BILKENT UNIVERSITY

ELECTRICAL AND ELECTRONICS ENGINEERING DEPARTMENT

EE313 PROJECT

Thermocouple Instrumentation Amplifier Controlled Heater

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I affirm that I have not given or received any unauthorized help on this report and that this work is my own.

Introduction:

-The purpose of this lab is to design and simulate a thermocouple-controlled heating system with using LTSpice environment.

-A heater is aimed to be kept at Ts=30+mod(BilkentID,40) °C above the room temperature. Since my number is 22203554, Ts=64 in my case.[1]

-The 18V voltage source feeds the heater resistance through an electronic switch (either ON or OFF). The switch should turn ON when the temperature of the heater resistance is lower than the aimed temperature and turn OFF when it is above (an ON/OFF controller). [1]

-For visual feedback, an LED should turn ON when the heater voltage is turned ON. The switch (a BJT) should be driven by a comparator having a small amount of hysteresis (0.1V) so that switching occurs abruptly.[1]

-At 1°C above the room temperature, the voltage source is set to 39.2µV. [1] At Ts, the voltage source is 39.2×Ts µV. In my case, 39.2*Ts µV= 2.5088mV.

Offset Values of the OPAMPs:

1	R1	110			
2	R2	1,00E+05			
3	R3	1,00E+05			
4				S1	S2
5	vout1	-1,92		ON	ON
6	vout2	-0,459		ON	OFF
7	vout3	-3,435		OFF	ON
8	vout4	-1,999		OFF	OFF
9					
10	VIO	2,11E-03	2,11	mV	
11	IB2	1,61E-08	16,07	nA	
12	IB1	1,67E-08	16,67	nA	
13	IIO	8,69E-10	0,87	nA	
14	IB1-IB2	5,94E-10	0,59	Na	
15					

Figure 1: Offset Values for OPAMP 1

1	R1	110			
2	R2	1,00E+05			
3	R3	1,00E+05			
4				S1	S2
5	vout1	0,333		ON	ON
6	vout2	-0,93		ON	OFF
7	vout3	-1,921		OFF	ON
8	vout4	-0,36		OFF	OFF
9					
10	VIO	-3,66E-04	-0,37	mV	
11	IB2	-1,39E-08	-13,89	nA	
12	IB1	2,48E-08	24,79	nA	
13	IIO	7,62E-09	7,62	nA	
14	IB1-IB2	3,87E-08	38,69	Na	

Figure 2: Offset Values of OPAMP 2

1	R1	110			
2	R2	1,00E+05			
3	R3	1,00E+05			
4				S1	S2
5	vout1	-1,7		ON	ON
6	vout2	-4,7		ON	OFF
7	vout3	-3,27		OFF	ON
8	vout4	-1,8		OFF	OFF
9					
10	VIO	1,87E-03	1,87	mV	
11	IB2	-3,30E-08	-33,00	nA	
12	IB1	1,73E-08	17,27	nA	
13	IIO	1,10E-09	1,10	nA	
14	IB1-IB2	5,03E-08	50,27	Na	
15					

Figure 3: Offset Values of OPAMP 3

R1	110			
R2	1,00E+05			
R3	1,00E+05			
			S1	S2
vout1	-1,45		ON	ON
vout2	-0,05		ON	OFF
vout3	-3,126		OFF	ON
vout4	-1,67		OFF	OFF
VIO	1,60E-03	1,60	mV	
IB2	1,54E-08	15,40	nA	
IB1	1,84E-08	18,44	nA	
IIO	2,42E-09	2,42	nA	
IB1-IB2	3,04E-09	3,04	Na	

Figure 4: Offset Values of OPAMP 4

Specification 1 for Design Phase:

The output voltage at 2V±0.5V when the thermocouple is at room temperature (thermocouple output voltage is zero).

This means that when the thermocouple voltage is 0V. The desired output voltage is between 1.5V and 2.5V.

Figure 5 shows the corresponding circuit design that meets all the specifications. Figure 6 and Figure 7 shows the LTSpice simulation results.

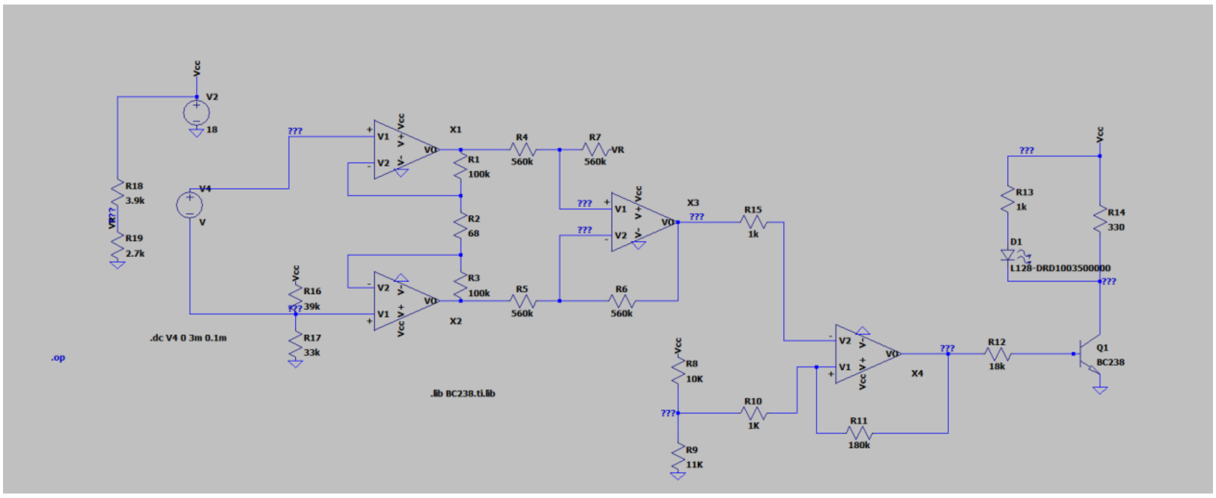

Figure 5: Corresponding Circuit

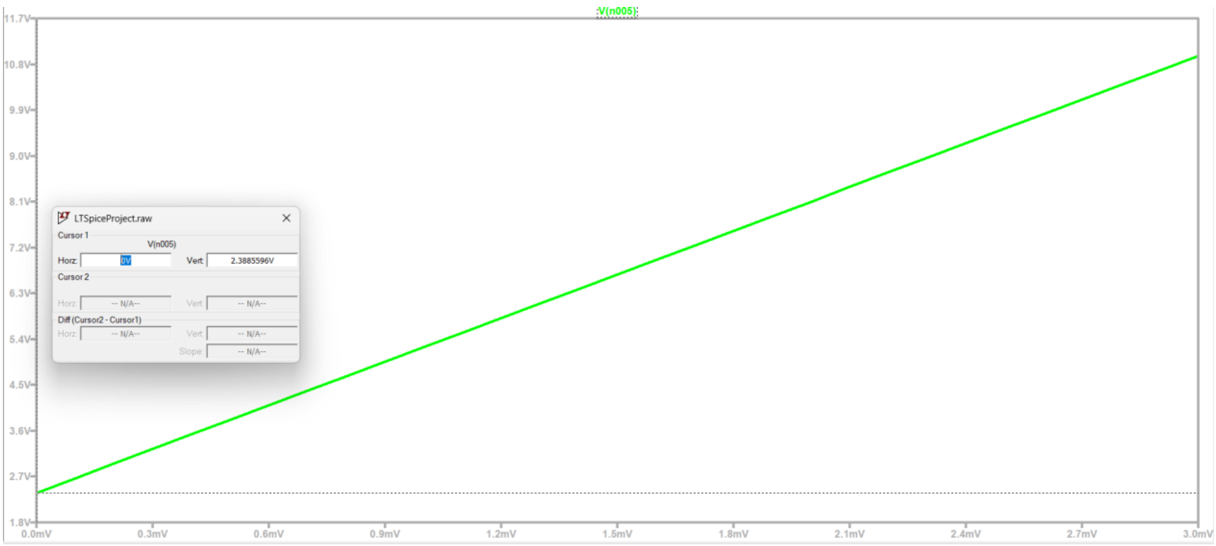

Figure 6: Output Voltage Plot when the Thermocouple Voltage Goes from 0 to 3mV

As it can be seen from the Figure 6, when the thermocouple voltage is 0V, the output voltage is 2.39V. Since it is in the boundary, the Specification 1 is satisfied. It is arranged greater than 2V on purpose, foreseeing there might be some voltage drop on the hardware circuit. The zoomed version of the analysis result is given in the Figure 7.

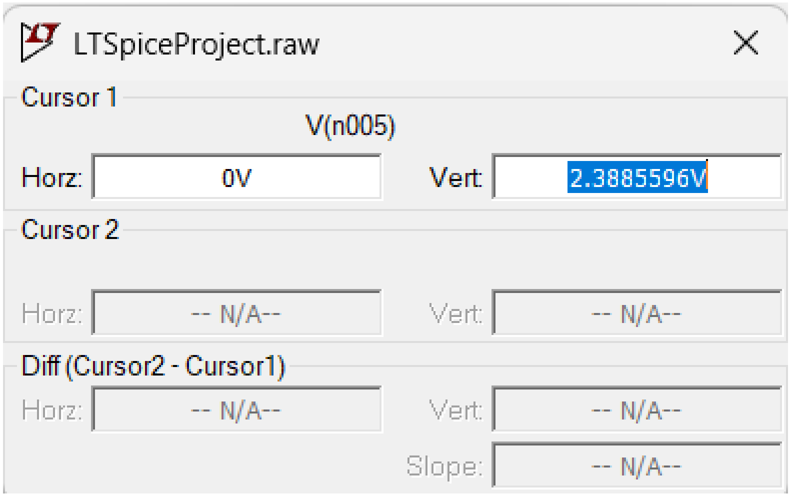

Figure 7: Zoomed Version of the Analysis Result

Specification 2 for Design Phase:

The output voltage is 9V±1V when the temperature is at the required temperature (thermocouple voltage is 39.2×TS μV).

This means that when the thermocouple voltage is 2.5088mV, the desired output voltage is between 8V and 10V.

Figure 8 and Figure 9 shows the LTSpice analysis results.

Figure 8: Output Voltage Plot when the Thermocouple Voltage Goes from 0 to 3mV

As it can be seen from Figure 8, when the thermocouple voltage is 2.5089mV, the output voltage is 9.56V. Since it is in the boundary, the Specification 2 is satisfied. Also, a zoomed version of the analysis result is given in the Figure 9.

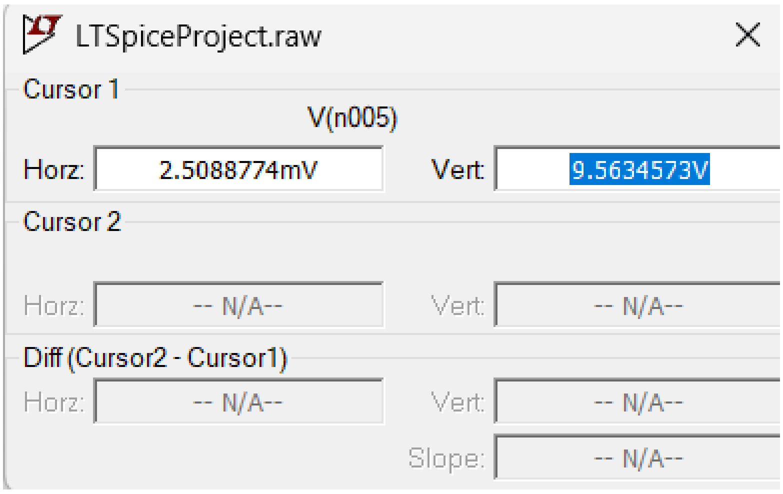

Figure 9: Zoomed Version of the Analysis Result

Specification 3 for Design Phase:

LED turns ON when the heater resistance is being heated. It should turn OFF when the heater is OFF.

Figure 10 and Figure 11 show that when the heater resistance is being heated, the LED is ON, until it reaches the threshold which is nearly 2.5mV. When it reaches upon the threshold, the current going on the led decreases drastically and the LED turns OFF. Also Figure 12 shows the relation between the current going on the LED and the heater resistance. Heater resistor is heated by a 54 mA current until the thermocouple voltage is at around 2.5088m. And at that time LED is ON since there is a 16mA current going on the LED. When the heater is OFF (there is no current on the heater), the LED also turns OFF instantly. And it remains OFF when the heater is OFF. Overall, Specification 3 is satisfied, since the threshold is very close to the 2.5088mV.

In the Figure 12, it's also evident that the heater turns OFF within a 100 µV range, which provides a very narrow hysteresis (smaller than the desired 0.1 V).

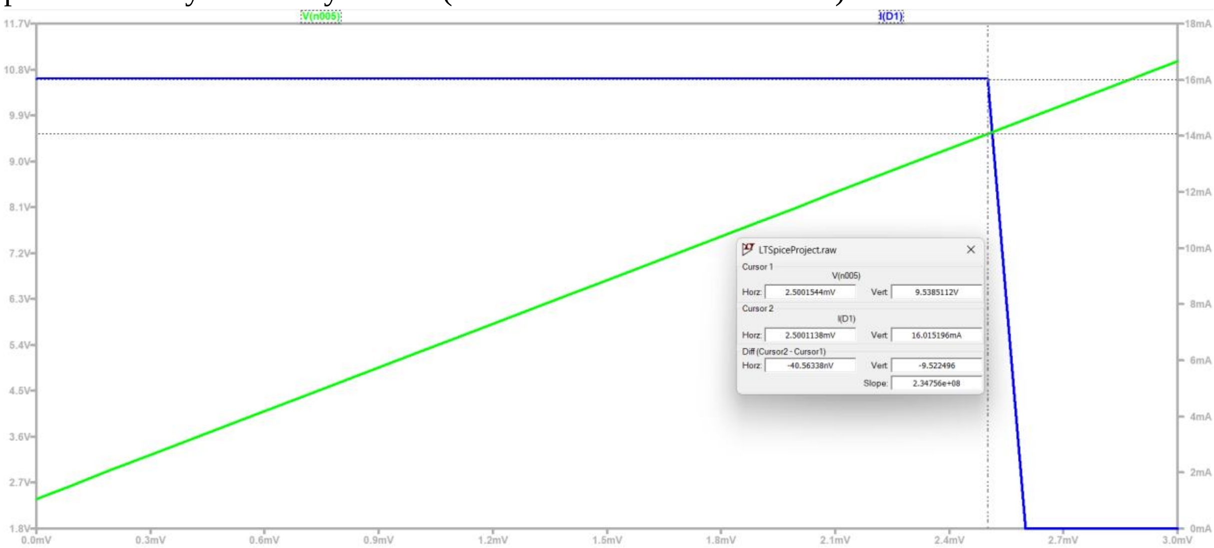

Figure 10: The Plot of the Output Voltage and the Current Going on the LED

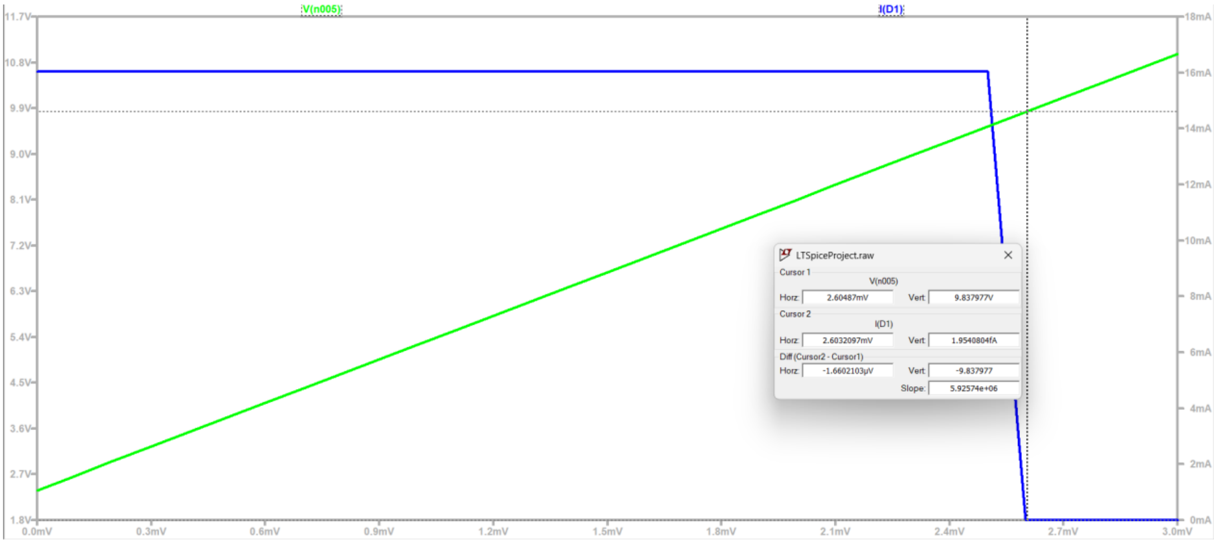

Figure 11: The Plot of the Output Voltage and the Current Going on the LED

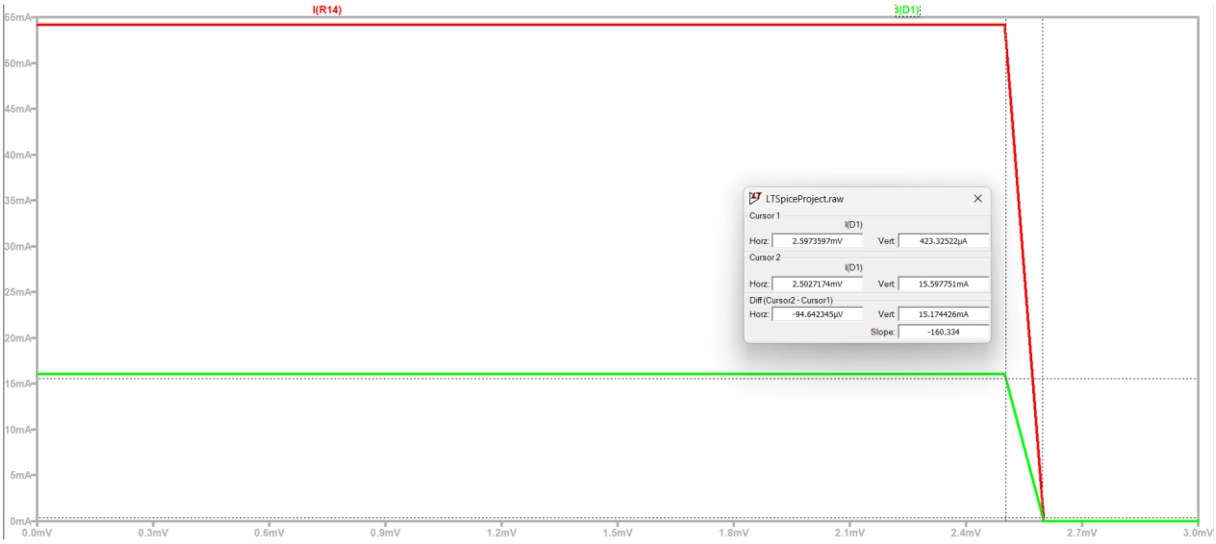

Figure 12: The Plot of the Heater Resistance Current and the LED Current

Conclusion:

In this design phase, I successfully developed a thermocouple instrumentation amplifier circuit in LTSpice to control a heater's temperature using an ON/OFF feedback system, driven by a comparator with hysteresis.

References:

[1]“2024-2025 Fall: Log in to the site,” *Bilkent.edu.tr*, 2024. https://moodle.bilkent.edu.tr/2024-2025-fall/pluginfile.php/96284/mod_resource/content/5/project.pdf (accessed Nov. 14, 2024).