Bilkent University

Electrical and Electronics Department

EE313-02 Term Project Final Report:

“Thermocouple Instrumentation Amplifier Controlled Heater”

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Introduction:

The main aim in this project is to design a single-supply thermocouple amplifier that generates a voltage proportional to the temperature at the output. A 250mW resistance between 220Ω and 390Ω is aimed to be kept at 39°C **above** the room temperature. The thermocouple is in contact with the heater resistance. A switch should turn the heating voltage on and off when the resistance temperature is below or above the desired temperature. Also, an LED provides visual feedback to show whether the heater voltage is on or off.

Design and Implementation Phase:

Here is the revised LTSpice circuit after the feedback I got **(Figure 1)**:

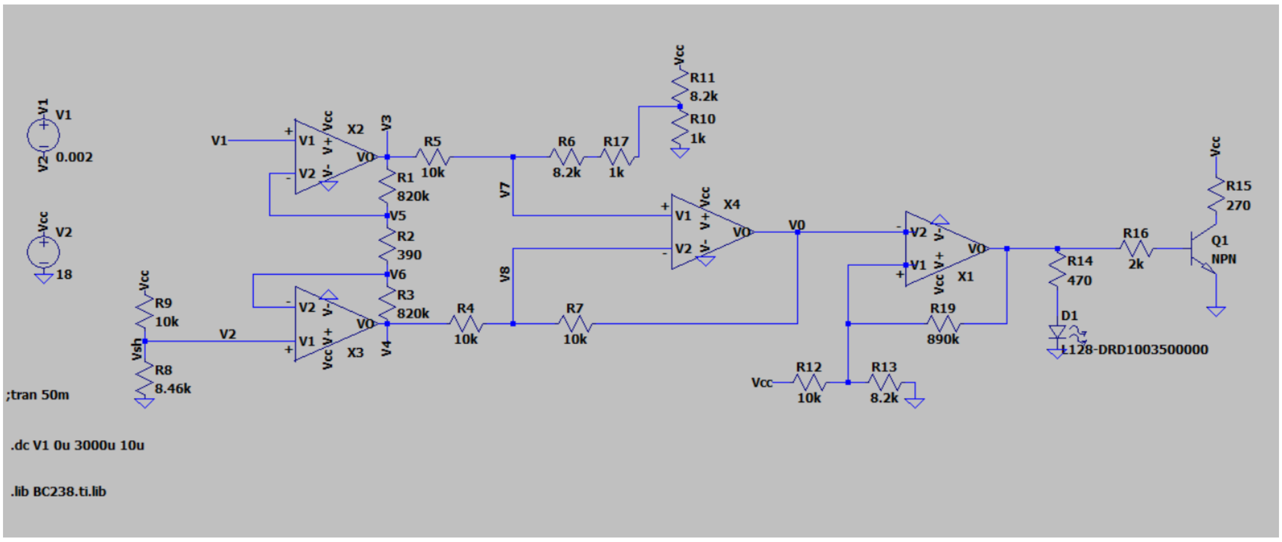
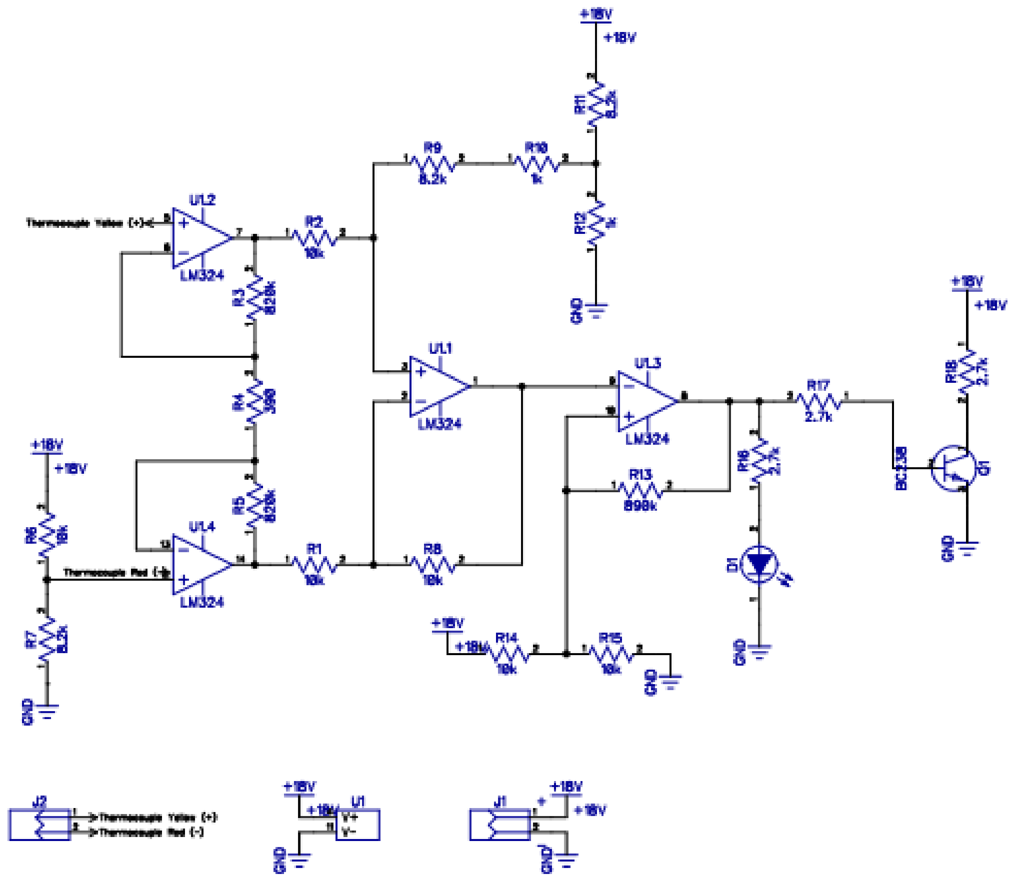


Figure 1: The Revised LTSpice Circuit

Then, I tested my hardware on a breadboard. After the design on the breadboard, I have created a DipTrace Schematic. Here you can see my DipTrace Schematic with a component list **(Figure 2)**:



#	RefDes	Value	Name	Quantity
1	D1		LED-3mm Round Red	1
2	J1		Power Connection	1
3	J2		Terminal (Screw)	1
4	Q1	BC238	BC238	1
5	R1, R2, R6, R8, R14, R15	10k	Resistor320	6
6	R3, R5	820k	Resistor320	2
7	R4	390	Resistor320	1
8	R7, R9, R11	8.2k	Resistor320	3
9	R10, R12	1k	Resistor320	2
10	R13	890k	Resistor320	1
11	R16, R17, R18	2.7k	Resistor320	3
12	U1	LM324	LM324	1
				23

Electronic Circuit Design
Term Project Schematic

Date: 25/11/2024 Fatih Mehmet Cetin

Figure 2: DipTrace Schematic with a Component List

After carefully designing the schematic, I then generated a PCB layout for my circuit. I used the 2-pin PCB connector to connect to the thermocouple and power supply. I used a one-layer board of size 55 mm × 55 mm. In fact, the project circuit was so simple that a second layer was not necessary.

Here you can see my PCB layout from both sides (top & bottom) **(Figures 3.1 & 3.2)**:

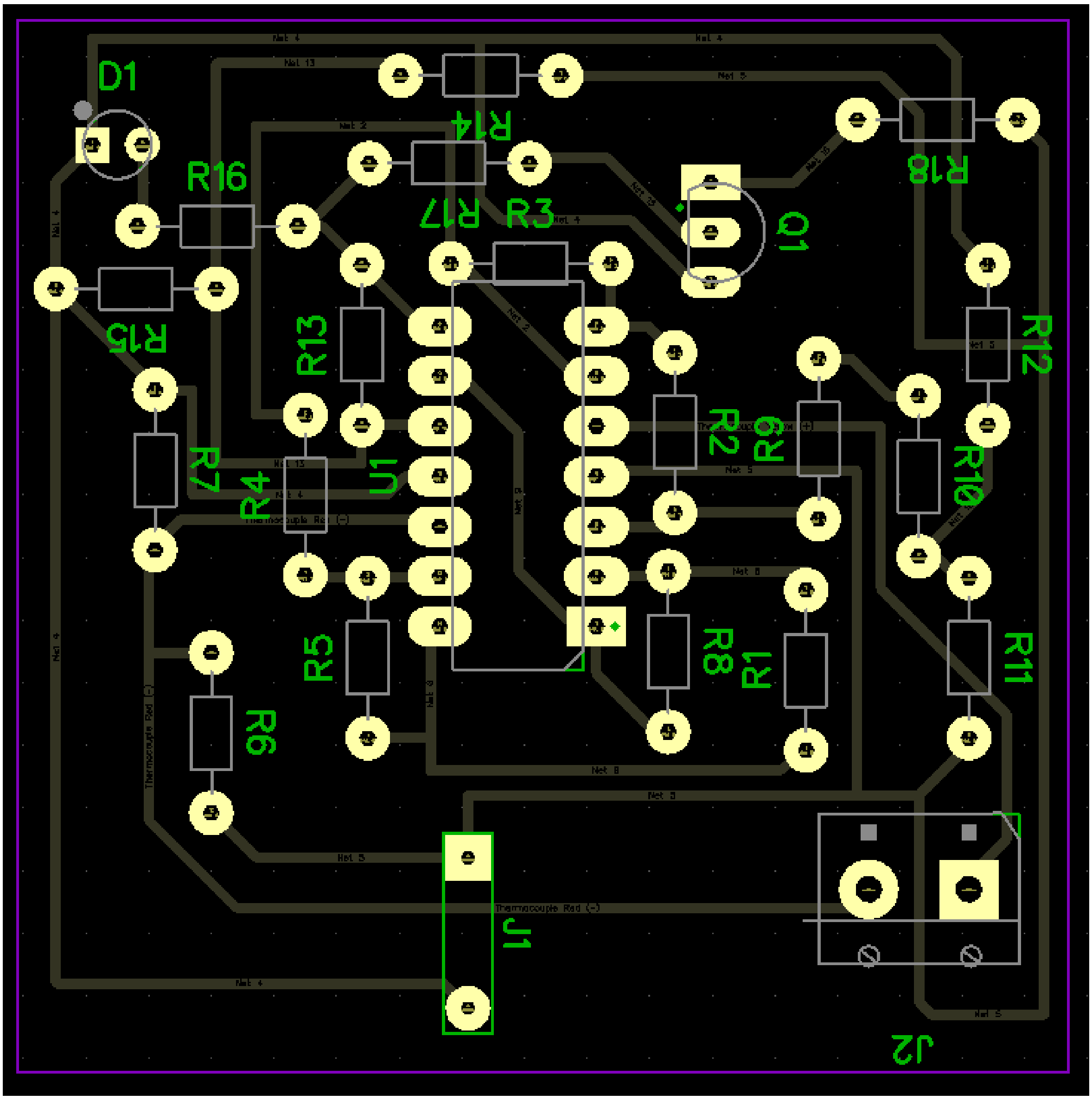


Figure 3.1: PCB Layout from the Top Face

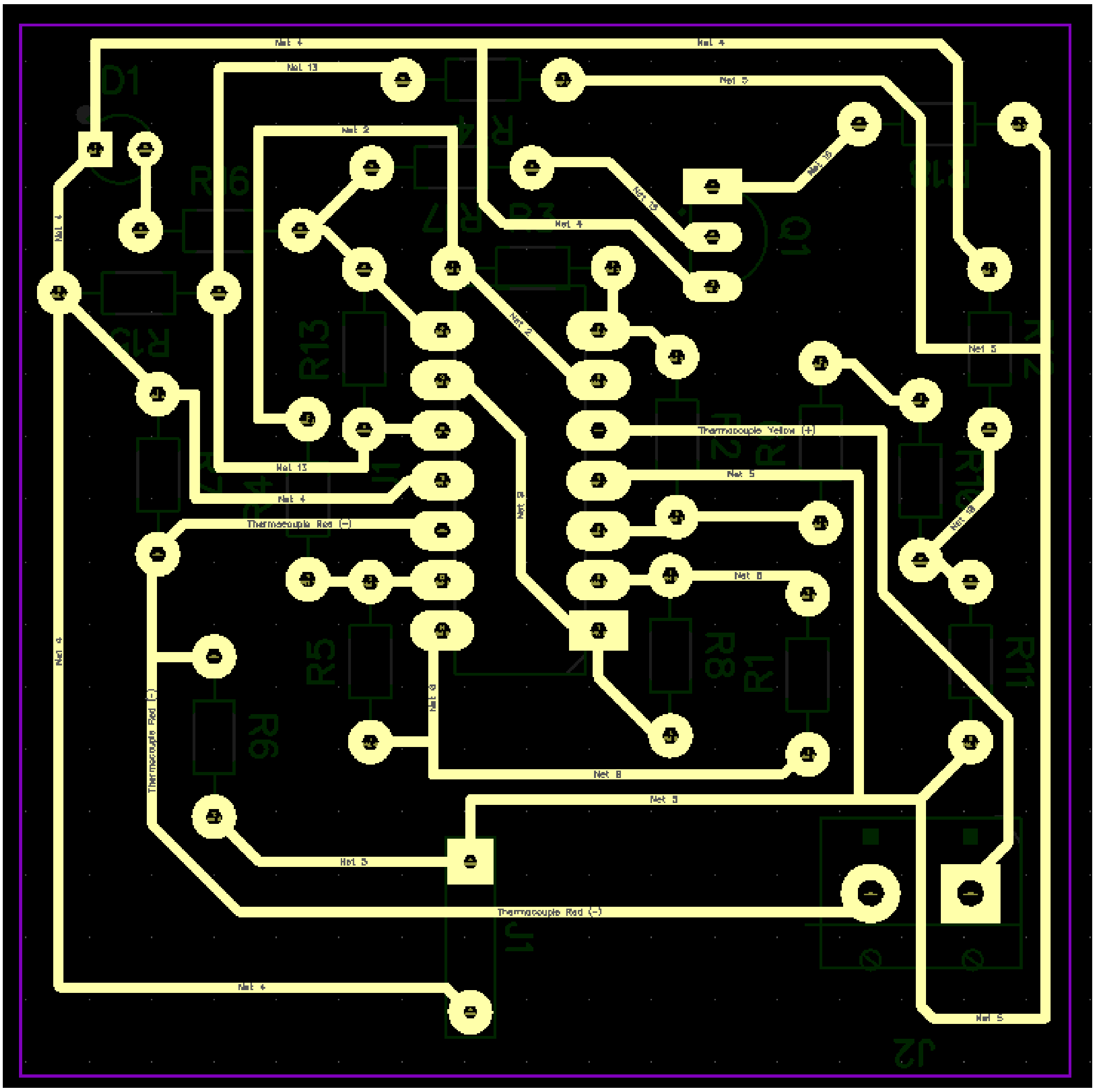


Figure 3.2: PCB Layout from the Bottom Face

Then, I submitted my gerber files to Prof. Abdullah Atalar. He took care of the fabrication of the PCB I designed. When I got my fabricated PCB back, I then started to work on it. I soldered the joints carefully such that no cold solder joints or short circuits occured. Since the fabricated PCB had no solder mask, I could easily short-circuit the nodes to each other, but this didn't happen, and the soldering process was relatively easy.

Here you can see the final circuit after the soldering was done **(Figures 4.1 & 4.2)**:

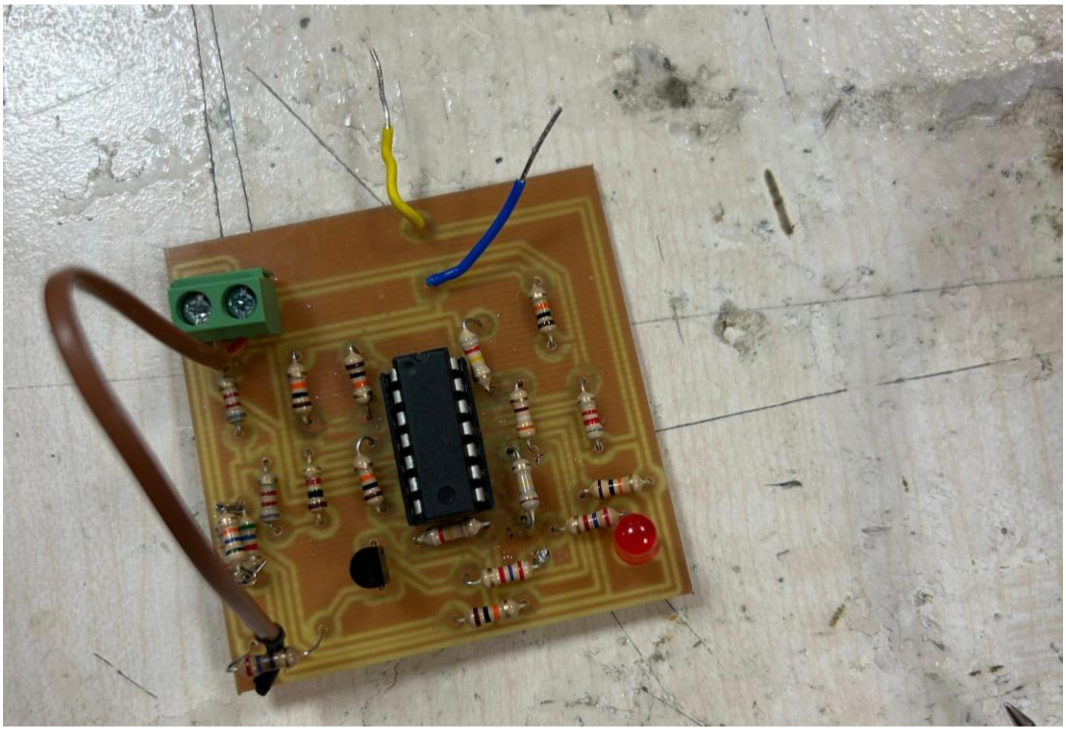


Figure 4.1: The Final Circuit Implemented on a PCB – Top View

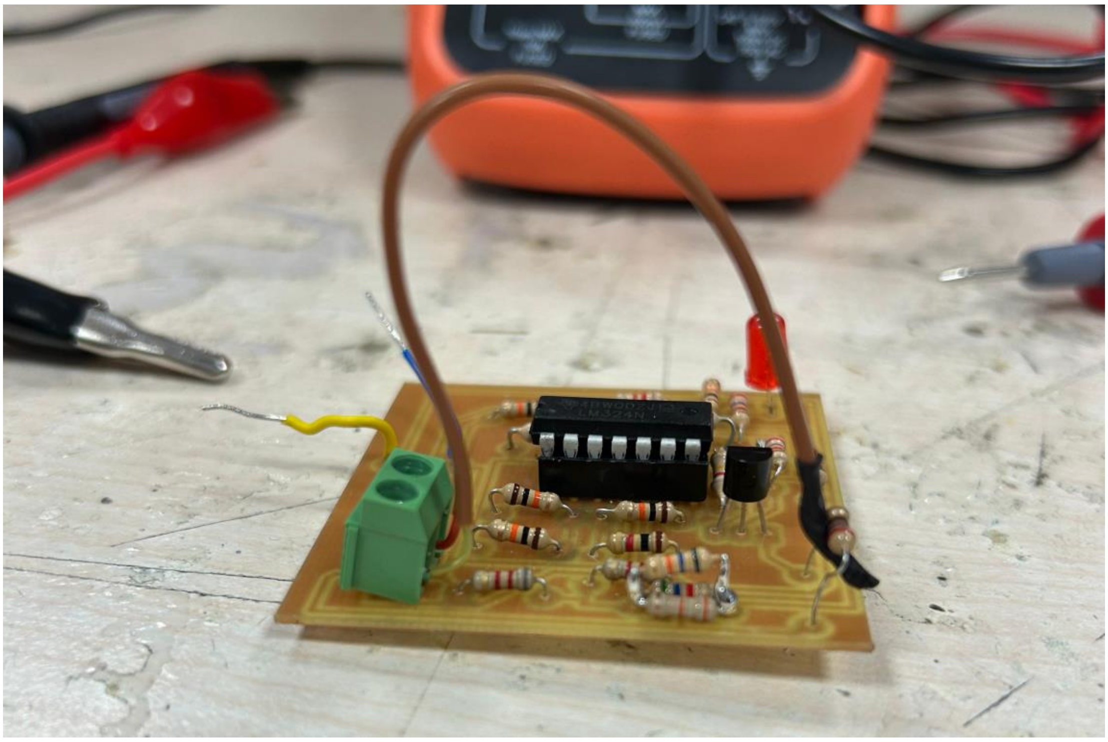


Figure 4.2: The Final Circuit Implemented on a PCB – Side View

Here you can see the 3 criteria that the circuit was to meet **(Figure 5)**:

Specifications:

1. The output voltage at 2V±0.5V when the thermocouple is at room temperature (thermocouple output voltage is zero).
2. The output voltage is 9V±1V when the temperature is at the required temperature (thermocouple voltage is $39.2 \times T_S$ μV)
3. LED turns ON when the heater resistance is being heated. It should turn OFF when the heater is OFF.

Figure 5: The Specifications of the Circuit

Now let's check each criterion one by one.

Criterion 1:

Here you can see the output voltage of the instrumentation amplifier being 2.4Volts when the thermocouple is at room temperature (i.e. when the power is first on) **(Figure 6)**:

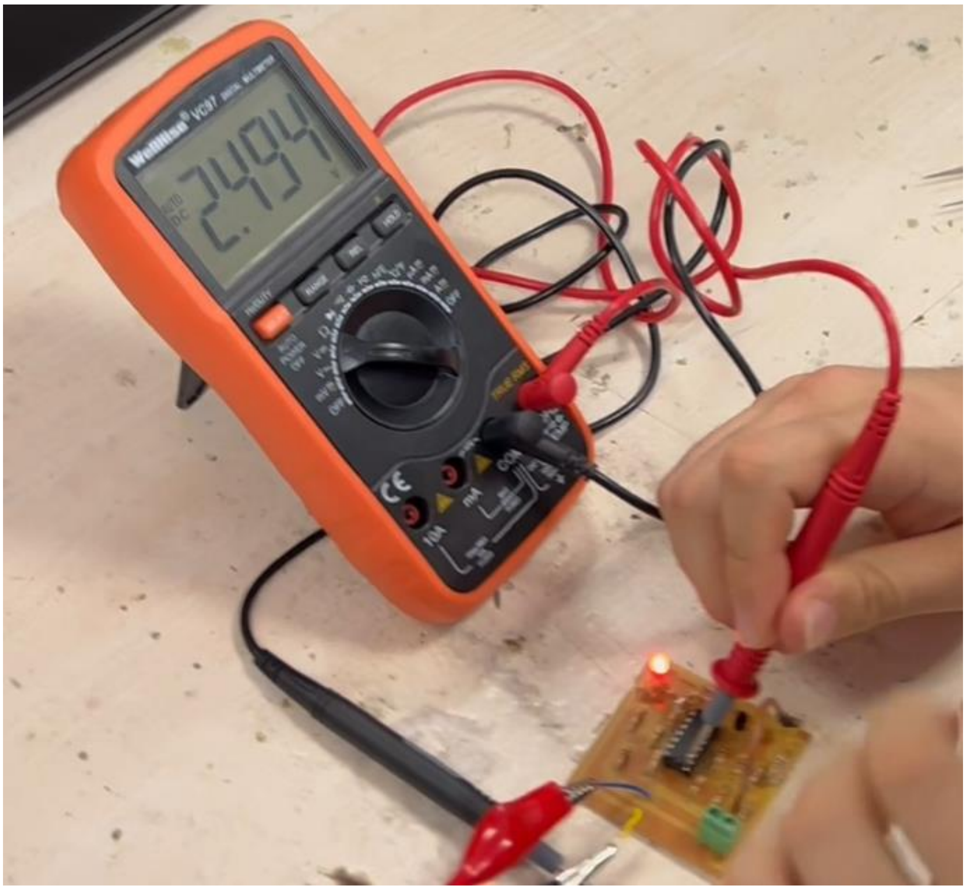


Figure 6: Output Voltage is 2.4Volts

Criterion 2:

Here you can see the output voltage at 8.96Volts when the resistor is at the desired temperature **(Figure 7)**:

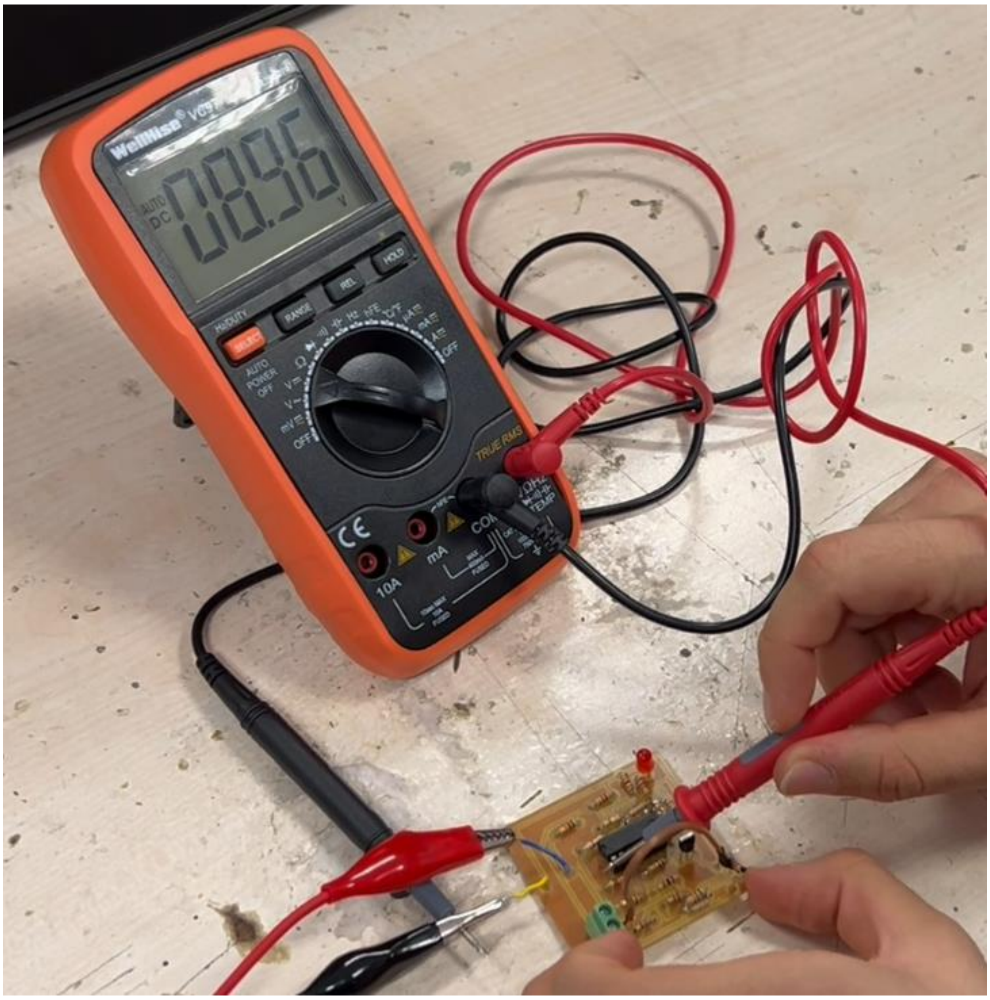


Figure 6: Output Voltage is 8.96Volts, LED is OFF

Criterion 3:

Here you can see the LED turning on at 8.93 Volts **(Figure 7)**. If you compare **Figure 7** with **Figure 6**, you can observe that LED turns on and off (i.e. the resistor being heated and not heated one after the other) as the output voltage goes up and down as well.

Figure 7: Output Voltage is 8.93Volts, LED is ON

The project was now complete, and it was working well in the limits. Here you can see myself happily and proudly showing my design to the camera right after finishing the project. **(Figure 8)**

Figure 8: Me Holding the Circuit Proudly and Happily

Conclusion:

In conclusion, the project was a total success. All 3 conditions were met on the implementation phase. The heater resistance had power on it when the heater voltage was on. I believe this project was very helpful in understanding how an idea turns into a product. Designing and fabricating something from zero is a really important skill that each engineer should have.

I also believe this project will help me a lot in my career and CV.