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A Study and an Analysis of Battery Management System for Electric Vehicle

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ABSTRACT

The Battery Management System (BMS) is crucial for the functioning of Electric Vehicles (EVs) and Hybrid Electric Vehicles (HEVs), ensuring the safe and reliable functioning of the battery. The primary objective of the BMS is to monitor and regulate the state of the battery, ensuring optimal performance and longevity. The main functions of the BMS include monitoring and assessing the state of the battery, controlling charging, and balancing the cells. These features are essential for maintaining battery safety and efficiency.

Rechargeable batteries supply power to the motor and auxiliary systems in electric vehicles. Over the past decade, battery technology has made significant advancements, leading to the development of high-performance batteries. This paper focuses on the critical tasks handled by the BMS, including monitoring the State of Charge (SoC), State of Health (SoH), State of Life (SoL), and maximum capacity of the battery. By examining the various methodologies used to assess these parameters, the paper identifies future challenges and potential solutions to enhance battery management systems.

. ***Keywords-*** *Battery management system (BMS), electric vehicle (EV), State of Charge (SoC), State of Health (SoH)*
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I. INTRODUCTION

Electric vehicles (EVs) are becoming increasingly important due to their zero emissions of harmful gases and efficient energy use. These vehicles rely on a large number of battery cells, making an effective Battery Management System (BMS) essential for their proper operation [1], [2]. A battery in an EV must be capable of providing both long-term energy storage and high power output. The most commonly used traction batteries in electric vehicles are lead-acid, lithium-ion, and nickel-metal hydride, with lithium-ion batteries being the preferred choice due to their superior performance and advantages. The battery capacity in electric vehicles typically ranges from 30 to 300 kilowatt-hours (kWh).

The Battery Management System (BMS) in electric vehicles is responsible for overseeing and regulating the charging and discharging processes of rechargeable batteries, enhancing the overall efficiency and cost-effectiveness of operation. The BMS makes real-time decisions based on factors such as the battery's charging and discharging rates, along with its current state of charge. [3], [4].

The definition of a Battery Management System (BMS) may vary depending on its specific application, but its fundamental tasks can be outlined as follows [5], [6]:

- It ensures the battery's energy is optimized to power the device or system.
- It minimizes the risk of damage to the battery.
- It monitors and controls the charging and discharging processes of the battery.

II. HARDWARE COMPONENTS

Here, describing about the main components used and their connections:

A. Ultrasonic Sensor (HC-SR04)

The HC-SR04 ultrasonic distance sensor is an affordable device designed to measure distances ranging from 2cm to 400cm without physical contact. It offers an accuracy of up to 3mm. The sensor is made up of an ultrasonic transmitter that emits sound waves through piezoelectric crystals, and a receiver that captures the reflected sound waves once they return from the target. Additionally, it includes a control circuit to manage the operation of the sensor.

To calculate the distance between the sensor and an object, the HC-SR04 measures the time it takes for the sound waves emitted by the transmitter to return to the receiver. The distance is then determined using the formula: $D = 1/2 \times T \times C$, where D is the distance, T is the time it takes for the sound to travel, and C is the speed of sound, which is around 343 meters per second. The HC-SR04 has four essential pins to focus on: VCC (Power), Trig (Trigger), Echo (Receiver), and GND (Ground).

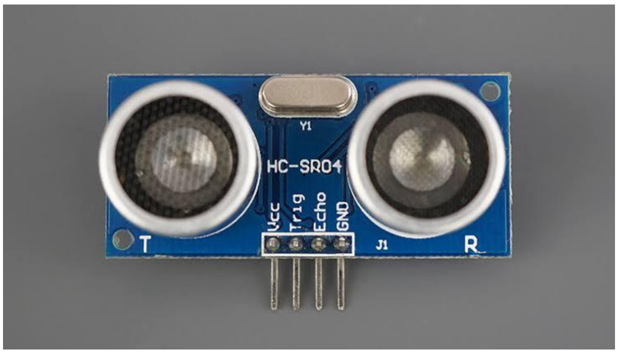

Fig.1. Ultrasonic Sensor

B. Arduino UNO

The Arduino UNO is an excellent choice for beginners looking to explore electronics and coding. The Arduino UNO is one of the most widely used and well-documented boards in the Arduino family. The board is based on the ATmega328P microcontroller and features 14 digital I/O pins, 6 of which can be used as PWM outputs. It also has 6 analog input pins, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button.

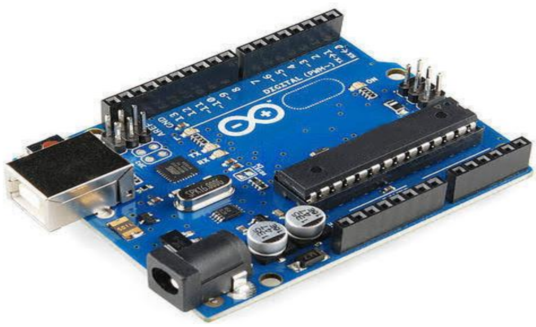

Fig.2. Arduino UNO

C. Motor Driver Controller (L298N)

The L298N Motor Driver Module is a durable driver designed for controlling DC and Johnson motors. It incorporates the L298 motor driver IC and is equipped with a 78M05 5V voltage regulator. This module can control up to 4 DC motors or 2 DC motors, offering precise control over both speed and direction.

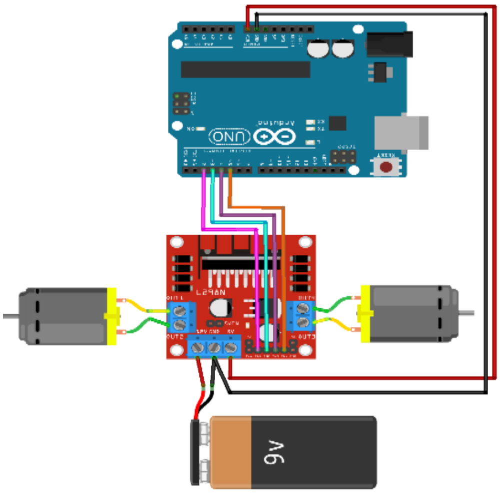

Fig.3. L298N powering Arduino

D. Lithium Ion Battery

Lithium is the lightest metal and possesses the highest electrochemical potential, resulting in the highest energy density per unit of weight. When used as the anode in rechargeable batteries, it offers high voltage, excellent capacity, and impressive energy density. Li-ion batteries are known for their high energy density, absence of memory effect (except for LFP cells), and low self-discharge rate. These cells can be designed to focus on either energy density or power density. However, they can pose safety risks due to the flammable electrolytes they contain. If damaged or improperly charged, they have the potential to cause fires or explosions. [7], [8].

E. Other Components

Some main components details are written above. Apart from the main components the other components are:

(i) Bluetooth module (HC-05)
(ii) LCD Display
(iii) Salzer Relay
(iv) Li-Po Battery Indicator
(v) Johnson Motor
(vi) Temperature indicator (W1209)
(vii) Power switch
(viii) Charging Jack
(ix) Power Adapter

III. COMPLETE BLOCK DIAGRAM AND WORKING OF PROPOSED SCHEME

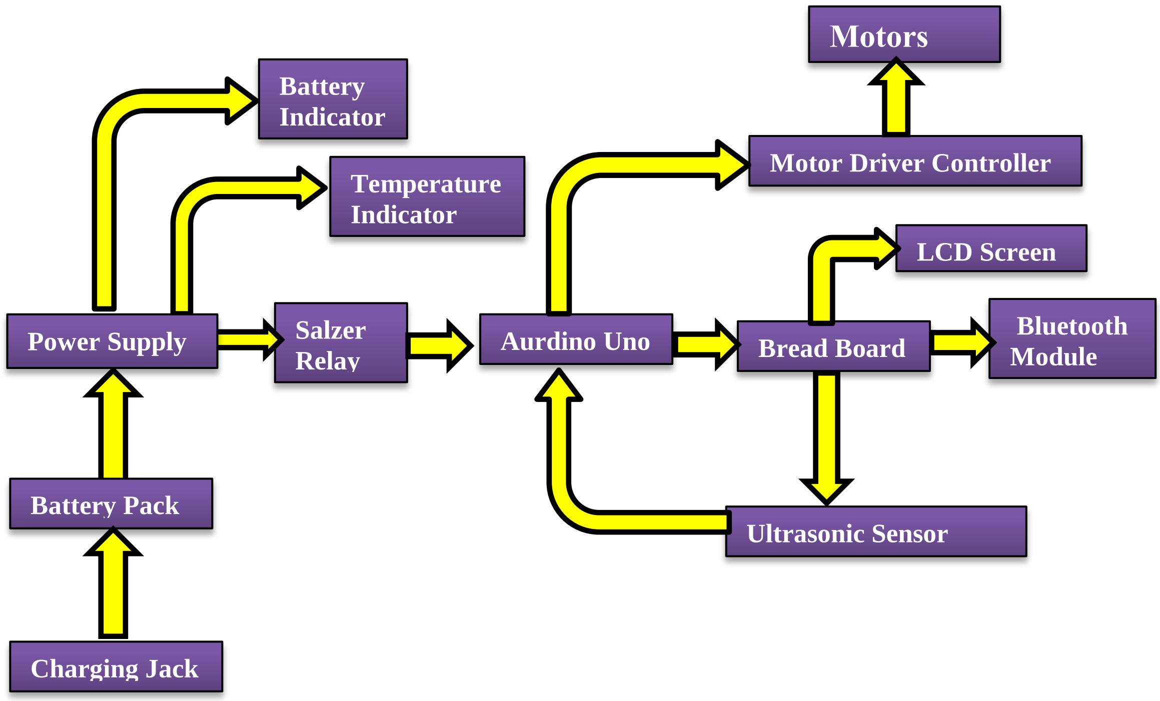

Fig.4. Complete block diagram of proposed scheme.

As shown in the block diagram depicted in Fig. 4, the circuit is mainly divided into two parts: the first part focuses on battery management systems, and the second part is for driving purposes.

In the first part, two main functions are performed: measuring the state of charge (SoC) of the battery and monitoring the state of health (SoH) or thermal protection of the battery. The 'Battery Indicator' block measures the SoC of each individual cell as well as the entire battery pack (which uses 3 Li-ion batteries of 3.7V). The 'Temperature Indicator & Thermal Protection' block monitors the SoH, i.e., the temperature of the battery pack. A certain temperature limit is set for protection, and if the temperature exceeds this limit, the circuit will be disconnected from the power supply. For overall protection, a 'Salzer relay' is used to prevent any damage caused by short circuits or abnormalities.

In the second part, power is supplied to the Arduino UNO, which is connected to motors via a motor driver controller, an LCD screen, a Bluetooth module, and an ultrasonic sensor, all connected through a breadboard as a common point. For driving purposes, the code is implemented on the Arduino, and instructions are sent via the Bluetooth module. The motor driver controller adjusts the motor speed and vehicle direction based on the Bluetooth instructions. Distance is measured and sent back to the Arduino. The ultrasonic sensor detects any obstacles, and if one is found, the vehicle stops automatically.

IV. HARDWARE SET-UP

The hardware set up is as depicted in the following image. Battery pack consists of three 3.7V, 3000mAh and connected in series. Arduino has been programmed as per our requirement and connected with motor driver, LCD display, ultrasonic sensor and Bluetooth module. Arduino has power supply from battery pack. Temperature indicator connected with salzer relay and battery pack. Also, temperature sensor is connected with battery pack to sense the temperature and help to protect from overheating. Li-Po Battery indicator is connected to battery pack in such a fashion that it can measure individual cell capacity and overall battery capacity and give us output.

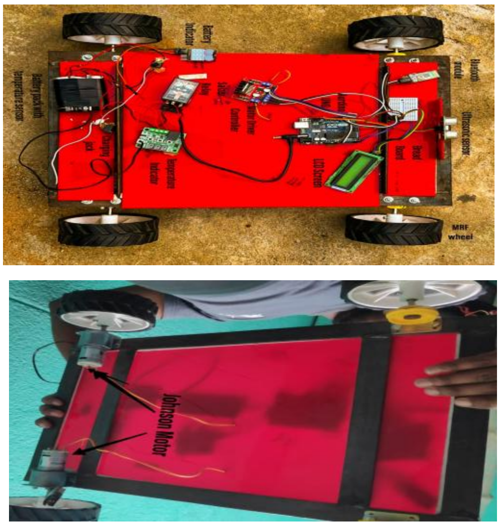

Fig.5. Hardware Set -Up

One terminal of the charging jack is connected to the power switch, which is then linked to the positive terminal of the battery pack. The other terminal of the charging jack is connected to another switch, which is then linked to the negative terminal of the battery pack.

V. OBSERVATIONS

The SoC of cells for different time duration and temperature of battery pack for different time duration are observed and their observation tables are given below:

Table 1. SoC of cells and battery pack for different time duration

Cells	SOC (in V) for different time duration					
	Without driving	First 30 sec	Second 9 sec	Third 30sec	Fourth 30 sec	Fifth 30 sec
Battery pack	11.0	10.8	10.6	9.4	7.2	4.22
1	3.66	3.60	3.53	3.13	2.25	1.4
2	3.66	3.60	3.52	3.13	2.30	1.4
3	3.70	3.64	3.58	3.23	2.55	1.42

Table 2. Temperature of battery pack for different time duration

Time Duration (in sec)	Temperature (in °C) of battery pack
Without driving	30.3
First 31	30.7
Next 9	30.6
Next 30	30.30
Next 30	30.8
Next 30	31.1

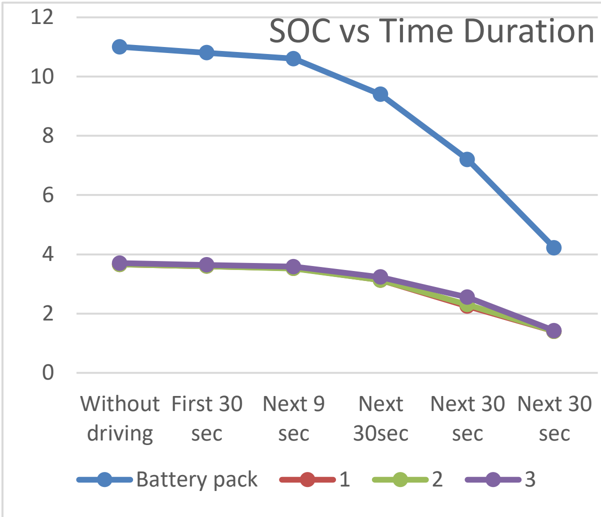

Fig. 6. SOC vs Time duration curve

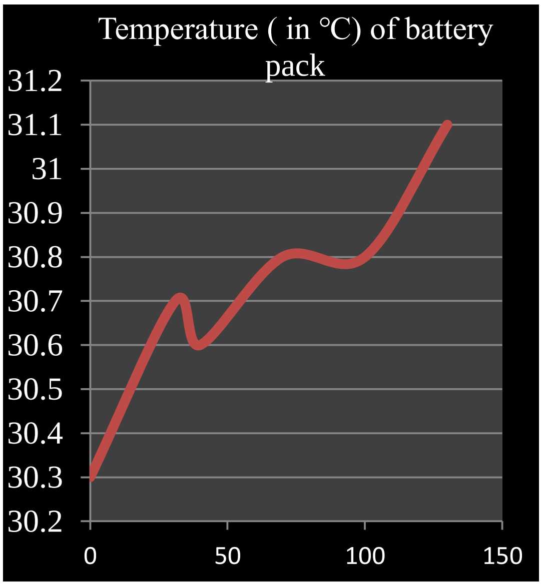

Fig. 7. Graph for Temperature of battery pack vs Time

V. RESULT

The devices set up in the entire prototype work together to monitor and display the state of charge, health, and thermal condition of the lithium-ion battery pack, as well as the individual cells.

The temperature indicator then shuts down the entire system with the help of a 5-pin, 12-volt DC relay if the thermal state reaches a certain level set by the user. Additionally, the Salzer relay trips in the event of a short circuit, causing the entire system to shut down. These features are implemented to protect the electric vehicle by managing the battery pack's thermal state and ensuring proper balancing.

VI. CONCLUSION

In conclusion, the analysis of the drainage of the entire battery pack, as well as individual cells, demonstrates that the discharge of all cells follows an approximately linear pattern, as shown in Observation Table 1 and Fig. 6. This linear discharge behavior supports the effectiveness of the cell balancing mechanism in the lithium-ion battery pack, ensuring consistent and efficient performance. Furthermore, the temperature variation of the battery pack, illustrated in Fig. 7, reveals a rise in temperature during vehicle operation, followed by cooling periods in response to environmental conditions. These findings highlight the importance of both thermal management and cell balancing in maintaining the optimal performance and longevity of the battery pack in electric vehicles. The implemented system effectively monitors and protects the battery pack from potential thermal and electrical hazards, ensuring safe and reliable operation.

VII. REFERENCES

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