METU EE 313 Laboratory Project

Fall 2016-2017

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Abstract

This document is created for the Electrical and Electronics Engineering Department 313 Laboratory Project. It gives information on the purpose of the project, the details of the problem and the details on the method followed for the solution of the given problem, the process of it being performed, the working principle of each subpart, the theoretical calculations, the simulations of the design and the results of the experimental work in the laboratory, the equipment that is used, the problems which we encountered and a conclusion with a reference list.

1. Introduction

In this project, we are required to build a feedback system where we receive two temperature signals from two sources to a receiver station via a wireless system and compare them. Later on, we are supposed to transmit another signal from the station to one of the sources where we can control the temperature. According to the received signal, we need to decide whether to run the DC motor of a fan to cool down the overheated station or not.

We began our solution with laser communication. However, we realized that we can construct a similar circuit using speakers and microphone with a lower cost. Switching to sound communication, we created signals for the speakers and managed to obtain the sounds with the required frequency. Using a microphone circuit we collected these signals from a distance. In the meantime, the filters to separate the two frequencies were established. However, we encountered some problems during this procedure that is mentioned up until now. These problems will be explained later in the report in part 3.5.

Having some problems in the wireless communication and also running out of time, we thought that it would be better to show that the overall system without a wireless communication does work and the transmission and receiving parts does work separately. When the system is brought together, due to some problems which we were not able to solve during the laboratory sessions, we could not manage to run the system in a proper way.

2. The Equipment Used for the Project

Various valued resistors, capacitors, LM358 op-amps, speakers, microphone, fan with a DC motor, ,BJTs, LM35s, power resistors, breadboards, oscilloscope, multimeter, DC supply, wires, computer.

3. The Overall System

The overall system contains a controller, two temperature stations and a DC motor controlled fan. Speaker and microphone circuits are explained additionally.

3.1. Reference Temperature Station

In this part, there is a temperature sensor LM35, which gives a DC output according to the environment's heat. This output is fed to a sinusoidal oscillator circuit also known as Wien Bridge Oscillator, so that a sinusoid with a 10 kHz frequency and an amplitude that is 22 times bigger than the LM35 output voltage is produced. For this, the general construction that is showed in Fig. 1. is used as shown in [1]. Equation (1) is used for stability and (2) for the frequency arrangement.

$$R_{\boldsymbol{b}} = \frac{\boldsymbol{R_f}}{\boldsymbol{2}} \tag{1}$$

$$f = \frac{1}{2\pi \cdot R \cdot C} \tag{2}$$

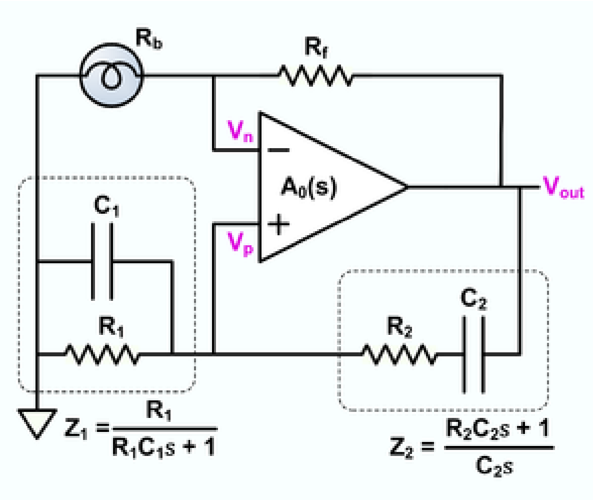

Fig. 1. General schematic for Wien Bridge Sine Wave Oscillator

This part's circuitry looks as in Fig. 2. when designed using LTSpice. And the simulation result for this oscillator is shown in Fig. 3. The laboratory construction is showed in Fig. 4. What we observed in reality was consistent with the simulation results.

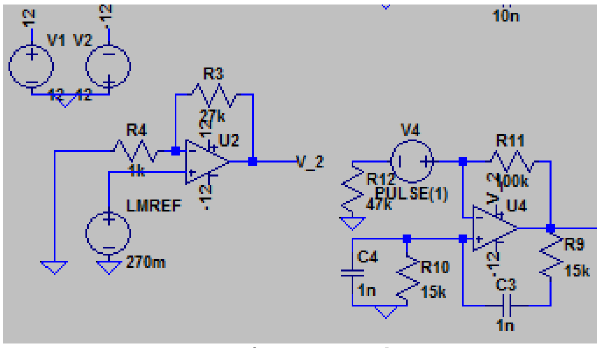

Fig. 2. Reference station design

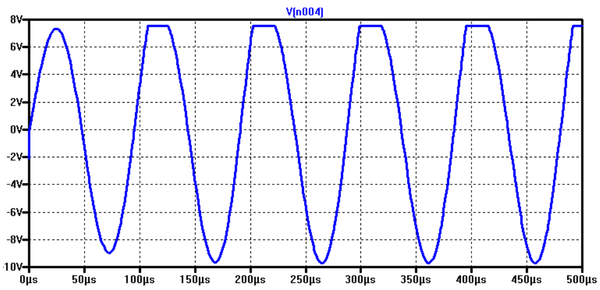

Fig. 3. 10 kHz signal simulation

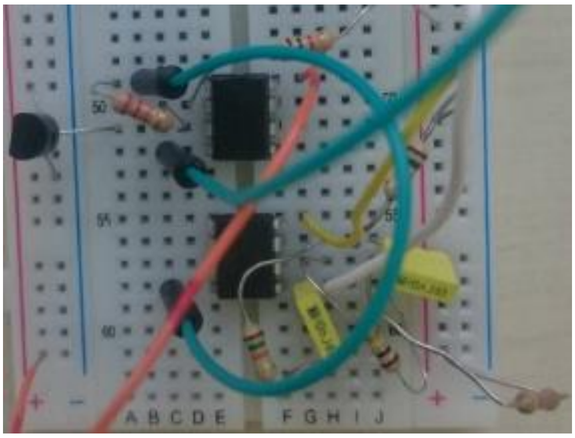

Fig. 4. Design on breadboard for 10 kHz reference signal

3.2. Controlled Temperature Station

In this part, similarly to the reference station, there is an LM35 heat sensor and a sine wave oscillator that will generate a sinusoidal signal with respect to the heat sensor's output. In this part, with the change in the capacitor value we create a 1 kHz signal. Same equations (1) and (2) hold.

Simulation results give the signal shown in Fig. 5. and our observations in the laboratory are consistent with this. When we change the temperature (i.e. warm the sensor), the amplitude of the signal changes as required. Here, we use the amplitude modulation for running the DC motor. The circuit on board is shown in Fig. 6.

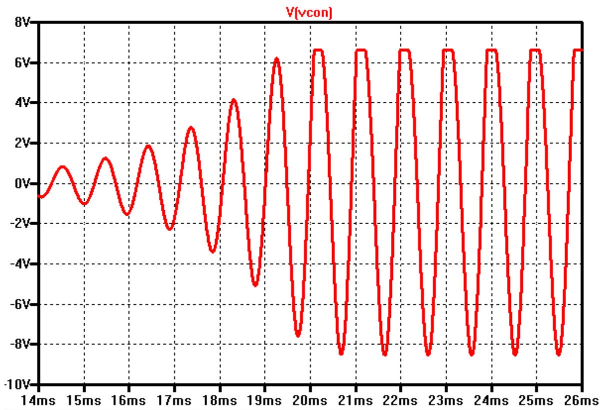

Fig. 5. 1 kHz signal simulation

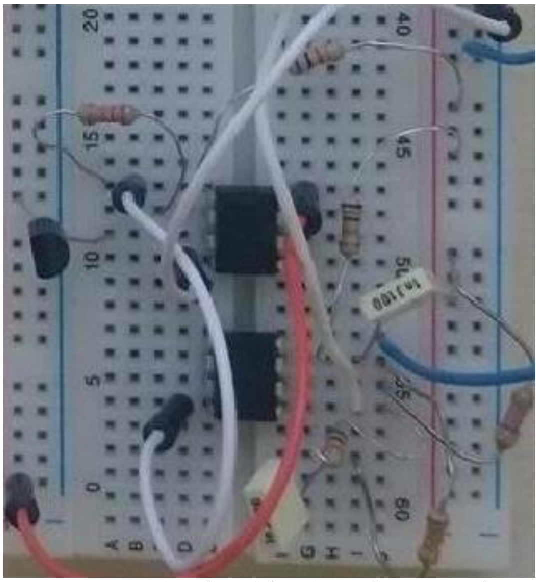

Fig. 6. Design on breadboard for 1 kHz reference signal

3.3. Controller Unit

In this part, two signals that are generated in two stations are summed using a summing amplifier. The connection is through a wire from the stations to the controller. The configuration in Fig. 7. is used with 1kΩ resistors. The output signal is given to two RC passive filters one of which filters the 1 kHz signal and one of which filters the 10 kHz signal.

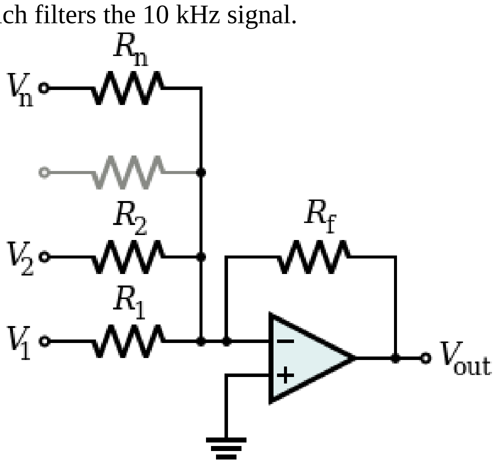

Fig. 7. Summing amplifier configuration [2]

For the low pass filter the configuration shown in Fig. 8. is used with the calculation for cut off frequency as indicated in (2). And similarly, for the high pass RC filter, configuration in Fig. 9. is used with the same cutoff frequency calculation. The capacitor values are 1nF and 10nF respectively with 15kΩ resistors.

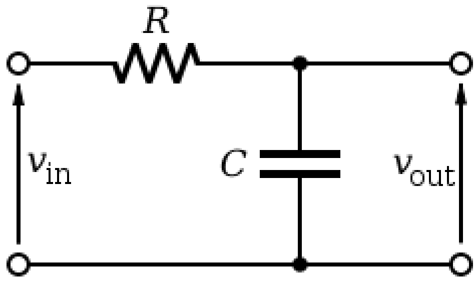

Fig. 8. Low pass passive RC filter [3]

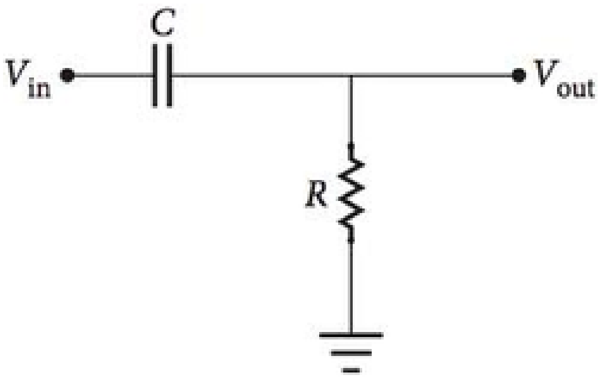

Fig. 9. High pass passive RC filter [4]

After the filtering, we convert the signals to DC by using a simple RC circuit with a diode. This gives a DC value according to the peak value of the AC signal. This can be observed from the simulation results for 35°C with 27°C reference in Fig. 10. This is consistent with the experimental results.

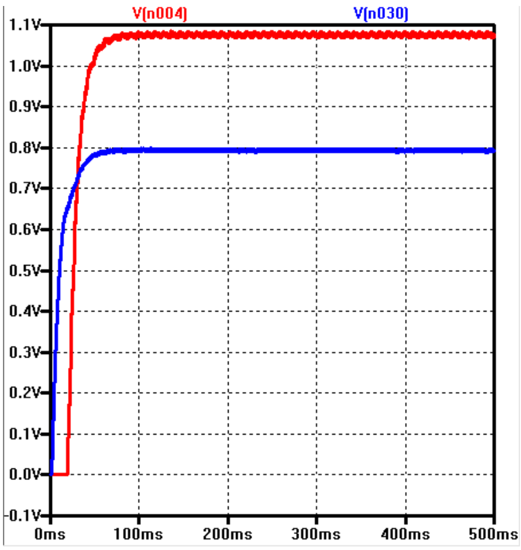

Fig. 10. Simulation result of DC converter for (a)35°C with red line, (b) 27°C with blue line

After the conversion step, a differential amplifier designed as in Fig. 11. is used to detect the difference in the temperature of the two stations. This small part is the decision unit. When there is a difference in the input voltages, this difference is multiplied by a constant that is determined by the variable values (3) and given output is the controller output that is responsible to drive the DC motor.

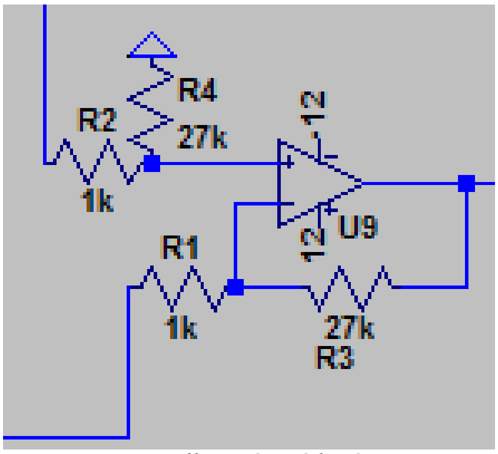

Fig. 11. Differential amplifier design

$$V_{out} = \frac{-R_3}{R_1} \cdot (V_2 - V_1) \tag{3}$$

3.4. DC Motor

This part is connected to the controller output and it has the circuit schematic designed in the LTSpice as in Fig. 12. Motor is driven with the help of a BJT. In this way, only when the output of the differential amplifier is positive and bigger than approximately 0.7 V, the motor starts running and its speed changes with the amplitude of the input DC signal that is received from the controller unit. Since this DC value is dependent on the voltage that is produced in the temperature station which also is dependent on the temperature, we managed to control the speed of the motor such that with increasing temperature, it gets faster and reverse is true as well.

The simulation results for the DC motor design is shown in Fig. 13. The measurement is taken for the base of the BJT when the controlled temperature is set to the selected one as before. (35℃) We see that the base-emitter junction is open and BJT works to run the motor. This is the result we observed in the laboratory as well. Experimental work is consistent with the simulations.

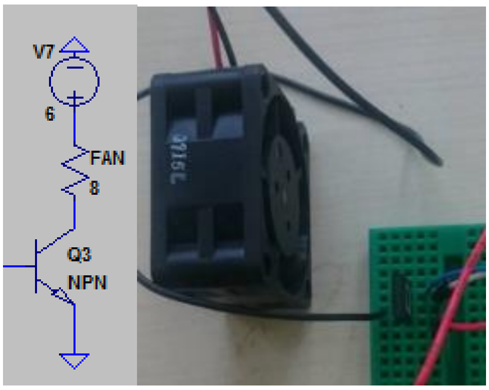

Fig. 12. Configuration of the DC Motor (a) with LTSpice (b) on breadboard

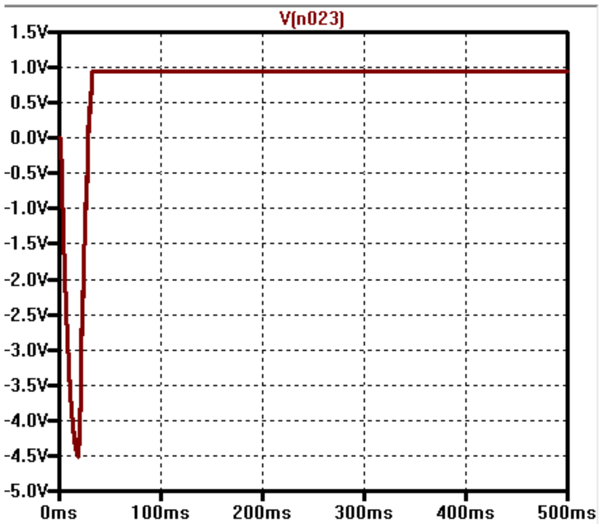

Fig. 13. Simulation result for motor driving BJT base-emitter voltage

3.5. Speaker and Microphone and the Problems During Their Implementation

For the wireless communication, we fed the signals that we generated in temperature stations to the two speakers via BJTs. We managed to obtain sound signals with 1 kHz and 10 kHz. However, what we observed was that when the frequency of the signal was increased the volume of it decreased. So in laboratory conditions, we came across with the limitation of the material and this limitation disturbed the theory of the two signals with the same magnitude at the same temperature for the two stations.

In theory, when the two signals have the same amplitude at the same temperature with the same construction, these signals are collected by the microphone, Here, microphone takes the role of the wire and summing amplifier in the wired communication. The output of the microphone is filtered with two filters as in wired communication. However, for this theory we constructed two active filters with op-amps, one being low pass with a 1.5 kHz cut-off frequency and the other with 10 kHz cut-off frequency. The filters were tested using signal generator for the same peak-to-peak voltage. The result was satisfactory.

The filters were passing their own frequency without a loss and filtering the other by a ratio of 6.

At this moment, we wanted to implement the filters, microphone and the speaker together into the circuit. What we encountered was that the system that works in the theory was not working properly no matter how hard we tried. To be more clear on the problem, we could not observe the magnitude modulation, although it worked very well when the system had wired connection.

We also had the major problem of the great decrease in the 10 kHz detected signal by the microphone. The filtered signal had a very low magnitude and it could not distinguish the two different frequencies very well. With this in hand, we could not possibly compare the two signals, since there was an imbalance which can be hardly annihilated due to the inconsistent laboratory conditions (i.e. changing temperature, noise, distance of the speaker and microphone etc.).

It is important here to note that, separately, the microphone circuitry that is designed as in Fig. 12. worked, that is it detected the sound signal that was generated by the signal generator's sinusoidal input given to the speakers. This means, we were able to generate the desired signals but with a limitation that we could not foresee and we were able to receive the signals generated according to the theory. However, because of the reasons that were explained, the system did not work as preferred, therefore we found it suitable to operate the whole system with a wired communication and in addition, to show the microphone circuit and speaker usage individually.

In Fig. 14. the circuit schematic that is designed to connect the microphone is shown. This design is the one used in the laboratory. The original design is shown in Fig. 18.

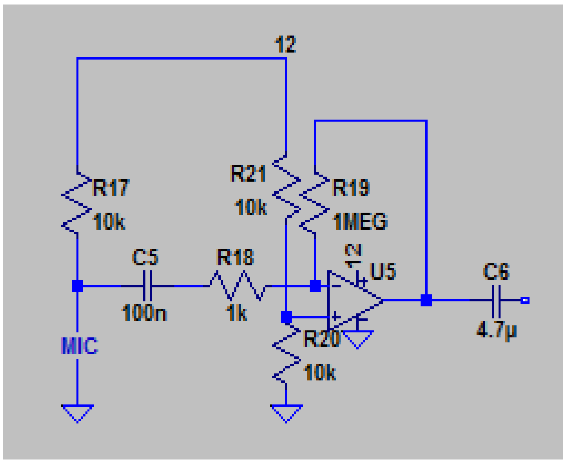

Fig. 14. Microphone circuitry used in the laboratory

Fig. 15. shows the speaker connections designed in LTSpice.

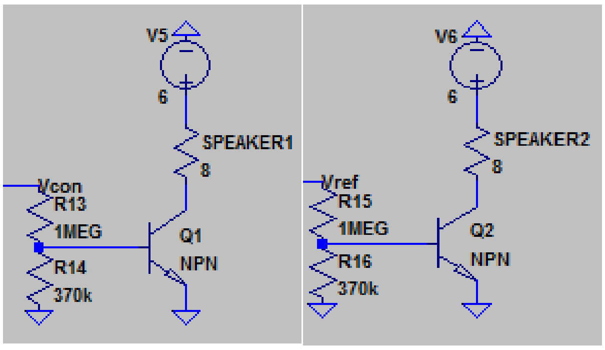

Fig. 15 Speaker designs for (a) controlled (b) reference

Fig. 16. shows the wireless communication to be put instead of a wire in Fig. 19 for transmitting and receiving the signal via a speaker and a microphone.

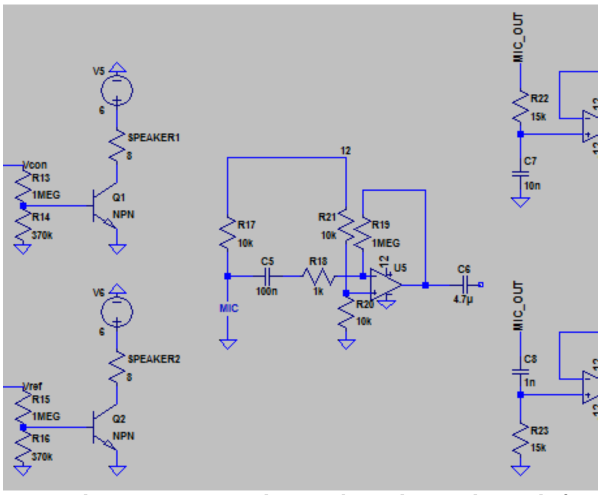

Fig. 16. Wireless communication design to be implemented instead of a wire.

The overall circuit design can be seen in Fig. 17, 18 and 19, showing on-board circuit with speakers, microphone design individually and LTSpice design respectively.

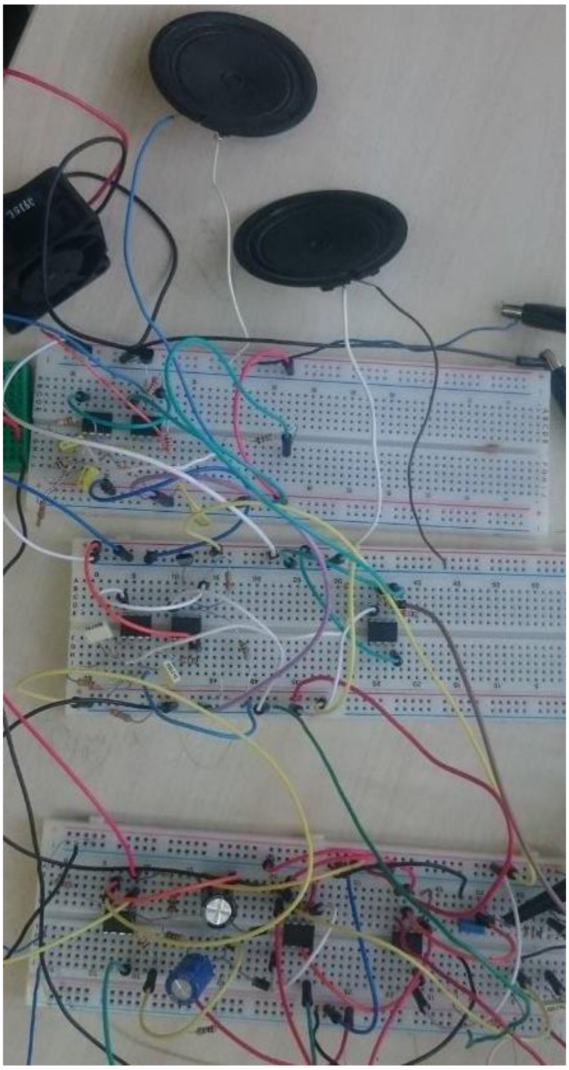
Fig. 17. Overall laboratory design of the system

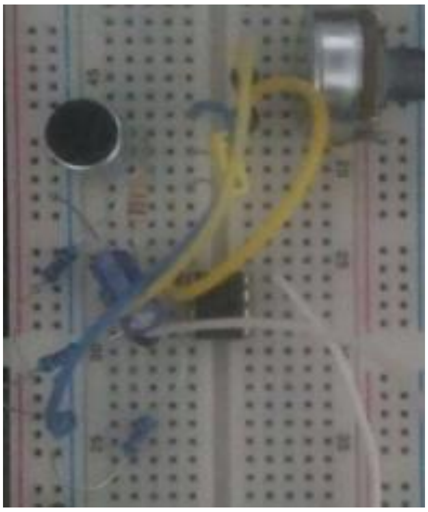
Fig. 18. Microphone design

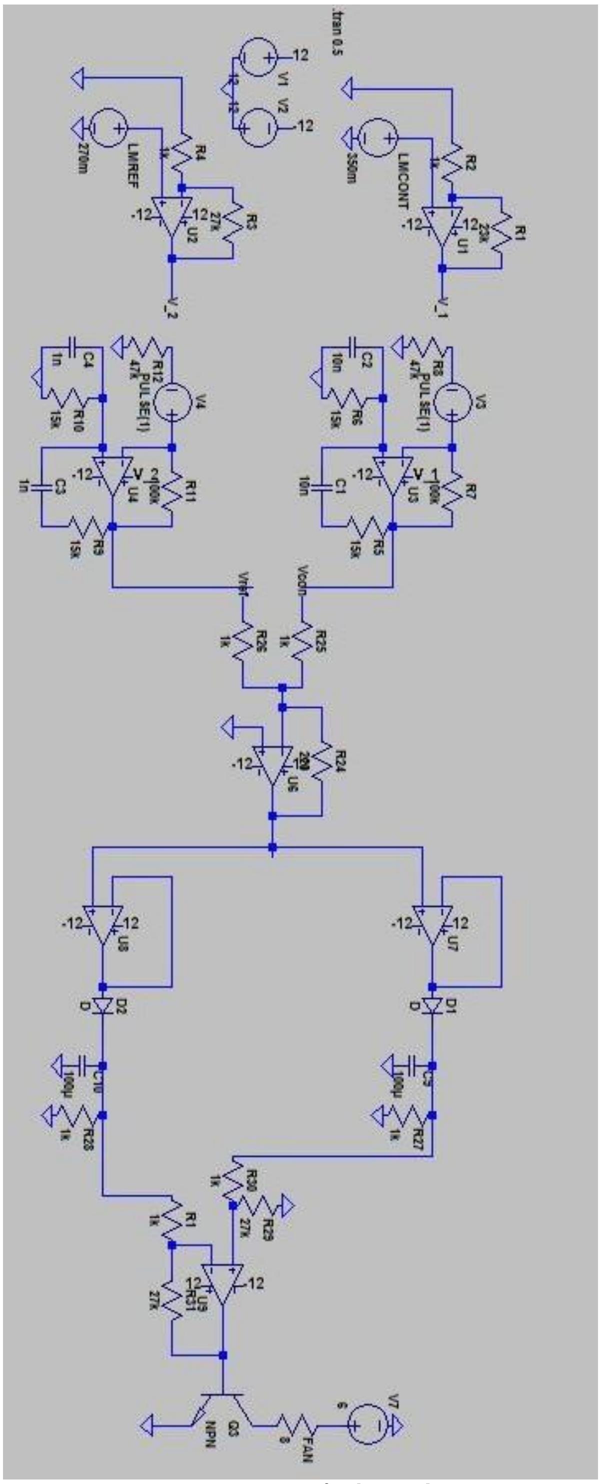
Fig. 19. LTSpice Design for the wired system

4. Conclusion

In this project, we were asked to build a responding system via a wireless communication. This was supposed to be done in an analog fashion and we were to use our analog electronics knowledge to find a proper solution for the given problem.

Based on this, we designed the overall system and separated it to sub-blocks as temperature stations, where we get two outputs, one being reference other being controlled and transmit the signals via speakers, a controller unit, where the signals were collected wirelessly via a microphone and where there is a DC converter and a decision unit to compare two DC outputs. This very last output determines to run the motor or not.

During the implementation of the project, we were confronted various problems. This is why, first we changed our approach to the project and changed our methodology. That is, we used sound system instead of laser communication. After taking this new approach, we came through additional problems on the wireless communication part of the system which could be due to the inadequacy of the materials or unsatisfactory external conditions. It is not believed that the problem arises from the way of our approach, since the wireless part works well unconnected to the rest of the system.

At this point, with lack of time, we found it appropriate to show the work in two parts as wired communication and the wireless section. These two parts worked as desired when separate. As a last attempt, we tried to bring them together but with the same negative result having the same problems.

In short, with this project, we put our analog electronics' theoretical knowledge into practice, to see that there are quite a lot of problems arising due to some ignoring in the calculations, different material's varying properties, connection-on-board inefficiencies, external disturbances, time and technical inabilities. We showed great care building the circuits over and over to overcome these difficulties, some being solved, some failed. We improved our ability to analyze a problem, brainstorm on possible solutions, create a blueprint, research, do group work, form additional plans in case of the one held does not work, use the time as efficient as possible, increase our endurance against the hard work we have been through while performing this project.

References

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