Experiment 2: Temperature Sensor Unit Using NTC Thermistor

Sensors Laboratory EE3019

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1 Introduction

This experiment aims to design and test a temperature sensor unit using an NTC (Negative Temperature Coefficient) thermistor. The thermistor's resistance decreases with increasing temperature, which can be exploited to build a temperature sensor. A signal conditioning circuit is used to convert the resistance changes into a voltage output.

The primary goal is to produce an approximately linear output voltage in the 30°C to 60°C temperature range, varying from 1.5 V to 4.5 V. This experiment reinforces key concepts in sensor interfacing, signal conditioning, simulation, and data acquisition.

2 Circuit Design

The signal conditioning circuit is designed using an MCP6004 op-amp and follows guidelines from the Texas Instruments application note. The thermistor used is a $10k\Omega$ NTC type.

2.1 Design Specifications

- V_{DD} = 5 V
- Output voltage range: 1.57 V at 30°C to 4.55 V at 60°C
- Thermistor nominal resistance: $10k\Omega$

2.2 Circuit Diagram

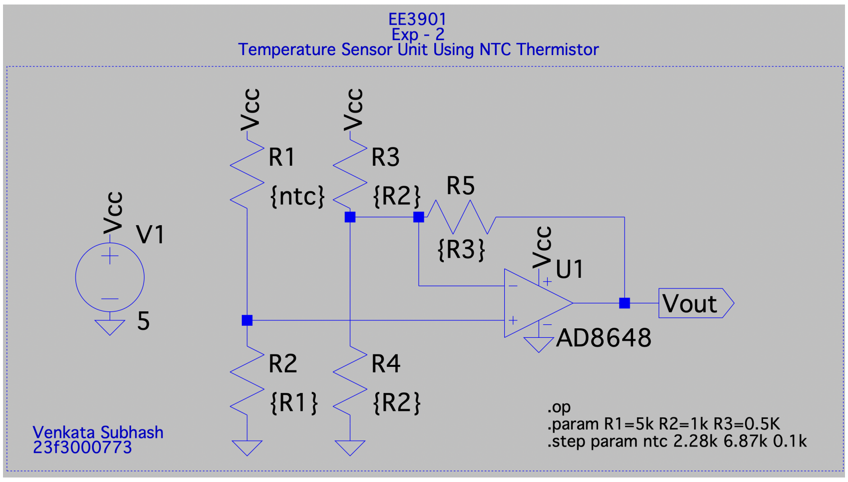


Figure 1: Signal conditioning circuit for temperature sensor

2.3 Operation and Calculations

I have used the formulae present in the application note to calculate the values of all resistors for desired output.

$$R_1 = \sqrt{R_{NTC@25C} * R_{NTC@50C}} = \sqrt{7.6294 * 3.8059}$$

$$R_1 \approx 5k\Omega$$

By using the other formulae and some trail and error the values of R_2 and R_3 are found.

$$R_2 = 1k\Omega$$

$$R_3 = 0.5k\Omega$$

Relation between Teperature and R_{ntc} (linearised)

$$R_{NTC} = -0.153 * Temp + 11.5$$

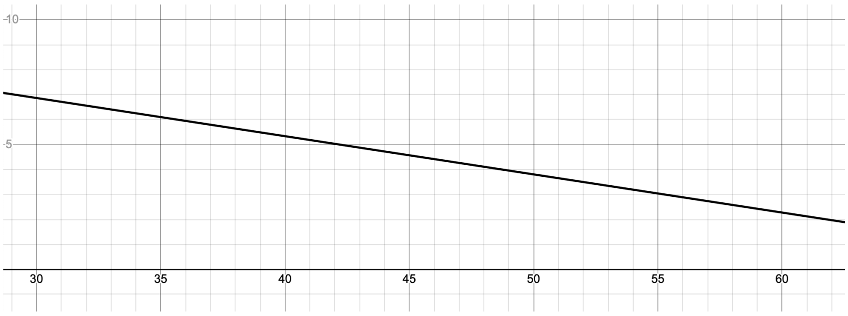


Figure 2: R_{NTC} vs Temperature

Relation between V_{out} vs Temp

$$V_{out} = -2.5 + \frac{50}{16.45 - 0.153 * Temp}$$

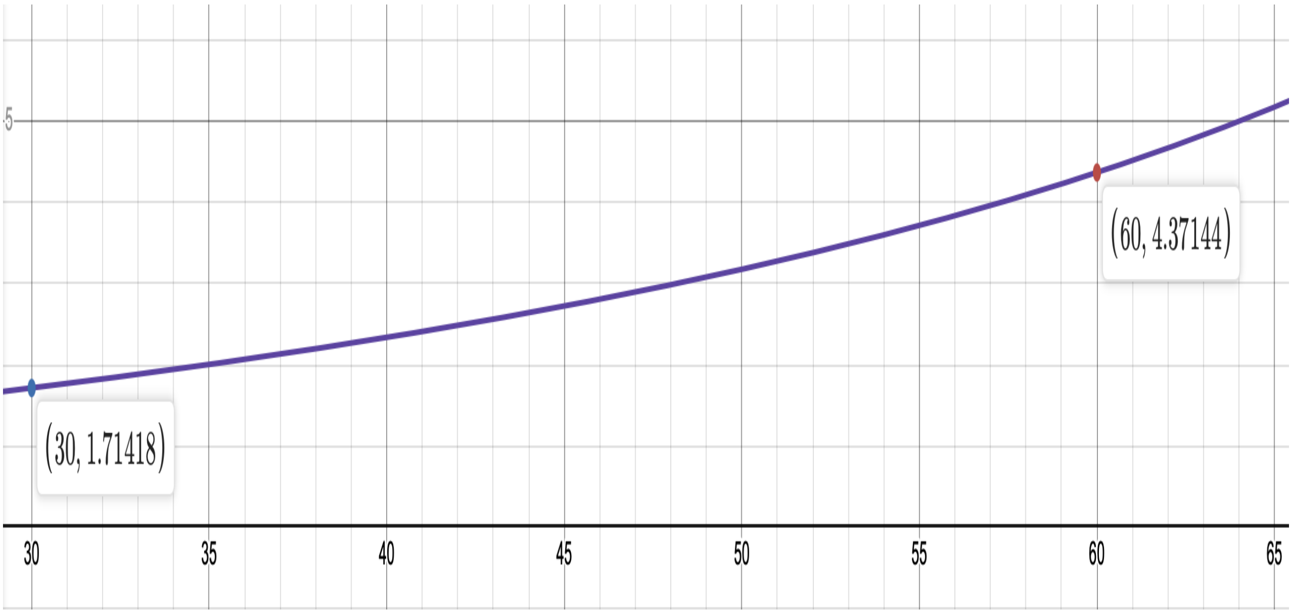


Figure 3: V_{out} vs Temperature

3 Simulation Results

Simulations were carried out using LTSpice.

3.1 Voltage input (voltage at the resistive divider using Rntc) vs Thermistor Resistance

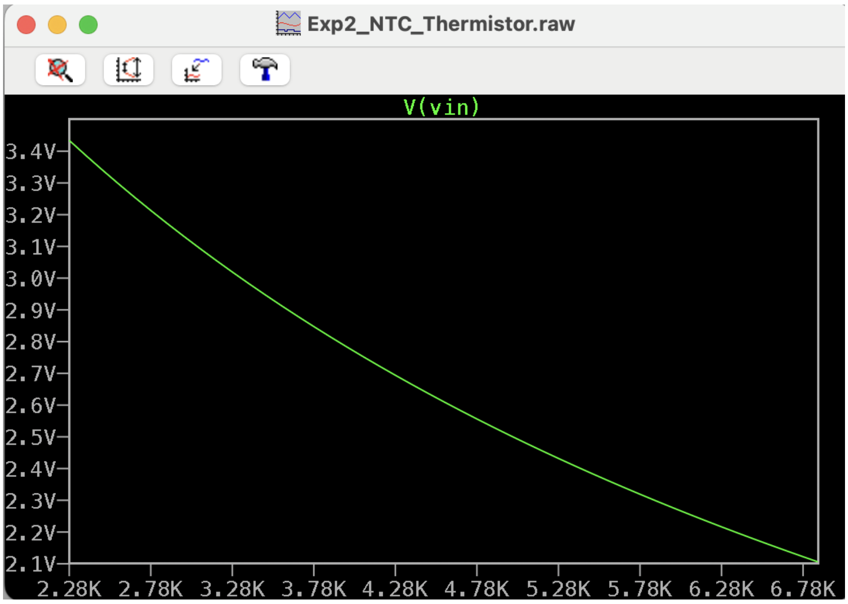


Figure 4: Simulated input voltage for varying thermistor resistance

3.2 Voltage output vs Thermistor Resistance

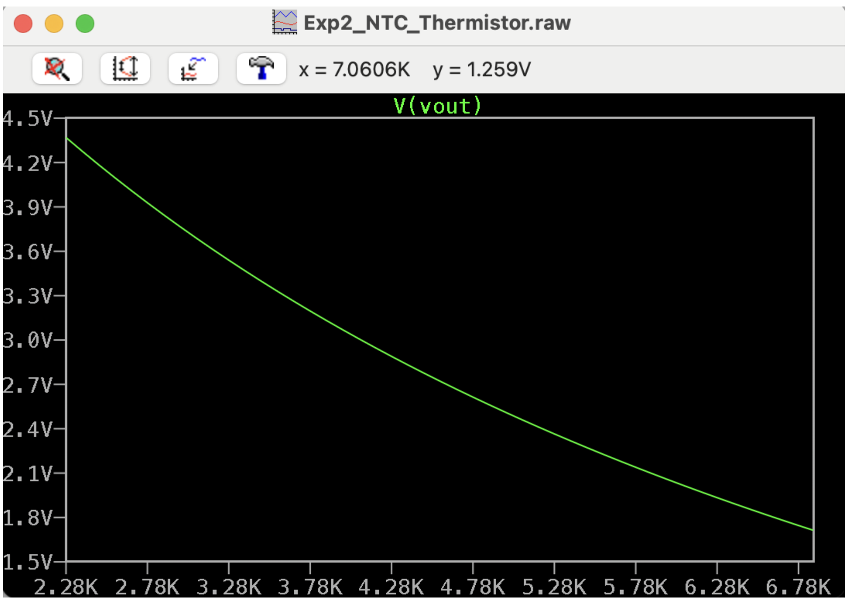


Figure 5: Simulated output voltage for varying thermistor resistance

4 Experimental Setup

The circuit was built on a breadboard using MCP6004, resistors, and a thermistor.

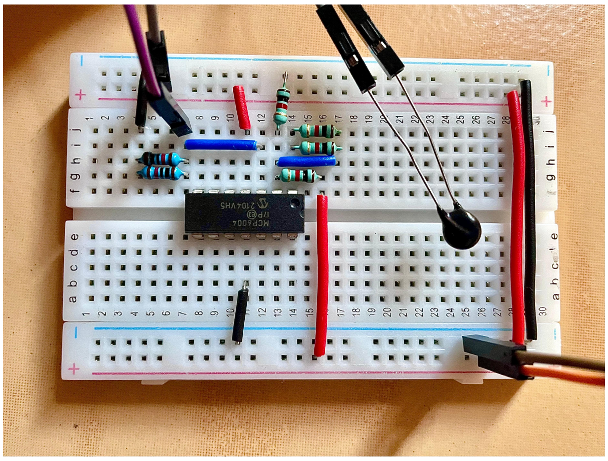


Figure 6: Breadboard setup of the temperature sensor unit

A temperature-measuring water bottle, which displays the water temperature on a digital screen on its cap, was used in this experiment. It was chosen because the clinical thermometer available had a limited range of 30°C **to** 42°C**, making it unsuitable for higher temperatures. The bottle's readings were cross-verified with the thermometer and found to be consistent. The corresponding output voltage was measured using Channel A of the ADALM1000. A picture of the water bottle used is attached below.**

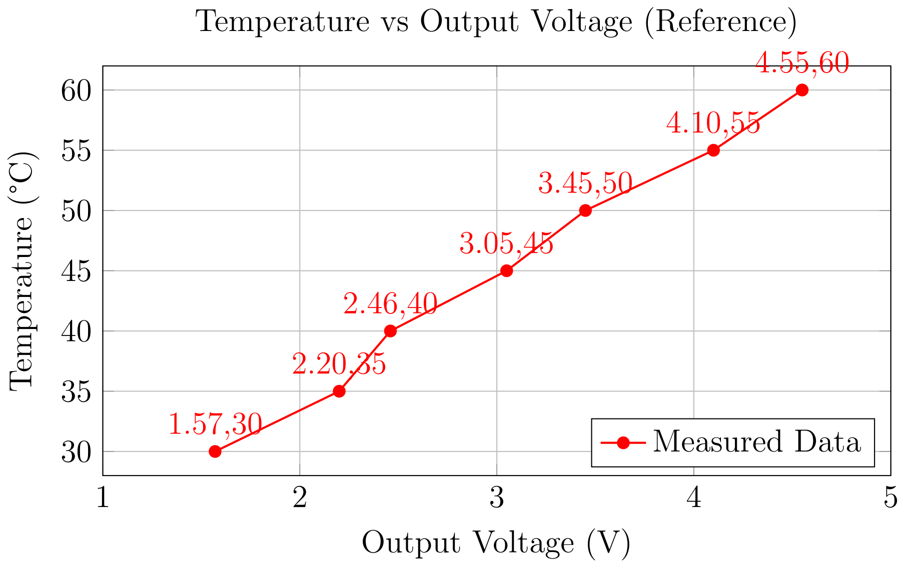
5 Data and Analysis

5.1 Measured Output Voltage (Actual Thermistor)

$$\text{Percentage Error} = \frac{|\text{Measured Temp} - \text{Reference Temp}|}{\text{Reference Temp}} \times 100\%$$

Table 1: Output Voltage vs Temperature for NTC Thermistor Circuit

Output Voltage (V)	**Reference Temperature (°C)**	**Measured Temperature (°C)**	**Percentage Error (%)**
1.57	30	29.22	2.6
2.20	35	36.05	3
2.46	40	41.36	3.4
3.05	45	46.67	3.7
3.45	50	51.632	3.26
4.10	55	56.033	1.87
4.55	60	61.205	2.02



5.2 Room Temperature Logging

Room temperature was recorded using the ADALM1000 every 30 minutes.

Table 2: Ambient temperature of my Room (on 15th Apr 2025)

Time (IST)	**Temperature (°C)**
14:00	39
14:30	40
15:00	39
15:30	38
16:00	35
16:30	35
17:00	36
17:30	33
18:00	33
18:30	32
19:00	31
19:30	30

I have measured my room temperature manually using the thermistor circuit.

6 Conclusion

The designed circuit successfully converted thermistor resistance variations into a nearly linear output voltage over the 30°C to 60°C range. Linearization improved the output characteristics significantly. The experimental results were found to match the simulation closely, validating the design. The room temperature monitoring demonstrated the practical utility of such sensor units.

Improvements:

- Further improve linearization using logarithmic compensation methods.
- Use higher-accuracy thermistors or instrumentation amplifiers for better precision.
- Automate temperature data logging using microcontrollers.