Faculty of Engineering & Technology
Electrical & Computer Engineering Department

ENEE2360 Project

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Section 3

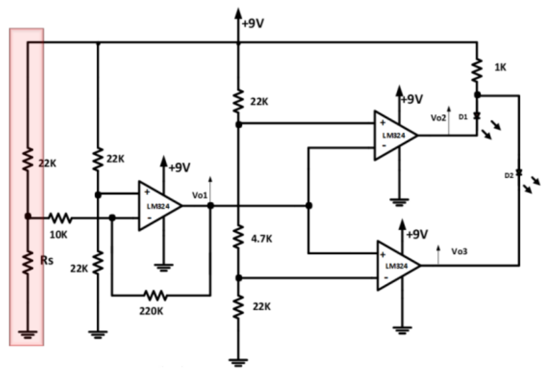
Contents

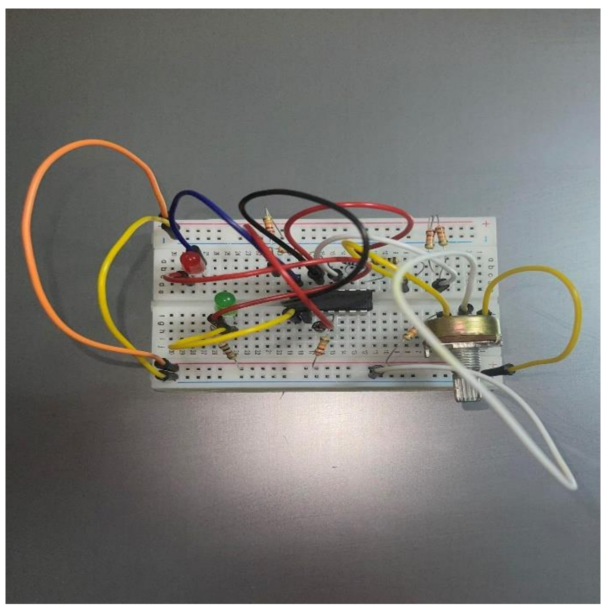
Abstract

Using a Thermistor and two LEDs, the circuit's goal is to track and signal temperature changes. Based on the temperature range, the circuit is designed to give visual feedback. The temperature sensor is a 20K Thermistor with a nominal resistance at 25°C. To show temperature conditions, the circuit uses two LEDs: a Red LED (D1) and a Green LED (D2).

Part1(Practical)

a) Construct the circuit to verify its function.





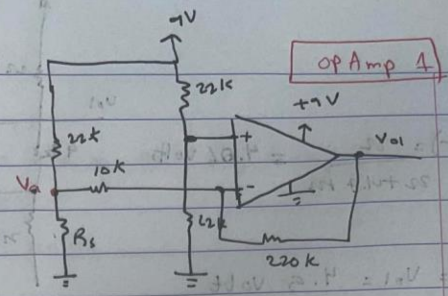
This circuit consists of three operational amplifiers. The first one is inverting subtractor such that the result will be the difference between it both terminals. It is also consisted of 2 others amplifiers which are comparators, if Vd>0 the output will be +Vsat, if Vd<0 the output will be -Vsat. And this what control the light of green and red leds.

b) Set Rs to 22KΩ , determine the value of Vo1,Vo2, Vo3, V(+) and V(-) of each OpAmp. Also indicate the status of each LED

part 1: practical:

set R_s to 22K

OpAmp 1



$$V_a = \frac{22k}{22k+22} \times 9V = 4.5 \text{ volts}$$

$$v(+) = \frac{22k}{22k+22k} \times 9V = 4.5 \text{ volts}$$

$$v(-) = v(+) = 4.5 \text{ volts}$$

$+V_{sat} = 7$ V

$-V_{sat} = 2$ V

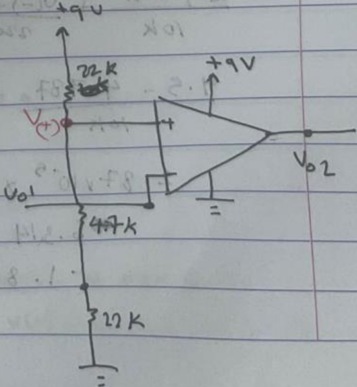
nodal at $v(-)$

$$\frac{v(-)-V_a}{10k} + \frac{V(-)-V_o}{220k} = 0$$

$$\cancel{\frac{4.5-4.5}{10k}}^{\,0} + \frac{4.5-V_o}{220k} = 0$$

$$\boxed{V_{o_1} = 4.5 \text{ volts}}$$

OpAmp 2



$$v(+) = \frac{4.7k+22k}{4.7k+22k+22k} \times 9$$

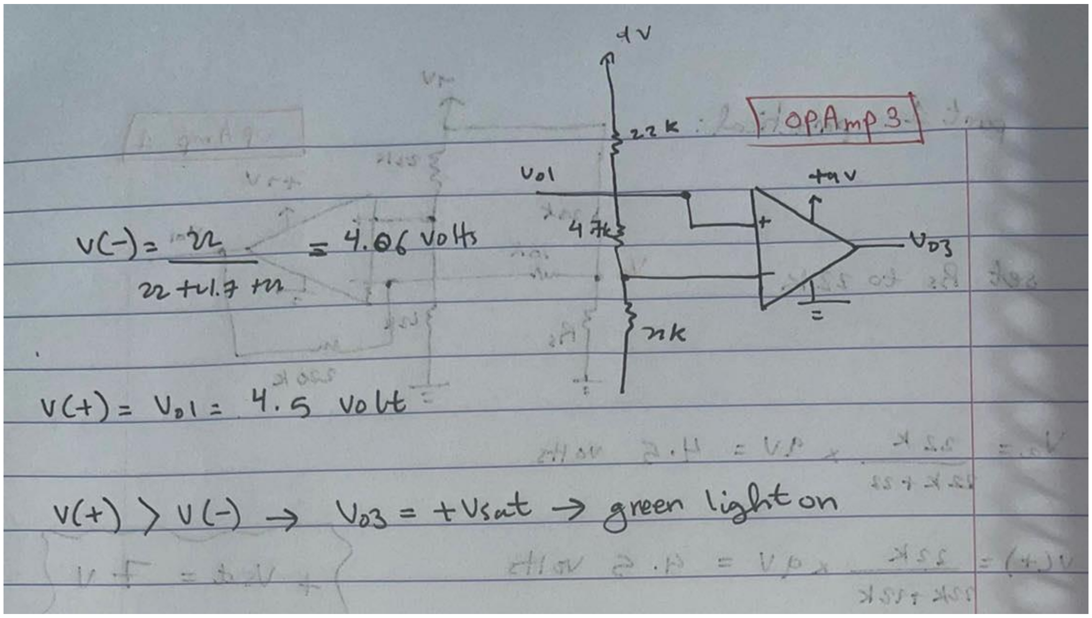
$v(+) = 4.934$ volts

$v(-) = V_{o1} = 4.5$ volts

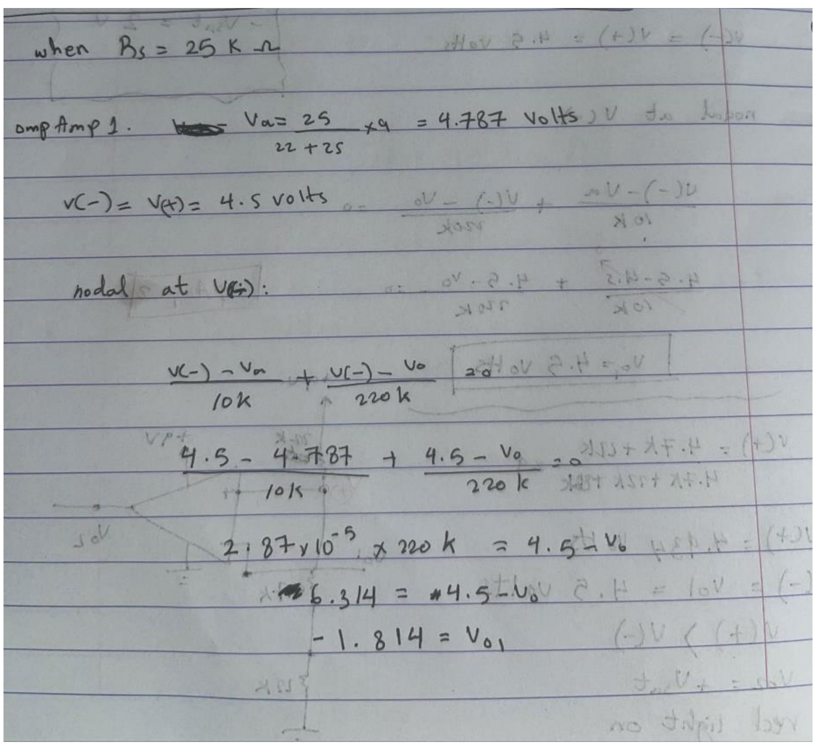
$v(+) > v(-)$

$V_{o2} = +V_{sat}$

red light on



c) Repeat step(b) for Rs = 25KΩ and Rs = 20K



when $R_s = 25\ K\Omega$

omp Amp 1. $V_a = \frac{25}{22+25} \times 9 = 4.787$ volts

$V(-) = V(+) = 4.5$ volts

nodal at $V(-)$:

$$\frac{V(-) - V_a}{10k} + \frac{V(-) - V_o}{220k} = 0$$

$$\frac{4.5 - 4.787}{10k} + \frac{4.5 - V_o}{220k} = 0$$

$$2.87 \times 10^{-5} \times 220k = 4.5 - V_o$$

$$6.314 = 4.5 - V_o$$

$$-1.814 = V_{o1}$$

at opamp 2:

$v(+) > v(-) \rightarrow V_{o2} = +V_{sat}$ red light on

$\therefore v(+) = 4.934$ volts

$v(-) = V_{o1} = -1.814$ volts

at opamp 3:

$v(-) = 4.06$ volts

$v(+) = -1.814$ volts

$v(-) > v(+)$, $V_{o3} = -V_{sat} \rightarrow$ green light is off

when $R_s = 20k$

at opamp 1 : $V_a = \frac{20}{20+22} \times 9 = 4.28$ volts

$v(-) = v(+) = 4.5$ volts

$$\frac{v(-) - V_a}{10\,k} + \frac{v(-) - V_o}{220\,k} = 0$$

$$\frac{4.5 - 4.28}{10\,k} + \frac{4.5 - V_o}{220k} = 0$$

$$\underline{V_{o1} = 9.214 \text{ volts}}$$

at opamp 2: $v(-) > v(+)$ $\therefore$ $v(+) = 4.934$ volts

$V_{o2} = -V_{sat} \rightarrow$ red light off

$v(-) = V_{o1} = 9.241$ volts

at opamp 3 :

$V(+) > V(-)$ since $V(+) = V_{o1} = 9.241$ volts

$V(-) = 4.06$ volts

$V_{o3} = +V_{sat}$

green Led is ON.

d) Determine the T upper limit and the T lower limit

T upper and lower limits when $R_s = 20k$ which is the critical thermostor resestance (from calculations)

T upper = 22.428°C this occure when resistance is 22200 Ω from data sheet (approximently)

T lower = 18.477 (from calculations), this occure when resistance is between 27 472 and 26.037 from data sheet (approximently).

Data sheet results

57	13.89	34165
59	15.00	32336
61	16.11	30615
63	17.22	28996
65	18.33	27472
67	19.44	26037
69	20.56	24674
71	21.67	23400
73	22.78	22200
75	23.89	21068
77	25.00	20001

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63	17.22	28996
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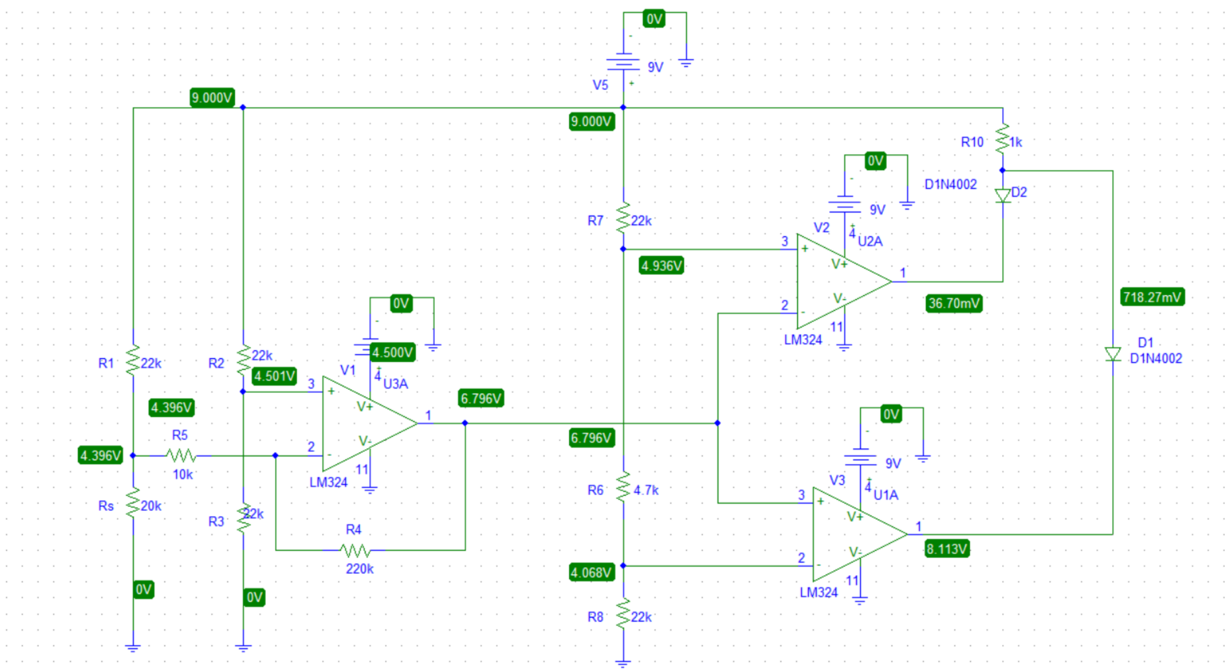
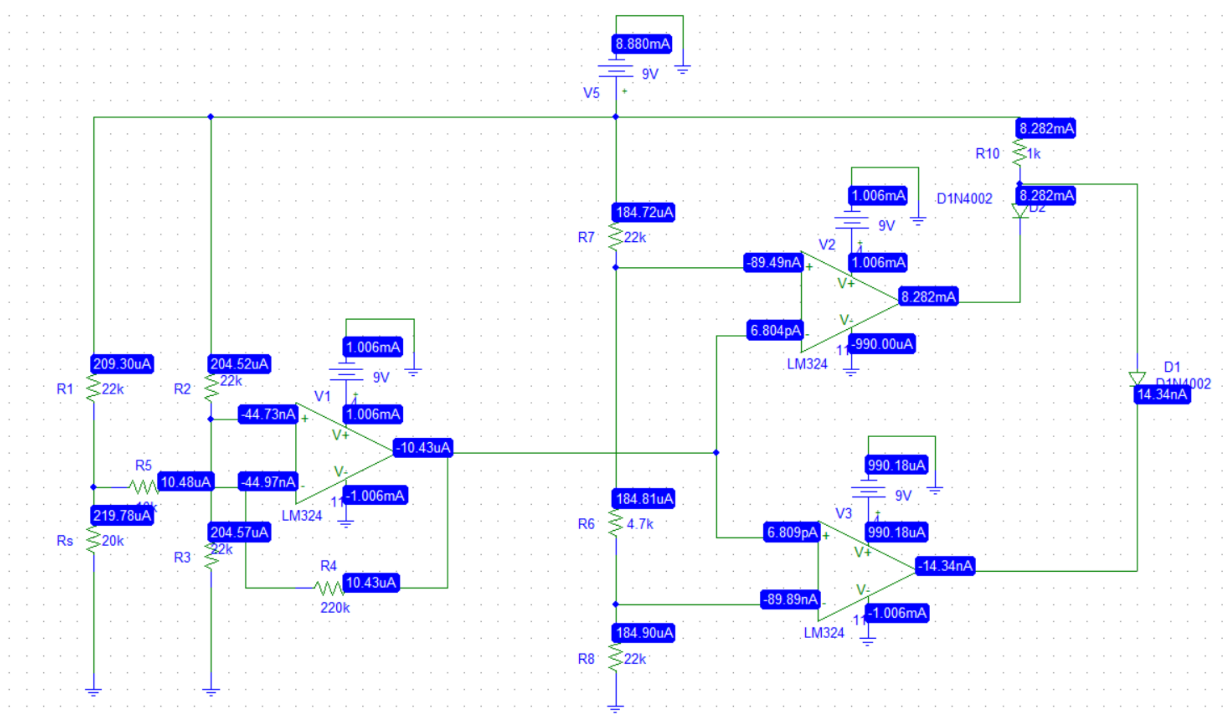
67	19.44	26037
69	20.56	24674
71	21.67	23400
73	22.78	22200
75	23.89	21068
77	25.00	20001

Part2 Simulation circuits and results

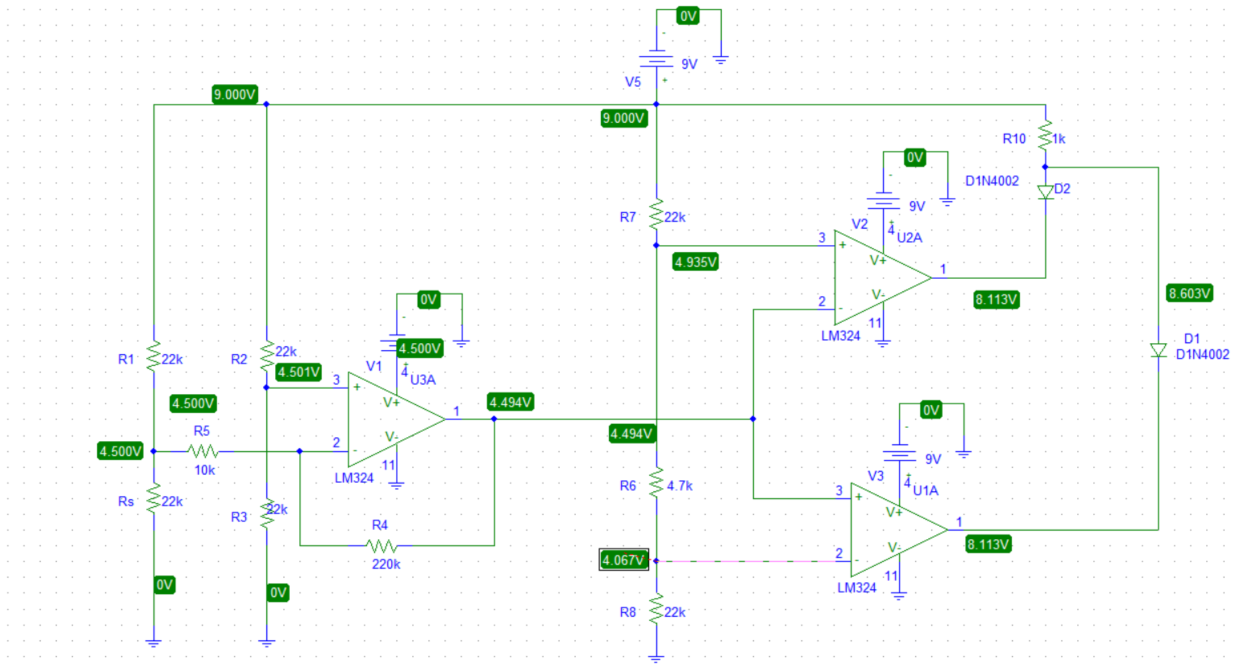
b) Simulate the circuit for Rs = 22K,25K, and 20K

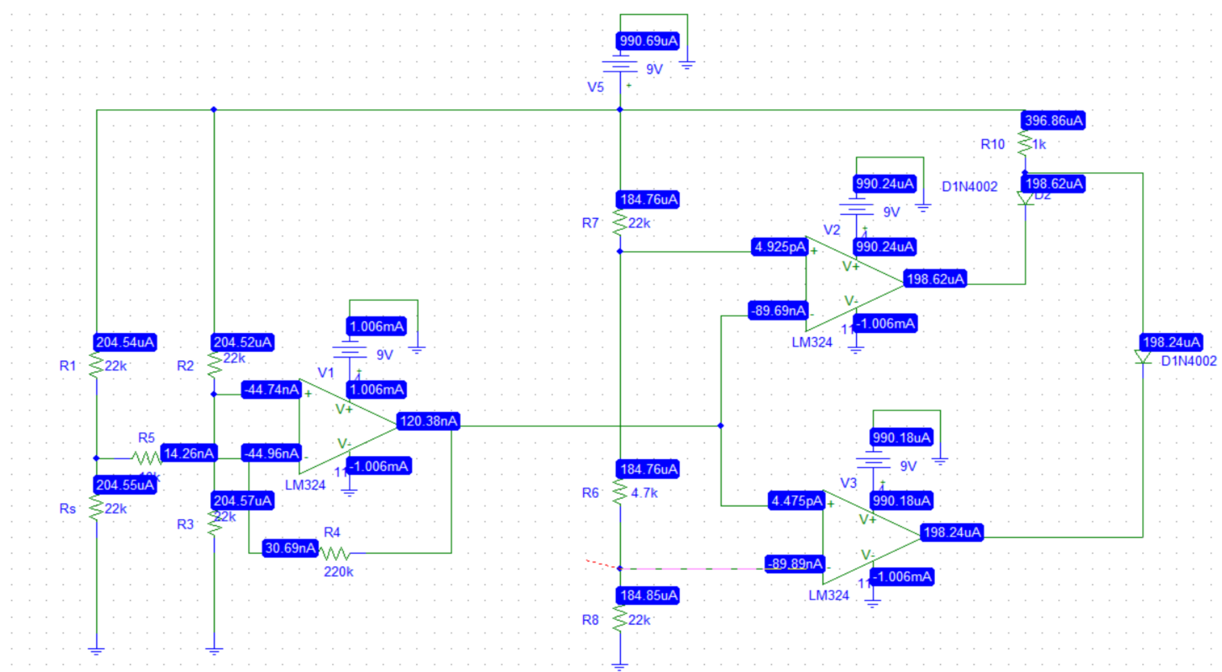
When Rs = 20K



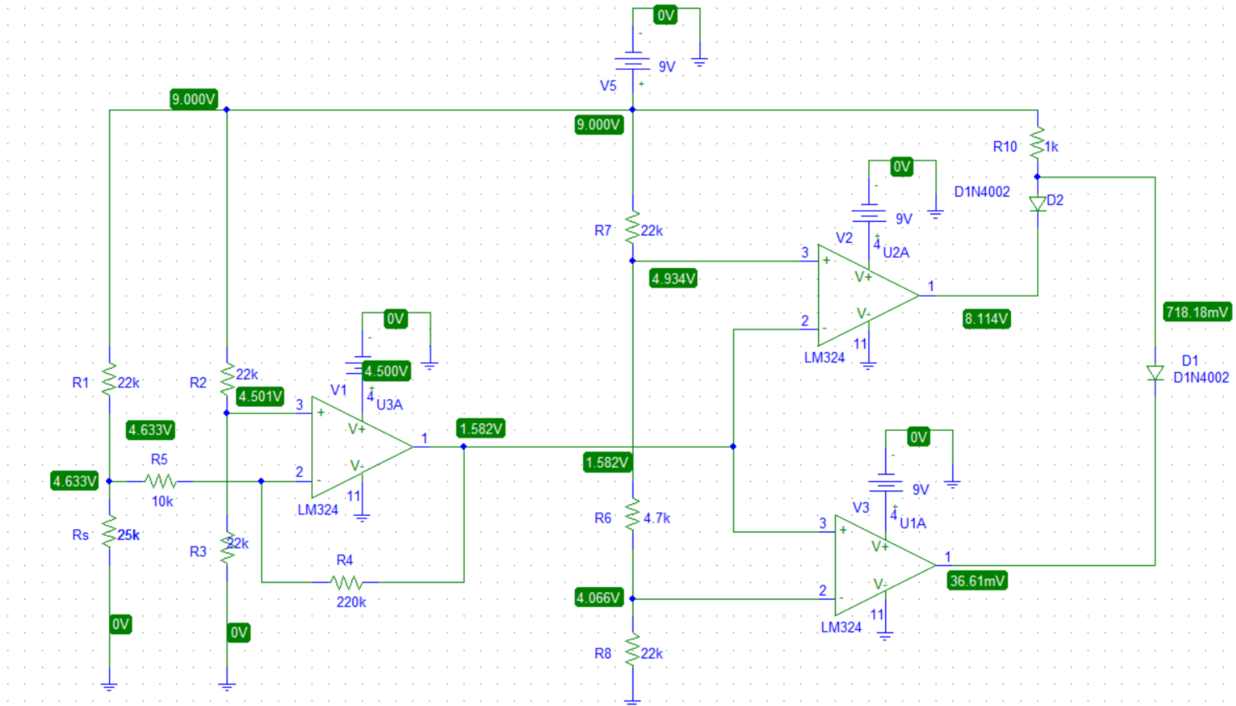


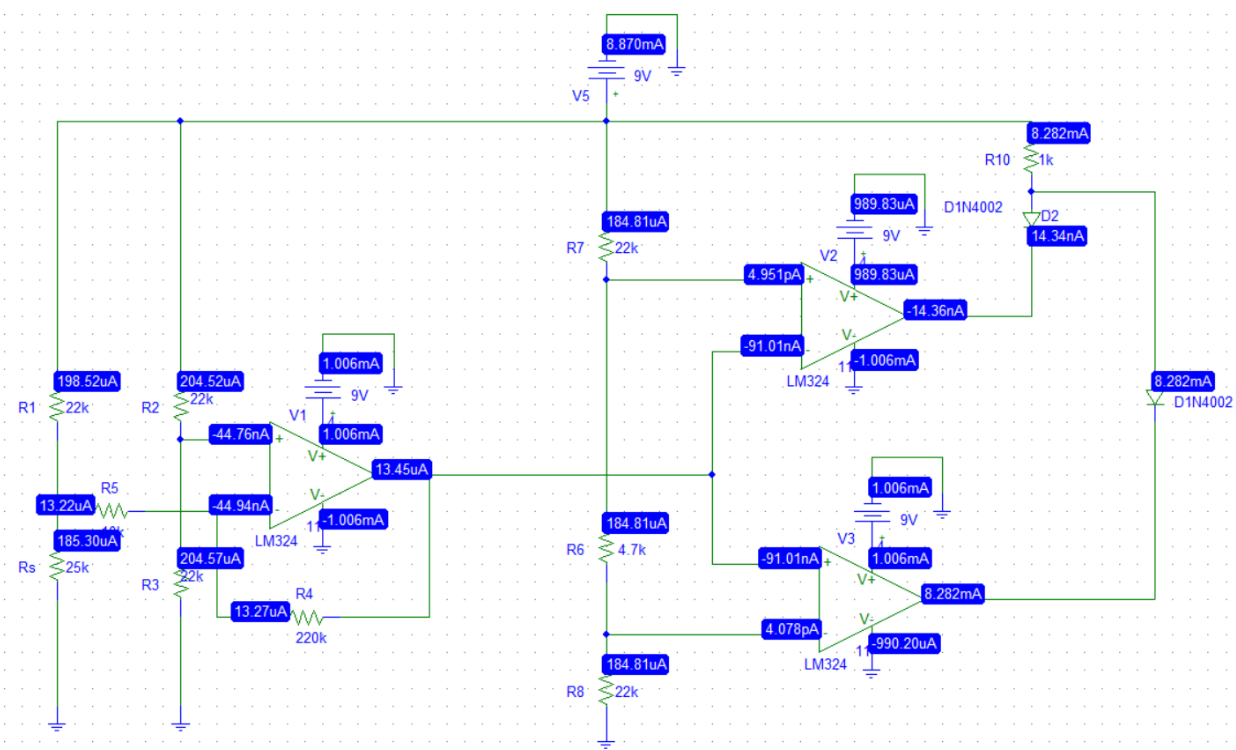
When Rs=22k


0V
9V
V5
9.000V
9.000V
R10
1k
0V
D1N4002
D2
R7
22k
9V
V2
U2A
4.935V
8.113V
8.603V
LM324
D1
D1N4002
0V
R1
22k
R2
22k
4.500V
4.501V
V1
U3A
4.500V
4.494V
R5
4.500V
10k
LM324
4.494V
0V
9V
V3
U1A
R6
4.7k
Rs
22k
R3
22k
R4
220k
8.113V
4.067V
LM324
0V
0V
R8
22k


990.69uA
9V
V5
396.86uA
R10
1k
990.24uA
D1N4002
198.62uA
184.76uA
9V
R7
22k
V2
4.925pA
990.24uA
198.62uA
-89.69nA
-1.006mA
LM324
1.006mA
198.24uA
204.54uA
204.52uA
9V
D1N4002
R1
22k
R2
22k
V1
-44.74nA
1.006mA
120.38nA
R5
14.26nA
-44.96nA
-1.006mA
990.18uA
9V
204.55uA
LM324
184.76uA
V3
Rs
22k
204.57uA
R6
4.7k
4.475pA
990.18uA
R3
22k
R4
198.24uA
30.69nA
220k
-89.89nA
-1.006mA
184.85uA
LM324
R8
22k

When Rs=25k


0V
9V
V5
9.000V
9.000V
R10
1k
0V
D1N4002
D2
9V
R7
22k
V2
U2A
4.934V
8.114V
718.18mV
0V
LM324
D1
D1N4002
R1
22k
R2
22k
4.501V
4.500V
V1
U3A
4.633V
1.582V
1.582V
R5
0V
4.633V
10k
LM324
9V
R6
4.7k
V3
U1A
Rs
25k
R3
22k
R4
220k
4.066V
36.61mV
LM324
0V
0V
R8
22k


8.870mA
9V
V5
8.282mA
R10
1k
989.83uA
D1N4002
D2
9V
14.34nA
184.81uA
R7
22k
V2
4.951pA
989.83uA
-14.36nA
-91.01nA
-1.006mA
LM324
1.006mA
198.52uA
204.52uA
8.282mA
D1N4002
R1
22k
R2
22k
9V
V1
-44.76nA
1.006mA
13.45uA
R5
13.22uA
-44.94nA
-1.006mA
1.006mA
9V
184.81uA
185.30uA
LM324
R6
4.7k
V3
Rs
25k
204.57uA
22k
-91.01nA
1.006mA
R3
R4
8.282mA
13.27uA
220k
4.078pA
-990.20uA
LM324
184.81uA
R8
22k

c) Replacing the shaded part by a VPWL Voltage source as shown in Fig.(2) , plot Vo1(t),Vo2(t), and Vo3(t).

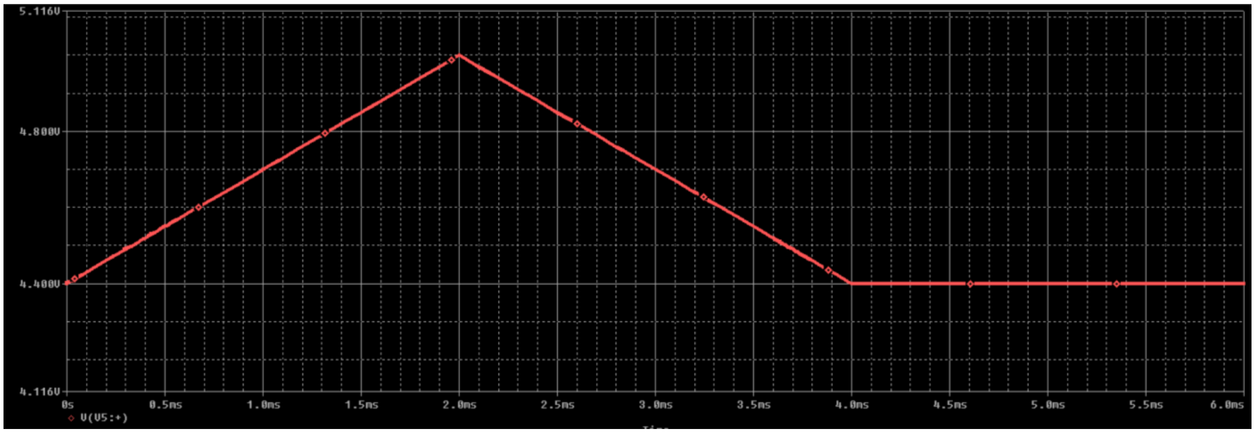


Figure 1: VPWL

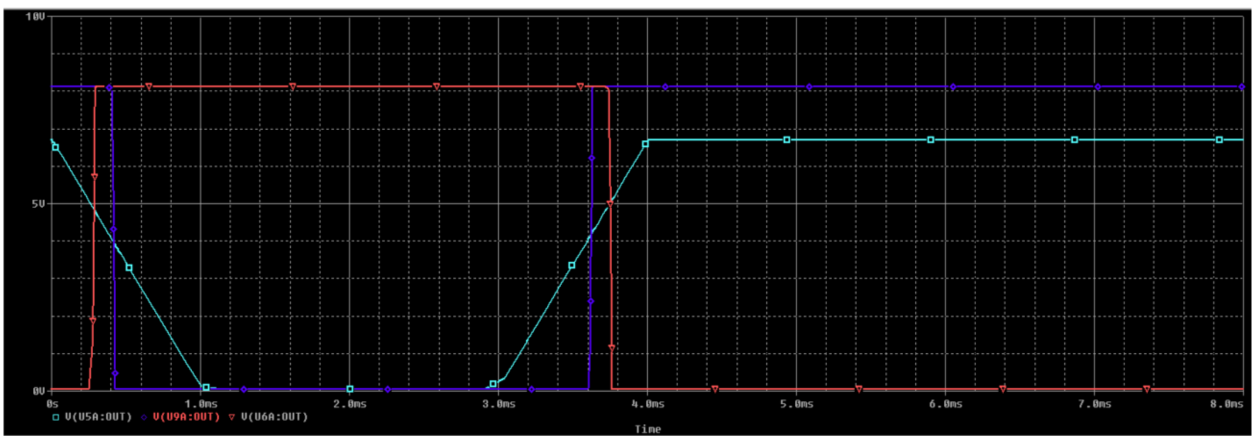
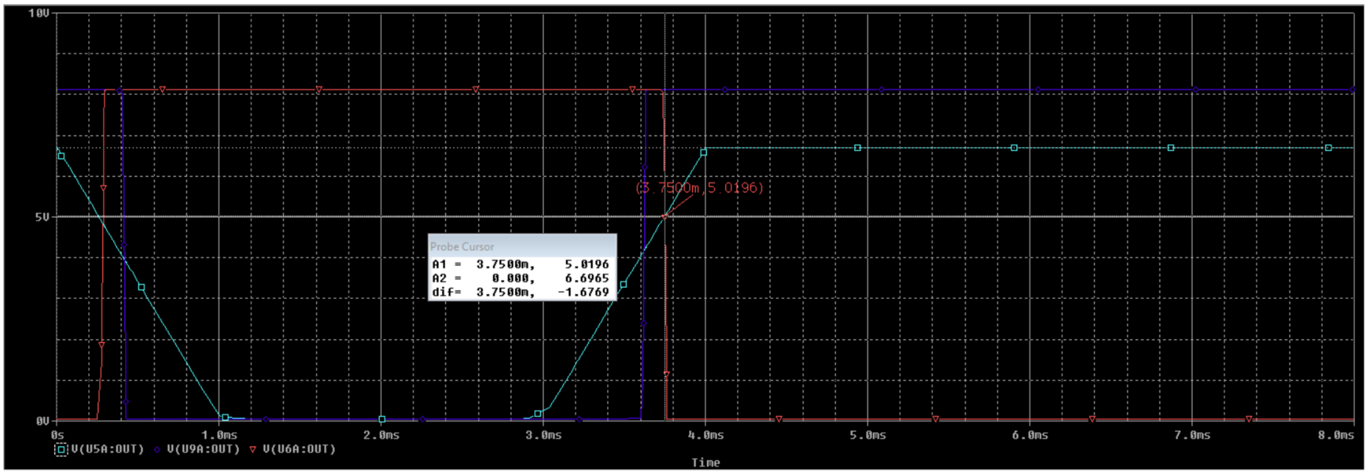


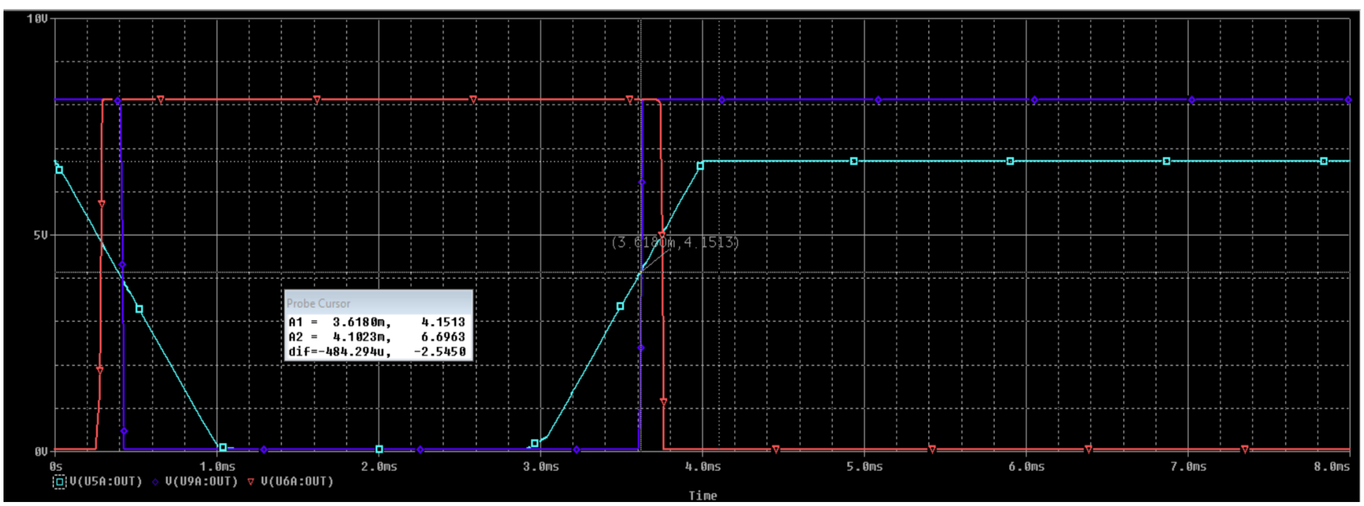
Figure 2: Vo1, Vo2, Vo3 plots

d) Estimate the upper limit and the lower limit temperatures fromVo2 and Vo3(t) plots.

Upper Threshold



Lower Threshold



From pspice :

opper threshold = 5.0196 , gain = 22

$$\frac{5.0196}{22} = 0.22816\ V = 228.163\ mV$$

$1 \rightarrow 10\ mV$ (from notes)

$? \rightarrow 228.163$

upper tempreture = 22.8163 °C

Lower threshold = 4.1513 volts

$$\frac{4.1513}{22} = 188.645\ mV$$

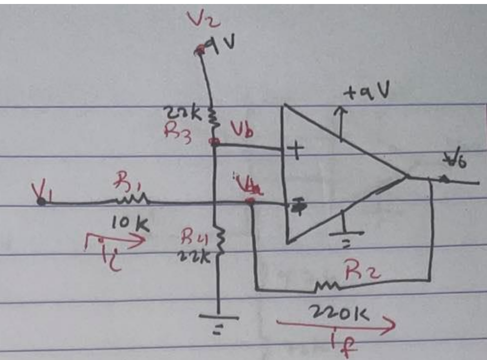
$1 \rightarrow 10\ mV$ (from notes)

$? \rightarrow 188.695$

Lowen tempreture = 18.8695

f) Calculate by hand the upper threshold and the lower threshold temperature

inverting subtractor



at node a:

$$i_f = i_i$$

$$\frac{V_1 - V_o}{R_1} = \frac{V_a - V_o}{R_2}$$

$$\boxed{V_o = \left(\frac{R_2}{R_1} + 1\right) V_a - \frac{R_2}{R_1} V_1} \text{ — } 1$$

at node b:

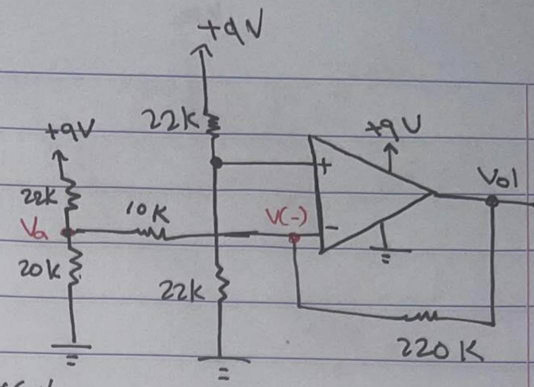
$$V_b = V_2 \cdot \frac{R_4}{R_3 + R_4} = V_a$$

$$\therefore \; V_o = \left(\frac{R_2}{R_1} + 1\right)\left[\frac{R_4}{R_3 + R_4} \cdot V_2\right] - \frac{R_2}{R_1} \cdot V_1$$

$$\boxed{V_o = \frac{R_2 (1 + R_1/R_2)}{R_1 (1 + R_3/R_4)} \cdot V_2 - \frac{R_2}{R_1} \cdot V_1}$$

$$\frac{R_1}{R_2} = \frac{R_3}{R_4} \Rightarrow \boxed{V_o = \frac{R_2}{R_1}(V_2 - V_1)}$$

$$\boxed{\text{gain} = \frac{R_2}{R_1}} = 22$$



$$V(+) = \frac{22K}{22K + 22K} \times (9V)$$

$$= \boxed{4.5\ V}$$

$$V_a = \frac{20K}{22K + 20K}(9) = 4.396\ V$$

nodal at $V(-)$:

$$\frac{V(-) - V(a)}{10k} + \frac{V(-) - V_{ol}}{220k} = 0$$

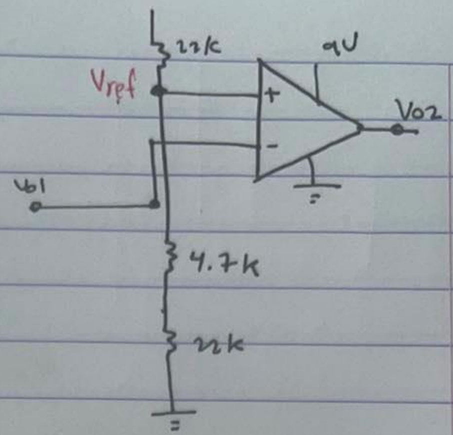
$V(-) = V(+) = 4.5$ volts since it is ideal opAmp

$$\Rightarrow \frac{4.5 - 4.396}{10K} + \frac{4.5 - V_{ol}}{220k} = 0$$

$$-1.64 \times 10^{-5} = \frac{4.5 - V_{ol}}{220k}$$

$$\boxed{6.788 \text{ Volts} = V_{ol}}$$

comparator:



$$V_{ref} = \frac{22+4.7}{22+4.7+22} \times 9V$$

$V(+) = V_{ref} = 4.9342$ Volts

$V(-) = V_{o1} = 6.788$

$V_d < 0V$; $V_o = -V_{sat} = 0+2 = 2$ volts $\Rightarrow$ red Led is off

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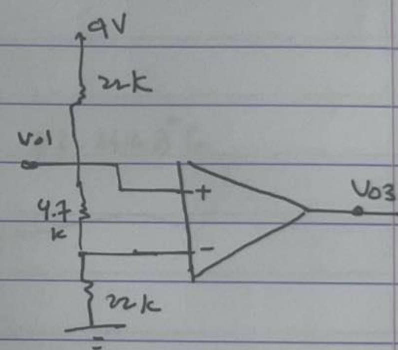

$$V_{ref} = \frac{22k}{22k+22k+4.7k} \times 9V$$

$V(-) = V_{ref} = 4.065$ volts

$V(+) = V_{o1} = 6.788$

$V_d > 0$, $V_o = +V_{sat} = 9-2 = 7$ volts $\Rightarrow$ green Led is on upper and lower tempretures.

gain = 22

Vref1 = 4.9342 volts

$$\frac{4.9342}{22} = 224.2818 \text{ mV}$$

$1 \rightarrow 10 \text{ mV}$

$? \rightarrow 224.2818 \text{ mV}$

$$UT = \frac{224.2818}{10} = 22.428^{\circ}C$$

Vref2 = 4.065 volts

$$\frac{4.065}{22} = 0.1847 \text{ volts} = 184.77 \text{ mV}$$

$1 \rightarrow 10 \text{ mV}$

$? \rightarrow 184.77 \text{ mV}$

$$LT = \frac{184.77}{10} = 18.477^{\circ}C$$

g) Comparison of simulation results to hand calculation:

From result in PSpice:

- **VUt=5.0196 volts VLt=4.1513 volt**
- **ut=22.8163C, lt=18.8965C**

Theoretical:

- **+Vsat=+vcc-2=9-2=7 volt**
- **-Vsat=-vcc+2=0+2=2 volt**
- **VUt=4.9342 volts, VLt=4.065 volts**
- **Ut=22.428 c ,Lt=18.477 c**

According to the results, the results are close.

The difference due to different reasons such as equations that are used in hand calculations are not fully accurate.

conclusion

In conclusion, the temperature change detection circuit described in this work uses a thermistor and LEDs to track temperature differences and offers a dependable and efficient solution. To clearly display temperature conditions, the circuit uses two LEDs: a Red LED (D1) and a Green LED (D2) also 3 Operational amplifiers in addition to different values of resistors and a temperature sensor which has 20K Thermistor.

If the temperature is within a specified range, the two LEDs will be off If the temperature increases above the upper limit, the Red LED D1 will glow If the temperature decreases below the lower limit, the Green LED D2 will glow.

Due to its ease of use and simplicity, this circuit is suitable for a range of applications.