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MIDDLE EAST TECHNICAL UNIVERSTY

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

EE214 ELECTRONIC CIRCUITS LABORATORY

2017-2018 SPRING

TERM PROJECT

WIRELESS FIRE DETECTION SYSTEM

PRE-REPORT

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1) INTRODUCTION

In this project, we are supposed to build a fire protection system sensing the temperatures of three different areas and light a LED according to which area is the hottest. As sensing and indicator units are far from each other, we use a wireless transmission system which is composed of a speaker and a microphone. In our design, we used circuit designs that we have learned in the laboratory such as Wien bridge oscillator and band-pass filter. We decomposed the project in 5 parts as below.

- Sensing Unit
- Signal Generator Unit
- Wireless Transmission Unit
- Filter Unit
- Indicator Unit

2) BASIC DESIGN DIAGRAM

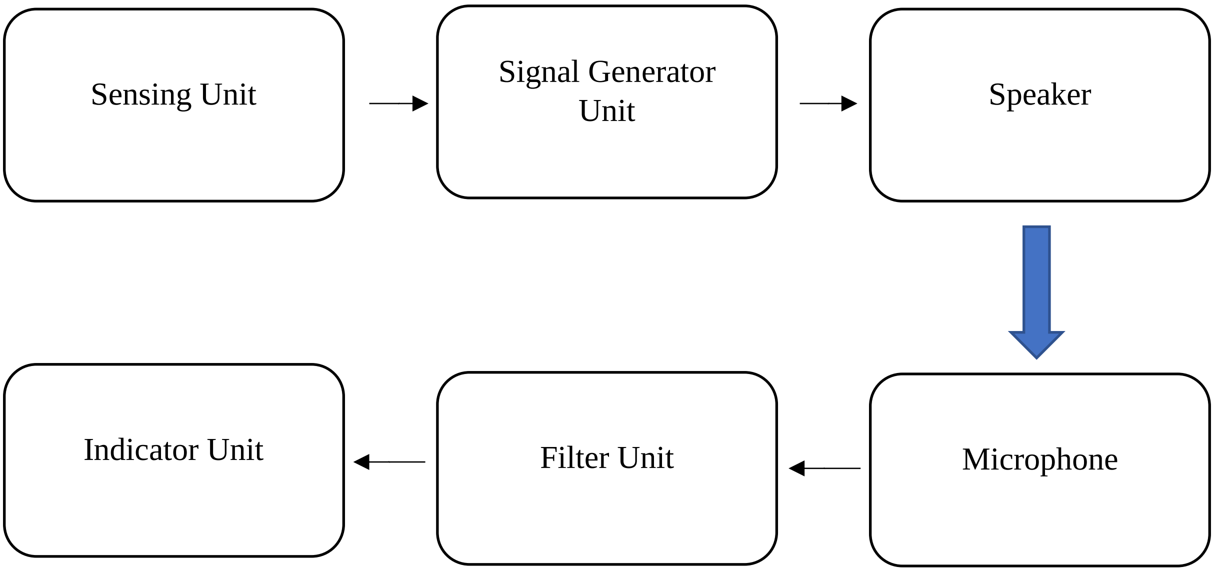


Figure 1: Design diagram of the project

The project consists of five parts as can be seen from Figure 1. Firstly, the LM35 temperature sensors in the sensing unit will observe the temperatures from three different places. Then, in the signal generator unit, two different sine waves which are 3kHz and 5kHz will be produced according to which area has the highest temperature. Later, these sine waves will be summed up with a summing amplifier, and the final signal will be sent to the speaker. The speaker will generate the necessary sound wave according to this signal. The microphone will observe this sound wave and convert it back to an electrical signal. Then, in the filter unit, this signal will be passed through two filters whose center frequencies are 3kHz and 5kHz. In this way, both the noise will be removed, and the desired frequencies will be obtained. Then, these signals will be sent to the indicator unit, and AC signals will be converted to DC signals with the help of full wave rectifier circuits. Finally, they will be compared with the reference voltages, and the RGB will light a different color of light for each case.

3) CIRCUIT SCHEMATICS

A) SENSING UNIT

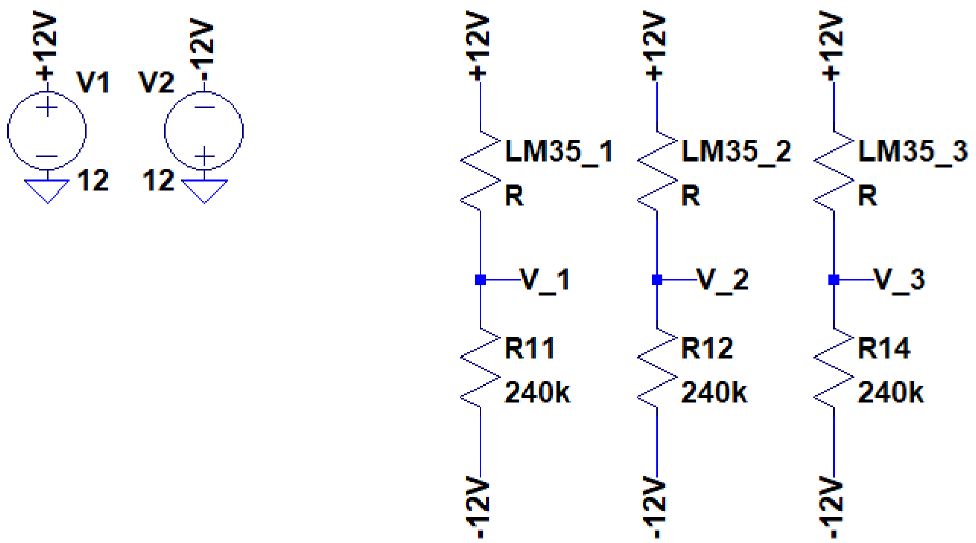


Figure 2: The circuit schematic of the sensing unit

The sensing unit will sense the temperatures of three different places and produce three voltage values accordingly. In this part, three LM35 temperature sensors will be used as can be seen from Figure 2. LM35 has three pins. Two of the pins are connected to positive voltage supply and ground, and the other pin generates a voltage value according to the temperature obtained via LM35. In the schematic, the pin connected to the ground is not shown. The resistance value connected to the output of the sensor is calculated as shown in the datasheet [1].

$$R = V_s / 50\ \mu A \quad (1)$$

$$V_s = 12\ V \quad (2)$$

$$\Rightarrow R = 240\ k\Omega \quad (3)$$

Therefore, as the temperature increases, the output voltage increases. Then, three voltage values proportional to measured temperatures are obtained in this part.

B) SIGNAL GENERATOR UNIT

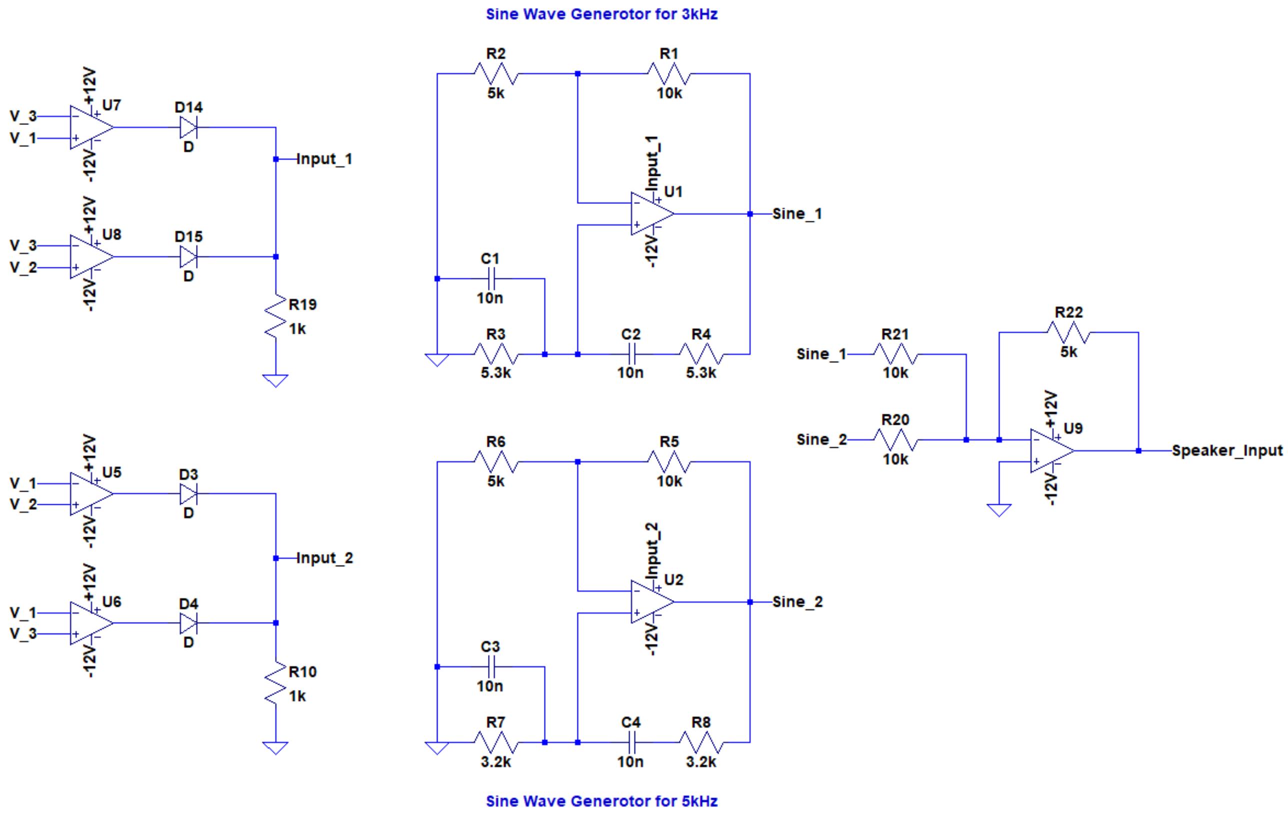


Figure 3: Circuit schematic for the signal generator unit

In this part of the project, according to comparisons between the temperature values, two different sine waves will be produced. As can be seen from Figure 3, firstly, different inputs for supplies of sine wave generators will be produced. It is wanted that if V_1 is highest, only 3kHz sine wave is generated; if V_2 is highest, both 3kHz and 5kHz sine waves are generated; if V_3 is highest, only 5kHz sine wave is generated. Therefore, if V_1 is highest, second generator won't work; and if V_3 is highest, first generator won't work. To obtain this result, for the first generator, we compared V_3 with V_1 and V_2 in two comparators. If it has the highest voltage, Input_1 will be 0V because an OR gate is used, and then the first generator won't produce sine wave. If it is not the highest one, Input_1 will be +12V, and the first generator will produce sine wave. The second generator works the same way as the first generator does. If V_1 has the highest value, it doesn't produce sine wave. If it is not the highest one, it will produce sine wave. Later, Input_1 and Input_2 will be connected to the supplies of the generators with the help of buffers.

As for sine wave generators, Wien bridge oscillators are used. Resistance and capacitance values for the circuit are calculated from the following equations [2].

For 3kHz sine wave generator:

$$fr = \frac{1}{2\pi RC} \quad (4)$$

$$fr = 3000Hz \quad (5)$$

$$C = 10nF \quad (6)$$

$$\Rightarrow R = 5.3\ k\Omega \quad (7)$$

For 5kHz sine wave generator:

$$fr = \frac{1}{2\pi RC} \quad (8)$$

$$fr = 5000Hz \quad (9)$$

$$C = 10nF \quad (10)$$

$$\Rightarrow R = 3.2\ k\Omega \quad (11)$$

After the sine waves are generated, they will be sent to the summing amplifier with the help of buffers. The summing amplifier will sum up these two sine waves. The output voltage for the summing amplifier is calculated as follows [3].

$$Vout = -(Vin_1 + Vin_2) * Rf / Rin \quad (12)$$

$$\Rightarrow Vout = -(Vin_1 + Vin_2) * 5\ k\Omega / 10\ k\Omega \quad (13)$$

$$\Rightarrow Vout = -(Vin_1 + Vin_2) / 2 \quad (14)$$

Later, this final signal will be sent to the speaker. The simulations for the Wien bridge oscillators and summing amplifier are as follows.

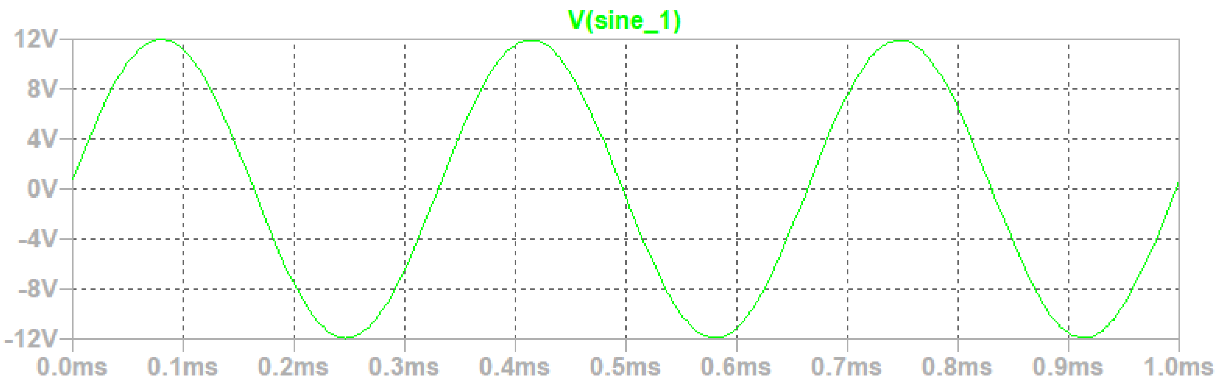


Figure 4: The sine wave generated by the first Wien bridge oscillator with frequency of 3kHz when Input_1 = 12V

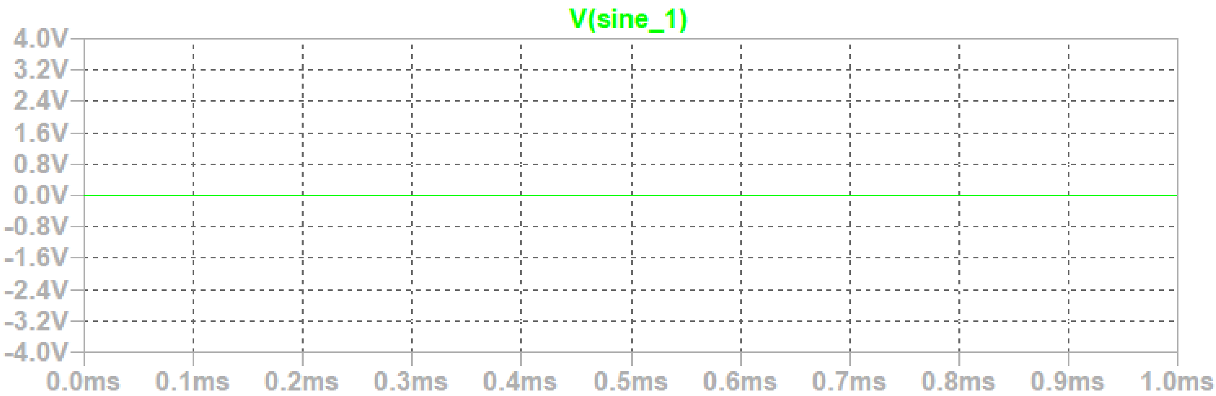


Figure 5: The sine wave generated by the first Wien bridge oscillator with frequency of 3kHz when Input_1 = 0V

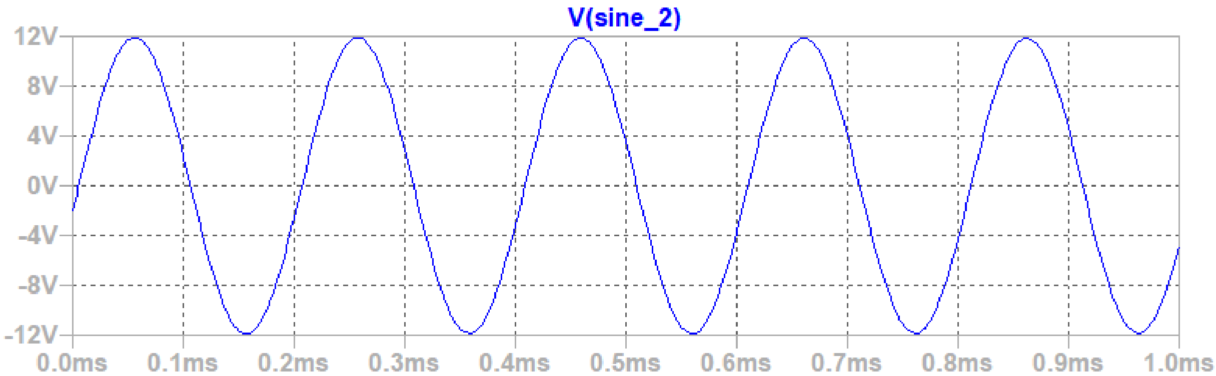


Figure 6: The sine wave generated by the second Wien bridge oscillator with frequency of 5kHz when Input_2 = 12V

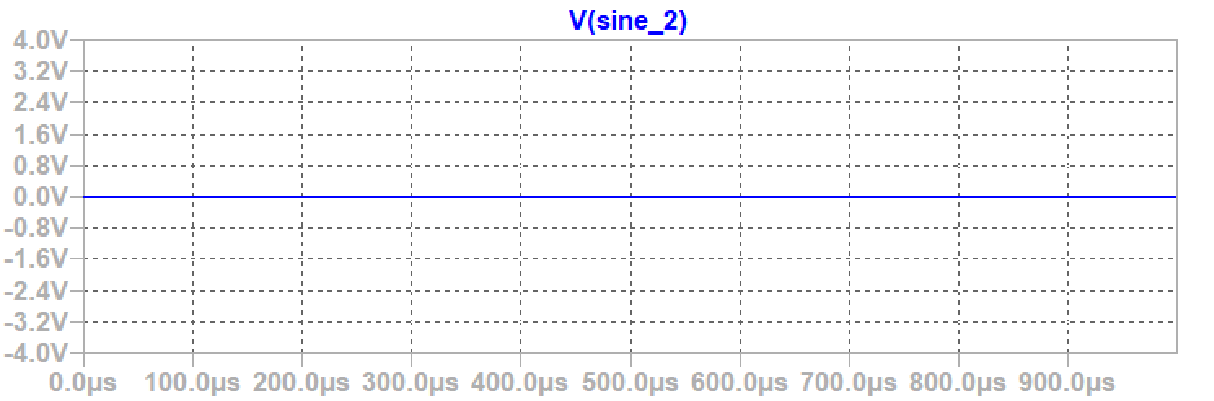


Figure 7: The sine wave generated by the second Wien bridge oscillator with frequency of 5kHz when Input_2 = 0V

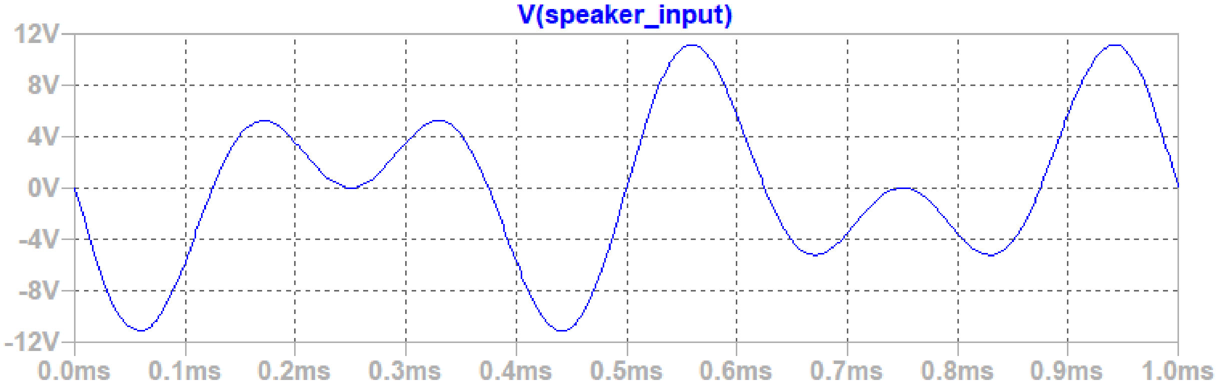


Figure 8: The voltage waveform of the output of the summing amplifier when both generators are working

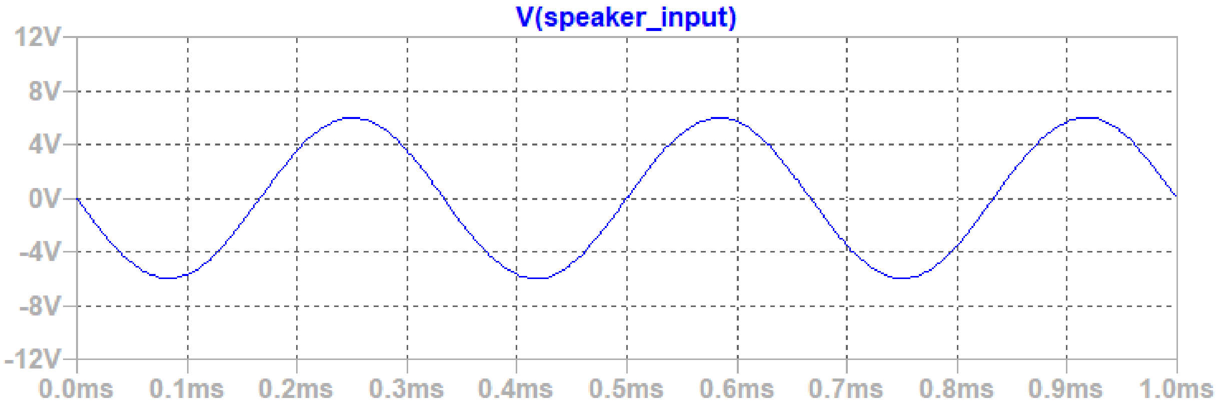


Figure 9: The voltage waveform of the output of the summing amplifier when only the first generator with frequency of 3kHz is working

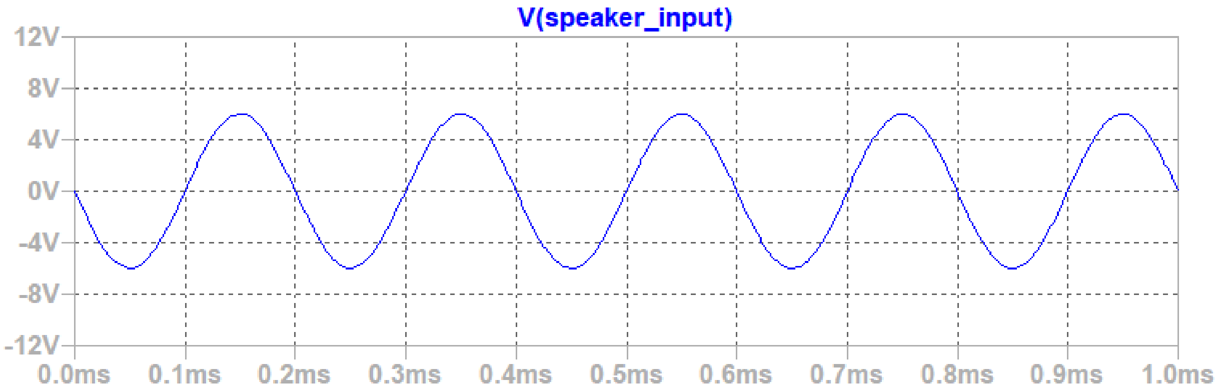


Figure 10: The voltage waveform of the output of the summing amplifier when only the second generator with frequency of 5kHz is working

C) WIRELESS TRANSMISSION UNIT

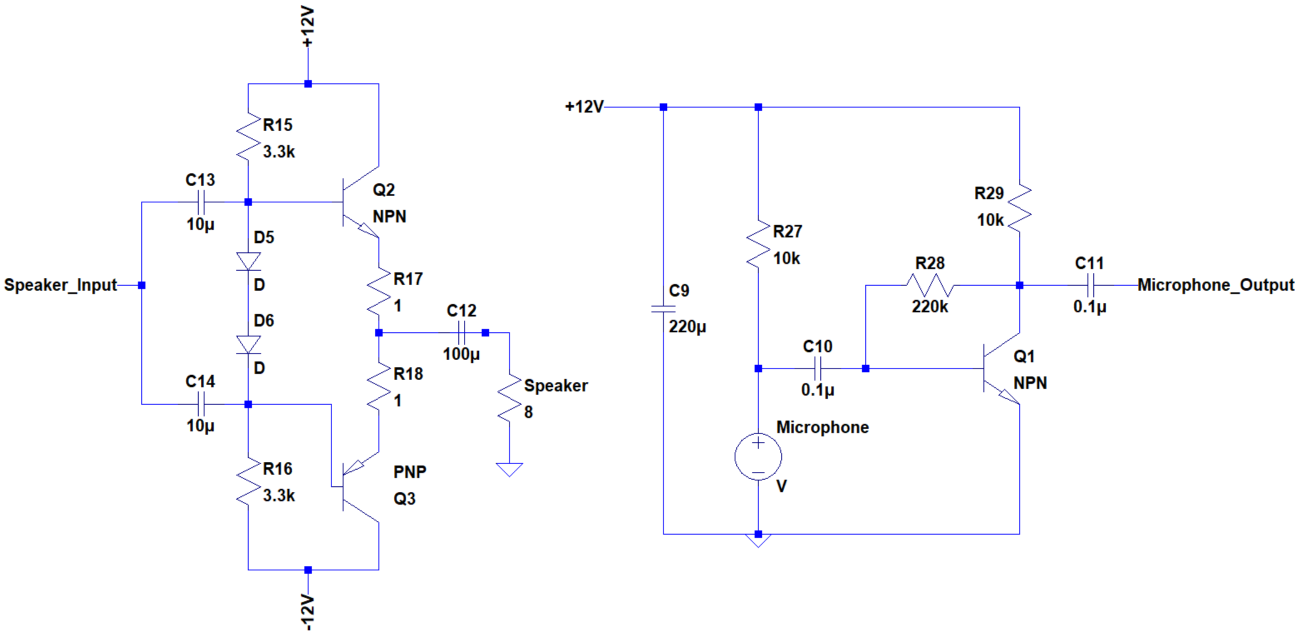


Figure 11: The circuit schematic for wireless transmission unit

Audio amplifiers are used for amplifying low power audio signals to a level which is sufficient for driving the speakers. There are a lot of topologies for audio amplifiers. Some of them are Class A, Class B, Class AB amplifiers. Class A amplifier is used while amplifying the small signal to protect details of small signal. However, it has low efficiency. The other one is Class B amplifier. Class B amplifiers are more efficient with respect to the Class A amplifiers. However, it degrades audio quality since the signal is lost when the transistors are off. Hence the best solution is to use Class AB topology. Class AB amplifier provides the sound quality of Class A topology with the efficiency of Class B topology. It consists of two transistors (npn and pnp types) to increase efficiency. The design has two diodes as can be seen from Figure 11. They are used to bias transistors and prevent distortion. We also added source degeneration to lower power dissipation on the BJTs. In our design, we used an 8Ω speaker.

Then, the microphone will get the signal from speaker, and this signal will go to the filter bank. Microphone works as a voltage source. It gets the signal, and it produces voltage signal according to this sound. In our case, the microphone takes sine waves from speaker. However, it produces very small signal, and we need to amplify it by a circuit. For this purpose, we used the circuit below. BJT is used to get gain, and capacitors are needed to decrease noise of microphone. Microphone produces voltage at 20mV and output voltage of the microphone circuit is 7.2 Vpp, so its gain is 360.

The output voltage waveforms of the speaker and microphone circuits are obtained as follows.

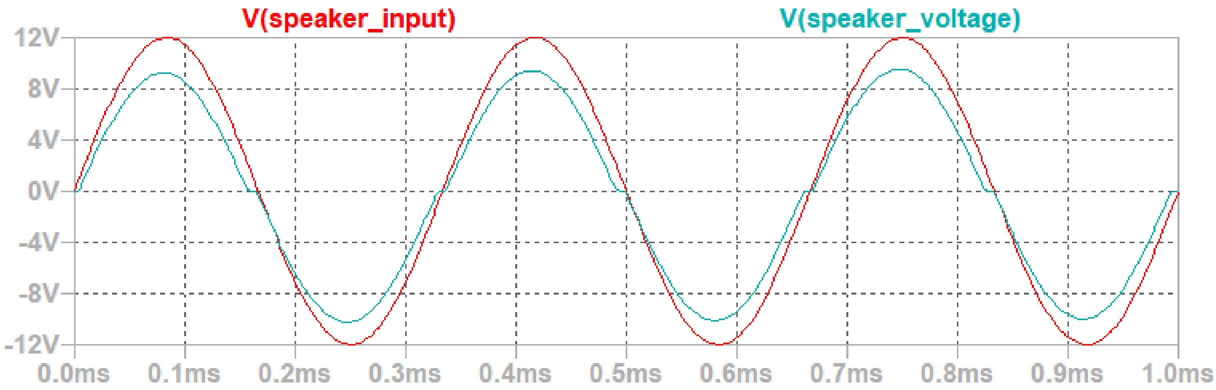


Figure 12: Input and output voltage waveforms of the speaker circuit

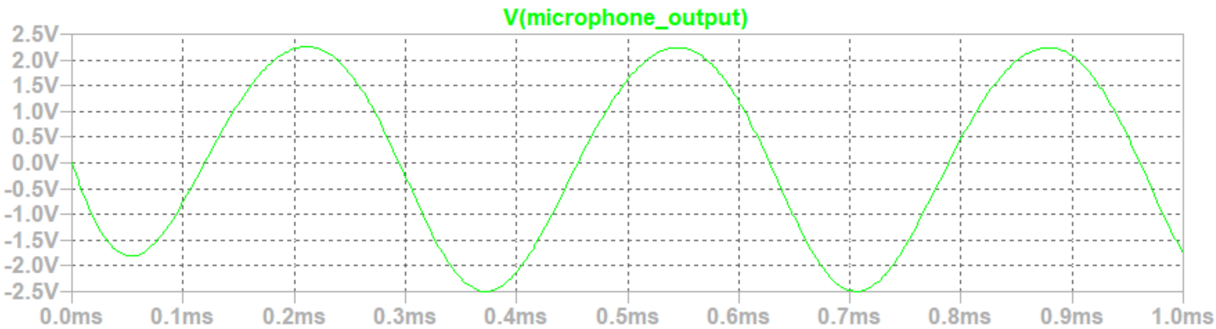
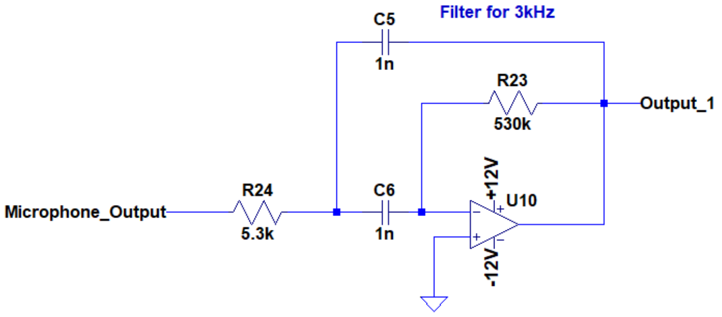


Figure 13: Output voltage waveform of the microphone circuit when microphone produces a sine wave with 10mV amplitude and 3kHz frequency

D) FILTER UNIT



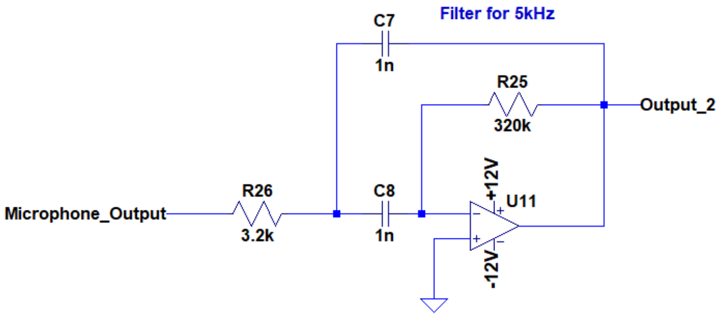


Figure 14: The circuit schematic for the filter unit

$$H(s) = \frac{-s*R2*C}{s^2*(R1*R2*C^2)+s*(2*R1*C)+1} \tag{15}$$

In this part of the project, we pass the output signal of the microphone circuit through the filters. As can be seen from Figure 14, there are two filters whose center frequencies are 3kHz and 5kHz. While connecting the output of the microphone to the filters, buffers are used to prevent distortion of the microphone circuit. The transfer function of the circuit is given above. The resistance and capacitive values in the filters are calculated as follows [4].

For the filter with center frequency of 3kHz:

$$\text{fr} = \frac{1}{2\pi\sqrt{R_1*R_2*C^2}} \tag{16}$$

$$Q = \frac{1}{2}\sqrt{\frac{R_2}{R_1}} \tag{17}$$

$$G = -2 * \frac{R_2}{R_1} \tag{18}$$

$$\text{fr} = 3\text{kHz} \tag{19}$$

$$Q = 5 \tag{20}$$

$$C = 1\text{nF} \tag{21}$$

$$\Rightarrow R_1 = 5.3\ \text{k}\Omega \tag{22}$$

$\Rightarrow R_2 = 530\ k\Omega$ (23)

$\Rightarrow |G| = 50$ (24)

For the filter with center frequency of 5kHz:

$$fr = \frac{1}{2\pi\sqrt{R_1 * R_2 * C^2}} \tag{25}$$

$$Q = \frac{1}{2}\sqrt{\frac{R_2}{R_1}} \tag{26}$$

$$G = -2 * \frac{R_2}{R_1} \tag{27}$$

fr = 5kHz (28)

Q = 5 (29)

C = 1nF (30)

$\Rightarrow R_1 = 3.2\ k\Omega$ (31)

$\Rightarrow R_2 = 320\ k\Omega$ (32)

$\Rightarrow |G| = 50$ (33)

After the signal is passed through the filters, we expect to obtain two sine waves whose frequencies are 3kHz and 5kHz. In the following figures, the magnitude responses of the filters are shown.

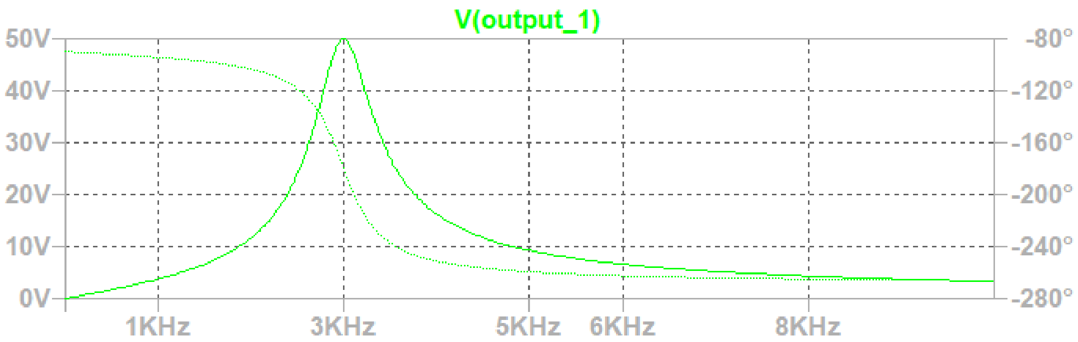


Figure 15: Frequency response for the first filter with center frequency of 3kHz

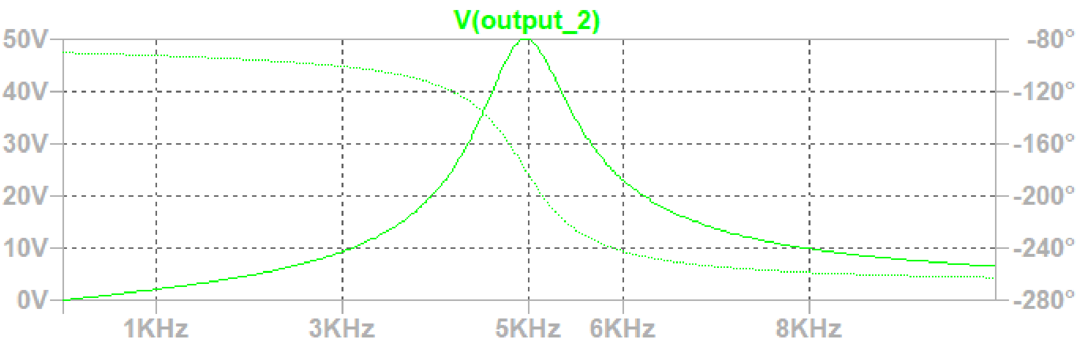


Figure 16: Frequency response for the second filter with center frequency of 5kHz

E) INDICATOR UNIT

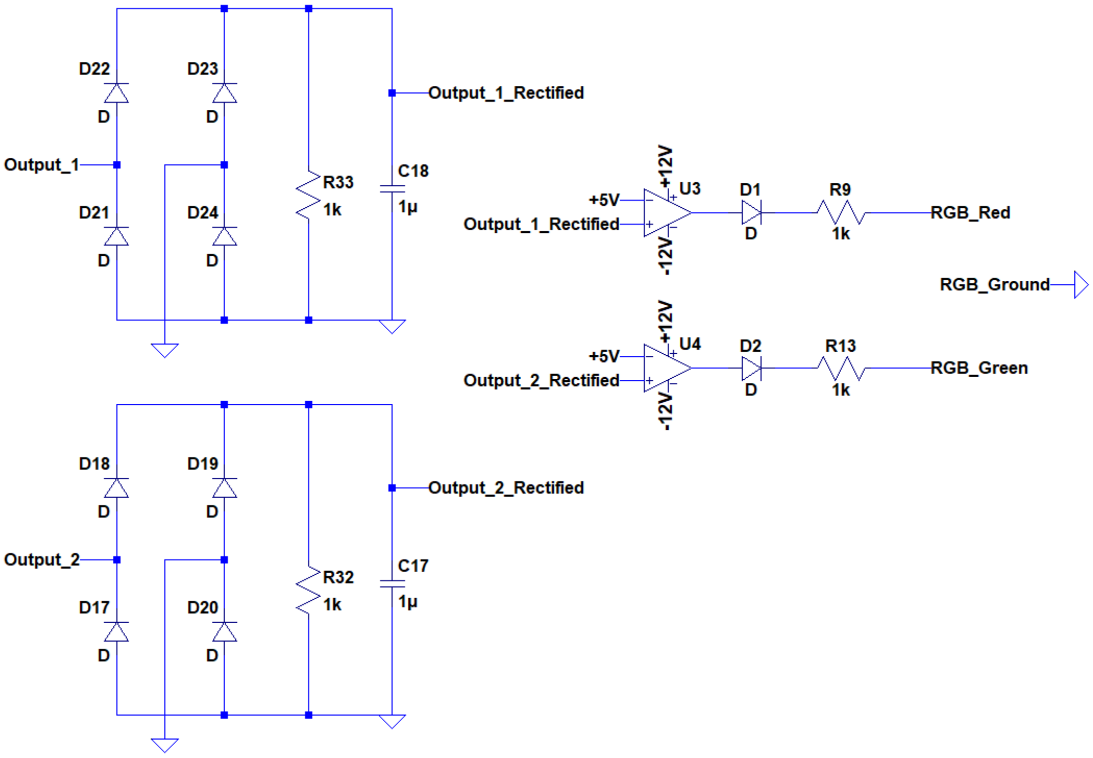


Figure 17: The circuit schematic for the indicator unit

In this part of the project, the outputs of the filters in the filter unit are connected to the full wave rectifiers with the help of buffers. As can be seen from Figure 17, two full wave rectifiers are used to convert the AC signal to the DC signal. This way, we can use this signals in our indicator unit in a proper way. Afterwards, Output_1_Rectified and Output_2_Rectified are connected to operational amplifiers to compare them with the reference voltage which is +5V. If they are larger than +5V, operational amplifiers will give +12V, or they will give -12V otherwise. Then, these amplifiers are connected the red node and the green node of the RGB. A common cathode RGB is used. When a sine wave is produced in Output_1, RGB lights red color. When a sine wave is produced in Output_2, RGB lights green color. When both Output_1 and Output_2 produces a sine wave, RGB light yellow color. This way, we differentiate the different situations we obtained in the sensing unit. In the following figures, output voltage waveforms of the full wave rectifiers and RGB_Red and RGB_Green nodes for different sine waves are presented.

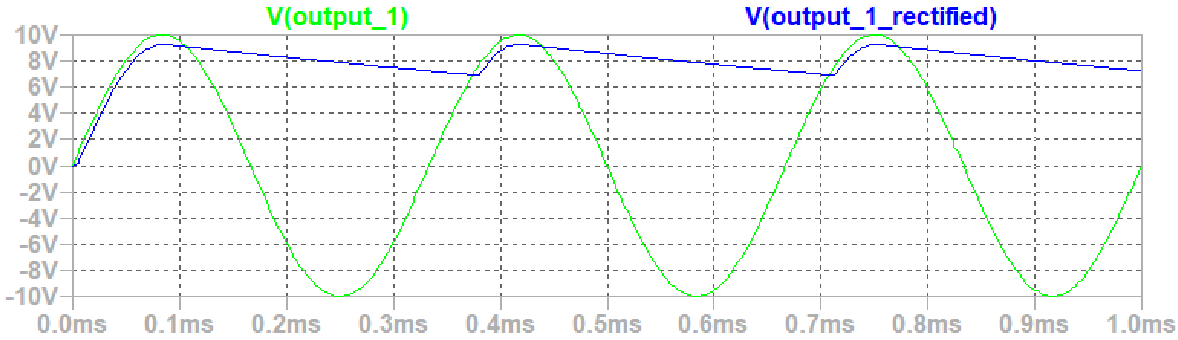


Figure 18: Output of the first full wave rectifier when Output_1 is a sine wave with 10V amplitude and 3kHz frequency

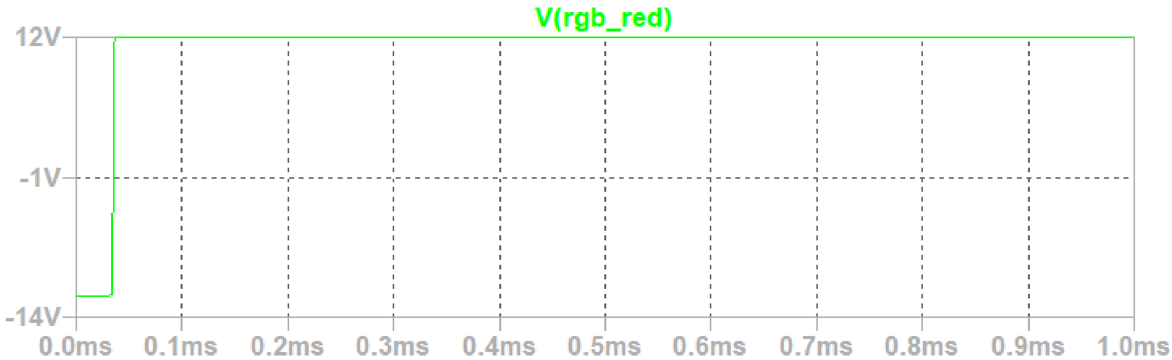


Figure 19: Voltage value of the RGB_Red when Output_1 is a sine wave with 10V amplitude and 3kHz frequency

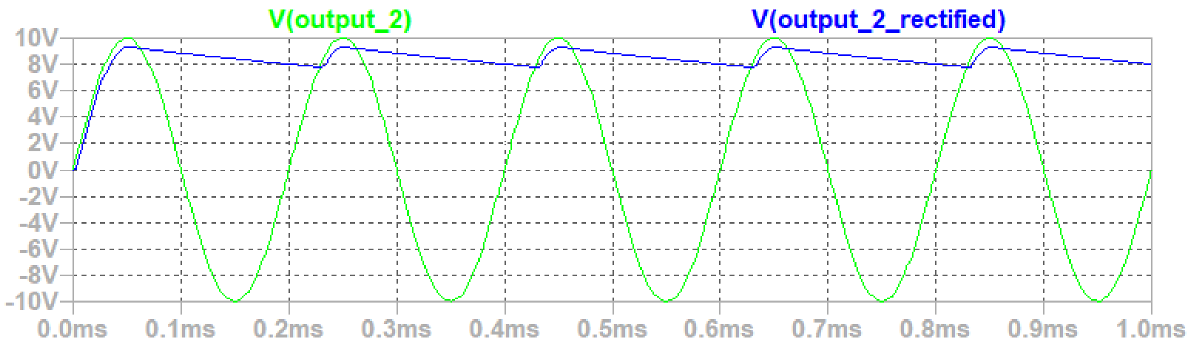


Figure 20: Output of the second full wave rectifier when Output_2 is a sine wave with 10V amplitude and 5kHz frequency

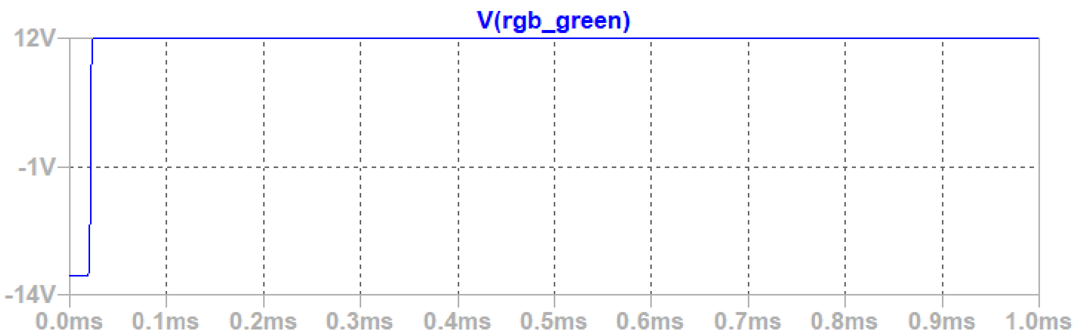


Figure 21: Voltage value of the RGB_Green when Output_2 is a sine wave with 10V amplitude and 5kHz frequency

4) OVERALL SCHEMATIC OF THE PROJECT

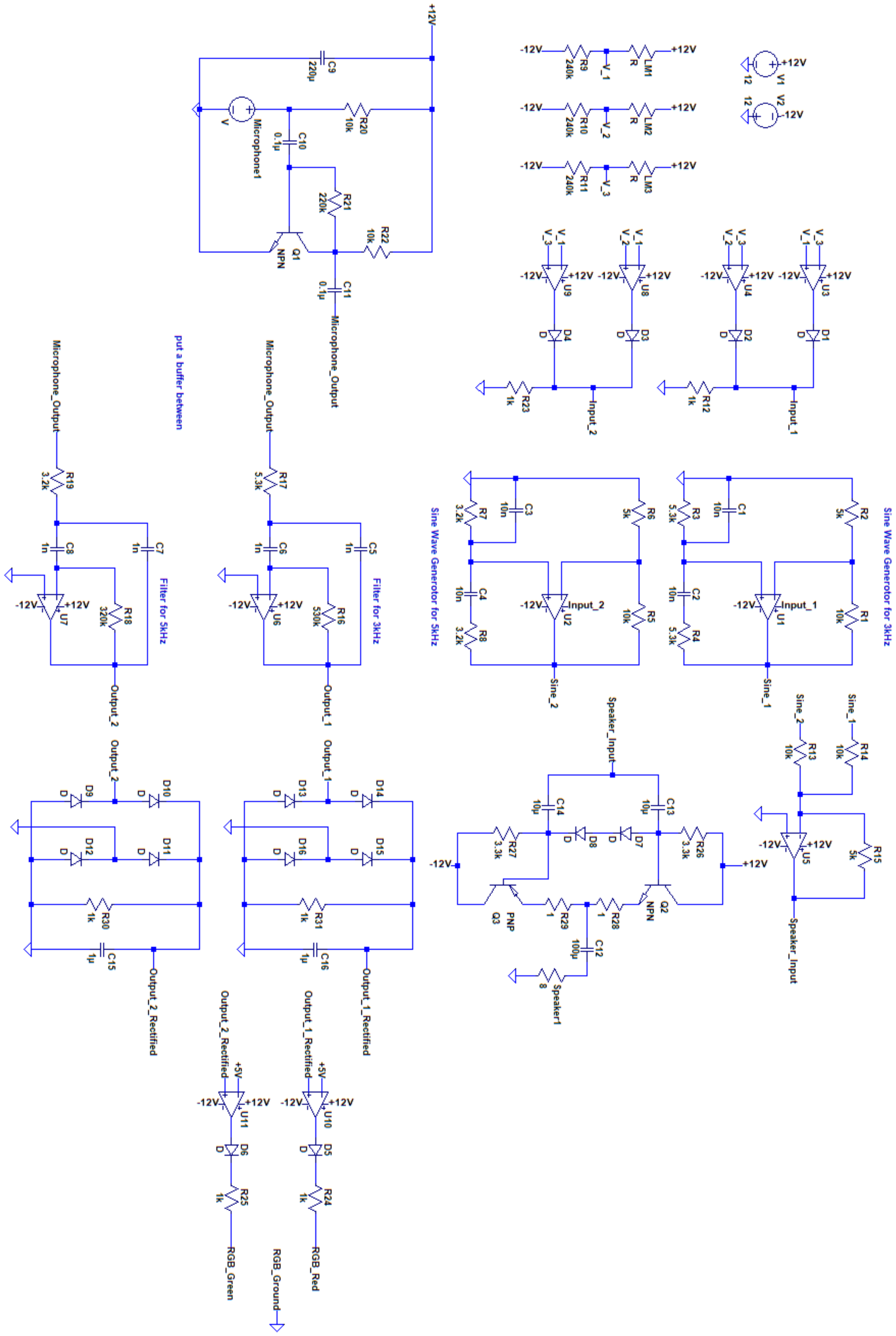


Figure 22: Overall schematic of the project

5) SELECTION OF EQUIPMENT

- LM741: basic, general purpose operational amplifier
- LM35: temperature sensor
- Diodes: for rectifier circuits, and necessary parts
- Resistors, Potentiometers and Capacitors: for filter design, and necessary parts
- Common Cathode RGB LED: to obtain different colors for different outputs
- Speaker and 8Ω Microphone: to set up a wireless system
- npn and pnp Transistors: for speaker and microphone circuits

6) CONCLUSION

In this project, our aim is to set up a wireless fire detection system. For this purpose, we have learned how to use temperature sensors in an analog circuit. We have used comparator circuits to see which sensor gives the highest value. We have used gate circuits to decide which sine generators will work, and according to this result, we have produced sine waves in different frequencies with the help of Wien bridge oscillators as we did in the laboratory experiments. To establish the wireless system, we will send sine waves via the speaker, and the microphone will take it. So, we will work on how to drive a speaker, and how to work a microphone. To handle these problems, we made an AB class amplifier, and we amplified the output of the microphone because we learned that it works as a voltage source which produces a signal with low amplitude. We have made use of filters to understand which sine wave is taken by the microphone. We decided to use band pass filter, and with the help of this, we differentiated two sine waves with different frequencies and eliminated the noise. Finally, we made an indicator unit which composes of full wave rectifiers for AC to DC conversion, comparators to compare the final voltages with the reference voltage and an RGB LED to indicate the result.

In conclusion, while designing our project, we practiced what we have learned from laboratory sessions, used special circuit designs whenever necessary and made a lot of Internet research to solve the problems we faced during designing the project. Also, we have learned to use logic gates when an algorithm needs to be implemented. Therefore, it was a good chance to put our theoretical knowledge into practical use.

7) REFERENCES

[1] LM35 Precision Centigrade Temperature Sensors Datasheet [Online]. Available: http://www.ti.com/lit/ds/symlink/lm35.pdf

[2] The Wien Bridge Oscillator [Online]. Available: https://www.electronics-tutorials.ws/oscillator/wien_bridge.html

[3] The Summing Amplifier [Online]. Available: https://www.electronics-tutorials.ws/opamp/opamp_4.html

[4] Active Band Pass Filter [Online]. Available: https://www.electronics-tutorials.ws/filter/filter_7.html