Study Unit

Charging and Ignition Systems

By

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Preview

This study unit is the second of three study units devoted to motorcycle and ATV electrical systems. In the previous study unit, you learned about the basics of electricity, where electricity comes from, and how to measure it. In this study unit, you'll learn how to apply this electrical theory to understand motorcycle and ATV charging and other related electrical systems. We'll begin by describing the basics of a charging system. Next, we'll take a closer look at each of the components in the charging system and show you how they operate. After we've discussed each of the components, we'll review the overall operation of the charging system and tell you how to maintain and troubleshoot charging systems. Finally, we'll take a look at some of the other electrical circuits found on motorcycles and ATVs.

When you complete this study unit, you'll be able to

- Explain why motorcycles and ATVs use charging systems
- Describe the theory behind a basic charging system
- Visually identify the different types of charging systems found on motorcycles and ATVs from the wiring diagrams
- Describe how alternators generate AC power
- Describe how a charging system changes alternating current into direct current
- Explain the electrical system of motorcycles and ATVs that don't use a battery
- List the steps required for maintenance and minor troubleshooting of a charging system
- Read block diagrams for various DC electrical system circuits

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Charging and Ignition Systems

INTRODUCTION

A charging system is necessary in any motorcycle or ATV which has a battery for powering electrical components. As we mentioned in the previous study unit on basic electricity fundamentals, the first step to understanding electrical systems and how they work is to start with the basics.

To understand how a charging system works, you must first understand what a charging system does. Then, you need to know the components that make up the charging system and how they work.

Charging System Overview

The purpose of a charging system is to replenish the power in a battery as it's used. An *alternator* provides the electrical power source for the charging system (Figure 1). The alternator provides an alternating current (AC) output. In order to convert the AC output of the alternator to direct current (DC), which is needed by the battery, a *rectifier* is used. The rectifier converts the AC (which you'll remember alternately flows in one direction, then in the other direction) into DC, which flows in only one direction. This process is known as *rectification*. The voltage from the charging system to the battery is maintained within certain limits by a *voltage regulator*. By controlling the output of the charging system, the regulator prevents undercharging or overcharging the battery.

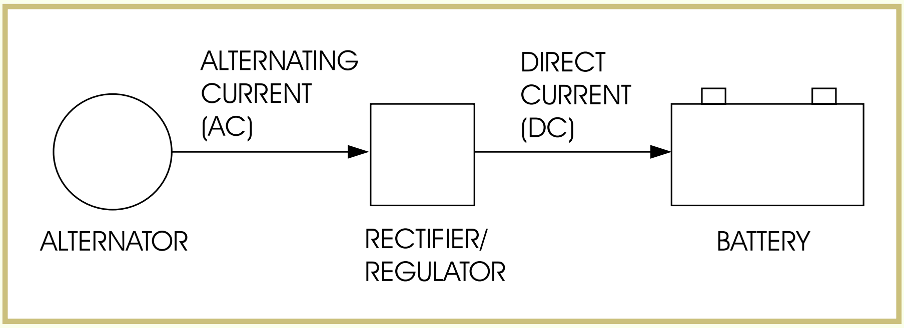


FIGURE 1—A simple block diagram of a charging system is shown here.

Some racing machines use what is known as a "total loss" electrical system. This means that the electrical system doesn't have a charging system. The battery has enough power to complete the race without recharging. When the battery becomes discharged, the machine will no longer operate and the battery must be recharged using an external battery charger. This study unit, however, will focus on machines having charging systems.

Charging System Components

From small 50cc ATVs to large 1500cc touring motorcycles, all charging systems have the same common basic components as shown in Figure 1. These components may have different designs in various motorcycles and ATVs, but still provide the same functions in the charging system.

Alternator

An alternator is a generator that produces an AC voltage. The alternator is driven by the rotation of the engine crankshaft. Thus, it only produces an electrical output when the engine is running. The output from the alternator varies with the speed of the engine.

Rectifier

A rectifier converts the AC from the alternator into DC that is used by the battery. There are basically two types of rectifiers: *half wave* and *full wave,* which will be discussed later in this study unit. The rectifier uses a diode or diodes to convert the AC into DC by allowing current flow in one direction only.

Voltage Regulator

A voltage regulator may be a separate device or it may be contained with the rectifier as a single unit. There are many types of regulators. The newer solid-state types of regulators use thyristors (SCRs) and Zener diodes, which provide a current limiting function to control battery charging.

Battery

A battery is an electrical storage device which supplies DC power for the motorcycle or ATV electrical systems. As the battery is discharged from use, the charging system charges the battery as needed.

In summary, the alternator generates AC voltage. The rectifier changes the AC into DC. The battery stores the DC voltage and the voltage regulator controls the voltage being sent to the battery. This is basically what a charging system does in a motorcycle or ATV (or an automobile, or lawn and garden tractor for that matter!).

Now, let’s begin by looking more closely at each of the components that make up the charging system. After we’ve learned more about each of these components, we'll look at the charging system operation in more detail.

ALTERNATORS

Depending on the manufacturer, there are many different terms used for an alternator including *generator*, *dynamo*, and *magneto*. For the purpose of this study unit, we'll simply refer to them as alternators.

All alternators are actually AC generators which are driven from the engine. An alternator has two main components—the *rotor* and the *stator*. The rotor has a series of magnets and rotates either inside (Figure 2A) or outside (Figure 2B) the stationary windings of the stator. The stator consists of several different coils which are used to produce power for the motorcycle or ATV electrical circuits and to charge the battery.

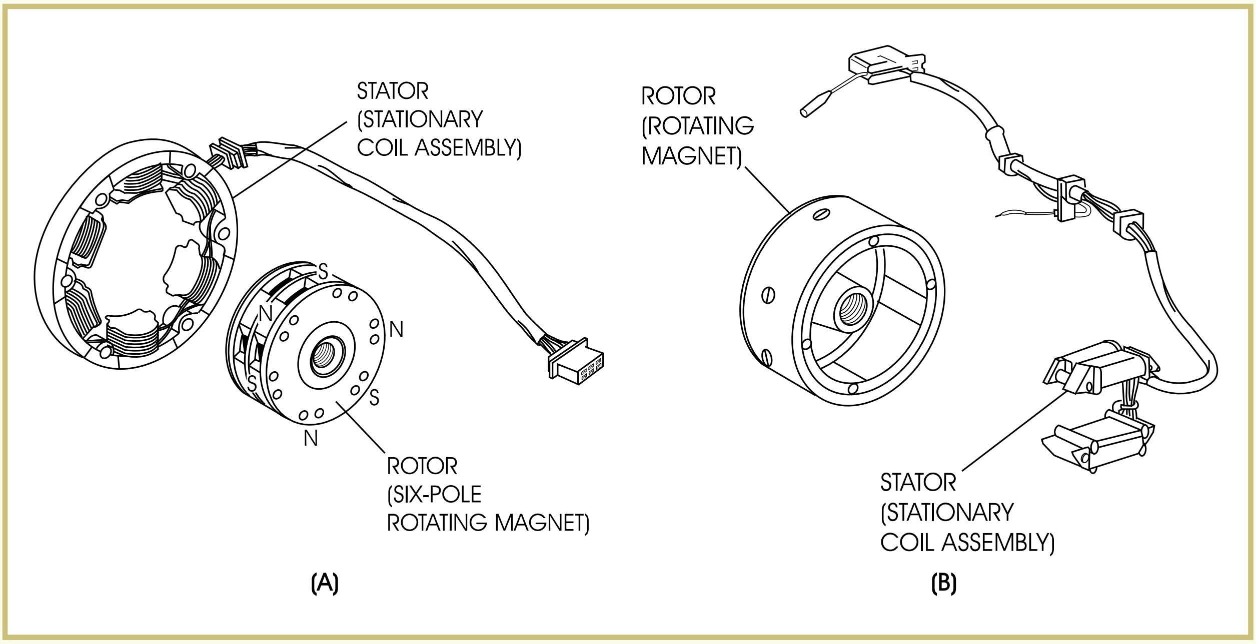


FIGURE 2—This illustration shows two types of rotors. The rotor in Figure 2A rotates inside the stator. The rotor in Figure 2B rotates on the outside of the stator. (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

From the viewpoint of construction design, alternators used in the motorcycle and ATV industry can be divided into two general types—*permanent-magnet alternators* and *excited-field electromagnet alternators.*

Permanent-Magnet Alternators

The permanent-magnet alternator is the most commonly used type of AC generating system found on motorcycles and ATVs. Permanent magnets are incorporated into the flywheel on the outside of the rotor as illustrated in Figure 2B. With this design, the flywheel is fitted onto a tapered crankshaft and is assured positioning by the use of a Woodruff key.

The inner rotor permanent magnet pictured in Figure 2A isn't currently in use because of the high cost of the special permanent magnet that's required.

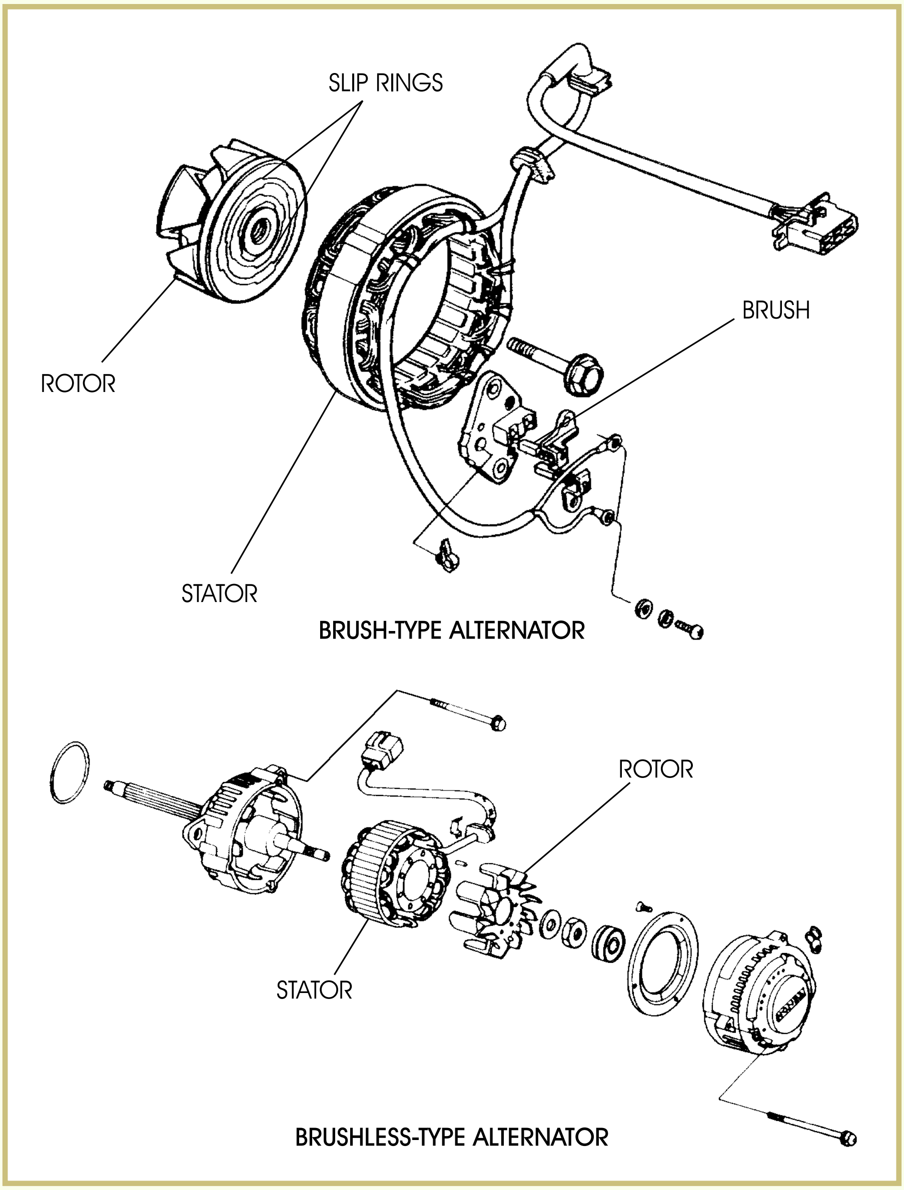
Excited-Field Electromagnet Alternators

Excited-field electromagnet alternators don't use a permanent magnet. Instead, they have a field coil which is energized with DC current. The field coil becomes a powerful magnet and magnetizes the rotor. Power is generated as the rotor spins past the stator. Excited-field electromagnets are located in different outside areas of the engine to help keep them cool. The rotor speed is generally multiplied by gears or chains to increase the rotor's speed of rotation.

The excited-field alternator is potentially the most powerful AC generator available because of the high amount of magnetism that it can create. This type of alternator is primarily used on larger displacement motorcycles. There are two types of excited-field electromagnet alternators (Figure 3).

- The *brush-type* excited-field coil has the field coil placed within the rotor. Current flows through the brushes to the field-coil slip rings. When current is applied, the rotor is induced electromagnetically and becomes a very strong magnet.
- The *brushless-type* excited-field coil eliminates the maintenance factor of the excited-field coil design by placing a two-piece rotor around the inner field coil. When the field coil is energized, the magnetic field magnetizes the rotor core. The rotation of the magnetized core acts on the stator coils to produce AC current.

FIGURE 3—Brush-Type and Brushless-Type Excited-Field Coil Systems (Copyright by American Honda Motor Co., Inc. and reprinted with permission)



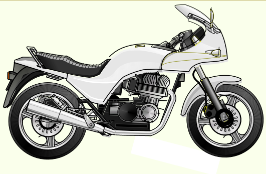
Alternator Maintenance

Problems seldom occur with alternators because they have few moving parts. Servicing is generally not required except on brush-type excited-field alternators. If a problem does occur on an alternator, the problem may be due to the stator coil. Stator coils are manufactured under very strict quality control and usually don't fail when they are new, but as a technician, you still need to be aware of possible coil failures such as the following.

Open stator wire. If the stator wire is open, there is no AC output. In this case, an ohmmeter will indicate no continuity (infinite resistance) between the terminals.

Shorted circuit. Diagnosis of a shorted circuit is a bit more difficult. The symptom may simply be poor AC output performance or low AC output when the engine is hot. Vibration or shock can be the cause of such problems.

When checking the continuity of a stator, remember to isolate the stator from the rest of the electrical system.



Road Test 1

At the end of each section of *Charging and Ignition Systems*, you'll be asked to check your understanding of what you've just read by completing a "Road Test." Writing the answers to these questions will help you review what you've learned so far. Please complete *Road Test 1* now.

1. What is used to produce AC in a motorcycle or ATV charging system?

2. Which type of alternator is the most popular system found on motorcycles and ATVs?

3. What are the two main components found in an alternator?

4. What are two problems that can occur in a stator coil?

5. Which type of alternator does not use permanent magnets?

6. Explain the difference between a permanent-magnet and an excited-field coil system.

7. On a permanent-magnet alternator, where are the magnets located?

8. *True or False?* It's unusual to see problems occur with the alternator portion of a charging system because it contains very few moving parts.

Check your answers with those on page 45.

REGULATORS AND RECTIFIERS

Although they are two separate components, regulators and rectifiers are normally integrated into the same housing on modern motorcycles or ATVs (Figure 4). A simplified schematic of a charging system is shown in Figure 5. Note the dotted lines surrounding the *regulator/rectifier*. Inside the lines you can see six diodes and three SCRs. The diodes make up the rectifier while the SCRs are used as part of the regulator. We'll discuss the rectifier and regulator separately even though they're combined as one unit.

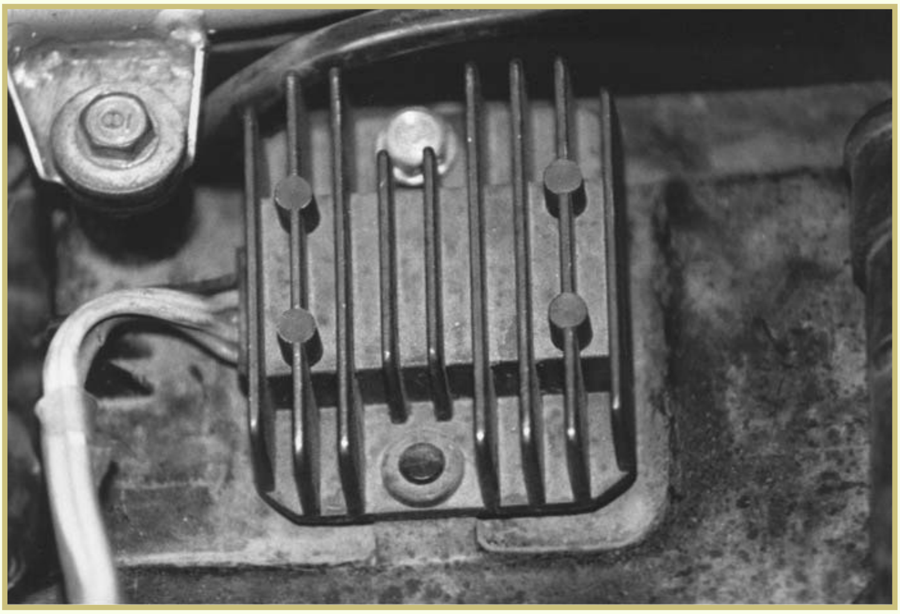


FIGURE 4—This is a picture of a typical regulator/ rectifier. The cooling fins help to remove the heat produced from the regulator when it sends current back to ground.

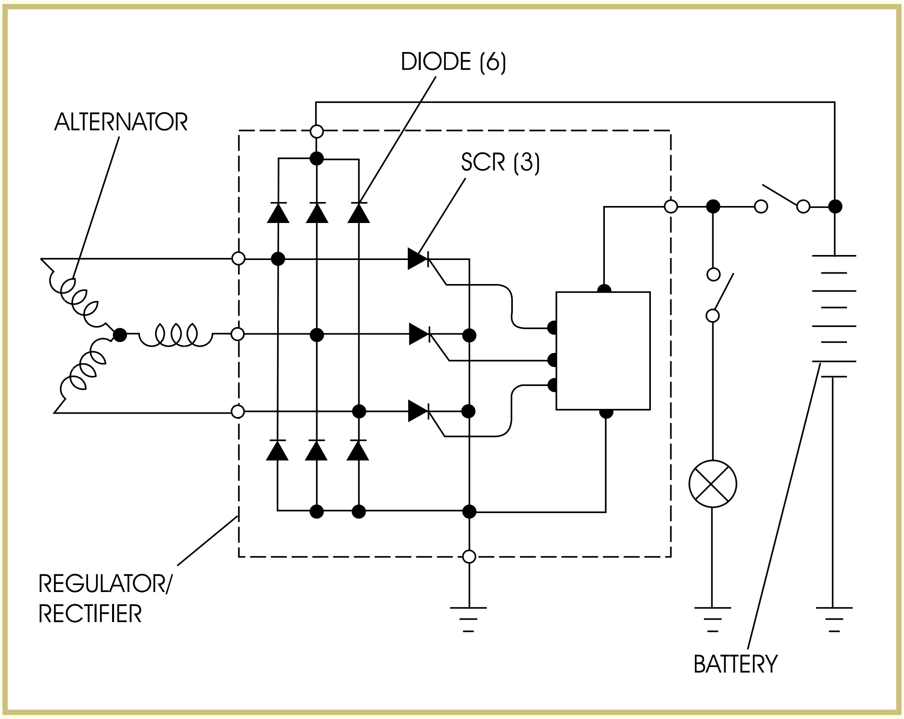


FIGURE 5—Charging System Schematic Diagram (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

Rectifiers

The purpose of a rectifier is to change the AC that's produced by the alternator into DC to charge the battery. A rectifier consists of as few as one or as many as six diodes, depending on the charging system. Remember that the diode serves as a one-way electrical valve.

The basic principle behind a rectifier's function is that it allows current to pass through in only one direction—kind of like a one-way gate. Because alternating current is continually reversing direction, the rectifier must change it to direct current so that it can be used by the battery, which is a DC device. A single diode rectifier wired in series into a circuit will block half of the AC current flowing into it and allow the other half of the current to flow to the battery as seen in Figure 6. This is known as *half-wave rectification*.

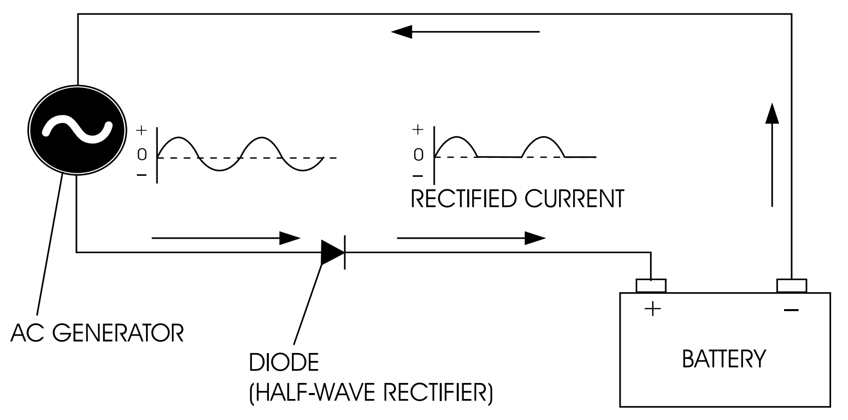


FIGURE 6—This simplified schematic shows a half-wave rectifier which blocks one-half of the AC waveform. (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

In order to allow all of the current produced by the alternator to reach the battery, more diodes are used. Four diodes can be used to allow both waves of the AC current to pass as shown in Figure 7. This allows all of the current created by the alternator to be converted into DC. When four diodes are used, it's known as *full-wave rectification*. We'll discuss these systems in more detail in a later section of this study unit. When rectifiers are defective, they can't be repaired and must be replaced. You'll also learn how to test rectifiers later.

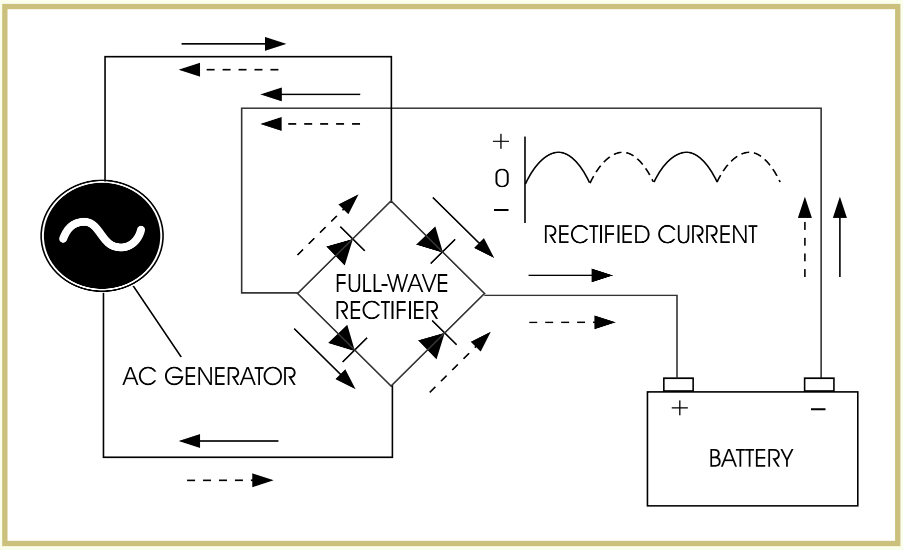


FIGURE 7—By using four diodes, both the upper and lower halves of the alternating current waveform are used and we have a full-wave rectification system. (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

Voltage Regulators

The purpose of the voltage regulator is to control the voltage to prevent undercharging or overcharging the battery. There are two types of voltage regulators—mechanical and electronic.

Mechanical Voltage Regulators

The mechanical voltage regulator was widely used on motorcycles until the mid-1970s, but now is all but extinct. In the mechanical voltage regulator, the alternator charges the battery through the adjustable contact points of the regulator (Figure 8). When the alternator output reaches approximately 15 volts on a 12-volt system, the relay coil is energized and pulls the armature down to open the contact points. Therefore, the regulator acts like a switch that opens or closes the circuit to control battery charging.

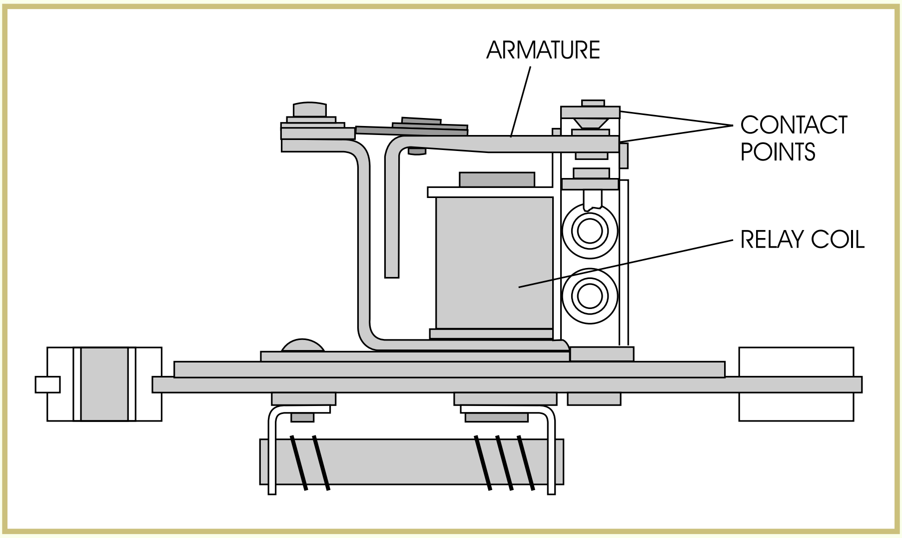


FIGURE 8—This figure shows an internal view of a mechanical voltage regulator. This type of regulator is no longer being used on motorcycles or ATVs. (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

Electronic Voltage Regulators

Electronic voltage regulators are commonly used on motorcycles and ATVs today. Electronic regulators contain no moving parts and never need to be adjusted. There are too many types of electronic regulators to try to discuss each and every type. Most electronic regulators, or *current limiters* as they are sometimes called, have a solid-state, transistorized arrangement of electronic devices, such as thyristors and Zener diodes. Because electronic voltage regulators are sealed units, they cannot be repaired. If tested and found to be defective, the unit must be replaced.

One disadvantage of having both the regulator and the rectifier assembled as one complete unit is that if either the regulator or rectifier portion fails, the entire unit must be replaced.

Regulator/Rectifier Inspection

As we've mentioned, electronic voltage regulators and rectifiers have no internal moving parts and must be replaced if found to be defective. The main symptoms of a faulty voltage regulator are the following:

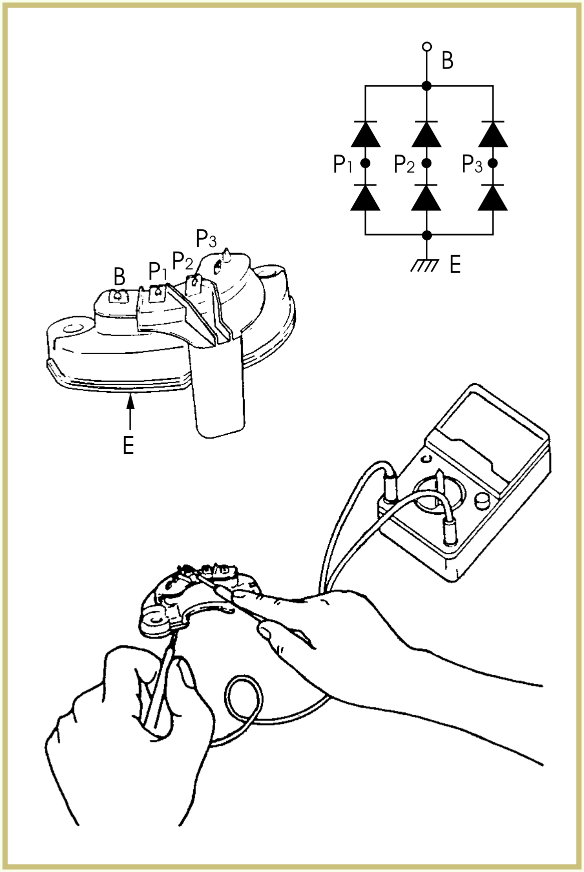
- The battery discharges.
- The battery becomes overcharged.
- The lights in the electrical system burn out quickly.

In most cases, to inspect a voltage regulator, you simply run the engine at the manufacturer's recommended engine speed and check for DC current at the battery. If the system is overcharging, the regulator is at fault and will require replacement. If the charging system is undercharging and all other charging system components have been proven to be in proper working order, the regulator is probably at fault.

Rectifiers are relatively easy to test. An ohmmeter is used to test rectifiers as shown in Figure 9. Simply connect the ohmmeter to the ends of each of the diodes and check the resistance in both directions. The resistance should be low in one direction and very high in the opposite direction. The specification should be given in the appropriate service manual. A general guideline for testing most diodes is to have 5–40 ohms of resistance in the forward bias direction (where current is allowed to pass) and infinite resistance in the reverse bias direction (where current isn't allowed to pass).

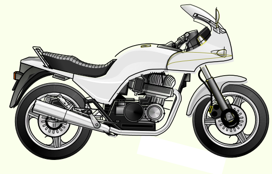
To test the rectifier in Figure 9, attach the black probe of the ohmmeter to the ground side of the rectifier (E) and the red probe to P1, P2, and P3. Record your measurements. Then swap the meter leads and take the three resistance readings again. You have now measured the ground side of the rectifier.

FIGURE 9—This illustration demonstrates how to test the diodes in a rectifier. (Courtesy Kawasaki Motor Corp.,U.S.A.)



You can now test the battery side of the rectifier by attaching the meter probes to the battery (B) side of the rectifier and test the diodes in the same manner. When you have completed testing, you should have 12 readings consisting of forward and reverse-bias measurements for each of the six diodes.

Road Test 2



1. *True or False?* Electronic voltage regulators are adjustable.

2. Generally speaking, how many ohms of resistance should a diode have in the forward-bias direction?

   ___

3. What are the three main symptoms of a faulty voltage regulator?

   ___

   ___

4. Generally speaking, how much resistance should a diode have in the reverse-bias direction?

   ___

5. *True or False?* Rectifiers and voltage regulators are contained as one complete unit on some motorcycles and ATVs.

6. *True or False?* A system that allows all of the AC current from the alternator to be rectified into DC current is called full-wave rectification.

7. What type of voltage regulator is adjustable?

   ___

8. What's another term used to describe a voltage regulator?

   ___

Check your answers with those on page 45.

MOTORCYCLE AND ATV BATTERIES

Motorcycle and ATV batteries are called lead-acid batteries. They're also referred to as storage batteries because of their ability to store electricity. Most modern motorcycles and ATVs use 12-volt batteries.

Conventional Batteries

A conventional wet-cell motorcycle or ATV battery consists of a series of cells (Figure 10). Each cell has positive and negative metal plates and is capable of storing approximately 2 volts of electricity. The plates fit into a casing that's filled with an electrolyte solution (a mixture of distilled water and sulfuric acid). The battery produces electricity from a chemical change that takes place between these positive and negative plates in the electrolyte solution (Figure

11). The distilled water in the acid solution has the tendency to evaporate in a conventional battery. When it does, replenish the battery with distilled water only! If you use any other liquid, you'll shorten the life of the battery. Distilled water has had the impurities removed, which prevents contamination of the sulfuric acid and the lead plates in the battery.

FIGURE 10—A Typical Wet-Cell Battery in an Exploded View

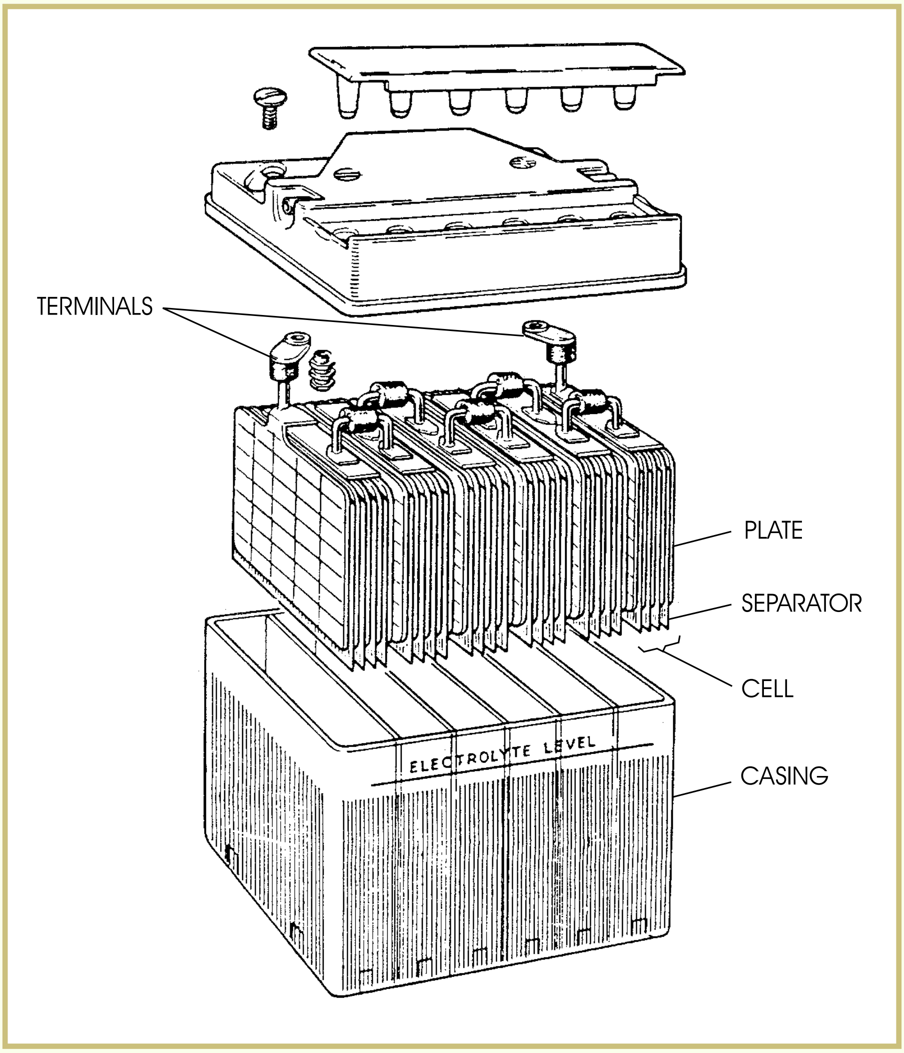
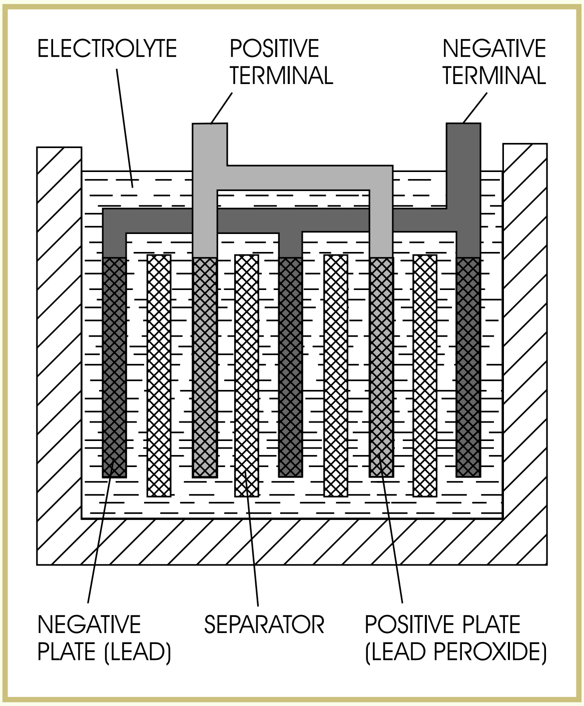


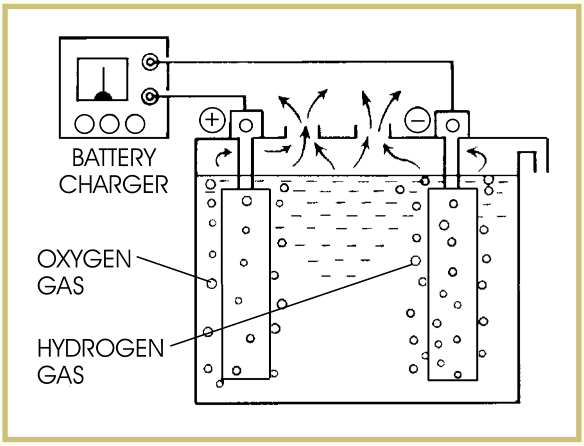
FIGURE 11—The plates in a battery are separated from each other. (Copyright by American Honda Motor Co., Inc. and reprinted with permission)



How Lead/Acid Batteries Work

When you charge a lead-acid battery, electrolysis breaks the water down into its components—hydrogen and oxygen gas. Because of the generation of these gases, you must remove the filler plugs while charging the battery (Figure 12). Conventional batteries have a vent, usually routed into a tube, to remove the gases produced during normal use.

FIGURE 12—As a battery is charged, it causes a chemical reaction that will pressurize the battery. Be sure to remove the battery vent caps when charging a battery. (Copyright by American Honda Motor Co., Inc. and reprinted with permission)



When excess current is supplied to the battery, the battery is said to be overcharged. When the battery is overcharged, gas is emitted from the plates, and electrolyte temperature increases. This increase in heat causes a rapid loss of water from the battery electrolyte if continued over a long period of time. The loss of water and increased heat drastically reduces the life of the battery and, if left uncorrected, will damage the battery beyond repair.

Because a battery is constantly subjected to charging and discharging cycles, the water in the electrolyte is slowly boiled off during normal use. When the water is evaporated to the point where the plates become exposed, a white crystalline deposit (lead sulfate) forms. This process is known as *sulfation*. This damages the battery and shortens the battery life. Sulfation can occur not only when the electrolyte level is low, but also when the battery is discharged for long periods of time.

Remember, as the electrolyte level goes down when the water in the battery evaporates, replenish the battery with distilled water only.

Maintenance-Free Batteries

Maintenance-free batteries are very similar in design to conventional batteries. The difference is that the positive and negative lead plates in the maintenance-free battery allow for a chemical reaction internally that produces water as it's needed. Therefore, you don't need to add water to a maintenance-free battery.

Unlike the conventional battery, maintenance-free batteries don't have a vent to allow for the escape of excess gases. Instead, they use a safety valve that's designed to open when extreme gas pressures are produced. The safety valve closes and seals the battery when the internal pressure returns to normal. Figure 13 shows a cutaway drawing of a typical maintenance-free battery and its internal components.

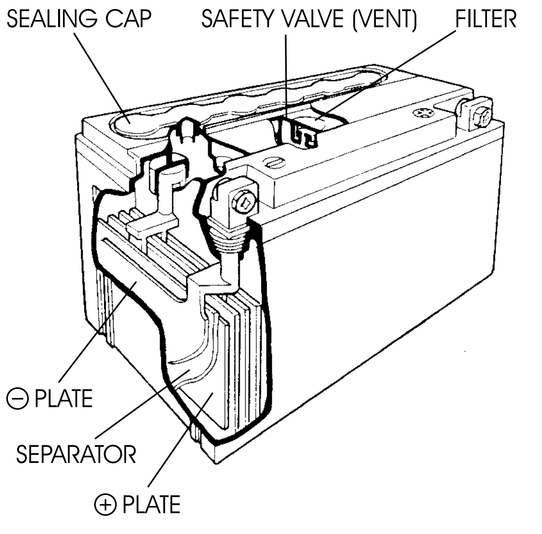


FIGURE 13—The parts of a maintenance-free battery are shown in this cutaway drawing. (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

Inspecting Batteries

Before doing any testing, you should always visually inspect the battery. If there are cracks in the casing, broken terminals, or other signs of severe damage, such as heavy white lead sulfate on the internal plates, the battery should be replaced.

Next, check the battery cables and ensure they have good contact with the battery terminals. If the cables or terminals are corroded or loose, be sure to clean and tighten the connection. A bad battery connection can cause very high resistance, which will interfere with the flow of electrical current. This can cause many different problems in the electrical system. Clean the battery cables and terminals with a wire brush. A smear of dielectric grease on the cables and terminals will help prevent corrosion.

The electrolyte in a battery is very caustic. The condition of a battery is determined by the *specific gravity* of the electrolyte. Specific gravity is measured by using a *hydrometer* (Figure 14), which is available from most automotive parts stores. When a battery is new or fully charged, you should get a specific gravity reading of 1.280 to 1.320 (depending on air temperature). As the battery is discharged, this reading will decrease.

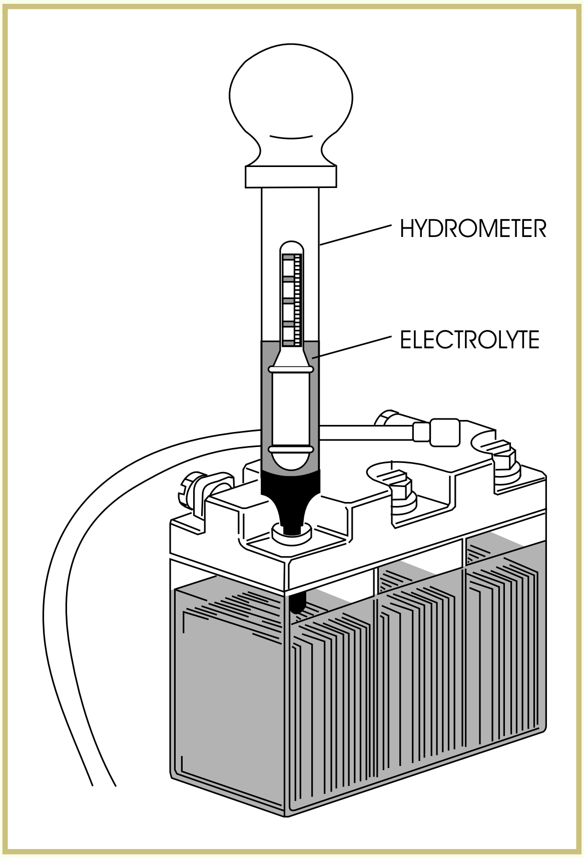


FIGURE 14—A hydrometer measures the specific gravity of the electrolyte in the battery. (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

A battery provides direct current for operating the motorcycle or ATV. One way of knowing the amount of current that can be drawn out of a battery is to know its ampere-hour capacity. For example, a 12-amp/hour battery will discharge fully if one amp of current is drawn out continuously for a 12-hour period.

Batteries are rated in ampere-hours. The larger the ampere-hour number, the stronger the battery. The voltage does not change in relation to ampere-hours of the battery. The ampere-hour rating of a battery is often indicated on its case. For example, a 12-amp/hour battery would have "12A" printed on the case.

Be very careful when working with a battery. Always wear safety glasses when working around batteries. Battery acid will destroy clothing, paint, etc., and could also cause severe burns if it gets on your skin. If you accidentally spill some battery acid, the spill should be washed quickly using water and baking soda to help neutralize the acid.

One last note about batteries. Always use a fully-charged battery when performing any charging system electrical tests to prevent false meter readings.

Motorcycles and ATVs Without Batteries

Many of the smaller motorcycles and ATVs that have lighting systems and other electrical circuitry don't have batteries in their electrical systems. These machines use AC power to generate electricity for their electrical components (Figure 15). The alternator generates the electricity, which is controlled by an AC regulator. For components that use transistors which require DC current, a small rectifier (DC power unit) is used.

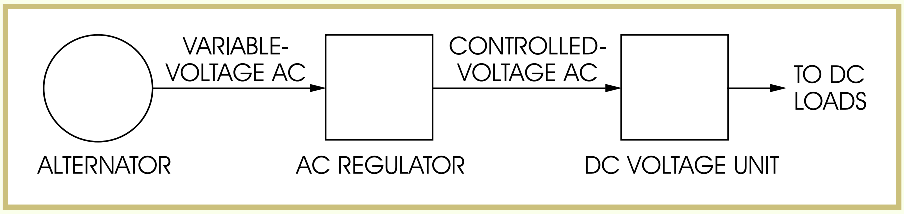


FIGURE 15—This illustration shows a block diagram of a motorcycle or ATV electrical system that doesn't use a battery.

AC Regulators

To provide a stable current without the use of a battery, a high-output alternator that can generate sufficient current at low rpm must be used. If the alternator output is allowed to rise as the engine rpm is increased, the excessive current will burn out the lighting system bulbs. To prevent this from occurring, the AC regulator maintains a predetermined output voltage by shorting any excessive current to ground.

An example of a type of AC voltage regulator is illustrated in Figure 16. The current from the alternator flows directly to the loads (lights, electric starters, etc.) at voltage levels lower than the voltage regulator value. As the engine rpm rises (increasing the AC voltage), the regulator directs the current to the thyristor, which in turn shorts the alternator output to ground. In this way, the voltage regulator cuts off the excess voltage to maintain a constant voltage output.

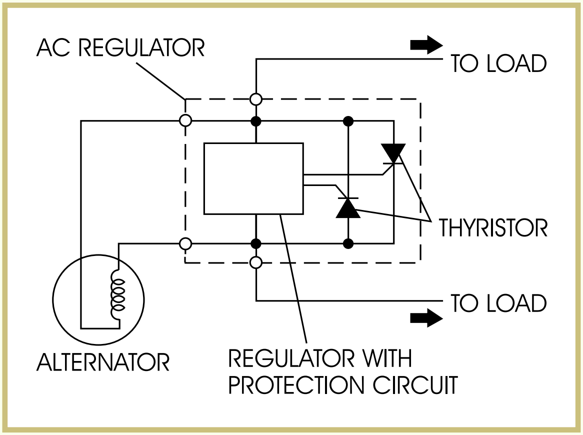
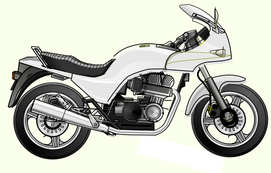


FIGURE 16—This illustration shows a simplified schematic diagram of an AC voltage regulator. (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

DC Voltage Units

Although most electrical components use AC power in electrical systems without a battery, there are a few systems that require DC current to operate. A compact DC voltage unit rectifies the AC into DC for these specific applications. The DC voltage unit will normally consist of a simple diode to change the AC power to DC.



Road Test 3

1. What is the solution called that's used in motorcycle and ATV batteries?

____

2. _______ current is used to charge a battery.

3. What is a battery hydrometer used for?

____

4. What is the name of the white crystalline material that develops on exposed battery plates?

____

5. What does "14A" stamped on a battery mean?

____

6. *True or False?* A motorcycle or ATV that doesn't use a battery can't use any DC-powered electrical components.

7. With a sulfuric acid spill, _______ can be used to neutralize the acid.

8. What are some of the items to look for when visually inspecting a battery?

____

9. What type of battery doesn't require that you add water to it?

____

10. What should be put back into a conventional battery after the plates have been exposed?

____

Check your answers with those on page 45.

CHARGING SYSTEM OPERATION

Now that you know the basic components of a motorcycle and ATV charging system, let's see how these components work together as a system. Later in this lesson, you'll learn how to perform various charging circuit tests. But first, let's look at an example of a complete schematic for a Kawasaki GPZ 500S, as shown in the *Wiring Diagram* included in this shipment. Note that all wires are color-coded and that a color-code chart is shown in the lower right corner of the schematic. At the bottom of the schematic, notice that the connections are shown for each position of the switches.

The schematic may seem quite complex at first, but if you break down the individual electrical system that you're working with in a schematic, it becomes much easier to read and understand. You can break down a schematic by drawing a "block diagram" of the system as seen in Figure 17. Use this figure to follow along as we talk about the operation of a basic charging system.

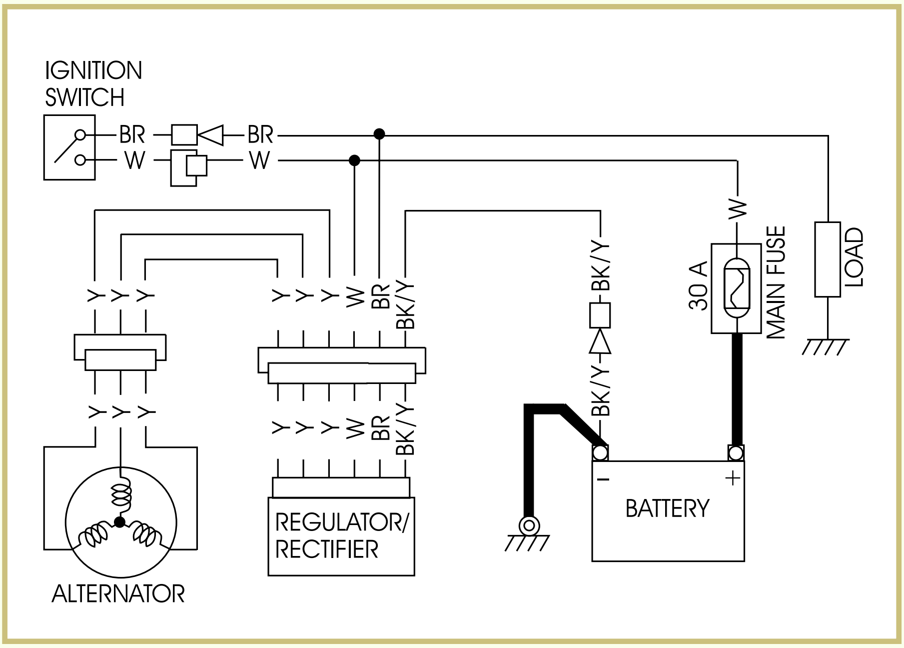


FIGURE 17—A block diagram of the charging system for the Kawasaki GPZ 500S is shown here. By separating the different electrical components from the complete wiring schematic, your job of working on the electrical system will become much easier. (Courtesy Kawasaki Motor Corp., U.S.A.)

Find the *alternator* on the block diagram. The alternator produces electricity in the form of alternating current when the engine is running. Now locate the alternator on the actual schematic. As we refer to each of the charging system components on the block diagram, locate them on the actual schematic as well to see how the block diagram was derived from the schematic.

Notice the three stator leads connected to the alternator. Current flows through these leads, which are color-coded and labeled *Y* (yellow). These wires carry AC current from the alternator to the *regulator/rectifier* as the alternator rotor spins past the stator windings. The AC current enters the rectifier and is changed to direct current, which leaves the rectifier through the *W* (white) wire. This white wire provides direct current to the *battery* for charging. The current in the *BR* (brown) wire travels from the ignition switch to the loads (lights, etc.) and to the regulator portion of the regulator/rectifier. The regulator is connected to the common ground system by the *BK/Y* (black with yellow tracer) wire. When the voltage reaches a predetermined level, the voltage regulator routes the excess rectified DC current to ground to prevent the battery from being overcharged.

As you can see, by connecting individual components to work together as a system, direct current is provided for charging the battery and supplying power to the lighting system. The alternating current is changed into direct current by the rectifier. The amount of charging voltage is controlled by the voltage regulator. Each component in the charging system must be kept in good working condition to allow the charging system to continue to function properly. This includes keeping all wiring connections clean and tight-fitting to prevent excessive resistance.

Types of Charging Systems

Now that you understand how a basic charging system operates and can identify the individual components in a charging system, we'll move on to a discussion of the various types of charging systems that are found on motorcycles and ATVs. We'll begin with the simplest charging system and then learn about the more complex systems. Remember, all charging systems operate in the same basic fashion; they just have different ways of producing AC current. One way that charging systems differ is related to the number of charging coils at the input. The charging system is also based on the needs of the electrical system. More electrical components require a larger output charging system.

Half-Wave Charging System

The half-wave charging system is the simplest charging system. This charging system uses only one "grounded" charging coil, and only one-half of the AC output is actually used. As shown in Figure 18, the alternator has two pairs of magnets; and it produces two cycles of AC for each rotation (360 degrees) of the rotor (flywheel).

A single diode is used to rectify the AC output into DC to charge the battery. When the AC flows through the diode, the negative voltage wave of the AC is cut off and the positive voltage wave is passed to charge the battery.

This type of charging system has a low output, and its small size is best suited for very small machines with small electrical loads. Because of its low-output potential, this charging system isn't used very much anymore.

These low-output systems regulate the DC voltage by the use of a relatively simple half-wave regulating system as shown in Figure 19. In this system, the charging current from the alternator is rectified by diode D1 and charges the battery. When the AC voltage increases as the engine rpm increases, the AC wave rectified by diode D2 goes through the Zener diode (ZD) and allows the gate of the SCR to open. The SCR shorts the AC input from the alternator to ground. Therefore, the half-wave charging system with a voltage regulator is either fully charging the battery or not charging the battery at all! This is the major disadvantage of the half-wave charging system and the main reason that it's not used much any longer.

FIGURE 18—A half-wave charging system uses a single grounded coil.
(Copyright by American Honda Motor Co., Inc. and reprinted with permission)

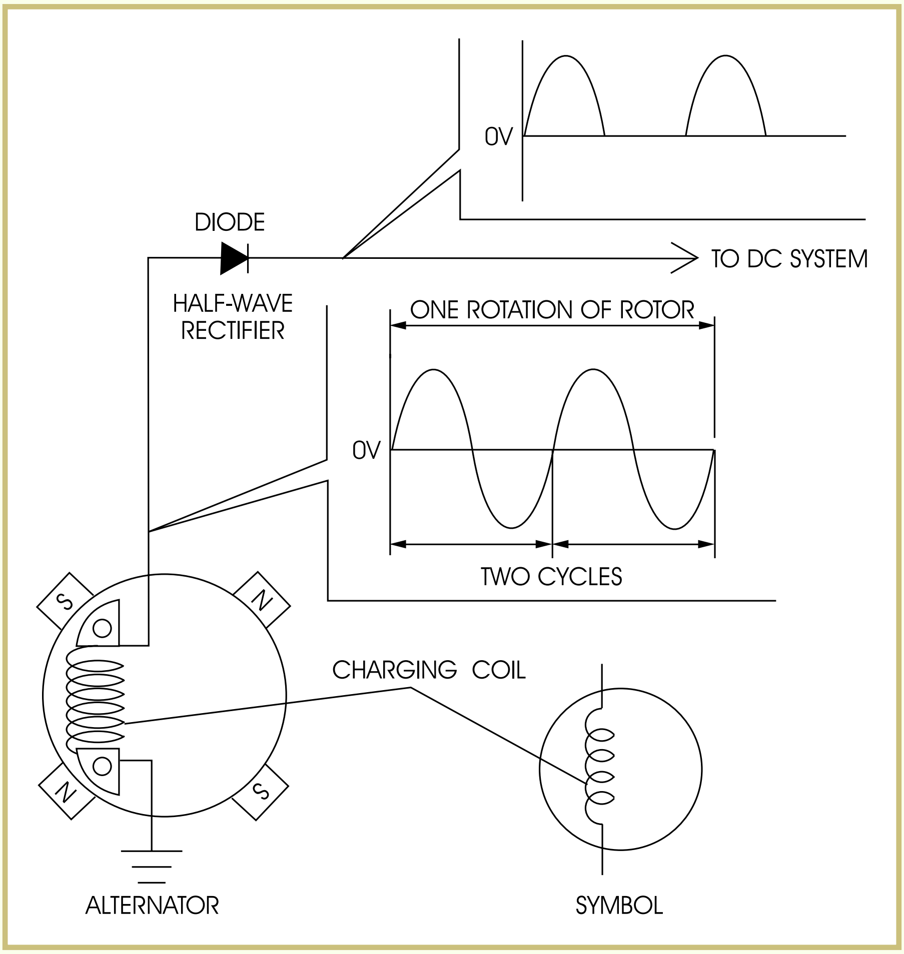
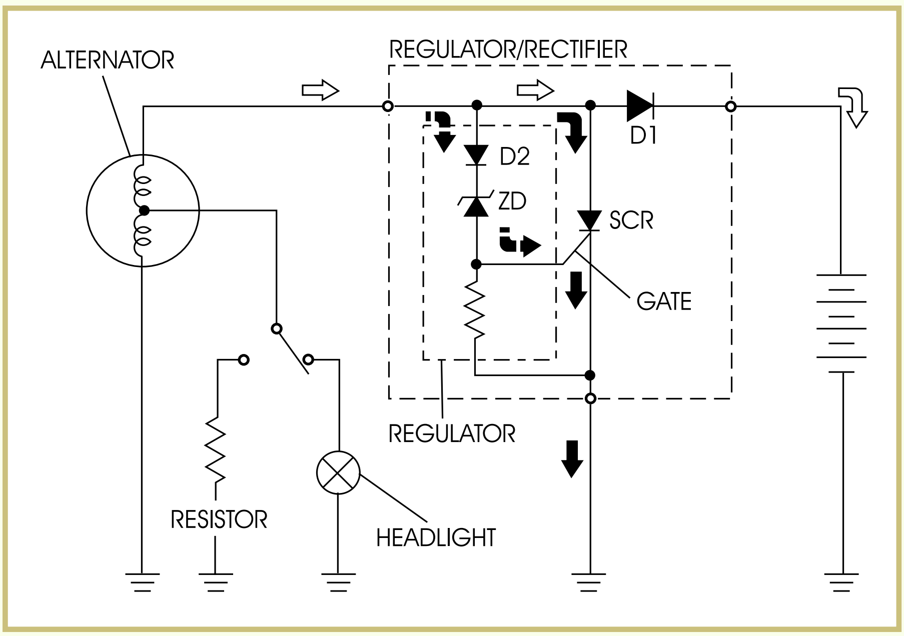


FIGURE 19—A Voltage Regulator in a Half-Wave Charging System (Copyright by American Honda Motor Co., Inc. and reprinted with permission)



One other type of voltage regulation found on some half-wave charging systems is known as the "balanced" charging system. In this system, the alternator is designed to allow a maximum amount of AC that won't overcharge the battery. The proper AC level is maintained independent of engine speed. Therefore, the balanced charging system needs no voltage regulator. The complete charging system consists of an alternator, a single diode, and a battery.

Full-Wave Charging System

A full-wave charging system also uses one charging coil similar to the half-wave system, but instead uses the full output potential of the charging coil. Full-wave charging systems are used on some medium-sized motorcycle and ATV engines. When comparing this system to the half-wave charging system, you'll notice that it's more efficient by using all of the alternator potential for charging the battery.

The full-wave charging system uses four diodes to rectify the AC from the alternator into DC (Figure 20). When the AC input voltage is positive, current flows from the alternator through diode D1, to the battery, through diode D2, and back to the alternator as shown by the white arrows. When the AC input voltage reverses direction, current flows from the alternator, through diode D3, to the battery, through diode D4, and back to the alternator as shown by the black arrows. Operating in this fashion, the AC output of the alternator is converted into a full-wave DC waveform.

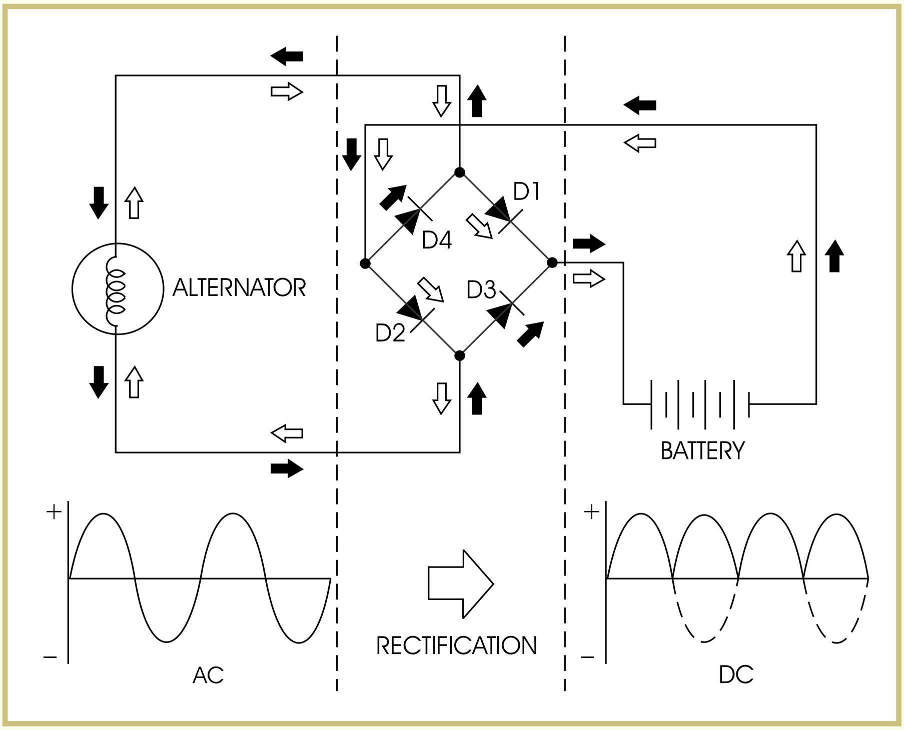


FIGURE 20—This illustration shows how current flows through a full-wave rectifier. (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

The voltage regulation system used on a full-wave charging system normally has a voltage feedback line (Figure 21). The feedback line tells the voltage regulator when the battery no longer needs charging. The regulator then opens the gates on the SCRs. The SCRs short the AC input from the alternator to ground and cut off the current to the battery.

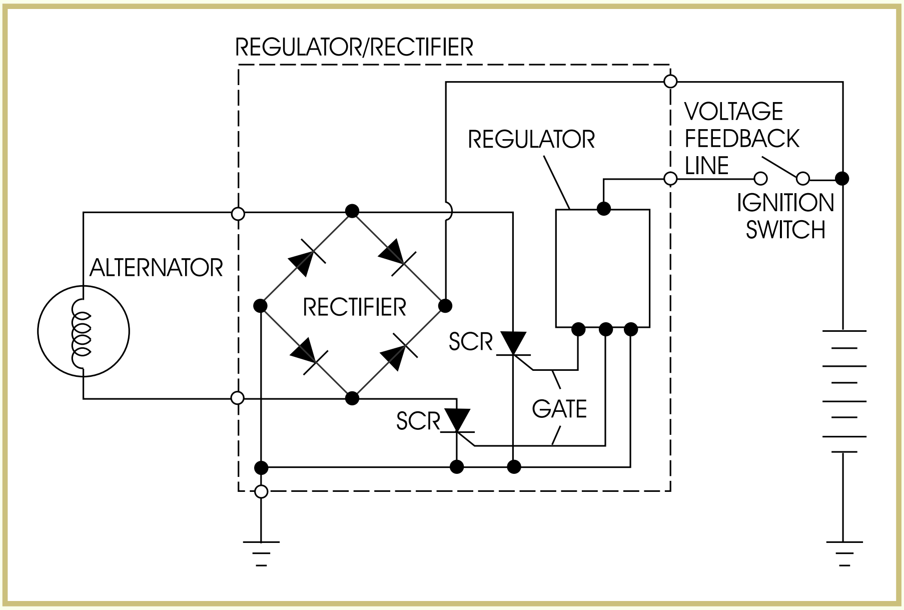


FIGURE 21—A Voltage Regulator in a Full-Wave Charging System (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

3-Phase Permanent-Magnet Charging System

The 3-phase permanent-magnet charging system is the most widely used system on both motorcycles and ATVs because of the large charging potential to the electrical system. This system uses permanent magnets like the charging systems previously mentioned; however, the 3-phase system uses three charging coils instead of one (Figure 22).

The rectifier in the 3-phase system consists of six diodes and is connected directly to the 3-phase alternator. The voltage regulation system is the same as the full-wave system except that it has the ability to change the charging system from 3-phase into a full-wave or a half-wave system as the battery approaches a full charge. This is done by independently controlling the gates to the three SCRs, which short the alternator output to ground. The waveform created by a 3-phase charging system more closely approximates a pure DC output because of the three AC waves that are produced in a single revolution of the alternator's rotor.

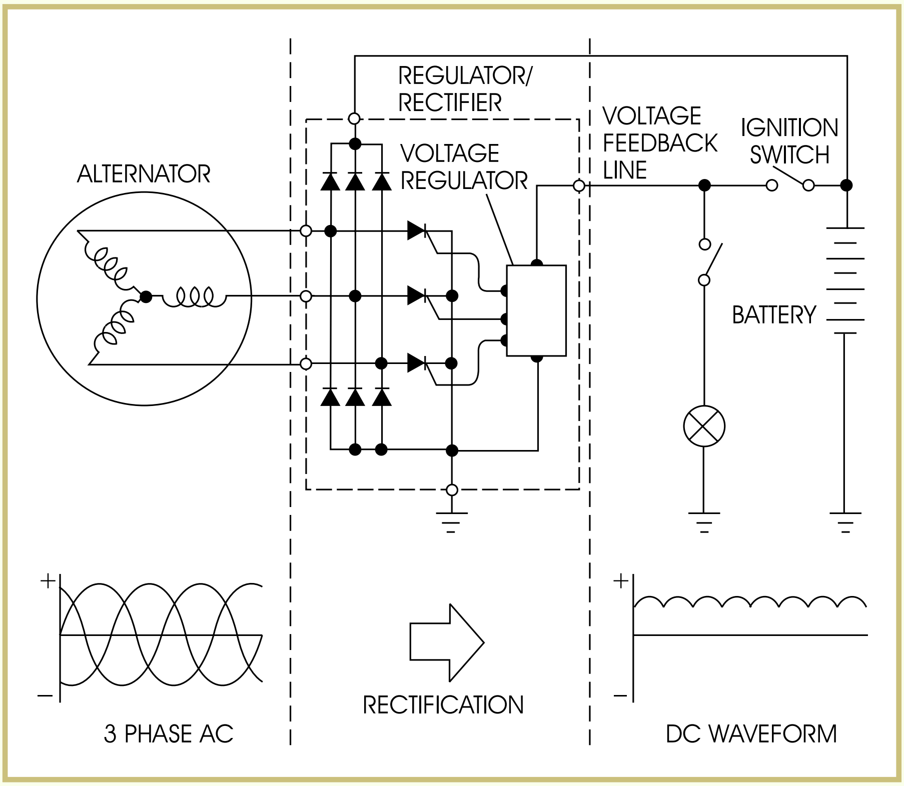


FIGURE 22—This illustration shows a typical 3-phase permanent-magnet charging system. (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

3-Phase Electromagnet Charging System

The 3-phase electromagnet charging system is used on many larger motorcycles and on motorcycles that have the alternator in a location that's not directly mounted on the crankshaft. The 3-phase electromagnet system differs from the 3-phase permanent-magnet system primarily because it uses an electromagnet instead of a permanent magnet in the alternator to produce the input AC (Figure 23).

In the 3-phase electromagnet system, the charging rate is controlled by controlling the strength of the magnetic field in the alternator field coil and, therefore, the output of the alternator. The voltage regulator monitors the voltage at the battery and controls the base of the transistor. When the regulator turns the transistor on, the battery feeds current through the ignition switch, field coil, and transistor to ground. The field coils magnetize the rotor and the alternator generates AC current as the engine rotates. The charging system waveform is the same as for the 3-phase permanent-magnet system.

When the charging system reaches a predetermined voltage, the voltage regulator turns the transistor off and cuts off the current to the field coil. This removes the magnetic field from the field coil and prevents the charging system from operating.

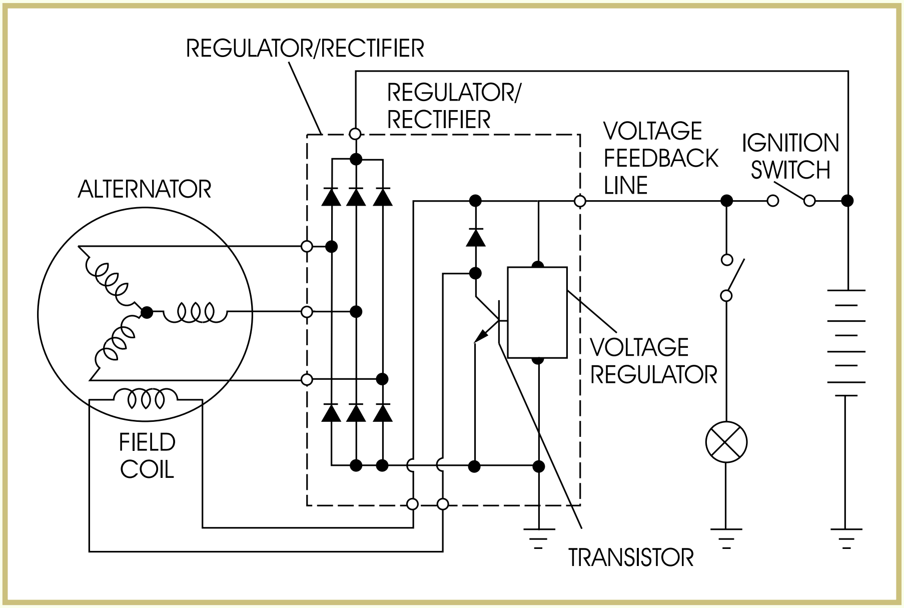


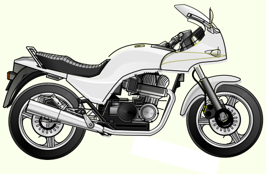
FIGURE 23—The 3-phase electromagnet charging system can easily be identified by the use of a field coil, as this illustration shows. (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

Another voltage regulation system used with the 3-phase electromagnet charging system allows for the field-coil voltage to be altered to create a stronger or weaker electromagnet. By having more current pass through the field coil, a stronger electromagnetic field is created. Conversely, having less current pass through the field coil produces a weaker electromagnetic field. In this way, the output from the alternator can be varied rather than simply turned on and off.

Charging Systems Summary

As you can see, the charging systems used in motorcycles and ATVs can be very simple or somewhat complex. All you need to do is to recognize the type of system that you're working on. Then you should know how it regulates the AC and DC current to control charging the battery.

Road Test 4



1. Which type of charging system uses six diodes to rectify the AC input?

____

2. *True or False?* A "balanced" charging system is a type of half-wave charging system.

3. Which type of charging system uses a field coil instead of permanent magnets?

____

4. Which charging system is the most widely used system found on both motorcycles and ATVs?

____

5. Of all the charging systems discussed, the _______ system is the most simple.

6. *True or False?* All charging systems operate in the same basic fashion; they just have different ways of producing AC current.

7. The half-wave charging system uses how many charging coils?

____

8. What is the difference between a half-wave charging system and a full-wave charging system?

____

____

Check your answers with those on page 45.

MAINTAINING AND TROUBLESHOOTING CHARGING SYSTEMS

In the previous sections of this study unit, we've briefly discussed how to inspect the different components of a motorcycle and ATV charging system. We're now going to combine that information and expand on it to help you understand how to maintain and troubleshoot problems found within the charging systems.

Hand Tools for Electrical Work

The basic hand tools you'll need for most electrical repairs are as follows:

- Soldering gun
- Diagonal cutters
- Needle-nose pliers
- Wire stripper/crimping pliers
- Electrical test equipment

Most electrical tests can be performed with a multimeter. A multimeter is very useful because it's actually at least four meters in one. To check the electrical components and systems found on motorcycles and ATVs, a multimeter should have at least the following measuring capabilities:

- DC Amps
- DC Volts
- AC Volts
- Ohms

Battery Maintenance

The condition of the battery should be your first concern when working on the electrical system of a motorcycle or ATV. Always begin with a thorough visual inspection of the battery as previously described in this study unit. Also, be sure to check the battery cables for corrosion and tightness. If necessary, clean the terminals as we previously described and use dielectric grease on the cables to prevent corrosion. Measure the specific gravity of the electrolyte using a hydrometer. Batteries that are weak or have been out of service for a long period of time can be recharged using a battery charger (Figure 24).

Batteries can be tested for their ability to hold a charge by using a battery load tester (Figure 25). The load tester tests the battery under a heavy electrical load condition while it's out of the motorcycle or ATV.

FIGURE 24—A battery charger provides DC current to recharge batteries.

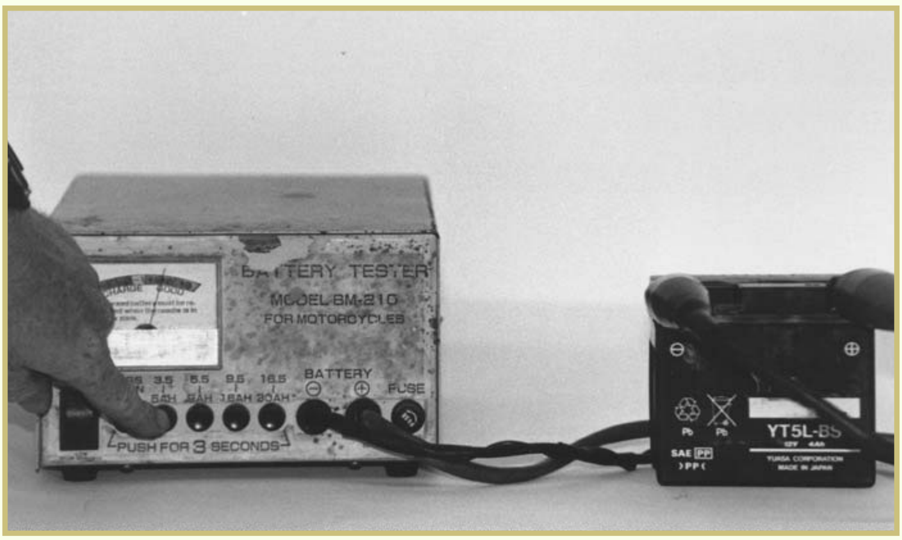


FIGURE 25—The technician is checking the battery under a predetermined load by pushing the button on the tester. This battery is satisfactory because the needle is in the "good" portion of the meter face.

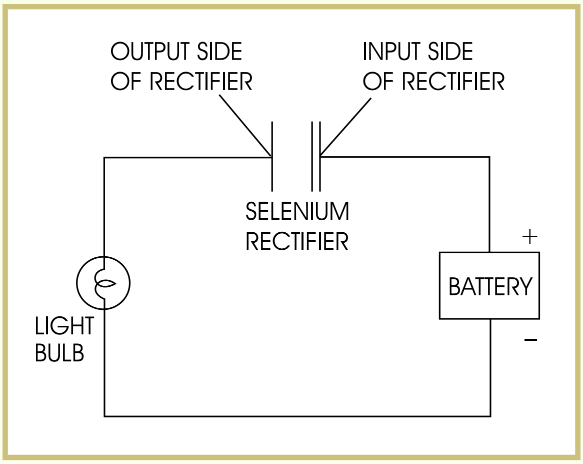
Remember the safety concerns we discussed earlier pertaining to batteries. Always wear safety glasses and be very careful when working around battery acid. Remember that the acid can cause burns and will destroy objects it comes in contact with. Use water and baking soda to clean up spills. Review the previous information in this study unit about the inspection, testing, and handling of batteries if necessary.

Rectifiers

When a rectifier is defective, it isn't repaired—it's replaced. To determine if a rectifier is defective, you can do a couple of simple tests.

The first test requires a 12-volt battery, two wires, and a light bulb. First, remove the rectifier from the circuit and from the motorcycle. Connect a wire from the positive terminal of the battery to the input side of the rectifier (Figure 26). Connect the other wire from the insulated part of the light bulb to the output side of the rectifier. Ground the light bulb to the negative battery post. The light bulb should light. Now, reverse the connection at the rectifier. The bulb shouldn't light. If the bulb doesn't light at all, or if it lights when the rectifier is reversed, the rectifier is defective and must be replaced.

FIGURE 26—Rectifier Test Circuit



Another way to test a rectifier is to use an ohmmeter or multimeter. Set the meter range to R×1 and connect the test leads to the ends of the diode (Figure 27). Read the resistance of the diode. Reverse the test leads to the diode and again read the resistance. The resistance should be low in one direction and infinite in the other direction. Generally speaking, the lower reading should be from 5–40 ohms. If the diode shows low or high resistance in both directions, the diode is defective and the rectifier must be replaced.

FIGURE 27—Testing a rectifier in the forward bias should give a reading of 5–40 ohms.

Voltage Regulators

As we learned earlier in our discussion of voltage regulators, the main symptoms of a defective regulator are a battery that discharges, a battery that overcharges, a battery that requires water frequently, or lights that burn out at high speeds.

Mechanical voltage regulators can be adjusted to correct some of these problems. Adjustments are made by increasing or decreasing the pressure of the springs that hold the points open. The pressure is adjusted by turning small screws located inside the regulator cover. Some regulators require that a cover be removed to gain access to the adjustment screws, while others have a rubber plug that can be removed to reveal the screws. When adjusting this type of regulator, the screws shouldn’t be turned more than one complete turn in either direction. If more turns are required, the regulator is defective and must be replaced.

Other problems with mechanical voltage regulators can usually be traced to one of the following faults:

- Dirty contact points
- Pitted or burned contact points
- Loose or bad wire connections
- Broken or shorted coils
- Bad ground connection

These faults must be corrected before returning the regulator to use. Points can be cleaned with emery paper or a point file. Wire connections and grounding should be checked to be sure they're tight.

Electronic voltage regulators are checked in different ways. Two common regulator tests are

- Checking for proper voltage output while the regulator is functioning in the motorcycle or ATV and the engine is operated at a specified rpm
- Removing the regulator from the motorcycle or ATV and using an ohmmeter to check the resistance between the various leads as shown in Figure 28.

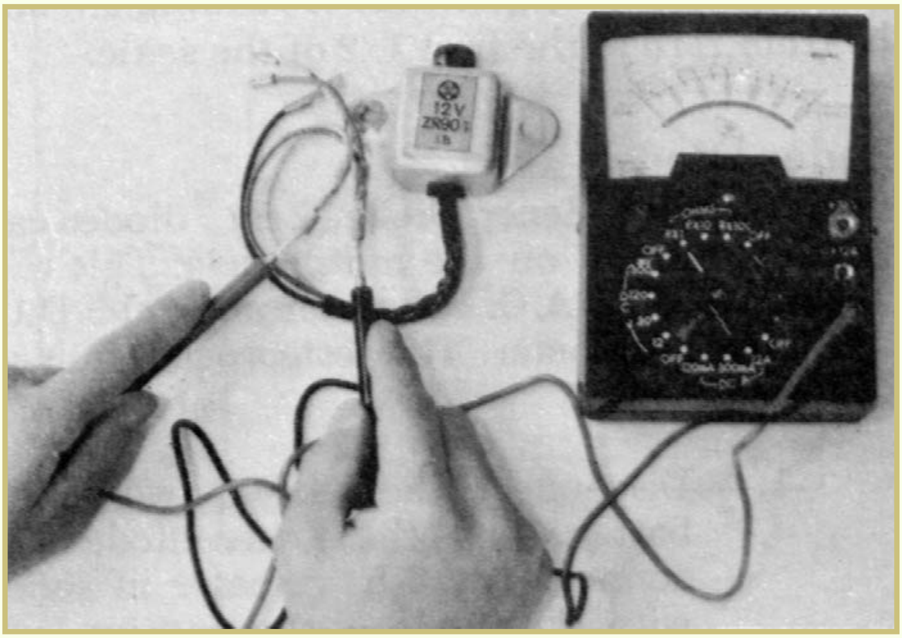


FIGURE 28—This picture shows a technician performing a resistance test on an electronic regulator. (Courtesy Kawasaki Motor Corp., U.S.A.)

Always be sure to use the specifications and recommended testing procedures from the Factory Service Manual for the motorcycle or ATV you are repairing.

Alternator Inspection and Testing

The function of the alternator is to produce electricity which can be used to charge the battery or supply current for other electrical system components such as the lights, horn, etc. As you learned before, the principal parts of an alternator are the rotor and the stator. Permanent magnets or electromagnets are attached to (or part of) the rotor and rotate when the crankshaft rotates. Rotors are positioned so that the magnets closely pass the stator coils. As the magnets pass the coils, electricity is induced in the coils.

Rotors

Rotors must not contact the stator coils as they turn. Therefore, care should be taken to ensure that the rotor is correctly positioned on the crankshaft. If the rotor is loose or crooked, it will wobble and damage the stator coils. Generally, a 0.002-inch clearance between each stator coil and the rotor is recommended.

Rotors don't require service; however, care should be taken to prevent the loss of magnetism, which can be caused in several ways, such as

- Accidentally dropping the rotor
- Hitting the rotor with a hammer (for example, to remove it)
- Allowing the rotor to come into contact with another magnetic field

Incidentally, this is one reason an arc welder is never used on a motorcycle when the magneto or rotor is in place. Electric welding (arc welding) creates a magnetic field which can destroy or weaken permanent magnets on the rotor. Weakened rotor magnets can result in a low voltage output. Therefore, if you need to use an arc welder on any part of a motorcycle, be sure you first remove the rotor.

Heat and aging are other factors that can cause rotors to lose their magnetism. If the magnets on the rotor are weakened for any reason, you should replace the rotor.

Electromagnet Rotor Coil Inspection

Electromagnetic rotor coils can be checked by measuring the rotor coil resistance. To measure the coil resistance, set an ohmmeter to the R×1 range. Connect the test leads of the ohmmeter to the slip rings as shown in Figure 29. If the meter doesn't read as specified in the service manual, replace the rotor. Rotor coil resistance should normally be about 4 ohms.

Stators

The stator can be tested by isolating (disconnecting) the stator coil and measuring the coil resistance. Set an ohmmeter to the R×1 range and connect the test leads between each of the sets of stator coil wires (Figure 30). The stator coil resistance should be less than 1 ohm for each coil.

Next, set the ohmmeter to the highest ohmmeter range. Measure the resistance between the stator coil core and each coil winding. The reading should be infinity. If there's a short, the stator is defective and must be replaced.

FIGURE 29—Measuring the Resistance of a Rotor Coil
(Courtesy Kawasaki Motor Corp., U.S.A.)

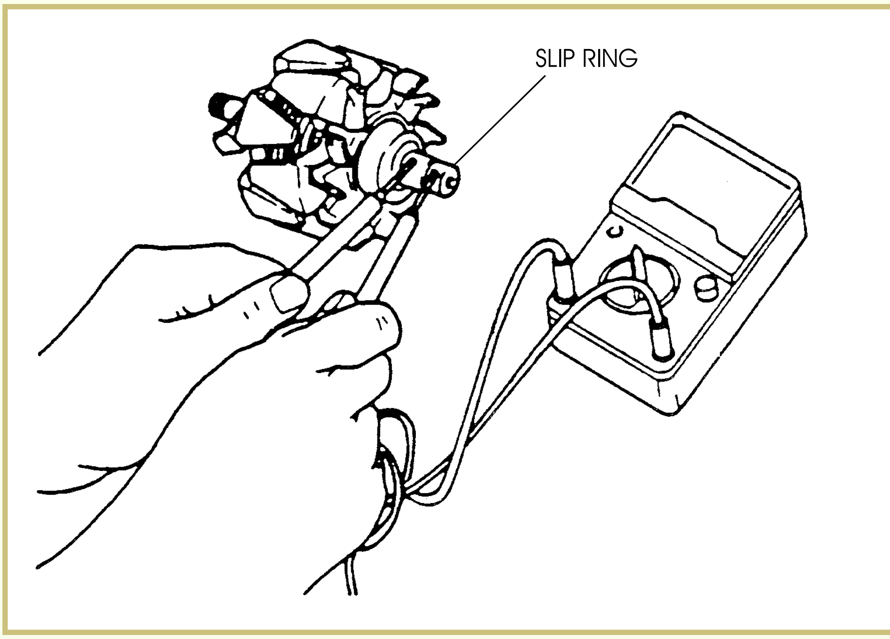
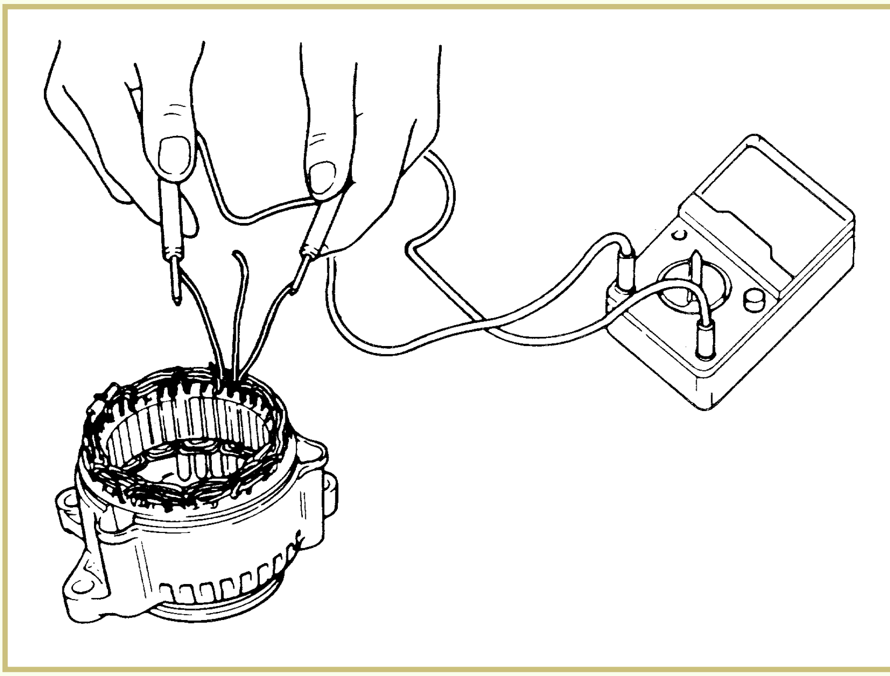


FIGURE 30—Measuring the Resistance of a Stator Coil
(Courtesy Kawasaki Motor Corp., U.S.A.)



Another test of the stator can be made with the engine running. Set your multimeter to measure AC voltage and connect the meter to the output of the alternator (Figure 31). Increase the engine speed to 3000–4000 rpm. The voltage should be at least 20 volts AC.

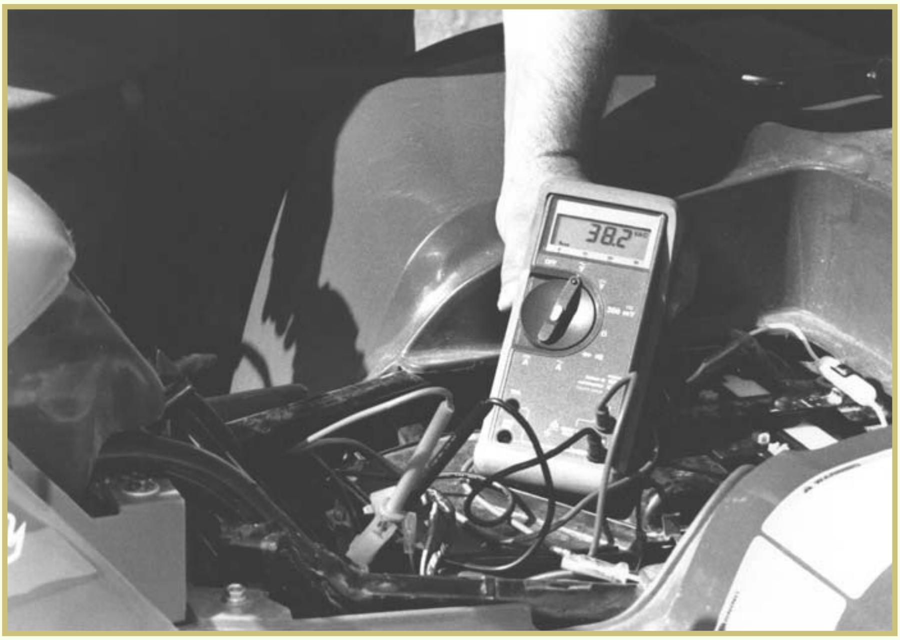
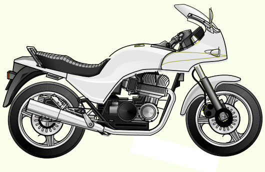


FIGURE 31—Measuring the Stator Output Voltage



Road Test 5

1. Generally, how much clearance should there be between the rotor and each stator coil?

2. What could happen to a rotor if it were dropped?

3. A multimeter used on a motorcycle or ATV should be able to measure what four types of electrical measurements?

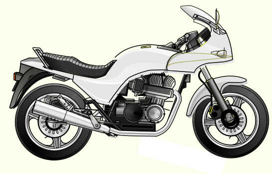
4. When working on the electrical system, what's the first component that should be examined and tested?

5. *True or False?* A defective rectifier will have a low resistance in one direction and infinite resistance in the other direction.

6. Arc welding on a motorcycle or ATV can weaken the magnetism of what component if it isn't removed?

(Continued)

Road Test 5



7. What should the resistance be for a good stator coil?

____

8. What are some of the problems that can occur with mechanical voltage regulators?

____

____

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Check your answers with those on page 46.

DC ELECTRICAL SYSTEM CIRCUITS

When electric current leaves the battery in a motorcycle or ATV electrical system, some of the current travels to the ignition, and another portion of the current goes to other electrical components. In this section of your study unit, we're going to discuss the various DC electrical circuits found on motorcycles and ATVs. We'll give a brief description of each circuit and show how it can be thought of as a separate electrical subsystem! Each of the systems that we're about to discuss has four things in common.

- Each is powered by the battery
- Each is operated by a switching device
- Each must complete its circuit to operate
- Each has a load device to create resistance in the system (lights, horn, etc.)

We'll begin by discussing the two most common problems in an electrical subsystem.

Light Bulbs

One common problem in an electrical system is burned-out light bulbs. Burned-out light bulbs must be replaced. To check a bulb that has been removed from a circuit, you can use a battery and two wires. Connect one wire to the negative side of the battery and to the ground on the light bulb. Connect the other wire to the positive side of the battery and to the insulated light bulb filament. If the bulb is good, it should light.

You can also use an ohmmeter to check light bulbs that have been removed (Figure 32). Connect one test lead from the meter to the ground side of the light bulb. Connect the other test lead from the meter to the insulated side of the bulb. The ohmmeter should show continuity (low resistance) if the bulb is good.

FIGURE 32—A technician is checking a headlight by testing for continuity.

The bases of some light bulbs having different wattages and voltages are the same size. Therefore, always be sure that the bulb you're replacing is of the same wattage and voltage as the one that you removed. Check the service manual if you aren't certain about the correct bulb size. Remember that a 12-volt system must use 12-volt bulbs and that a 6-volt system must use 6-volt bulbs.

Headlight bulbs have two different designs—sealed beam and bulb type (Figure 33). The sealed-beam headlight comes as a complete unit. A headlight may also consist of a lens with a replaceable bulb. As with other bulbs, headlights are made in various sizes. Be sure to use a light of the wattage called for in your service manual. A headlight may be labeled 12V-45W40W. This means that it's 12-volts and it uses 45 watts on high beam and 40 watts on low beam. A 12V-35W30W light uses less current because it has a lower wattage.

Light bulbs often become defective because of the vibration of the motorcycle or ATV. Vibration causes the filament inside the light bulb to break. When this happens, the light bulb must be replaced.

FIGURE 33—This picture shows a headlight and a replaceable headlight bulb.

Other problems that you may encounter concerning light bulb failure include

- A faulty ground connection in the light bulb socket or circuit. Usually, this causes the light to flicker or get brighter and dimmer. To repair this problem, merely tighten the faulty connection.
- A light bulb with a lower voltage rating is used. If a light bulb with a lower voltage rating is used as a replacement bulb, it will burn brighter but will soon burn out. This problem is solved by using the correct light bulb.

Switches

Switches are designed to open and close an electrical circuit. If a switch is defective it must be replaced. You can check a switch using an ohmmeter. The ohmmeter should indicate continuity when the switch is in the "On" position and should indicate infinite resistance when the switch is in the "Off" position. Some switches have more switch positions and leads than the simple On/Off type of switch. These switches should have a switch matrix shown in the motorcycle or ATV electrical schematic similar to that shown in Figure 34. A switch matrix shows you the switch positions and the switch leads that should have continuity for each position. Look again at the sample motorcycle *Wiring Diagram* included in this shipment and note the switch matrices at the bottom of the schematic.

FIGURE 34—A typical switch matrix is pictured here. When the switch is in the L (left) position, the orange and gray wires are connected to complete the circuit. When the switch is in the R (right) position, the blue and gray wires are connected to complete the circuit. (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

EXAMPLE: TURN SIGNAL SWITCH

WIRE COLOR / SWITCH POSITION		ORANGE	GRAY	BLUE
L	(LEFT)	○—	—○	
N	(NORMAL)			
R	(RIGHT)		○—	—○

Headlight Circuits

The headlight is turned on whenever the ignition switch is in the "On" position, but is momentarily turned off as the electric starter motor is activated. The purpose of this is to allow maximum current flow from the battery to the starting circuit. The headlight is momentarily turned off during starting by the starter switch. When the starter button is pressed, the starter switch opens a set of contacts in the lighting circuit (Figure 35).

FIGURE 35—The headlight is on when the starter switch is in the "Free" position. When the starter button is pressed ("Push" position), the HL and HL1 contacts are opened and interrupt the current to the headlight. (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

STARTER SWITCH

	IG2	ST	HL	HL1
FREE			○—	—○
PUSH	○—	—○		

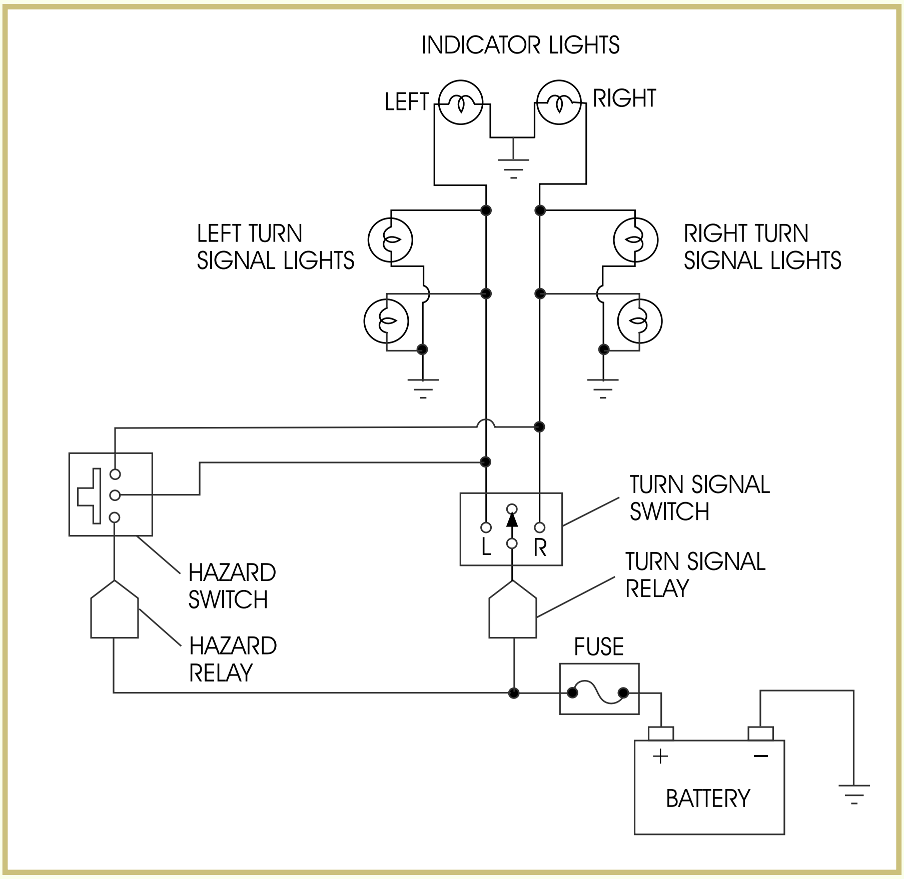
IG2 = IGNITION
ST = STARTER
HL/HL1 = HEADLIGHT

Turn Signal/Hazard Relay Circuits

A typical turn signal and hazard relay wiring diagram is illustrated in Figure 36. The diagram illustrates the system as it would be with the turn signal and hazard switches in the "Off" position.

When the turn signal switch is turned on (either left or right), power flows from the battery, through the turn signal relay, through the L (left) or R (right) switch contacts, and through the left or right indicator and signal lights to ground.

FIGURE 36—A Typical Turn-Signal and Hazard Light Wiring Diagram



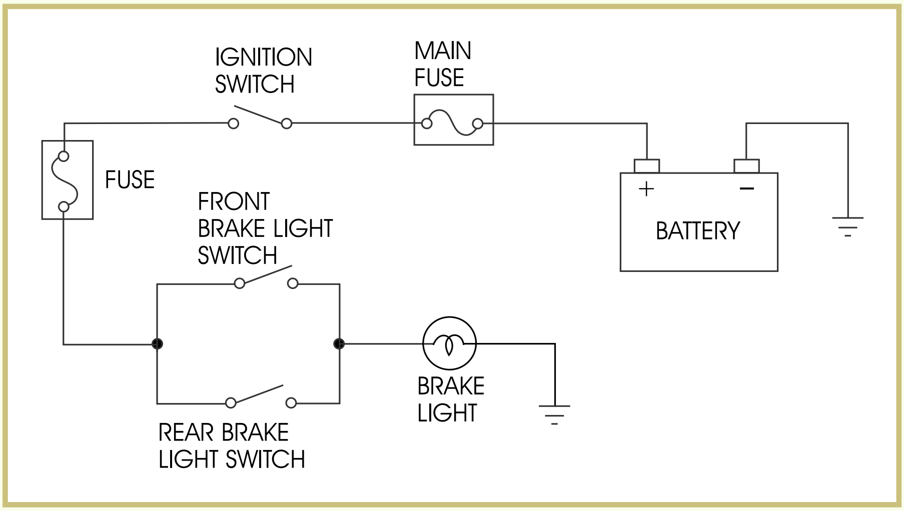
When the hazard switch is activated, power flows from the battery, through the hazard switch contacts, and through both the left and right indicator and signal lights to ground.

The hazard relay and turn signal relay are special circuits that open and close to make the lights flash.

Brake-Light Circuits

A typical brake-light circuit is shown in Figure 37. Note that there are two separate brake-light switches—one for the front brake and one for the rear brake. As either brake switch is activated (by applying the brakes) the circuit is completed and the brake light is illuminated. The ignition switch in the brake-light circuit keeps the brake light from operating except when the ignition switch is turned on.

FIGURE 37—A Typical Brake-Light Circuit (Copyright by American Honda Motor Co., Inc. and reprinted with permission)



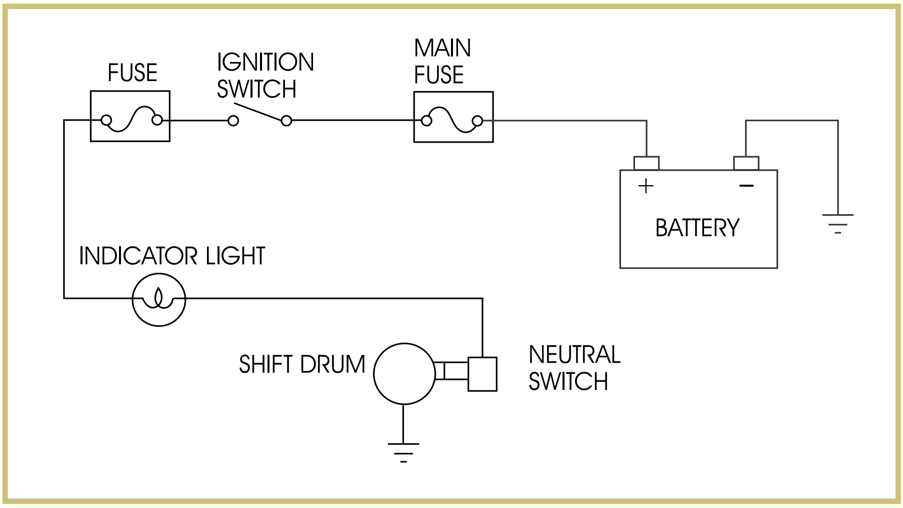
Horn Circuits

Horn circuits are almost identical in design to the brake circuit just mentioned except that there's only one switching device (the horn button). A horn circuit may have its switching device located on the ground side of the horn instead of the positive side as the brake-switch diagram illustrates.

Neutral-Light Circuits

When the ignition switch is turned on and the transmission is in neutral, the neutral indicator light turns on (Figure 38). The neutral switch is operated by the shift drum. When the transmission is in any gear other than neutral, the path to ground is broken and the neutral light is turned off.

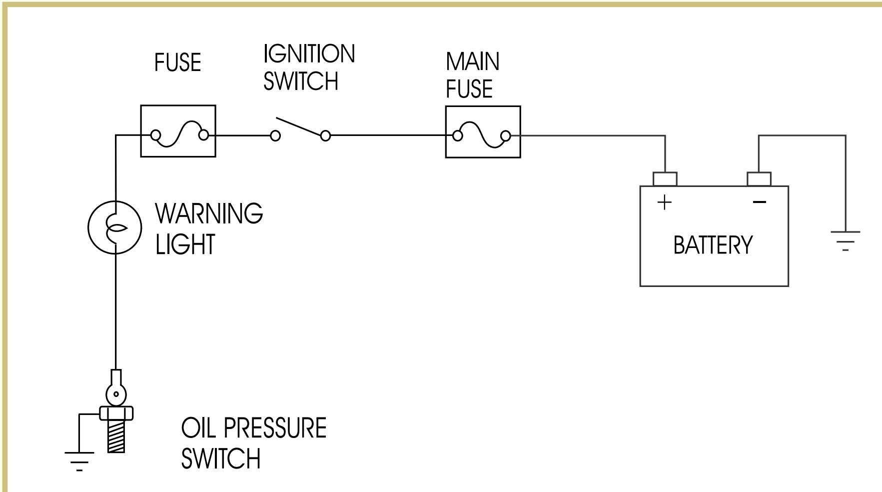
FIGURE 38—A Typical Neutral-Light Circuit (Copyright by American Honda Motor Co., Inc. and reprinted with permission)



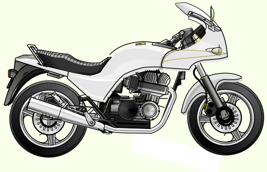
Warning Lights

A typical oil-pressure warning-light system used on a four-stroke engine is shown in Figure 39. If the engine oil pressure falls below a specified amount, the oil pressure switch senses it and turns on the warning light. When the oil pressure is too low, the switch provides a ground to turn on the indicator. When the oil pressure is satisfactory, the oil-pressure switch removes the ground connection and the light turns off.

FIGURE 39—A Typical Oil-Pressure Warning-Light Circuit (Copyright by American Honda Motor Co., Inc. and reprinted with permission)



Road Test 6



1. What are the two types of headlight designs?

____

2. Explain the meaning of a headlight that's labeled 12V-40W35W.

____

3. Why is the headlight momentarily turned off when the electric starter motor is activated?

____

4. Horn circuits are almost identical in design to what other electrical circuit?

____

5. What type of problem would cause a light bulb to flicker?

____

6. What is a switch matrix used for?

____

Check your answers with those on page 46.

Road Test Answers

1

1. Alternator (also known as generator, dynamo, or magneto)
2. Permanent magnet
3. Rotor and stator
4. An open coil or a shorted coil
5. Excited-field electromagnet alternator
6. An excited-field system uses DC current to create a magnetic field. A permanent-magnet system uses permanent magnets.
7. On the outside of the rotor
8. True

2

1. False
2. Between 5 and 40 ohms
3. Overcharging the battery, undercharging the battery, and burned-out light bulbs
4. Infinite resistance
5. True
6. True
7. Mechanical voltage regulator
8. Current limiter

3

1. Electrolyte
2. DC (Direct Current)
3. To measure the specific gravity of the electrolyte solution
4. Sulfation
5. The battery is rated at 14 ampere-hours.
6. False
7. baking soda and water
8. Cracking, broken terminals, sulfation deposits
9. A maintenance-free battery
10. Distilled water

4

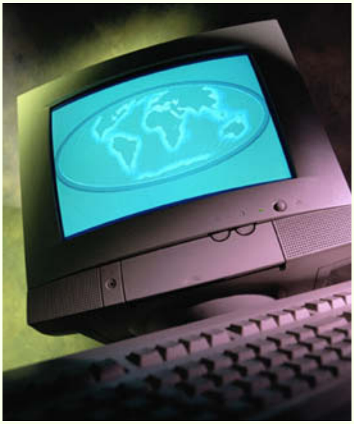
1. 3-phase permanent magnet or electromagnet
2. True
3. Electromagnet charging system
4. 3-phase permanent-magnet system
5. half-wave
6. True
7. One
8. The half-wave system uses only one-half of the AC input. The full-wave system uses both the forward and reverse phases of the AC input.

5

1. 0.002 inch
2. It could lose its magnetism.
3. AC volts, DC volts, ohms, DC amps
4. The battery and connections
5. False
6. Permanent-magnet rotor
7. Less than 1 ohm
8. Incorrect adjustment, dirty contact points, pitted or burned contact points, loose or bad connections, broken or shorted coils, bad ground connection

6

1. Sealed beam and replaceable bulb
2. The headlight is designed to operate on 12 volts and will use 40 watts on high beam, 35 watts on low beam.
3. To divert all possible current to the starter motor
4. Brake-light circuit
5. Bad ground
6. To show when continuity should exist at different points of the switch



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