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EV BMS Fire Protection and Charge Monitoring

B. Sai Krishna [1], Syed Sabeel [2], Mohammed Azlaan [3], Abdul Basith [4], Nimra Fathima [5]
[1]Assistant professor, [2,3,4,5]Students,
Department of Electronics and Communication Engineering, Lords Institute of Engineering and Technology, Hyderabad, Telangana.

Abstract
With the rise of electric vehicles (EVs), ensuring the safety and efficiency of their battery management systems (BMS) is crucial. This project aims to develop an integrated fire protection and charge monitoring system using an Arduino. The system uses a fire sensor and voltage sensor to detect hazards and monitor battery levels. If a fire risk is detected, it triggers an alert and safety protocols via an LCD. The system also provides real-time battery charge data. The goal is to enhance EV safety and operational efficiency.

I. Introduction

Electric Vehicles (EVs) use electric motors powered by battery packs instead of traditional internal combustion engines. They offer benefits like reduced emissions, quieter operation, and lower running costs. However, EVs are prone to risks such as battery overheating, internal short circuits, and potential fire hazards due to thermal runaway. To ensure safety, a Battery Management System (BMS) is essential. It monitors voltage, detects Fire , and protects the battery from damage caused by overcharging, overheating, or low temperatures. It also ensures the battery operates within safe limits to extend its lifespan.

Li-ion batteries, commonly used in EVs, require precise monitoring. Overcharging or overheating can lead to failure or fire. In our project, we developed a small robot embedded with sensors to monitor battery voltage, temperature, and fire. If high temperature is detected, the system cuts off battery power using a relay. The robot is controlled via an Android app, demonstrating a compact and functional EV safety prototype.

II. Literature Review:

Electric vehicles (EVs) rely heavily on battery storage for power, making the Battery Management System (BMS) a vital component for ensuring both safety and performance. According to Liu, Qian, and Guan (2013), an efficient BMS is essential to monitor battery parameters such as current, voltage, and temperature. It calculates the State of Charge (SoC), protects the battery from damage, and ensures the cells operate within safe limits. Their model also incorporates features like battery status detection and LCD display, supporting real-time monitoring and control.

Li, Fan, and Li (2019) introduce an innovative active cell balancing scheme for series-connected batteries in EVs. Their system improves energy efficiency and battery lifespan by ensuring equal charge distribution among cells—an essential feature for preventing cell degradation and maintaining pack stability. Wang, Xu, and Xu (2017) focus on thermal management within the BMS. They highlight that overheating is one of the leading causes of battery failures, and an integrated BMS can help regulate temperature and avoid hazards like thermal runaway. Their work supports the implementation of real-time temperature control and protection mechanisms.

Guo, Ang, and Cheng (2016) extend the safety functionality of BMS by combining charge monitoring with a fire detection system. Their integrated model can detect abnormal behavior in voltage, current, or temperature and automatically disconnect the power supply, thus reducing the risk of battery fires or explosions—an increasing concern as EVs become more common. Cheng, Luo, and Yang (2018) present a neural network-based approach for early fault diagnosis in lithium-ion batteries. By using ensemble learning, their model can detect faults with high accuracy, allowing for predictive maintenance and minimizing the risk of sudden failures.

Together, these studies reinforce the importance of advanced BMS in EVs for real-time monitoring, thermal management, cell balancing, fire prevention, and fault detection—ultimately enabling safer, more reliable, and longer-lasting electric vehicle systems

III. Proposed System

This project proposes a cost-effective, integrated system using an Arduino with fire and voltage sensors. It provides real-time monitoring and alerts for fire hazards and battery charge levels. This user-friendly system enhances safety and efficiency and can be implemented in various EV models.

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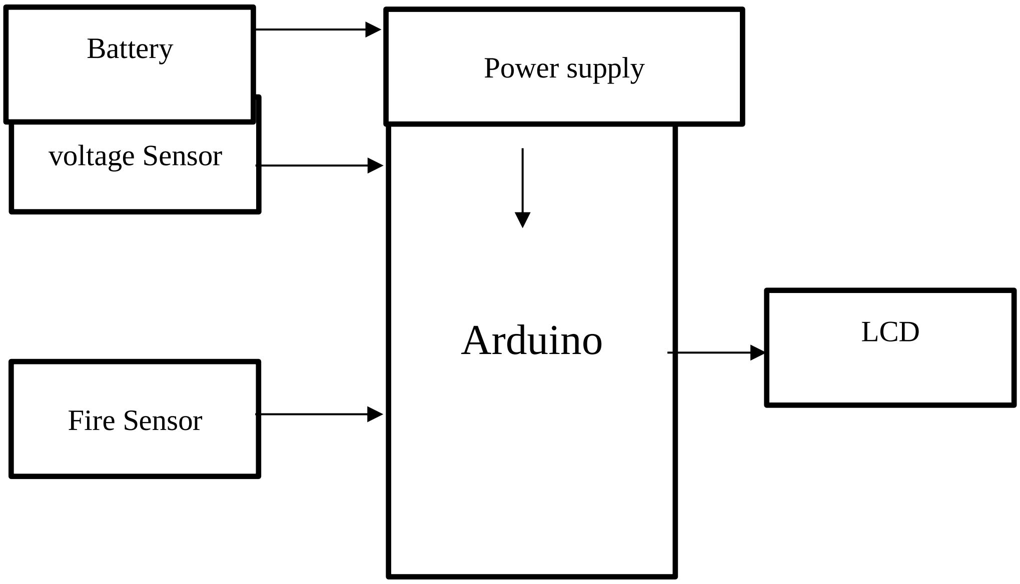
IV. Block Diagram

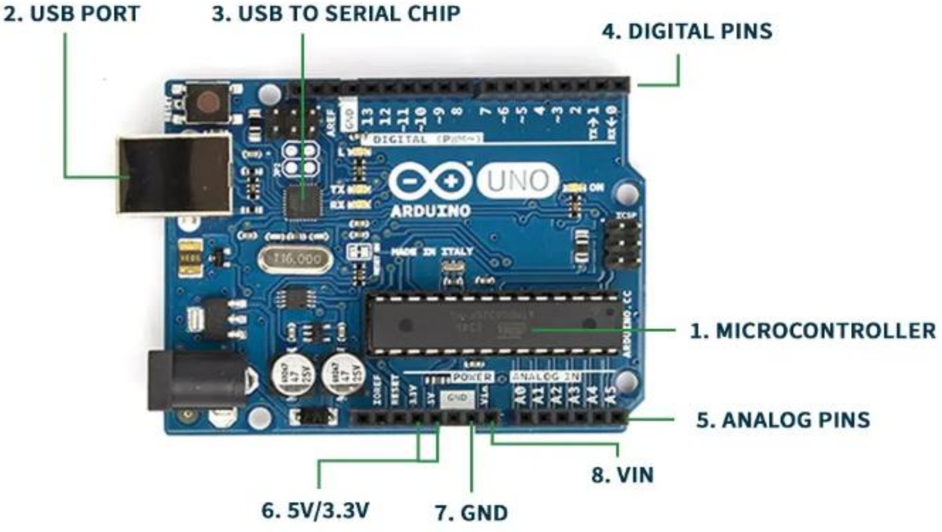


Block diagram of EV BMS Fire Protection and Charge Monitoring

Arduino Uno

The Arduino is one of the most popular and widely used Arduino boards. It's based on the ATmega328P microcontroller and offers a good balance of features, performance, and affordability, making it suitable for a wide range of projects, from simple to moderately complex.

Most electronic devices involve circuit-making using hardware components. The purpose of introducing Arduino was to make an easy-to-use device that can offer the feature of programming along with circuit making. Therefore, Arduino is a programmable device that is used mostly by artists, designers, engineers, hobbyists, and anyone who wants to explore programming in electronics.



Arduino UNO Board – Component Layout

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Features of Arduino UNO:

- Microcontroller – (ATmega328P)The heart of the Arduino Uno is the ATmega328P microcontroller, an 8-bit AVR chip that executes the code uploaded from the Arduino IDE.
- Operating Voltage – 5V
- Input Voltage (Recommended) – 7 to 12V
- Digital I/O Pins – There are 14 general-purpose digital input/output pins. Out of these, 6 pins (pins 3, 5, 6, 9, 10, 11) support PWM output, allowing simulation of analog output.
- Analog Input Pins – The board includes 6 analog inputs (A0 to A5) which can read voltage signals from analog sensors and convert them to digital values.
- Flash Memory – (32 KB) Used to store your program code.
- SRAM – 2 KB Used for creating and manipulating variables while the program runs.
- Clock Speed – 16 MHz
- USB Connection- Used to connect it to a computer for programming and serial communication
- Power Jack-An external DC power supply can be connected via the barrel jack.
- Reset Button- To reset the microcontroller manually. Pressing it restarts the program from the beginning.
- Arduino IDE-The board is programmed using the Arduino IDE, a beginner-friendly environment with a simple language (based on C/C++), ideal for students and hobbyists.

Arduino UNO Pin Description:

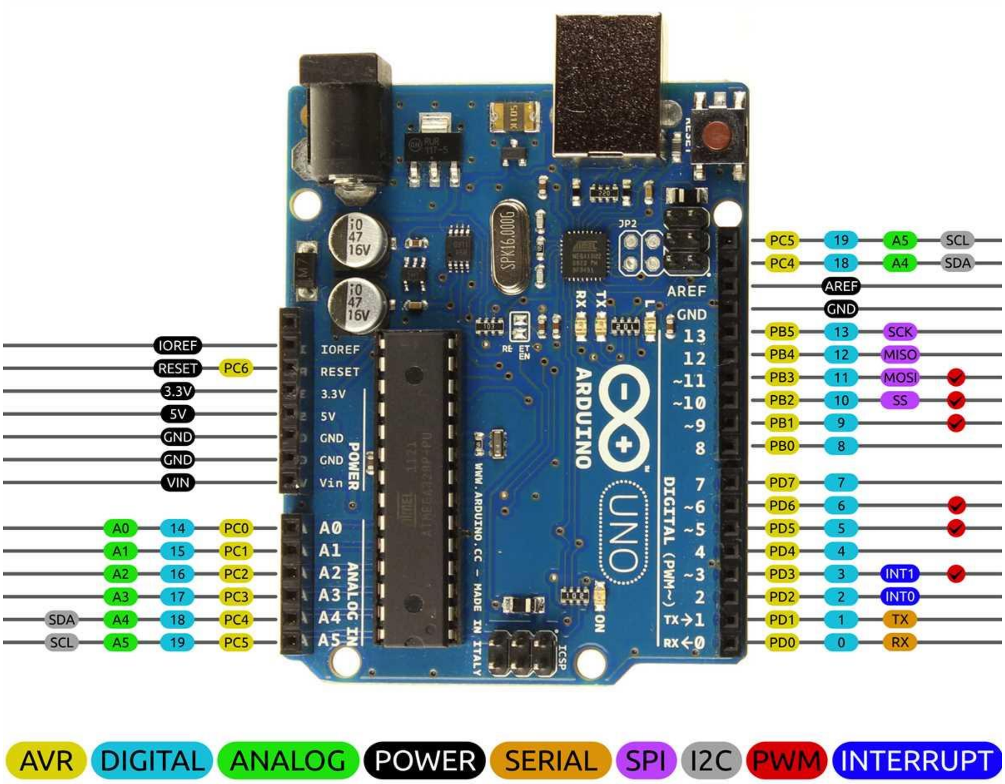

Fig- Arduino Uno Pinout

Voltage Sensor:

This sensor is used to monitor, calculate and determine the voltage supply. This sensor can determine the AC or DC voltage level. The input of this sensor can be the voltage whereas the output is the switches, analog voltage signal, a current signal, an audible signal, etc. Some sensors provide sine waveforms or pulse waveforms like output & others can generate outputs like AM, PWM or FM_. The measurement of these sensors can depend on the voltage divider.

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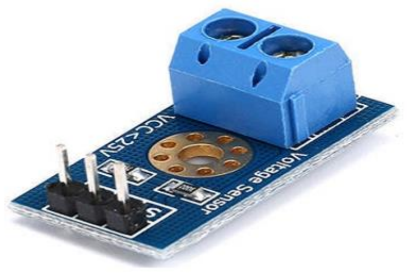

Voltage Sensor

This sensor includes input and output. The input side mainly includes two pins namely positive and negative pins. The two pins of the device can be connected to the positive & negative pins of the sensor. The device positive & negative pins can be connected to the positive & negative pins of the sensor. The output of this sensor mainly includes supply voltage (Vcc), ground (GND), analog o/p data.

Types of Voltage Sensor:
1) Resistive Type Sensor.
2) Capacitor Type Sensor.

Applications:
- Safety switching
- Controlling temperature
- Controlling of power demand
- Detection of fault
- Detection of power failure

Fire sensor/ Flame sensor:

A flame-sensor is one kind of detector which is mainly designed for detecting as well as responding to the occurrence of a fire or flame. The flame detection response can depend on its fitting. It includes an alarm system, a natural gas line, propane & a fire suppression system. This sensor is used in industrial boilers. The main function of this is to give authentication whether the boiler is properly working or not. The response of these sensors is faster as well as more accurate compare with a heat/smoke detector because of its mechanism while detecting the flame.

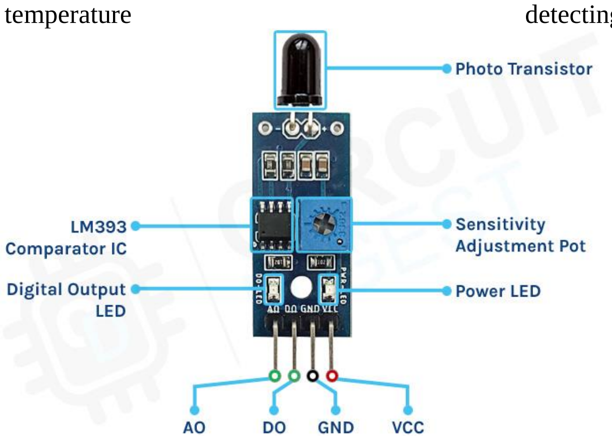

Fig- Flame-sensor

This sensor/detector can be built with an electronic circuit using a receiver like electromagnetic radiation. This sensor uses the infrared flame flash method, which allows the sensor to work through a coating of oil, dust, water vapor, otherwise ice.

LCD:

LCD is a flat display technology, stands for "Liquid Crystal Display," which is generally used in computer monitors, instrument panels, cell phones, digital cameras, TVs, laptops, tablets, and calculators. It is a thin display device that offers support for large resolutions and better picture quality. The older CRT display technology has replaced by LCDs, and new display technologies like OLEDs have started to replace LCDs. An LCD display is most commonly found with Dell laptop computers and is available as an active-matrix, passive-matrix, or dual-scan display. The picture is an example of an LCD computer monitor. The Liquid Crystal library allows you to control LCD displays that are compatible with the Hitachi HD44780 driver. There are many of them out there, and you can usually tell them by the 16-pin interface.

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Fig- 16x2 LCD

Power Supply Module:

A regulated power supply module, which is used to convert an unregulated DC voltage (typically 9V or 12V) to a stable 5V DC output, suitable for powering microcontrollers and other low-voltage circuits.

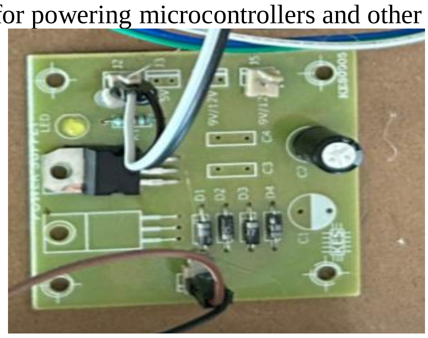

Fig- Regulated Power Supply

Key Components:

- Voltage Regulator (IC 7805): This 3-pin IC regulates the input voltage down to a constant 5V output.
- Bridge Rectifier (D1–D4): Four diodes arranged in a bridge configuration convert AC to pulsating DC.
- Electrolytic Capacitor (C1): Smoothens the DC output by filtering voltage ripples.
- Indicator LED with Resistor: Provides a visual indication that the circuit is powered.
- Terminal Connectors: Used for input voltage supply and regulated output connections.

V. Schematic diagram

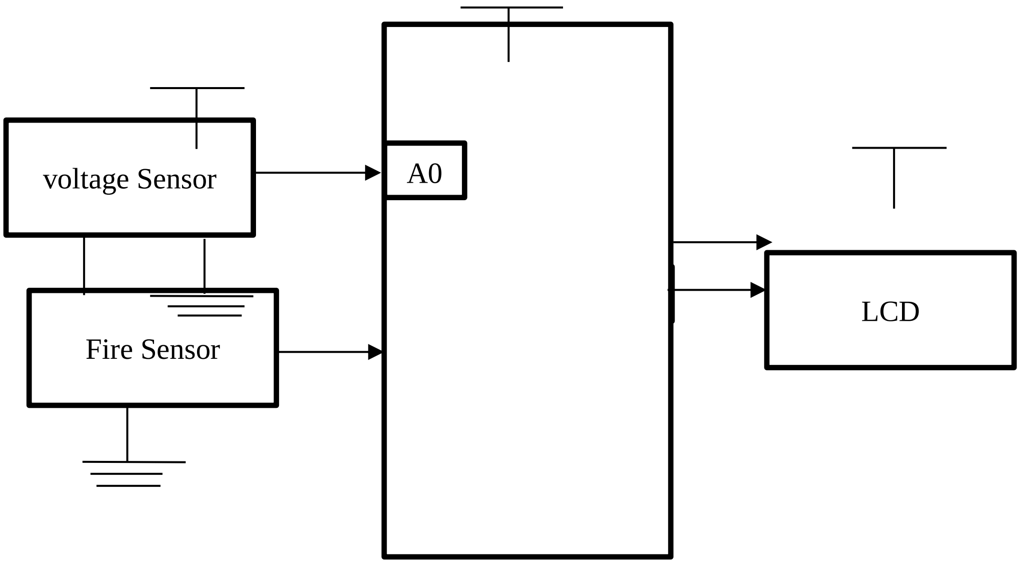

Fig: schematic diagram of proposed system

VI. Result

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Prototype Demonstration:

The following images show the working model of the project titled: "EV BMS Fire Protection and Charge Monitoring."

This system successfully integrates:

- A fire sensor to detect the presence of heat or flame,
- A voltage sensor to monitor battery voltage in real time, - An Arduino UNO microcontroller to process sensor data, - An LCD display to show the current system status.

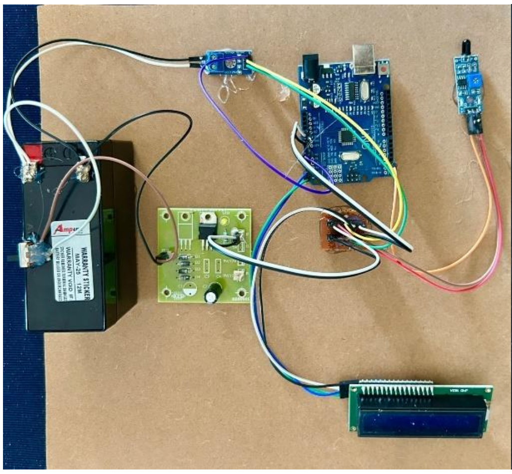

Fig 8.1: Circuit Connections.

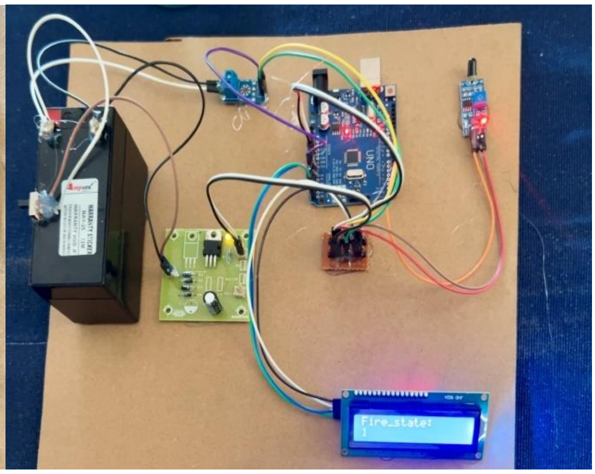

Fig 8.2: Working Condition.

Description of the Setup:

- The first image shows the complete circuit connections between the battery, sensors, Arduino, and LCD on a wooden mounting base.
- The second image shows the LCD displaying "Fire_state: 1", indicating fire detection by the flame sensor.

The project has been successfully tested, and the LCD output confirms that the system can detect a fire condition and display alerts in real time. The setup is powered by a rechargeable battery, and all components are connected through jumper wires with proper interfacing.

VII. Future Scope

The developed prototype of the EV Battery Management System (BMS) with integrated fire protection and charge monitoring presents promising opportunities for further development and deployment.
The future scope of this project includes:

- **Add IoT** to monitor battery and fire alerts from mobile or computer.
- **Use GSM and GPS** to send SMS alerts and track EV location during fire.
- **Add thermal camera** for better and faster fire detection.
- **Make it suitable** for different EVs like bikes, cars, and buses.
- **Connect with braking system** to save energy while braking.
- **Create a mobile app** to see battery level and get safety alerts.
- **Follow safety rules** to make it ready for real-world.

VIII. References

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