# Analysis of Battery Management Systems

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**ABSTRACT**: The battery management systems also referred to as BMS is a battery management unit that is not only responsible to measure the state of battery accurately, but it also ensures safe operation and also a prolonged battery life. Because of their high energy density, lifespan, nominal voltage, power density, and low cost, lithium-ion (Li-ion) batteries have received a lot of attention in the EV industry. A smart battery management system (BMS) is an essential component in electric vehicles it not only measures the states of the battery accurately, but it also ensures safe operation and extends battery life. Estimating the state of charge (SOC) of a Li-ion battery accurately is difficult due to the battery's highly time variant, non-linear, and complex electrochemical system. So in this paper we will study about the various parameters related to battery performance like the state of charge, state of health and also look at over charge and under charge circuits that were designed to monitor the battery health.

**KEYWORDS**: State of charge, state of health, lithium ion batteries, matlab.

## I. INTRODUCTION

What is BMS

The lithium ion batteries that are used now a days are very fragile in nature when compared to lead-acid, or NiCd batteries which makes them useful in various applications like cell phones or industrial equipment etc. these lithium ion batteries that are used, needs a management system to monitor its health by calculating various parameters. The complexity of any battery management system totally depends on the type of application for which this system has to be designed. for applications like mobile phones or e-book readers etc, a simple BMS IC can be used, this IC will monitor the voltage, current, state of charge and various other parameters. these parameters will give us the overall health of the battery. But for bigger applications like electronic vehicles, we need a better alternative. A normal IC won't be sufficient. We need very high-end algorithms and processing to measure various parameters. We will go through these in detail as we move further with our paper.

First in this paper we will go through various battery management system requirements in detail to understand how can we actually optimise the performance of the lithium ion batteries in any system.

Battery Management System Requirements

Several factors must be considered when designing a bms. There are various Relevant parameters include temperature acquisition, voltage and current acquisition, battery pack etc that are important to ensure proper EMI robustness, functional safety in terms of redundancy, galvanic isolation, balancing, and power consumption.

Temperature acquisition: One of the most difficult tasks in BMS design is determining the most accurate temperature possible. It is sometimes necessary to obtain peripheral temperatures, such as those of contactors, fuses, or even the electric busbar. Heavy copper bus bars should be avoided as much as possible. Temperature requirements must take into account three use cases: charging, discharging, and storage. Temperature sensor to voltage sensor channel ratios typically range from 2:3 to 2:12. At too high current rates, the significant effect of lithium plating can occur in the normal temperature range.

Voltage acquisition: A battery management system for lithium based batteries needs to have at least one voltage acquisition channel per serially connected cell. High data acquisition rates are advisable, if oversampling is chosen to have a positive effect on the system behaviour. When large pulses occur in an application, faster monitoring can be necessary.

Current acquisition: For dynamic SOC determination, coulomb counting is used. This method simply integrates the current flowing into or out of a battery. The determined SOC will be different from the actual SOC due to noise and offsets. There are approaches using algorithms and parametrised models to retrieve usable SOC values.

Balancing: There are several factors that have to be taken care of before a battery can be charged and discharged, e.g., resulting from weight constraints, or required charging currents that lead to balancing currents.

So in this paper our main objective is to study about the the state of charge and state of health of the battery. Once studied, the simulation results are then observed using MATLAB (Matrix Laborotory). The flow of the paper will be such that we will first Monitor the cell voltage and temperature. Then the values of state-of-charge and state-of-health are estimated. Once that is done for those values we will limit thepower input and output for thermal and overcharge protection.

As lithium ion cells are used so we need to balance the state of charge of these individual cells. After this is done we need to isolate the battery pack from the load whenever necessary to avoid unnecessary loading effects in the circuit. Then the entire design was implemented on the software using MATLAB and Simulink. Once the simulation was done, the algorithm was deployed on a raspberry pi microcontroller and finally it was tested on a lithium ion battery pack.

## Literature Survey

[1]Many battery-operated industrial and commercial equipment use battery management systems (BMSs) to make battery operation more efficient and battery estimates nondestructive state. The study is related to existing BMS methodologies and proposes a new design methodology for a generalized dependable BMS. This BMS has a number of advantages over existing systems, the most important of which is that it is fault-tolerant and has battery protection. The proposed BMS is made up of a series of smart battery modules (SBMs), each of which performs battery equalization, monitoring, and protection for a string of battery cells. In the lab, an evaluation SBM was designed and tested, and the practical findings back up the theoretical predictions.[2] The hardware components of battery management systems (BMS) for electric vehicles and stationary applications are the subject of this research. The goal is to provide a high-level overview of existing principles in cutting-edge systems, allowing the reader to estimate what has to be considered when creating a BMS for a specific application. Following a brief review of general needs, various different battery pack topologies and their implications for the BMS' complexity are considered. As examples, four battery packs from commercially available electric vehicles are displayed. Later on, implementation difficulties such as measuring required physical variables (voltage, current, temperature, etc.) as well as balance issues and solutions are examined. Finally, safety and dependability factors are explored.[3] The battery is an important component of a hybrid electric vehicle's (HEV) drivetrain. The battery's unpredictable internal resistance change throughout the operating cycle is a significant constraint to its effective performance and reliability. Because temperature has a significant impact on internal resistance, the battery management system keeps track of cell and battery pack temperature in relation to the state of charge to avoid thermal runaway. In order to improve their performance, Li-ion batteries, which provide prospective solutions to HEVs' energy and power density demands, require a good thermal management system. The goal of this work is to create a battery pack model that looks at how internal resistance changes as a function of temperature.[4]A battery management system (BMS) is a system that controls the operation of a rechargeable battery (cell or battery pack) by preventing the battery from exceeding its safe operating limits and monitoring its state of charge (SoC) and condition of health (SoH). BMS has been a vital component of hybrid and electric vehicles (HEVs) for many years (EVs). With run-time battery monitoring for any critical hazard circumstances, the BMS ensures the system's and user's safety. The design and simulation of BMS for EVs are presented in this paper. The whole BMS model, as well as all other BMS functional blocks, are implemented in the MATLAB R2012a Simulink toolbox. The Neural Network Controller (NNC), Fuzzy Logic Controller (FLC), and Statistical Model are the BMS given in this research study. The testing results are used to extract the battery parameters needed to construct and simulate the BMS, which are then incorporated into the model. The SoC is estimated using the Neuro-Fuzzy technique, which is utilized to mimic the electrochemical behavior of the Lead-acid battery (chosen for case study). The Statistical model is utilized to address the SoH of the battery. The findings of the battery cycle tests were used for initial model design, Neural Network training, and later, BMS design and simulation using Simulink. Experiments and MATLAB/Simulink simulations are used to validate the simulation results. This model has a SoC accuracy of about 97 percent and a SoH accuracy of about 97 percent.[5]The qualities and performance of batteries under various operating situations are critical in their applications, particularly in the field of electric vehicles (EVs). It is possible to forecast and optimize battery performance using an accurate and efficient battery model, particularly in practical runtime applications such as Battery Management Systems (BMS). Before building a solid battery model, an accurate method for predicting battery parameters is required. For battery modeling, three well-known battery models are often used: the Partnership for a New Generation of Vehicles (PNGV), Thevenin, and the second order Battery Model. For the prediction of three battery models, a new technique of parameter estimation was developed utilizing the Matlab/Simulink® parameter estimation tool. A 12Ah 3.7V Lithium Polymer (Li-Po) battery is put through a series of conventional tests at various states of charge (SoC), temperatures, and current rates, and the three model parameters are estimated based on the results. The spreadsheet approach for PNGV battery parameter estimate is compared to the Matlab/Simulink method for parameter estimation.

## 2. Technical specifications

In this paper there are 2 methods that we used to measure the State Of Charge(SoC). First is the Open Circuit Voltage Measurement method. Here we collect various parameters like voltage and current and then finally using MATLAB simulation results are seen.

### 1.1 Data collection circuits for current measurement

First we will need the current and the voltage values for further data processing. In the circuit shown below, the current measurement is been carried out

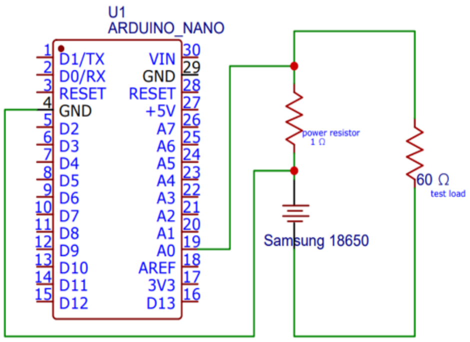



Fig.no. 1a

Here battery connected the to a 1 Ω power resistor and a 60 Ω test load using a setup similar to the Arduino voltmeter. The Arduino analyses the voltage drop across the power resistor before using Ohm's Law: I=V/R. The Arduino then uses the Serial monitor to send the current value to Python.

This is the complete circuit which has a relay and we will see the functioning of this circuit in detail

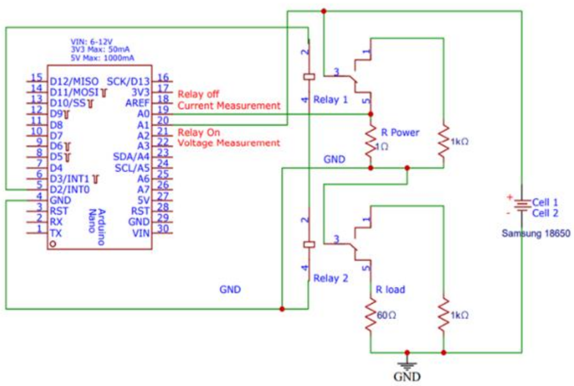



Fig.no.1b

Relay Off: Current Measurement: The battery is connected to load and discharges through R-Power. Arduino measures the voltage drop across R-Power by measuring the drop between A0 and GND.

Relay On: OCV Measurement: Arduino writer D2 to HIGH, which energizes the relay and disconnects the batteries from load. Arduino measures the voltage drop between A1 and GND to determine the OCV of the batteries. R1 and R2 create a voltage divider so the OCV reading stays within the Arduino's 5V measurement bounds.

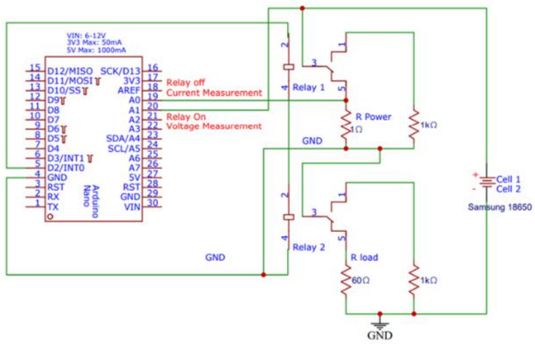



Fig.no. 1c

Over-Charge Protection circuit

Over charge protection is a very important step to ensure that our battery performance is optimised.

The circuit given above cuts off the charging half of the circuit by reverse biasing a Zener diode.

The batteries charge when the relay is in its non-energized state, so to stop charging the cells, the relay must become energized when the voltage drop across the cells reaches 8.4V. To prevent the relay from energizing before then, the ground terminal is connected to the collector of a transistor whose base is connected to a Zener diode, a Schottky diode, and a resistor.

When the batteries are below 8.4V, the voltage drop across the components in the base is insufficient to reverse bias the Zener, which prevents current flow and keeps the transistor in its non-conducting state (which acts as an open circuit to the relay).

When the batteries reach 8.4V, though, base current flows which turns on the transistor, which allows current to flow through the relay, which opens the switch and disconnects the batteries. An LED then turns on to indicate that the batteries are fully charged.

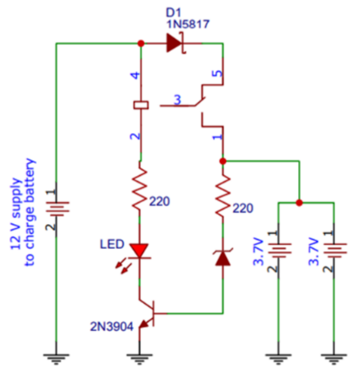
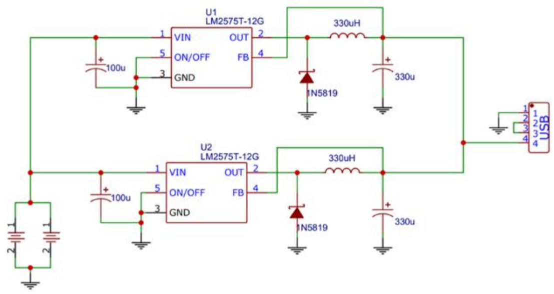



Fig.no.1d

Over-Discharge Protection circuit

A 5V regulator needs at least 5V to operate, and we need to disconnect the batteries at 2.5V So, since the 5V regulator is the only component the batteries are connected to, the circuit will open if the batteries fall below 5V as the regulator will turn off and produce no output.




2.2a Deployment of the model on raspberry pi and testing it on lithium ion battery pack

We trained a model on raspberry pi . the inputs to this model are voltage, current and the charging , discharging rate of the battery. We took this as an input since these are some parameters that has the maximum effect on the battery performance.

Finally the output can be observed a display/monitor connected to Raspberry Pi 3. The following parameters line the SOC(State Of Charge), SOH(State Of Health) , Qm (measured maximum capacity in A-hr) and EoL are observed as the output.

2.3 Data Analysis

SOC based on OCV measurements

- During data collection, the Arduino collected over 50k data points during a ~21 hour discharge.
- OCV measurements as [measurement number, OCV], normalized the data points to a 0 to 100% scale, from which a polynomial function is fitted to get the state of charge as a function of open circuit voltage(OCV).

SOC based on Current measurements

- The 18650 cell is rated at 1.2Ah, so we can easily calculate the total number coulombs the battery can hold.
- We can then calculate the coulombs used from our current reading. By dividing the coulombs used over our total coulombs, we get the state of charge used. And by subtracting/adding that to the initial state of charge, we end up with the state of charge as a function of time and current.

Total Coulombs Charge of the system = 1.2 Amphr*(60mins/1hr)*(60sec/1min)

The value of the above equation comes out to be 4320 coulombs.

Therefore, the total coloumbs used will be given by:

l*(change in t)

The SoC(State of charge) used in percentage is given by ,

(coulombs used/ total coulombs)*100

So finally SoC(t,l)= SoC0 - SoCused

SoC - (l*(change in t/4320))*100

This is how the state of charge and the state of health of the lithium-ion battery back is determined.

Once the value of the SoC is found by using both the methods mentioned above, we use a Kalman Filter model to check which output is the best for our application. As shown in the diagram below, first the data is collected and then SoC is found as a function of both current and voltage. Then these 2 values are compared and the best is then given at the output.

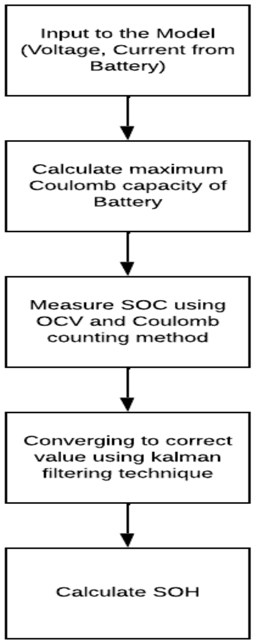



Fig 3: Flow of proposed model

## 3. Results:

In the OCV method, for simulation Tamb ambient temperature is considered. There are 2 lithium-ion cells that are connected to a voltage load in parallel. This is used to calculate the battery voltage. The input current is also measured as shown in the figure. Finally, these are the simulation results that were obtained. Figure below shows 2RC model taken as a reference from mathworks website and changed few parameters as per condition.

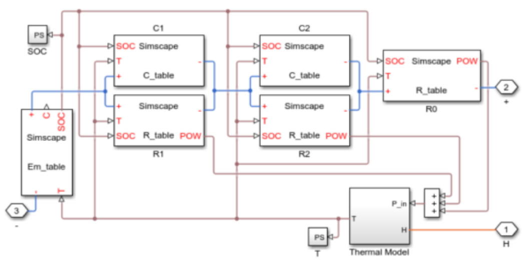



Fig.no.4

To calculate the SoC based on current measurements, mathematical analysis is done which is mentioned in section 2.3. So finally, after both these results are obtained, we pass them through a Kalman Filter model to find the best value of SoC.

After the SoC is found we need to find the State of Health. It is expressed as a percentage and is defined as the ratio of the maximum battery charge to the rated capacity.

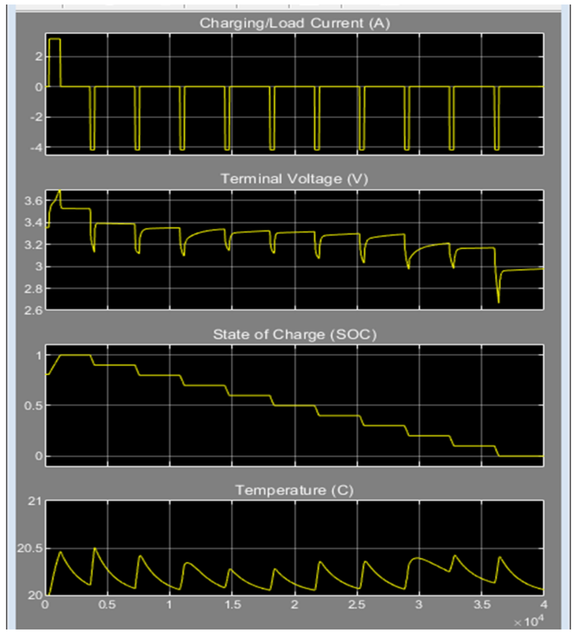
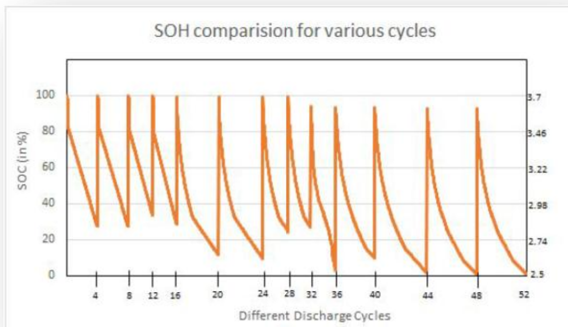



Fig 5

When the battery is manufactured, the SoH of the battery is 100% but as time goes by and battery is used, the charges in the battery are permanently lost. This affects the battery performance thereby affecting the battery health.

Using the values of the SoC this graph of SoH was obtained.




In the above graph we can clearly see that as the number of charge- discharge cycles increase, the SoH of the battery keeps on reducing. Once this value reaches below a threshold value battery should no longer be used for any application.

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