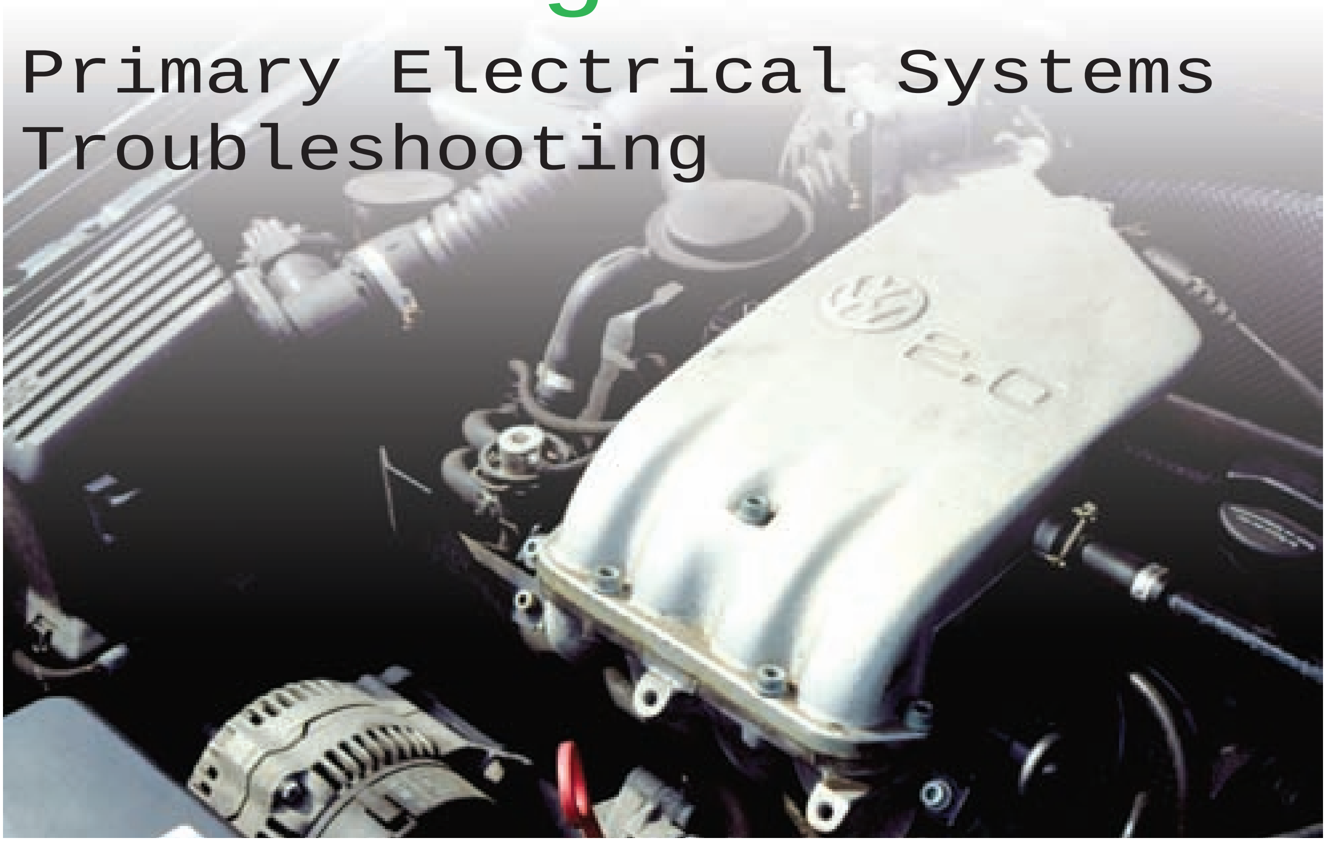
Volkswagen

Primary Electrical Systems Troubleshooting

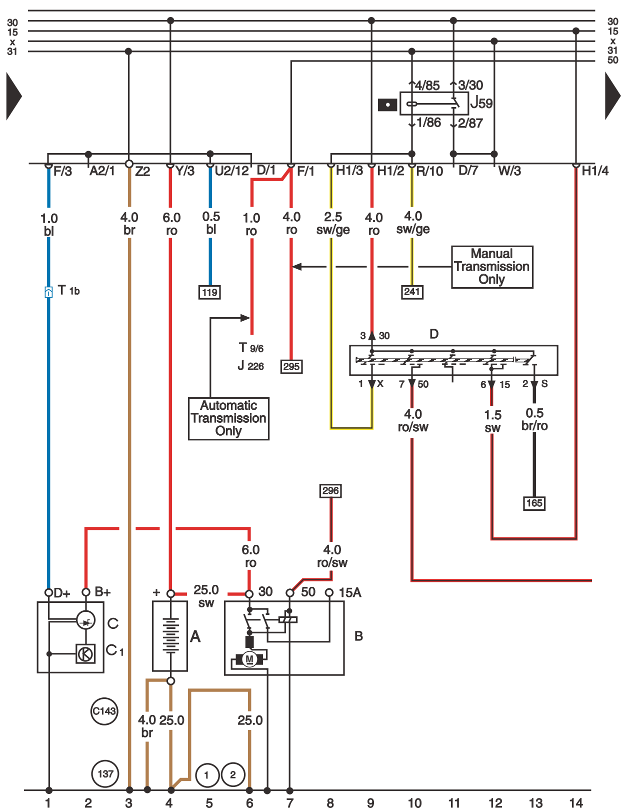


Several years ago, I had the opportunity to work with some factory engineers who were in the middle of designing a new vehicle electrical system. They had some design concerns and asked whether I would be available to talk while they were in town. I'd be lying if I told you I wasn't flattered. Besides the ego gratification, I saw an opportunity to pick the engineers' brains and learn what they do when they're designing, testing and measuring vehicle electrical systems. I couldn't wait.

What a shock I got when the day arrived. They were people just like me, and they even had the same problems. Their analog voltmeter (this was before digital meters became affordable) looked just as weather-beaten as mine. They had trouble zeroing the ohms scale and had to stop to change the meter battery. They had trouble making good electrical connections on the metal with the probe tips while taking readings — just like me. They did a series of voltage measurements and voltage drop tests — just like me. Nothing exotic at all compared to the techniques I was using to repair vehicle electrical systems. My biggest surprise came when I asked a few probing questions. I wasn't prepared for their "I don't know for sure, but ..." answers!

I thoroughly enjoyed the day and the free lunch at a nice restaurant, but I came away with the clear realization that engineers do the same testing and measuring when they are designing cars that we do when we are repairing them. That day reconfirmed my belief in the importance of basic voltage, voltage drop and current measurements when testing electrical systems. Some of the most bizarre electrical problems have some of the most basic fixes. And the more bizarre the symptoms, the simpler the fix often turns out to be. That's why we can never get enough of the basics, no matter how sharp we think we are.

Let's look at some of these basic tests. **Figure 1** *(page 46)* is a shop-manual schematic for a 1996-97 Volkswagen Jetta showing the generator, battery, starter motor and ground circuits. If you find this schematic diagram difficult to understand, you are not alone. In **Figure 2** *(page 46)* we have redrawn the schematic, using what we believe is a clearer format. Now we can look at some of the basic troubleshooting steps we should never forget to apply when using this new schematic.

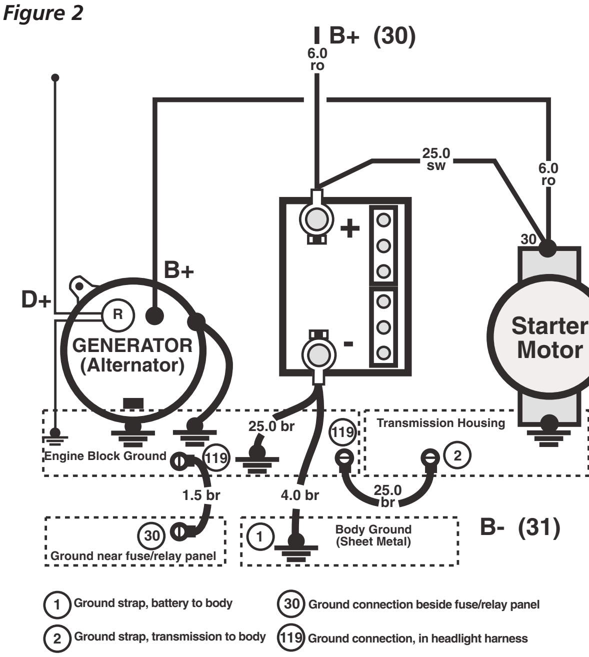


A -Battery
B -Starter
C -Generator (Gen)
C1 -Voltage Regulator (VR)
D -Ignition/Starter Switch
J59 -Load Reduction Relay
J226 -Park/Neutral Position (PNP) Relay
T1b -Single Connector, near Battery
T2 -Double Connector, behind fuse/relay panel, only on automatic transmission

1 -Ground Strap, battery to body
2 -Ground Strap, transmission to body
137 -Ground connection, in Motronic MFI wiring harness
C143 -Wire connection, in Motronic MFI wiring harness

Figure 1

Figure 2



Battery Problems

How can you quickly determine whether there is a battery problem? Measure open circuit voltage, or OCV for short. **Figure 3** *(page 48)* illustrates how to measure battery OCV. This test is only accurate when the battery has been allowed to rest and cool for several hours, preferably overnight. OCV readings are not accurate if the battery is still warm and chemically active following recent charging or discharging.

What should the DMM reading be? **Figure 4** *(page 48)* is a reference chart that explains the relationship between OCV and battery charge. We would like to see 12.66 volts, which indicates the battery is fully charged (or 100%). Lower than 12.66 means the battery has less than full charge. If OCV is 12.45 volts, the state of charge is about 73%. If the OCV is 11.89 volts, the battery has no charge at all (0%). A low OCV means either the battery discharges while the vehicle is parked with the key off, or the alternator is not charging the battery properly when the engine is running.

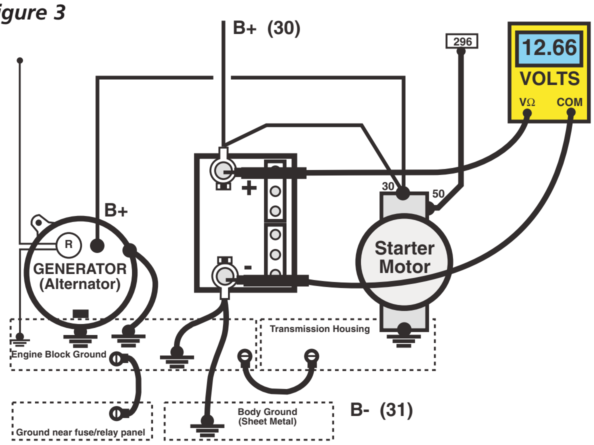
To check for key-off battery discharge, disconnect the battery's negative cable. Place a DMM set to the highest current reading capability (usually 10 amps) between the battery negative post and negative cable end. Any key-off drain will read out on the meter. A reading of less than 0.1 amps (100 mA) is acceptable. More than 0.1 amps usually indicates excessive drain and should be investigated.

One common cause of key-off drain is a computer that does not shut down completely after the key is turned OFF. Any computer that does not shut down draws current and will stay warm as long as the battery maintains the current. If the key has been off for one hour and a computer is still warmer than the surrounding metal, this may mean the computer should be replaced. We'll cover low-voltage charging as a cause of low OCV later in this article.

Cranking Problems

A slow cranking engine may mean a weak battery or a faulty starter motor with its armature dragging inside the starter housing. **Figure 5** *(page 48)* shows two tests that will get to the cause of the problem. DMM #1 is checking cranking voltage. We know battery voltage falls when cranking. So how low can it go? That's important to know. Look at the cranking voltage chart in **Figure 6** *(page 48)*.

Figure 3



The voltage chart in **Figure 6** is used when load-testing a battery with a variable carbon pile load tester. A load test is a very strenuous battery test. Cranking the engine with the starter motor places less than half that much load on the battery. So if you do a cranking test and find the cranking voltage drop very close to the minimum load test voltage for the battery temperature at the time of the test, that's probably a weak battery that cannot provide adequate voltage to crank the engine.

Minimum Battery Load Test Voltage	Battery Temperature in ¡F
9.90V	100¡F
9.80V	90¡F
9.70V	80¡F
9.60V	70¡F
9.50V	60¡F
9.40V	50¡F
9.30V	40¡F
9.10V	30¡F
8.90V	20¡F
8.70V	10¡F
8.50V	0¡F

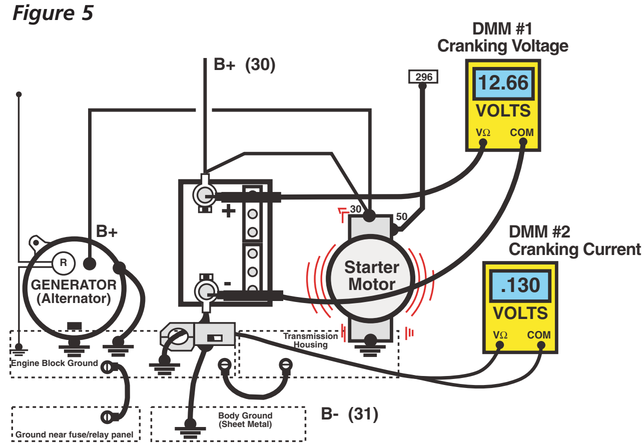
Figure 4

This battery would almost certainly fail a load test if you performed it according to 'the book.' To find out for sure, set the current draw with the carbon pile load tester to 1/2 the CCA rating of the battery and hold it for 15 seconds. If the load test voltage drops below the chart voltage for the battery temperature indicated in the chart, the battery is bad.

DMM #2 in **Figure 5** is checking cranking current using a current clamp designed to measure from 1.0-600 amps. The reading of 0.130 on the DMM indicates 130 amps of cranking current. That's normal for an engine in a moderate climate. If the weather is very cold, the cranking current will be higher because a cold engine cranks slower and the starter motor draws more current. If the reading is lower and the engine cranks, that's all the better.

Of course, if the engine is cranking normally, you probably aren't bothering to check the cranking current. To build a baseline of information, take the time to learn the typical cranking current for the vehicles you commonly work on. You won't find this information in any service literature.

Figure 5



If the cranking current is much higher than normal, say 250-300 amps or more, and if the temperature is moderate, it means the starter is not turning the engine over fast enough. You should be able to hear the rpm of the cranking engine is lower than normal or dragging as we say. This often indicates a binding starter motor. This is common on starters that have been in service a long time. If a starter is incorrectly installed (less than adequate clearance between the drive gear and the flywheel), the starter can drag while cranking even when newly installed. The lower cranking rpm will cause the cranking current to be much higher than normal. Normal cranking current is determined by checking known good vehicles for practice; otherwise you won't know what normal cranking current is for each make and model.

Battery Open Circuit Voltage (OCV) vs. State of Charge	
Voltage	% Charge
12.66	100%
12.58	90%
12.51	80%
12.45	73%
12.43	70%
12.35	60%
12.28	50%
12.20	40%
12.12	30%
12.04	20%
11.97	10%
11.89	0%

Figure 6

Charging Problems

Never disconnect a battery cable while the engine is running to determine whether the generator is 'putting out.' You can destroy a solid-state generator and fry memory chips in vehicle computers. Never *means* never! Enough said?

First check the charging voltage as shown in **Figure 7** *(page 50)*. It's really pretty simple to measure charging voltage at the battery terminals. After all, the voltage that *charges* the battery is the voltage that *gets* to the battery terminals.

Charging voltage varies with ambient temperature to meet the charging needs of the battery.

Figure 7

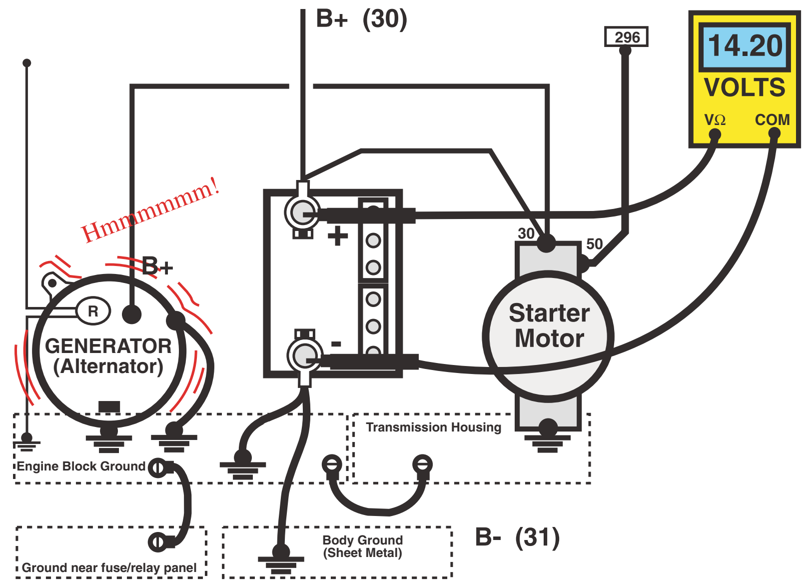
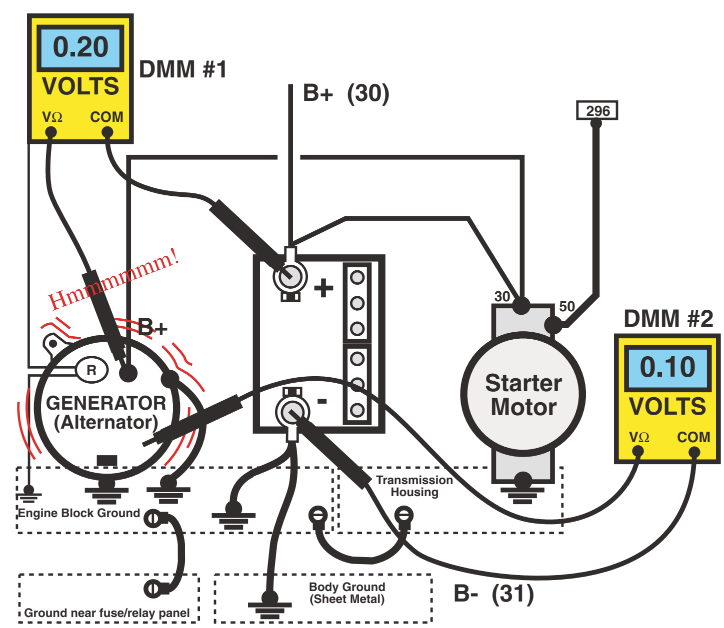


Figure 8



A wet-cell battery charges poorly when cold and easily when hot — so charging voltage should be higher in cold weather, typically in the range of 14.80-15.10 volts in the coldest weather. Charging voltage is lower in hot weather — in the range of 13.3 -13.5 volts — to keep the generator from boiling the battery electrolyte away. That's why you must correlate the actual charging voltage found in a vehicle with the ambient temperature, to recognize and properly diagnose a charging system failure.

How do you do that? Check charging voltage on various known-good cars to get used to the range of charging voltage found in your area on various makes and models at various ambient temperatures. Only then will you know. Do not expect to find this information in a service manual. As I travel around the country and talk with techs, I have found only a few who know the correct range of charging voltages for the ambient temperatures in their area. This tells me many techs are not paying enough attention to the basics of electrical troubleshooting.

A charging voltage in the neighborhood of 14.60 volts during the hot summer months is too high and will boil a battery's electrolyte away and cause battery failure. Excessive charging voltage in hot weather can be due primarily to a voltage regulator failure or a bad connection between the generator and battery. We will show you how to check for a bad connection in the charging circuit later in this article.

A charging voltage of around 13.30 volts in the cold winter months is too low and will undercharge a battery, making cranking on cold mornings too slow to start the engine. Reasons for low charging voltage in cold weather are:

- **a loose generator belt,**
- **a frozen serpentine belt idler arm which doesn't take up the slack in the drive belt as it stretches,**
- **a defective diode in the generator,**
- **a bad connection between the generator and the battery.**

To find a bad connection between the generator and the battery, simply perform the two voltage drop tests shown in **Figure 8** *(page 50)*. A bad connection or cable can produce resistance on either the voltage or the ground side of the charging circuit and can have an adverse effect on charging voltage that cannot be corrected by changing the generator or the battery. You have to find and correct the resistance in the form of a bad connection or corroded cable. The engine must be running to perform these two voltage drop checks.

DMM #1 is shown checking the voltage side of the charging circuit. A good reading is 0.20 volt (200 mV) or lower. A bad connection at the generator B+ terminal, a corroded cable between the generator and starter, a bad connection on the starter, a corroded cable from the starter to the battery B+ terminal or a bad battery terminal connector will cause an increase in the voltage drop on the voltage side. If the voltage drop exceeds 0.30 volts, start checking the individual voltage drop of each of these components or connections on the voltage side to find and repair where the corrosion (resistance) has developed.

DMM #2 is shown checking the voltage drop of the ground side of the charging circuit. A reading of 0.10 volt (100 mV) or lower is acceptable. More than that indicates corrosion has begun to develop between the generator ground and the battery-to-engine ground cable. Check each component or connection individually for an excessive voltage drop to find the source of the high reading over 0.10 volt.

While the electrical tests we've described in this article may seem basic, they will continue to help us solve electrical problems for as long as there are cars with charging systems and storage batteries on the road. They will help us find *the cause* of the problem, *before* we decide which parts to change. And remember, if you decide which part to replace without doing any testing, get ready to be embarrassed when the part you changed doesn't fix the problem. ■

— By Vince Fischelli