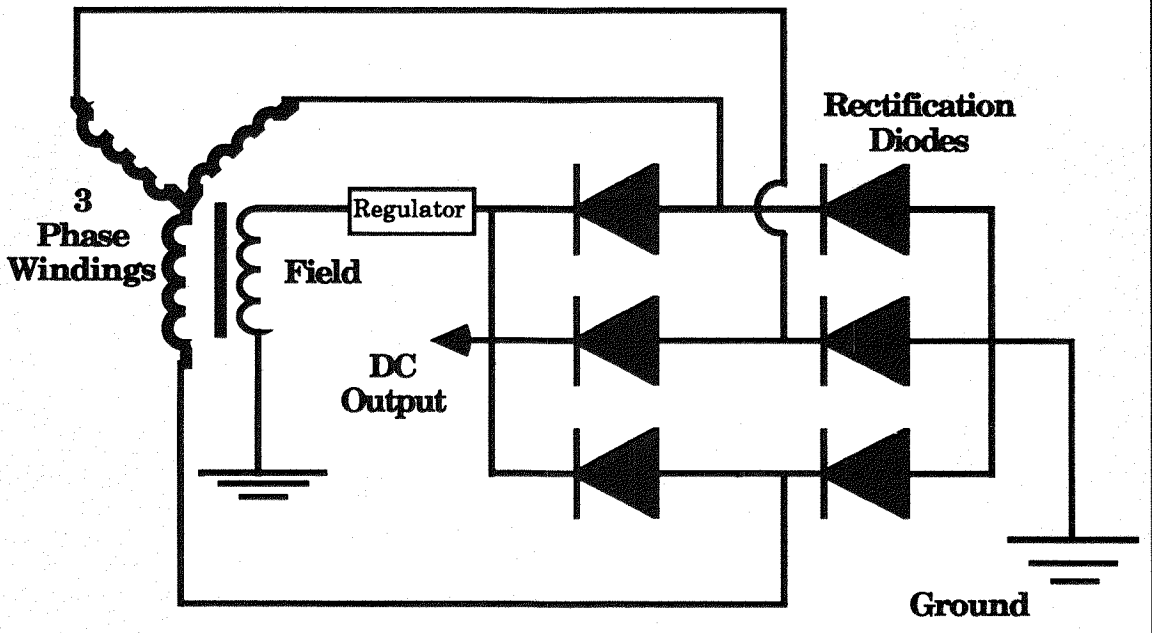
The Automotive Alternator



MTM Technical Press

The Automotive Alternator

MTM Technical Press

Introduction

Automotive Alternators are used in many homebuilt energy projects because they are inexpensive and easily obtained. Automotive alternators are efficient generators of electrical power. This booklet explains how alternators work. It also provides performance data on an off-the-shelf alternator to help experimenters design their Project.

Standard alternators require high rotational speeds (RPMs) to begin producing 12 Volt power. Simple energy projects, like Windmills and Pedal Power Bikes, quickly become complicated when speed increasing drives are used to increase alternator RPMs. This booklet explains how a standard alternator can be modified to produce higher voltage at low RPM by using off-the-shelf parts.

Regulating the output of an automotive alternator is another common challenge for Experimenters. This booklet explains how to build a special inexpensive regulator which is ideally suited for home energy projects. Our special regulator makes it possible to use an alternator in a project without connecting it to a battery system.

By using the information in this booklet a simple, rugged and inexpensive generating system, that runs at low RPM and without batteries, can easily be part of any energy project.

How Alternators Work

Alternators convert mechanical power into electrical power. The mechancial power enters the alternator through the shaft and the electrical power leaves the alternator through wires. Powerful magnets are on the spinning shaft inside the alternator. The magnets sweep past small coils of copper wire that are held stationary in the alternator's housing. The coils are wound on an iron frame. Electricity is generated in the copper coils when the magnets move past them. A diagram of a simple alternator is shown in Figure 1.

The alternator shown in Figure 1 has one magnet, two copper coils and an iron frame called a yoke. The magnet is in the center of the alternator and rotates on a shaft. Lines of magnetic action called flux travel from the North to the South poles of the magnet. The iron yoke provides an attractive magnetic path for the traveling flux. As the magnet rotates the flux travels through the iron, always from the North to the South. Therefore, the direction of the flux through the iron yoke changes direction twice per revolution of the magnet. Coils of wire are wound on both sides of the yoke. As the flux travels through the yoke it also passes through the coils. When magnetic flux passes through a coil of wire it generates a voltage. The voltage produced by the coils reverses sign twice per revolution because the direction of flux changes twice per revolution. The voltage **alternates** between positive and negative.

The voltage output of an alternator depends on 3 main things: How fast the magnets are rotating, the number of turns in the coils and the strength of the magnets. *Every modification or circuit we describe in*

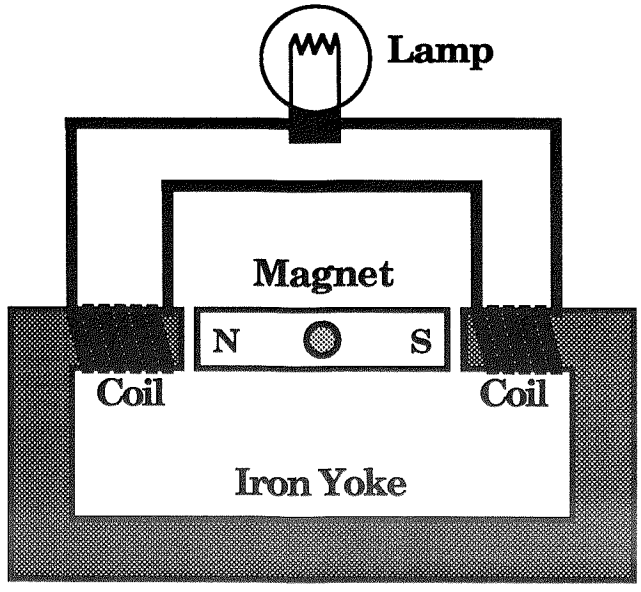


Figure 1. A simple alternator consists of a Magnet, Coils and an Iron Yoke. When the Magnet rotates it induces a voltage in the Coils. The induced voltage can be enough to operate the load: a Lamp.

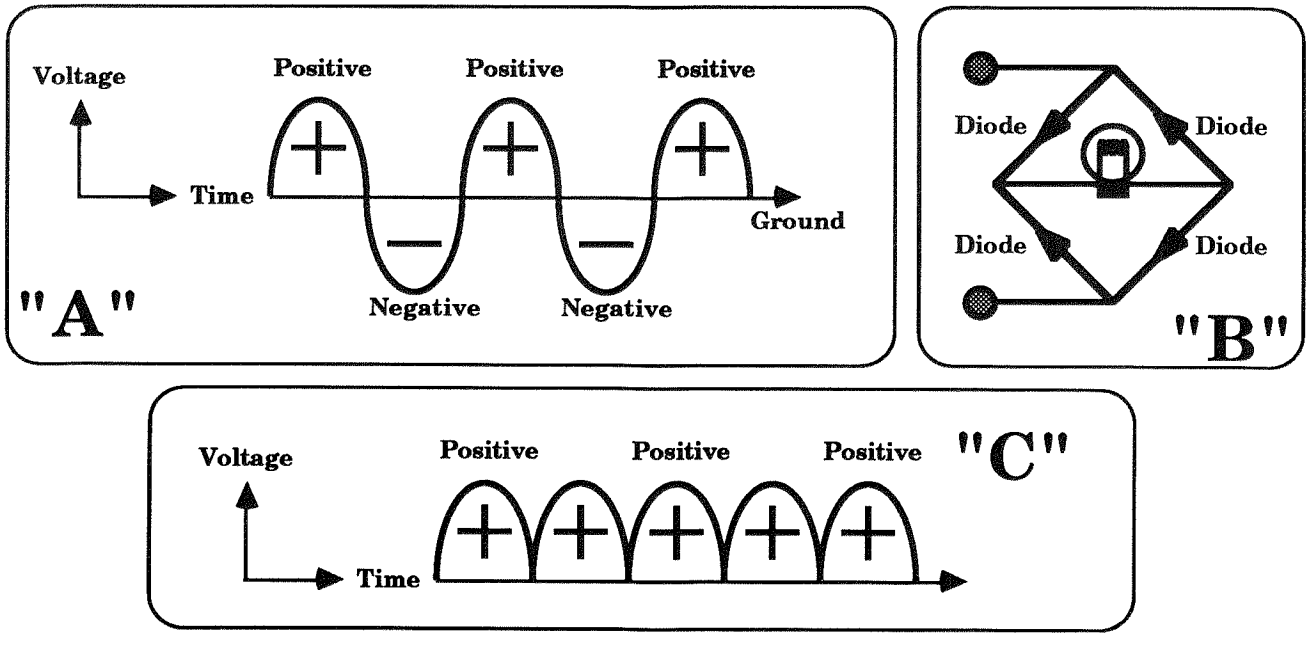


Figure 2. The output of a simple alternator "A" cycles between positive and negative. A rectification circuit made of diodes 'B' can control the direction of the current and send it through the lamp in always the same direction, as shown by 'C'.

this booklet will be changing or controlling one of these three basic things. The effect on output voltage caused by changing these three is easy to remember. Rotating the magnets twice as fast doubles the voltage, doubling the number of turns in the coils doubles the voltage and doubling the strength of the magnets doubles the voltage!

The simple alternator shown in Figure 1 produces an alternating voltage. The output of automotive alternators is not alternating because a special electronic circuit is built into the case of the alternator. The special circuit is called a rectification bridge. Rectification circuits use electronic components called diodes to control the flow of electricity. Diodes are like one way valves for electricity. They allow electricity to flow through them in the direction of the arrow, but prevent flow in the opposite direction. Diodes make the electricity flow through the load in the same direction all the time. Electricity that always flows in the same direction is called Direct Current, or DC for short. Figure 2 illustrates how diodes could be used to convert the output of a simple alternator into DC.

The Automotive Alternator

The automotive alternator has many of the same general features as the simple alternator shown in Figure 1; Magnets on a rotating shaft sweep past copper wire coils wound on an iron yoke. In an automotive alternator the magnets on the rotating shaft are not permanently magnetized. The magnets must be energized with electric current before they produce a magnetic field. Magnets which use electricity to

operate are called electromagnets. The magnetic field strength of an electromagnet increases with increasing current flow. The electromagnets in an automotive alternator require about 3 amps of current to develop full magnetic strength. The current supplied to the electromagnets is called the Field current. In an alternator the current is provided to the spinning electromagnets using two carbon brushes. The brushes rub against copper slip rings situated on the rotating shaft.

The electromagnets inside an automotive alternator have more North and South poles than the simple alternator in Figure 1. For example, the Delco-Remy alternator has seven North poles and seven South poles. Adding more magnets on the spinning shaft makes better use of the space available inside the iron yoke. With seven magnets on the spinning shaft more electricity per revolution is generated.

The magnetic field strength produced by electromagnets increases with increasing field current. Since stronger magnetic fields increase the voltage output of an alternator, it is possible to get higher output voltage by increasing the field current. This works, but only up to a point. Eventually a region is reached where increasing the current doesn't make an electromagnet stronger. The electromagnet becomes "saturated". For example, the electomagnets inside a Delco-Remy alternator become saturated at a field current of about 3 amps. Figure 3 shows how the output voltage of a standard alternator varies with field current, when rotational speed is held constant at 1000 RPM.

The most important difference between a simple alternator and an

automotive alternator is the physical arrangement of the iron yoke and the power producing coil windings. In the simple alternator, shown in Figure 1, the space above and below the spinning magnetic poles is empty. Automotive alternators use this wasted space by adding more copper coils. In fact, automotive alternators have three different sets of windings for producing power. They are wound around the entire circumference of the alternator housing. Electrical machines built with three sets of windings are called three phase machines, where each set of windings is considered a phase. The three windings are connected together in a special three phase connection called a "wye". The electrical power from the three phases is rectified into DC power using 6 diodes. Figure 4 is an electrical diagram of the wiring inside a modern automotive alternator.

The voltage output from an automotive alternator is controlled by adjusting the field current. The device which controls voltage output is called a regulator. Regulators work by sensing the voltage output from the alternator and adjusting the field current; up for more voltage and down for less voltage. The regulator can be mounted inside or outside of the alternator housing, depending on the manufacturer. Most modern alternators mount the regulator inside the housing. Since we use a special regulator for our energy projects, we prefer the older style alternator with an external regulator.

Alternator Performance Data

Automotive alternators are used in many home energy projects because

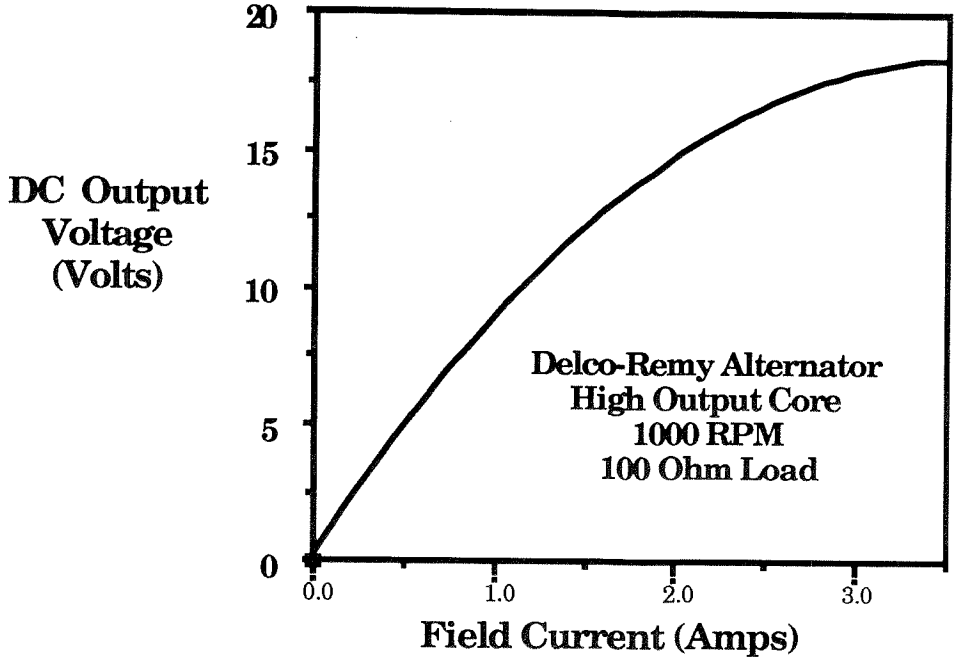


Figure 3. The DC output voltage from an alternator increases when the field current increases, but only up to a point. In this example the limit is about 3 amps.

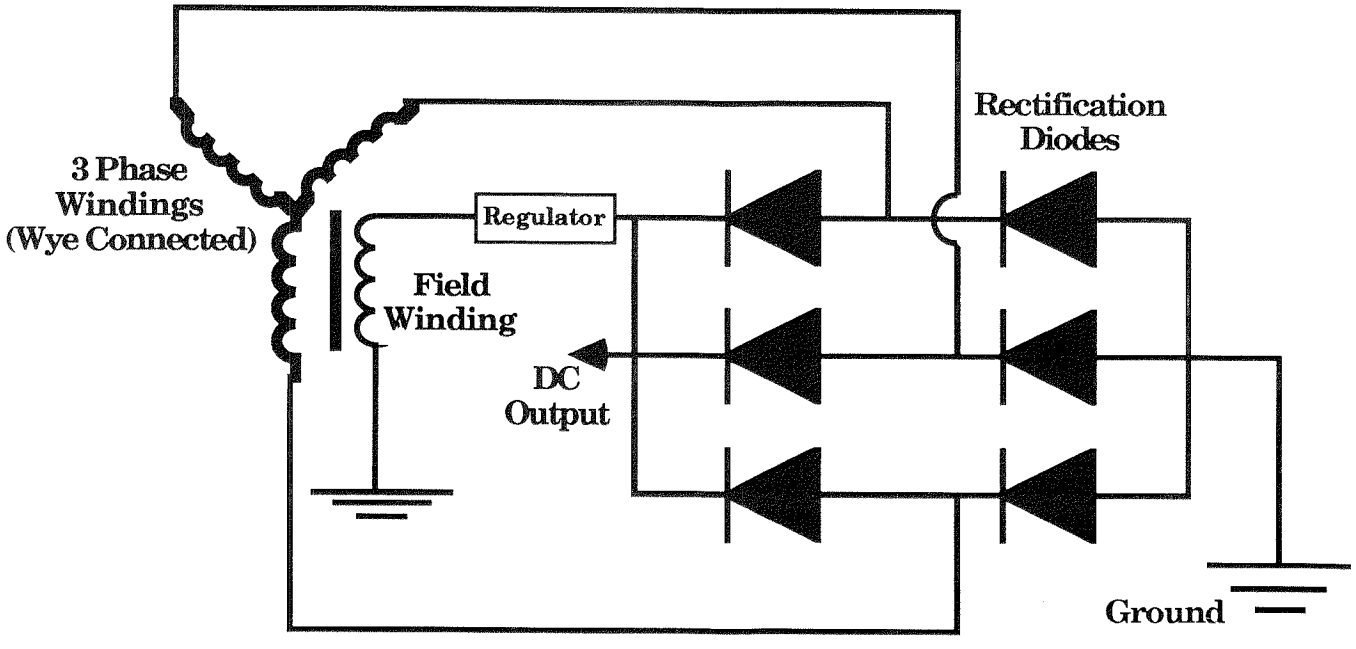


Figure 4. A modern automotive alternator has 3 phases. The DC output voltage is produced by a group of 6 rectifiction diodes. The field winding is on the spinning shaft. A regulator controls output.

they are readily available and inexpensive. Experimenters are often interested in generating 12 Volt power using the lowest possible rotational speeds, such as on a direct drive windmill or a pedal power bike. A standard alternator can be modified to produce higher voltages at low RPM. The three basic options are: 1) a stronger magnetic field, 2) higher RPMs, or 3) more turns of wire in the coils. We have already seen that it is not possible to increase the magnetic field strength beyond a certain point (because of saturation effects), and using higher RPMs to get higher voltage is what we are trying to avoid, therefore our last option for increasing voltage output is to *change the number of turns wound on the iron yoke inside the alternator housing*. Fortunately, this change is very easily made by installing a professionally wound high voltage output winding.

We have measured the electrical performance of a standard and modified Delco-Remy alternator in the low RPM range. The test results are displayed in Figure 5. The results show that, with maximum field current, a standard alternator requires a minimum speed of 1100 RPM to produce 12 Volts. However, an alternator with a high voltage output winding can produce 12 Volts at only 650 RPM. The reduced RPM requirements of the modified alternator make it much easier to use in energy related projects.

Modification Instructions

The alternator we have found to be the least expensive and most easily modified is the Delco-Remy model. It is used on automobiles built by

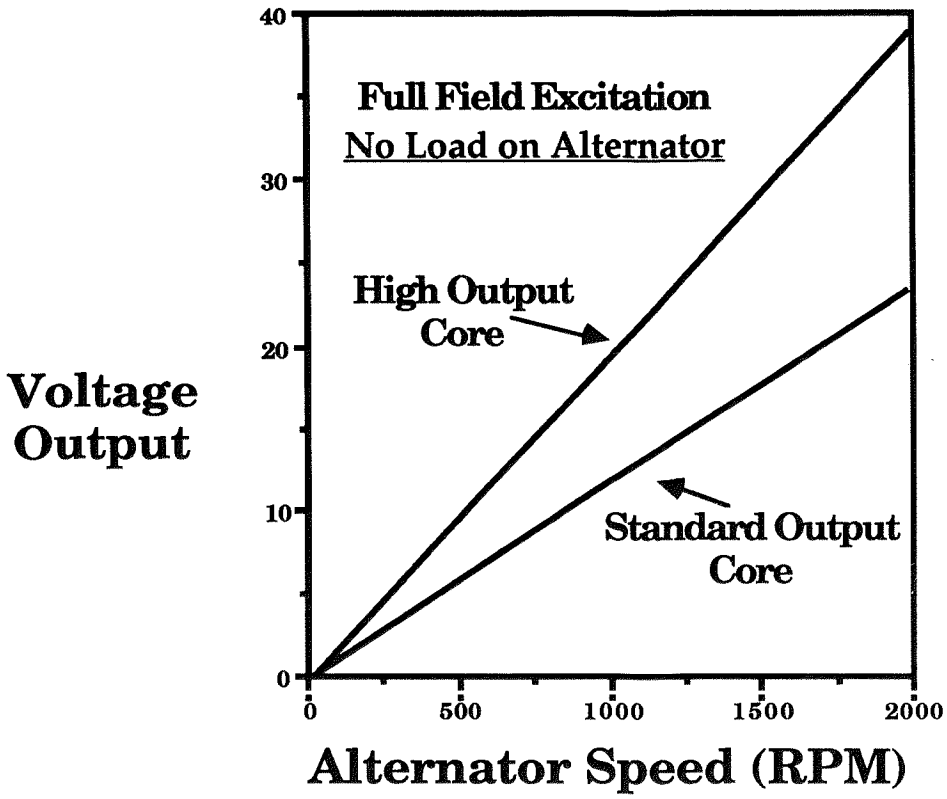


Figure 5. Alternator output voltage increases with faster speeds. With no load, a standard output core produces 12 Volts at 1100 RPM, while a high output core produces 12 Volts at only 650 RPM.

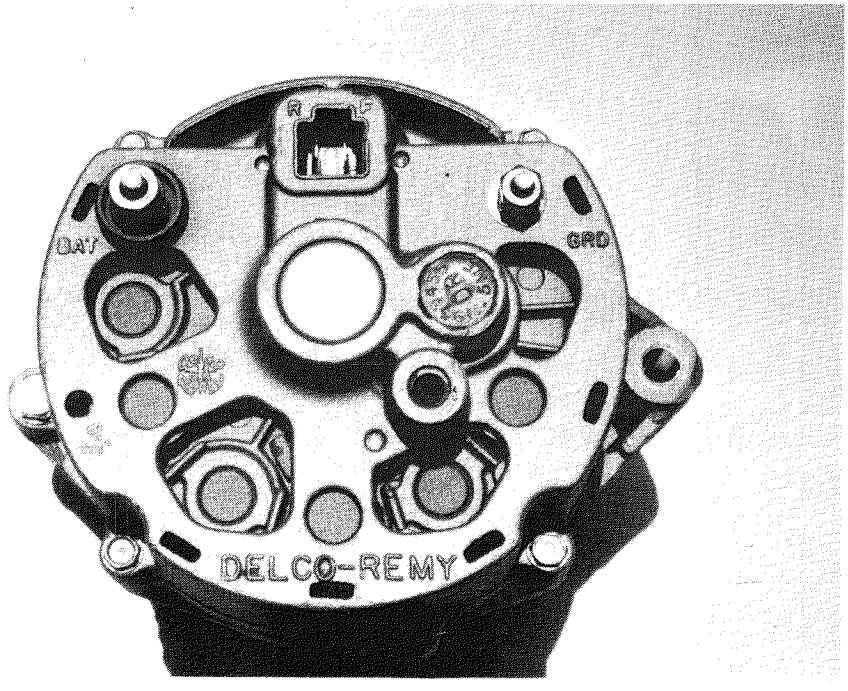


Figure 6. The backside view of this Delco-Remy alternator clearly indicates it was built to use an external regulator.

General Motors. There are two basic styles of Delco-Remy alternators: internally regulated and externally regulated. Make sure to get an externally regulated alternator. They make it easy to attach the special "self exciting" regulator described in the next section. The externally regulated type is also less expensive. A rebuilt alternator, in perfect condition, can be purchased for about $25 at a discount auto parts store. The photograph in Figure 6 shows an externally regulated Delco-Remy Alternator. *When purchasing an alternator for your project carefully compare it to the photograph.* The words "Delco" or "Delco-Remy" should be clearly visible. Avoid alternators with internal cooling fins visible through holes in the backside housing, they are internally regulated. Again, the alternator you buy should look exactly like the one shown in the photograph.

High output cores are available as an "off-the-shelf" item from electrical companies that specialize in winding alternators for the automotive industry, such as Able Armature Service in Chicago, Illinois. The high output cores are wound for special applications of the Delco-Remy alternator. Because the high output cores use smaller diameter wire the maximum rated output current is limited to 32 amps, compared to 65 amps with a standard core. These high output cores are usually referred to as "24 Volt Cores", even though we are using them to produce 12 Volts.

Installing the high output core into a Delco-Remy alternator is easy to do. Four screws hold the alternator housing together. Once they are removed the alternator can be disassembled into halves, as shown in Figure 7. The core is sandwiched between the two halves of the

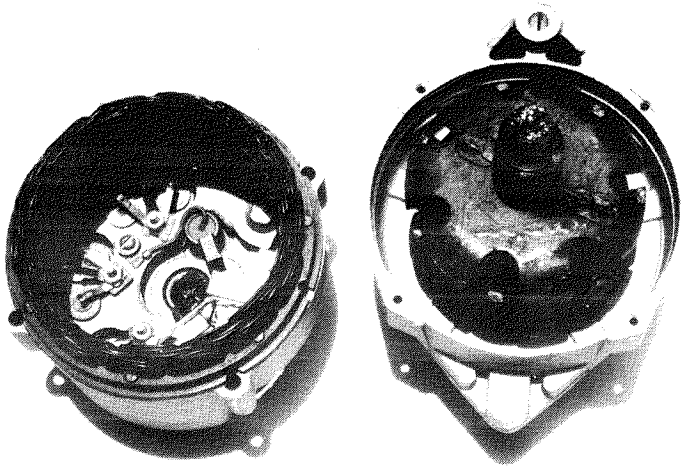


Figure 7. The Delco-Remy alternator housing is disassembled by removing four bolts. The high voltage core can then be installed.

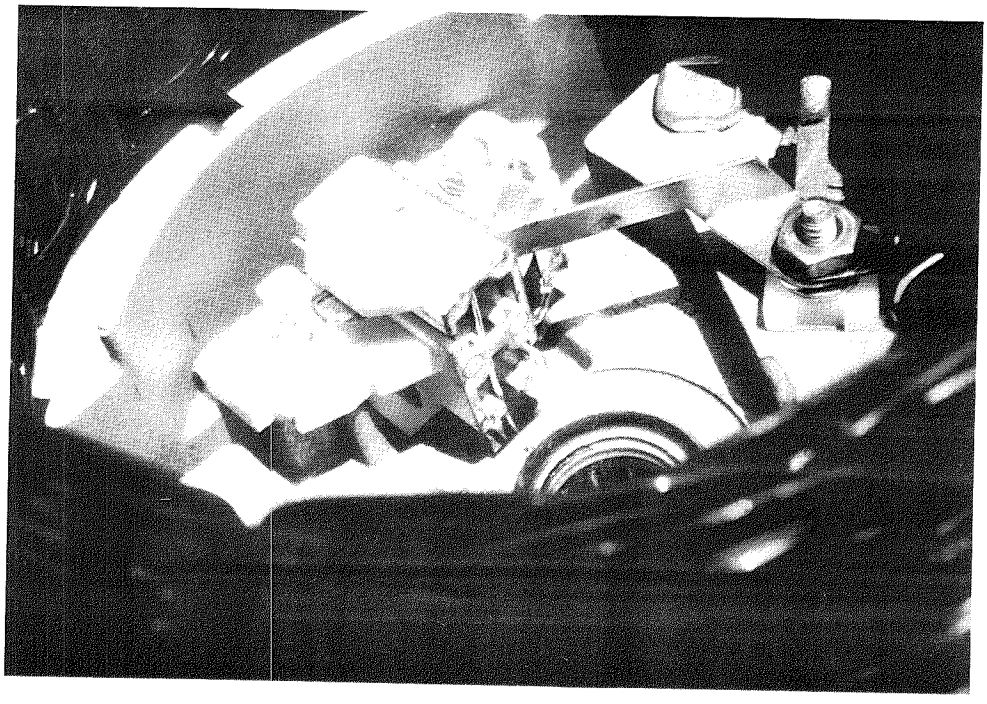


Figure 8. The two carbon brushes and their springs are held in place by a simple paper clip during reassembly.

alternator housing, it can be removed by loosening the three nuts holding down the output leads. Then, it is only a matter of inserting the high output core and electrically connecting the 3 leads. [Note: The special regulator described in the next section is wired to the same 3 output leads on the high output core. Therefore by adding 3 wires for the electrical connection now, before closing up the housing, you won't need to open up the alternator again later.]

The most difficult part of installing the high output core is putting the alternator halves back together. That's because the two carbon brushes and their springs will have popped out of the brush holder when the alternator was taken apart. However, there is a simple trick in getting the halves back together with the brushes in the right place. The designers of the alternator have placed a small hole in the backside of the alternator housing. The hole allows a retaining pin, such as a large straightened paper clip, to be inserted from outside the housing to hold in the two brushes and springs during assembly. Figure 8 shows the brushes in their holder being retained by just such an arrangement. After the alternator is put back together, the retaining pin is withdrawn to allow the brushes to make contact with the copper slip rings.

Regulating the Alternator Output

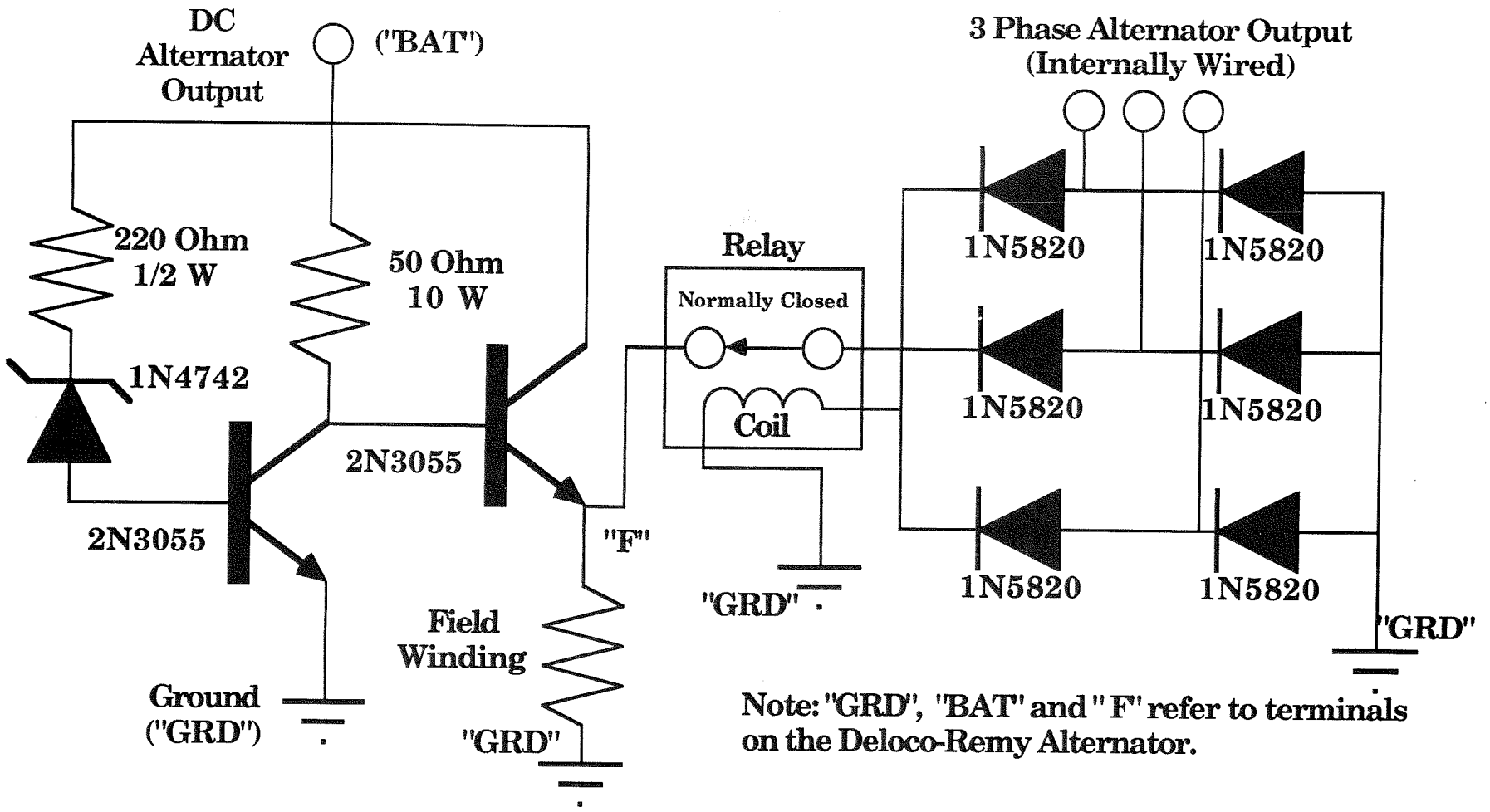
Without a regulator the voltage output of an automotive alternator changes when the RPM changes. So, unless the device driving the alternator maintains a constant RPM, the voltage output will be changing. The purpose of a regulator is to maintain constant output

voltage with variable input speeds. A regulator controls the output voltage by adjusting the field current.

Standard automotive regulators can be used in home energy projects, but they have several disadvantages. One disadvantage is the way they are designed to be either "on or off". The issue of whether a car is "on or off" is simple. When the ignition key is engaged the car is considered "on" and the regulator starts energizing the field windings. But consider the same situation with a windmill. It can start spinning at any hour of the day or night. Unless the regulator is left "on" continuously, the alternator won't produce electrical power when the wind begins to blow. Unfortunately, a continuously energized regulator quickly drains down the battery!

Another disadvantage of automotive regulators is their dependence on a battery to supply the field current. Since automobiles depend on a battery to start the engine, automotive regulators were designed to depend on the same battery to provide the field current for the alternator. But with energy projects, like windmills or pedal bikes, a battery is an extra expense that the designer may want to avoid ... if the regulator can be designed to work without one.

We have designed a special regulator for energy projects which is smart enough to know when to turn "on" at the right time. It also supplies the initial Field current without using a battery. The electrical circuit of the regulator is shown in Figure 9. The 12 volt zener diode is the circuit element which senses the voltage output of the alternator. The zener diode supplies base current to an NPN power transistor wired in an



Note: "GRD", "BAT" and "F" refer to terminals on the Deloco-Remy Alternator.

Qty	Description/Specification	Radio Shack #
2	Transistor, 2N3055 or Equivalent	276-2041
1	Power Resistor, 50 Ohm, 10 Watt	271-133
1	Zener Diode, 1N4742, 12 V, 1 W	276-563
1	Relay, 12 VDC Coil, SPDT	275-248
6	Diodes, 1N5820, Schottky	Not Avail.
1	Resistor, 220 Ohm, 1/2 W	271-015

Note: Additional Parts available from...
ALL ELECTRONICS CORPORATION
P. O. Box 567, Van Nuys, CA 91408

DIGI-KEY CORPORATION
P.O. Box 677, Thief River Fall, MN 56701

inverting configuration. The inverted signal controls the base current to the second NPN power transistor, which in turn controls the Field current. The regulator also uses 6 Schottky diodes to form a special low forward voltage drop rectifying bridge to supply the initial field current at low RPM. After the alternator begins producing 12 Volt power, the mechanical relay disconnects the Schottky diode bridge from the circuit to prevent an overload of the diodes.

Building the regulator is simple, but a few special precautions must be taken for the circuit to work properly. Most of the parts for the regulator are available from Radio Shack, except for the Schottky diodes. They are available via mail order from All Electronics in Van Nuys, California. Don't be tempted to substitute a supposedly "equivalent" part for the Schottky diodes! We have tested many different types and styles of diodes for this circuit. The 1N5820 diodes were found to be the absolute best for energizing the alternator at low RPM. Another important precaution concerns the transistors. During operation the transistors become warm, especially the main transistor supplying the Field current. It is very important to do a good job of heat sinking the main power transistor, otherwise it gets too hot and eventually burns out. A breadboarded version of the regulator circuit is shown in Figure 10, note the heat sink on the main power transistor.

The regulator circuit can easily be built on a piece of printed circuit board and enclosed in a plastic or metal case, depending on the specific application. Connecting the regulator to the alternator is not difficult. Three wires from the Schottky diode bridge must be connected to the

three output leads on the high voltage core inside the alternator housing. The wiring order is not important because the leads are interchangeable. The regulator must also be connected to the "BAT" and "GRD" terminals on the back of the alternator. Finally, the output of the regulator's main power transistor must be connected to the "F" spade connector on the back of the alternator. (The "R" connector isn't used.)

This regulator circuit works with either the high output core or the standard core inside the alternator. With a standard core the alternator will begin producing 12 Volts at about 1700 RPM, but with a high output core the 12 Volt output will begin at a much slower shaft speed; around 900 RPM. In all cases the amount of useful power available from the alternator will increase with increasing RPM. (For example, with the high output core inside the alternator, expect about 100 Watts of 12 Volt power at 1400 RPM.)

If you plan on charging a lead acid battery with the alternator, substitute a 15V zener diode, such as the 1N4744 (Radio Shack #276-564), into the regulator circuit. When charging a battery it is important to include a high current diode in the output line from the alternator, such as a 1N1183A (Available from Digi-Key, Thief River Fall, MN) Place the diode in the circuit where the output line connects to the battery. The diode prevents backflow current from draining down the battery system when the alternator is idle.

Whether you are charging batteries or not, it is important to include a protection fuse in the output line from the alternator. The maximum

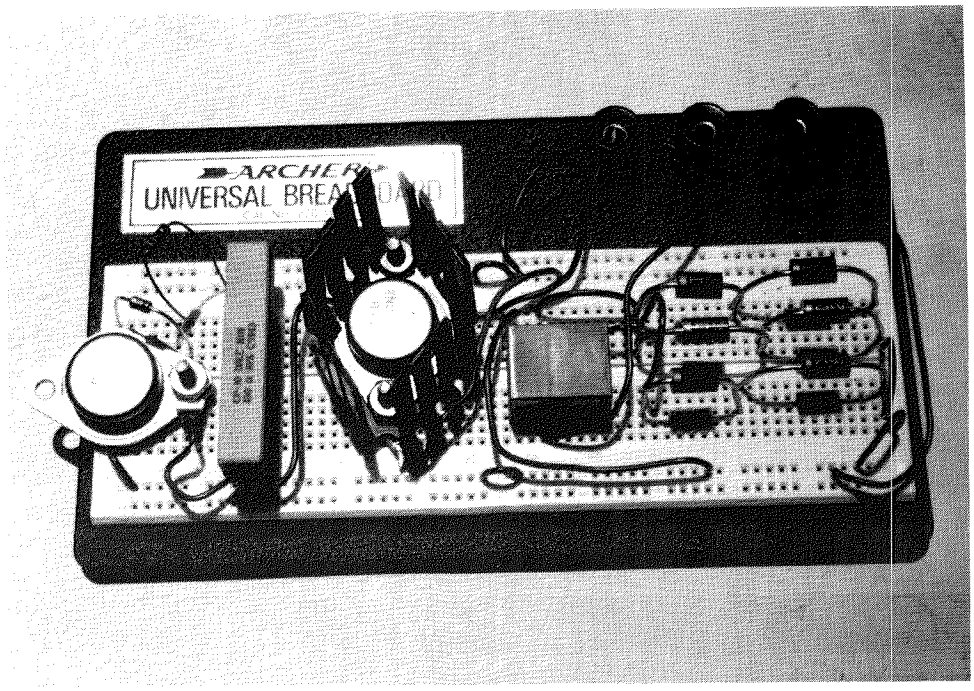


Figure 10. The alternator voltage regulator can be easily breadboarded into a compact package as shown here. Note the heat sink on the main power transistor.

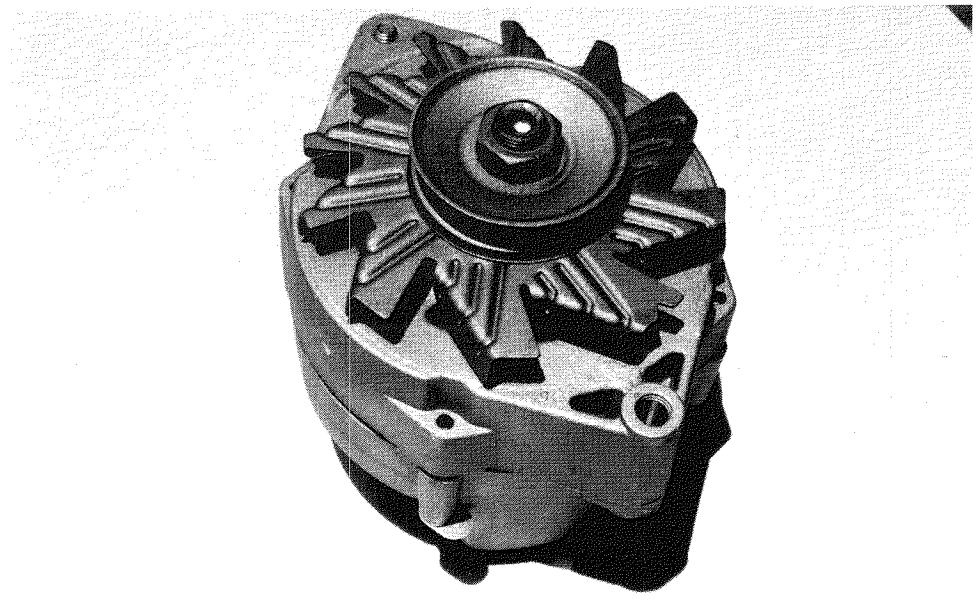


Figure 11. The Delco-Remy alternator is a nicely engineered piece of electrical machinery that can be used in many homemade energy projects. Always keep safety the first priority in your projects...and Happy Experimenting!

current from a high output core is 32 amps. A standard core can produce 65 amps maximum. **Choose the lowest fuse current adequate to operate the intended load.** For example, a 100 Watt television should be protected with a 10 amp fuse. It is much less expensive to replace a blown fuse rather than replace the television or radio!

Energy Project Ideas

A modified alternator with the special voltage regulator is an ideal electrical generator for many different types of energy projects. One of the easiest projects to build is a Pedal Power Bike. The idea with a Pedal Power Bike is to generate electricity while riding a stationary bike, like an exercise cycle. The output power can be enough to operate a 12V radio or television. This makes a great project for the kids, who ride the bike in order to watch TV. A simple "V-grooved" nylon pinion can be machined that attaches to the alternator's shaft. The pinion runs on the outside diameter of the moving tire, held in place by a spring.

Another energy project worth considering is a windmill. There are several types of commercially sold windmills that are nothing more than a simple small diameter airfoil blade directly connected to the shaft of an automotive alternator. The special high output winding makes it feasible to build a windmill in this manner. Usually, the alternator is mounted on a spring loaded pivot point that tilts the blade out of the wind, if the windspeed becomes too great. The special "self-exciting" regulator we have described is ideal for this application because it eliminates the need for fancy electrical control systems.

Please keep safety the first priority in all your projects. **WARNING: Automobile alternators can produce potentially lethal voltages if they are operated at high RPM with full Field Current.** Always treat the output wiring as if it were carrying a lethal voltage. Also, with any type of rotating machinery, be sure to install guards to prevent loose clothing or fingers from straying into the spinning hardware. Use common sense. Remember young people and pets may not share your cautious respect of things electrical or mechanical. So whatever your interest or desire, please be careful...and happy experimenting!

References

The Wind Power Book, by Jack Park and published by Cheshire Books, Palo Alto, California in 1981. (Excellent source of design information on all types of windmills. Ideal resource for experimenters.)

The Art of Electronics, by Horowitz and Hill and published by Cambridge University Press in 1980. (Excellent source of easy to understand information about modern electronics and circuits.)

"Real Good's" Catalog, 966 S. Mazzoni, Ukiah, CA 95482 (A free mail order catalog of alternative energy products. Interesting photos of a "commercial" pedal power bike and a direct drive alternator type windmill.)

MTM Scientific
P.O. Box 522
Clinton, MI 49236

ALTERNATOR CONVERSION KIT

Start your project right with MTM's Alternator Kit!

Our ALTERNATOR CONVERSION KIT is the fast and economical way to get started on your project. The Kit includes a high output conversion core for a Delco-Remy alternator, as shown in the booklet. It also includes six of the special Schottky diodes for building the regulator. Our kit makes it possible for you to complete your project with locally available parts. It also helps you avoid minimum order charges when dealing with other suppliers. We have what you need to get started, and make every effort to ship promptly.

Yes! I want to start my project right. See current pricing for the Alternator Conversion Kit on our website:

WWW.MTMSCIENTIFIC.COM

Name_____

Address_____

City_____ State_____ Zip_____

Make Checks or Money Orders payable to MTM Scientific, Inc.
Money back if not satisfied. Mail to:

MTM Scientific, Inc.
P.O. Box 522
Clinton, MI 49236 U.S.A.

IN A HURRY TO GET STARTED? Go to our website and place your order using the Paypal link. *We ship promptly.*