

# An Approach for Designing and Developing Lithium Ion Battery Pack with Power Charger for Electric Bike

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**ABSTRACT:** This paper illustrates an approach for designing and developing lithium ion battery pack with power charger for electric bike. This battery pack system is rechargeable, eco-friendly, reliable and budget friendly too. In this paper comparison of various types of Batteries and working principle of Lithium-ion batteries has been done. charging and discharging time of battery pack has been tested by using it on electric bike having an electric motor of 24 volts and 250 watts. The bike frame is made up of steel and it can with stand a maximum load of 120 kg. The components such as electric motor, battery pack, controller, hand lever and pedal system are mounted on bike frame. The bike frame is designed in CATIA software and analysis is performed in ANSYS software.

**KEYWORDS:** lithium ion battery pack, Power charger, Electric bike, Battery management system, CATIA and ANSYS software.

## I. INTRODUCTION

The Lithium-ion battery is a rechargeable type of battery. Lithium-ion batteries are widely used in portable electronics and electric vehicles, and are becoming increasingly popular for military and aerospace use. In 1985, Akira Yoshino developed a prototype Li-ion battery based on earlier work by John Goodenough, Stanley Whittingham, Rachid Yazami, and Koichi Mizushima during the 1970s–1980s, and then a commercial Li-ion battery was produced in 1991 by a team led by Yoshio Nishi, Sony and Asahi Kasei. In the batteries, during discharge, lithium ions pass from the negative electrode through an electrolyte to the positive electrode, and back when charging. Li-ion batteries use an intercalated lithium compound in the positive electrode and usually graphite in the negative electrode as the fuel. The batteries have a high energy density, no effect on memory and low self-discharge.

### A. TYPES OF BATTERIES AVAILABLE IN MARKET

A) *Nickel-Cadmium Batteries:* Nickel – cadmium battery (NiCad battery or NiCd battery) is a type of rechargeable battery that is built using hydroxide of nickel oxide and electrodes of metallic cadmium. Ni-Cd batteries excel when not in service when maintaining voltage and retaining charge. Nevertheless, when a partially charged battery is recharged, Ni-Cd batteries quickly fall victim to the dreaded "memory" effect, reducing the battery's potential capacity. The small packs are used in portable devices, appliances and toys, while the larger ones are used in batteries starting from aircraft, electric vehicles and power supply standby.

B) *Nickel-Metal Hybrid Batteries:* Another type of chemical configuration used for rechargeable batteries is the Nickel metal hydride (Ni-MH). The chemical reaction on the positive battery electrode is similar to that of the nickel – cadmium cell (NiCad), with both types of batteries using the same nickel oxide hydroxide (NiOOH). Negative electrodes in nickel-metal hydride, however, use a hydrogen-absorbing alloy rather than cadmium which is used in NiCad batteries. Because of their high power and energy density NiMH batteries find use in high drain devices. A NiMH battery may have the power of a NiCad battery of the same size twice to three times that of a lithium-ion battery, and its energy consumption could be higher. Like the NiCad chemistry, NiMH-based batteries are not prone to the "memory" effect encountered by Nicads.

C) *Lead-Acid Batteries:* Lead acid batteries are effective low-cost power workhorses used in heavy duty applications. They are usually very broad and are often used in non-portable applications such as solar-panel energy storage, vehicle ignition and lighting, backup power and load levelling in power generation / distribution because of their weight. The lead-acid is the oldest form of rechargeable battery and is still very common in the world today. Lead acid batteries have very low volume-energy and weight-energy ratios, but it has a fairly large weight-to-weight ratio and as a result can provide massive surge currents when needed. These attributes alongside its low cost makes these batteries attractive for



use for use in several high current applications like powering automobile starter motors and for storage in backup power supplies.

*D) Lithium-ion Batteries:* One of the most common types of rechargeable batteries is the lithium ion batteries. They can be found in various portable devices, including mobile phones, smart devices and a number of other battery appliances used at home. Thanks to their lightweight design, they also find applications in the aerospace and military applications. Lithium-ion batteries are a type of rechargeable battery in which lithium ions from the negative electrode migrate during discharge to the positive electrode and then migrate back to the negative electrode while charging the battery. For contrast with the metallic lithium found in non-rechargeable lithium batteries, Li-ion batteries use an intercalated lithium compound as one electrode.

Compared to other types of batteries, lithium ion batteries typically have high energy capacity, little to no memory effect and low self-discharge. Li-ion batteries used in portable electronic devices are typically based on lithium cobalt oxide (LiCoO<sub>2</sub>), which offers high energy density and low safety risks when used in various applications. Damaged though Lithium iron phosphate-based Li-ion batteries with lower energy density are more stable due to a reduced risk of unfortunate events are commonly used in driving electrical tools and medical devices. Lithium ion batteries provide the best weight-to-performance ratio with the highest-ratio lithium Sulphur battery.

Many Li-ion cell characteristics show enhancements over its competitors. It has been shown that it can withstand over 1000 load /discharge cycles and can still retain 80 per cent of its initial power. Ni-Cads deliver up to around 500 cycles, but this depends very much on how they are used. A cell being treated badly can give only 50 or 100. NiMH cells are worse still and that is one of the main areas receiving development. They can only offer at the very best 500 cycles before their efficiency drops to 80 percent of the initial charge level.

Table I. Comparison of li-ion & lead acid battery

Sr. No.	Parameters	Li-Ion Battery	Lead Acid Battery
1	Charging Efficiency	96%	70%
2	Charging Time	1 Hour	6 to 8 hours
3	Effect of Climate on Battery	No Effect	<b>Winter</b> -never charge completely and during <b>Summer</b> - gasify too much
4	Battery Weight	9 Kg for Kwh	30 Kg for kWh
5	Maintenance	Easy	Gas disposal & water demineralization
6	Service Life	Last 3-4 Times Longer	Last 3-4 times shorter
7	Safety, Waterproofing and Emissions	<b>Ip67</b> Rating and no release of gas	Releases hydrogen gas during charging

## II. METHODOLOGY

### A. Required components for making power charger

In making of li-ion battery charger we need some components like mentioned below.

*i) Power supply of 24 volts:* A power supply is an electrical device which supplies an electrical charge with electric power. Both power supplies have a power input link that receives energy from a source in the form of electrical current, and one or more power output connections that supply current to the charge. The source power can come from the electrical grid, such as an electrical socket, devices for storing electricity. The input and output are usually hardwired circuit connections.

*ii) BMS with balance charging:* A battery pack designed with a battery management system including an external data bus for communication is a smart battery pack. A smart battery pack has to be charged by a smart adapter.

A BMS can track the battery condition as described by different objects, such as:

- Voltage: total voltage, voltages of individual cells, minimum and maximum cell voltage, or voltage of periodic taps

- Temperature: average temperature, coolant intake temperature, coolant output temperature, or temperatures of individual cells
- State of charge (SOC) or depth of discharge (DOD), to indicate the charge level of the battery
- State of health (SOH), a variously-defined measurement of the remaining capacity of the battery as % of the original capacity
- State of power (SOP), the amount of power available for a defined time interval given the current power usage, temperature and other conditions
- State of Safety (SOS)
- Coolant flow: for air or fluid cooled batteries
- Current: current in or out of the battery

*iii) Voltage step down converter:* A buck converter (step-down converter) is a DC-to - DC power converter that slides down voltage from its input (supply) to its output (load) while stepping up current. This is a switched-mode power supply (SMPS) class that usually includes at least two semiconductors and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made from condensers are usually applied to the output and input of such a converter to reduce the voltage ripple. As DC-to - DC converters, switching converters have much greater power efficiency than linear regulators, which are

simpler circuits that lower voltages by dissipating power as heat, but do not increase the output current. Buck converters can be highly effective (often more than 90 percent), making them useful for tasks such as converting the main (bulk) supply voltage (often 12 V) from USB, DRAM and CPU voltages (1.8 V or less).

*iv) Multimeter:*

A multimeter or multitester, also known as a VOM (volt-ohm-milliammeter), is an electronic measurement device integrating several measurement functions in one form.

*v) Battery status indicator:*

A battery indicator (also known as a battery gauge) is a device which provides battery information. Typically, this would be a visual indicator of charging status for the battery. This is particularly relevant in the case of an electric battery vehicle.

**B. LI-ION BATTERY CHARGING**

Charging lithium ion batteries can be split into two main stages:

•*Constant current charge:* The charge current is regulated during the first stage of charging a li-ion battery or cell. This will usually be between 0.5 and 1.0 C. A charge rate of max. 0.8C is recommended for consumer-based LCO cells and batteries.

•*Saturation charge:* The voltage peaks for an LCO cell at 4.2 Volts after a certain time. At this point the cell or battery has

to reach a second charging stage known as the saturation charge. A constant voltage of 4.2 volts is maintained, and a gradual decrease in current. When the current falls to around 10 per cent of the valued current, the end of the charge period is reached.

The charge time for this stage could be about two hours, depending on the type of cell and the manufacturer, etc.

The efficiency of charging, i.e. the amount of charge that the battery or cell maintains versus the amount of charge that enters the cell, is high. It is possible to achieve load efficiencies of about 95 to 99 per cent. This represents relatively low rise in cell temperature. The mechanism needed for charging and discharging by the lithium ion battery includes:

•*Charge current:* The charge current must limit for li-ion batteries. Typically, the maximum value is 0.8C, but lower values are more usually set to give some margin. Some faster charging may be possible for some batteries.

•*Charge temperature:* The li-ion battery charge temperature should be monitored. The cell or battery must not be charged when the temperature is lower than 0°C or greater than 45°C.

•*Charge current:* Discharge current protection is required to prevent damage or explosion as a result of short circuits.

- Over-voltage: Charge over-voltage protection is required to prevent a voltage that is too high being applied across the battery terminals.
- Over-charge protection: The over-charge protection circuitry is required to stop the Li-ion charging process when voltage per cell rises above 4.30 volts.
- Reverse polarity protection: Li-ion battery reverse polarity protection is needed to make sure the battery is not charged in the wrong direction as this could lead to serious damage or even explosion.
- Li-Ion over-discharge: Over-discharge protection is required to prevent the battery voltage falling below about 2.3 Volts dependent upon the manufacturer.
- Over temperature: Over-temperature protection is often incorporated to prevent the battery operating if the temperature rises too high. Temperatures above 100°C can cause irreparable damage.

**C. MAKING OF A LITHIUM ION BATTERY PACK:**

We have made a Lithium-Ion battery pack with the battery cells of Ultrafire company having 3.7 volts and 7800 mAh capacities. Each pack contains 8 battery cells and connection made such as it gives around 150 watts power output.



Figure 1. Lithium-Ion battery pack

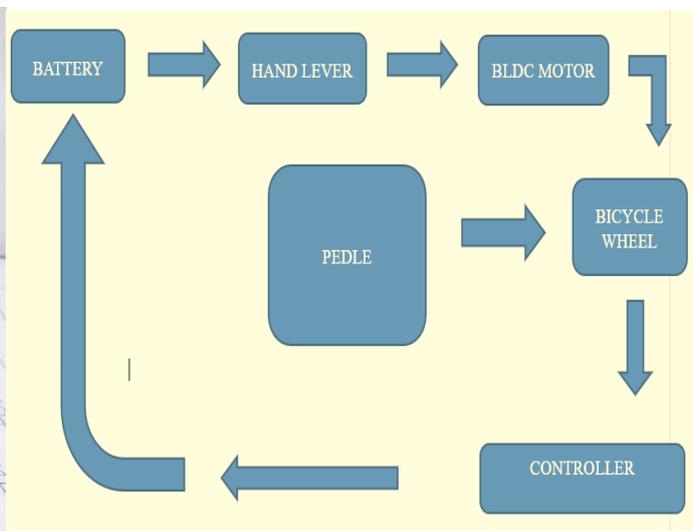


Figure 2. Flow chart of E-Bike

**D. CALCULATIONS**

For the battery pack we have got the li-ion cells of rating 3.7 volts and 7800 mAh. So, the power of one cell will be:

$$P = VI$$

Where, P = power (watts), V = voltage (v), I = current (Ah)

$$P = 3.7 \times 7.8 = 28.86 \text{ watts}$$

We have the two packs of 8 cells in a battery pack hence total power will be  $P = 8 \times 28.86 = 230.88$  watts for single pack

For the charging we have to set charger voltage and current ratings for the normal and rapid charging.

**Normal charging time:** For the normal charging we have set ratings at 4Ah and 15 volts. Hence, charging period will be  $P = 15 \times 4 = 60$  watts and  $T = \text{total power of package} / \text{power input by charger} = 230.88 / 60 = 3.85$  hours i.e. At normal speed it will take 4 hours.

**Fast charging time:** For the fast charging we have set ratings at 10Ah and 15 volts. Here the voltage is kept constant for avoid the over-heating issue in the charger. As well as the current also kept in control for the avoid the burning of the circuit.

$P=15 \times 10 = 150$  watts and  $T = \text{total power of package} / \text{power input by charger} = 230.88 / 150 = 1.54$  hours. i.e. At the fast charging it will take 1.54 hours to full charge.

**E. PROCEDURE FOR CHARGING BATTERY PACK WITH CHARGER**

In the making of battery charger we have gone through following stepwise procedure:

- At the very first step, we have connected the battery pack to the BMS system.
- At the next step we have got the required power output for the system that is 24 volts.
- We have connected the BMS to the step-down converter.
- We have done all the calculations required for the charging time and setting of the charger.
- The power supply is connected to the step-down converter.
- The voltage is set by the setting screw available on the step-down converter.
- The voltage has been set at the required setting that of 15 volts.
- The voltage is kept low for avoiding the heating of the charger or the batteries.
- The next step is to set the current at required rate that of 4 A.
- The total required output is of 230.88 watts for full charge of battery pack and the charger output will be around 56 watt per hour.
- As per calculations we will get the full charge battery at 4 hours at normal speed.
- At the end we will connect the system with the battery status indicator; which will help to provide information about the battery status at the charging and non-charging conditions also.

**III. TESTING OF BATTERY PACK ON E-BIKE**

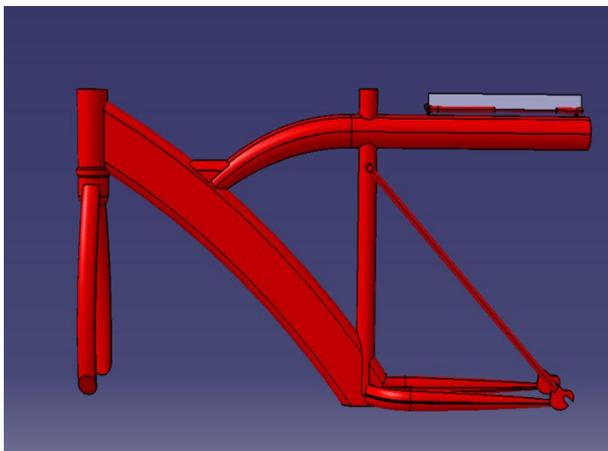


Figure 3. CATIA modelling of E-Bike frame

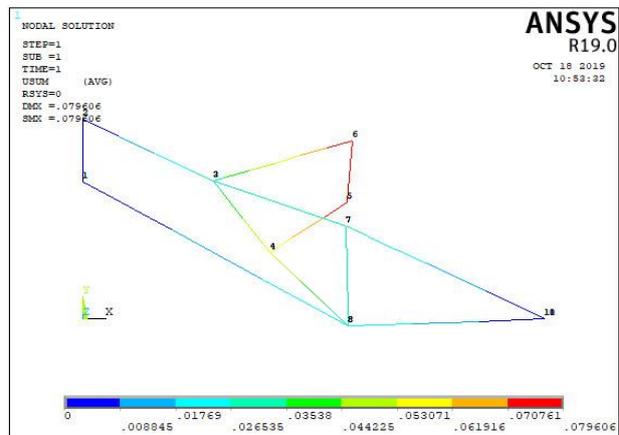


Figure 4. ANSYS analysis of E-Bike frame for 120 kg load

The designed battery pack has been tested on developed e-bike. The bike has 24 volts 250watt electric motor mounted on bike frame in such a way that it can run the rear wheel of the bike. The working flow chart is given in figure 2.

The bike frame is made up of steel and it can with stand a maximum load of 120 kg. The components such as electric motor, battery pack, controller, hand lever and pedal system are mounted on bike frame. The bike frame is designed in CATIA software and analysis is performed in ANSYS software.

During testing the E-Bike the following observations have been observed:

- 1.The developed li-ion battery pack of capacity 230 watt supplies rated power to electric motor.
- 2.The E-Bike has traveled 24 km of distance for one completely charged li-ion battery pack at optimum conditions.
- 3.There is no any heating issue or any electric damage observed.
- 4.The same E-Bike has been tested using lead acid battery of capacity 250 watts for which it has covered 18 km of distance
- 5.The weight of li-ion battery pack of capacity 230 watt is six time lighter than that of using lead acid battery of capacity 250 watts.

#### IV. CONCLUSION

The basic knowledge about electronic and electrical connections for making power charger and Li-ion battery pack has acquired. By the pack of two 8 cells of 3.7V and 7.8Ah we have got power pack of 230.88 watts of lithium-ion battery pack. At the normal speed with rating of 15V and 4 A we will get the battery full charged in 4 hours approximately and at the fast charging stage with ratings of 15V and 10A we will get battery full charged at 1.54 hours approximately. The use of CATIA and ANSYS software for E-Bike frame design has been utilized successfully. During testing the E-Bike with li-ion battery pack has covered six more kilometer of distance than using lead acid battery pack.

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