# SCHOOL OF ELECTRICAL AND ELECTRONICS ENGINEERING

## Minor Project Report

## On

## THERMAL MANAGEMENT FOR EV BATTERIES

## Academic year 2023-2024

Under the Guidance of:

**Prof. Shweta Koraddi**


**Project associates**

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## SCHOOL OF ELECTRICAL AND ELECTRONICS ENGINEERING

# CERTIFICATE

*This is to certify that the Minor-Project entitled **"Thermal Management for EV Batteries"** is a work carried out by Raksha Kulal(01fe21bee005), Shrinidhi Shambhoji (01fe21bee011), Krithika Patgar (01fe21bee017), Parveen Khatal (01fe22bee019), bonafide students of VI Semester, School of EEE, KLE Technological University, Hubballi, for the partial fulfillment of the Minor-Project assigned for VI-Semester, BE in Electrical and Electronics Engineering. The project report has been approved as it satisfies the academic requirements specified by the University.*

I.TITLE

# THERMAL MANAGEMENT FOR EV BATTERIES

# II.ABSTRACT

Maintaining the battery temperature within safe limits is critical for the performance and longevity of electric vehicles (EVs). Overheating can lead to reduced efficiency, accelerated degradation, and potential safety hazards such as thermal runaway. Effective thermal management ensures the battery remains within an optimal temperature range, balancing performance, safety, and longevity. In this project, we developed a temperature monitoring and control system using a Cortex M3 microcontroller to ensure the battery operates within safe temperature ranges. The system continuously monitors the battery temperature and displays real-time readings on an LCD. If the temperature exceeds a predefined threshold, a DC fan is automatically activated to cool the battery. This method prevents overheating and thermal damage, thereby enhancing the battery's health and efficiency. By integrating this thermal management system into EVs, we improve safety and reliability, reduce the risk of battery fires, and extend the battery's lifespan, resulting in lower replacement costs. This technology supports the increasing adoption of EVs, contributing to environmental sustainability and global efforts to reduce carbon emissions.

# III. ACKNOWLEDGEMENT

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This project's success is a result of the collective contributions of these individuals, and we are truly grateful for their guidance and support.

# IV. TABLE OF CONTENTS

# CHAPTER 1: INTRODUCTION

In today's context, the significance of electric vehicles has grown substantially. As the adoption of electric vehicles continues to rise, heightened attention has been directed towards battery thermal safety, emphasizing the paramount importance of personal safety and vehicle operational security. This is meticulously designed to regulate and maintain the optimal temperature of the battery, ensuring safety and reliability. Advanced thermal management systems are crucial for mitigating the risks associated with lithium-ion batteries.

Lithium-ion batteries are susceptible to temperature, which impacts their cycle life, efficiency, reliability, and safety. During charging and discharging, significant heat is produced within the battery due to electrochemical reactions and internal resistance, leading to a rise in temperature. Excessive heat can cause thermal runaway, electrolyte fires, and explosions. Therefore, effective thermal management is essential for ensuring safety by preventing overheating and fires, enhancing performance and efficiency, and extending the lifespan of batteries. It also supports regulatory compliance, sustainability, and reliability, fostering greater consumer confidence and adopting battery-powered technologies across various applications. Furthermore, with the growing emphasis on green technology, optimizing battery performance through effective thermal management also contributes to environmental sustainability by maximizing energy efficiency and reducing waste. As electric vehicles become more mainstream, the role of thermal management in ensuring their safety and efficiency will only become more critical.

# CHAPTER 2: LITERATURE SURVEY

G.Joga Rao et al. work aims to implement an automatic fan speed controller that adjusts the fan speed based on environmental conditions. An Arduino board and a temperature sensor were used to sense the surrounding temperature. The fan speed is then controlled accordingly to maintain the desired temperature [1]. A digital thermometer was built using an LM35 temperature sensor and a microcontroller. This paper served as a guide for interfacing the ADC with the sensor and microcontroller, as well as for interfacing with the LCD [2].

Shashank Arora [3] presented that the performance of Li-ion battery cells is significantly impacted by both low and elevated temperatures. At low temperatures, such as -40°C, there is a notable decrease in energy and power capacities, primarily due to limitations in electrolyte conductivity and electrode activity. Conversely, elevated temperatures above 40°C accelerate battery aging, leading to the breakdown of the solid electrolyte interphase (SEI) film and subsequent loss of energy capacity and power output. Despite challenges, ongoing research focusing on improving electrolytes and cathode materials offers promising avenues for enhancing battery performance under extreme temperature conditions, while effective thermal management strategies are essential for ensuring safety and preventing thermal runaway.

The comparison between air-cooled and liquid-cooled thermal management systems in Mohsen Akbarzadeh et al. work [4] for a 48 V battery module with prismatic-shaped cells demonstrates that increasing coolant flow rate reduces the average temperature of the hottest cell more significantly in the air-cooled setup.

A.G. Olabi et al. work discusses various cooling strategies, including liquid, air, PCM, HP, and hybrid-based approaches, the review provides insights into the diverse options available for mitigating temperature-related issues. However, it highlights the necessity of careful consideration and evaluation of different configurations and methods to ensure optimal performance and efficiency. Ultimately, as battery demands increase for greater specific energy, power, and longevity, the development of advanced thermal management techniques becomes increasingly imperative to meet these evolving needs [5].

# CHAPTER 3: METHODOLOGY

The proposed system integrates both software and hardware assemblies. This project involves designing a temperature monitoring and fan control system using the LPC1768 microcontroller. The system uses an LM35 temperature sensor and an operational amplifier (LM324-OpAmp) circuit to condition the sensor signal for the microcontroller's ADC input.

## 2.1. Signal Conditioning Circuit

The LM35 temperature sensor outputs a voltage proportional to the temperature, with an output of 10 mV/°C. To interface this low-voltage output with the ADC of the LPC1768, which requires an input range of 0-3.3V, an OpAmp-based signal conditioning circuit is used.

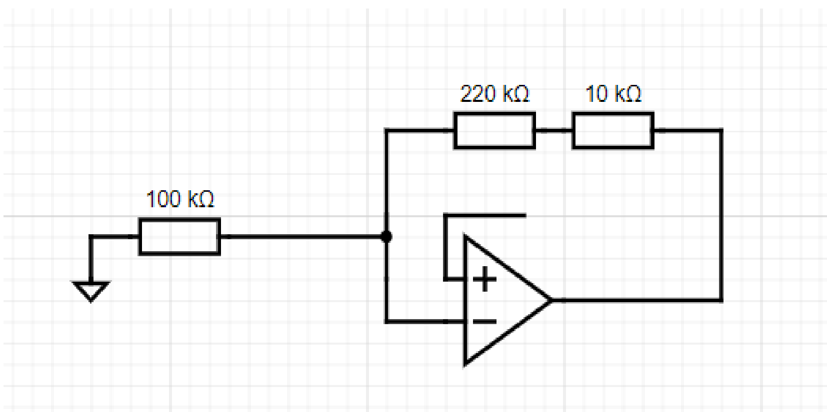



Fig No.1. Signal Conditioning Circuit

The non-inverting terminal of the OpAmp receives the output from the LM35 sensor. A 100kΩ resistor is connected to the inverting terminal, and the output of the OpAmp is connected to the ADC input (P0.23) of the LPC1768. The circuit amplifies the sensor output by a factor of 3.3, achieved using resistors R1 = 100kΩ and RF = 230kΩ (220kΩ in series with 10kΩ). The gain of 3.3V was chosen to scale the temperature range of 0-150°C into the 0-3.3V range required by the LPC1768.

The formula determines the gain of the OpAmp (LM324):

$$\text{Gain} = 1 + \frac{R_F}{R_1}$$
$$\text{Gain} = 1 + \frac{220k\Omega + 10k\Omega}{100k\Omega} = 1 + \frac{230k\Omega}{100k\Omega} = 3.3$$

## 2.2. ADC Configuration and Temperature Processing

The ADC on the LPC1768 is configured to read the amplified voltage. The following formula converts the ADC digital value to the corresponding input voltage:

$$\text{in\_vtg} = \left(\frac{\text{adc\_temp} \times \text{V}_{ref}}{4095}\right)$$

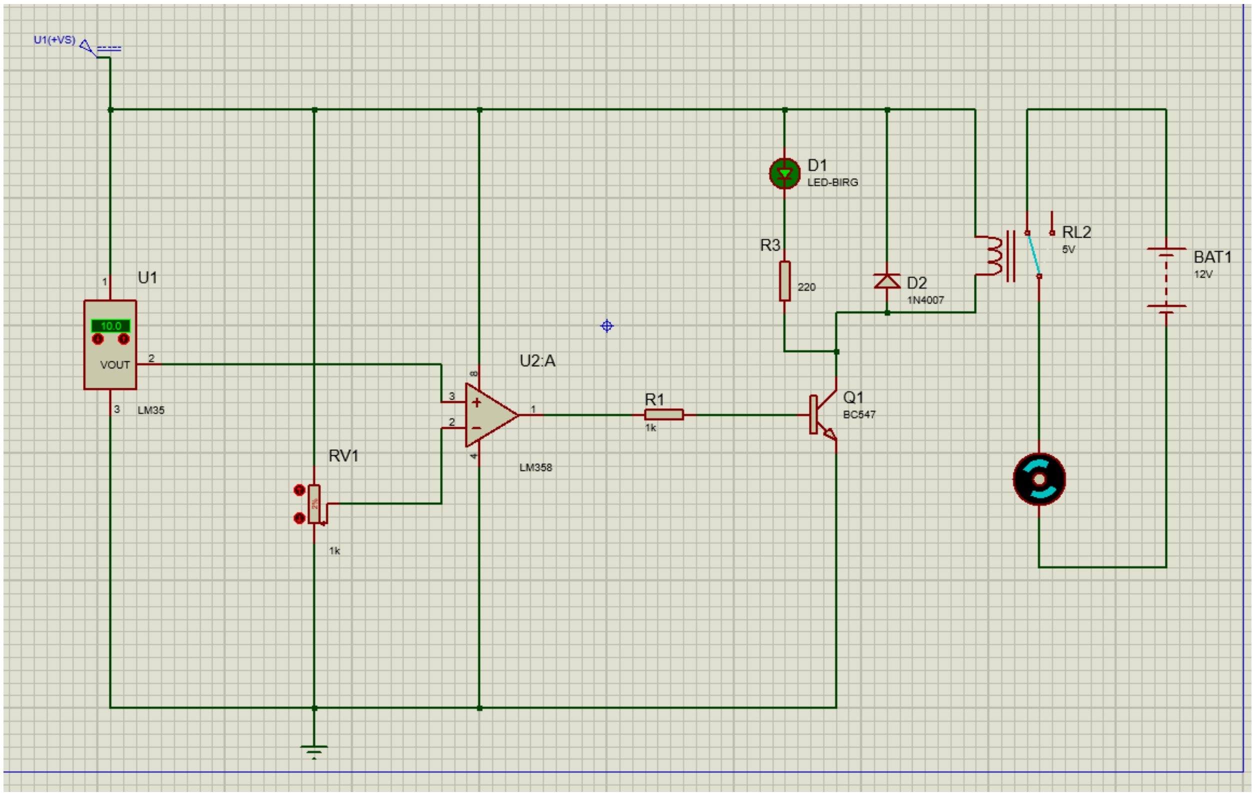
Here, 4095 is the full-scale reading of cortex-M3's 12-bit ADC obtained from 2^12 -1.

To calculate the temperature from the input voltage, the following relationship is used:

$$\text{temperature} = \left(\frac{\text{in\_vtg}}{\text{Gain} \times 10\text{mV}}\right)$$
$$\text{temperature} = \left(\frac{\text{in\_vtg}}{3.3 \times 0.01}\right)$$

Here, the sensor's 10 mV/°C scaling factor is used for converting the input voltage to temperature. The gain of 3.3 from the OpAmp is factored into the calculation, ensuring the temperature reading accurately reflects the sensor output.

## 2.3. Software Design




We simulated a circuit incorporating an LM35 temperature sensor, a potentiometer, a DC fan, a relay, and an LED to demonstrate temperature monitoring and cooling control. The LM35 sensor generates an analog voltage proportional to ambient temperature, adjusted by the potentiometer to set a threshold. As temperature rises, the LM35's voltage increases, triggering the relay when it surpasses the set threshold. This action illuminates an LED to indicate high temperature and activates a DC fan for cooling until temperatures drop below the threshold. This setup showcases effective temperature management using basic components.

## 2.4. Hardware setup

During the hardware phase, the system's circuit was physically assembled and a prototype was created to test its functionality. The components used to develop the circuit include:

**LPC1768:** The LPC1768 is a 32-bit ARM Cortex-M3 microcontroller developed by NXP Semiconductors, known for its versatility and robust performance, the LPC1768 is widely used in various embedded systems, industrial applications, and educational projects.

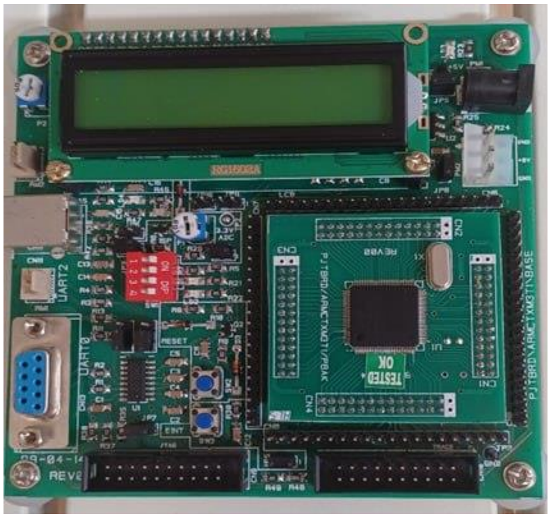


Fig No.3. LPC1746 Microcontroller

**LM35 (temperature sensor):** The LM35 temperature sensor features an analog output with a linear voltage proportional to temperature, providing 10mV per degree Celsius. It boasts high accuracy, with a calibration error of ±0.5°C and an operating temperature range from -55°C to +150°C.

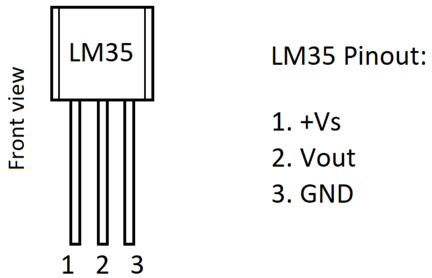



Fig No.4. LM35 Temperature Sensor

**LM324:** The op-amp is configured as a non-inverting amplifier to amplify the small output voltage of the LM35, ranging from 0-1V for temperatures between 0-100°C, to a 0-3.3V range suitable for the ADC.t is designed for a wide range of applications, including signal conditioning, voltage buffering, and analog computation.

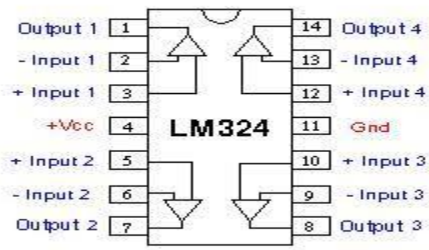



Fig No.5. LM324 op-amp

**2N2222A transistor:** It has a maximum collector-emitter voltage of 40V and a maximum collector-base voltage of 75V. The maximum emitter-base voltage is 6V, and it can handle a continuous collector current of up to 800mA. It operates reliably within a temperature range of -65°C to +200°C.

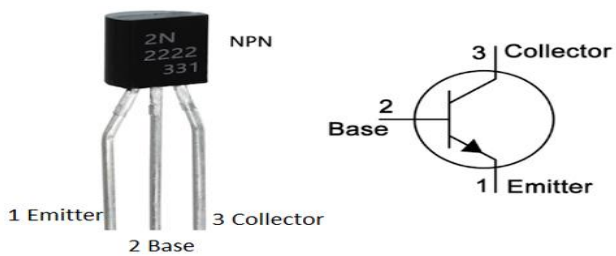



Fig No.6. 2N2222A Transistor

**DC fan:** The DC fan operates at 12V DC and has an operating current of 0.08A ±10%. It is designed to run at a rated speed of 5200 RPM ±10%, providing an air volume of 15.5 CFM. The fan produces a noise level of 18 dBA and measures 50mm in length, 50mm in width, and 10mm in height, with a weight of 20g. This compact and efficient fan is ideal for cooling electronic devices and components.

Fig No.7. 12V DC Fan

## 2.5 Working

Utilizing all the aforementioned components, the hardware circuit was meticulously assembled to create a system designed to sense temperature using the LM35 sensor. This system not only detects temperature variations but also cuts off the load when the temperature exceeds predefined thresholds.

The system is equipped with various indicators: different temperature ranges are signaled through distinct LEDs, providing a clear visual representation of the current temperature status. Additionally, an LCD is integrated to show both the temperature readings and the corresponding fan speed, enhancing the user interface.

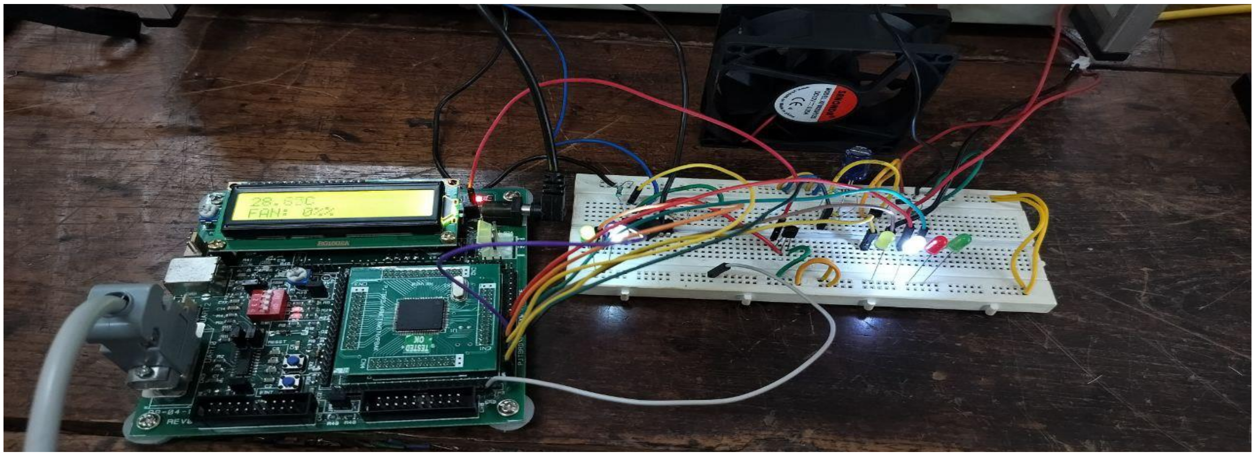


Fig No.8. Hardware Circuit

Fig No. 9 illustrates the room temperature scenario, where the fan speed is at 0%, indicated by the illumination of a white LED. In this state, both connected loads, represented by LEDs, remain active. This setup signifies that the temperature is within the normal range, requiring no cooling intervention from the fan. The white LED serves as a clear visual cue that the system is functioning under normal conditions, and both loads are fully operational, reflecting a stable and controlled environment.

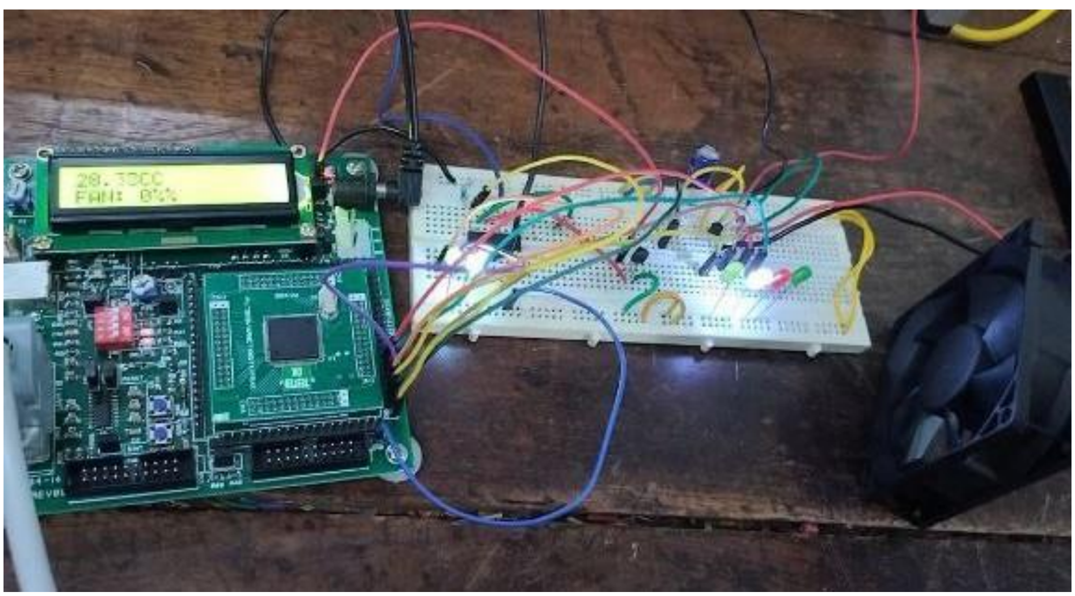


Fig No.9. Circuit working at room temperature (below $30^0$ C)

Figure 10 depicts a scenario where the temperature has slightly increased to 31°C, just above room temperature. In response to this moderate rise, the fan operates at 33% of its full speed, as indicated by the glowing yellow LED. Despite this increase in temperature, both connected loads, represented by LEDs, remain active. The yellow LED provides a visual indication that the temperature is slightly elevated but still within a manageable range, ensuring the system continues to function efficiently with both loads operational. The fan's activation at 33% capacity demonstrates the system's proactive approach to maintaining a stable environment by providing a measured cooling response.

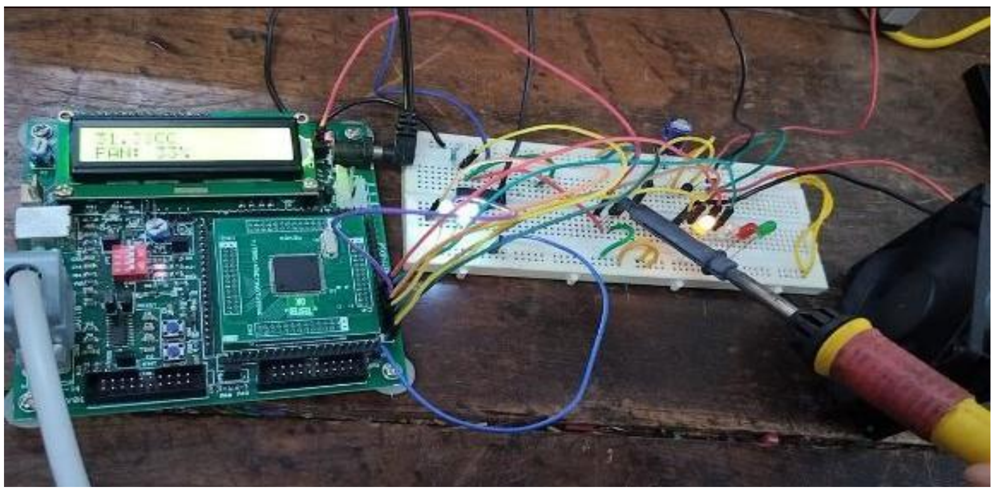



Fig No.10. Circuit working at $31^0$C temperature

Fig.11 illustrates a condition where the temperature has risen to 33°C. Correspondingly, the fan speed has increased to 66%, indicated by the illumination of a red LED. At this elevated temperature, the system initiates a safety protocol: one of the connected loads is disconnected. The red LED serves as a visual alert, signaling a significant temperature rise. This proactive measure of cutting off one load ensures the system mitigates any potential risk of overheating while maintaining partial operational capacity. The fan's operation at 66% capacity exemplifies the system's dynamic response to higher temperatures, striving to restore a stable environment efficiently.

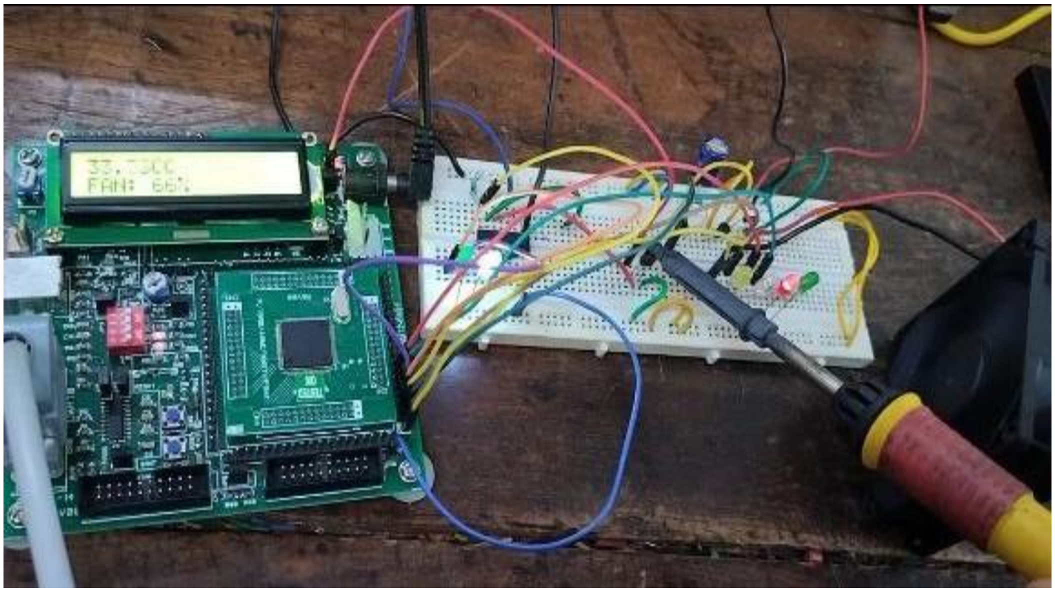


Fig No.11. Circuit working above $33^0C$

Fig No.12 presents a scenario where the temperature has reached or exceeded 36°C. In response to this critical condition, the fan operates at 99% of its full capacity, indicated by the glowing green LED. At this high temperature, both connected loads are disconnected as a precautionary measure. The green LED serves as a visual signal of the urgent need for maximum cooling. This decisive action of cutting off both loads highlights the system's commitment to safety and preventing potential overheating. The fan's operation at near full capacity reflects the system's robust response to extreme temperatures, ensuring the environment is rapidly stabilized.

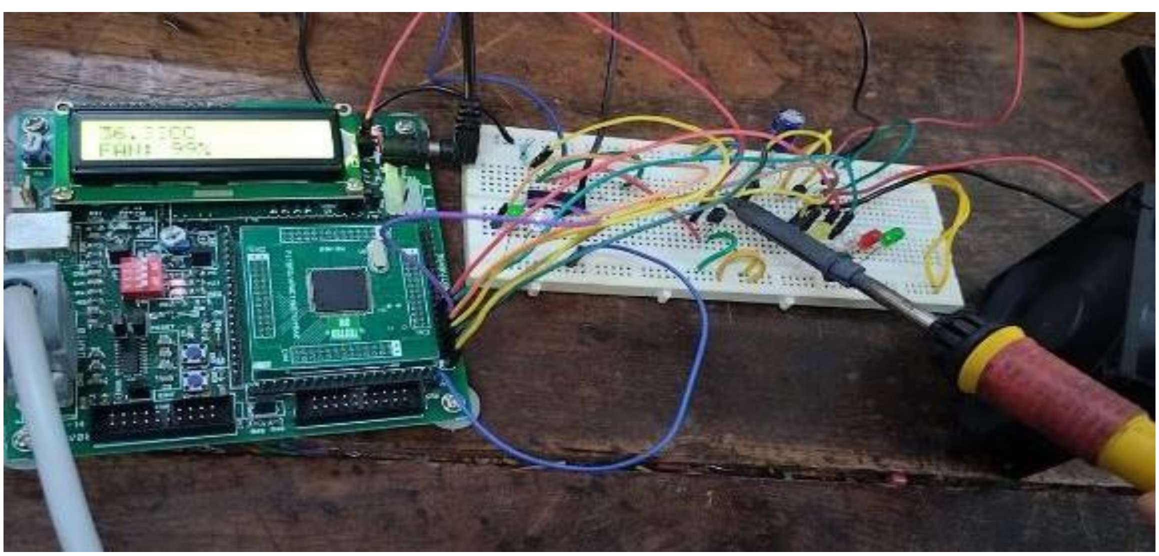


Fig No.12. Circuit working at $36^0C$

# CHAPTER 4: RESULTS

Table No.1 presents the results of the hardware circuit designed for sensing temperature using the LM35 sensor. When the temperature is normal, at or below 30°C, LED 1 glows, indicating that the temperature is within the normal range, and the fan remains off. As the temperature rises to 31°C and below 33°C, LED 2 illuminates, and the fan begins to rotate at 33% of its capacity. When the temperature increases to 33°C and below 36°C, LED 3 lights up, and the fan speed increases to 66%. Once the temperature exceeds 36°C, LED 4 turns on, and the fan operates at 99% of its full speed.

Furthermore, the load connected to the circuit remains on when the temperature is below 33°C. When the temperature reaches 33°C or higher, one load disconnects to indicate the rising temperature. If the temperature continues to increase beyond 36°C, both loads disconnect, providing a clear signal of the elevated temperature.

| SERIAL NUMBER | TEMPERATURE (degree Celsius) | LED1 | LED2 | LED3 | LED4 | LOAD1 (LED) | LOAD2 (LED) | FAN SPEED (In %) |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 to 30 | ON | OFF | OFF | OFF | ON | ON | 0 |
| 2 | 30 to 39 | OFF | ON | OFF | OFF | ON | ON | 33 |
| 3 | 40 to 49 | OFF | OFF | ON | OFF | OFF | ON | 66 |
| 4 | Above 50 | OFF | OFF | OFF | ON | OFF | OFF | 99 |

Table No.1.Results

# CHAPTER 5: CONCLUSIONS

The project aimed to develop a control and monitoring system for EV battery temperature using DC fan cooling, evaluating its effectiveness across different temperature ranges. However, the use of lithium-ion batteries was precluded due to safety concerns such as flammability and temperature instability. Despite these limitations, the project underscored the crucial role of robust thermal management solutions in enhancing both performance and safety in electric vehicles. Additionally, a soldering gun was employed for temperature monitoring, with LEDs indicating varying temperature levels. This approach provided practical insights into managing battery temperature, highlighting the importance of careful consideration and innovation in the development of such systems for future applications.

# REFERENCES:

[1] G. Joga Rao, G. Satish, D. Abhinav, P. Mothi Manoj Nageswara Rao, P. Satish Ganesh," Temperature Controlled Fan using IOT", International Journal of Scientific Research in Science, Engineering, and Technology, volume 4, March-April,2018.

[2] B. O. Oyebola, V. T. Odueso," LM35 Based Digital Room Temperature Meter: A Simple Demonstration", Equatorial Journal of Computational and Theoretical Science,2017.

[3] Shashank Arora," Selection of thermal management system for modular battery packs of electric vehicles: A review of existing and emerging technologies", Journal of Power Sources 400,2018.

[4] Mohsen Akbarzadeh, Theodoros Kalogiannis, Joris Jaguemont, Lu Jin, Hamidreza Behi, Danial Karimi, Hamidreza Beheshti, Joeri Van Mierlo, Maitane Berecibar," A comparative study between air cooling and liquid cooling thermal management systems for a high-energy lithium-ion battery module", Applied Thermal Engineering,2021

[5] A.G. Olabi, Hussein M. Maghrabie, Ohood Hameed Kadhim Adhari a, Enas Taha Sayed, Bashria A.A. Yousef, Tareq Salameh, Mohammed Kamil, Mohammad Ali Abdelkareem," Battery thermal management systems: Recent progress and challenges", International Journal of Thermofluids,2022.