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Battery Management System for EV’s

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***Abstract*—A battery management system (BMS) is an essential part of electric vehicles (EVs). It monitors and manages the battery system, or pack, in EVs. This chapter looks at the makeup and typical hardware of BMSs and highlights some of their commercial products. BMSs for EVs have five main hardware functions: acquiring battery parameters,managing battery information, handling battery thermal management, and controlling battery charge. BMSs can generally be divided into two categories based on the number of cells in a battery system: centralized and distributed.The objective of this project is to describe a real-time BMS implemented using an Arduino Nano as the central control unit. It is designed to monitor and process critical parameters of a battery pack: voltage, current, and temperature. Power is supplied by a Buck Converter that efficiently reduces the 12V input to a regulated 5V. The voltage of the battery is measured using a Voltage Divider Circuit (R1, R2, R3) that scales the high battery voltage for the microcontroller’s analog-to-digital converter. Current flow is monitored by an isolated ACS758 Hall- effect sensor, and the battery temperature is sensed with an NTC Thermistor integrated into a fixed resistor network. These analog inputs are read from the Arduino Nano, which in turn computes the State of Charge using a linear voltage-based approximation between a maximum of 48.4 V and a minimum of 36.0 V and calculates the State of Health based on a capacity-retention model. All real-time data and estimations are presented visually on an OLED Display. The overall design puts the emphasis on a compact size, efficiency, and real-time capability for portable battery monitoring.**

***Index Terms*—State of Charge (SOC), State of Health (SOH), Battery Management System (BMS)**

I. INTRODUCTION

Conventional vehicles are replacing electrical vehicles be- cause they are environmentally friendly and emit no hazardous gasses. The decline of non-renewable energy sources neces- sitates the development of fully efficient electric automobiles. Because it uses a variety of electrical and electronic circuits to monitor and achieve efficient battery system output, BMS is a crucial component of electric vehicles. EV batteries should not be overcharged or overdrained because doing so can cause severe damage to the batteries, raise the temperature, and shorten their lifespan. SoC and SoH is a crucial feature to take into account in order to calculate how much energy is left in the battery since excess charging and discharging of BMS may be eliminated based on the knowledge of residual energy left in the battery. As a result, BMS is an essential component of electric cars since it keeps an eye on the battery pack, which is made up of several battery cells, to ensure that it operates safely and doesn’t damage itself. Since batteries are the primary energy source for electric vehicles and inappropriate battery use can be dangerous, it is essential to supply electric vehicles with electricity from an energy storage system. Battery control and monitoring are therefore crucial to EVs, and BMS can accomplish this. Due to cell variations inside a battery pack, it is challenging to establish an accurate battery management system model to study the performance of lithium-ion cells, and several methods are used to ascertain the status of charge in different circumstances.

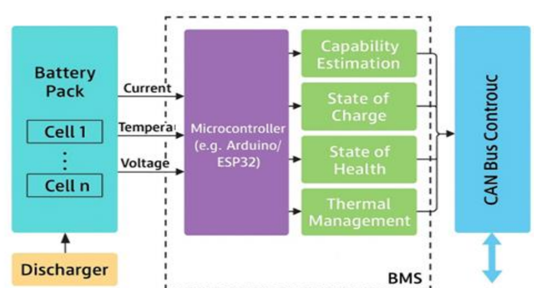

Fig. 1. Block Diagram

A. Definations

I. SOC

is mapped to its soc using ocv and soc curves. However the accuracy is limited. he terminal voltage of a battery

The State of Charge (SOC) of a battery provides a quan- titative measure of the remaining energy available within the battery pack. It is defined as the ratio of the remaining battery capacity to its nominal capacity. SOC is a fundamental parameter in battery management systems, as it indicates the level of charge left in the battery. Accurate estimation of SOC helps in determining when the battery should be charged or discharged, thereby ensuring efficient energy utilization, pro- longing battery life, reliability and maintaining safe operation of the system

$$SOC = \frac{Qr}{Qn} * 100 \quad (1)$$

Here Qr represents the remaining capacity and Qn is the nominal capacity . soc is represented in percentage

B. Methods that can be used to measure the soc, are coulomb counting, Kalman filtering, open circuit voltage

- Coulomb Counting: This is one of the most common methods used for calculating soc of the battery, also called as current integration method. This method deter- mines SOC of a battery by measuring the current flowing into and out of it over time and mathematically integrating these current readings. This method essentially accu- mulates the charge transferred during the charging and discharging processes to estimate the remaining capacity. Even though it is widely used , it gives potential errors in reading as it completely relies on the estimated current and initial soc value , both of which can be imperfect . A little error in current or initial soc keeps up accumulating can lead to large deviation in the actual soc value because of these limitations coulomb counting method can not be used alone and so advanced algorithms are used to improve accuracy. pack varies with different charge and discharge rates, so when the current fluctuates significantly, the OCV–SOC relationship becomes unreliable. Additionally, increase in internal resistance due to aging and other factors can lead to inconsistent voltage and reduced accuracy moreover, temperature also has a strong influence on the discharge characteristics. Making it unsuitable for real world applications where operating conditions keeps on changing.

II. SOH

The State of Health (SOH) of a battery represents its overall health and its performance capability compared to a new battery. It indicates how much the battery has aged and how effectively it can store and deliver energy. SOH is usually expressed in percentage Mathematically, SOH can be defined as:

Ccurrent

$$SOH = \frac{Ccurrent}{Crated} * 100 \quad (3)$$

Here ccurrent is current capacity of battery and Crated is the rated capacity As the battery undergoes repeated charge–discharge cycles, its capacity, internal resistance, and efficiency gradually deteriorate due to aging, tem- perature effects, and side reactions within the cells. This degradation reduces both the available energy and power output, resulting in a lower SOH value.Monitoring SOH is essential for battery management systems (BMS) to ensure safe operation, predict remaining useful life, and schedule maintenance or replacement. Together with State of Charge (SOC), SOH provides a comprehensive understanding of a battery's performance, safety, and longevity.

$$SOC(t + \delta t) = soc(t) - \frac{(I(t)\delta t}{Cn} \quad (2)$$

- Kalman filtering: Kalman filtering is an advanced method developed to estimate hidden or internal state of any dynamic system , it can also be used to measure soc of the battery .It provides a recursive and optimal approach for predicting in real time .It not only estimates soc but also dynamic error bounds that tells how accurate the predicted value is. Here soc is considered as the internal state the Kalman filtering updates the estimated value by comparing current and voltage to predicted model output and then applies error correction step providing with real time and adaptive soc prediction . Despite its accuracy and adaptability, the need of well-defined battery model, precise parameter identification, and high computational power makes it more complex than coulomb counting

- Open circuit voltage: The ocv estimates soc of battery using the relation between ocv and soc. This method is simple and easy to implement, it is calculated in no load condition in this approach the ocv ofd the battery

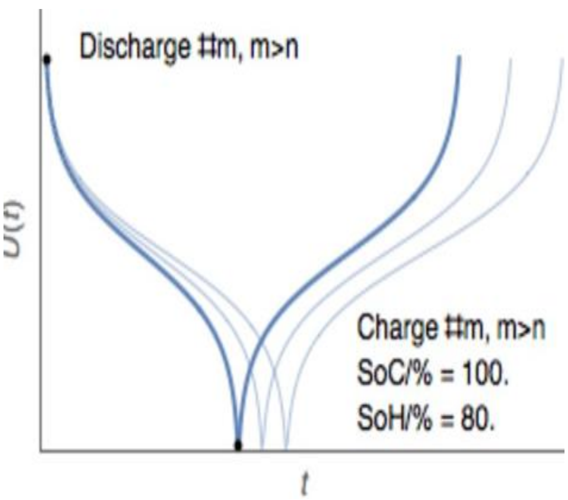

Fig. 2. Graph of SOC and SOH

III. SYSTEM DESIGN

B. General Information

A Battery Management System (BMS) is a critical com- ponent in Electric Vehicles (EVs), essential for ensuring the safe, reliable, and optimal operation of the lithium- ion battery pack. Its primary functions are to monitor key parameters such as voltage, current, and temperature; protect against unsafe conditions such as overvoltage or overheating; balance the charge among individual cells; and estimate vital metrics such as the State of Charge (SOC) for vehicle range and State of Health (SOH) for battery degradation. This project details a low-cost prototype BMS for a 48V (12s1p) battery pack, using sen- sors such as the ACS758 and an ESP32 microcontroller. The system actively monitors all parameters, calculates SOC/SOH, provides fault detection, and displays real- time data on an OLED screen, while also integrating wireless communication for remote diagnostics. This de- sign bridges theoretical BMS concepts with a practical and scalable implementation aimed at improving battery safety, performance, and longevity.

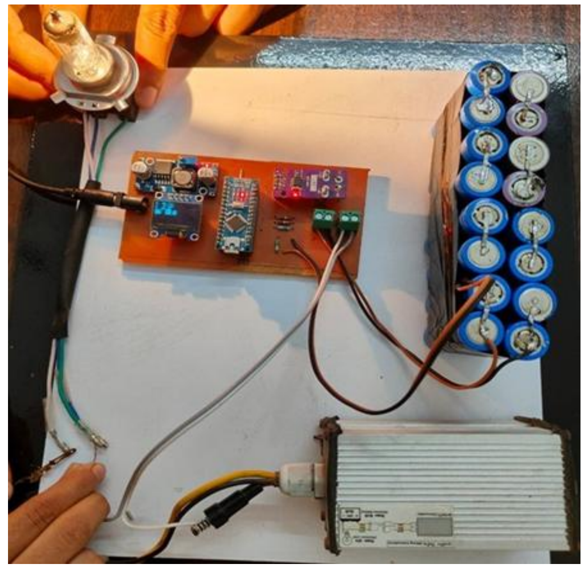

Fig. 3. Connections

C. About Components

- Buck Converter: A buck converter is DC-DC step- down converter. It is used to re duce the input voltage from 12 V to a stable 5 V which is required power the control circuitry. In the system, it provides 5 V DC supply to the Arduino Nano. The converter oper- ates with pulse-width modulation (PWM) switching, ensuring minimum power loss and heat dissipation while maintaining voltage stability across varying load conditions.
- OLED Display: An Organic Light Emitting Diode (OLED) display module is used to show the real-time parameters of the BMS , including voltage, current, temperature, State of Charge (SOC), and State of Health (SOH). The OLED screen offers high contrast, low power consumption, and wide viewing angles, making it suitable for compact embedded systems where both efficiency and readability are important.
- ACS758 Current Sensor: The ACS758 is a Hall-effect based current sensor . It is used to measure

the current flowing through the battery pack. It provides a percise and isolated analog output proportional to the current flowing , enabling accurate monitor- ing without direct electrical contact with the high- voltage supply . This sensor ensures reliable current measurement for SOC estimation using OCV-SOC method and contributes to the overall safety of the system.

- Voltage Divider Circuit: A voltage divider circuit consists of precision resistors. It is utilized for battery voltage sensing. Since the battery's total voltage exceeds the microcontroller's ADC input range, the voltage divider scales down the battery voltage to a measurable level (0–5 V). This scaled signal is then processed by the Arduino Nano's analog-to-digital converter to determine the real-time voltage of the battery pack.
- NTC A Negative Temperature Coefficient (NTC) thermistor is integrated into the system to sense the battery temperature. The thermistor's resistance de- creases with increasing temperature, this allows the Arduino Nano to calculate temperature variations by reading voltage changes across the fixed resistor net- work. This data is crucial for ensuring thermal safety of the system , as it helps prevent over-temperature conditions and supports temperature compensation in SOC/SOH estimation
- Arduino Nano : The Arduino Nano serves as the central control unit of the BMS. It is responsible for data acquisition, processing, and display con- trol. The microcontroller reads analog data from the voltage divider, current sensor, and thermistor, estimates parameters such as SOC and SOH, and outputs the results to the OLED screen. Its compact size, consumes low power and has integrated com- munication capabilities making it ideal for portable battery monitoring applications.
- PCB Layout Design: The entire circuitry is designed on EasyEDA. The schematic was converted to a PCB layout with proper routing of tracks and pads.The layout was printed in mirror format using a laser printer . A copper-clad board was used to transfer and etch the circuit pattern ensuring a compact, stable, and reliable hardware setup for the monitoring system.

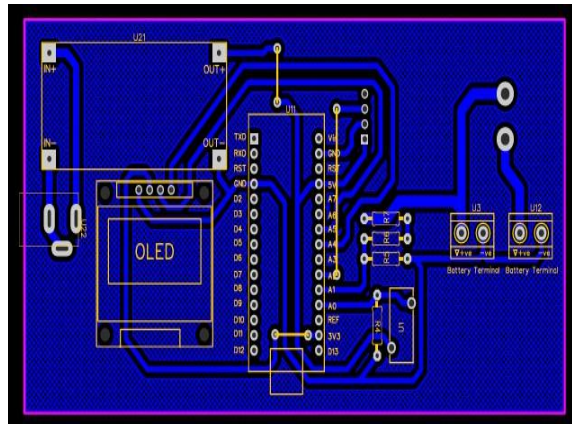

Fig. 4. Pcb Layout

D. Methodology

A 48V, 2Ah lithium-ion battery pack(12s1p)is the main component as It serves as the subject to be monitored. A DC-DC buck converter converts 12V power supply to a stable 5V. This 5V output powers the Ardiuno Nano through its 'Vin' pin, which will then provide 3.3V to its peripherals. The Ardiuno Nano connects with all sensing components and OLED. For measuring voltage of the battery pack a 200k ohm/10k ohm resistive voltage divider between the 48V battery's positive terminal and the ground is integrated. The central tap then connects to an ADC pin(GPIO34) , for safe voltage measurement. The ACS758 current sensor is integrated into the main positive power path. Its analog 'VIOUT' pin connects to another ADC pin(GPIO35). At the same time, NTC thermistors with a 10k fixed resistor connects to an ADC pin(GPIO32) , to monitor the battery's temperature. An important step is con- necting the Ardiuno Nano's 'GND' to the battery's negative terminal that will create a common ground

TABLE I
OCV TO SOC LOOKUP TABLE

SOC%	SOH%
100	4.20
90	4.10
80	4.00
70	3.92
60	3.83
50	3.75
40	3.68
30	3.62
20	3.55
10	3.45
0	3.30

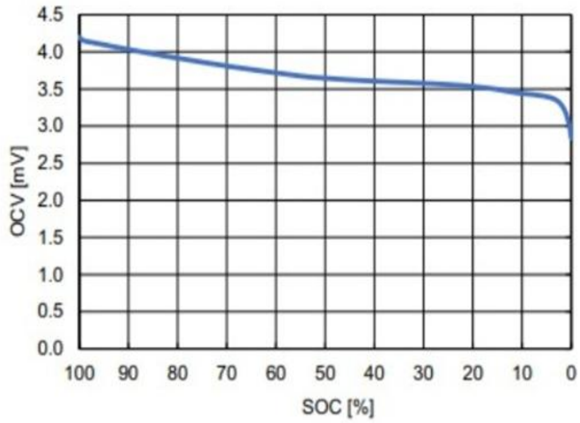

Fig. 5. relation between OCV to SOC graph

Interpolated Formula, if a full lookup table is not available but we have two points around the measured voltage SOC can be found using this :

$$SOC = SOC1+(SOC2-SOC1)*\frac{V\,OCV - V1}{V2 - V1} \quad (4)$$

IV. RESULT

The designed Battery Management System (BMS) effec- tively fulfills its primary purpose as the intelligent control center of an Electric Vehicle (EV) battery pack. By continuously monitoring and managing key parameters, the system ensures maximum operational safety, accurate State of Charge (SoC), State of Health (SoH) estima- tion and enhanced battery longevity . The integration of these functions results in a reliable, efficient, and durable battery performance, thereby delivering a secure and optimized electric vehicle experience for the user.

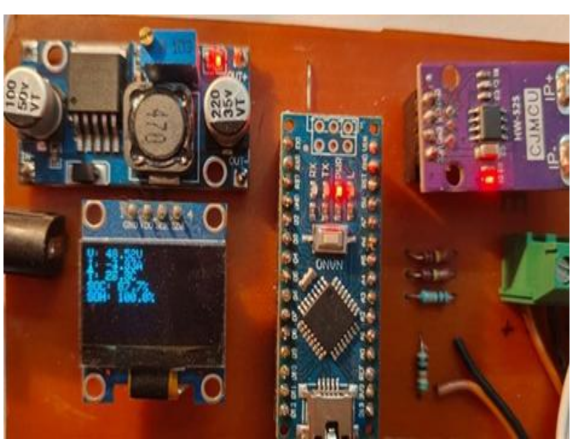

Fig. 6. Result

V. CONCLUSION

Battery Management Systems is essential for electric vehicles to ensure the reliable, and efficient operation of the battery. A BMS continuously monitors key pa- rameters like voltage, current, temperature, and estimates state of charge(SOC) and state of health(SOH) of the battery cells to prevent overcharging, over-discharging, overheating and takes preventive measures if the battery is aged or shows any abnormal behaviour , thereby pro- tecting the battery from damage and extending its lifes- pan. Advanced BMS architectures integrates hardware and software solutions for cell balancing, temperature management, and communication protocols to optimize battery performance, safety, and longevity. Future trends in BMS development involve adopting AI and machine learning for predictive maintenance, integration with re- newable energy and smart grid systems, and expanding IoT capabilities for real-time remote monitoring and control. These innovations will further enhance safety, life expectancy, and user convenience, making BMS a critical component in the sustainable advancement of EV technology.

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