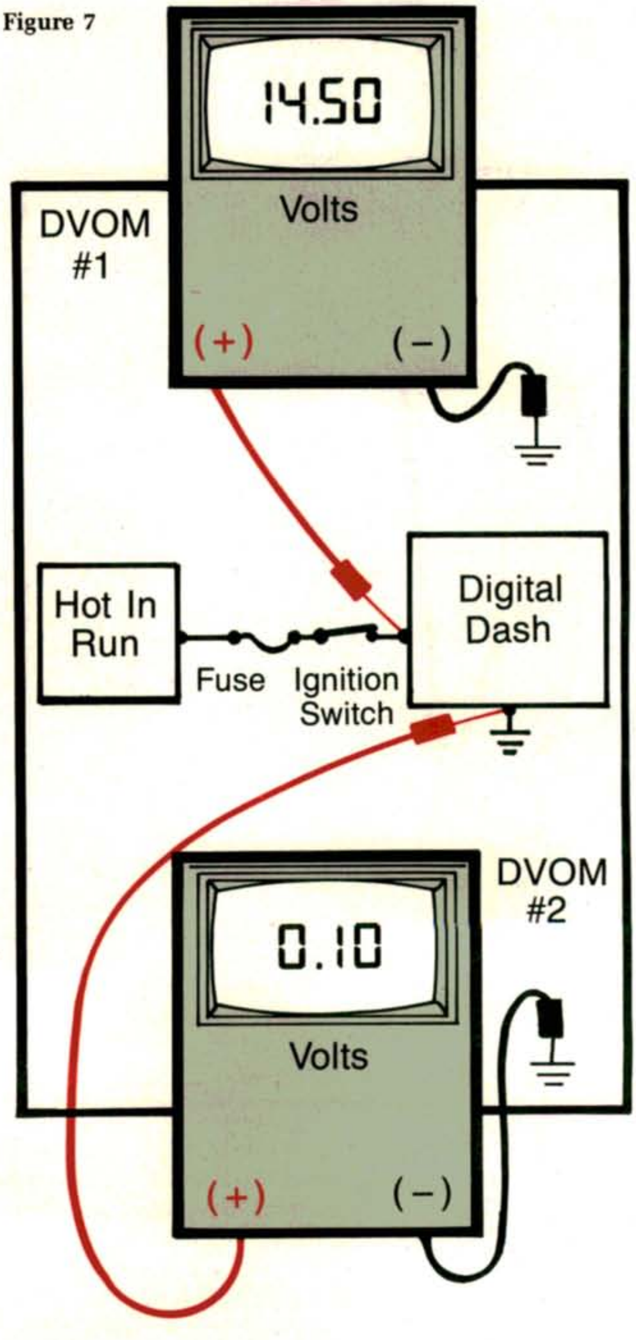
I'm going to ask you cowboys two questions. What is the operating voltage for the electrical and electronic system when the ignition switch is on and the engine is NOT running? Next, what is the operating voltage with the engine running? I call this second situation the Hot-In-Run condition. Well pardner, if you answered 12.6 volts with the engine off and charging voltage with the engine running, you can come to the dance tonight. Just be sure to check your Colt at the door!

Figure 6



Now look at Figure 6. The electronic circuit gets operating voltage through the fuse and the ignition switch. When the DVOM measures 14.5 volts at Point A and 12.2 volts at Point B, you've identified a voltage drop of 2.3 volts (14.5 − 12.2 = 2.3) between A and B. As you might expect, the electronic circuit will not function well at the lower voltage of 12.2 volts. The voltage drop may be in the ignition switch, in a high resistance connection in the fuse box, or a high resistance connection in the wiring. If you connected the DVOM between points A and B, it would read 2.3 volts to confirm the voltage drop. To pinpoint the reason for the voltage drop, measure the voltage drop of each component or section of the positive side of the circuit. This means performing a separate voltage drop across each length of wire, each connection, each fuse, and each switch in that circuit.

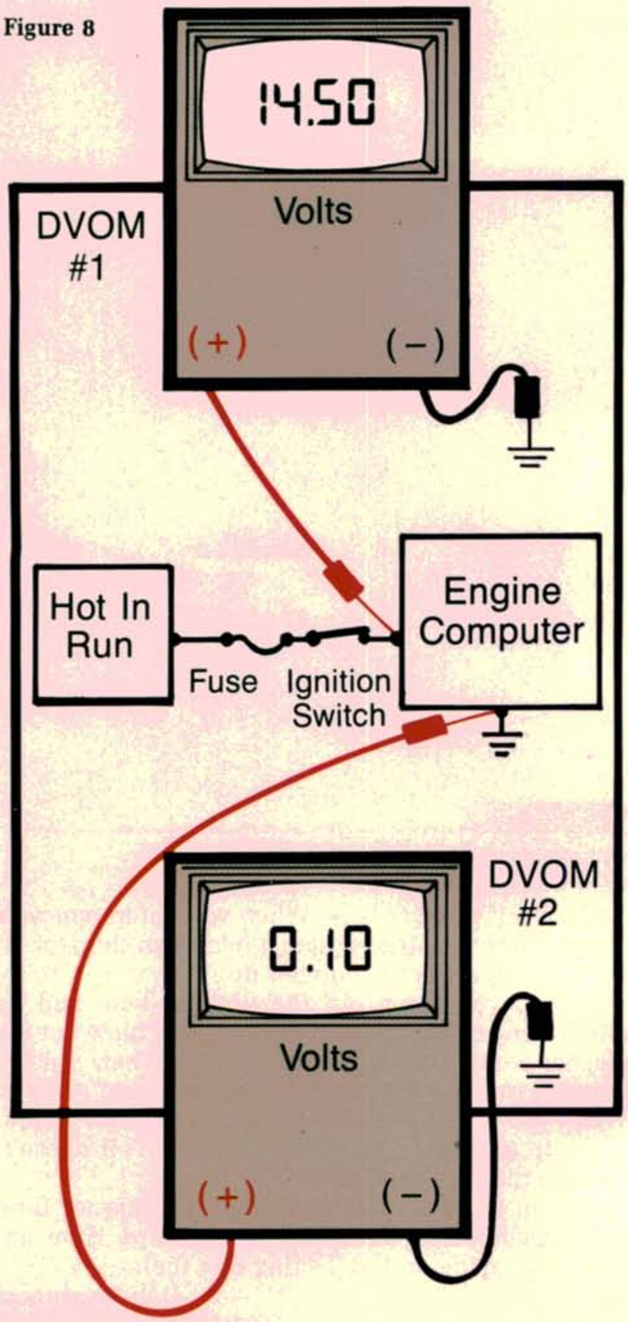
Figure 7



Dastardly Digital Dashboards

Now let's apply the voltage drop principle to some examples in the electronic system of a typical horse, I mean vehicle, that you encounter today. Figure 7 shows the operating voltage and ground to a digital dash. DVOM number 1 measures the operating voltage to the ignition input of the digital dash. The reading should be the same as the Hot-In-Run voltage. If not, a voltage drop exists in the positive side of the circuit. This would cause the digital dashboard to operate erratically whenever its operating voltage is low.

Figure 8



DVOM number 2 in Figure 7 measures the voltage drop of the ground connection for the digital dash. The reading should be no more than 0.1 volt as shown in DVOM number 2. If a voltage drop exists in either side of the digital dash circuit, some of the dash segments may be on or off at the wrong time. Other segments may be on very dimly when they should be off. Of course, changing the digital dash doesn't fix the problem. Correcting the voltage drop does, but first you have to know which side of the dash circuit has the voltage drop. The only way to tell is to perform voltage drop measurements on both the positive and negative sides of the circuit. If there's no voltage drop in either side of the circuit, the digital dash is probably defective.

The final example of voltage drop measurement is shown in Figure 8. It shows how the engine computer gets operating voltage and its ground connection. Suppose the owner has a driveability complaint about this vehicle. If a voltage drop in either side of the engine control computer circuit is causing the problem, it won't matter how many times you change the computer or tune up the vehicle. Until you find the voltage drop and repair it, the driveability problem will recur. You must check both the positive and negative sides of the engine computer circuit. DVOM number 1 reads the operating voltage to the computer's ignition voltage input. Voltage at this input should read the same as the Hot-In-Run voltage. DVOM number 2 reads the voltage of the engine computer ground. The reading across this ground should not exceed 0.1 volt as shown in DVOM number 2. A voltage drop in either side of the engine computer circuit reduces the ability of the computer to control engine performance. Consequently, fuel delivery and spark timing are not precise. The vehicle may run sluggishly, surge, or idle poorly. Always voltage-drop the entire engine computer circuit before you replace anything!

Meanwhile, Back in the Gulch . .

Now back to Shade Tree Gulch where the two technicians were facing off out in Main Street. Well, what do you know—everything happened while you were reading this article. The streets are quiet again. People are strolling around like nothing happened.

But folks all agree it was over pretty quick. Naturally, the technician in the white hat won. Yeah, he was quicker than the feller in the black hat. But his holster held something more powerful than a Colt .45—he packed a loaded voltmeter!

Take my advice, pardner. Strap a DVOM to your side before you ride into Shade Tree Gulch. Be ready to use it.

Adios, all. Happy trails to you!

—By Vince Fischelli