MIDDLE EAST TECHNICAL UNIVERSITY

ELECTRICAL AND ELECTRONICS ENGINEERING DEPARTMENT

EE214 Electronic Circuits Laboratory

2015-2016 Spring

Term Project

Remote Controlled Vehicle

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Table of Contents

1. Introduction

A remote control vehicle is defined as any vehicle that is remotely controlled without a restriction to its motion externally. This is usually a radio control device with a cable between control and vehicle or an infrared controller. Remote control vehicles have various scientific uses such as those at hazardous environments like in the deep ocean and space exploration. Furhermore, remote control vehicles are also popular among hobbyists.

In this project, we are required to make a very simple version of a remote controlled vehicle moving on the ground, of which the transmission of the control signal is supposed to be through a wire. To do this, we are supposed to design a remote controller (i.e. transmitter) and an actuating mechanism (i.e. receiver) for this device. The vehicle is supposed to move on the ground and contain two motors.

2. Overall Block Diagram

For this project we designed the circuit diagram in Figure 1. using LTspice. The related subblocks to our design are shown in the figure.

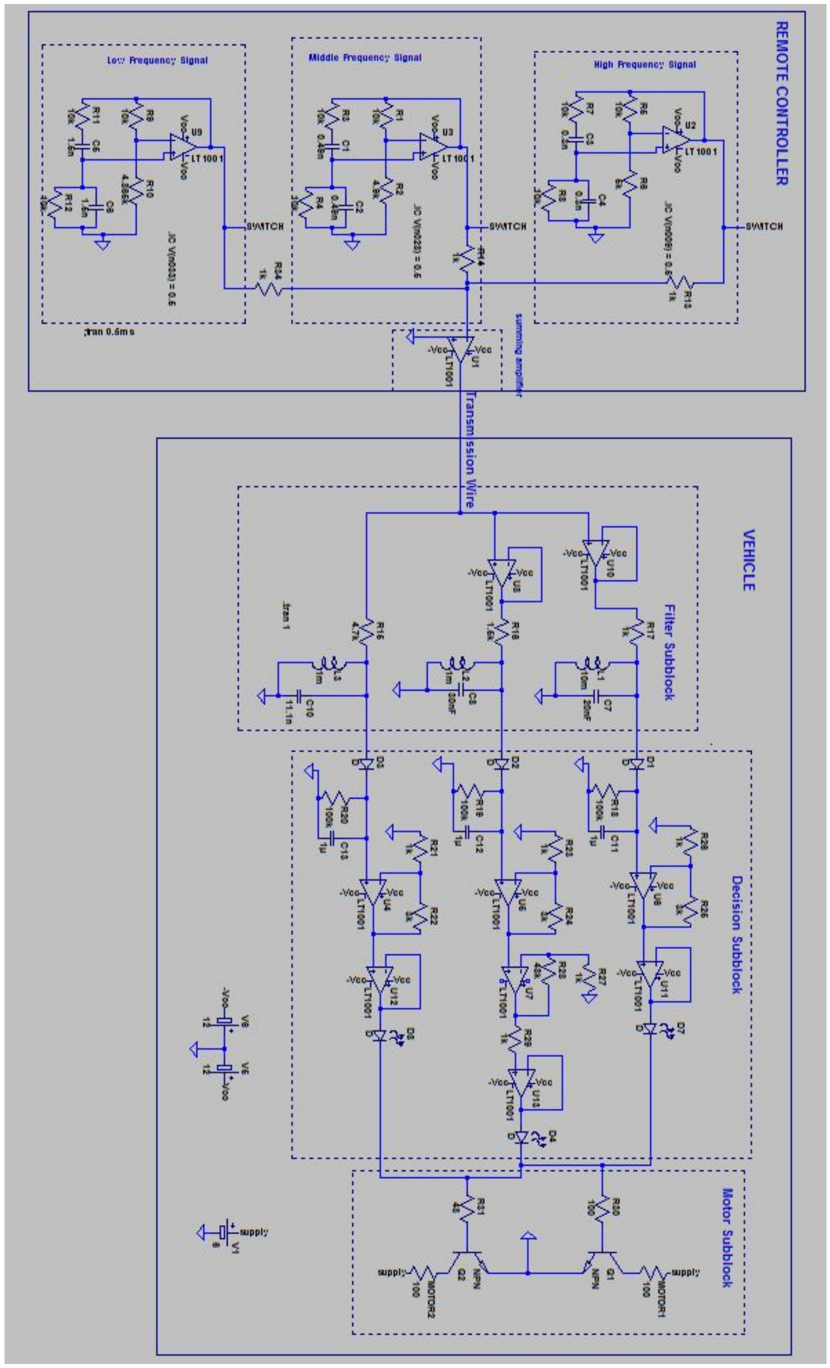

Figure 1. Overall Block Diagram

3. Operation of Sub-blocks

There are the remote controller sub-block in the transmitter, filter sub-block, decision sub-block and motor sub-block in the vehicle.

3.1 Remote Controller Sub-block

This block shown in Figure 2. is used to control the vehicle remotely and it generates three sinusoidal input signals which will be transmitted via a transmission wire. The signals are generated using Wien Bridge Sinewave Oscillator which we used in laboratory experiments to generate a pure sinusoid. There are three different signals with different frequencies which will correspond to three movements of the vehicle: left, right and forward respectively. First signal with lowest frequency activates left motor making the device turn right and similarly highest frequency activates right motor for a left turn, whereas middle frequency generates a forward movement. Signals are controlled by switches so that only one switch at a time will be active and only one signal will be transmitted through the line.

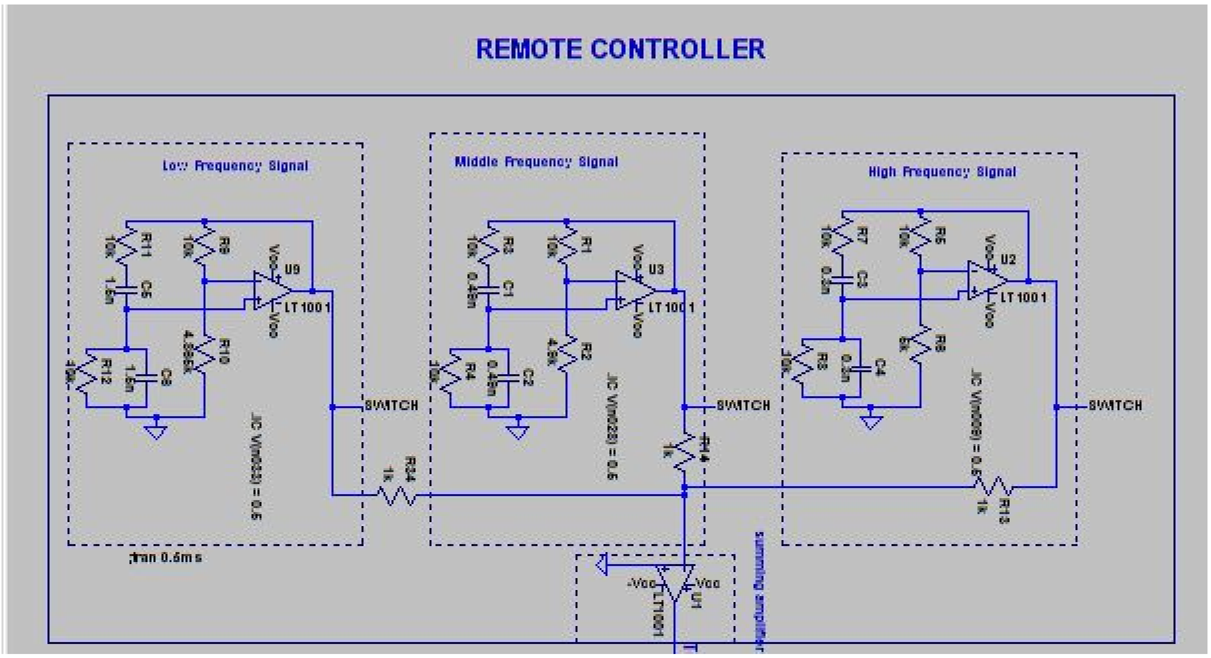

Figure 2. Remote Controller Block

The numbers on the figure are theoretical numbers calculated. The frequencies are calculated according to the Equations 1-3.

$$f1 = 20 * Z1Z2 + 10000 \text{ (Hz)} \quad (1)$$

$$f2 = 40 * Z1Z2 + 30000 \text{ (Hz)} \quad (2)$$

$$f3 = 60 * Z1Z2 + 50000 \text{ (Hz)} \quad (3)$$

while Z1Z2 is the average of the last two digits of our team members' IDs. The frequencies are 11160 Hz, 32320 Hz and 53480 Hz respectively.

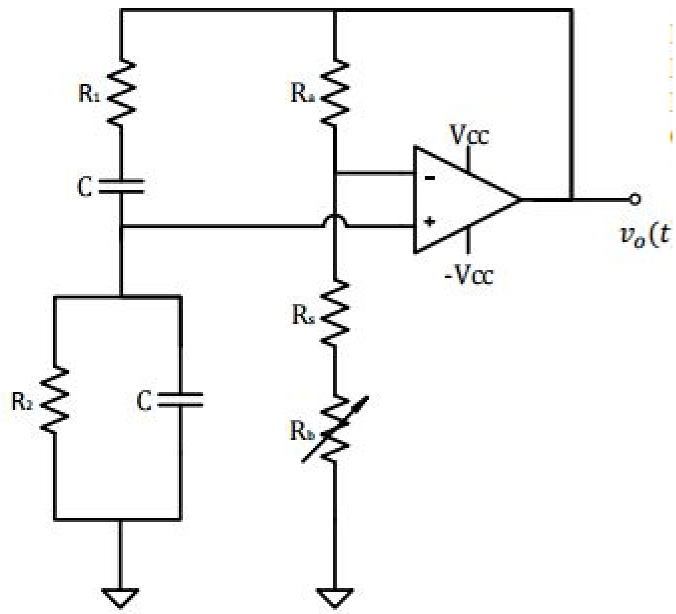

Figure 2.a. Wien Bridge Oscillator

The differential equation of the output voltage is in second order and also contains first order term. When first order term is set to zero as we have learned in the experiments, a pure sinusoid is obtained. When the necessary calculations are done following formula (4) is obtained

$$\frac{R_a}{\frac{R_1+R_2}{R_2}} - R_S = R_b \qquad (4)$$

meaning that R_b is equal to $R_a/2$. And when second order differential equation is solved for the desired frequency, formula (5) is obtained.

$$f = \frac{1}{2\pi CR} \qquad (5)$$

To work correctly after the initial start-up, the gain must be 3 by formula (6)

$$\frac{(R_a+R_b)}{R_a} = 3 \qquad (6)$$

By using these formulas we arranged the values of the circuits to be tested and made proper arrangements in theis values since the real world has deviations from the theoretical values.

Since these Wien Bridge sinewave oscillators are unstable circuits and they generate the pure sinusoid in a very narrow range of adjustable resistor values, we thought that it would be more accurate and appropriate to arrange the right values with the capacitances and laboratory conditions we have.

For this, we figured out that it is better to use LM833 opamap for high frequencies and with the help of potentiometers, we obtained the following output waves with the same amplitude that is 21.8 V for all sinusoids. The frequencies were within the range of the given 10% limit.

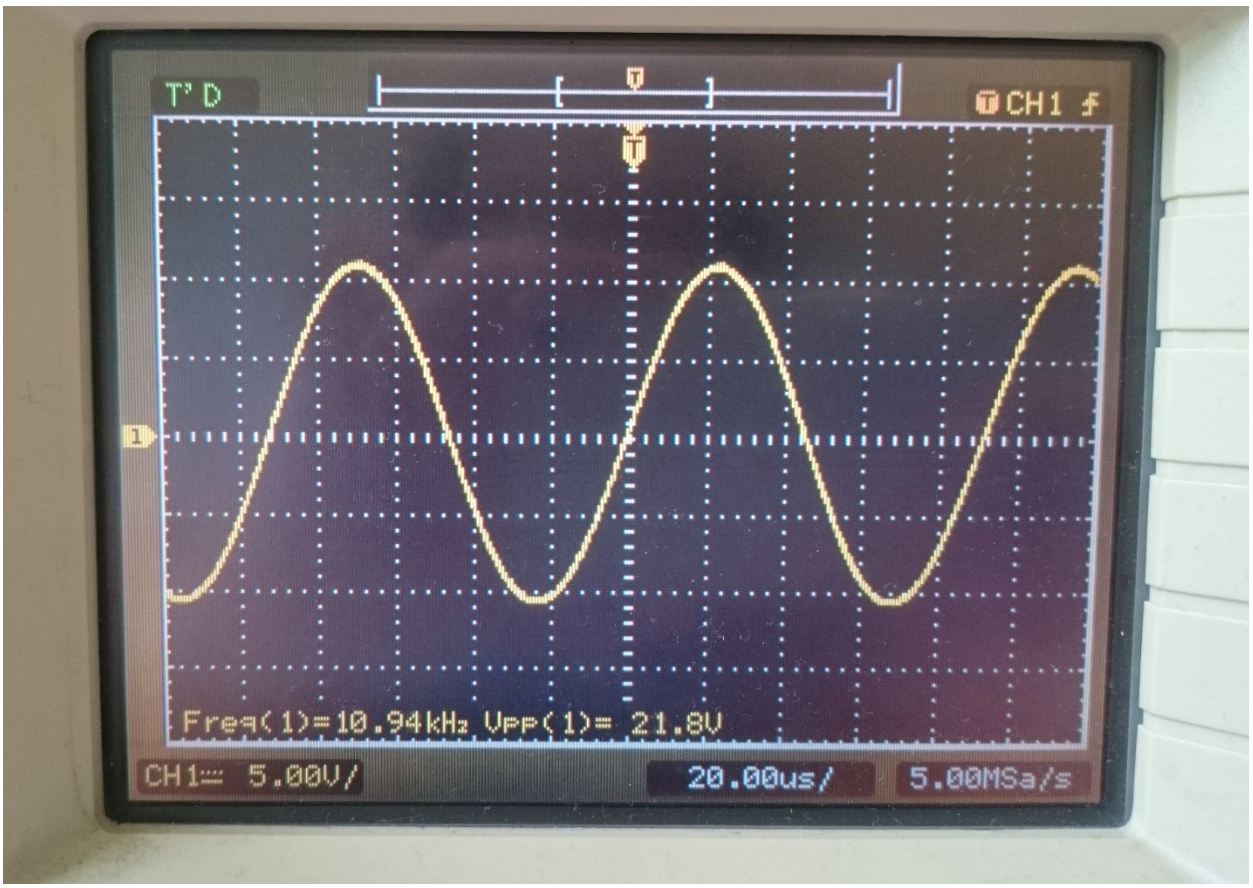

Figure 3. Low frequency signal at the output of remote controller

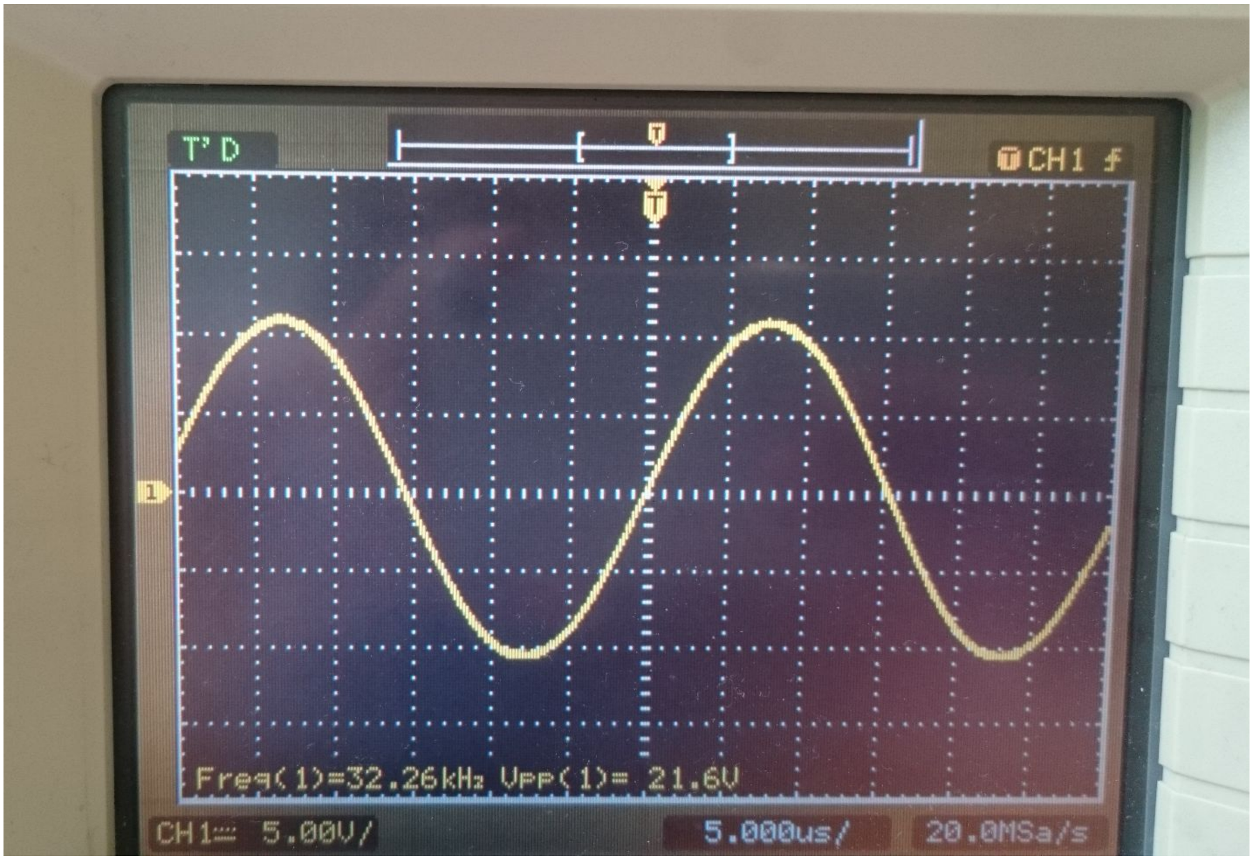

Figure 4. Middle frequency signal at the output of remote controller

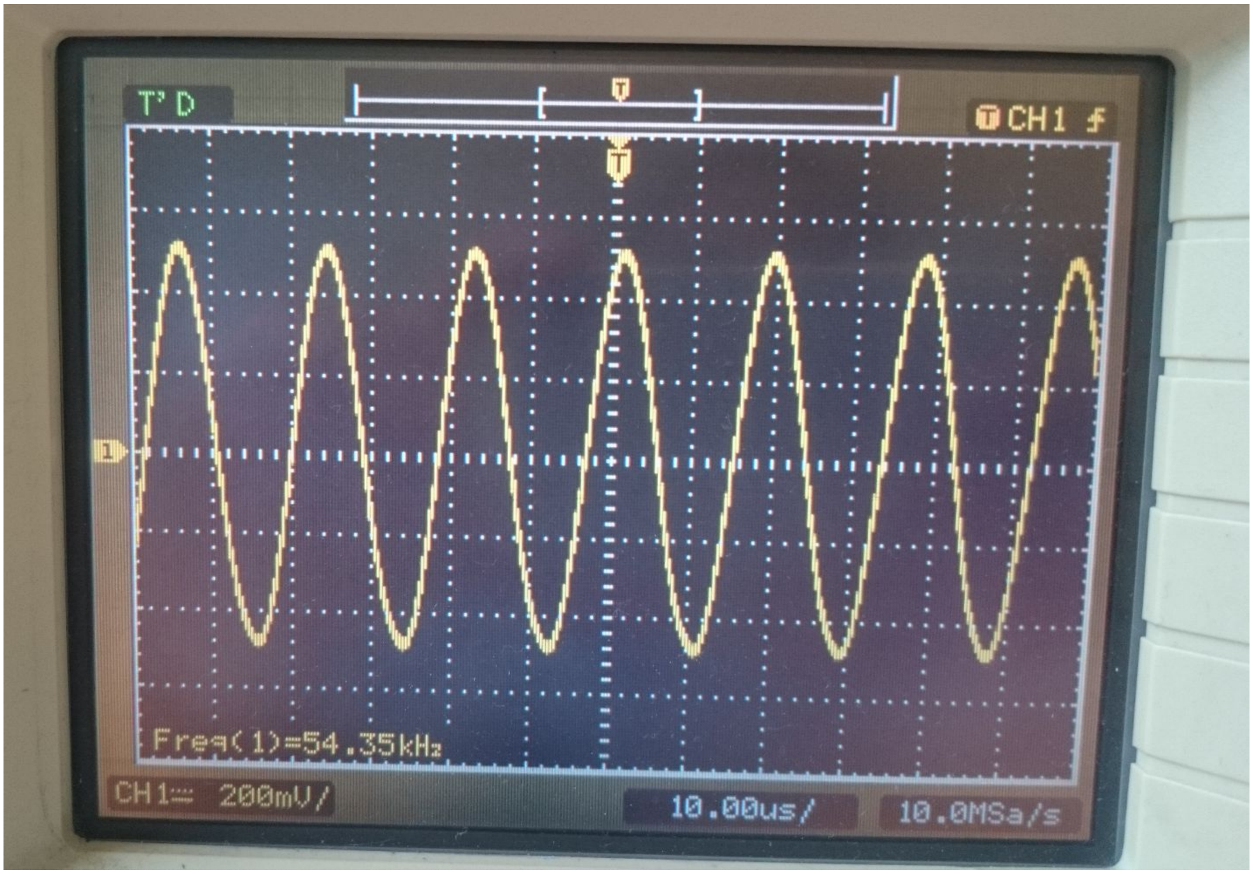

Figure 5. High frequency signal at the output of remote controller

Furthermore, a summing amplifier is added to the output of three signals so that when all switches are on, all waves are seen at the output and this way, they can be tested by filters to see whether the filters work properly.

3.2 Filter Sub-block

Filters are circuits used for seperate signals with different frequencies. Filters let only desired signals to pass. There are different types of filters for different purposes, such as low pass filters, high pass filters, band pass filters,etc.

In transmission line, we created signals with different frequencies. Since we send all signals from the same transmission line, we need to use filters. Therefore we set up three band pass filters.

In filter subblock, before sending the summed signal into the filters, we used two buffers only for two filters to prevent any distortion in the signals when addition of further subblocks is performed.

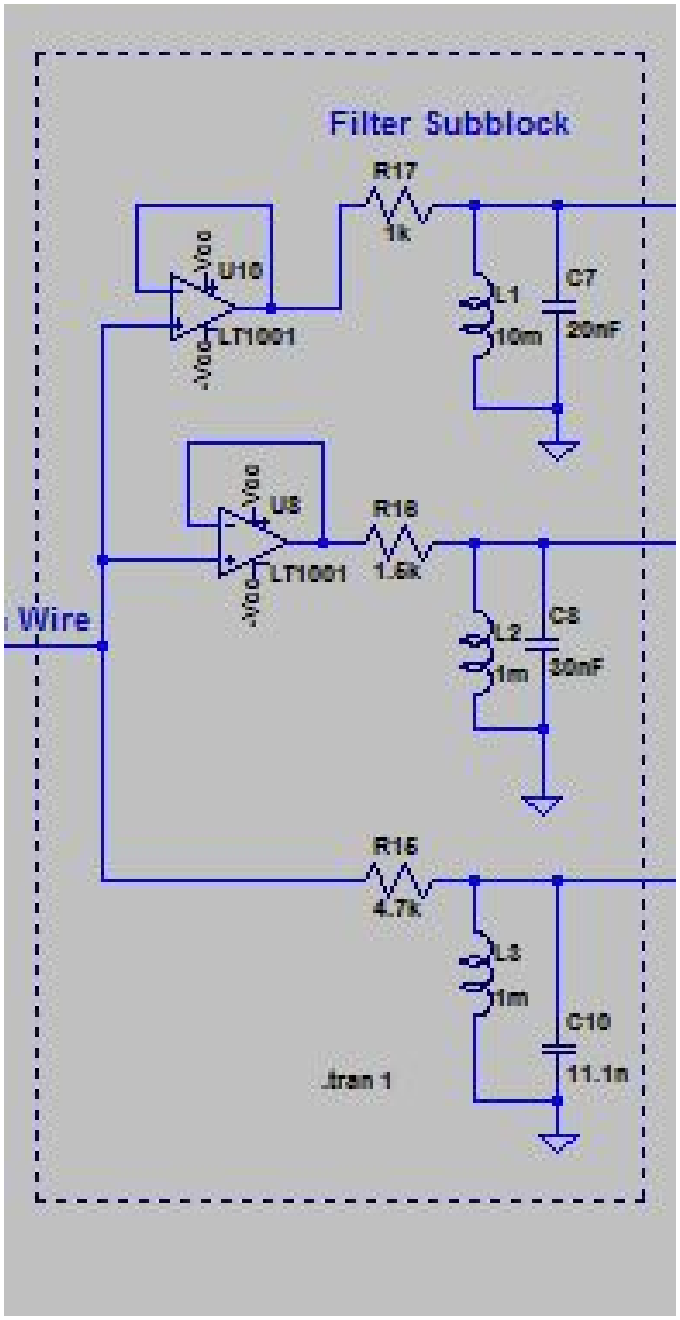

Figure 6. Filter Sub-block

As seen in the figure there are three different filters with different inductance and capacitance values. Our aim is such that:

- **Filter 1:** Allows only Signal 1 to pass
- **Filter 2:** Allows only Signal 2 to pass
- **Filter 3:** Allows only Signal 3 to pass

Where, Signal 1: 11160 Hz , Signal 2: 32320 Hz , Signal 3: 53480 Hz

Before we start to set our filter circuits, we simulated them to see whether they are working properly. In order to simulate and observe their frequency responses, we used AC analysis of LT Spice program for AC amplitude 1.

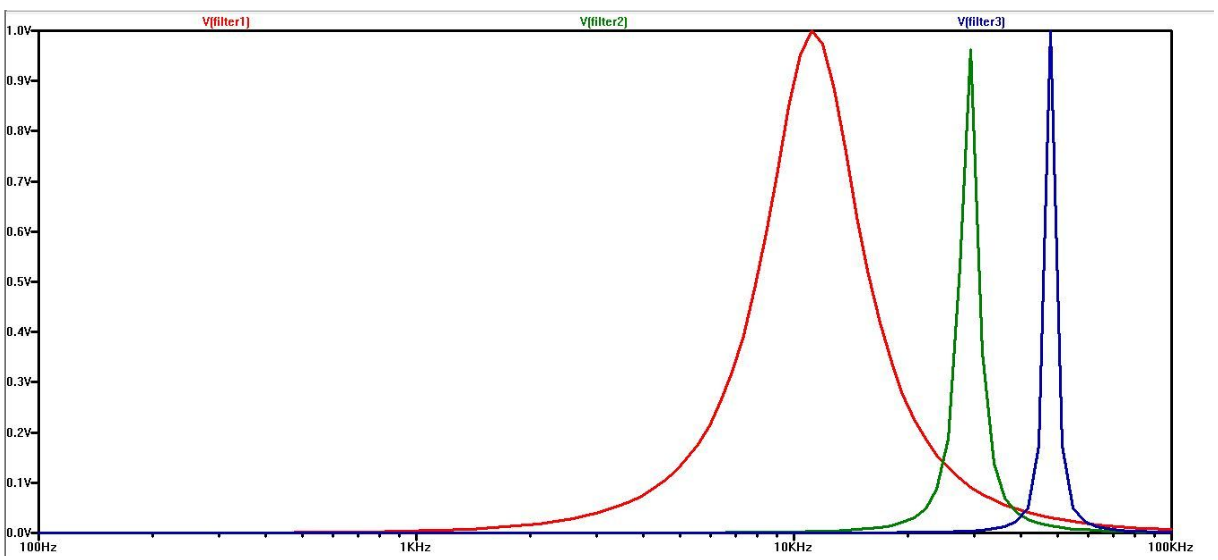

Figure 7. Frequency Response of the Filters

In the figure, red curve is AC response of Filter 1, green curve AC response of Filter 2 and blue curve is the response of Filter 3. We can observe that the peak values of AC response curves are very close to desired frequency values of each filter.

We used the parallel connected passive second order bandpass filters and while selecting the proper values for the filters we used the formulas given below. First of all, for the filters' quality factor,Q, following formula (7) is used

$$Q = R \cdot \sqrt{\frac{C}{L}} \qquad (7)$$

And for the center frequency, w_0, we used the formula (8)

$$w_0 = 1/\sqrt{(C \cdot L)} \qquad (8)$$

Since we arranged the frequency to be selected with L and C values, to increase the quality of the filter easily and decrease the bandwidth we increased R values. For the frequency responses of the designed filters, we used the VEEE computer program available in the laboratory. Following figures 8,9,10. As a note, in the first and last filters shown in figure 8 and 10 respectively, it can be thought that the filter's resonance frequency do not match with signals' frequency. However, it is vital to realize that we changed the quality factors of fthe filters many times by changing the resistances and their frequencies by changing capacitances and obtain exactly the desired resonance frequency although the figures may not match with the final filter designs. It is again important to highlight for us that the filters worked properly during the laboratory session which was under the charge of our instructor.

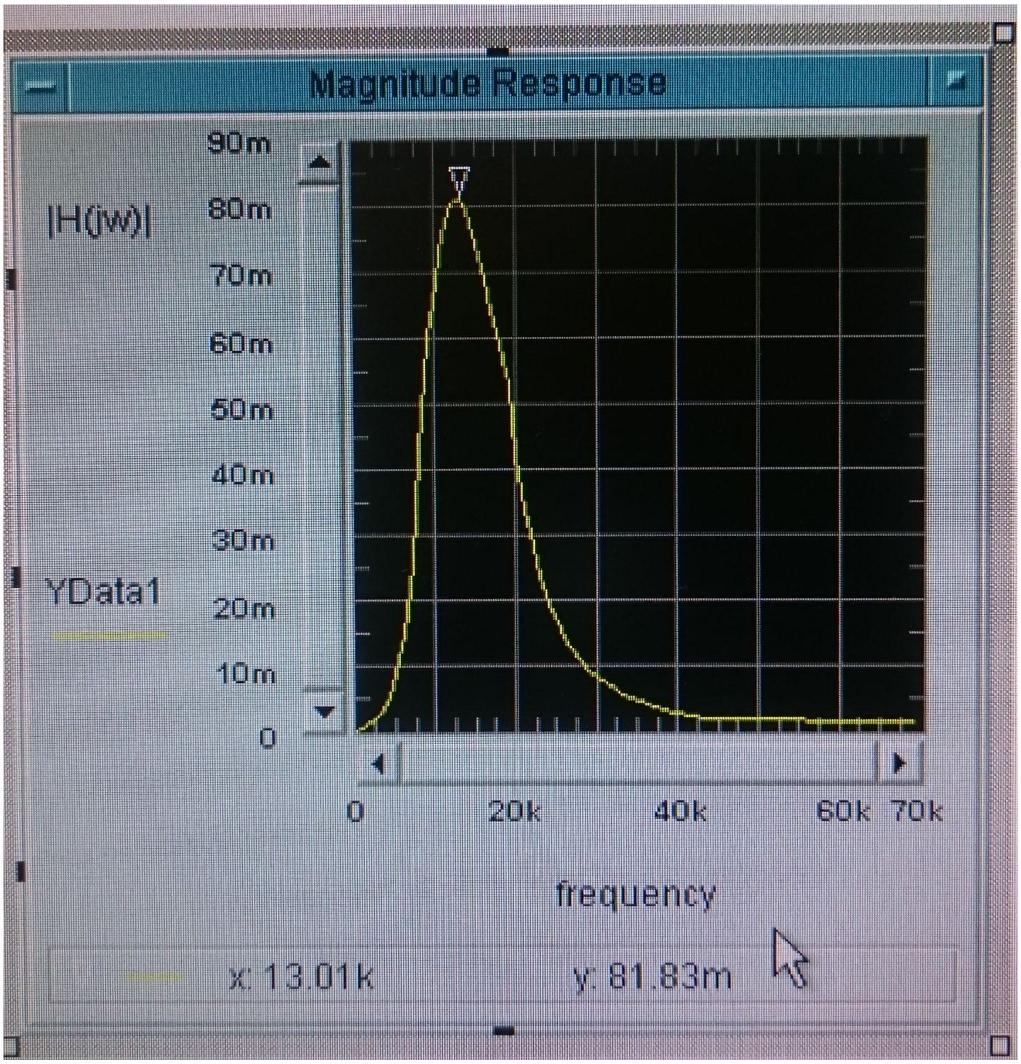

Figure 8. Magnitude Response of Low Freqency Band-pass filter

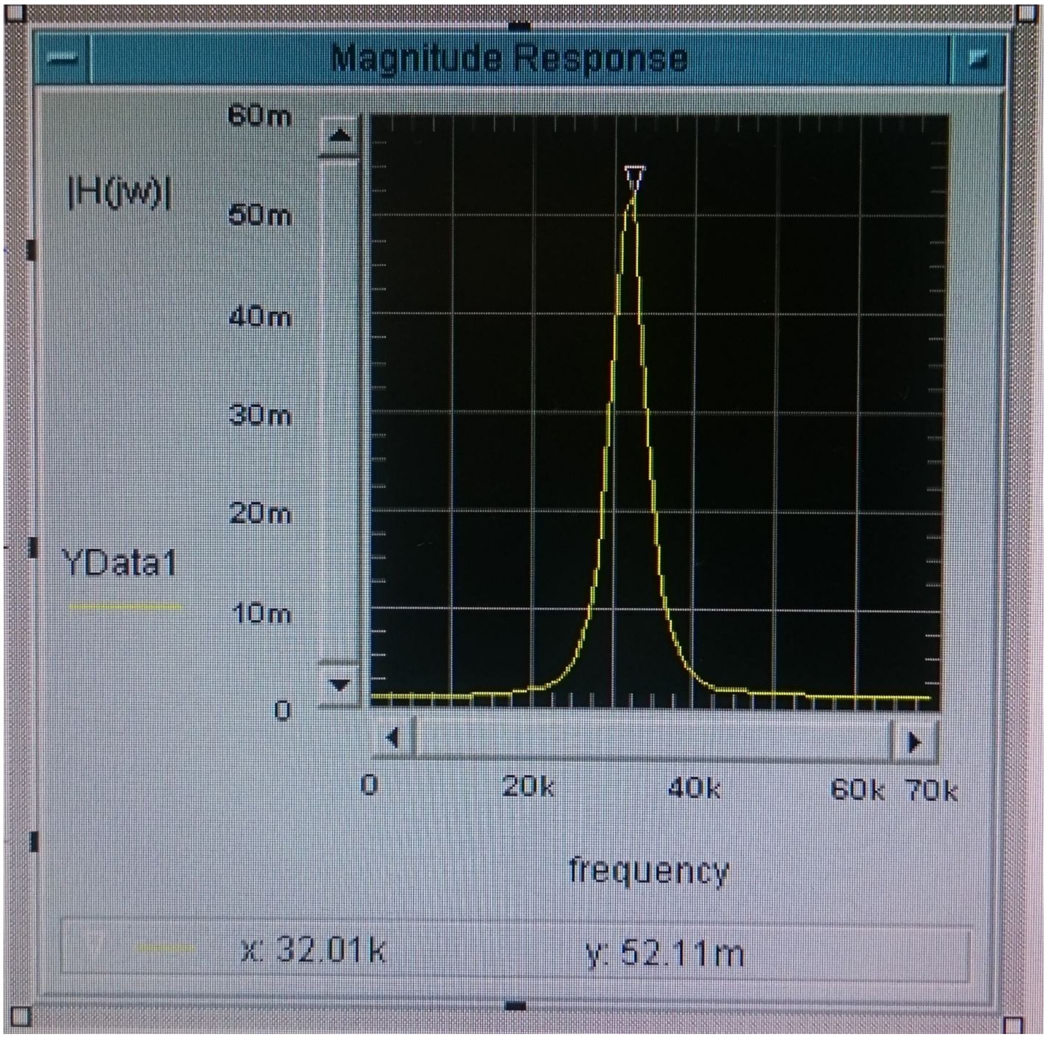

Figure 9.Magnitude Response of Middle Freqency Band-pass filter

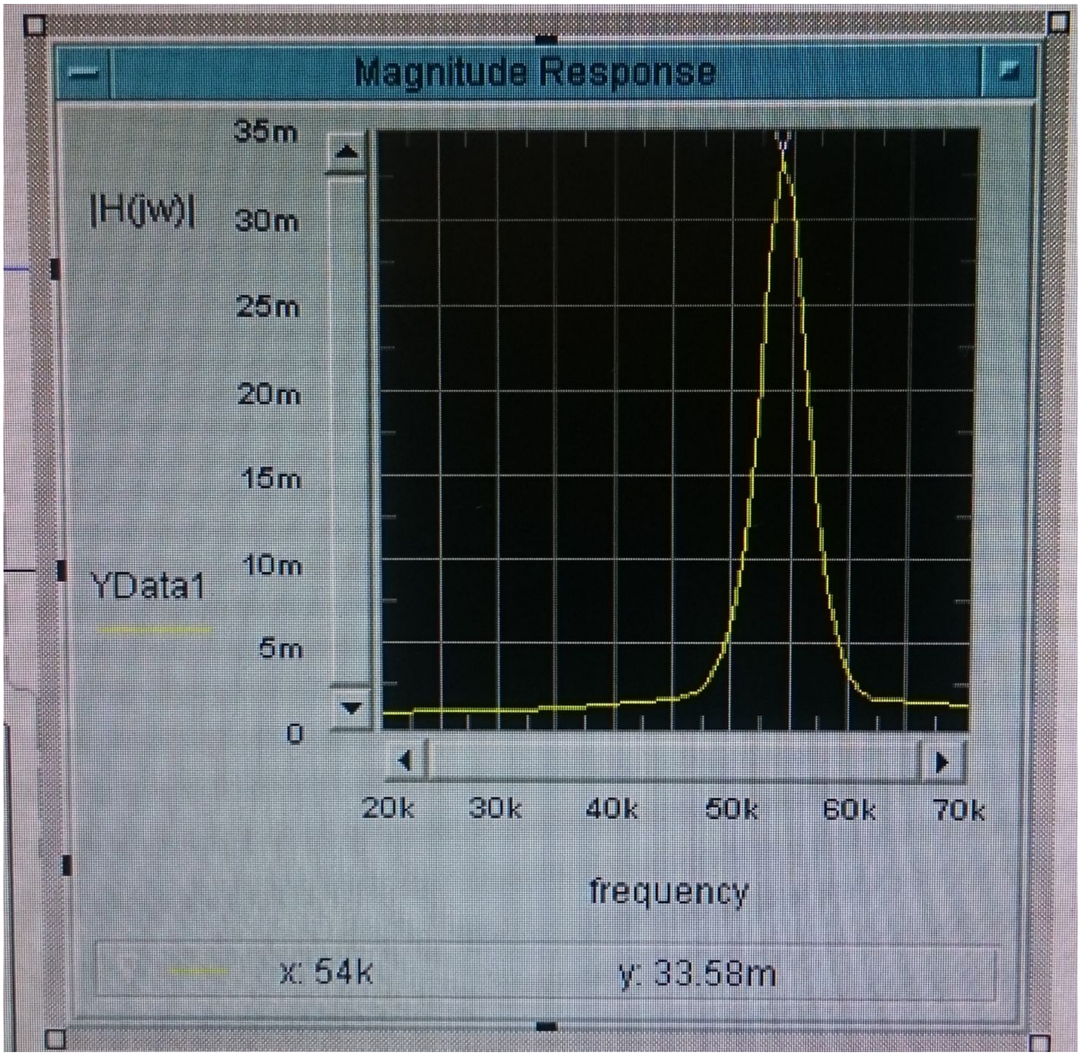

Figure 10.Magnitude Response of High Freqency Band-pass filter

Although the filters worked properly and let pass only the frequency which they were arranged to, the loss in gain we obtained in the second filter could not manage to fall in the desired range with 5% to 10% but fall behind up to 20%.

3.3 Decision Sub-block

After we seperate our signals we need to convert them form AC to DC and amplify in order to use them with transistors. In this circuit after each filter we used half-wave rectifier parallel with a capacitor to set our AC to DC converter. After convert the signals we amplify them with non-inverting amplifiers so that we obtain enough gains at transistors.

Since in addition to our preliminary report we used buffers before the signals were filtered, we obtained higher DC voltages at the output of the desicion unit which were araound 4 to 5 V. However, we added a non-inverting amplifier to the second filter’s desicion part since the DC obtained from there were at 1 to 2 V due to this filter’s low gain.

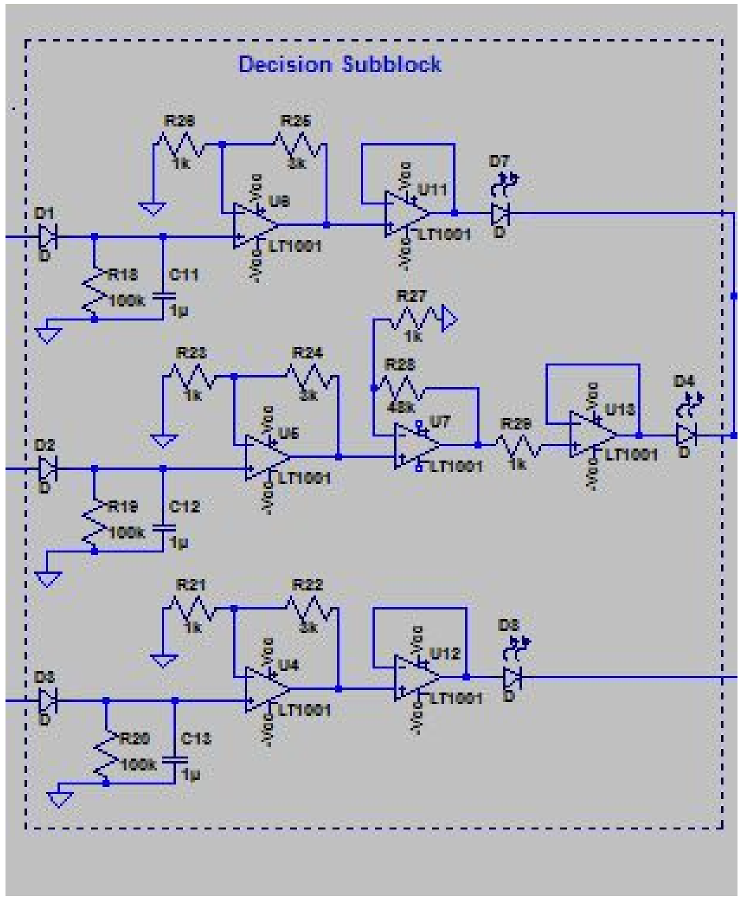

Figure 8. Decision Sub-block

- If we simulate our circuit with a 11kHz signal, we observe only “output1” has a voltage around 4V DC.

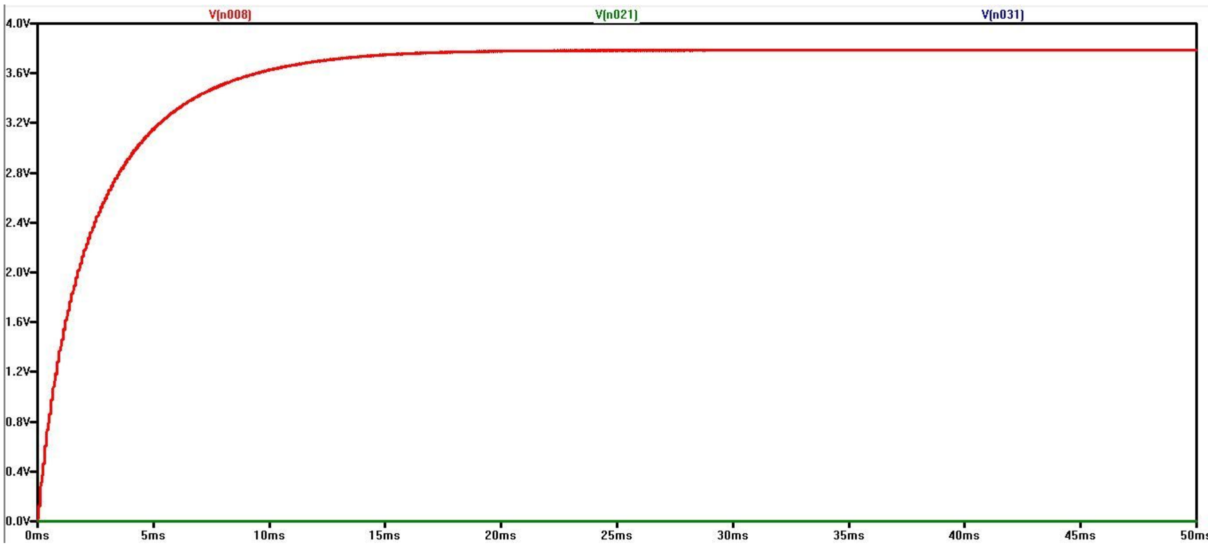

Figure 9. Output waveforms at f1

- If we simulate our circuit with a 32kHz signal, we observe only “output2” has a voltage around 3V DC, which is enough to activate a transistor.

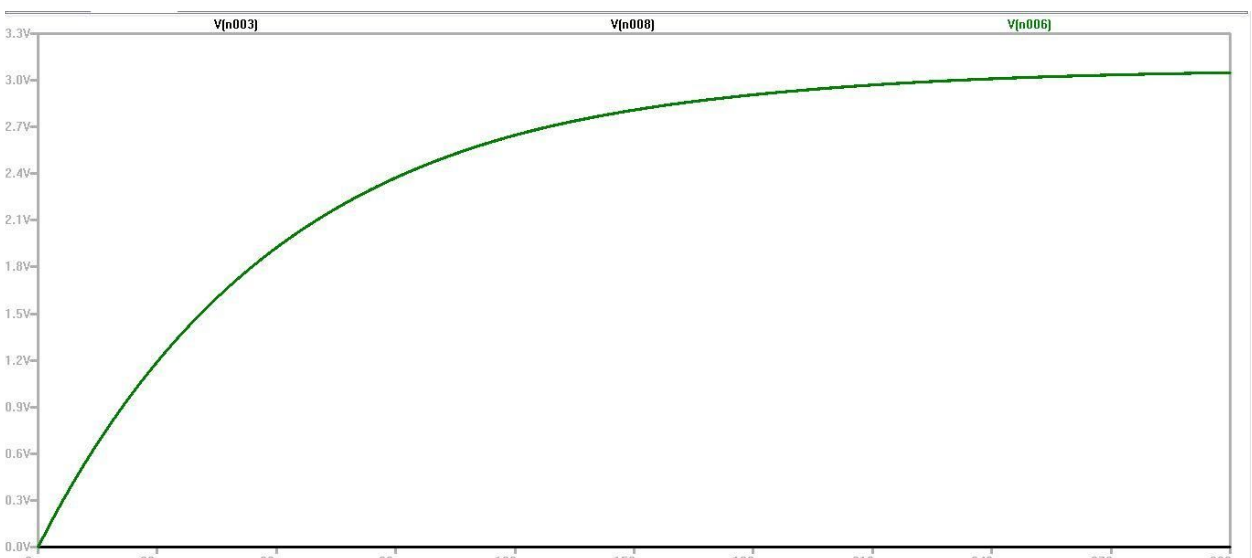

Figure 10 . Output waveforms at f2

- If we simulate our circuit with a 53kHz signal, we observe only “output3” has a voltage around 3V DC, which is enough to activate a transistor.

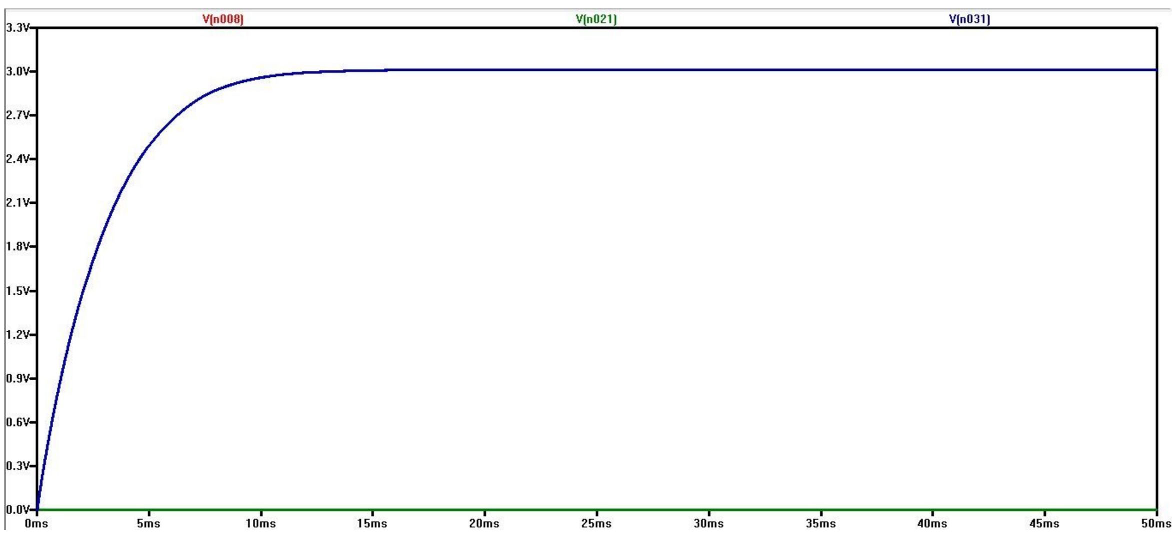

Figure 11. Output waveforms at f3

3.4 Motor Sub-block

After we obtain, convert and amplify the signals; we use these signals to work motors as expected. To achieve this, we used NPN transistors as switches as shown in the figure.

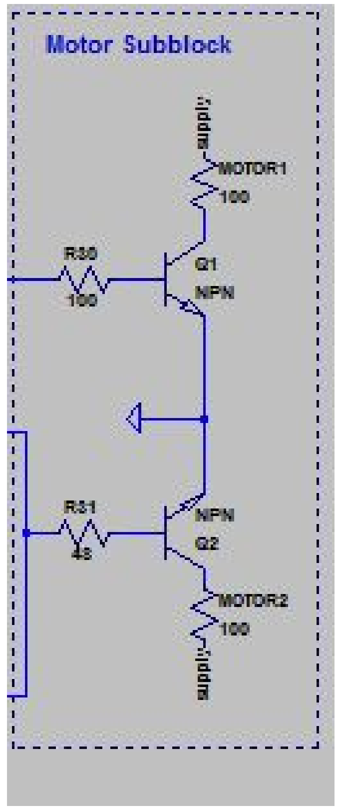

Figure 12. Motor Sub-block

We drove the motors with the DC voltages we obtained. Since the motors need a start-up impulsive force to begin working, they need a higher current for the start-up and the current they drive decreases afterwards. We gave this start-up by hand although we also observed that when a higher voltage is applied to the base of the transistor, the motors start working without an external force. This can be achieved simply using a non-inverting amplifier before the input of the motors which we did not include due to the limited time we had. Nevertheless, we observed that both of the motors work properly when enough voltage is applied with amplification of the DC base input i.e. output of the decision unit. They also work with an external impulsive start-up force.

Since we have three different signals, we have three different cases.

Case 1: Remote Controller Transmits only Signal 1 (11160 Hz).

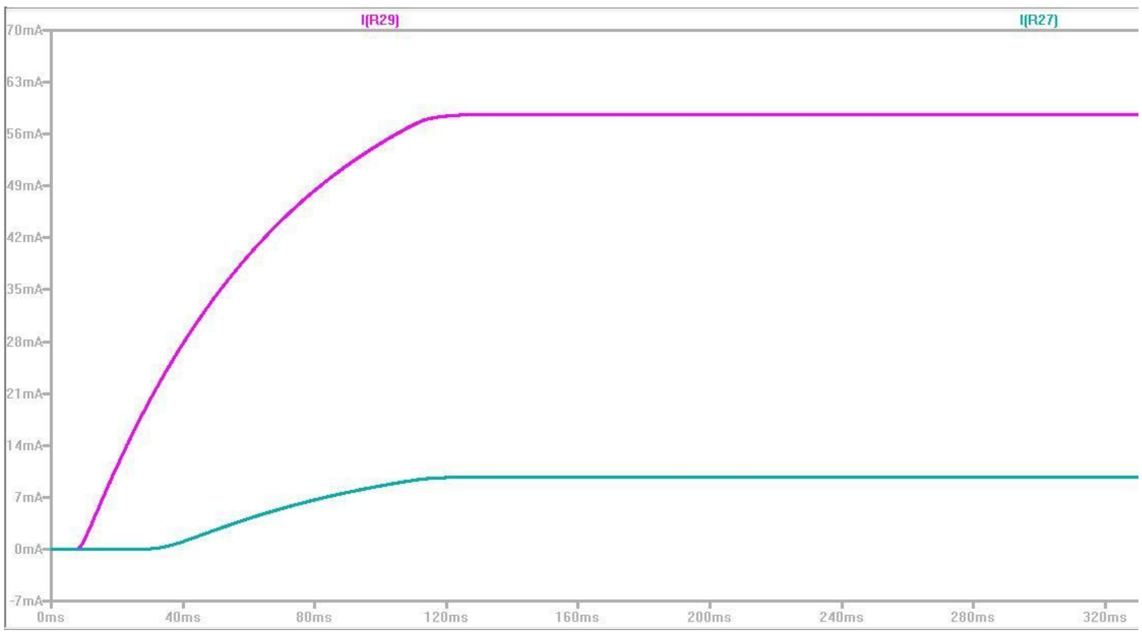

Figure 13. Motor Currents at Case 1

Case 2: Remote Controller Transmits only Signal 2 (32320 Hz).

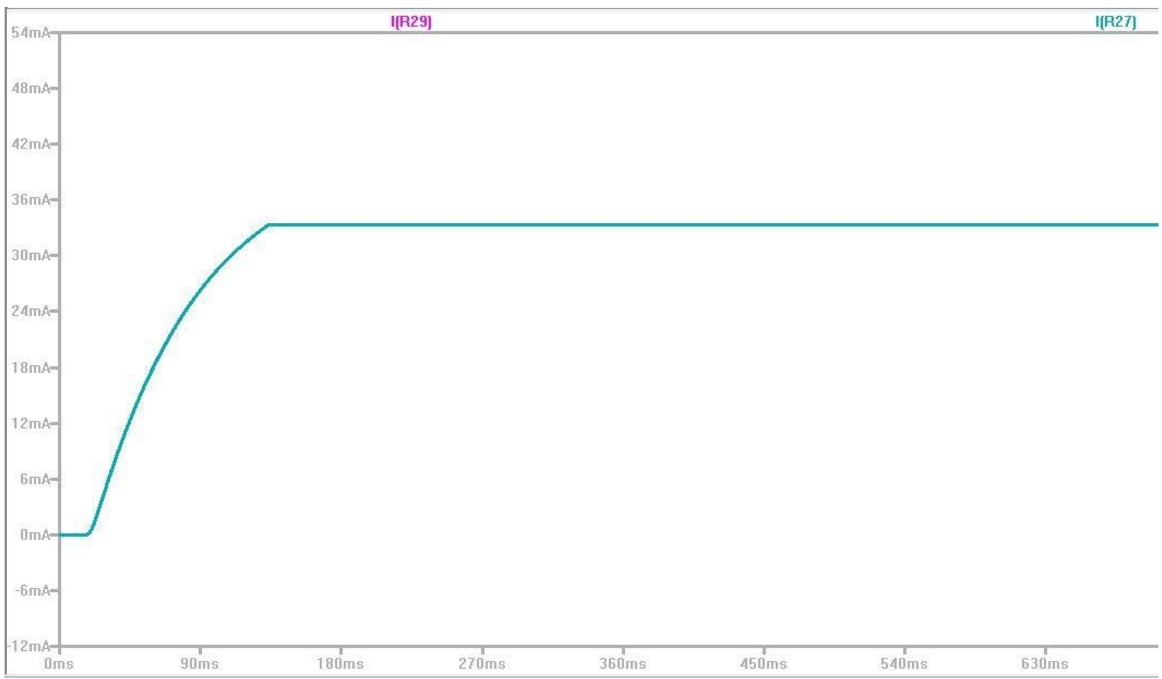

Figure 14. Motor Currents at Case 2

Case 3: Remote Controller Transmits only Signal 3 (53480 Hz).

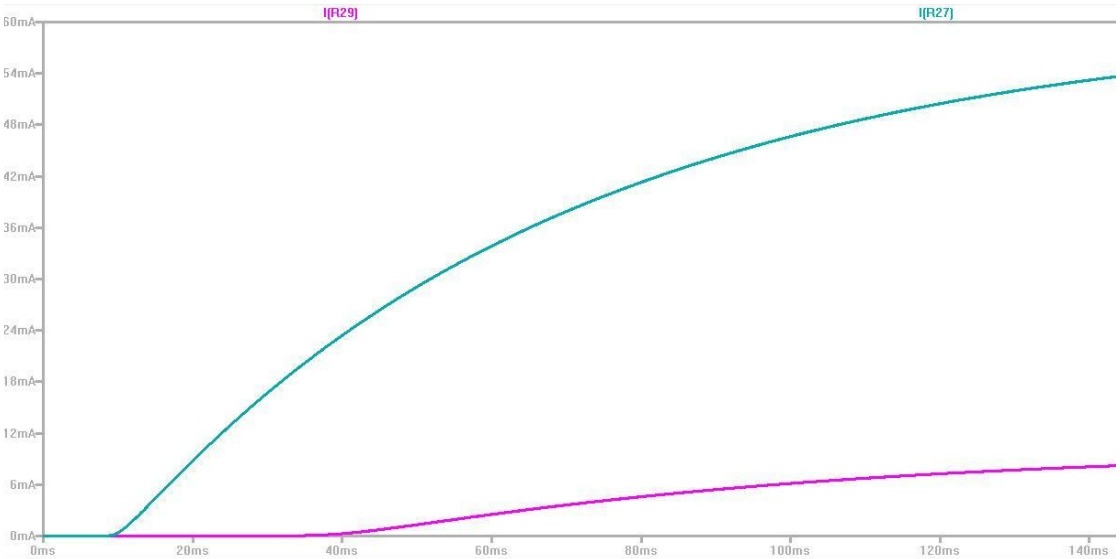

Figure 15. Motor Currents at Case 3

Our simulation results indicated that at Case 1, only Motor 1 ; at Case 3, only Motor 2 is active. If only one motor is active, our vehicle rotates. For example, if our DC Motor 1 is on the right and DC Motor 2 is on the left; at Case 1, our vehicle turns left and at Case 3, it turns right. The direction of rotation changes if we switch the place of motors. At case 2, since both motors active, our vehicle goes forward.

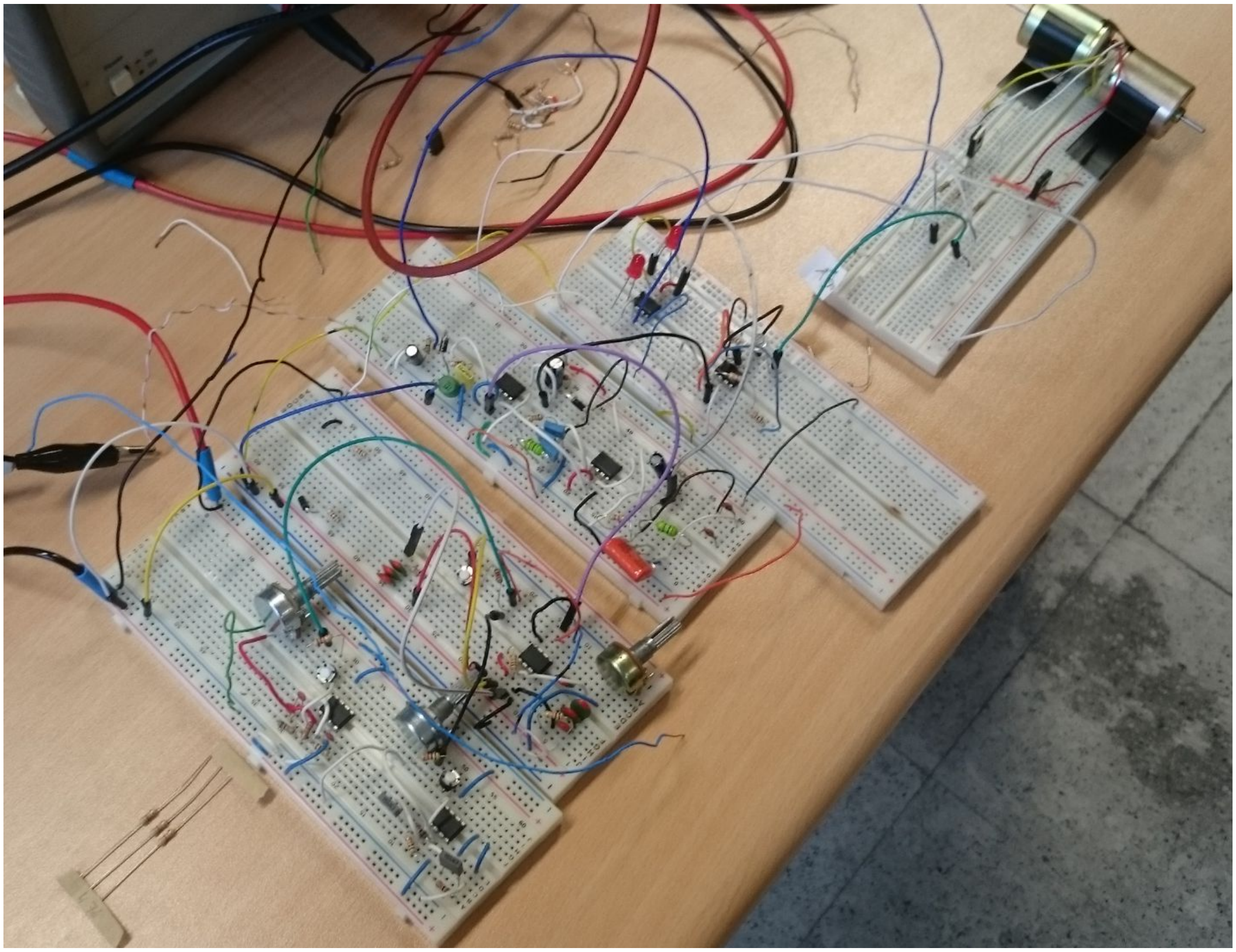

Figure 16. Photograph of the project

4. Power and Cost Analysis

4.1 Power Analysis

In this project, we used +12V, -12V and +6V DC power supplies. Our remote controller part is supplied by +12V and -12V DC suppliers with 15mA and 35mA respectively. Therefore with the following power calculation given in (9),

$$P\,controller = 12 * 0.015 + 12 * 0.035 = 0.6\,W \qquad (9)$$

Our vehicle part is supplied by +6V DC supply with a current value between 0.49 and 0.35 Amps according to how many motors avtive at the same time (1 or 2 DC motors).

$P\,vehicle$ varies between 2.9 and 2.1 W

And total power, $P\,total$ is calculated through equation (10)

$$P\,total = P\,controller + P\,vehicle = Changes\ between\ 3.5W\ and\ 2.7W \qquad (10)$$

4.2 Cost Analysis

In this project, we used some basic materials and electronic components to set up our circuits, such as breadboards, BJT transistors, DC motors, OP-AMPs, capacitors, resistors, inductors, potentiometers, diodes, LEDs etc. We bought most of this components from Konya Sokak. Our total spent was approximated as nearly 40 Turkish liras.

5. Conclusion

In this project, we have designed a circuit to control a vehicle remotely by using our knowledge which we had gained throughout the whole laboratory sessions and by making new researches on the topic. We learned to use the circuits and operations we have seen in our laboratory experiments in a given real life application which is a fundamental step into an area, i.e. remote controlled vehicles, having various uses such as military usages, scientific usages and as for hobby space.

Mainly we have taken advantage of filters to select a specific frequency range to filter our signals which were created through unstable circuits, we also used diodes as half-wave rectifiers with capacitors to convert AC signals to DC, we used operational amplifiers to amplify our DC voltage and used BJT's amplifying properties to amplify the DC current in order to run DC motors.

In laboratuary sessions, we did some important observations. Firstly, our oscillator circuits didn't worked properly in the first lab session, especially for 33kHz and 53kHz frequencies. This was due to the fact that the operational amplifiers we used during the semester LM358 were not compatible with high range freuencies such as those we needed to generate and has very low gain for signals higher than 10kHz. Therefore, we needed to use high frequency op-amps which was LM833 in our case. Figuring this out took quite a good amount of our time which was already limited, since we spent very much time on generating the new sine-waves. In this process, we were faced with lots of connection problems based on resistors' and other components' not fitting in the breadboard which was a design problem that was out of our control.

Secondly, we observed that our band-pass filters we designed at the beginning with theoretical values in hand, have very low quality factors than we needed. This was causing undesired signals to pass from other filters. Hence, we increased this factor by changing the values of mainly resistors and meanwhile controlling the filter quality by use of VEEE program available in laboratories. In this way, we managed to get the desired bandwidth by not changing the center frequencies.

Moreover, we noticed that BC547 transistor could be easily broken when we tried to drive DC motors with it. In order to overcome this problem, we decided to use BD139 transistor, which can carry higher currents than BC547, to drive DC motors.

Briefly, during the process of this project, we increased our knowledge, practice skills and learned to enlarge our variety of materials as well as the importance of team work and sharing information. Although, we were faced with some problems which was completely expected and normal, at the end we managed to overcome the problems and finalise the project. However, we ran out of time to look for the bonus part which included the wireless communication and we were also a little remote to make the circuit extra neat since we had observed the fact that little external physical disturbances to the circuit components created great loose connection problems which were very hard to detect and eventually consumed a very great amount of time. Nevertheless, we believe that this project was really stimulating for both of the team members since we could really put on practice by all means what we have learned with the help of the project. And it is also notable that obtaining something that does work as an answer to a problem or a desired specification and finding out the problems and getting through them was quite satisfactory. We believe that we gained a valuable knowledge to act and responde as engineers.

6. References

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[2] Eric Coates MA BSc. (2016, March 31). *Module 3.4 Wien Bridge Oscillators* [Online]. Available http://www.learnabout-electronics.org/Oscillators/osc34.php

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