" بسم الله الرحمن الرحيم "

Faculty of engineering and technology.

Department of electrical and computer engineering.

Analog Electronics – ENEE2360.

Course project.

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Partners names (prepared by): **ID:**

Razan Abdelrahman. **1200531.**

Omar Masalmah. **1200060.**

Instructor's name: Dr. Nasser Ismail.

Section: 3.

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1. Abstract.

This circuit provides a visual indication of temperature conditions using the two LEDs, with the red LED (assuming the red led is D1) indicating a temperature above the upper limit and the green LED (assuming the green led is D2) indicating a temperature below the lower limit.

When the temperature is within a specified range, both LEDs will be off. If the temperature increases above the upper limit, the red LED (D1) will light up. Conversely, if the temperature decreases below the lower limit, the green LED (D2) will light up.

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2. Theory.

❖ Components:

➢ OpAmp (LM324).

The LM324 IC consists of 14-pins with four independent op-amps in one package. These electronic voltage amplifiers are available in high gain with differential input as well as a single output. The voltage difference among the input terminals of the IC is very less than the output voltage. These comparators operate with a single power supply and need of dual supply is removed. These ICs can be utilized as comparators, oscillators, amplifiers, rectifiers, etc. By using this IC several applications can be implemented very easily [1].

In this circuit, the op-amps of the LM324 are used as comparators to compare the voltage from the thermistor with the reference voltages that determine the upper and lower temperature limits.

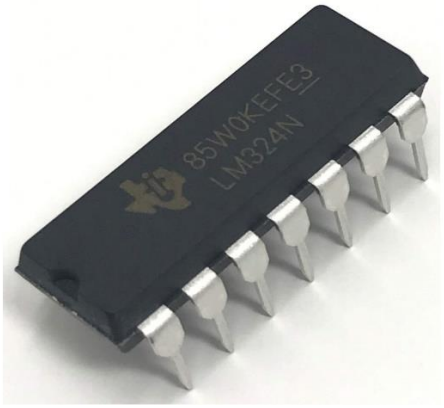


Figure 1 LM324

➢ Diode (D1N4002).

The **1N4002** is a general-purpose **diode** from the 1N400x family. It is widely used in electronic appliances for rectification purposes and also for other purposes such as voltage blocking, voltage boosting, etc [2].

The purpose of the diodes would likely be different. Instead of indicating temperature conditions directly through illumination, the diodes could be used for temperature compensation or voltage reference purposes.

Figure 2 D1N4002.

- **LED.**

Is a semiconductor device that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons [3].

Figure 3 LED.

- **Potential meter.**

Is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider, If only two terminals are used, one end and the wiper, it acts as a variable resistor or rheostat [4].

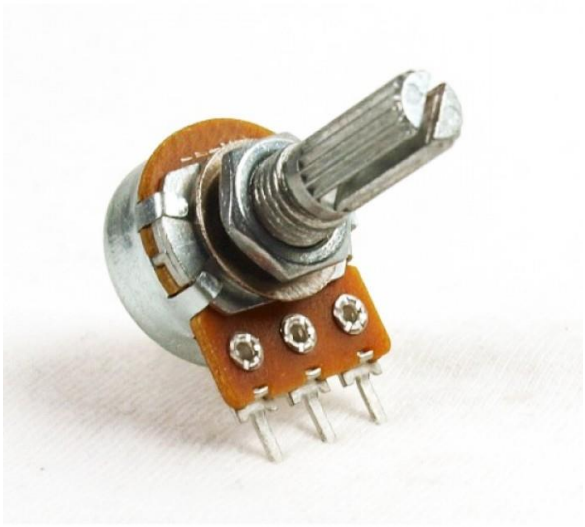


Figure 4 Potential meter.

3. Procedure.

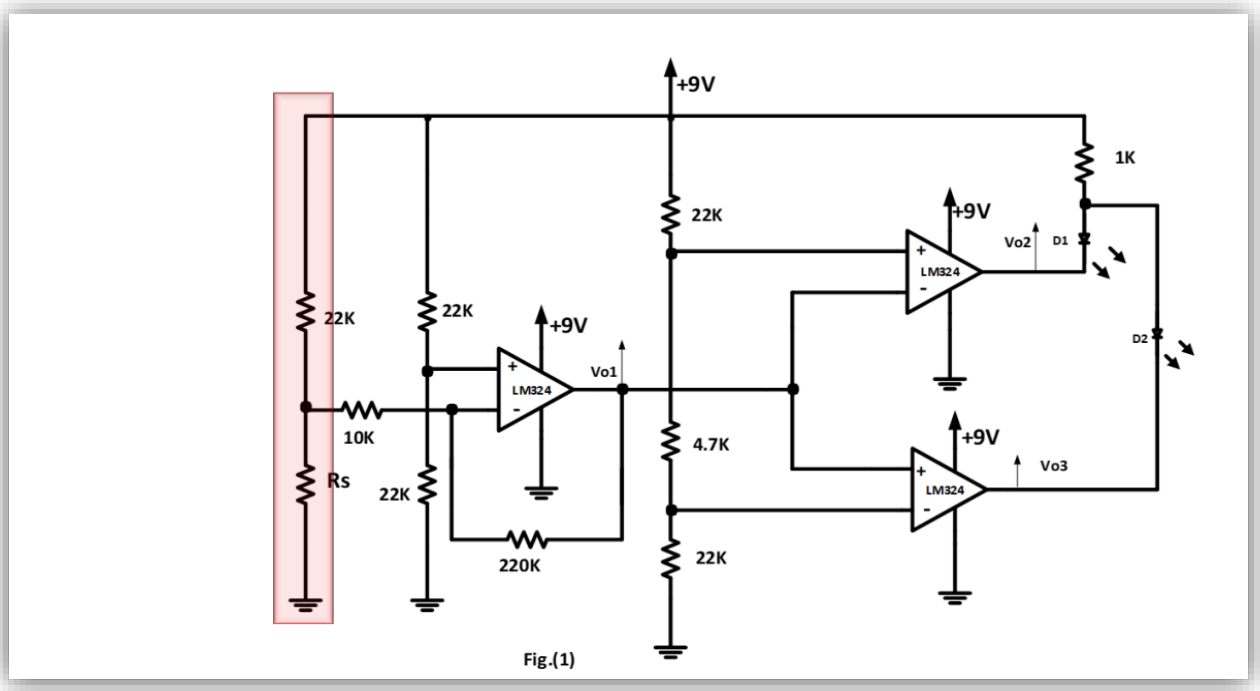


Figure 5 Required circuit.

- **Circuit explanation.**

The circuit uses a Thermistor 20K @ 25°C as a temperature sensor. Two diodes are connected to create a voltage divider network, with their common connection linked to the non-inverting terminal of Op Amp 1. The cathode of D1 is connected to the output terminal of Op Amp 1, and the cathode of D2 is connected to the output terminal of Op Amp 2. The thermistor and a resistor (R1) are connected in series, with their connection point attached to the inverting terminal of Op Amp 3. The non-inverting terminals of Op Amps 2 and 3 are connected to a reference voltage. The output of Op Amp 1 controls the Red LED (D1), while the output of Op Amp 2 controls the Green LED (D2). When the temperature is within the specified range, D1 and D2 remain off. If the temperature exceeds the upper limit, D1 (Red LED) turns on. Conversely, if the temperature drops below the lower limit, D2 (Green LED) turns on. This circuit design enables the detection of temperature changes using the Thermistor and appropriate LED indications based on the temperature readings.

- **Part1.**

We construct the circuit as it required.

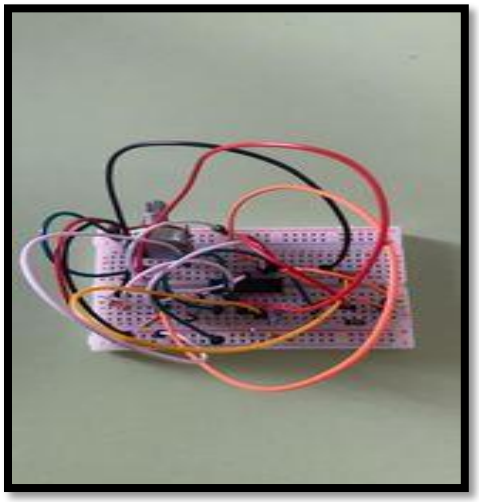


Figure 6 The constructed circuit.

- **Part2.**

A| Replace the Red and Green LEDs with D1N4002.

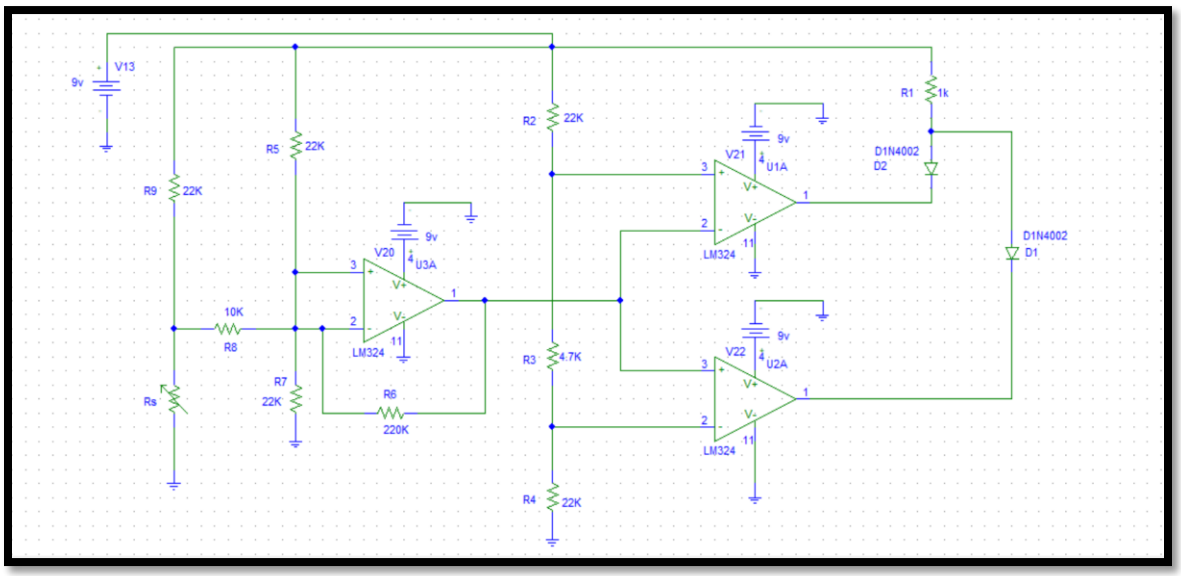


Figure 7 Circuit simulation of part2.

B| Simulate the circuit with for Rs = 22K, 25K, and 20K.

- **Rs=22K.**

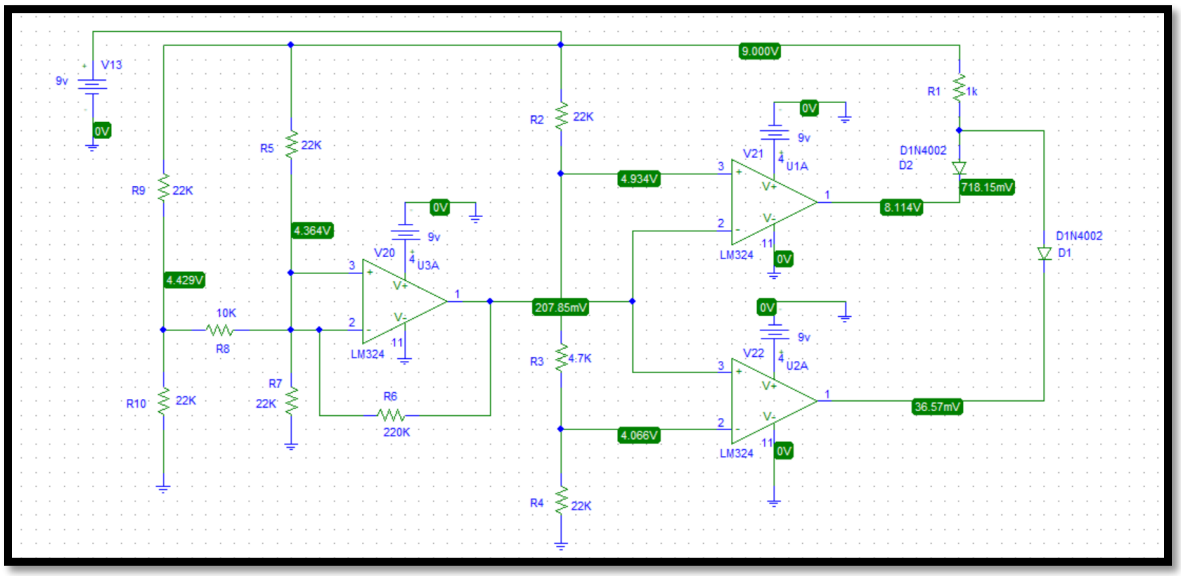


Figure 8 Circuit simulation with value of RS 22K.

- **Rs=25K.**

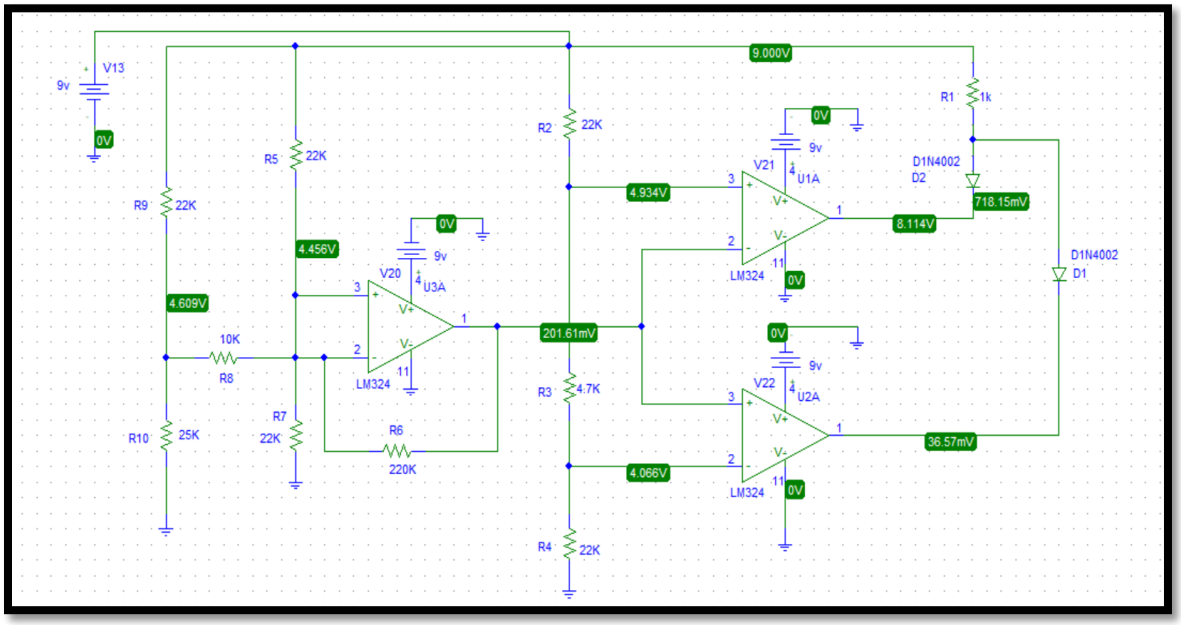


Figure 9 Circuit simulation with value of RS 25K.

❖ **Rs=20k.**

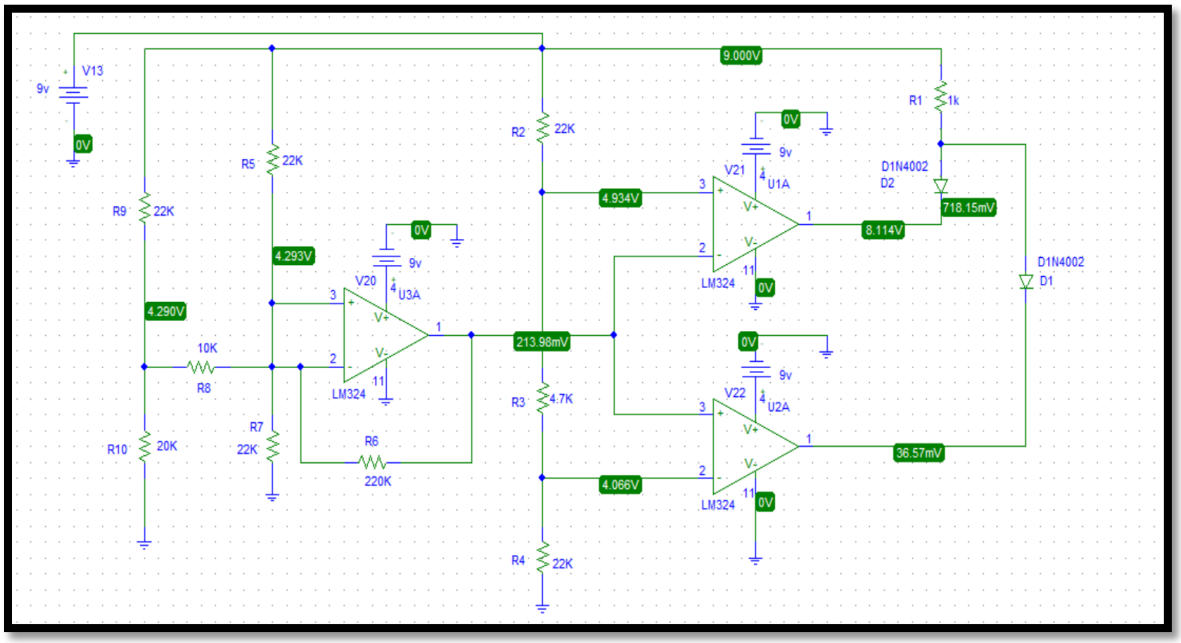


Figure 10 Circuit simulation with value of RS 20K.

C| Replacing the shaded part by a VPWL Voltage source as shown in the circuit, plot Vo1 (t), Vo2 (t), and Vo3 (t).

- VPWL:

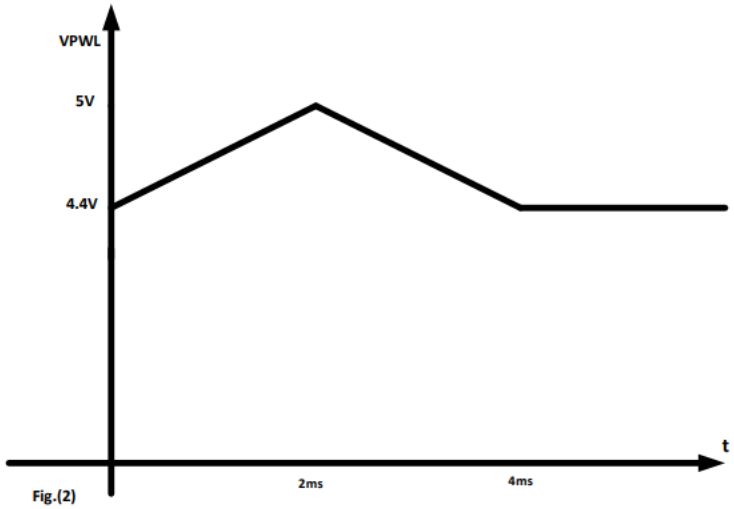


Figure 11 VPWL.

- Plot of Vo1(t),Vo2(t) and Vo3(t):

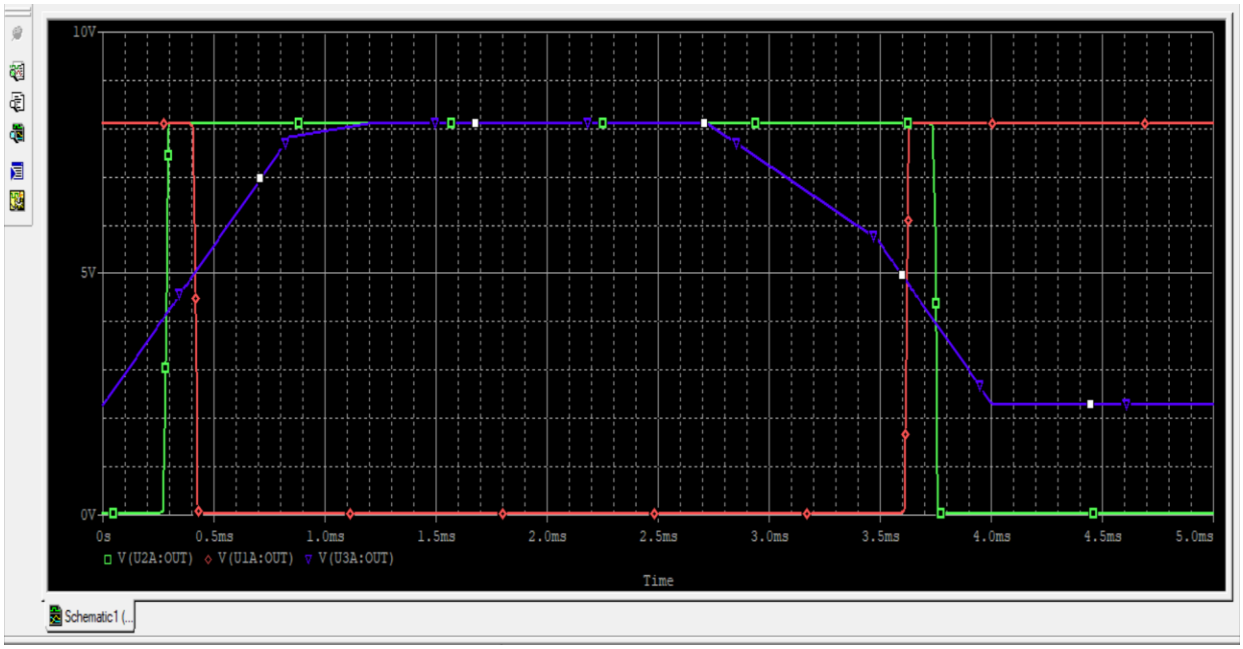


Figure 12 Plots of V1, V2 and V3.

Vo1 (t):

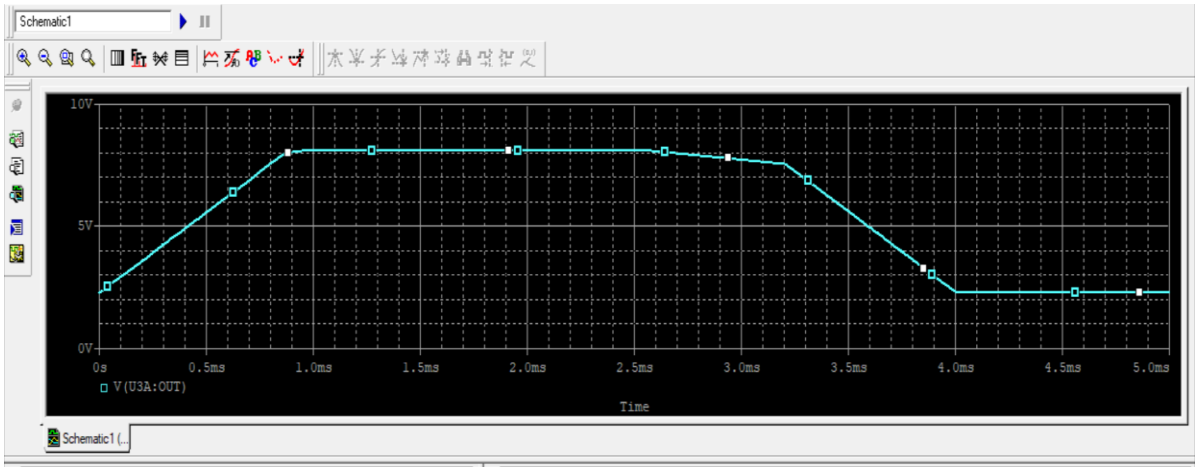


Figure 13 Plot of Vo1 (t).

Vo2 (t):

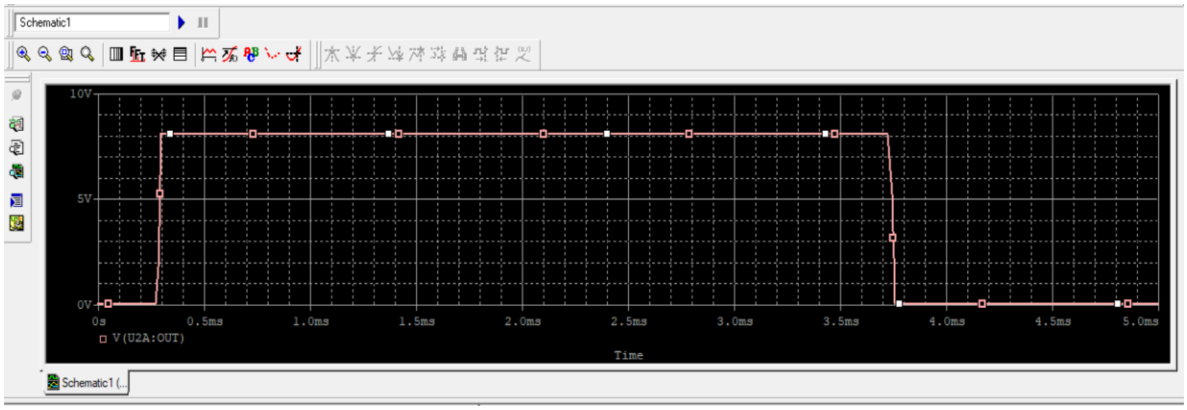


Figure 14 Plot of Vo2 (t).

Vo3 (t):

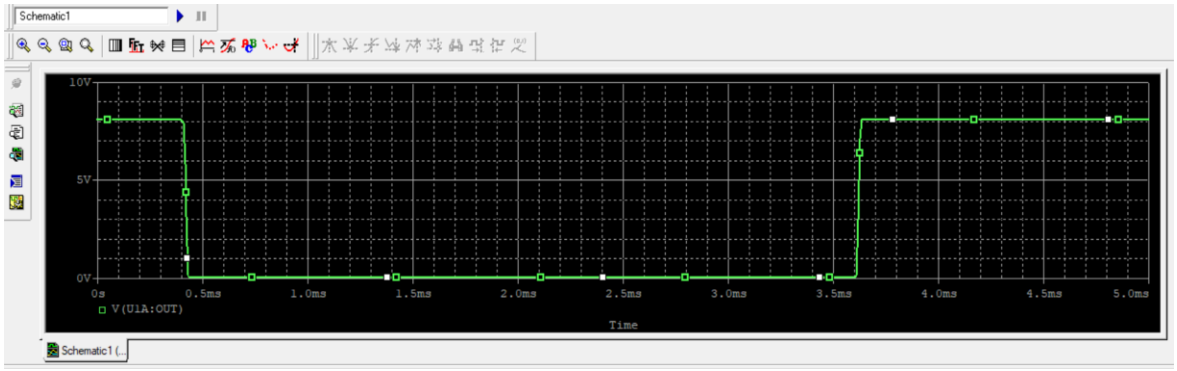


Figure 15 Plot of Vo3 (t).

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

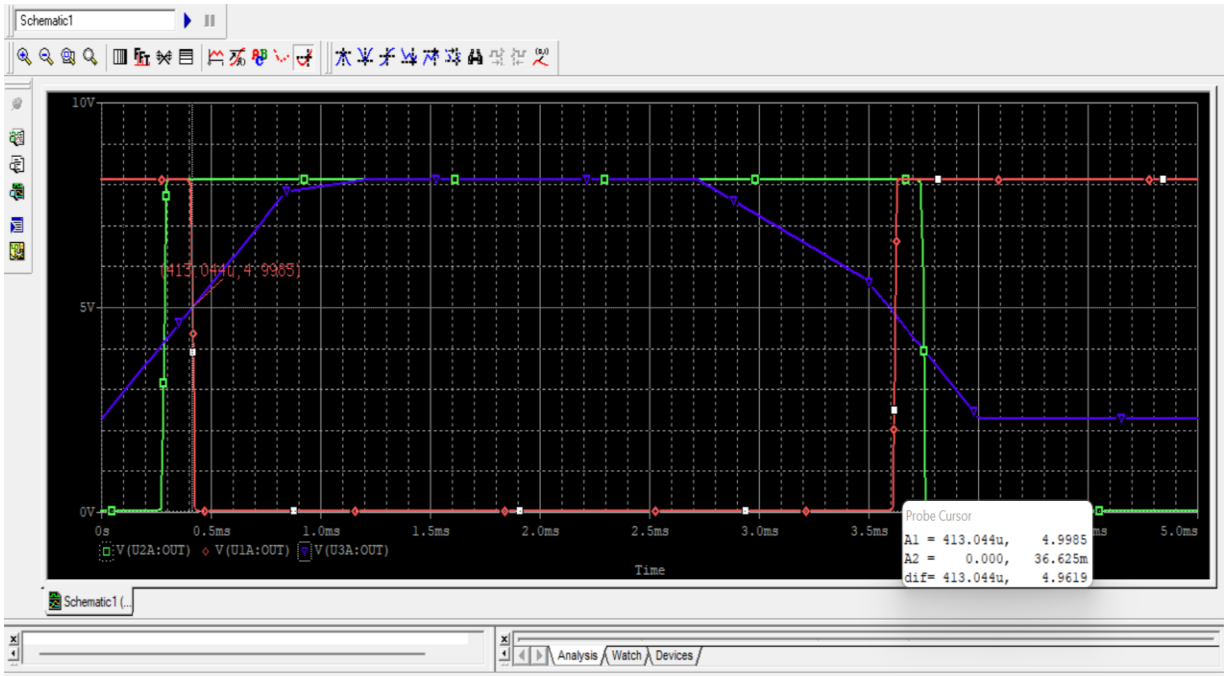


Figure 16 Upper threshold.

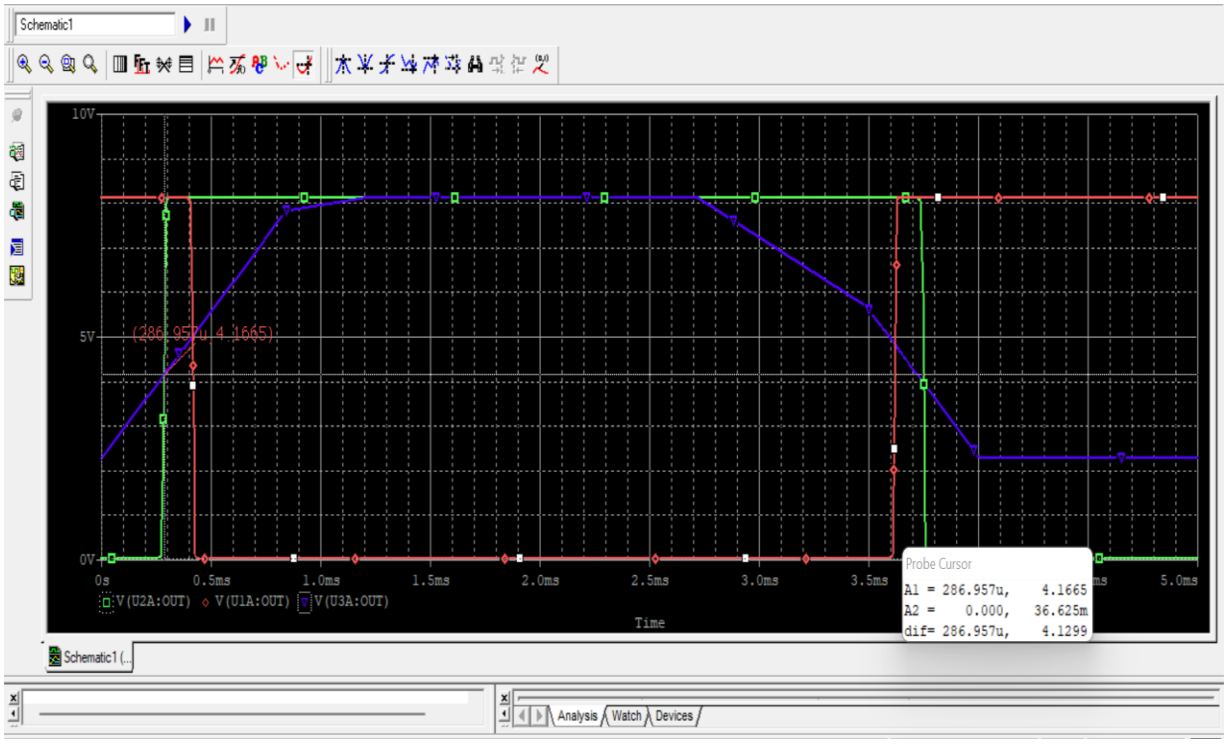


Figure 17 Lower threshold.

Then, we calculated by hand the value of Rs in order to find the upper and lower temperature:

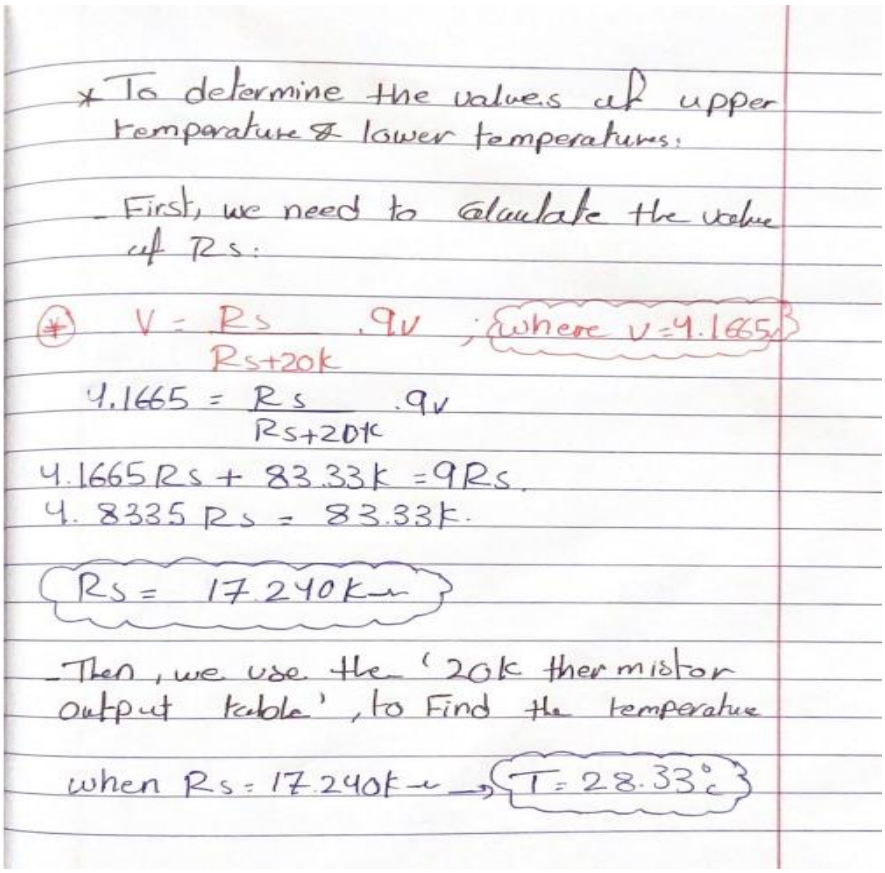


Figure 18 Upper temperature value.

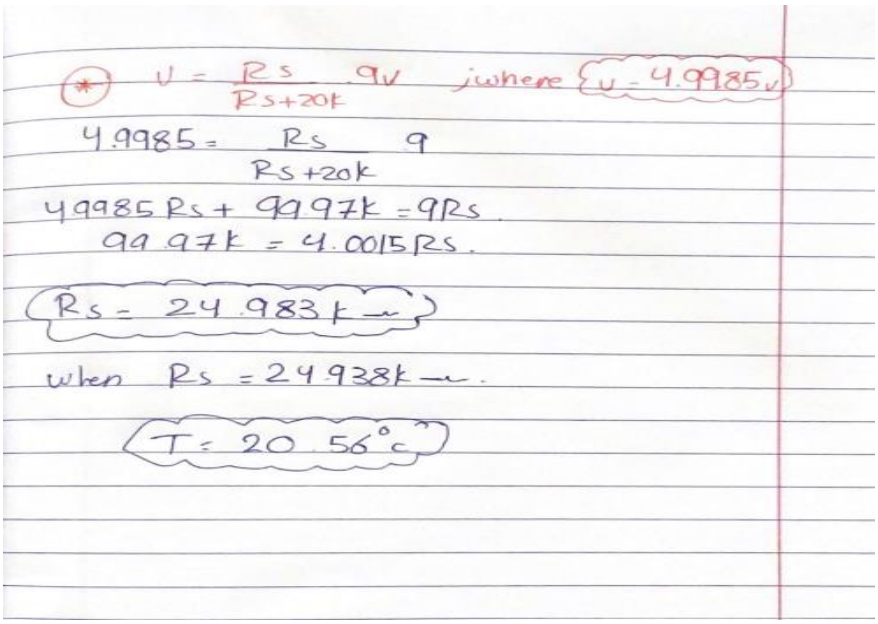
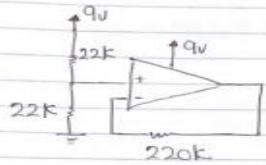


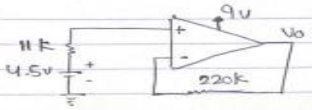
Figure 19 Lower temperature value.

F| Calculate by hand the upper threshold and the lower threshold temperature.

(f) Calculate by hand the upper threshold & the lower threshold temperature.



- $R_{th} = 22k \parallel 22k = \frac{22k \cdot 22k}{(22+22)k} = 11k\Omega$
- $V_{th} = \frac{22k}{22k+22k} \cdot 9 = 4.5v$



- $V_{sat} = V_{cc} - 2$
  $= 9 - 2$
  $= 7V$
- $V_o = +V_{sat} = 7V$

- $V_o > V$
  $V(+) > V(-)$.

① $V(-) = V_{in}$

② $V(+) = \frac{220k}{220k+11k} \cdot 4.5 + \frac{11}{11+220k} \cdot V_o$
$= 4.28 + 0.047 V_o$

→ IF $V_o = V_{sat} = 7V$
$V(+) = 4.28 + 0.047(7)$
$= 4.28 + 0.33$
$= 4.613V$

→ $V(+) > V(-)$
$4.613 > V_{in}$
$V_o = V_{sat} = 7V$

else
$V_o = -V_{sat}$
$= -V_{cc} + 2$
$= 0 + 2$
$= 2V$

- Assume $V_o = -V_{sat}$
  $V(+) < V(-)$
  ↳ $V(+) = 4.28 + 0.047 V_o$
  if $V_o = -V_{sat} = 2$
  $V(+) = 4.374V$

→ if $V(+) < V(-)$
$V_{in} > 4.374 \rightarrow V_o = -V_{sat} = 2V$
else
$V_o = +V_{sat} \rightarrow V_o = 7V$

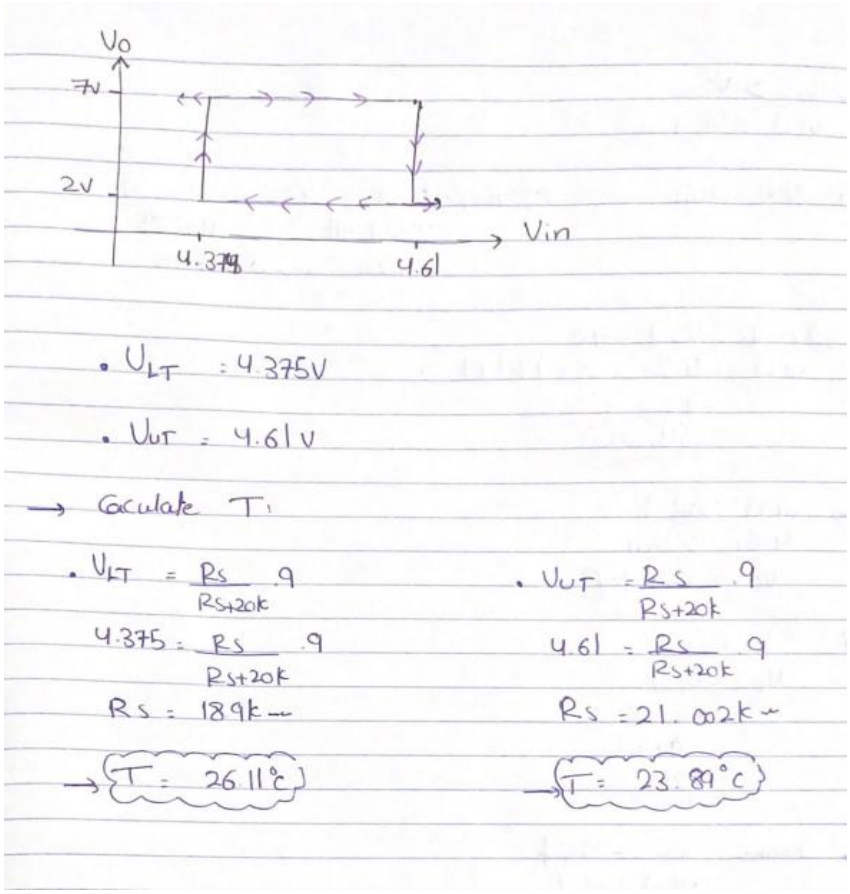


Figure 20 Calculations by hand.

- **Comparison of simulation results to hand calculation.**

Simulation results:

- Vlt = 4.1665v.
- Vut=4.9985v.
- Tl=20.65 C.
- Tu=28.33 C.

Hand calculation:

- Vlt = 4.375v.
- Vut=4.61v.
- Tl=23.89 C.
- Tu=26.11 C.

4. Conclusion.

This temperature sensing circuit provides an efficient and reliable means of detecting temperature changes. It offers visual indications through the activation of the Red LED (D1) when the temperature exceeds the upper limit and the Green LED (D2) when the temperature falls below the lower limit. The circuit's simplicity and functionality make it suitable for various applications requiring temperature monitoring and control.

5. References.

[1] [Online]. Available: https://www.elprocus.com/lm324-ic-pin-configuration-and-its-applications/. [Accessed 9 July 2023].

[2] [Online]. Available: https://www.utmel.com/components/1n4002-diode-pinout-datasheet-and-equivalents?id=318. [Accessed 9 July 2023].

[3] [Online]. Available: https://en.wikipedia.org/wiki/Light-emitting_diode. [Accessed 9 July 2023].

[4] [Online]. Available: https://en.wikipedia.org/wiki/Potentiometer#:~:text=A%20potentiometer%20is%20a%20three,a%20variable%20resistor%20or%20rheostat.. [Accessed 9 July 2023].