A Project Report on

Battery Characteristics and Fast charging for Li-ion Batteries

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Certificate

This is to certify that the dissertation titled, **Battery Characteristics and Fast charging for Li-ion Batteries**, submitted by **Aditya Kolte** is approved as the Mini Project for seventh semister in the course of Engineering in Instrumentation and Control of Vishwakarma Institute of Technology, Pune.

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Abstract

A battery charger or recharger is a device used to put energy into the secondary cell or rechrgable battery by forcing an electric current through it. In this paper we discuss how to minimise the charging time of cell based batteries. The setup made as a prototype consists of Variable voltage-Variable current power supply, Discharge module and the Battery charger. Also a new design of the battery pack is proposed. The results and observation are recorded and documented.

Chapter 1

Introduction

There are two major caterigories for classifying storage elements - Rechargable and Non-rechargable. In this project we focus on rechargable Batteries(mainly Li-ion).
Every Battery consists of two electrodes and an electrolyte. Different types of batteries can be made by changing the materials used for the electrodes and the electrolyte used.

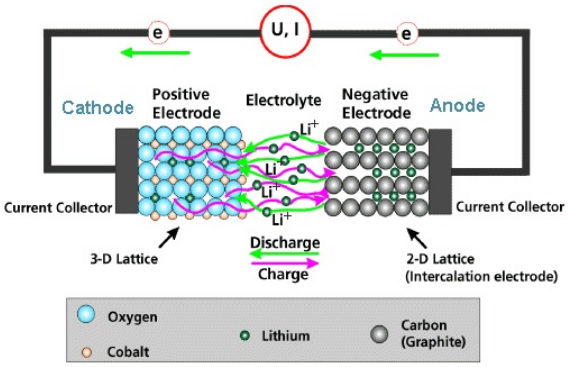

Figure 1.1: Basic working of a battery

Advancements of technolgy have lead to vast developments in storage technologies and still research is being conducted. The main objective is to store maximum amount of energy for longer durations.
Also the time required to store the energy i.e. the charging time, is also an important factor of consideration when we talk about the different storage elements. In the next figure we can observe the different storage technologies available and also different types of battery technologies.

As we can see from the above figures that there are better storage options like Hydrogen cells. But still it will be atleast a few decades before that technology becomes

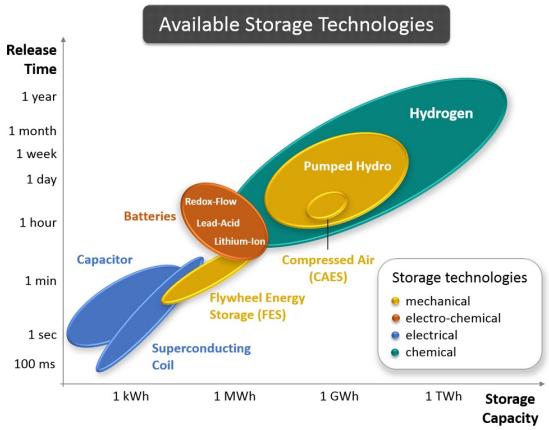

Figure 1.2: Available Storage Technologies

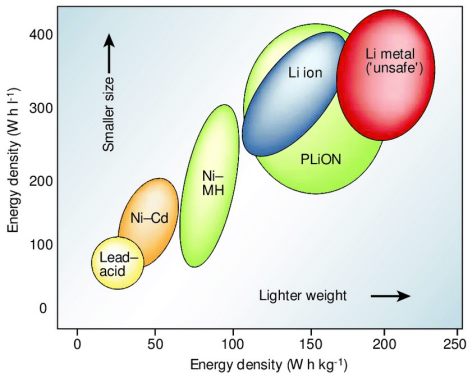

Figure 1.3: Available Battery Technologies

available to everyone.
Currently worldwide the most used type of batteries are Li-ion batteries amd just like Lead Acid batteries these batteries are here to stay with us for a long time.
The advantages of Li-ion being - their low self discharge and longer lasting health. A number of cells can be put together to get a battery of a required Current/Voltage rating.

Basic Comparison between Lead Acid and Li-ion batteries can be seen below -

Please note that the comparison given is a generalised comparison and the characteristics may vary for a particular type of battery variant of the battery family.

Li-ion Batteries further can be differentated by the battery chemistry. Some examples of different Li-ion batteries and their uses are given in the table below -

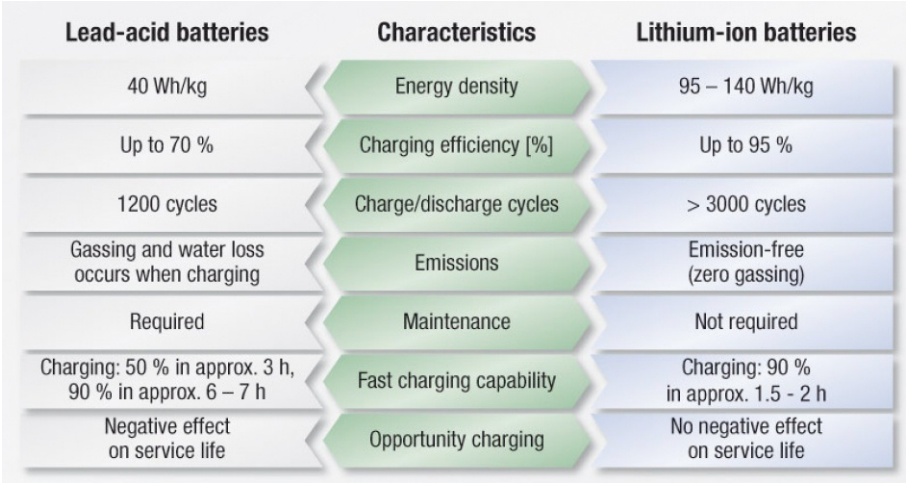

Figure 1.4: Lead acid vs Li-Ion

Cathode Type	Chemistry	Example Metal Portions	Example Use
NCA	LiNiCoAlO2	80% Nickel, 15% Cobalt, 5% Aluminum	Tesla Model S
LCO	LiCoO2	100% Cobalt	Apple iPhone
LMO	LiMn2O4	100% Manganese	Nissan Leaf
NMC	LiNiMnCoO2	Nickel 33.3%, Manganese 33.3%, Cobalt 33.3%	Tesla Powerwall
LFP	LiFePO4	100% Iron	Starter batteries

Figure 1.5: Li-Ion Types

CHARACTERISTICS OF THE MAIN LITHIUM BATTERY SYSTEMS

Primary Lithium	$LiSOCl_2$/bobbin w/Hybrid Layer Capacitor	$LiSOCl_2$ Bobbin-type	$LiSOCl_2$ Spiral Wound	$LiSO_2$	$LiMnO_2$
Energy Density (Wh/l)	1420	1420	800	410	650
Power	High	Low	High	High	Moderate
Voltage	3.6-3.9V	3.6V	3-3.6V	2-3V	2-3V
Pulse Amplitude	High	Small	Moderate	High	Moderate
Passivation	Low	Fair	Moderate	Fair	Moderate
Performance at Elevated Temp.	Excellent	Fair	Moderate	Moderate	Fair
Performance at Low Temp.	Excellent	Fair	Excellent	Excellent	Poor
Operating Life	Excellent	Excellent	Moderate	Moderate	Fair
Self Discharge Rate	Very Low	Very Low	Moderate	Moderate	Moderate
Operating Temp.	-55°C to 100°C	-55°C to 125°C	-55°C to 85°C	-55°C to 60°C	0°C to 60°C

Figure 1.6: Li-Ion Characteristics

Chapter 2

Standard Charging Techniques

The most common cell charging methods adapted is a two phase method. Constant current phase followed by constant Voltage. Many developments have been made in the charging techniques and advances include trickle charge, pulse charge, etc. But the basics remain the same.

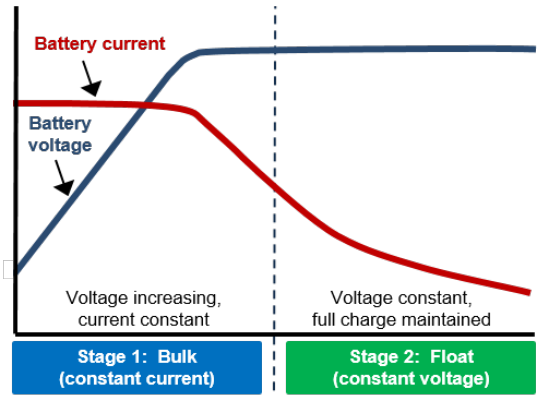

Figure 2.1: Basic Two stage charging

In the constant current phase the charging current is kept constant, i.e. constant charge is supplied to the cell per unit of time. This is continued till the cell reaches 0.8-0.9 times its full charge voltage. After this the Charger output Voltage is maintained constant and thus constant voltage phase is started. In constant voltage phase the current to the cell starts to decline. This indicates that the cell is reaching its max capacity. The important points to consider are -

1) Maximum current during Constant Current phase
2) At what Cell Voltage should we shift from CC to CV
3) At what value of Current should we stop the charging

These 3 points can play an important role in the efficiency of charging and maintainting healthy Cell life.

Now some other parameters to consider is - Temperature of the Cell during charging. Temperature plays important role in preserving cell life. Commonly heating in cells is observed due to uncontrolled or heavy current flow through the battery.

2.1 Cell vs Battery

There is a common confusion among cell and battery as most of the times battery is used to refer to an energy storage element.
A cell is an individual unit, and a series and parallel combination of cells is what makes up a battery.
Example of a battery can be seen in the image below -

Figure 2.2: Li-ion Cell

Figure 2.3: Li-ion Battery Pack

As we can see in the above images a battery pack is a combination of a number of cells.

So consequently charging of a battery pack has its own challenges -

1) As cells are connected in series higher Voltages are required to charge the battery.
2) Cell balancing has to performed to ensure that all cells are charged to same Voltage.
3) As many cells are stacked close to each other heating of the cells is more prominent.
The first and third point are of less concern, the main point of our focus is cell balancing.

Another point to note is if a cell has minimum charging time T, then a battery pack consiting of N such cells requiers a time 2-3 times T.
Theoretically speaking the minimum time that a battery pack can be charged in, should ideally be the charging time of one cell. So after achieving this minimum time the only advancements possible are chemical advances in cells to minimise their individual charging times.

2.1.1 Cell balancing

Typically the individual cells in a battery are not exactly identical and may be at different state of charge(SOC). This is due to the manufacturing variances, assembly variances, differnet histories experienced amongst the cells in a battery pack.

Without effective and appropriate balancing, discharging during use must stop whrn the cell with the lowest capacity is empty(even though other cells aren't), this limits the energy that can be taken from and returned to the battery.

Without balancing the cell with the lowest capacity can be easilty overcharged or overdischarged whilst the cells with higher capacities are only partially discharged.

Another problem that arrises due to variation of cell voltages in a battery pack is that due to existance of potential difference present a current satarts to flow within the cells, the magnitude of this current is depending on the differnce in Voltage of two cells. This could lead to heating of the battey pack and naturally will decrease the life of the cells.

Here, in this paper we focus on cell balancing at the time of charging and later part of the paper includes a circuit design to ensure that all Cells are charged to same Voltage.

Chapter 3

Prototype setup

The prototype consits of -
1) Adjustable Voltage – Adjustable Current SMPS supply
2) Voltage/Current Measurement + Display
3) Discharge test Module
4) Charging circuit
5) Proposed Battery pack design

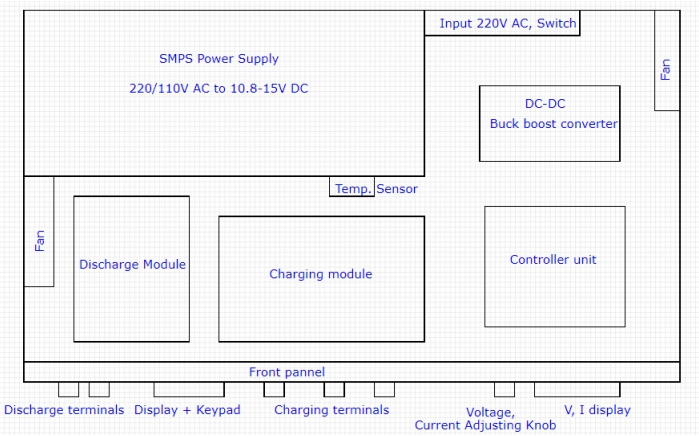

Figure 3.1: Prototype layout

The SMPS and Buck make up the Adjustable V/I power supply. The SMPS acts as the supply unit for the entire prototype.
SMPS rating - 12V, 10A , 120Watt.

3.1 Discharging Module

The circuit diagram is as shown below -

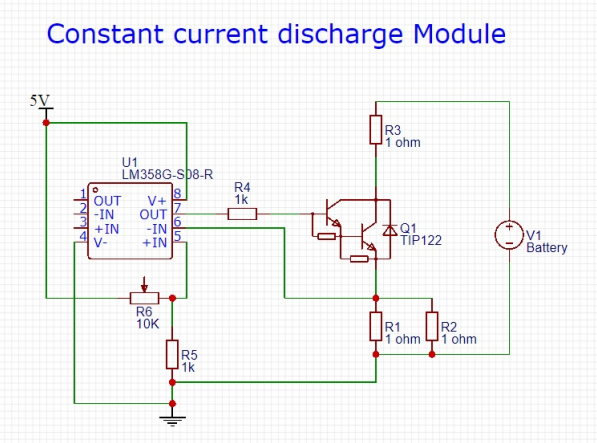

Figure 3.2: Discharging Module Schematic

The discharging Module consists of TIP122 Power transistor, Op Amp LM358 and 1 ohm, 0.5 ohm 10W resistors. The circuit a constant current sink ciruit. The voltage accross the 0.5 ohm resistor is copared with a reference value set by adjusting the POT. When the Voltage across the 0.5 resistor is greater than reference the op amp output becomes low and TIP122 is turned OFF, and When the Voltage across the 0.5 resistor is less than reference the op amp output becomes HIGH and TIP122 is turned ON.
In practicle the TIP122 operates in active state and the C-E Voltage drop is adjusted by the op amp output to limit the current in the 0.5 ohm resistor.
The current and the Voltage of the source to be discharged is monitored and displayed on the LCD screen. When the required End of discharge voltage is reached the discharge is stoped.

3.2 Charging Circuit

The charging circuit for one cell is designed using LM2576adj Voltage regulator IC. LM2576adj is a switching mode voltage regulator IC. It has a closed loop control circuit inside it. The Duty cycle of switching is varied according to the voltage at the feedback pin. If Feedback voltage greter than 1.23V then the duty cycle is reduced and if feedback voltage is less than 1.23V then the duty cycle is increased. An adjustable Voltage Buck converter is implemented as shown in the figure.
A 0.1 ohm shunt resistor is connected in series. The Voltage across this shunt resistor is used to measure the current flowing into the cell. The measured current is compared

to the a predefined Current limit Ilim. If the current is greater than Ilim then the feedback pin of LM2576adj is made high thus reducing the duty cycle which leads to reduction of the current. This adds a current control feature to the charging circuit.

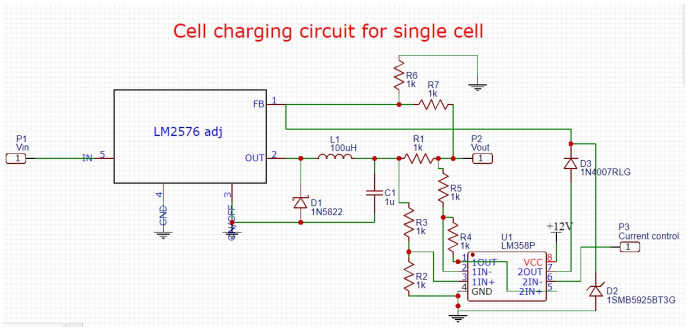

Figure 3.3: Charging Circuit for 1 cell

The above circuit is for one individual cell. In the prototype there are 6 such channels in parrallel so it can charge a maximum of 6 cells at a time. The design can be further extended to any number of cells. The cell voltage and charging current are monitored by the microcontroller and it automatically shifts from CC to CV. The Charging current of each cell will be displayed on the LCD display. The charging will be terminated for each cell as soon as the current falls below the define (0.1*C) rating of the battery(can be fed to the uC).

3.3 Proposed Battery Pack

The main objective to design the charger with 6 parallel channels is to minimise the charging time of the whole battery pack to the charging time of 1 cell. Therefore all cells should be isolated and in parallel at the time of charging. But during discharge they can be in any series parallel combinations.
For the above the proposed battery pack structure is shown below -

The circuitary consists of -
1) IBM - This is an individual cell module, which is the overcurrent and overcharge protection circuit. It also consists of switching elements, here-relay to switch between discharging and charging module.
2) Discharging Module - The discharging module ensures the series and parallel combination of cells during discharge operations.
3) Charging circuit - This circuit is such that all the cells are isolated from each other,

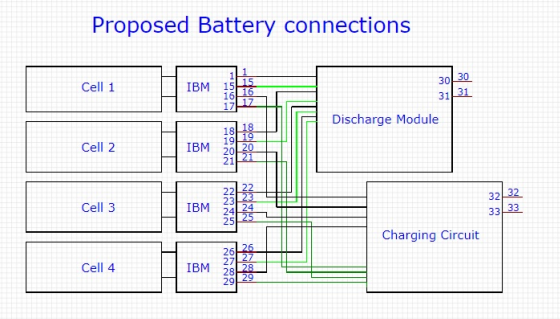

Figure 3.4: Proposed Battery Pack connetions

the ground of all the cells is shorted and the cells are connected to the charging cable.

The USPs of this battery pack and charger combinations are -
1) Cells are isolated from each other during charging, no interaction among the cells.
2) Balancing is done easily as every cell individually is charged to its max Voltage(ensured by charger).
3) No heating was observed even during Fast charging.
4)The time required to charge the whole Battery pack is almost equal to charging of one cell.

Along with the above advantages there are some minor disadvantages -
1) Number of wires in the battery pack is increased.
2) Size of the battery pack has a small increment.
3) Non identical properties of ICs, passive components used in the circuit are to be taken care of by the microcontroller.

Chapter 4

Protype Images -

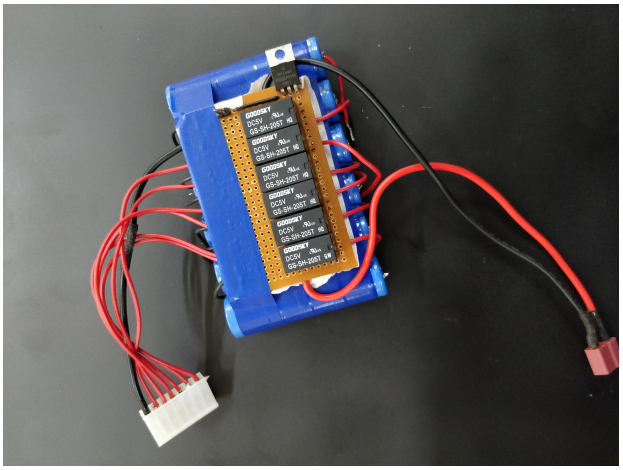

Figure 4.1: Proposed Battery Pack connetions

Figure 4.2: Testbench

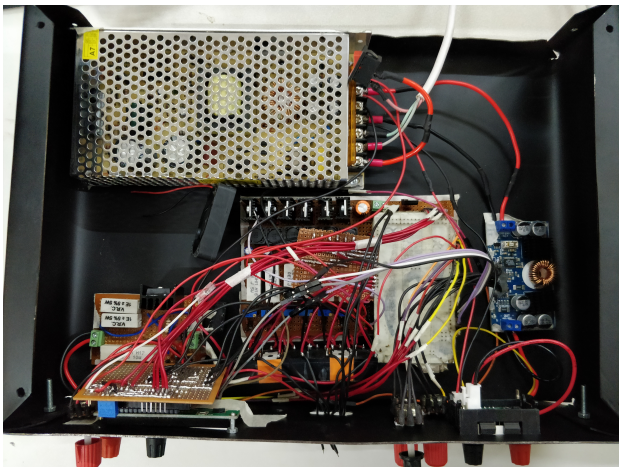

Figure 4.3: Top View

Figure 4.4: Front View

Chapter 5

Conclusion and Future Scope

This paper is Proof of concept of a Battery pack and Charger design to get the minimised charging time for a Battery pack. A whole setup consisting of A V/I adjustable power supply, 6 cell battey charger, Constant current discharger was designed and implemented. A battery pack design was proposed to minimise charging time and get better cell voltage balancing. The charging time of the battery pack was recorded to be about 1hr which is almost equal to charging time of the lgdas31865 cells used. Effective cell balancing was achieved. No heating of the cells was observed during the charging process, indicating no harm to battery life. The discharge module can be used to discharge a battery at const current and also determine the capacity of the battery.

As we move towards Non Conventional Energy Systems, the need of energy storage increases thus batteries with good storage capacities will gain popularity. Around the globe Li-ion technology is currently at peak as sufficient research has been done on the topic. With proper design the same circuit design can be extended to higher current rating batteries. The method though demonstrated on a Li-ion battery/cell, can be extended to any type of cell based battery. The Relays used in the battery pack design can be replaced by ststic switches to reduce size, also shortcircuit and overcurrent protection can be added for each cell individually(Circuit diagram discussed). So overall the circuit has no battery size limitations and can be replicated for any size of the battery.

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