Faculty of Engineering & Technology
Electrical & Computer Engineering Department

ANALOG ELECTRONICS ENEE2360

Project 2

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Section: 1

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Abstract

This report presents the design and simulation of an analog electrical circuit which turning on or off the LED depending on temperate sensor. The circuit consists of a LM35DZ (temperature sensor), amplifier, Schmitt trigger, potentiometer, PNP transistor and Green Led. The main goal of simulation is to plot Vo1 which generated by the first OP-AMP (Amplifier), Vo2 which generated by the second OP-AMP (Schmitt comparator), finally plot Vo3 (the output of the PNP transistor). The report concludes that the proposed analog electrical circuit provides an effective and efficient solution for temperature-based LED control.

Contents

List Of Figures

1.Theory

1.1 Temperature SensorLM35

The LM35 as shown in figure 1 is a linear temperature sensor that provides a proportional voltage output to the temperature measured, with a range of -55°C to 150°C and an accuracy of ±1°C. The output voltage is directly proportional to the temperature in degrees Celsius, with a sensitivity of 10 mV/°C. It is a low-cost, easy-to-use device that can be interfaced with microcontrollers, data loggers, or other circuits to measure temperature.[1]

The equation relating the temperature to the output voltage of the LM35 is: Temperature (°C) = (Output voltage (mV) / 10). For example, if the output voltage is 500 mV, the temperature measured is 50°C. [1]

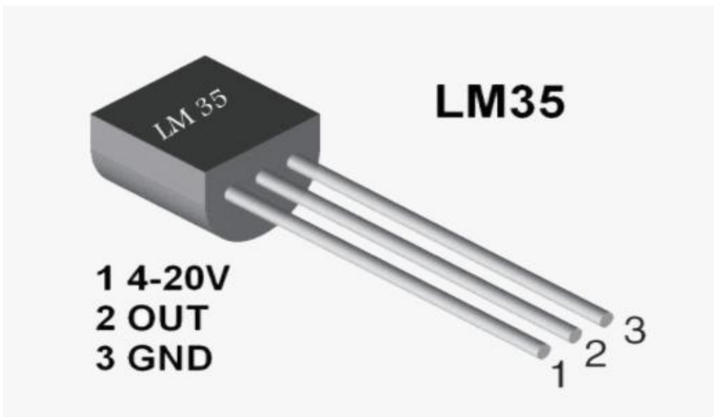

Figure 1: Temperature Sensor LM35

In a simulation, you can set the output voltage of the voltage source to match the desired temperature readings, just as the LM35 provides a proportional output voltage to the temperature it measures. You can also adjust the sensitivity and range of the voltage source to match those of the LM35.

By using a voltage source instead of a temperature sensor, you can have greater control over the input signals in your simulation, which can be useful for testing and debugging. However, keep in mind that the results obtained from a simulation using a voltage source may not perfectly match real-world temperature readings obtained using an LM35.

1.2 First Op Amp LM324

LM324 is a Quad op-amp IC integrated with four op-amps powered by a common power supply. The differential input voltage range can be equal to that of power supply voltage. The default input offset voltage is very low which is of magnitude 2mV. The operating temperature ranges from 0˚C to 70˚C at ambient whereas the maximum junction temperature can be up to 150˚C. Generally, op-amps can perform mathematical operations.[2]

LM324 first op amp is non inverting with negative feedback the figure 2 shows the LM324 in the circuit and figure 3 show the data sheet. It works as amplifier in this circuit.In general, it takes the amount of voltage coming from the temperature sensor and amplifies it, because the voltage coming from the temperature sensor is small

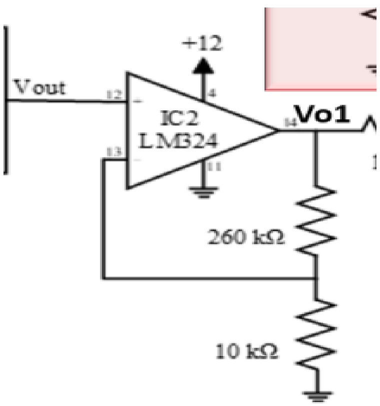

Figure 2: First Op Amp LM 324

Figure 3: LM 324 Data Sheet

1.3 Second Op Amp uA741

The Schmitt trigger as shown in figure 4 is a useful component in a room thermostat circuit. It helps regulate the room temperature by comparing the output of a temperature sensor, such as the LM35, to predetermined temperatures T(max) and T(min). When the room temperature exceeds T(max), the Schmitt trigger turns off the heating element. When it falls below T(min), the trigger turns on the heating element.[3]

In this way, the Schmitt trigger keeps the room temperature within the desired range. It can be used with other components, such as relays, to control the heating and cooling elements in the room. The output of the trigger can also be fed into a microcontroller or other control system for further processing.[3]

To summarize, the Schmitt trigger plays a crucial role in a room thermostat circuit by comparing temperature readings to predetermined temperatures and switching heating and cooling elements accordingly, thus maintaining the room temperature within the desired range, also the figure shows the data sheet for.

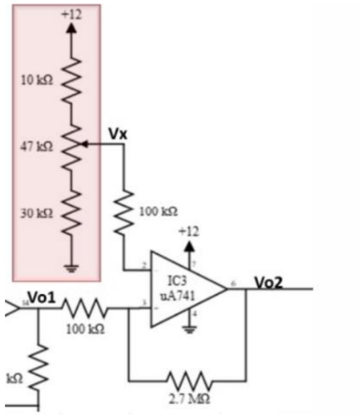

Figure 4: Second Op Amp uA741

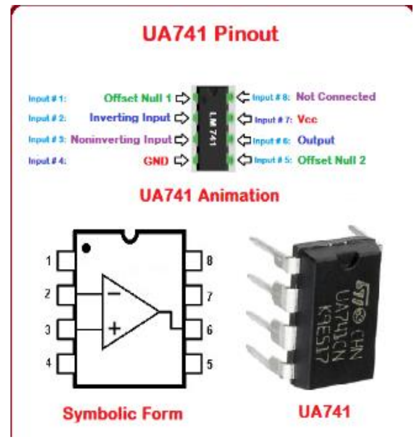

Figure 5: uA741 Data Sheet

In general, it will compare the output coming from the sensor after amplification with the values coming from the circuit in red, so that it is considered the fixed value on which the lighting of the thermostat will be based on

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1.4 PNP Transistor

PNP (Positive-Negative-Positive) transistors are bipolar junction transistors that are commonly used in electronic circuits. They are typically used as amplifiers or switches in various applications. The PNP transistor has three terminals: the collector, the base, and the emitter. The base-emitter junction is forward-biased, and the collector-emitter junction is reverse-biased.

In a PNP transistor, when a small current flows into the base terminal, it controls a larger current flowing between the collector and emitter terminals. This is known as the current amplification factor (hFE) and is used to amplify the input signal. When the base-emitter junction is forward-biased, the collector-emitter junction is turned on, allowing current to flow from the collector to the emitter. This makes the PNP transistor useful as a switch in many applications.

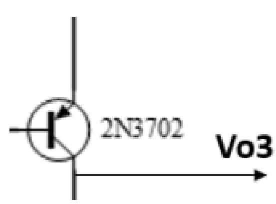


Figure 6: PNP Transistor

1.5 Diode

Thermistors are semiconductors, which means they have a higher resistance than conducting materials but a lower resistance than insulating materials. The temperature-to-resistance relationship of a thermistor is greatly reliant on the materials used in its construction. Because this is the major criterion of importance to thermistor purchasers, the manufacturer normally determines this property with a high degree of accuracy.

In the simulation part we have replaced the green light by diode.

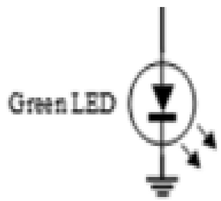


Figure 7:Green LED Symbol in circuit

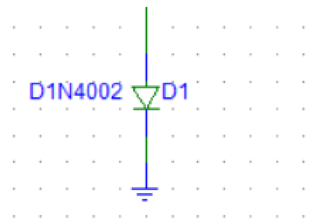


Figure 8: Diode Symbol in PSPICE

2. Simulation Circuits and Results

We connected the circuit as shown in figure 9 on the PSPICE as shown in figure 10.

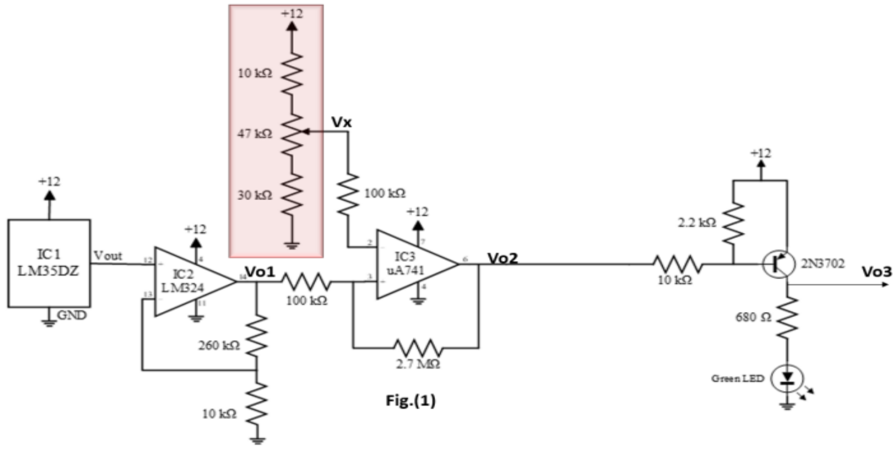


Figure 9: The Circuit

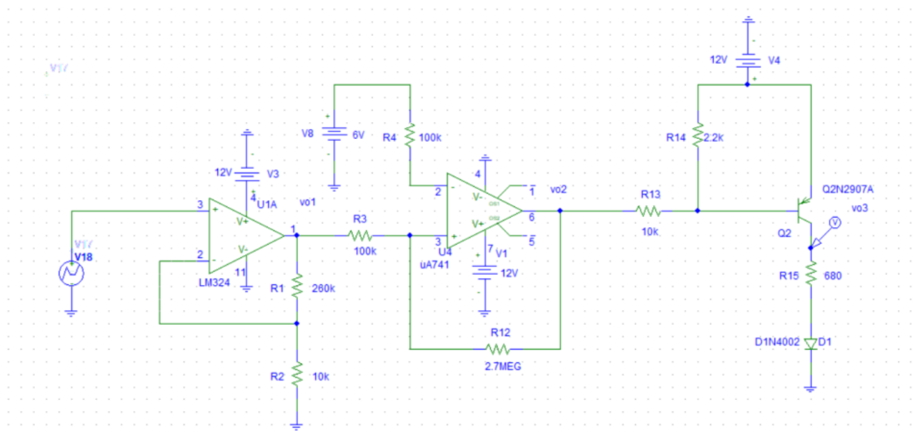


Figure 10: Connected Circuit in PSPICE

First, we replaced the circuit to the left of Vx as shown in figure11 by a 6V battery as shown in figure12.

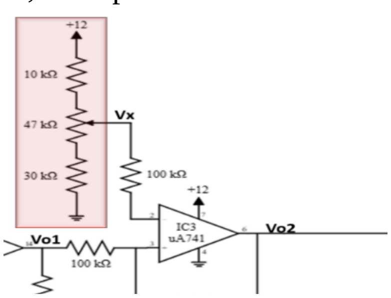


Figure 11: Circuit to the Left of Vx

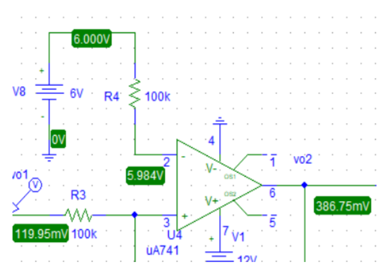


Figure 12: Replace the left of Vx by Battery

Then we replaced the green LED as shown in figure14 with D1N4002 as shown in figureز13

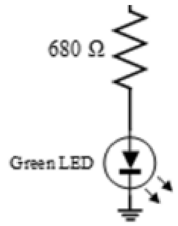


Figure 14: Green LED

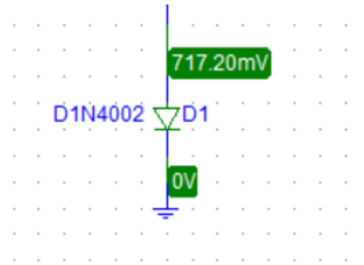


Figure 13: Diode D1N4002

After that we replaced the temperature sensor as shown in figure16 by a VPWL Voltage source as shown in figure15 , and the value of VPWL shown in figure18 according to figure17 .

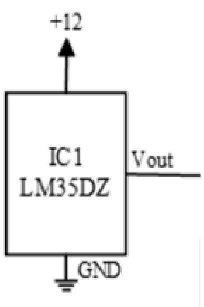


Figure 16: Temperature Sensor

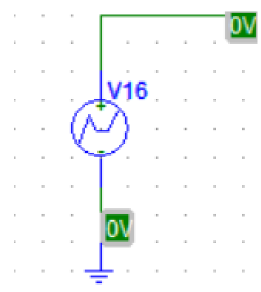


Figure 15: VPWL in PSPICE

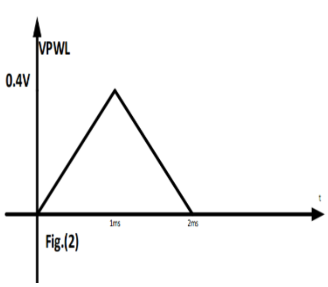


Figure 18: VPWL datagram

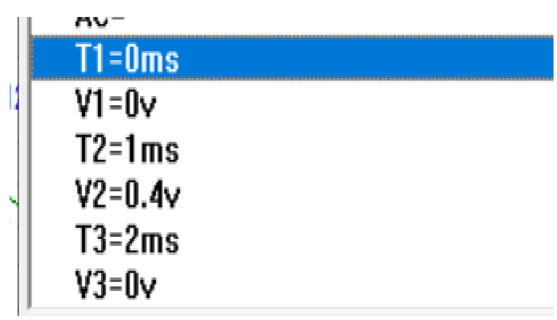


Figure 17 : Value of VPWL in PSPICE

2.1 Plot vo1

Figure 19 show the V_{O1} on the circuit, also figure 20 show the plot of V_{O1}.

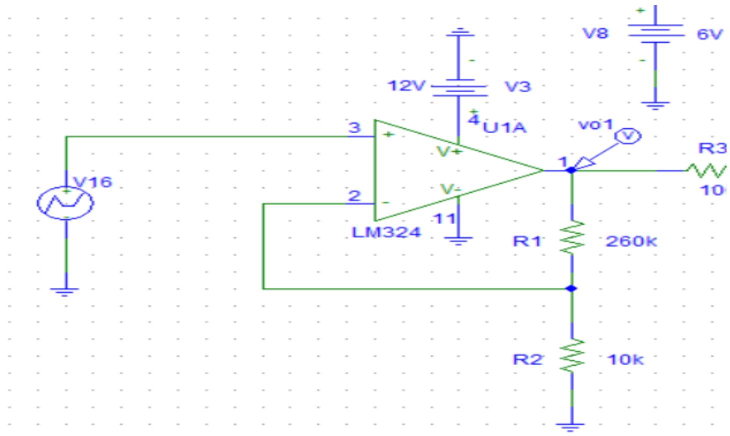


Figure 19: VO1 in the Circuit

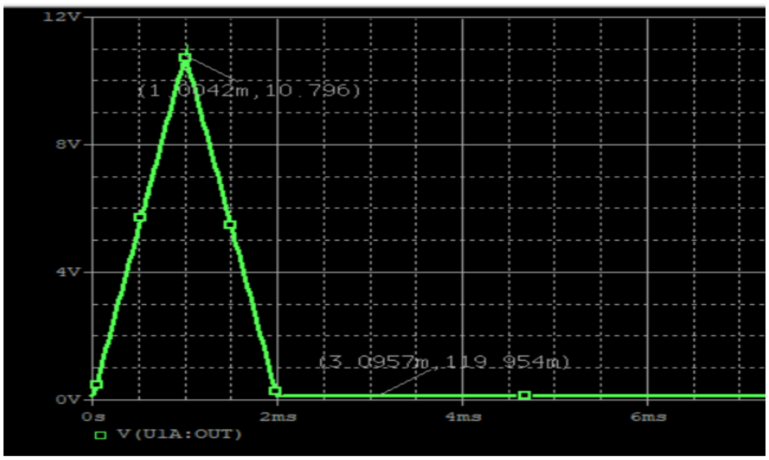


Figure 20: Plot VO1

It expresses the amount of voltage coming from the VPWL after it has been amplified and its amount has been increased mainly - and here it is solved according to the laws of Op amp that it represents, published to the type LM324 first op amp is non inverting with negative feedback

We will notice from the leg drawing, that it is similar to the VPWL drawing, the difference is that the amplitude is only increased by a fixed amount (multiplied by 27).

Vo1 = (1+R1/R2) V_{out}

Example: when V_{out} = 0.4volt (maximum value) then vo1= 27(.4) =10.8 volt.

(We can verify through the point shown in the picture).

2.2 Plot vo2

Figure 21 show the V_{O2} in the circuit, also figure 22 show the plot of vo2.

The voltage (V_{out}) is entered on non-inverting **Schmitt trigger (V+)** and compared with a fixed reference voltage for the process, and it was determined here to be equal to 6 volts through the inverting **Schmitt trigger (V-)**. If the result of their subtraction is positive, then the output in that case is Vsat positive and vice versa is negative. And they, will affect the work of a diode that was previously explained.

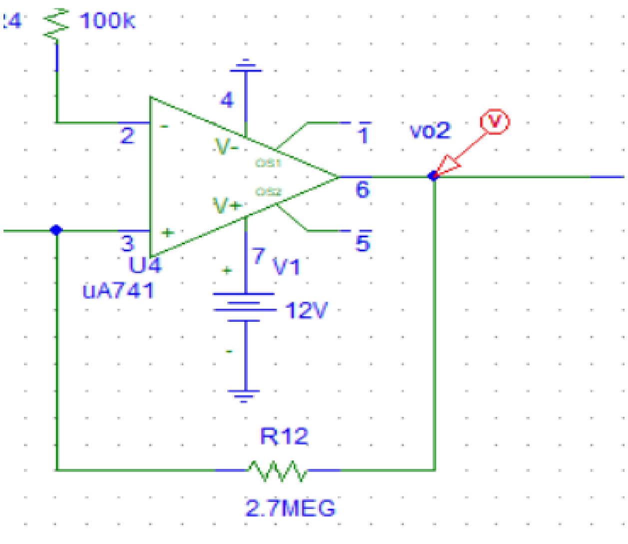


Figure 22: Vo2 in the Circuit

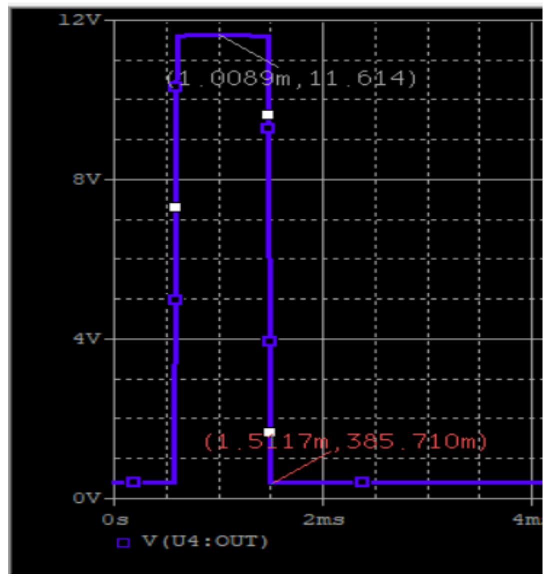


Figure 21: Plot the Vo2

+Vsat=11.6V AND -Vsat=.4 V

* Assume $V_{O2} = +V_{sat}$

$$V_{(+)} = \frac{R1}{R1+R2}(11.6) + \frac{R2}{R1+R2}(V_{O1})$$

$$V_{(+)} - V_{(-)} > 0$$

Else:

* Assume $V_{O2} = -V_{sat}$

$$V_{(+)} = \frac{R1}{R1+R2}(0.4) + \frac{R2}{R1+R2}(V_{O1})$$

$$V_{(+)} - V_{(-)} < 0$$

2.3 Plot vo3

Figure 23 show the vo3 on the circuit, also figure 24 show the plot of vo3

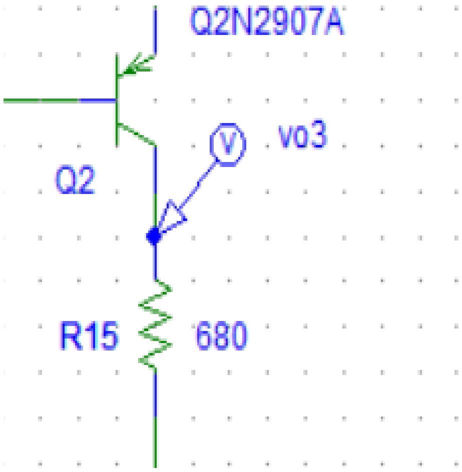


Figure 24: Vo3 in the Circuit

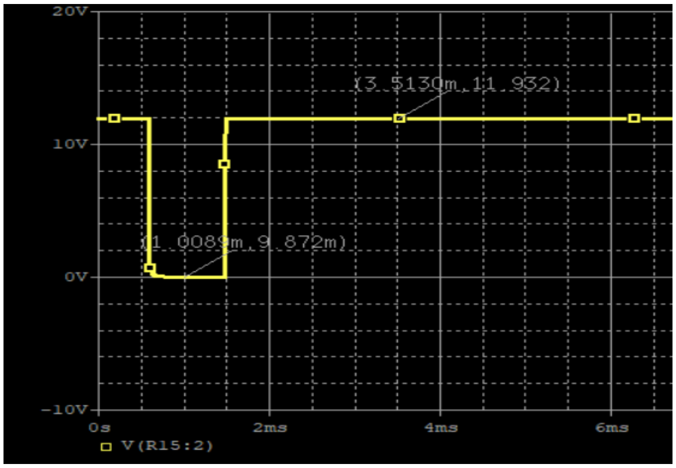


Figure 23: Plot Vo3

At 0 .5<t<1.5 :
VO2 = 11.61V
VO3 = 9.872mV (we can see that from the plot of Vo3at this domain)
Ve=12V
to find Vb we using super position. Will be more 12v

then:
The status of the BJT:
1)Veb is reverse v(e) less than v(b)
1)Vcb is reverse v(c) less than v(b)
for PNP

VE < VB > VC Cutoff

the transistor is in the cut-off mode.

The status of the diode: Since the v(a)-v(k) less than 0.7volt,
v(a) less than Vo3 and v(k)=zero. the diode is off.
(SO THE DIODE IS OFF WHEN Vo2 EQUAL +Vsat)

___

At 0.0<t<0.5 and 1.5<t:
VO2 = 0.386V=-Vsat (we can see that from the plot of Vo2 at this domain)
VO3=Vc = 11.932V(we can see that from the plot of Vo3 at this domain)
Ve=12V

then:
The status of the BJT:
1)Veb is forword v(e) more than v(b)
1)Vcb is reverse v(c) less than v(b)
for pnp

VE > VB > VC Active

the transistor is in the active mode.

The status of the diode: Since the v(a)-v(k) more than 0.7volt,
v(a) less than Vo3(11.932) and v(k)=zero . the diode is on.
(SO THE DIODE IS one WHEN Vo2 EQUAL -Vsat)

2.4 Calculate upper and lower threshold temperatures

Estimate the upper threshold and the lower threshold temperatures from Vo1 and Vo2(t) plots.

The value of Vo1 when VO2 shifts from -Vsat (0.4V) to +Vsat (11.6V) is:

V_{O1}=6.3325V

Then the value of V_{out} ($VPWL_{UT}$)=Vo1/27=234mV

$T_H = V_{out}/10mv = 23.4° C$

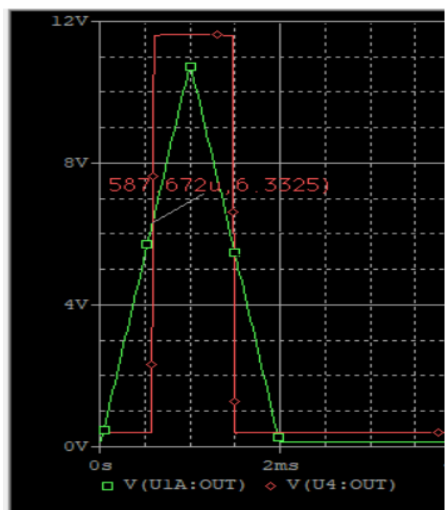


Figure 25:Plot Vo1 and Vo2

The value of VPWL when VO2 shifts from $+V_{sat}$ (11.6V) to $-V_{sat}$ (0.4V) is:

V_{O1}=5.5338V

Then the value of V_{out} ($VPWL_{LT}$)==Vo1/27=205mV

T_L = Vout/10mv = 20.5 ° C

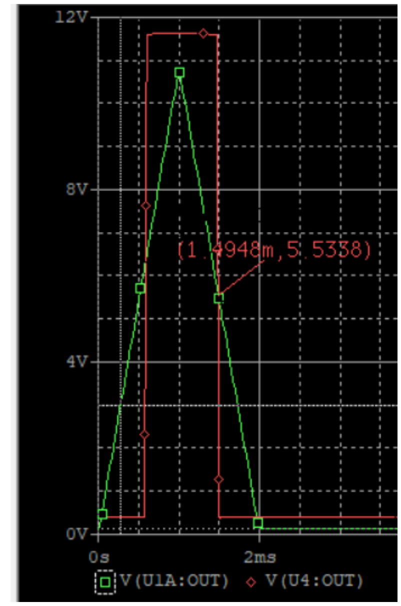


Figure 26: Figure 27:Plot Vo1 and Vo2

3. Hand Calculation

How do we use +V_{sat} and –V_{sat} to find the magnitude of the temperature upper threshold and the lower threshold temperature?

In general, we worked to find the solution in the reverse way, we start with the outputs back until we reach the main input is the temperature.

1) The process begins with knowing that (the diode that represents the LED in practice) is affected by temperature through the following processes.

Temperature will change the amount of voltage output from the Temperature SensorLM35, which will be represented by V_{out}.

V_{out} =T* 10mv

2) Then it will enter the op amp LM324 is non inverting with negative feedback, in turn it will amplify the amount of voltage, which will be represented by Vo1.

Vo1 = (1+R1/R2) V_{out}

3) The voltage (V_{out}) is entered on non-inverting **Schmitt trigger (V+)** and compared with a fixed reference voltage for the process, and it was determined here to be equal to 6 volts through the inverting **Schmitt trigger (V-)**. If the result of their subtraction is positive, then the output in that case is V_{sat} positive and vice versa is negative. And they, will affect the work of a diode that was previously explained.

$$0 < \frac{R1}{R1 + R2} VO2 + \frac{R1}{R1 + R2} Vsat - 6$$

3.1 Find the Temperature lower Threshold

1) By using the equations and values from the Schmitt trigger.

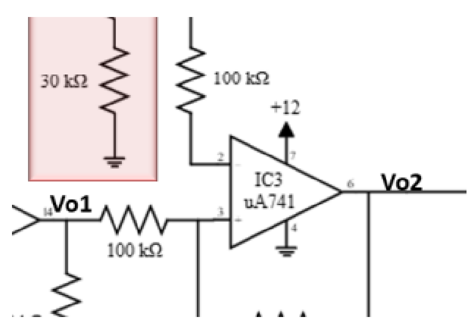
Given VO2 = +Vsat =11.614
V (-) = 6volt

$then 0 < V$d

$$0 < \frac{R1}{R1 + R2} Vsat + \frac{R2}{R1 + R2} VO1 - 6$$

$$0 < \frac{100k}{100k + 2.7M} 11.614 + \frac{2.7M}{100k + 2.7M} Vo1 - 6$$

$$0 < 0.4147 + .964V01 - 6$$



$5.79volt < V01$

Then the Vout1 should be more than 5.79V, and as we know when $V_{out2}=+V_{sat}$ the lower threshold temperatures will be.

2) Find V_{out} From op amp LM324 which is non inverting.

$Vo1 = (1+R1/R2)\ V_{out}$

$5.79 = (1+260K/10K)\ V_{out}$

then $V_{out} =0.214$ V

3) Find Lower Temperature from SensorLM35.

$V_{out} =T_L * 10m$

$0.214V=T_L * 10m$

TL = 21.4 C

So, the temperature **lower threshold = 21.4 C**

3.2 Temperature upper threshold:

1) using the equations and values from the Schmitt trigger.

Given $V_{O2} = -V_{sat} =0.4v$
$V (-) = 6volt$

$then 0 > V\mathrm{d}$

$$0 > \frac{R1}{R1+R2}Vsat + \frac{R2}{R1+R2}VO2 - 6$$

$$0 > \frac{100k}{100k+2.7M}0.385 + \frac{2.7M}{100k+2.7M}VO2 - 6$$

$$0 > 0.00142 + 0.964V02 - 6$$

$$6.22volt > V02$$

Then the Vout1 should be less than 6.22V, and as we know when V_{out2}=+Vsat the lower threshold temperatures will be.

2) **Find V_{out} From op amp LM324 which is non inverting**

$V_{O1} = (1+R1/R2)\ V_{out}$

$6.22 = (1+260K/10K)\ V_{out}$

then $V_{out} = 0.2304V$

3) Temperature Sensor LM35

Vout =TL* 10m

0.2304 V=TL* 10m

TL = 23.0 C

So, the temperature **upper threshold = 22.9 C**

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4 . Comparison of simulation results to hand calculation

$+V_{sat}$=11.615 $-V_{sat}$=0.385

	Vo1 when $+V_{sat}$	Vo1 when $-V_{sat}$	Vo1 when $-V_{sat}$	Vo1 when $-V_{sat}$	**T_L**	**T_H**
Our value	5.79	6.209	0.214	0.229	21.4	22.9
Simulation value	5.538	6.3325	205 mV	234 mV	20.5	23.4
Error	0.256	0.1235	9mV	5MV	0.9	0.5

Figure 28: Comparison of simulation results to hand calculation

As we see, there's a small error. The reason why there is such a small difference in our or the expected values and the simulated values is that the expected values are ideal (we got them by considering the components are ideal models) while Pspice does not consider them to be 100% ideal. And this is precisely the reason for the difference between the values.

5. Practical

We connected the circuit as shown in figure 29. The Electronic components which we used in the project was unusable due to manufacturing issues, the issues were have been significant enough to affect the performance of the circuit.

To avoid this kind of issues in future projects it is important to make ensure that all components are usable. Since we do not have enough time to buy new components and connect the circuit again, we connected it using the available components, then the teacher assistant confirmed that the connection of the circuit was true, also we understood the basic aim of it.

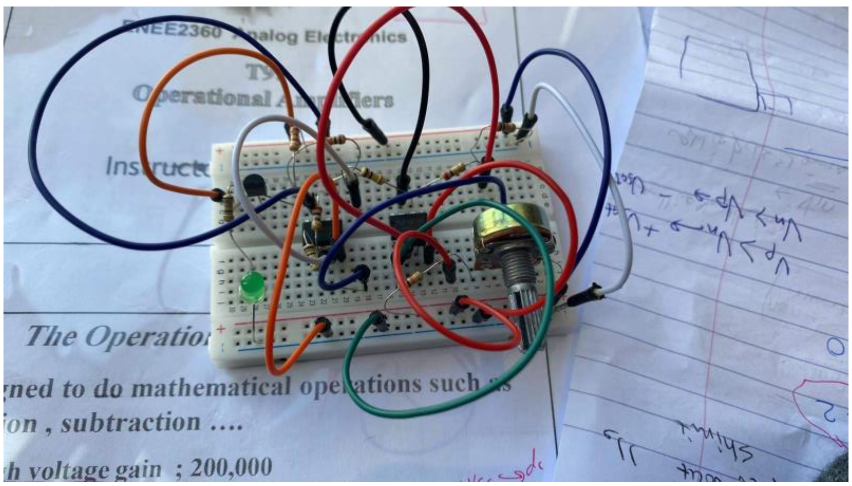

Figure 29: Practical connected circuit

6. Conclusion

In this project, we have two opAmps:

1- Schmitt trigger.

2- non-inverting amplifier.

The first opAmp is the non-inverting amplifier. Non-inverting opAmps are utilized in a wide range of applications, including none inverting adders, filter circuits, programmable gain amplifiers, clippers, buffers, and so on.

The second opAmp is Schmitt trigger is a form of logic input that offers hysteresis or two separate threshold voltage levels for rising and falling edges.

Our circuit that contains the two mentioned opAmps works as a thermostat. The heater will be turned on if the temperature is less than 21.4°C. And it will be turned off if the temperature is more than 22.9° C

In conclusion, the design and simulation of the analog electrical circuit presented in this report demonstrate its effectiveness and efficiency in controlling the activation of an LED based on temperature readings from a LM35DZ sensor. The circuit, provides a reliable and robust solution for temperature-based LED control. The simulation results show that the circuit operates as expected, and the proposed design can be adapted and improved to suit various applications. The study highlights the importance of designing efficient and reliable analog electrical circuits for practical applications in the field of electronics.

7. References

[1] https://www.ti.com/lit/ds/symlink/lm35.pdf . Accessed on 2-02-2023 at 10:27AM.

[2] https://components101.com/ics/lm324-quad-op-amp-ic. Accessed on 2-02-2023 at 11:35AM.

[3] https://www.ti.com/lit/ds/symlink/ua741.pdf . Accessed on 31-01-2023 at 11:35AM.