MIDDLE EAST TECHNICAL UNIVERSITY

DEPARTMENT OF ELECTRICAL-ELECTRONICS ENGINEERING

2017-2018 SPRING EE214 ELECTRONIC CIRCUITS LABORATORY

TERM PROJECT

WIRELESS FIRE ALARM SYSTEM

FINAL REPORT

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ABSTRACT

This report includes all works related to EE214 Electronic Circuits Laboratory Term Project namely a Wireless Fire Alarm System which is designed by authors.

INTRODUCTION

In this project we designed a simple fire alarm system. This system is composed of three main units. First unit is called sensing unit. In this unit, temperature sensors which locate in different places provides data about the ambient temperature and this data is evaluated to decide which signals should be produced to represent this data. Second unit is called transmission unit. This unit takes the data about fire location, which is sinusoidal waveform, from the sensing unit and transmits it by using sound waves to a microphone which placed at a certain point. In other words, temperature information is transported wirelessly. The last unit is called indicator unit. This unit decides the location of the fire place from transported signals and warns the users of the system in case of fire. The block diagram of the design is shown in the Diagram 1.

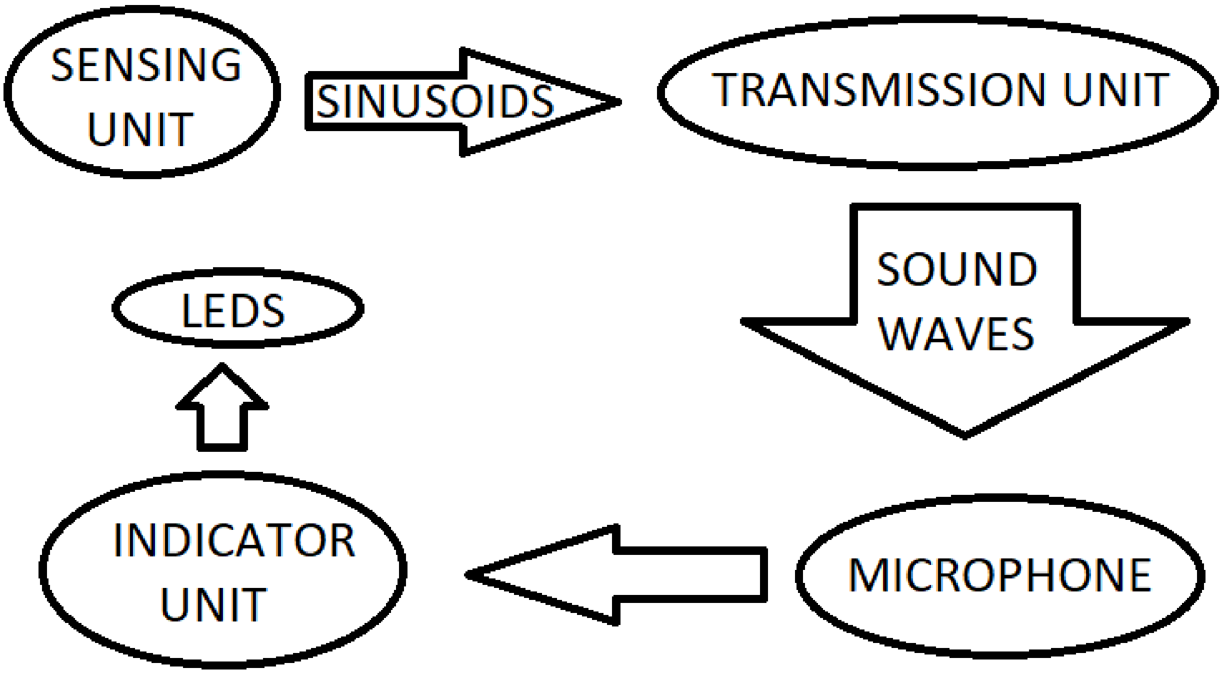

Diagram 1. Block Diagram of the Design

1) SENSING UNIT

The first part of our design is called sensing unit which detects location of the highest temperature place by using three temperature sensors which are located in differents places. The temperature sensors are illustrated as voltage sources in Figure 1 because if we apply independent supply voltage to the sensors, they give a DC voltage with respect to temperature. However this voltage values are quitely smaller (voltage value is 250 mV for 25 centigrades and voltage level changes 10 mV for each degree) than 1 Volt therefore we would like to amplify these voltage values by using simple non-inverting amplifiers which have a gain nearly 11. Note that the gain of non-inverting amplifier is can be found as A=1+R2/R1= 1+10=11.

After amplification process, we compared these voltage valuse to decide which sinusoids should be produced in the next stage. We used comparator circuits to detect different voltage values. This is a very simple operation. If

(+) input has a larger value than (-) input, the output becomes +Vcc and if (-) input has a larger value than (+) input, the output becomes –Vcc.

Then we constructed simple logic circuits based on the information given in Table 1. In Figure 1, output 1 represents required voltage to produce $A1 \sin \omega 1t$ and output 2 represents required voltage to produce

$A2 \sin \omega 2$.

For example, if both outputs are high, both sinusoids should be produced. Notice that T1>T3 or T2>T3 are sufficient conditions to produce first sinusoid and T2>T1 or T3>T1 are sufficient conditions to produce second sinusoid. Therefore, we constructed OR operation by using two BJTs for each output. The simulation results for all scenarios are showed in Figure 2, Figure 3 and Figure 4 respectively.

Table 1: The output signal of the sensing unit for the system states

Condition	System State	Output Signal
T1>T2 & T1>T3	L1	$A_1 \sin \omega_1 t$
T2>T1 & T2>T3	L2	$A_1 \sin \omega_1 t + A_2 \sin \omega_2 t$
T3>T1 & T3>T2	L3	$A_2 \sin \omega_2 t$

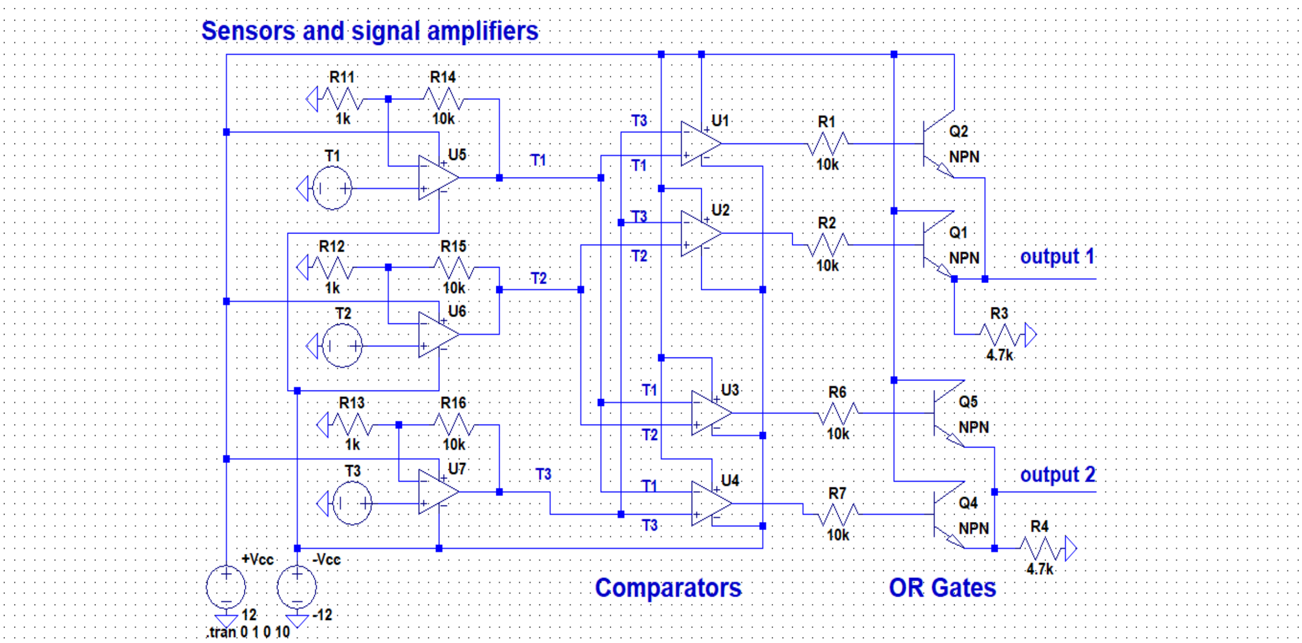

Figure 1. DC part of Sensing Unit

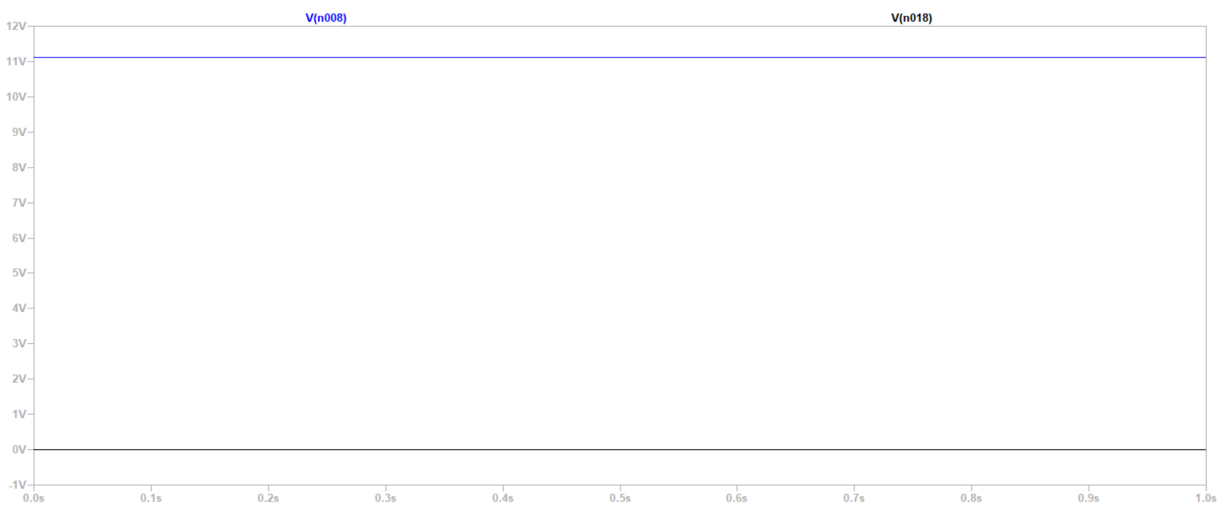

Figure 2: Output 1 (High) and Output 2 (Low) Plot when T1>T2 and T1>T3

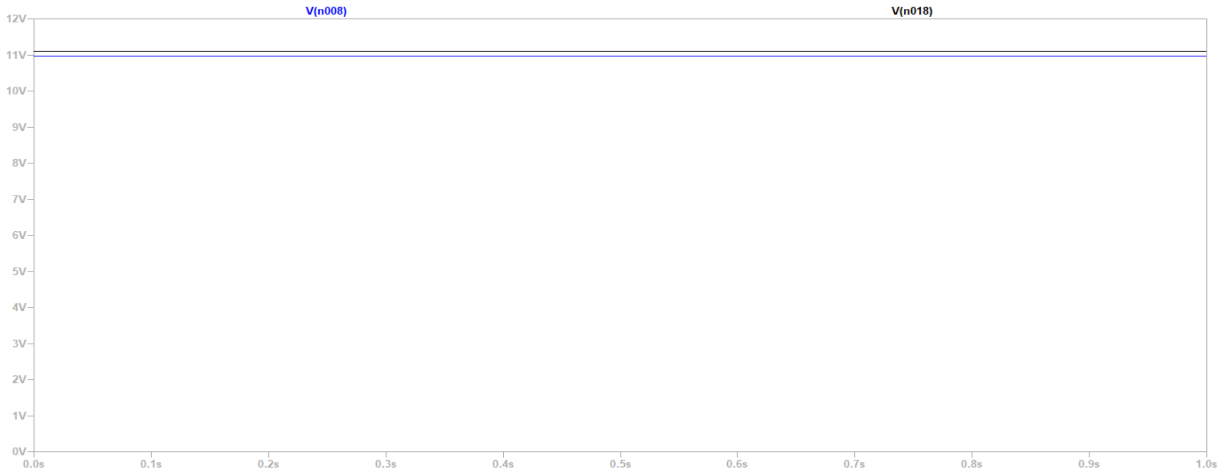

Figure 3. Output 1 (High) and Output 2 (High) Plot when T2>T1 and T2>T3

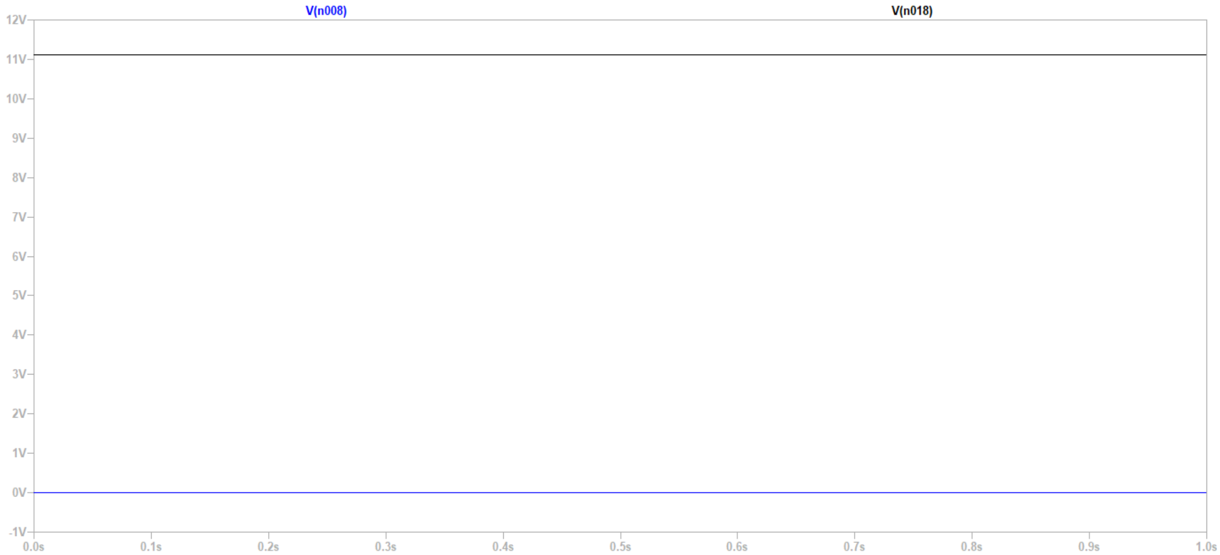

Figure 4. Output 1 (Low) and Output 2 (High) Plot when T3>T1 and T3>T2

After deciding which temperature is the highest and which sinusoids should be produced we constructed sinusoidal generator circuits.

a) Sinusoidal generators

For sinusoidal generators, we constructed wien bridge oscillator circuit for 3KHz and 5KHz. These oscillator circuits are shown in Figure 5 and Figure 8 . The working principle of these circuits are quiet simple. One RC pair works as high-pass filter and the other RC pair works as low-pass filter. The effects of these filters completed each other. Total phase shift is 360 degree which is enough to create an oscillation. The capacitors produces a signal which has a similar shape to very small magnitude sinusoid and this wave is amplified in the op-amp. In the end, we got a sinusoid with a certain frequency. This frequency can be found from f=1/2πR1C1. Note that under all circumstances, R1=R2 and C1=C2 conditions should be satisfied to get a pure sinusoids. Ra and Rb resistance values are taken as constants and Rs value was arranged by a 1 KOhm potentiometer according to practical conditions. We changed Ra, Rb and Rs values many times to arrange peak to peak value of the sinusoids.

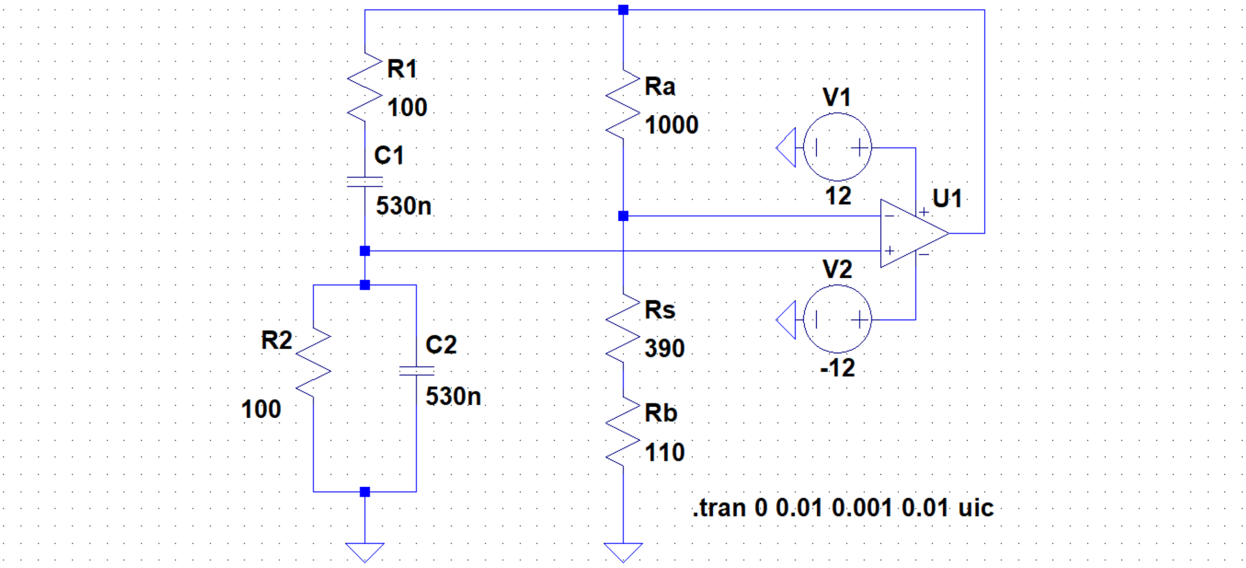

Figure 5: 3KHz sinusoidal wave

The simulation result for KHz sinusoidal wave is shown in Figure 6 and the frequency information is shown in Figure 7.

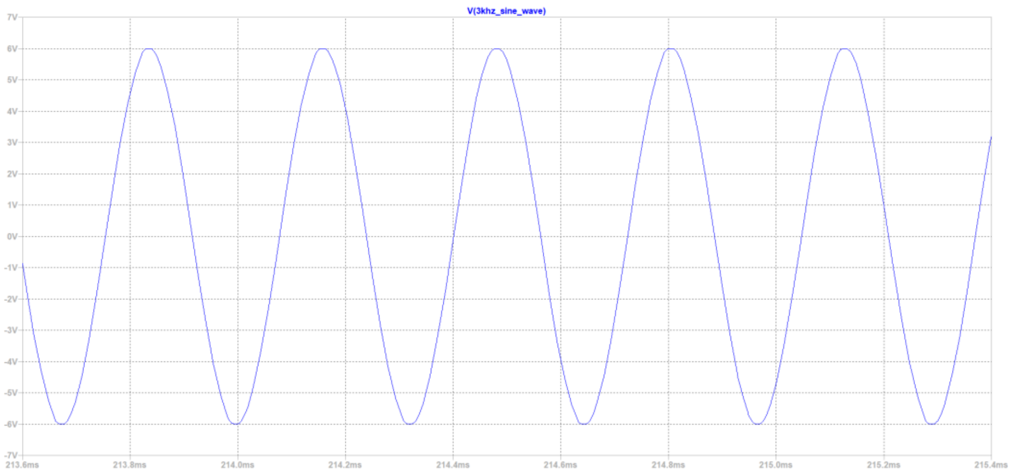

Figure 6: Output waveform of 3KHz sinusoidal oscillator

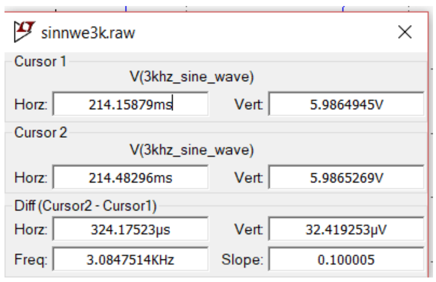

Figure 7: Frequency information of 3KHz sinusoidal oscillator

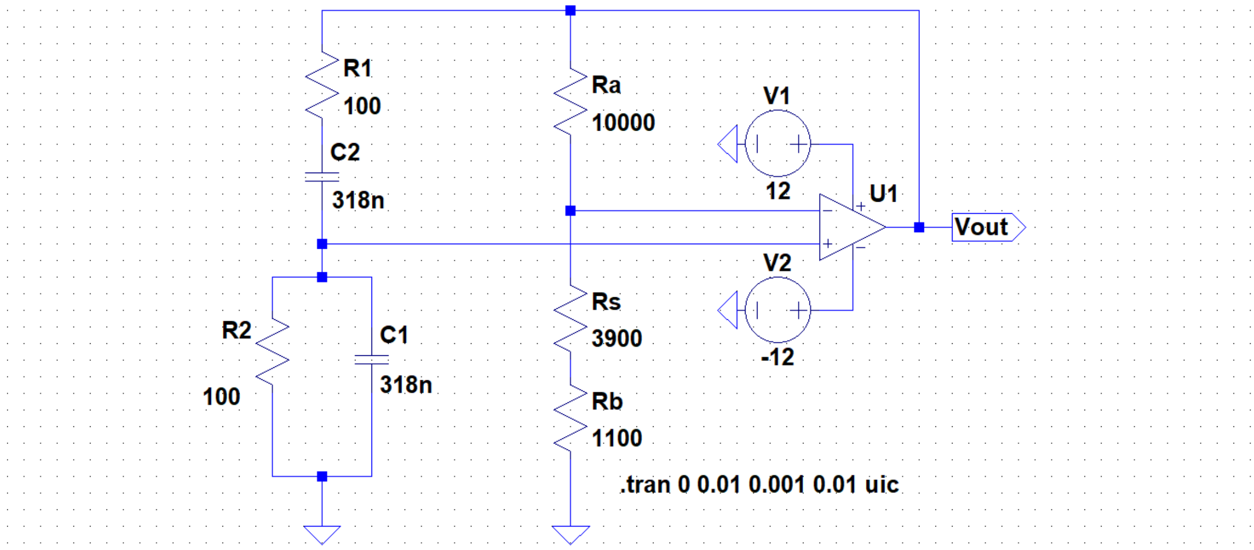

Figure 8: Circuit schematic of 5KHz sinusoidal oscillator

The output waveform of 5KHz sinusoidal oscillator is shown in Figure 9 and the frequency information is shown in Figure 10.

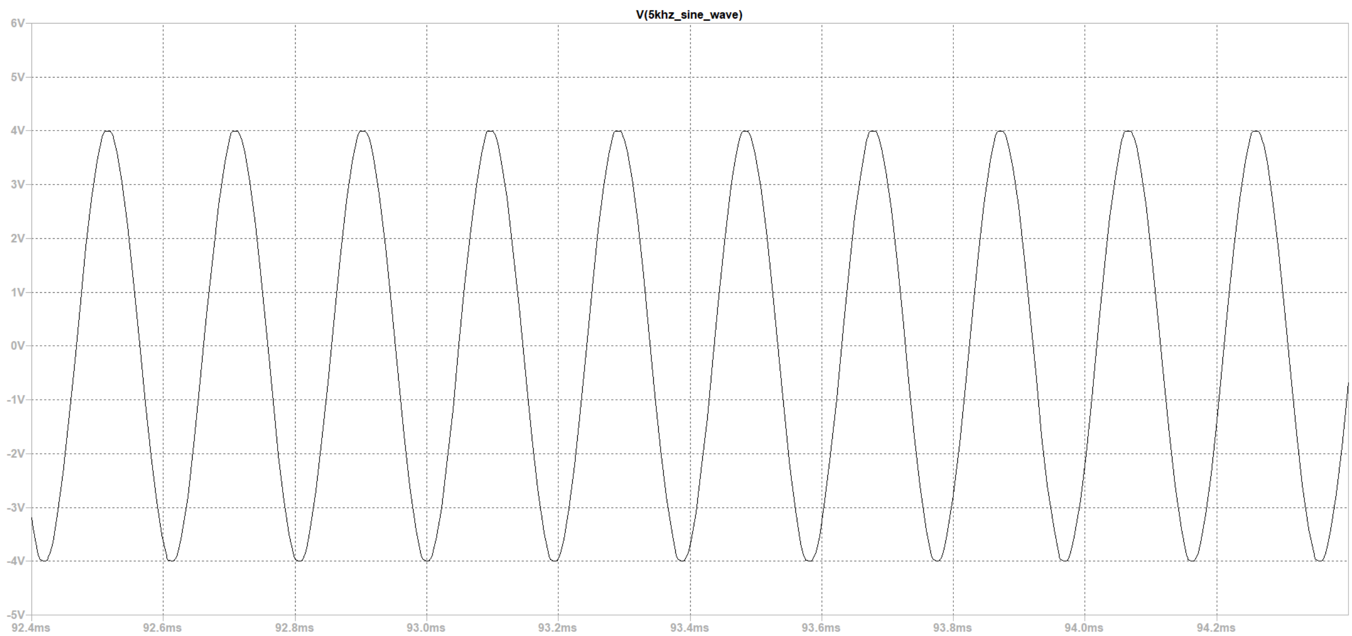

Figure 9: output waveform of 5KHz sinusoidal oscillator

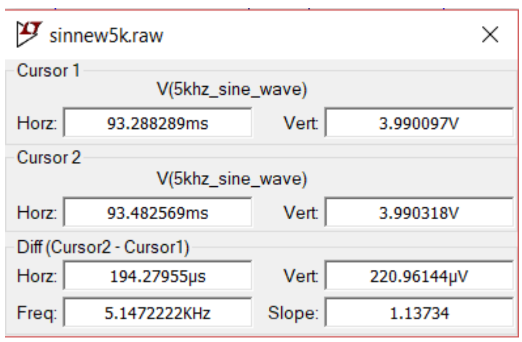

Figure 10: frequency information of 5KHz sinusoidal oscillator

b) Switch connections

To connect sensing unit and the sinusoidal oscillators, we used a NMOS inverter circuit, and we connected the output of this inverter to VCC of sinusoidal generator and connected the gate voltage to sensing unit outputs. This switch produces 12 V or 0 V and this supplies the VCC of the amplifier for sinusoidal generator. When gate voltage is 12 V, sinusoid cannot be produced otherwise, when gate voltage is 0 V, sinusoids can be produced because inverter inverts the 0 V to 12 V. We want to obtain the sinusoid when the output of sensing unit is +12 Volt but the situation here is visa versa. Thus we also construct 2 inverting amplifiers with unity gain to match the conditions. 3KHz oscillator switch is shown in Figure 11 and 5KHz oscillator switch is shown in Figure 12.

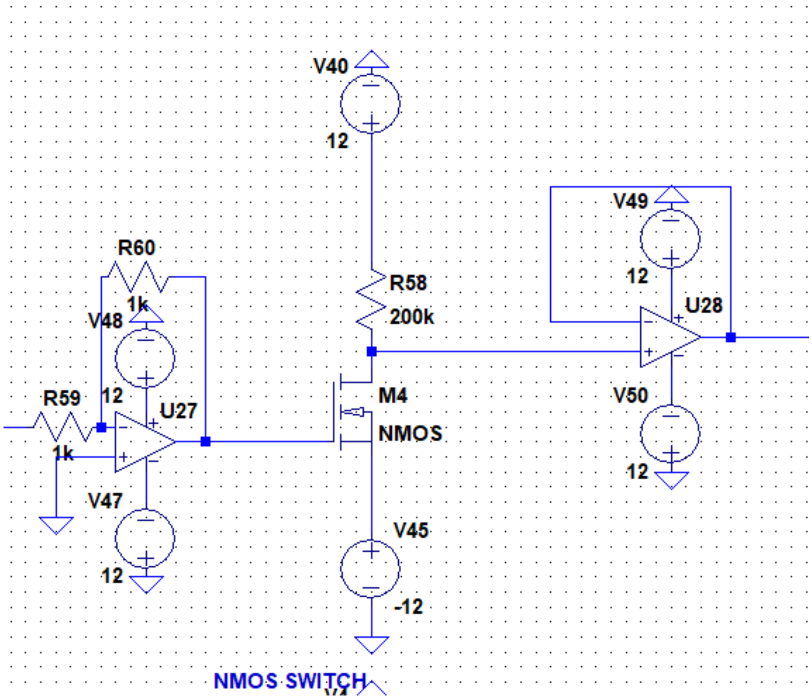

Figure 11: Switch circuit for 3KHz sinusoid

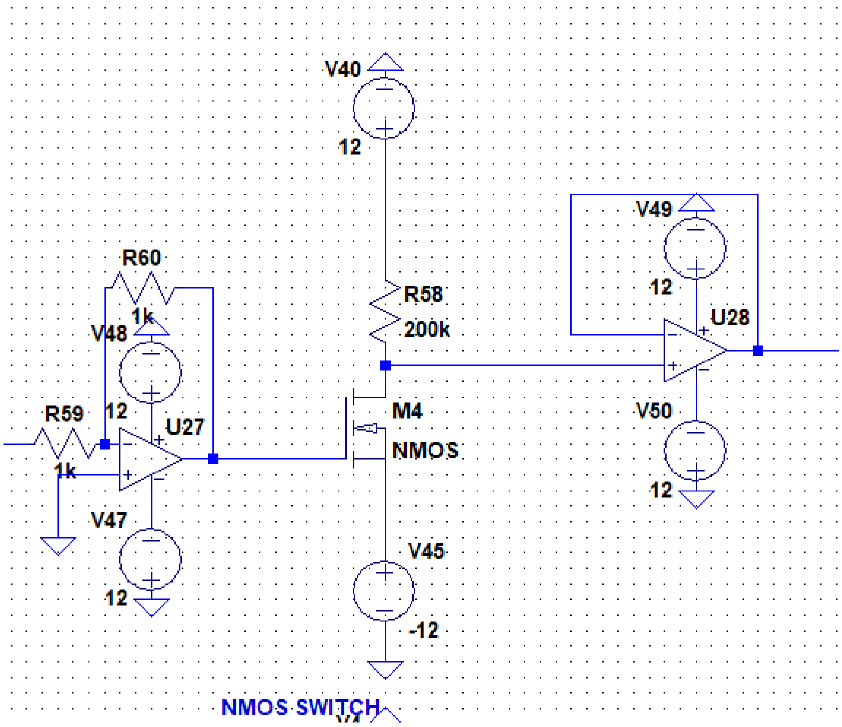

Figure 12: switch circuit for 5KHz sinusoid

To simulate switching circuits, we used an independent voltage source for sensing unit outputs.

The conditions are shown in Table 2.

Output of sensing unit 1 (determines the 3KHz Sine)	Output of sensing unit 2 (determines the 3KHz Sine)	Output of switch 1	Output of switch 2
12	12	12(3 Khz sine)	12(5 Khz sine)
12	-12	12(3 Khz sine)	0
-12	12	0	12(5 Khz sine)

Table 2: Conditions for outputs of switch circuits.

After this switching operation we construct a summing amplifier to sum two sinusoids as shown in Figure 13.

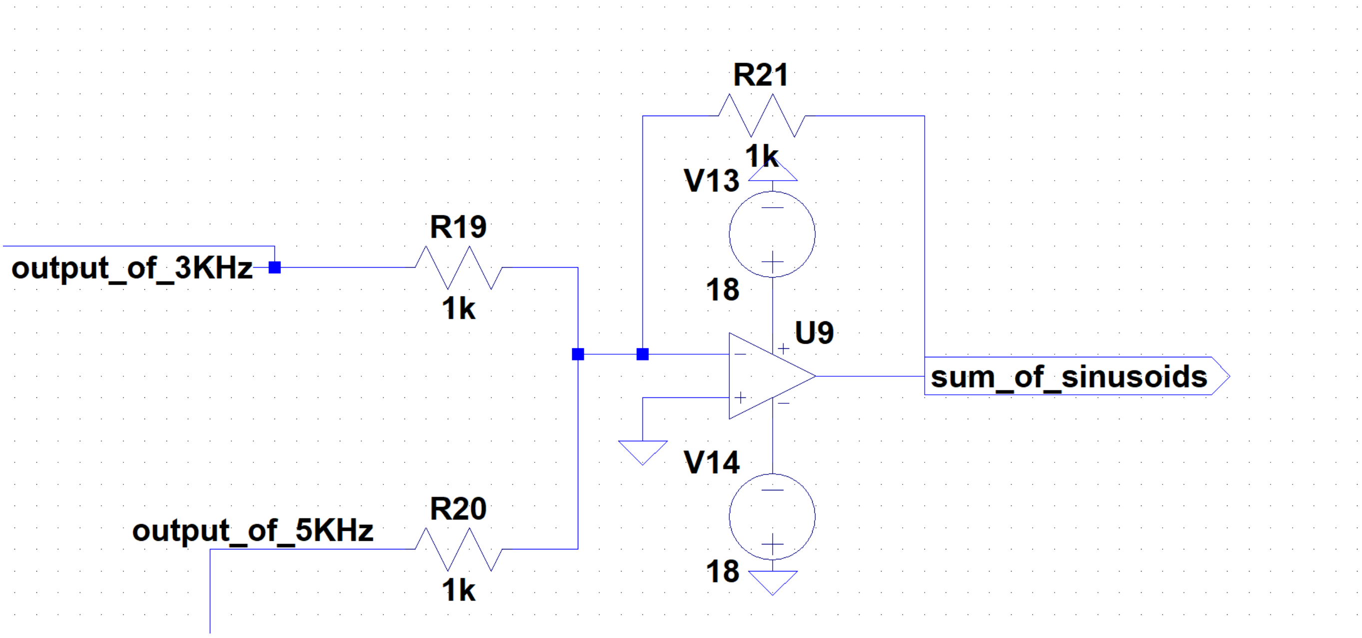

Figure 13: summing amplifier for 2 sinusoids

The output waveforms of summing amplifier is shown in Figure 14, Figure 15 and Figure 16.

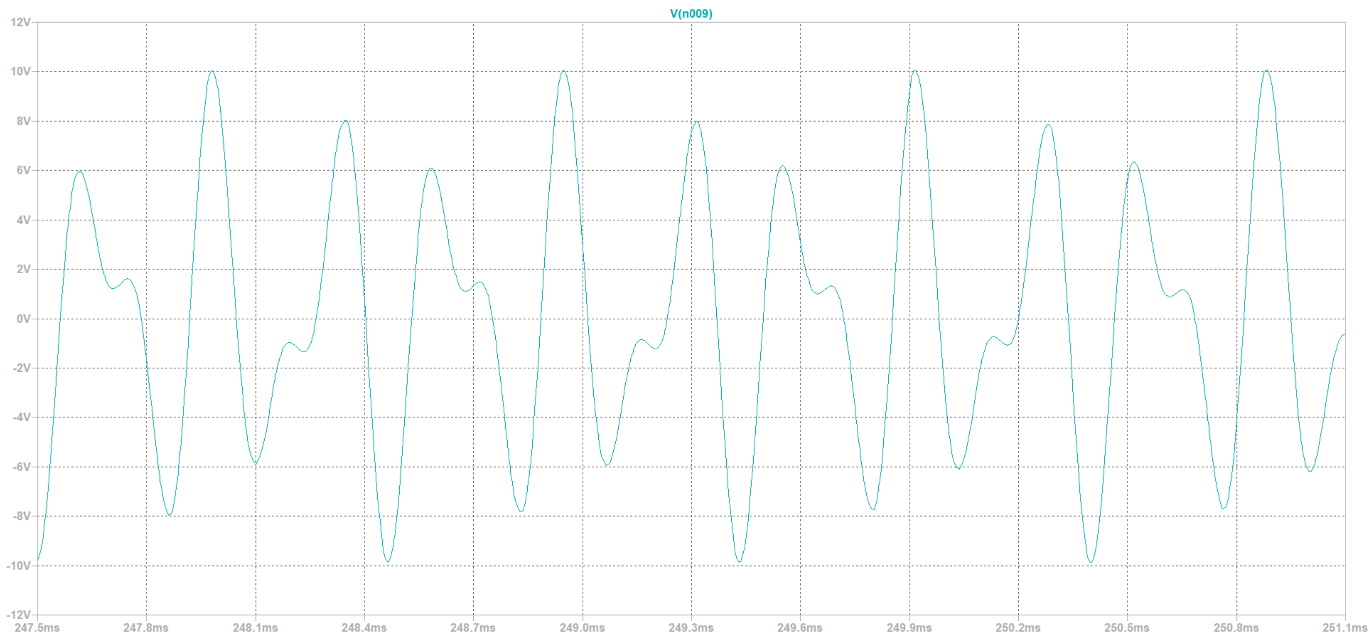

Figure 14: Output of summing amplifier when two sinusoid are produced together

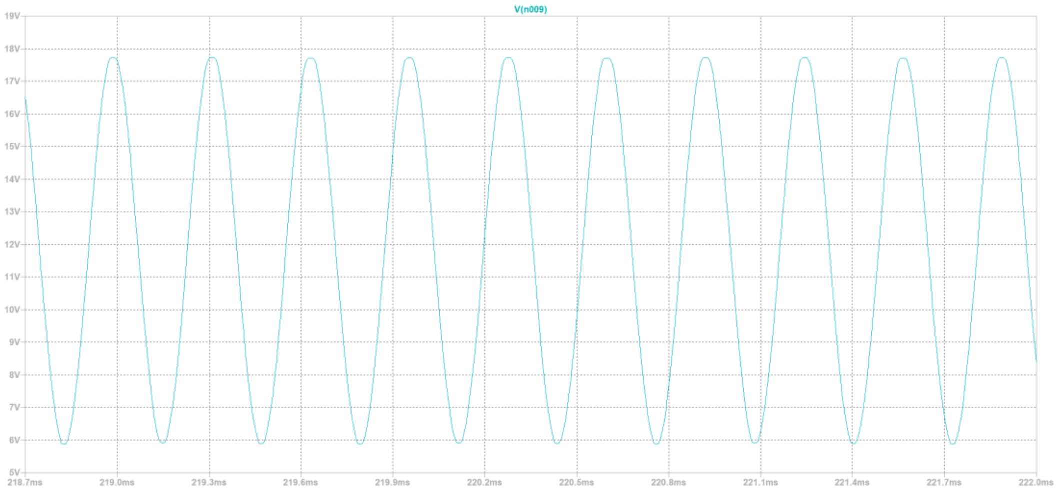

Figure 15: Output of summing amplifier when 5 3KHz sinusoid is produced

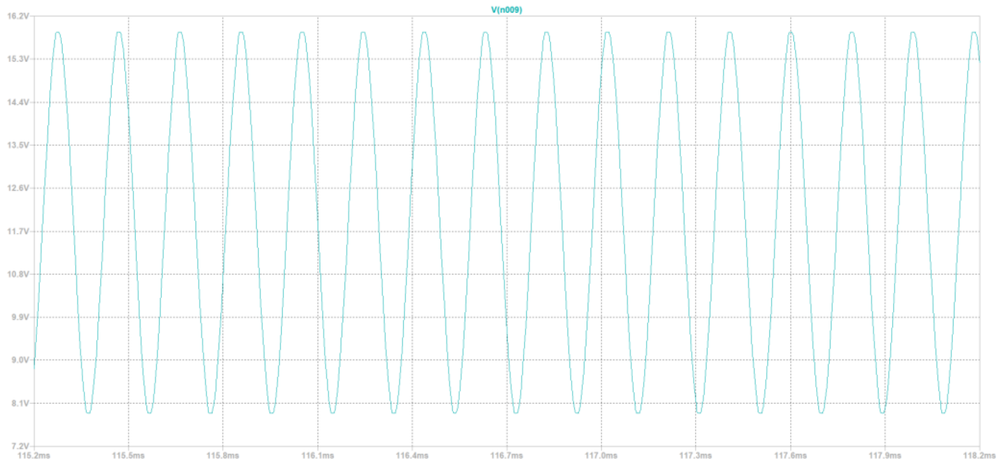

Figure 16: Output of summing amplifier when 5KHz sinusoid is produced

2) TRANSMISSION UNIT

To transmit the sinusoidal signals, we used a class AB output stage as shown in Figure 17. We used this circuit as a current amplifier. In Figure 18, it is clearly shown that the output current was incresed to a desired value to drive the speaker.

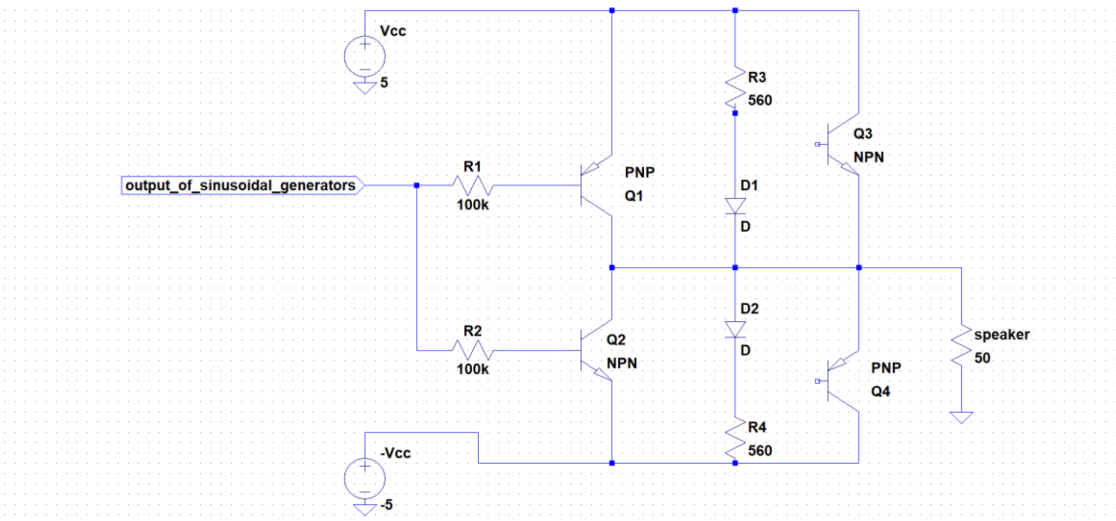

Figure 17: class AB output stage

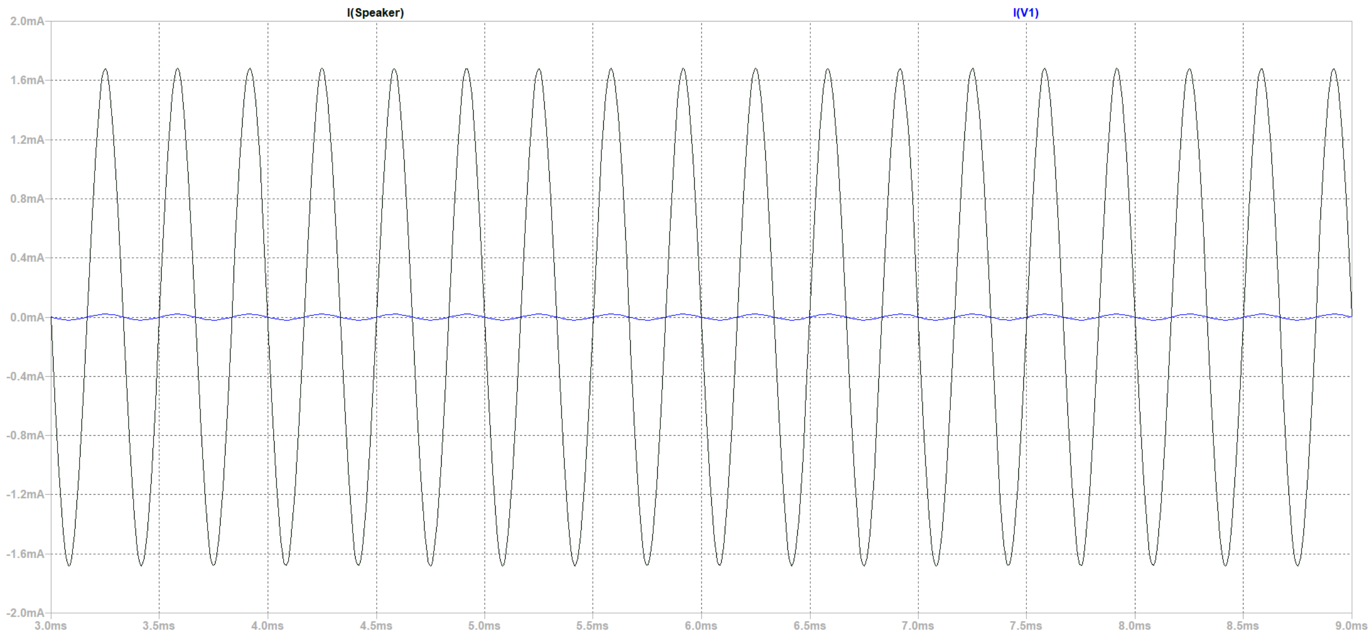

Figure18: Output and input currents of class AB output stage

a) Microphone Driver

We took the signal coming from the trasmission unit and amplified this signal using a simple microphone driver circuit which consists of a pullup circuit, RC filter and OPAMP amplifier. Thus, we changed our design from common emitter amplifier circuit to this new driver circuit after experimental procedure because the small signal range for the transistor aplifier circuit is very low and this caused a nonlinear amplification process. The function of this circuit is that the pull up circuit activates the microphone and divides the voltage drop on the microphone, RC filter attenuates the noisy components and amplifier amplifies the very low signal to a reasonable voltage value. The driver circuit configuration is shown in Figure 19. Output waveform of this circuit is shown in Figure 20.

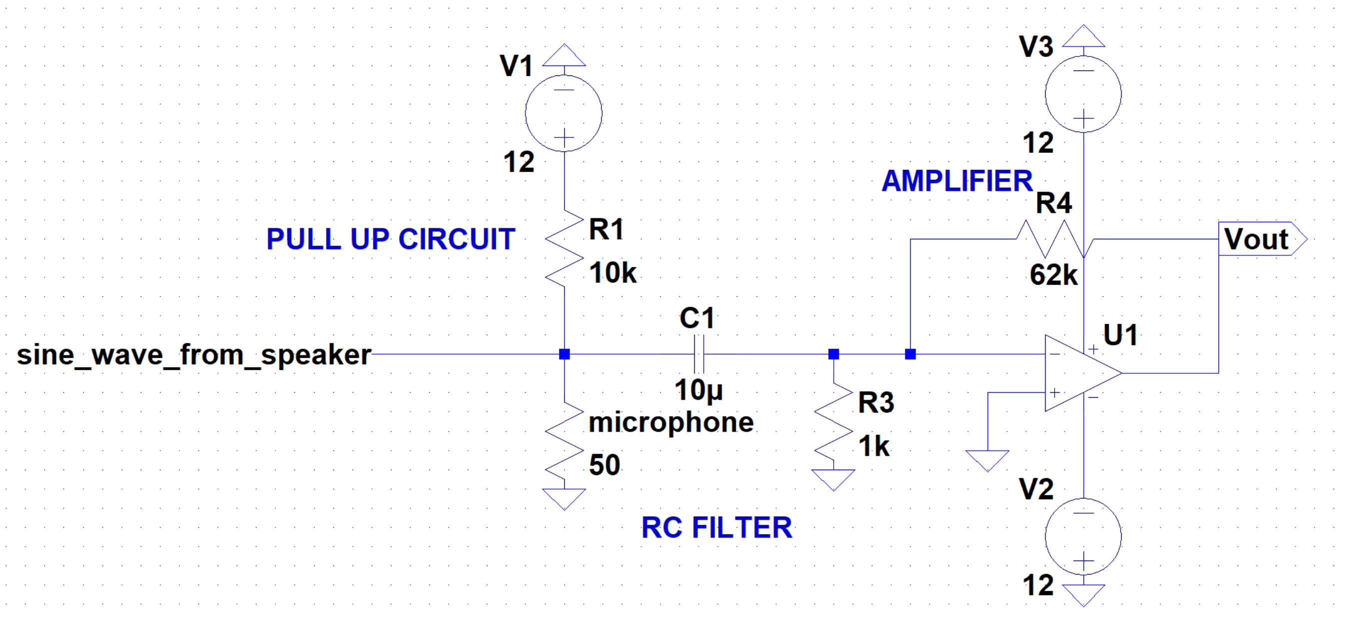

Figure 19: Driver circuit for microphone

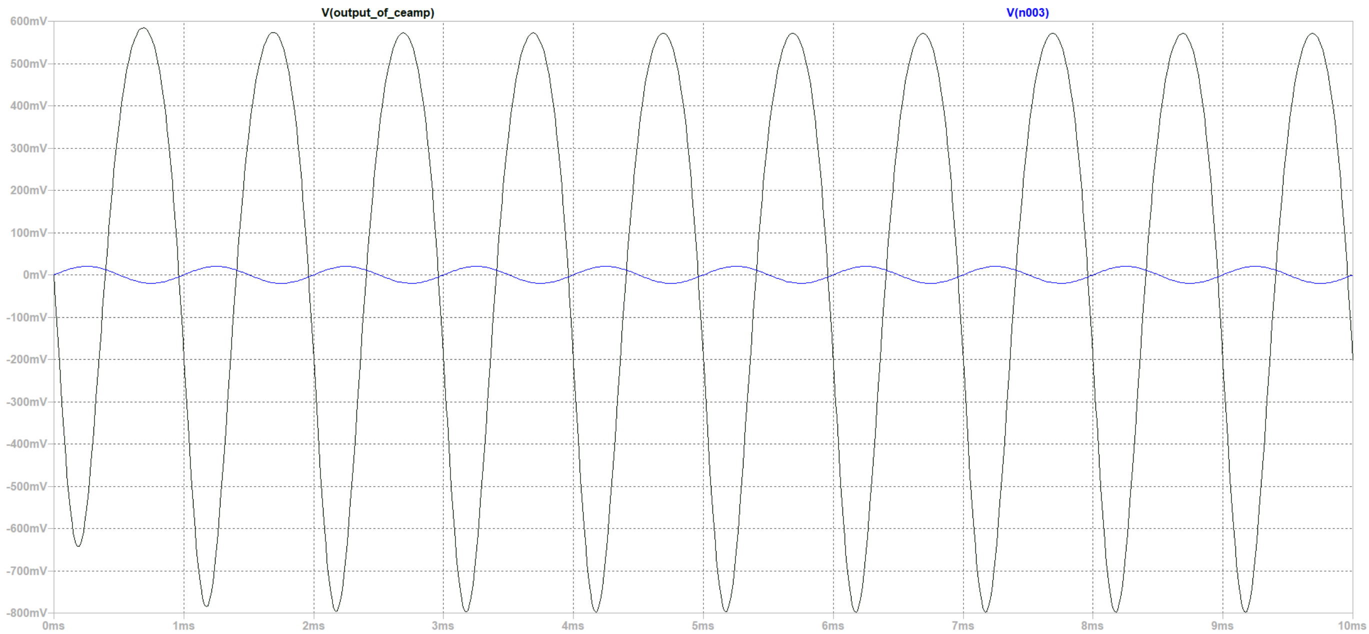

Figure 20: Input and output waveforms of the driver circuit

3) INDICATOR UNIT

In indicator unit we decided which temperature is the highest and which led should be onAfter that we filtered the sinusoidal signal coming from microphone driver output using two bandpass filters which have 5KHz and 3KHz center frequencies. After that we converted the outputs of filters to dc voltage to compare their magnitudes. Then we summed these waveforms by using summing amplifier and used an inverting amplifier with 0.5 gain. After that we constructed a logic unit to distinguish the magnitudes values.

a) Filter Bank

For filtering, we constructed a chebyshev bandpass filter to obtain high quality filter.

This filter type is shown in Figure 21 .

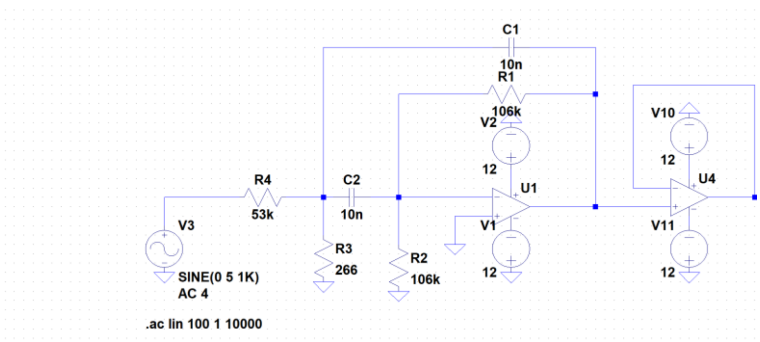

Figure 21: Single bandpass filter

To calculate resistance and capacitance values, we constructed transfer function firstly as shown below. After that, when we simplified the transfer function, we can find center frequency. Using below equations for resistance and capacitance calculations, we found the necessary component values. To find out these values we used MATLAB. We chose the quality factor as 20, gain as 1 and capacitance as 10nF and calculated resistance values.

$$\frac{V_{out}}{V_{in}} = -\frac{\frac{S}{C1 * R4}}{S^2 + \frac{C1 + C2}{C1 * C2 * R1} * S + \frac{R3 + R4}{C1 * C2 * R1 * R3 * R4}}$$

$$R4 = \frac{Q}{2\pi f C A_f}$$

$$R1 = R2 = \frac{Q}{\pi f C}$$

$$R3 = \frac{Q}{2\pi f C(2Q^2 - A_f)}$$

To increase the quality factor of this bandpass filter we cascaded this filter 2 times before experiment but after practical implementation, we decided to use this filter as a single stage.

The magnitude response of 3KHz bandpass filter in LT Spice is shown in Figure 22.

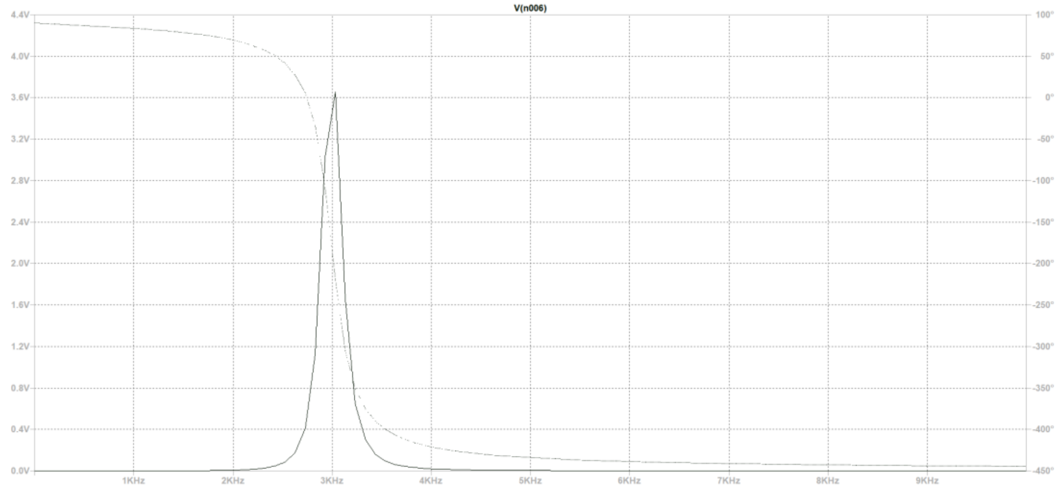

Figure 22: Magnitude response of 3KHz bandpass filter

The magnitude response of 3 Khz bandpass filter in the benchvenue is shown in Figure 23.

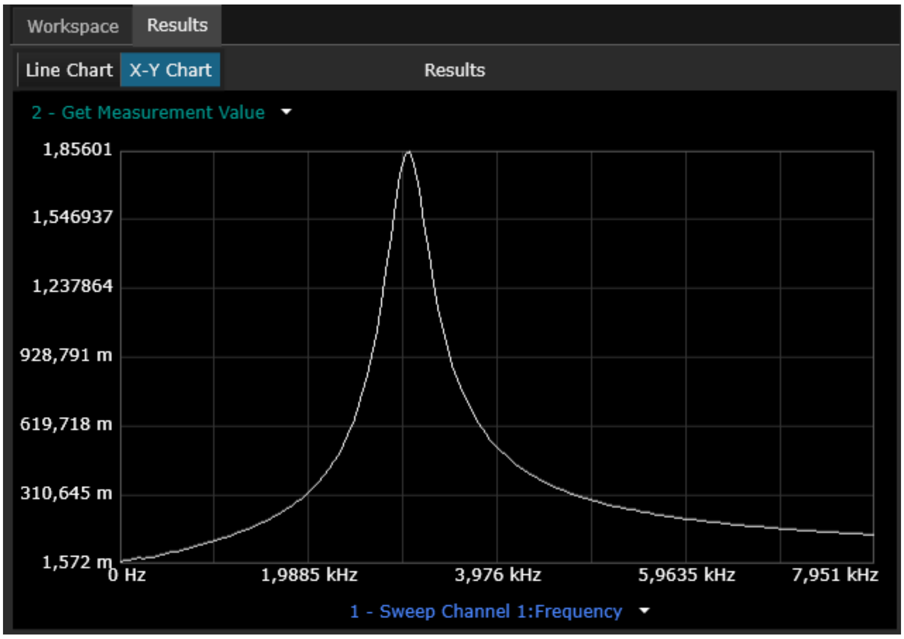

Figure 23: Benchvenue response for 3 KHz bandpass filter

The magnitude response of 3 KHz band pass filter in MATLAB is shown in Figure 24.

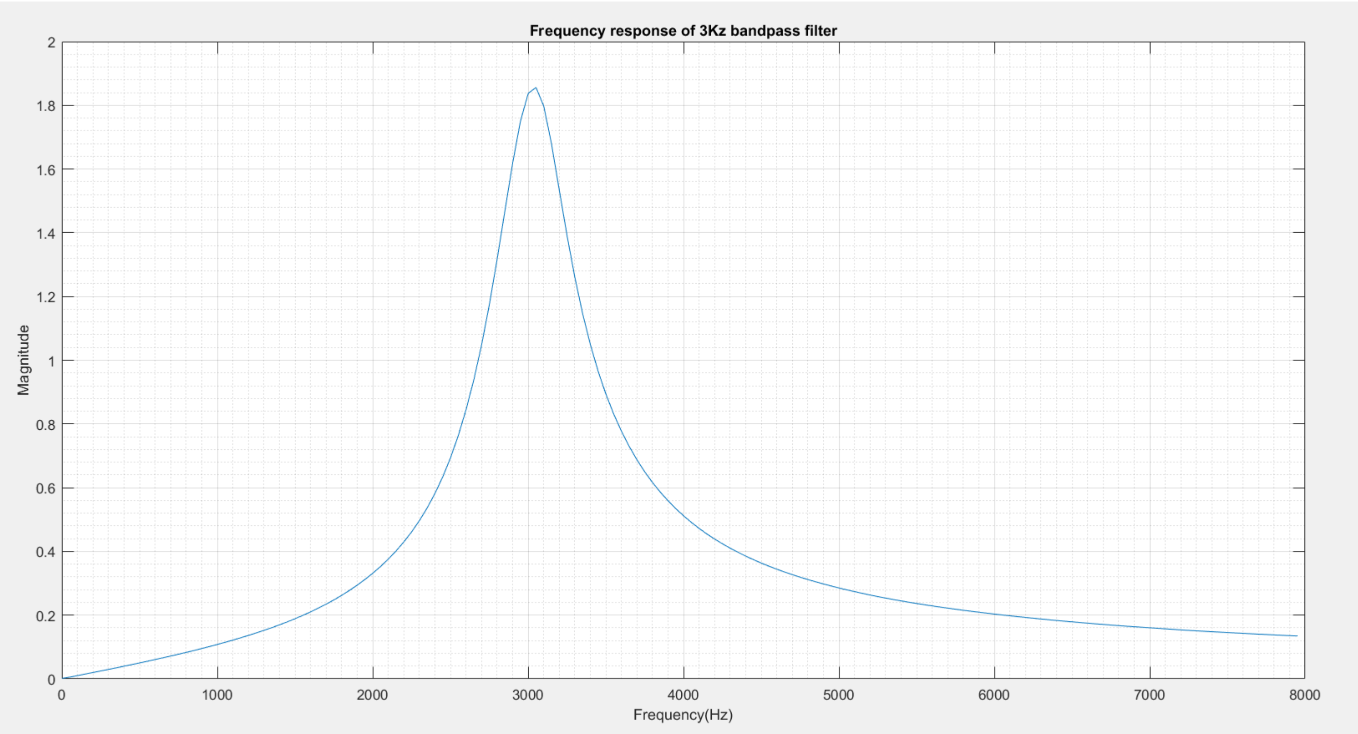

Figure 24: Magnitude response for 3 KHz in MATLAB

By using above equations to obtain 3KHz bandpass filter R1=R2=103Kohm, R3=266ohm, R4= 53Kohm.

In the experimental precedure we obtained a bandpass filter with nearly 10 quality factor but in practical, when we conbined all the circuits, the quality of bandpass filters decreased but that quality was enough to distinguish two different sine waves.

The circuit schematic of 5KHz center frequency filter is shown in Figure 25. For 5 KHz bandpass filter R1=R2=126Kohm, R4= 63Kohm and R3= 79 ohm. The 5KHz band pass filter is shown in Figure. Magnitude response of this filter in LT Spice is shown in Figure 26.

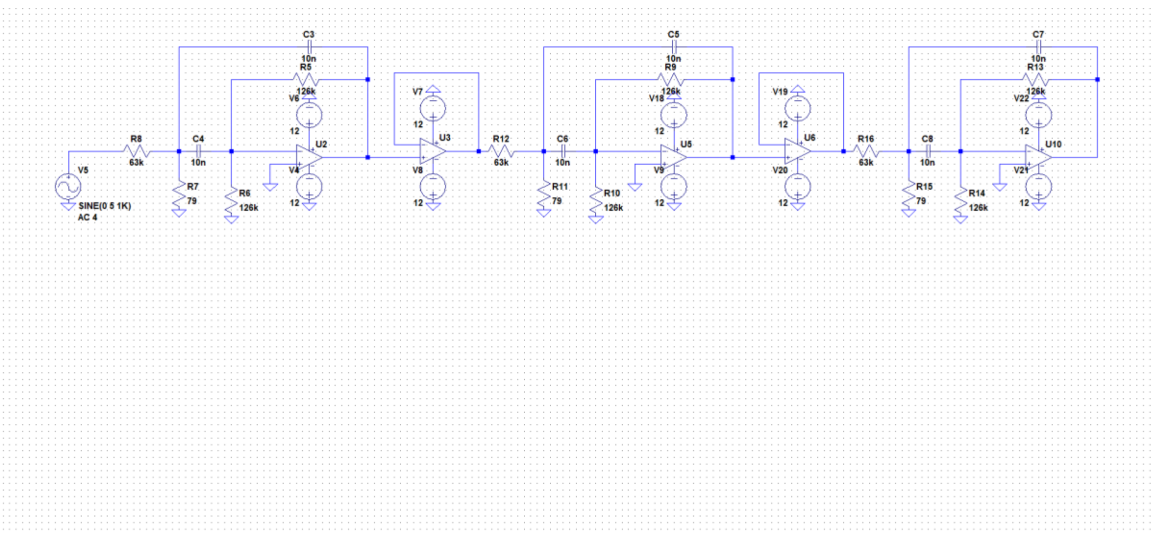

Figure 25: Bandpass filter for 5KHz center frequency

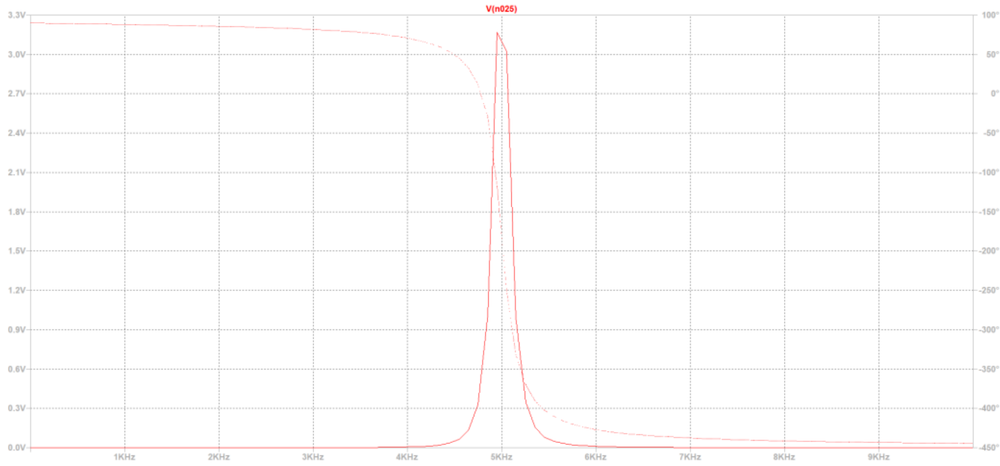

Figure 26: Magnitude response of 5KHz bandpass filter

The magnitude response of 5 KHz band pass filter in MATLAB is shown in Figure 27.

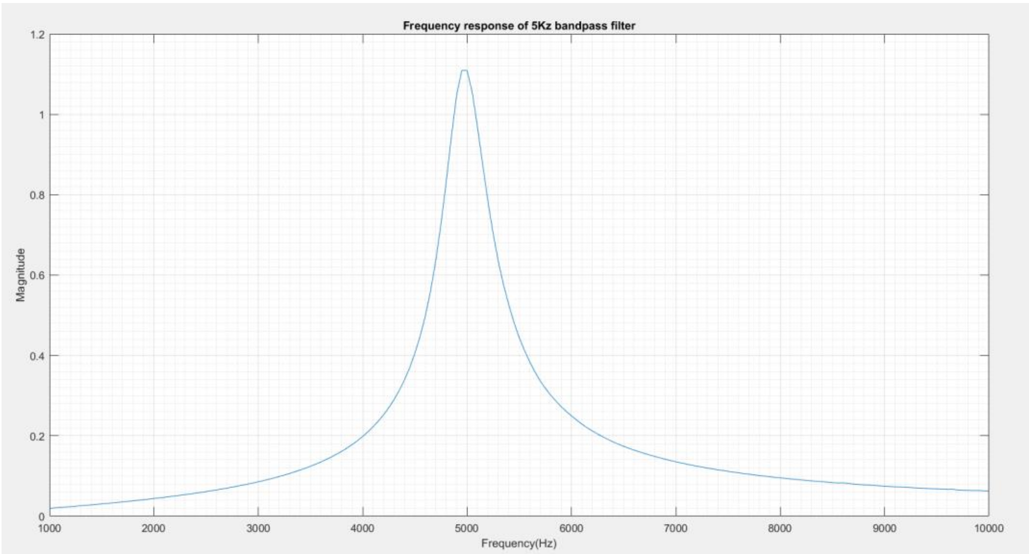

Figure 27: Magnitude response for 5 KHz in MATLAB

The magnitude response of 5 Khz bandpass filter in the benchvenue is shown in Figure 28.

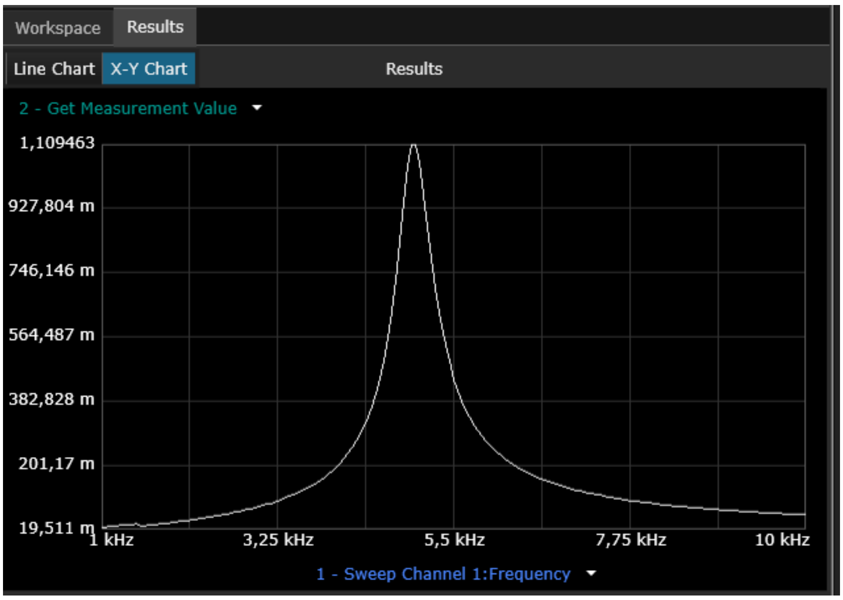

Figure 28: Benchvenue response for 5 KHz bandpass filter

b) Decision unit

The circuit schematic of decision unit is shown in Figure 29. The filtered output waveforms are summed using a summing amplifier and inverted with 0.5 gain using inverting amplifier. After that, we compared the output with two reference voltages which are 3 and 2 Volts. For state 1, we inverted the output of comparator for 3 volt reference and we used a nand gate with the output of second comparator. For state 2, we just take the output of firs comparator. For state 3, we inverted the output of second comparator.

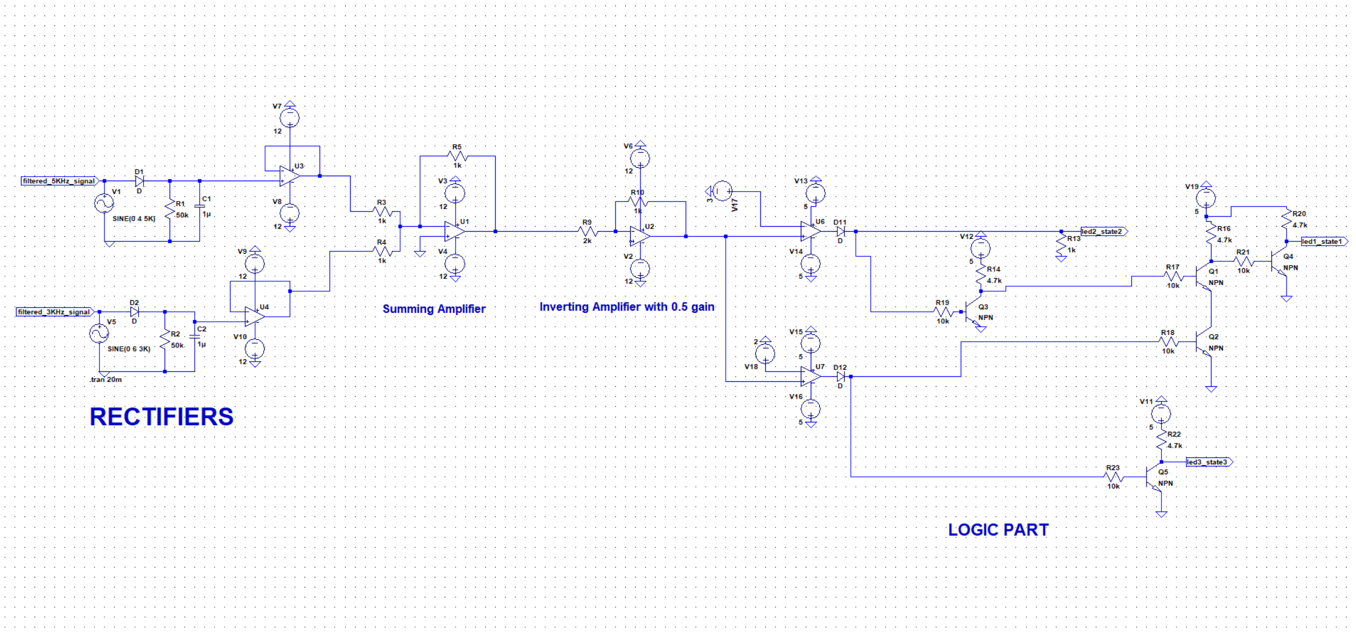

Figure 29: Circuit schematic of decision unit

The output signals for three different case are shown in Figure 30, Figure 31 and Figure 32.

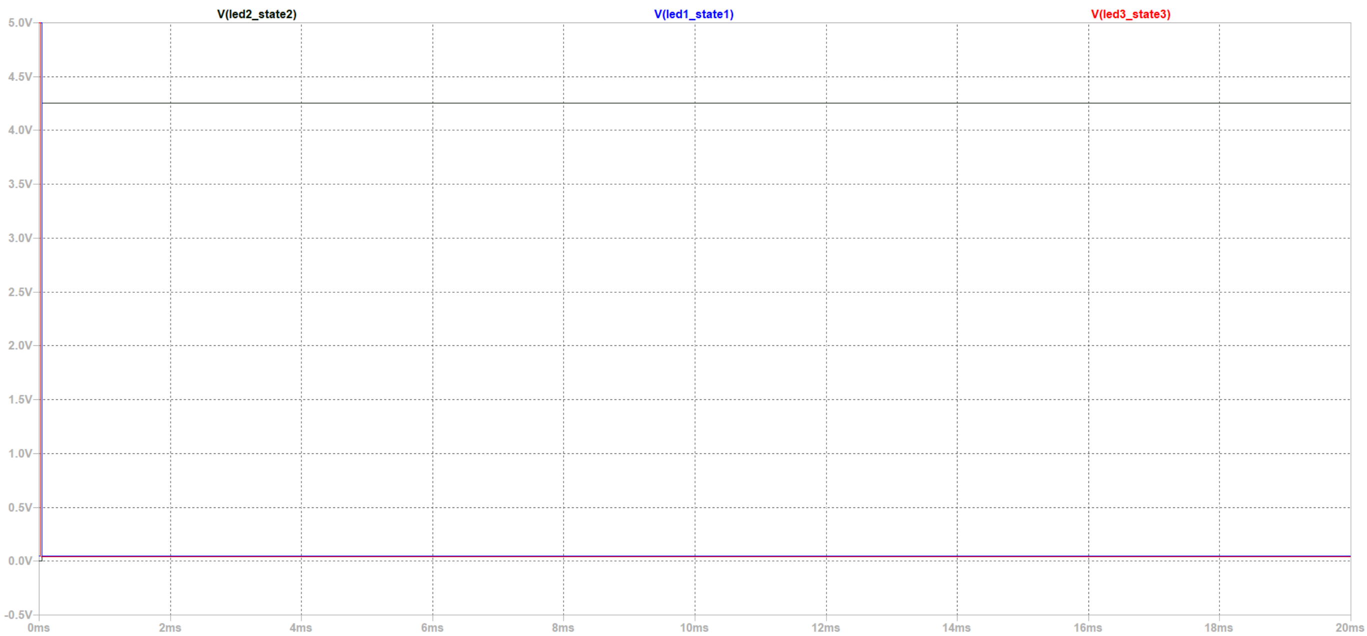

Figure 30: Output waveform of indicator unit when 2 sinusoids are produced

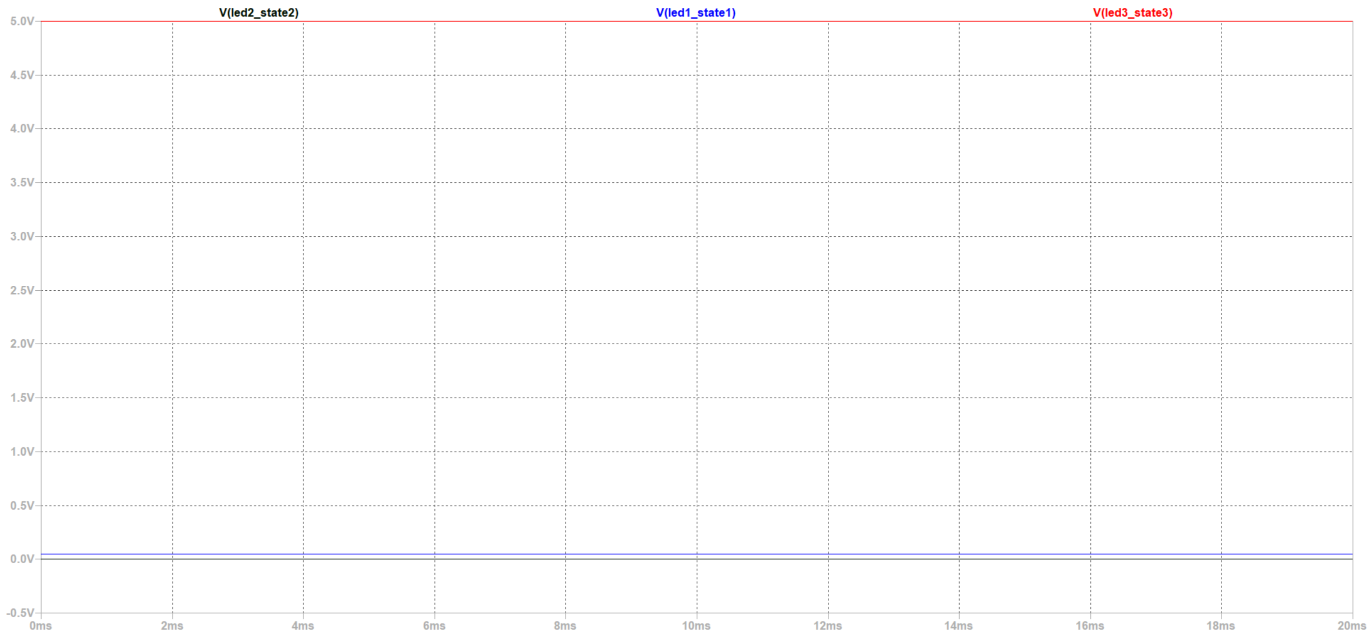

Figure 31: Output waveform of indicator unit when 5KHz sinusoid is produced

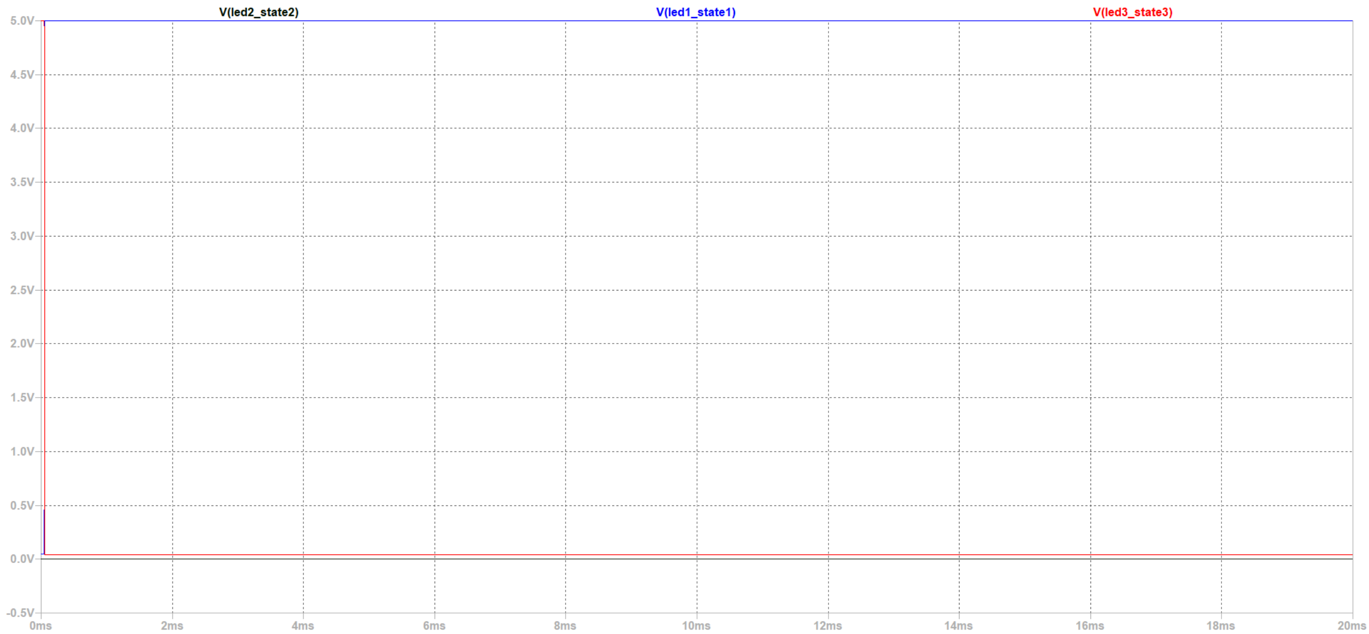

Figure 32: Output waveform of indicator unit when 3KHz sinusoid is produced

4) POWER CONSUMPTION

The power consumption for 3 different cases are shown in Table 3.

Condition	Current of VCC	Current of -VCC	Power consumption
T1 is the highest (3KHZ)	0,35 A	0,21 A	12*0.35+12*0.21= 6.72W
T2 is the highest(3&5 KHz)	0,42 A	0,24 A	12*0.42+12*0.24=7.92W
T3 is the highest(5 KHz)	0,28 A	0,17 A	12*0.28+12*0.17=5.4W

Table 3: Total power consumption for 3 different cases

5) COST ANALYSIS

We bought lots of components for this projects. The cost analysis in terms of Turkish Lira is listed below.

Number of Component	Component Name	Cost
120	Resistors (with different resistance values)	0.02X120=2.4
45	Capacitors (with different values)	0.1X45=4.5
40	Op-amp (UA741, LM358)	0.8X50=40
4	LM 35 Temperature Sensors	6X4=24
6	Breadboard	6X6.5=39
2	NMOS	2.5X2=5
20	BJT 15	0.15X20=3
2	BD138-139 Power Transistor	0.5X2=1
10	P-N junction diode 5	0.05X10=0.5
100	Jumpers	0.1X100=10

Total cost is 129.4 Turkish Liras.

CONCLUSION

In this project, we constructed a fire alarm system using 3 temperature sensors. The aim of this project is to produce sinusoidal signals with different frequencies and to distiguish them using high quality bandpass filters. In our project we used a lot of OPAMP and transistor circuits to obtain different functions. We constructed oscillator circuits, logic circuits and also output stage circuits. We had some problems with out desing in switching part in preliminary work, but we fixed this problem and our system worked properly in demonstration. We understand that the theoretical calculations are not mathced with experimental results sometimes and we learned how to come up with this problems. All in all, this project work was very beneficial for our designer skills. Also our overall design is shown in Figure 33.

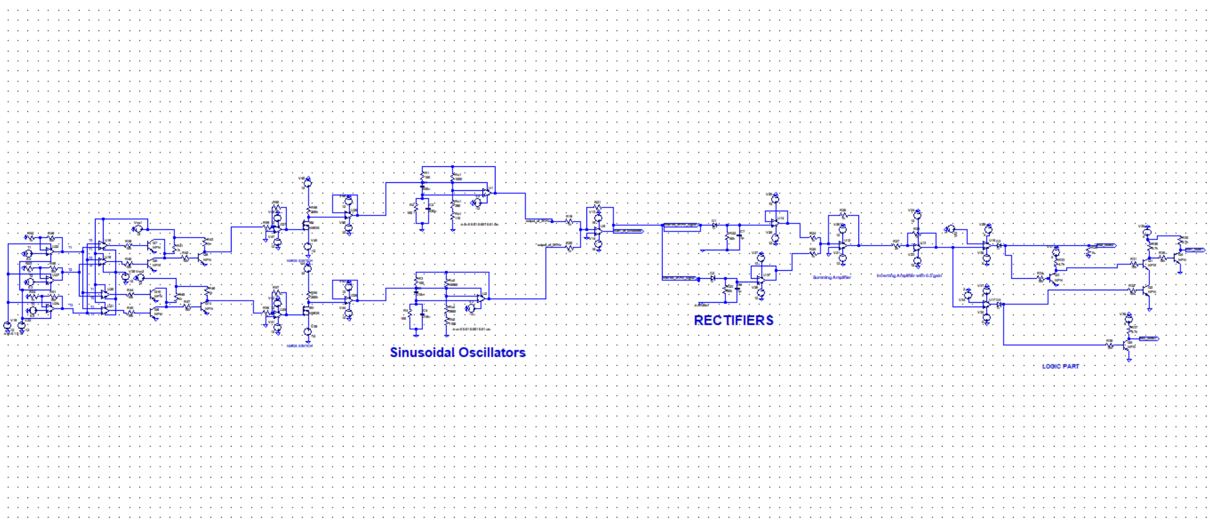

Figure 33: Overall design