Voltcare - Battery Charge Monitoring and Fire Prevention System

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***Abstract*—With the rise in electric vehicle (EV) adoption, battery safety has emerged as a pivotal concern. Lithium-ion batteries are susceptible to overcharging, overheating, and thermal runaway, which can lead to catastrophic failures. This paper introduces VoltCare, a microcontroller-based Battery Management System (BMS) engineered for real-time battery monitoring and fire prevention. Developed using the STM32 platform, VoltCare actively monitors voltage, current, and temperature parameters and enforces automated safeguards against thermal or electrical anomalies. The system incorporates dual-mode charging, a shutdown mechanism triggered by unsafe thresholds, and a user interface for real-time status visualization. Experimental validation on a working EV prototype demonstrates the effectiveness of VoltCare in extending battery life, preventing hazardous scenarios, and enhancing the overall safety and performance of the vehicle.**

***Index Terms*—Battery Management System (BMS), Electric Vehicle Safety, STM32 Microcontroller, Smart Charging, Lithium-ion Batteries.**

I INTRODUCTION

A. Background

The growing demand for environmentally sustainable alternatives to fossil-fuel-based transportation has fueled the adoption of electric vehicles (EVs) worldwide. Advances in lithium-ion battery technology and increasing environmental awareness have positioned EVs as the future of mobility. Lithium-ion batteries are favored for their long cycle life and rapid charging capabilities.

B. Safety Challenges

Despite their advantages, lithium-ion batteries present significant safety risks. These include thermal runaway, overcharging, over-discharging, and fire hazards. Battery fires in EVs have been reported globally, often resulting from excessive heat, improper charging, or hardware malfunctions. Existing Battery Management Systems (BMS) often offer limited functionality, focusing on charge level indication without incorporating proactive safety mechanisms.

C. Problem Statement

To ensure safety and operational reliability, modern EV systems require intelligent BMS solutions capable of real-time parameter monitoring, fault detection, and preventive intervention. These systems must be scalable, energy-efficient, and capable of reacting swiftly to abnormal conditions to avoid battery degradation and hazards.

D. Overview of VoltCare

VoltCare is proposed as an advanced Battery Management System that integrates real-time monitoring, intelligent charge control, and fire prevention mechanisms. Developed using the STM32 microcontroller, it continuously assesses voltage, current, and temperature parameters.

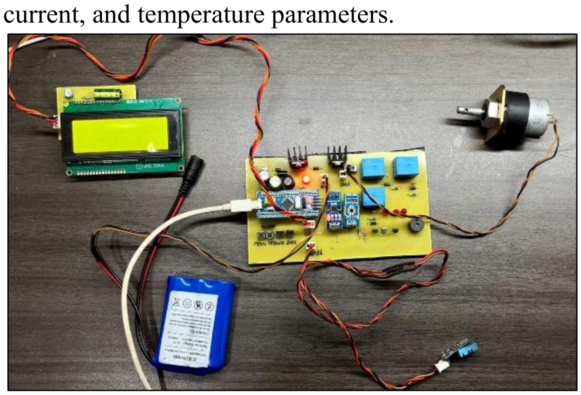

Fig 1.1 – Demonstration of VoltCare System

The system uses predefined thresholds and initiates a shutdown protocol when values exceed safe limits. It also supports dual-mode charging (fast/slow), provides visual alerts through an LCD display, and includes an audible alarm for emergencies. This paper elaborates on the design methodology, system implementation, and experimental evaluation of VoltCare, demonstrating its potential to enhance battery safety and performance in electric mobility applications.

II METHODOLOGY

A. System Architecture

The VoltCare system architecture integrates various sensor modules with a central STM32 microcontroller. The sensors include a DHT11 for temperature, voltage divider circuits for voltage detection, and shunt-based current sensors. These sensors continuously collect data and send it to the STM32, which processes the data using embedded logic programmed through Thonny IDE. Threshold values for safe operating conditions are pre-defined in the firmware. When readings exceed these values, interrupts are triggered, resulting in an immediate system shutdown to prevent damage or hazards.

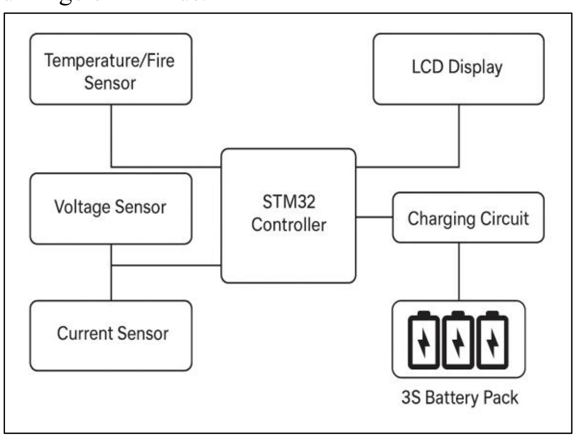

Fig 2.1 – Block Diagram of the VoltCare System

B. Hardware Components

Key hardware components used in VoltCare include the STM32 microcontroller, 11.1V Li-ion battery, DHT11 temperature sensor, LCD display, LM2576 voltage regulator, IC 7812, resistors, capacitors, switches, and connectors. A custom PCB was designed using Eagle CAD software. After printing the traces, the components were soldered in sequence, and the board was connected to a DC motor and load to simulate an EV scenario. A 16x2 LCD module was integrated for real-time display of system parameters. A backup model was kept on standby.

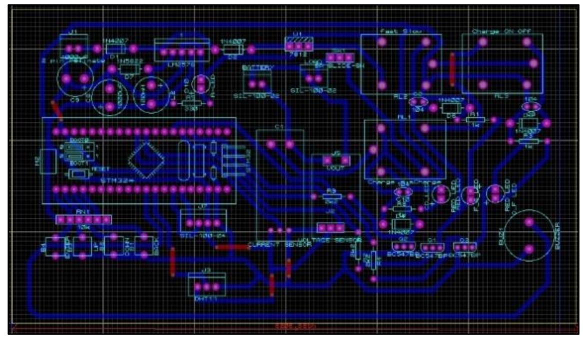

Fig 2.2 – PCB Traces Layout

C. Firmware and Software Implementation

The firmware was developed in Python and embedded into the STM32 controller using Thonny IDE. Functions included data acquisition, threshold comparison, interrupt generation, charging mode control, and LCD data output. The logic enabled switching between fast and slow charging modes based on temperature and voltage readings and activated a buzzer when an anomaly was detected. The system was tested iteratively to ensure all edge cases were addressed.

III RESULTS AND DISCUSSION

A. Sensor Accuracy and Response

During experimental testing, the DHT11 temperature sensor reliably detected thermal variations, initiating automatic shutdown when the temperature exceeded 50°C. Voltage and current sensors effectively flagged deviations, with the microcontroller disabling operations when values fell outside safe thresholds. This demonstrated the accuracy and responsiveness of the system to environmental and electrical anomalies.

B. Charging Mode Control

The system accurately toggled between fast and slow charging modes based on battery state and temperature. Fast charging was initiated when the battery level was low and temperature was within safe limits. If the temperature increased during charging, the controller seamlessly switched to slow mode or halted the process altogether. This helped reduce stress on the battery and enhanced its operational safety.

C. User Interface Performance

The LCD module displayed real-time battery parameters effectively, including temperature, voltage, and current. Alerts such as 'High Temp' or 'Voltage Spike' were shown promptly, helping users take immediate action. The buzzer alert feature worked reliably during anomaly detection, enhancing the system's safety awareness mechanism.

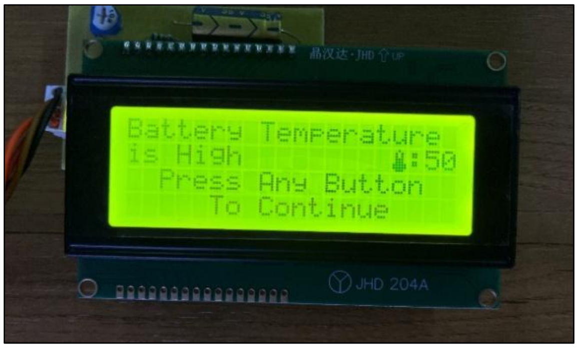

Fig 3.1 – System Cut-off at High Temperature

D. Overall System Evaluation

VoltCare performed consistently across multiple test cycles. The safety protocols were enforced every time an unsafe condition was simulated. The modular nature of the design indicates that it can be easily integrated into other electric mobility platforms. The experimental prototype confirmed its scalability and practical applicability for real-world use.

Table I – System Safety Parameter Thresholds, Triggered Actions and Responses

Parameter	Safety Range	Trigger Condition	System Response
Temperature	0°C – 50°C	> 50°C	Cut-off load, buzzer alert
Voltage	10.5V – 12.6V	< 10.5V or > 12.6V	Stop charging/discharging
Current	0A – 2.0A	> 2.0A	Stop current flow and display warning

IV CONCLUSION

This paper presents VoltCare, a comprehensive battery management and fire prevention system developed for electric vehicle platforms. By combining sensor-based real-time monitoring, intelligent charging control, and emergency shutdown mechanisms, VoltCare addresses critical safety challenges associated with lithium-ion batteries. The use of the STM32 microcontroller ensures low-power consumption, fast response times, and a compact design suitable for scalable deployment. The system's ability to detect and mitigate risk factors such as overheating, overcharging, and irregular current flow significantly enhances the safety and efficiency of EV operations. Prototype validation demonstrated VoltCare's effectiveness in real-world scenarios, offering a practical pathway to safer and more reliable electric mobility solutions. positioned EVs as the future of mobility

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