

# Battery Health Management System with Digital Twin Technology

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## I. ABSTRACT

This project introduces a monitoring system designed to oversee the key parameters of an electric vehicle (EV) battery, such as voltage, current, temperature, and battery charge level. The system integrates sensors to continuously monitor the battery's performance and automatically activates safety measures when certain thresholds are exceeded, such as turning on a cooling fan for high temperatures or initiating charging when the battery voltage drops too low. Additionally, the system includes mechanisms to ensure safe motor operation based on monitored conditions. Data is transmitted to a cloud platform for remote tracking and displayed locally for real-time monitoring. The proposed model aims to improve battery health management, enhance safety, and prevent damage caused by overheating, overcurrent, or low battery levels in EVs.

**Keywords:** Battery Management System (BMS), Electric Vehicles (EVs), Relays, Overcharging, Temperature Monitoring, IoT-based monitoring, Battery Protection, DC Motor, Voltage Sensor, Current Sensor, Temperature Sensor,

## II. INTRODUCTION

rapid growth of electric vehicles (EVs) and renewable energy systems has highlighted the importance of effective efficiency, safety and

operational lifespan of the devices they power. However, monitoring and maintaining battery health is often challenging due to factors such as temperature fluctuations, voltage drops, and overcurrent conditions, which can lead to damage or system failure.



Fig.1.Revolutionizing Battery Management in Mobile Devices using Digital Twin Technology

This project aims to address these challenges by developing an integrated Battery and Fire Monitoring System. The system continuously tracks key battery parameters, such as voltage, current, temperature, and charge level, and automatically activates corrective actions, such as turning on a cooling fan or initiating battery charging, when unsafe conditions are detected. With the use of sensors, relays, and IoT technology, the system not only ensures the safe operation of electric vehicles and other battery-powered systems but also provides real-time data monitoring and cloud-based analysis for remote tracking.

The performance, safety, and life of Electric Vehicles (EVs) critically depend on the health of their lithium-ion batteries. As these batteries suffer continuous charging and discharging cycles, they witness gradual declination in capacity and effectiveness. To ensure optimal operation, it's essential to directly cover two pivotal parameters State of Health (SOH) and State of Charge (SOC). These parameters companion battery operation systems in estimating remaining usable life and functional charge, enabling safer and further effective EV operation. In this study, we present a data-driven Digital Twin frame that focuses simply on predicting SOH and SOC using real-world lithium-ion battery cycle data. The dataset spans over 1,000 full charge-discharge cycles and includes essential parameters analogous as voltage, internal resistance (Re and Rct), temperature, and capacity. The design channel involves drawing and pre-recycling the dataset, homogenizing the values, and applying regression and recursive estimation ways to predict SOH and SOC. SOH is calculated predicated on capacity declination, while SOC is estimated using Coulomb counting styles, further bettered using voltage-time analysis and Kalman filtering. This frame forms the base for intelligent battery diagnostics and provides precious insight into battery declination trends. By fastening solely on SOH and SOC estimation, the system enables real-time monitoring that can be integrated into broader battery operation operations in electric vehicles as multi-leveled equations, graphics, and tables are not prescribed, although the various table text styles are provided.

### III. LITERATURE SURVEY

Battery Management Systems (BMS) play a crucial role in ensuring the safety, efficiency, and

longevity of electric vehicle (EV) batteries. Several researchers have contributed to the development of advanced monitoring and management techniques for EV batteries.

Zubair Baig, Muhammad Shoaib, et al., in their work titled *"Battery Management System for Electric Vehicles: A Review"*, discussed various techniques used to monitor key battery parameters such as voltage, current, and temperature. Their study highlights both conventional and IoT-based monitoring approaches and identifies major challenges like overcharging, overheating, and inefficient battery utilization. The authors emphasize the need for integrated systems that ensure safe and optimized battery operation.

Santosh K. Gupta, Ruchi Gupta, et al., presented an *"IoT-Based Battery Health Monitoring System for Electric Vehicles"*, where real-time battery parameters are continuously monitored using IoT technology. Their system uses cloud platforms for data storage and analysis, enabling predictive maintenance and improved battery performance. The study also points out challenges such as data accuracy, network reliability, and security issues in IoT systems.

S. G. Rao, P. S. Bhat, et al., in their paper *"Design of a Battery Management System Using Embedded Systems for Electric Vehicles"*, proposed an embedded system-based BMS that monitors voltage, current, and temperature. Their system ensures protection against overcharging, deep discharge, and overheating by controlling relays and charging circuits. This approach significantly improves battery lifespan and operational safety and can be extended to renewable energy storage applications.

R. K. Pandey, A. S. Kumar, et al., developed a *"Smart Battery Management System for Electric Vehicles Based on IoT"*. Their work integrates sensors with cloud connectivity to enable remote

remote monitoring and automated control actions such as cooling and charging. The system enhances battery safety, efficiency, and performance by responding dynamically to abnormal conditions.

#### IV. BLOCK DIAGRAM



Fig.2.Block Diagram of Proposed Model

#### V. PROPOSED MODEL

The proposed model introduces an integrated monitoring system for electric vehicle (EV) batteries, designed to track voltage, current, temperature, and battery charge level. It features automated safety measures that respond to abnormal conditions, such as activating a cooling fan when the temperature exceeds a set threshold, triggering a battery charging relay when the voltage drops below a critical level, and ensuring safe motor operation based on monitored current and voltage. The system also includes a multiple mobile charger feature, enabling the simultaneous charging of multiple devices within the EV, enhancing convenience for users. It provides real-time data display on an LCD and uploads data to a cloud platform for remote monitoring. By

integrating sensors, automated control, IoT-based data transmission, and the multiple charger functionality, the system enhances battery health management, prevents overheating and overcurrent situations, ensures safety in EVs, and adds user-centric features for improved utility.

#### VI .HARDWARE COMPONENTS

S.NO	HARDWARE COMPONENTS
1.	Raspberry pi
2.	Battery(12v)
3.	Voltage sensor
4.	Current sensor
5.	Ds18b20 temperature sensor
6.	Relay (5V) – 4
7.	Dc motor
8.	Cooling fan
9.	Lcd display
10.	Buzzers
11.	5V and 12V Power Supply
12.	5V adapter
13.	Slide switch
14.	Potentiometer
15.	Gas sensor
16.	LED's

#### VII. SOFTWARE COMPONENTS

- RASBIAN 
- PYTHON 
- THINKSPEAK 

WORKING PRINCIPLE

Current Sensor detects the current in a wire or conductor and generates a signal proportional to the detected current either in the form of analog voltage or digital output.

Current Sensing is done in two ways – Direct sensing and Indirect Sensing. In Direct sensing, to detect current, Ohm’s law is used to measure the voltage drop occurred in a wire when current flows through it.

A current-carrying conductor also gives rise to a magnetic field in its surrounding. In Indirect Sensing, the current is measured by calculating this magnetic field by applying either Faraday’s law or Ampere law. Here either a Transformer or Hall effect sensor or fiberoptic current sensor are used to sense the magnetic field.

ACS712 Current Sensor uses Indirect Sensing method to calculate the current. To sense current a liner, low-offset Hall sensor circuit is used in this IC. This sensor is located at the surface of the IC on a copper conduction path. When current flows through this copper conduction path it generates a magnetic field which is sensed by the Hall effect sensor. A voltage proportional to the

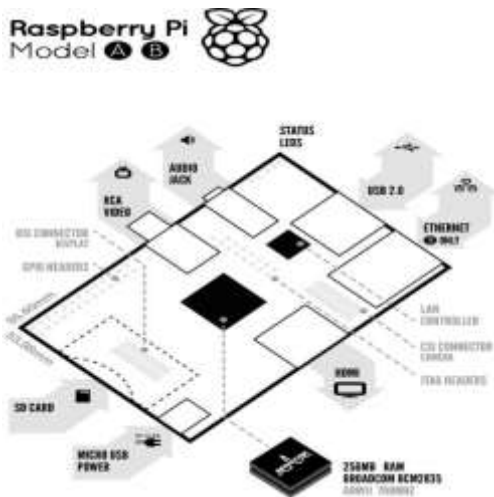


Fig.3.Block Diagram of Raspberry Pi

VIII.SPECIFICATIONS OF RASPBERRY PI 2 MODEL-B

	Model A	Model B	Model B+
<b>Target price:</b>	US\$25	US\$35	
<b>SoC:</b>	Broadcom BCM2835 (CPU, GPU, DSP, SDRAM, and single USB port)		
<b>CPU:</b>	700 MHz ARM1176JZF-S core (ARM11 family, ARMv6 instruction)		
<b>GPU:</b>	Broadcom Video Core IV @ 250 MHz		
<b>Memory</b>	256 MB	512 MB (shared with GPU)	
<b>USB 2.0 ports:</b>	1 (direct from BCM2835 chip)	2 (via the on-board 3-port USB hub)	4 (via the on-board 5-port USB hub)
<b>Video input:</b>	15-pin MIPI camera interface (CSI) connector, used with the Raspberry Pi		
<b>Video outputs:</b>	Composite RCA (PAL and NTSC) –in model B+ via 4-pole 3.5 mm jack HDMI (rev 1.3 & 1.4), raw LCD Panels via DS		
<b>Audio outputs:</b>	3.5 mm jack, HDMI, and, as of revision 2 boards, I <sup>2</sup> S audio (also potentially		
<b>Onboard storage:</b>	SD / MMC / SDIO card slot (3.3 V card power support only)		MicroSD
<b>Onboard network:</b>	None	10/100 Mbit/s Ethernet (8P8C) USB adapter on the third/fifth port of the USB hub	
<b>Low-level peripherals</b>	8× GPIO, UART, I <sup>2</sup> C bus, SPI bus with two chip selects, I <sup>2</sup> S audio +3.3 V, +5 V,		17× GPIO

ACS712 can be used in applications requiring electrical isolation as the terminals of the conduction path are electrically isolated from the IC leads. Thus, this IC doesn't require any other isolation techniques. This IC requires a supply voltage of 5V. Its output voltage is proportional to AC or DC current. ACS712 has a nearly zero magnetic hysteresis.

Where Pin-1 to Pin-4 forms the conduction path, Pin-5 is the signal ground pin. Pin-6 is the FILTER pin that is used by an external capacitor to set the bandwidth. Pin-7 is the analog output pin. Pin-8 is the power supply pin.

## IX. SOFTWARE REQUIRMENTS

### **RASPBIAN:**

Raspbian is the recommended operating system for normal use on a Raspberry Pi.

Raspbian is a free operating system based on Debian, optimized for the Raspberry Pi hardware. Raspbian comes with over 35,000 packages; precompiled software bundled in a nice format for easy installation on your Raspberry Pi.

Raspbian is a community project under active development, with an emphasis on improving the stability and performance of as many Debian packages as possible.

### **PYTHON:**

Python is a general purpose, dynamic, high level and interpreted programming language. It supports Object Oriented programming

approach to develop applications. It is simple and easy to learn and provides lots of high-level data structures. It is easy to learn yet powerful and versatile scripting language which makes it attractive for Application Development. Its syntax and dynamic typing with its interpreted nature, makes it an ideal language for scripting and rapid application development. It supports multiple programming patterns, including object oriented, imperative and functional or procedural programming styles. It is not intended to work on special area such as web programming. That is why it is known as multipurpose because it can be used with web, enterprise, 3D CAD etc. We don't need to use data types to declare variable because it is dynamically typed so we can write `a=10` to assign an integer value in an integer variable. It makes the development and debugging fast because there is no compilation step included in python development and edit-test-debug cycle is very fast.

**THINGSPEAK:** ThingSpeak is an IoT analytics platform service that allows you to aggregate, visualize, and analyze live data streams in the cloud. You can send data to ThingSpeak from your devices, create instant visualization of live data, and send alerts.

### X. RESULTS AND OBSERVATIONS



Fig.4.Real Photography of Existing System



Fig.5.Output on LCD when Gas Sensor Alert



Fig.6.Output when all paraments are in Good condition.



Fig.7.Thingspeak Graph Analysis of Gas value, Temperature and Voltage

## XI. CONCLUSION & FUTURE SCOPES

The proposed Battery and Fire Monitoring System for electric vehicles (EVs) and other battery-powered devices offers a reliable solution to ensure the safety, health, and performance of batteries. By continuously monitoring critical battery parameters such as voltage, current, temperature, and charge levels, the system enables proactive management and control over the battery's condition. The integration of sensors, IoT technology, and automated responses like cooling and charging ensures the prevention of issues such as overcharging, overheating, and deep discharging.

Additionally, the cloud-based monitoring via ThingSpeak facilitates remote tracking and analysis, providing valuable insights into battery health and helping detect potential failures early. This system's flexibility extends beyond EVs to applications in renewable energy storage, UPS systems, and other battery-dependent technologies, offering scalability for various industries. In conclusion, this approach enhances the efficiency, safety, and longevity of battery systems, supporting the wider adoption of electric vehicles and sustainable energy solutions.

- The system can be applied in electric vehicles to provide real-time monitoring and protection of battery parameters, thereby improving safety and performance.
- The invention enables IoT-based remote monitoring, allowing users to track battery status and receive alerts through cloud platforms and mobile applications.
- The invention can be implemented in smart charging stations to prevent overcharging, optimize charging cycles, and extend battery life.

- The system supports automatic fault detection and isolation, making it suitable for industrial applications like UPS systems and backup power units.
- Future enhancements include integration of Artificial Intelligence and Machine Learning techniques for accurate prediction of battery health parameters such as State of Charge (SoC) and State of Health (SoH).
- The system can be extended with wireless communication technologies to develop a Wireless Battery Management System (WBMS), reducing wiring complexity.

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