Basic Electricity

PART THREE

The Battery, Starter and Alternator

The battery provides energy to the starter motor to crank the engine to get it going. Once the engine gets running, the alternator, driven by the engine, generates the electrical energy required by whatever is turned on in the system. The alternator restores to the battery the energy that was used in operating the starter motor. Of course, the restoration of energy to the battery is called charging the battery.

The battery acts like a buffer or a stabilizer, a ballast, an electric shock absorber. At the times that the alternator's speed is too low to supply all of the demands of the system (the system load), the battery fills in. It also absorbs any excess energy the alternator may produce. We want to take good care of this guy!

A battery has 6 lead-acid cells. Each cell has a set of positive plates of one kind of lead, and a set of negative plates of another chemical form of lead. Both sets are completely immersed in the sulphuric acid.

The battery is called a 12-volt battery, but that is a nominal voltage. At an actual voltage of 12 volts the lead-acid battery is almost dead.

Each cell when fully charged will produce 2.1 volts. So 6 cells in series will produce 12.6 volts fully charged. These are numbers you can depend on, to the extent that they can be used to determine the state of charge of the battery. The chart of Fig. 13 gives voltage readings for other states of charge. Because these readings are only tenths of volts (0.1 volts) apart, an accurate meter must be used. A digital meter is usually more accurate than an analog unit if only because there is no needle or pointer mechanism to stick or get bent.

Capacity Test

A battery capacity rating indicates the amount of energy the battery can store. Practically, it tells how long it will supply a certain amount of current. For example, any fully charged battery will supply 125 amps to a starter when the switch is turned to start. But how long it will supply that current depends on how big the battery is in terms of electrical capacity.

The usual time that the battery needs to be checked is when the starter fails to operate, the starter operates sluggishly, or the solenoid chatters. Note that when a battery has been run down by repeated attempts to start the engine, the solenoid will chatter or click.

The first thing that needs to be determined is whether or not the battery is capable of providing the approximately 100-120 amps the starter needs to crank a small engine, or up to 220 amps to crank a big V8.

A voltmeter across the battery will tell the state of charge, but may not tell the whole story because cells can break down under load. With the ignition disabled so that the engine cannot start, and with the voltmeter still connected across the battery, the key is turned to start. If the voltage quickly drops below 9.6, it is probable that the battery is not able to provide the power necessary for the starter. The battery may only need to be charged. But it should be given a full load test to determine its ability to accept and hold a charge.

A capacity test will also help to determine the condition of the plates.

Voltage Drops

Lets look at a couple of other starter-battery system problem situations.

Suppose that the voltage stays right at 12.3 when the key is turned to start and there is no starter or solenoid action at all. The problem can be thought through this way.

The meter staying at 12.3 says that there is no heavy or even medium load on the battery. And no starter noise tells us that either no current is getting through the key to the switch terminal of the solenoid, or the winding of the solenoid is open. So further checking with the voltmeter is necessary. Finding 12 volts at the S terminal of the solenoid says that the key switch and the wiring to the solenoid is okay. So the problem is either in the solenoid, or in the solenoid's ground path through the starter. If you discover that there is no voltage or very low voltage at the switch terminal, then check the wire that runs from this terminal back to the ignition switch.

A common fault here is a break in the wire under the insulation right at the terminal end.

Here's another situation. When the key is turned to start, the voltmeter reading across the battery drops just a few tenths of a volt but the starter turns very slowly or the solenoid chatters. The very small drop in voltage would indicate that the battery is capable of supplying the necessary current but the current is either not getting to the starter or an internal problem within the starter won't let the current pass. Which is it? Is the conduit or cable between the battery and starter big enough? Are there obstructions in the stream? We can tell by looking for voltage drop in the cables.

Voltage drop across a cable means that voltage is

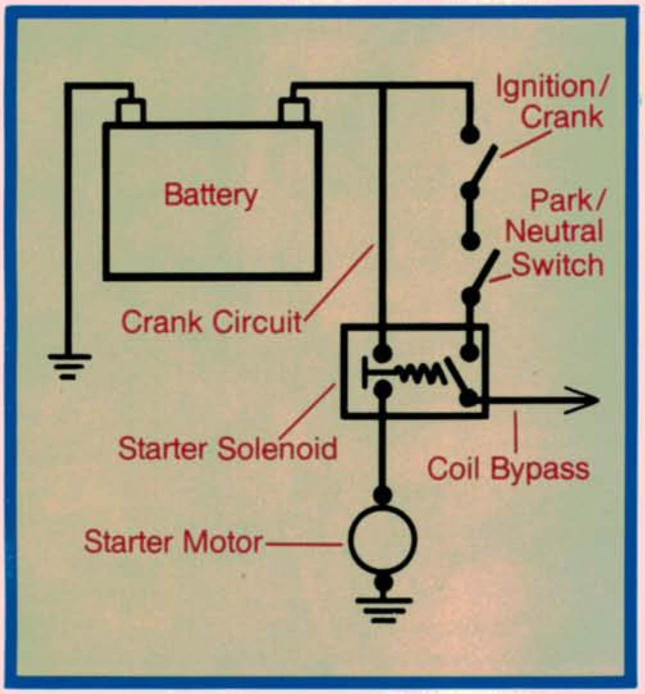

Diagram of A Typical Starting System

being used up in the resistance of the complete cable assembly. Voltage drops are caused by problems such as:

- corroded connections.
- broken strands of wire.
- undersized gauge of wire.
- too small a gauge for the given length of cable.

We can look for a loss (drop) across a cable by connecting a voltmeter across that cable, but in such a way that the measurement will include the terminal ends and the quality of the connections. We'll put the positive lead of the voltmeter on the positive post of the battery and the negative voltmeter lead on the starter's input post. (If the solenoid had chattered, the negative voltmeter lead would go to the battery terminal of the solenoid.) Now we'll try turning the start switch again while reading the voltmeter. Whatever the meter reads is a voltage loss or a voltage drop. Most car manufacturers say this loss should be about 0.3 volt, certainly no more than 0.5 volt. Should we check the ground side of the circuit? If your answer is not a quick yes, please re-study the section on basic circuitry.

The voltmeter can be hooked up across any device, any wire, cable or set of cables to determine that the proper amount of electrical pressure is available to that device.

Starting Circuits

Let's suppose that we run the voltage drop test on a starting system that is in good condition, and analyze the circuit.

With the switch in the start position, a good starting circuit will show:

- 11.5 volts across the battery
- 0.3 volt or less voltage drop from the positive battery post to the starter input terminal.
- 0.3 volt or less voltage drop from the starter case (ground) to the negative post of the battery.

What's the voltage left for the starter? 11.5-0.3=11.2-0.3=10.9 volts, which is well within specs given in the shop manual.

Lets go back to where we had a slowly operating starter and found the following with the key in start. Voltage across the battery = 11.4. Voltage across starter = 9.0 (red meter lead on starter input post, black meter lead on bare metal of starter case). Where's the problem? With the large voltage difference between the reading at the battery and at the starter, surely there is a big loss in either the positive or negative cables or their connections.

CAUTION! The numbers given in the examples above apply when the temperature is warm. Strictly speaking, that means room temperature, about 72 degrees F. The car should be allowed to sit for a while in a room that's at least comfortable for the person working on it. When the temperature goes below 50 degrees F, however, start making some adjustments considering the following factors:

- Battery efficiency goes down with a decrease in temperature.
- Oil in the engine and transmission gets heavier, presenting a greater load to the starter. It will draw more current.

Charging the Battery

What does it take to charge a battery? You'll need a source of electrical current at a pressure higher than the pressure in the battery. The higher the voltage of the charging source, the faster the battery will be brought up to its full charge.

But if the battery is brought up very quickly with a high voltage, an overcharge condition may result. When the battery is being charged on the bench, the charge rate should be adjusted or a timer should be used to prevent overcharge. On the car, this must be done automatically.

How much voltage should be used? A higher voltage to keep the battery fully charged during start-stop, around town driving? Or do we want to lower voltage to prevent overcharge during long distance, high speed driving?

A compromise most generally used is to charge the battery at a rate about 2 volts higher than normal battery voltage. At maximum, the battery voltage will be about 14.6. Let's round that off and call it 14.5 volts and label it "nominal voltage." In actual practice the range is 14.2 to 14.8 volts. Some manufacturers will even vary from that. Amazingly, most of us driving passenger cars get along just fine with this wide variation.

These fluctuations can be tolerated by a good battery. A computer needs stable voltage, however, and most power feeds to automotive computers are limited by a separate voltage regulator.

The voltage regulator of the car's charging system should limit peak voltage output to the nominal 14.5 volts. The maximum capacity of the alternator is determined mainly — but not exclusively by the windings of the stator.

We promised you earlier that we'd discuss electromagnetism a little later. Later is now. Basically, the movement of a magnet near a conductor produces a current in that conductor.

The alternator, for example, has two windings. One is called the field coil. It's in the rotor (the part that rotates). The other is called the stator (the stationary part) and it is on a stack of laminated plates.

With the ignition key in the on position, current from the battery flows through the voltage regulator to the brushes riding on slip rings. From the slip rings, current flows to the field coil. This current in the field coil causes the rotor to become a controllable electromagnet. The two pole pieces of the rotor have opposite polarity although it doesn't matter which is which.

The rotor is turned by the engine, and as it passes the windings on the stator, an electric current is generated in those windings.

The current generated is alternating current, however. The car uses direct current. This alternating current must be converted to direct current, or rectified. This is a job for a set of diodes in the alternator.

A diode is a one-way valve controlling the flow of electricity. Current can flow only one way through a diode, from positive to negative. Three positive diodes connect current flow to the output post of the alternator. Three negative diodes connect to the case, or ground (assuming we have a negative ground system).

Since there is no perfect rectifier available at this time, a tiny bit of alternating current sneaks through. It usually amounts to only 0.2 volts AC riding on top of 14.5 volts DC.

In the alternator design used on most automotive vehicles, output voltage is above 14.5 when the current is low. The output voltage is below 14.5 when the current is high. The cross-over point is different for different designs and even for different output ratings of the same basic types of alternators.

Although 14.5 is the nominal voltage, the actual voltage can be between 14.2 and 14.8 for most vehicles. If there is a problem with under- or overcharging because of the way a vehicle is being driven or used, consult the service manual for that particular vehicle for its recommended setting.

Checking the Charging System

Here's a simple operational check of a typical alternator system:

• Connect a voltmeter across the battery or output terminal of the alternator and ground. (Red lead to the battery terminal of the alternator, black lead to the case of the alternator.)
• Start the engine and run it at 1200-1500 RPM.
• Watch the voltmeter. Voltage should climb slowly for the first few minutes. Alternator output is high during this time as it tries to replace the battery energy consumed by the starter.
• Watch for the reading at which the voltage levels off. This is the regulator setting.

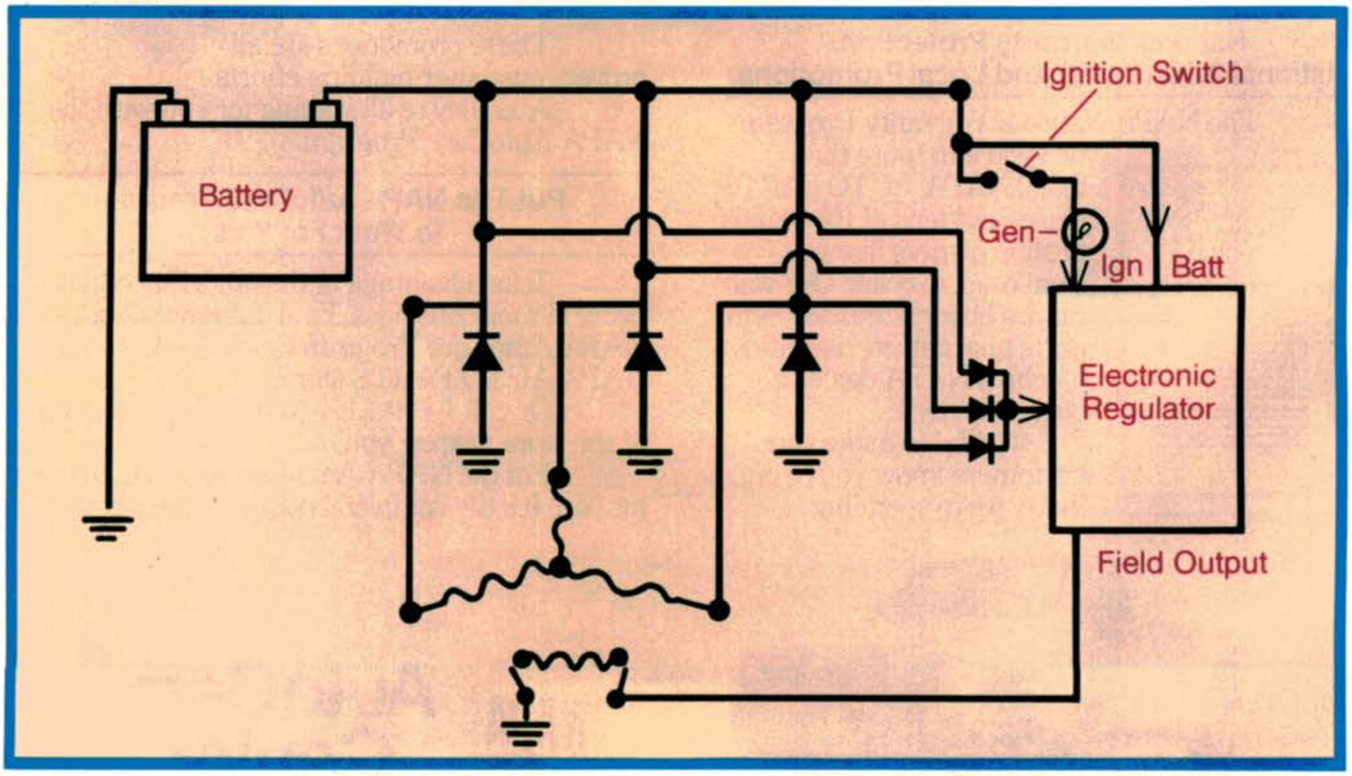

Diagram of A Typical Charging System

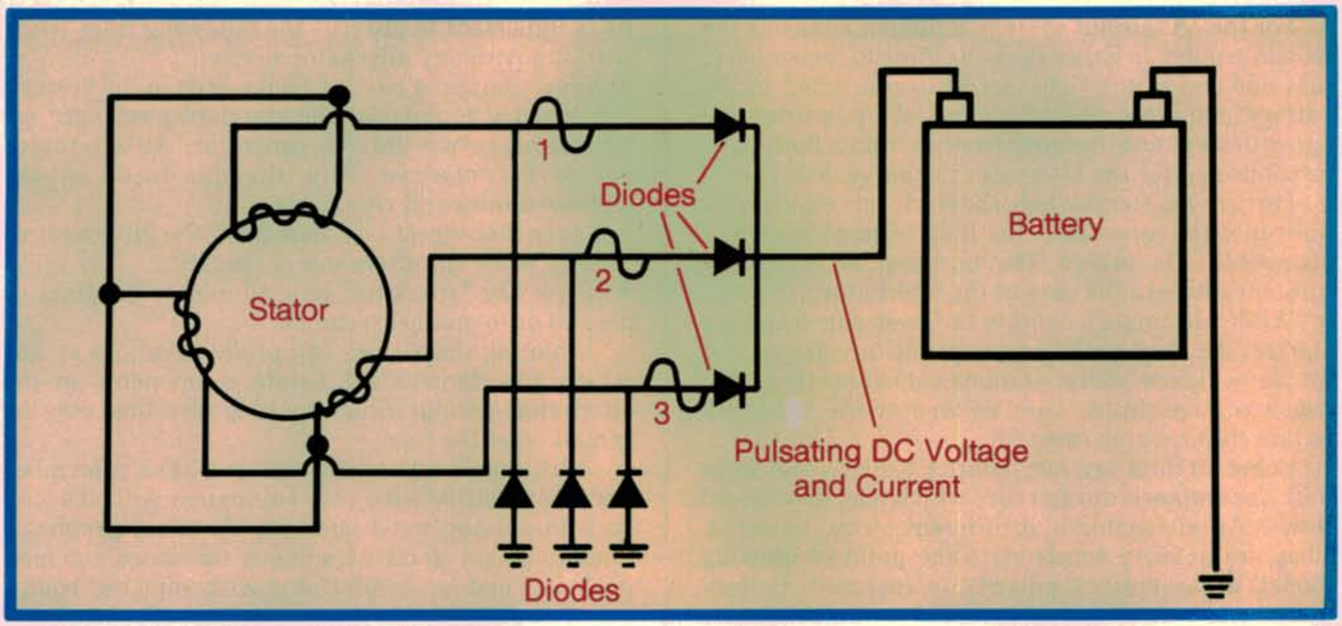

Diagram of An Alternator Converting Sine Wave to Pulsating Direct Current

This simple test informs us that the system is working — at least at minimal levels. If we want to know more about the total capacity of the system and its ability to keep the battery fully charged under adverse conditions, we need to use a charging system analyzer.

This analyzer will have a voltmeter, an ammeter, and some sort of device to load the battery. This loading device is usually an adjustable carbon-pile, or a bank of resistors activated by a rotary switch. We're going to goof off a little here and just tell you to follow the instructions provided by the manufacturer of the tester. Different methods are used to connect and operate these testers by different manufacturers.

In general, however, with the ammeter and voltmeter hooked to the charging system and the engine running at about 1500 RPM, the battery is loaded to determine its maximum capacity, read in amps. Note: if the battery is loaded too much, the charging rate will go down. Adjust the load knob to get the highest reading from the alternator. The current reading should be within 10 amps of the rating for the alternator as it is stamped on the case.

Voltage Regulators

The voltage regulator is an on/off switching device. It is connected in series with the field coil. The regulator also has a circuit that senses system voltage at the battery.

When the system voltage exceeds 14.5 volts:

- The regulator switch opens.
- The current through the field coil drops.
- The rotor's magnetic strength decreases.
- The alternator's output starts to drop.

As the alternator output falls below 14.5 volts:

- The regulator switch closes.
- The current through the field coil increases.
- The rotor's magnetic strength increases.
- The alternator output rises.

The switching portion of the regulator goes on and off many times a second to keep the system voltage at 14.5.

The switch in the regulator may be a set of contact points operated by a relay-type setup. This is called an *electro-mechanical* regulator and was the first regulator to be used with alternators. In later cars, the *electronic* type regulator replaced the electro-mechanical style. The electronic type uses a transistor to switch the regulator on and off.

Since electronic regulators operate through the magic of solid-state, there are no points to arc, burn, or wear out.

As we found out earlier, the switching part of the regulator can be connected to either the "hot" side or the "ground" side of the charging circuit. In a circuit using the electro-mechanical regulator, the switching points are between the battery and the field, that is, in the hot side of the coil. This is called the "B" circuit.

When the electronic regulator is used, the transistor is usually, but not always, located between the field and ground. This one is called the "A" circuit.

Without battery current passing through the field coil, the alternator cannot produce current. Since the regulator must provide a path for that current, a blown transistor may result in a no-charge condition.

So if the alternator is not producing, where is the fault, in the alternator, or the regulator? Let's short the regulator and put full battery voltage across the field coil. If the alternator charges this way, the regulator is bad. If it still doesn't charge, the alternator is the culprit. This process of shorting the regulator is called *full fielding*.

For the "B" circuit system, a small jumper wire is used to connect the alternator's field post with the battery, or output, post.

For the "A" circuit system, a jumper connects the field to ground. In either case, the thing to remember is that one end of the field circuit is connected to the battery, the other end to ground. We can interrupt either to stop the alternator from charging. Both must be connected for the alternator to charge, however.

On many systems where the electronic regulator is built into the alternator, the field terminals are not accessible. On others, the terminal is accessible through a hole in the case of the alternator.

While alternators operate at lower currents than starters do, they are still susceptible to voltage drop problems. Loose, dirty, or damaged connections will cause voltage drops. Low voltage at the field will reduce the charging rate.

Some circuits are not polarity sensitive. A light bulb, for instance, doesn't care which way the current flows. An alternator is a different story, however. They are polarity sensitive to the point of blowing diodes if the battery polarity is reversed. Battery polarity should never be reversed on an alternator equipped car.

In the past few years, manufacturers have made their alternator systems much more resistant to damage caused by voltage spikes which result from loose and/or dirty connections.

Its is important to observe the following rules when working with any alternator system:

- Never connect a battery backwards in the system.
- Never try to polarize the standard passenger car alternator as we did the generator. An alternator cannot be polarized. Any attempts to do so can damage diodes and regulators.
- Never disconnect any wire from the alternator or battery while the alternator is operating.
- Never try "sparking" any alternator terminal to ground or to another terminal.

Violating these rules can produce voltage spikes which can damage solid-state components in the alternator, regulator, or anything else that may be turned on at the time.

A little logic, an understanding of basic principles, and a familiarity with your equipment will go a long way in solving most common electrical problems. Once you get good at solving the more common problems and get comfortable with your test equipment, you'll probably find electrical problems fascinating — and a lot less frightening.

You may even want to try your hand at electronics. ■