The charging system provides electrical energy for all of the electrical components on the vehicle. The main parts of the charging system include:
- The battery
- The alternator
- The voltage regulator, which is usually integral to the alternator
- A charge warning, or indicator light
- Wiring that completes the circuits

The battery stores an electrical charge and provides the electrical energy for starting. The alternator converts some of the mechanical energy of the engine into electrical energy to supply all the electrical components of the vehicle.

The alternator charges the battery. The voltage regulator prevents overcharging.

The alternator converts mechanical energy into electrical energy by electromagnetic induction. As the polarity of the voltage reverses, so does the direction of current flow.

Current that changes direction in this way is called alternating current (AC).

The value of the electromotive force (EMF) induced by an alternator depends on the strength of the magnetic field. Increasing the strength of the magnetic field increases the value of the induced EMF.

The EMF value also depends on the speed at which the magnet rotates and on the number of turns of wire on the stationary coil.

In AC, the magnitude and direction of the current vary cyclically, as opposed to direct current (DC), in which the direction of the current stays constant.

The alternator consists of:
- A stationary winding assembly, called the stator
- A rotating electromagnet, the rotor
- A slip-ring and brush assembly
- A rectifier assembly
- Two end frames
- A cooling fan

A voltage regulator monitors battery voltage and varies current flow through the rotor field circuit, thus controlling the strength of the rotating magnetic field. This keeps system voltage at a safe level.

Rectification is a process that converts AC into DC. Automotive alternators use diodes in the rectifier assembly. A diode allows current to flow in the forward direction, but blocks the flow of current in the reverse direction.

A three-phase bridge rectifier has six diodes to rectify the total alternator output: three positive and three negative. One of each is used to rectify current in each of the three-phase windings.

In each revolution of the magnet, the polarity of each phase winding changes. As a result, the current changes direction.

As the rotor moves through its various positions, individual phase currents change in magnitude and polarity, but the output current to the battery and the electrical circuits remains unidirectional.

Two methods of connection can be used for the stator or phase windings: star (or wye connection) and delta connection.

In the star method, one end of each phase winding is taken to a central point—known as the star, or neutral, point—where they are connected together. The other ends are connected in the bridge rectifier circuit between a positive and a negative diode. Each winding is then always part of a complete circuit.

In the delta method, the windings are connected in the shape of a triangle. Connections are then taken from each point of the triangle to the bridge circuit.

In either case, current is provided to the rotor by means of the slip rings and brushes.

When the engine is running, most alternators supply the field current directly by means of three extra diodes connected to the bridge rectifier circuit.

When the ignition switch is closed, current can flow from the battery positive terminal to the L terminal of the alternator. The circuit is completed through the slip rings and rotor field winding, and through the voltage regulator to ground on the vehicle frame.

The small amount of current flowing in the circuit illuminates the indicator lamp and provides the initial excitation of the field winding. This magnetizes the rotor pole shoes and produces a weak magnetic field.

When the rotor is driven by the engine crankshaft, the rotating magnetic field induces a voltage in the
phase windings, which is applied to the B-positive alternator output terminal.

- However, this voltage is also impressed on the exciter diodes, and current can now flow directly to the field circuit, restricted only by the resistance of the field winding. This strengthens the magnetic field, and the output voltage rises quickly.

- The voltage regulator now takes over to control the field circuit current and maintain a preset regulated output voltage at the B-positive terminal voltage of approximately 14 volts. As the voltage on each side of the charge indicator lamp is now equal, there can be no current flow through the lamp, and the lamp is extinguished.

- The alternator is now said to be charging. Because the output voltage at the B-positive alternator terminal is greater than that of the battery, the current flows to the battery to begin the recharging process.

- The alternator output voltage can be controlled or regulated by varying the rotor current.

- When the engine is running and voltage output is low, the regulator switches the rotor circuit to ground, and maximum current flows through the rotor field winding. The high-intensity magnetic field created raises the value of the induced voltage in the stator windings, and alternator output rises. The output voltage is also impressed on the exciter diode circuit, and the output voltage is sensed by the regulator control circuits via the regulator “L” terminal.

- When the maximum allowable voltage has been reached, the control circuits switch off the rotor field circuit, and the magnetic field at the pole shoes reduces in size (“decays”). The decaying magnetic field reduces the magnitude of the voltage induced in the stator windings and lowers the alternator output voltage. This is sensed by the voltage regulator control circuits, and the rotor circuit is switched on.

- The regulator switches rapidly between the ON and OFF conditions, within the preset maximum and minimum voltages, to allow the alternator to maintain an output voltage of approximately 14 volts and at the same time deliver the current needed for electrical system operation.

- As the load on the system increases, the current output to the circuits must be increased and the output voltage must be maintained.

- The regulator adjusts the rotor field circuit but increases the current flow and therefore the magnetic field strength. The induced voltage in the stator rises to maintain system voltage and increase current output.

- As the number of electrical components increases, vehicles require increasing amounts of available electricity.

- Higher voltage systems means more power for systems and accessories, fewer concerns about voltage drop, and the use of smaller diameter wires, which reduces the overall weight of the vehicle.

- One method of producing high-power output is to combine the vehicle starter motor and charging system into a single unit. A number of hybrid gasoline-electric vehicles use this system and mount the starter/generator on the flywheel between the engine and transmission.

Alternator Construction

The rotor is an electromagnet that rotates freely in the alternator. It consists of a coil of wire, wound on an iron core and pressed on a steel shaft. An iron segment is fastened on each side of the coil assembly so that the projections or claws interlace. The ends of the rotor coil are connected to insulated slip rings mounted on the shaft. Spring-loaded brushes maintain contact with the slip rings at all times.

- When a current is passed through the slip rings and the coil winding, it establishes a north and south pole at the ends of the iron core and the shaft. The projections then take on the same polarity as the end of the shaft on which they are mounted. This forms pairs of north and south poles around the rotor circumference.

- The rotor usually has 8 to 12 poles, which are tapered to reduce noise as the rotor rotates.

- The stator is mounted between two end brackets; it provides a stationary external magnetic field. It consists of a cylindrical, laminated iron core, which carries the three-phase windings in slots on the inside.

- The windings are insulated from each other and also from the iron core. They form a large number of conductor loops, which are each subjected to the rotating magnetic field.

- The two end frames are normally made from aluminum and form housings to accept the bearings. These bearings support the rotor at the drive end and at the slip-ring end. Ball bearings are normally used at each end.

- Slip rings are a way of making an electrical connection through a rotating assembly. They are normally copper bands, molded onto an insulating...
material and then pressed on the steel shaft of the rotor.

- Each end of the rotor winding is connected to one of the copper bands so that, as the rotor rotates, the brushes can make a connection with each end of the winding.
- The brushes conduct the current between stationary and moving parts. They are made of a combination of copper and carbon and are carried in brush holders mounted in the end frame.
- The diodes for rectification (converting AC to DC) are mounted on heat sinks, in packs of three. One heat sink has three positive diodes and the other has three negative diodes.
- The positive diode heat sink is insulated from the frame and is connected through the output terminal to the battery positive (B+) terminal.
- The negative diode heat sink is connected to the frame. This allows the return circuit via the battery negative terminal to be completed.
- The alternator’s cooling fan is a powerful centrifugal type. It is mounted on the rotor shaft and may be an integral part of the drive pulley or part of the rotor.
- It is essential to maintain a cooling stream of air over the diodes and stator. Due to the short length of the rotor, the cooling air needs to be spiraled in.
- To achieve this spiraling effect, the cooling fins on the plate have different openings: small and large.
- An exhaust fan draws in air through the opening at the back of the alternator and through the stationary stator windings.
- The greater the AMP rating of the alternator, the more heat it can generate.

### Charging Procedures

**READY FOR REVIEW**

- The main reasons for batteries using excess water include faulty batteries or excessive charge rate.
- To diagnose charging system issues, perform the following checks in sequence:
  1. Visually inspect the battery.
  2. Check the battery charge with a hydrometer and battery load tester.
  3. Check the vehicle charge rate with a digital multimeter.
- Personal safety includes using personal protective clothing and equipment, such as:
  - Work clothing
  - Eye protection
  - Ear protection
  - Hand protection
  - Respiratory equipment
- Safety check for checking a charging system:
  - Hood stay rod is secure.
  - Work area/environment is safe.
  - Prevent damage to the vehicle you are servicing.
- Instructions for checking a charging system:
  1. Set up the meter for a voltage check.
  2. Check the meter function.
  3. Check the battery voltage.
  4. Check the voltage after starting.
  5. Check the voltage with additional load.
  6. Carry out the load test.