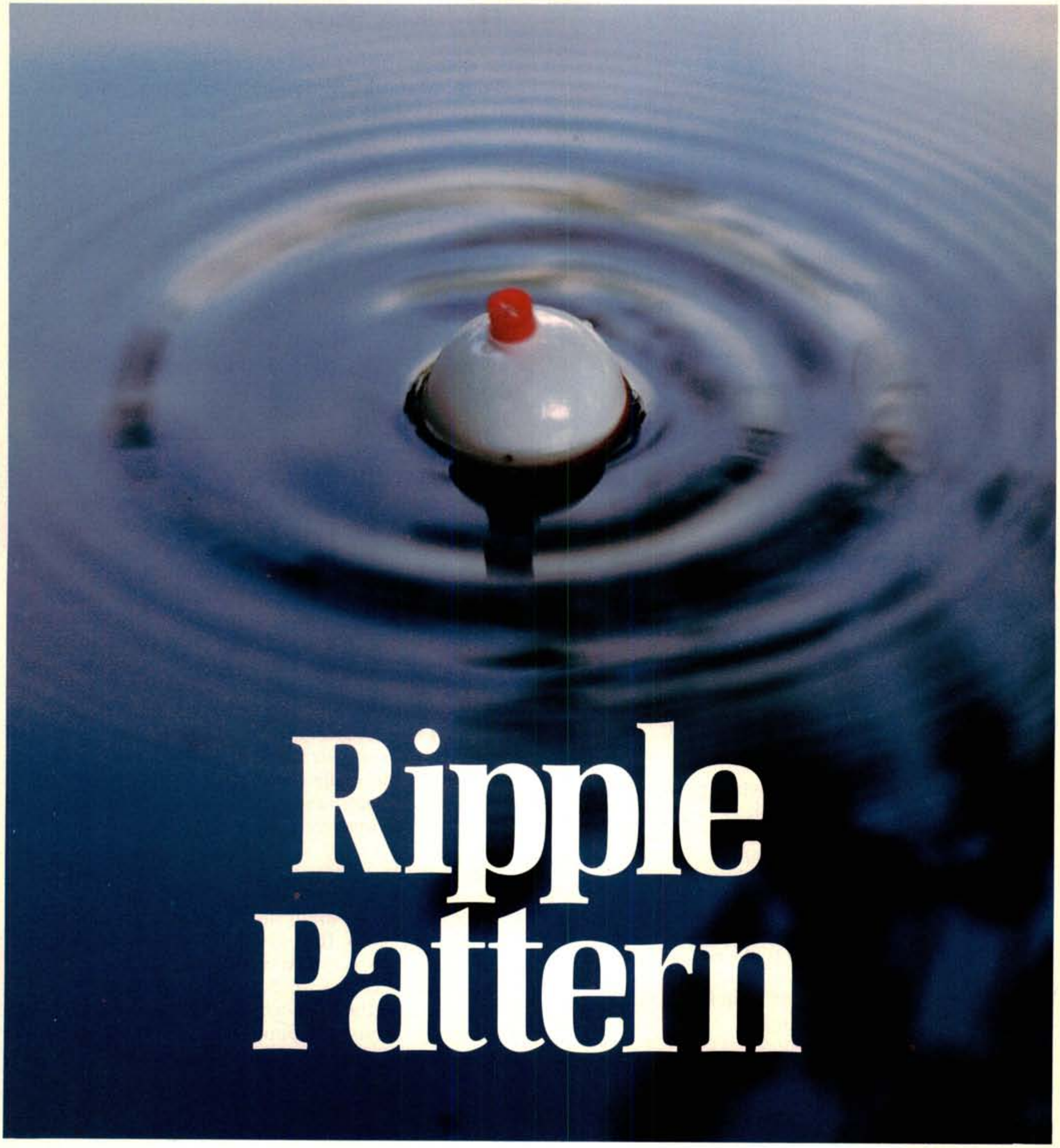


Ripple Pattern

PART ONE

We thought this peaceful photo of a relaxing ripple pattern might put you in a receptive mood for this first part of a two-part article about alternators. Besides, if you don't understand how an alternator works, the best you can do with a charging system problem is ''go fishing''—and hope for the best.

In Part One, we'll take the mystery out of alternator operation by showing you how an alternator does it's job. Once you've learned the Three Easy Steps, the theory behind alternator operation isn't extremely complicated. We'll also get into some advanced theory with a quick look at how some newer models are using a computer to control charging rates.

Next month, we'll put this theory to good use testing alternators. We'll show you how to do some quick alternator tests, some without even opening the hood of the car. These tests will save you time, and make you look good with your customers.

Three Easy Steps

Numerologists in the audience may find some deep meaning in the number three before we're finished. There are three windings in the stator, making three phase current. And a little item called a diode trio is essential to alternator operation.

But the Three Easy Steps of alternator operation are the most important threesome of all. We introduce them in their order of appearance.

- Excitation
- Induction
- Rectification

If you can remember the familiar version of Ohm's Law, $E = I \times R$, it will help you remember both the names of the big three, and the order in which they take place.

Before we get into any great detail about the big three of alternator operation, let's start with a brief working definition of each.

Excitation—Most automotive alternators have no useful residual magnetism like old generators had. So alternators need a little excitement to get them charging. It's a little like your first cup of coffee in the morning. The alternator needs a little jolt to get going too.

Induction—The excitation current in the rotor field winding turns the winding into an electromagnet. When the magnetic rotor turns inside the stator windings, an alternating current is induced in the stator windings.

Rectification—Since the AC current induced in the stator is unusable in the car's DC circuits, the current must be rectified, or ''made right.'' Diodes rectify the AC current to make it usable.

Keep this overview in mind as we take a closer look at alternator operation.

Excitation

Have you ever jump started a car with a totally dead battery only to find that the alternator wouldn't recharge the battery? And later testing showed that the alternator was just fine? Ever wonder why?

If the battery is totally discharged (or if it's sulfated), there isn't enough power left to excite the alternator. Without that little blast of energy, the alternator never gets going. Sometimes, during the jump start process, enough extra charge enters the battery to begin exciting the alternator, and then it will charge. But this is hardly a sure way to excite an alternator, and no way to recharge a totally dead battery.

An alternator that refuses to recharge that totally dead battery is also giving us a warning. Today's alternators aren't designed to run at full output current for very long. If we ask the alternator to run wide open for the amount of time it takes to recharge a dead or nearly dead battery, we may overheat the unit and fry the alternator diodes.

The alternator wants no part of this.

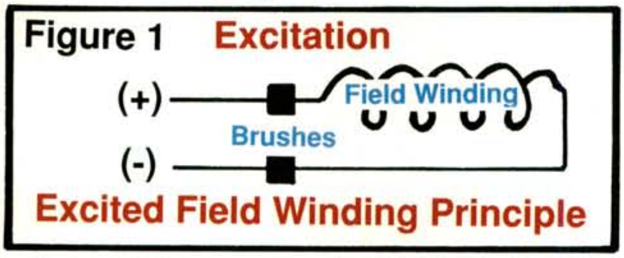
Initial Excitation

Initial Excitation occurs when a small current is applied to the rotor assembly to get it to start charging.

The rotor assembly of the alternator is nothing more than a long wire wrapped in a tight coil. When a small current, usually about 5.0 amps, is supplied to the rotor coil winding, an intense electromagnetic field is created. This current is called Excitation.

We call the rotor a rotor because it rotates. As a result, the connections to the field winding are made through brushes riding on slip rings. Each ring is connected to one end of the "long wire" that makes up the rotor field winding.

Figure 1 Excitation



Excited Field Winding Principle

Figure 1 shows us an excited field winding. This assumes that the rotor's coil winding is neither open, nor shorted to ground, and that we have a good connection between the slip rings and brushes.

Since we have two connections at the rotor, we have two possible ways to limit field excitation. We can control field excitation by switching the circuit to either brush. Logically enough, we end up with two types of voltage regulators. See **Figure 2.**

If the voltage regulator is solid state, make sure the field winding is not shorted. Normally, a field winding will have about 3-5 ohms of resistance. If the resistance drops to less than 1-1.5 ohms, the regulator will be destroyed. It relies on the 3-5 ohms of resistance to keep it from burning up.

Full-Fielding

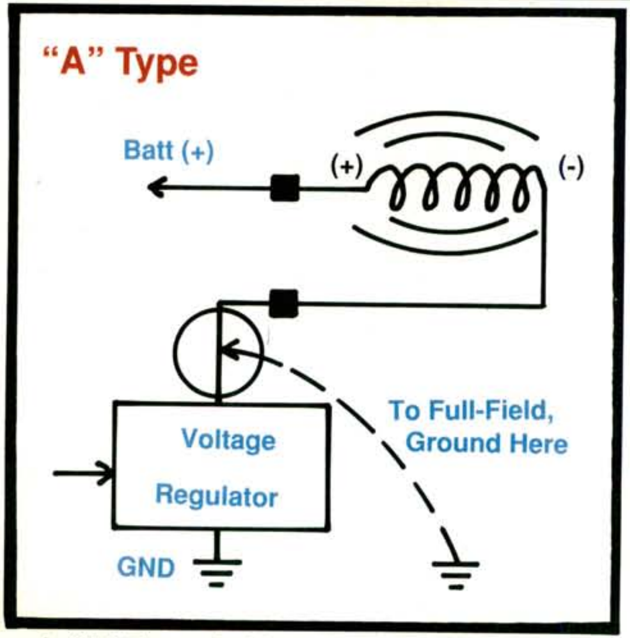
We've all heard the term "full-fielding." But just what does that mean? **Figure 1** also illustrates full fielding. Here, our field is connected directly across the battery. In this state, the alternator is running wide open.

But a car shows up with a no-charge, or low-charge condition. Is it the regulator, or is it the alternator. Which one do we blame?

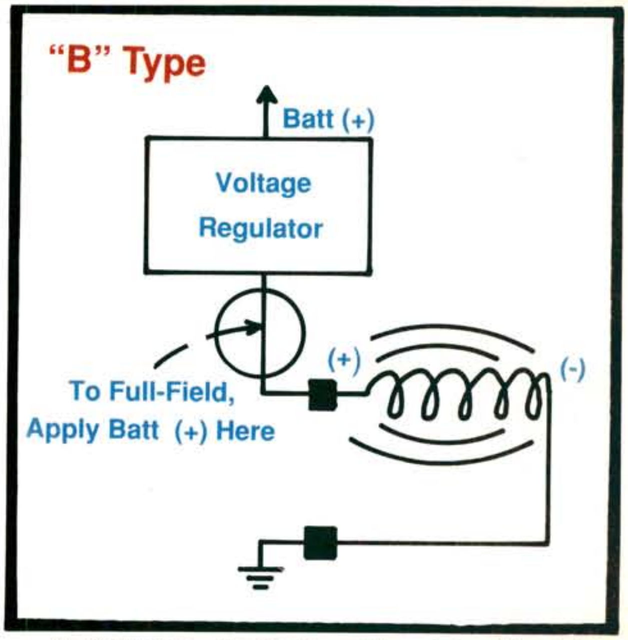
Full-fielding by-passes the regulator and sends a direct order to the alternator telling it to charge "to the max." The alternator should respond immediately, and should produce at it's rated maximum output. If it doesn't produce this higher charging voltage, there is a problem with the alternator. Perhaps it has a bad rotor winding, worn brush contacts, or bad diodes.

If full fielding does get the alternator charging at acceptable levels, then the "regulating circuit" is not properly exciting the field winding. We say regulating circuit here, because more than one voltage regulator has been mistakenly accused, convicted, and executed for wiring, ground, or voltage problems that weren't its fault.

Figure 2

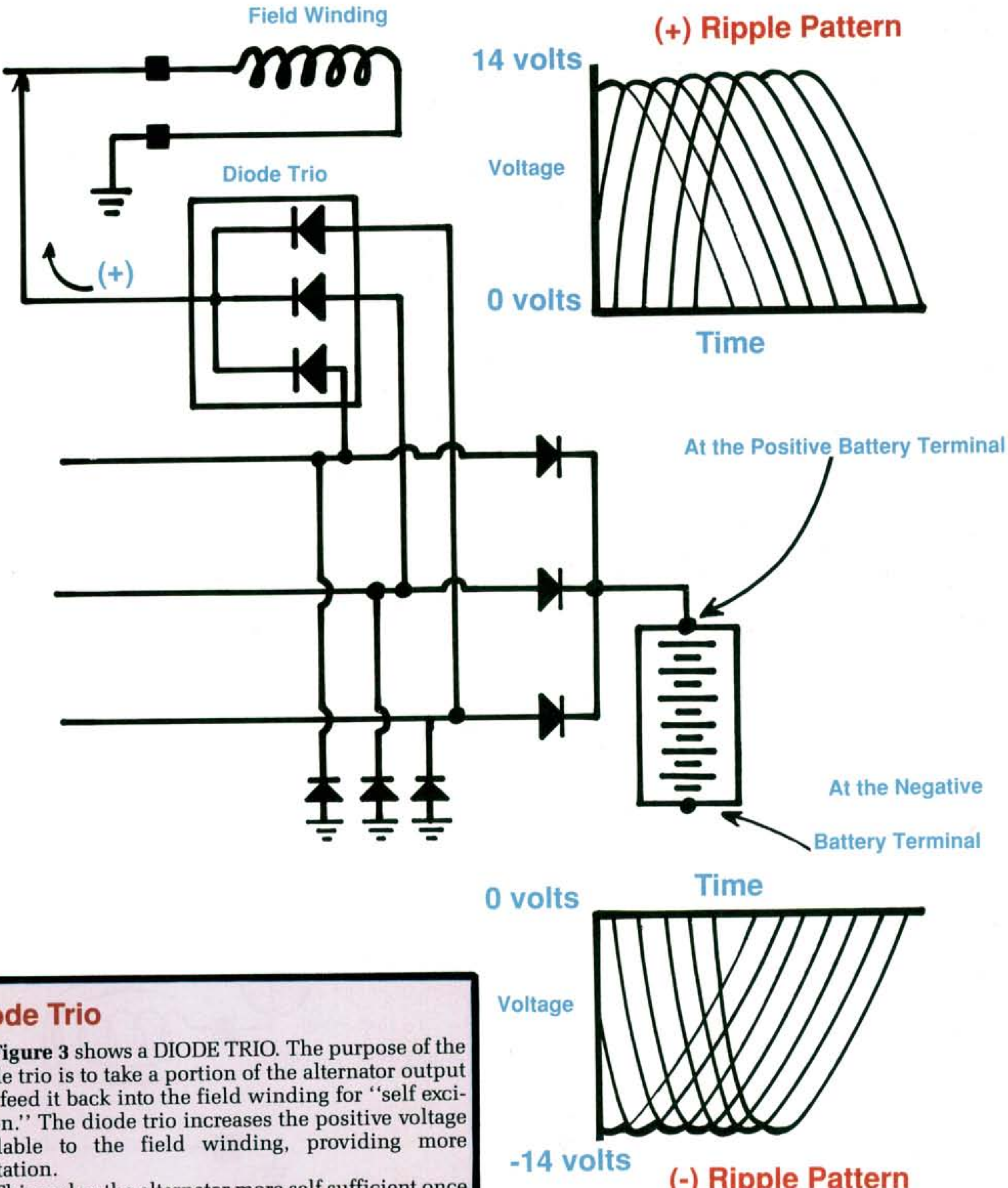


In "A" Type, the Voltage Regulator Provides Ground for the Field Winding



In "B" Type, the Voltage Regulator Provides Voltage for the Field Winding

Figure 3



Diode Trio

Figure 3 shows a DIODE TRIO. The purpose of the diode trio is to take a portion of the alternator output and feed it back into the field winding for "self excitation." The diode trio increases the positive voltage available to the field winding, providing more excitation.

This makes the alternator more self sufficient once it starts charging, and less dependent on the battery to supply excitation current.

Induction

The stationary part of the alternator is called the stator. Brilliant. But unlike the rotor, the stator has three separate windings or phases. As the electromagnetic field in the rotor passes each winding of the stator, it induces an alternating current into each of the stator windings. Each induced waveform is called a SINEWAVE. The stator winding and sinewave are shown in **Figure 4.**

The three phases are not on-line at the same time. When one phase is on-line another is just coming online, and the third is just going off-line. The end result is that the three phases overlap one another producing a pulsating DC voltage. We refer to this as the alternator's ripple pattern. It is the alternator voltage appearing at the battery positive terminal when viewed with a scope.

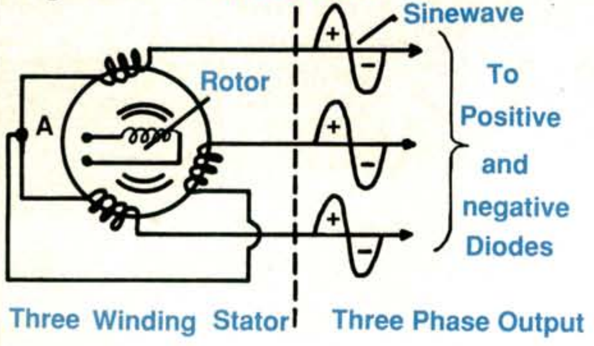
Notice that each sinewave has a positive part, and a negative part. Also notice that there is a separate sinewave induced in each of the three stator windings.

Two things determine the height (amplitude) of the sinewave:

- **The strength of the electromagnetic field in the rotor.**
- **The speed (RPM) of rotor rotation.**

Now you can see why lower excitation voltage results in lower charging voltage, and vice versa.

Figure 4 Induction



Rectification

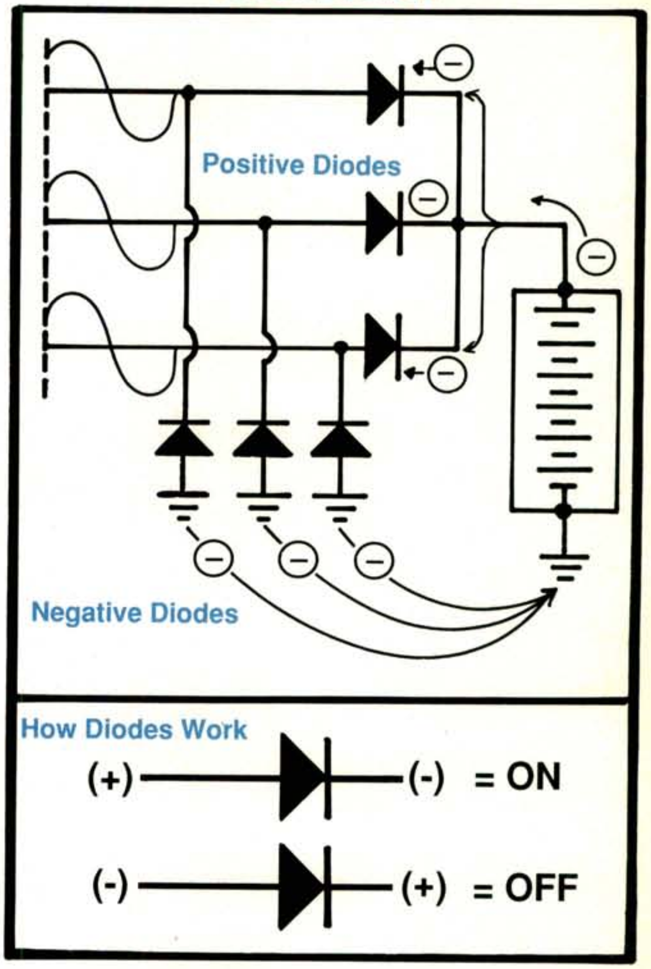
When an alternator charges a battery, electrons are removed from the positive plates and added to the negative plates. To accomplish this, the alternator must generate enough voltage to force a reverse current through the battery to charge it.

Our old diode friends make this possible. Diodes control the direction of the alternator's charging current because they only pass electrons in one direction. The diodes in the circuit keep the current flowing in the proper direction to charge the battery.

This one way street for electron traffic is called Rectification, which means "to make it right." The stator's AC voltage waveform is made right, or rectified, and in the process AC is converted to DC.

Figure 5

Rectification



Push and Pull

Here's how the diodes get the job done.

There is a positive and a negative diode connected to each stator winding. In many alternators the positive and negative diodes are identical. They're just hooked up using opposite polarity. In other alternators, the negative and positive diodes are of slightly different types, but the principles of operation are the same.

When we're in the positive part of the sinewave, the POSITIVE diode turns on and connects the positive stator voltage to the positive battery post.

This pulls electrons out of the positive battery plates, making the plates more positive. During this time, the negative diode connected to the same stator winding is turned off.

Then when the sinewave goes through its negative part, the NEGATIVE diode turns on, connecting the negative part of the sinewave to the battery negative post.

This pushes electrons into the negative battery plates. The positive diode stays off here.

Computer Control of Alternators

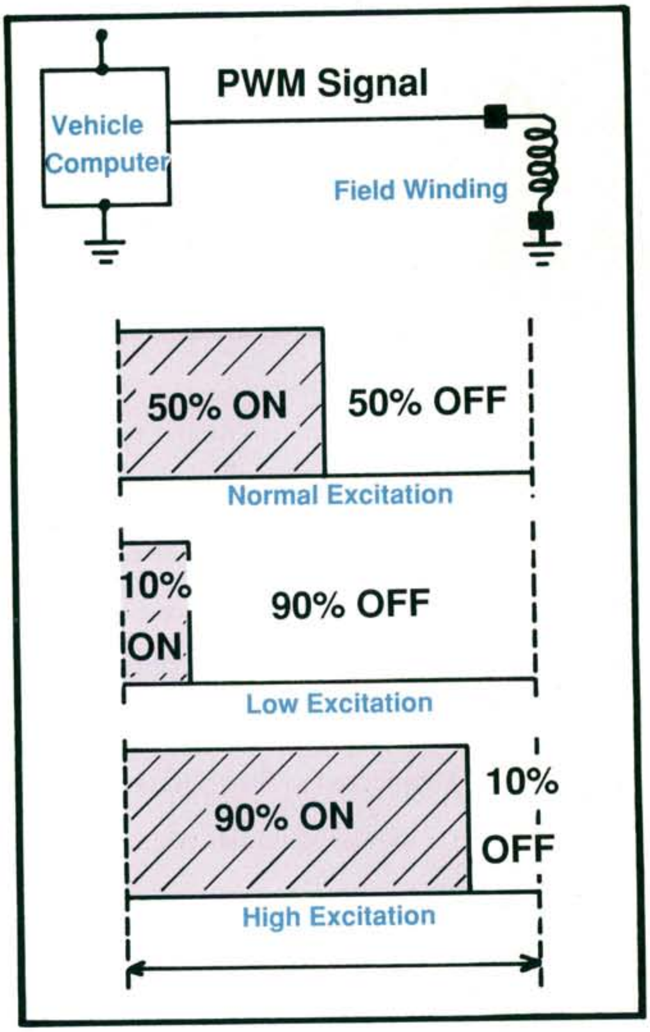
Recent developments show that computers will eventually control charging voltage. The voltage regulator function will be taken over by the computer. Computer signals to the field winding will be a Pulse-Width-Modulated signal or PWM.

This is shown in **Figure 6.**

The duty cycle of the PWM controls the amount of time the field winding is excited during each cycle. (Think of a fuel injector duty cycle as an example.)

When electrical demand is high, the duty cycle will be long, nearing 90 per cent. When electrical demand is low, the duty cycle may go to a low of about 10 per cent. The frequency, or repetition rate of the PWM is about 400 times a second. This allows more precise control of charging voltage. It also lets the alternator respond almost instantaneously to changes in electrical demand.

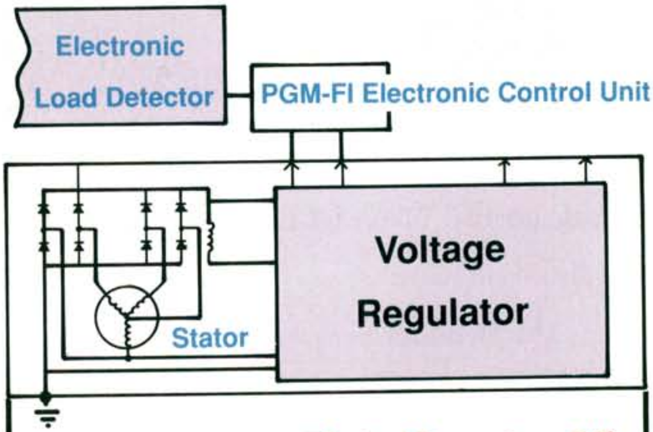
Figure 6 PWM Signal



Current and Voltage

Next month we'll look at the difference between charging voltage and charging current as an aid to diagnosing charging problems. For now, we need to remember that charging voltage and charging current are very different.

- The component (alternator or battery) with the higher voltage controls current flow.
- The alternator cannot output any current to the battery unless the charging voltage is higher than the battery voltage.
- Current to the vehicle can be supplied by either the alternator or the battery. The one with the higher voltage supplies the current.
- As the demand for current increases (increased load), the charging voltage decreases. If you've ever thrown a load into the charging circuit and watched the voltage drop, you know what we mean. If the alternator cannot generate enough current to satisfy the overall load, there's a possibility that charging voltage will fall below battery voltage. In this situation, battery voltage takes over since it becomes greater than charging voltage, and battery current is used to make up for current the alternator cannot deliver. If this condition continues too long, we end up with a dead battery.



Hondas Can Turn Their Alternators Off

Hondas can turn off the alternator when electrical demand is very low at cruising speeds. This saves fuel and reduces emissions. Look at our simplified diagram of the wiring circuit controlling the alternator.

Notice that the Electrical Load Detector senses low electrical demand and sends a signal to the PGM-FI Control Unit (ECU). The control unit determines if it is a good time to shut off the alternator. If it is a good time, the alternator stays off until increased electrical demand is sensed, and the alternator is turned on again.

Looking at Both Sides of the Ripple

We are used to looking at the positive diode output and positive ripple pattern, because we always ground our scope to the negative terminal of the battery. It's easy to forget about the negative set of diodes.

Try this. Connect the ground cable of your oscilloscope to the positive battery terminal. NOTE: This will make the case of the scope "hot" as far as the car is concerned. Make doubly sure that the case of the scope does not come in contact with the metal body of the car.

Then probe the negative battery terminal to see the negative diodes and negative ripple pattern. This measurement is possible as long as the only two connections between the scope and the car are the ground cable and the scope probe.

Come back next month for troubleshooting and testing of alternators. See you then.

—By Vince Fischelli