EDITION 1

Assembly Manual

Add-on Regulator for 12V Battery Chargers

K-3127

(Shortform - PCB & Components only)

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KIT

This simple project turns a 'bare bones' automotive battery charger into a fully regulated charger that can be left connected to a battery indefinitely. It uses readily available components such as a 555 timer, and the circuit board containing the regulator can be built into most low cost chargers. It has been designed to adapt an Arlec 4 charger, which is available from most supermarkets.

Lead-acid battery chargers come in all shapes and sizes, but perhaps the most popular are the basic chargers available from a supermarket. Most of us need to charge a car battery now and again, usually when you least expect it.

As well, it's good practice to keep a lead-acid battery topped up, as discharging it below about 80% of its capacity can shorten its life, (unless it's specially designed for heavy discharge).

A typical low cost automotive battery charger generally has a charge current capability of between four and eight amps. When using it to charge a battery, you have to monitor the charge state of the battery and disconnect it from the charger when it's fully charged. Otherwise the battery will overcharge, and possibly lose electrolyte or even sustain damage.

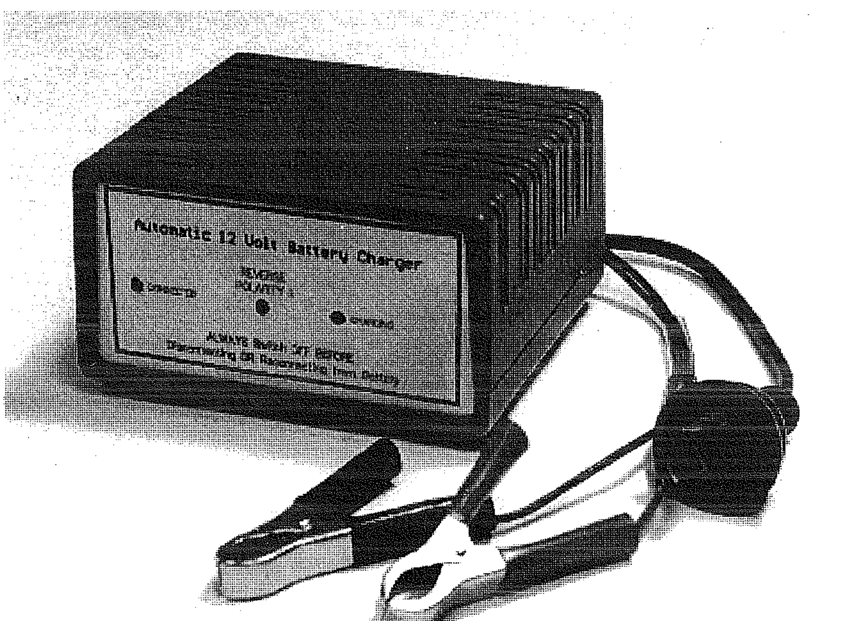
To keep a battery topped up, you could use a timer to switch a basic charger on for several hours every few days. However this is not a reliable method as it doesn't take into account the charge level of the battery.

A better way is a simple add-on regulator circuit so the charger can be left connected to a battery continuously; which is what this project does. It works on the principle that once the battery reaches a predetermined voltage, the charger is switched on and off to maintain that value indefinitely. But surprisingly, such an add-on circuit is not as easy as it might first appear.

Development process

In my search for information, I looked through a range of electronics magazines, but to no avail. Certainly there were charger circuits, some using a switch-mode regulator and others based around a series regulator, but I found none that I could simply add to a basic charger.

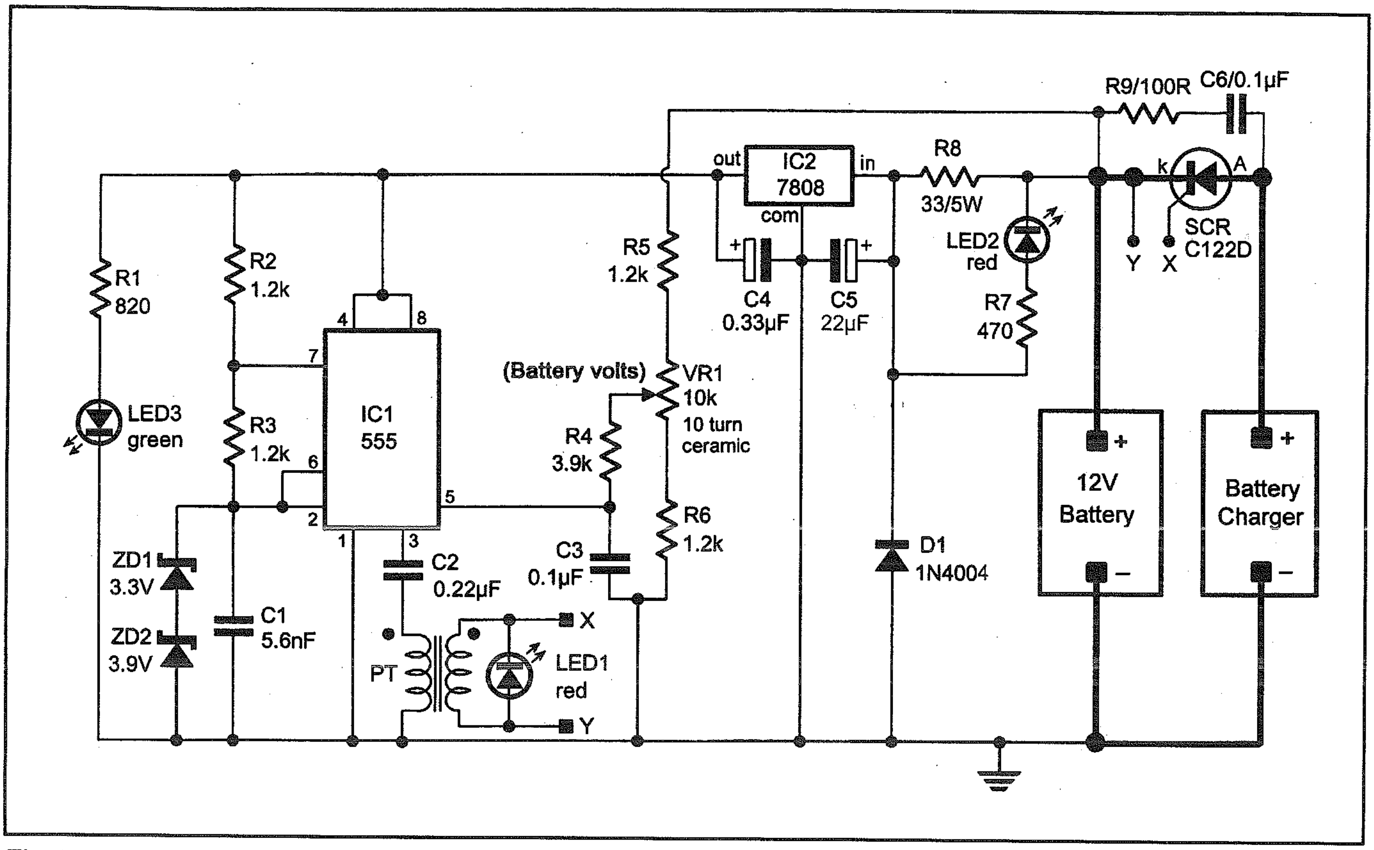
I then remembered that around 20 years ago, I built a simple charger based on a Motorola application note. This circuit (see Fig.1) had a UJT (unijunction



Upgrade your basic charger by adding this simple regulator. It lets you leave a battery on charge as long as you like, without risk of overcharging.

Text and illustrations courtesy of Electronics Australia

9V 10V 11.5 12V 13.8 → 15V
1 2 3 4 5 FULL BRIGHT.



The 555 astable oscillator provides trigger pulses to the SCR. When the battery is fully charged, the oscillator stops, keeping the SCR turned off. When the battery voltage falls slightly, the oscillator starts again. The circuit cycles between these two states, keeping the battery voltage at the value set by VR1.

transistor) relaxation oscillator triggering an SCR. While the battery voltage is less than a preset value, the UJT oscillator produces trigger pulses to trigger the SCR, allowing charge current to flow. Because the output of the charger is a series of positive half-cycles of the AC supply voltage (unfiltered DC), the SCR turns off at the end of each half-cycle of the input.

When the battery voltage reaches a preset value (normally 13.8V to 14V for a 12V battery), the oscillator stops running and the SCR is held off. The battery voltage will fall slightly, to a point where the oscillator starts, and charge current flows, causing the battery voltage to increase. The circuit now cycles between its off and on states, keeping the battery voltage constant at the preset value.

But technology has moved on, and it's now difficult to buy a UJT. I decided to try a PUT (programmable unijunction transistor) in place of the UJT, as its operation is rather similar. However, in a UJT circuit the timing resistor (R1) can be a relatively low value, allowing a comparatively large value of timing capacitance (C1). This is important as the timing capacitor also supplies the energy to the pulse transformer that triggers the SCR. A PUT oscillator circuit needs a higher value of timing resistance, and a subsequently lower value of timing capacitance for the same operating frequency.

This means there's not enough energy in the capacitor to reliably trigger the SCR. Changing the values to get reliable triggering gives an operating frequency that is too low, causing triggering to occur later in the cycle, therefore giving less charge current. There's also a possibility of RFI (radio frequency interference) being generated, caused by the SCR switching on after the input voltage has passed through its zero point. So it was back to the drawing board!

I then decided to try a 555 timer as the oscillator, as apart from being readily available, the timing components would be independent of the triggering components.

The circuit

The final circuit is as shown, and has a similar operation to the original Motorola UJT regulator. The 555 timer is configured to run as an astable oscillator, with the advantage that it can operate at a higher frequency than that possible with either a UJT or PUT circuit. The battery voltage is sampled by the network of R4-6, C3 and VR1, and a fraction of this voltage (set by VR1) is applied to the modulating input terminal

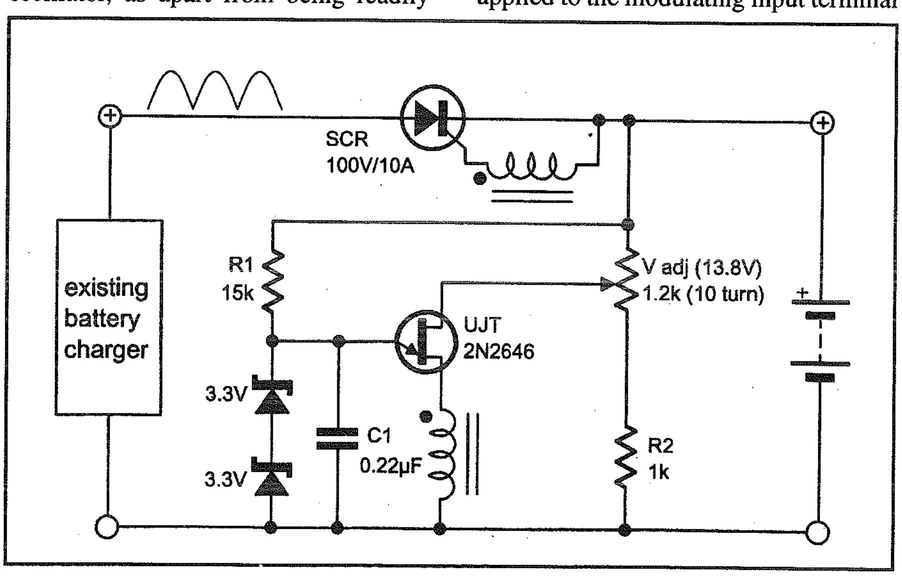


Fig.1: This simple regulator uses a UJT relaxation oscillator to trigger an SCR. When the battery voltage reaches a preset value, the oscillator and the charge current stops. The circuit then maintains this voltage.

(pin 5) of the 555. When the voltage at this pin reaches the preset value, the oscillator stops, and the charger cycles between its off and on states, as for the UJT oscillator described before.

This arrangement allows the voltage at which charging stops to be set to within a few millivolts of the required value, typically around 14 volts at 25°C. Because the oscillator is running at about 40kHz, there's very little RFI, as the SCR is always triggered close to the zero point of the input voltage. Remember, the input voltage to the circuit is unfiltered DC, so it varies from zero to its maximum value every 10ms.

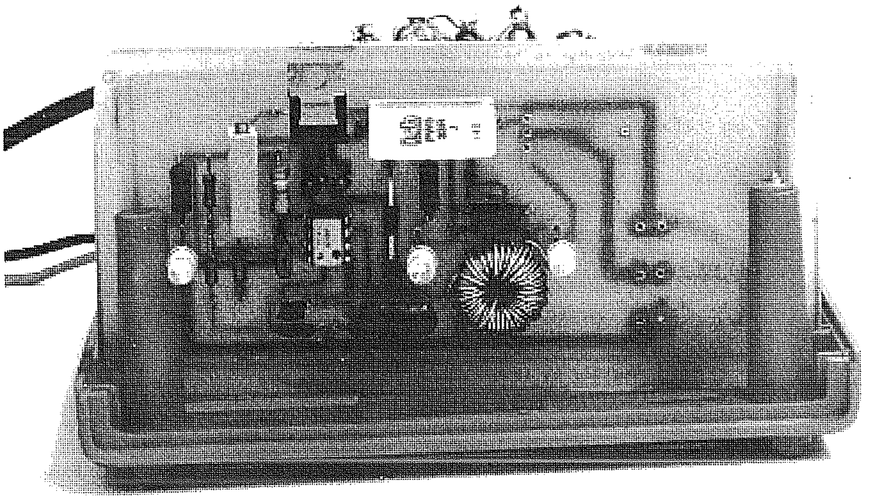
Zener diodes ZD1-2 clamp the charging voltage across capacitor C1 in a similar way to that of the UJT circuit. Their purpose here is for temperature compensation, as the specified zener diodes have a negative temperature coefficient. Hence the use of series-connected 3.3V and 3.9V zeners rather than a single 7.2V zener, which has a positive temperature coefficient. This results in a regulated battery voltage of around 14V on a hot day, and up to 16V on a cold day. The voltage regulator for an automotive generator used to be set at 14.2 - 15V at 40°C and 15.6 - 16.4V at 1.67°C.

The output of the 555 feeds the primary of a pulse transformer, via capacitor C2. The transformer in the prototype was constructed on a 15mm OD powdered iron toroid. The windings are bifilar (i.e., both windings wound at the same time), with about 20 turns of 0.25mm enamelled wire.

LED1 (a high efficiency LED) is connected in parallel with the secondary of the pulse transformer, and indicates that the 555 is operating. It lights when the output pulse goes negative and the SCR is triggered when the pulse is going positive. Capacitor C2 prevents the DC component of the output from saturating the core of the pulse transformer.

For the circuit to work, the charger leads must be connected correctly (right polarity), and the battery must not be completely flat. This is usually the case for most serviceable batteries, as they maintain a voltage of around 10 to 12V under no load. If the voltage is below this, it's probable that the battery has reached the end of its useful life.

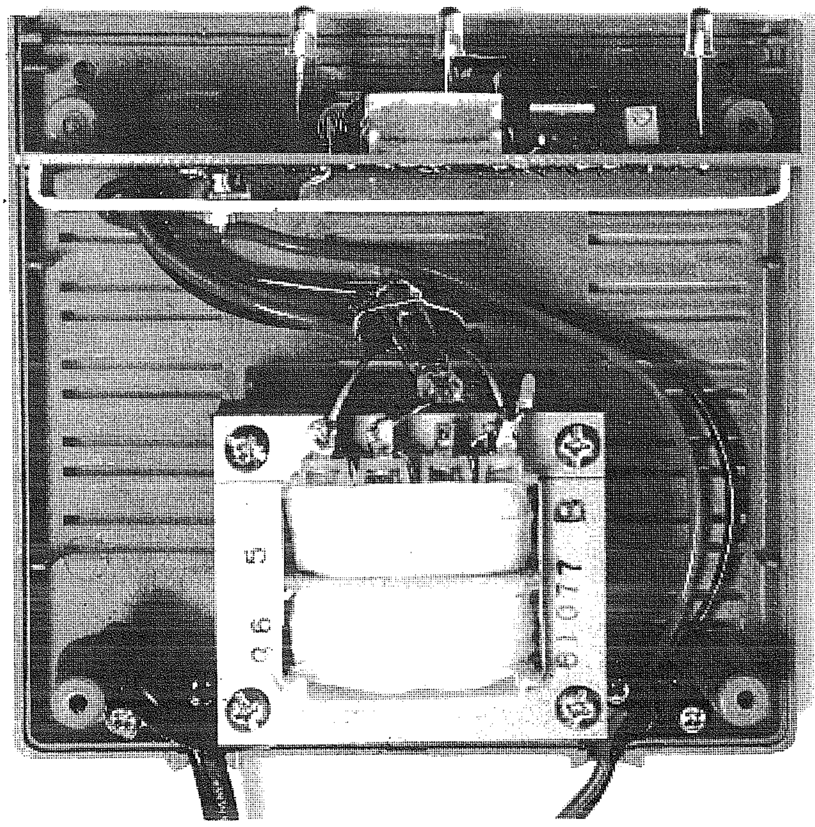
Because the regulator circuit is powered by the battery and not the charger, if you short the leads together (before they're connected to the battery), no current will flow, as there's no supply voltage for the circuit, and hence no trigger pulses to the SCR. This means that the circuit is short circuit proof.



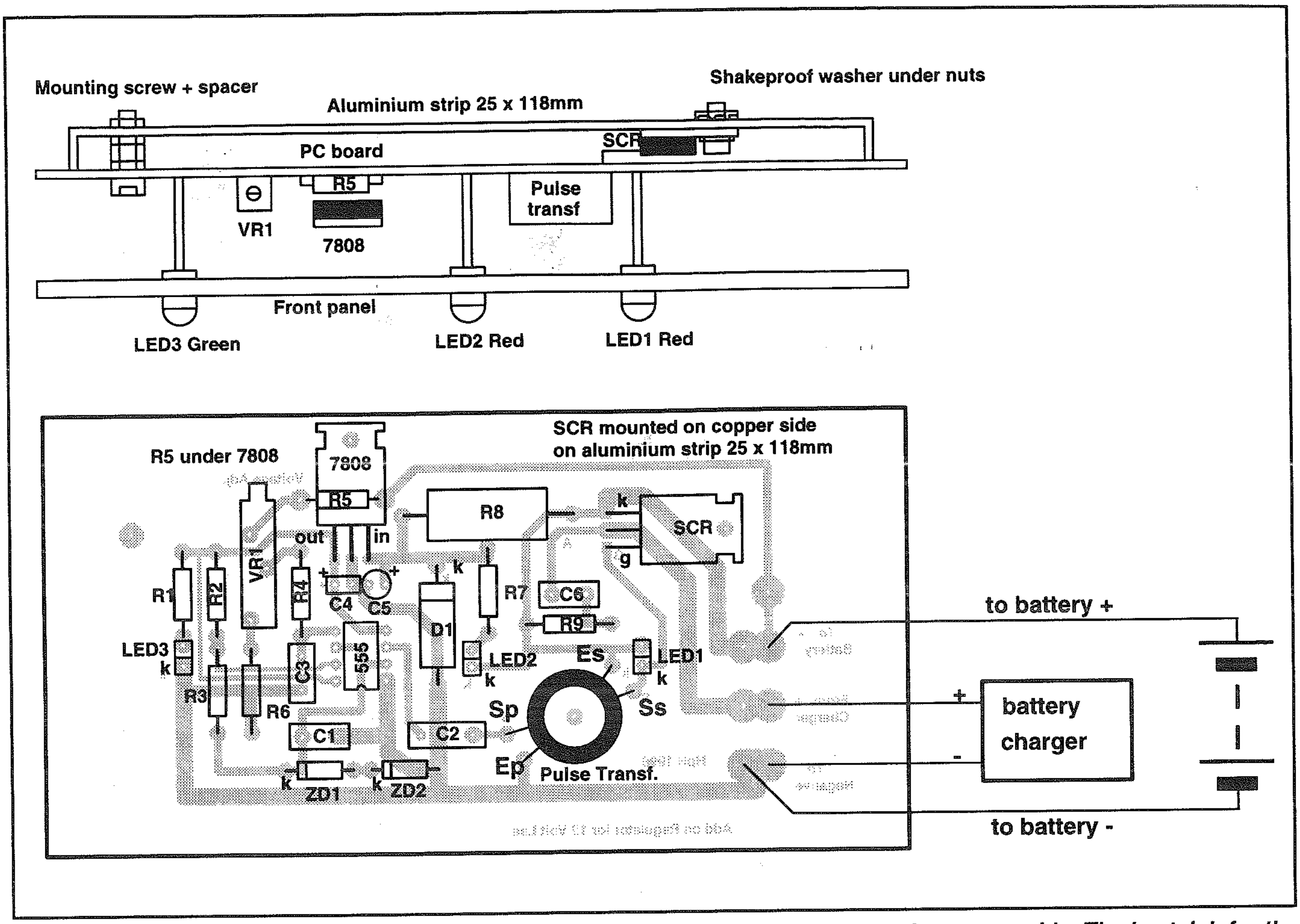
A closeup of the component side of the PCB. The reguator is bent over to conserve inside the space.

The three-terminal regulator (IC2) provides a regulated voltage of 8V for the regulator circuit, and prevents damage to the 555 when the battery or supply voltage is 16 volts or more. Diode D1 and resistor R8 protect the circuit if the battery is connected with reverse polarity. Under these conditions, LED2 lights as a warning.

Correct battery connection is indicated by LED3 (green) glowing. LED1 varies in intensity depending on the battery's state of charge. This LED is brighter when the battery is discharged, and pulses slightly when the battery is at full charge. Resistor R9 and capacitor C6 form a snubber network to reduce the possibility of 'rate effect turn on' which occurs when a rapid voltage change is



As the photo shows, the heatsink for the SCR is close to the same length as the PCB except for a few millimetres on both sides, and is 'live', so keep it away from other exposed wiring. The photo also shows how everything fits inside an Arlec 4 Charger. You might need to trim the PCB to allow for the contour of the case.



The layout/overlay diagram for the circuit board. Note that the SCR is mounted on the copper side. The heatsink for the SCR and mounting details are also shown here.

applied across the SCR.

Construction

The prototype was constructed on a PCB coded ZA1164. We mounted the board behind the front cover of an 'Arlec 4' 12V battery charger, which was purchased from a supermarket for around $35. The construction diagrams shown are for this charger.

Most chargers, like the Arlec, have a double insulated, centre-tapped transformer, two diodes and a thermal cutout. Notice that there's no filter capacitor. Some also have several LEDs to show the state of the battery being charged, but this indication is often too rudimentary to be useful.

All components mount on the board, as shown in the layout diagram. Note that the SCR solders to the copper side of the board. The SCR needs a heatsink which is simply a strip of 1.5mm aluminium measuring 118 x 25mm. The heatsink is held to the PCB with a single nut and bolt, separated from the PC board with a suitable spacer. If you bolt the SCR directly to the heatsink, the heatsink is 'live', so make sure it doesn't contact any other components in the charger.

Notice also that the 7808 voltage regulator is bent at right angles to the board. This means the regulator body is over resistor R5, but as the regulator doesn't produce much heat, this is not a problem. Mount resistor R8 a few millimetres above the board, to allow for its heat dissipation.

To wind the pulse transformer, cut two lengths of 0.25mm enamelled wire about 500mm long, and wind 20 turns of both wires around the toroid. The pads for soldering the start and end of each winding are marked on the layout diagram as Sp (start primary) and Ep (end primary), and Ss and Es (secondary). If a winding is reversed, the trigger pulse for the SCR will have the wrong polarity.

I used the original front panel of the charger as support for my own front panel. This required three holes, one for each LED, to be drilled in the panel. For the Arlec charger, there are slots in the case to support the front panel, and extra

Parts List

Resistors

All resistors 1/4W, except R8

R1	820 ohm	Gry-Red-Brn-Brn
R2,3,5,6	1.2k	Brn-Red-Red-Brn
R4	3.9k	Org-Wht-Red-Brn
R7	470 ohm	Yel-Vio-Brn-Brn
R8	33ohm 5W	Wirewound
R9	100 ohm	Brn-Blk-Brn-Brn
VR1	10k, 10 turn ceramic trimpot	

Capacitors

C1	5.6nF/562/.0056uF polyester or MKT
C2	0.22/224/220n polyester or MKT
C3,6	0.1uF/104/100n monolithic
C4	0.33uF 35VW tantalum
C5	22uF 25/35VW Electro

Semiconductors

IC1	555/DS555/LM555CN/NE555 TTL timer
IC2	7808/LM340T-8 8V regulator
ZD1	1N746/1N5226 400mW zener
ZD2	1N4730/BZX85C3V9 1W zener
LED 1,2	Red LED
LED 3	Green LED
D1	1N4004 1A diode
SCR	C122E SCR, 8A 400V or TYN608 800V 8A or BT151-650R

Miscellaneous

15mm OD iron powder toroid; 1m x 0.25mm enamelled copper wire; PCB 130 x 65mm coded ZA1164; "U" bracket heatsink 118 x 25; solder; screws, nuts washers & spacer.

slots that can be used to support a PCB. This means mounting the LEDs around 16mm or so from the PCB, so they can project through the front panel.

If you build the regulator into the charger, simply cut the leads from the charger, and connect them to the board as shown in the layout diagram. This will shorten the leads by about 80mm.

Options

The regulator can also be mounted in a separate box and linked to the output of the charger. If you do this, drill ventilation holes in the case.

Or you might want to build your own basic charger for use with this regulator. You'll need a transformer with a centre-tapped secondary of 26V (or so), giving 13V RMS per side. The secondary should be rated at around 5A, and connects to two diodes that must also be rated at 5A. A centre-tapped rectifier circuit has less loss (and less heat dissipation) compared to a bridge circuit, as there's only two diodes.

While the charger being described here is rated at 4A, the regulator can handle more current if you use a suitably rated SCR. For a 15A charger, use a 20A rated SCR. These devices are more expensive than a 10A SCR, and are generally stud mounted. They are also often less sensitive than a lower current device. I have not tested this regulator with a high current SCR.

Adjustment

Once you've built the regulator and connected it to the charger, it remains to adjust it. This means you must be able to get access to the trim pot VR1. A small hole drilled in the case directly above and in line with the trim pot is ideal. For the Arlec charger, a ventilation slot is directly above the trim pot so you won't need to drill a hole. Normally you would make the adjustments before putting the case together, but it's handy to be able to make later adjustments without dismantling the case.

Testing and calibration can be done by using an adjustable power supply with an output voltage variable between 10 to 18 volts. A 12 volt tail/stop lamp as a load is also required. Use a digital multimeter to accurately set the output voltage.

The procedure is relatively simple. Connect the battery charger leads across the lamp. When you apply mains power to the charger, the lamp should remain off. All LED indicators should also be off. If this is the case, proceed to the next step. If the lamp is lit or pulses on and off, then the SCR is conducting for some reason. Check the circuit and wiring before continuing.

If all is well, switch off the charger and connect the output of the regulated power supply across the lamp and set its output voltage to around 14 volts. The lamp should now light and so should LED3 and possibly LED1.

If LED2 lights, check the wiring, as it indicates reverse polarity to the regulator. Now adjust the trim pot until LED1 just turns off. Verify this by varying the power supply voltage by a small amount either side of 14 volts. As the supply voltage drops below 14 volts, LED1 should light up brightly. When the voltage is slightly above 14 volts, it should go out completely. This should occur for a very small change in the power supply voltage, possibly a few millivolts. Once this value is found, adjusting the trim pot by one or two turns either way should turn LED1 on or off. If you need more turns check the circuit.

If everything is working as described, apply power to the battery charger, and watch the test lamp. You should find that when the power supply voltage is increased to slightly above 14 volts, LED1 should be off and the lamp brightness should decrease by a noticeable amount, as the SCR will be off. The reverse applies when the power supply voltage is below 14 volts. That is, LED1 is on, and the lamp glows more brightly.

If you use an oscilloscope to look at the current from the charger, you'll find that when a battery is fully charged, the charger applies charging pulses at random. These can vary from several (rectified) full wave cycles to one or two cycles every second or so. This might cause an erratic reading on an ammeter, but is quite normal.

Using the charger

There are several things to be aware of when charging any lead-acid battery. The most important is to realise that a lead-acid battery generates explosive gases that can be ignited by a spark, cigarette or naked flame. Make sure the battery is in a well ventilated area while it's being charged.

Another safety aspect to watch is the possibility of a short circuit across the battery terminals. Apart from generating sparks (which can ignite the surrounding gases), a short across a typical car battery can cause considerable damage to the battery or the object (like a screwdriver) that is causing the short.

Because the charger is supplied from the mains, don't expose it to rain or water. Also, take care when handling the electrolyte of a lead-acid battery. The electrolyte is sulphuric acid, which will quickly burn holes in clothing. If you accidentally spill electrolyte on yourself, flush it away immediately with large amounts of cold water.

In case of accidental eye contact with battery acid, flush your eyes for at least five minutes with clean water. Your eyes should be submerged under water and kept open while you do this. You should also see a doctor as quickly as possible. Don't use eye drops or other medication unless instructed by a doctor.

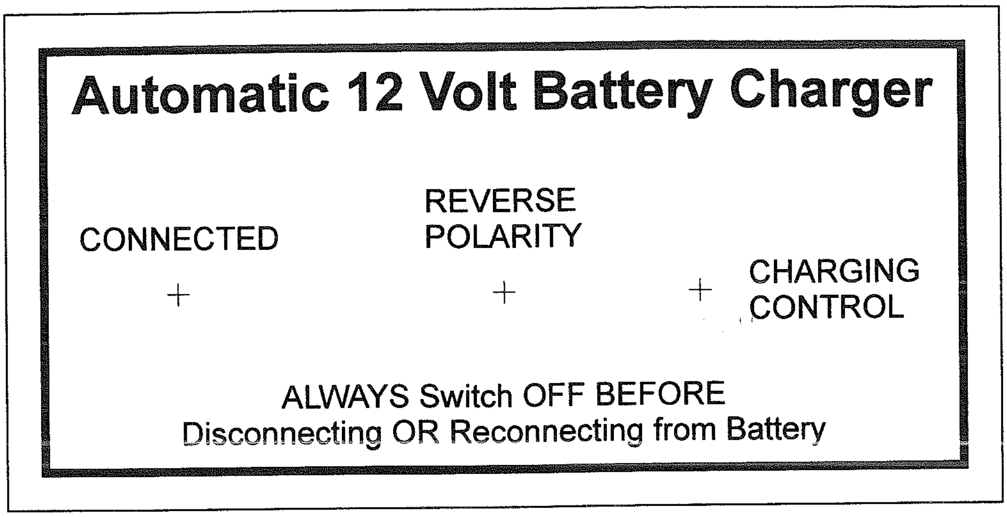
Having read the safety precautions, and wearing wrap-around safety goggles, it's time to attach the charger to a car battery and verify that it works properly. Ideally the battery should be removed from the vehicle.

Make sure the charger is disconnected from the mains supply (to avoid sparks that could ignite gases from the battery), then connect the charger leads across the battery terminals. LEDs 1 and 3 should light. If so, connect the charger to the mains and switch on. Monitor the battery voltage and observe that it slowly rises to around 14 volts. At this point LED1 should decrease in brightness and possibly flash randomly at several pulses per second. The time taken depends on the battery's charge state, so it could take several hours to reach full charge.

If you are using a commercial unit as your basic charger, its internal thermal cutout might operate if the battery is discharged. This is not a problem as the cutout will reset itself. Its purpose is to prevent damage to the charger caused by a high charge current.

If you have a battery with removable vent plugs, you should remove these and check that the battery does not produce excessive bubbling while charging. If some cells do this, it's possible the battery is faulty, as most batteries don't produce a lot of bubbling during charging. A typical lead-acid battery should last for around four to five years. In that period you could have to top up the electrolyte once or twice, more often is usually abnormal.

There are many reasons why the electrolyte level in a battery drops. One reason is that the engine could be idling too slowly, causing the battery to cycle between high discharge and recharge currents. A heavy electrical load, slipping alternator drive belt, low alternator output current or high output voltage are other reasons. A continually high ambient temperature around the battery caused by insufficient air flow can also cause premature loss of the electrolyte.



This artwork is for replacement front panel of an Arlec 4 charger fitted with the reguator.

Notes & Errata

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