University of Moratuwa

Faculty of Engineering

Department of Electronic & Telecommunication Engineering

EN2091 - Laboratory Practice and Projects

Group 07

Project Report - Analog Function Generator

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Abstract

In this report there is a detailed description of how to build an analog function generator which can generate Sine, Saw-tooth, Square (with adjustable duty cycle) waves with adjustable amplitude, frequency and a DC shift. The amplitudes can be varied from 0 V to 10 V and frequencies can be varied from 20 Hz to 20 kHz. This project was done by mainly using op-amps, resistors and capacitors.

Contents

1 Introduction

For this project, we were asked to make a fully functional function generator which includes all the key functionalities of a laboratory function generator.Generation of sine, square, triangular, sawtooth and PWM wave forms are the main functionalities of the function generator.Other than that, this function generator is capable of changing the frequency of the wave forms from 20Hz to 20kHz and the amplitude from 0 to 20V. Adding a DC offset to the wave forms and add a changing the duty cycle of square wave are the other functionalities of the function generator.In the past, these functionalities were produced b7y some popular Integrated Circuits(ICs).Now these old analog ICs are replaced with new Direct Digital Synthesis chips.In this project, only opamps, transistors, resistors capacitors and potentiometers were used to generate all the wave forms.In this report, the different techniques which were used to generate wave forms and change the characteristics of the wave forms will be described.

2 Electronic Design

2.1 Design Guidelines

For the analog function generator project we were given the following specifications to be fulfilled.

1. The function generator should be able to generate sine, triangular, saw-tooth, square and pulse width modulation (PWM) waves.
2. The frequencies of the waves should be able to vary from 20 Hz to 20 kHz.
3. The amplitudes of the waves should be able to vary up to 20 V peak-to-peak.
4. In PWM wave, the pulse width should be able to vary from 1% up to 99%.
5. The function generator should be able to supply the waves to a 50 Ω load.

2.2 Waveform Generation

As the given specifications, the function generator should be able to generate five functions namely, sine wave, square wave, triangular wave and PWM wave. We used separate methods to generate these wave forms to reduce the effect of one waveform on other wave forms.

2.2.1 Square Wave and PWM wave Generation

Both the square wave and PWM wave forms can be generated using the same circuit because the square wave is the PWM wave with a duty cycle of 50%.
To generate the square wave, we used a schmitt trigger circuit.Schmitt trigger circuit produces a square wave when producing clock or timing signals which swaps between high and low.The frequency of the square wave depends on the value of Resistance and the capacitance.

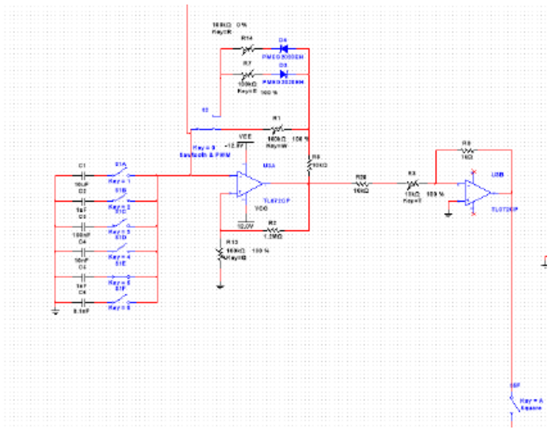

Figure 1: Square wave generator circuit.

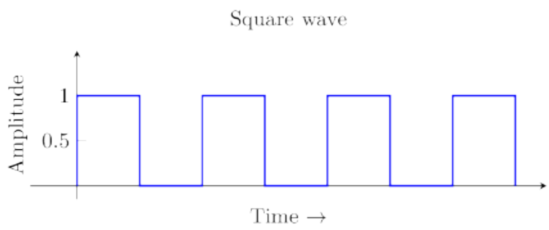

Figure 2: Square wave

The square wave generated from Schmitt trigger circuit will be headed to a Inverting attenuator in order reduce the output voltage to a more useful voltage.It is because the the highest output voltage from the relaxation oscillator will be not useful at this point of the circuit.
The duty cycle of the square wave generated by the Schmitt trigger circuit can be controlled by the Schottky Diodes circuit.

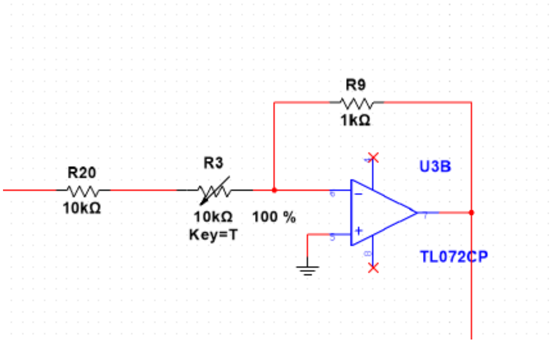

Figure 3: Square wave attenuator circuit.

By adjusting the potentiometers we can control the duty cycle percentage. The frequency of the square wave depends on the value of Resistance and the capacitance.

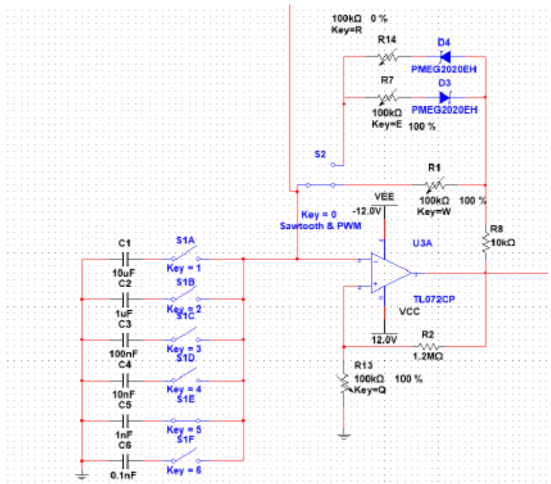

Figure 4: PWM circuit.

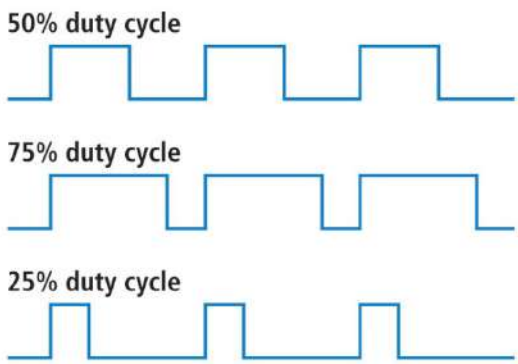

Figure 5: PWM Wave

2.2.2 Triangular Wave and Saw tooth Generation

The triangular waveform is generated using the simple charging and discharging property of a capacitor.The frequency can be varied by changing the value of the capacitor and the variable resistors of the Schmitt Trigger circuit.This is the same that was used to generate square wave. The out from

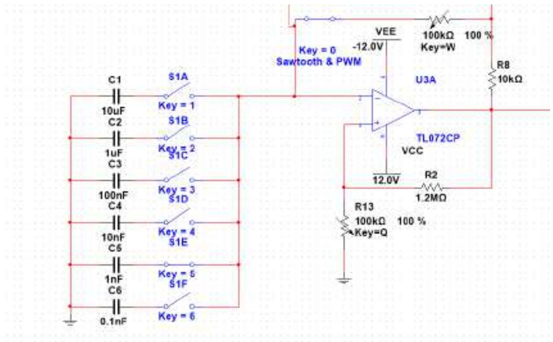

Figure 6: Schmitt trigger circuit of triangular wave generator

the capacitor panel will then be connected to a non-inverting amplifier that "picks off" the triangle wave from the capacitor.Non-inverting amplifier configurations are useful because they have extremely high input impedance. The actual charge on the capacitor is very small, and any significant current draw from that point can ruin the operation of the relaxation oscillator. The

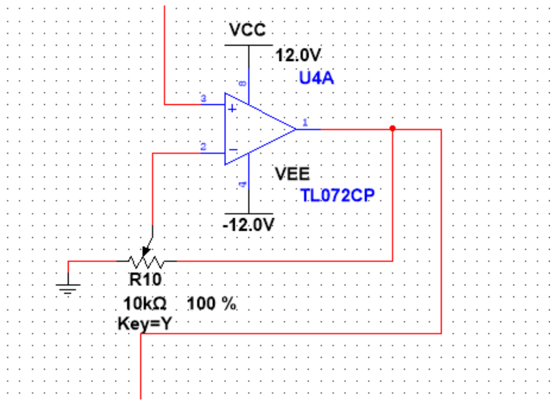

Figure 7: Non-inverting amplifier of triangular wave generating circuit

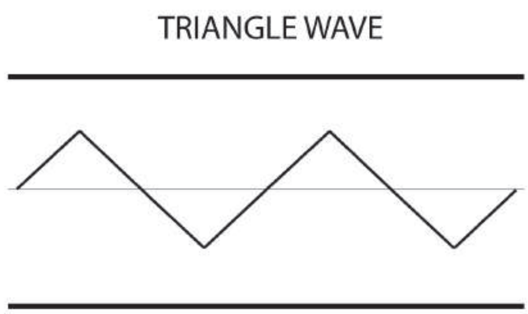

Figure 8: Triangular wave

saw-tooth waveform is generated using the simple charging and discharging property of a capacitor and the Schottky diodes circuit along with the Schmitt Trigger circuit .The ramp of the saw-tooth can be controlled by potentiometers.Frequency control is same as the triangular waveform.

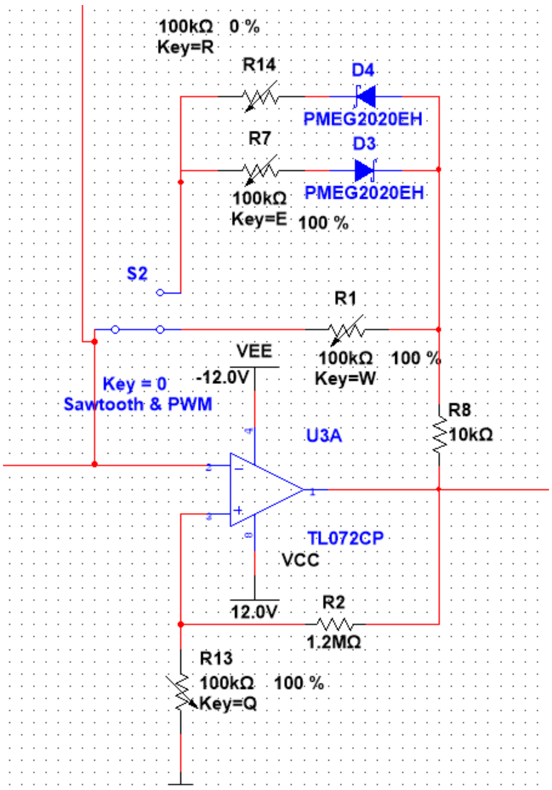

Figure 9: Saw tooth waveform generating circuit

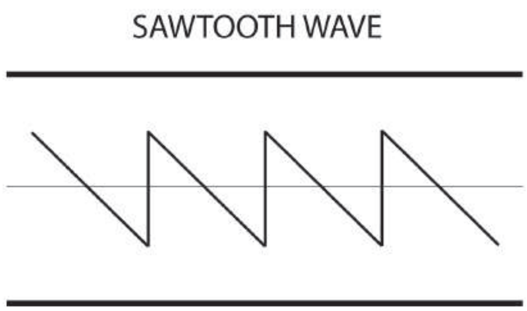

Figure 10: Sawtooth wave

2.2.3 Sine Wave Generation

To generate the sine wave, in our project, wien bridge oscillator is used.This generates a sine wave at the resonance frequency (fr), given by the equation,

$$F = \frac{1}{2\pi rc}$$

The frequency of the sine wave can be changed by varying the values of the two resistors or the two capacitors simultaneously. An Inverting Amplifier that is used to calibrate the sine wave.A low-pass filter before will be useful to eliminate some of the overtones and make a prettier sine wave.A high pass filter after the amplifier will eliminate any offset remaining after the drift correction.

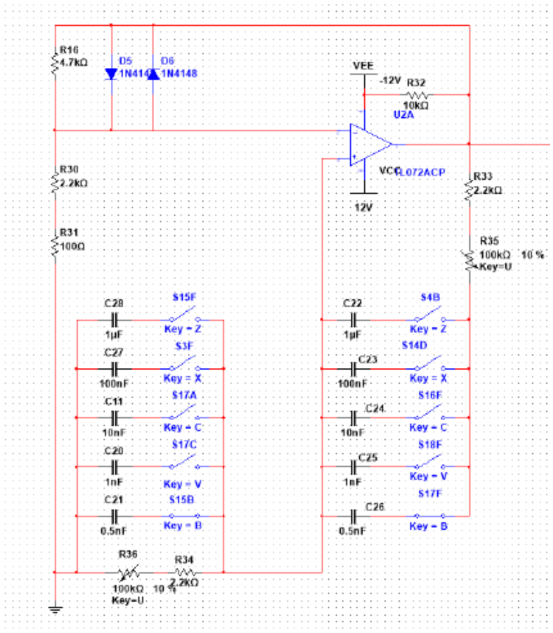

Figure 11: Wien bridge oscillator for sine wave generation

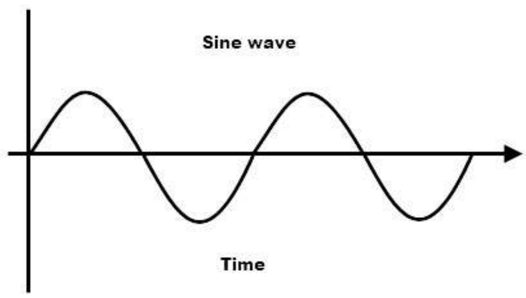

Figure 12: Sine wave.

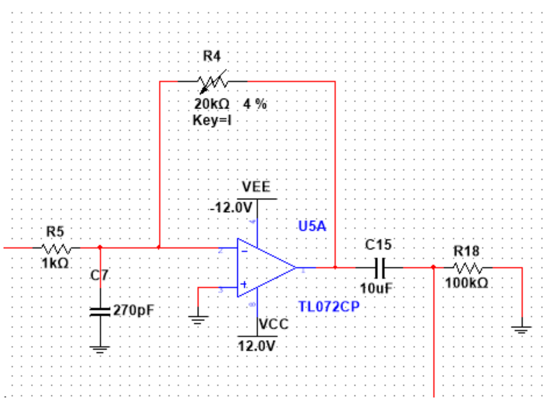

Figure 13: Inverting amplifier of sine wave generating circuit

2.3 Output Circuit

The output circuit of the function generator gives the ability to change the amplitudes, give dc shifts and to provide the output through a small load.The amplitude variation is done using an inverting amplifier. A push-pull amplifier is used to drive the load.

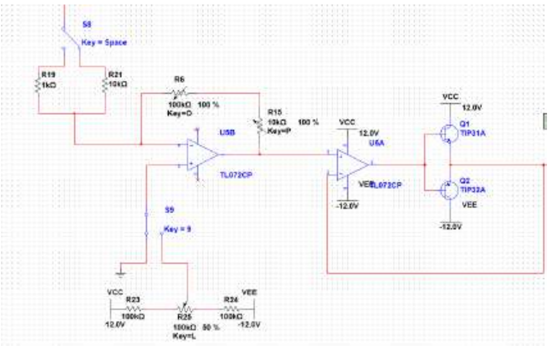

Figure 14: Output circuit

2.3.1 Waveform selection

Between the sine,square,triangular circuits and the output circuit, a switch is used to select which waveform generating circuit should be connected to the output circuit.

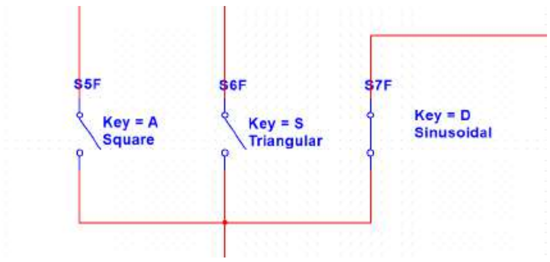

Figure 15: Waveform selection

2.3.2 Probe selection

This switch is used to change the probe between 1x and 10x. It can be used to change the amplitude range.

2.3.3 Amplitude control

An inverting amplifier is being used to vary the amplitude of he waveform.The main amplitude change of the wave forms is done using this amplifier.

2.3.4 Push pull amplifier

At the output stage of the function generator a push-pull amplifier is used to amplify the current. This helps it to drive a small load without any distortion in the wave. In the design a class-AB push-pull amplifier is used.The two pnp and npn transistors are complementary to each other. The npn transistor drives the output during the positive half cycle of the input while the pnp transistor drives the output during the negative half cycle. These transistors should also be capable of handling the desired amount of power and current. The two diodes keep both the transistors biased thus eliminating the crossover distortion.

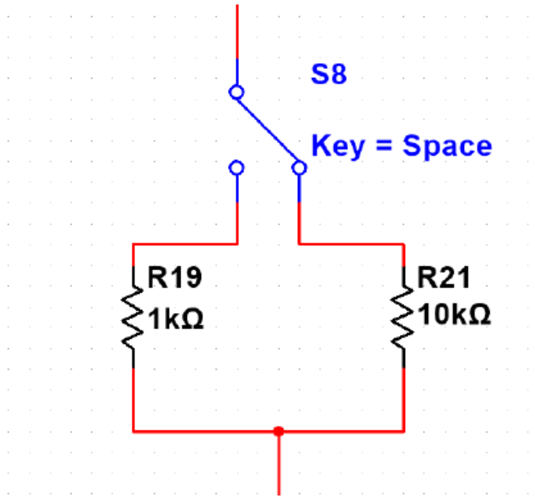

Figure 16: Probe selection

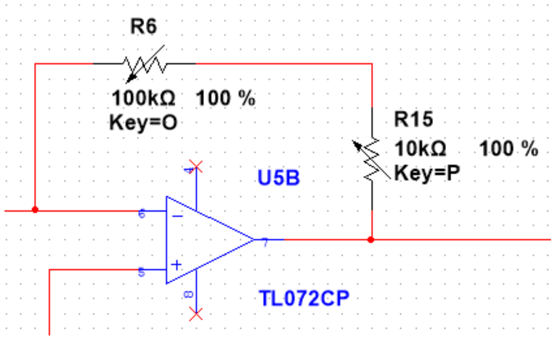

Figure 17: Amplitude Control

3 Calculations and Component Selection

For the correct functionality of the function generator, selecting components is very important. We have done this using necessary calculations and by referring to the data sheets of the components.

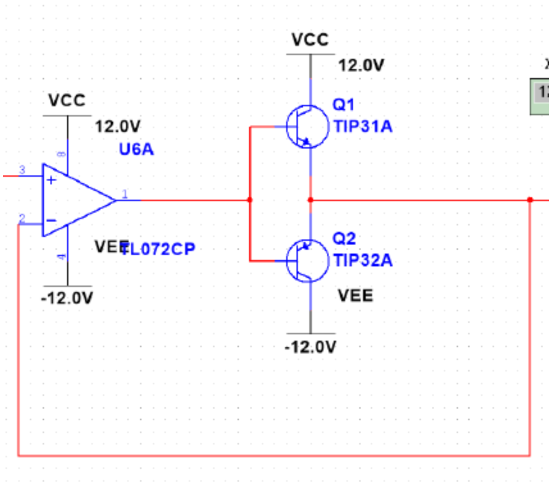

Figure 18: Push pull amplifier

3.1 Opamp selection

In this circuit, all the waveform generations and amplifications are done using opamps.We have selected NE5532n opamp to meet the given specifications. This low noise op-amp

Figure 19: NE5532 Opamp

has a high slew rate of 9 V/µs. This is an important factor specially in square wave generation. This op-amp also has a gain-bandwidth product(GBP) of 10 MHz. The required bandwidth for the function generator is 20 kHz. Therefore the maximum gain that can be achieved without any distortion can be calculated as below.

$$MaximumGain = \frac{10x10^6}{2x10^3} = 500$$

This is more than sufficient to generate the 20V peak to peak output waveforms.

3.2 Transistor selection

To drive a small current through the function generator, push pull amplifier is used. Maximum power calculations of 50Ω load is given below.

$$MaximumPower = \frac{10^2}{50} = 2W$$

$$MaximumGain = \frac{10}{50} = 200mA$$

The transistors we used are TIP31C and TIP32C and these transistors are capable of providing 40W power and a maximum collector current of 3A and these can handle required power and current easily.

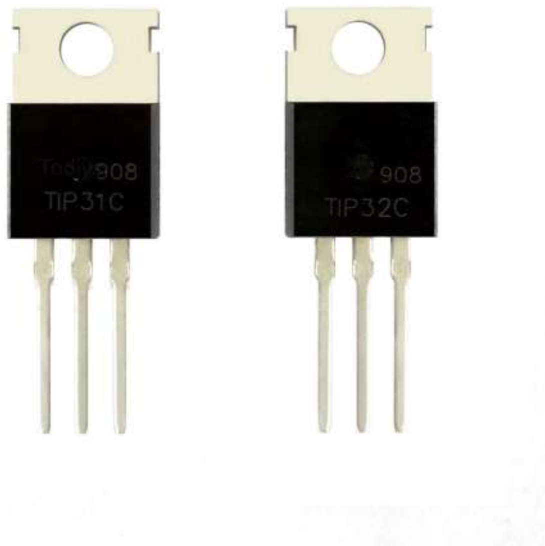

Figure 20: TIP31C AND TIP32C Transistors

4 Simulations

We used NI Multisim to simulate the circuit before designing the PCB.All the required waveforms were generated and their characteristics could be changed correctly using the simulation.NI Multisim simulation is shown below.

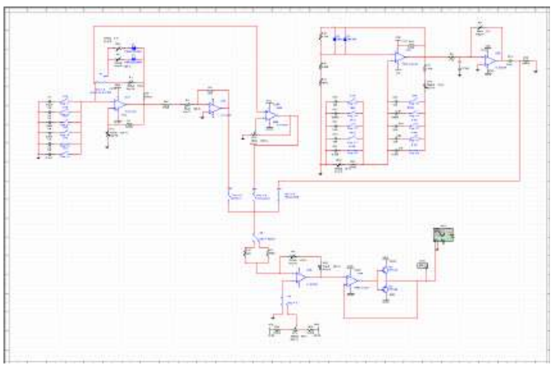

Figure 21: NI Multisim simulation circuit

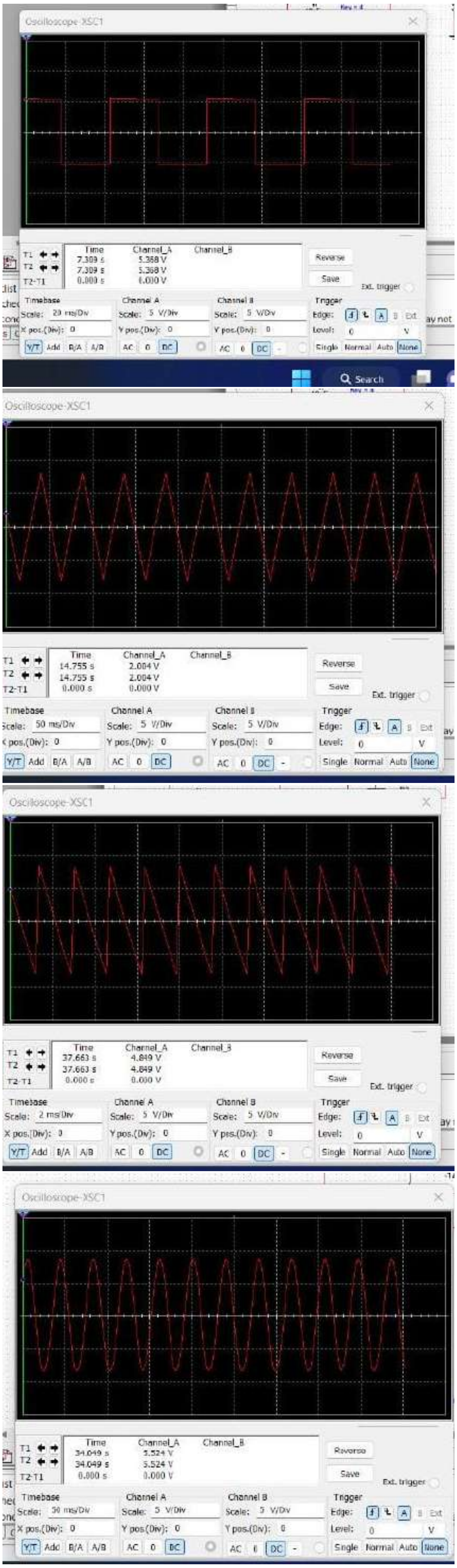

Figure 22: NI Multisim simulation waveforms

5 Testing

After the circuit simulations, we implemented the circuit in the breadboard and tested it. We encountered some issues but after a few attempts, we could get clear waveforms with adjustable frequencies and amplitudes in the advised range. The Wien bridge oscillator generated sin wave was affecting the other square and triangular wave forms. We could minimize this issue up to a certain level using decoupling capacitors for each IC.We concluded that the major instabilities of the wave forms were due to loose connections and a breadboard and wire resistance.

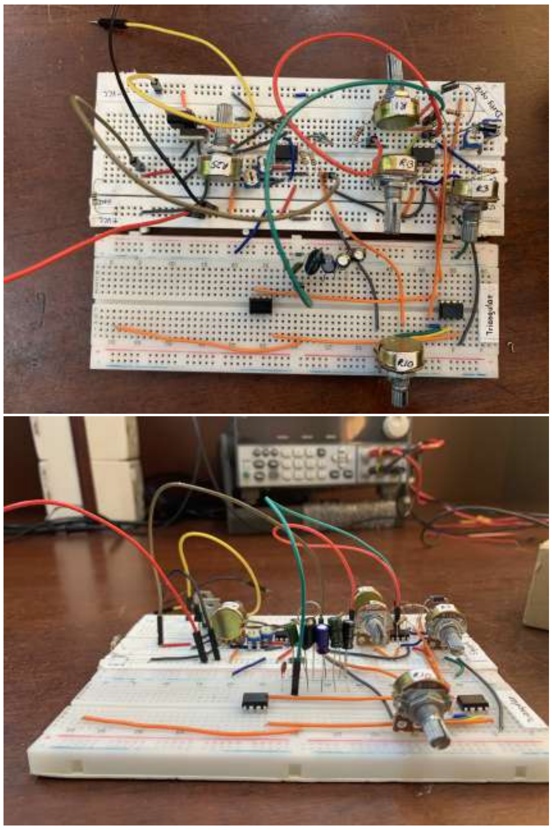

Figure 23: Breadboard Testing.

6 PCB Designing and Soldering

Next, we proceeded with the PCB design. We designed a two-layer PCB using Altium designing 22.4.1. The two planes were connected to the ground. We added a separate copper pour for the copper plane for better signal quality. Since our circuit does draw a current of more than A, we set our trace normal line trace width to 0.2mm while the power line width was kept at 3mm. We printed our PCB design from JLCPCB China. Then we soldered the PCB with locally sourced components and then tested the connections. Upon confirming that there were no disconnections, we tested PCB in the lab and checked if we got the relevant wavefoams.

Figure 24: PCB Soldering.

7 Results

The results we achieved are as follows.

Square and PWM Wave

- we were able to achieve a frequency of more than 20kHz.

  10μF : 10Hz - 270Hz

  1μF : 200Hz - 2kHz

  100nF : 2kHz - 66kHz

  1nF : more than 20kHz

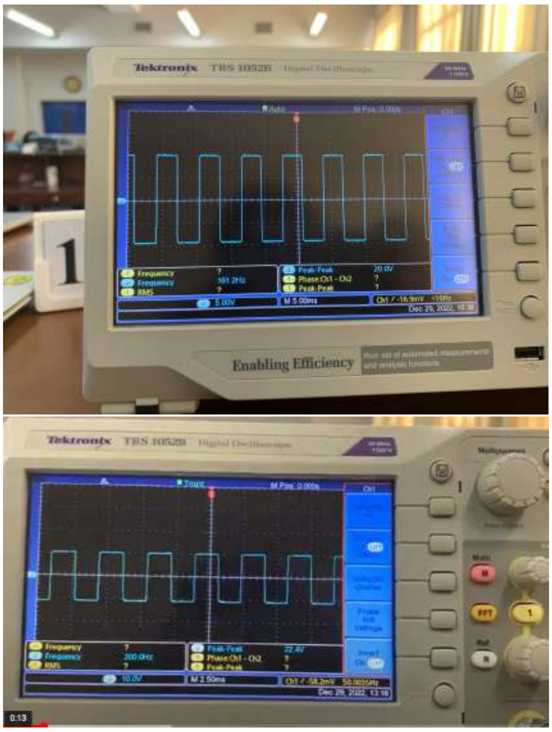

Figure 25: Resulted square wavefoams at testing.

Triangular and Saw Tooth Wave

- we were able to achieve a frequency of more than 20kHz.

  10μF : 17Hz - 400Hz

  1μF : 35Hz - 700Hz

  100nF : 350Hz - 6kHz

  1nF : 3.5kHz - 27kHz

  100pF : 3.5kHz - 27kHz

Sine Wave

- we were able to achieve a frequency of more than 20kHz.

  10μF : 17Hz - 400Hz

  1μF : 35Hz - 700Hz

  100nF : 350Hz - 6kHz

  1nF : 3.5kHz - 27kHz

  100pF : 3.5kHz - 27kHz

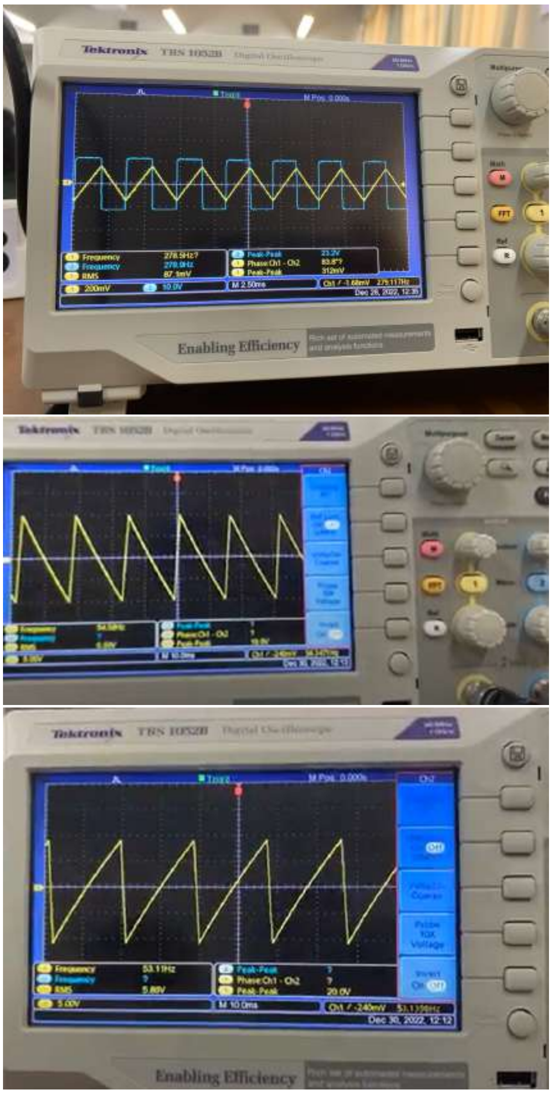

Figure 26: Resulted Triangular and Sawtooth wavefoams at testing.

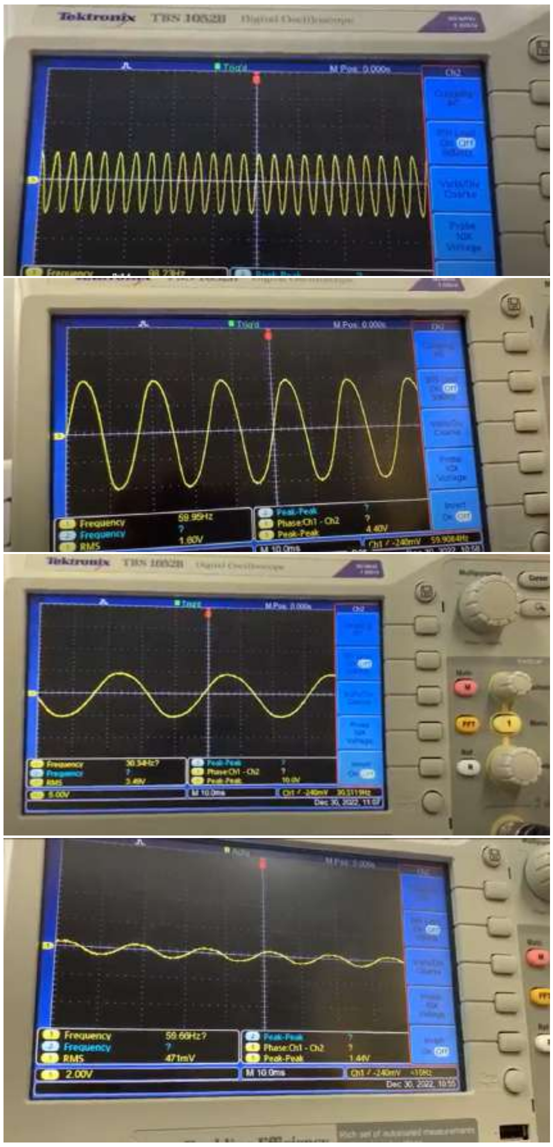

Figure 27: Resulted sin wavefoams at testing.

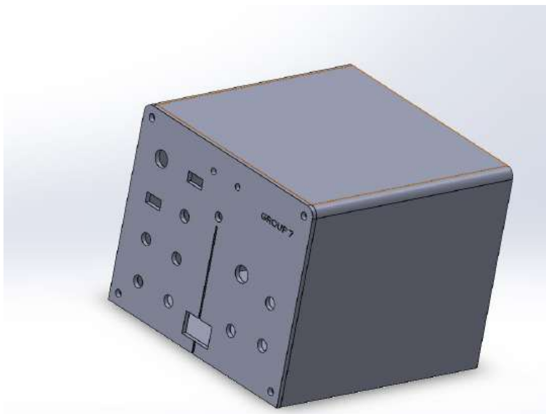

Figure 28: Enclosure design.

8 Enclosure Design

The enclosure was designed using Solidworks 2020. Further images attached in the appendix

9 Discussions

At high frequencies, there are distinct distortions at some waveforms. We can implement strategies to further reduce those distortions.

- Using high-quality resistors, capacitors, and opamps will help.
  The change in capacitor values results in distorted sin waves. Morever we had an issue with locally sourced dual gang potenneiometers.

- Wires can have considerable resistance which results in distortions. So we can minimize the use of wires and ensure the stability of the connections.

10 Acknowledgement

Throughout this project, we were guided and aided by so many personalities. We would like to extend our sincere gratitude to our project mentors, Mr.Pahan, Mr.Chamath and Ms. Sandani, whose unwavering commitment and keen enthusiasm in our undertaking contributed to the success of our project. Additionally, we would like to thank all those who contributed in even the slightest way for us to achieve this goal.

11 Bibliography

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5. Waveform Generator using Op Amp 741
6. Wien Bridge Oscillators
7. Limited Wien-Bridge Oscillator Amplitude
8. Analog Function Generator
9. Increase Amplifier Output Drive Using a Push-Pull Amplifier Stage

12 Appendices

12.1 Schematic Design

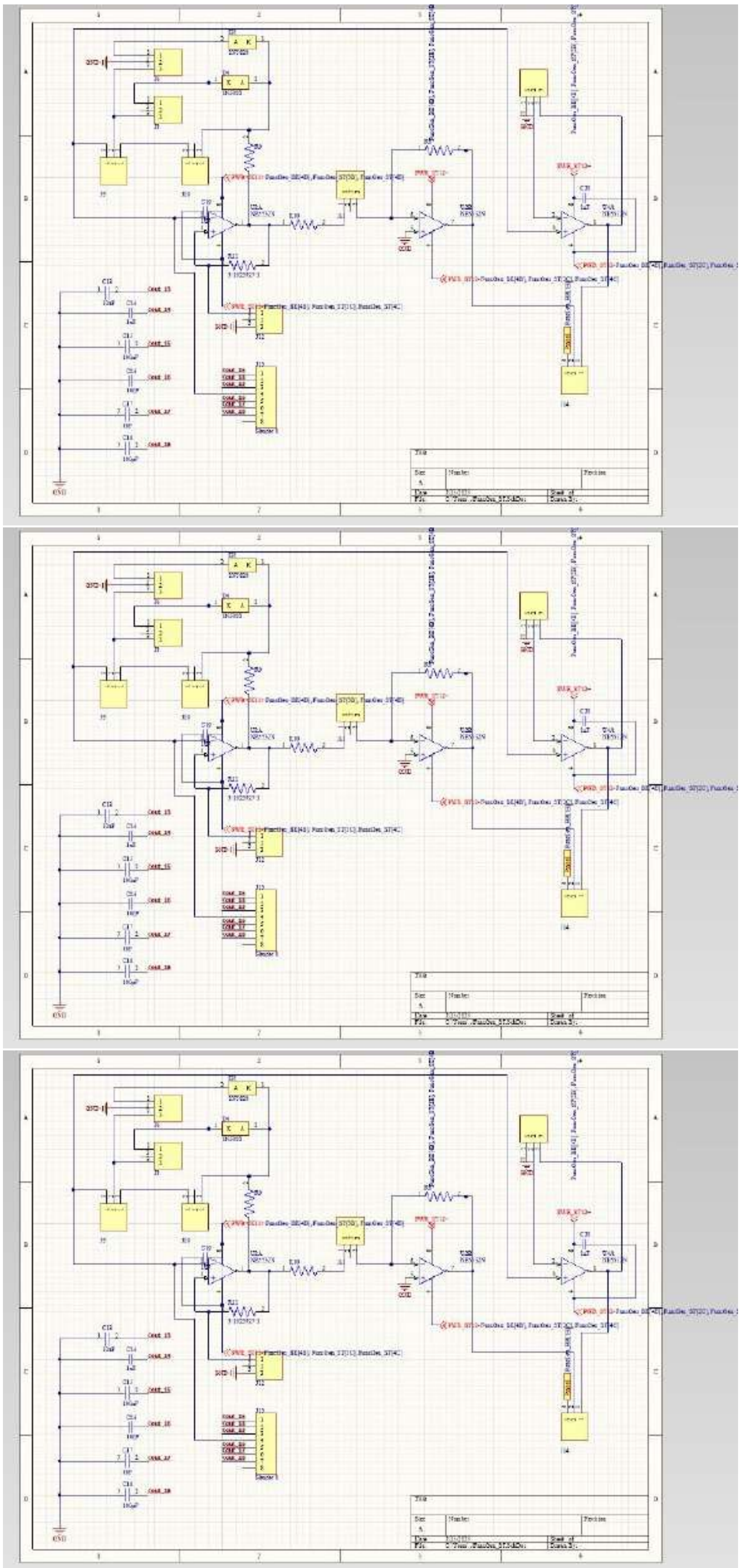

Figure 29: Schematic

12.2 PCB Design

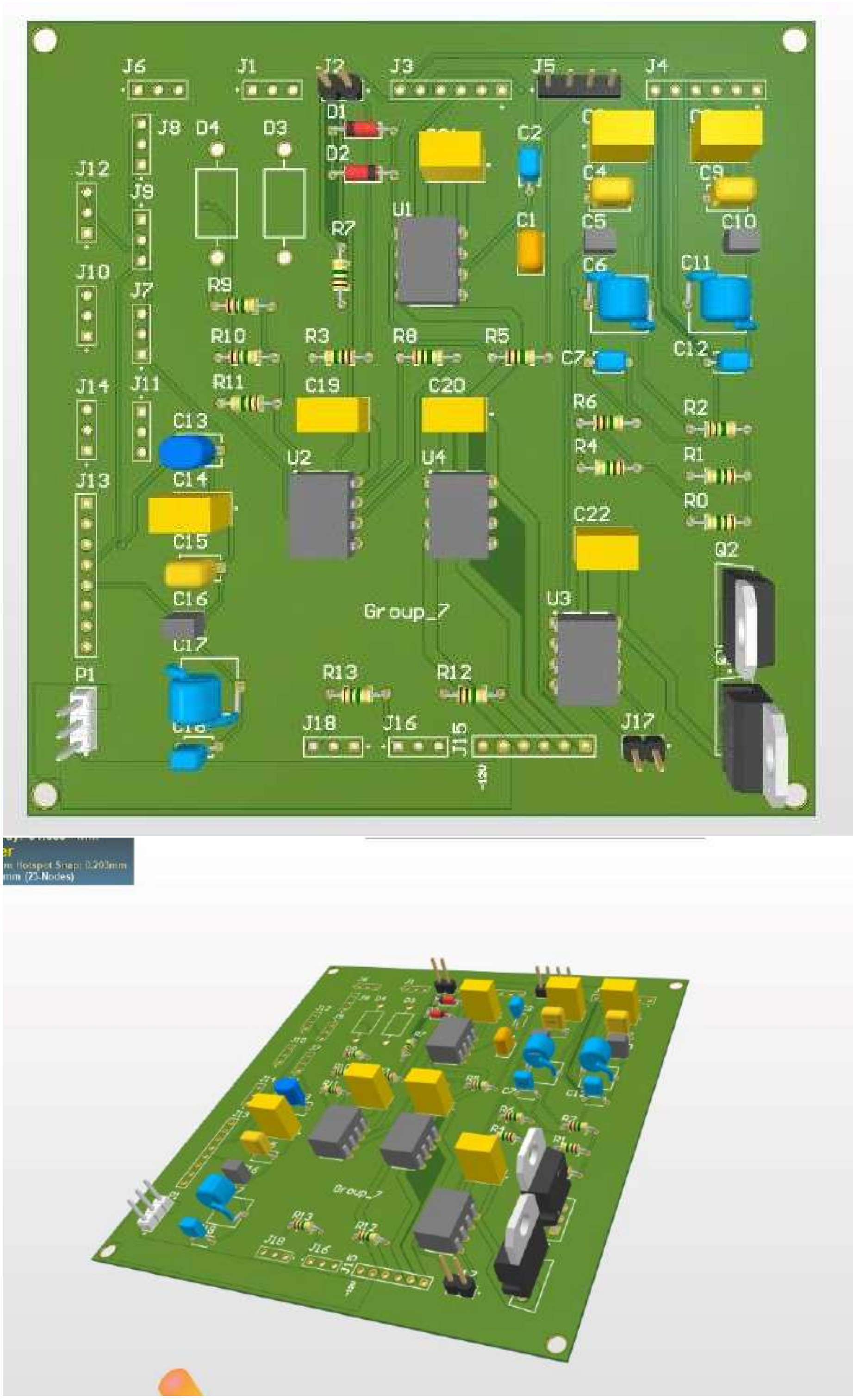

Figure 30: PCB

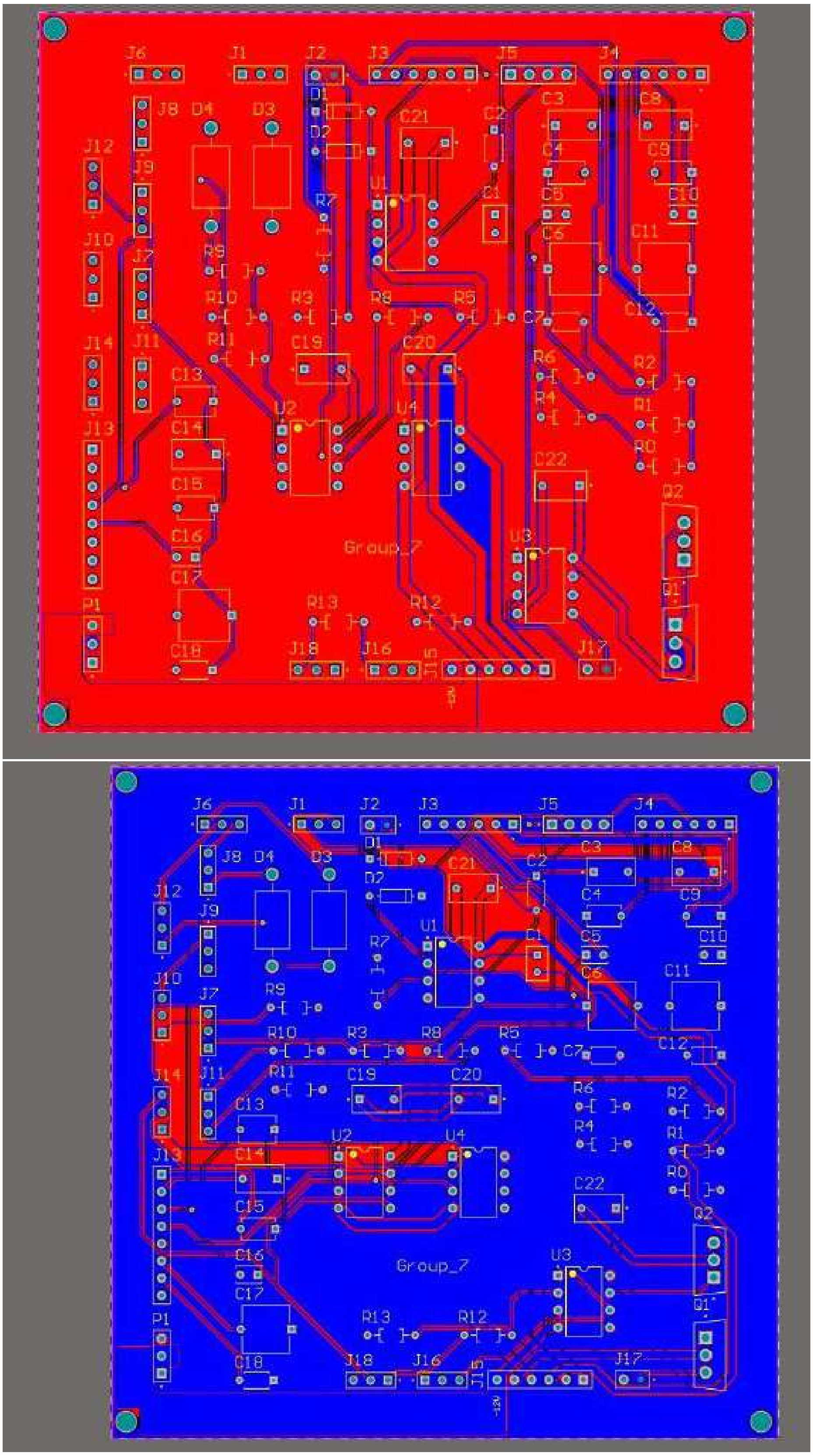

Figure 31: PCB

12.3 Enclosure Design

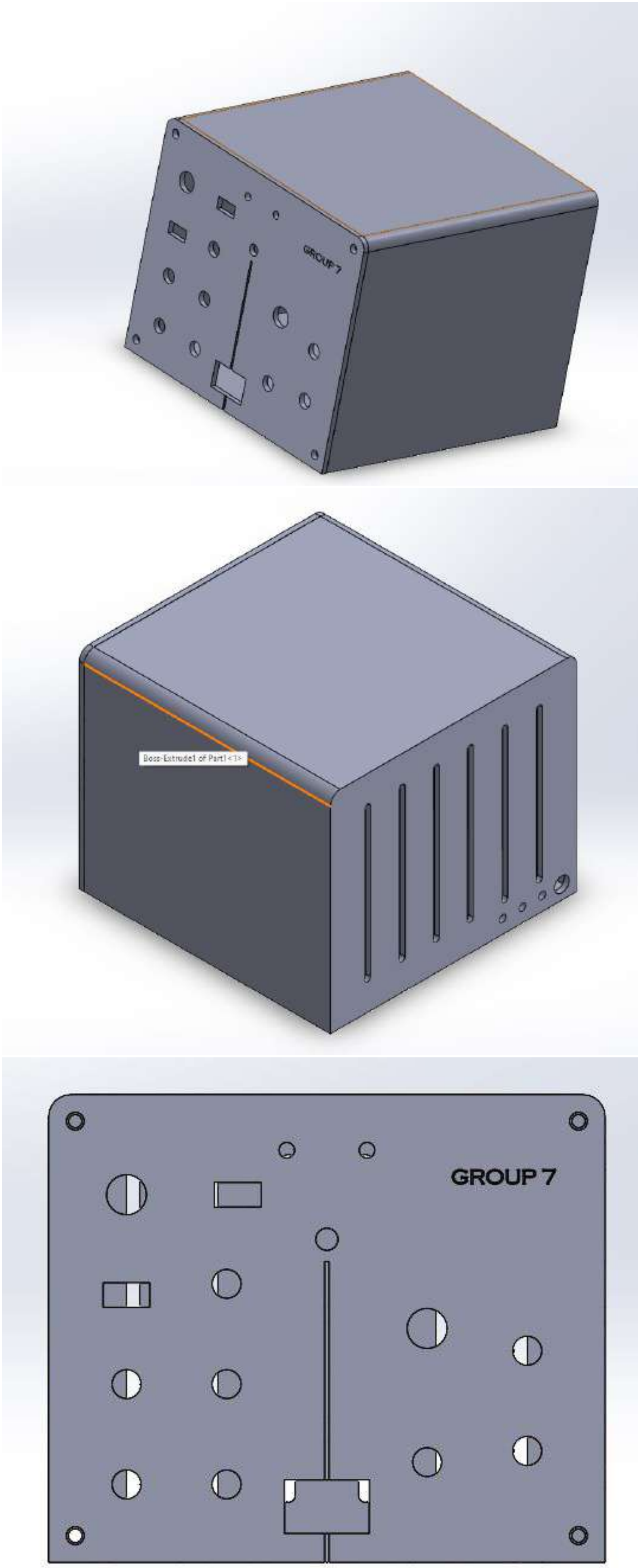

Figure 32: Enclosure