Emir Arda Bayer
22201832

Introduction

For this lab, two input OPAMPs input offset voltages and input bias currents were evaluated to design a thermocouple instrumentation amplifier controlled heater. A comparator was added to turn on an LED when the heat is below a certain selected temperature (62℃).

Methodology, Design and Results

The following circuit was designed to satisfy three requirements.

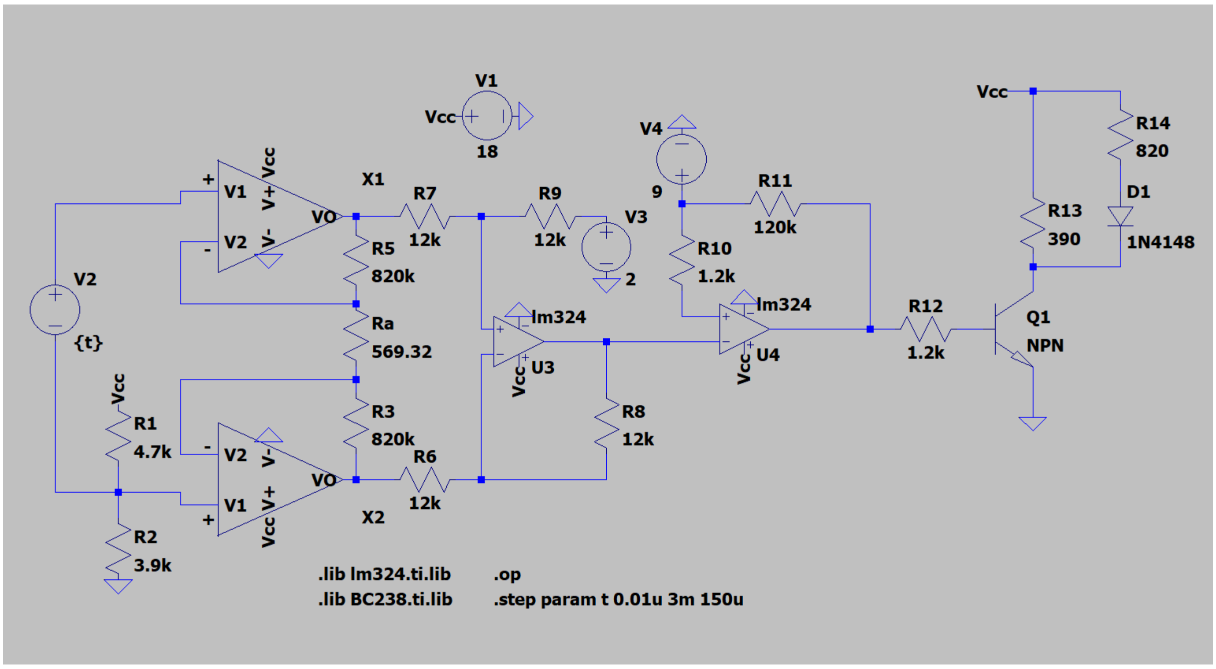


Figure 1: Designed Circuit on LTSpice

The offset voltages and input bias currents of LM324 OPAMP was measured in the lab by investigating the OPAMP output voltages on the following circuit with two switches.

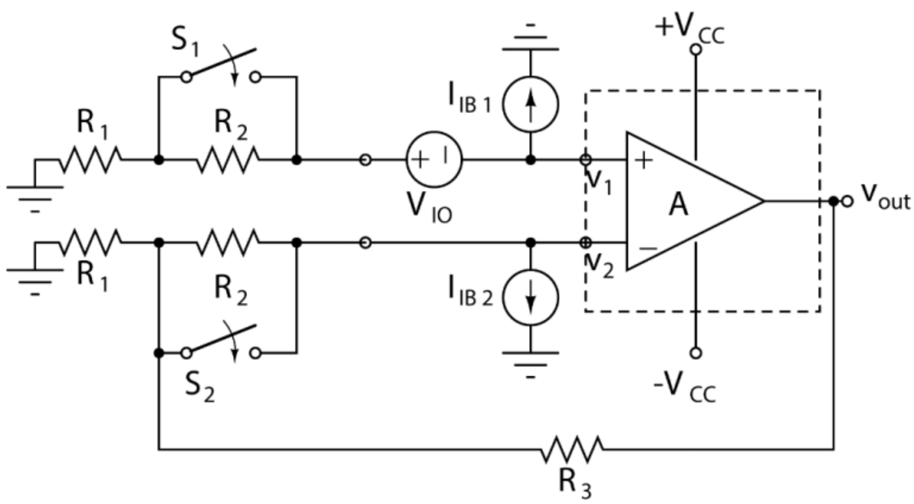


Figure 2: Test Circuit to Investigate OPAMP Output Voltage

Emir Arda Bayer
22201832

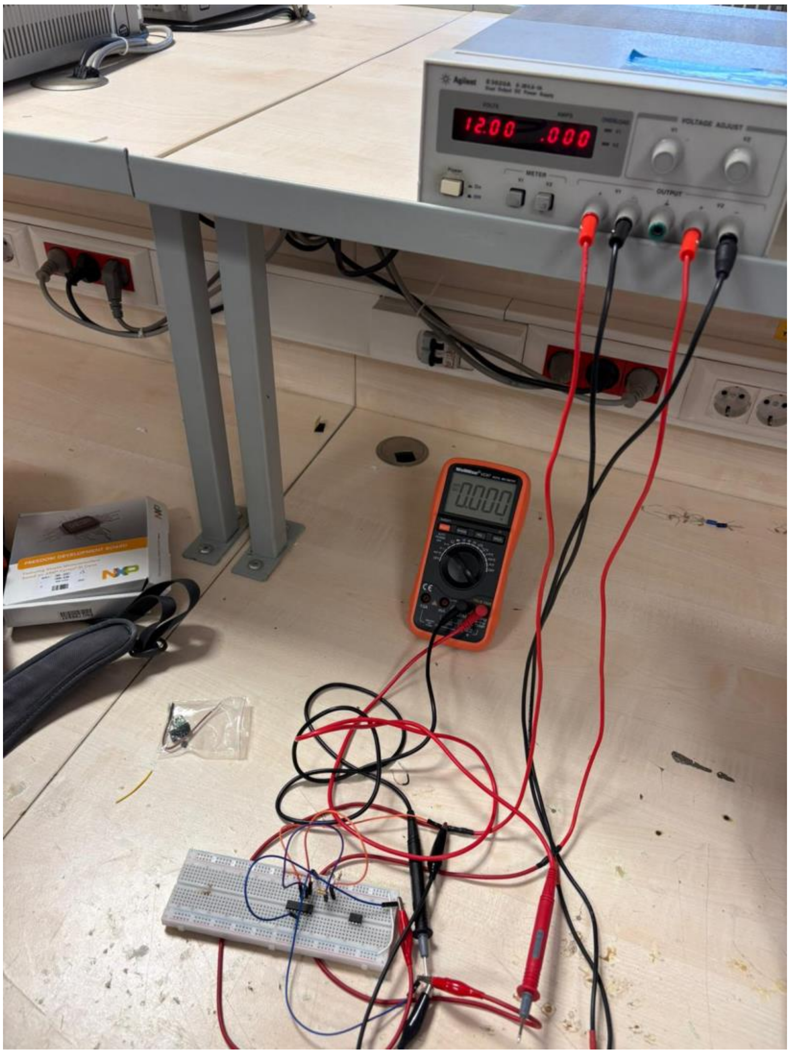


Figure 3: Setup in Hardware Lab

The setup in Fig. 3 was designed to evaluate the behavior of LM324's 1st and 4th OPAMPs outputs when S1 and S2 are turned ON and OFF in every combination. To obtain the switches, simply jumper cables were placed to shortcut R2 resistors. The following values were obtained in the provided Excel file when placing the measurements (Excel demonstrates written values as integers when not clicked, calculations are made with values upto 3 decimals).

	A	B	C	D	E
1	R1	100			
2	R2	1,00E+05			
3	R3	1,00E+05			
4				S1	S2
5	vout1	-1,238		ON	ON
6	vout2	1		ON	OFF
7	vout3	-4		OFF	ON
8	vout4	-1		OFF	OFF
9					
10	VIO	1,24E-03	1,24	mV	
11	IB2	2,68E-08	26,84	nA	
12	IB1	2,67E-08	26,70	nA	
13	IIO	-4,00E-11	-0,04	nA	
14	IB1-IB2	-1,40E-10	-0,14	nA	

Figure 4: Findings for OPAMP1

	A	B	C	D	E
1	R1	100			
2	R2	1,00E+05			
3	R3	1,00E+05			
4				S1	S2
5	vout1	-2		ON	ON
6	vout2	0		ON	OFF
7	vout3	1		OFF	ON
8	vout4	-2		OFF	OFF
9					
10	VIO	1,69E-03	1,69	mV	
11	IB2	1,25E-08	12,46	nA	
12	IB1	-2,61E-08	-26,11	nA	
13	IIO	1,04E-09	1,04	nA	
14	IB1-IB2	-3,86E-08	-38,57	nA	

Figure 5: Findings for OPAMP2

Figure 6: OPAMP1 OFF/OFF

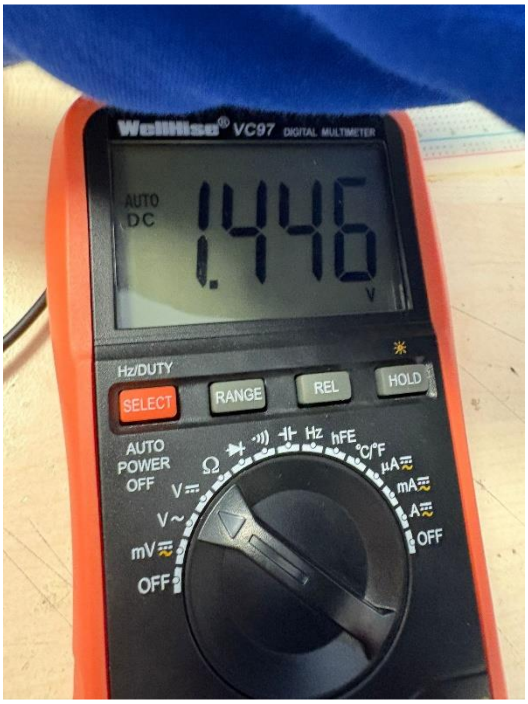


Figure 7: OPAMP2 OFF/ON

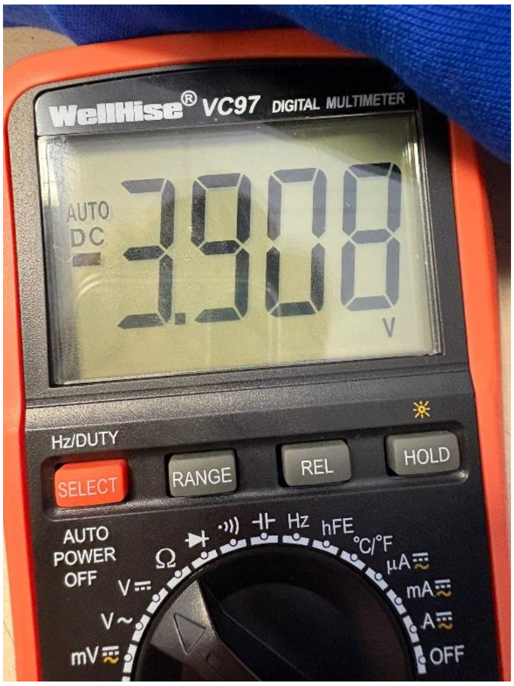


Figure 8: OPAMP1 ON/OFF

Figure 9: OPAMP1 ON/ON

Figure 10: OPAMP2 OFF/OFF

Figure 11: OPAMP2 OFF/ON

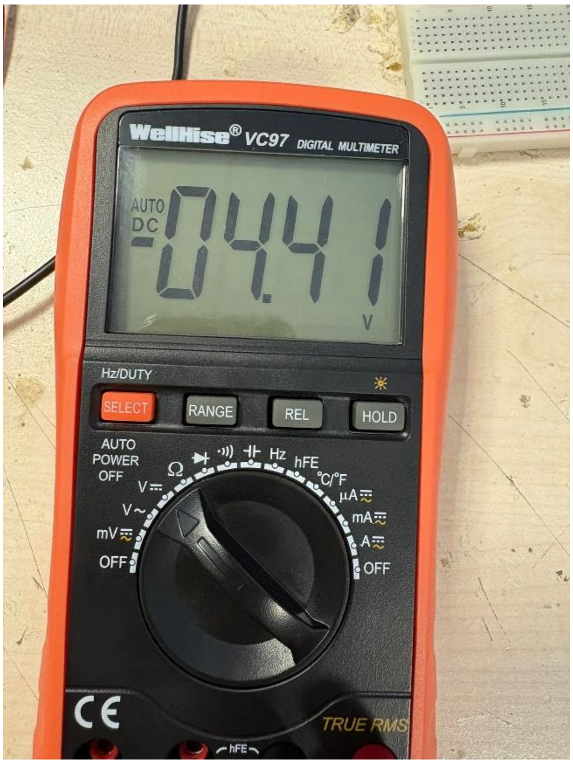


Figure 12: OPAMP2 ON/OFF

Figure 13: OPAMP2 ON/ON

Then, using these found offset and bias values, the circuit in Fig. 1 was obtained. The following three requirements were met.

REQUIREMENT 1

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

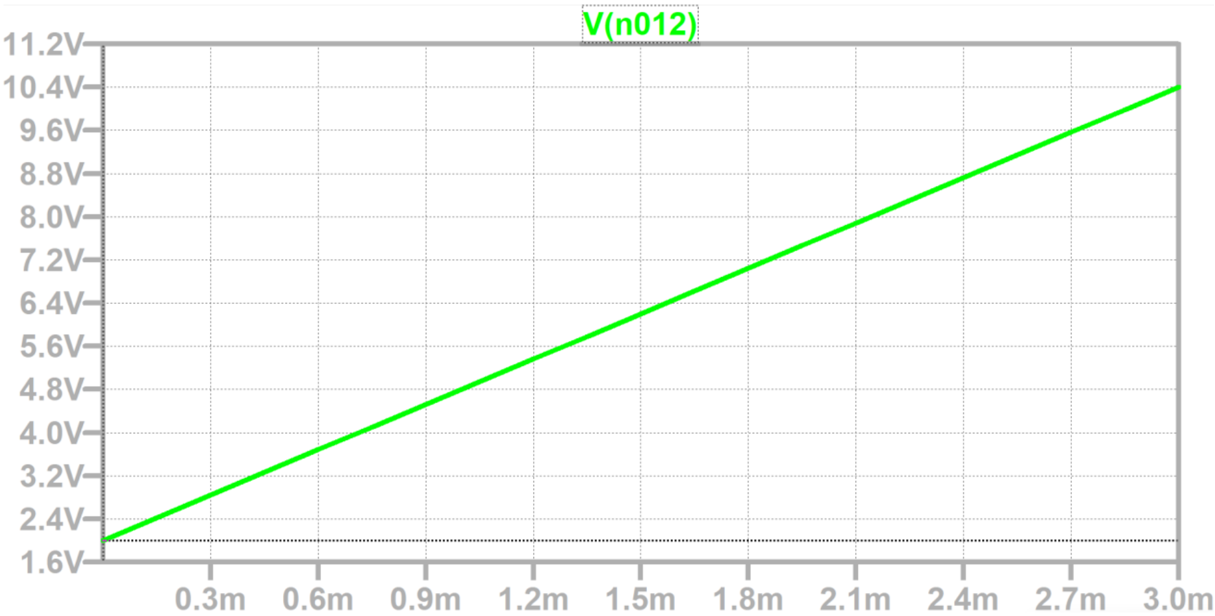


Figure 14: Output Voltage at 2V at Room Temperature (0mV x-axis)

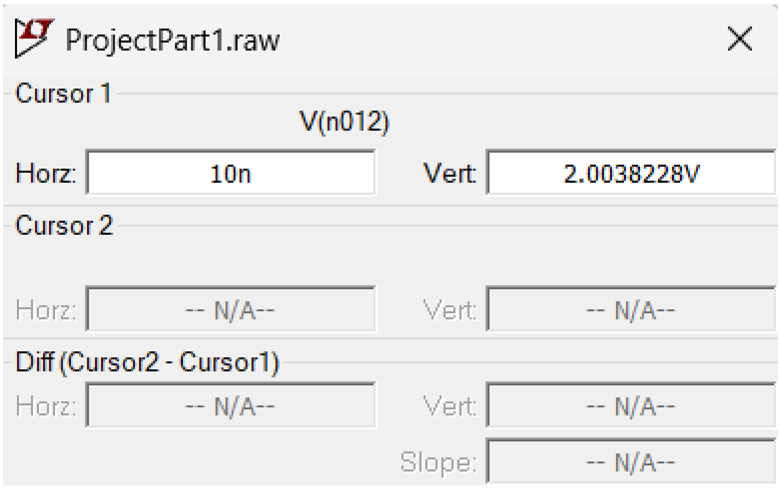


Figure 15: Cursor at 2.0038V

When input = 0V, output = 2V.

REQUIREMENT 2

The output voltage is 9V±1V when the temperature is at the required temperature (thermocouple voltage is $39.2 \times T_S$ μV)

(Required Temperature = 62°C, meaning Vin = 2.430 mV, Av=(9-2)/Vin=2881, R/Ra=2881/2=1440.5)

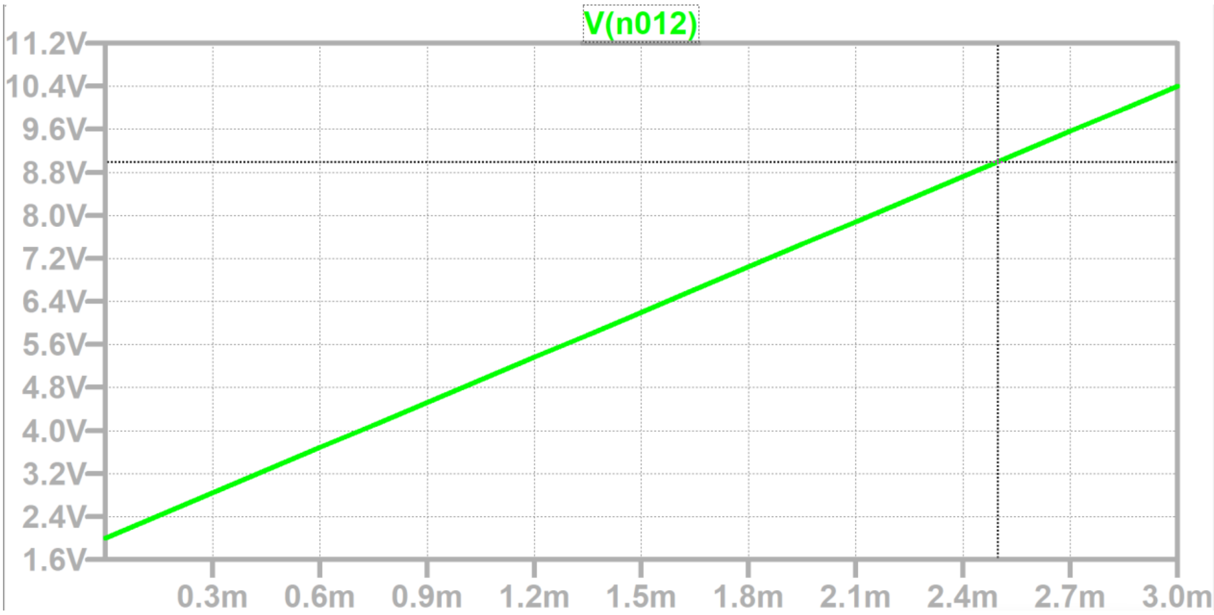


Figure 16: Output 9V when 2.490mV Input

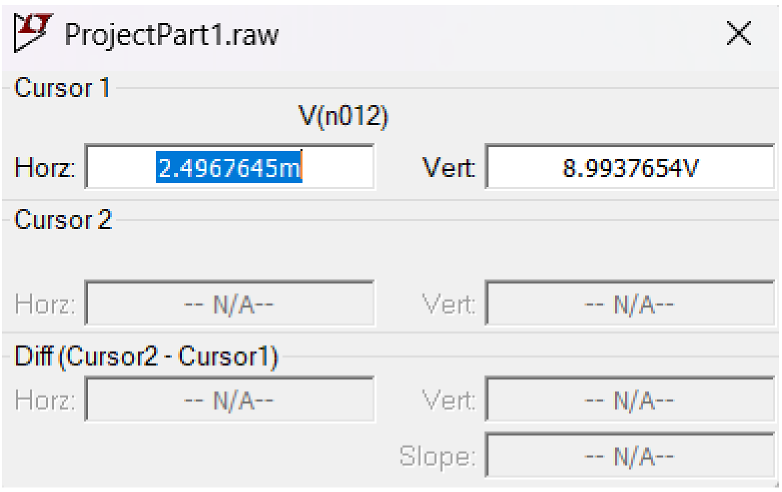


Figure 17: Cursor at 2.4968mV Input

Output 9V when input is 2.4968mV.

REQUIREMENT 3

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

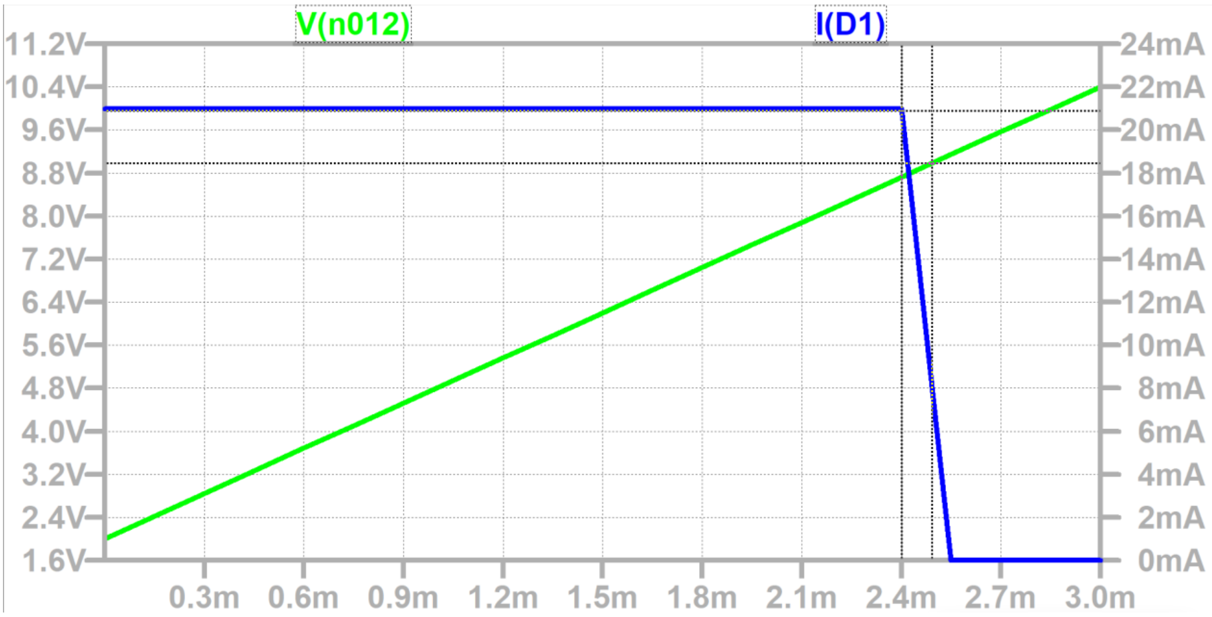


Figure 18: LED turns OFF at 9V OPAMP Output

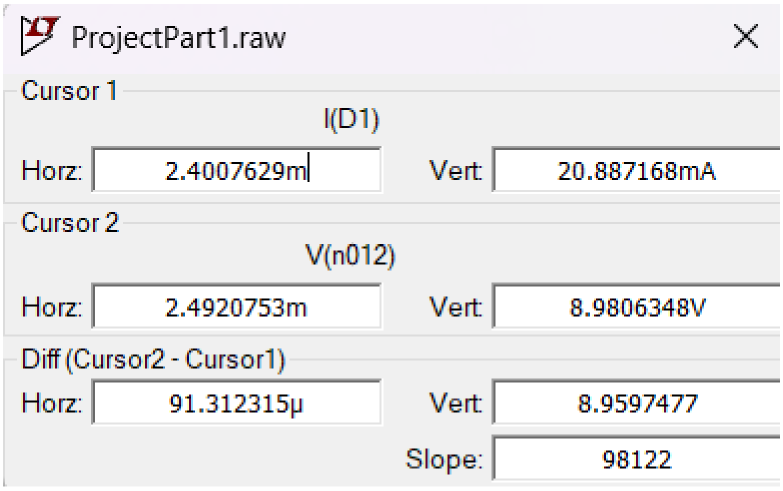


Figure 19: LED turns OFF at 2.40076 mV Input, with 91 microvolt Difference From 9V Output Point

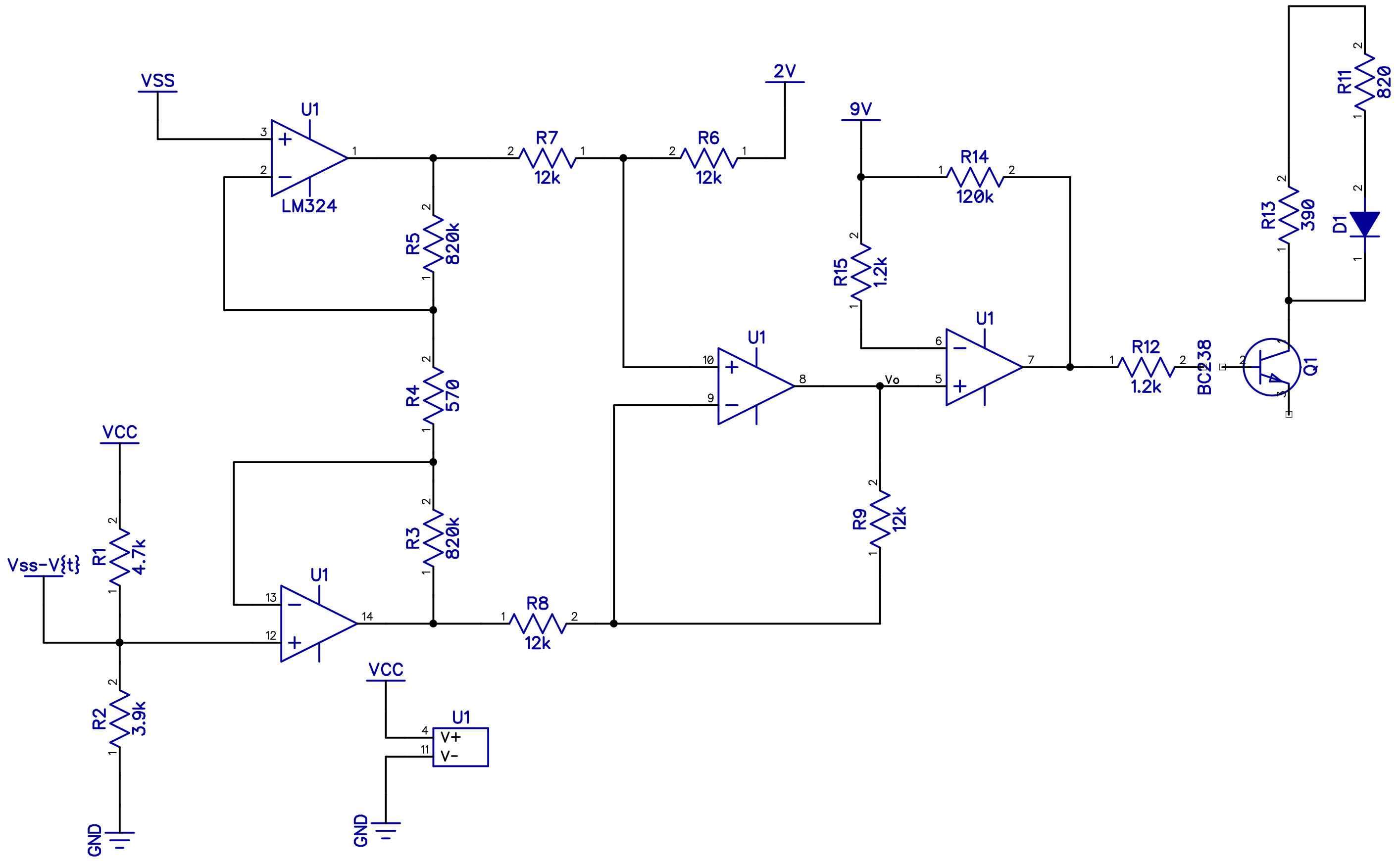
LED turns off at 2.40076 mV, with difference 91 microvolt from 9V Output input voltage.

Conclusion

ALL THREE REQUIREMENTS ARE SATISFIED.

The following is the Diptrace Schematic for the design.

RevNo	Revision note	Date 14.11.2024	Signature	Checked



D1		1N4148	1
Q1	BC238	BC238	1
R1	4.7k	Resistor100	1
R2	3.9k	Resistor100	1
R3, R5	820k	Resistor100	2
R4	570	Resistor100	1
R6, R7, R8, R9	12k	Resistor100	4
R11	820	Resistor100	1
R12, R15	1.2k	Resistor100	2
R13	390	Resistor100	1
R14	120k	Resistor100	1
U1	LM324	LM324	1

Title
ProjectPart1Design

Size	Number	Rev

Date

Drawn by
Emir Arda Bayer

Filename

Sheet