Lord Kelvin Helps Diagnose Connections

COLUMN BY NATHAN UNGER

Lord Kelvin was a brilliant mathematician who held 25 different patents on things relating to electrical test instruments. He at one time took the stance that there was nothing new to be discovered except to become more and more precise in one's measurements. Which is partly wrong of course. There are many new things to discover by becoming more and more precise, such as which connections are bad in a vehicle's wiring system.

I was helping a friend who couldn't get his old Dodge work van started. He got a 'mechanic' to help him and they tried everything until they were both stumped. Then my friend took his starter out, brought it to me and I looked it over, changed the contacts and cleaned the ground connections inside a bit, but opined that the trouble was not in the starter.

The contacts looked as if they were really arced up, which is always a sign that the solenoid has been chattering. If the solenoid windings are both good and balanced to each other, the chattering indicates a low voltage condition. What happens is that there is just enough voltage available to power the solenoid, but when the contacts close, then the heavier draw of the starter drops the voltage so much that the solenoid lets go. Now the voltage bounces back up, and the cycle starts all over again.

He phoned back to ask if I would come to his place to help him figure it out. I seldom do service calls, but since he was my friend, I went to help.

First, I put my voltmeter on the battery, measured the at-rest voltage (12.5 volts), then asked him to crank the engine. While the starter was trying to operate, I observed the voltage again—11.5 volts. Good so far; the battery was not the problem.

Second, I put the voltmeter from the battery negative post to the starter case. This would cover all the connections along the ground circuit. I asked him to crank the engine again—6 volts. Aha! He had a bad ground. Let's do the math: V/I = R which means normal cranking amps for that starter is about 250A. 6V/250A = 0.024 ohms. No wonder you would never see that problem with an ohmmeter.

Third, I put the voltmeter from the block to the wire coming out of the connector that was bolted to the block. I asked him to crank again and we got 5.5 volts. We found the bad connection without even unbolting anything. He later bought a whole new cable and installed it.

Now what I have done in the third step by putting my voltmeter across the connector is actually a form of a Kelvin connection. You see, the contact resistance of the ground connector, as well as the resistance of the cable itself would cause an inaccurate measurement.

In the first step where I measured the battery voltage while it was cranking assumed that all the available voltage was applied across the starter, and thus did not show a problem. But when I put the voltmeter by itself across the connection, then the problem was very obvious.

This is a principle used in measuring very low resistances, down to .0002 ohms with some more expensive meters.

The Kelvin principle can also be used to measure the conductance of slip rings. Have you ever noticed that some alternators work well on the test bench even though the customer complains that it was not working in the vehicle? What I think happens is that the slip rings get a sort of oxide glaze on them which has excessively high resistance and a smoothness to it which when sanded off with 400 grit paper solves the problem.

Here's how to prove that the glaze has resistance using the Kelvin connection principle:

a) Using a 12 volt battery with an old rotor coil in series to limit the current to about 3 amps, connect the battery negative to one of the old glazed brushes and the other lead of the old rotor coil to the other glazed brush;

b) Touch both brushes onto the same slip ring about 1 cm apart. Have your trusty voltmeter's alligator clips, one on each brush; and measure the voltage lost due to the glaze of the one brush, slip ring and other brush. Compare that to the same measurement with two new brushes and a clean slip ring. You may find as much as 1 volt difference!

The Kelvin principle (using appropriately high currents in the loaded circuit) can be used to measure the conductance of brushes for quality control, bad ground rivets inside starters, and poor solder connections in a commutator. Field coils and stators can be compared for amp ratings if you factor in the number of windings. Don't hold the current on so long that they get warm.

If you block the starter drive of a starter, and pulse it with 3 volts (6 volt battery in series with a carbon pile), using the Kelvin connections and your handy amp clamp, use Ohm's Law to find the overall resistance of a starter.

Compare notes with other similar starters. (This one came from a Delco bulletin.) This will reveal whether there are bad grounds inside, how well the brushes are seated, and how the connections inside are conducting. These are some things that directly affect starter torque.

You could also measure the quality of solenoid contacts this way. Use a high current, like a 100 amp stator in series with a 12 volt battery, or appropriate to what the contacts are meant for, and energize the solenoid, reading the voltage across the contacts from separately connected voltmeter leads.

Again, don't put your voltmeter leads on the clips that conduct the heavy current because they may have voltage drops where they touch the solenoid, and your voltage reading would be off by that amount. Put the voltmeter leads on the solenoid directly.

You could even troubleshoot wiring in the car by disconnecting the wire in question from the voltage source and from the load, then putting your 3 amp current through it, measuring the voltage drop, and you will know if there are any faulty connectors along the way.

To focus on my point, Kelvin connections are about having one set of

leads to carry the current, and another, independently connected set of leads to measure what voltage the device under test is actually seeing.

This is done to prevent the contact resistance of the high current connection from affecting the voltmeter reading. And using Ohm's Law, you can measure very low resistances.

Nathan Unger is owner of ASI Rebuilders, Abottsford, B.C.