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Department of Electrical & Computer Engineering

Analog electronics

Report No.2

ENEE2360

Student’s Name & ID :

Rama Abdlrahman (1191344)

Instructor: Mohammad Jehad Al Ju'Beh

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Abstract :

In this project , we will complete a design of room thermostat using important electronic devices like Schmitt trigger comparator , transistor, diode (led), and learning how they work. And we will show the simulation of the design, and will compare results and find a conclusion.

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Theory

Room Thermostat

Room thermostat which is used to control heating has been one of the common device used in residential and industrial buildings to control the temperature of a space in a room or an office. It is basically consists of a comparator that controls the ON and OFF of the circuit based on the sensor temperature.

The temperature range of thermostat here is from 26 °C to 28 °C. The LM358 Op Amp is used as a comparator to sense the inputs of the reference voltage and room temperature .

When the room temperature increases than Vut, the thermistor resistance will drop and hence the output of the operational amplifier will be high. This cause transistor to turn off and the led is turn off. And when the room temperature decreasing than VLt, the output of the operational amplifier will be low. This cause transistor to turn on and the led is turn on.

The problem :

Complete the design of the room thermostat to keep the room temperature between two threshold temperatures TH (28 ºC) and TL (26 ºC)

a) Determine by calculation the values of R1 , R2, and R3 .(Consider that +Vsat= 11.6V And –Vsat = 0.4V)

b) Using PSPICE ,determine Vx,Vo1,Vo2, Vo3, and the status of (the BJT and the diode) at T = 8 ºC and T =32 ºC (Vout = 0.08V and Vout = 0.32V)

c) Using PSPICE, plot Vo2(t) as the temperature increases from 8 ºC to 32 ºC . (replace the temperature sensor by VPWL piece wise linear voltage source).

d) Using PSPICE, plot Vo2(t) as the temperature decreases from 32 ºC to 8 ºC. (in pspice replace the temperature sensor by VPWL or Vpulse voltage source).

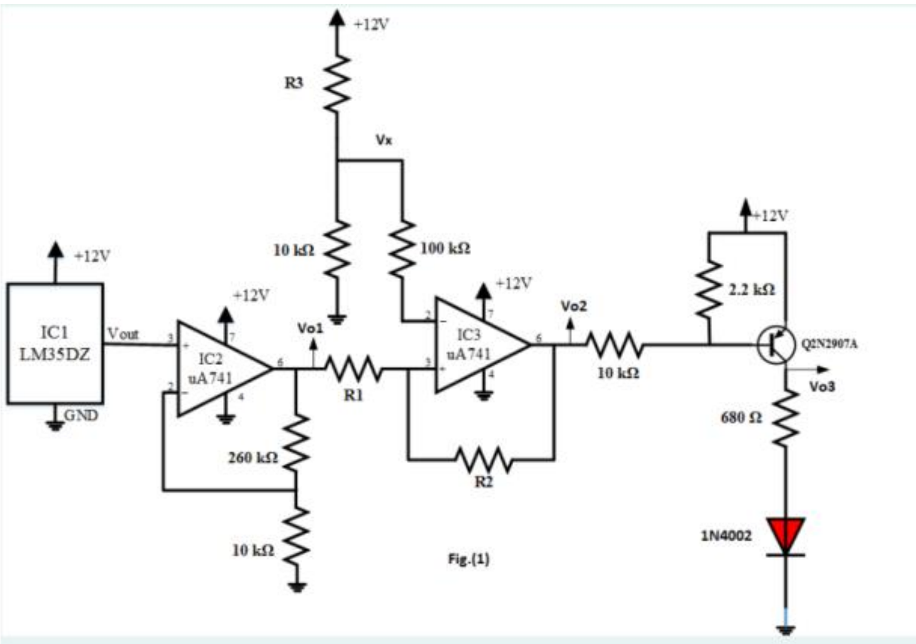

Figure 1 the problem

The calculations of R1,R2,R3

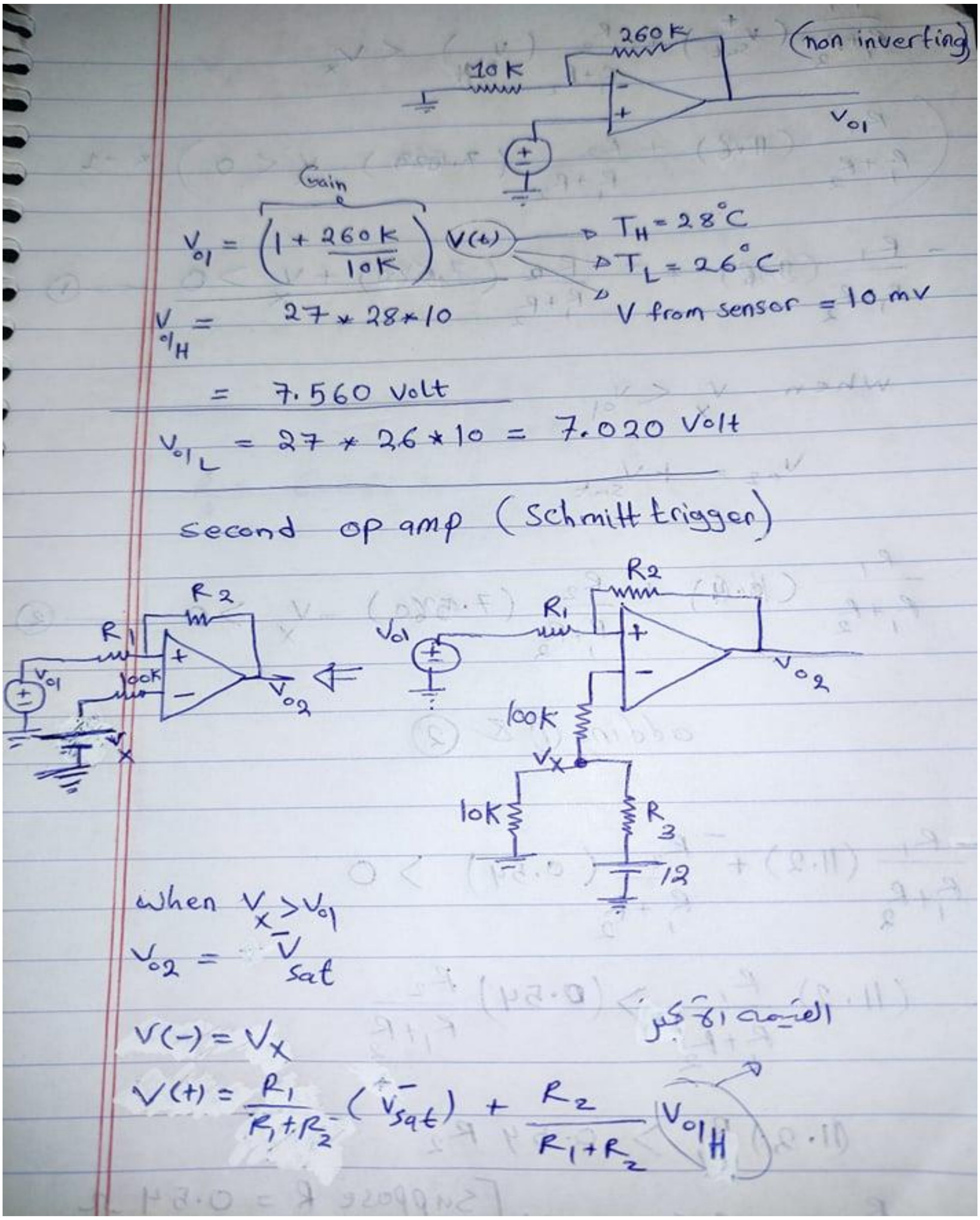

Figure 2 calculations

$$\frac{R_1}{R_1+R_2}(V_{sat}^-) + \frac{R_2}{R_1+R_2}(V_{o1_H}) < V_x$$

$$\left(\frac{R_1}{R_1+R_2}(0.4) + \frac{R_2}{R_1+R_2}(7.560) - V_x < 0\right) \times -1$$

$$-\frac{R_1}{R_1+R_2}(0.4) + -\frac{R_2}{R_1+R_2}(7.560) + V_x > 0 \quad \text{—— ①}$$

when $V_x < V_{o1}$

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

$$\frac{R_1}{R_1+R_2}(11.6) + \frac{R_2}{R_1+R_2}(7.020) - V_x > 0 \quad \text{—— ②}$$

adding ① & ②

$$-\frac{R_1}{R_1+R_2}(11.2) + -\frac{R_2}{R_1+R_2}(0.54) > 0$$

$$(11.2)\frac{R_1}{R_1+R_2} > (0.54)\frac{R_2}{R_1+R_2}$$

$$(11.2)R_1 > 0.54\,R_2$$

$$\frac{R_1}{R_2} = \frac{0.54}{11.2}$$ ⟶ [suppose $R_1 = 0.54\ \Omega$ then R_2 will be $11.2\ \Omega$

Figure 3 cont. calculations

$$V_x = \left(\frac{10}{10+R_3}\right)(12)$$

Suppose :- $V_x = \frac{V_{o,H} + V_{o,L}}{2}$

$$= \frac{7.560 + 7.020}{2}$$

$$= 7.29 \text{ Volt}$$

So, $7.29 = \left(\frac{10}{10+R_3}\right)(12)$

$R_3 = 6.461\ \Omega$

Figure 4 cont.. calculations

- So, I found above the values of R1,R2,R3.

  R1=0.54 OHM

  R2=11.2 OHM

  R3=6.461 OHM

Values Vx,Vout1&2&3 at T = 8 oC

determine Vx,Vo1,Vo2, Vo3, and the status of (the BJT and the diode) at T = 8 ∘C (Vout = 0.08V)

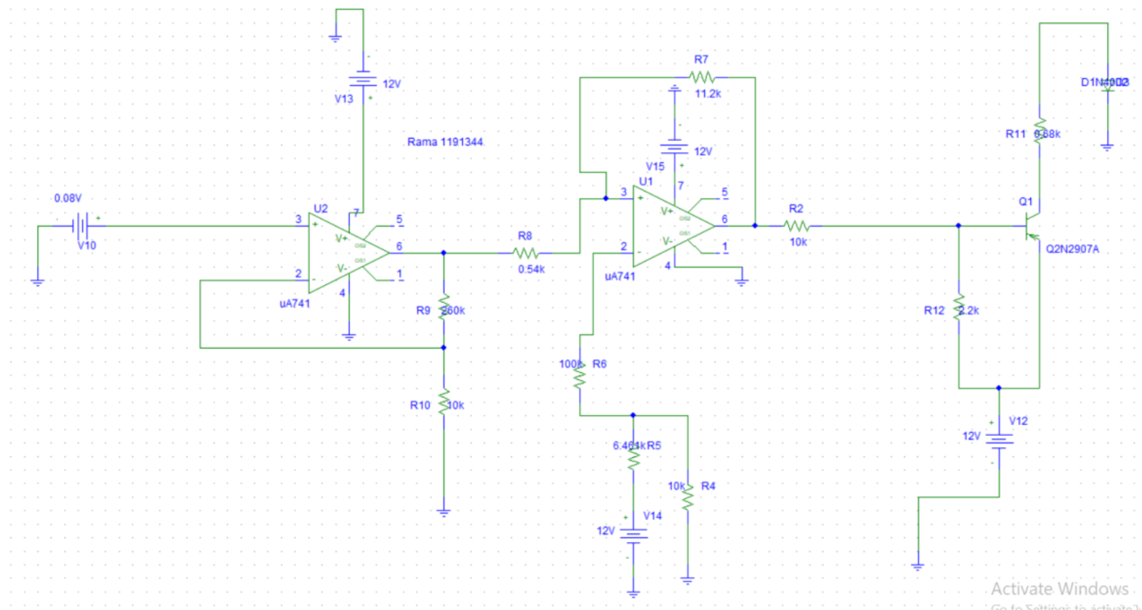

Figure 5 part b (1)

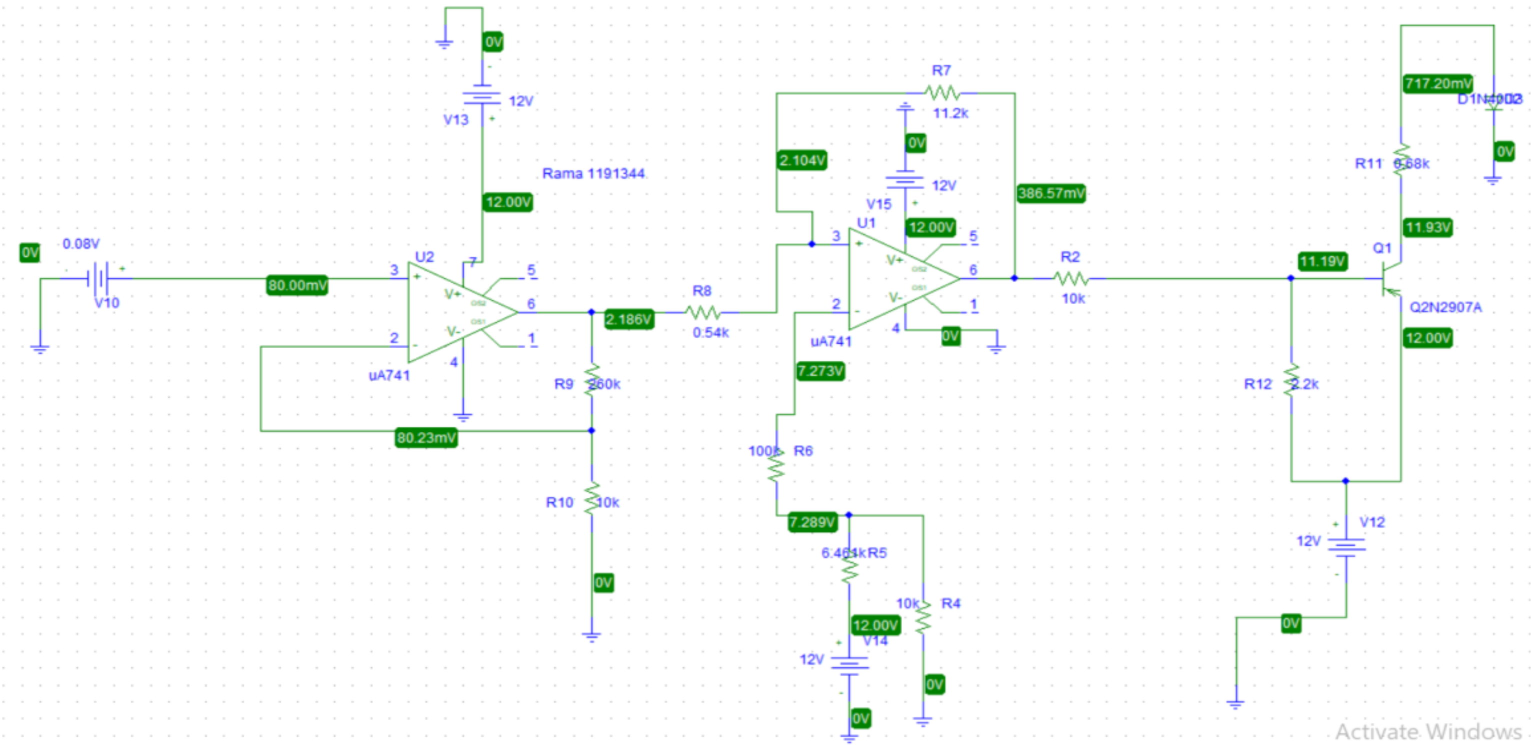

Figure 6 part b (1) determining voltages on design so from design in pspice we notice that :

vx=7.289v , vo1= 2.186v, vo2= 386.57mv , vo3= 11.93v

About BJT and diode :

transistor is PNP junction, Ve=12v , Vb=11.19, Vc=11.93, Vcb =0.07(Revese biased), Veb= 0.74(forward biased), so transistor is in active region, it is working , and current flow through diode , so diode on.

Or we can just look at the voltage on anode of diode :

the voltage that enter the diode (voltage on anode) is 717.20mv (shown in figure bellow) , it is high enough, so diode on , and because diode will not work unless BJT is on (in active mode), so BJT is workig. BJT works (active) and diode on .

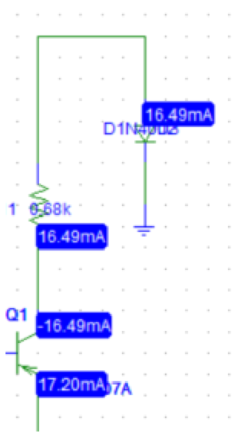

Figure 7 current flow through diode , diode on

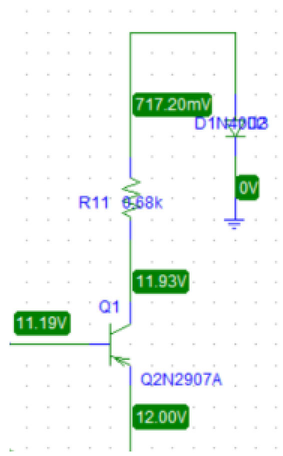

Figure 8 voltage on avode is high, diode on

Values Vx,Vout1&2&3 at T = 32 oC

determine Vx,Vo1,Vo2, Vo3, and the status of (the BJT and the diode) at T =32 ºC (Vout = 0.32V)

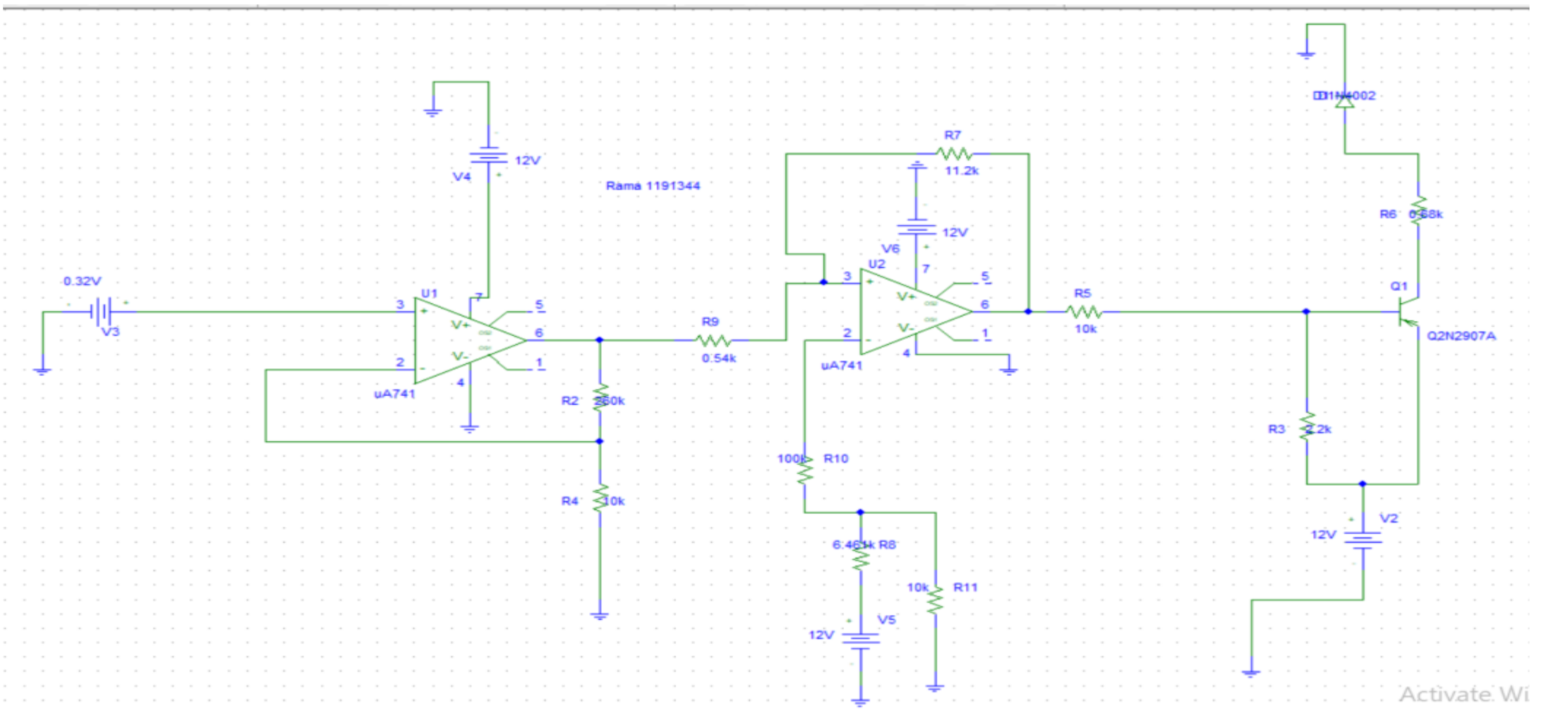

Figure 9 part b (2)

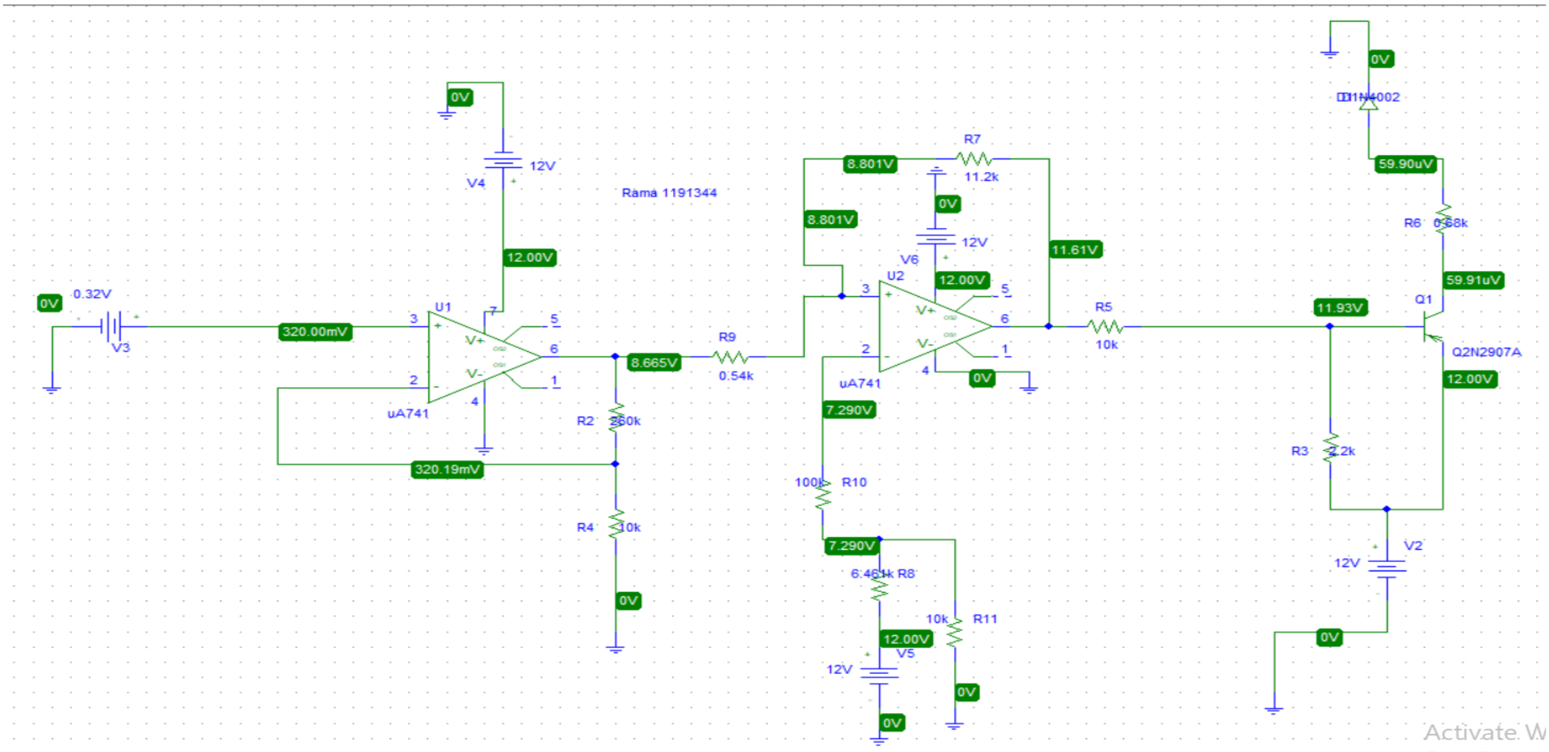

Figure 10 part b (2) determining voltages on design so from design in pspice we notice that :

vx=7.290v , vo1= 8.665v, vo2= 11.61v , vo3= 59.91uv

about BJT and diode :

transistor is PNP junction, Ve=12v , Vc=59.91uv, Vb=11.93v, Vcb (Revese biased), Veb nearly (reversed biased), so transistor is in cut off region, it is not working , and current doesn’t flow through diode(current flowing through diode nearly zero) , so diode off.

Or we can just look at the voltage on anode of diode :

the voltage that enter the diode (voltage on anode) is 59.90uv (shown in figure 12) , it is very low, so diode off , and because diode will not work unless BJT on (in active mode) so BJT is not workig.BJT doesn’t work and diode off.

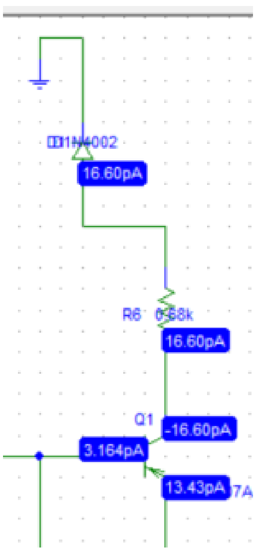

Figure 11 nearly no current flow through diode , diode off

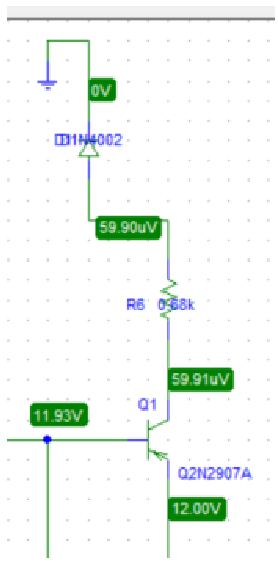

Figure 12 voltage on avode is very small, diode off

Increasing & Decreasing of tempreture (part C&D of project)

Ploting Vo2(t) as the temperature increases from 8 ºC to 32 ºC and as the temperature decreases from 32 ºC to 8 ºC. (I replaced the temperature sensor by Vpulse voltage source).

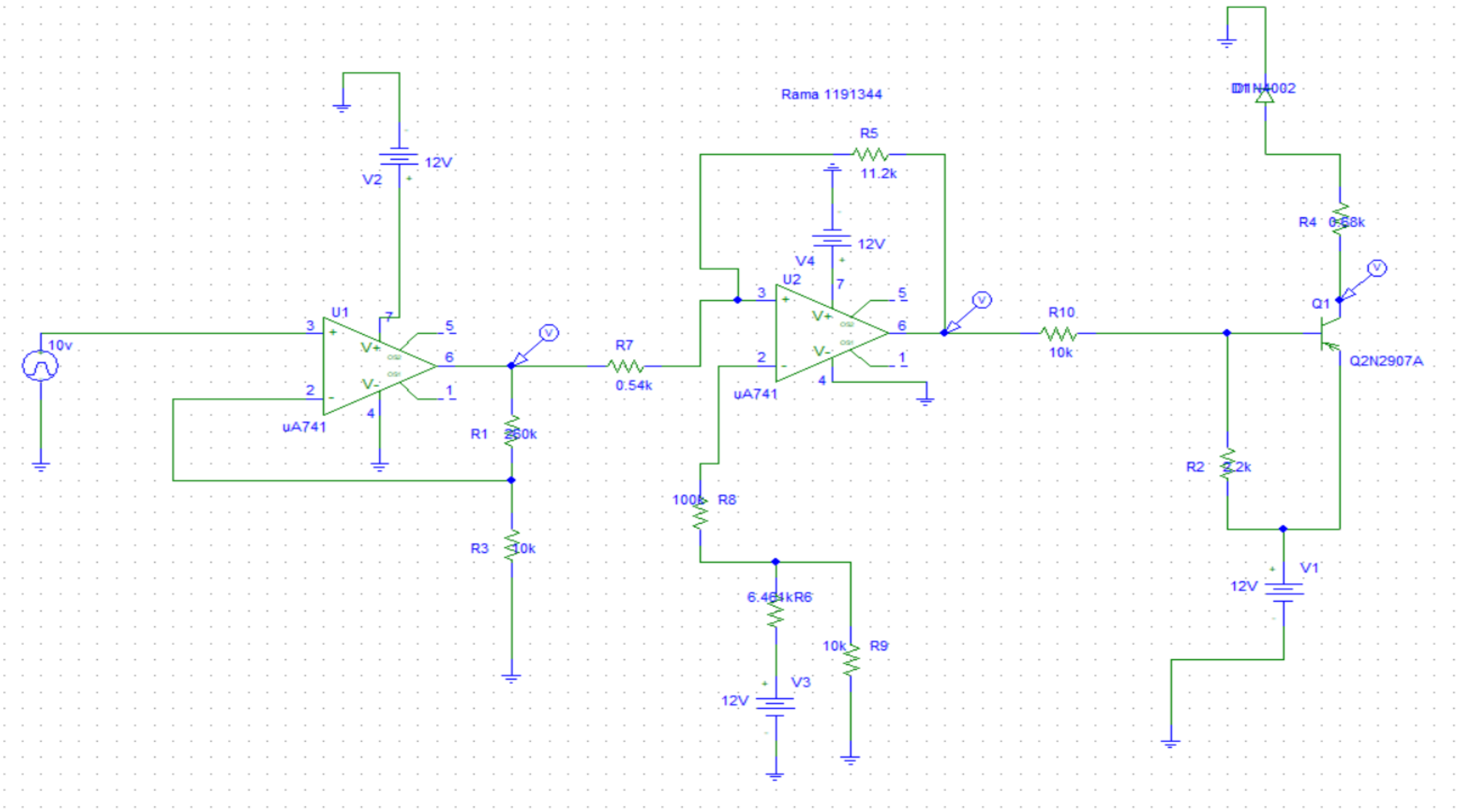

Figure 13 the design of last two parts using Vpulse

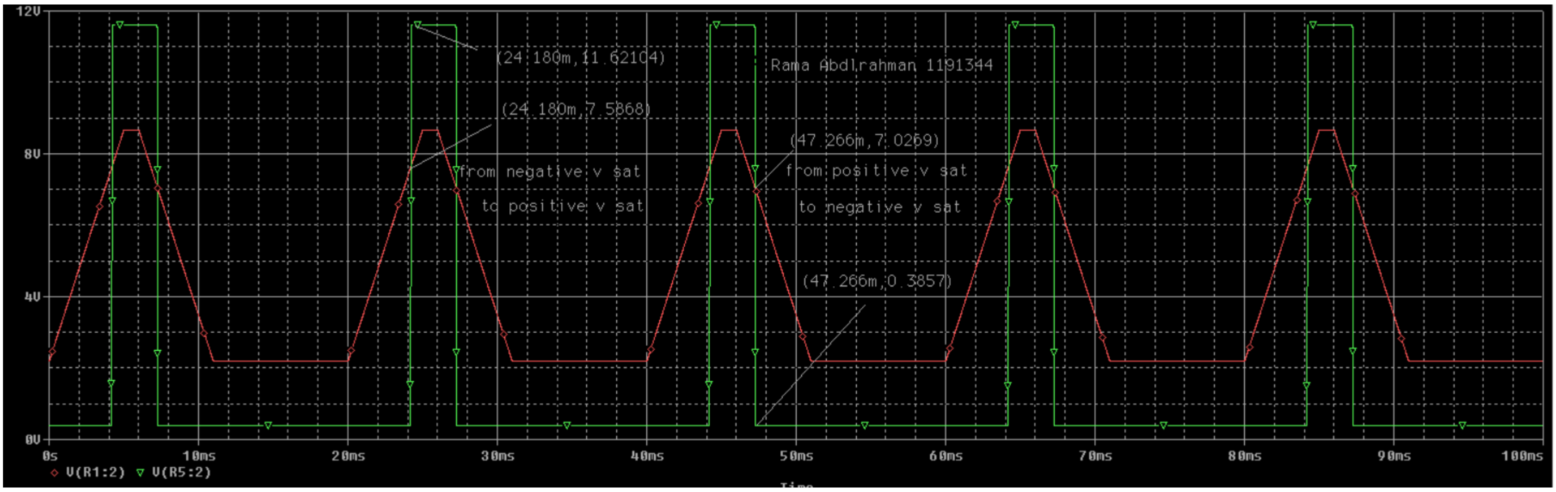

Figure 14 simulation of last two parts of project

The red wave shoes the output of non inverting op amp (vo1).

The green wave shoes the output of schmitt trigger (vo2).

On figure 14 , I determined the point where vo2 increase from –vsat to +vsat , and the point where vo2 decrease from +vsat to –vsat.

The values on simulation(+vsat,-vsat, vo1 upper threshold, vo1 lower threshold) are nearly the same of the values I have theoretically .

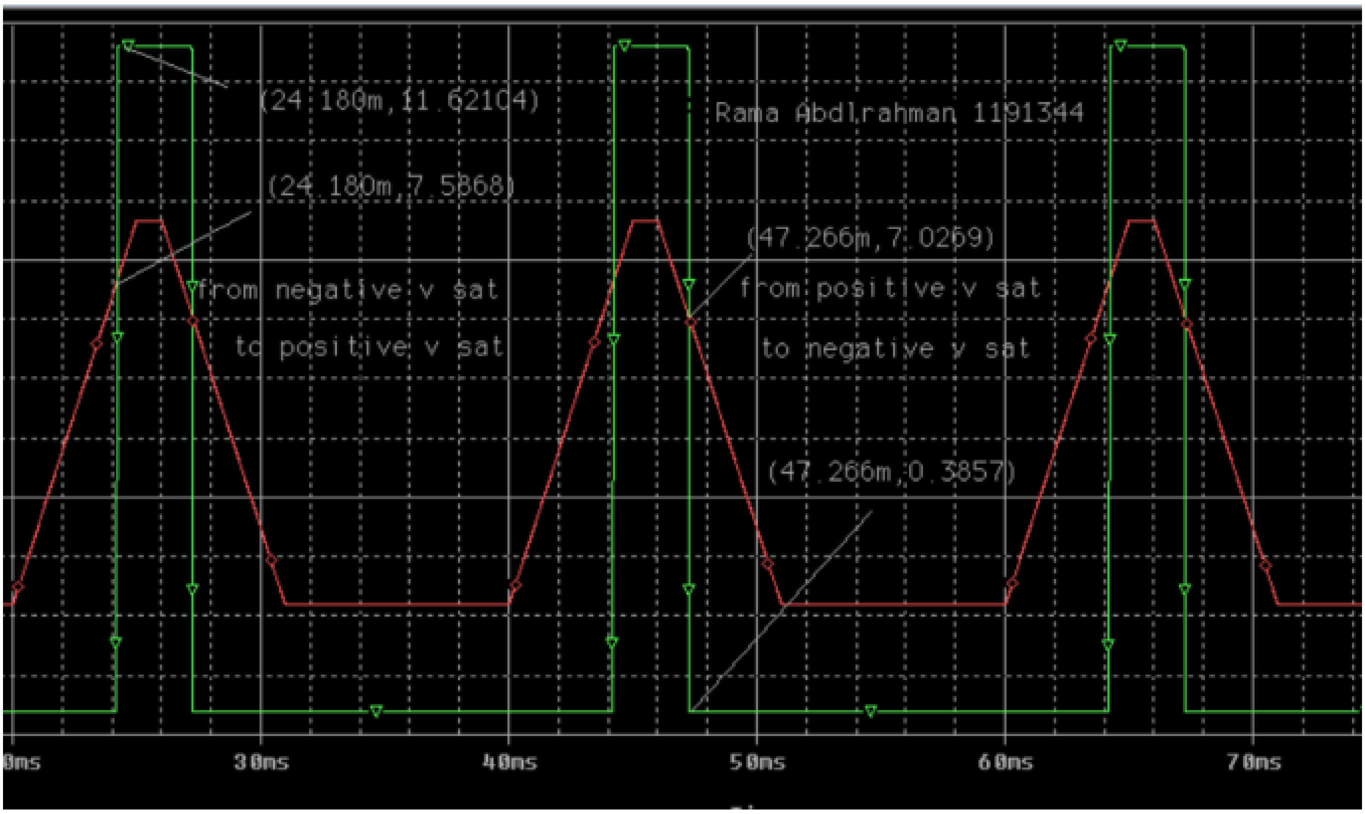

Figure 15 zoom in the previous figures to see the points clearly

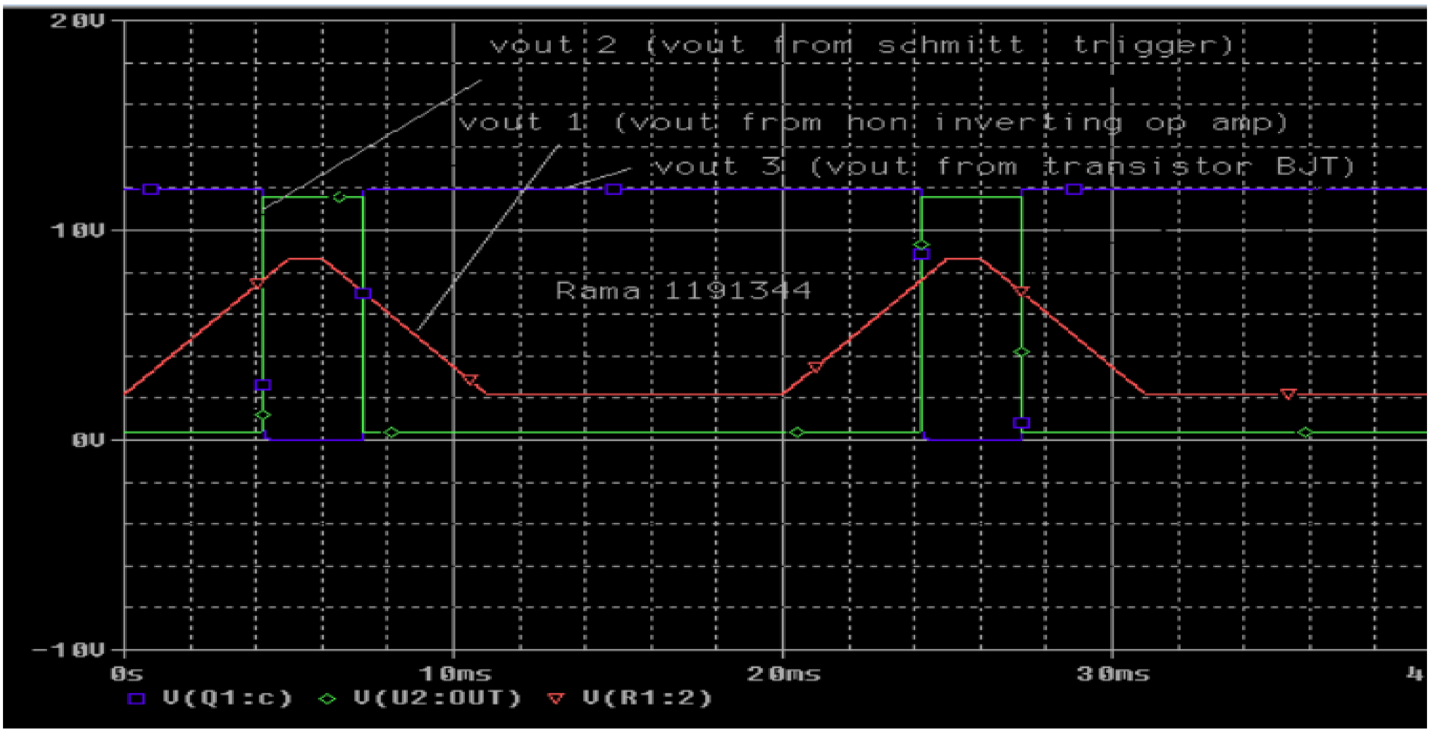

Figure 16 zoom in the figure of the simulation of vo1,vo2,vo3

- We have here another wave (blue wave), which shows vo3, the output of transistor (the voltage which will move through the diode).

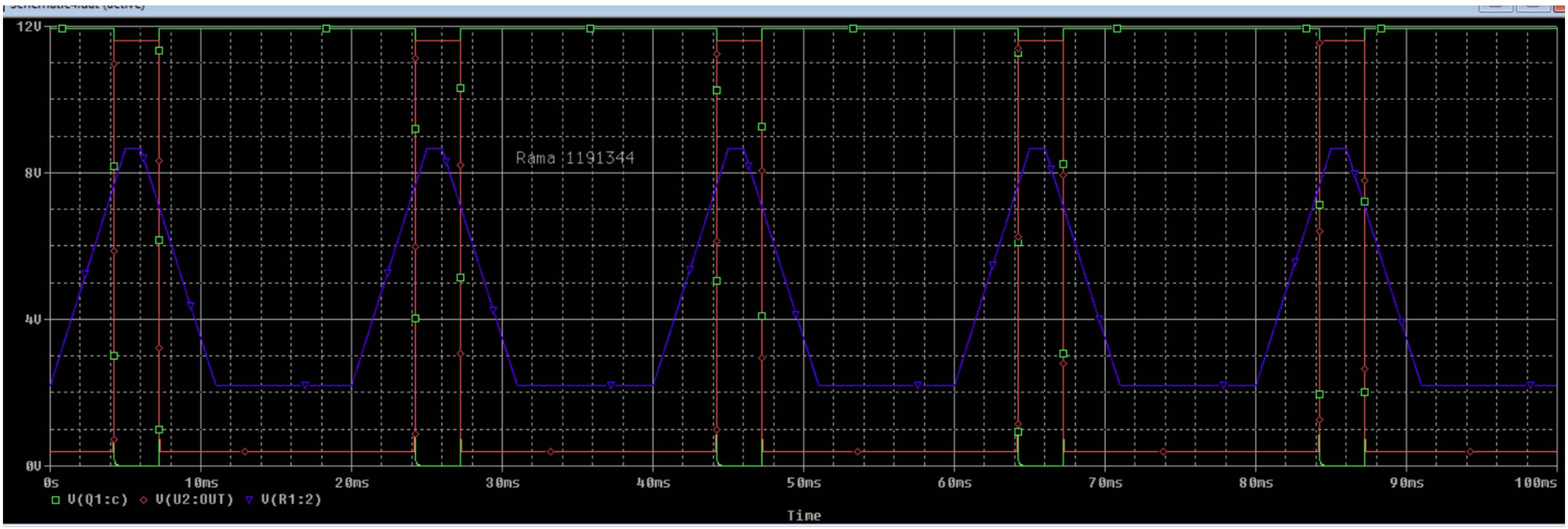

Figure 17 figure of the simulation of vo1,vo2,vo3 without zoom in

- I will explain in the result and conclusion part .

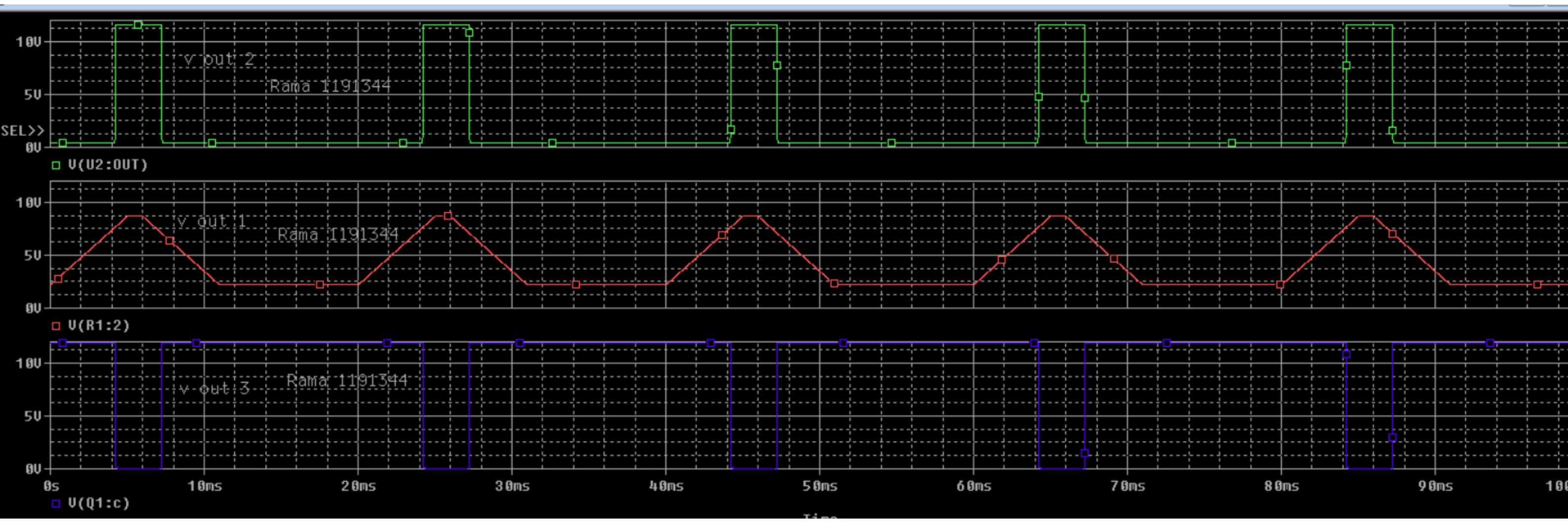

Figure 18 Vo1,Vo2,Vo3 each on its own plot

Comparison of results and Conclusion

In part 1 we got the values of resistors by solving some equations and supposing some values as shown previously.

In part 2 I have used the values of resistors I found to design the circuit .

At vout=0.08v, we found that:

vx=7.289v , vo1= 2.186v, vo2= 386.57mv , vo3= 11.93v

And at t= 0.32v, we found that:

vx=7.290v , vo1= 8.665v, vo2= 11.61v , vo3= 59.91uv

Now ,we can notice that :

vo1 at t=0.32v is greater than vo1 at t=0.08v

vo2 at t=0.32v is greater than vo2 at t=0.08v

vo3 at t=0.32v is less than vo3 at t=0.08v

and we found in part b of project that at t=0.32v diode off, and at t=0.08 diode on.

so we can conclude from the above comparasion that:

when vo1 is a great value (greater than vx) , vo2 will be also great.

When vo2 is a great value , vo3 will be very small, and BJT not working so diode off. Also, when vo2 is a small value , vo3 will be great, and BJT working so diode on. Which means when vo2= (high value) positive vsat, BJT not working , diode off. And when vo2= (low value) negative vsat, BJT working, diode on .

(Figues in simulation shows that)

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From simulation for part 3 &4 of project :

We can notice that the red wave(in Fig.14,15,16) is the vo1 , it's the output for the first non inverting op amp . It is increasing from 0.08 volt to 0.32 volt then become fixed for instance of time then decreasing from 0.32 volt to 0.08volt , and that's done by controlling the settings of vpulse voltage source.

Then the vo1 will be the input of the second op amp (Schmitt trigger comparator), the green wave (in Fig.14,15,16) shows the output of Schmitt trigger comparator (vo2). It's a square wave because its output is either +vsat or –vsat only one of these two.

Vo3 is also square wave (the blue wave in figure 16) , because it is the output of transistor which will pass through the diode , diode is either on or off, vo3 either +12v or (0v), and because of that it is square wave.

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The details:

Since vo1 and vx are the input of Schmitt trigger comparator:

When vo1>vx , then vo2 equal (+ v saturation) , So transistor and diode off and voltage and current don't pass through it (the heat degree in room greater than particular value, **the heater off**).

When vo1<vx , then vo2 equal (-v saturation), So transistor and diode on and voltage and current pass through it (the heat degree in room less than particular value, **the heater on**).

So, you can notice from figures of simulation that:

When vo1= 7.560v (Upper Threshold voltage), the wave of vo2 increasing from - Vsat to +Vsat , and diode will turn off .

When vo1= 7.020v(Lower Threshold voltage), the wave of vo2 start decreasing from +Vsat to –Vsat, and diode will turn on . And notice that I calculated these two values at the first part of project.

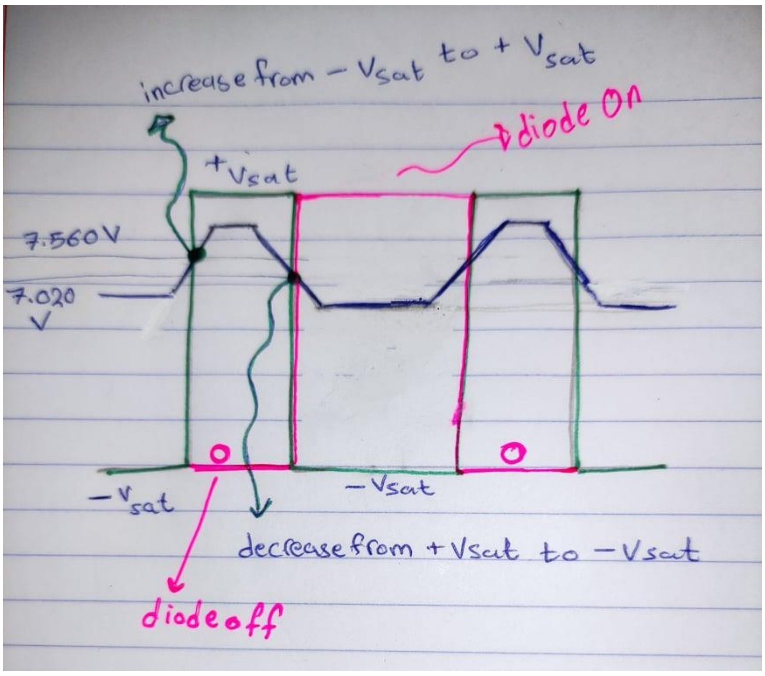

Figure 19 explanation

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So in conclusion, in this project we have built a room thermostat to keep room temperature between 28º C and 26º C (between 7.560 volt and 7.020 volt) , the heater turns off when temperature goes over 28º C and turns on when temperature goes under(bellow) 26º C . We did that using electronic parts that we learnt in this course, Temp Sensor, transistor , diode and Schmitt trigger comparator , and we learnt the role of each part in this circuit. And we have become more flexible in dealing with these models on Pspice and during calculations.