

Alternator and Racing Cycle Generator

BASIC ALTERNATOR PEDAL GENERATOR

There are a lot of ways of making pedal generators; all sorts of things can be used as the generator, with either bicycle parts or exercise bicycles as the base. There are pros and cons to all the approaches, but for people who haven't built one before and want to get a useful amount of energy out, I think the alternator and racing bicycle one is best as it can be built without special tools such as lathes or welding gear.

Alternators and racing bicycles can both be found in rubbish or from Free Ad papers, the awkward problem of voltage regulation is automatically done by stuff in the alternator, and the electrical circuit is simple to wire up. This page is a long overdue rewrite of the 1996 'Hippo' leaflet which has been used by many people to make working generators. The idea is not so much to show a design to be followed exactly as to get you a basic working generator so you are inspired to develop and improve it yourself.

One of the things you should be aware of before you start is the energy output of an average person. Although some athletes can produce amazing power outputs for short periods, the maximum continuous output you can get from an average person is an eighth of a horsepower or a bit less than 100 Watts. (Makes you think about making a horse powered generator doesn't it). Not only that, 100 Watts of mechanical energy translates to maybe 60 W or so of electrical by the time it's been converted.

Almost all car alternators work the same way, have the same connections and automatically produce the correct voltage output for charging lead acid batteries of either sealed or wet acid type. You should note however that unlike permanent magnet motors or stepper motors, an alternator won't work without a battery and will be damaged if you spin it fast without one connected.

The problems a pedal generator design has to overcome are that an alternator needs to be turning at 3000 rpm or so to work effectively, and the output power of a car engine is a lot more than that of a person. The first problem is easily overcome by getting a racing bicycle with a nice large rear wheel, and then using the wheel without a tyre as a giant pulley: suitably large belts are surprisingly cheap and easy to get.

The maximum power problem is a bit more tricky - if you just copy the charging circuit from a car's circuit diagram you are likely to find that in some conditions (a flat battery or a heavy load like a 12V PA at high volume) the thing is unpedallable. Clever ways around this would be to rewind the alternator or build an electronic control box to override the alternator's own one at high current demands. However, neither of these are suitable for first time home construction. Luckily, there is a simpler way out of it which is to detune the alternator a bit by deliberately putting some resistance between the output terminal and the battery.

This sounds like a daft idea as it obviously wastes some of the power (generally between 6 and 10 percent) but in practice it means that if the batteries in your pedal power sound system get low, it can still be pedalled by average people instead of needing an athlete to get it going again.

Even with the resistance in line, you can still sometimes have a problem with getting it to start up on a heavy load. Because of the way the alternator's regulator works, the faster you pedal the less force you need to use. It's quite an odd feeling, nothing like riding a normal bicycle. If the battery is low and the alternator cuts in and starts generating before the revs have built up, the generator can stall the cyclist which tends to be unpopular. A crude way around this one is to have a start button which the operator uses to put current into the field coil, or an electronic circuit which puts a pulse of current in at regular intervals.

There is a simpler and more elegant way around it and that is to put in a very small light bulb as the charge warning light. The current in the charge warning light also flows through the field coil, providing it with the initial magnetism needed to make it start generating. With a suitably small bulb, for instance 24V 3W running on 12V, the alternator has to spin much faster before it can cut in, reducing the start up effort.

PRACTICAL STUFF

You will need an old racing bicycle (women's ones are better for getting on and off but harder to find with bigger wheels) with a reasonably straight back wheel and the highest gear ratio you can find; a 27" wheel and 52t front sprocket would be nice but my first one which only had a 26" wheel and a 46t sprocket worked OK. You will only need top gear so you can get rid of the gearchange lever.

Take off all the bits you don't need; brakes, front wheel, rear tyre etc. It's a good idea to keep the handlebars to give the cyclist something to hold on to; also you will need somewhere to mount the switch, light and voltmeter. Make a stand out of scrap bits of metal, wood or whatever to securely mount the cycle (the bike went when you got rid of the front wheel) so that the rear wheel is just clear of the ground.

If you use a K1 alternator (used on many cars such as Fords from Fiestas and Escorts to Granadas and many Vauxhall/Opels) it often comes with an ideal pulley with two size settings already fitted; otherwise you might have to make your own. It's probably worth avoiding Lucas alternators as they are not as efficient as Bosch or Motorola ones; ideally go for cars with larger engines as their alternators will be designed to work at lower revs.

The Ford/Bosch N1 found on Sierras and some Volvos is quite good but a bit larger and heavier than the K1. Do make sure that whatever alternator you get is a self contained one and does not require an external control box - some Japanese ones can be complicated to wire up.

Try to get one with two big tags and one small one. The two big tags are connected together and are the Plus connection, the small one is the charge light connector, and a good solid connection such as a 5mm earth tag bolted to the body will do for the Minus.

If you haven't seen the alternator working, it's a good idea to do a basic test on it. You can use the small light bulb you're going to need for a charge warning light. Alternators which pass the test aren't absolutely guaranteed to generate, but they won't blow the fuse and the test will pick up most common faults like worn brushes or a blown diode pack.

Once you get more experienced you can often fix alternators by swapping good control boxes or diode packs from alternators where the bearings have failed. Don't be put off by rusty or dirty looking alternators; if they pass the tests they're likely to be OK.

Get your alternator, clean it up, take off the cooling fan (it's noisy and you don't need it) and mount it on some brackets behind the seat so that its spindle is about 10 or 12 cm out from the wheel rim like this picture.

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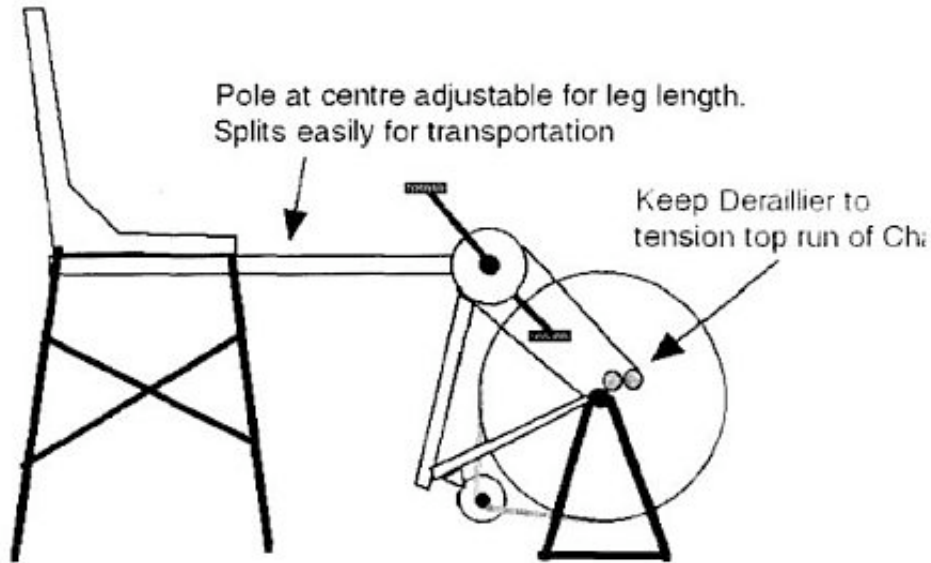
Hold it in position and use a length of string or cable to measure the circumference of the belt you need. Suppose it is 82 inches; go to your local bearing and transmission dealer (e.g. Bearing Services Ltd. - check your Yellow Pages) and ask for an A82 'V' belt (they come in one inch steps from stock or within a day or so and cost about 10 pounds. Belts like that are still used a lot in old agricultural machinery which presumably explains why they still go by inch sizes).

When the alternator was on a car it had a plate with a slot for tension adjustment; replace this with some sort of spring tensioner (a piece of the inner tube you just took off?) to allow for irregularities and spoke ends in the wheel. The belt should run quite slack to reduce friction as the torque needed is very low.

Unless you've got the nice K1 type pulley you may have to make one - anything will do as long as it's smooth and not at all wobbly - turn one out of wood or build one out of washers aiming for about an inch and a half diameter and then count the alternator revolutions for one turn of the crank. Anything over about 45 is OK, 60 is ideal. If you've got the K1 split pulley take it apart and put the spacer in between the two dishes so the belt comes further inside it, giving the fastest speed.

Once the mechanics are finished, you should rig up some guards for all the moving parts if the generator is to be used in public places. Bear in mind that small children are attracted by sparkly moving objects such as your wheel rim, and that the person pedalling can't see what's happening behind them! Even though you don't need the gears, don't be tempted to remove the derailleur; apart from automatically keeping the chain adjusted, the extra slack it allows could make the difference between a bruised finger and an amputation.

Although the above 'upright cycle on a stand' version is probably the simplest and most obvious way, it's actually not much more difficult to do a chair-based version. All you need extra is a plastic stacking chair, something to extend the legs, maybe bits of an old tent frame, and two bits of large diameter tube one of which fits inside the other or possibly the height adjuster from a swivel chair. Some people say the chair based ones are easier to pedal, and they're certainly easier to transport if you make them splittable in the middle. You can eliminate the belt tensioner spring by mounting the alternator so that its own weight tensions the belt.



The racing bicycle's lack of flywheel effect has been criticised compared to exercise cycle designs. If this is a problem, it's quite easy to add weights around the INSIDE of the wheel rim and preferably bolted through the rim with 4mm or so bolts. Ideally make them out of something U shaped which wraps around the rim; think very seriously about fitting them so that there is absolutely no way they could come off. Don't put too much weight on! I've seen someone else's lead loaded wheel rim break up!

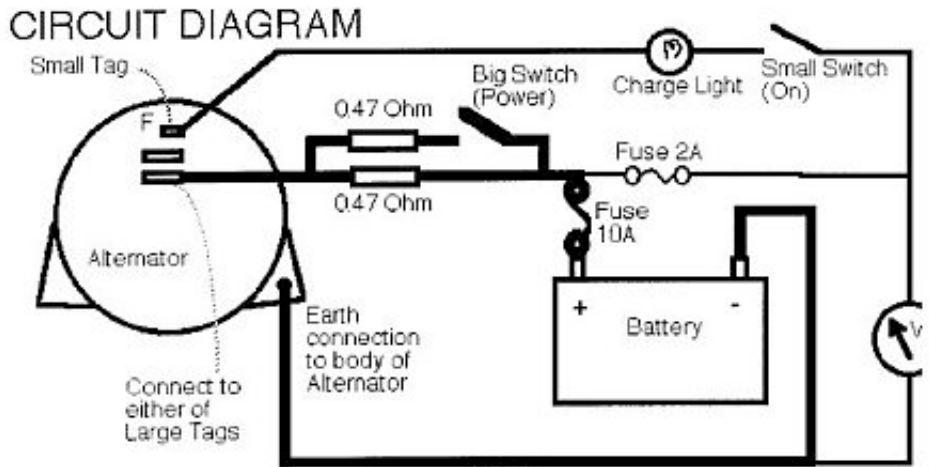
THE ELECTRICS

This is the part a lot of people think is going to be difficult but the bit that controls the alternator really isn't. It's just two simple electric circuits which could be made up with terminal block if you don't fancy soldering. The voltmeter we use is just a bit cleverer, but even that only uses one electronic component.

The main thing to bear in mind when designing the wiring is to find a way of making sure it's very difficult to connect a battery the wrong way around, which would instantly destroy the alternator. (We keep all our batteries in boxes and use polarised plugs and sockets which are wired the same way on all our pedal generators and solar panels).

Another important thing is to make sure you've got a fuse in the battery circuit, as close as possible to the positive battery terminal, and of the right rating so that it blows well before the wiring does.

Ideally the wiring from the alternator to the battery should be something like 20 Amps rating - at least 2.5sqmm section and protected by a 10A fuse. If you're having a remote voltmeter, for instance on the handlebars or on a stick for the audience to see, it only needs connecting with thin wire, but that circuit should be protected by a smaller fuse of one or two Amps.



This is the Circuit Diagram of the simplest version of the circuit. We've done a demonstration version of it so you can see what it actually looks like. Here's a list of the main parts, with Maplin and Farnell part numbers. Maplin's have high street shops in many large towns in the UK and a web site at www.maplin.co.uk. However they've helpfully discontinued the 0.47 Ohm 25W resistors used in the original design along with many other useful components and seem to be going over to selling much more consumer stuff. Farnell have a site www.farnell.co.uk and will accept credit card orders but not cheques.

1 x Small Switch (1 Amp or less) - MAPLIN: FH00; FARNELL: 148-705

1 x Big Switch (5 Amps or more) - MAPLIN: YX64; FARNELL: 140-600

2 x 0.47 Ohm 25 Watt Resistor - MAPLIN: discontinued; FARNELL: 344-941

1 x 24V 3W Lamp - MAPLIN: WL82; FARNELL: 328-388

1 x Lamp Holder - MAPLIN: JX87 or RX86; FARNELL: 140-259

You may have to adjust the size of the lamp to suit your alternator. If it cuts in at too low revs you will need a lamp which takes a lower current and vice versa. None of the parts are particularly critical and the whole thing could be made from recycled stuff. People with a good knowledge of electricity will have spotted that the 25 W resistors are vastly over-rated.

This is to allow for the much higher currents which could flow in a fault situation before the fuse blows. If you are intending to use the generator for public demonstrations it's a good idea to bolt them to a metal plate or heat sink for extra safety. (For some reason, people are impressed by heat sinks - they think it makes it look more powerful or something!)

THE VOLTMETER

A good voltmeter is quite an essential part of the generator, at least for encouraging the cyclist if not for the benefit of an audience. Ideally use some kind of analogue meter - digitals are no use for measuring things that change all the time. The design we use is an analogue meter with a suppressed zero, so it only reads from 12 Volts upwards.

After all, if the battery is below 12 Volts something has gone seriously wrong with it, and the bigger pointer movement when the generator starts up is more impressive. The design I usually give is based on the cheapest (and smallest) meter in the Maplin catalogue, but larger meters can often be found at car boot sales and surplus auctions. Unfortunately Farnell don't do any cheap analogue meters.

The Meter Circuit is quite simple. The Zener diode doesn't conduct below 11V so it subtracts 11V off the voltage. The resistors convert the meter into a voltmeter reading 0 to 4 Volts, so it actually reads from 11 to 15. The meters on our display boxes actually have an even narrower range, with a 12V Zener and a 2.5 Volt range.

An extra resistor and a three way switch in the control box circuit can be used to put a whole Ohm between the battery and the alternator, making the generator more child-friendly. The other switch setting could short it out altogether for really powerful cyclists or putting that last bit of charge in faster.

HOW TO OPERATE THE GENERATOR

Before starting to pedal, check that the voltmeter is reading the battery voltage (generally between 12 and 13), select the low power setting, switch the generator on and check that the warning light comes on. Start pedalling, increasing speed quickly until the generator cuts in - the warning light will go out and the voltmeter will kick up to between 13 and 14 Volts depending on the state of charge.

Because of the voltage regulator, the faster you pedal the less force will be needed. If you slow right down, the force needed will become too much as the regulator desperately tries to keep the power up - if this happens it is better to stop so that the alternator shuts down and then start up again as it will not cut back in until the revs are higher.

The power switch may be set to the high setting if the cyclist feels up to it, increasing the charging current. The generator is more efficient in the high setting, but if the battery is well down or if there is a heavy load such as a sound system on high volume or a mains convertor the effort may be too much. For heavy loads it may be better to run on the low setting and then put the power back in on high once the load is off.

If you want to use the generator as an alternative energy demonstration where children will want to have a go, it may be worth adding an even lower power setting with a total of one Ohm in series so that maximum power is limited to 25 Watts or so. If you need more power, two or more generators of this design can be connected to the same battery at once.

Do not switch the generator off or on while it is spinning; turn it off after you have finished pedalling. Be careful also not to spin the alternator very fast with no battery connected (e.g. when checking the mechanics) as residual magnetism in the field can cause it to start generating and blow the rectifier diodes.

Similar damage will happen if it disconnects from the battery while it is generating. If the voltmeter goes well below 12 or up to 15 at any time disconnect the generator and check it for faults. There's no need to disconnect the generator from the battery when it's not generating. With the charge light switched off, the current drain of the voltmeter is probably less than a battery's internal leakage.

SORTING OUT PROBLEMS

Many generators built to this design have worked first go, and most of the ones that didn't seem to have been due to mistakes in wiring or defective alternators.

If it won't start generating no matter how fast you pedal, try putting a much higher current light bulb in - such as 12V 5W. If that doesn't work, try another alternator.

Luckily most alternators are physically similar so it shouldn't be too difficult.

I've heard of one case where the charge light went out but the voltmeter didn't go up which was a bit of a mystery for a while. It turned out the constructor had been supplied with 47 Ohm resistors instead of 0.47 Ohm, reducing the output current to 1% of what it should have been!

On cars, there is often a suppression condenser (capacitor) connected from the output to Earth or from the Field connection to Earth (Minus). Generally alternators will work without them but you can sometimes get interference on audio equipment. We had one with a broken condenser which made 'dolphin' noises on one of our PA's as it was slowing down, though it hadn't affected our other system.

Do make sure you have the circuit correctly fused - at least then a mistake or accidental short circuit won't cause a fire!

If you do find a problem I haven't thought of, send us an email, even if you've solved it - you could get someone else out of a jam.

OPERATING TIPS

Old fire guards which you can get from car boot sales or free ads are ideal for making safety guards,

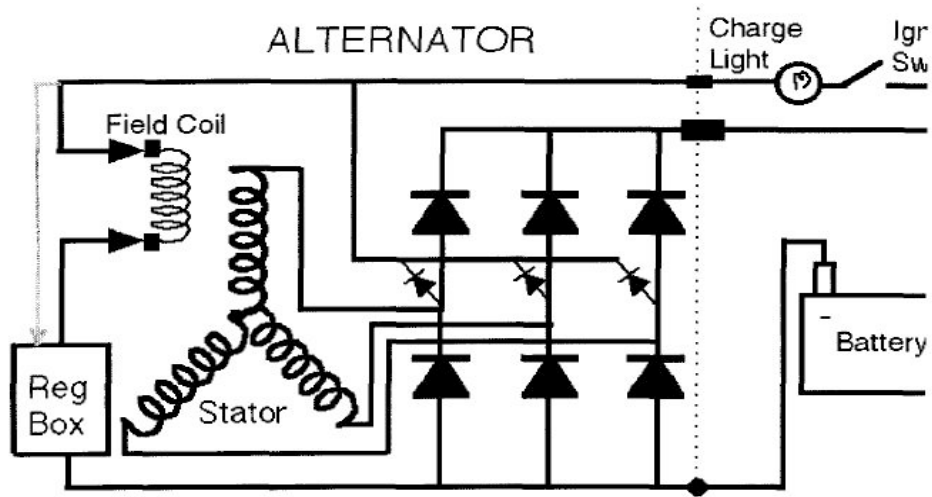
When loading generators into a vehicle, unscrewing the pedals first (put some copper grease on the threads) makes them much less likely to catch in everything.

We wore out the seat height adjuster on our upright generator in two festivals. If you drill an 8mm hole through the top of the frame tube and a series of similar holes in the seat tube you can use a pin made from the unthreaded part of a long M8 bolt to set the seat height, like the top of a car axle stand.

TECHNICAL SUPPLEMENT

For people who are more technically minded, here is a description of how the alternator works.

A Ford car alternator is slightly misnamed as it also contains its own rectifier and regulation system, requiring only a small light bulb and a switch to make a charging system. The alternator part of it produces three phase AC from a set of fixed coils (called the stator); this is then rectified by an array of six big diodes to produce DC to feed into a battery. The AC is induced by a rotating magnetic field from a coil which spins around in the middle of it (the field coil or rotor), getting its current through the brushes and slip rings.



A small DC current is fed into the field coil and controlled by the regulator box which tries to keep the output constant at just over 14V. Most alternators are capable of producing outputs of at least 45 Amps when driven by a car engine. In a car the alternator will be running at 3000 rpm or more - if you look at the relative sizes of the fanbelt pulleys you'll notice there's a gear up of two or three to one from the engine speed.

When the alternator first starts up, there won't be any output to feed back into the field, and nothing would happen if it wasn't for the charge warning light which is a lot cleverer than it looks. The current in the charge warning light flows through the field coil, providing it with a small bit to start it off with. Once the revs build up, the output comes up and provides the power for the field through the three small diodes so the warning light goes off, showing that the alternator is working.

The three small diodes form another three phase bridge rectifier which 'borrows' the three lower diodes of the main rectifier for its negative return path. By changing the size of the warning light, you can control the revs at which the alternator cuts in. Once an alternator has been used for a while, the iron core of the field coil often becomes permanently magnetised.

If it is spun fast enough, this magnetism can be enough to start it generating, and without a battery to act as a load the output voltage will quickly reach over a hundred Volts as the magnetism isn't controlled. For that reason you shouldn't pedal it without a battery, and be careful when setting up or at the end of an event when unknowing members of the public are likely to try pedalling it.

<http://www.c-realevents.demon.co.uk/altgen/altpedgen.htm>

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