BIRZEIT UNIVERSITY

Faculty of Engineering & Technology

Electrical & Computer Engineering Department

Analog Electronics ENEE2360

Project Report

Prepared by:

Mohammad Abu Shams 1200549

Joud Hijaz 1200342

Mohammad Owda 1200089

Instructor: Dr. Nasser Ismail

Section: 3

Date: 9-2-2023

Abstract

The purpose of this project is to design a circuit (room thermostat) that is used to maintain the room temperature within predetermined temperatures T (max) and T (min). This circuit contains one sensor, 10 resisters with different values, one BJT pnp transistor, green LED, non-inverting amplifier, Schmitt trigger comparator and a potentiometer with a value 47k ohm. We used these components to build the circuit practically and show it to teaching assistant Eng. Shadi. Then we will use PSPICE software to do this project.

Table of Contents

List of figures

Theory

Components

1- LM35DZ sensor

The LM35DZ is an integrated circuit analog sensor that can be used to measure temperature with an electrical output proportional to the temperature (this is why it is an analog sensor). It can measure temperature more accurately than a thermistor. The sensor circuitry is sealed and not subject to oxidation. The LM35DZ generates a higher output voltage than thermocouples and may not require that the output voltage be amplified. The LM35 has an output voltage that is proportional to the temperature. The scale factor is 10mV/°C (Celcius). [1]

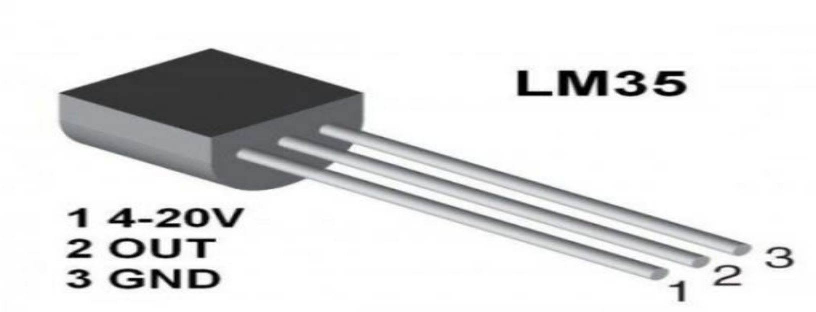


Figure 1: LM35DZ

2- LM324 op-amp

This IC is a non-inverting amplifier and it comprises four independent op-amps internally. This IC has designed with low-power, bandwidth and high stability for operating with single power supply over extensive voltage ranges. The range of operating voltages of this IC includes 3.0 V for low and 32 V for high. It consists of 14-pins. [2]

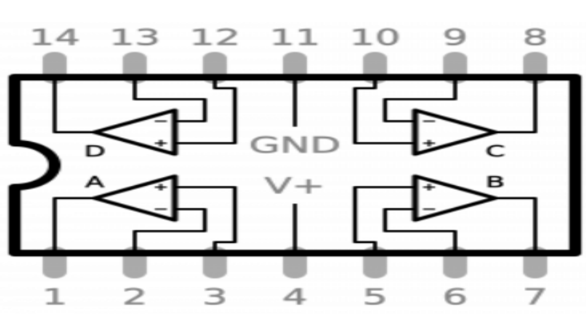


Figure 2: LM324

3- uA741 op-amp

uA741 is a monolithic op-amp with high-performance, and it is designed on an only Si (Silicon) chip. This IC is used in a broad variety of analog applications. The operating voltage of broad range as well as high-gain provides better performances within the applications like integrators, general feedback, and summing amplifier applications. The inner recompense network ensures constancy within closed-loop circuits. [3]

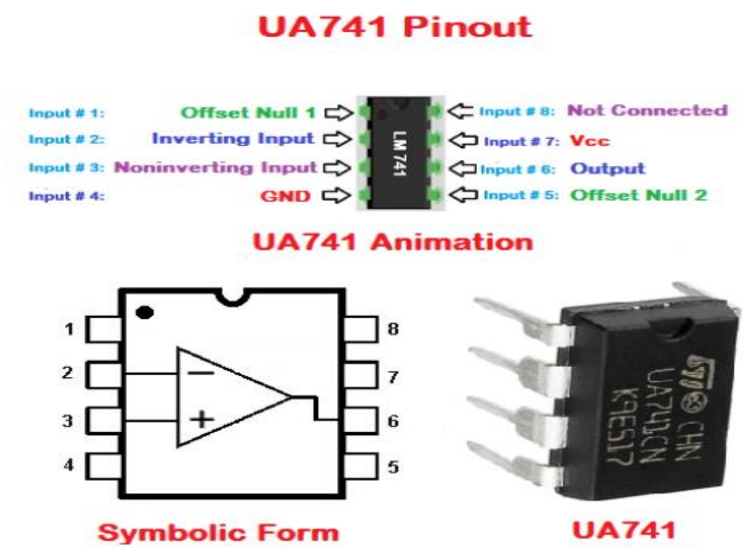


Figure 3: uA741

4- 2N3703 Transistor

The 2N3702 is a PNP Transistor with VCE of -25V and a collector current of 500mA. It can be used as a small signal switching transistor and any other small-signal application. It also has a low base voltage of -5V. [4]

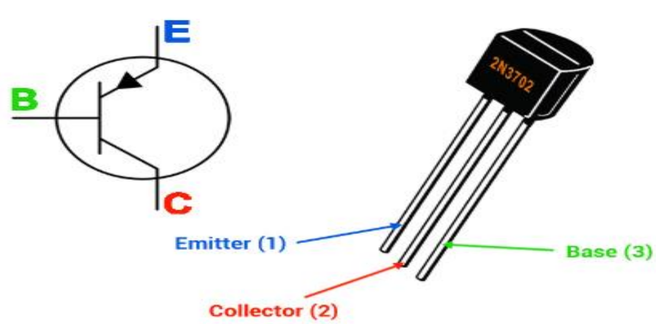


Figure 4: 2N3703 Transistor

5- Green LED

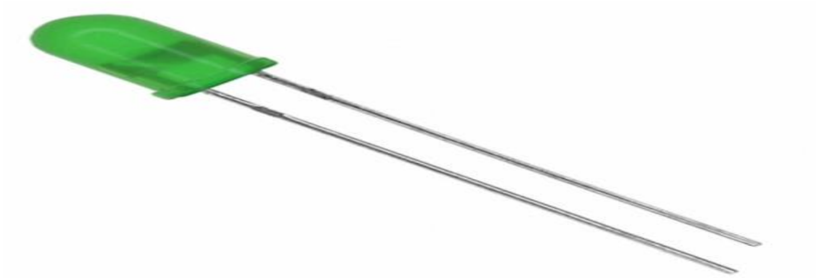


Figure 5: Green LED

In the simulation, we replace it with D1N4002.

6- D1N4002

It 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.

The 1N4002 can handle up to 100V reverse voltage and up to 1A of continuous current with a surge peak of 30A. The reverse current is 5uA which is negligible. And it can withstand reverse voltage peak up to 100V. [5]

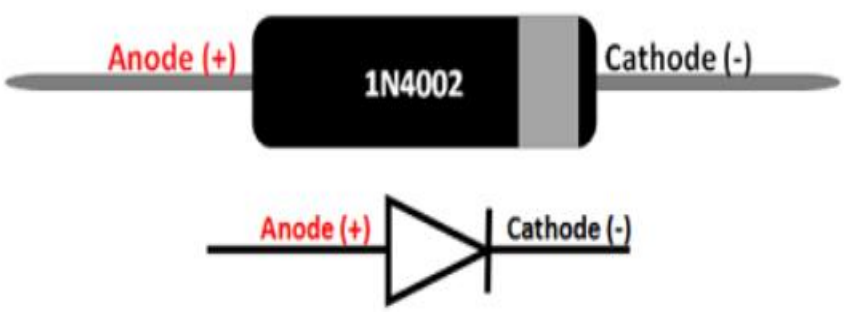


Figure 6: D1N4002

7- Resisters

The resistor is a passive electrical component that creates resistance in the flow of electric current. In almost all electrical networks and electronic circuits they can be found. The resistance is measured in ohms (Ω). [6]

Figure 7: a resistor

8- Potentiometer

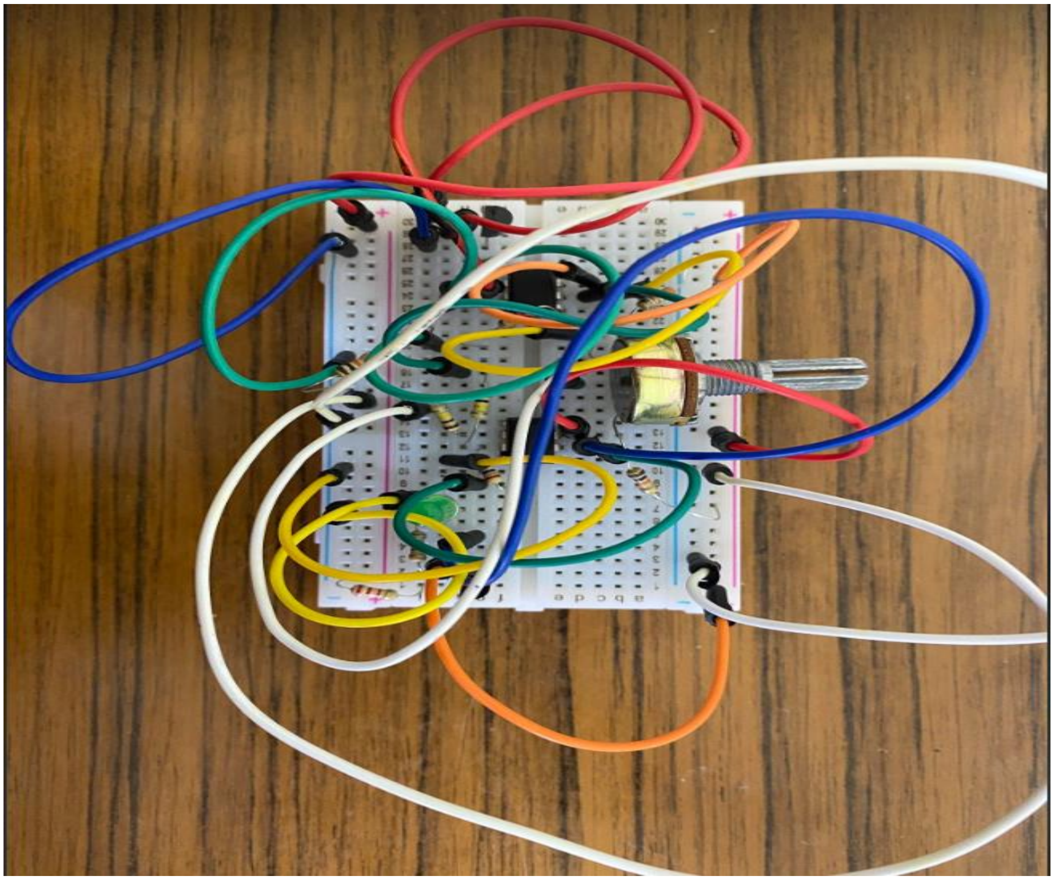
A potentiometer is a manually adjustable variable resistor with 3 terminals. Two of the terminals are connected to the opposite ends of a resistive element, and the third terminal connects to a sliding contact, called a wiper, moving over the resistive element. The potentiometer essentially functions as a variable resistance divider. The resistive element can be seen as two resistors in series (the total potentiometer resistance), where the wiper position determines the resistance ratio of the first resistor to the second resistor. If a reference voltage is applied across the end terminals, the position of the wiper determines the output voltage of the potentiometer. [7]

Figure 8: Potentiometer

Procedure

Part1 (Practical)

We built the circuit correctly. We had a discussion with the TA. Shadi about it. We had a problem in operating the circuit and most of our colleagues had it, because of the source of the components is the same, there was a defect in the work of the sensor.



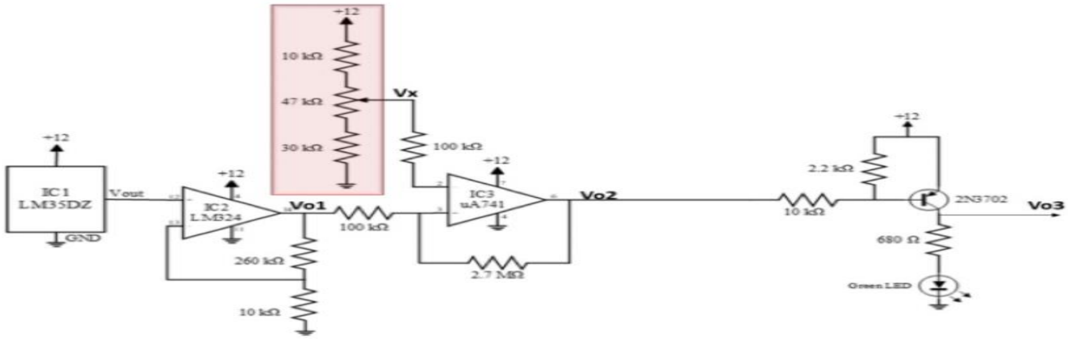


Figure 9: The circuit

Explanation of the function of the circuit of Fig. (9)

Firstly, the LM35DZ sensor gives us 10mv for every 1^{o}c, it has three pins, one of them connected to the ground, and the second pin connected to the +12volt, while the third pin connected to the positive input of the non-inverting amplifier.

Secondly, the LM324 is a non-inverting amplifier, the positive input connected to the output of the sensor, also it has a negative feedback resister, and it has the gain of 27. The output connected to the positive input of the Schmitt trigger comparator.

Thirdly, the uA741 is a Schmitt trigger comparator, the positive input connected to the output of the non-inverting amplifier, also it has a positive feedback resister. **If V (+) > V (-), then the output is +Vsat, otherwise, if V (+) < V (-), then the output is –Vsat.**

Finally, we have a pnp transistor, it has a collector, base and emitter. Also we have a green LED. If the output of the Schmitt trigger comparator is –Vsat then the transistor will be in saturation mode, and the green LED is on. While If the output of the Schmitt trigger comparator is +Vsat then the transistor will be in cutoff mode, and the green LED is off.

Part2 (Simulation circuits and results)

a- We replace the circuit to the left of Vx by a 6V battery.

b- We replace the green LED with D1N4002 which I mentioned above.

c- We replace the temperature sensor by a VPWL Voltage source as shown in Figure 10.

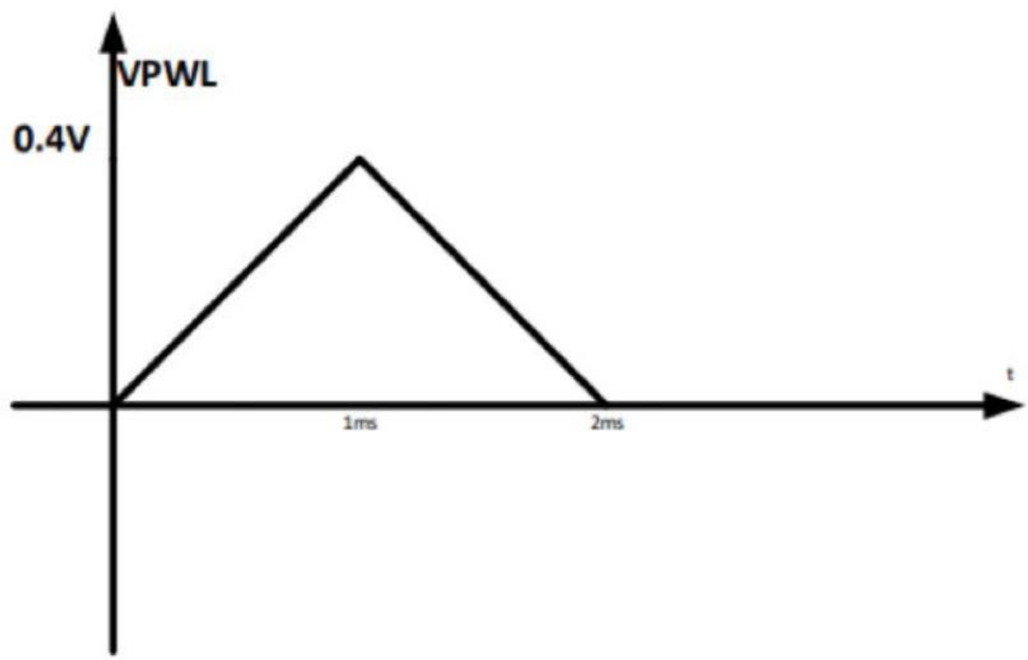
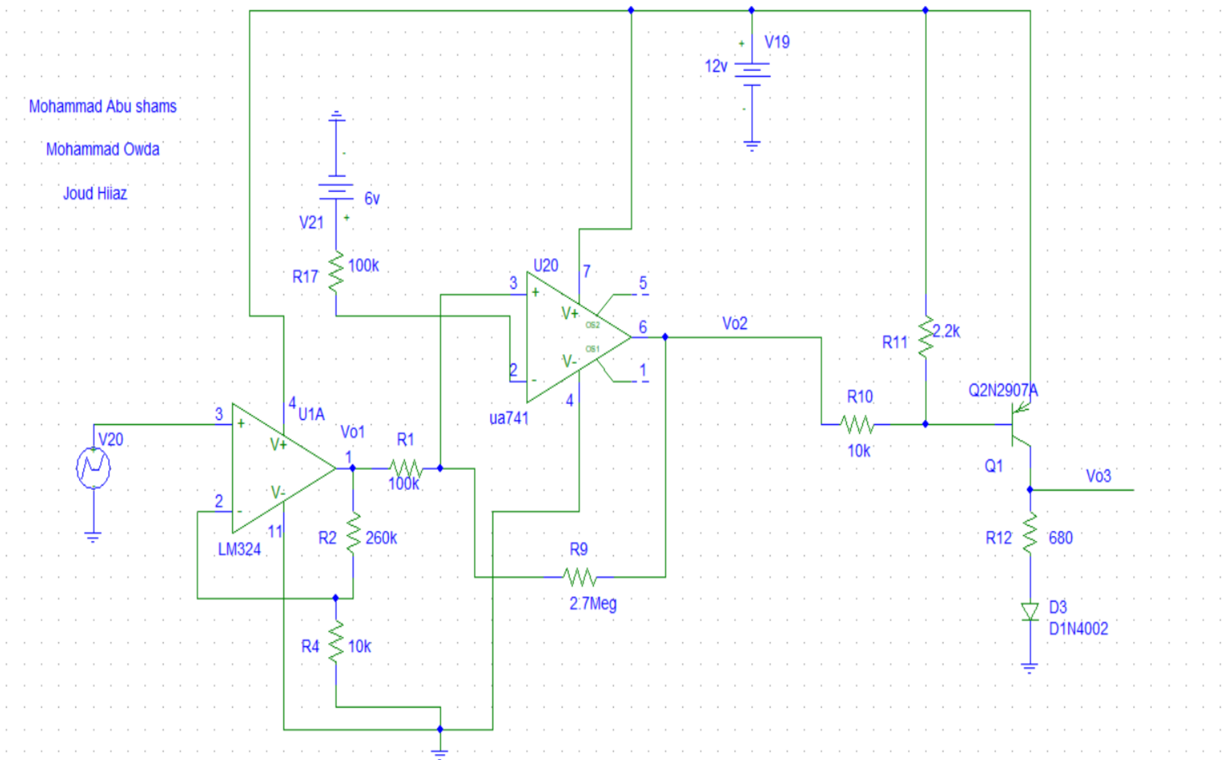


Figure 10: VPWL Voltage source

Then we built the circuit in the PSPICE:



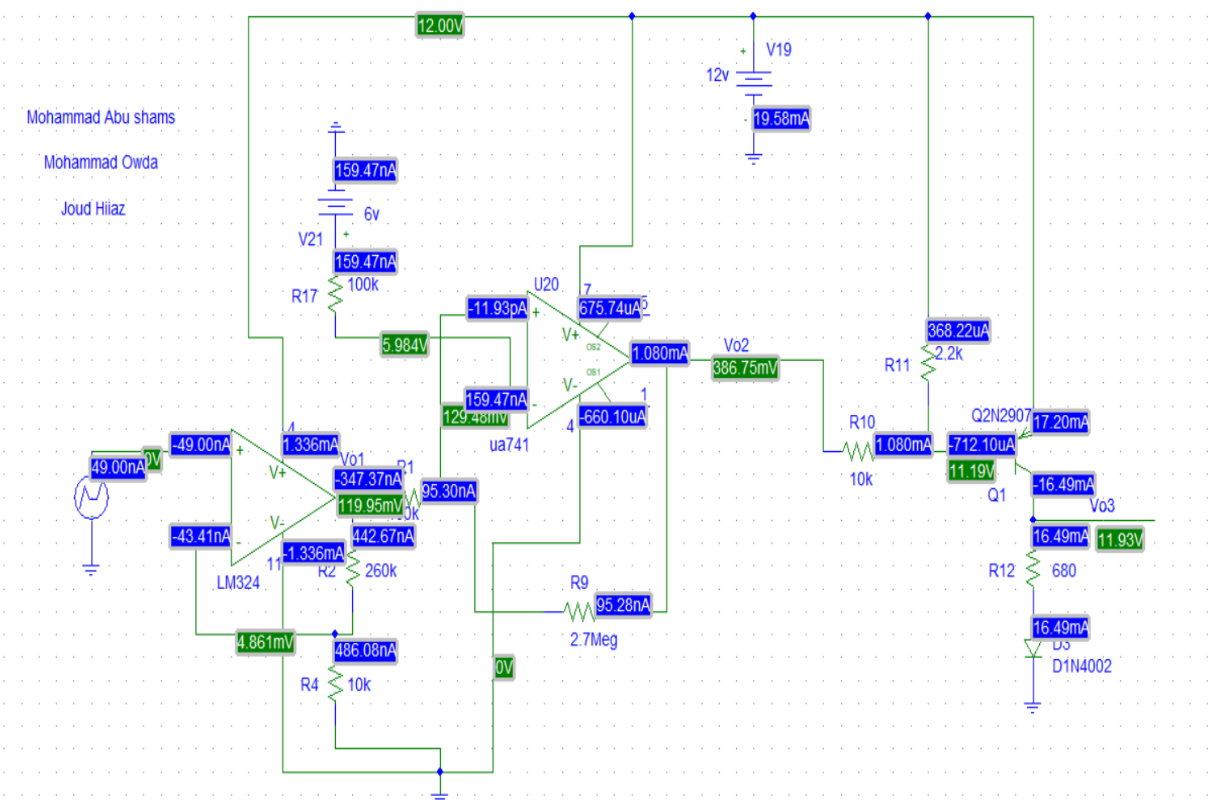


Figure 11: Simulation

We put the voltage marker on the output of the non-inverting amplifier and we plot Vo1:

Figure 12: Voltage marker

Vo1:

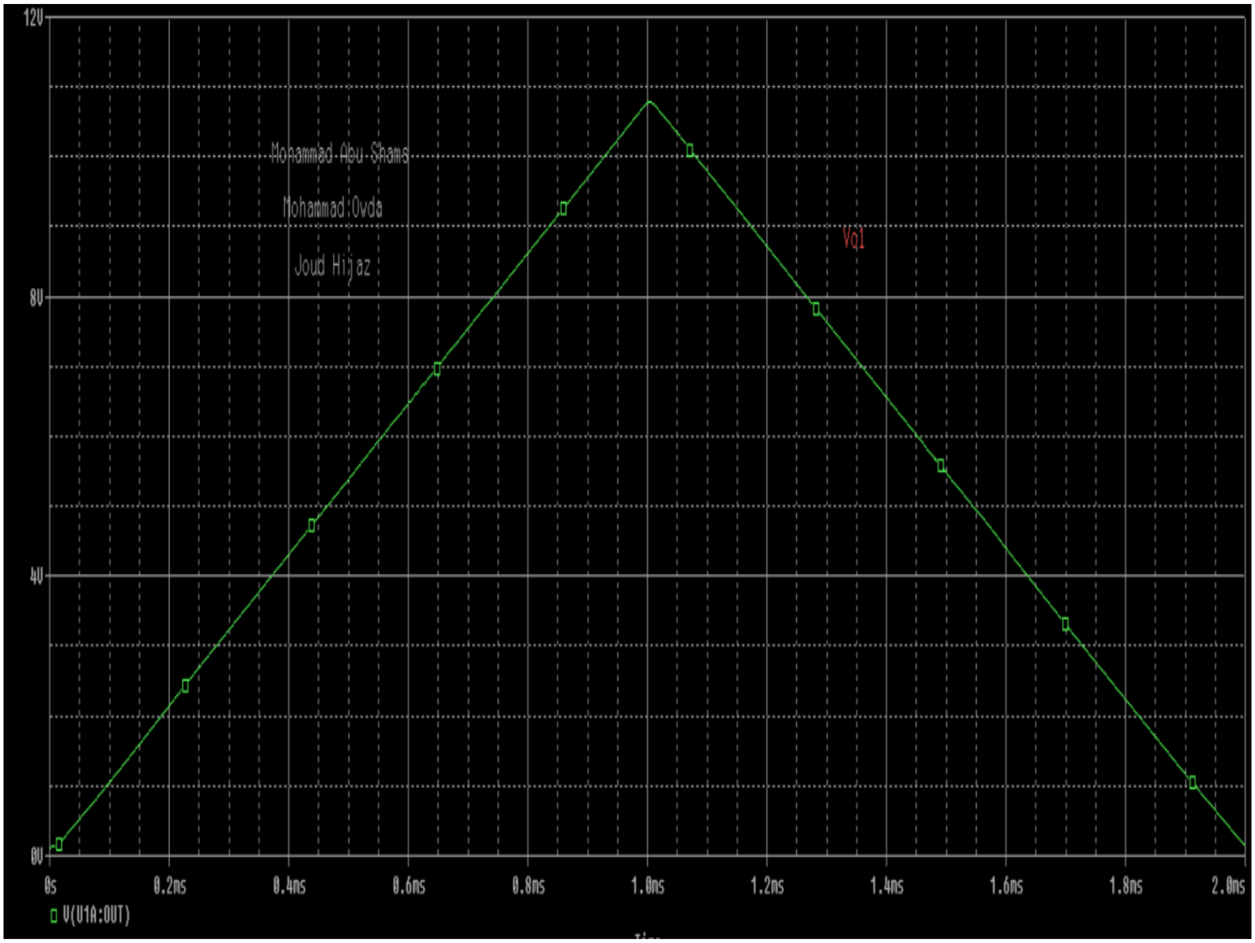


Figure 13: Plotting Vo1

Then we put the voltage marker on the output of the Schmitt trigger comparator and we plot Vo2:

Vo2:

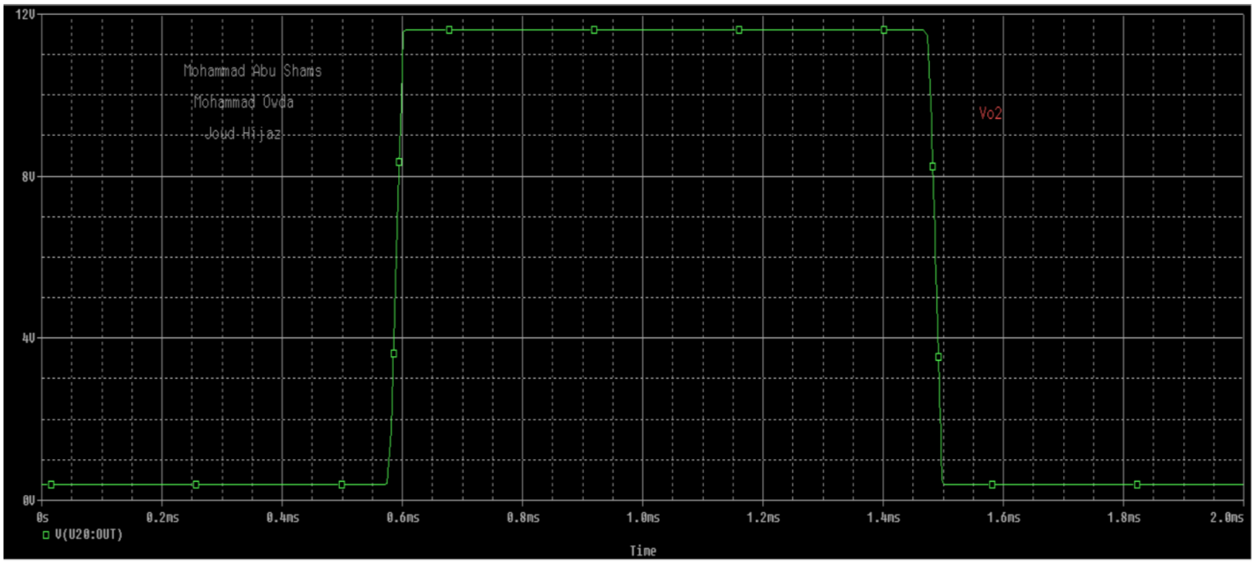


Figure 14: Plotting Vo2

Then we put the voltage marker on the collecter of pnp transistor and we plot Vo3:

Vo3:

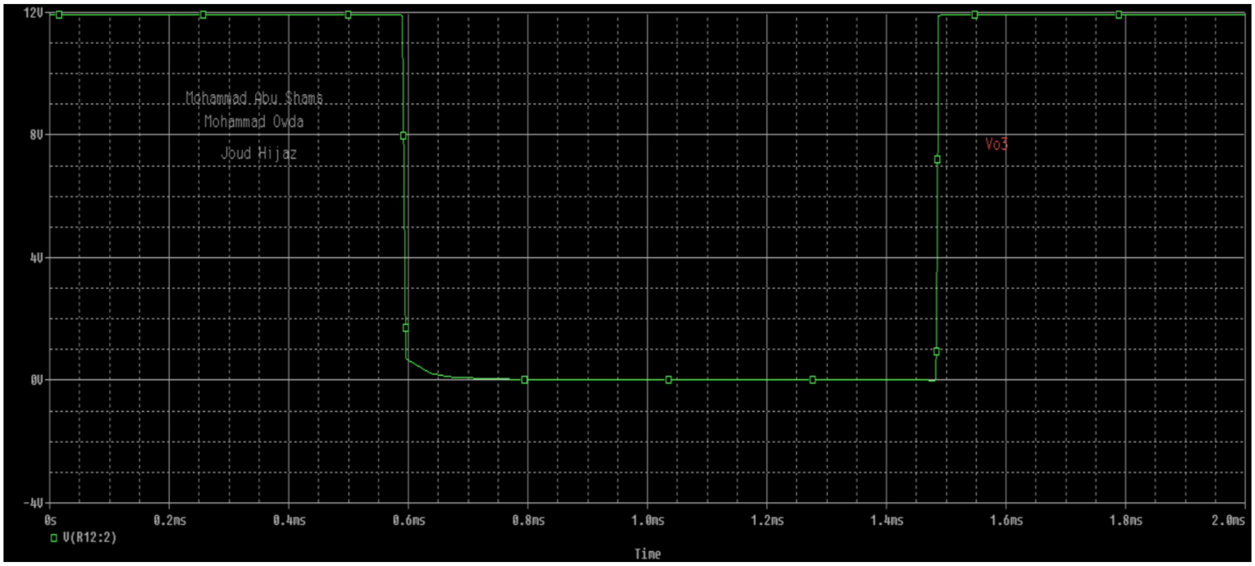
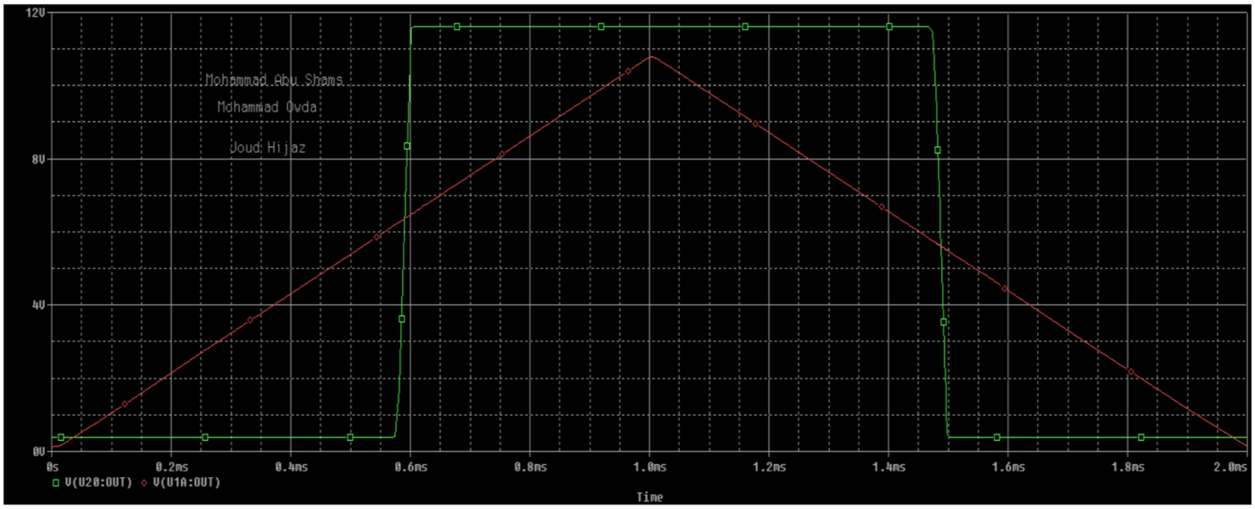
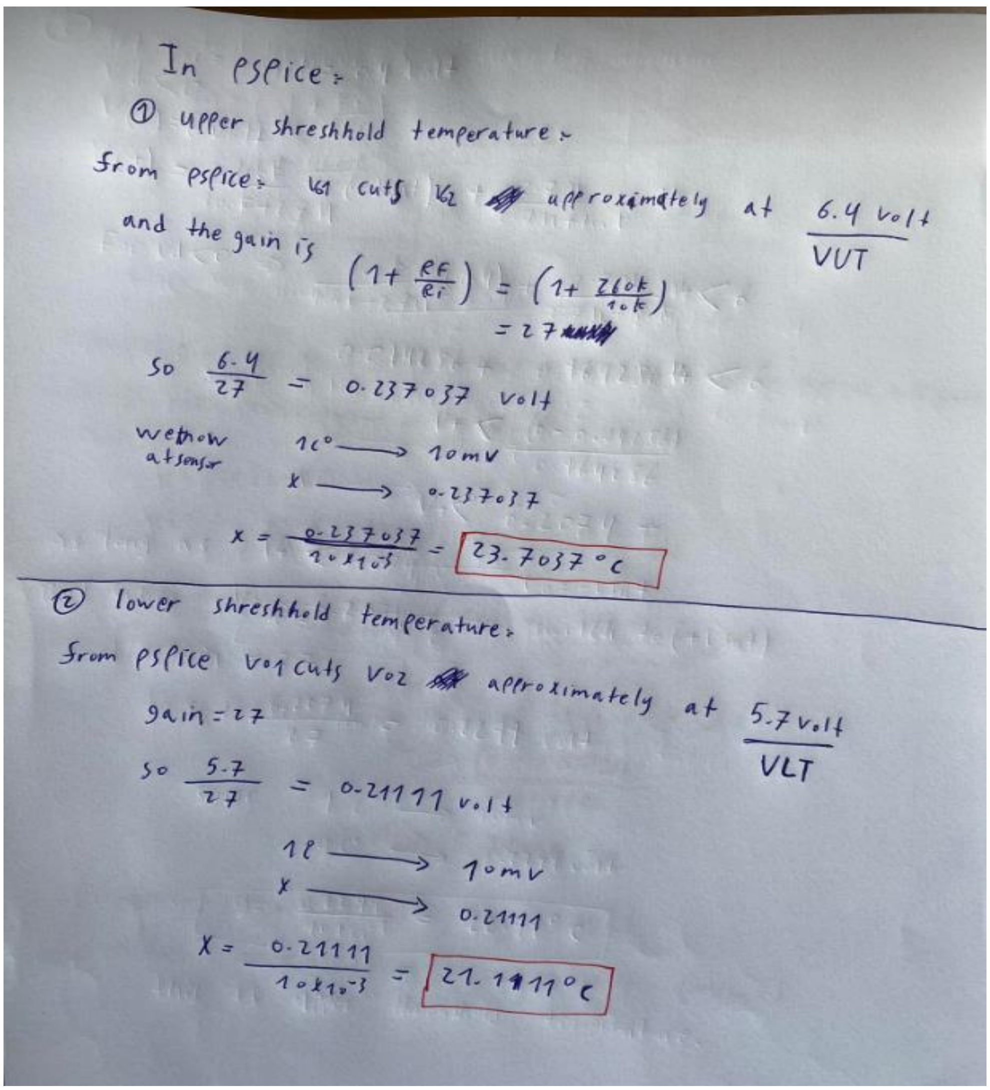


Figure 15: Plotting Vo3

d- Estimate the upper threshold and the lower threshold temperatures fromVo1 and Vo2(t) plots.





In pspice:

① upper shreshhold temperature:

from pspice: V_{o1} cuts V_{o2} approximately at $\frac{6.4\ \text{volt}}{VUT}$

and the gain is $\left(1+\frac{R_f}{R_i}\right) = \left(1+\frac{260k}{10k}\right)$

$= 27$

so $\frac{6.4}{27} = 0.237037$ volt

we know at sensor $1c° \longrightarrow 10mV$

$x \longrightarrow 0.237037$

$x = \frac{0.237037}{10\times10^{-3}} = \boxed{23.7037\ °c}$

② lower shreshhold temperature:

from pspice V_{o1} cuts V_{o2} approximately at $\frac{5.7\ \text{volt}}{VLT}$

gain = 27

so $\frac{5.7}{27} = 0.21111$ volt

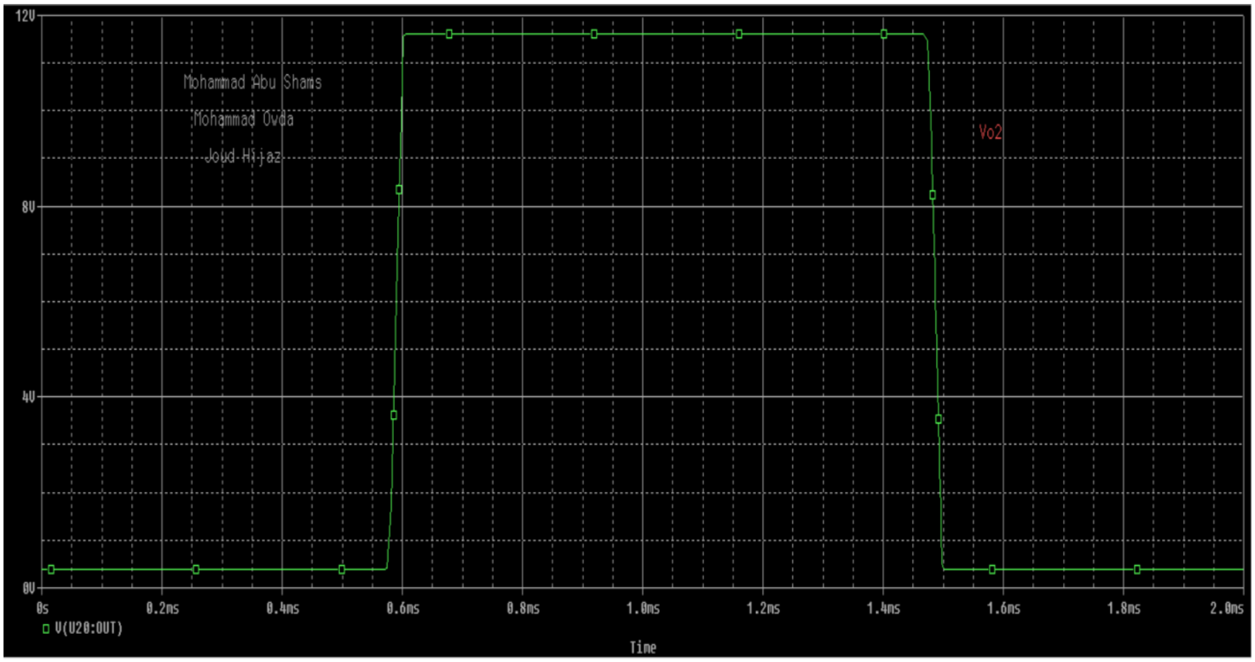
$1c \longrightarrow 10mV$

$x \longrightarrow 0.21111$

$X = \frac{0.21111}{10\times10^{-3}} = \boxed{21.1111\ °c}$

e- Determine $+\boldsymbol{Vsat}$ and $-\boldsymbol{Vsat}$.

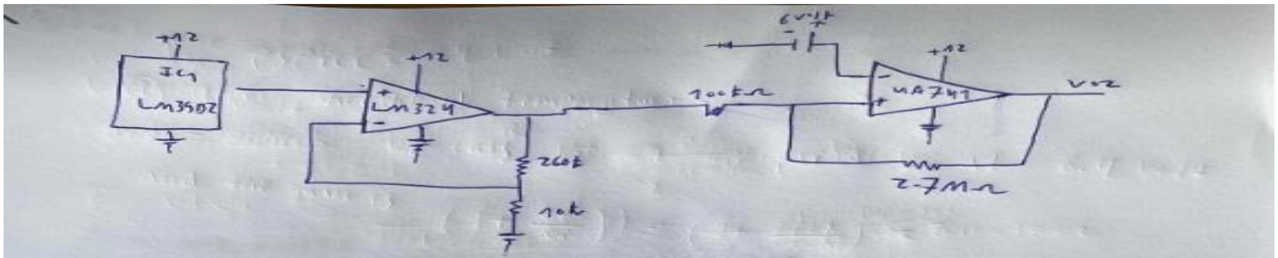
From the plotting of vo2:



+Vsat approximately equal 11.6 Volt

-Vsat approximately equal 0.4 Volt

f- Using results of part e, calculate by hand the upper threshold and the lower threshold temperature.



from Part e : we found that $+V_{sat} \approx 11.6$ volt and $-V_{sat} \approx 0.4$ volt

Now : ① let $V_{o2} = +V_{sat} = +11.6$ volt

$V_d > 0$

$V(-) = 6$ volt

$$V(+) = \frac{100k}{100k + 2.7M}(+V_{sat}) + \frac{2.7M}{2.7M + 100k} V+$$

For $V_d > 0$; $\Rightarrow$ $\frac{100k}{100k + 2.7M}(11.6) + \frac{2.7M}{2.7M + 100k} V+ > 6$

$V(+) > V(-)$

$$0.414286 + 0.964286\, V+ > 6$$

$$V+ > \frac{(6 - 0.414286)}{0.964286}$$

$$V+ > 5.79259\ v$$

As long as $V+ > 5.79259$; $V_o = +V_{sat}$

But when $\boxed{V+ < 5.79259}$; V_o switch to $(-V_{sat})$

VLT

Now we find the gain of Non inverting Amplifier

$$\text{Gain} = \left(1 + \frac{R_F}{R_i}\right)$$

$$= 1 + \frac{260k}{10k}$$

$$= 27$$

Now we divide $\frac{5.79259}{27} = 0.21454$ volt

Since in the sensor : 1° leads to 10mV

$1° \longrightarrow 10mV$

$x° \longrightarrow 0.21454$

$$x = \frac{0.21454 \times 1}{10 \times 10^{-3}} = 21.45°C$$

this is the lower threshold temperature.

2 let $V_{o2} = -V_{sat} = 0.4$ volt

$V_d < 0$

$V(-) = 6$ volt

$$V(+) = \frac{100k}{100k+2.7M}(-V_{sat}) + \frac{2.7M}{2.7M+100k} V_+$$

For $V_d < 0 \Rightarrow$
$V(+) < V(-)$

$$\frac{100k}{100k+2.7M}(0.4) + \frac{2.7M}{2.7M+100k} V_+ < 6$$

$$0.014286 + 0.964286\, V_+ < 6$$

$$V_+ < \frac{(6 - 0.014286)}{0.964286}$$

$$V_+ < 6.2074\ V$$

As long as $V_+ < 6.2074\ V$, $V_o = -V_{sat}$

But when $V_i > \underset{V_{UT}}{\boxed{6.2074}}$, v_o switch to $(+V_{sat})$

the Gain $= 27$

So $\frac{6.2074}{27} = 0.2299$ volt

Since $1\ C^\circ \longrightarrow 10\ mV$

$y\ C^\circ \longrightarrow 0.2299$ volt

$$\boxed{y = \frac{0.2299}{10 \times 10^{-3}} = 22.99^\circ C}$$

this is upper threashold temperature.

Comparison of simulation results to hand calculation

1- Vo1 from PSPICE approximately equal 10.8 volt.

And from hand calculations it is the same:

$$V_{o1} = \left(1 + \frac{R_f}{R_i}\right) V_+ \quad \text{(non-inverting)}$$
$$= \left(1 + \frac{260k}{10k}\right) \times 0.4$$
$$= (1+26) \times 0.4$$
$$= 27 \times 0.4$$
$$= 10.8 \text{ Volt}$$

2- Vo2 from PSPICE:

+Vsat approximately equal 11.6 Volt.

–Vsat approximately equal 0.4Volt.

When **Vd>0 (V(+) > 6)**Volt the output is +Vsat … and When **Vd<0 (v(+) <6)** Volt The output is –Vsat.

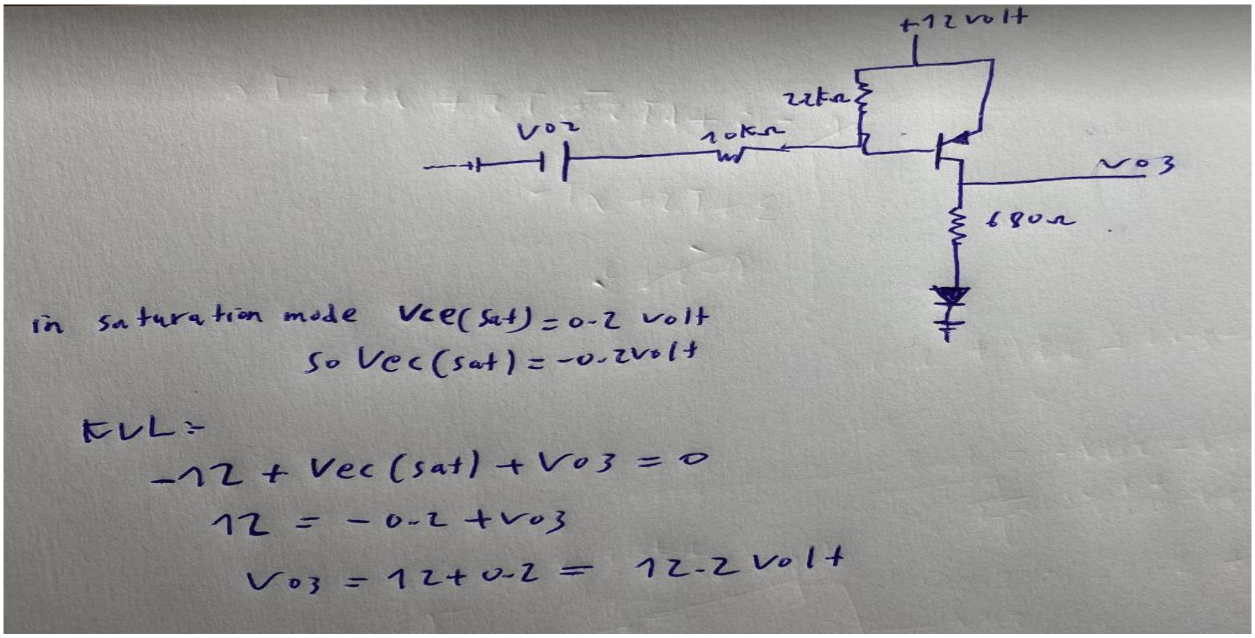
$$+V_{sat} = V_{cc} - 2$$
$$= 12 - 2 = 10 \text{ Volt}$$

$$-V_{sat} = -V_{cc} + 2$$
$$= -0 + 2 = 2 \text{ Volt}$$

And from hand calculations the different between them is 1.6 Volt.

3- Vo3 from PSPICE approximately equal 11.9 when the Vo2 is –Vsat, and approximately equal 0 when Vo2 is +Vsat.

When the Vo2 is –Vsat, then the transistor is in saturation mode and the Vo3 equal 12.2 volt from hand calculations:



Also When the Vo2 is +Vsat, then the transistor is in cutoff mode and the Vo3 equal 0 volt because Ic =0 in cutoff mode

Vo3=Vc=IcRc= 0 Volt.

Conclusion

In conclusion, we learnt how to build a room thermostat circuit, and we know about circuit's components, and how each components work, and we know the datasheet of them. We learnt how to simulate the circuit in PSPICE. We became able to find Vo1 and Vo2 and Vo3, and find the upper and lower threshold temperature. The result in PSPICE is closer to the result by hand calculations, that's mean our results is true.

Feedback

This project is a nice one, we learnt some new ideas in Analog electronics and we became more familiar with PSPICE.

References

[1] ANALOG LM35DZ. (2023, 2 9). Retrieved from https://cpham.perso.univ-pau.fr/LORA/HUBIQUITOUS/solution-lab/arduino-lora-tutorial/sensors/temperature/lm35/?fbclid=IwAR0m1YGBRncwAUpSOZ5jp2VIlMsyyY29Ymiwu4bjiUsOU3OLb48bFQeFn1g#:~:text=The%20LM35DZ%20is%20an%20integrated,and%20not%20subject%20to%20oxida

[2] LM324 IC Pin Configuration and Its Applications. (2023, 2 9). Retrieved from https://www.elprocus.com/lm324-ic-pin-configuration-and-its-applications/?fbclid=IwAR3dpAz3GPV_AZSITVZgFEo5cPPI54BLuxnGThu4mi3OG9HFwMYHe491sEk

[3] UA741 IC: Pin Configuration, Circuit Diagram and Applications. (2023, 2 9). Retrieved from https://www.elprocus.com/ua741-ic-op-amp-pin-configuration-specifications/?fbclid=IwAR28tVJE_ThHPHjj7543E6HnIJUNXbRTfrlREoCTyIue7ckSx0j-gtS-_-0

[4] 2N3702 Transistor. (2023, 2 9). Retrieved from https://components101.com/transistors/2n3702-transistor-pinout-datasheet-equivalent-circuit-specs?fbclid=IwAR3RaYHoOzhjw7vqW3oEgnkObwwnKyOSG7zkWMkFn0_8qEuBDir7yb_XxZI#:~:text=The%202N3702%20is%20a%20PNP,low%20base%20voltage%20of%20%2D5V

[5] 1N4002 Diode. (2023, 2 9). Retrieved from https://www.utmel.com/components/1n4002-diode-pinout-datasheet-and-equivalents?id=318&fbclid=IwAR1MHS_J-djHDInnyxQGOCa4C6ySmQy3yib-mEP2sEJPlroFuSVpd8j92qc

[6] Resistor. (2023 , 2 9). Retrieved from https://eepower.com/resistor-guide/resistor-fundamentals/what-is-a-resistor/?fbclid=IwAR0aoUaQhzYZ_7pF0_tm_57sK7K2mC7nJbHqKPLjdM9AJlpg6YF2et1jJtA#

[7] Potentiometer. (2023, 2 9). Retrieved from https://eepower.com/resistor-guide/resistor-types/potentiometer/?fbclid=IwAR0YggOGX_dVovJKFXLKKgDE248iptspyVDcEaAPnRGD7XP7EcZLs3nuMf8