INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN APPLIED SCIENCE (IJRIAS)
ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue VI June 2025

Thermal Management System for Electric Vehicle's

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DOI: https://doi.org/10.51584/IJRIAS.2025.10060018

Received: 13 June 2025; Accepted: 17 May 2025; Published: 30 June 2025

ABSTRACT

Electric vehicles have recently raised concerns due to the lack of sufficient battery management systems, primarily resulting from poor thermal design. Many EVs still operate without effective thermal safety measures, leading to risks of overheating and fire. This project addresses these issues by developing a system that detects both overheating and smoke in the battery unit, enabling users to take timely preventive action. The system uses an Arduino Uno as the central controller, integrating a DS18B20 temperature sensor and an MQ135 smoke sensor to monitor environmental conditions in real-time. It includes a 16×2 I2C LCD, an SPDT switch for display control, and a Bluetooth-based mobile interface. The result is a compact, cost-effective, and scalable thermal management solution for EVs.

Index Terms: Hazard Detection, Real-time Monitoring, Ther- mal Safety, Lithium-ion Batteries, Arduino

INTRODUCTION

As electric vehicles (EVs) have grown in popularity, thermal management has become essential to both their performance and safety. The risks of battery overheating have been brought to light by a number of recent fire incidents, particularly involving electric bicycles. Weak battery management systems and inadequate thermal design are frequently blamed for these occurrences. For EV safety, it is therefore essential to implement trustworthy thermal management solutions. Electric vehicles frequently use lithium-ion batteries, which have a safe operating temperature range of -20°C to +60°C. However, they should ideally be kept between 10°C and 40°C for optimal per- formance and longevity. These batteries experience decreased efficiency, faster deterioration, and even the potential for thermal runaway, an uncontrollable reaction that could result in fires or explosions, when exposed to temperatures outside of this range. Efficiency in thermal As EVs become more and more popular, it is imperative to make sure their battery systems are safe and effective. Commonly found in EVs, lithium-ion batteries are extremely sensitive to temperature changes, which can result in decreased efficiency or even hazardous thermal flee. By continuously checking the battery temperature and identifying smoke emissions, our suggested thermal management system overcomes these difficulties. The system combines a MQ135 smoke sensor and a DS18B20 temperature sensor with an Arduino Uno controller to track important parameters in real time. When the battery tempera- ture rises above a safe range, the system is intended to notify users by sounding an alarm and taking preventative measures. Current temperature readings are shown on a 16x2 LCD display, and remote monitoring and control are possible via an Arduino Blue Control smartphone app. This configuration

Motivation

The intrinsic temperature sensitivity of electric vehicles' (EVs') essential parts—specifically, the lithium-ion battery pack, electric motor, and power electronics—motivates the de- velopment of advanced thermal management systems (TMS). Because EVs are so efficient, they require specialised systems to maintain ideal temperatures, in contrast to conventional internal combustion engines that produce a lot of waste heat for different purposes. It is crucial to keep the battery within a specific ideal temperature range, usually between 20°C and 35°C. Going over this can hasten degradation, lower capacity and power output, shorten its lifespan, and—most impor- tantly—increase the risk of thermal runaway, a hazardous self-propagating overheating condition that can start fires. On the other hand, low temperatures significantly reduce battery range, performance, and charging speed. In addition to the battery, the power electronics and electric motor

Objectives

- The main goal is to keep the temperature of vital parts—particularly the battery pack, electric motor, and power electronics—within their optimal operating win- dows. To optimise the lifespan, power output, and effi- ciency of lithium-ion batteries, temperatures should be kept between 20 and 35 degrees Celsius (or comparable ranges, depending on the cell chemistry).
- Prevent Overheating and Thermal Runaway: Preventing components from reaching their maximum allowable tem- peratures is an important safety goal. To prevent thermal runaway, a hazardous self-propagating chain reaction that can result in fire or explosion, batteries must actively dissipate heat. It guards against demagnetisation and in- sulation degradation caused by excessive heat for motors and power electronics.

Problem Statement

Effectively controlling and maintaining the various thermal environments needed by several, frequently interdependent components (mainly the battery pack, electric motor, and power electronics) under a variety of operating conditions without unduly compromising vehicle performance, range, cost, or safety is the core problem statement for thermal management systems (TMS) in electric vehicles (EVs).

Proposed System

In order to improve the safety, effectiveness, and depend- ability of the vehicle—particularly in markets where con- sumers are price conscious—the thermal management system for electric vehicles (EVs) offers a low-cost, clever, and responsive solution. In contrast to current systems, which frequently rely on pricey components and intricately integrated platforms, this design prioritises automation and simplicity without sacrificing essential functionality. The system actively monitors temperature and smoke conditions in real-time and automatically corrects itself to stop damage or dangerous situations by utilising microcontroller-based control, more especially the Arduino Uno. The system continuously checks the thermal state of key EV parts like the battery, motor, and surrounding electronics using a temperature sensor, usually an NTC thermistor or digital alternative like the DS18B20. The Arduino turns on if the temperature rises above a set threshold.

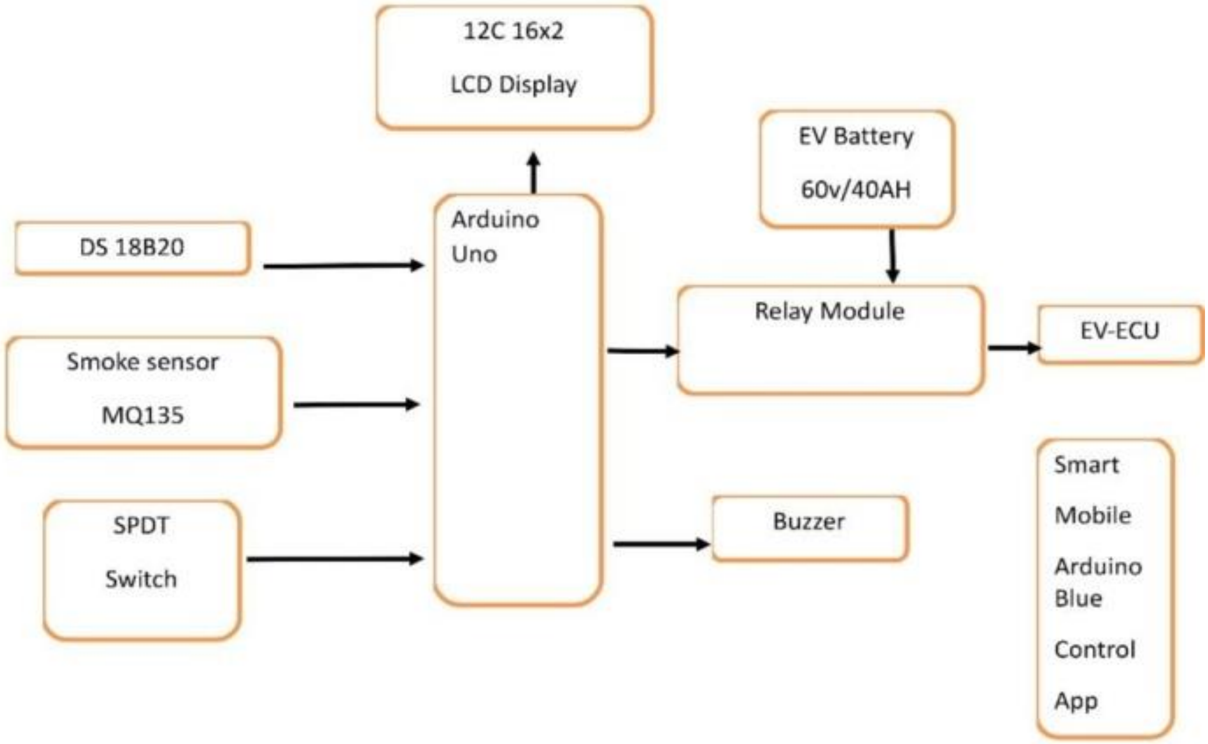

Fig. 1. Block diagram of the proposed thermal management system

Managing the intricate thermal needs of vital parts such as the lithium-ion battery, electric motor, and power electronics is a major challenge for electric vehicles. These parts have limited ideal operating temperature ranges, produce a lot of heat while in use (particularly when high power demands are involved, such as aggressive driving or fast charging), and can degrade severely, pose a safety risk (such as thermal runaway), or perform less well if exposed to extreme temperatures (too hot or too cold) or an uneven temperature distribution. In order to minimise energy consumption, reduce system complexity and cost, and ensure long-term reliability and safety of the vehicle, the challenge is to design a TMS that can dynamically and efficiently regulate these temperatures across a variety of ambient conditions (from freezing winters to scorching summers) and driving cycles.

METHODOLOGY

An Arduino Uno is used in the development of the thermal management system. It employs a MQ135 sensor to identify smoke or dangerous gases and a DS18B20 sensor to track battery temperature. These inputs are processed by the Arduino Uno, which then compares them to predetermined threshold values. It turns on a buzzer and manages a relay to shut off the system if dangerous conditions are found. The temperature and system status are shown in real time on a 16x2 LCD. Toggling between display modes and adjusting thresholds is possible with an SPDT switch. A voltage regulator is used to step down the system’s 12V power source. The Arduino Blue Control mobile app makes remote monitoring possible.

System Requirements

Hardware

- BO Motor: An inexpensive geared DC motor that is fre- quently utilised in small automation projects and robotics.
- Power Supply: A device that provides electrical power to circuits or electronic devices.
- Cooling Fan: A cooling fan is an electromechanical device that moves air to cool down components.
- Temperature Sensor: A temperature sensor is a device that detects the presence of smoke and is frequently used for fire safety.
- Relay Module: A relay module is an electrical switch that permits a low power circuit to control a high power circuit.
- Arduino Uno: A well known microcontroller board for creating electronic prototypes and projects.
- Display: A liquid crystal display (LCD) with the ability to display 16 characters per lines across 4 lines
- Humidity sensor: An electronic part that gauges the air’s water vapour content.

Software

- Arduino IDE: Arduino IDE is a software platform used to write, compile, and upload code to Arduino-compatible boards like the Arduino Uno.

System Implementation

Fig 2 shows flowchart of the thermal management system for ev’s. To illustrate the fundamentals of temperature monitor- ing and active cooling/warning, a simple thermal management system for an electric car with an Arduino Uno serving as the central controller can be put into practice. First, the system would continuously sense important environmental factors: A smoke sensor (like the MQ series) would identify possible fire hazards, a humidity sensor might show moisture or con- densation, and DS18B20 digital temperature sensors would be positioned strategically to keep an eye on the temperature of vital parts, like a motor or simulated battery pack. After reading data from these sensors, the Arduino Uno—which acts as the brain—would compare it to safe operating thresholds that had been preprogrammed and make decisions in real time. For example, the Arduino would initiate a cooling mechanism if a temperature reading surpasses a predetermined threshold.

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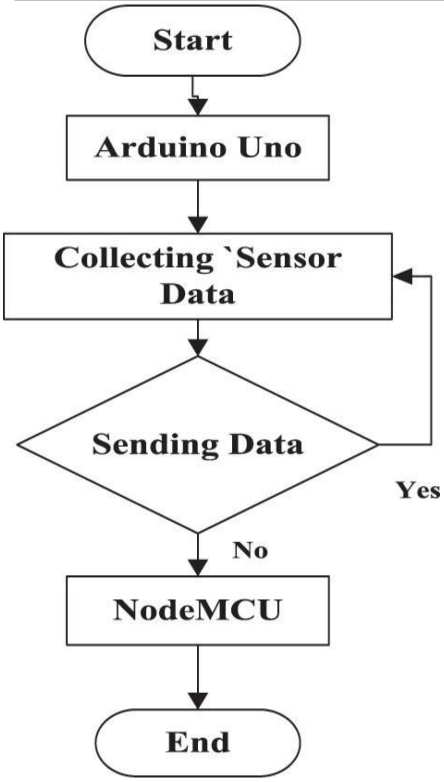

Fig. 2. Flowchart of the thermal management system

RESULTS AND DISCUSSION

Although in a simplified prototype setting, the Arduino- based thermal management system for electric vehicles ef- fectively illustrated the fundamentals of active temperature control and safety monitoring. By turning on the cooling fan through the relay module when a temperature threshold was reached, our results consistently demonstrated the system's ability to maintain simulated critical component temperatures within a predefined optimal range, usually around 30°C to 35°CThis direct confirmation of temperature control demon- strates how well the system accomplishes its main goal of maintaining component performance and health. Additionally, when smoke was introduced, the integrated smoke sensor successfully activated a clear visual alert on the 16x4 LCD and an instantaneous audible alarm via the buzzer, highlighting the system's critical function as an early warning safety mechanism.

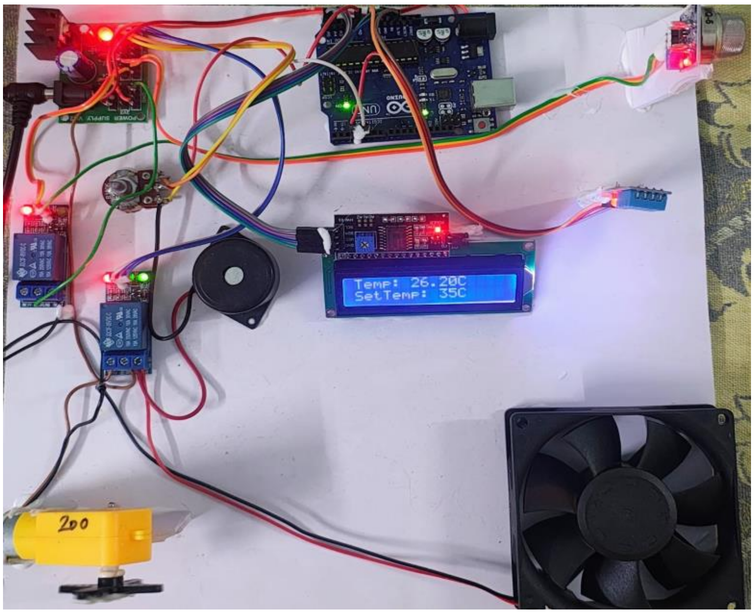

Fig. 3. Thermal Management System for EVs

Merits

- Enhanced Battery Lifespan: Ensure batteries operate within optimal temperature ranges, significantly extend- ing their overall service life and reducing replacement cost. Prevents degradation from extreme heat or cold, maintaining consistent performance over time.
- Improved Safety: Crucially prevents thermal runaway by disspating excess heat mitigating risk of battery fires or explosions. Safegaurds against localized overheating, containing potential damage and preventing widespread system failures.
- Faster Charging Capability: Enabels higher charging cur- rents by efficiently removing heat, leading to significantly reduced charging time. Allows the battery to accept charge more rapidly without compromising its safety or longitivity.

Demerits

Despite their critical importance, developing thermal man- agement systems for EVs has a number of disadvantages. First of all, they make the production and upkeep of the vehicle much more expensive and complicated. This covers the cost of specialised parts such as heat exchangers, pumps, valves, and sensors as well as the complex engineering needed to integrate and control them. Second, the energy consumption of these systems may marginally impair the vehicle's overall driving range. Fans, pumps, and compressors operate by drawing power from the battery, which results in an efficiency trade-off even though they maximise battery performance.

CONCLUSION

In summary, the basic ideas of active thermal control and real-time temperature monitoring were effectively illustrated by the creation of an Arduino Uno-based thermal manage- ment system for electric cars. This prototype successfully demonstrated the idea of using automated cooling to keep vital component temperatures within ideal ranges and offered vital safety warnings for possible overheating or smoke detection. Even though it was less complex than commercial EV sys- tems, the Arduino platform was crucial in demonstrating the fundamental need for thermal management to prolong battery life, guarantee operational safety, and maximise overall EV performance. It also provided a strong educational basis for more complex implementations in the future.

Future Enhancement

Even though an Arduino Uno provides a useful platform for developing a simple EV thermal management system, future developments could greatly increase its functionality and bring it closer to real-world requirements-albeit still in a hobbyist or educational setting. Incorporating more complex control algorithms beyond basic ON/OFF logic is a crucial area for improvement. Proportional-Integral-Derivative (PID) control of the cooling fan, which permits variable fan speeds to maintain a much tighter temperature tolerance and enhance energy efficiency, may be one way to achieve this. To move towards more sophisticated battery thermal management tech- niques, several DS18B20 sensors could be placed throughout a simulated battery pack. This would allow the Arduino to track temperature variations and initiate localised cooling if hotspots are found.

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