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Dual Thermometer
Project Report

Group Members

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Abstract

Accurate and simultaneous monitoring of body and fluid temperatures is critical in various clinical and day-to-day applications. This study presents the design and implementation of a dual thermometer system capable of independently measuring body and fluid temperature using separate probes. The system integrates analog electronics and a microcontroller to display temperature data on a digital interface. The body temperature probe employs a high-sensitivity thermistor optimized for rapid and precise response to physiological temperature ranges, while the fluid temperature probe is calibrated for broader thermal conditions. Experimental validation demonstrates a measurement accuracy of ±1°C within the body temperature range (32–42°C) and ±2°C for fluid temperatures (0–100°C). The proposed system offers a cost-effective, reliable, and portable solution for applications requiring concurrent temperature monitoring. Future work will focus on integrating wireless data transmission, improving the accuracy, and enhancing user interface functionality to expand its utility in remote monitoring scenarios.

Contents

1 Introduction

Our project focuses on designing and implementing a dual-temperature monitoring system that measures 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 versatile system can be used in healthcare, laboratory, and household settings. We achieve a seamless combination of accuracy, reliability, and user-friendly design by integrating analog electronics with digital components.

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 Architecture

3.1 Block Diagram

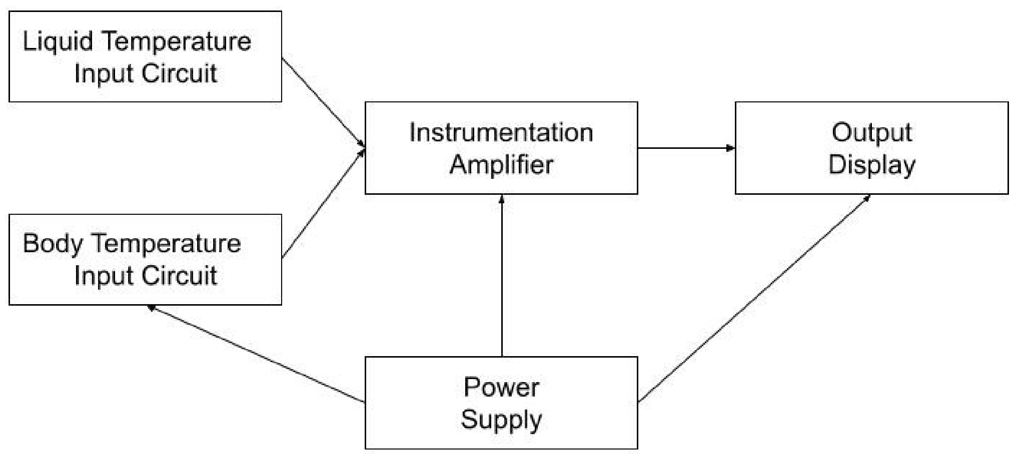

Figure 1: Block Diagram

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 Equations and Theorems

The frequency response of the first-order filters used in the input circuits is given below.

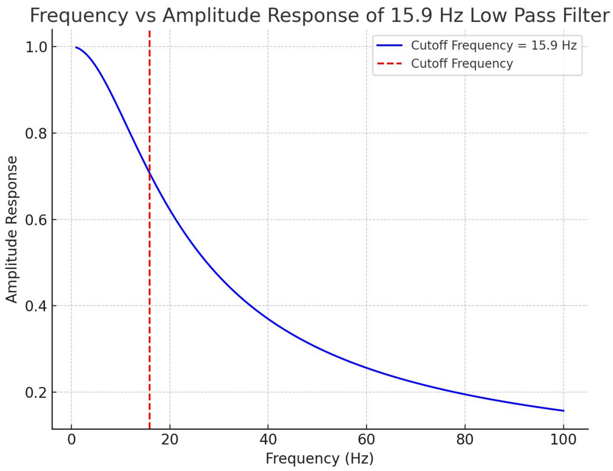

Figure 2: Frequency Response

The voltage gain of an instrumentation amplifier is given from the below equation.

$$A_v = 1 + \frac{2R}{R_f} \tag{1}$$

The voltage gain of the instrumentation amplifier we used in the circuit is

$$\begin{aligned} A_v &= 1 + \frac{2 * 10}{6.6} \\ A_v &= 4.03 \end{aligned} \tag{2}$$

4 Component Selection

Component	**Reasons for Selection**
Transformer (230V to 30V double tap)	• According to the power requirement of the OPAMPs and other circuit components and • proper functionality of the whole circuit
TL702 CP OPAMPs	• Wide supply voltage range (+/-2.25V +/-20V) • Low offset voltage - ensures precise signal amplification • High slew rate (60 V/μs) and stability
TIP41C	• Capability to switch currents up to **500 mA** • 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 • Simplified Design - easy gain adjustment • 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

5 PCB Design

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

5.1 Power Supply Unit

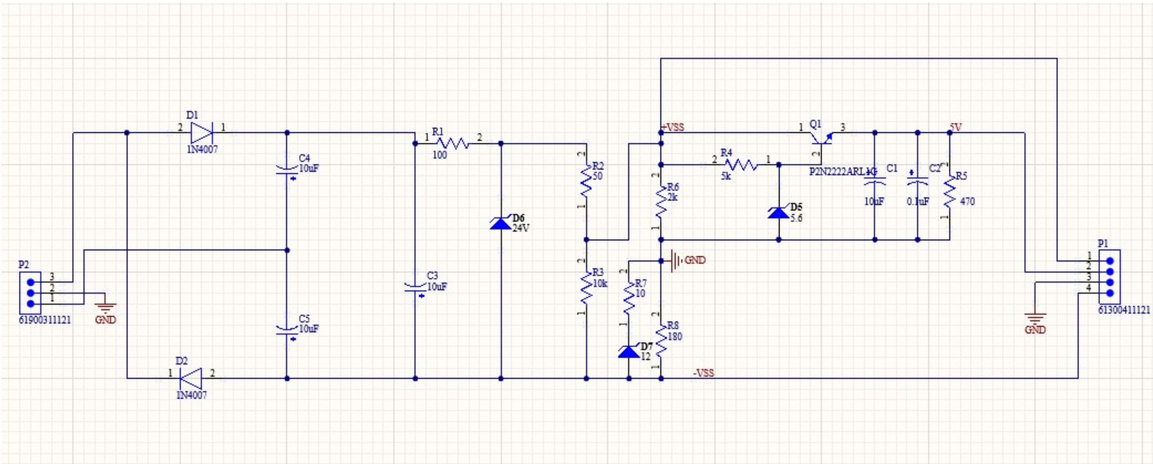

Figure 3: Power Supply PCB

- 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.

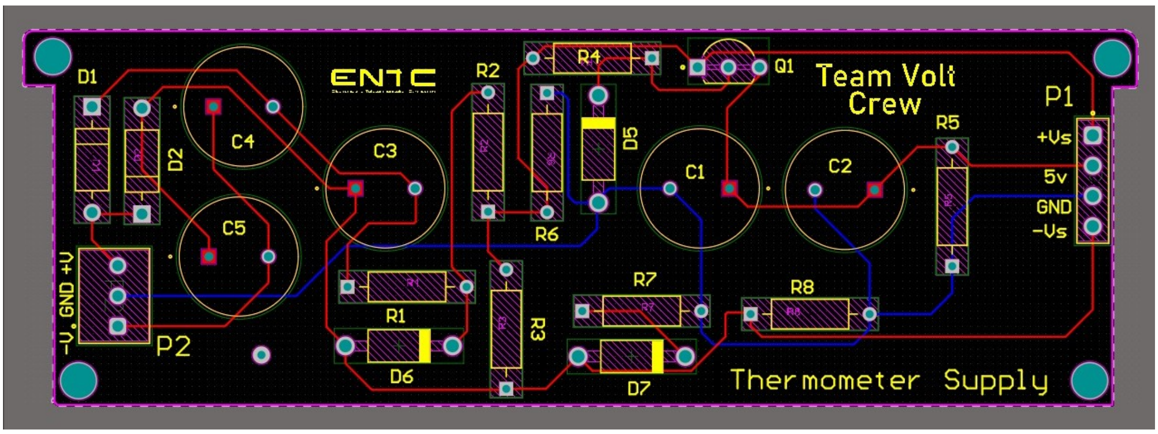

Figure 4: Power Supply PCB

5.2 Thermometer Circuit

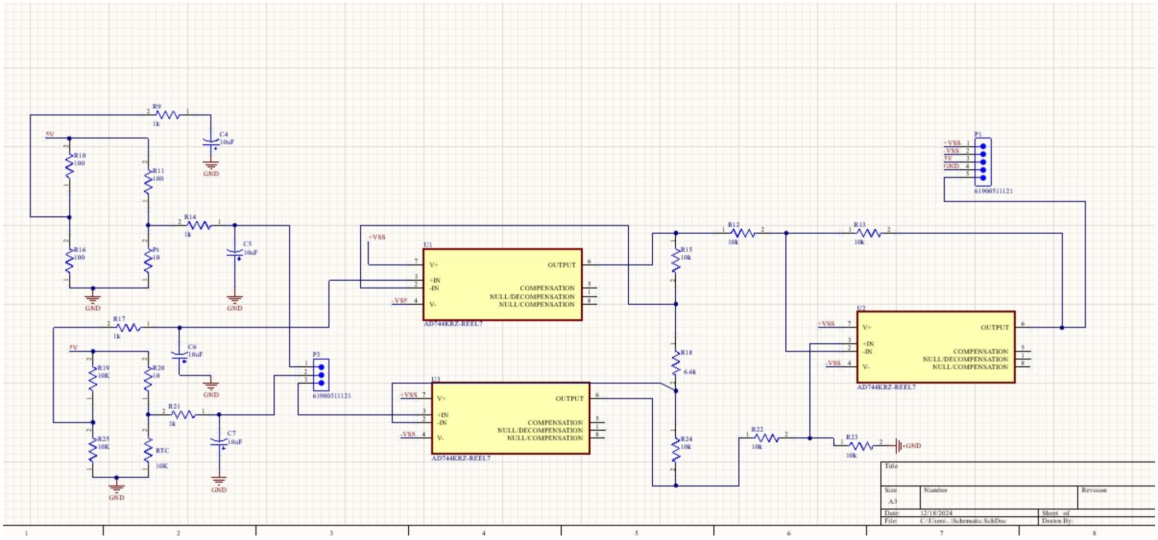

Figure 5: Thermometer PCB

- 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.

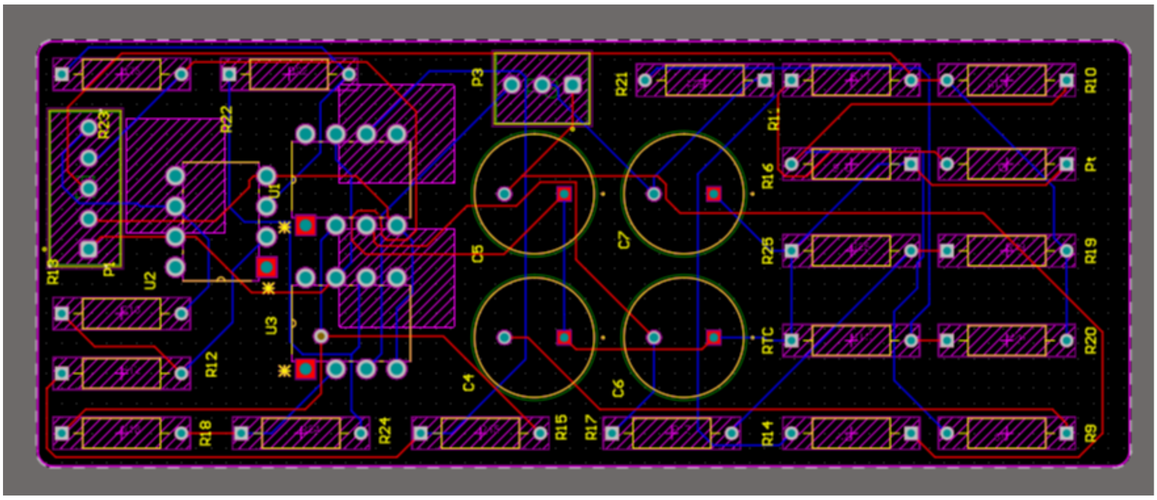

Figure 6: Thermometer PCB

Final PCBs

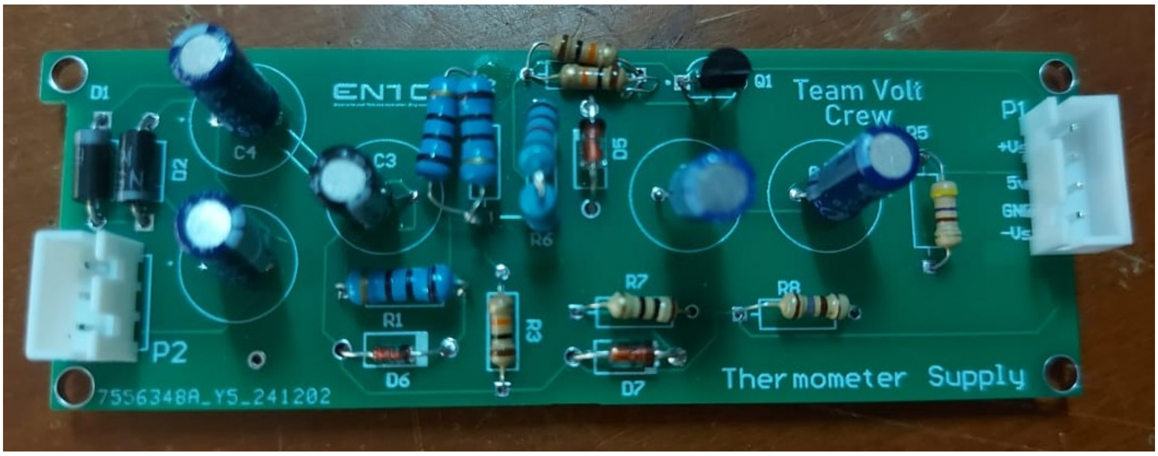

Figure 7: Power Suuply

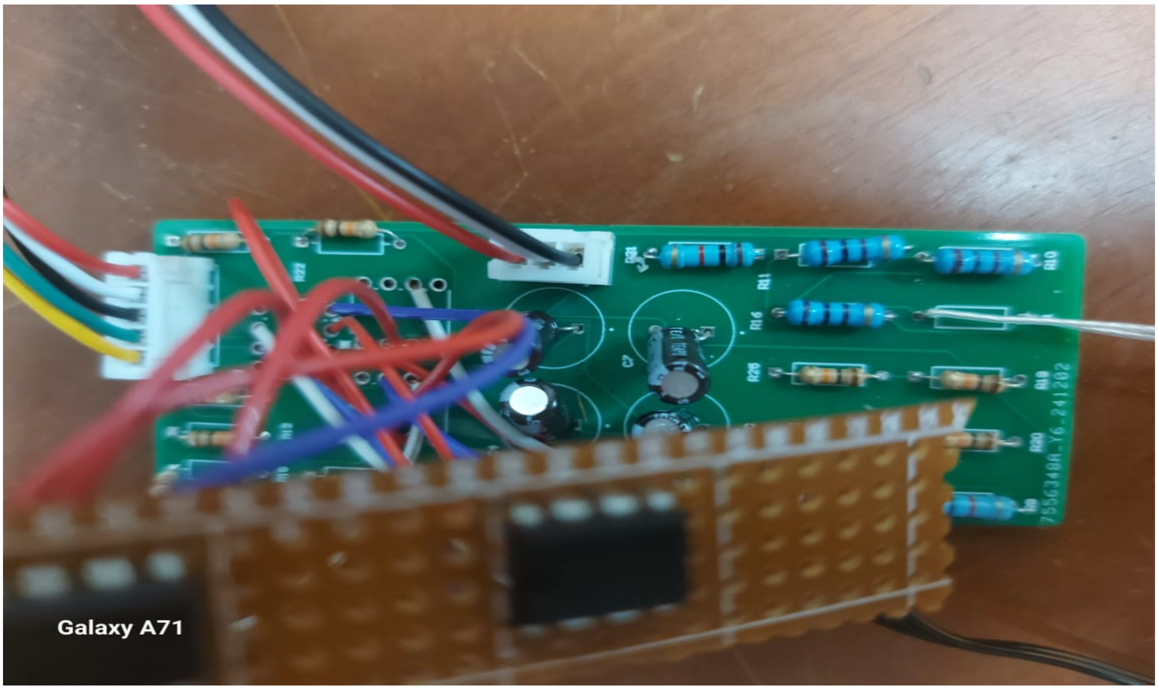

Figure 8: Thermometer Circuit

6 Enclosure Design

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

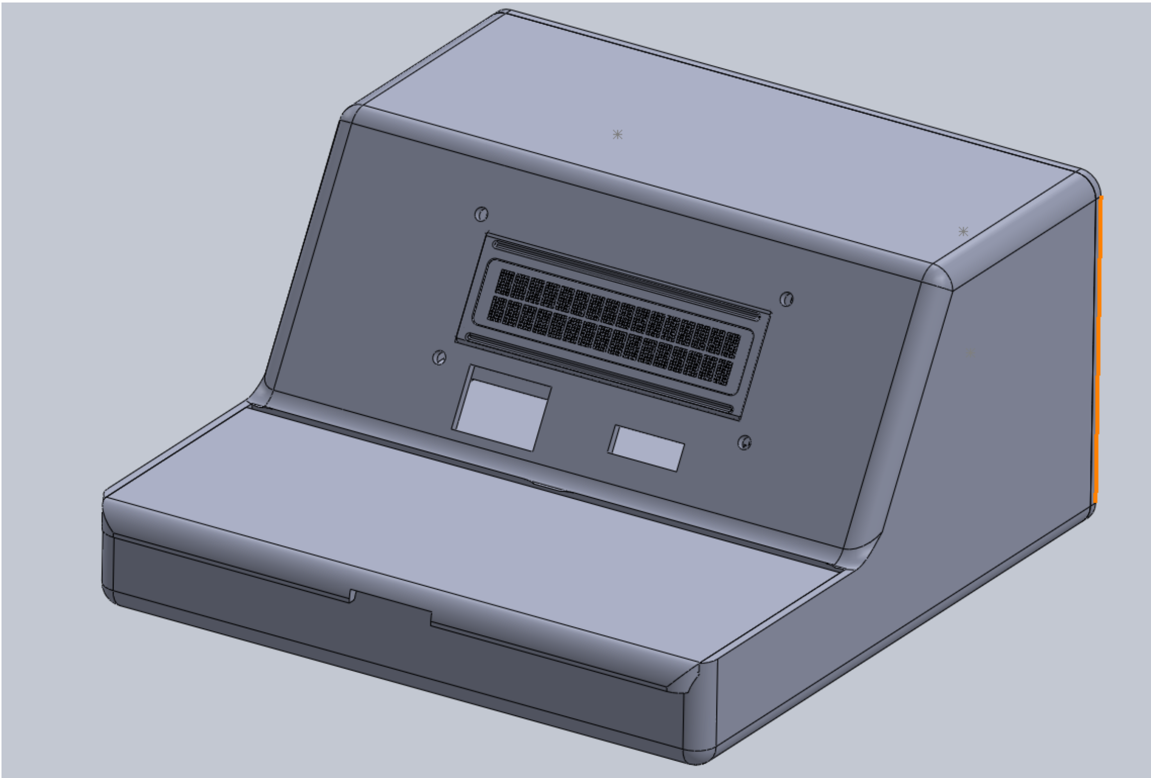

Figure 9: Enclosure

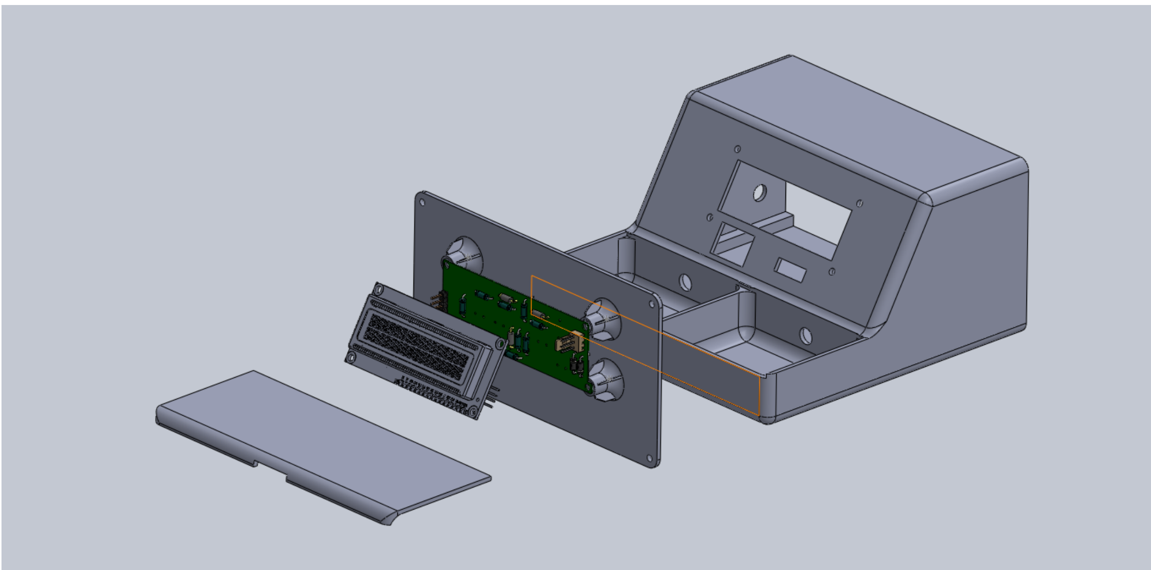

Figure 10: Exploded View

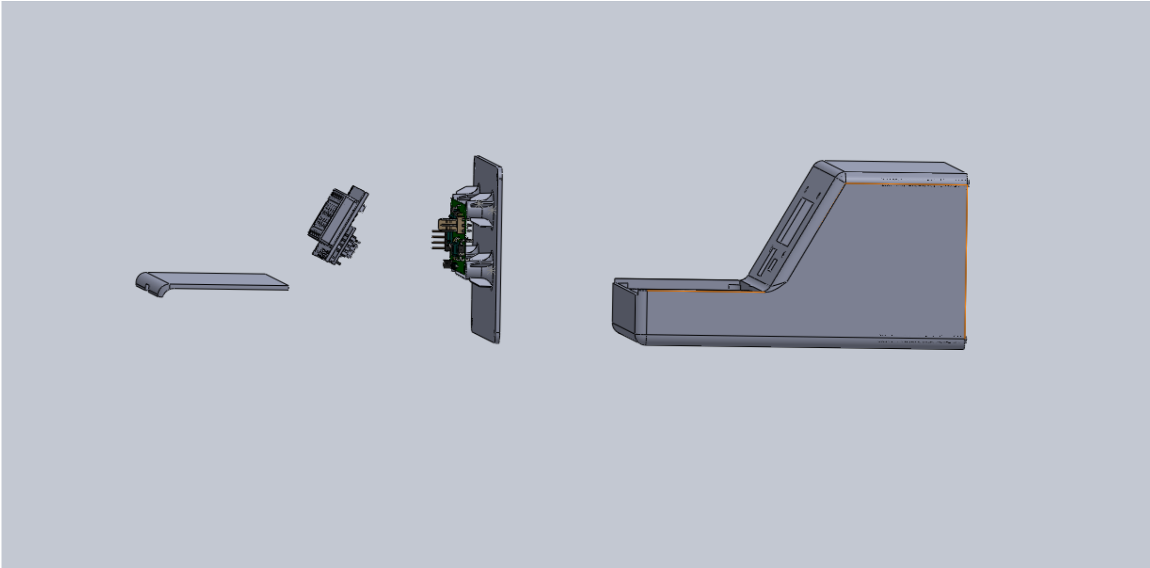

Figure 11: Side View

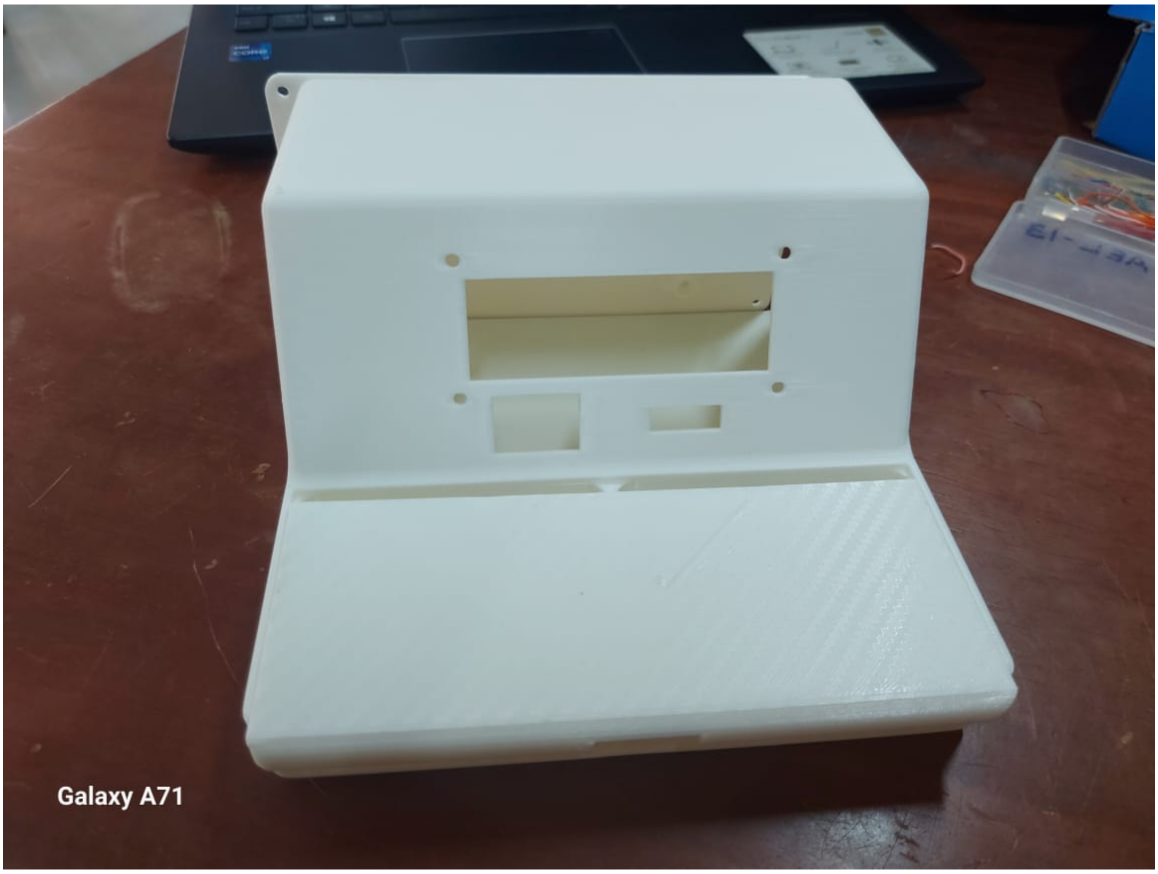

Figure 12: Finished Enclosure

7 Software Simulation

The initial schematic was created using LT Spice software.

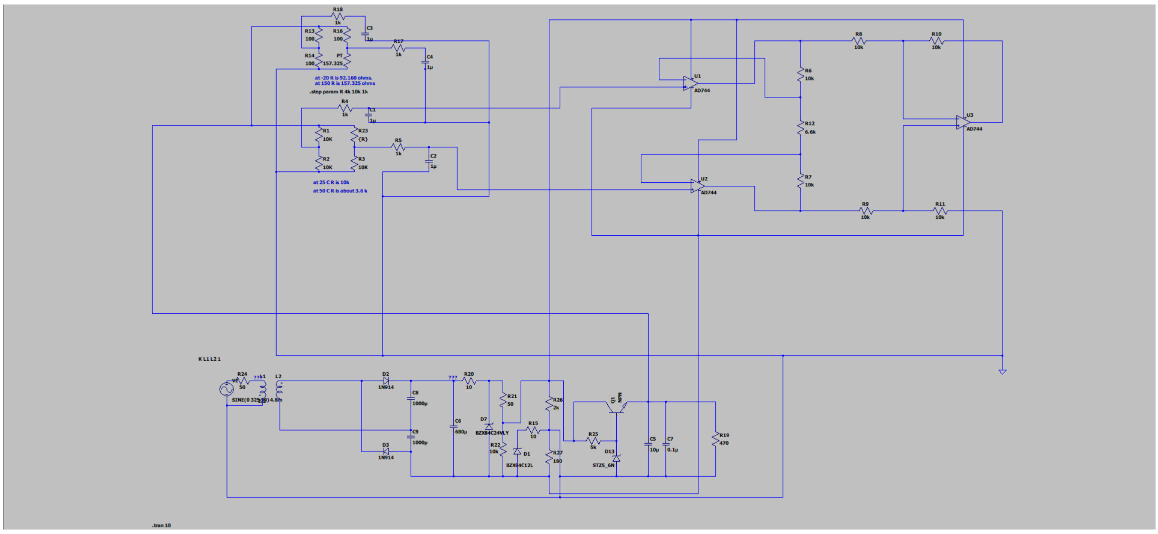

Figure 13: LT Spice Schematic

The parts of the circuit are as follows.

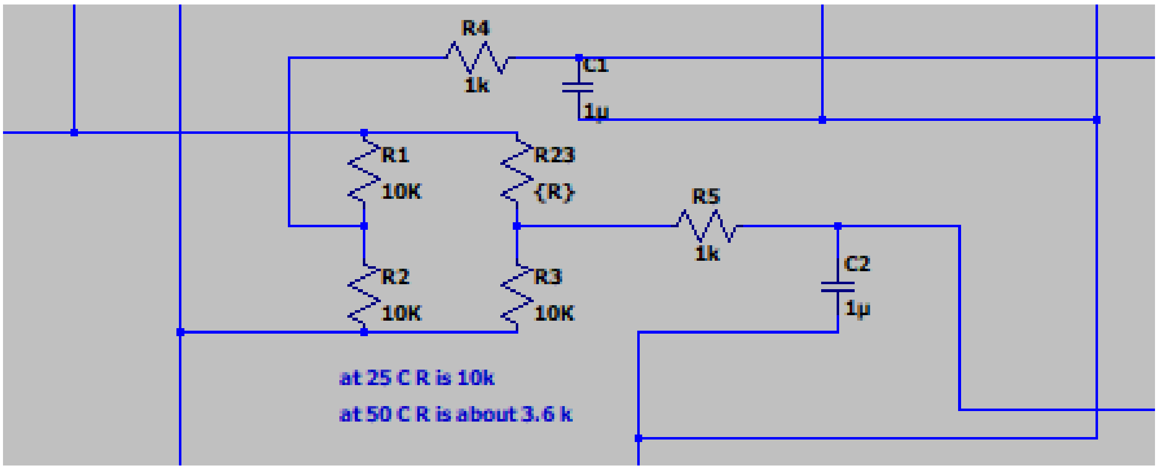

Figure 14: Liquid Temperature Input Circuit

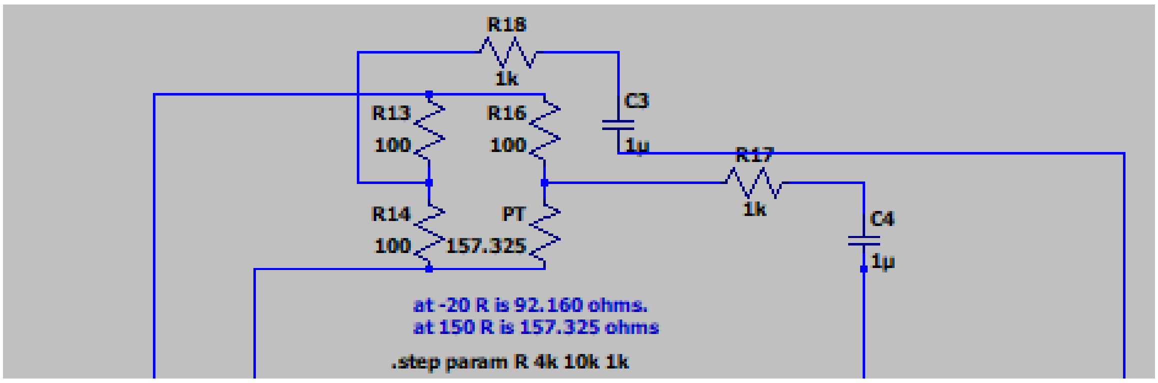

Figure 15: Body Temperature Input Circuit

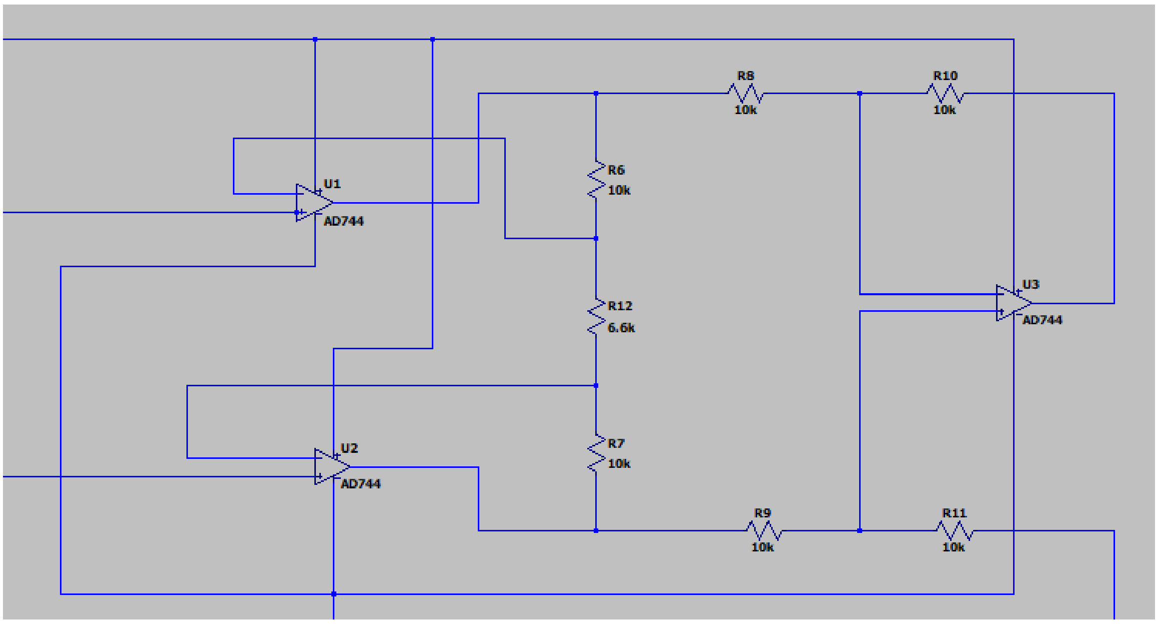

Figure 16: Instrumentation Amplifier Circuit

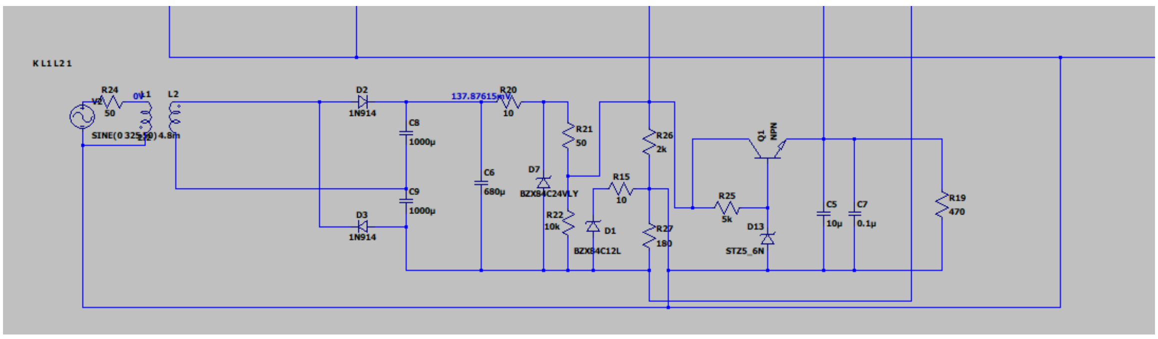

Figure 17: Power Supply Circuit

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

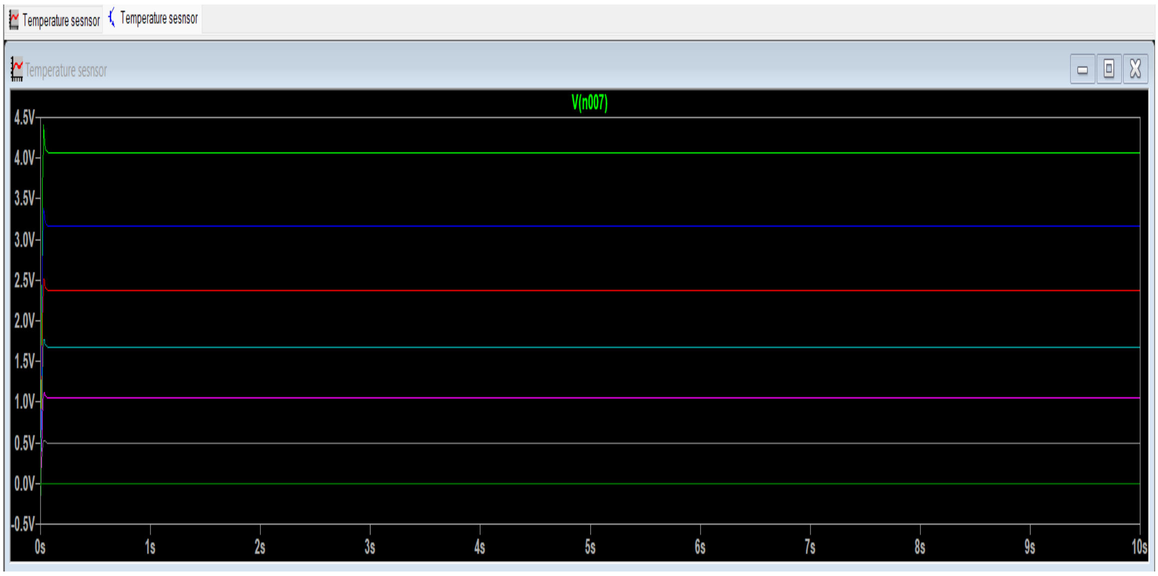

Figure 18: Output Voltage Change with the Change in NTC Resistor Value

8 Hardware Testing

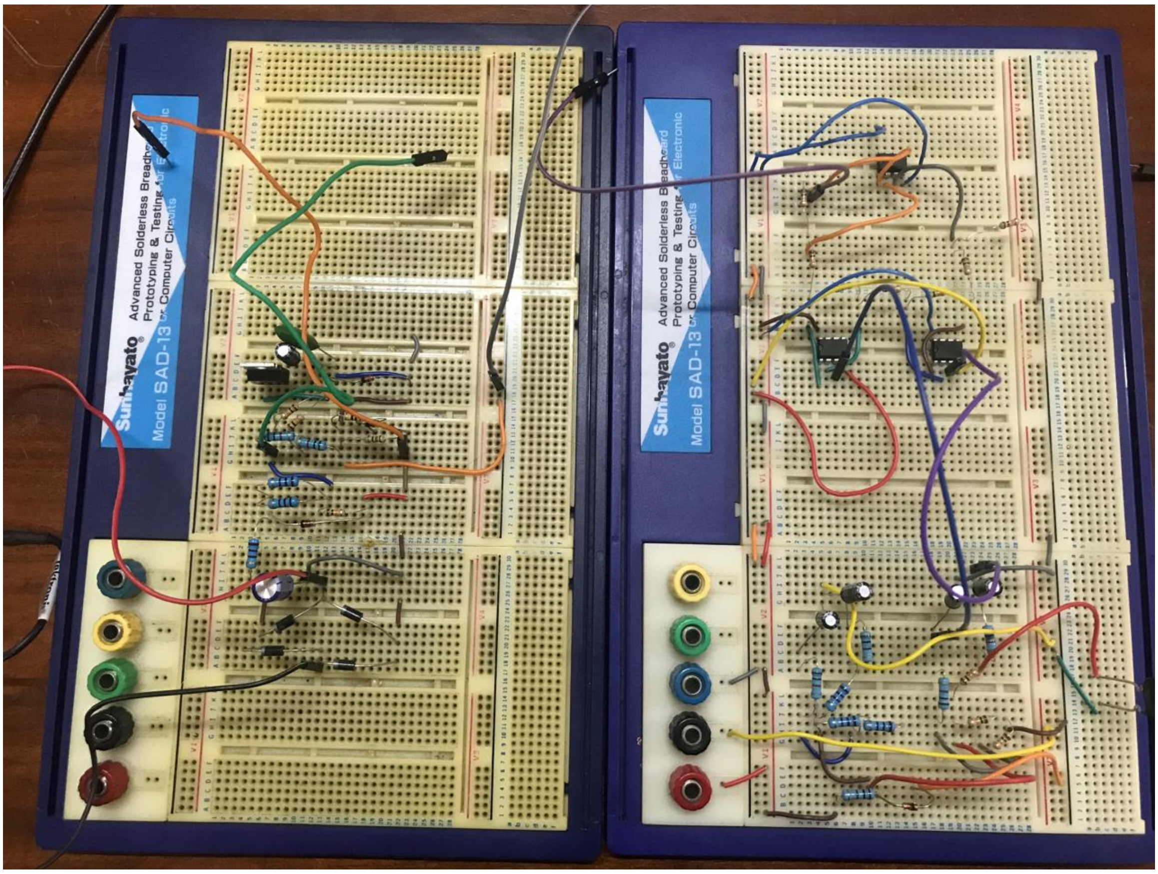

Figure 19: Whole circuit

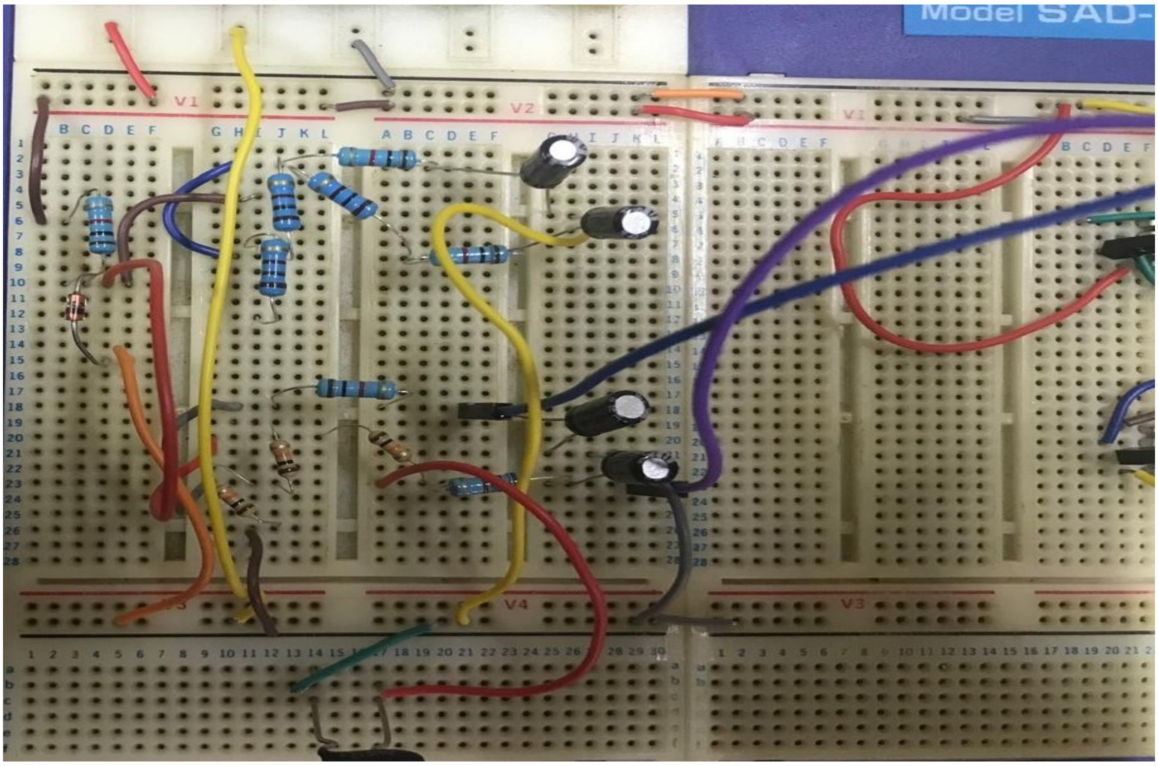

Figure 20: Input circuit

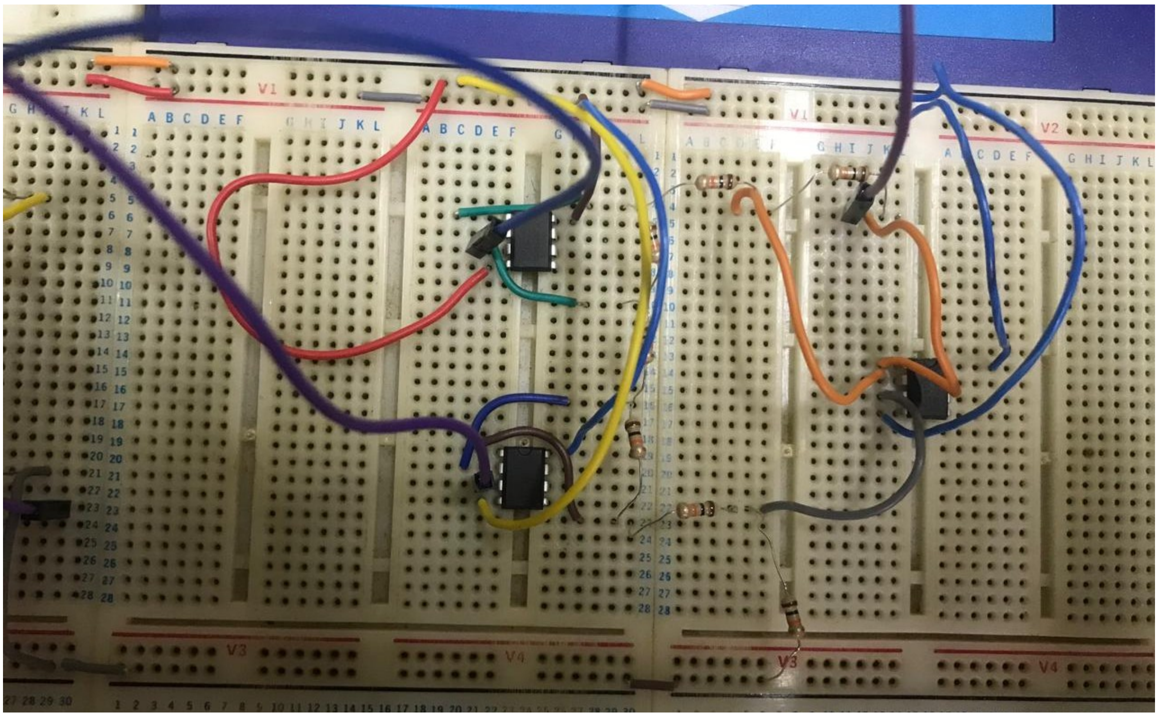

Figure 21: Amplifier Circuit

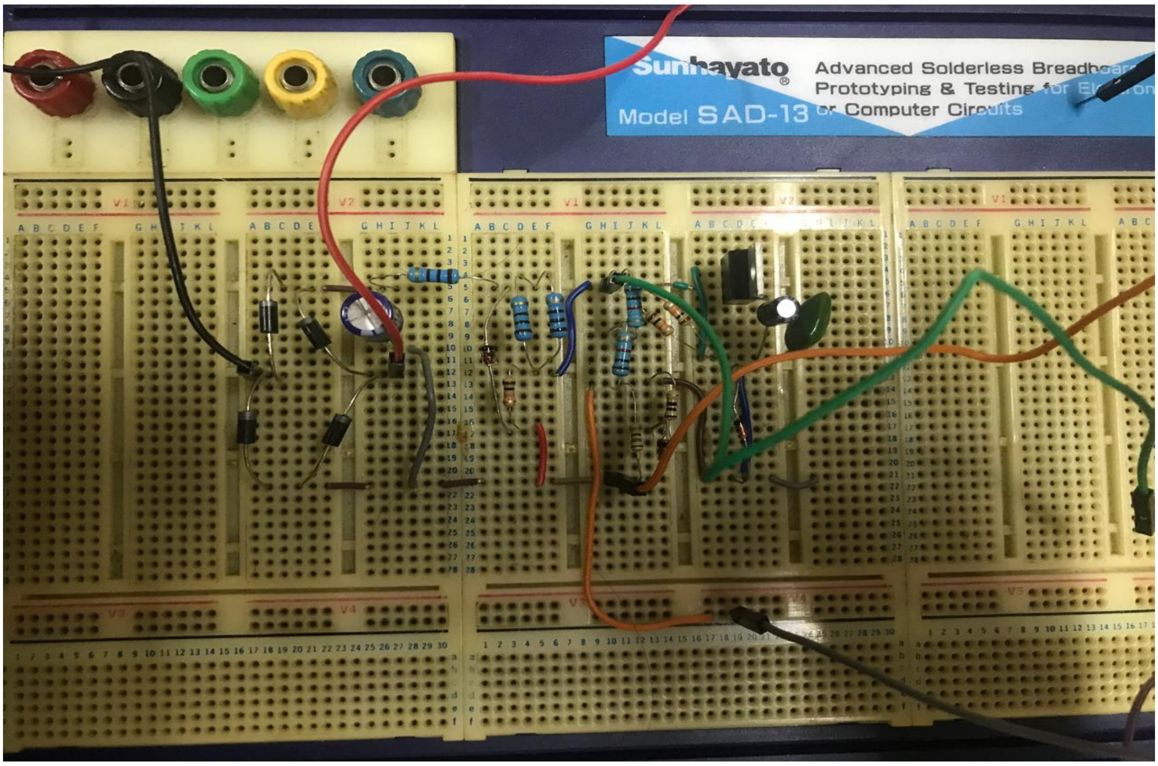

Figure 22: Power Supply Circuit

We gave a 5V supply to each one of the input circuits and a 10V supply to the op-amps and connected the output to an oscilloscope. Then we could see that the output changes with the temperature of the thermistor i.e its resistance.

9 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.

10 Future Works

10.1 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.

10.2 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.

10.3 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 high-precision applications.

11 Contribution of Group Members

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

References

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