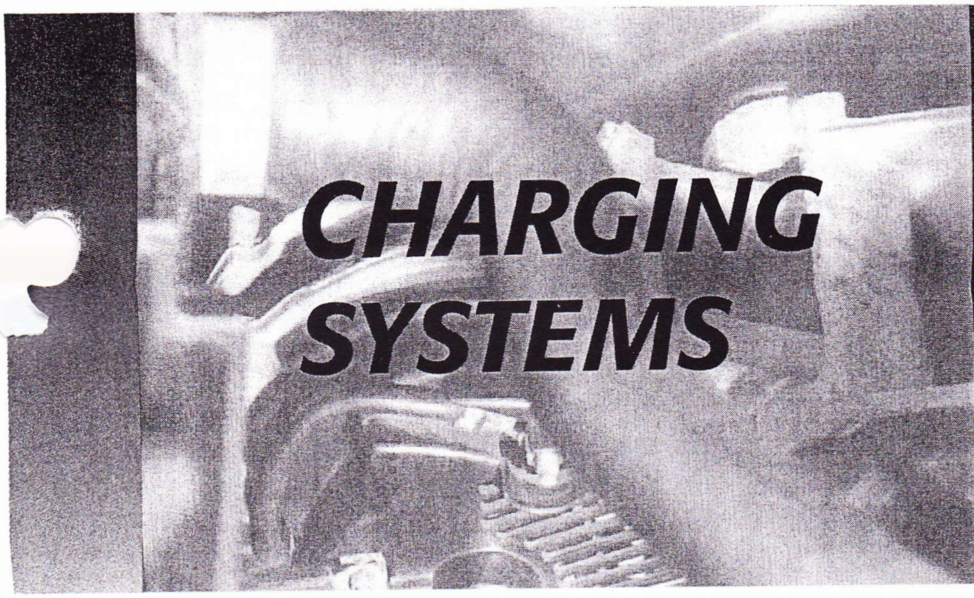
Charging Systems



18 CHARGING SYSTEMS

OBJECTIVES

◆ Explain the purpose of the charging system. ◆ Identify the major components of the charging system. ◆ Explain the purposes of the major parts of an alternator. ◆ Explain half- and full-wave rectification, and how they relate to alternator operation. ◆ Identify the different types of AC voltage regulators. ◆ Describe the two types of stator windings. ◆ Perform charging system inspection and testing procedures using electrical test equipment.

The primary purpose of a charging system is to recharge the battery. After the battery has supplied the high current needed to start the engine, the battery, even a good battery, has a low charge. The charging system recharges the battery by supplying a constant and relatively low charge to the battery. Charging systems work on the principles of magnetism to change mechanical energy into electrical energy. This is done by inducing voltage.

INDUCED VOLTAGE

Figure 18–1 shows a straight piece of conducting wire with the terminals of a voltmeter attached to both ends. If the wire is moved across a magnetic field, the voltmeter registers a small voltage reading. A voltage has been induced in the wire.

It is important to remember that the conducting wire must cut across the flux lines to induce a voltage. Moving the wire parallel to the lines of flux does not induce voltage.

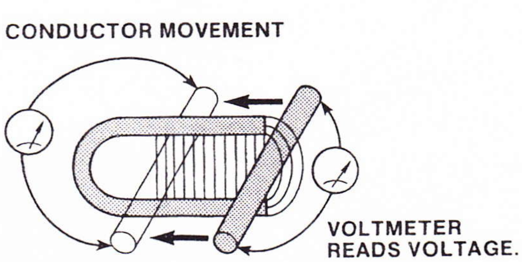


FIGURE 18–1 Moving a conductor so it cuts across the magnetic lines of force induces a voltage in the conductor.

The wire need not be the moving component in this setup. Holding the conducting wire still and moving the magnetic field at right angles to it also induces voltage in the wire. In fact, this is the exact setup used in a vehicle's alternator. A magnetic field is made to cut across stationary conductors to produce voltage and current.

The wire or conductor becomes a source of electricity and has a polarity or distinct positive and negative end. However, this polarity can be switched depending on the relative direction of movement between the wire and magnetic field (Figure 18–2). This is why an alternator produces alternating current.

The amount or **magnitude** of the induced voltage depends on four factors.

1. The stronger the magnetic field, the stronger the induced voltage.
2. The faster the field is being cut, the more lines of flux are cut and the stronger the voltage induced.

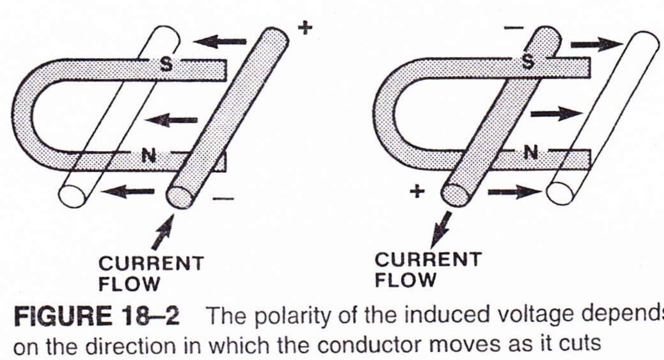


FIGURE 18–2 The polarity of the induced voltage depends on the direction in which the conductor moves as it cuts across the magnetic field.

3. The greater the number of conductors, the greater the voltage induced.
4. The closer the conductor(s) and magnetic field are to right angles (perpendicular) to one another, the greater the induced voltage.

ALTERNATING CURRENT CHARGING SYSTEMS

During cranking, the battery supplies all of the vehicle's electrical energy. However, once the engine is running, the charging system is responsible for producing enough energy to meet the demands of all the loads in the electrical system, while also recharging the battery (Figure 18–3). With all of the electronic and electrical devices used on cars today, the demands on the charging system are great.

During the early days of the automobile, the automotive charging system produced direct current, or DC, using a belt-driven generator that operated like a typical electrical motor. In a DC generator, a conductor (armature) spins inside a stationary magnetic field (Figure 18–4A). This induces an output voltage in the conductors. Although these generators are called **DC generators**, they produced AC but the output was purely DC. The conversion of AC to DC was accomplished internally through the position and polarity of the armature's brushes.

These DC charging systems offered limited current output, particularly at low speeds or idle. For this reason, AC charging systems, called **alternators**, were developed and are now universally used. Unlike the generators they replaced, alternators are compact, lightweight, and efficient at all engine speeds.

Alternators use a design that is basically the reverse of a generator. In an alternator, a spinning magnetic field rotates inside stationary conductors (Figure 18–4B). As the spinning north and south poles of the magnetic field pass the conducting wires, they induce voltage that first flows in one direction and then in the opposite direction. Because automotive electrical systems operate on direct current, this alternating current must be changed or rectified into direct current. This is done using an arrangement of diodes that will be explained later in the chapter.

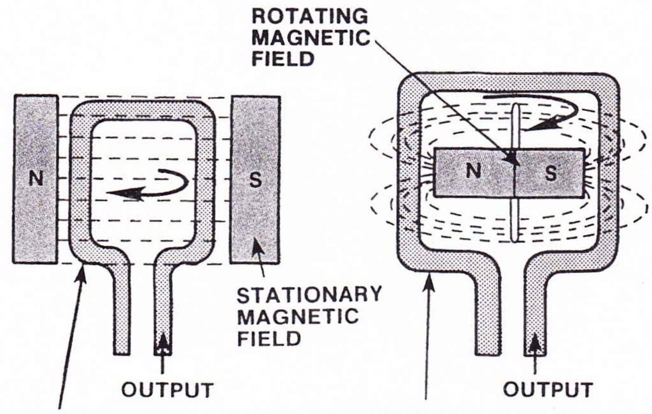


FIGURE 18–4 (A) DC generator and (B) AC alternator construction.

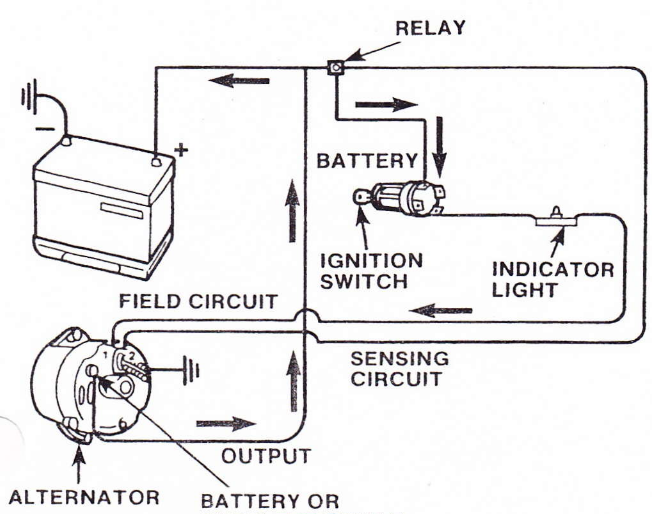


FIGURE 18–3 Component and current flow in an AC charging system.

Alternator Construction

Figure 18–5 illustrates the major parts of an alternator.

Rotor The rotor assembly consists of a drive shaft, coil, and two pole pieces (Figure 18–6). A pulley mounted on one end of the shaft allows the rotor to be spun by a belt driven by the crankshaft pulley.

The **rotor** is a rotating magnetic field inside the alternator. The coil is simply a series of conductive windings wrapped around an iron core. The core is located between the two sets of **pole pieces**. A magnetic field is formed by a small amount (4.0 to 6.5 amperes) of current passing through the coil windings. As current flows through the coil, the core is magnetized and the pole pieces assume the magnetic polarity of the end of the core that they touch. Thus, one pole piece has a north polarity and the other has a south polarity. The extensions of the pole pieces, known as **fingers**, form the actual magnetic poles. A typical rotor has fourteen poles, seven north and seven south, with the magnetic field between the pole pieces moving from the N poles to the adjacent S poles (Figure 18–7).

Slip Rings and Brushes Current to create the magnetic field is supplied to the coil from one of two sources, the battery, or the alternator itself. In either

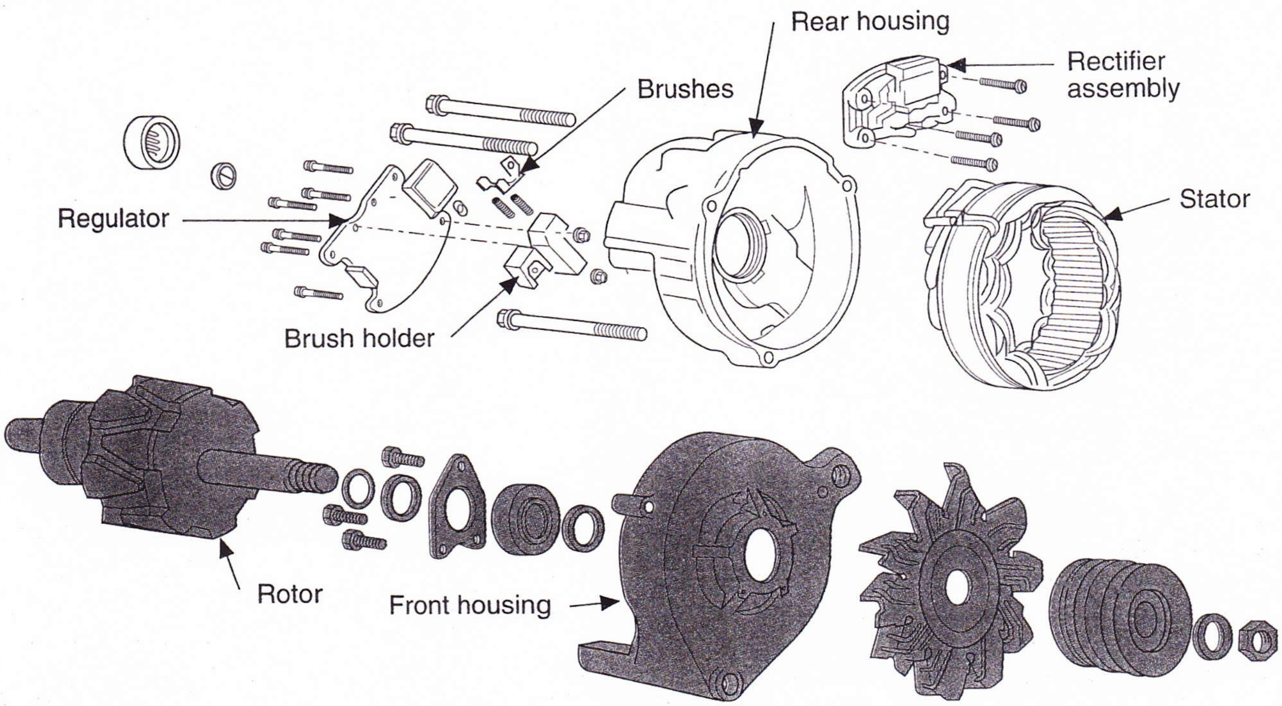


FIGURE 18–5 Components of a typical alternator. *Courtesy of Ford Motor Company*

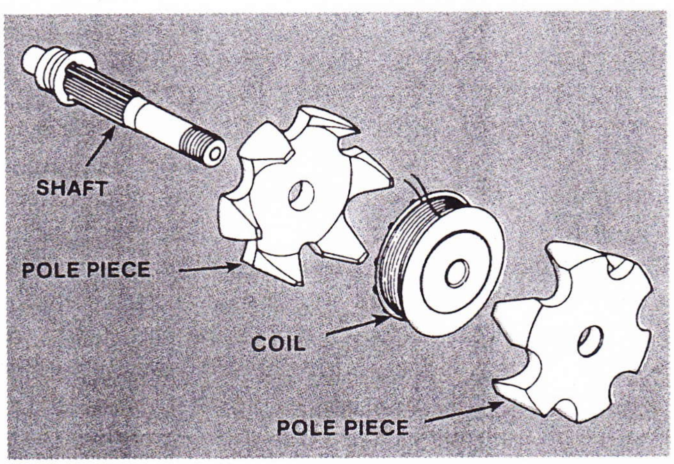


FIGURE 18–6 The rotor is made up of a coil, pole pieces, and a shaft.

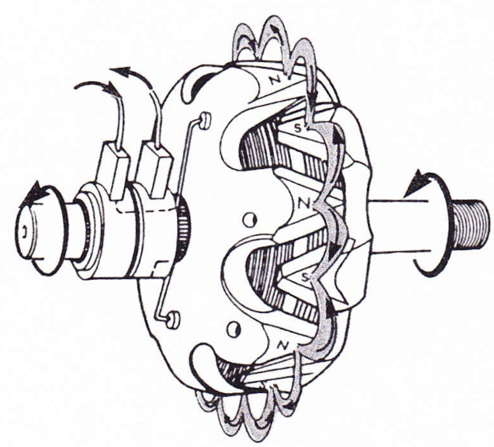


FIGURE 18–7 The magnetic field moves from the N poles, or fingers, to the S poles.

case, the current is passed through the alternator's voltage regulator before it is applied to the coil. The voltage regulator varies the amount of current supplied. Increasing field current through the coil increases the strength of the magnetic field. This, in turn, increases alternator voltage output. Decreasing the field voltage to the coil has the opposite effect. Output voltage decreases.

Slip rings and brushes conduct current to the rotor. Most alternators have two slip rings mounted directly on the rotor shaft. They are insulated from the shaft and each other. Each end of the **field coil** connects to one of the slip rings. A carbon brush (Figure 18–8) located on each slip ring carries the current to and from the field coil. Current is transmitted from the field terminal of the voltage regulator through the first brush and slip ring to the field coil. Current passes through the field coil and the second slip ring and brush before returning to ground (Figure 18–9).

Stator The **stator** is the stationary member of the alternator. It is made up of a number of conductors, or wires, into which the voltage is induced by the rotating magnetic field. Most alternators use three windings to generate the required amperage output. They are placed in slightly different positions so their electrical pulses are staggered in either a **delta** config-

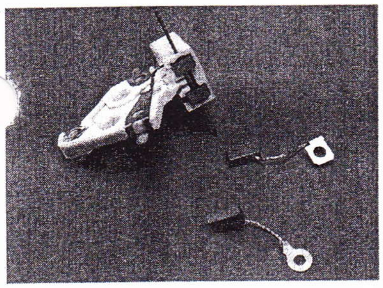


FIGURE 18–8 Brushes are the stationary electrical contact to the rotor's slip rings.

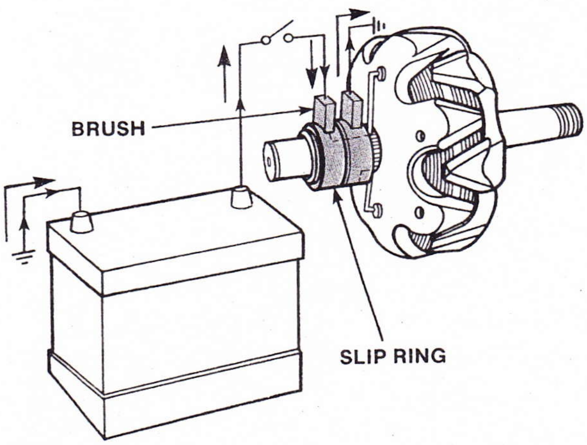


FIGURE 18–9 Current is carried by the brushes to the rotor windings via the slip rings.

uration or a **wye** configuration (Figure 18–10). The delta winding received its name because its shape resembles the Greek letter delta, Δ. The wye winding resembles the letter *Y*. Alternators use one or the other. Usually, a wye winding is used in applications where high charging voltage at low engine speeds is required. Alternators with delta windings are capable of putting out higher amperages.

The rotor rotates inside the stator (Figure 18–11). A small air gap between the two allows the rotor to turn without making contact with the stator. The

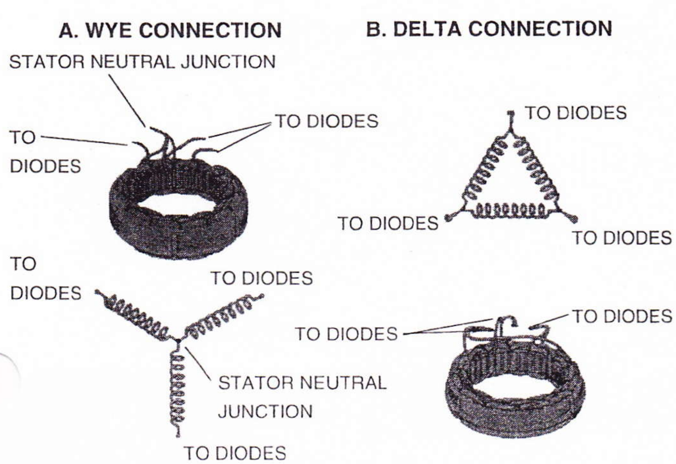


FIGURE 18–10 (A) Wye wound and (B) delta stators.
Courtesy of Ford Motor Company

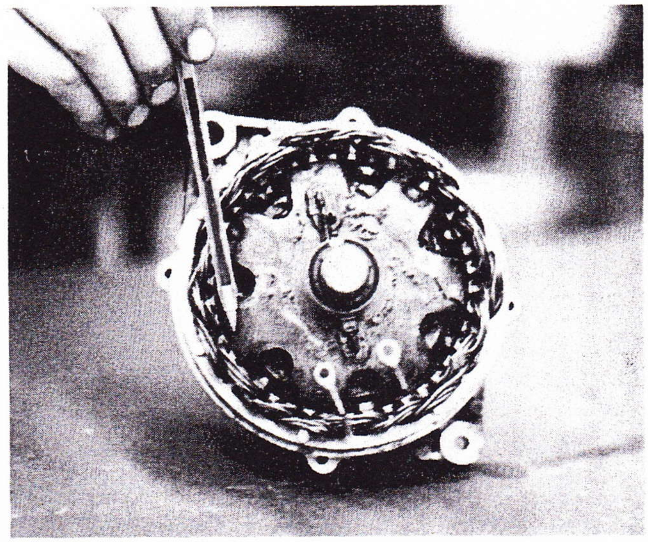


FIGURE 18–11 A small air gap exists between the spinning rotor and the stationary stator.

magnetic field of the rotor is able to energize all of the stator windings at the same time. Therefore, the generation of AC can be quite high if needed.

Alternating current produces a positive pulse and then a negative pulse. The resultant waveform is known as a sine wave, This **sine wave** can be seen on an oscilloscope (Figure 18–12). Notice that the complete waveform starts at zero, goes positive, then drops back to zero before turning negative. The angle and polarity of the field coil fingers are what cause this sine wave in the stator. When the north pole magnetic field cuts across the stator wire, it generates a positive voltage within the wire. When the south polarity magnetic field cuts across the stator wire, a negative voltage is induced in the wire. A single loop of wire energized by a single north then a south results in a single-phase voltage. Remember that there are three stator windings overlapped. This produces the overlapping sine wave (Figure 18–13). This voltage, since it was produced by three windings, is called **three-phase voltage**.

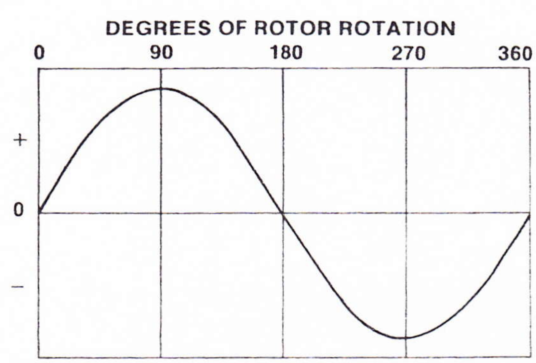


FIGURE 18–12 Sine wave from a stator, as displayed on an oscilloscope.

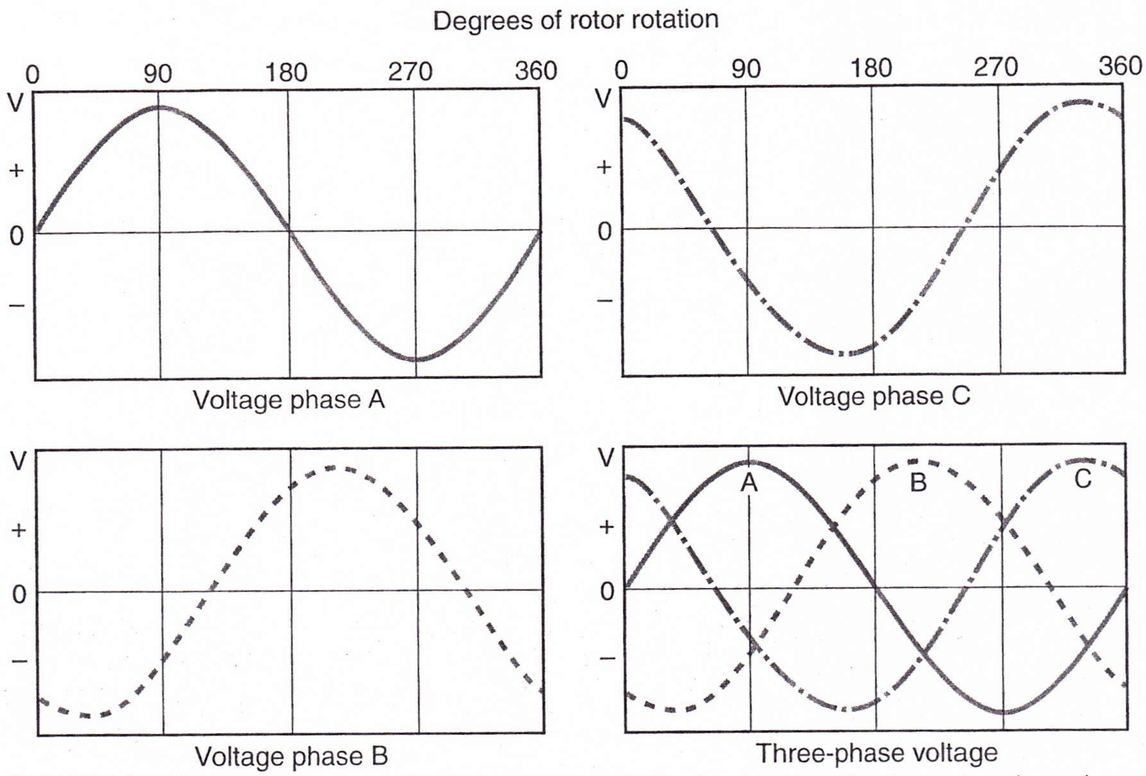


FIGURE 18–13 The voltage produced in each stator winding is added together to create a three-phase voltage.

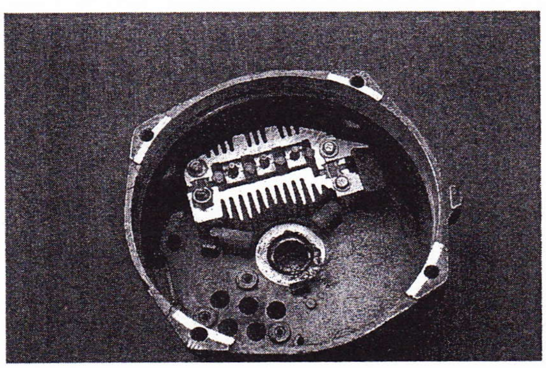


FIGURE 18–14 Bridge rectifier.

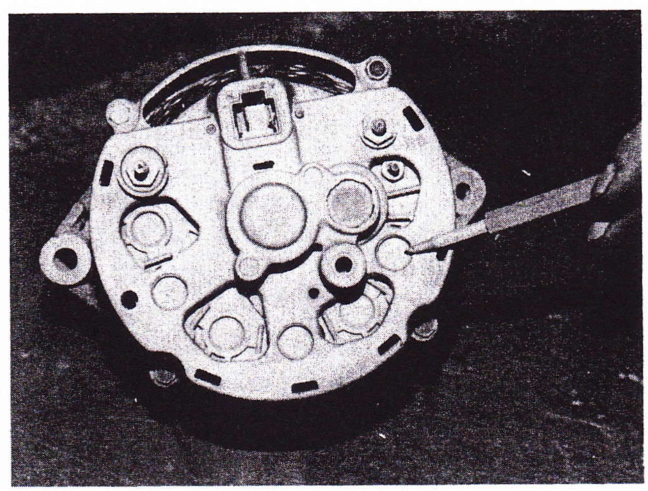


FIGURE 18–15 AC current rectified to a pulsating DC current after passing through a positive-biased diode.

End Frame Assembly The end frame assembly, or housing, is made of two pieces of cast aluminum. It contains the bearings for the end of the rotor shaft where the drive pulley is mounted. Each end frame also has built-in ducts so the air from the rotor shaft fan can pass through the alternator. Normally, a heat sink containing three positive rectifier diodes is attached to the rear end frame. Heat can pass easily from these diodes to the moving air (Figure 18–14). Three negative rectifier diodes are contained in the end frame itself (Figure 18–15). Because the end frames are bolted together and then bolted directly to the engine, the end frame assembly is part of the electrical ground path. This means that anything connected to the housing that is not insulated from the housing is grounded.

Alternator Operation

As mentioned earlier, alternators produce alternating current that must be converted, or rectified, to DC. This is accomplished by passing the AC through diodes.

DC Rectification

Figure 18–16 shows that if AC runs through the diode, the negative pulses are blocked off to produce the scope pattern shown. If the diode is reversed, it blocks off current during the positive pulse and

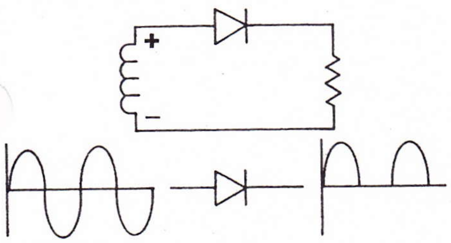


FIGURE 18–16 Half-wave rectification, diode positively biased.

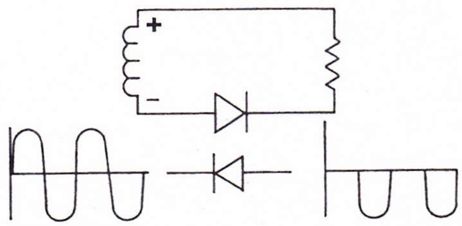


FIGURE 18–17 Half-wave rectification, diode negatively biased.

allows the negative pulse to flow (Figure 18–17). Because only half of the AC current pulses (either the positive or the negative) is able to pass, this is called **half-wave rectification.**

By adding more diodes to the circuit, more of the AC is rectified. When all of the AC is rectified, **full-wave rectification** occurs.

Full-wave rectification for stator windings requires another circuit with similar characteristics. Figure 18–18 shows a wye stator having two diodes attached to each winding. One diode is insulated, or positive, and the other is grounded, or negative. The center of the *Y* contains a common point for all windings. It can have a connection attached to it. It is called the stator neutral junction. At any time during the rotor movement, two windings are in series and the third coil is neutral and inactive. As the rotor revolves, it energizes the different sets of windings in different directions. However, the uniform result is

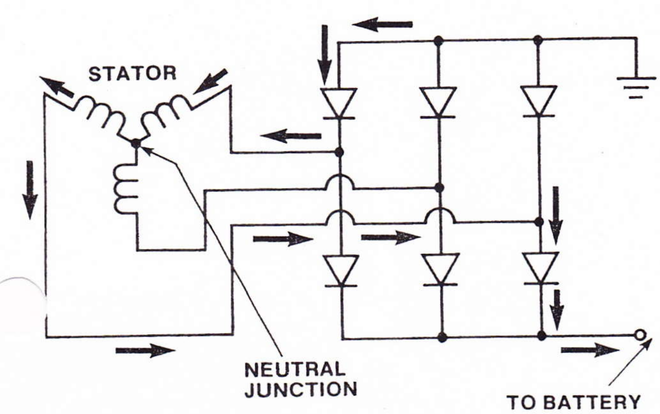


FIGURE 18–18 Wye stator wired to six diodes.

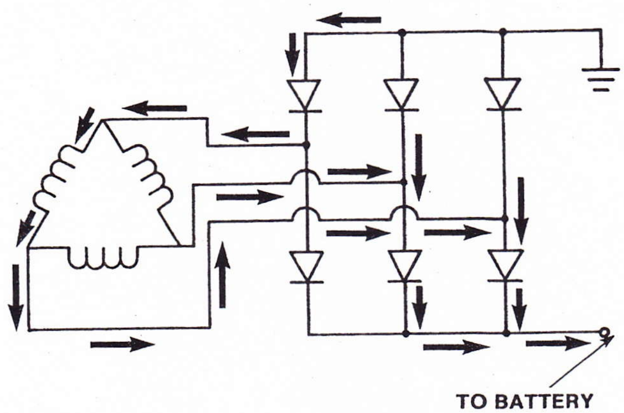


FIGURE 18–19 Delta stator wired to six diodes.

that current in any direction through two windings in series produces the required DC for the battery.

The diode action does not change when the stator and diodes are wired into a delta pattern. Figure 18–19 shows the major difference. Instead of having two windings in series, the windings are in parallel. Thus, more current is available from a delta wound alternator because the parallel paths allow more current to flow through the diodes. Nevertheless, the action of the diodes remains the same.

Some alternators have additional diodes, which connect the stator windings to the rotor coil (Figure 18–20).

Voltage Regulation

A **voltage regulator** controls the amount of voltage produced by the alternator and thus the voltage level in the charging circuit. Without a voltage regulator, the battery would be overcharged and the voltage level in the electrical systems would rise to the point where lights would burn out and fuses and fusible links would blow. Controlling the voltage is particularly important for on-board computers and other digital equipment. Microprocessors and electronic sensors and switches are easily damaged by voltage spikes and high-voltage levels.

The regulation of the charging circuit is accomplished by varying the amount of field current flowing through the rotor. Output is high when the field current is high and low when the field current is low. The operation of the regulator is comparable to that of a variable resistor in series with the field coil (Figure 18–21). If the resistance the regulator offers is low, the field current is high and if the resistance is high, the field current is low. The amount of resistance in series with the field coil determines the amount of field current, the strength of the rotor's magnetic field, and thus the amount of alternator output. The resistance offered by the regulator varies

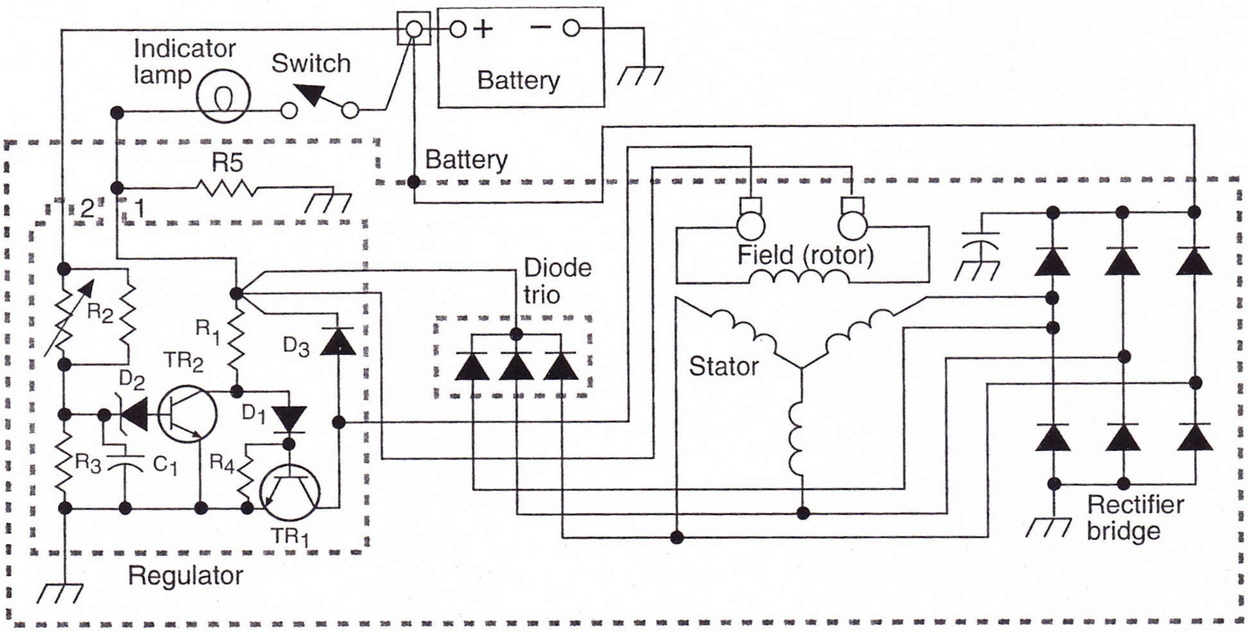


FIGURE 18–20 Wiring diagram of a charging circuit with a diode trio.

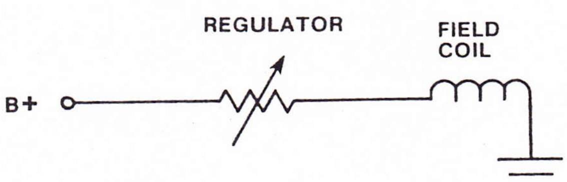


FIGURE 18–21 The voltage regulator acts like a variable resistor to control voltage.

according to charging system demands or needs. These needs are determined by the regulator as it interprets voltage and temperature inputs.

Many newer electronic voltage regulators turn the current flow to the rotor on and off to control an alternator's output. When more charge is needed, current flows for a longer period of time.

Voltage Input

Charging voltage is critically important to the process of fully charging the battery. If the charging voltage is only 12.5 volts, the battery never comes all the way up on charge. Not only does the entire vehicle operate at 12.5 volts, but current is being drawn from the battery instead of charging it. By raising the voltage of the alternator about 2 volts above the voltage of the battery, the alternator now becomes the source of current for the vehicle and of current to charge the battery. Most regulators are set for a system voltage between 14.0 and 14.7 volts so the charging voltage is higher than the 12.6 volts of the battery. A full charge is ensured.

To regulate the charging system, the regulator must have system voltage as an input. This voltage is also called sensing system voltage because the regulator is sensing system voltage. The regulator determines the need for charging current according to the level of the sensing voltage. When the sensing voltage is less than the regulator setting, the regulator increases the field current to increase the charging current. As sensing voltage rises, a corresponding decrease in field current and system output occurs. Thus, the regulator responds to changes in system voltage by increasing or decreasing charging current. For example, if a car is running down the road with no accessories on and a fully charged battery, the regulator senses a high system voltage because the battery is fully charged. So it maintains the charging voltage at a level sufficient enough to run the ignition system and to supply a 2- to 4-ampere trickle charge to the battery. If the headlights are turned on, the additional draw drops or loads the system voltage down. When the regulator senses this reduced voltage through the sensing circuit, it reduces the field circuit resistance to increase the field current and, as a result, the charging current. This adjustment takes place in less than a second. Of course, turning off accessories reverses the process. In response to a system voltage rise, the regulator reduces field current and alternator output.

Temperature Input

Temperature is the second input to the regulator. All regulators are temperature compensated (Table 18-1) because the battery is less willing to accept a charge if it is cold. So, as the temperature goes down, the regulator raises the system voltage until it is at a level that the battery readily accepts. In this way, the bat-

TABLE 18–1 REGULATOR TEMPERATURE VS. VOLTAGE

Temperature	Volts	
	Minimum	Maximum
20°F	14.3	15.3
80°F	13.8	14.4
140°F	13.3	14.0
Over 140°F	Less than 13.8	—

tery can be brought up on charge quickly, even in very cold climates.

Regulator Circuit

There are basically two ways the regulator circuit is connected to the alternator. The A-circuit has the regulator wired between the field terminal of the alternator and ground. Field current is regulated by changing the resistance in the ground path as shown in Figure 18–22. This circuit is commonly used with solid-state regulators. A B-circuit has the regulator between the B+ feed and the field coil as shown in Figure 18–23. The field coil is grounded inside the alternator. The result is the same as it was in the A-circuit. B-circuits are often used with older electromagnetic voltage regulators.

Voltage Regulator Design

All voltage regulators are designed to control the amount of current flowing through the field windings. The relationship between rotor speed, field current, and the regulated voltage is shown in Figure 18–24. To keep the regulated voltage con-

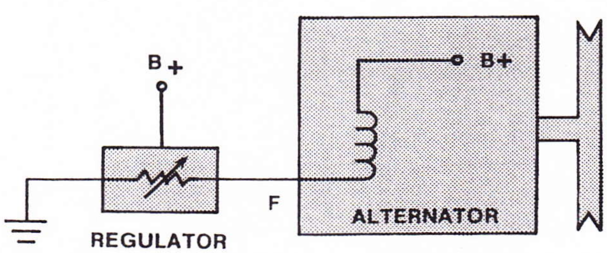


FIGURE 18–22 A-circuit.

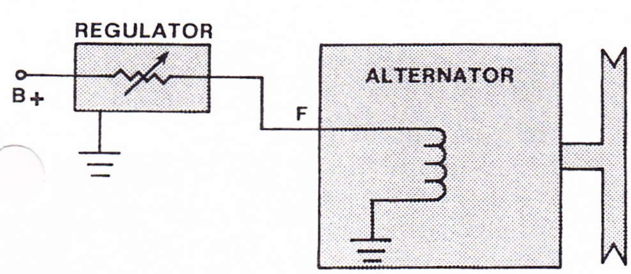


FIGURE 18–23 B-circuit.

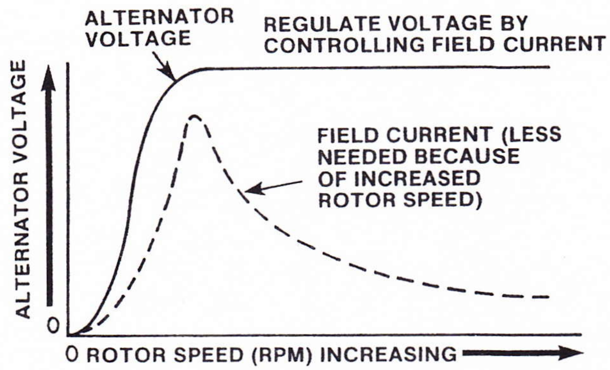


FIGURE 18–24 This chart shows the relationship between rotor speed, current in field windings, and output voltage. As the rotor speed increases, field current is reduced to keep the regulated voltage controlled.

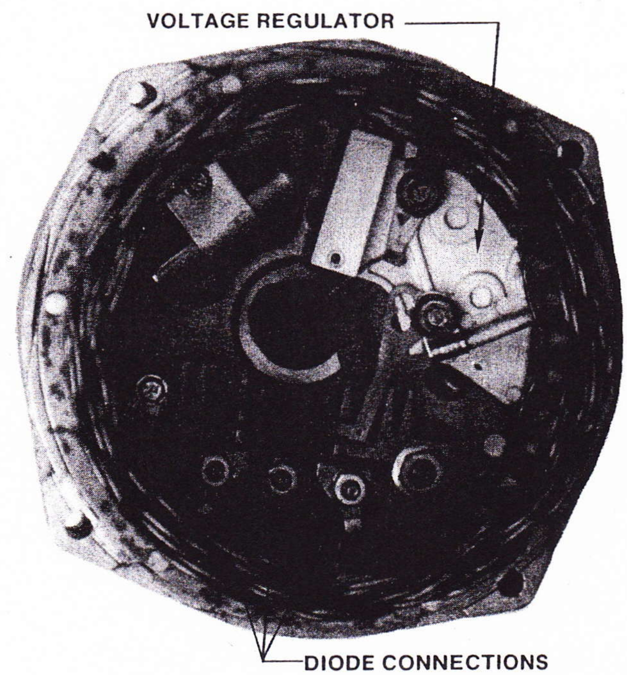


FIGURE 18–25 Alternator with an internally mounted voltage regulator.

trolled, the field current is reduced as the rotor speed increases.

Integrated circuit voltage regulators are used on most late-model vehicles. This is the most compact regulator design. All of the control circuitry and components are located on a single silicon chip. The chip is sealed in a plastic module and mounted either inside or on the back of the alternator (Figure 18–25). Integrated circuit regulators are also nonserviceable and must be replaced if defective.

Figure 18–26 illustrates a solid-state integrated regulator. It mounts inside the alternator slip ring end frame along with the brush holder assembly. All voltage regulator parts are enclosed in a solid mold. The rectifier bridge contains the six diodes needed to

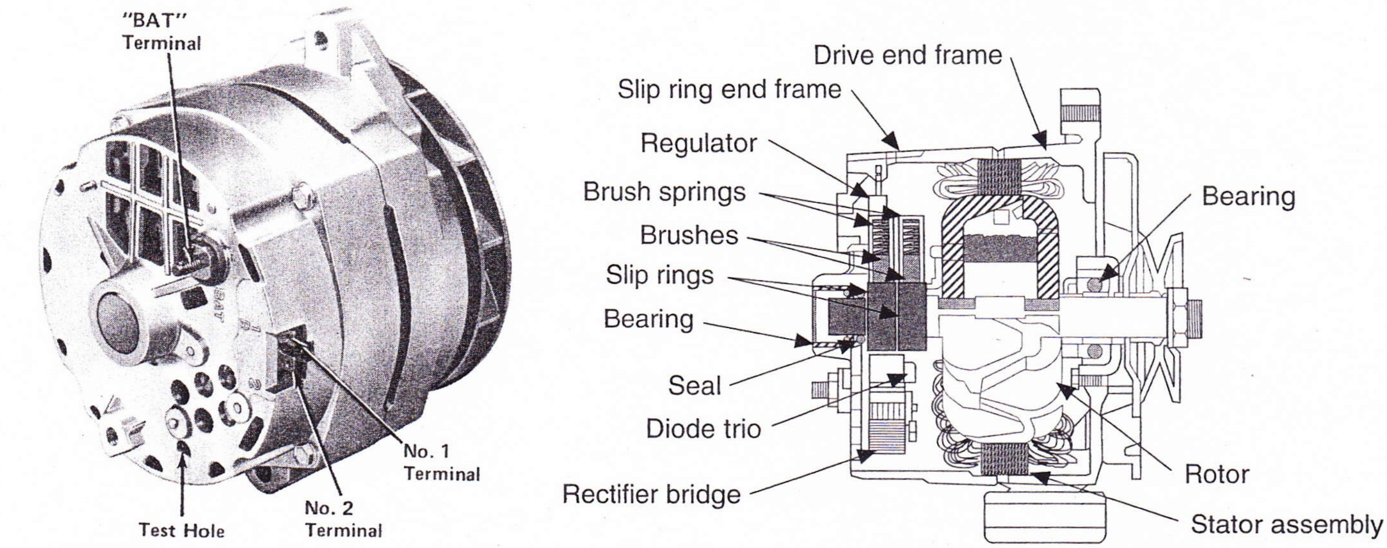


FIGURE 18–26 Component locations of an alternator with an internally mounted voltage regulator. *Courtesy of General Motors Corporation*

change AC to DC, which is then available at the output battery terminal. Field current is supplied through a diode trio, which is connected to the stator windings.

FAIL-SAFE CIRCUITS To prevent simple electrical problems from causing high-voltage outputs that can damage delicate electronic components, many voltage regulators contain **fail-safe circuits**.

A detailed explanation of how these circuits operate can be quite confusing. All you need to know is what a fail-safe circuit does, not how it does it. If wire connections to the alternator become corroded or accidently disconnected, the regulator's fail-safe circuits may limit voltage output that might rise to dangerous levels. Under certain conditions, the fail-safe circuits may prevent the alternator from charging at all. A fusible line in the fail-safe circuitry confines damage to the alternator. Delicate electronic components in other vehicle systems are not damaged.

Computer Regulation

On a growing number of late-model vehicles, a separate voltage regulator is no longer used. Instead, the voltage regulation circuitry is located in the vehicle's electronic control module or unit (Figure 18–27).

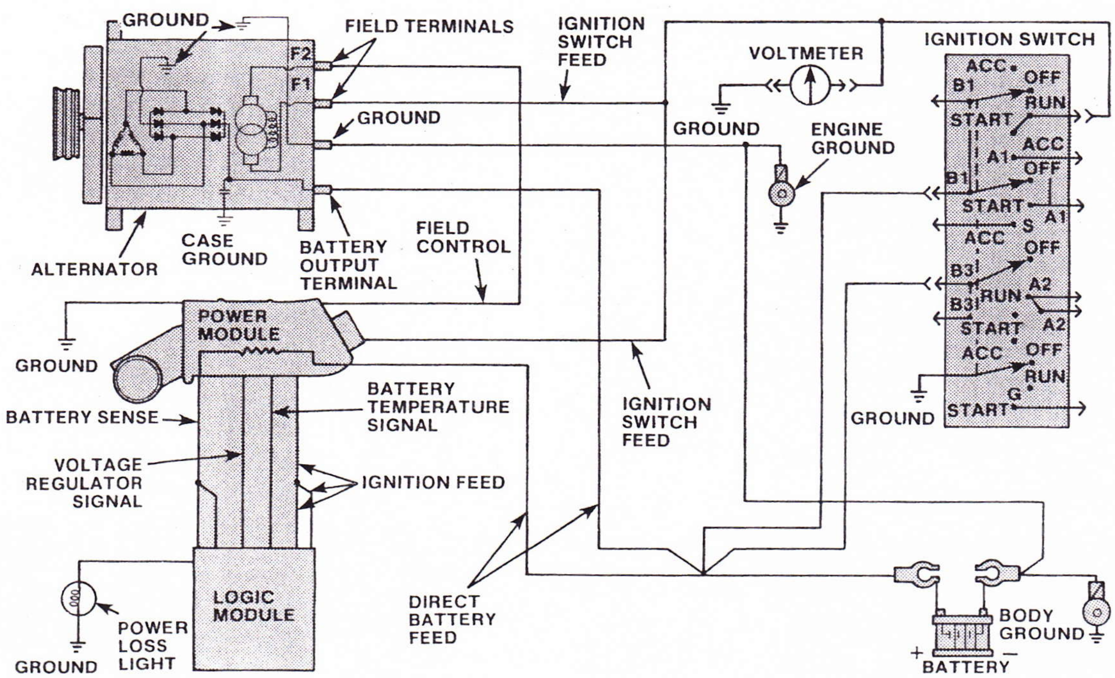


FIGURE 18–27 Wiring diagram of a charging system that uses the on-board computer system for voltage regulation control. *Courtesy of Chrysler Corporation*

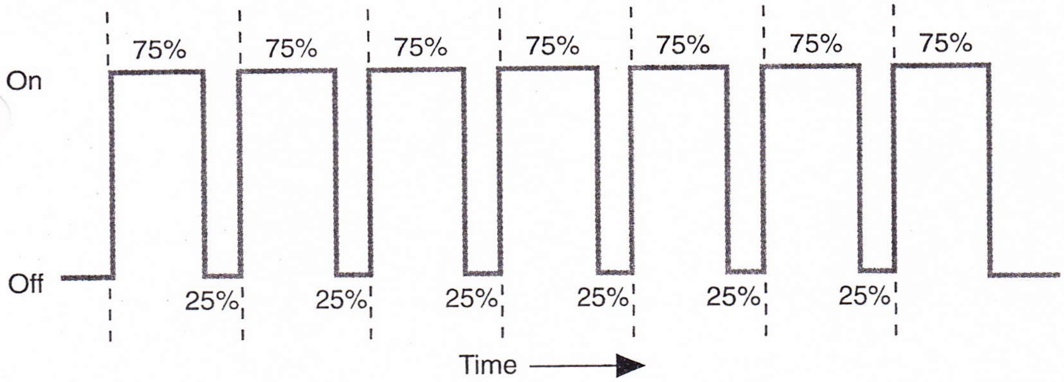


FIGURE 18–28 Pulse width modulation of charging system with 75 percent on-time.

The module computer is used to control current to the field windings in the rotor.

This type of system does not control rotor field current by acting like a variable transistor. Instead, the computer switches or pulses field current on and off at a fixed frequency of about 400 cycles per second. By varying on-off times, a correct average field current is produced to provide correct alternator output. At high engine speeds with little electrical system load, field circuit on time may be as low as 10 percent. At low engine speeds with high loads, the computer may energize the field circuit 75 percent or more of the time to generate the higher average field current needed to meet output demands (Figure 18–28).

A significant feature of this system is its ability to vary the amount of voltage according to vehicle requirements and ambient temperatures. This precise control allows the use of smaller, lighter, storage batteries. It also reduces the magnetic drag of the alternator, increasing engine output by several horsepower. Precise management of the charging rate can result in increased gas mileage and eliminate potential rough idle problems caused by parasitic voltage loss at low idling speeds. Most importantly, it allows the computer's diagnostic capabilities to be used in troubleshooting charging system problems, such as low- or high-voltage outputs.

Older Voltage Regulator Designs

Older vehicles may be equipped with electromagnetic or partially transistorized voltage regulators. Electromagnetic regulators use two electromagnetically operated contact point relays to control the charging circuit (Figure 18–29).

A **field relay** closes when the alternator begins to produce voltage. It allows a portion of the output current to energize the field coils. A second relay, known as the voltage limiter, has two sets of contact points. When the lower set of contact points open, field current passes through a resistor, and generated voltage decreases. When the possibility of excessive voltage exists during high speed operation, the upper contact closes shutting off all current flow to the field windings.

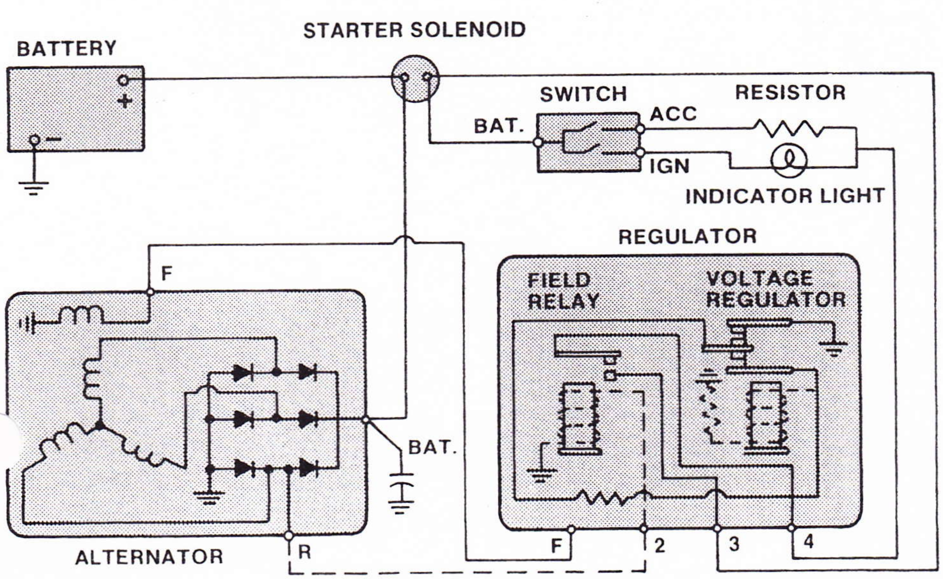


FIGURE 18–29 Older electromagnetically controlled alternator that uses solenoid-controlled field and voltage relays.

Transistors can be used in place of the electromagnetic relays. Older transistorized voltage regulators often used an electromagnetic field relay and a transistorized voltage relay. As explained in previous sections, modern solid-state regulators are completely transistorized.

Indicators

It is very important to monitor charging system performance during the course of vehicle operation. Vehicles are equipped with an ammeter, voltmeter, and indicator light. These allow the driver to monitor the charging system.

Indicator Light This is the simplest and most common method of monitoring alternator performance. When the charging system fails to supply sufficient current, the light turns on. However, when the ignition switch is first activated, the light also comes on. This is due to the fact that the alternator is not providing power to the battery and other electrical circuits. Thus, the only current path is through the ignition switch, indicator light, voltage regulator, part of the alternator, and ground, then back through the battery (Figure 18–30). Once enough power is provided, the contact in the regulator changes. Only the battery, regulator, and alternator are in the circuit. With no current flowing through the indicator light, it goes out.

With the engine running, the indicator light comes on again if the electrical load is more than the alternator can supply. This occasionally happens when the engine is idling. If there are no problems, the light should go out as the engine speed is increased. If it does not, either the alternator or regulator is not working properly.

SHOP TALK

On late-model cars, the indicator light can be combined with the oil pressure warning light; it usually is labeled "engine." If this light turns on while the engine is running, either the alternator is not charging or the oil pressure is low—or both. ■

Voltmeter Voltmeters indicate the amount of voltage across an electrical circuit. The voltmeter shown in Figure 18–31 measures battery voltage when the ignition switch is in the run position. A fully charged battery indicates just over 12 volts. As energy is taken from it, the battery's voltmeter reading drops. At the same time, the voltage regulator senses this and raises the charging voltage output to 14 volts or more. When the battery has been recharged, the alternator cuts back. The voltmeter now shows the fully charged battery voltage of just over 12 volts again. This on again, off again action of the alternator is constantly monitored by the voltmeter.

Ammeter The ammeter is placed in series with the circuit to monitor current flow into or out of the battery (Figure 18–32). When the alternator is delivering current to the battery, the ammeter shows a positive (+) indication. When not enough current (or none at all) is being supplied, the result is a negative (–) indi-

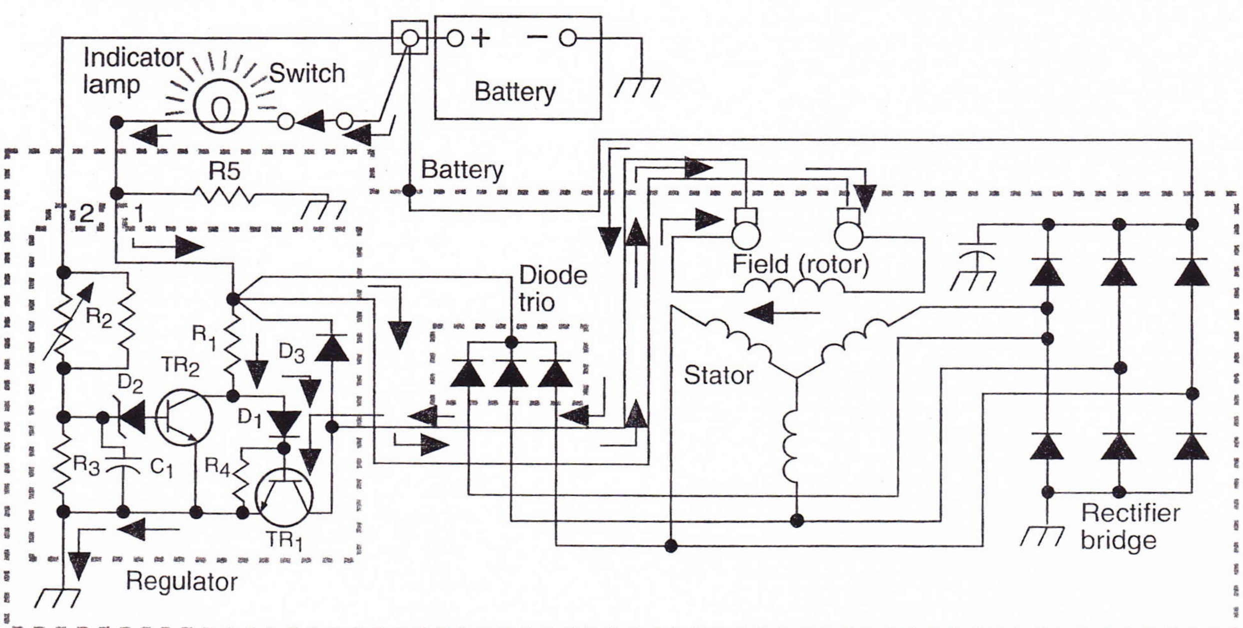


FIGURE 18–30 Electronic regulator with an indicator light "on" due to no alternator output.

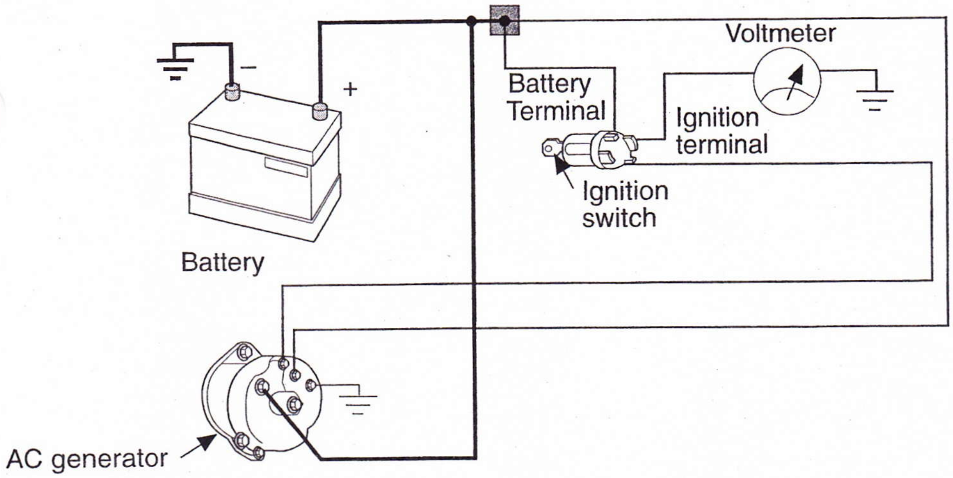


FIGURE 18–31 Voltmeter connected to the charging circuit to monitor its operation.

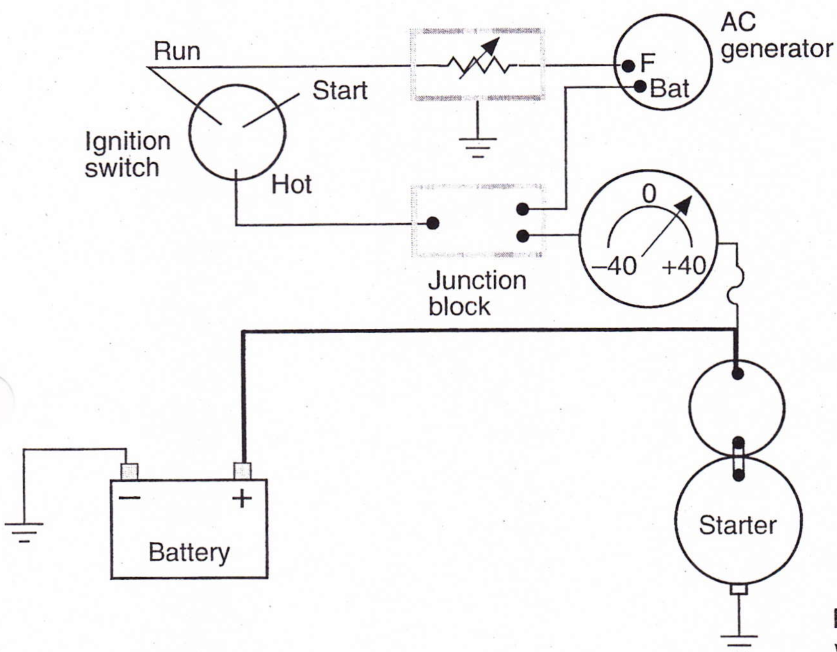


FIGURE 18–32 Ammeter connected in series with the charging system to monitor its operation.

cation. This is because the current flow is in the opposite direction, from the battery to the electrical system.

PRELIMINARY CHECKS

The key in solving charging system problems is getting to the root of the trouble the first time. Once a customer drives away with the assurance that the problem is solved, another case of a dead battery is very costly—both in terms of a free service call and a damaged reputation. Add to this the many possible hours of labor trying to figure out why the initial repair failed, and the importance of a correct initial diagnosis becomes all too clear.

When it comes to choosing equipment, the best tool to use for diagnosing the full spectrum of charging system problems is a charging-starting battery (CSB) analyzer. While a voltmeter helps in making intelligent decisions, the analyzer pinpoints the exact source of the trouble. Choose an analyzer that combines the functions of the carbon pile and separate meters to test the battery, alternator, regulator, and wiring.

Safety Precautions

- Disconnect the battery ground cable before removing any leads from the system. Do not reconnect the battery ground cable until all wiring connections have been made.
- Avoid contact with the alternator output terminal. This terminal is hot (has voltage present) at all times when the battery cables are connected.
- Always make sure the ignition switch is off, except during actual test procedures.
- The alternator is not made to withstand a lot of force. Only the front housing is relatively strong. When adjusting belt tension, apply pressure to the

front housing only to avoid damaging the stator and rectifier.

- Never operate the alternator without first connecting an external load to it. Failure to do so can cause extremely high voltage and possibly burn out the alternator.
- When installing a battery, be careful to observe the correct polarity. Reversing the cables destroys the diodes. Proper polarity must also be observed when connecting a booster battery, positive to positive and negative to ground.
- Always disconnect the battery ground cable before charging the battery. This greatly lessens the chance of flying sparks that could cause the battery to explode.
- Keep the tester's carbon pile off at all times, except during actual test procedures.
- Make sure all hair, clothing, and jewelry are kept away from moving parts.

Inspection

In addition to observing the ammeter, voltmeter, or indicator light, there are some common warning signs of charging system trouble. For example, a low state of battery charge often signals a charging problem, as does a noisy alternator. A detailed troubleshooting chart for charging systems is given in the *Tech Manual* that accompanies this textbook.

Many charging system complaints stem from easily repairable problems that reveal themselves during a visual inspection of the system. Remember to always look for the simple solution before performing more involved diagnostic procedures. Use the following inspection procedure when a problem is suspected.

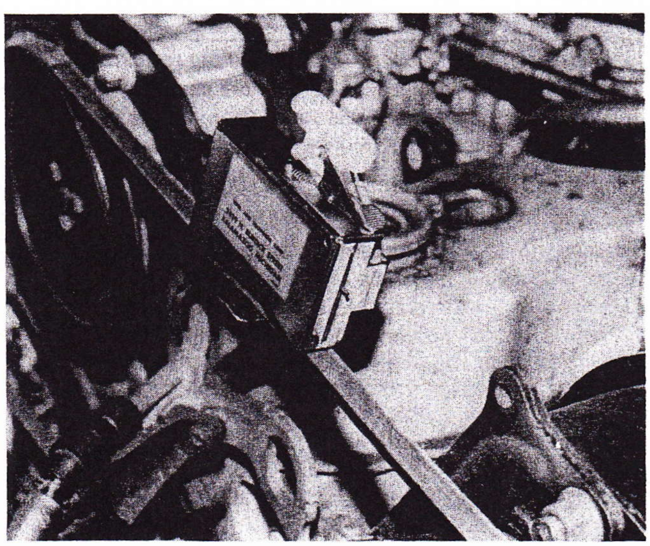


FIGURE 18–33 Using a tension gauge to check the tightness of an alternator's drive belt.

PROCEDURES
Inspections

1. Before adjusting belt tension, check for proper pulley alignment. This is especially critical with serpentine belts.
2. Inspect the alternator drive belt. Loose drive belts are a major source of charging problems. If a belt does not have the proper tension, it might produce a loud squealing sound. Use a belt tension gauge to check the tension as shown in Figure 18–33. Keep in mind that different belts (V, cogged V, and multi-ribbed V) require different tensions. Always consult the manufacturer's specifications. In addition, check the belt for signs of fraying, cracking, or glazing; replace if needed (Figure 18–34).
3. Inspect the battery. It might be necessary to charge the battery to restore it to a fully charged state. If the battery cannot be charged, it must be replaced. Also, make sure the posts and cable clamps are clean and tight, since a bad connection can cause reduced current flow.
4. Inspect all system wiring and connections. Many automotive electrical systems contain fusible links to protect against overloads. These

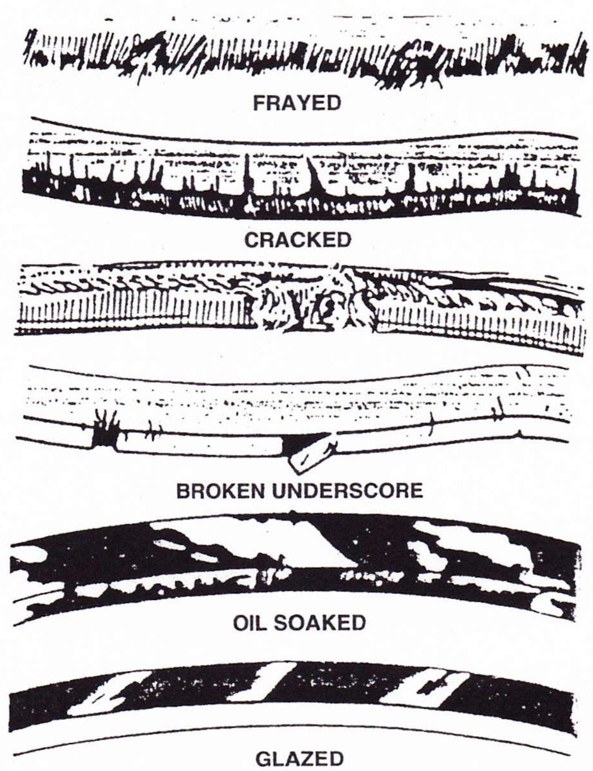


FIGURE 18–34 The alternator's drive belt must be replaced if any of these conditions exist.

are wires that melt at a lower temperature than the current-carrying wires they protect. Fusible links can blow like a fuse without being noticed. Also, look for a short circuit, an open ground, or high resistance in any of the circuits that could cause a problem that would appear to be in the charging system.

5. Inspect the alternator and regulator mountings for loose or missing bolts. Replace or tighten as needed. Remember that the circuit completes itself through the ground of the alternator and regulator. Most alternators and regulators complete their ground through their mounting. If the mountings are not clean and tight, a high resistant ground will result.

SHOP TALK

Some late-model Chrysler engines require a torque reading to be taken when tension is applied to the alternator drive belt. This is especially important on the longer, multiribbed V-belts. ■

If the vehicle passes all preliminary visual checks, listen for noisy belts, bad bearings, or the whirring sound of a bad diode. If no unusual sounds are heard, it is time to test the charging system.

General Test Procedure

Troubleshooting charts help a technician diagnose the charging system (Figure 18–35). They give several possible causes for the customer's complaint. They also help the technician decide what tests to conduct next or what service is required.

On-car charging system tests for all cars are basically the same, except for wire color and location and specifications. Not all vehicle manufacturers require all of these tests to be performed, while others suggest even more. During all of these tests, it is very important to refer to the manufacturer's specifications. Even the most accurate test results are no good if they are not matched against the correct specs. If a CSB is not available, separate voltmeters and ammeters can be used.

WARNING!

All of the meter readings that follow apply to 12-volt systems. While it is possible to test 6-, 24-, and 32-volt systems, do not attempt to do so without first checking the specifications provided by the manufacturer of the vehicle or the charging system. ■

Voltage Output Test To check charging system output, begin by recording battery open circuit voltage. To do this, connect the negative lead of the voltmeter to the negative battery cable clamp and the positive lead to the positive battery cable clamp. Note the voltage reading.

Next, start the engine and run it at the manufacturer's suggested rpm for this test. This is usually around 1,500 rpm. With no electrical load, the charging voltage should be approximately 2 volts higher than the open circuit voltage. The exact acceptable

Basic Types of Trouble	Probable Causes	Service Procedures
Alternator noise Note: Water pump noise is sometimes confused with alternator noise. A sound detecting device, such as a stethoscope, will eliminate indecision in this respect.	Alternator drive belt (squealing noise)	Adjust or replace belt, as required. (An application of belt dressing may eliminate noise caused by minor surface irregularities.)
	Alternator bearing (squealing noise)	Replace bearing if found to be out-of-round, worn, or causing shaft scoring.
	Alternator diode (whining noise)	Test alternator output. (A shorted diode causes a magnetic whine and a reduction in output.) Test diodes and replace, as required. Replacing rectifier assembly may be most feasible fix.
Indicator gauge fluctuates —or— ndicator light flickers.	Charging system wiring	Tighten loose connections. Repair or replace wiring, as required.
	Regulator contacts	Oxidized or dirty regulator contacts. Replace regulator, if necessary.
	Brushes	Check for tightness and wear. Replace, if necessary.

FIGURE 18–35 Charging system troubleshooting chart. *Courtesy of Ford Motor Company*

Basic Types of Trouble	Probable Causes	Service Procedures
Indicator light stays on.	Broken, loose, or slipping drive belt	Adjust or replace, as required.
	Battery cables, charging system wiring	Clean battery cables and terminals. Tighten loose connections. Repair or replace as required.
Ammeter registers constant discharge.	Battery specific gravity	If unsatisfactory, replace battery.
Battery will not hold charge.	Alternator output low, or no alternator output	Perform the voltage output test to Determine if trouble is in the regulator, wiring harness or the alternator itself.
	Alternator drive belt	Adjust or replace belt, as required.
	Battery cables, charging system wiring	Clean battery cables and terminals. Tighten loose connection. Repair or replace, as required.
Battery low in charge	Electrolyte (specific gravity)	Test each cell and evaluate condition:
Headlights dim at idle.		All readings even at 1.225 or above—Battery OK.
Note: A history of recurring discharge of the battery, which cannot be explained, suggests the need for checking and testing the complete charging system.		All readings even , but less than 1.225—Recharge and retest. High-low variation between cells less than 50 gravity points—Recharge and retest.
	Battery (capacity)	Test capacity and evaluate condition:
		Minimum voltage 9.6 for 12 volt battery or 4.8 for 6 volt battery. (Both values under specified test load conditions.)
		If capacity is under minimum specifications, perform 3 minute charge test. If below maximum (15.5 volts for 12 volt battery or 7.75 volts for 6 volt battery at 40 and 75 amps, charge rate, respectively) battery is OK—recharge. If above maximum, battery is sulfated. Slow charge at 1 amp/positive plate. Replace battery if it doesn't respond to slow charge.
Lights and fuses fail prematurely.	Charging system wiring, including regulator ground wire	Tighten loose connections. Repair or replace wiring, as required.
Short battery life.	voltage limiter setting	Perform the voltage output tests to verify The condition of the regulator.
Battery uses excssive water.		
Burning of distributor points		
Burning of resistor wire.		
Coil damage.		
High charging rate.		

FIGURE 18–35 *Continued*

range varies from model to model, but generally this reading will be between 13.5 to 15.0 volts.

A reading of less than 13.0 volts immediately after starting indicates a charging problem. No change in voltage between battery open circuit and charging voltage means the system is not producing voltage. A reading of 16 or more volts indicates overcharging. A faulty voltage regulator and control voltage circuit are the most likely causes of overcharging.

If the unloaded charging system voltage is within specifications, test the output under a load. To do this, increase engine rpm to about 2,000 rpm and turn on the headlights and other high-current accessories. The charging system output while under

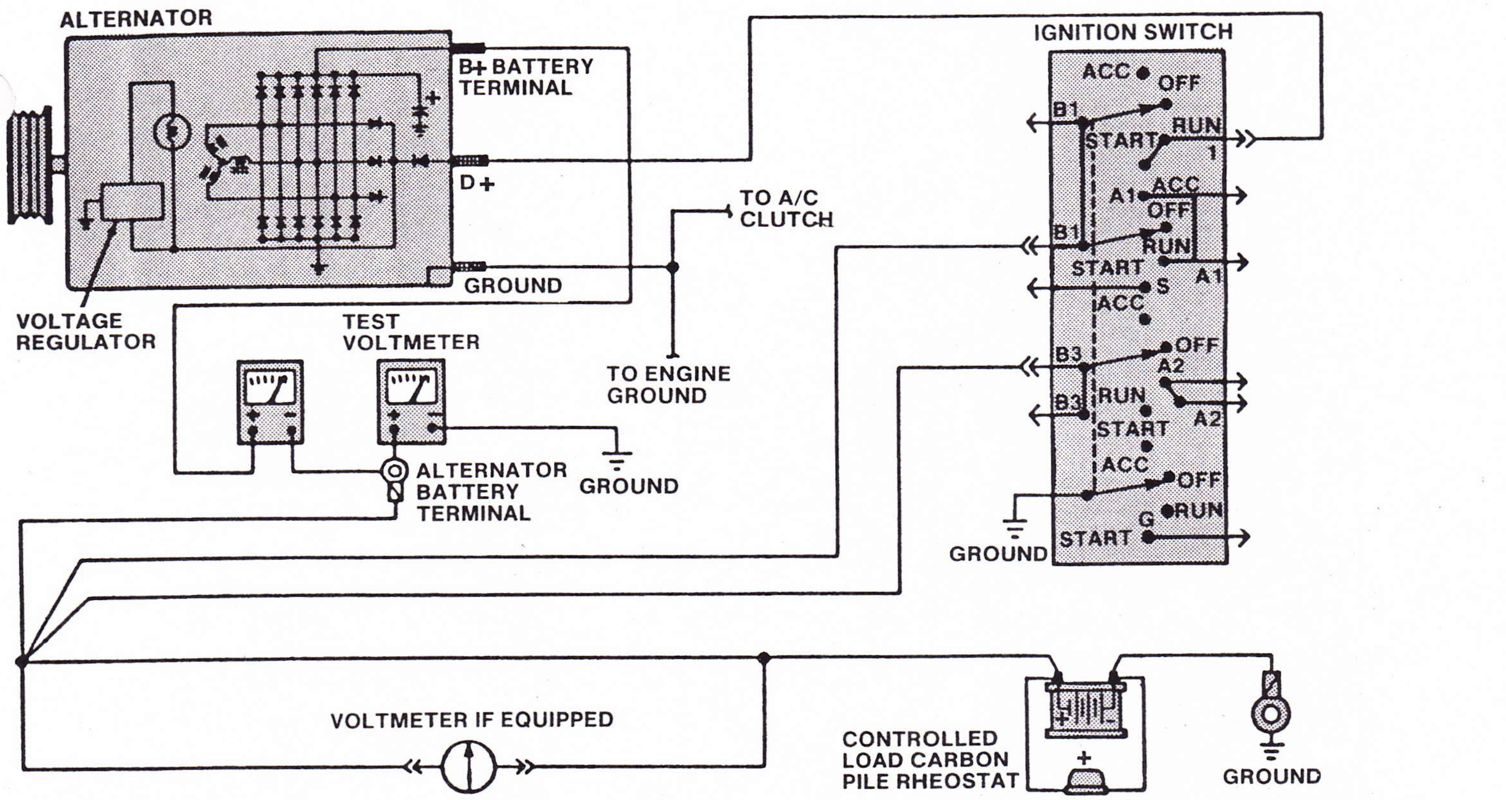


FIGURE 18–36 Ammeter, voltmeter, and carbon pile hook-up for a current output test on an alternator with an internal voltage regulator. *Courtesy of Chrysler Corporaton*

heavy load should still be around 0.5 volt above battery open circuit voltage.

Current Output Test The condition of the charging system can also be checked by testing alternator current output. The exact test procedures vary according to the vehicle and alternator model. Some test procedures call for connecting an ammeter in series between the alternator output terminal and the positive battery terminal. A carbon pile regulator is then connected across the battery terminals. The engine is then operated at moderate speeds and the carbon pile adjusted to obtain maximum current output. This reading is compared against the rated output. Normally, readings more than 10 amperes out of specifications indicate a problem.

When performing a current output test, the use of an inductive ammeter is highly recommended. An inductive ammeter eliminates the need to break battery connections. If you must break connections to hook up an ammeter, make sure you do not create an open circuit any time the alternator is generating current.

Other current output tests can be done by hooking up a voltmeter, ammeter, and carbon pile (Figure 18–36). With the engine running at a set speed, the carbon pile is adjusted to obtain the specified voltage reading. The ammeter will then read the system's current output. Always follow the appropriate instructions when conducting a current output test. Photo Sequence 10 shows a typical procedure to test a charging system.

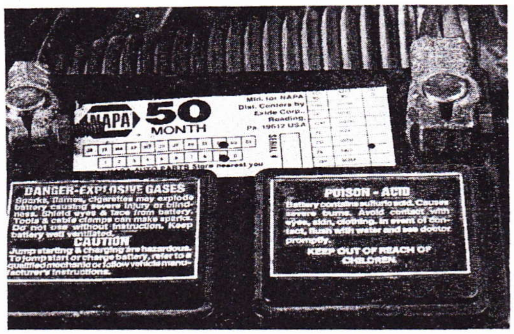
Regulator By-Pass Test If no or low voltage or current output is indicated, bypassing the voltage regulator by **full-fielding** the alternator will tell you if the alternator is bad. The exact procedure for full-fielding an alternator, which makes it produce maximum output current, varies according to the application. On alternators where the terminals are not very accessible, jumper wires may be needed to make the connections. Some new model alternators cannot be full fielded at all.

On many internal regulator alternators, full-fielding can be done by inserting a screwdriver through a special hole on the back of the unit (Figure 18–37). The normal procedure for full-fielding an A-circuit alternator is to ground the field terminal. If the A-circuit alternator has two field terminals, ground one and feed battery positive voltage to the other to full-field the alternator. With B-circuit alternators, the alternator is full-fielded by connecting the field terminal to battery positive.

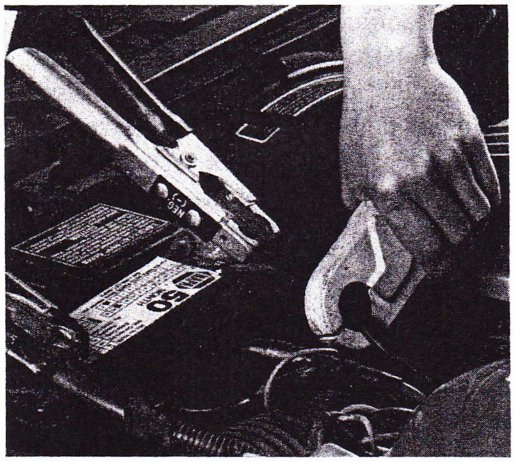
An A-circuit alternator has one carbon brush connected to positive battery voltage and the voltage regulator switches between field and negative to control output. With B-circuit systems, one brush is connected to the negative of the battery and the regula-

PHOTO SEQUENCE 10

USING A VOLT AND AMP TESTER TO TEST THE CHARGING SYSTEM

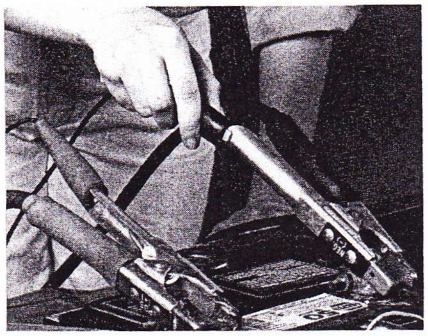


P10–1 Testing the charging system begins with a visual inspection of the battery and its cables. Make sure they are clean and free of corrosion. The alternator drive belt should also be inspected and its tension checked.

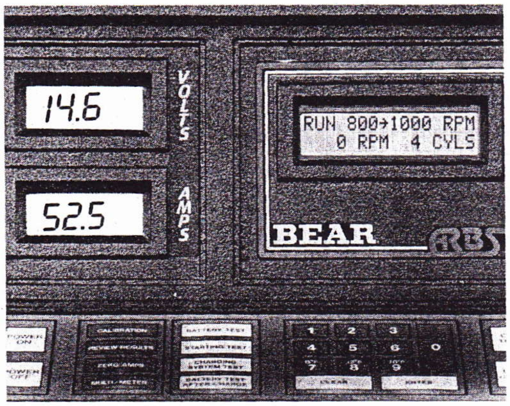


P10-2 To test the charging system, the tester's ampere pick-up probe must be positioned around the battery's negative cable and its cables connected to the battery.

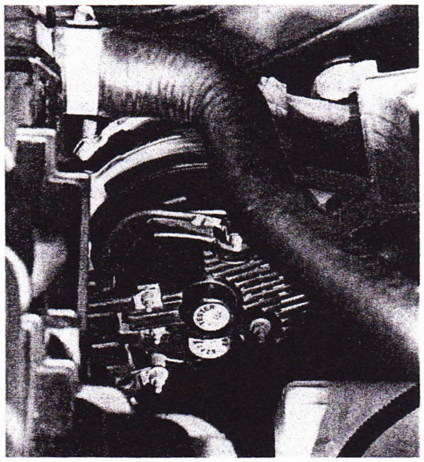
P10-3 To observe the tester's meters during this test, the tester should be placed where it can be easily seen from the driver's seat.



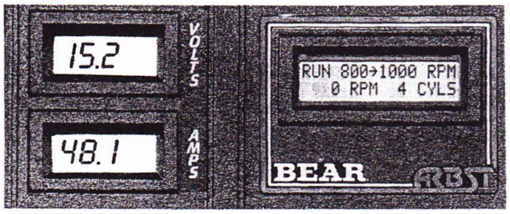
P10-4 It is recommended that engine speed be monitored. Therefore, connect a tachometer to the engine. Some testers, such as the one shown, are equipped with a tachometer that monitors ignition pulses at the battery.



P10-5 At about 2,000 rpm, the charging system will deliver a maximum amount of charge to the battery. This charging system is providing 14.6 volts at 52.5 amperes. Readings should be compared to specifications. Engine rpm doesn't show in the photo because the photo was taken after the test, not during it.



P10-6 If the readings are low, this may indicate that there is a fault in the charging system or that the battery is fully charged and not allowing the alternator to work at its peak. To determine the cause, the voltage regulator should be bypassed according to the procedures outlined in the service manual.



P10-7 With the regulator bypassed, this alternator increased its voltage output. This indicates that the regulator had been regulating voltage output. The amperage reading is also well within specifications. Therefore, the charging system is functioning properly

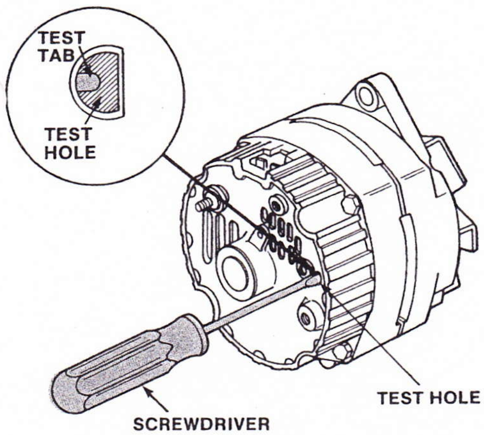


FIGURE 18–37 Grounding the field terminal with a screwdriver inserted into a special test hole on the back of the alternator.

tor switches between field and positive to control output. If an A-circuit regulator loses positive voltage, the alternator will overcharge if the field coils still have power. If the A-circuit regulator loses its ground, the system will go dead.

In B-circuit alternators, the opposite is true. If a B-circuit system loses ground, it will overcharge. If it loses positive voltage, it will go dead.

If full-fielding an alternator suddenly brings charging system voltage or current output up to specifications, the voltage regulator, not the alternator is at fault. If charging output is still low or nonexistent when full-fielding, the alternator is bad.

Oscilloscope Checks Alternator output can also be checked using an oscilloscope. Figure 18–38 illustrates common alternator voltage patterns for good and faulty alternators. The correct pattern looks like the rounded top of a picket fence. A regular dip in the pattern indicates that one or more of the coil windings is grounded or open, or that a diode in the rectifier circuit of a diode trio circuit has failed. Most battery/charging system testers also have a test function that detects faulty diodes.

Circuit and Ground Resistance These tests measure voltage drop within the system wiring. They help pinpoint corroded connections or loose or damaged wiring.

Circuit resistance is checked by connecting a voltmeter to the positive battery terminal and the output, or battery terminal of the alternator. The positive lead of the meter should be connected to the alternator output terminal and the negative lead to the positive battery terminal. To check the voltage drops across the ground circuit, connect the positive lead to the alternator housing and the negative meter lead to the battery negative terminal. When measuring the voltage drop in these circuits, a sufficient

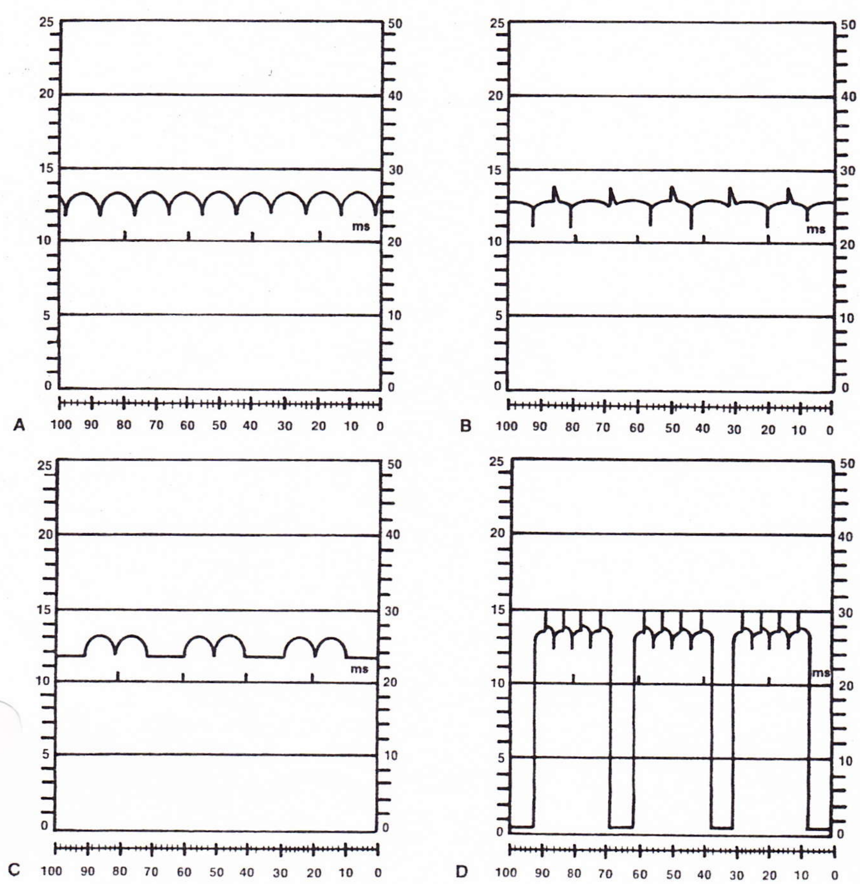


FIGURE 18–38 Alternator oscilloscope patterns: (A) good alternator under full load, (B) good alternator under no load, (C) shorted diode and/or stator winding under full load, and (D) open diode in diode trio.

amount of current must be flowing through the circuit. Therefore, turn on the headlights and other accessories to ensure that the alternator is putting out at least 20 amps. If a voltage drop of more than 0.5 volt is measured in either circuit, there is a high resistance problem in that circuit.

ALTERNATOR SERVICE

A faulty alternator can be the result of many different types of internal problems. Diodes (Figure 18–39), stator windings (Figure 18–40), and field circuits (Figure 18–41) may be open, shorted (Figure 18–42 and Figure 18–43), or improperly grounded. The brushes or slip rings can become worn. The rotor shaft can become bent and the pulley can work loose or bend out of proper alignment.

After diagnosing a faulty alternator, many shops simply replace it with a new or rebuilt unit. Follow service manual procedures when removing and installing the alternator. Remember, improper connections to the alternator can destroy it.

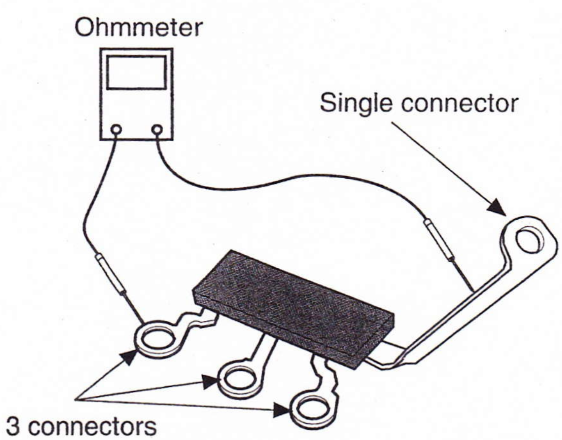


FIGURE 18–39 Using an ohmmeter to test a diode trio.

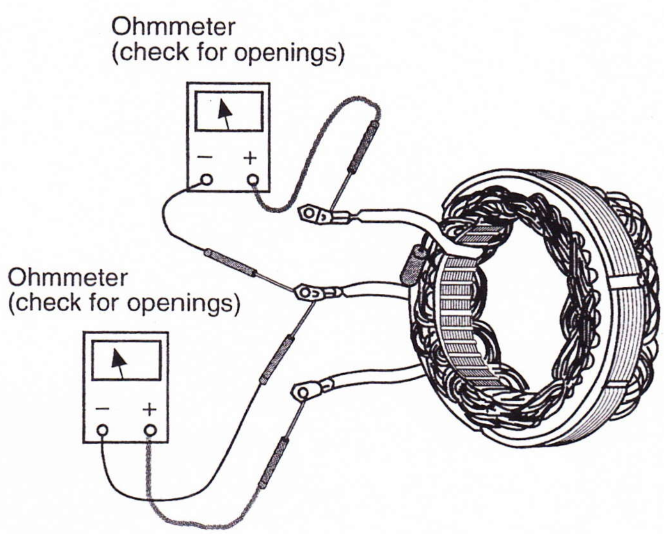


FIGURE 18–40 Testing a stator for opens.

Most alternator repair or rebuilding work is performed in specialty shops. Internal problems that cause alternator failure include open, shorted, or improperly grounded diodes, stator windings, or field circuits. Brushes and slip rings can also become worn. Rotor shafts and pulleys can become loose or bent out of alignment.

Follow service manual procedures for disassembling, inspecting, testing, and rebuilding alternators. Basic procedures for testing diodes and internal circuits are given in the *Tech Manual* that accompanies this textbook.

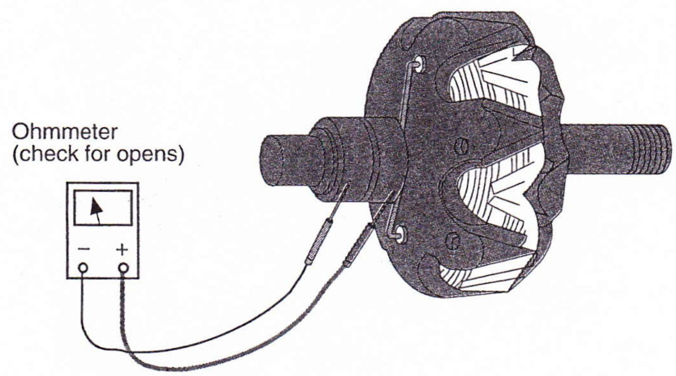


FIGURE 18–41 Testing a rotor for opens.

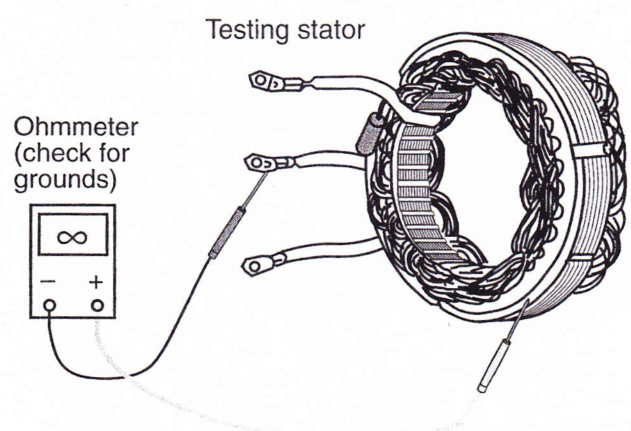


FIGURE 18–42 Testing a stator for a short to ground.

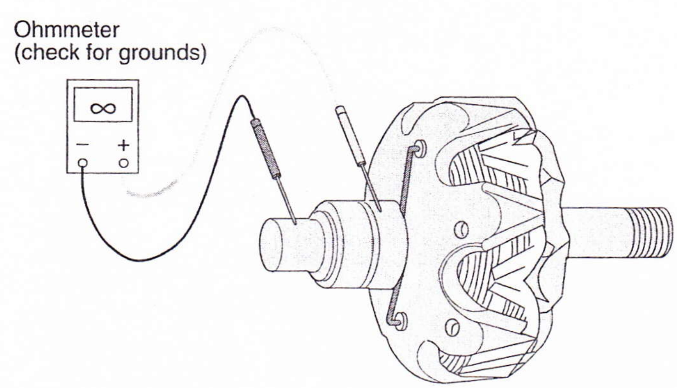


FIGURE 18–43 Testing a rotor for a short to ground.

CASE STUDY

***A** customer brought his pick-up truck into the dealership with a complaint that the truck must be jumped to get it started and once it is started, it runs for about 10 minutes then dies.*

The technician verified the complaint then did a visual inspection of the charging system. Based on the complaint, he knew that the battery was not being kept in charge by the alternator or that the battery was unable to hold a charge. He found the alternator drive belt extremely frayed and glazed. Knowing this could cause the problem, he replaced the belt. However, before releasing the truck back to the customer he tested the battery to make sure it was able to hold a charge if the alternator was capable of charging it. The battery checked out fine. He then checked the alternator output and found it to be within specifications. This was a good technician, he knew that he shouldn't assume that the obvious problem was the only problem. As a result, the customer was happy and should be for quite some time.

KEY TERMS

Alternator
DC generator
Delta
Fail-safe circuit
Field coils
Field relay
Fingers
Full-fielding
Full-wave rectification
Half-wave rectification
Integrated circuit voltage regulator
Magnitude
Pole piece
Rotor
Sine wave
Slip rings
Stator
Three-phase voltage
Voltage regulator
Wye

SUMMARY

- Inducing a voltage requires a magnetic field producing lines of force, conductors that can be moved, and movement between the conductors and the magnetic field so the lines of force are cut.
- Modern vehicles use an alternator to produce electrical current in the charging system. Diodes in the alternator change or rectify the alternating current to direct current.
- A voltage regulator keeps charging system voltage above battery voltage. Keeping the alternator charging voltage above the 12.6 volts of the battery ensures current flows into, not out of, the battery.
- Modern voltage regulators are completely solid-state devices that can be an integral part of the alternator or mounted to the back of the alternator housing. In some vehicles, voltage regulation is the job of the computer control module.
- Voltage regulators work by controlling current flow to the alternator field circuit. This varies the strength of the magnetic field, which in turn varies current output.
- The driver can monitor charging system operation with indicator lights.
- Problems in the charging system can be as simple as worn or loose belts, faulty connections, or battery problems.
- Circuit resistance, current-output, voltage-output, field-current draw, and voltage regulator tests are all used to troubleshoot AC charging systems.

TECH MANUAL

The following procedures are included in Chapter 18 of the *Tech Manual* that accompanies this book:

1. *Visually inspect the charging system.*
2. *Adjust drive belt.*
3. *Remove and replace an alternator.*
4. *Test the charging system.*
5. *Disassemble and assemble the alternator.*
6. *Test components of an alternator.*

REVIEW QUESTIONS

1. Which of the following is *not* a way to increase the amount of voltage induced in an alternator?
   a. Increase the number of conductors.
   b. Move the conductors through the magnetic field slowly.
   c. Move the conductors at a right angle to the magnetic field.
   d. Increase the current going through the electromagnet.