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MIDDLE EAST TECHNICAL UNIVERSTY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

EE214 ELECTRONIC CIRCUITS LABORATORY

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TERM PROJECT

WIRELESS FIRE DETECTION SYSTEM

FINAL REPORT

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1. INTRODUCTION

In this project, our aim was to build a fire detection system which senses the temperatures of three different areas and light a LED according to which area is the hottest. we had to use a wireless transmission system so that the information can be transmitted between the two parts of the project. We decomposed the project in 5 parts as explained below.

Parts of our project are sensing unit, signal generator unit, wireless transmission unit, filter unit, and indicator unit. Sensing unit contains LM35 temperature sensors to understand the temperatures of three areas. Signal generator unit contains Wien bridge oscillator to generate some sinusoidal signals. Wireless transmission unit contains speaker and microphone, and they communicate with sine waves. The distance between the sensing and the indicator unit is modelled with 10 cm distance between speaker and microphone. Filter unit is basically two band pass filters to understand which sine wave is generated according to temperatures. Finally, indicator unit is basically a LED system to show which area is hottest.

In our design, we used the special circuit designs that we learnt and built at the laboratory sessions such as Wien bridge oscillator, band pass filter, some logic gates, AB class amplifier and so on. However, our design contains some new things for us such as microphone amplification.

2. BASIC DESIGN DIAGRAM

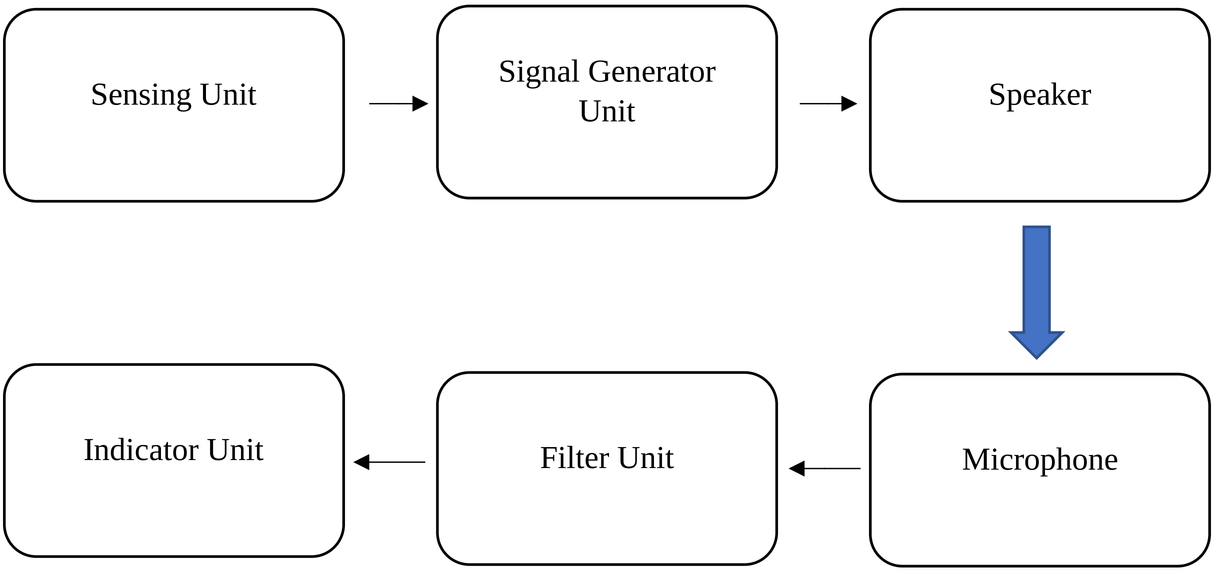

Figure 1: Design diagram of the project

The project consists of 6 parts as shown in Figure 1. First, the sensing unit generates three voltage values according to the temperature levels in three different areas. Then, these values are compared, and necessary sine waves with 3kHz and 5kHz frequencies are generated. Then, with the help of speaker circuit, these sine waves are converted into a sound wave. In the other part of the project, the microphone senses the sound wave and generates a signal accordingly. This signal is amplified as the microphone has a very low output voltage value. Then, filters decompose the signal into two different signals. The 3kHz and 5kHz parts are rectified so that their DC values can be compared to each other. By comparing them in the indicator unit, according LEDs shine and we differentiate which area has the highest temperature.

1) CIRCUIT SCHEMATICS

A) SENSING UNIT

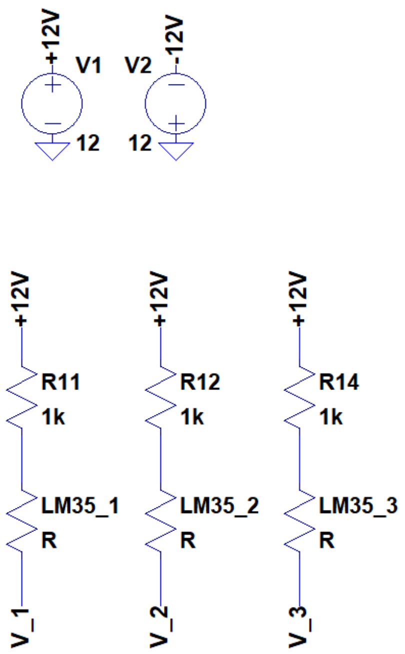

Figure 2: The circuit schematic of the sensing unit

As shown in Figure 2, in this part, LM35 temperature sensors are used and three voltage values are obtained. LM35 sensors have three pins which are input, output and ground. Resistors are connected between the +12V and LM35 input pin so that LM35 doesn't draw too much current. The ground pins are not shown in the figure. From the output pins of the sensors, three voltage values are obtained to be used later in the project.

B) SIGNAL GENERATOR UNIT

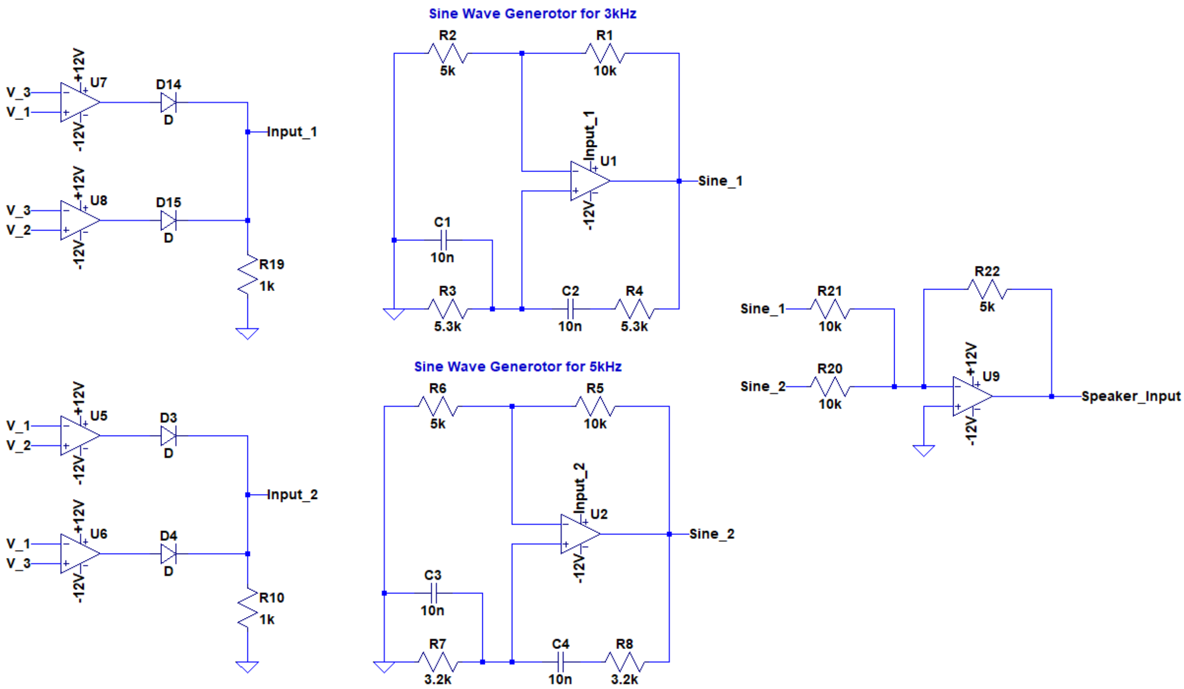

Figure 3: Circuit schematic for the signal generator unit

In this part of the project, 2 OR gates with diodes are used as shown in Figure 3. If V_1 has the highest value, only Input_1 becomes a high value. If V_2 has the highest value, both Input_1 and Input_2 become a high value. If V_3 has the highest value, only Input_2 becomes a high value. That way, by connecting this Input values to the voltage supplies of the operational amplifiers used in Wien bridge oscillators, we managed to produce sine waves according to the temperature levels. Afterwards, by using summing amplifier circuit, these sine waves are summed up and taken to the speaker circuit. Input values are connected to the supplies of the op-amps with the help of buffers so that the Wien bridge oscillators doesn't affect the OR gates.

The voltage signals of the Speaker_Input for three different cases are shown below in the following figures.

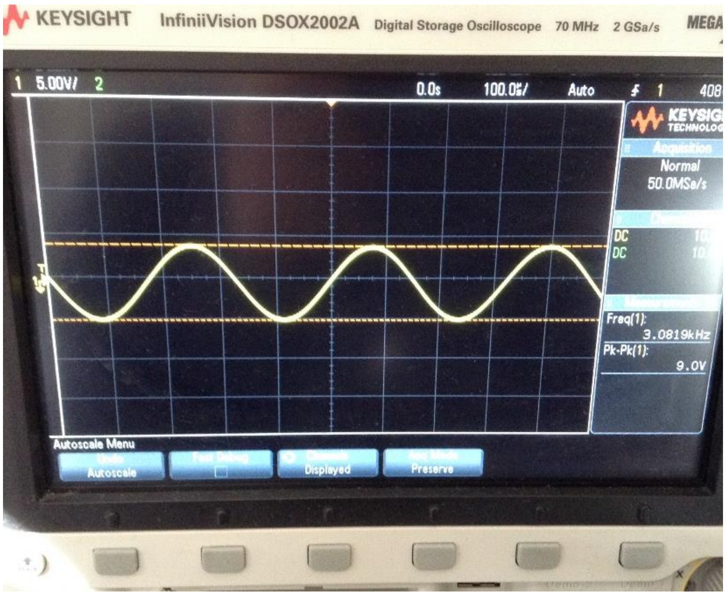

Figure 4: Voltage waveform of Speaker_Input when V_1 has the highest value

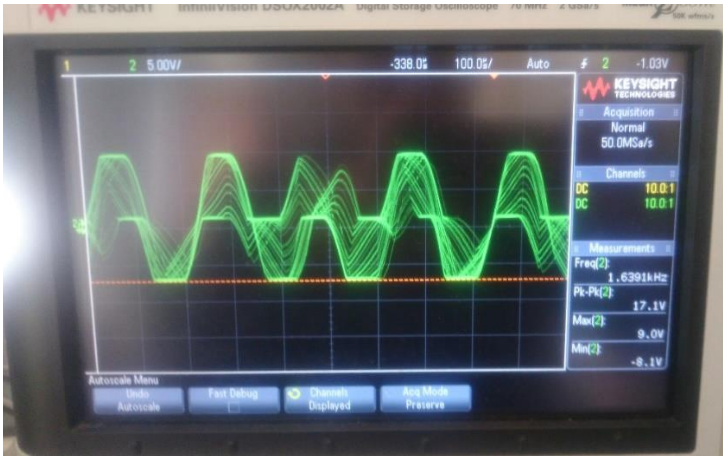

Figure 5: Voltage waveform of Speaker_Input when V_2 has the highest value

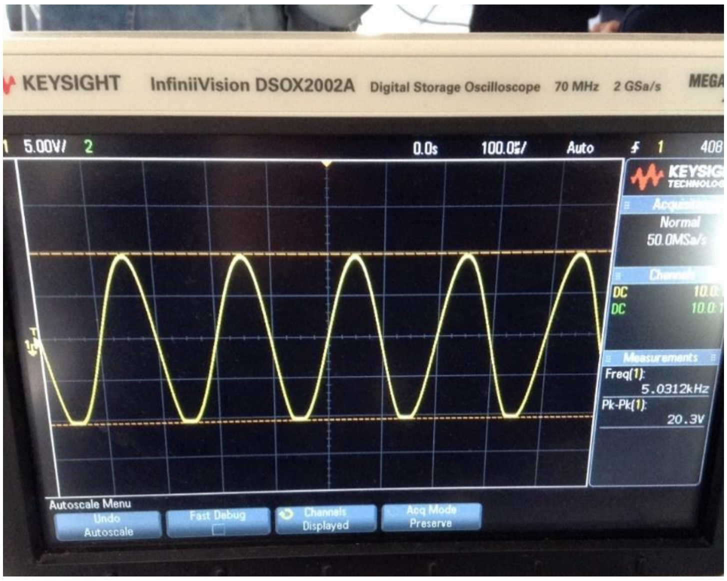

Figure 6: Voltage waveform of Speaker_Input when V_3 has the highest value

C) WIRELESS TRANSMISSION UNIT

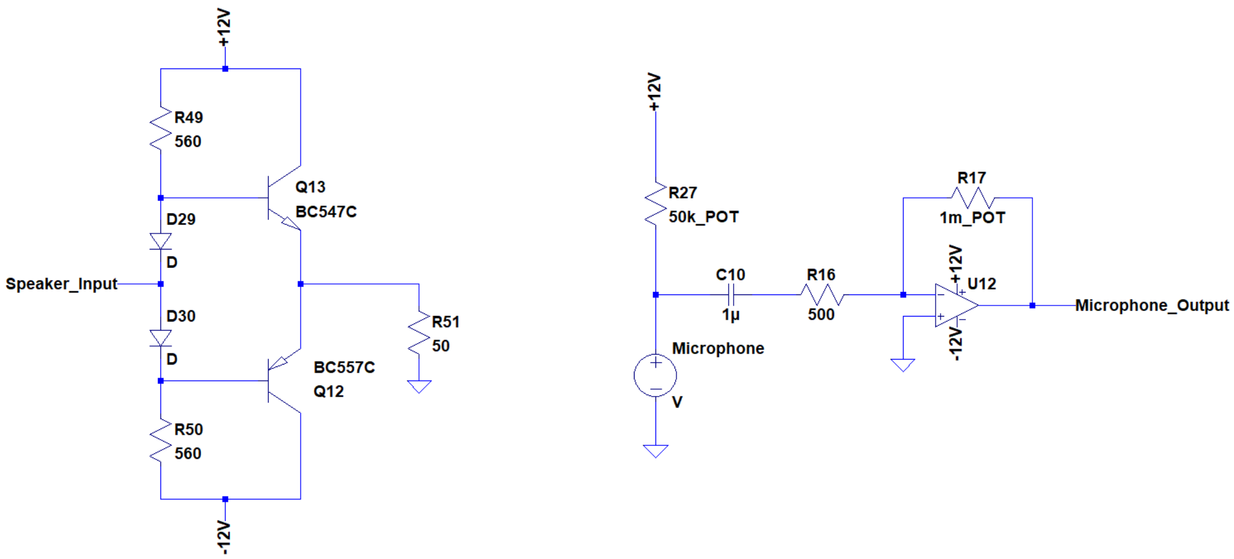

Figure 7: The circuit schematic for wireless transmission unit

As shown in Figure 7, this part consists of speaker and microphone circuits. As indicated, to send the data about which area is the hottest we used wireless transmission system because the sensing subsystem and the indicator subsystem of our design are apart from each other. For that purpose, a speaker and a microphone are used. To drive the speaker, we used an audio amplifier circuit because low power audio signals need to be amplified to reach a level which is sufficient to hear. Without an amplifier, the speaker cannot draw the sufficient current. Hence. We decided to use Class AB because Class AB amplifier provides the sound quality of Class A topology with the efficiency of Class B topology, so the best solution was to use Class AB topology. It consists of two transistors (npn and pnp types) to increase efficiency. The design has two diodes. 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. However, we could not be successful, so we changed it with 50Ω speaker, and we got good results.

To complete wireless transmission system, we tried to make microphone part. The microphone got the signal from speaker, and this signal is sent to the filter bank. Microphone works like a voltage source. It absorbs the sound wave, and it generates a voltage signal according to coming sound. In this project, the microphone gets sine waves from the speaker part. However, it generates very small signal, and it is needed to be amplified by a circuit. For this purpose, we used the circuit above. Inverter amplifier is used to amplify the signal, and capacitors are needed to remove the DC part of the signal. However, we could not manage to work the microphone part.

D) FILTER UNIT

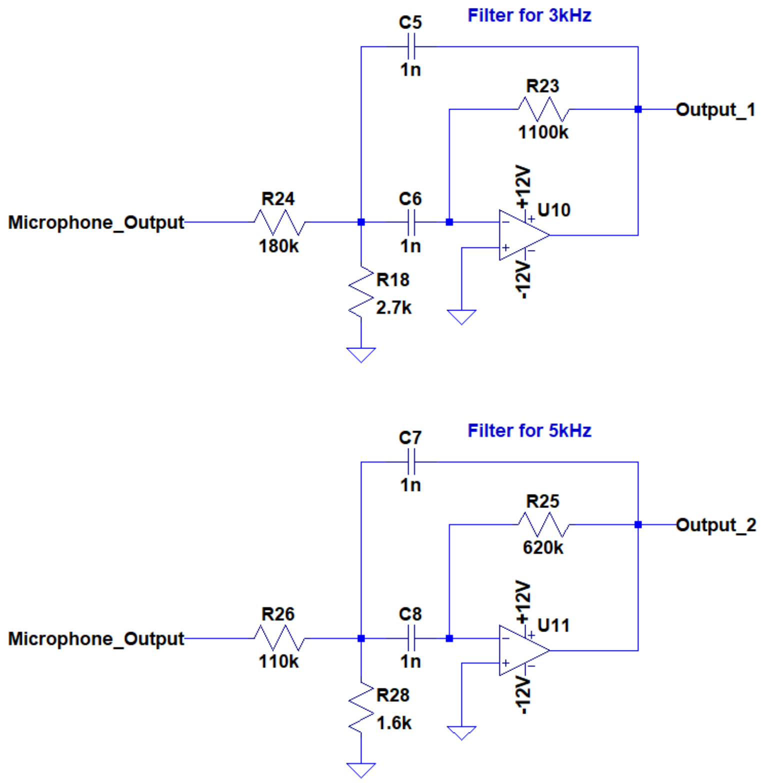

Figure 8: The circuit schematic for the filter unit

In this part, two band-pass filters with center frequency of 3kHz and 5kHz are used as shown in Figure 8. In the pre-design, we used only two resistors. However, the filter was not that efficient, so we changed the design by adding the third resistor. The transfer function, the center frequency, the quality and the gain at the center frequency of the filter is calculated theoretically as below [1].

$$H(s) = \frac{-\frac{1}{R1*C}s}{s^2+s\left(\frac{1}{R2*C}+\frac{1}{R2*C}\right)+\frac{1}{R2*C^2}*\left(\frac{1}{R1}+\frac{1}{R3}\right)} \quad (1)$$

$$\mathrm{fr} = \frac{1}{2\pi\sqrt{R_2*C^2}} * \sqrt{\frac{1}{R1}+\frac{1}{R3}} \quad (2)$$

$$Q = \pi * fr * R3 * C \quad (3)$$

$$G = -\frac{R_2}{2*R_1} \quad (4)$$

For the filter with 3kHz center frequency:

fr = 3kHz (5)

Q = 10 (6)

$C = 1nF$ (7)

$\Rightarrow R_1 = 180\ k\Omega$ (8)

$\Rightarrow R_2 = 2.7\ k\Omega$ (9)

$\Rightarrow R_2 = 1.1\ M\Omega$ (10)

$\Rightarrow |G| = 3$ (11)

For the filter with 5kHz center frequency:

$fr = 5kHz$ (12)

$Q = 10$ (13)

$C = 1nF$ (14)

$\Rightarrow R_1 = 110\ k\Omega$ (15)

$\Rightarrow R_2 = 1.6\ k\Omega$ (16)

$\Rightarrow R_2 = 620\ k\Omega$ (17)

$\Rightarrow |G| = 2.8$ (18)

The experimental magnitude responses of the filters are obtained by KeySight and are shown in the following figures.

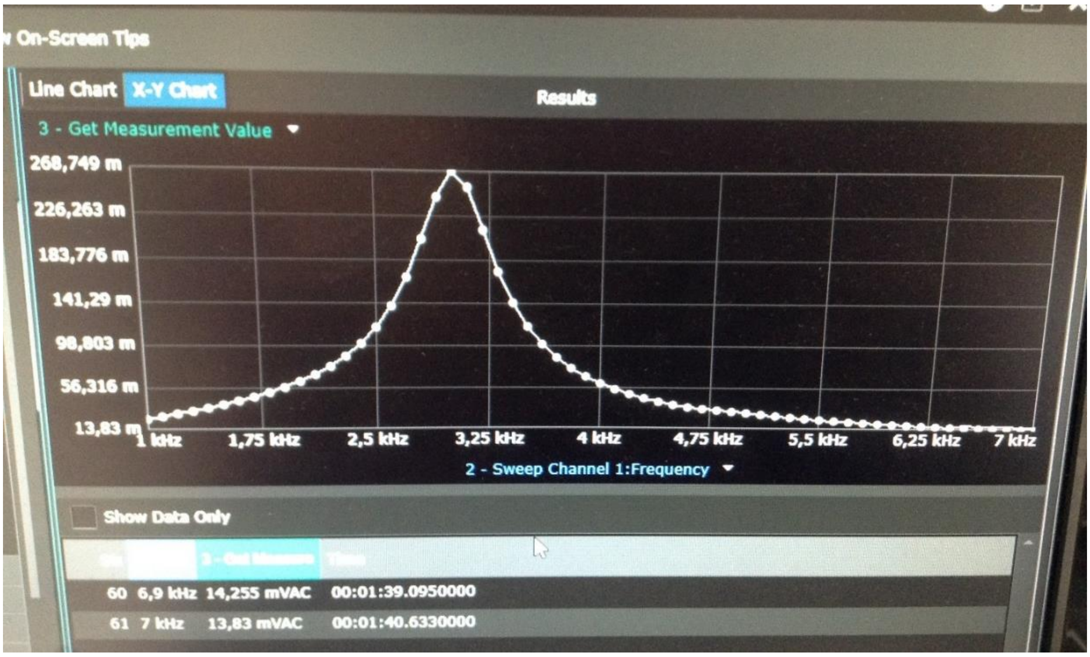

Figure 9: Magnitude response of the filter with 3kHz center frequency

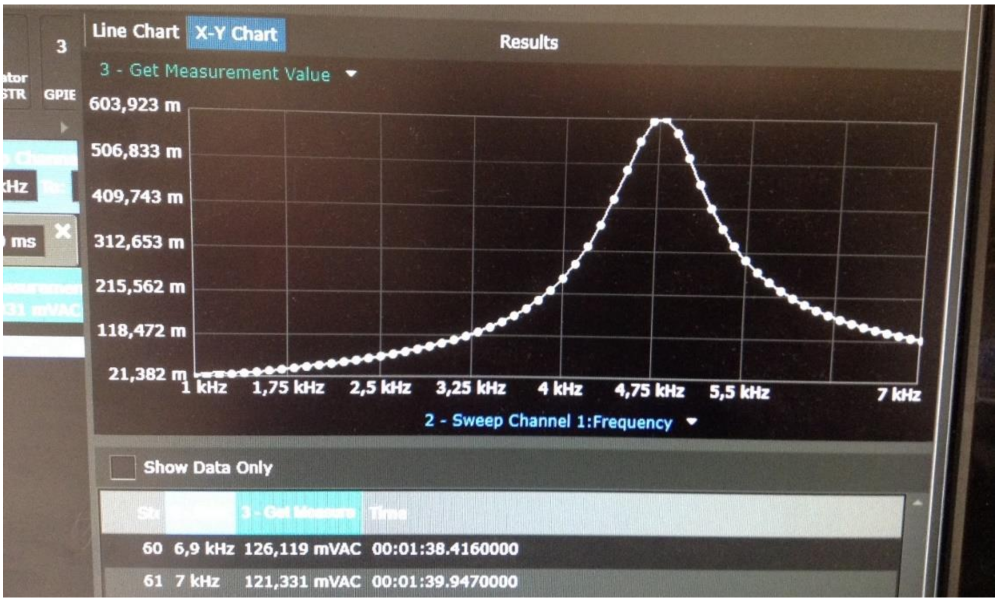

Figure 10: Magnitude response of the filter with 5kHz center frequency

Experimentally found specifications of 3kHz filter:

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

$$Q = \frac{3}{3.2 - 2.8} = 7.5 \tag{20}$$

$$\Rightarrow |G| = 0.27 * 2\sqrt{2} = 0.76 \tag{21}$$

Experimentally found specifications of 5kHz filter:

$$fr = 4.8kHz \tag{22}$$

$$Q = \frac{4.8}{5.2 - 4.4} = 6 \tag{23}$$

$$\Rightarrow |G| = 0.6 * 2\sqrt{2} = 1.7 \tag{24}$$

E) INDICATOR UNIT

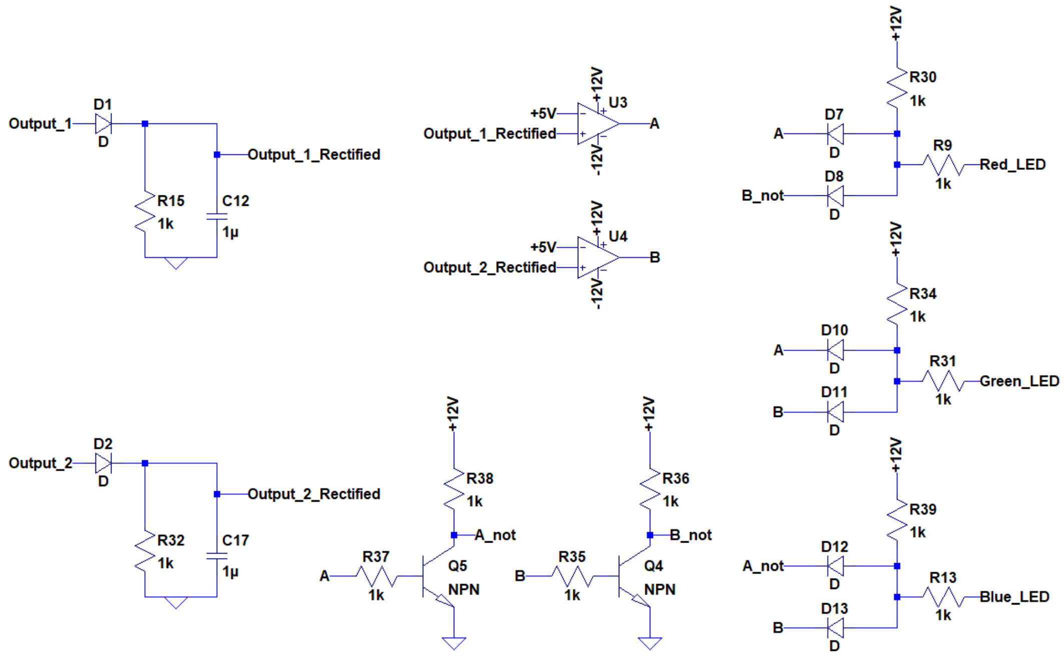

Figure 11: The circuit schematic for the indicator unit

In this part, two half-wave rectifiers are used as shown in Figure 11. Sine waves obtained by filters are converted to a DC voltage value with the help of rectifiers so that they can be compared to each other. Afterwards, they are compared to some reference voltage to see if they are high enough to show if that sine wave is produced via microphone or because of some noise. In the design, the reference voltage can be adjusted via a potentiometer used as a voltage divider. Therefore, as the distance between the speaker and the microphone increases, reference voltage can be decreased to make it work. Later, the opposite voltage values of A and B are produced via NOT gates. Finally, with the help of three AND gates, the area with the highest temperature is indicated. If A is high and B is low, red LED shines. If both A and B are high, green LED shines. If A is low and B is high, blue LED shines.

4. OVERALL SCHEMATIC OF THE PROJECT

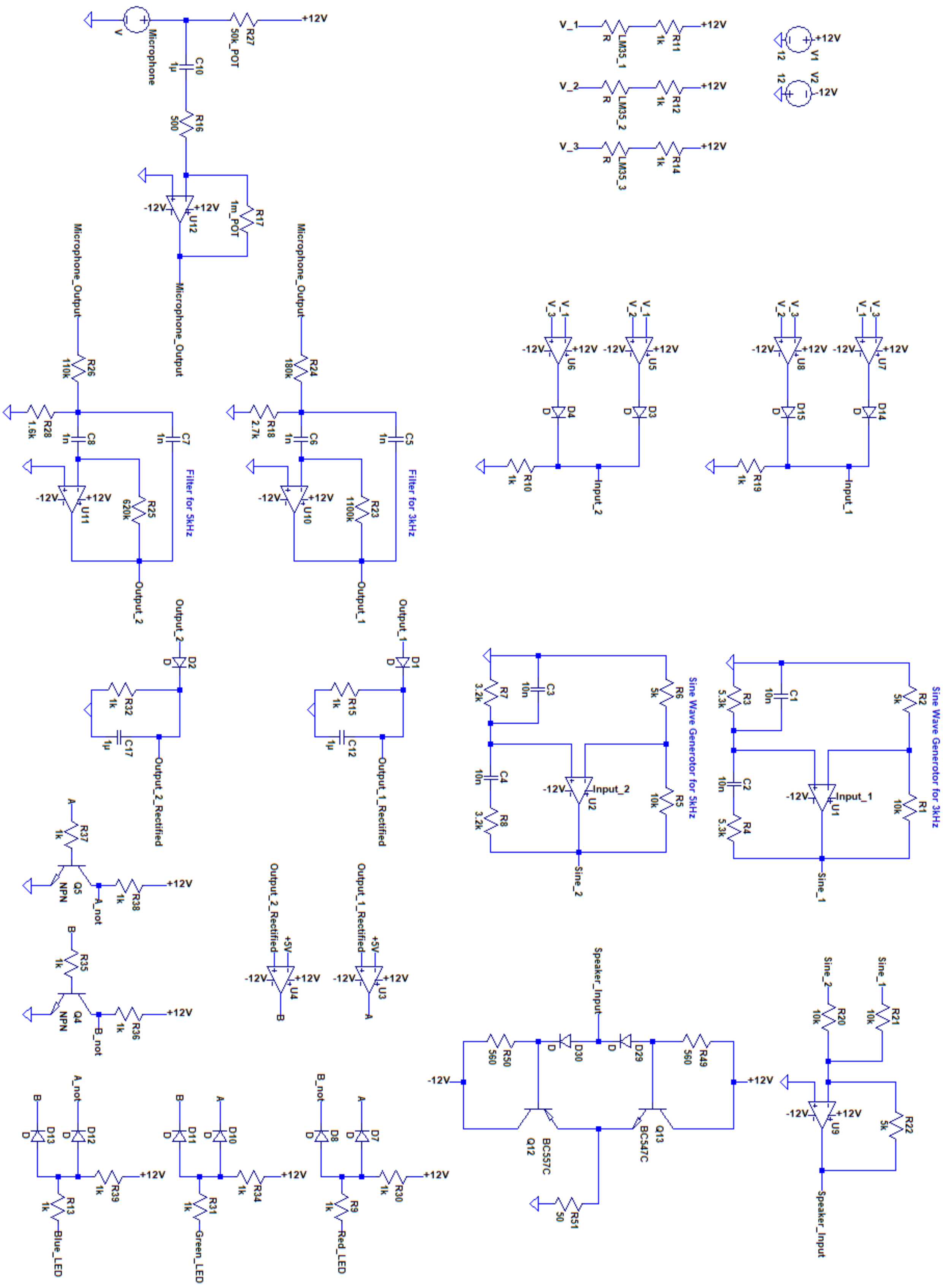

Figure 12: The overall schematic of the project

5. POWER ANALYSIS AND BUDGET

The following components are used in the project.

- 3 x LED	3 * 0.09 TL = 0.27 TL
- 3 x LM35	3 * 6.87 TL = 20.61 TL
- 14 x Diode	14 * 0.14 TL = 1.96 TL
- 16 x Potentiometer	16 * 1.05 TL = 16.80 TL
- 6 x Breadboard	6 * 7.33 TL = 43.98 TL
- 1 x 50Ω Speaker	1 * 4.53 TL = 4.53 TL
- 1 x Electret Microphone	1 * 2.50 TL = 2.50 TL
- 30 x Resistor	46 * 0.01 TL = 0.46 TL
- 1 x BDX53C	1 * 0.82 TL = 0.82 TL
- 1 x BDX54C	1 * 0.82 TL = 0.82 TL
- 2 x BC547	2 * 0.14 TL = 0.28 TL
- 11 x Capacitor	11 * 0.07 TL = 0.77 TL
- 15 x LM741	15 * 0.73 TL = 10.95 TL
Total	104.75 TL

We used +/- 12V DC source in our project, and we measured the currents withdrawn from the source as 90mA and 30mA when only 3kHz sine wave is generated, 100mA and 50mA when both 3kHz and 5kHz sine waves are generated, 100mA and 40mA when only 5kHz sine wave is generated. Hence, the power dissipated in the project is calculated as follows:

$$P = V * I \tag{25}$$

When only 3kHz sine wave is generated:

$$P = 12V * (90mA + 30mA) = 12V * 0.12A = 1.44\ W \tag{26}$$

When both 3kHz and 5kHz sine waves are generated:

$$P = 12V * (100mA + 50mA) = 12V * 0.15A = 1.8\ W \tag{27}$$

When only 5kHz sine wave is generated:

$$P = 12V * (100mA + 40mA) = 12V * 0.14A = 1.68\ W \tag{28}$$

6. CONCLUSION

In this project, we made a wireless fire detection system. For this purpose, we made a design that contains 5 main parts to handle the problem as indicated in this report.

To solve the problem, we did lots of work. We learnt how to use LM35 temperature sensors in an analog circuit, and we used it at sensing unit. We worked on comparator circuit to understand which sensor gives the highest value. We made gate circuits to understand this, and according to result we implemented Wien bridge oscillator to produce sine waves in different frequencies as we did in the experiments. To obtain the wireless system, we made a design that sends sine waves via a speaker to a microphone and a microphone takes it. Therefore, to realize this idea, we worked on how to drive a speaker and how to work a microphone. To handle these problems, we made an AB class amplifier, we learnt what heatsink is and how to use it. We learned that as speaker resistance decreases, it gets harder to drive it. We amplified the output of the microphone because we learnt that it works as a voltage source. We worked on filter design to understand which sine wave is taken by microphone. We used band pass filter in the filter unit, and thanks to this, we also eliminated noise. Finally, we made an indicator unit, we worked on AC to DC conversion with the help of half-wave rectifiers.

We also gained lots of experience about converting theoretical experience to practical work. For signal generating part, when we generate sine waves, we observed that required resistance and capacitance values calculated by theoretically are different then practical work. We also could not work microphone unit during demonstration session, but it should work theoretically.

We also experienced the things that we do not know such as AB class amplifier. We made search, we did our design, and we made it work, so it was a real engineering experience. We got it thanks to our project.

7. REFERENCES

[1] Multiple Feedback Band-Pass Filter [Online]. Available: http://www.ecircuitcenter.com/Circuits/MFB_bandpass/MFB_bandpass.htm