BIRZEIT UNIVERSITY

Faculty of Engineering and Technology

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Analog Electronics

----------Project #2: Room Thermostat----------

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ABSTRACT:

The aim of this project is to build a room thermostat circuit that will measure the temperature through a thermal sensor, then the LED lights up or turns off according to the value of the temperature and the value of Vx, this operation will be done using some components, such as temperature sensor that measures the temperature and converts it to voltage, two OP-AMPs which are non-inverting amplifier and Schmitt trigger as a comparator, resistors with different values, Potentiometer to set the value of Vx, BJT P-N-P transistor which works in two modes (saturation or cutoff), and LED which will be on in saturation mode and off in cutoff mode. As in The room thermostat circuit shown in Fig. 1:

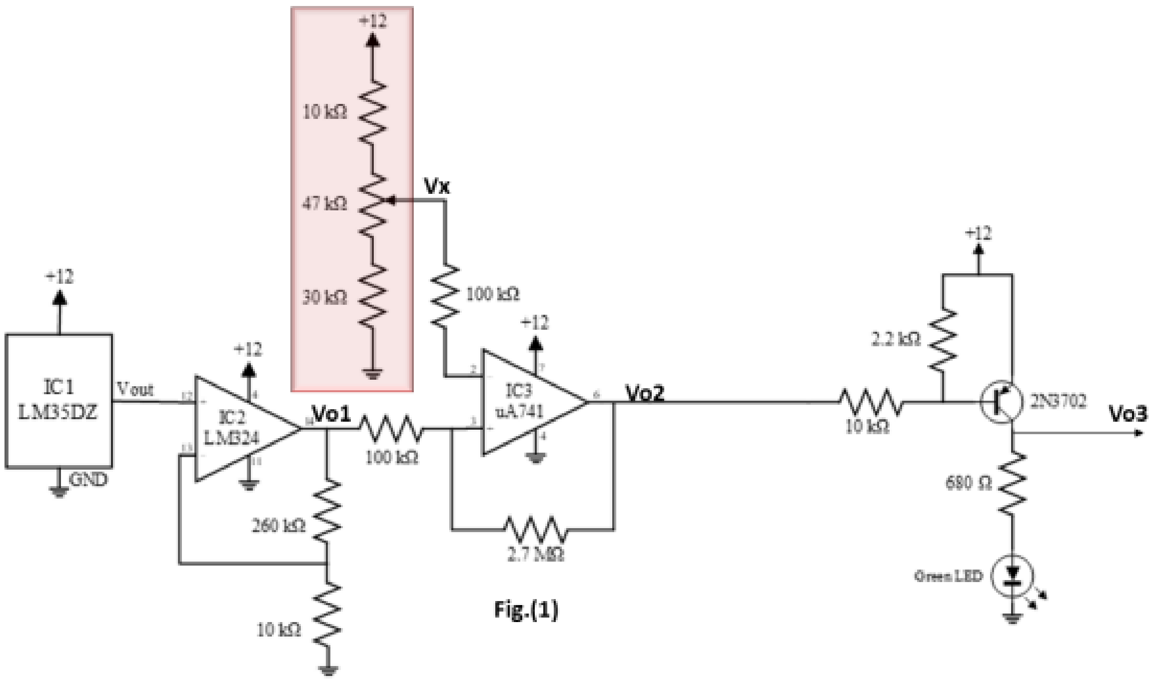

Fig.(1)

Figure 1: Room Thermostat circuit

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THEORY:

DESCRIPTION

The circuit measure the environment temperature using temperature sensor LM35DZ, which converts this temperature to voltage by using this equation: **1°C = 10m volts**, assume the temperature is 20°C, then the output of the sensor will be 200m volts. The output of the sensor (Vout in Fig. 1) will be an input for the non-inverting amplifier (Op-Amp uA741), this component will amplify the input in non-inverting pin using this equation: Vo1 = (1+ R-feedback/Ri) * Vout. There is a Schmitt trigger that compare the voltages in its input pins, the non-inverting pin (Vo1) will be compared with the inverting pin (Vx), the value of Vx is set by using the potentiometer 47k, the output of this Schmitt trigger will be either +Vsat (VCC **-** 2) or –Vsat (VCC +2). If the Vo1 is greater than Vx, then the output of the comparator will be +Vsat and the P-N-P transistor will be in cutoff mode so the LED will be off. If the Vo1 is smaller than Vx, then the output of the comparator will be -Vsat and the P-N-P transistor will be in saturation mode so the LED will be on.

PROJECT COMPONENTS:

TEMPERATURE SENSOR LM35DZ:

This sensor is an electronic device that measures the temperature of its environment and converts the input data into electronic data to record, monitor, or signal temperature changes.

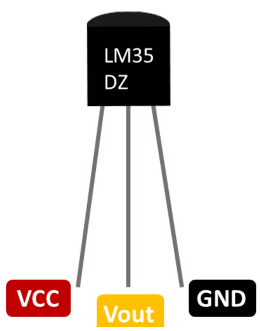


Figure 2: LM35DZ

OP-AMP UA741:

The µA741 device is a general-purpose operational amplifier featuring offset-voltage null capability. The high common-mode input voltage range and the absence of latch-up make the amplifier ideal for voltage-follower applications. The device is short-circuit protected and the internal frequency compensation ensures stability without external components. A low-value potentiometer may be connected between the offset null inputs to null out the offset voltage.

Figure 3: UA741

BJT, P-N-P 2N3702:

This is a general-purpose PNP transistor designed for use as general-purpose amplifier and switch [1].This 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 [2].

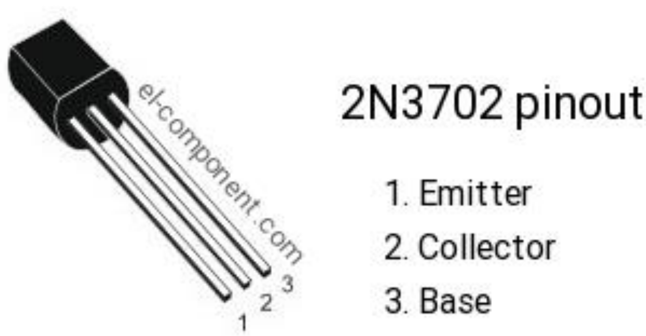


Figure 4: PNP transistor 2N3702

LED:

A light-emitting diode 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. The color of the light is determined by the energy required for electrons to cross the band gap of the semiconductor.

Figure 5: LED

POTENTIOMETER 47K:

This 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 [3].

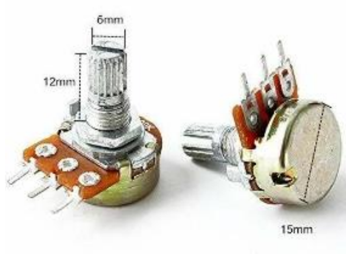


Figure 6: POTENTIOMETER 47K

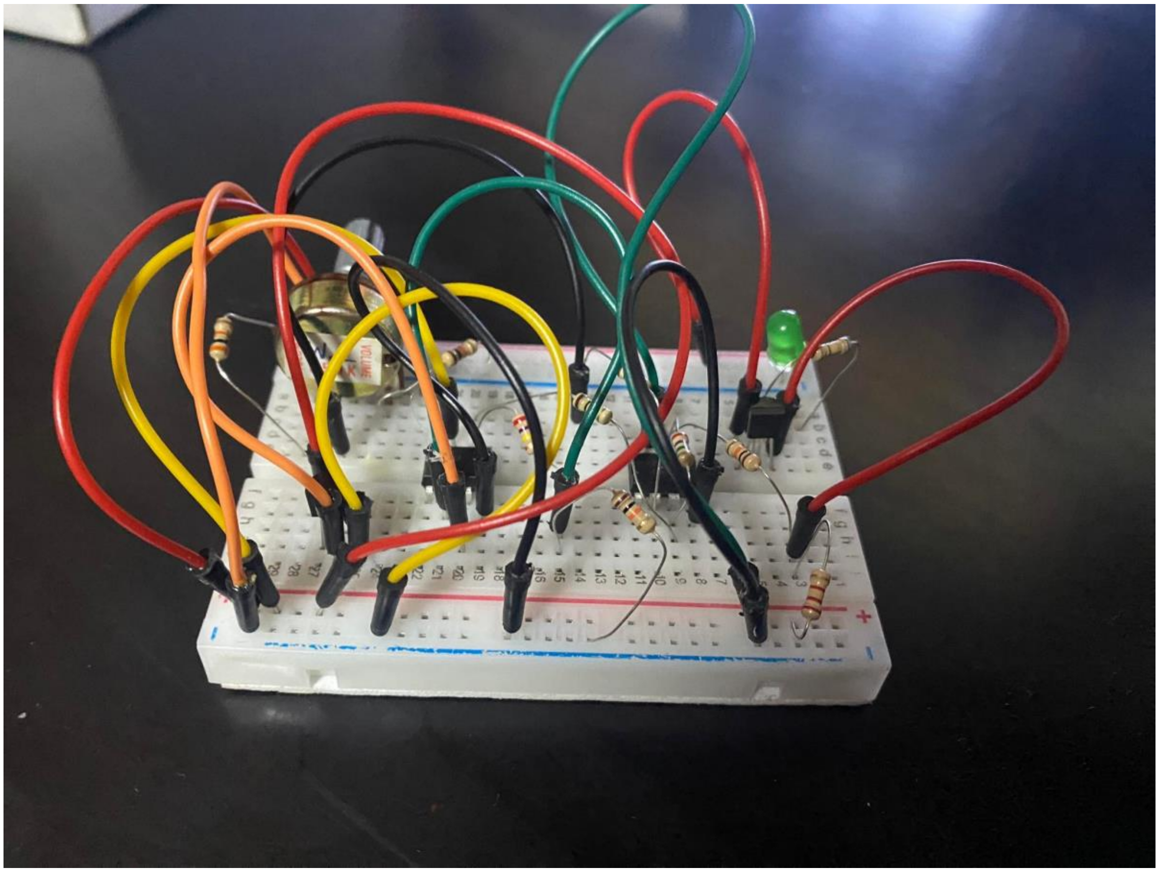
RESISTORS:

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). An ohm is the resistance that occurs when a current of one ampere (A) passes through a resistor with a one volt (V) drop across its terminals [4].

Figure 7: Resistor

PRACTICAL CIRCUIT:

We built the circuit as shown below:



The resistor of value 260k ohm was not found in the components of this project (these components had been provided from our electrical and computer engineering club), instead of this resistor, there was another resistor with value 270k ohm, so we used it. This is the feedback resistor of the non-inverting amplifier.

This circuit worked well.

PROCEDURE & DISCUSSION:

SIMULATION:

a. We replaced the circuit to the left of Vx by a 6 volts, replaced the LED with D1N4002 and replaced the temperature sensor by a VPWL Voltage source as shown in Fig. 8:

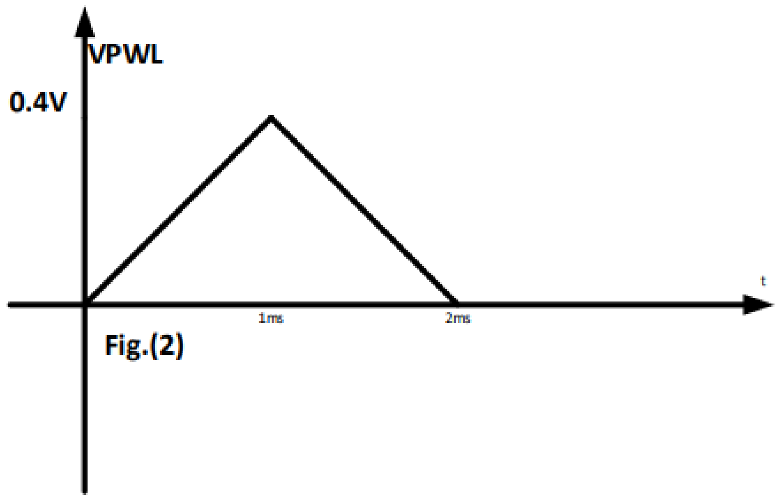
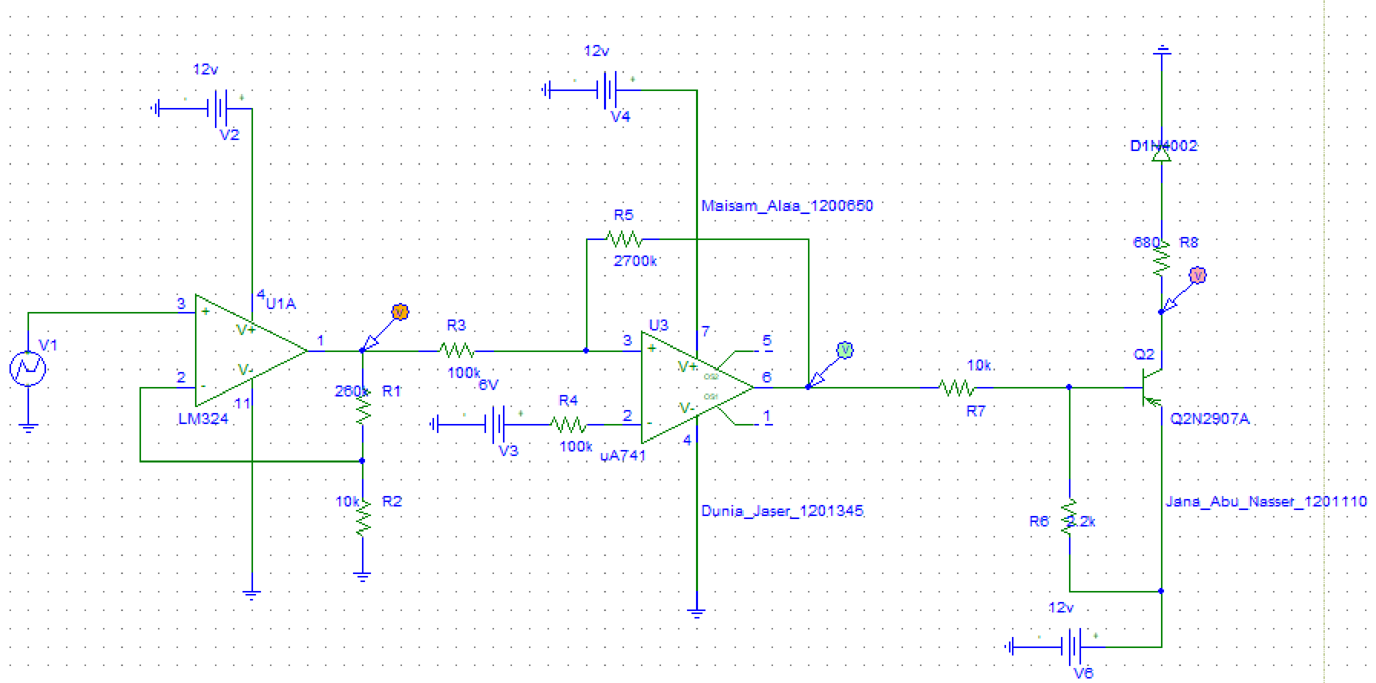
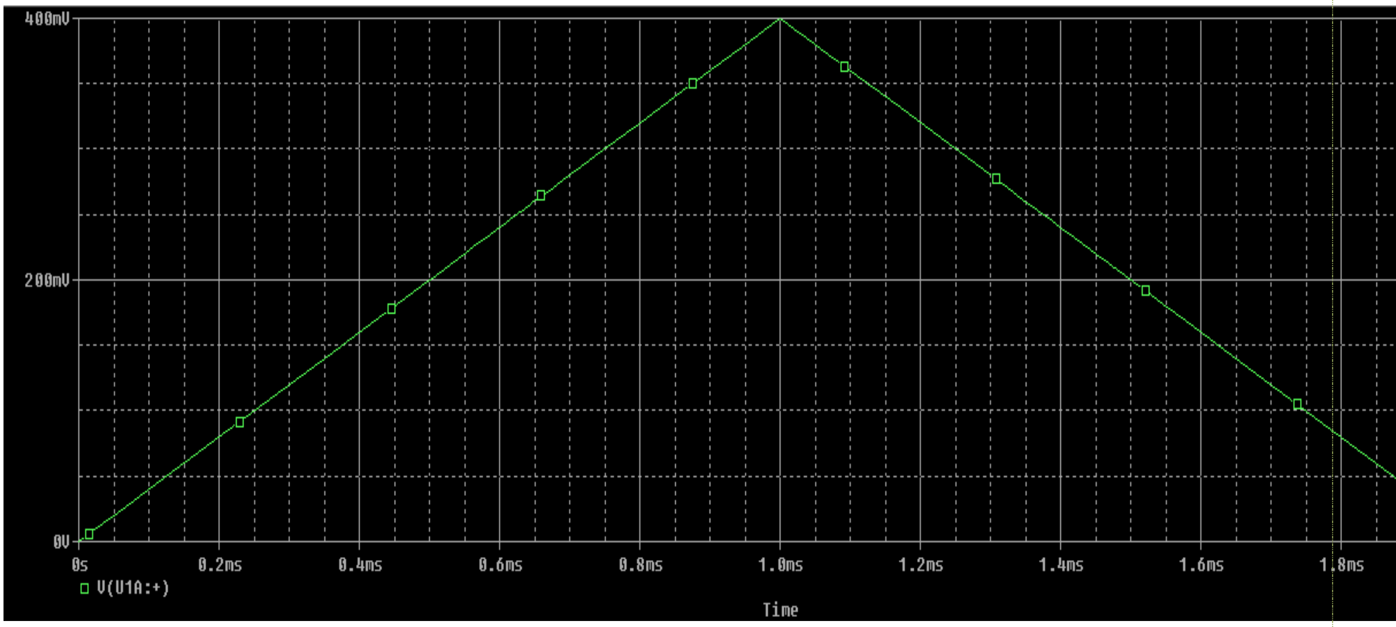


Figure 8: VPWL

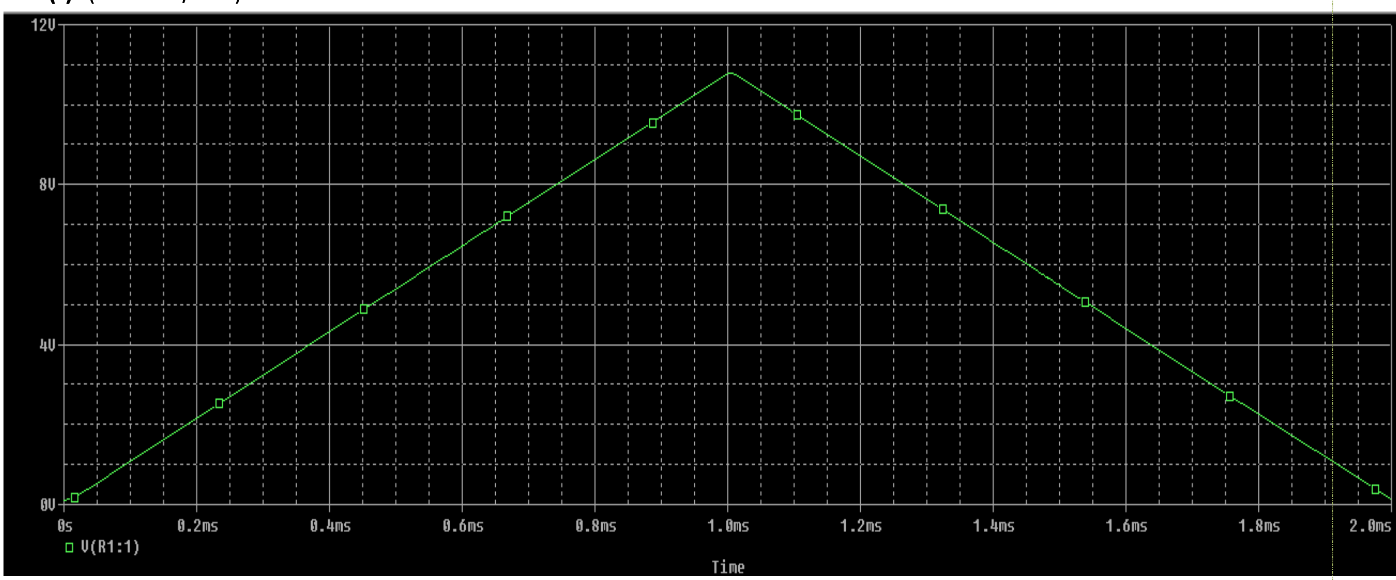
The circuit we built using Pspice:



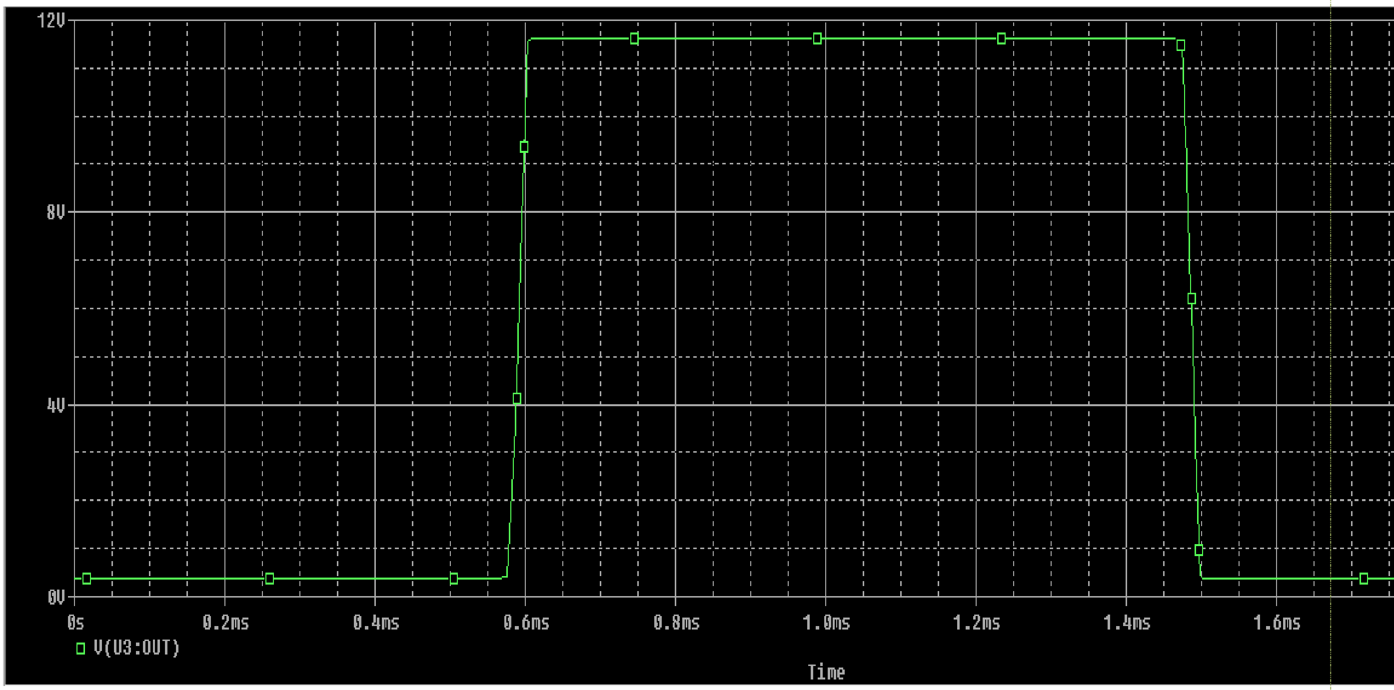
b. **VPWL:**



Vo1(t): (1 +260K/10K)*VPWL = 27*VPWL

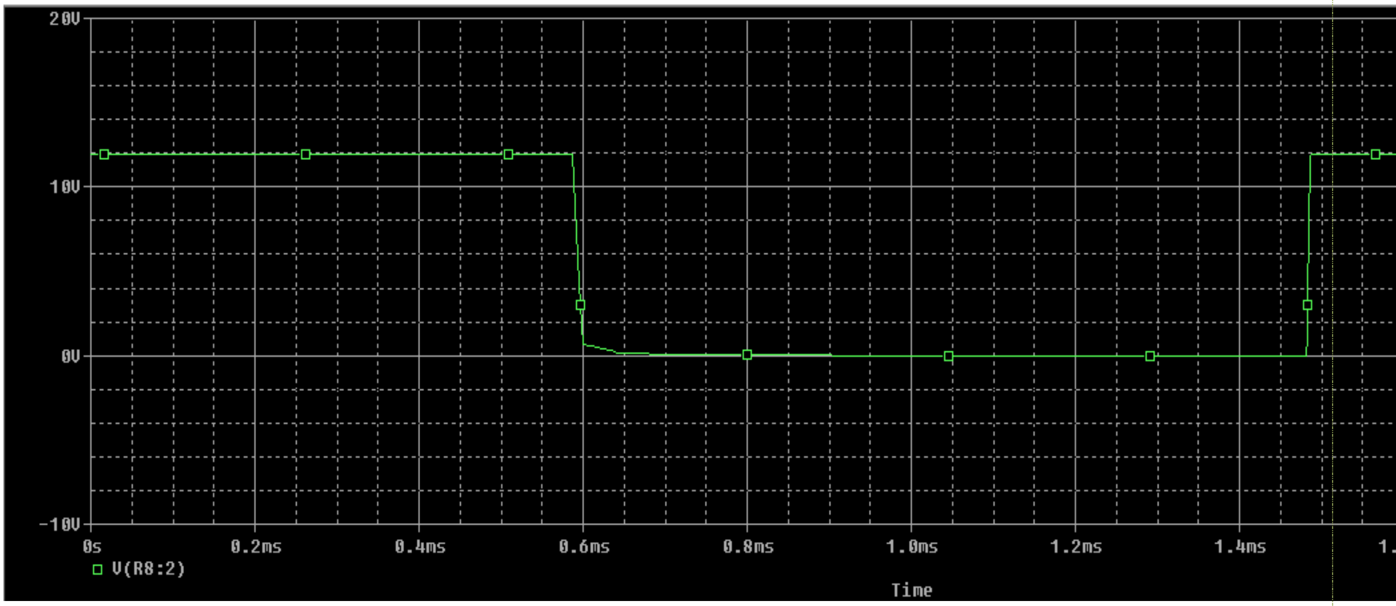


Vo2(t): This is the Schmitt trigger output which is a clean square wave output

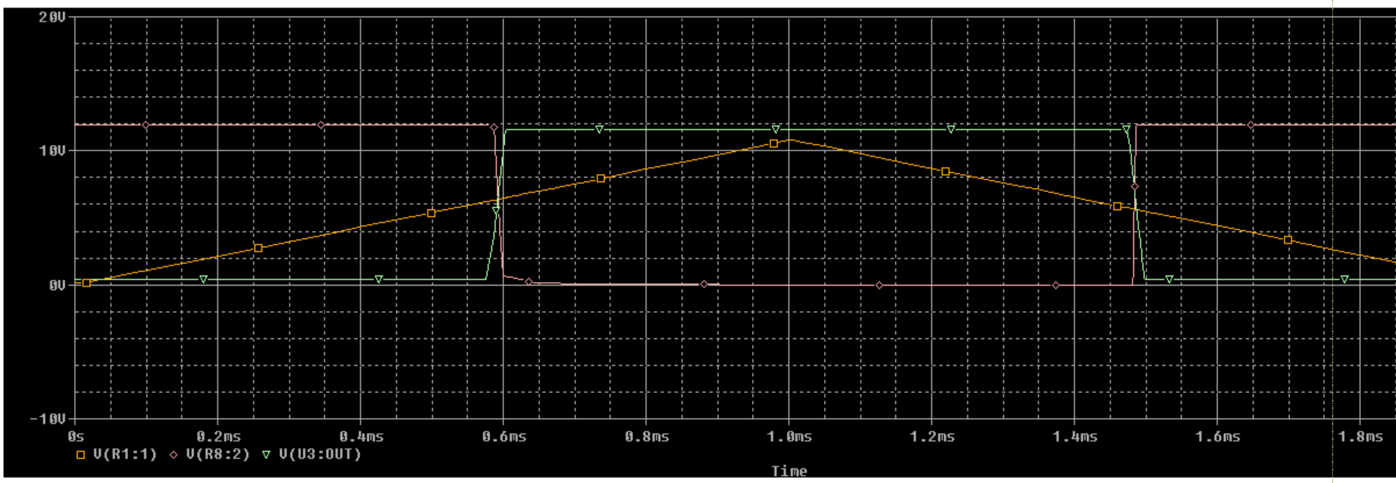


The value of V02 is either +Vsat = 11.6 or –Vsat = 0.4 as shown above.

Vo3(t):



All the plotes of Vo1, Vo2 and Vo3 in the same graph:



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

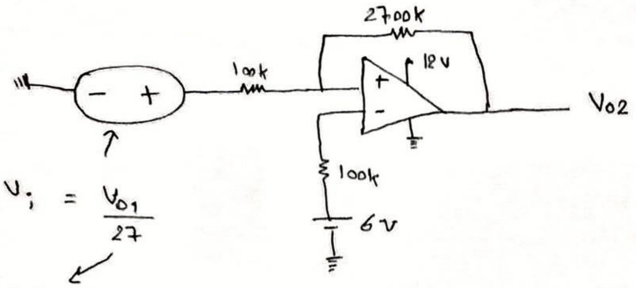
We found the values from the graph above (intersection points between Vo1(Orange) and Vo2(Green)) which the upper threshold (VUT) is 6.4 v and the lower threshold (VLT)is 5.7 v.

d. Determine +$\boldsymbol{Vsat}$ and $-\boldsymbol{Vsa}$t: from the graph of Vo2→ +Vsat = 11.6, -Vsat= 0.4.

CALCULATION:

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

Schmitt Trigger Comparator



$V_i = \frac{V_{o1}}{27}$

gain of non-inverting amplifier

⇒ we need to find min temp. and max temp. (T_{LT}, T_{UT})

⇒ sensor ⇒ $1^{\circ C}$ ⇒ 10 mV

⇒ from PSpice → $+V_{sat} = 11,6$, $-V_{sat} = 0,4$

$V_{(-)} = 6$ v

$$V_{(+)} = \frac{100k}{100k + 2700k} \cdot (+V_{sat}) + \frac{2700k}{2700k + 100k} \cdot (V_i)$$

⇒ from Circuit $V_{PWh} = \frac{V_{o1}}{27}$

$$V_{o1} = \left(1 + \frac{R_{feedback}}{10k}\right) V_{PWh}$$

⇒ we take intersection points between V_{o1} and V_{o2}

$V_{o1} = V_{UT} = 6.4$ v

$V_{o2} = V_{LT} = 5.7$ v

$$T_{UT} = \frac{V_{PWL_1}}{10m} = \frac{6.4 \backslash 27}{10} = 23,7^{\circ}c$$

$$T_{LT} = \frac{V_{PWL_2}}{10m} = \frac{5.7 \backslash 27}{10} = 21,1^{\circ}c$$

⇒ from Simulation

$\Rightarrow$ from d we find $+V_{sat} = 11,6$ v & $-V_{sat} = 0,4$ v

$V(-) = 6$ volt

$V(+) = \frac{100k}{100k + 2700k} \cdot (+V_{sat}) + \frac{2700k}{2700 + 100k} \cdot (V_i)$

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

$\Rightarrow$ for $V_{out} = +V_{sat}$ $\Rightarrow$ The transistor works in cutoff region.

$V(+) > V(-)$

$\frac{100k}{2800k} \cdot 11.6 + \frac{2700k}{2800k} \cdot V_i > 6$

$\frac{27}{28} V_i > 6 - 0,414285$

$V_i > 5.79$ Volts

$\Rightarrow$ if V_{input} $\Rightarrow$ the non-inverting amplifier output to let the V_{o2} be $+V_{sat}$

$V_{o1} > 5.79$

$T > 21.45°$

$(T \times 10m) \times 27$

$V_{o1} = 27 \cdot T_m$

Scanned by TapScanner

CONCLUSION:

Our objective in this project was to introduce to how to deal with electrical elements such as µA741 (non-inverting amplifier), Temperature sensor LM35DZ, Schmitt trigger comparator and the BJT transistor, and we concluded a lot of things from them:

- The sensor measures the temperature and converts it to voltage.
- The output voltage of the sensor passes through the non-inverting amplifier, so the voltage will be greater 27(1+260k/10k) times.
- This voltage will be compared to the voltage Vx (6 volts in simulation) through the Schmitt trigger.
- The LED connected to the transistor will turn on if the output of the comparator is –Vsat, this means that the transistor in the saturation region, and when the comparator is +Vsat, the transistor will be in the cutoff region so the LED will turn off.

Our opinion about this project:

The project was very useful because it helps us to learn how to design and build the circuit and make the simulation on PSpice.

In addition, it helps us to imagine how the electronic device such as the transistor works in the different region “cut off region and saturation region”. The transistor is working in the saturation region when the voltage of the Schmitt trigger is -Vsat, in this case the lamp will light. On the other hand, when the voltage of the Schmitt trigger is +Vsat, the lamp won’t light.

REFERENCES:

[1]: https://www.utmel.com/components/2n3702-pnp-transistor-pinout-datasheet-and-alternatives?id=434

Accessed on 8-2-2023 at 1:00PM

[2]: https://components101.com/transistors/2n3702-transistor-pinout-datasheet-equivalent-circuit-specs

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[3]: https://en.wikipedia.org/wiki/Potentiometer

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[4]: https://eepower.com/resistor-guide/resistor-fundamentals/what-is-a-resistor/?fbclid=IwAR3pAuqVDvkgOXNMKgmTi09IuSjmyOsOqFSs874e1uJQTdeX78WbmSPaacE

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