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Emir Arda Bayer
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EEE 313 Lab – 1
Diode Characterization and Differential Temperature Sensor

Introduction

This lab session included two parts, one being the design of a circuit to measure I_S on a diode, and the other one being the correct implementation of a differential temperature sensor by calculating correct values of circuit elements using certain phenomenon and equations.

Purpose

The purpose was initially to make use of basic circuitry and diode formulization to understand and use 1N4148 diodes, and then to use the same diode characteristics to evaluate a differential temperature sensor and correctly implement it on software and hardware.

Methodology and Design

First Part

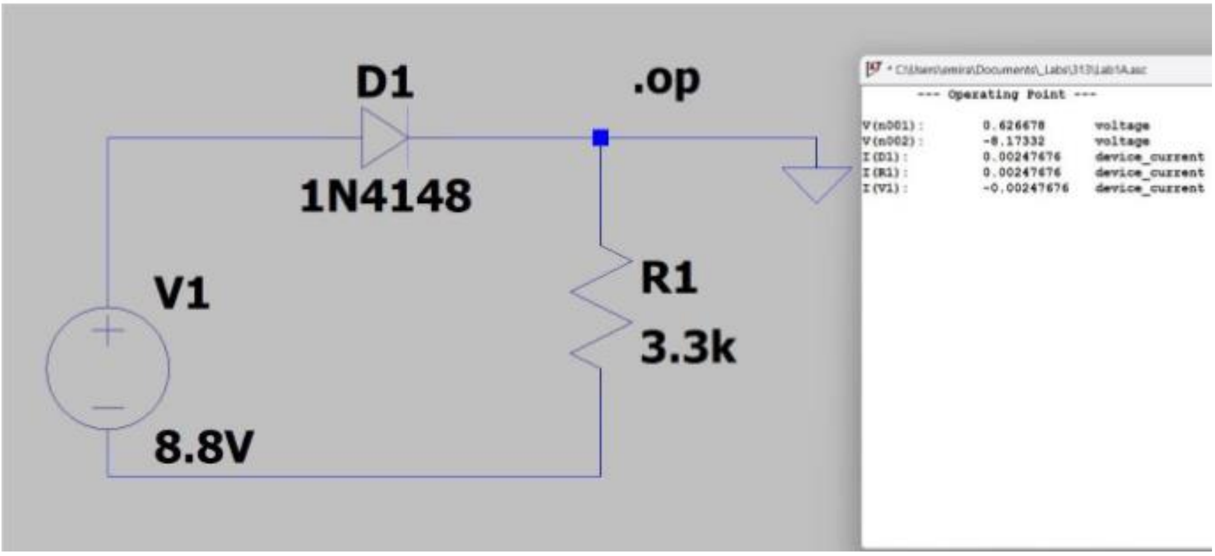

Figure 1: Part A Circuit on LTSpice

A circuit of a DC voltage supply and a 3.3kΩ resistor was combined with a 1N4148 diode was implemented on LTSpice as in Figure 1 to later use the following equation to find I_S.

$$I_D=I_s(e^{V_D/(nV_T)}-1)$$

The simulation results were used for V_D and I_D being 0.63V and 2.48 mA. The values for n and V_T were as n=1.752, V_T = kT/q = 0.02586V. The result was 2.44 nA, with a 3.17% error rate from 2.52 nA. Later, the same experiment was handled in hardware on a breadboard with a 3.3kΩ resistor and 8.8V voltage from the DC power supply.

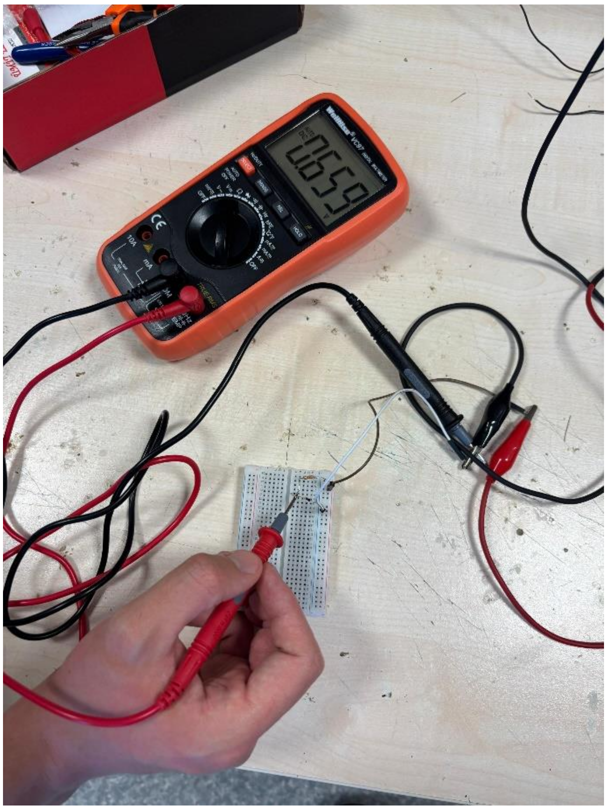

Figure 2: Measuring the Voltage

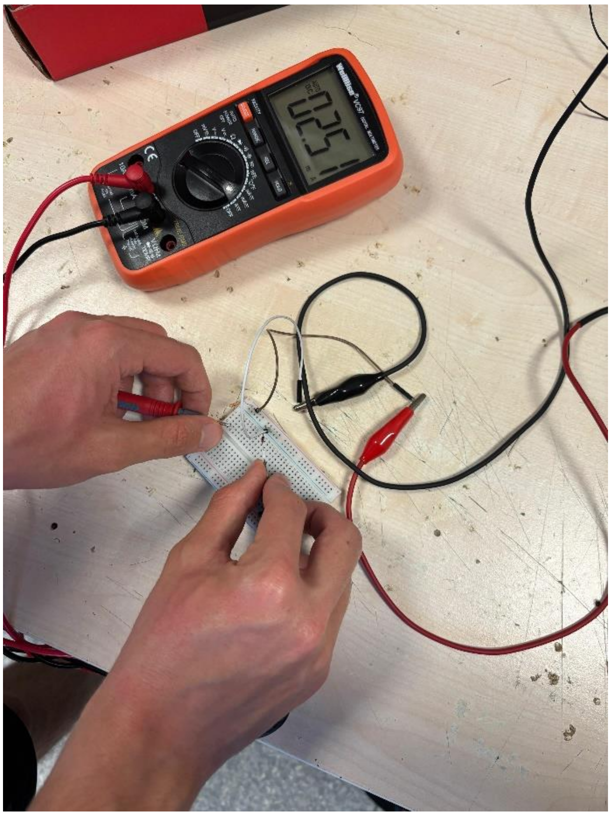

Figure 3: Measuring the Current

	I_D	V_D	I_S
Simulated	2.48 mA	0.63 V	2.44 nA
Measured	2.51 mA	0.659 V	1.51 nA
Error Rate (%)	1.2 %	4.4 %	38 %

Table 1: Part A Calculations

There was a 4.4% voltage difference in measurements most likely due to external factors such as temperature or internal errors such as internal resistances or manufacturing differences from desired values for resistor and diode, or errors of the lab equipment being the multimeter or power supply.

Part B

A schematic for a differential temperature sensor was introduced as in Figure 4 and the students were asked to find the values for the circuit elements.

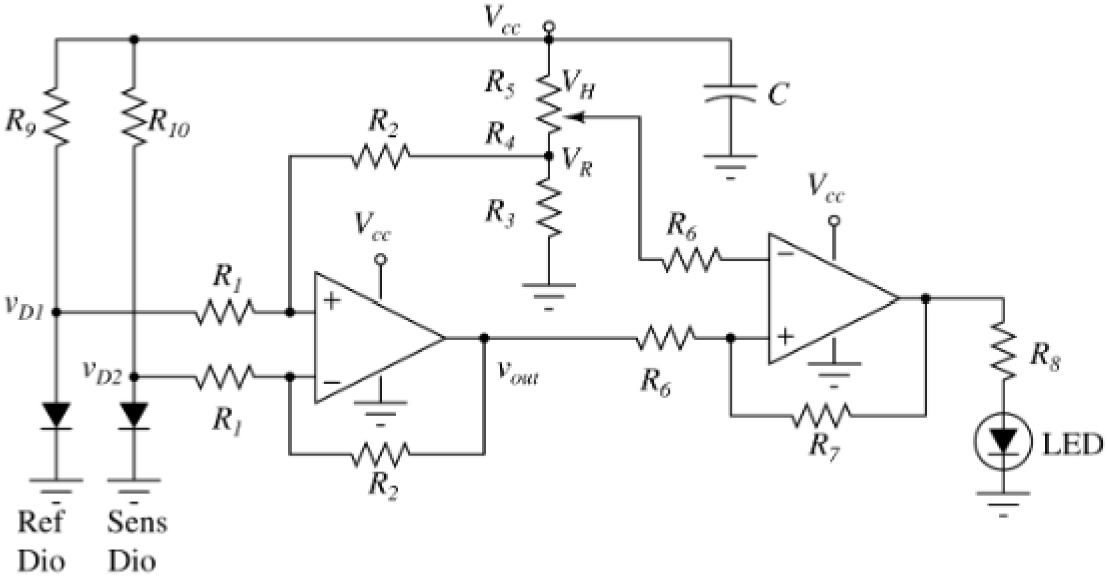

Figure 4: Given Schematic

The following conditions were stated for the students to properly evaluate the values for the circuit elements, and the circuit in Figure 6 was designed in LTSpice accordingly.

1. When both diodes are at room temperature (v_{D1}=v_{D2}), the output voltage, v_{out}, should be at (V_{cc}−2)/4
2. The output voltage should show the temperature difference between the room temperature and the temperature of the sensor diode in degrees with a 10% tolerance. For example, if the sensor diode is +1-degree warmer, v_{out} should change by +1V.
3. A red LED should turn on when the sensor's temperature exceeds +5±0.5°C the room temperature.
4. The LED should never flicker around the thresholds: It should have a 0.1°C (0.1V) hysteresis.

Figure 5: Stated Conditions

The value for the DC power supply (Vcc) was found as 12V, and the circuit was designed to turn on the LED when the temperature is around 28 degrees. The following statements from the manual were used while calculating the values for circuit elements.

Choose R_9 and R_{10} so the reference and sensor diodes have a current of about I_D=1mA.
$R_9=R_{10}=(V_{cc}-0.6)/(I_D)$.

The analysis of the difference amplifier gives:

$$v_{out}=(R_2/R_1)(v_{D1}-v_{D2})+V_R$$

The comparator analysis gives the two threshold voltages:
To turn on the LED, $v_{out}>V_H(R_7+R_6)/R_7$.
To turn off the LED, $v_{out}<V_H(R_7+R_6)/R_7-(R_6/R_7)(V_{cc}-2)$
Hence, the hysteresis value is $(R_6/R_7)(V_{cc}-2)$.

Choose $V_R=V_{cc}\,R_3/(R_3+R_4+R_5)$ assuming $R_2 \gg R_3$ (e.g., $R_2 \geq 20\,R_3$)
Use a multiturn pot of 10K for R_4+R_5 for a fine adjustment of V_H:
$V_H=V_{cc}\,(R_3+R_4)/(R_3+R_4+R_5)$

Choose (R_2/R_1) to give the required gain.
Choose the LED current limiting resistor to generate an LED current of 10mA: $R_8 \approx (V_{cc}-4)/0.01$

Figure 6: Statements from Manual

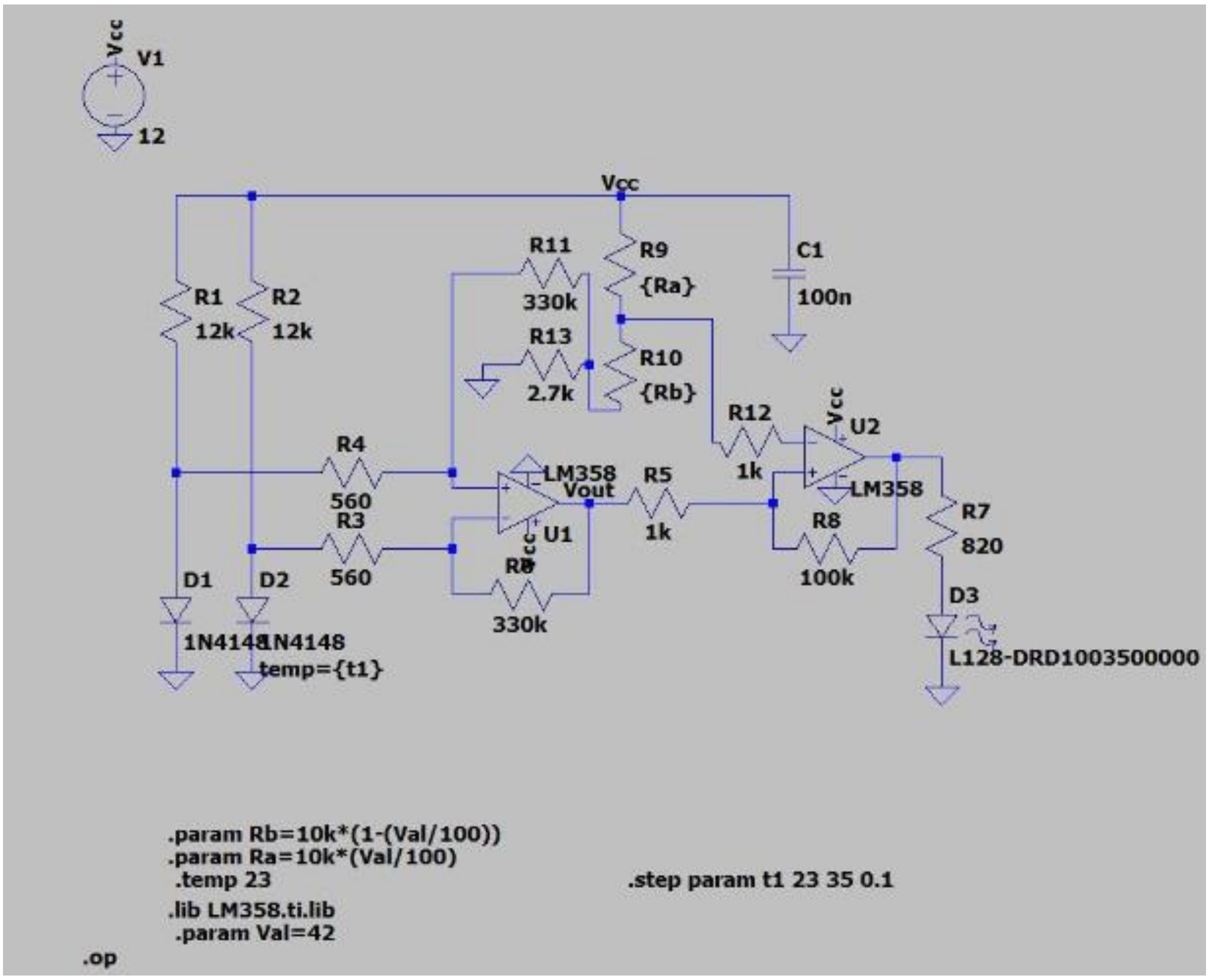

Figure 7: Designed Differential Temperature Sensor

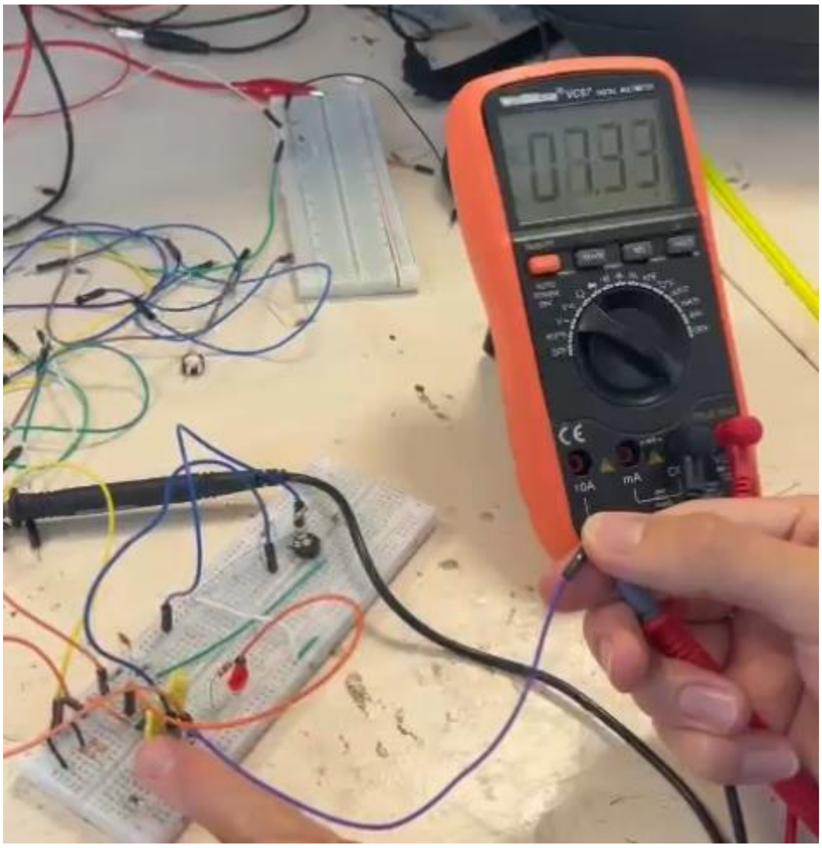

Figure 8: LED is OFF at 7.33V

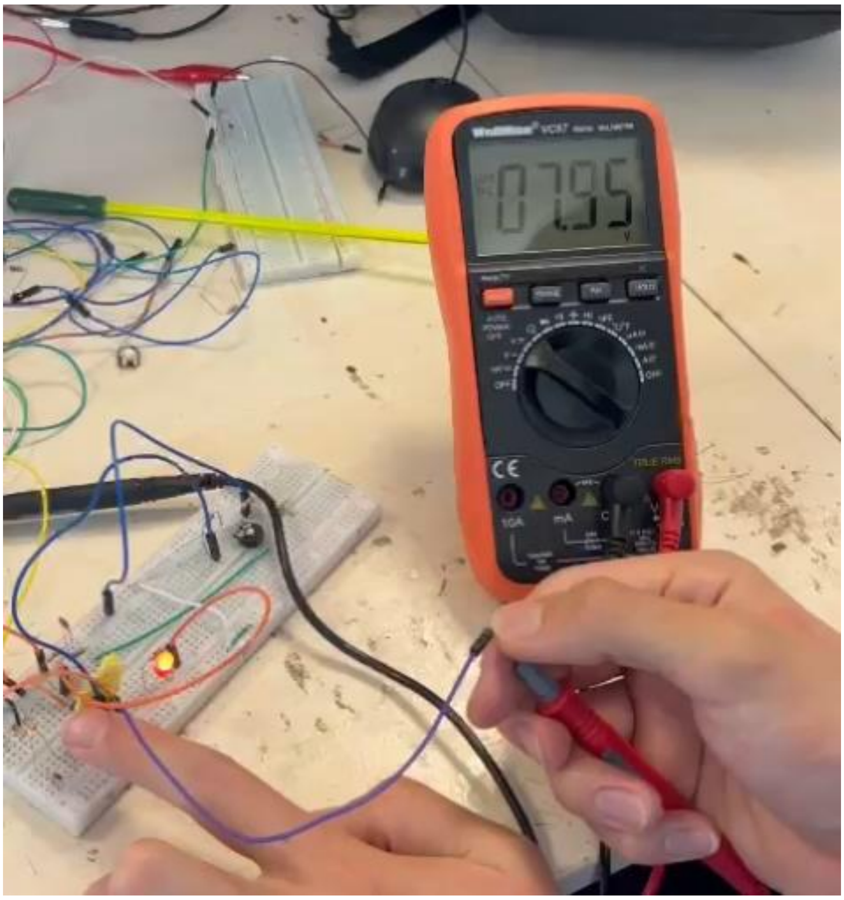

Figure 9: LED turns on at 7.55V (28°C)

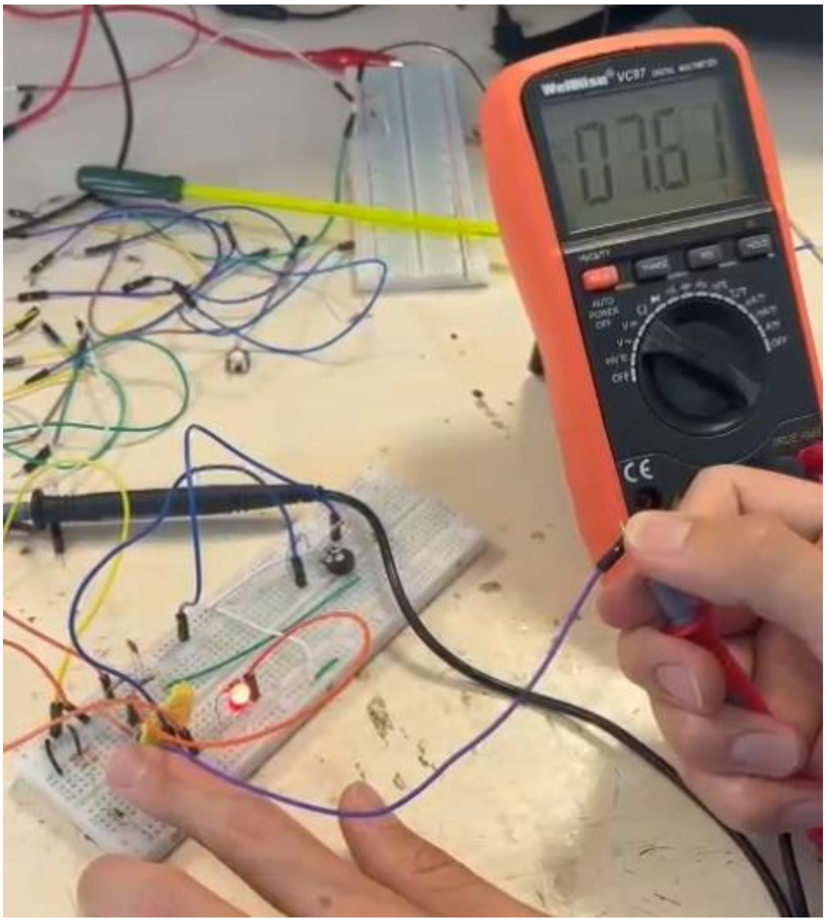

Figure 10: LED is ON After Threshold

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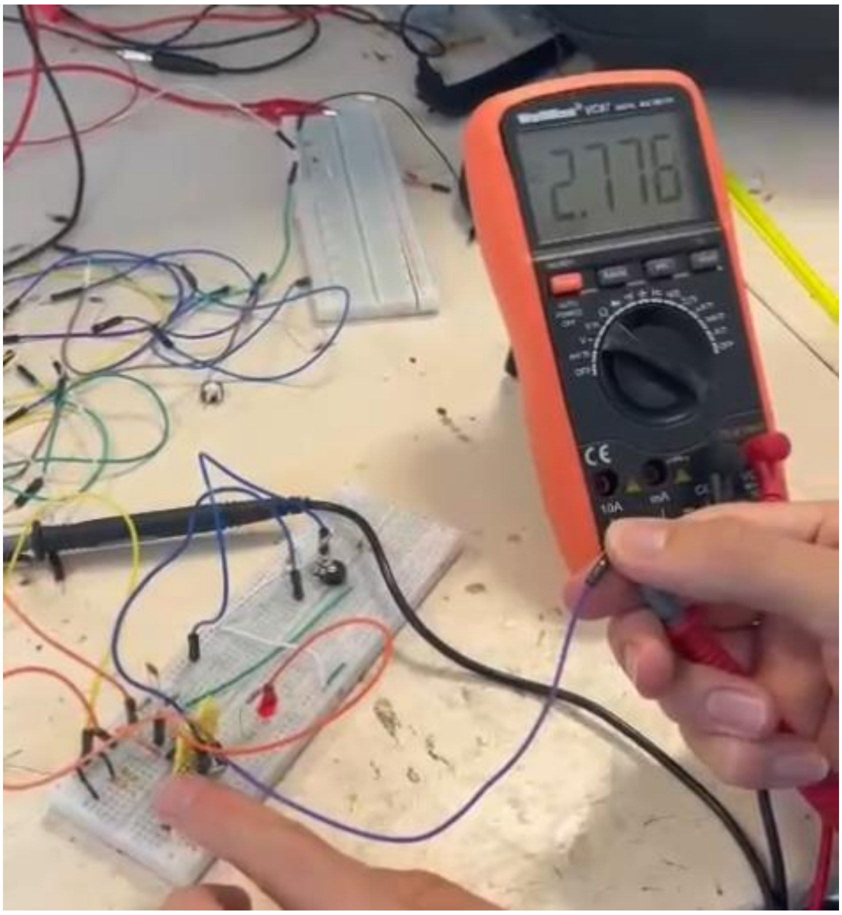

Figure 11: Voltage at 23°C (2.78V)

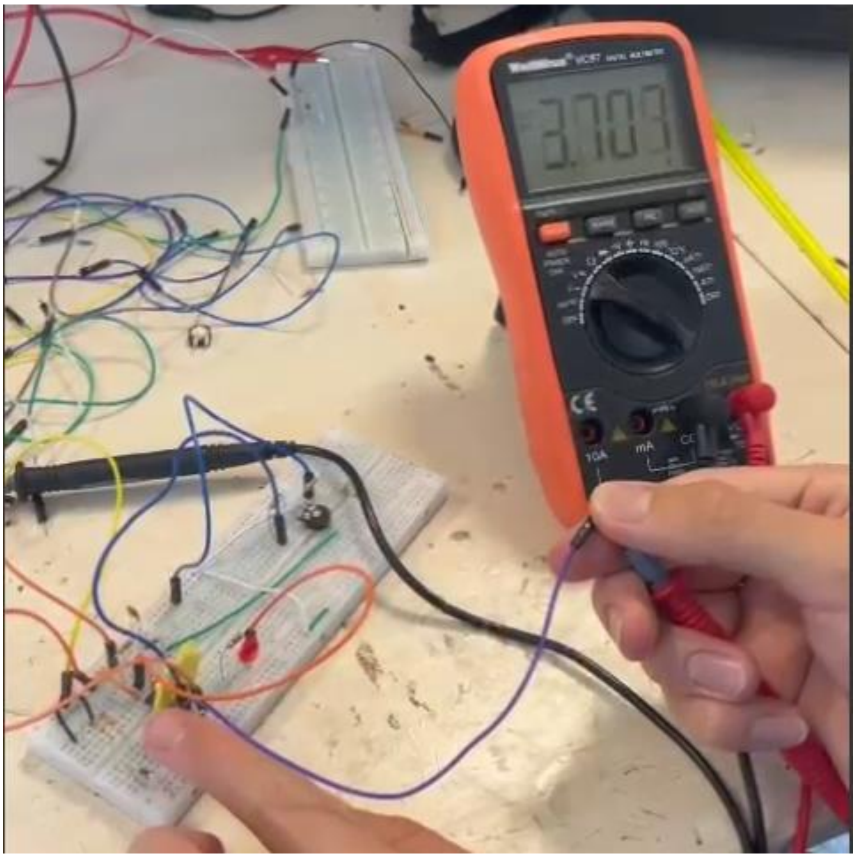

Figure 12: Voltage at 24°C (3.71V)

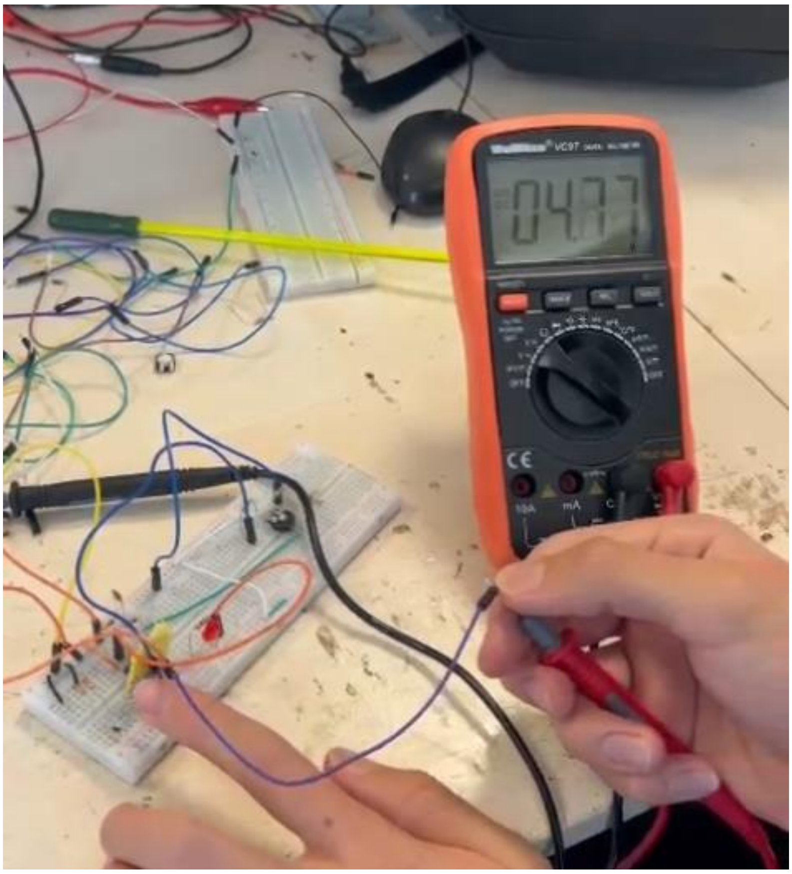

Figure 13: Voltage at 25°C (4.77V)

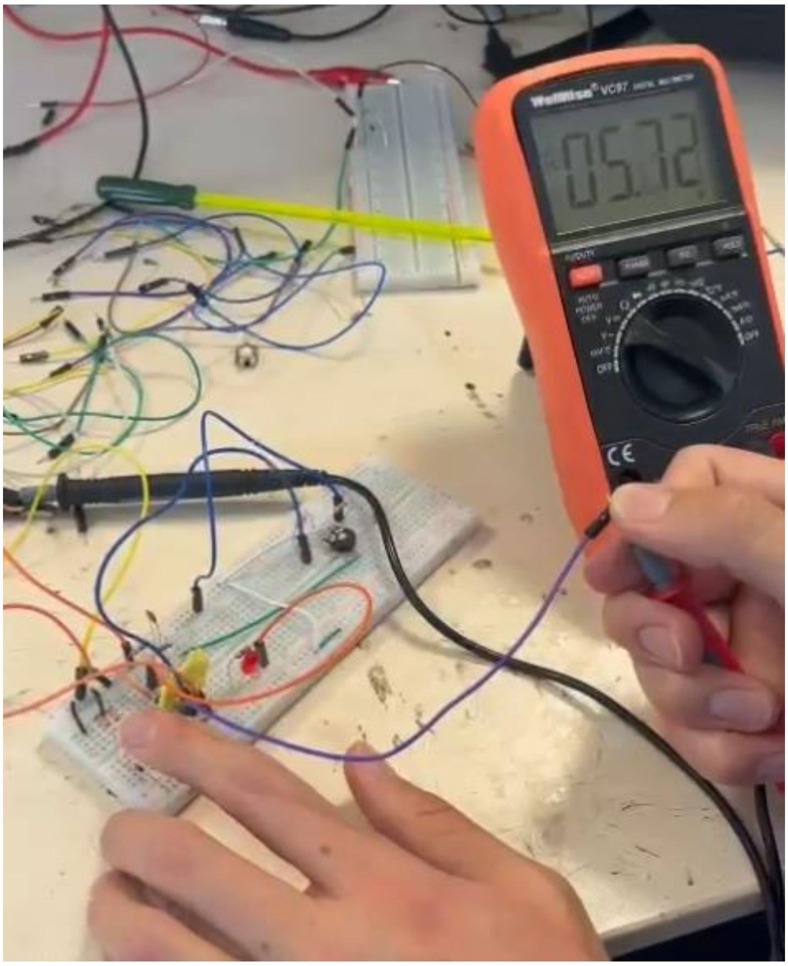

Figure 14: Voltage at 26°C (5.72V)

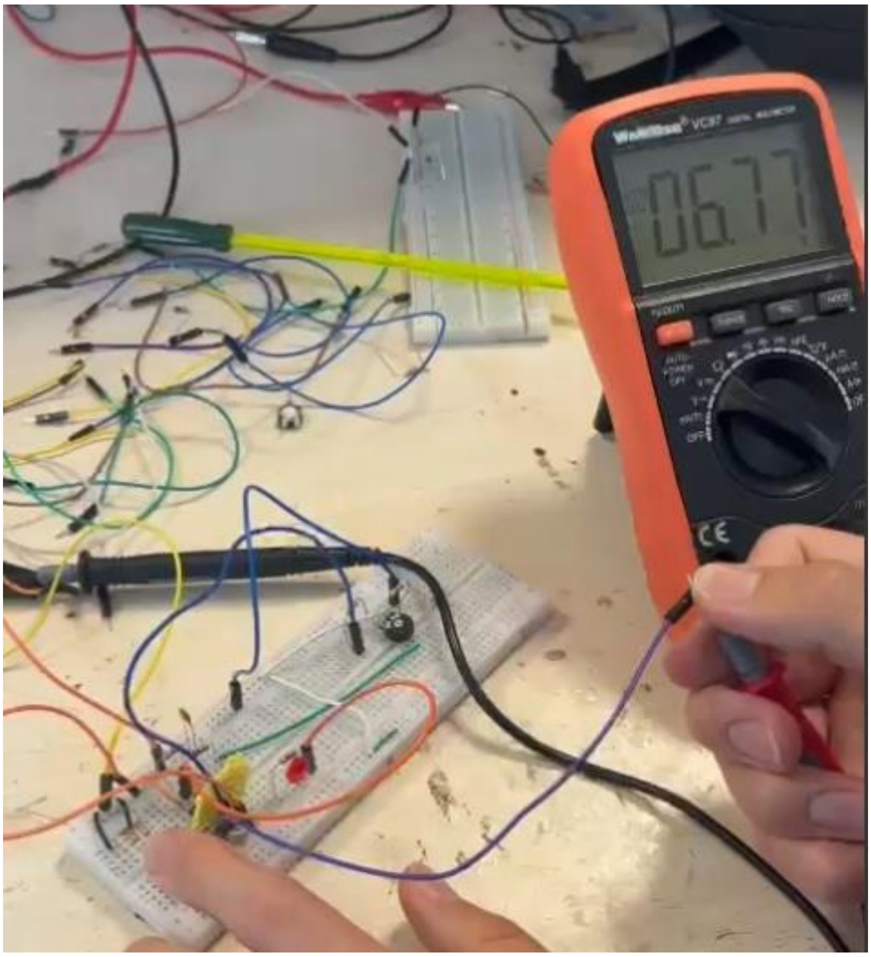

Figure 15: Voltage at 27°C (6.77V)

The results were as Table 2 and the simulated linear voltage increase of 1.078V was reflected on the hardware results.

	23°C	24°C	25°C	26°C	27°C	28°C
Voltage (V)	2.77	3.74	4.77	5.75	6.77	7.55
Increase (V)	0	0.97	1.08	0.98	1.05	0.98
Error Rate (%)	0	10.0	0.2	9.09	2.5	9.09

Table 2: Part B Results

Conclusion

This lab taught students about diode characterization and building differential temperature sensors in software and hardware implementations. There were similar results in both implementations and the found discrepancies may be due to temperature, internal resistances, multimeter or other lab equipment errors, mistakes in circuit element values. The lab was useful in terms of understanding the behavior of diodes and p-n junctions necessary for the EEE313 course.