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# IoT Based Smart Battery Management System (BMS) for Electric Vehicles

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***Abstract*: Fuel prices are increasing day by day, and there is also a need to use cleaner and more sustainable transportation. Because of this, electric vehicles are becoming more popular. In an electric vehicle, the battery pack supplies power to the system, so its proper monitoring is very important. If the battery is not monitored regularly, problems like overvoltage or high temperature can occur. These problems can reduce battery life and may also affect safety. In this project, an IoT-based Smart Battery Management System is developed using an ESP32 microcontroller, a voltage sensor and a DHT11 sensor are used to measure battery voltage and temperature. Relay module is also connected to the system to disconnect the battery automatically if the voltage goes above the safe value. This project shows a simple and low-cost method for improving battery monitoring and safety in electric vehicles.**

***Keywords*: Battery Management System, Electric Vehicles, Battery Monitoring, Temperature & Voltage Sensing.**

## 1. Introduction

As compared to conventional vehicles, the electric vehicles rely fully on to the battery system [1], [4]. There are various mis happenings which are caused to the battery of the EV. The modern EVs requires the attention of the user immediately at the time of mishappening & provides the preventive measures if applicable but the remote monitoring of battery is lacking to address these problems.

This paper provides the preventive measures & the control techinques on the management of the battery pack to avoid overvoltage issues. This paper is organized as Section II presents literature review of present BMS, Sect III present problem formulation, Section IV explain proposed methodology, Section V present results & after that Section VI concluding the paper by following the references.

### *A. Literature Review*

#### *1) BMS Architecture and Design Considerations*

The hierarchical structure of BMS in large EV battery packs typically involves cell-level monitoring, module-level control, and pack-level management. This distributed architecture allows for scalability and redundancy while maintaining precise control over battery parameters [1]. Design considerations include voltage range optimization, current distribution management, and communication bus architecture selection. Thermal pathways and electrical isolation requirements further influence the overall BMS design strategy.

#### *2) Safety and Protection Functions*

Safety is paramount in BMS design, with multiple protection layers implemented to prevent hazardous conditions such as over-voltage, under-voltage, over-current, and thermal runaway [4], [7]. The BMS must continuously monitor these parameters and take corrective action, including cell isolation or pack disconnection when necessary. Redundancy in critical sensors and communication pathways ensures that safety functions remain operational even under single-point failures. Modern BMS designs also incorporate sophisticated algorithms to detect anomalous conditions that might indicate incipient failures.

#### *3) Integration with Vehicle Control Systems*

The BMS operates as part of a larger vehicle management ecosystem, interfacing with the vehicle control unit (VCU), motor controller, and thermal management system. Real-time communication between these systems enables coordinated management of power flow, thermal conditions, and driving dynamics. The integration strategy significantly impacts overall vehicle efficiency and performance. Standards such as CAN bus and ethernet-based protocols have become increasingly important for reliable inter-system communication.

#### *4) Motivation*

The world is shifting towards the Electric Vehicles which increases the user's expectation for the safer & efficient battery managing system without the problem of unusual failures.

## 2. Problem Formulation

Battery bank is the foundational part of the Electric Vehicles, because it holds the energy needed to run them. An effective battery management system (BMS) is essential to maximizing a battery's performance and guaranteeing its safe functioning. To ensure the battery runs safely, the BMS keeps an eye on a number of variables, calculates the state of charge (SOC), and provides necessary services. In electric vehicles (EVs) and other battery-powered devices, a Battery Management System (BMS) is essential. It guarantees the battery pack's optimal performance, longevity, and safety by controlling and regulating its operation.

Many problems arise at this stage of development as EVs are implemented, such as battery packs catching fire, overheating,

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and inefficient battery operation [1], [7].

## 3. Methodology

### A. System Architecture

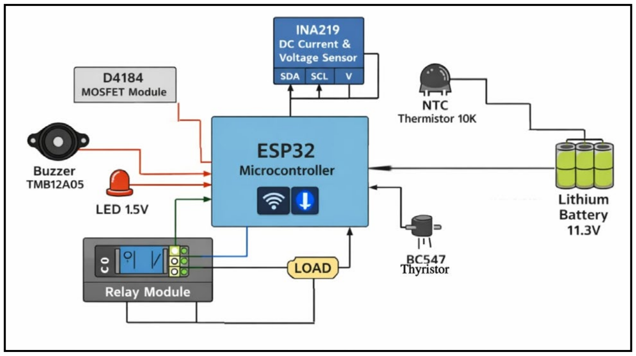


Fig. 1. Block diagram of the proposed battery monitoring and protection system using the ESP32

#### 1) ESP32 Microcontroller

The ESP32 is basically in charge of everything. It's the one that gathers all the readings from the sensors, figures out what they mean, and then tells the safety system what to do. People use the ESP32 a lot in electronics projects because it's pretty powerful, has Wi-Fi and Bluetooth built-in, plenty of connection points, and can talk to other devices using common methods like I²C and SPI.

In this setup, the ESP32 constantly checks the battery's voltage and how much current is flowing using the INA219 sensor. It also gets temperature readings from sensors on the battery. Based on all this info, the ESP32 decides if the battery is behaving normally or if something's wrong. If everything stays within the safe limits it's been told, the system just keeps doing its thing. But if the ESP32 notices something weird, like a huge spike in current that suggests a short circuit, it immediately tells the protection circuit to cut off the battery.

#### 2) Monitor Power with the INA219 Sensor

To check how the battery pack is doing electrically, we're using the INA219 sensor. This sensor can measure both voltage and current at the same time, and it's pretty accurate. It talks to the ESP32 using I²C, which is a neat way to send digital information back and forth using just two wires [8].

The INA219 measures the main voltage and the current going through a small resistor. By looking at these numbers, the ESP32 can tell how much power is being used right now. Constantly watching the current is super important because a sudden jump in current can mean a short circuit or some other problem. If the current goes over a certain limit, the ESP32 figures out that something's up and kicks in the safety measures.

#### 3) Monitor Temperature with Thermistors

How hot the battery gets is really important for both its safety and how well it works. In this setup, we're using thermistors to check the battery pack's temperature. A thermistor is basically a resistor that changes its electrical resistance depending on how hot or cold it is. When the temperature goes up, the thermistor's resistance changes, which in turn causes a voltage change that the microcontroller can read.

The ESP32 takes these voltage readings from the thermistors and uses some calibration math to figure out the actual temperature. By constantly watching the battery's temperature, we make sure it stays within safe operating limits. If the temperature gets too high, the microcontroller can step in to prevent problems, like cutting off the battery or sending out a warning.

#### 4) Battery Cutoff with a MOSFET Switch

The way we protect the battery is by using a power switch, specifically the D4184. A MOSFET, which stands for Metal Oxide Semiconductor Field Effect Transistor, is a popular choice for electronic switches in power systems because it can switch on and off very quickly and efficiently.

In this design, the D4184 MOSFET is placed between the battery pack and whatever it's powering. When everything is running normally, the MOSFET is turned on, letting electricity flow from the battery to the device. But, if the ESP32 notices something wrong, like a short circuit or too much current, it sends a signal to the MOSFET's gate, telling it to turn off. This instantly disconnects the battery from the device, protecting the battery and stopping any potential damage.

#### 5) Visual Status Lights

Two LEDs are built into the system to give you a quick look at how it's doing.

*Green Light:* This light means the battery system is working just fine. If everything like voltage, current, and temperature is within safe levels, the green light stays on.

*Red Light:* This light signals a problem. If the system notices anything off, like bad current, a short circuit, or a temperature that's too high, the red light comes on. It's letting you know the battery has been cut off for your safety.

This visual cue helps people quickly see if the system is running as, it should.

#### 6) Buzzer for Sounding Alarms

Besides the lights, the system also has a buzzer that makes a sound when there's a fault. If the ESP32 detects anything wrong, like a short circuit or it's getting too hot, it triggers the buzzer. This audible alarm makes sure you get alerted right away, even if you're not looking at the screen or the LEDs.

## 4. Results

The tests showed that our battery monitoring and protection system works well when everything is running as it should. It kept track of the battery's voltage and current with the INA219, and its temperature with thermistors. The ESP32 processed all this information and showed it live on the IoT interface. When things were normal, the green light stayed on, meaning the battery was safe. The system gave steady and correct readings for voltage, current, and temperature, so we could always see how the battery was doing.

Table 1
Operational states of the system under normal and fault conditions, indicating the response of the LEDs, MOSFET switching element, and buzzer alarm

| Condition | LED Status | MOSFET State | Buzzer Status |
|---|---|---|---|
| Normal Operation | Green LED ON | ON (Battery connected to load) | OFF |
| Fault Detected | Red LED ON | OFF (Battery disconnected) | ON |

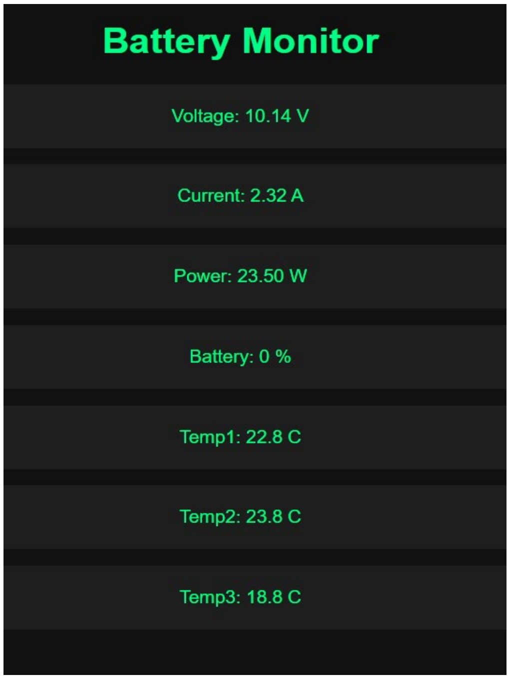


Fig. 2. Real time data monitoring on the IoT platform which shows the values of voltage, current, power & cell temperature

We also put the system through its paces with some problems to see how well it protected things. If there was a short circuit or a weird current spike, the system caught it with the INA219. The ESP32 then quickly kicked in the protection by controlling the D4184, which cut off the battery from whatever it was powering to stop any damage. At the same time, the red light came on and a buzzer went off to let us know there was a problem. This quick reaction proved the system is good at keeping the battery safe from dangerous situations.

On top of the local warnings from the lights and buzzer, the system also sent out alerts to let the user know about problems. Because it was always watching and protecting, the battery was automatically disconnected when things went wrong, making the whole setup safer and more dependable. Our experiments confirmed that this monitoring system we designed is an efficient and low-cost solution for battery safety management.

## 5. Conclusion

This paper presented the implementation of IoT based smart battery management system for electric vehicles.

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