

Diagnosing voltage drop

Electrical automotive troubleshooting

Application Note

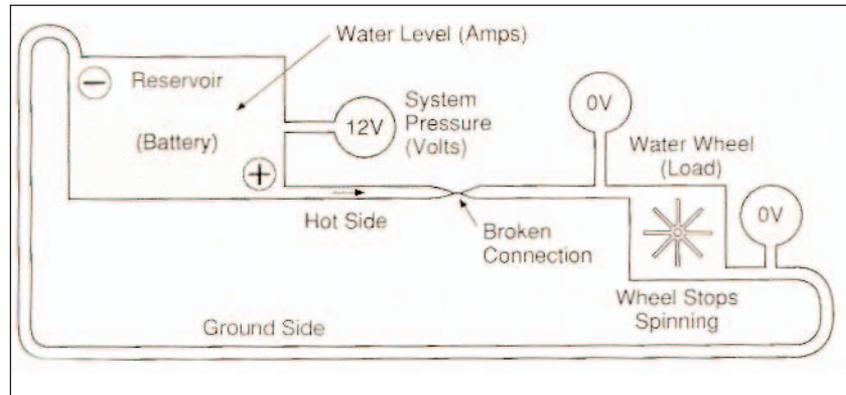
One of the most rampant electrical maladies showing up in automotive service bays today is the phenomenon known as voltage drop. Left unchecked, voltage drop causes countless unsolved electrical mysteries, especially when it infects the ground side of a circuit. It can also trick you into replacing parts that are not bad. The more connections and wiring a vehicle has, the more vulnerable the electrical system is to voltage drop.

To contain electrical voltage drop, practice safe electrical service. This means measuring voltage drop before reaching any conclusions. "Voltage dropping" a circuit will tell you when the circuit is too restricted to operate a component (motor, relay, light bulb, etc.) or operate it correctly. If the circuit is restricted, repair it and retest. If there is no restriction and the component still does not run or run correctly, then replace the component.

Symptoms of voltage drop

Often confusing and contradictory, electrical voltage drop symptoms vary according to the circuit's job and the severity of the voltage drop.

- inoperative electrical parts
- sluggish, lazy electrical devices
- erratic, intermittent devices
- devices that work sluggishly or erratically during periods of high electrical loads
- excessive radio interference or noises in the radio
- damaged throttle or transmission cables or linkage
- repeated throttle or transmission cable failures



In this example, if the water pipe completely collapses, water stops flowing, pressure drops to zero and the water wheel stops turning. Electrically, the same thing happens when a wire falls off or a connection breaks. Current stops flowing, voltage drops to zero. A starter motor would quit or a headlight would go out.

- damaged drivetrain parts
- engine or transmission performance complaints
- no-starts or hard starts
- high sensor or computer voltages
- erratic engine or transmission computer performance
- false trouble codes in the memory of any on-board computer
- premature or repeated A/C compressor clutch failure.

This symptom list brings up several points.

1. Visual inspections miss most cases of electrical voltage drop. You usually can't see the corrosion inside a connection or the damaged wire that is causing the problem.
2. Ground-side voltage drop, a commonly overlooked cause of electrical trouble, can cause most of these symptoms. Any circuit or component is only as good as its ground.

3. The more sophisticated electrical systems become, the more important their grounds are. The number of electrical components has increased exponentially and most do not have separate ground wires. Instead, these devices are grounded to the engine or body. Rust, grease, vibration and/or careless repairs often restrict the circuit from the engine/body back to the battery.

4. Many components such as engine sensors share a common ground. Therefore, a bad ground complicates diagnosis because it affects several components at once.

5. Some shop manuals and diagnostic charts or fault trees recommend checking grounds last. In reality, it is much quicker to check ground circuits before you climb that fault tree.

6. It's quicker and smarter to routinely check a circuit's voltage drop than it is to memorize long lists of symptoms. If experience has taught us nothing else, it's that chasing symptoms is no substitute for routine and thorough voltage drop testing.

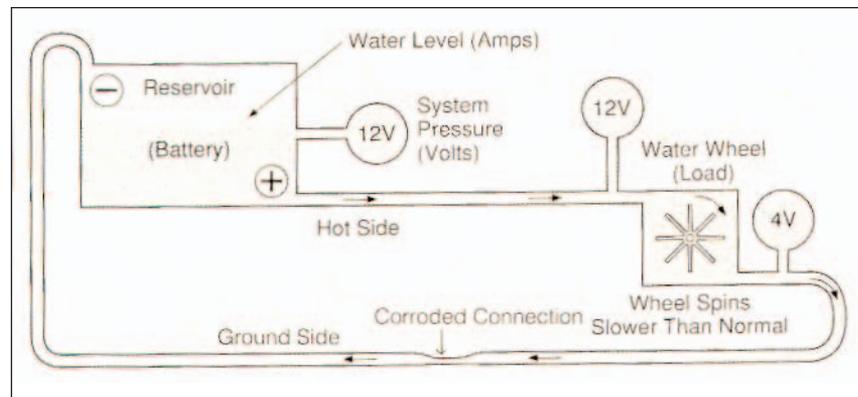
Experience has taught us other reasons to check voltage drop first. Voltage drop, usually on the ground side, causes inaccurate or bizarre voltmeter readings and oscilloscope patterns. Moreover, when you connect a voltmeter or scope to a system with bad grounds, the test equipment itself can create a good substitute ground. This can be frustrating: as long as your equipment is connected, the circuit works and you can't find anything wrong!

Basic procedures

Whenever an electrical problem gives you fits, take a deep breath and think of the basic electrical building block, the series circuit. The drawings depict basic series circuits. No matter how complicated a system is you can always simplify it into mini-series circuits. Then, inspect each circuit for voltage drop.

Also, relate electricity to water flowing through a water circuit. Water pressure inside the reservoir pushes gallons of water through the pipe. The water turns the water wheel and then flows back into the reservoir. In an electrical circuit, electrical pressure (voltage or volts) pushes electrical volume (current or amps) through the circuit, operating a load. The load may be a computer, a motor, a lamp, a relay, or other device. In the water circuit, the water uses up most of its energy turning the water wheel. Water continues flowing toward the reservoir, but it flows at a lower pressure.

Likewise, electrical pressure (voltage) is used up operating the load. Therefore, voltage falls to about zero on the ground side, but current keeps flowing toward the battery. Because the voltage in a healthy ground circuit should be about zero, some technicians call it *ground zero*.



A kinked return pipe restricts water flow back to the reservoir, slowing down the water wheel and causing a pressure reading on the return side of the wheel. Likewise, ground side voltage drop hurts load performance and causes a voltage reading at the ground side of the load.

Resistance-restriction

When you think of excessive resistance, imagine a dent or kink that is restricting water flow through a pipe. Common sense should tell you that a kink anywhere in the water circuit (supply side or return side) restricts water flow, causing the water wheel to slow down or stop turning. Excessive resistance has the same effect on an electrical circuit. Bad connections and broken or under size wires act like a pipe with a kink, restricting current flow. Like the water circuit, restricting current flow anywhere — hot side or ground side — hurts the performance of the load. The

effect on the load is hard to predict because it varies with the severity of the restriction. For example, the motor in a restricted circuit may stop working or just run slower than normal.

A restricted circuit can cause an A/C compressor clutch to slip and prematurely burn out. A computer on a restricted circuit may shut off or else work erratically. When corrosion, loose connections or other types of resistance restrict a circuit, volts and amps both drop. If volts drop, amps drop too. That is why when you find a voltage drop in a connection or cable, you know the connection or cable is restricted.

Look at the water circuits in our drawings and remember two critical points. First, a free-flowing ground side is as important as a free-flowing hot side. Second, a ground side restriction is the only thing that causes voltage readings greater than 0-0.1V in any ground circuit.

Voltage drop tests

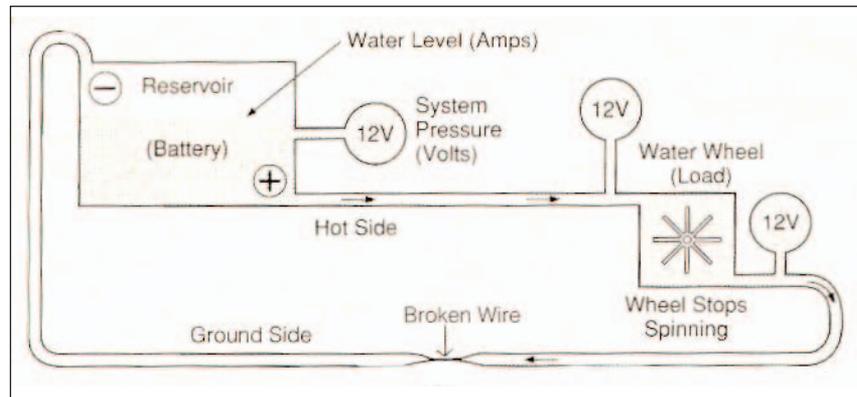
Electrical voltage drop varies according to current flow. Unless you operate the circuit so current flows through it, you can't measure voltage drop. Because an ohmmeter's battery can't supply the current that normally flows through most circuits, ohmmeter tests usually can't detect restrictions as accurately as a voltage drop test.

Open-circuit problems such as broken or disconnected wires or connections stop current flow. After you fix an open circuit, switch the circuit on again and check for lingering voltage drop. Until you get current flowing and check the circuit again, you can't know if the entire circuit is healthy.

Although resistance-free connections, wires and cables would be ideal, most of them will contain at least some voltage drop. If your manuals do not list voltage drop values, use the following as maximum limits:

- 0.00 V across a connection
- 0.20 V across a wire or cable
- 0.30 V across a switch
- 0.10 V at a ground

Because most computer circuits operate way down in the milliamp range, they don't tolerate voltage drop as well as other circuits do. Note that a milliamp is one-thousandth (0.001) amp. The recommended working limit is 0.10 V-drop across low-current wires and switches. Testing low-current circuits also requires a high-impedance (10-megohm) voltmeter. A low-impedance voltmeter may load a low-current circuit so much that it gives an incorrect reading or no reading whatsoever! Most professional-grade digital multimeters (DMMs)



A completely collapsed return pipe stops water flow, stalling the water wheel and causing a system pressure reading at the return side of the wheel. Likewise, a broken ground wire totally blocks current flow, shuts off the load and causes the ground side of the load to read system voltage.

have 10-megohm input impedance. Using a DMM is the fastest way to accurately measure voltage drops. If the DMM you own does not have autoranging capability, use a low-voltage (0-1 V) scale for voltage drop testing. Remember that test lights are not accurate enough to diagnose electrical voltage drop.

Quick ground tests

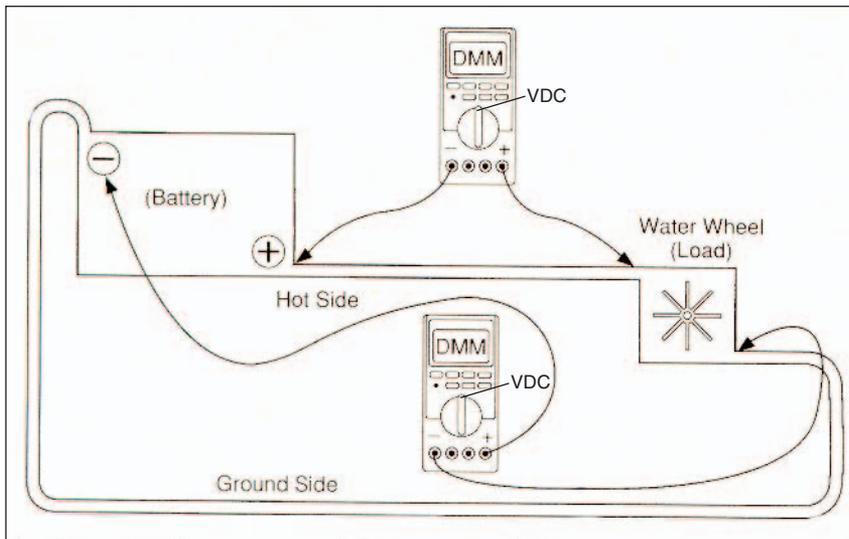
Because ground circuit voltage drop can cause most of the symptoms listed earlier, consider adopting this new work habit: test grounds first! Before you do a tune-up, check out electrical problems, or test a starting, charging, ABS or air conditioning system, routinely test the engine and body grounds. Connect your DMM between the engine and negative battery terminal. Safely disarm the ignition and crank the engine for a few seconds.

If the voltage drop is excessive, repair the engine ground circuit and retest. Note that on some distributorless ignition systems, the simplest way to prevent the engine from starting during the ground test is to pull the fuel pump fuse. Next, connect the DMM between the negative battery terminal and the vehicle's firewall. Then start the engine and switch on all the major electrical accessories. Too much voltage drop? Then fix the body ground and retest.

Once engine and body grounds are within limits, test the positive connection between the battery, alternator, starter and so on, and then proceed with your diagnosis. Do not be surprised if fixing these grounds solves the car's problems. The fact that a vehicle passes the body ground test does not mean you can safely ground your voltmeter wherever you want. Some technicians have run themselves in circles for hours because their voltmeters were not well grounded. For safe electrical service, make yourself a 20- or 30-foot jumper wire with an alligator clip on each end. When you have to test an electric fuel pump, lighting system or ABS computer in the rear of the vehicle, ground your DMM to the battery with the jumper wire. (Or to the rear of the alternator case with engine running).

Computer ground kinks

Because computer circuits operate on such low current, the standard ground tests may not reveal a marginal ground on an on-board computer. Before you condemn any on-board computer, check its grounds first. Operate the computer system and backprobe each computer ground terminal. If you measure anything greater than 0.10 V, trace that ground circuit and locate the problem.



Connect a DMM across part of a circuit and it directly reads the voltage drop across that wire, cable, switch, or connection. Here, one DMM would display the voltage loss between the battery and the load. The other would show the voltage loss from the ground side of the load to the battery.

Sometimes, computer grounds are connected to a spot where they are easily disturbed or prone to corrosion, such as a thermostat-housing bolt. Computer connector terminals also can corrode. Removing the connector and spraying the terminals with electrical cleaner may be all it takes to eliminate the voltage drop.

Experience shows that as little as 0.30 V on a computer ground terminal can cause trouble. Try pinpointing that with a test light! Poor computer and/or sensor grounds can cause higher-than-normal sensor voltages and false trouble codes. In many cases, the bad ground prevents the computer or sensor from pulling a voltage signal down to or near *ground zero*. Sure, accessing the computer to check grounds may be a hassle. Nevertheless, mistakenly replacing expensive sensors and computers is a bigger hassle.

Body ground gremlins

Keep your eyes peeled for missing body grounds. If someone else worked on the vehicle, he may have forgotten to reconnect body ground wires or cables. Remember that when the body ground is restricted, current tries to find another route back to the battery. The easiest alternate route may be through the transmission shift cable or the throttle cable. Not only can this current weld the cable together, it also can pit or erode bushings and bearings inside the transmission.

If you find the insulation on the body ground wire is burnt or blistered, you can bet that starter current overheated the wire. When the engine ground is restricted, starter current tries to return to the battery through the body ground circuit. Experience shows that if the body ground circuit can handle the current load, the customer may not notice the problem right away.

Under periods of heavy current flow, a restricted body ground may hamper or shut off a component. For example, turn signals have been known to stop blinking when the driver steps on the brake pedal. Testing confirmed that a restricted body ground choked off the turn signals. The ground could not handle current from the turn signals and brake lights at the same time.

Safe service

Practicing safe electrical service helps you solve electrical problems quicker and more profitably than guessing and swapping parts. Put your DMM to work wiping out electrical voltage drop today. It is the responsible thing to do.

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