Microcontroller based smart battery charger

by **SHARANYADAS** on February 16, 2016

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I'm a senior telcom engineer by profession.My hobby is designing circuits and successfully implement them.Microcontroller coding is the main area of interest.Analog electronics is another hot favourite. I think,if analog electronics can be properly combined with microcontroller.....then anything can be done.

Intro: Microcontroller based smart battery charger

The circuit what you are about to see is a smart battery charger based on ATMEGA8A with auto cut off.Different parameters are shown via a LCD during different charge states.Also the circuit will make sound via a buzzer upon charge completion.

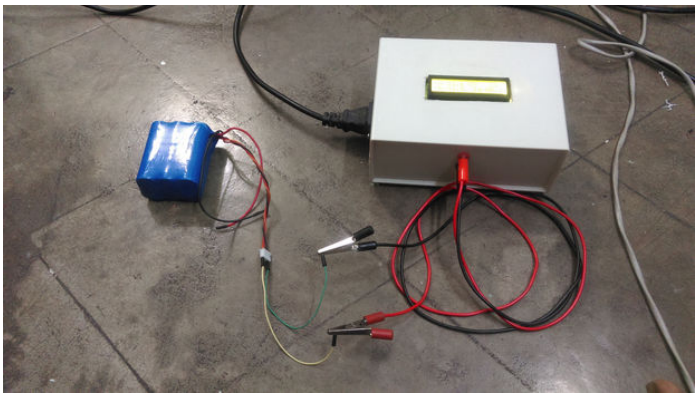
I built the charger basically to charge my 11.1v/4400maH Li-ion battery.The firmware is basically written to charge this particular battery type.You can upload your own charge protocol to fulfill your needs to charge other battery types.

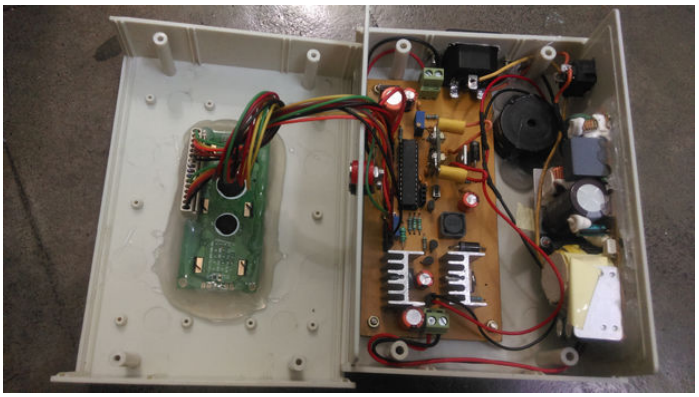
As u know,smart battery chargers are readily available in the markets.But being an electronic enthusiast,it is always preferable for me to build my own rather than buying one which will have static/unchangeable functions.In this module,i have plans to upgrade in future so i have left space regarding that.

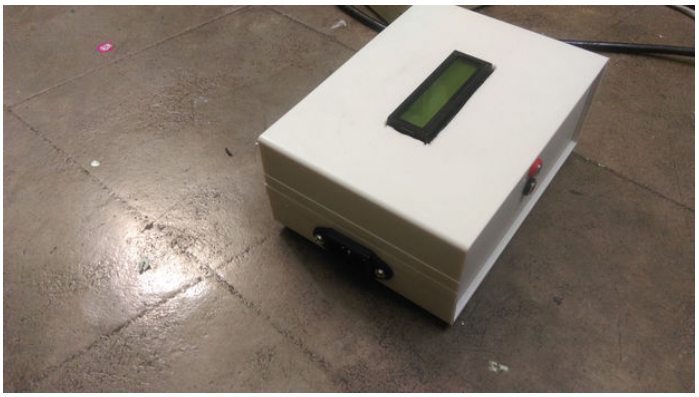
When i first bought my previous 11.1v/2200mah Li-ion battery,i searched for DIY battery chargers with smart control on the internet.But i found very limited resources.So for then,i made a battery charger based on LM317 and it worked really well for me.But as my previous battery died over time(for no reason),i bought another Li-ion battery of 11.1v/4400mah.But this time,the previous setup was inadequate to charge my new battery.To meet my requirement,i did some studying on the net,and was able to design my own smart charger.

I am sharing this as i think that many hobbyist/enthusiasts are out there who are really passionate about working on power electronics & microcontroller and also in a need to build a smart charger of their own.

Let's take a quick look at how to charge a Li-ion battery.







Step 1: Charge protocol for a Li-ion battery

To charge Li-ion battery,certain conditions must be fulfilled.If we don't maintain the conditions,either the battery will be undercharged or they will be set on fire(if overcharged) or will be permanently damaged.

There is a very good website to know everything necessary about different type of batteries and of course you know the name of the website if you are familiar with working on batteries...Yes,i am talking about batteryuniversity.com.

Here is the link to know the necessary details to charge a Li-ion battery.

If you are lazy enough to read all those theories,then the gist is as follows.

1.Full charge of a 3.7v Li-ion battery is 4.2v.In our case,11.1v Li-ion battery means 3 x 3.7v battery.For full charge,the battery must reach at 12.6v but for safety reason,we will charge it upto 12.5v.

2.When the battery is about to reach it's full charge,then the current drawn by the battery from the charger drops to as low as 3% of the rated battery capacity.For ex,the battery capacity of my cell-pack is 4400mah.So when the battery will be fully charged,the current drawn by the battery will be reached as nearly 3%-5% of 4400ma i.e between 132 to 220ma.To safely stop the charge,charging will be stopped when the drawn current will go below 190ma(nearly 4% of rated capacity).

3.The total charge process is divided into two main parts 1-Constant current(CC mode), 2-Constant voltage(CV mode).(Also there is topping charge mode,but we will not implement that in our charger as the charger will notify the user upon full charge by alarming,then the battery must be disconnected from the charger)

CC mode -

In CC mode,the charger charges the battery with 0.5c or 1c charge rate.Now what the hell is 0.5c/1c????To be simple,if your battery capacity is for say 4400mah,then in CC mode,0.5c will be 2200ma and 1c will be 4400ma charge current.'c' stands for charge/discharge rate.Some batteries also support 2c i.e in CC mode,you can set the charge current upto 2xbattery capacity but that is insane!!!!!

But to be safe,i will choose charge current of 1000ma for 4400mah battery i.e 0.22c.In this mode,the charger will monitor the current drawn by the battery independent of the charging voltage.i.e The charger will maintain 1A of charge current by increasing/decreasing the output voltage until the battery charge reaches to 12.4v.

CV mode -

Now as the battery voltage reaches to 12.4v,the charger will maintain 12.6 volt(independent of the current drawn by the battery) at it's output.Now the charger will stop the charge cycle depending on two things.If the battery voltages crosses 12.5v and also if the charge current drops below 190ma(4% of rated battery capacity as previously explained),then the charge cycle will be stopped and a buzzer will be sounded.

Step 2: Schematic and explanation

Now lets take a look at the circuit's working.

The input voltage of the circuit can be 19/20v.I have used a old laptop charger to get 19v.

J1 is a terminal connector to connect the circuit to input voltage source.Q1,D2,L1,C9 is forming a buck converter.Now what the hell is that???This is basically a DC to DC step down converter.In this type of converter,u can achieve the desired output voltage by varying the duty cycle.If you want to know more about buck converters,then visit this page.but to be frank,they are totally different from theory.To evaluate proper values of L1 & C9 for my requirements,it took 3 days of trial & error.If you are going to charge different batteries,then it can be possible that these values are going to change.

Q2 is the driver transistor for power mosfet Q1.R1 is a biasing resistor for Q1.We will feed the pwm signal in Q2's base to control the output voltage.C13 is a decoupling cap.

Now the output is then fed to Q3.A question can be asked that "What is the use of Q3 here??".The answer is pretty simple,It is acting like a simple switch.Whenever we will measure the voltage of the battery,we will shut off Q3 to disconnect the Charging voltage output from the buck converter.Q4 is the driver for Q3 with a biasing resistor R3.

Note that there is a diode D1 in the path.What the diode is doing here in the path??This answer is also very simple.Whenever the circuit will be disconnected from input power while battery attached at the output,the current from battery will flow in the reverse path via the body diodes of the MOSFET Q3 & Q1 and thus the U1 and U2 will get the battery voltage at their inputs and will power up the circuit from the battery voltage.To avoid this,D1 is used.

The output of the D1 is then fed to the current sensor input(IP+).This is a hall effect base current sensor i.e the current sensing part and the output part are isolated.The current sensor output(IP-) is then fed to the battery.Here R5,RV1,R6 are forming a voltage divider circuit to measure the battery voltage/output voltage.

The atmega8's ADC is used here to measure the battery voltage and current.The ADC can measure max of 5v.But we will measure a max of 20v(with some headroom).In order to cut down the voltage to the ADC range,a 4:1 voltage divider is used.The pot(RV1) is used to fine tune/calibration.I will discuss it later.C6 is decoupling cap.

The output of the ACS714 current sensor is also fed to atmega8's ADC0 pin.Via this ACS714 sensor,we will measure the current.I have a breakout board from pololu of 5A version and works really great.I will talk about in the next stage on how to measure the current.

The LCD is a normal 16x2 lcd.The lcd used here is configured in 4 bit mode as the pin count of atmega8 is limited.RV2 is the brightness adjustment pot for the LCD.

The atmega8 is clocked at 16mhz with a external crystal X1 with two decoupling caps C10/11.The ADC unit of the atmega8 is being powered via the Avcc pin through a 10uH inductor.C7,C8 are decoupling caps connected to Agnd.Place them as closely as possible to the Avcc and Aref correspondingly while making PCB.Notice that the Agnd pin is not shown in the circuit.The Agnd pin will be connected to ground.

I have configured the ADC of the atmega8 to use external Vref i.e we will supply the reference voltage via the Aref pin.The main reason behind this to achieve max possible reading accuracy.The internal 2.56v reference voltage is not so much great in avrs.That's why i configured it externally.Now here is a thing to notice.The 7805(U2) is supplying only the ACS714 sensor and the Aref pin of atmega8.This is to maintain optimum accuracy.The ACS714 gives a stable 2.5v output voltage when there is no current flow through it.But for say,if the supply voltage of the ACS714 will be lowered(say 4.7v) then the no current output voltage(2.5v) will also gets lowered and it will create inappropriate/erroneous current reading.Also as we are measuring the voltage with respect to Vref,then the reference voltage on Aref must be error free and stable.That's why we need a stable 5v.

If we would power the ACS714 & Aref from the U1 which is supplying the atmega8 and the lcd,then there would be substanial voltage drop at U1's output and the ampere and voltage reading would be erroneous.That's why U2 is used here to eliminate the error by supplying a stable 5v to Aref and ACS714 only.

S1 is pressed to calibrate the voltage reading.S2 is reserved for future use.You can either add/not add this button according to your choice.

File Downloads

BIN.PDF (66 KB)
[NOTE: When saving, if you see .tmp as the file ext, rename it to 'BIN.PDF']

Step 3: Functioning.....

At being powered up,the atmega8 will turn on the buck converter by giving 25% pwm output at the Q2's base.In turn,Q2 will then drive Q1 and buck converter will be started.Q3 will be driven off to disconnect the buck converter's output and the battery.The atmega8 then reads the battery voltage via the the resistor divider.If no battery is connected,then the atmega8 shows a message "Insert battery" via 16x2 lcd and waits for the battery.If a battery is then attached,the atmega8 will check the voltage.If the voltage is lower than 9v,then the atmega8 will show "Faulty battery" on the 16x2 lcd.

If a battery with more than 9v found,then the charger will first enter into CC mode and turn on the output mosfet Q3.Charger mode (CC) will be updated to display immediately.If the battery voltage is found more than 12.4v,then the mega8 will immediately leave the CC mode and will enter into CV mode.If the battery voltage is less than 12.4v,then the mega8 will mantain 1A charge current by increasing/decreasing output voltage of the buck converter by varying duty cycle of the pwm.The charge current will be read by the ACS714 current sensor.The buck output voltage,charge current,PWM duty cycle will be periodically updated in the lcd.

.The battery voltage will be checked by turning off Q3 after every 500ms interval.The battery voltage will be immediately updated to the lcd.

If the battery voltage gets more than 12.4 volt during charging,then the mega8 will leave the CC mode and will enter into CV mode.Mode status will be immediately updated to the lcd.

Then the mega8 will maintain the output voltage of 12.6 volt by varying the duty cycle of the buck.Here the battery voltage will be checked after every 1s interval.As soon as the battery voltage will be greater than 12.5v,then it will be checked if the drawn current is below 190ma.If both the conditions are met,then the charge cycle will be stopped by permanently turning off Q3 and a buzzer will be sounded by turning on Q5.Also mega8 will show "Charge complete"via the lcd.

Step 4: Parts required

Listed below are the required parts to complete the project.Please refer to datasheets for pinout.Only crucial parts datasheet link provided

1) ATMEGA8A x 1.(datasheet)

2) ACS714 5A current sensor from Pololu x 1 (I strongly recommend to use the sensor from Pololu as they are the best accurate among all other sensors i've used.You can find it here).Pinout is described in the image.

3) IRF9540 x 2.(datasheet)

4) 7805 x 2(recommended from Toshiba genuinespare as they give the most stable 5v output).(datasheet)

5) 2n3904 x 3.(datasheet)

6) 1n5820 schottky x 2.(datasheet)

7) 16x2 LCD x 1.(datasheet)

8) 330uH/2A power inductor x 1 (recommended from coilmaster)

9) 10uH inductor x 1(small)

10) Resistors -(All resistors are 1% MFR type)

150R x 3

680R x 2

1k x 1

2k2 x 1

10k x 2

22k x 1

5k pot x 2(pcb mount type)

11) Capacitors

Note: I didn't use C4.There is no need to use it if you are using Laptop power supply/Regulated power supply as 19v power source

100uF/25v x 3

470uF/25v x 1

1000uF/25v x 1

100n x 8

22p x 2

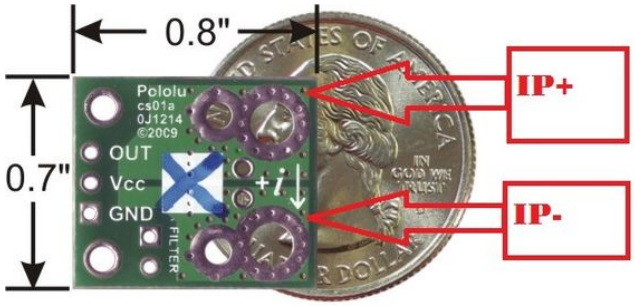
12) PCB mount momentary push switch x 2

13) 20v Buzzer x 1

14) 2 pin Terminal block connector x 2

15) Cabinet(I used a cabinet like this.).You can use whatever you like.

16) 19v laptop power supply(I modified a hp laptop power supply,You can use any type power supply as you want.If you want to build one,then visit my this instructables.)



ACS714 PINOUT

Step 5: Time to Calculate.....

Voltage measurement calculation :

The max voltage,we will measure using the atmega8 adc is 20v.But atmega8's adc can measure max of 5v.So in order to make20v within 5v range,a 4:1 voltage divider is used here(as 20v/4=5v).So we could implement that by simply using two resistors,but in our case,i've added a pot in between two fixed resistors so that we can manually adjust the accuracy by turning the pot.The resolution of the ADC is 10bit i.e the adc will represent the 0v to 5v as 0 to 1023 decimal numbers or 00h to 3FFh.('h' stands for hex numbers).The reference is set to 5v externally via the Aref pin.

So the measured voltage = (adc reading) x (Vref=5v) x (resistor divider factor i.e 4 in this case) / (max adc reading i.e 1023 for 10bit adc).

Suppose we get a adc reading of 512.Then the measured voltage will be -

(512 x 5 x 4) / 1023 = 10v

Current measurement calculation :

The ACS714 will give 2.5v stable output at the out pin when no current will flow from IP+ towards IP-.It will give 185mv/A over the 2.5v i.e for say,if 3A current is flowing through the circuit,the acs714 will give 2.5v+(0.185 x 3)v = 3.055v at it's out pin.

So the current measurement formula is as follows -

Measured current=(((adc reading)*(Vref=5v)/1023)-2.5)/0.185.

for say,the adc reading is 700,then the measured current will be - (((700 x 5)/1023) - 2.5)/0.185 = 4.98A.

Step 6: The software

The software is coded in Winavr using GCC.I have modularized the code i.e i've created different libraries like adc library,lcd library etc.The adc library contains the necessary commands to setup & interaction with the adc.The lcd library contains all the functions to drive the 16x2 lcd.

The main.c file contains the main functions.The charging protocol for li-ion is written here.Please define the ref_volt in the main.c by measuring the output of U2(7805) with a precise multimeter to get accurate readings as the calculations are based on it.

You can simply burn the .hex file directly in your mega8 to bypass the headche.

For those,who want to write another charge protocol,i have put enough comments by which even a child can understand whats going on for each line execution.Just you have to write your own protocol for different battery type.If you are using Li-ion of different voltage,you have to only change the parameters.(Though this is not tested for other li-ion/other battery type.You have to work it out by yourself).

I strongly recommend not to build this circuit,if this is your first project or you are new to microcontroller/power electronics.

I have uploaded each and every file as it's original format except the
Makefile as it is creating problem to open.I have uploaded it in .txt format.Just copy the content and paste it into a new Makefile and build the whole project.Voila....you are ready to burn the hex file.

File Downloads

adc.c (2 KB)
[NOTE: When saving, if you see .tmp as the file ext, rename it to 'adc.c']

adc.h (458 bytes)
[NOTE: When saving, if you see .tmp as the file ext, rename it to 'adc.h']

lcd.c (1 KB)
[NOTE: When saving, if you see .tmp as the file ext, rename it to 'lcd.c']

lcd.h (493 bytes)
[NOTE: When saving, if you see .tmp as the file ext, rename it to 'lcd.h']

main.c (6 KB)
[NOTE: When saving, if you see .tmp as the file ext, rename it to 'main.c']

main.hex (9 KB)
[NOTE: When saving, if you see .tmp as the file ext, rename it to 'main.hex']

Makefile.txt (17 KB)
[NOTE: When saving, if you see .tmp as the file ext, rename it to 'Makefile.txt']

Step 7: Enough of theory.....let's buld it

Here are the pics of my prototype from breadboarded to finalized in pcb.Please go through the notes of the pics to know more.The pics are arranged serially from starting to end.

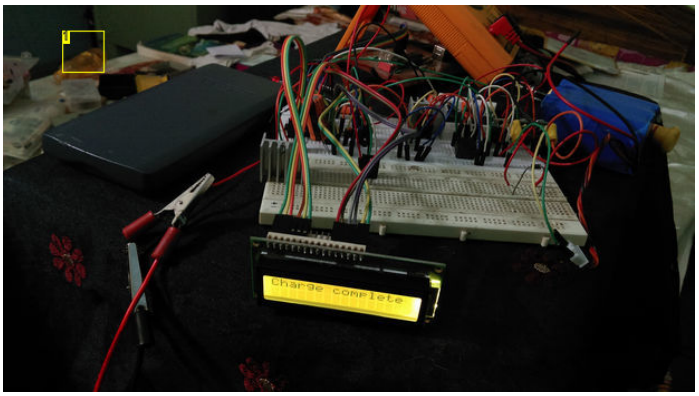


Image Notes
1. Total circuit assembled on breadboard.Display is showing a successful completion of a charge cycle.

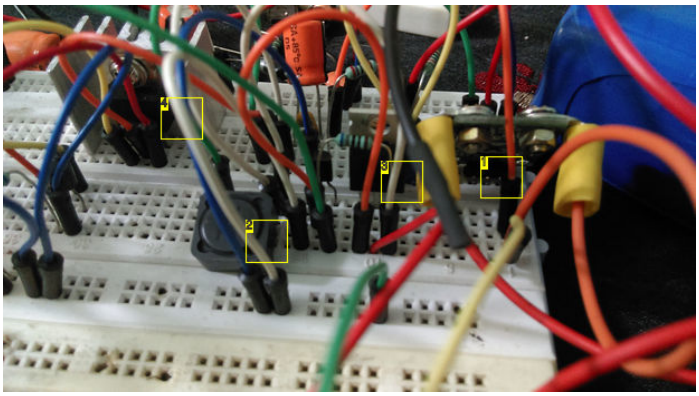
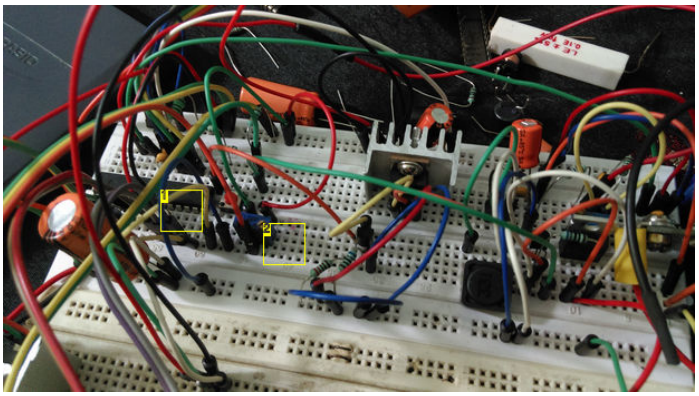


Image Notes
1. The acs714 current sensor
2. The 330uH inductor
3. Q3 output mosfet
4. Q1 buck mosfet mounted on heatsink



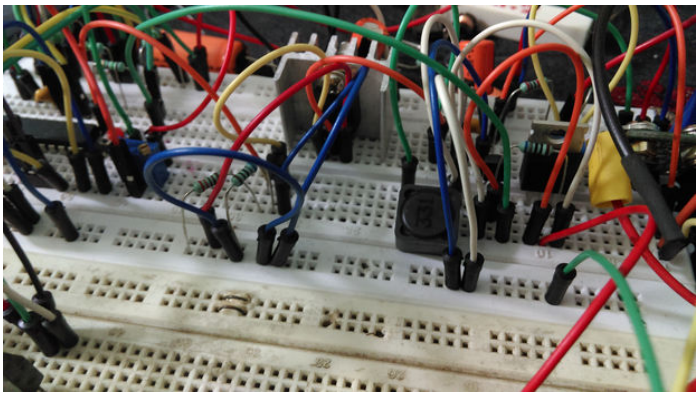


Image Notes
1. atmega8a...the heart of the circuit
2. lcd brightness adjustment pot

Image Notes
1. Hammer is needed to extract the laptop charger circuit from cabinet
2. Minus screwdriver bit is used to hit the joint of the laptop charger during extraction of circuit board

Image Notes
1. Laptop charger circuit extracted from cabinet
2. Cabinet extraction done
3. chassis part of cabinet

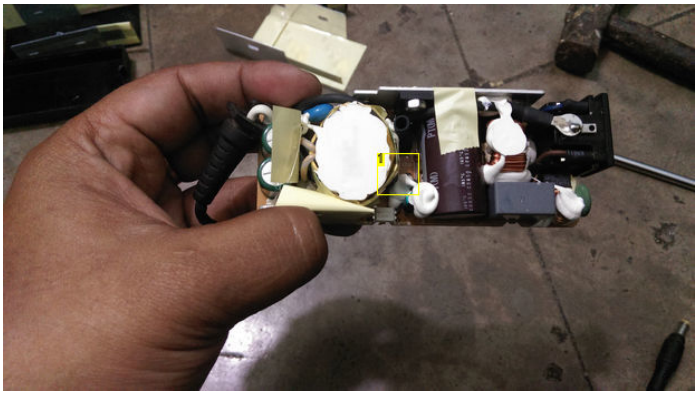


Image Notes
1. The total power supply circuit extracted successfully....

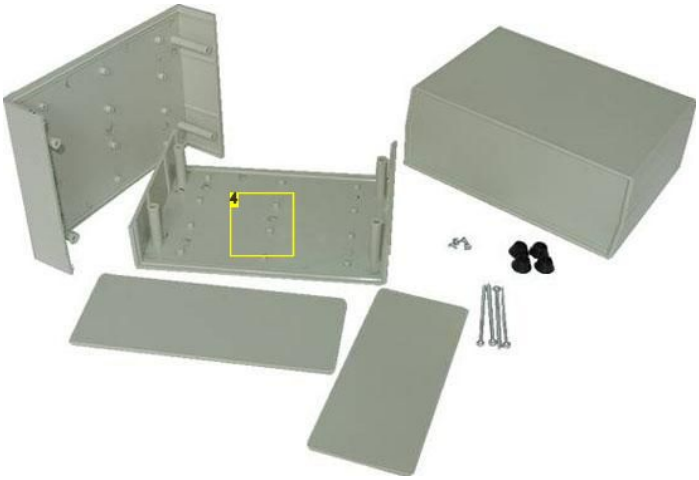


Image Notes
1. This is the cabinet i used to enclose the whole circuit
2. This is the cabinet i used to enclose the whole circuit
3. This is the cabinet i used to enclose the whole circuit
4. This is the cabinet i used to enclose the whole circuit

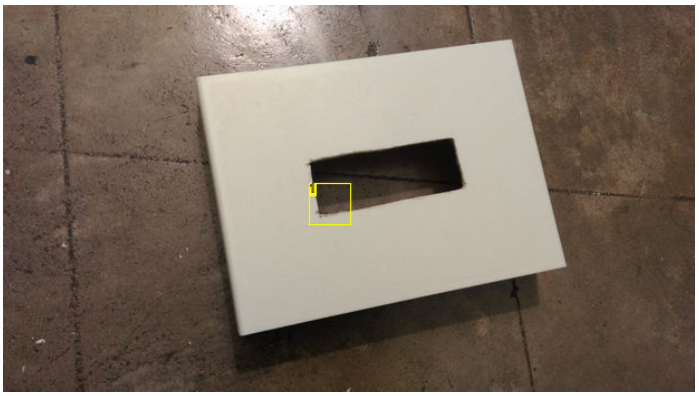


Image Notes
1. Top cover cutted for lcd installation using dremel tool

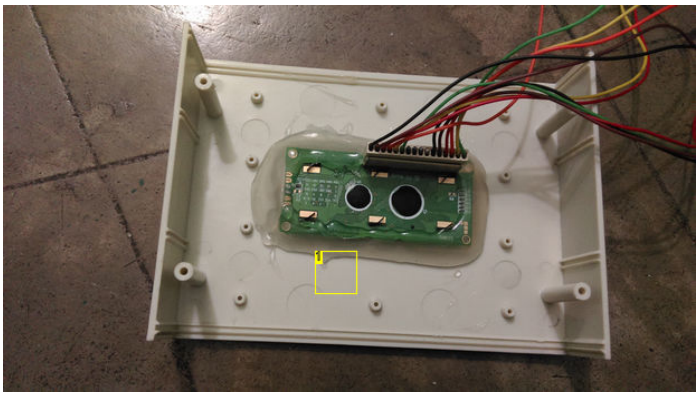


Image Notes
1. Installation done of the 16x2 lcd using hot glue.Obviously you can use screw/nut/bolt to secure it...

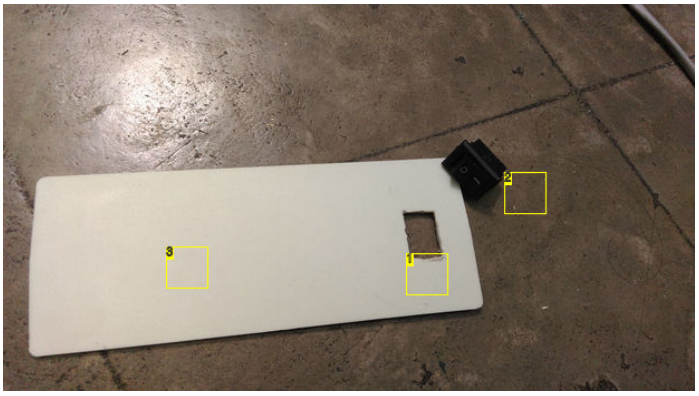


Image Notes
1. Small cut for the on/off switch
2. The on/off switch
3. the back cover

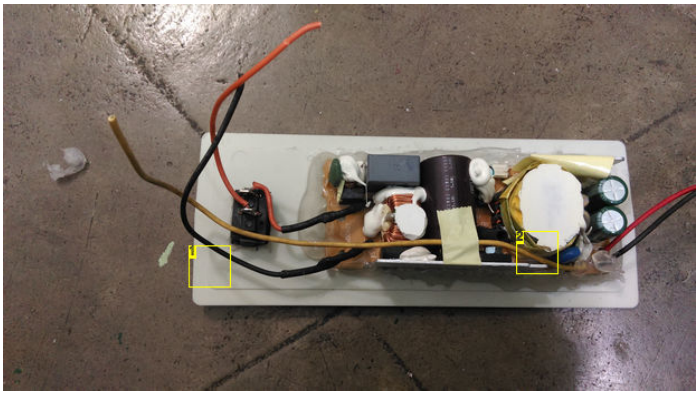


Image Notes
1. A small on/off switch is installed in the back cover
2. Laptop power circuit is installed in the inside of the back cover using hot glue.

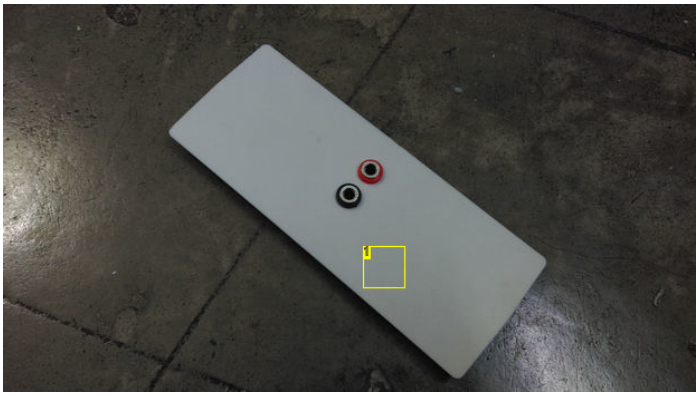


Image Notes
1. Banana female socket is installed in the front cover

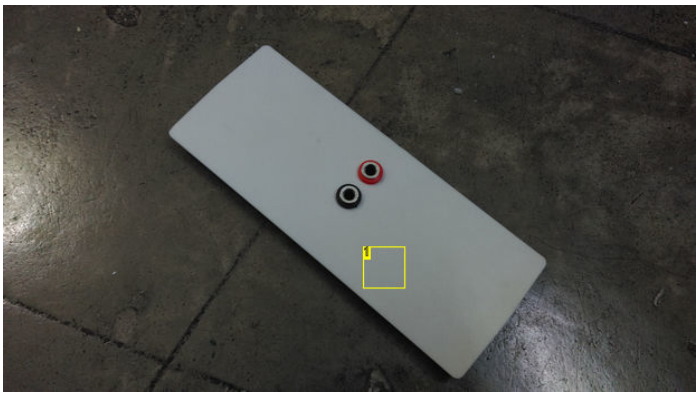


Image Notes
1. elcom power socket is fixed in the bottom cover using M3 nut/bolt

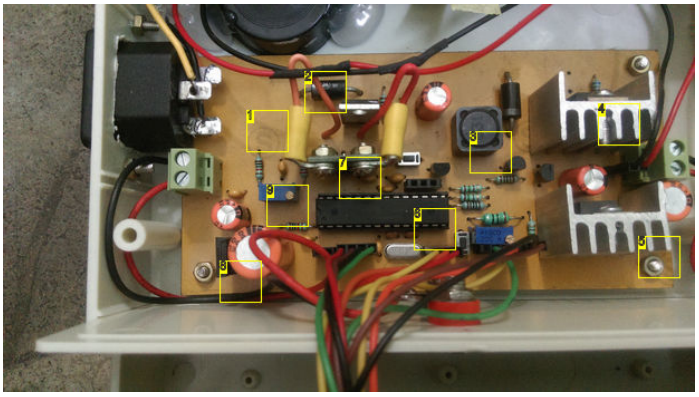


Image Notes
1. The main circuit board installed in the bottom cover
2. D1 diode
3. 330uH inductor
4. Q1 buck power mosfet must be installed on heatsink
5. U1 7805 must be installed on heatsink.
6. atmega8a

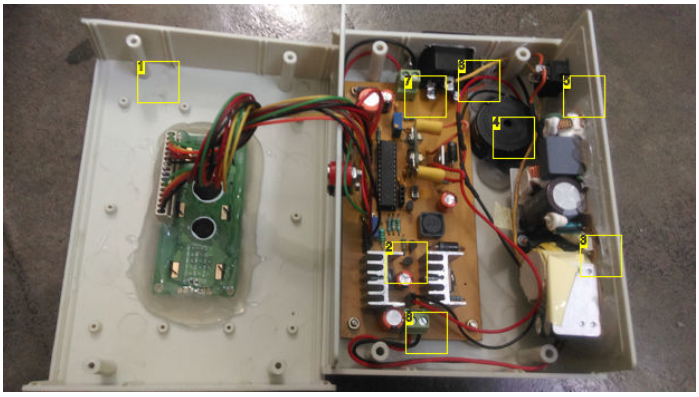


Image Notes
1. Full circuit connected
2. Main board
3. Power supply
4. Buzzer
5. Power switch
6. Power connector

7. acs714 current sensor board
8. U2(7805)
9. RV1 pot for calibration

7. output terminal connector
8. Input terminal connector

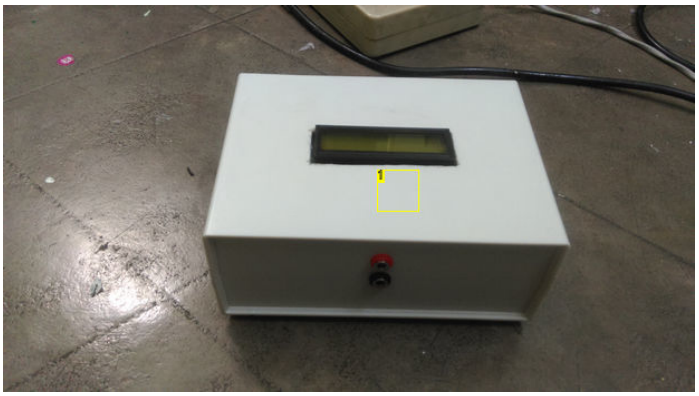


Image Notes
1. The complete product

Step 8: Before first charge cycle.....Calibrate!!!!

Before charging a battery using the charger,you must calibrate it first.Otherwise it will not be able to charge the battery/overcharge it.

There are two type of calibration 1) Voltage calibration. 2)Current calibration.Steps are as follows to calibrate.

At first,measure the output voltage of the U2.Then define it in the main.c as ref_volt.Mine was 5.01.Change it as per your measurement.This is the main necessary step for Voltage & Current calibration.For current calibration,nothing else is necessary.Everything will be taken care of by the software itself

Now as you have burnt the hex file after defining the ref volt in main.c,kill the power of the unit.

.Now measure the battery voltage which u will charge by using a multimeter and connect the battery to the unit.

Now press the S1 button and hold it and power the circuit while the button is pressed.After a short delay of about 1s,release the button S1.Note that the unit will not enter into calibration mode if u power the circuit first,then press S1.

Now you can see in the display that the circuit is entered into calibration mode.A "cal mode" will be displayed in the lcd along with the battery voltage.Now match the battery voltage shown on the lcd with your multimeter reading by turning the pot.After you are done,press the S1 switch again,hold it for about a second and release it.You will be out of the calibration mode.Again reset the charger by powering it off and on.

The above process can also be done without a battery connected.You have to connect a external power source to the output terminal(J2).After entering into calibration mode,calibrate using the pot.But this time first disconnect the external power source then press S1 to get out of the calibration mode.This is necessary to first disconnect the external power source to avoid any type of malfunction of any units.

Step 9: Turning on after calibration.....now you are ready to rock

Now as the calibration is complete,you are now able to start the charge process.Attach the battery first,then turn the unit on.Rest will be taken care of by the charger.

My circuit is 100% working and tested.But if you notice anything,please let me know.Also feel free to contact for any queries.

Happy building.

Rgds//Sharanya

Image Notes
1. After calibration,while turning on with no battery connected

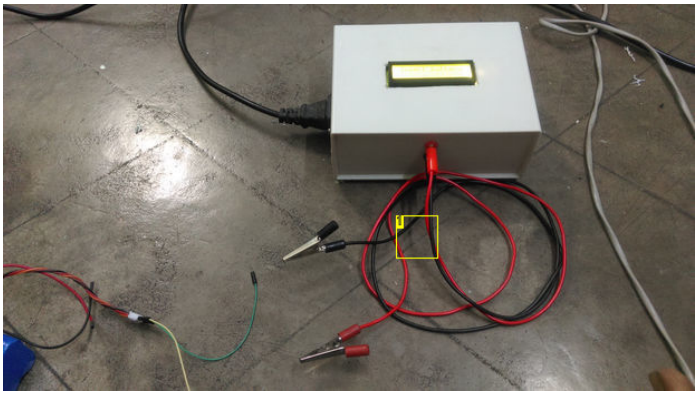


Image Notes
1. Attaching banana cables with croc connector

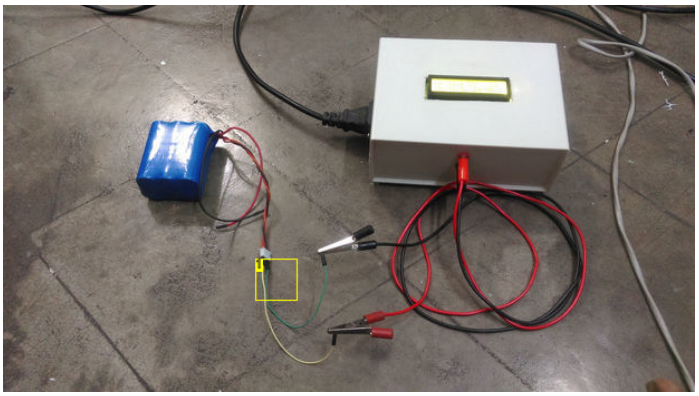


Image Notes
1. Attaching the battery to the charger

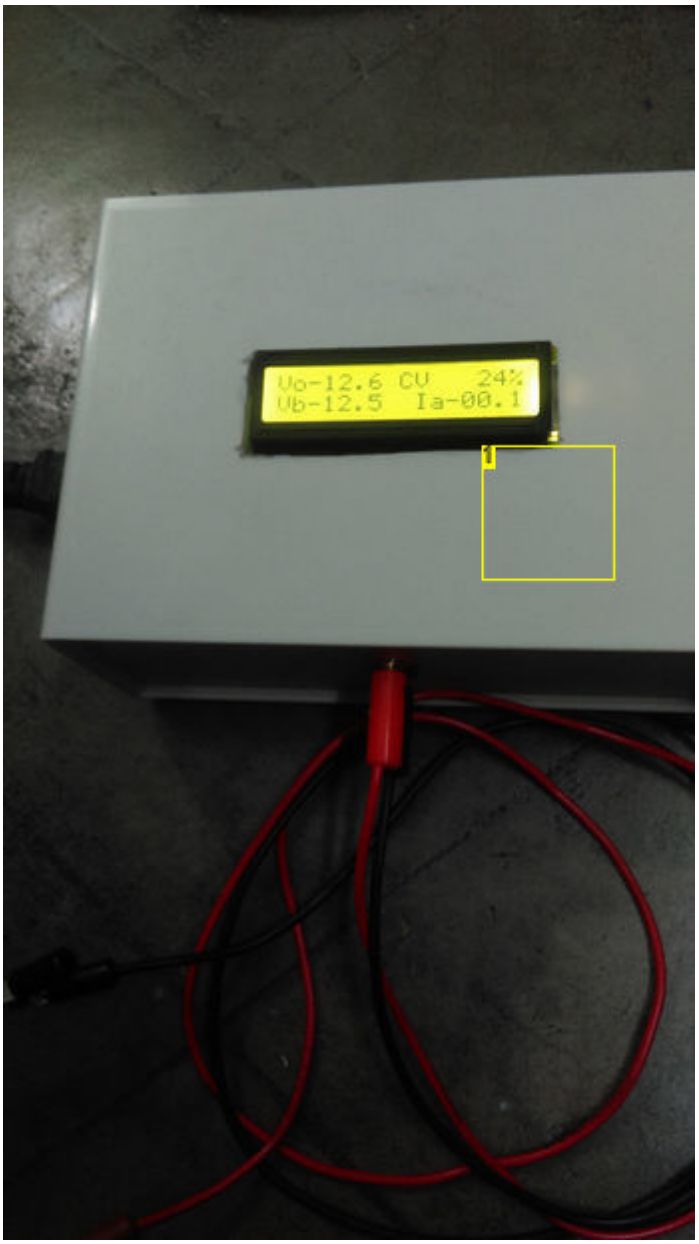
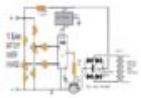


Image Notes
1. Displaying of different datas

Image Notes
1. Charge complete notification

Step 10:

Related Instructables



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