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Battery Management System using Passive Elements and Arduino

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Abstract: ***Li-ion batteries are used in the fields of electric vehicles and energy storage because of low self-discharge rate, long cycle life high energy density, and have wide operation temperature range. For safety and proper management of Li-ion battery packs, a battery management system (BMS) is required. Balancing process is important for keeping battery lifespan and protecting the battery cell in series connection. Commonly, passive balancing is widely used in BMS because it is cheap and simple to implement. The passive balancing used passive element (resistor or diode) to discharge the excess charge of battery. A BMS is designed using hardware components like resistors, diode, transistors, led etc. Here we are using MOSFET for switching voltage to balance the cells and with the help of a diode and resistor we will discharge the battery. The experimental platform has the following functions: voltage and current measurements, SOC calculation, cell balancing, and charging of cells, etc.***

Keywords-battery; BMS; battery pack; lithium ion; transistor; passive balancing

1. Introduction

Nowadays, battery technology is growing very fast to store energy in traction and power applications like Hybrid Electric Vehicles, Electric Vehicles, industrial vehicles, Energy Storage Systems. The lithium batteries are used for energy storage because of its high-power density and long lifespan. Depending on the application, a large number of cells are connected in series to increase the voltage or in parallel to increase the current of the battery pack. After several charge/discharge cycles, an individual cell can have lower performance and capacity, so the capacity of the entire battery pack will be reduced. A Battery

Management System (BMS) has the main role to ensure safety as well as prolong the service life of batteries. The most important feature of a BMS is balance the cell (Cell Balancing), which distributes the energy among battery cells equally. BMS should contain methods to measure and estimate the SOC (State of Charge), DOD (Depth of Discharge). Also, it has protection for overcharging and deep discharging. After discharging there is a difference in voltage of the cells which are connected in series. This is caused due to imbalance in SOC (State of Charge) or total capacity imbalance.

Basically, there are two kinds of cell balancing methods, namely passive cell balancing and active cell balancing. The main difference between these two methods is that passive cell balancing balance the series connected cells by burning the extra energy of the most charged cells, whereas in active cell balancing it redistributes the energy of the strong cells to the weak cells. Passive cell balancing is widely used in industrial applications due to its reliability, simplicity, and cost-efficient characteristics Usually, the passive method disposes of some electric charge from overcharge cell through resistor element until matches to SOC (State of Charge) reference or voltage reference. In this paper, MOSFET is used as a switch, which is control by PWM (Pulse Width Modulation) waves, given by a micro controller to balance the overcharged cells to match the threshold voltage during the charging process.

However, many challenges still remain in developing BMS:

1) The circuit of BMS is complex as we are using passive element (MOSFET, resister, diode)for balancing.
2) SOC is difficult to estimate perfectly.
3) The balance control of cell in an Arduino is difficult.

2. Literature Survey

Through this concept, the aim is to design a system which manages voltage and SOC (state of charge) of the battery pack by balancing the cells. Here balancing is usually done during charge process when the voltage of a cell has reached full voltage limit. This method is appropriate for charging, because a some of the energy in a battery will be disposed of. Balancing algorithms for passive cell balancing usually based on voltage balancing strategy. The balancing strategy consists of detecting the voltage of all cells and compared with a threshold voltage. If the voltage of a cell exceeds the threshold voltage, then the energy in the battery will be disposed of through the resistor combined with an internal resistance of MOSFET and prevents the cell from overvoltage. If the voltage of a cell is less than the threshold voltage, then it will increase in charging process.

A. Resistor

A resistor is a component that limits or regulates the flow of electrical current in an electronic circuit. Here resistors are used to discharge cells. Which helps in the balancing process and prevent from overvoltage. It decapitates the extra energy in the form of heat.

B. Diode

Diode is a two-terminal electronic component in which the electric current flows in one direction. Here diode is connected in series with resistor and parallel to the cells. It is used block the current in the backward direction.

C. MOSFET

MOSFET (Metal Oxide Semiconductor Field Effect Transistor) transistor is a semiconductor device which is used for switching in the electronic devices. Here MOSFET is used for switching the terminals of cells for cell balancing. MOSFET is operated with PWM (Pulse Width Modulation) Which is generated by micro controller.

D. Micro Controller

A microcontroller is a device which integrates the number of components of a microprocessor system on a single chip. Here Arduino is used as a micro controller which generates PWM (Pulse Width Modulation). First, the cell voltage is measured by the Arduino from analog pin then it is compared with the threshold voltage, and switch the MOSFET accordingly.

3. Approach

Here we are using a battery pack of 4 li ion cells in series as given in the simulation.
4*3.6V=14.4V and 1*2600mAh=2600mAh

The battery pack is of 14.4V,2.6Ah (which can be used as auxiliary battery in electrical vehicle) Each cell positive is connected to the analog pin and negative terminal to ground pin of the Arduino. Which will measure the voltage value by taking input from analog pin. The range of analog pin is up to 5V so, we can measure easily. A resister, MOSFET and diode is connected in series with all cells for discharging of cells. Resister works as a load for discharging the cell, Diode make it unidirectional so, that it will not discharge while charging and MOSFET for switching it from charging to discharging.

The microcontrollers now compares the cell voltage with the reference voltage (4.2V) and switch the MOSFET accordingly by PWM signal which is also generated by microcontroller. If any cell reaches to the full voltage then it gives PWM signal to MOSFET and the resister circuit activates by which the cell started discharging while other are charging at that time. Likewise, this process continuous till all cell reaches full voltage.

In this process all cells are charge and balanced equally.

Calculations of components

Resistor =V/I =4.2/0.8 = 5.25 ~ (5-10) ohm

Diode =1N4007
Average Forward Current IF(AV) 1.0A
Peak Forward Surge Current IFSM 30A 8.3ms
Instantaneous Forward Voltage VF 1.1V

MOSFET= N channel IRF540
As its switching characteristics are
VDD = 30 Vdc, ID = 15 Adc, VGS = 10 Vdc, RG = 4.7 Ω.

We ae using these components because these are satisfying our requirement.

Duty cycle of PWM wave

Duty cycle = {pulse width (Tw) / time period (T)}*100
= {2/10} *100 =20%
This depends upon the input taken by the microcontroller.

Switching Frequency of MOSFET

Fsw = 100kHz

Power Losses of MOSFET

D = 0.2, fsw = 100kHz, Vin = 12v, I = 1A, VDD = Vin =12v, Rds=4.7Ω, tr = tri = trv = 10ns, tf = tfv = tfi = 8ns
Pcond=0.94W
ton = 18ns
Eon = 0.108μj, Eoff = 0.108μj,
Pon = 0.0108W,Poff = 0.0108W
Totalloss=Pcond +Pon + Poff=(0.94+0.0108+0.0108)W
Total loss =0.9616W

4. Calculation

SOC calculation for the pack

SOC is one of the most important parameters of Li-ion batteries, which plays an important role in BMS. Accurate SOC estimation is also a basic parameter to determine the mileage of electric vehicles, as well as a control index for BMS to improve the performance of the system. The SOC for a battery is calculated by the formula:

$$SOC = SOC_0 - \frac{1}{Q_N}\int_0^t \eta I \, dt \qquad (1)$$

Soc% = {(amount of charge now / actual charge) *100}
If the capacity is measured to be 2000mAh and the actual Capacity is 2600mAh.
Soc = (2000/2600) *100 =76.92%.

5. Block Diagram

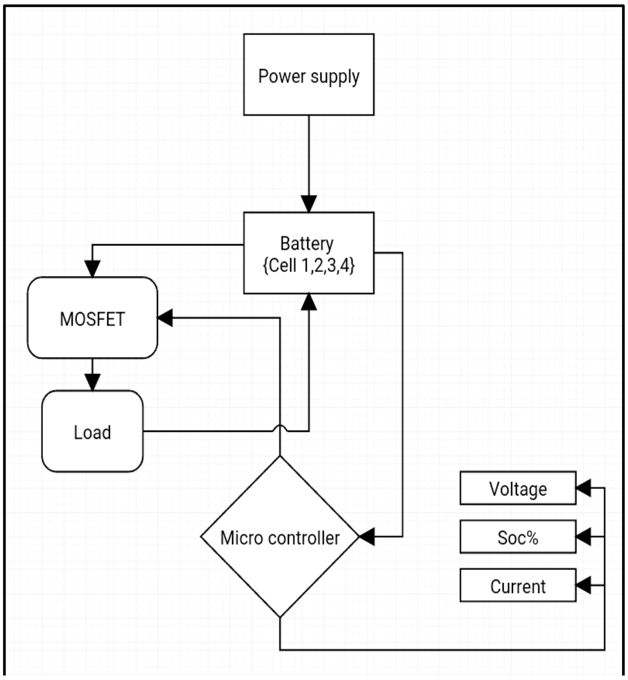

Figure 1: Block diagram of proposed system

6. Circuit Diagram & Output Graph

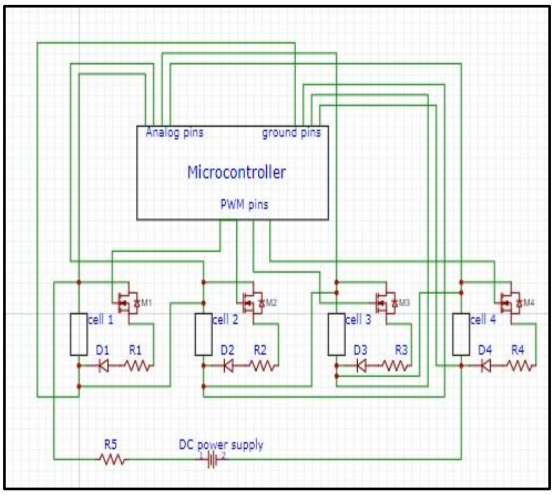

Figure 2: EasyEDA circuit diagram

7. Simulation

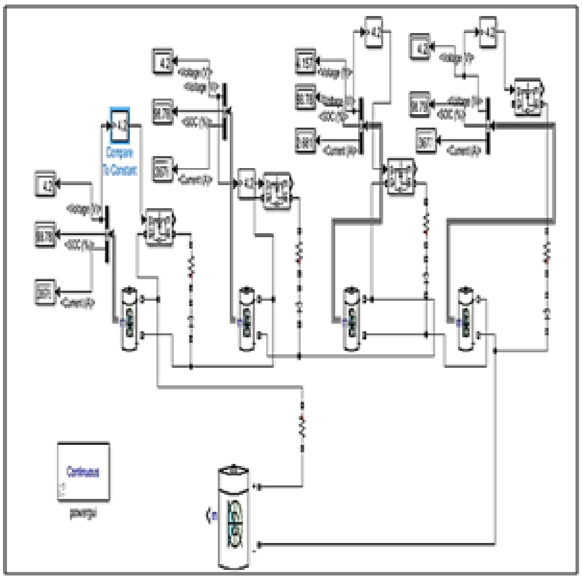

Figure 3: MATLAB Simulation of proposed system

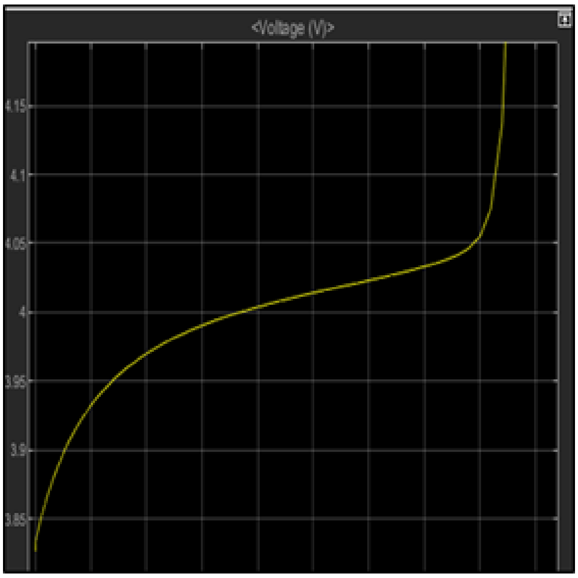

Figure 4: Charging curve of single cell

Real Model

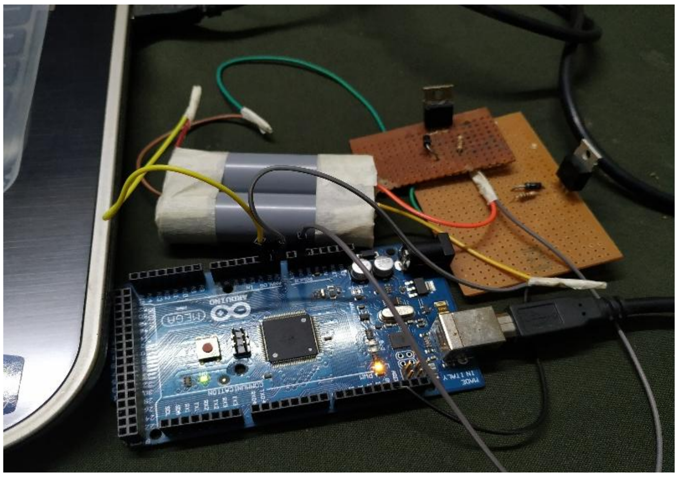

Figure 5: BMS control system and batteries of two cells

Main parameters of the lithium ion battery
Type Lithium cobalt ion battery
• actual capacity 2.6 Ah • lower limit voltage 2.8 V • upper limit voltage 4.2 V • nominal voltage 3.6V

8. Advantages of the System

- Can be made with simple passive components.
- As we are using passive balancing so, simple operation of the circuit.
- Cost efficient.
- Can be used in any small configuration battery pack.

9. Conclusion

By the end of this project we get an easy and simple solution of making Battery Management System BMS using passive elements. With the help of this BMS we can make auxiliary Battery for electric Vehicle, the desired objective is achieved in the proposed paper.

10. Future Scope

More components like temperature sensor, current sensor, cooling unit can be added for better charging and protection of the battery pack. In place of microcontroller we can use transistor and variable resistance for reference voltage (4.2V) and balance the cell accordingly. Also, Active balancing (like capacitor can be used to store the excess energy and supply back to the cell for charging) can be done to avoid heat losses and make energy efficient.

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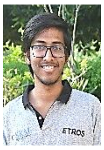

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