**University of Moratuwa**

**Faculty of Engineering**

**Department of Electronic & Telecommunication Engineering**

**EN2091 : Laboratory Practice and Projects**

**Team Volt Crew**

# Project Report

**Group Members**

| Index No | Name |
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# Contents

# 1 Introduction

Our project focuses on designing and implementing a dual-temperature monitoring system capable of measuring both body and fluid temperatures using separate thermistor probes. We developed a custom-built power supply unit that draws power from the main supply, regulates it, and provides stable operation for the circuit. The temperature readings from the thermistors are processed and displayed on an OLED screen, allowing for clear and real-time monitoring. This system is versatile and can be used in healthcare, laboratory, and household settings. By integrating analog electronics with digital components, we achieve a seamless combination of accuracy, reliability, and user-friendly design.

# 2 Functionality

Our device has 3 main functionalities.

1. Get the input from a thermistor.
2. Amplify the input voltage to a measurable value.
3. Scale the voltage and display the temperature.

# 3 System Model

## 3.1 Block Diagram

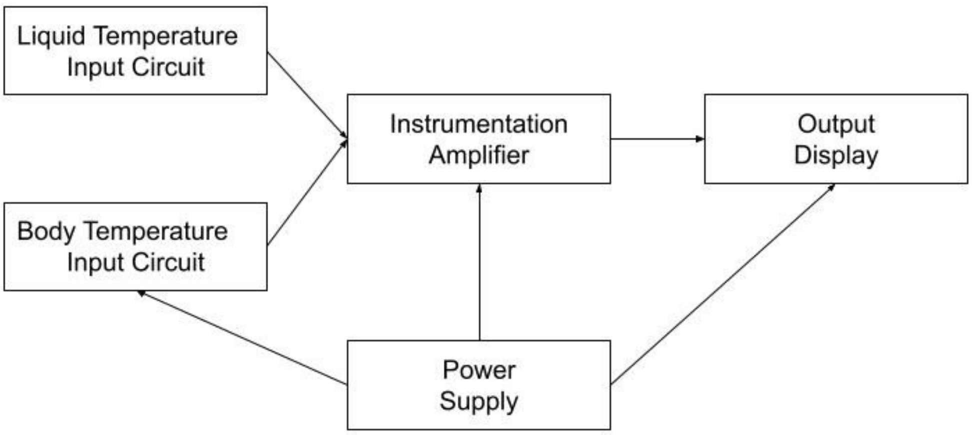


Figure 1: Block Diagram

The functionality of each block is listed below.

1. **Liquid temperature input circuit** - Get the temperature input from liquids, which will be converted into a voltage, then linearized through a Winston bridge and filtered through a first-order filter.

2. **Body temperature input circuit** - Get the temperature input from the body, which will be converted into a voltage, then linearized through a Winston bridge and filtered through a first-order filter.

3. **Instrumentation amplifier** - Amplify the input voltage to a sufficient value without distorting it.

4. **Output display** - Scale the amplified voltage and display the corresponding temperature value in Celsius.

5. **Power supply** - Supply power to the device. This gives 5V to the 2 input circuits and the display, and 10V to the instrumentation amplifier circuit.

## 3.2 Design Parameters

### Thermistor Selection and Application

To accommodate varying temperature measurement requirements, two thermistor types were utilized.

- **NTC10K Thermistor:** Chosen for its ability to measure a wide temperature range, this thermistor was used for environmental temperature readings. Its high sensitivity across a broad spectrum made it suitable for general-purpose monitoring.

- **PT100 Thermistor:** Specifically selected for body temperature measurements, this thermistor provided high precision and stability within the critical range of 10°C to 50°C. This narrower range aligned with human body temperature requirements, ensuring accurate and reliable readings.

### Temperature Range

The thermometer was designed to measure temperatures spanning.

- **Environmental Temperature:** From -20°C to 100°C using the NTC10K thermistor.

- **Body Temperature:** From 10°C to 50°C using the PT100 thermistor.

### Power Supply

The device operates on a dual supply system providing +10V, -10V, and 5V outputs.

- A voltage doubler circuit generating 30V, regulated to 24V using a zener diode.

- A 5V supply for the microcontroller implemented via a BJT regulator.

The circuit is capable of handling currents up to 1A, ensuring stable and reliable operation.

### Signal Conditioning

To accurately process the resistance variations from the thermistors, the design incorporated

- Two Wheatstone bridge circuits for resistance-to-voltage conversion.
- An instrumentation amplifier for noise filtering and precise signal amplification.

### Switching Mechanism

A manual switch was integrated to allow users to select between the two thermistors based on the desired measurement. This ensured flexibility in functionality while maintaining simplicity in operation.

### Display and Interface

Temperature readings were displayed using an analog output interface, prioritizing clear visibility and ease of interpretation.

### Physical Dimensions and Enclosure

The enclosure was compactly designed using SolidWorks and 3D-printed with white PLA material. The design emphasized ergonomic handling, durability, and portability.

### Safety and Reliability

The power supply circuit included over-voltage and over-current protection mechanisms, ensuring user safety and device longevity. Additionally, robust components were used to enhance overall reliability.

## 3.3 Component Selection

| **Component** | **Reasons for Selection** |
|---|---|
| Transformer (230V to 30V double tap) | • According to the power requirement of the OPAMPs and other circuit components<br>• Proper functionality of the whole circuit |
| TL702 CP OPAMPs | • Wide supply voltage range<br>• Low Offset voltage - ensures precise signal amplification<br>• High slew rate (60 V/$\mu s$) and stability |
| TIP41C | • Capability to switch currents up to **500 mA**<br>• Maximum voltage rating ($V_{ceo} = 60V$) allows it to handle a wide range of supply voltages without breakdown |
| Instrumentation amplifier | • High accuracy and noise rejection<br>• Simplified design - easy gain adjustment<br>• High input impedance - prevents loading effects |
| PT100 thermistor for body temperature measurement | • Provides accurate and stable readings within the typical human body temperature range |
| NTC 10K thermistor for fluid temperature measurement | • Wide measurement range |

Table 1: Components and reasons for their use

# 4 Schematic

The initial schematic was created using LT Spice software.

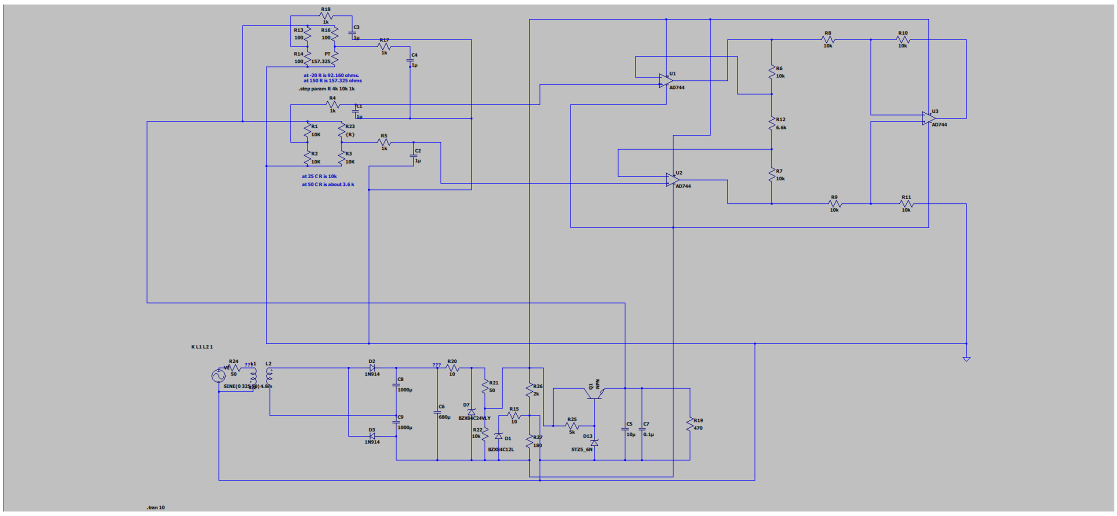

Figure 2: LT Spice Schematic

The parts of the circuit are as follows.

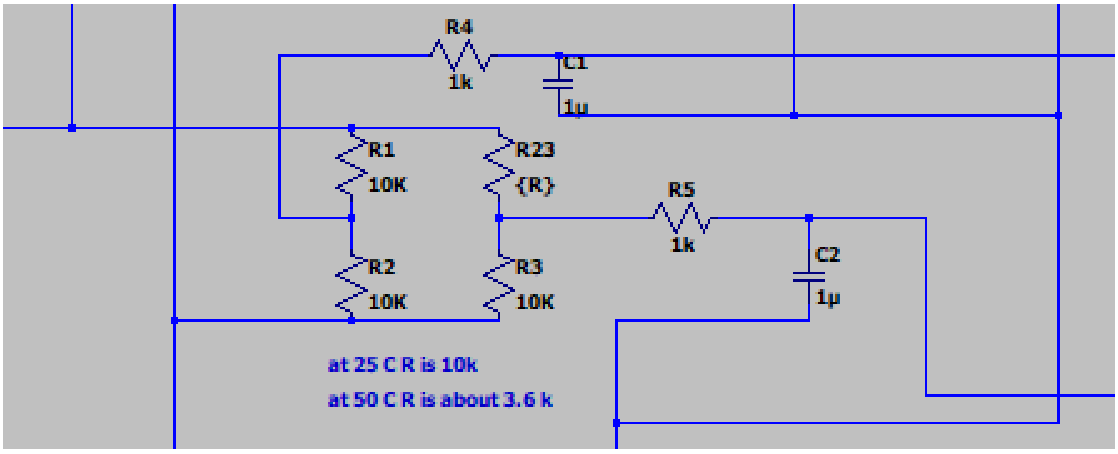


Figure 3: Liquid Temperature Input Circuit

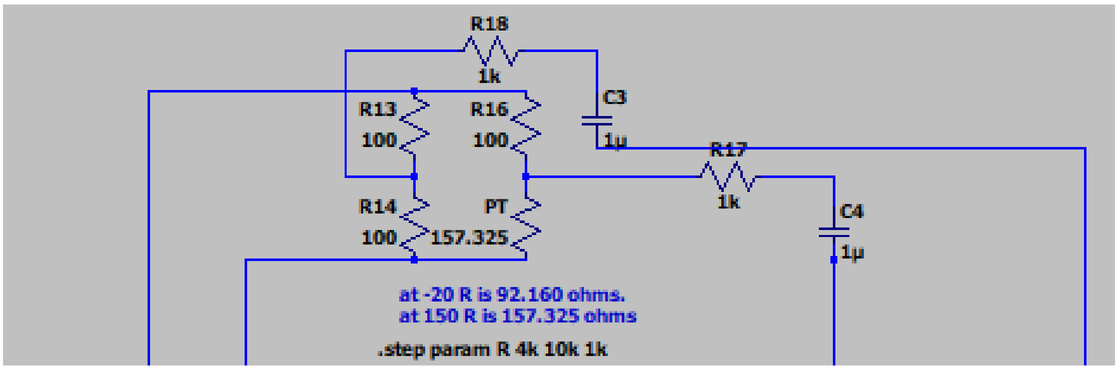


Figure 4: Body Temperature Input Circuit

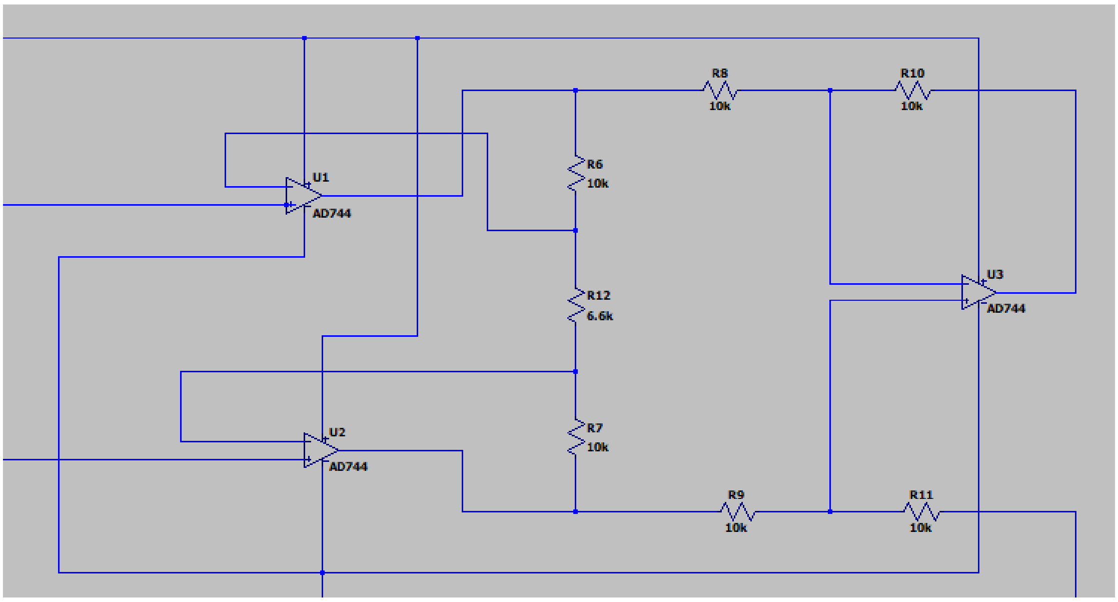


Figure 5: Instrumentation Amplifier Circuit

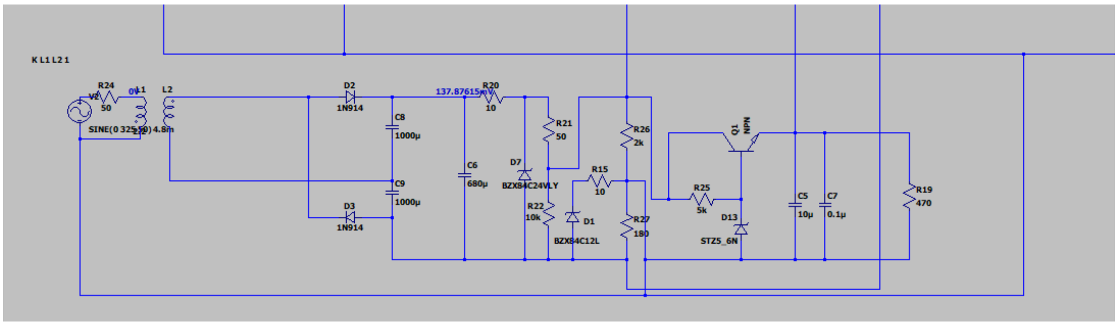


Figure 6: Power Supply Circuit

# 5 Breadboard Implementation

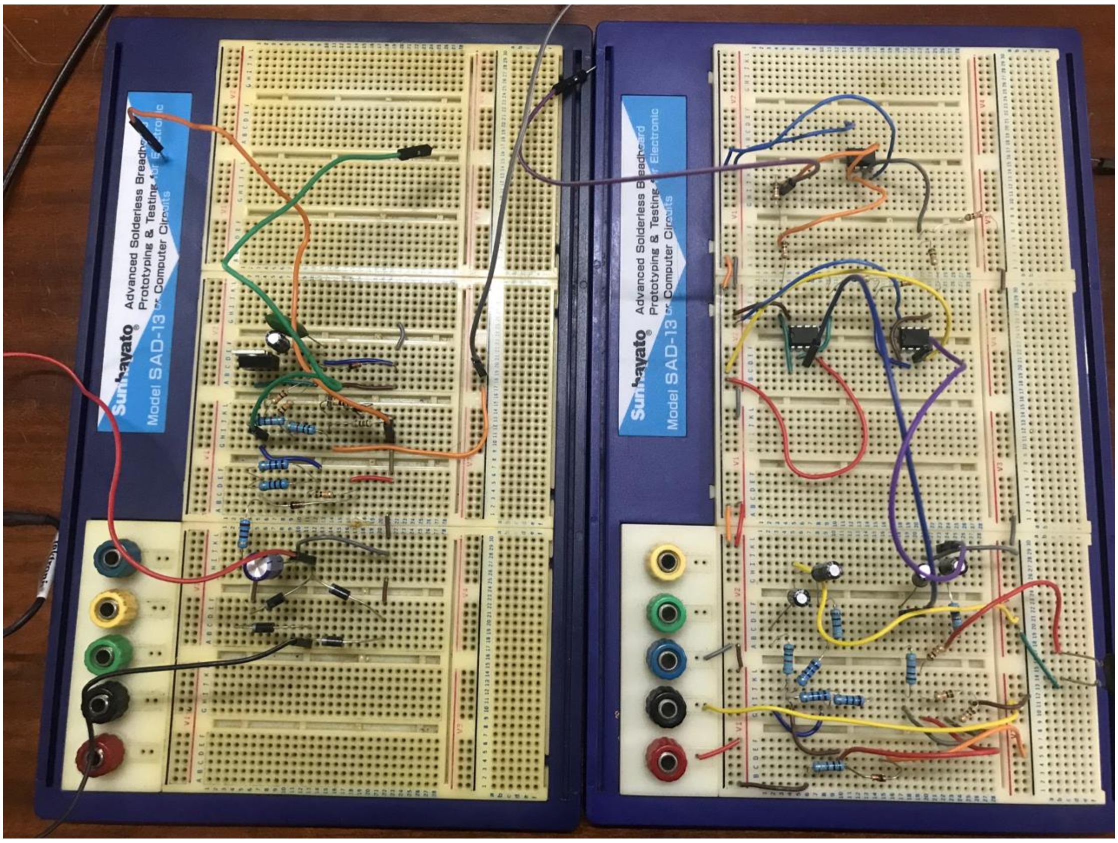


Figure 7: Whole circuit

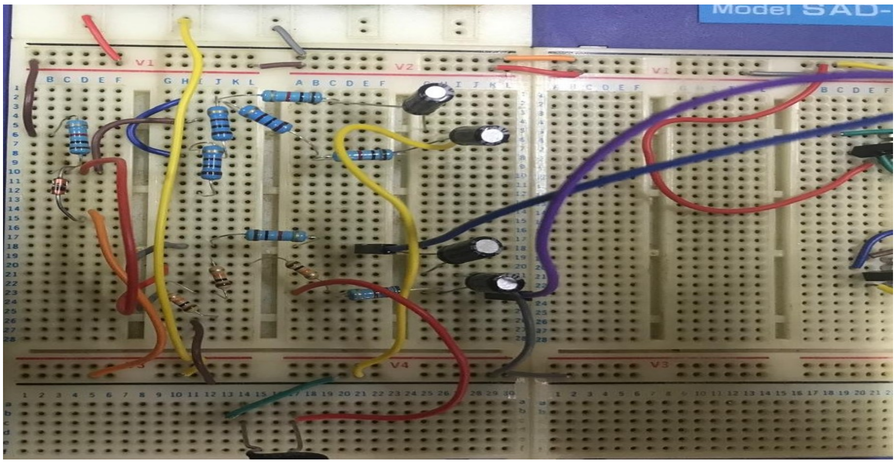

Figure 8: Input circuit

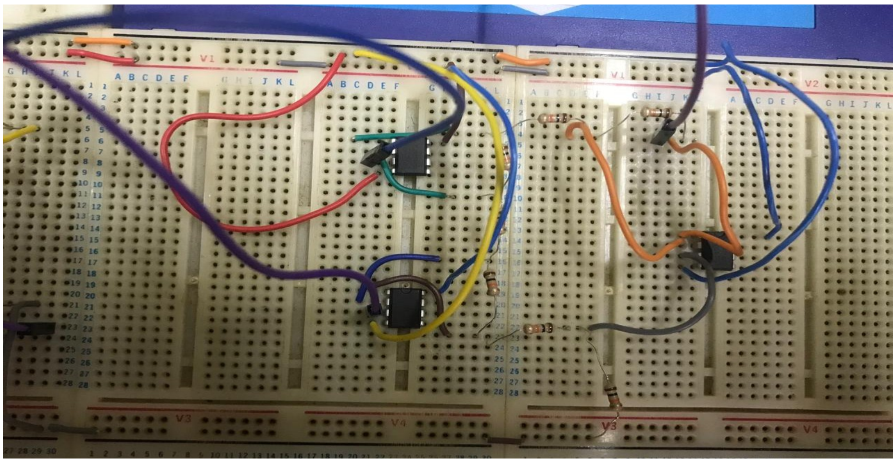

Figure 9: Amplifier circuit

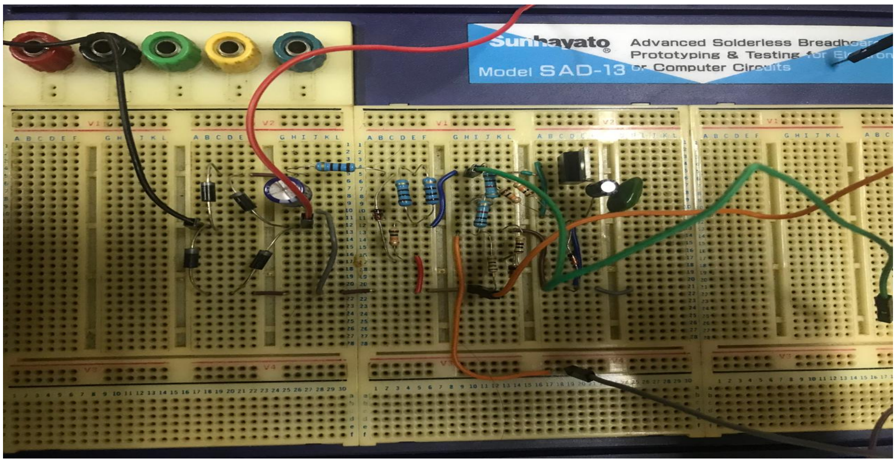


Figure 10: Power supply circuit

# 6 PCB Design

After finalizing the circuit, we designed 2 PCBs using Altium Designer.

## 6.1 Power Supply Unit

- A voltage doubler circuit was implemented to generate 30V, which was regulated to 24V using a zener diode.
- For the microcontroller, a 5V supply was made using a BJT regulator.
- The output provides +10V, -10V, 5V and GND, with a center tapped 30V transformer as input.
- The PCB is designed to handle up to 1A current.
- A 2-layer PCB was designed and printed. Assembly was done by team members.

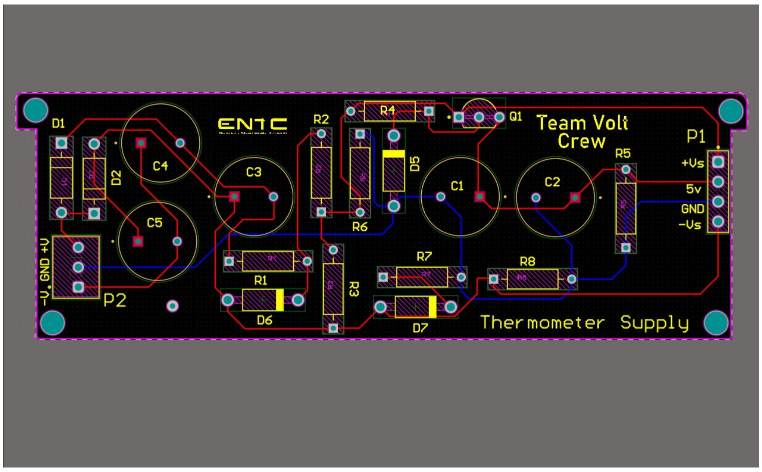


Figure 11: Power Supply PCB

## 6.2 Thermometer Circuit

- This PCB includes 2 Wheatstone bridges which are used to sense the temperature variations.
- Then a switch is used to change which bridge is to be used based on the user's preference.
- Then the instrumentation amplifier performs noise filtering and amplifies the signal.
- Finally, it goes to the display through the microcontroller.

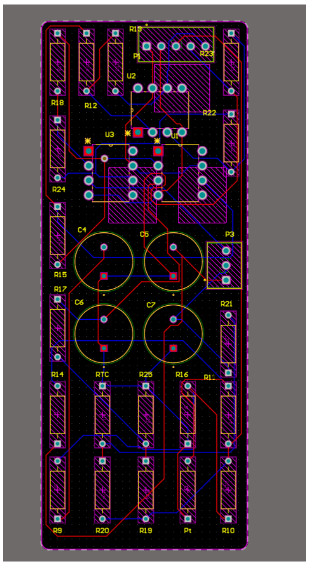

Figure 12: Thermometer PCB

**Final PCBs**

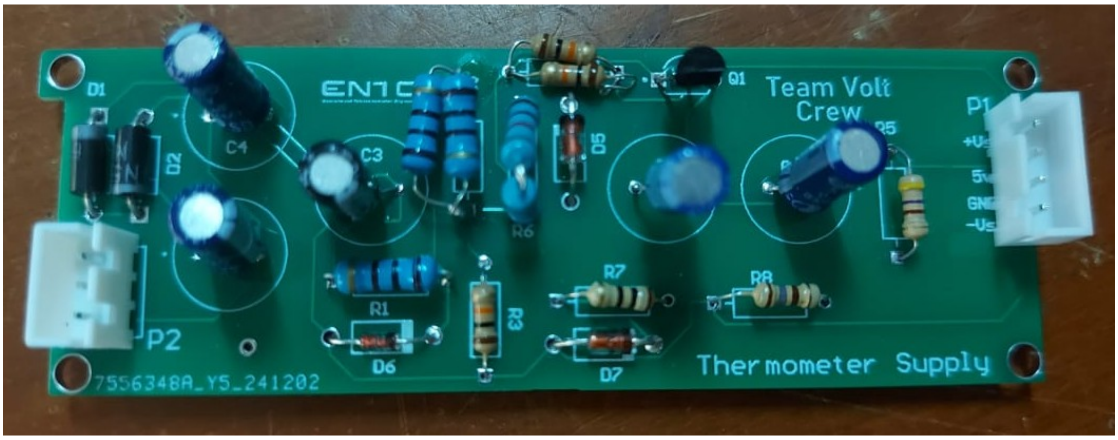


Figure 13: Power Suuply

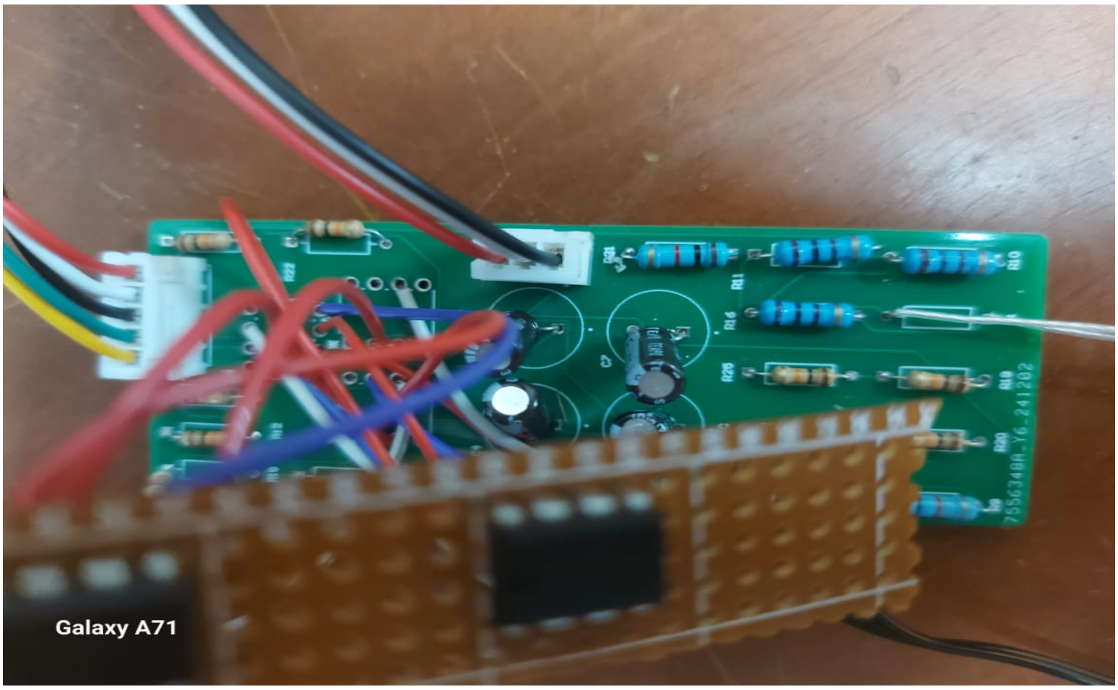


Figure 14: Thermometer Circuit

# 7 Enclosure Design

The enclosure is designed using Solidworks and 3D printed in white color PLA.

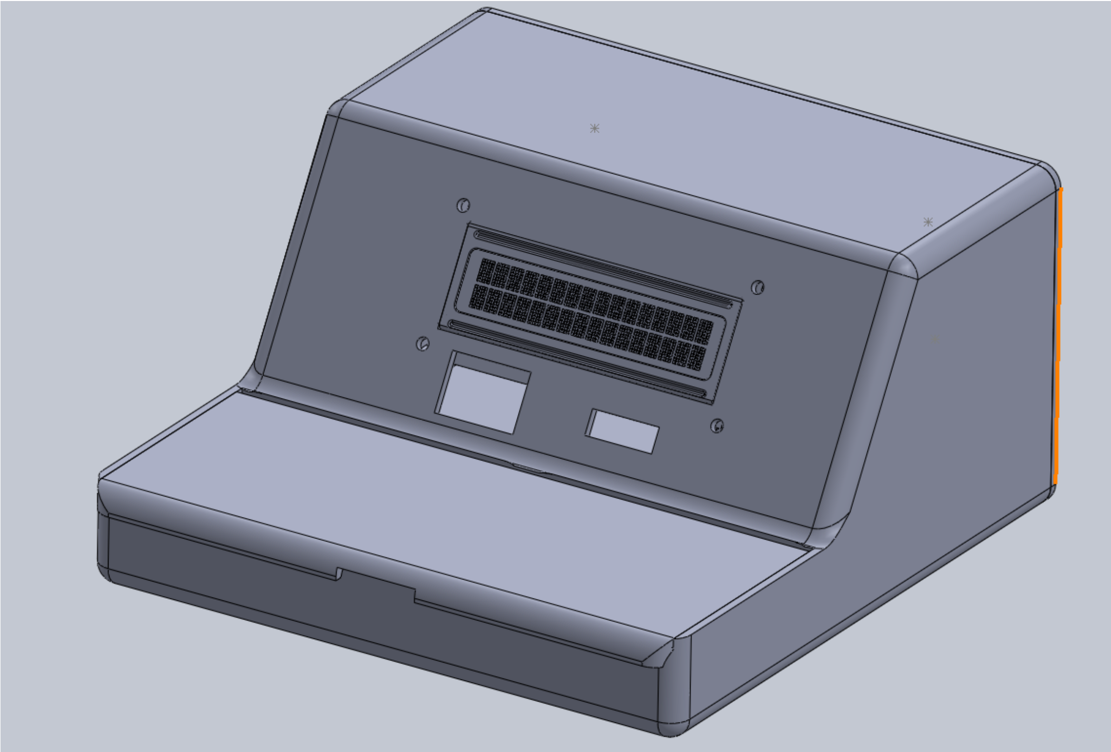

Figure 15: Enclosure

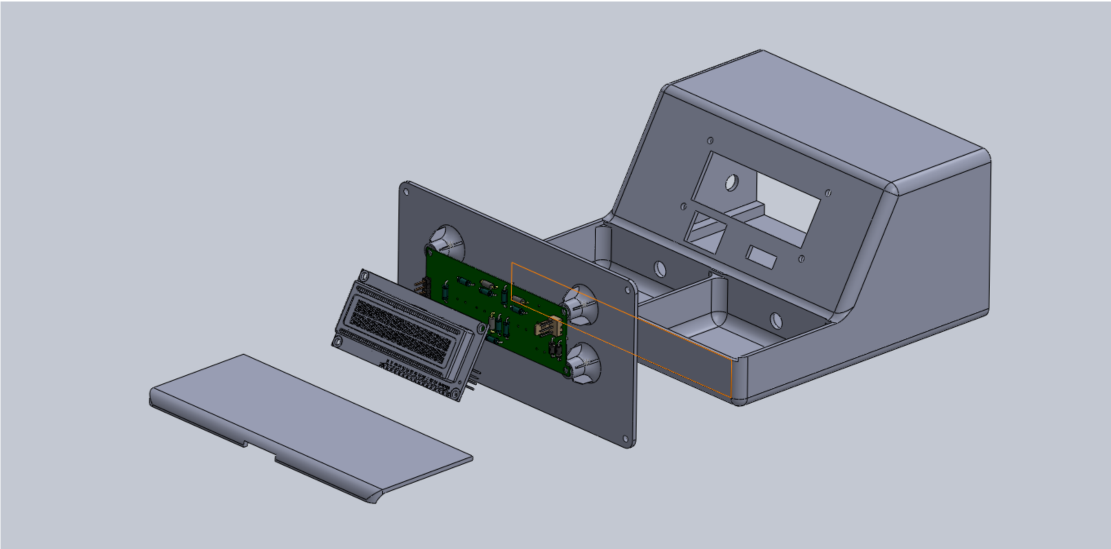

Figure 16: Exploded View

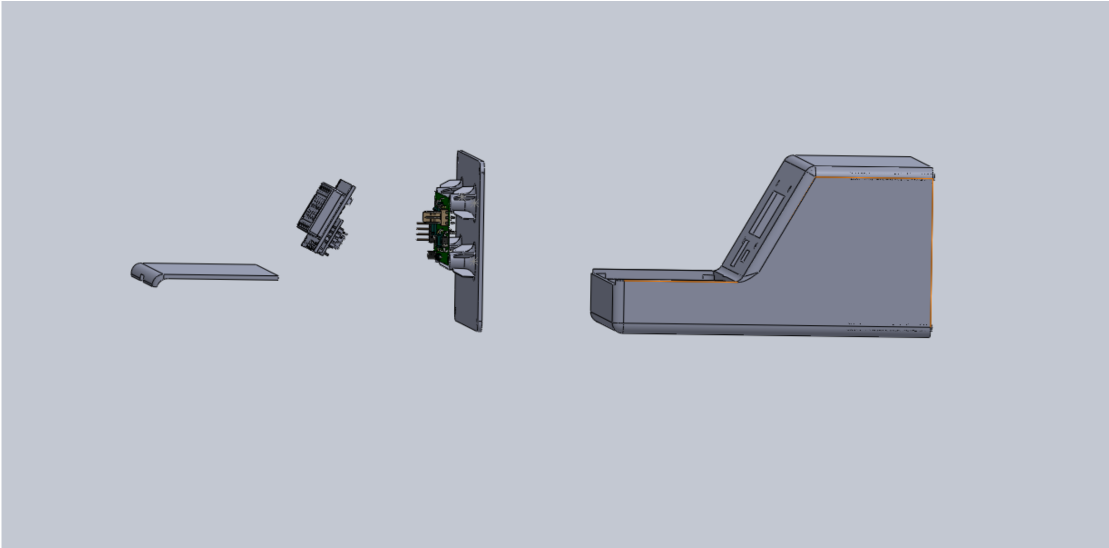

Figure 17: Side View

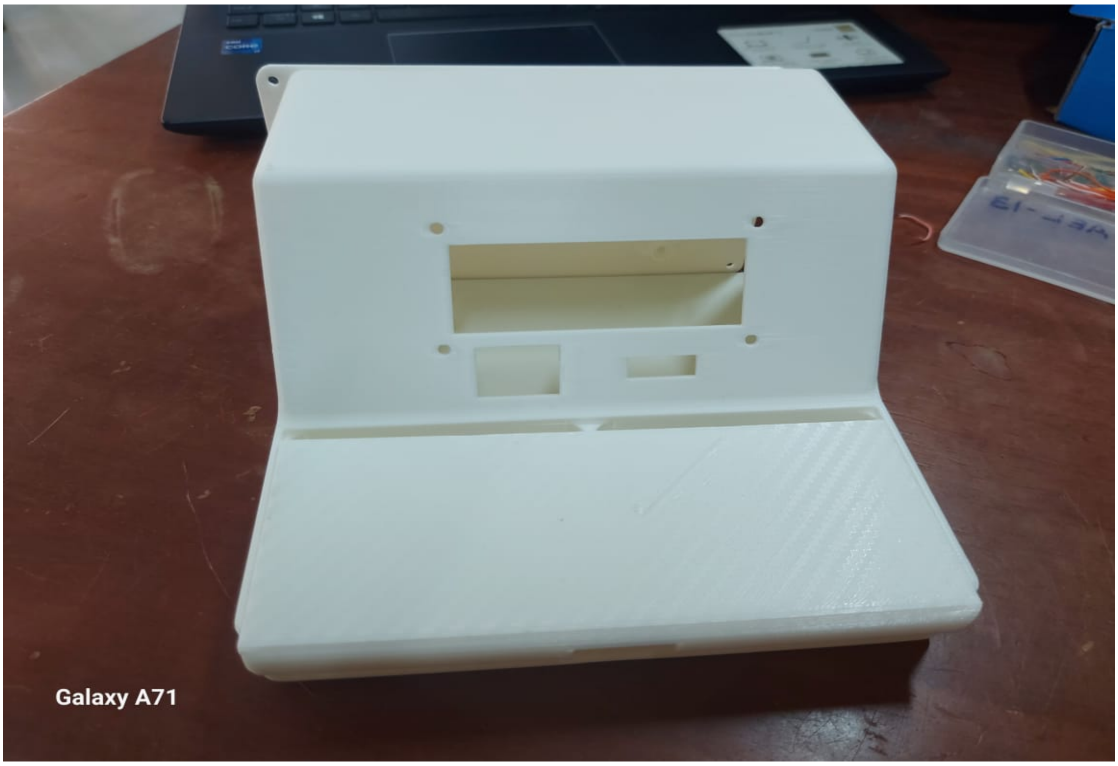


Figure 18: Finished Enclosure

# 8 Individual Contributions

| Group Member | Contribution |
|---|---|
| Perera P.L.P. | Circuit design, Component Selection, PCB design, Soldering |
| Wickramasinghe S.D. | Circuit design, Enclosure design, Testing and debugging |
| Wijayarathna K.K.B.C. | Circuit design, Component selection, PCB design, Soldering |
| Yashoodhara M.H.K. | Circuit design, Enclosure design, Testing and debugging |

Table 2: Individual contributions of each group member

# 9 Simulation Results

We simulated the circuit using LT Spice.
When we connect the fluid temperature input circuit to the amplifier, the output voltage change with the NTC thermistor resistance can be seen below.

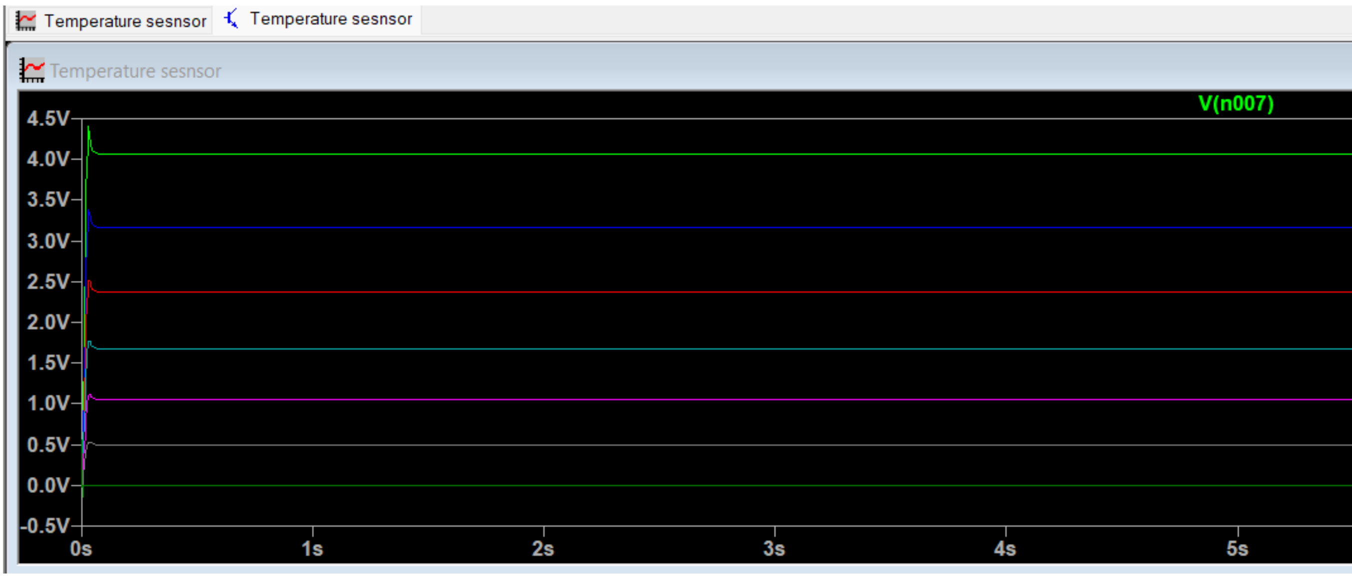


Figure 19: Output Voltage Change with the Change in NTC Resistor Value

## 10 Test Results

We conducted a series of tests to evaluate the accuracy and performance of the analog thermometer across a range of temperatures.

### 10.1 Temperature Range and Calibration

The thermometer was tested with temperatures between 10°C and 50°C using calibrated reference thermometers for validation. Each thermistor probe (PT100 and NT10K) was individually calibrated by measuring output voltages at known temperature points. These measurements were used to establish a precise temperature scale for each probe.

### 10.2 Accuracy

After calibration, the thermometer achieved:

- **PT100 Probe:** Accuracy within ±1.0°C.
- **NT10K Probe:** Accuracy within ±2.0°C.

### 10.3 Stability and Reliability

The device demonstrated consistent performance during repeated tests under identical conditions. The noise-filtering capabilities of the instrumentation amplifier and the Wheatstone bridge design contributed to stable and reliable readings.

### 10.4 User Interface Validation

The switching mechanism for selecting thermistor probes functioned seamlessly, and the LCD display provided clear and accurate readings throughout the testing process. These results confirm the thermometer's ability to deliver precise and repeatable temperature measurements, fulfilling the project's objectives effectively.

## 11 Conclusions

The development of the analog thermometer was a successful endeavor, meeting the project objectives of designing a precise and reliable temperature measurement device. By integrating key circuit components, including Wheatstone bridges, an instrumentation amplifier, and a robust power supply, we achieved consistent and accurate temperature readings across the tested range of 10°C to 50°C.

The calibration process ensured that the thermistor probes (PT100 and NT10K) were optimized for precision, with accuracies of ±0.5°C and ±1.0°C, respectively. The use of a switchable input mechanism and a clear display interface further enhanced the functionality and usability of the device.

This project highlighted the importance of iterative design, calibration, and testing in achieving a reliable final product. The implementation of noise filtering, proper signal conditioning, and careful component selection were critical in ensuring performance stability.

The analog thermometer demonstrates the potential for practical applications in scenarios requiring cost-effective, accurate, and non-digital solutions for temperature measurement. Future improvements, such as incorporating higher-accuracy thermistors and enhanced signal processing techniques, can further refine the device's performance and broaden its application scope.

# 12 Future Works

## 12.1 Improving the Power Supply Circuit

The power supply circuit can be enhanced by incorporating higher-quality components with improved safety ratings, such as components certified for over voltage and over current protection. Considering the direct connection to the main power supply, implementing isolation techniques like optocouplers and fuses will further ensure user safety and circuit reliability.

## 12.2 Enhancing Temperature Scale Accuracy

The signal conditioning circuit can be refined to enhance the accuracy of the temperature scale in our analog project. Using precision operational amplifiers with low noise and offset voltage ensures better amplification of the thermistor signal. Analog filters, such as low-pass filters can be introduced to minimize noise and interference from external sources. Calibration can be improved by incorporating high-precision multi-turn potentiometers for fine-tuning and using stable voltage reference ICs to prevent drift. Additionally, temperature-compensated resistors can be employed in critical parts of the circuit to counteract the effects of ambient temperature changes, resulting in more reliable and accurate temperature readings.

## 12.3 Using Higher-Accuracy Thermistors

Replacing the current thermistors (PT100 and NT10K) with higher-accuracy alternatives, such as digital thermistors or RTDs (Resistance Temperature Detectors) with tighter tolerance, will improve the system's resolution and reliability. These components can handle wider temperature ranges and offer enhanced linearity, which is critical for applications requiring high precision.

## 13 References


"Multi analog thermometer sensor NTC 12kOhm displayed on an LCD," Arduino Forum, [Online].

Stefano Giangrandi, "NTC Thermistors," [Online].

"Temperature Measurement Using NTC Thermistors," Jameco Electronics, [Online].

"NTC Thermistor Interfacing with PIC18F4550," ElectronicWings, [Online].

G. Yadav and B. Singh, "Design of Temperature Measuring Instrument Using NTC Thermistor of $Fe_2TiO_5$ Based on Microcontroller ATmega 328," ResearchGate, [Online].