The Right Diagnostic Tools Can Save You From Extensive — and Expensive — Disassembly Time

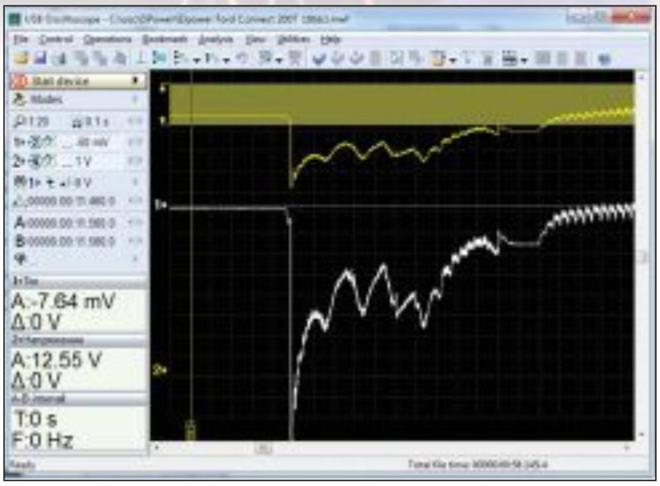

Figure 1: Example of a waveform obtained when analyzing a vehicle's starting system.

A frequent reason for customers showing up at a vehicle repair facility is difficulty starting or simply a no-start. Often, the major suspects are the battery, starter and alternator.

If the problem is obvious, then it is easily diagnosed. For example, if the starter does not crank the engine, we can check the power and ground at the starter, before and after the solenoid, as well as solenoid mechanical operation. As a result, we can easily identify the faulty circuit or component of the starter system. Similarly, a discharged battery or an inoperative alternator is easily diagnosed with a digital multimeter.

It can be significantly more difficult to make the correct diagnosis when the starter does crank the engine, but slowly, or the engine is hard to start. The starting or charging system may be partially damaged or not compatible with the vehicle. The problem may be a bad connection or contact. Insufficient cross-section of the connecting wires, due to corrosion or misapplication, may also exist.

These components may even have to be removed for inspection or replacement, only to find that the problem lies elsewhere. Diagnostic time may be extensive, causing significant expense for the customer. In many vehicles, the access to the battery is difficult, as is access to the alternator or starter, again causing significant labor charges.

To facilitate troubleshooting of the charging and starting system without extensive disassembly, an oscilloscope or engine analyzer can be used.

Unfortunately, the shape of the waveform sometimes makes it difficult to make a correct diagnosis. A detailed analysis of obtained waveforms, such as the waveform shown in **Figure 1**, and manual calculations of the relevant parameters can be time-consuming.

Tools such as the USB Autoscope have the ability to automatically analyze the waveform. In the case of the USB Autoscope, the necessary algorithms for various waveform analysis processes are contained in files called scripts. A number of different scripts exist for analysis of various vehicle faults.

A script called the "ElPower" script is used for automatic analysis of battery voltage and current waveforms in order to obtain a fast and comprehensive diagnostic of starting and charging systems. The script in conjunction with the oscilloscope is providing an advanced report on the battery, alternator and starter condition. Additionally, other high-power electrical consumers may be analyzed very quickly. The measurement is made at the terminals of the battery. If the connections are made anywhere else other than

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directly to the battery terminals, the results obtained may not be valid. Do not use jumper cables.

The measurement procedure is as follows: Connect the USB Autoscope to the battery as shown in **Figure 2** in order to obtain the battery voltage and current waveform. Start the waveform recording and then start the engine.

The recorded waveform is analyzed by the ElPower script and the results are shown in table form with parameters and graphs. The script automatically highlights in color parameters that deviates from nominal and warrants a closer look. Yellow color highlights values outside the allowable range while red color highlights critical deviations.

Some examples:

The first example is from a **2009 Kia** equipped with a 1.6L engine. The result of the analysis indicates that all components of the charging and starting system are in good condition. A quick look at the information from the script and shown in **Figure 3** reveals the following: the initial voltage at the beginning of the measurement was 12.45 V. A table of voltage vs. charge level is shown in **Figure 4**, and, according to the table, the battery SOC (state of charge) is approximately 80%.

However, the script takes a number of variables into account and will be more accurate in determining SOC than relying on this table. Let the software do the hard work! For best accuracy when using the script, let the vehicle rest for one hour before performing any measurements if the vehicle was recently driven. Note that modern batteries have slightly higher voltage levels than older batteries, due to improved chemistry.

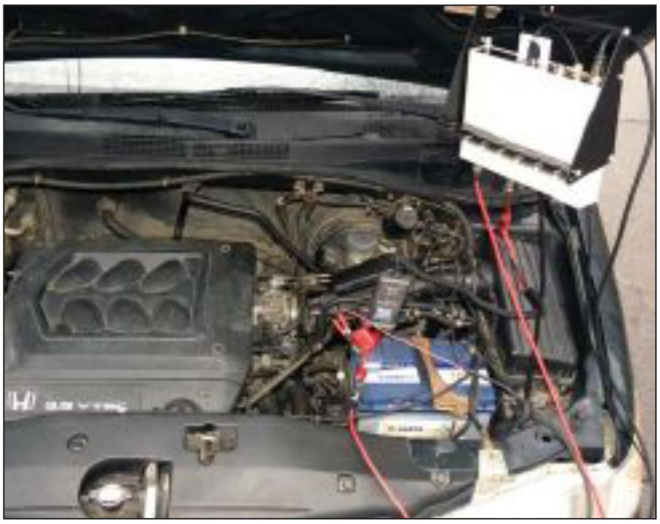

Figure 2: Connecting the USB Autoscope to the vehicle's battery to obtain voltage current waveforms.

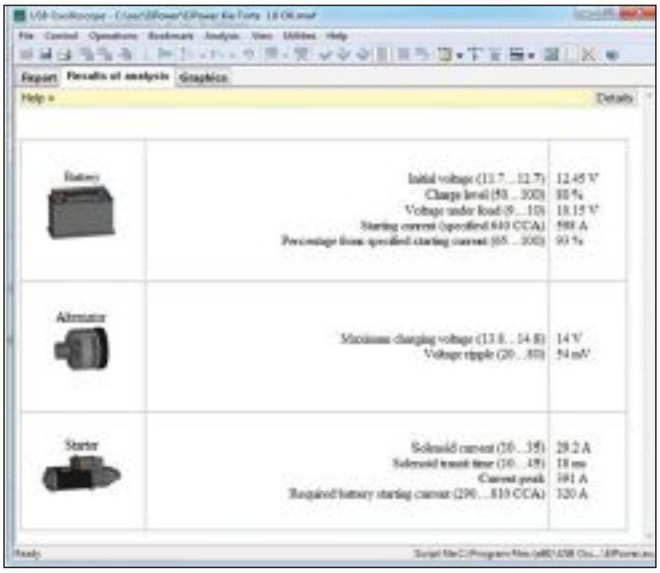

Figure 3: Data provided by the "ElPower" script.

Modern maintenance free battery	
State of charge	**Voltage**
100%	12.7V
90%	12.5V
80%	12.4V
70%	12.3V
60%	12.2V
50%	12.1V
40%	11.9V
30%	11.8V
20%	11.6V
10%	11.3V
0%	10.5V

Figure 4: A table of voltage vs. charge level on modern batteries. Room temperature is assumed.

The data in **Figure 3** also shows that during cranking the voltage did not fall below 10.25 V.

The measured current flow from the battery during cranking was 598 A. The battery in the Kia is specified at 640 CCA. So our battery is capable of delivering 93% of the specified starting current in this specific instance, which is good. Note that new batteries can be capable of supplying starting current in excess of what the manufacturer indicates on the label.

The alternator produces a voltage of 13.96 V. The peak voltage during the measurement did not rise above 13.98 V. These measurements are normal. The ripple or as some erroneously say, AC voltage, was 44 mV.

The response time of the starter solenoid was 18 mS, and the solenoid current was 29.2 A. The peak current of the starter was 391 A. The script calculated that a battery with a starting current of 320 CCA would be sufficient for the starter. Referring back to the measured starting current capability of the battery, which was equal to 598 CCA, we see that the installed battery has good starting current reserve.

The second example is from a **2012 Chevrolet Aveo** equipped with a 1.6L engine. The diagnostic result as shown in **Figure 5** on page 10 indicates a defective charging system. The analysis also shows that during engine cranking the system voltage drops very low. Actual measurements of the cranking current of the battery at 297 A is significantly lower than the required current of 542 CCA. On this vehicle, the battery was specified as having a cranking current of 540 CCA. The available current (297 A) is only 55% of the specified current (540 CCA). This indicates a significantly lowered battery capacity. Note that for batteries with low current capability, it is recommended to perform a full charge and repeat the test.

After replacing the voltage regulator in the alternator, the charging voltage returned to a normal value. However, even with a fully charged battery, the drop in battery voltage during engine cranking was still significantly more than normal, indicating a worn battery. The vehicle owner was recommended to install a new battery with a cranking current capacity of at least 542 CCA.

This next example was recorded from a **Volkswagen** equipped with a 2.8 VR6 engine. The analysis result shown in **Figure 6** indicates significant problems with starter current drop outs.

The actual starter current waveform is shown in **Figure 7**.

Starter current drop outs may be the result of wear of the brushes, commutator or poor contact in the electrical connections in the starter circuit. A disassembly and visual inspection of the starter components revealed the damage (**Figure 8** on page 12).

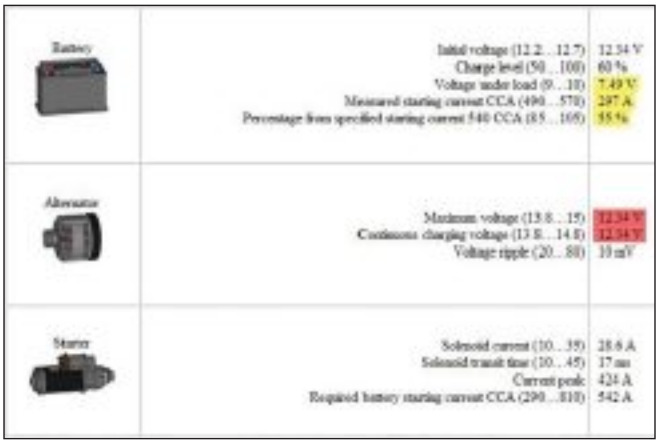

Figure 5: A weak or discharged battery and a defective alternator.

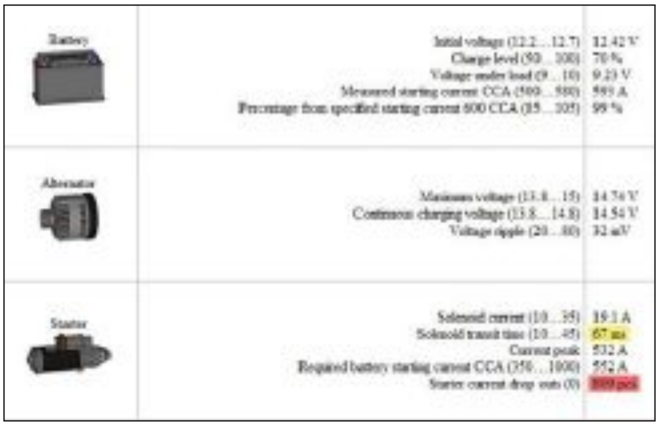

Figure 6: A very large number of starter current drop outs.

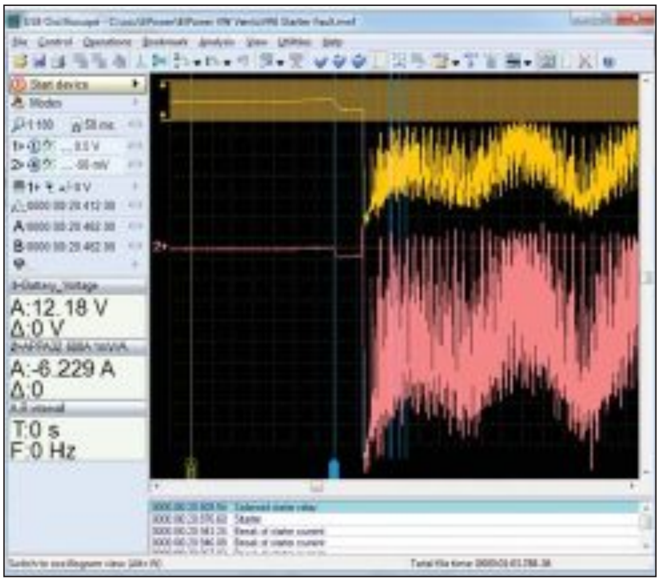

Figure 7: Waveform showing starter current dropping out a large number of times.

The increased switching time of the solenoid, measured at 67 ms, was also caused by the burned commutator segments. Once the starter was repaired, all the measured parameters returned to normal.

This next example is an alternator problem. The vehicle is a **Volkswagen Passat** 1.8L with a complaint of an undercharged battery. The script determined that the problem was caused by a missing phase. Most alternators have three phases, but this alternator had one missing. This problem causes a loss of alternator capacity and a chronically undercharged battery. The missing phase causes a large voltage ripple to exist in the electrical system as shown in the data in **Figure 9** on page 14. Both a lack of charge output and large ripple will eventually cause battery failure. The ripple may cause difficult-to-diagnose driveability problems.

Note that the exact amount of capacity loss depends on the type of stator winding, whether it is a delta wound or a star wound stator, and whether the alternator is equipped with additional diodes to rectify the neutral junction. If the alternator has neutral junction diodes and one phase fails, the two other phases will operate normally, causing approximately a 33% loss of output. If there are no neutral junction diodes, the remaining two windings will effectively be in series, creating a single-phase circuit. The current in the two windings are 120 degrees out of phase with each other, causing very low or no output. A delta wound stator losing a phase will simply have about a 33% loss of output. If the alternator is equipped with a system that uses stator current to power the field, loss of one phase may cause a total loss of charge, especially at low rpm.

After repairing the alternator and charging the battery, all the measured parameters returned to normal.

Figure 8: Badly burned commutator segments on a starter armature.

The last example is taken from a **Mercedes Sprinter minibus** equipped with a 2.7L common rail diesel engine. **Figure 10** on page 14 lists the measured data. Note that the script makes an evaluation as to the condition of the glow plugs and circuit.

The waveform processing and analysis show us that this particular vehicle needs a battery capable of delivering approximately 1,023 CCA. Because the battery, although fully charged, does not have adequate capacity, the system voltage drops to 8.22 V while cranking. The battery can only deliver 663 A while maintaining adequate system voltage.

The script did not detect any problems with the charging system.

During the measurement period, the engine control unit turned on the glow plugs. The script then performed an analysis of the glow plug current and determined that the system probably has two to three faulty glow plugs. The script basically suggests that the technician investigate further the glow plug circuit, based on the measurement.

The script can measure, as well as display, data and graphs of battery current and voltage waveforms under various operating conditions. An example of this capability is shown in **Figure 11**. The calculated data and graphs are not completely accurate, but they may certainly help to visualize and understand the processes occurring in the vehicle's electrical system.

Here we will consider the processes occurring in the vehicle's electrical system during the measurement period. After starting the waveform recording, we briefly turned on the high beam headlights. This is reflected as a short drop of the red graph (**A**). Then the ignition was switched on, and the engine control unit turned on the glow plugs (**B**) for 26 seconds, at which point the control unit turned off the glow plug relay. After turning the key to the start position, the starter began cranking, which is reflected as a relatively brief drop of the red graph (**C**).

After the engine started, the alternator did not immediately start charging and it is clear that the current consumption from the battery was significant. The engine control unit switched the glow plugs back on for reheating (**D**). Even after the alternator output has reached full capacity, the system voltage did not rise to the nominal 14 V, since the glow plugs consumed significant current, and there simply was not current available to bring up the voltage. The alternator maximum current was limited to 99 A (**E**).

In this example, the total vehicle current consumption was 64 A while the battery charge current was 35 A. After 10 seconds, the glow plugs turned off, as shown by the gray graphics, and more of the alternator's current was used to charge the battery. After a few seconds, the system voltage rose to 14 V, and the alternator began to limit the charging current to maintain the required system voltage (**F**). Next, we briefly turned on the high beam headlights again, as is visible on the gray graph. However, neither the battery voltage nor the battery charging current changed appreciably since the additional load was easily carried by the alternator, increasing the charging current. This can be seen by the lift of the green graph (**G**). At the end of the measurement, we switched off the engine.

In addition to the reviewed examples, the script can also automatically determine too high alternator charging voltage, battery weaknesses, battery parasitic drain, problems with the starter solenoid and other problems.

Using the ElPower script saves time on the diagnostics of vehicle charging and starting systems, and can also help to determine difficult-to-diagnose and subtle problems in the starter and alternator circuits. TS

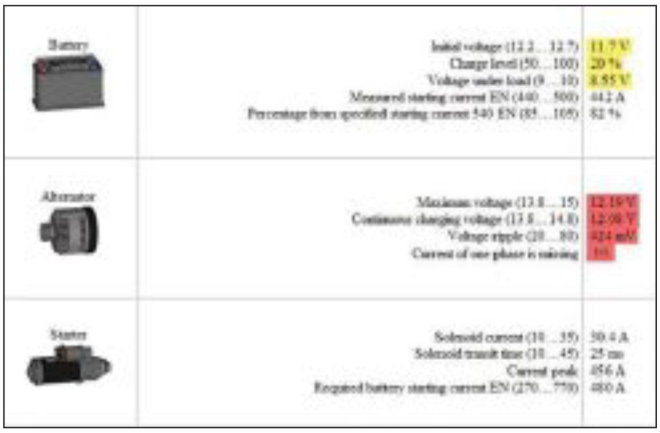

Figure 9: The battery is discharged, the charge output is low and there is excessive ripple.

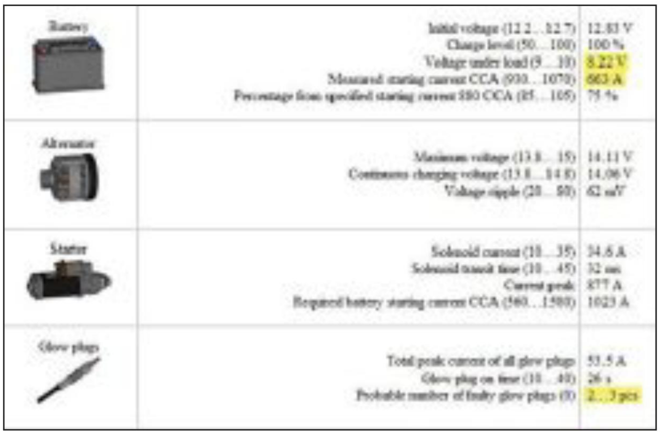

Figure 10: Measured parameters from a vehicle equipped with a diesel engine.

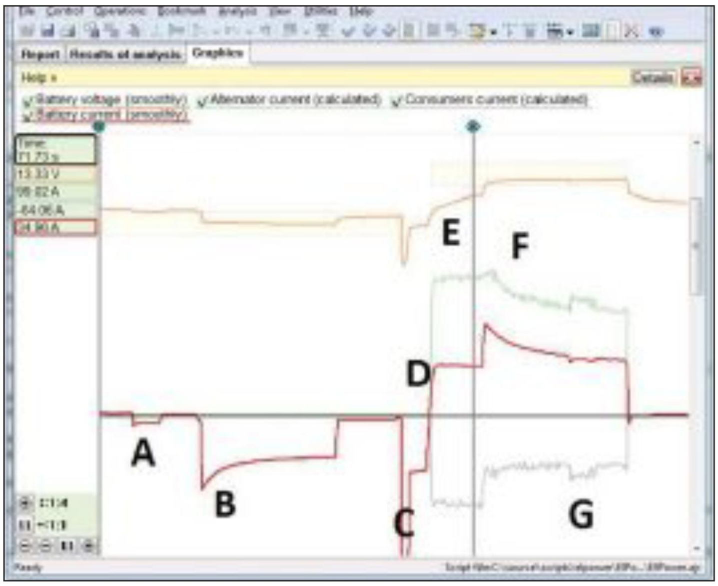

Figure 11: Various graphs as they relate to a vehicle's electrical system.