# Three Band Temperature Indicator
# Interim Report

SincGrid LLP, New Delhi

# Acknowledgement

I extend my sincere gratitude to those who have contributed to the completion of the project and therefore my training. Special thanks to my project supervisor, Arun Kumar, whose guidance and expertise were invaluable throughout the journey. I am also appreciative of the contributions made by subject matter experts, colleagues, and team members. Additionally, I acknowledge the support of Sincgrid LLP for providing the necessary resources and facilities. Thanks to my family and friends for their unwavering support. Lastly, I want to express my appreciation for the learning resources that have enriched my understanding of the technologies involved. This project has been a rewarding experience, and I am thankful for the collective effort that has gone into its realization.

Sincerely,
Reshul Jindal
$3^{rd}$ August 2023

# Contents

# 1 About the Industry

Sincgrid is into designing, developing, and innovating in the domain of embedded hardware and software. They have designed systems based on embedded hardware and software for IoT applications such as home automation, automated food vending machines, and Smart city products. They are focused on this type of development so that new and innovative products based on the market can be worked upon. Apart from hardware-based solutions, their team also provides IT-based solutions. They have also worked in the domain of professional teaching in the field of electronics. They have provided workshops at various universities, colleges, and schools. Their key focus area for schools is related to tinkering and experimentation in science and related fields. They have developed various kits for the experimentation. For college students kits based on B. Sc. Electronics course and B. Tech. Electronics/Computer science has been developed by them. You can find more information on their website: `https://store.sincgrid.com/`

# 2 Training Schedule

The training continued for about 9 weeks and there were following tasks and objectives that were covered each week.

- Week 1-2: Understanding Requirements and Research
  - Days 1-3: Project Overview and Requirement Understanding
    - Study the project specifications in detail.
    - Understand the functionality and purpose of each component.
  - Days 4-7: Research on LM35, LED, and Voltage Regulators
    - Learn about LM35 temperature sensor characteristics.
    - Explore the working principles of LEDs.
    - Understand the role and types of voltage regulators.
  - Days 8-10: Initial Schematic Design
    - Start drafting a schematic of the entire circuit.
    - Identify potential challenges and solutions.
- Week 3-4: Deepening Knowledge of Components
  - Days 11-14: In-Depth Study of Op-Amps and BJT
    - Dive into the working of operational amplifiers (op-amps).
    - Understand the basics of bipolar junction transistors (BJTs).

- Days 15-21: Detailed Component Analysis
  * Focus on detailed study and analysis of LM35, LEDs, and voltage regulators.
  * Explore datasheets and application notes for each component.

- Week 5-6: Schematic Refinement and Simulation
  - Days 22-28: Schematic Refinement
    * Refine the circuit schematic based on detailed component understanding.
    * Ensure compatibility and proper connections.
  - Days 29-35: Circuit Simulation
    * Use simulation tools to verify the circuit's functionality.
    * Address any issues or improvements identified during the simulation.

- Week 7-8: PCB Design and Fabrication
  - Days 36-42: PCB Layout Design
    * Begin designing the PCB layout based on the finalized schematic.
    * Consider factors like component placement, routing, and signal integrity.
  - Days 43-49: Fabrication and Soldering
    * Fabricate the PCB using the designed layout.
    * Practice proper soldering techniques to assemble the components.

- Week 9: Testing and Iteration
  - Days 50-56: Prototype Testing and Iteration
    * Assemble the prototype and conduct initial testing.
    * Identify and address any issues or improvements needed.
    * Iterate on the design as necessary.
  - Day 57-63: Finalization and Documentation
    * Finalize the design based on testing results.
    * Document the entire project, including schematics, PCB layout, and working prototype.

# 3 Introduction

The Three Band Temperature Indicator is a sophisticated analog electronics-based project, developed at SincGrid LLP. It houses a robust circuitry system that effectively translates temperature readings into intuitive Three Band visual indications, providing users with real-time feedback on the prevailing temperature conditions without relying on a microcontroller. This documentation provides a comprehensive overview of the project's objectives, design, components, and functionality.
This device is designed to accurately measure and indicate temperature levels within three distinct bands:

- Hot - above 30 °C
- Normal - between 20 and 30 °C
- Cold - below 20 °C

It utilizes a single LM35 temperature sensor, the project simplifies the hardware architecture while maintaining accuracy and reliability. This project not only serves as a functional tool but also as an educational platform for enthusiasts and learners to grasp analog electronics principles and temperature measurement techniques.

# 4 General Six-Block Model

Any Electronic gadget or instrument has certain distinguishable segments that when brought together make the complete electronic circuitry of that instrument. It is important for each segment to operate properly so that the instrument can perform all the functions it is meant to without any faults.

A Six- Block Model(Fig 1) can be made by breaking down a complete system into six general segments and any Electronic instrument can be made by the involvement of some or all of these segments.

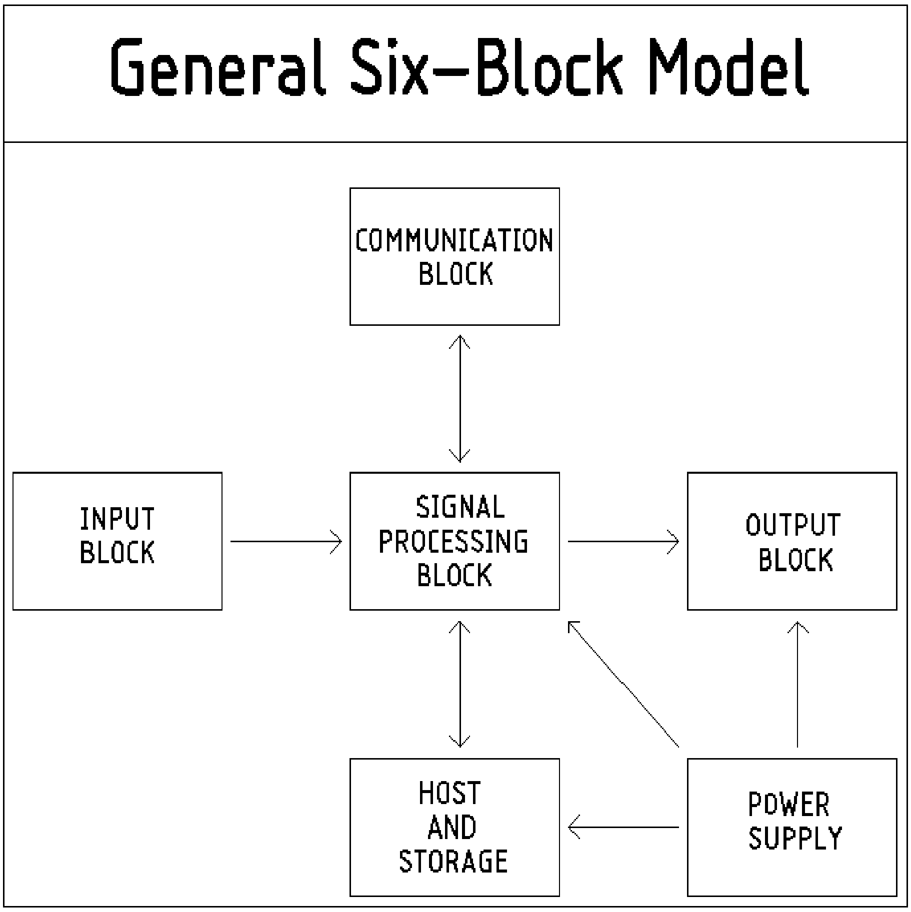



Figure 1: General Six-Block Model

# 5 Device Block Diagram

A block diagram is presented(Fig 2) so as to get a complete view of the functioning of this device.

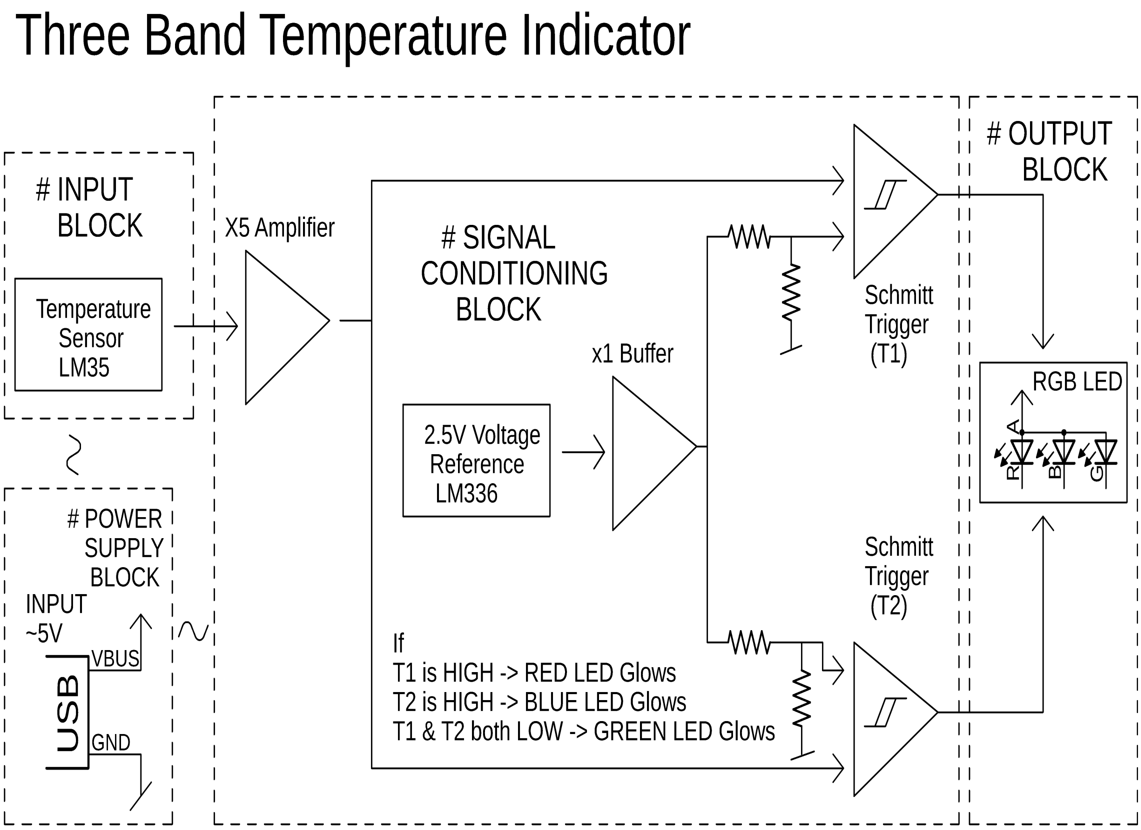



Figure 2: Device Block Diagram

From the block diagram above a clear analogy can be drawn between the Six-block model and the device such that:

- Power Supply Block - The input '5VDC supply to the USB connector.
- Input Block - The temperature is sensed using the temperature sensor LM35 and given as an input to the device.
- Signal Processing/Conditioning Block - The input signal is processed according to the requirement of the device and output signals are thus generated after processing.
- Output Block - The Output is to be received on an RGB LED.

# 6 Device Description

This Section will guide you through the various blocks of the device showing the Hardware used to implement it.

## 6.1 Mini USB Port - Power

The most fundamental or the Heart of any electronic project is the power supply, without which our project is just another board with components soldered on it. The USB port provided has to be connected to a 5V DC adaptor, you may also use a Power Bank to Connect it. This provides our board with access to power. You will observe that as you plug the USB port the Power on LED as shown in the picture below starts to Glow. You will also observe a color displayed by the diffuser (will talk about it later).

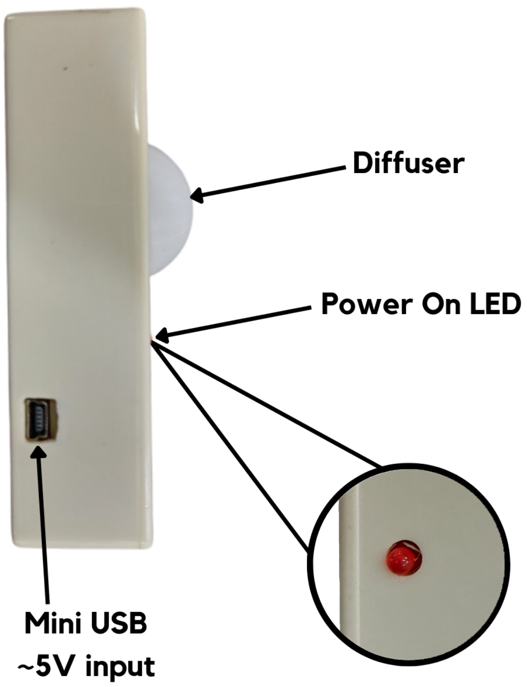



Figure 3: USB port and Power On LED

## 6.2 LM35 Temperature Sensor - Input

The LM35 is a precision analog temperature sensor integrated circuit (IC) that provides an analog voltage output that is linearly proportional to the temperature it is measuring in Celsius (Centigrade). The output voltage of the LM35 changes at a rate of 10 mV per degree Celsius change in temperature. This linear relationship simplifies temperature measurements, as you can directly convert the analog voltage to a temperature reading without complex calculations. The LM35 sensor typically comes in a small TO-92 package, and it only requires a power supply and a ground connection to operate. Here we use LM35 to provide input Analog voltage corresponding to the Temperature it measures.

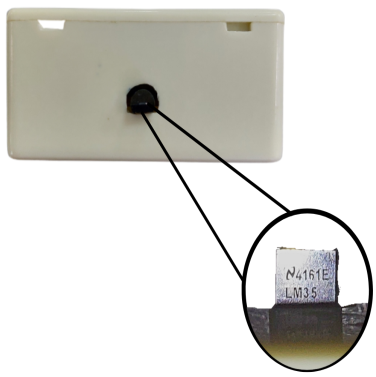



Figure 4: LM35

## 6.3 Amplifier and Buffer - Signal Processing

Under the Signal Processing block, we first have our amplifier and a buffer. The amplifier used is an op-amp LM358 in a non-inverting configuration providing an amplification of 5 to the input signal received from the LM35 temperature sensor. The buffer is used to provide a voltage reference of 2.5V via an LM336 TO-92 package Voltage Reference of 2.5V. A voltage buffer is simply an op-amp with the signal applied to the non-inverting terminal and output shorted with the inverting terminal. Since LM358 is a dual op-amp the same IC is used both for the amplifier and the Buffer (as shown in Fig5.).

## 6.4 Schmitt Trigger and PNP Switches - Signal Processing

A Schmitt trigger is a type of electronic circuit that functions as a comparator with hysteresis. It is used to convert an input signal that varies between two voltage levels into an output signal that has only two distinct voltage levels (typically high and low). The hysteresis feature of a Schmitt trigger makes it particularly useful for noise

Figure 5: Amplifier and Buffer

filtering and signal conditioning applications. It compares an input voltage (Vin) to two threshold voltages, often referred to as the upper threshold (VUT) and lower threshold (VLT). These thresholds determine when the output state of the Schmitt trigger changes. When the input voltage crosses the upper threshold (VUT) while rising, the output switches to the high state. Conversely, when the input voltage crosses the lower threshold (VLT) while falling, the output switches to the low state. A PNP transistor can be used as a switch in electronic circuits to control the flow of

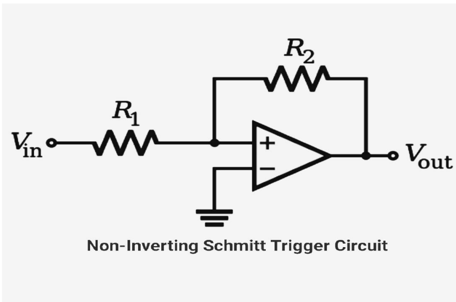



Figure 6: Schmitt Trigger

current between its collector and emitter terminals.

- OFF State: When sufficient voltage is applied to the base terminal (base-emitter junction is not forward-biased), the transistor is in the off state. In this state, there is minimal or no current flow between the collector and emitter.
- ON State: When no voltage is applied to the base terminal relative to the emitter (forward-biasing the base-emitter junction), it allows current to flow from the emitter to the base. This, in turn, allows a larger current to flow from the collector to the emitter, effectively turning the transistor on and allowing current to pass through the collector-emitter path.

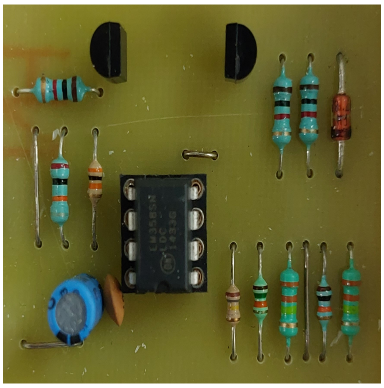


Figure 7: Schmitt Trigger and PNP Switches

## 6.5 RGB LED - Output

RGB LED stands for Red, Green, Blue Light-Emitting Diode. It is a type of LED (Light-Emitting Diode) that can emit light in three primary colors: red, green, and blue. To control an RGB LED, you typically need to provide a separate voltage or current signal to each of the three color pins (R, G, and B) of the LED. We have used a 3W RGB SMD LED here and covered it with a 3D-printed hemispherical diffuser. Through this LED, the device shows the color of the diffuser relative to the Temperature of the surrounding. i.e.

- RED for Hot - above 30 °C
- GREEN for Normal - between 20 and 30 °C
- BLUE for Cold - below 20 °C

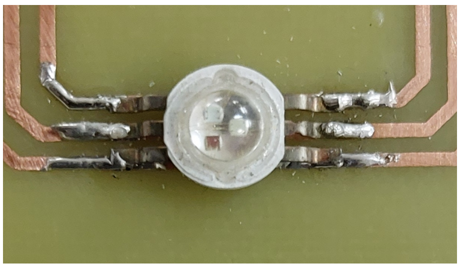


Figure 8: 3W RGB SMD LED

# 7 Board Schematic

A circuit schematic showing the actual circuit of the complete device was made on the Eagle CAD shown as:

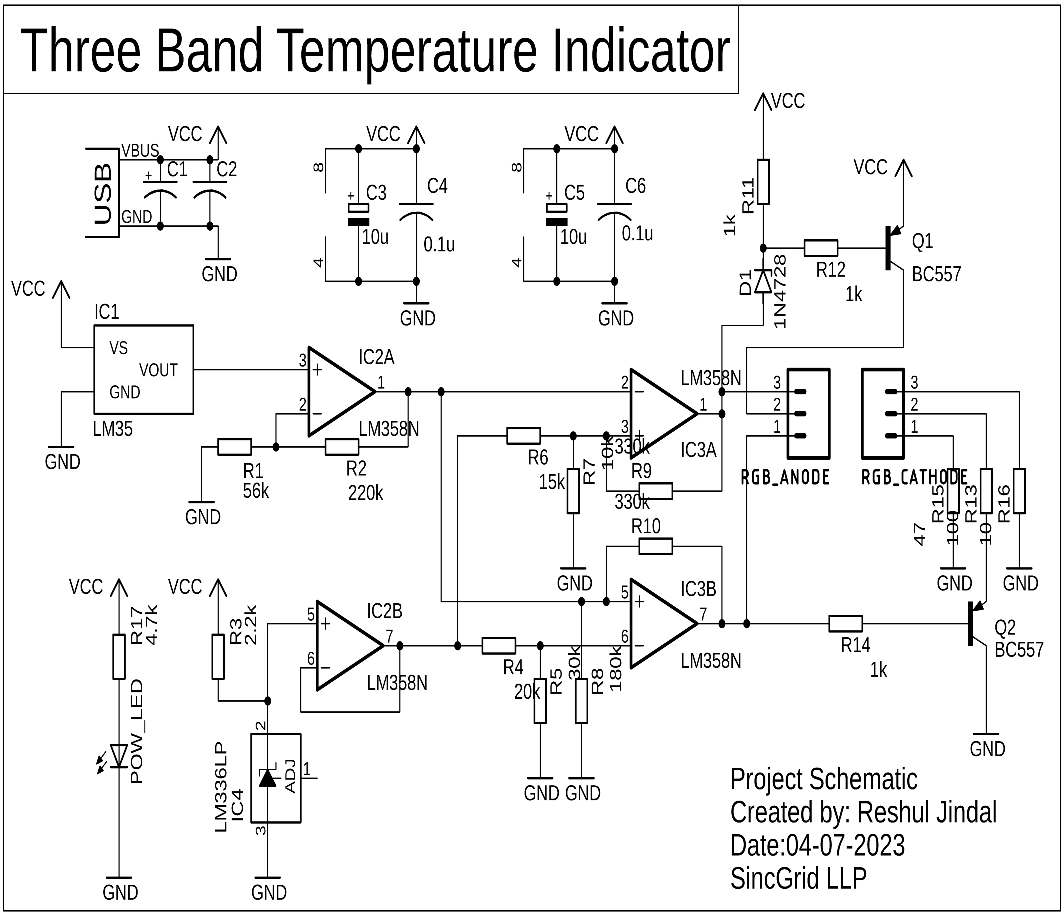



Figure 9: Project Schematic

# 8 Board Layout

From the circuit schematic the following board of the complete device was made on the Eagle CAD shown:

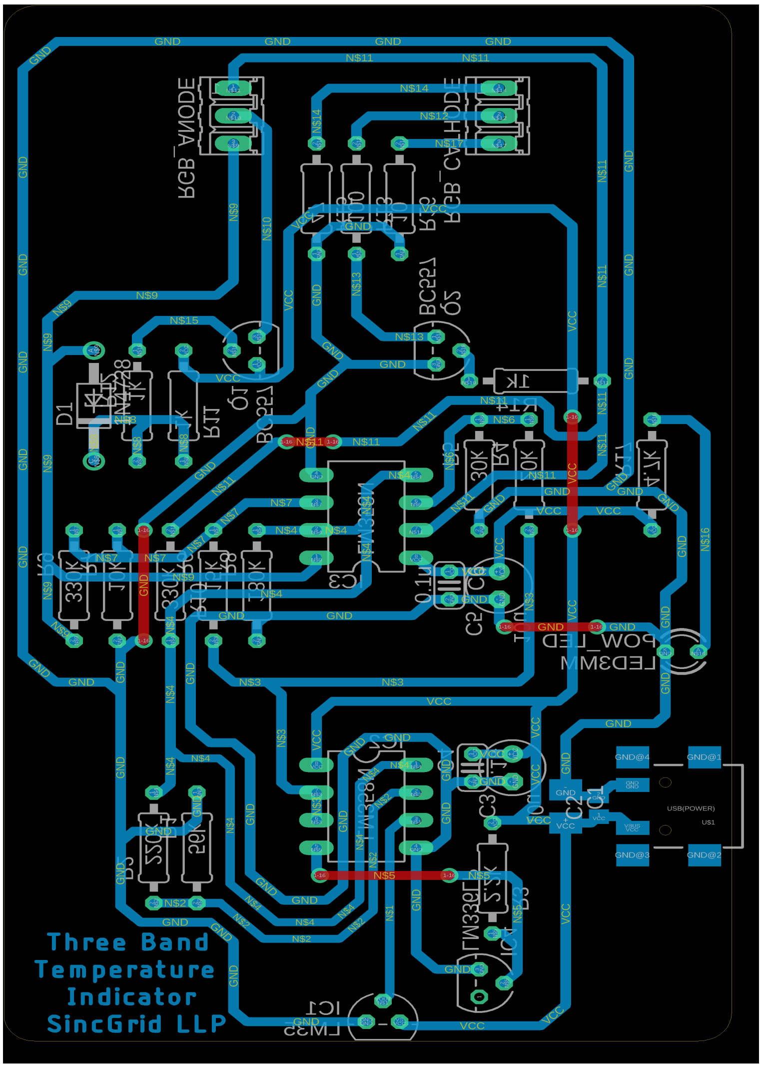
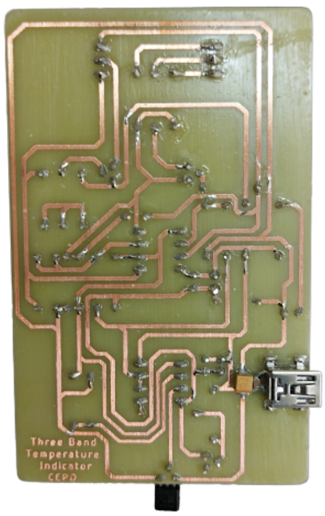


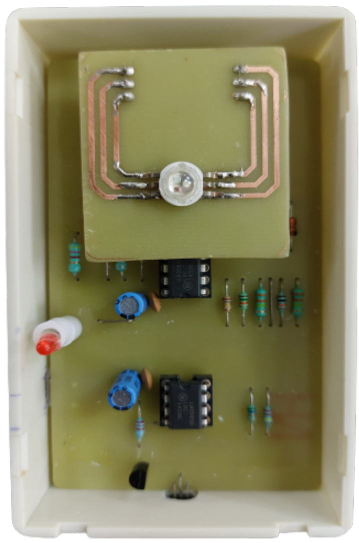

Figure 10: Board Layout

# 9 Complete PCB

We Fabricated this board and soldered the components onto it.




PCB Fabricated



PCB in an enclosure

Figure 11: Completed PCB

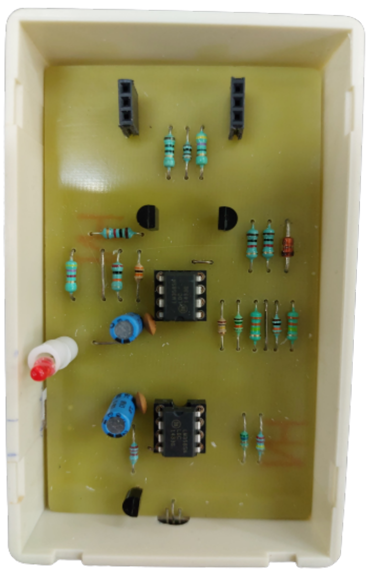


Figure 12: Figure showing the board under the RGB LED

# 10 Working Project

Device not-powered

Green for Normal

Blue for Cold

Red for Hot

Figure 14: Completed Working Device

# 11 Learning after Training

Upon completing this project, I have gained a comprehensive set of skills and knowledge in various areas. Here's a description of the learning outcomes:

1. Electronic Components and Circuits Understanding
    - Acquired in-depth knowledge of electronic components, including LM35 temperature sensors, LEDs, op-amps, BJTs, and voltage regulators.
    - Developed a solid understanding of how these components function individually and in integrated circuits.
2. Circuit Design and Simulation
    - Learned the process of designing a circuit schematic, including the iterative refinement of the design to ensure functionality and efficiency.
    - Gained experience in using simulation tools to predict and analyze circuit behavior before physical implementation.
3. PCB Design and Fabrication
    - Acquired skills in PCB layout design, considering factors like component placement, routing, and signal integrity.
    - Gained hands-on experience in fabricating and soldering PCBs, ensuring proper assembly and connection of electronic components.
4. Temperature Sensing and Display
    - Developed expertise in using LM35 temperature sensors to measure external temperature accurately.
    - Learned how to interpret temperature data and display it visually using LEDs with different colors for different temperature ranges.
5. Problem Solving and Troubleshooting
    - Acquired problem-solving skills through the identification and resolution of issues during the design, simulation, and prototyping phases.
    - Learned to troubleshoot and iterate on the design based on testing results.
6. Project Management and Documentation
    - Gained experience in project management by following a structured schedule and dividing the project into manageable phases.

- Developed documentation skills by creating detailed schematics, PCB layouts, and testing procedures.

7. Integration of Multiple Disciplines

   - Integrated knowledge from various disciplines, including analog circuits, sensor technology, and microelectronics, to create a functional and cohesive project.
   - Developed the ability to apply theoretical knowledge to practical applications.
   - Gained hands-on experience in assembling and testing a physical prototype, enhancing practical skills in electronics fabrication and testing.

# 12 Summary

The three-band temperature indicator project involved the conceptualization, design, and fabrication of a functional prototype capable of sensing external temperature using LM35 temperature sensors. The visual representation of temperature was achieved through LED colors, with red indicating hot temperatures (above 30 degrees Celsius), green for pleasant temperatures (between 20 to 30 degrees Celsius), and blue for cold temperatures (below 20 degrees Celsius). The project required a comprehensive understanding of electronic components such as op-amps, BJTs, LEDs, and voltage regulators, along with the successful completion of the phases of schematic design, circuit simulation, PCB layout, fabrication, and soldering. The outcome is a working prototype that showcases technical proficiency in analog circuits.