IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 6, June 2025
Impact Factor: 7.67

Electric Vehicles Battery Management System With Charge Monitor And Fire Protection

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Abstract: *This paper explores the design and implementation of an Electric Vehicle Battery Management System (EVBMS) with Charge Monitoring and Fire Protection. Developed for Li-ion battery packs in electric vehicles, the system ensures continuous monitoring and protection. Utilizing hardware components such as Li-ion batteries, monitoring systems, microcontrollers, LCD displays and sensors, the EV-BMS facilitates safe charging and proactively prevents accidents. Integrated fire protection utilizes advanced sensors and algorithms to detect and mitigate fire hazards. Through microcontrollers and user-friendly interfaces, the project offers a comprehensive solution, contributing to the safety and efficiency of electric vehicles.*

Keywords: *Fire Protection.*

I. INTRODUCTION

An electric vehicle EVs is a type of vehicle that uses one or more electric motors for propulsion. Instead of using an internal combustion engine (ICE) that burns fuel, an EV use a battery pack to store electrical energy to power an electric motor, which turns the wheels. Compared to conventional ICE vehicles, EVs provide a number of benefits, such as decreased emissions, quieter operation, and a lessened reliance on fossil fuels. Since electricity is frequently less expensive than gasoline and electric motors are more efficient than ICEs, they also typically have reduced operational expenses. [2]

The popularity of EVs is fast rising as the globe moves towards a cleaner, more sustainable future. Governments all around the world are granting incentives to stimulate the use of EVs, and numerous automakers are already selling a variety of EV models. In addition to its benefits, common EV problems include internal cell shorts that may result in thermal runaway. An EV typically catches fire because of excessive heating. The electric vehicle's battery warms up, and when that heat interacts with petrol that has leaked, the battery simply catches fire.

A battery management system (BMS) is an electrical device that controls and keeps track of the operation of rechargeable batteries, such as those found in renewable energy sources and electric cars. By regulating the charging and discharging process, keeping track of the battery's state of charge and overall health, and guarding the battery from harm brought on by overcharging or overheating, the BMS aids in ensuring the safe and effective operation of the battery.

The BMS normally consists of a number of parts, such as sensors for measuring the temperature, voltage, and current of the battery as well as control circuits for controlling how the battery is charged and discharged in response to various conditions. [3]Software algorithms that forecast the battery's remaining capacity and project its remaining life may also be present in the BMS.

One of the key functions of a BMS is to prevent the battery from being overcharged or over-discharged, which can cause permanent damage to the battery and reduce its lifespan. The BMS accomplishes this by controlling the charging and discharging process and shutting down the battery if any abnormal conditions are detected. Another important function of a BMS is to ensure that the battery is operating within a safe temperature range. If the battery gets too hot, the BMS may reduce the charging rate or shut down the battery to prevent damage. [5]If the battery gets too cold, the BMS may increase the charging rate to help warm up the battery

Overall, a BMS is an essential part of any rechargeable battery system since it ensures the battery's safe and effective operation and increases its longevity. EV batteries that are frequently utilised are 2-cell lithium-ion (Li-ion) batteries. A 2-cell Li-ion battery should have a voltage of roughly 6.0V when it is fully depleted, and a maximum charge voltage of roughly 8.4V

The balancing charger will keep track of each cell's voltage during the charging procedure and modify the charge rate as necessary to guarantee that all of the cells receive an equal charge. The balancing charger will automatically cease charging when the battery is fully charged. It is crucial to remember that overcharging a Li-ion battery might cause it to malfunction, which could cause a fire or explosion. As a result, it's crucial to pay close attention to the charging process and prevent leaving the battery alone while it's being charged. In our project, we keep an eye on battery voltage, temperature, and detect the presence of fire. If the battery temperature rises beyond a certain threshold, the power to the lithium-ion battery is automatically shut off using a relay.We create a little model that can be operated by an contains all the systems mentioned above [6].

II. LITERATURE SURVEY

Lithium-ion batteries have emerged as the cornerstone of the electric vehicle (EV) industry, owing to their remarkable energy and power density, extended life cycles, high voltage output, and low self-discharge rates. However, these batteries are not without their challenges. Susceptibility to aging and temperature variations necessitates vigilant management to prevent physical damage, premature aging, and thermal runaways (Bhowmik et al., 2020).

The Battery Management System (BMS) serves as a key element in the optimal functioning of EVs, particularly in safeguarding lithium-ion batteries. An effective BMS is tasked with a multitude of responsibilities, including data acquisition, communication with battery components, user interface feedback, temperature regulation, fault diagnosis and handling, and prolonging battery life. [6]

Charge Monitoring: Charge monitoring stands out as a critical aspect of BMS functionality emphasize the importance of precise voltage and current sensing, alongside state-of-charge estimation algorithms, to optimize charging efficiency and mitigate the risk of overcharging-induced damage. [7]Furthermore, studies by Zhang et al. (2019) and Li et al. (2021) delve into the integration of smart charging strategies and enhance charge monitoring accuracy and adaptability.

Fire Protection: Given the potential hazards associated with lithium-ion batteries, effective fire protection mechanisms are indispensable. Zhang et al. (2018) stress the significance of early fire detection and suppression systems to mitigate fire risks and ensure passenger safety[4]

This chapter reviews various research studies on Battery Management Systems (BMS) and Battery Energy Storage Systems (BESS) for electric vehicles and grid-scale applications. It highlights the inefficiencies in current power grids and how BESS with advanced BMS can address these by accurately managing energy storage and usage.[8]

Key advancements include modular and multilevel BMS designs (BM^3), which improve flexibility, fault tolerance, and efficiency by allowing dynamic configuration of battery cells. These systems overcome the limitations of traditional BMS, which are affected by mismatched or defective cells.[9] Additionally, bus-network-based BMS solutions using control techniques like loop shaping enhance performance, reliability, and cost-effectiveness in multi-battery electric vehicles.

Across the literature, BMS is shown to be essential for ensuring battery safety, longevity, and optimal performance. Key features include temperature monitoring, cell balancing, overcurrent protection, and integrated fire safety mechanisms like fire-resistant materials and automatic extinguishers.

The studies collectively emphasize the importance of intelligent, adaptable BMS designs that include both charge monitoring and fire protection for modern energy systems.[10]

III. METHODOLOGY

A microcontroller is an integrated circuit containing a complete microprocessor system. Microprocessors had to be built into low-cost products, leading to the development of microcontrollers. Since microprocessors are a reasonable choice for many product implementations, when an entire microprocessor system is placed on his single chip, the yield of basic products that rely on microprocessor performance is dramatically reduced. To do. As a result, the idea of using

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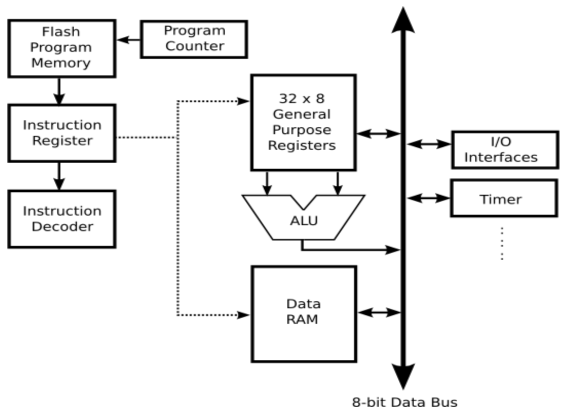
microprocessors in low-cost items is often brought up.Typical 8-bit microprocessor systems such as the Z80 and 8085 are expensive. Both the 8085 and Z80 require additional circuitry in order to be integrated into a microprocessor system. Each element has a price. Even if the product design may just call for a straightforward system, the components are necessary to make this system a low-cost item. A single-chip microcontroller is used in a microprocessor system as a solution to this issueDue to the fact that all required components are contained on an integrated circuit, it is sometimes referred to as a microcomputer. Due to the fact that they are used to control operations, they are more commonly referred to as microcontrollers. The fig 2 shows the basic block diagram of microcontroller is given below



The microcontroller has a full implementation of the standard MICRO PROCESSOR, ROM, RAM, I/0, CLOCK, TIMER, and SERIAL PORTS. Some other names for microcontrollers include "computers on a chip," "systems on a chip," and "single chip microprocessor systems." A microcontroller is a single-chip computer, also referred to as a computer-on-a-chip. The phrase "controller" notifies you that the gadget can direct objects, actions, or events. Micro signifies the device's diminutive size. Since a microcontroller frequently integrates with the devices it controls and the supporting circuitry it employs, it is also sometimes referred to as an embedded controller. Microcontrollers are widely used in a variety of smart products nowadays. For instance, a microcontroller is used to build the majority of personal computer keyboards. Circuitry for serial transfer, debounce, matrix decoding, and scan is completely replaced. A large variety of low-cost products, such as toys, electric drills, microwaves, VCRs, and many more consumer and commercial products, use microcontrollers.

IV SYSTEM DEVELOPMENT

The system architecture is the foundation of a Smart Battery Management System (BMS) designed to ensure the efficient, reliable, and safe operation of electric vehicle (EV) battery packs. This chapter presents an in-depth design and integration of key components, including charge monitoring, fire detection and suppression mechanisms, communication protocols, hardware implementation, and control logic. The architecture is designed with modularity, scalability, real-time data processing, and fail-safe operation, all critical for the high-reliability requirements of EV applications. The aim is to build a system that not only monitors battery health and charge status but also detects potential fire hazards early and acts autonomously to mitigate risks.

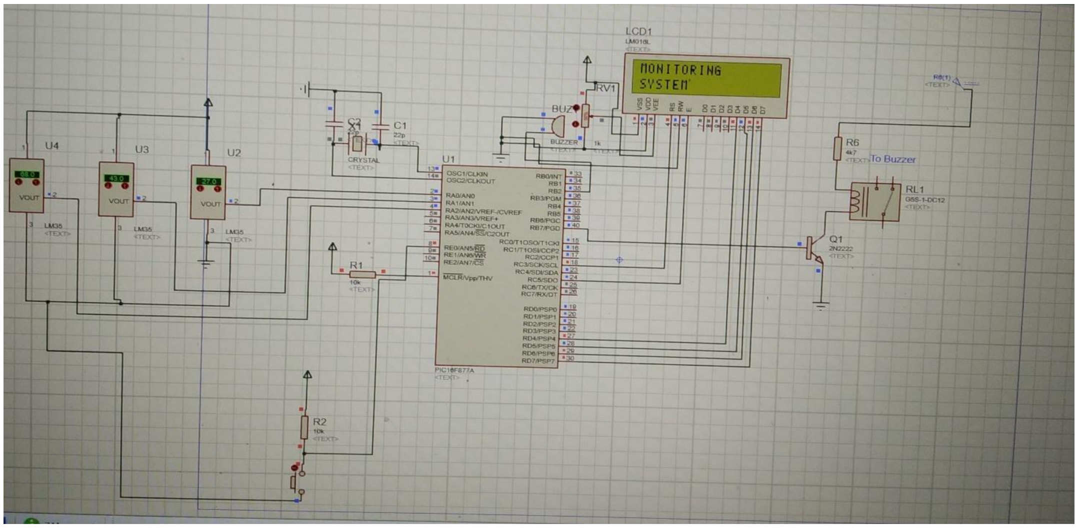


Fig 3.1 (a) : Circuit Dig Of BMS

Battery management in EVs involves multiple hierarchical layers:

- **Cell Level:** This is the fundamental unit of the battery pack. Each lithium-ion cell is equipped with sensors to monitor voltage, temperature, and internal resistance. Monitoring individual cells allows early detection of anomalies such as overvoltage, undervoltage, or temperature spikes that could indicate impending failure or safety risks.
- **Module Level:** Cells are grouped into modules (e.g., 12 or 24 cells per module). A module controller aggregates data from all cells in its group, performing initial health checks and balancing operations to maintain uniform charge distribution. This level reduces communication load on the system and enables localized fault detection.
- **Pack Level:** The highest layer coordinates all modules. The pack controller manages overall charging and discharging, fault isolation, thermal management, and communicates with the EV's Vehicle Control Unit (VCU). It oversees safety protocols such as disconnecting the battery in emergencies.

Benefits of Modularity

The modular architecture offers multiple advantages:

- **Maintainability:** Faulty cells or modules can be replaced without dismantling the entire pack.
- **Fault Isolation:** Localizes faults, preventing cascading failures that could lead to fires or system shutdown.
- **Scalability:** Enables easy scaling to different battery sizes for varying EV models.

Charge Monitoring Subsystem

State of Charge (SoC) Estimation Techniques

Accurate SoC estimation is critical for battery performance and safety. Key methods include:

- **Coulomb Counting:** Measures the current flow into and out of the battery to estimate the net charge. Although straightforward, errors accumulate over time due to sensor noise and drift.
- **Open Circuit Voltage (OCV):** Voltage measurement during rest periods is correlated with SoC to recalibrate the Coulomb counter and reduce drift.
- **Kalman Filtering:** An advanced algorithm combining sensor data and a predictive battery model to provide real-time, noise-filtered SoC estimates with improved accuracy.

State of Health (SoH) Monitoring

SoH tracks battery aging, capacity fade, and internal resistance increase, informing maintenance schedules or battery replacement. SoH is derived from historical charge/discharge profiles, temperature exposure, and voltage behavior.

Cell Balancing Methods

Passive Balancing: Excess charge from higher-voltage cells is dissipated as heat using resistors, ensuring all cells reach a uniform voltage level.

Active Balancing: Energy is transferred from higher to lower voltage cells, improving efficiency and battery lifespan, especially critical in large packs.

Fire Detection and Protection Subsystem

Fire and Thermal Runaway Risks

Thermal runaway is a self-accelerating process where battery temperature increases uncontrollably, caused by internal shorts, overcharging, mechanical damage, or manufacturing defects. It can lead to fires or explosions.

Sensor Types for Early Detection

Temperature Sensors: Detect hotspots inside cells and modules.

Gas Sensors: Identify dangerous gases such as CO, hydrogen, or electrolyte vapors released during decomposition.

Fire Suppression Techniques

Passive Methods: Use heat-resistant or intumescent materials to slow fire propagation.

Active Methods: Aerosol suppressants, dry chemicals, or liquid sprays that rapidly cool or smother flames.

Detection Logic and Safety Protocols

Data from multiple sensors are fused to minimize false alarms. Upon fire detection, the BMS isolates the battery pack electrically, alerts the driver, and triggers fire suppression. It can also communicate with the EV's emergency systems to enhance occupant safety.

Communication and Data Interface

Communication Protocols

CAN Bus: The automotive standard for real-time battery data transmission and diagnostic messaging.

I2C/SPI: Internal sensor and peripheral communication within the BMS.

UART: Used for debugging and external diagnostic tools.

Product Details:

To ensure effective system operation, several essential components and sensors are embedded within the BMS. These products form the hardware layer of the system and work together with software algorithms for real-time monitoring and control

Temperature Sensor

Function: Measures the temperature of individual battery cells or the entire battery pack.

Purpose: Detects overheating and activates cooling mechanisms or triggers alarms in case of thermal anomalies.

Types: Negative Temperature Coefficient (NTC) thermistors are commonly used due to their sensitivity and cost-effectiveness.

Integration: Sensors are placed at strategic locations within the battery pack for accurate thermal profiling.

Smoke Sensor

Function: Detects smoke or flammable gases such as hydrogen, which may indicate early-stage thermal runaway or cell leakage.

Purpose: Acts as a fire prevention mechanism by providing early warnings before visible flames occur.

Placement: Mounted near the battery pack or inside a sealed compartment where gas accumulation is likely.

Action: On detection, triggers alarms and disconnects the battery from the load or charger.

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Voltage Sensor
Function: Monitors the voltage of individual cells and the total battery pack.
Purpose: Ensures that cells do not overcharge or discharge beyond safe limits.
Type: Analog or digital sensors with high resolution and isolation are used for accuracy and safety.
Role in BMS: Enables SoC estimation, cell balancing, and over-voltage protection.

Current Sensor
Function: Measures the current flowing in and out of the battery pack.
Purpose: Detects overcurrent conditions and provides data for power consumption analysis.
Type: Hall effect sensors are preferred for non-intrusive, isolated measurements.
Application: Used in Coulomb counting methods to estimate charge usage over time.
These components collectively provide the sensory input required for the BMS controller (usually a microcontroller or embedded processor) to execute algorithms related to monitoring, protection, and reporting.

V. RESULT AND DISCUSSIONS

Battery aging is affected by charge and discharge cycles, atmosphere, and certain materials. Analyze the state of the battery before discharging at constant temperature and current flow. Here we present some experimental data for lithium-ion batteries at different temperatures and discharge rates. Lithium-ion is the most efficient, lightest, and most reactive type of battery. Lithium-ion batteries charge and discharge faster than conventional batteries. To prevent a chain reaction of multiple chemical reactions, lithium-ion batteries must be operated outside of their safe operating voltage range. Cells can vent and start a fire as a result of increased temperature. As a result, the battery can operate within its safe zone thanks to the battery management system or his BMS.

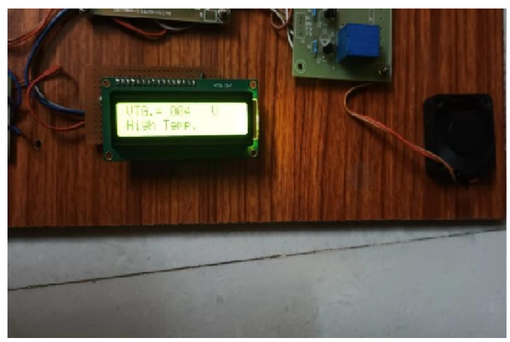

Fig :- Smoke Detected

Fig :- Battery over heat

DOI: 10.48175/IJARSCT-27912

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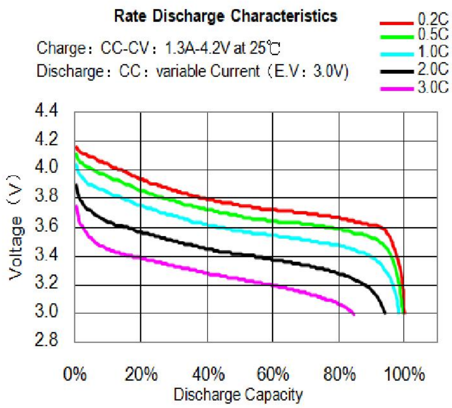

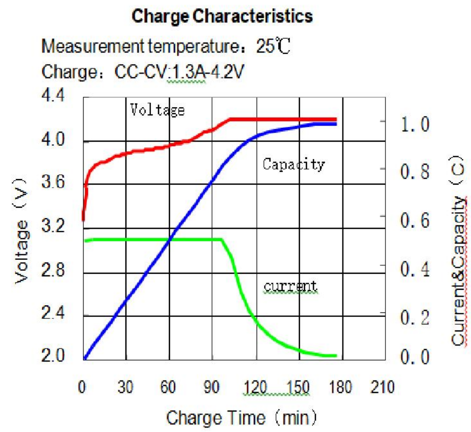

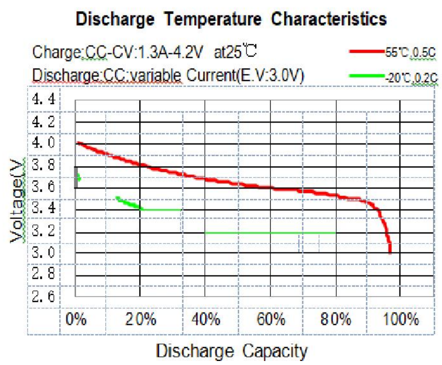

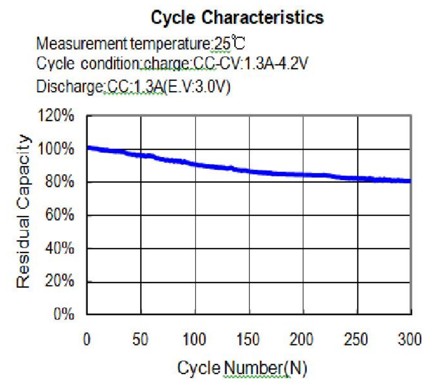

VI. CONCLUSION

In conclusion, this project is a big step forward in making electric cars better. The Electric Vehicle Battery Management System with Charge Monitor and Fire Protection is like the brain of an electric car's battery. As more people are choosing electric cars, having a smart system to manage and protect the battery is crucial. The system uses different parts like a special battery, a charging and monitoring system, buttons, a screen, and sensors to keep an eye on the electric car's battery all the time. It's designed to be safe and prevent accidents when charging the battery. What makes it stand out is its Fire Protection system, which is like having a smart firefighter inside the battery. It can sense and stop potential fires before they happen, making electric cars even safer. The project also made sure that people can easily use and understand the system. With a simple interface, users can interact with and check on the battery without any hassle.
In summary, this project is making electric cars better and safer by tackling the challenges of managing the battery. It's a smart solution that brings together new ideas, easy use, and extra safety features, pushing electric cars forward in the world of technology and making them more widely accepted.

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