

Application Note: Safe Use and Charging of Lithium Ion Batteries

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Abstract

This paper discusses the usefulness of the high density lithium ion batteries of present day, as well as some of the dangers that they pose. Presented are some safety tips and a step by step instruction on designing a fast lithium ion battery charger with built in temperature protection.

Background

Batteries allow the use of all modern day electronics and are an essential part of making electronics mobile. As processing power has been shrinking exponentially since computational electronics were first invented, power electronics has struggled to keep pace. Lithium Ion batteries are currently one of the highest capacity for weight batteries on the market today.

Most batteries consist of two electrolytes and rely on a chemical reaction to produce the power that batteries offer. One of the first batteries that could deliver a decent amount of current was the Daniel cell, rated at 1.1 volts; it used a copper sulfate solution, sulfuric acid solution, and a zinc electrode. [1] Nickel Cadmium batteries, invented in 1893, have an energy density of 50-150W*h/L, which has still been one of the most energy dense batteries until recent years. Alkaline magnesium batteries, invented in 1949, also have a high energy density, but their capacity is very dependent on the load, so the application defines their usefulness. [1]

Lithium ion batteries were first invented in the 1970's, and far surpass its predecessors with maximum energy densities up to 620 W*h/L at the present day. [2] Lithium ion batteries have a much lower self-discharge rate, compared to other batteries, and they don't have "memory" which means charging and discharging without giving them a full cycle causes them to retain less charge over time. Lithium ion batteries are actually best utilized when the charge remains closer to the middle of its capacity as opposed to either end of the spectrum. [2]

Safety Concerns

Lithium Ion batteries have been particularly criticized because of many safety concerns they pose if not carefully used. Overcharging or allowing the batteries to overheat can cause thermal runaway, which may cause the cells to rupture or combust. [3] Over discharging the cells may cause physical short-circuits within the cell which can render it useless and dangerous to attempt to charge. Fortunately laws within the U.S. prevent manufacturers from selling lithium ion cells without protection circuitry, though it is possible to purchase them from outside the US. It is also very cheap and easy to buy protection circuit modules for a wide range of lithium ion batteries. Most protection circuitry provided though, only protects against over voltage charging, and under voltage discharging.

Designing a Lithium Ion Battery Charger - Basics

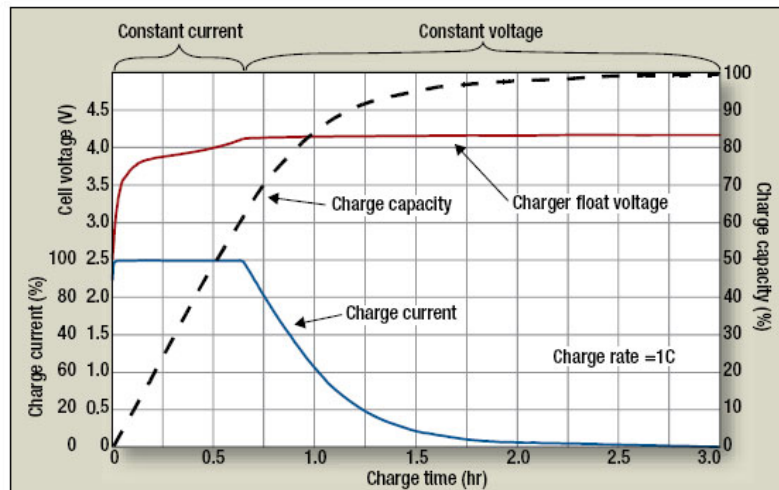
The first consideration to take into account is the size and ratings of your battery pack. The voltage is the main concern, but the C rating and capacity is very important to determine the max charge rate which can be safely applied to the battery. For example, in the charger designed in this example, the battery pack has a nominal voltage of 7.4 volts and a 6600 mAh capacity, the C rating defines the



maximum charge and discharge of the pack. The data sheet gives a maximum discharge current as $.75C$, and a maximum charge current as $.265C$. This means the battery pack can supply up to 5 amps of current to the application it is being used for, while the maximum charge current is 1.75 amps. Some battery packs will allow much greater discharge/charge rates so it is important to read the specs associated with the battery pack and design to meet the

needs of your application.

When charging lithium ion batteries, there are two stages of charging: constant current and constant voltage. During the constant current stage, the maximum current allowed (or designed for) will flow into the battery as the voltage level increases to the rated voltage of the battery pack. Once the voltage is reached, current will continue to decrease as the capacity of the battery is filled; during this stage the voltage stays constant.



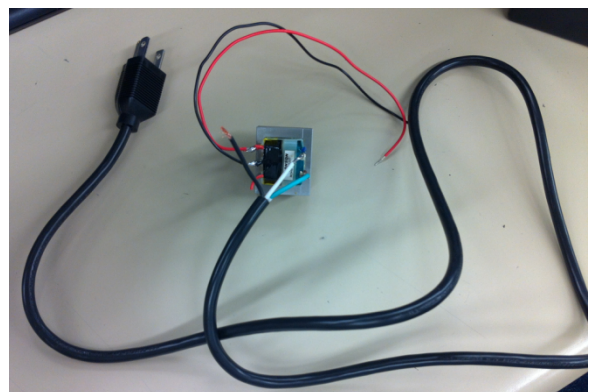
http://powerelectronics.com/site-files/powerelectronics.com/files/archive/powerelectronics.com/portable_power_management/battery_charger_ics/804li-ion-battery-life-Figure01.jpg

Some needed and important components for a good battery pack charger include a transformer, bridge rectifier, voltage and current regulator. For extra safety, a temperature sensor is included in the design which requires an extra voltage regulator for a reference voltage.

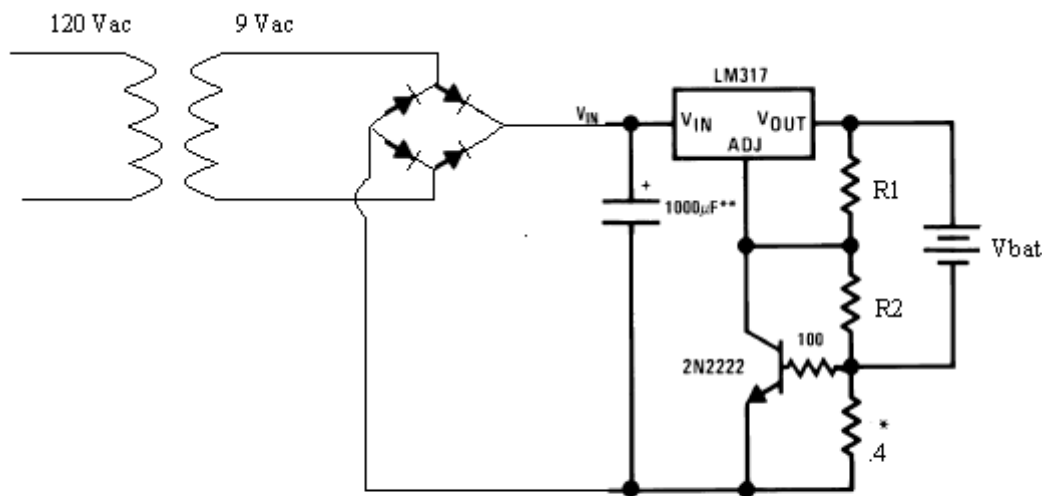
The Design

A battery operates on a DC voltage, and since this design includes the use of a wall outlet, it will require the transformation from 120 volts AC, to a usable DC voltage. The regulators used in this design allow for 15 volts to be dropped across them without affecting the current limit, so a standard transformer was used to bring the wall outlet voltage down to 9 volts AC.

Next, a bridge rectifier was required to acquire DC voltage and a large capacitor was placed across the output to reduce the voltage ripple.



The LM317 is a regulator that can be used to set a voltage or limit current. In the data sheet several examples are shown, one in particular shows its use as a battery charger [4]. Using this example, with a few modifications, we can design a custom battery charger with temperature protection. Setting the voltage desired to charge the battery pack to is the first consideration to make, and this depends on the values of the resistors R1 and R2 as shown in the schematic. The voltage of the battery, V_{bat} , can be used to solve for R1 and R2.



*Sets peak current

**The 1000µF is recommended to filter out input transients

↳

I used a 2200 uF (largest I could find)

Since the application of this battery pack was to power an RC car, a higher voltage was desirable. The battery charger was in turn designed for 7.8 volts. (Each lithium ion cell can be charged between 3-4.2 volts).

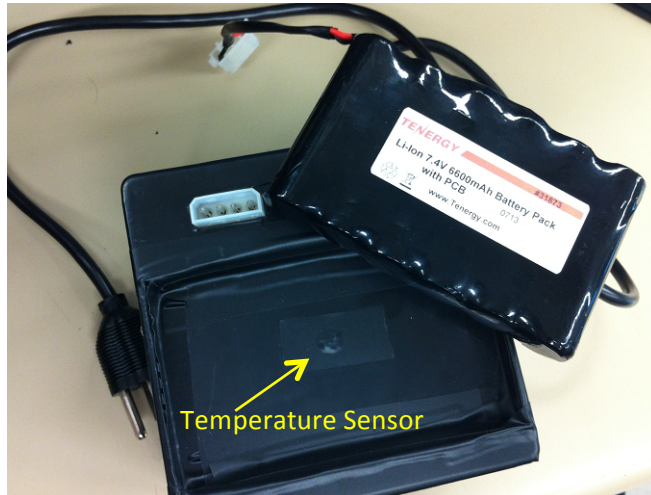
$$V_{bat} = 1.25 \left(1 + \frac{R2}{R1} \right) = 7.8$$

Solving this equation for R1 and R2, the ratio of R2/R1 is about 5.25.

I chose R2=1600 and R1=300, which gave me a ratio of 5.33. This will set the voltage across the battery pack as 7.9125 volts, which is still under the maximum voltage rating for the battery pack.

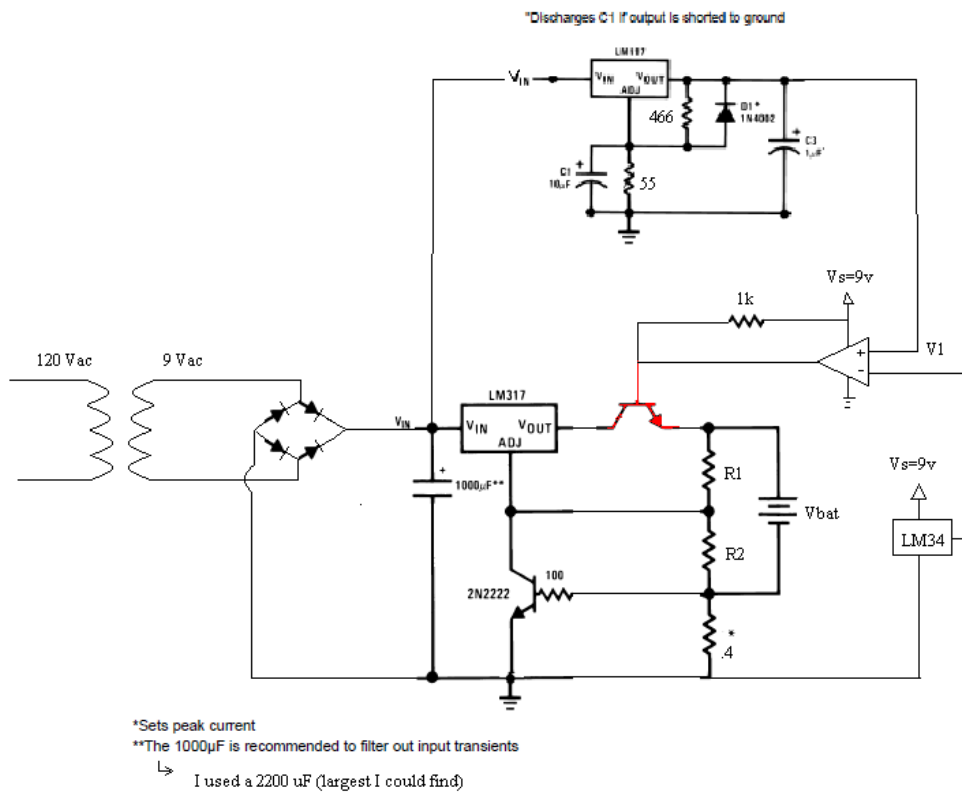
The LM317 can provide currents above 2.2 amps, so if the battery pack isn't rated for that much current, a current limiting resistor needs to be added from the negative side of the battery pack to ground. This charger was designed to limit current to about 1.5 amps because of the .4 ohm resistor. This resistor will have a considerable amount of current, and therefore must be able to handle a considerable power load. The resistor I used was rated for 5W, though a 3W power rating should suffice.

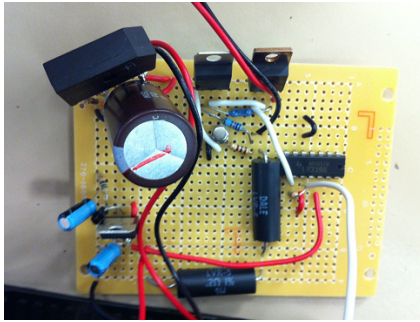
In order to add some extra safety to this charger, a temperature sensor can be placed near where the battery pack will be while charging. By taking the output of the temperature sensor and comparing it to a set threshold voltage with a comparator, we can use the output to control a BJT as a switch, so if the battery pack gets too hot, the charger will stop charging.



The LM34 outputs 10 mV * the temperature reading in degrees Fahrenheit, so if it is 70 degrees in the room, the output would read .7 V. [5] The data sheet for the lithium ion battery pack I was designing for gave temperature recommendations, so I designed the charger to shut off if a temperature above 137 degrees was reached. In order to have the temperature sensor compare the current temperature to the threshold temperature, a DC voltage of 1.37 V needs to be the positive input for the comparator. It is possible to transform the supply DC voltage using a buck converter, but a

voltage regulator was chosen here for simplicity. Again the LM317 was used and an example in the data sheet shows an adjustable regulator with improved ripple rejection. Using this example, I designed an output voltage of 1.37 volts by setting $R1=466$ ohms, and $R2=55$ ohms.



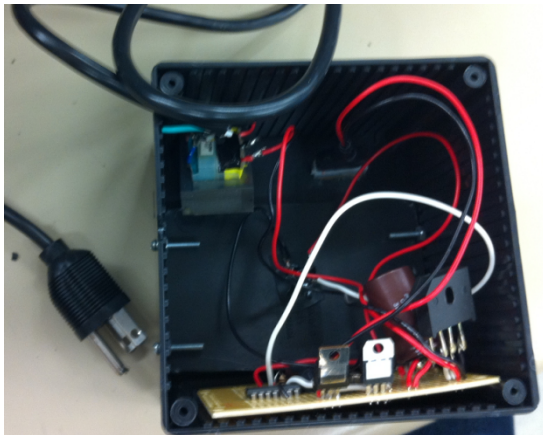


Now by inserting a BJT between the first LM317 and the battery pack we can turn off the current if the temperature exceeds the set 137 degrees Fahrenheit. This BJT needs to be able to hand a lot of current, so a TIP31 was used. [6]

Conclusion

Designing a battery pack charger requires careful considerations for safety precautions and timely charging rates. Given the procedure described, many battery configurations could be designed for. There are also several other improvements that could be made on this design, including a hysteresis or permanent charger shut off when the temperature exceeds a threshold (opposed to continuing charge when the temperature drops back below the threshold) as well as current sensing so when the battery pack is almost full, it will stop charging.

Inside finished charger



Outside finished charger



References

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