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Beginner's Battery Charger

A simple project to get you going.

This KISS (Keep It Stupidly Simple) battery charger can keep your rechargeable batteries fully charged, worry-free. The charger can recharge 1.2 volt NiCds, 12 volt lead acid batteries, or any rechargeable battery. The battery voltage isn't important. Just plug it in to keep your batteries charged and ready when you are. However, be aware that the charger can represent a shock hazard under some conditions and should be treated as a live 120 V wire. If it is plugged into a ground fault interrupter (GFI), you can't get stung.

How does a GFI protect you from a shock? If the hot side of the line is connected to the automobile's frame (the negative side of the battery) and the neutral line is open, the circuit is completed from the line to the car's frame and from frame to you and ground. Ouch! The GFI senses current in the earth (you) and disconnects the power.

The National Electric Code requires GFIs in the kitchen, the bathroom, the laundry, and garage, but not in other wiring branches in the building. The requirement for GFIs is relatively new, and some houses are wired without a green or "bonding wire." The bare wire in the non-metallic cable (Romex cable) is the bonding wire. It is the green wire in appliances and the green screw in the wiring receptacle. Metal wiring conduit can take the place of a bonding wire. The green wire carries current only in the case of a fault in the ground wire.

The (GFI) may already be in the house, or if the house was wired before the National Electric Code required GFIs, you may have to add one. When you install a GFI, connect the GFI wiring with black to black, white to white and green to earth ground. If your house is wired with only two wires, black and white, white is grounded by the electric company — if you trust the electrician that did your wiring. If you don't trust him or her, measure the voltage from wire to earth. It had better be zero, if not, corrective action is required; change the wiring in the receptacle. The black wire should go to the brass screw and white to the chrome screw. But, if the electrician swapped the lines somewhere, white may not be neutral.

If you plug into a properly wired GFI, you won't get stung when the ground wire is open and you become part of the circuit.

The charger shown in **Fig. 1** is the utmost in simplicity. It can probably be built out of your junk box, but if your junk box is empty, the parts can be bought from your local hardware store and Radio Shack. The light bulb, socket, and plug are from the hardware store, and the rectifier diode and battery clips from Radio Shack. Of course, if you want to charge a "D"-size cell, then a battery holder will have to be used, but you won't need battery clips.

Any rectifier with a PIV greater than 200 V, such as 1N4004,5,6,7, can be used. The 1N4003 has a PIV of 200 V and costs maybe a dime less than the 400 volt 1N4004. The 1N4000 series of diodes has a 1 A current rating, and 1 A is the maximum charging current that the charger can supply. That's enough for most uses.

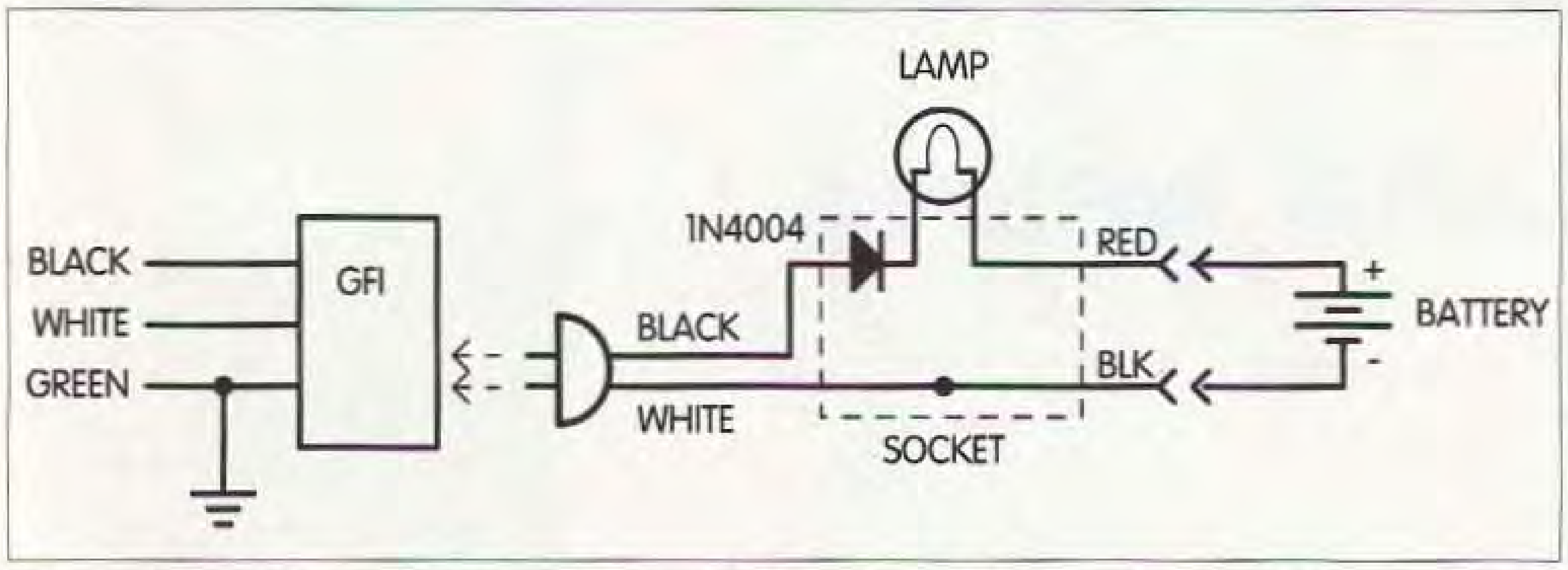

Fig. 1. A simple current-limited battery charger uses half-wave rectification.

The peak inverse voltage on the diode is the peak line voltage plus battery voltage. Therefore, a 120 volt line (169 V peak) and a 12 V battery applies a PIV of 183 volts to the diode. A 12 volt lead acid battery has a voltage of 13.8 volts when charging. In the case of a fully charged battery, the PIV on the diode is 169 V+14 V = 183 V. Compare this to a half-wave rectifier operating from 120 volts with a capacitive input filter. The capacitor is charged to the peak, 169 V, and on the reverse half cycle the maximum voltage is the negative peak, so voltage across the diode is $2E_{pk}$.

The rectifier converts the 120 volt line current into half-wave rectified current, with the lamp limiting the current. The lamp can be anything up to 200 W. The higher the wattage, the higher the charging DC current. The diode can be put into the lamp socket with room to spare.

The resistance of the lamp limits the charging current and provides a constant charging current to the battery. The current in a lamp with half-wave current is not easy to calculate exactly, because an incandescent lamp has a very nonlinear resistance characteristic that is dependent on the current. But a first-cut estimate can be made that assumes a linear resistance vs. current.

The full-wave current in a lamp is $I = P/E$, where E is the rated voltage for the lamp and P is the watts. The average full-wave (DC) current calculates to be $0.9 \times I_{RMS}$. The half-wave current is half that, or $0.45I_{RMS}$. The measured currents for a number of bulbs are given in **Table 1**.

The resistance of a lamp with half-wave current is found to be lower than the first-cut estimate. The calculated half-wave current for a 200W bulb is 0.75 but the measured current is 1 A_{DC}. In any event a 200 W lamp will recharge a "dead" car battery in a day or so.

Lamp Watts	DC Current (A)
200	1
100	0.42
60	0.26
40	0.17
25	0.1
15	0.065

Table 1. Bulb currents.

Ideally, a trickle charge just replaces the charge lost through the battery's internal self-discharge mechanism. Prudence says to provide a little more current than the minimum, but not enough to boil away the electrolyte. A 15 W night light is appropriate for trickle charging most lead acid car batteries, but a 40 W bulb is also sufficient.

While the batteries are assumed to be 12 V lead acid car batteries (SLI, Starting, Lighting, and Ignition, batteries), NiCds or any rechargeable battery can be charged when an appropriate lamp or resistor is used to limit the current. A resistor instead of the lamp is appropriate for small, low-amp-hour batteries like NiCds.

Most car batteries have an amp hour rating of about 60 Ah, motorcycle batteries about 15 Ah, and NiCds in the order of 450 mAh. The physical size of a lead acid battery is good indication of its amp hour capacity. The watts per cubic inch of lead acid batteries are very similar across all manufacturers.

The current required to charge the battery depends on its amp hour rating, not its cranking amps. A charging rate equal to the amp hour rating is a good fast charge rate, and a "hot shot" would be about five times that. Of course, the KISS charger can only provide 1 A. The trickle charge rate is 10% or less of the amp hour rate, but that depends on the condition of the battery and how it has been used or abused. I've found that a trickle charge of about 0.1% into a two-year-old battery in a garden tractor will maintain a full charge. That is 60 mA into a 60 Ah battery.

When fast charging a battery, care must be taken not to overcharge. The capacity after overcharging is actually less than maximum. Overcharging quickly shortens life, and can boil away the electrolyte. That's sure not good for the battery. In a word, overcharging a battery doesn't do it any good. In the days when a car's voltage regulator was essentially calibrated relays, overcharging was the primary cause for the relatively short battery lives. With today's electronic regulators, battery life can extend to ten years.

Since the charging current is the important item, finding the desired current-limiting resistor becomes critical. Calculating the fixed current-limiting resistance is more certain: The average (DC) half-wave current is:

$$I_{av} = 0.318 \times I_{pk} = 0.318 \times \sqrt{2} \times E / R$$

or $0.45 \times I_{RMS}$.

Therefore, a 12 kΩ 1/2W resistor instead of a 120 volt light bulb would be needed to provide a 4.5 mA trickle charge current for a 450 mAh NiCd, while a 15 W light bulb would supply about 60 mA to a car battery. A 15 W lamp will keep a trolling motor battery or garden tractor battery fully charged over the winter to be ready to go when spring comes around.

There is some merit to the conventional wisdom that says keep the battery off the garage floor. At least off a cold floor. The plastic case doesn't care where it sits. Some say that when the battery sits on the cold garage floor, the temperature difference between the floor and the top of the battery causes the electrolyte to circulate and speed up the self-discharge. I won't get into that argument. It makes sense to set the battery on a couple of pieces of two by four even in a warm shack. The boards will protect the floor and keep the battery and XYL happy.

A battery can be charged with either a voltage source or a current source. Charging from a voltage source requires close control of the voltage and usually some upper current limit control as well as sensing the condition of charge. With current charging the charging is slower but independent of battery voltage and is a better "set and forget" approach.

The KISS charger is essentially a current source with the charging current limited by the light bulb or a fixed resistor. The current is essentially the same whether the battery is fully charged or completely discharged.

A charging current equal to the amp-hour rating of the battery is a fast charge while a current of less than 10% of the amp-hour rating is considered a trickle charge. A trickle charger will probably recharge a discharged battery but it will take just short of forever. I've found a trickle current of 0.1% times the amp-hour rating to be adequate for a garden tractor battery.

A typical 60 Ah car battery can be charged with 60 A in a little over an hour, but that rate can seriously overcharge the battery if you forget it. A 6 A charge for 10 hours is safe enough, but it too can overcharge the battery if it's left on too long. 0.06 A (a 15 W lamp) can trickle charge the battery for months without problems. Essentially set it and forget it.

The efficiency of the charger is very low. An amp from a 120 volt line to put an amp into a 12V battery is really pretty poor efficiency, but that's the price paid for simplicity.

The measured charging current versus lamp wattage is given in **Table 1**.

These measured currents are for a completely dead, zero volts, battery and the actual resistance of the lamp not known with certainty. Nevertheless, it's better than a WAG. The currents can be extrapolated for other lamp wattages. For example, a 7 W lamp will have a current that is a little more than 0.11 times that of a 60 W lamp. Using lamps with the same bases makes it convenient to change the charging current. You can change from a 1 amp rate to a 60 mA rate just by changing the light bulb.

The modern "maintenance-free" batteries are really just "low maintenance" batteries. They still should be checked occasionally by prying off the covers to make sure the electrolyte covers the plates. Add distilled water to bring the electrolyte a quarter inch above the plates if required. It won't be a catastrophe if you have to add plain tap water, but it's not the best thing for the long battery life.

For the typical automotive lead acid battery, the charging voltage is a reasonable indication of the state of the battery's charge. A typical 12 volt lead acid car battery has a charging voltage of about 13.8 volts, while the voltage under a light load is 12 volts. The specific gravity is the usual measure of the state of charge of a battery, but with sealed batteries, that's a bit inconvenient. So the terminal voltages, with all of their uncertainties, are used to indicate the state of charge.

While the main thrust here is toward lead acid car batteries, NiCds or other rechargeables can be recharged equally well. Just keep in mind the lower current ratings of these small cells. For low charging current, even a 15 W lamp will probably produce too much current and the lamp will have to be replaced with a resistor. To check the maximum charging current for a particular resistance or lamp, connect a DC current meter in place of the battery, then plug the charger into the 120 V mains. The indicated current is the charging current.

A rundown car battery can be recharged over the weekend with a 200 W lamp limiting the current. It's worth mentioning that if you expect to need a little extra help on a cold morning, put the lamp under the hood near the battery to keep things warm for the next morning's start. But don't forget to take off the charger before you crank the engine. The fan belts can chew things up in a hurry, and probably blow the line fuse as well.

A word to the wise: the voltage at the battery clips is 120 volts while the battery is disconnected. Unplug the charger while you're making the connection.

A simple charger can keep your shack's auxiliary battery up to snuff without constant attention. The charging current has to be a little more than the average discharge current. It doesn't take much of a charger to keep a battery charged.