INTRODUCTION

It is the purpose and function of the charging system to keep the battery fully charged. The Society of Automotive Engineers (SAE) term for the unit that generates electricity is generator. The term alternator is most commonly used in the trade. Figure 1.

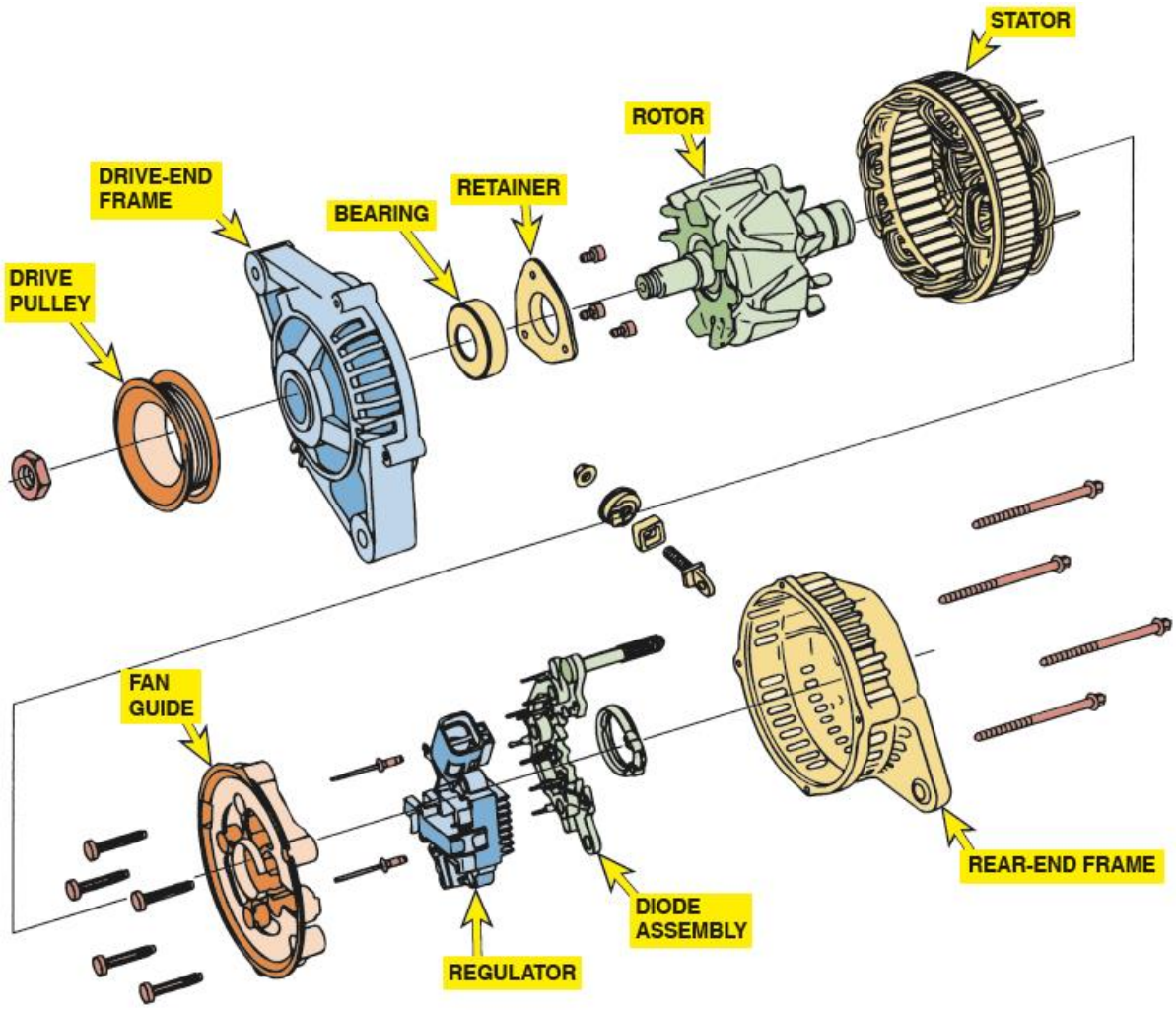

Figure 1. Alternator and components.

Alternators use the principle of electromagnetic induction to generate electrical power from mechanical power. Electromagnetic induction involves the generation of electric current in a conductor when the conductor is moved through a magnetic field. The amount of current generated can be increased by the following factors:

- Increasing the speed of the conductors through the magnetic field
- Increasing the number of conductors passing through the magnetic field
- Increasing the strength of the magnetic field

An alternator generates an alternating current (AC) because the current changes polarity during the alternator's rotation. However, a battery cannot "store" AC; therefore, this AC is changed to direct current (DC) by diodes inside the alternator.

Rotor Construction. The rotor is the rotating part of the alternator and is driven by the accessory drive belt. The rotor creates the magnetic field of the alternator and produces a current by electromagnetic induction in the stationary stator windings. Figure 2.

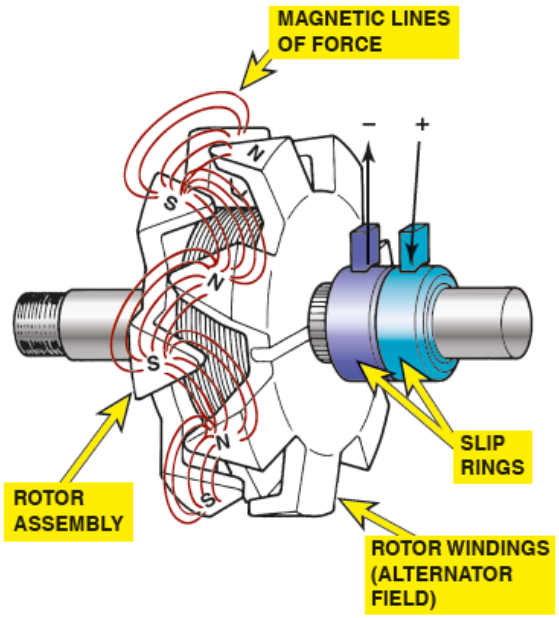

Figure 2. Rotor and magnetic fields.

Stator Construction. The stator consists of the stationary coil windings inside the alternator. The stator is supported between the two halves of the alternator housing, with three copper wire windings that are wound on a laminated metal core. As the rotor revolves, its moving magnetic field induces a current in the stator windings. Figure 3.

Figure 3. The stator has from three to six separate windings.

Rectifier. Alternators use at least six diodes (one positive and one negative set for each of the three stator windings) to convert alternating current to direct current. If the stator has more sets of winding there will

be more diodes used. The diodes used in alternators are packaged in a single part called a rectifier, or rectifier bridge. Figure 4.

Figure 4. A rectifier bridge includes the diodes and heat sink for cooling.

Voltage Regulator. Current for the rotor flows from the battery positive post, through the rotor positive brush, into the rotor field winding, and exits the rotor winding through the rotor ground brush. Most voltage regulators control field current by controlling the amount of field current through the ground brush. The voltage regulator opens the field circuit if the voltage reaches a predetermined level, then closes the field circuit again, as necessary, to maintain the correct charging voltage.

Computer Control. Many vehicles control alternator output by using the PCM to modulate the voltage regulator. The computer controls the field of the alternator, which can pulse it on or off, as needed, for maximum efficiency, thereby saving fuel.

A typical system is called an electrical power management (EPM). It uses a Hall-effect sensor attached to the negative or positive battery cable to measure the current leaving and entering the battery. The engine control module (ECM) controls the alternator by changing the on-time of the current through the rotor. Figure 5.

Figure 5. A Hall-effect current sensor attached to the positive battery cable is used as part of the EPM system.

ASE TEST TOPICS

1. Diagnose charging system problems that cause a no-charge, a low charge, or an overcharge condition; determine needed repairs.

The charging system can be tested as part of a routine vehicle inspection or to determine the reason for a no-charge or reduced charging circuit performance. The battery must be at least 75% charged before testing the alternator and the charging system. A weak or defective battery causes inaccurate test results. If in doubt, replace the battery with a known good shop battery for testing.

The charging voltage test is the easiest way to check the charging system voltage at the battery. Specifications for charging voltage = 13.5to15 volts.

- If the voltage is too high, check that the alternator is properly grounded.
- If the voltage is lower than specifications, then there is a fault with the wiring or the alternator.
- If the wiring, fuses, and the connections are okay, then additional testing is required to help pinpoint the root cause.
- If the alternator is computer-controlled, a defective current sensor or PCM could be the reason for a no-charge condition.

2. Inspect, reinstall and/or replace pulleys, tensioners and drive belts; adjust belts and check alignment.

It is generally recommended that all belts be inspected regularly and replaced as needed. Replace any serpentine belt that has more than three cracks in any one rib that appears in a 3 inch span. Newer belts

are made from ethylene propylene diene monomer (EPDM). This rubber does not crack like older belts and may not show wear, even though the ribs do wear and can cause slippage. Figure 6.

Figure 6. A belt wear gauge should fit tightly into the belt groves. A loose fit means the belt is worn and should be replaced.

If the belt needs replacement, first make note of the belt routing. There may be a diagram under the hood. Use a tool to release the tensioner and then remove the belt. Install the new belt and release the tensioner. Figure 7.

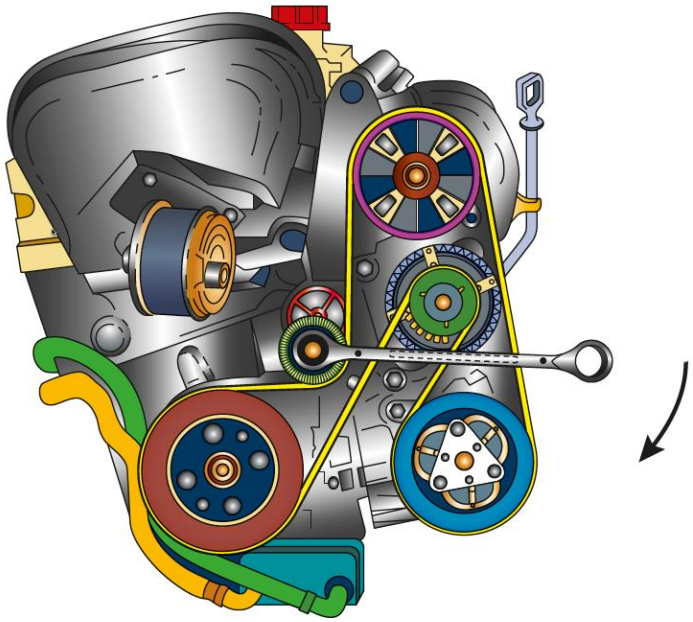

Figure 7. Turn the wrench in the direction indicated to loosen the belt tensioner.

3. Perform charging system voltage output test; determine needed repairs.

Use a digital multimeter to check the voltage, as follows:

STEP 1 Select DC volts.

STEP 2 Connect the red meter lead to the positive (+) terminal of the battery and the black meter lead to the negative (–) terminal of the battery.

STEP 3 Start the engine and increase the engine speed to about 2,000 RPM (fast idle) and record the charging voltage. Figure 8.

Figure 8. Charging system voltage test.

Specifications for charging voltage = 13.5to15 volts.

- If the voltage is too high, check that the alternator is properly grounded.
- If the voltage is lower than specifications, then there is a fault with the wiring or the alternator.
- If the wiring, fuses, and the connections are okay, then additional testing is required to help pinpoint the root cause.
- If the alternator is computer-controlled, a defective current sensor or PCM could be the reason for a no-charge condition.

4. Perform charging system current output test; determine needed repairs.

An alternator output test measures the current (amperes) of the alternator. A charging circuit may be able to produce correct charging circuit voltage but not be able to produce adequate amperage output.

A carbon pile tester uses plates of carbon to create an electrical load. The tester is used to load test a battery and/or an alternator. The testing procedure for alternator output is as follows:

STEP 1 Connect the starting and charging test leads according to the manufacturer's instructions. Place the amp clamp around the output wire near the alternator.

STEP 2 Turn off all electrical accessories to be sure that the tester is measuring the true output of the alternator.

STEP 3 Start the engine and operate it at 2,000 RPM (fast idle). Turn the load increase control slowly to obtain the highest reading on the ammeter scale. Do not allow the voltage to drop below 12.6 volts. Note the ampere reading.

STEP 4 Compare the output reading to factory specifications.

5. Inspect and test generator (alternator) control components including sensors, regulators, and modules; determine needed repairs.

Most vehicles that use a computer-controlled charging system can be diagnosed using a scan tool. Not only can the charging voltage be monitored, but also, in many vehicles, the field circuit can be controlled and the output voltage monitored to check that the system is operating correctly. Figure 9.

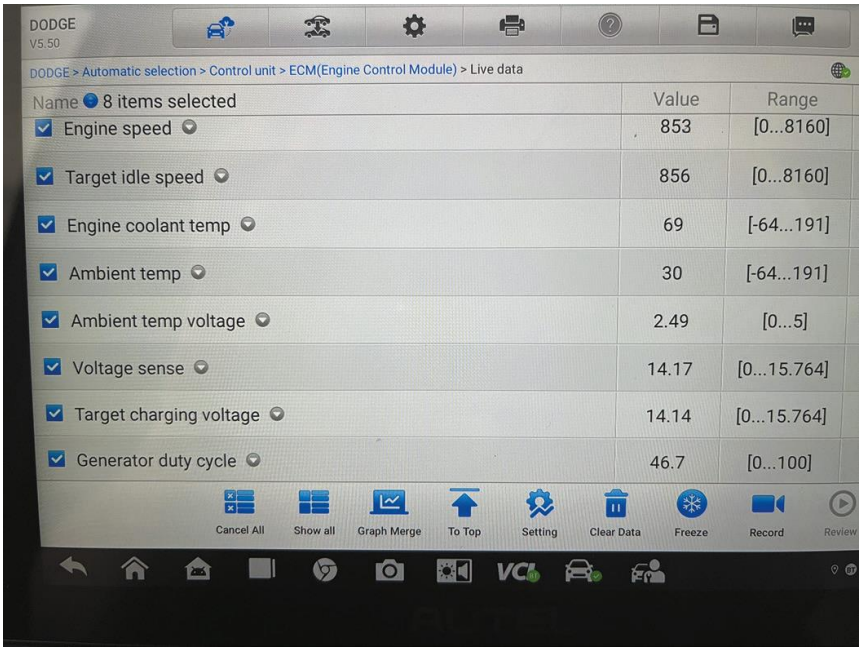

Figure 9. A scan tool showing alternator voltage and field duty cycle (46.7%).

6. Perform charging circuit voltage drop tests; determine needed repairs.

For the proper operation of any charging system, there must be good electrical connections between the battery positive terminal and the alternator output terminal. The alternator must also be properly grounded to the engine block.

Many manufacturers of vehicles run the lead from the output terminal of the alternator to other connectors or junction blocks that are electrically connected to the positive terminal of the battery. Any faults in these cables or connections will cause a voltage drop between the alternator output post and the battery. Figure 10.

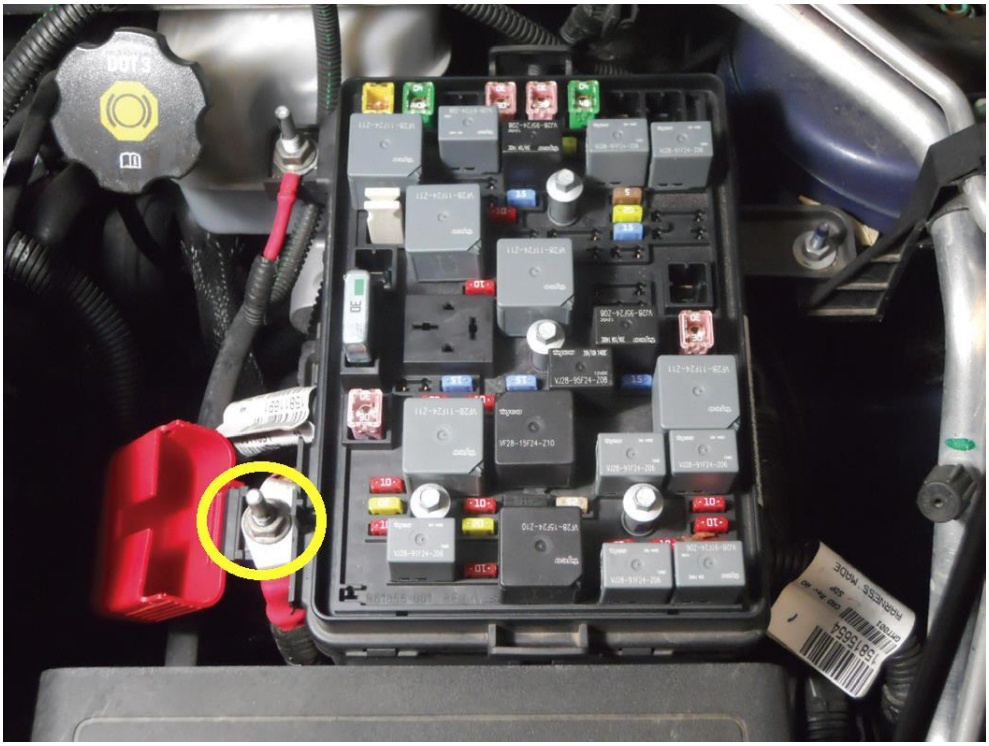

Figure 10. Both the alternator and battery are connected at this post on the fuse block. (Circle)

Follow these steps to measure the voltage drop of the insulated (power-side) charging circuit.

STEP 1 Start the engine and run it at a fast idle (about 2,000 engine RPM).

STEP 2 Turn on the headlights to ensure an electrical load on the charging system.

STEP 3 Using any voltmeter set to read DC volts, connect the positive test lead (red) to the output terminal of the alternator. Attach the negative test lead (black) to the positive post of the battery.

The results should be interpreted as follows, figure 11.

- If there is less than a 0.4 volt (400 millivolts) reading, then all wiring and connections are satisfactory.
- If the voltmeter reads higher than 0.4 volt, there is excessive resistance (voltage drop) between the alternator output terminal and the positive terminal of the battery.

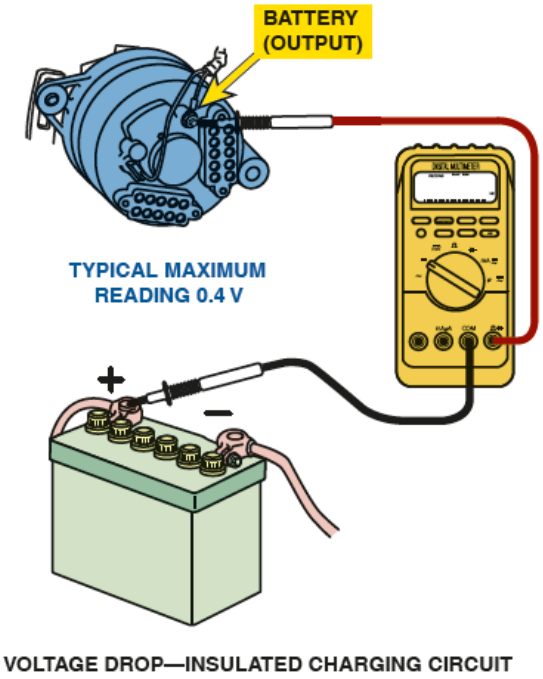

Figure 11. Voltage drop test on the positive wiring and connections.

To determine whether the alternator is correctly grounded, maintain the engine speed at 2,000 RPM with the headlights on. Connect the positive voltmeter lead to the case of the alternator and the negative voltmeter lead to the negative terminal of the battery. The voltmeter should read less than 0.2 volt (200 millivolts). Figure 12.

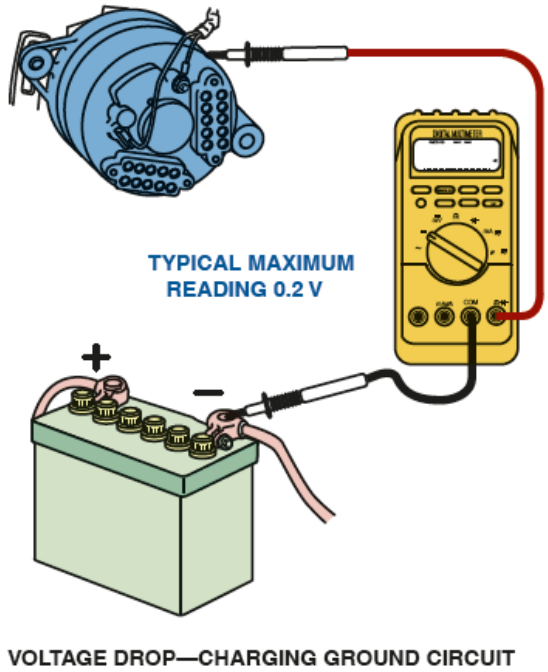

Figure 11. Voltage drop test on the ground circuit cables and connections.

7. Inspect, test, repair and/or replace connectors, terminals, and wires of charging system circuits.

A terminal is a metal fastener attached to the end of a wire, which makes the electrical connection. The term connector usually refers to the plastic portion that snaps or connects together, making the mechanical connection. Wire terminal ends usually snap into, and are held by, a connector.

Terminals are retained in connectors by the use of a lock tang. Using a pick in the slot in the plastic connector where the lock tang is located, depress the lock tang, and gently remove the terminal from the connector. Figure 13.

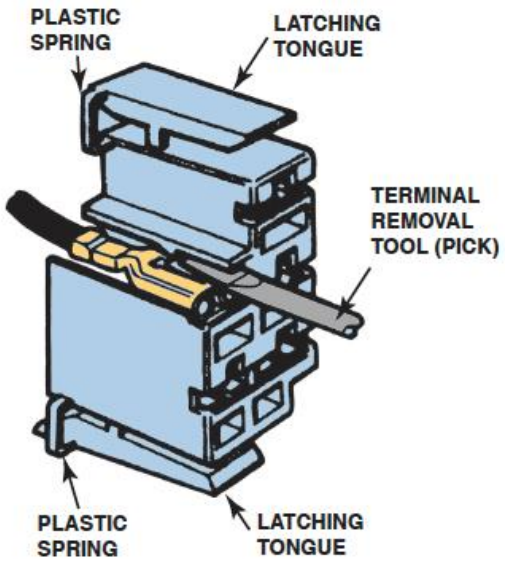

Figure 13. Removing a terminal from the plastic connector.

For splicing wires, some manufacturers recommend the use of crimp-and-seal connectors as the method for wire repair. Crimp-and-seal connectors contain a sealant and shrink tubing in one piece.

This type of connector is first crimped to retain the ends of the wires and then it is heated. The tubing shrinks around the wire splice, and thermoplastic glue melts on the inside to provide an effective weather-resistant seal. Figure 14.

Figure 14. Crimp-and-seal connectors.

8. Remove, inspect, and replace generator (alternator).

A typical removal procedure includes the following steps:

- Disconnect the negative (−) terminal from the battery. (Use a memory saver to maintain radio, memory seats, and other functions.)
- Remove the accessory drive belt that drives the alternator.
- Remove electrical wiring, fasteners, spacers, and brackets, as necessary, and remove the alternator from the vehicle. Figure 15.

Figure 14. Alternator removal. Many alternators are difficult to access and will require the removal of other components.

Reverse the instructions to install the alternator, noting these points:

- Check the condition of the drive belt and replace, if necessary.
- Tighten all fasteners to factory specifications.
- Reconnect the negative battery cable.
- Start the engine and verify proper charging circuit operation.