University of Moratuwa

Faculty of Engineering

Department of Electronic & Telecommunication Engineering

EN2091 - Laboratory Practice and Projects

Group 15

Project Report - Analog Function Generator

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Abstract

The design and development of an analogue function generator that can produce sine, sawtooth, square, and PWM waves with tunable amplitude, frequency, and DC shift is covered in depth in this report. It is feasible to adjust the frequencies from 20 Hz to 20 kHz and the amplitudes between 0 V and 10 V. The major components used in this project are resistors, capacitors, and op-amps.1

Contents

1 Introduction

We were required to create a fully functioning function generator for this project, which consists of every essential laboratory function generator feature.creation of sine PWM wave, sawtooth, square, and triangle forms are the primary features of the generator of functions.Aside from that, this function generator can modify the wave patterns' frequency ranges from 20Hz 20kHz in frequency , 0 to 10V in amplitude . 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.

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 10 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 sine wave and other waves in colborate .

2.2.1 Square Wave Generation

The relaxation oscillator utilizes the charging and discharging of a capacitor through resistive elements to create a periodic square wave output. By integrating this oscillator configuration with operational amplifiers, the circuit can achieve precise control over frequency and amplitude. This innovative approach provides insights into the synergistic application of operational amplifiers and relaxation oscillators for reliable square wave generation, offering potential advantages in electronic signal processing and modulation applications.

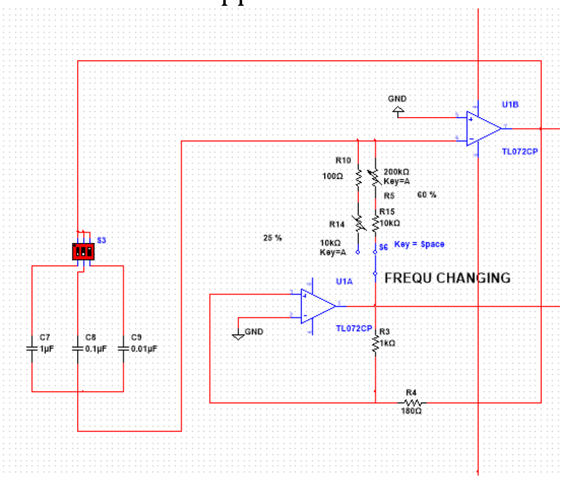


Figure 1: Square wave generator circuit.

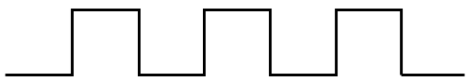


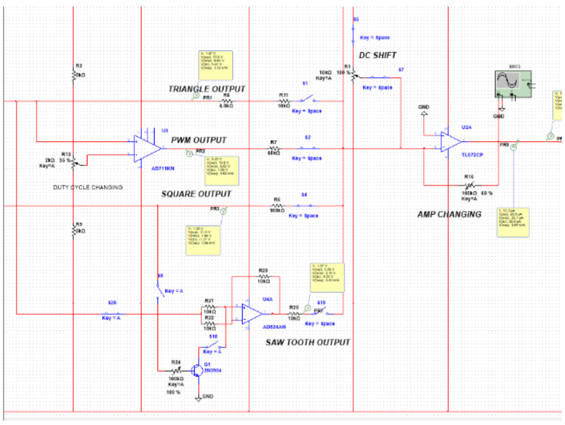
Figure 2: Square wave

Here we are using Op-Amp - AD711JN with Slew rate – 16V/us and Unity gain bandwidth – 3MHz

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

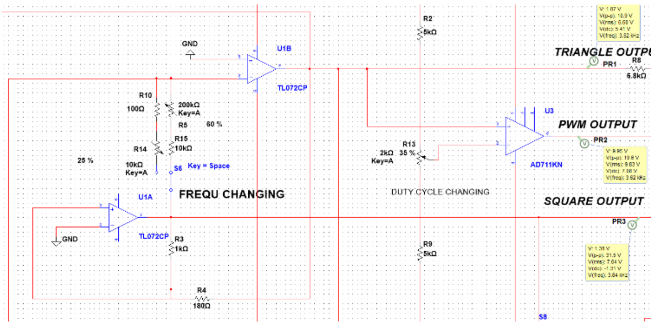
2.2.2 Triangular Wave Generation

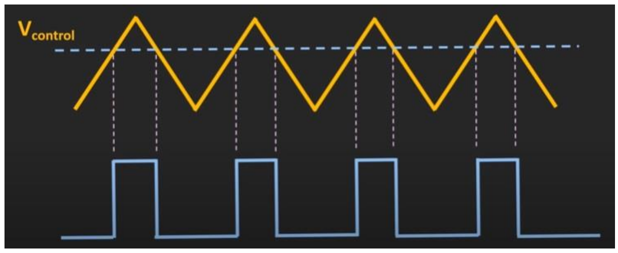
The design uses a cascade combination of an integrator and a Schmitt trigger circuit to produce both square and triangular waveforms in the goal of creating a flexible analogue function generator. Hysteresis is introduced by the Schmitt trigger, guaranteeing a pure and noise-free square wave output. After being fed into an integrator, this square wave becomes a continuous triangular waveform. A distinct triangle waveform is produced as a result of the integration process, which smoothes the transitions between the high and low states.

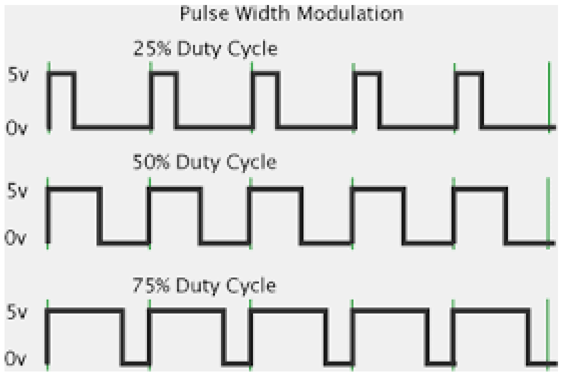


2.2.3 PWM Wave Generation

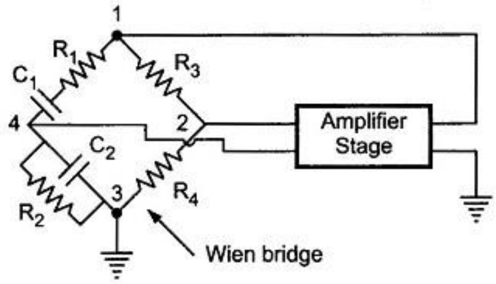
By comparing a triangular waveform with a DC level, the experiment investigates the c reation of Pulse Width Modulation (PWM) signals, With this technique, the amplitude of a triangle waveform is used to modulate the width of pulses in a square wave. It is possible to efficiently vary the PWM si gnal's duty cycle by varying the resistance value in the circuit.DC value is obtained as a series connection through up and low voltage values.







2.2.4 Sine Wave Generation

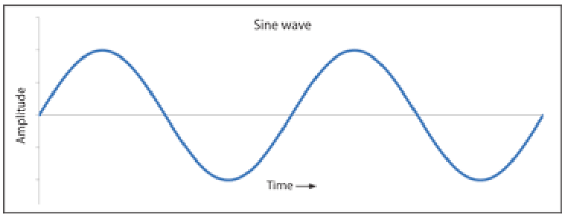


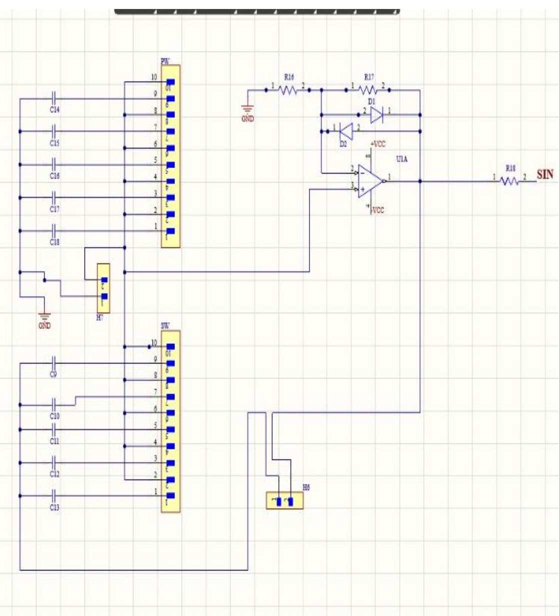
The bridge's frequency-sensitive arms are made up of the resistance R and capacitor C. The feedback path is composed of the resistances Rf and R1. The resistances Rf and R1 can be used to change the noninverting op-amp's gain. The op-amp's gain is

$$A = 1 + \frac{R_f}{R_1}$$

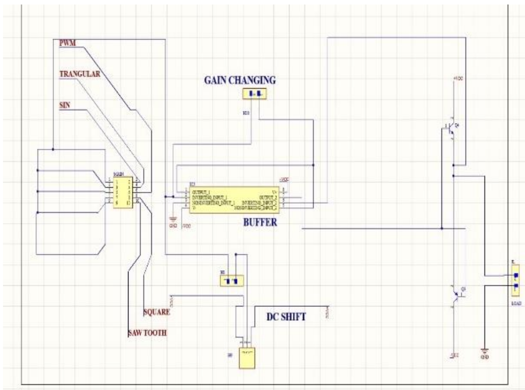
In order to meet the requirements of Barkhausen , where Aβ must be greater than 1, the noninverting op-amp amplifier's gain must be at least 3. So with that we get the equation for the frequency as

$$f = \frac{1}{2\pi RC}\ \text{Hz}$$



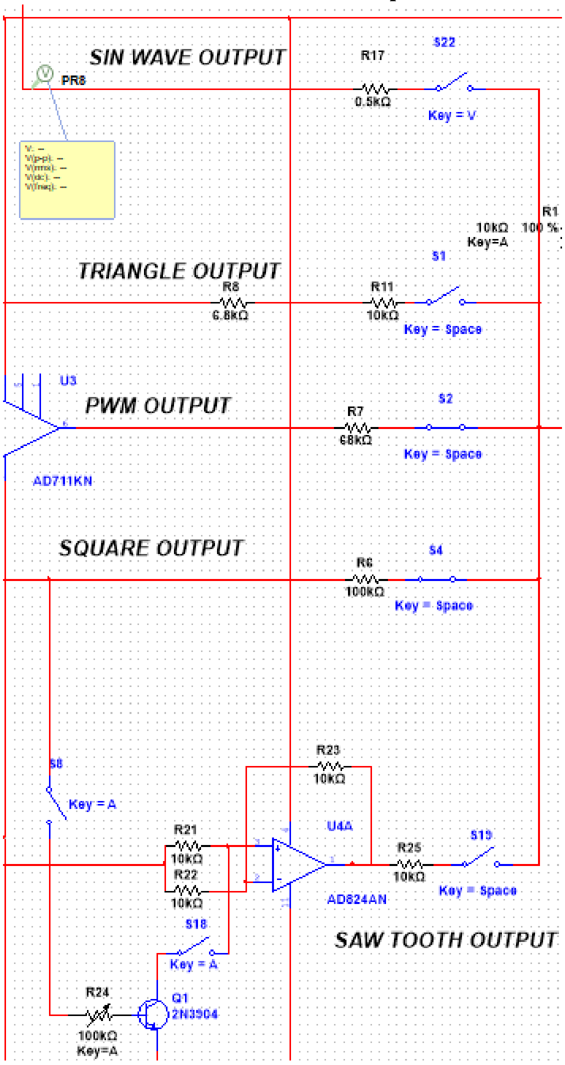


2.3 Output Circuit



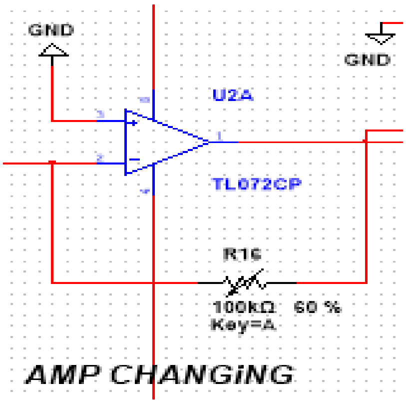
2.3.1 Waveform selection

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.



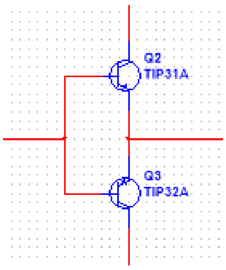
2.3.2 Amplitude control

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.

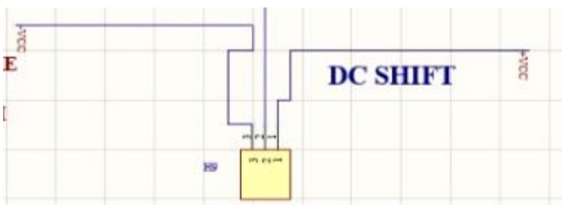


2.3.4 Push pull amplifier

At the output stage of the function generator a push-pull amplifier is used to am plify 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.



2.3.5 DC Shift



3 Calculations and Component Selection

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

3.1 Opamp selection

In this circuit, all the waveform generations and amplifications are done using several opamps.We have selected AD711JN,Tl072CP5,AD712JN opamp to meet the given specifications.

3.1.2 AD711JN

We have selected the AD711JN operational amplifier to meet the specified requirements. This precision op-amp is chosen for its low noise characteristics, a crucial factor in achieving accurate signal processing. The AD711JN features a commendable slew rate 16V/us, ensuring swift voltage transitions, which is particularly vital for square wave generation. Additionally, this op-amp possesses a gain-bandwidth product (GBP) of 3MHz. Considering the function generator's required bandwidth of 20 kHz, the maximum gain achievable without introducing distortion can be calculated using the formula:

Maximum Gain = GBP/Bandwidth. Substituting the values, we obtain 150 which is more than sufficient to generate the desired 10V peak-to-peak output waveforms

Here for Square and triangular wave generation we are using this opamp.

3.1.2 TL072CP

TL072CP operational amplifier from Texas Instruments has been integrated into the circuit design. Renowned for its versatility and widespread use, the TL072CP operates with a wide bandwidth, typically in the MHz range. This op-amp features low input bias and offset currents, making it suitable for audio applications and general-purpose amplification. For sine and sawtooth wave generation we are using this opamp.

3.1Transistor selection

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

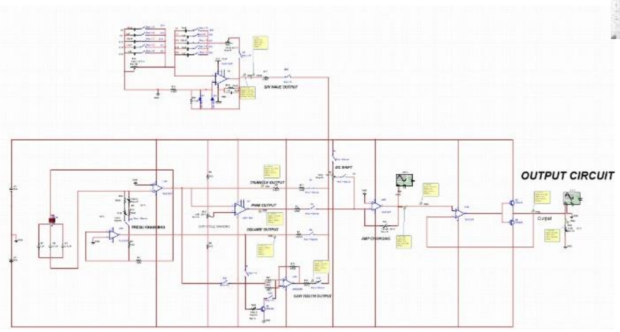
Maximum Power = 10^2 /50 = 2W

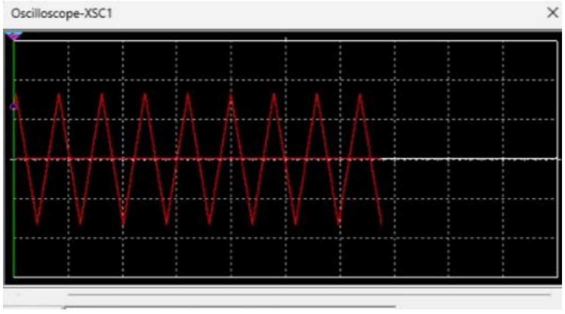
Maximum Gain = 10/50 = 200mA

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.

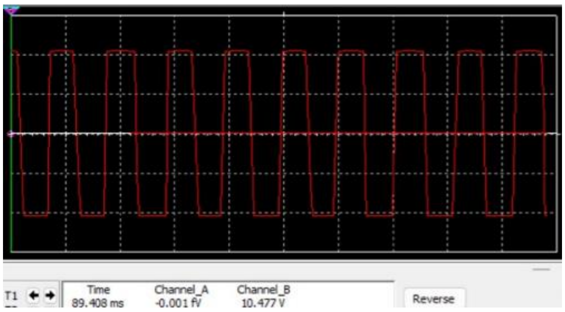
4 Simulations

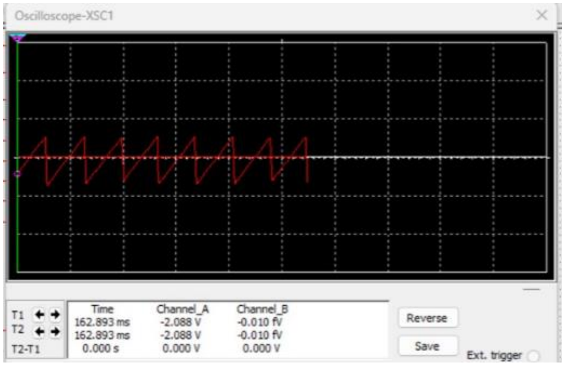
NI Multisim was use to simulate the circuit before designing the PCB.All the required waveforms were generated and their characteristics could be changed correctly using the simulation.NI Multisim simulation

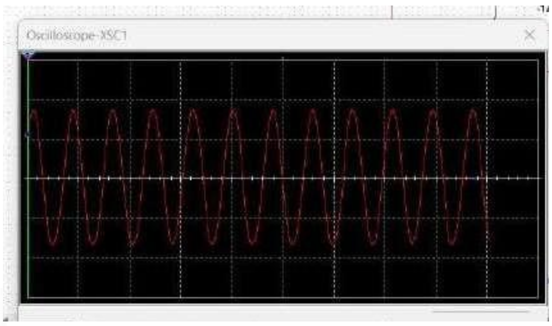




is shown below .

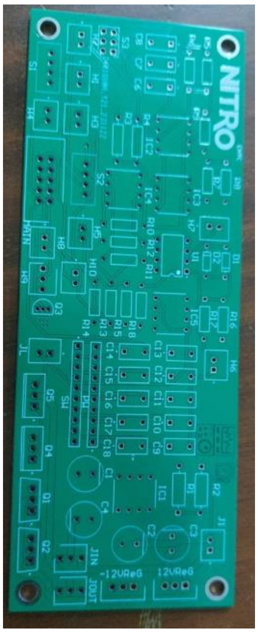


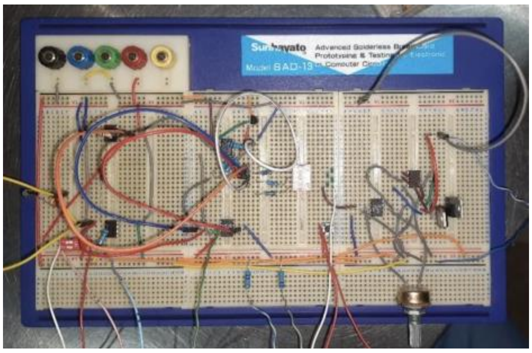


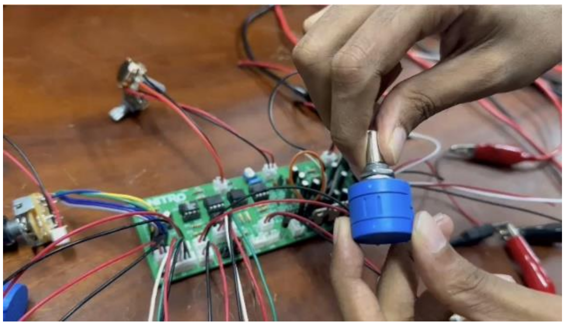


5 Testing

We built and tested the circuit on a breadboard following the circuit simulations. After a few tries, we were able to obtain distinct waveforms with tunable frequencies and amplitudes within the recommended range despite some initial difficulties. The other square and triangle wave shapes were being impacted by the sin wave produced by the Wien bridge oscillator. We could reduce this problem with decoupling capacitors for each integrated circuit to some extent.We came to the conclusion that a breadboard, wire resistance, and sloppy connections were the main causes of the wave forms' instabilities.







6 PCB Designing and Soldering

With Altium, we created a two-layer PCB. The ground was connected to both of the planes. We kept the power line width at 3mm and the normal line trace width at 0.2mm as our circuit does take more current than A. Our PCB design was printed by JLCPCB China.

After that, we checked the connections after soldering the PCB using parts that we sourced locally.

After making sure there were no disconnections, we examined the PCB in the lab to see if the appropriate waveforms were there.

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

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

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

8 Enclosure Design

The enclosure was designed using Solidworks 2020.Photos are shown 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 can minimize the use of wires and ensure the stability of the connection.

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.Pankajan, 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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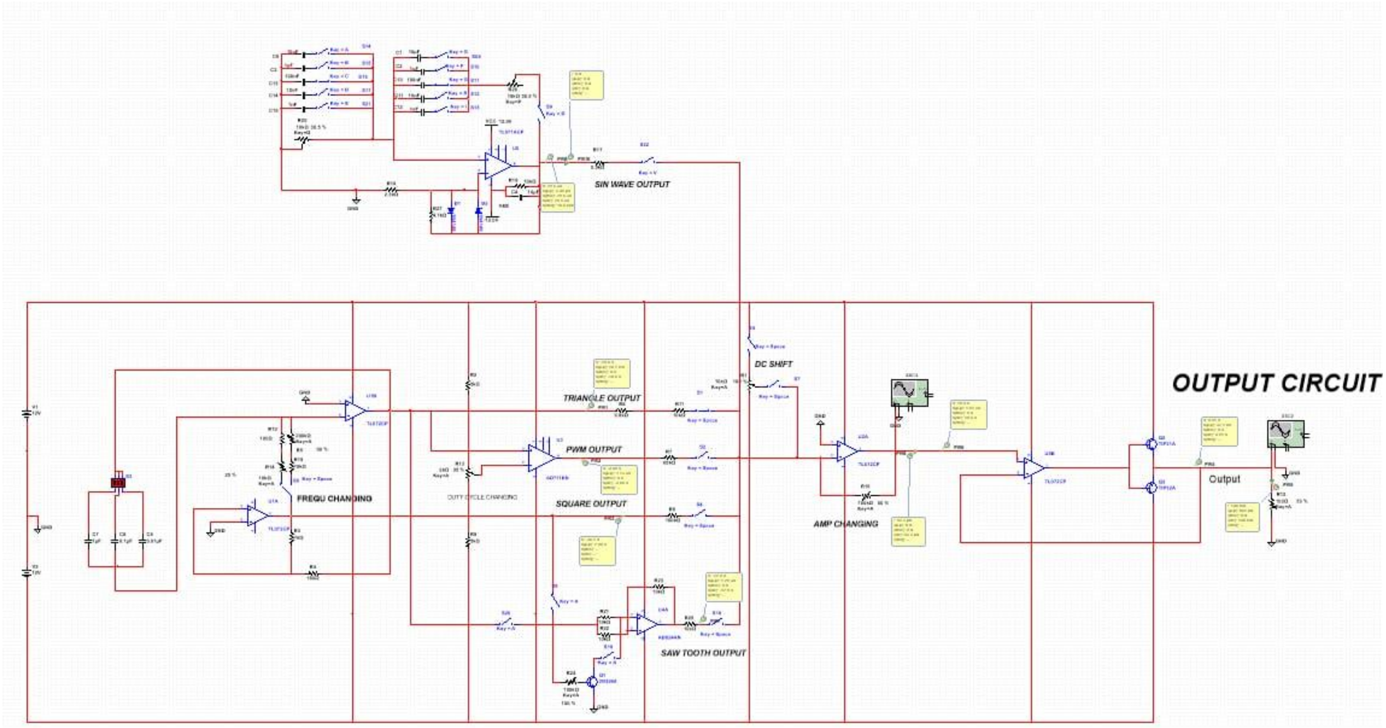
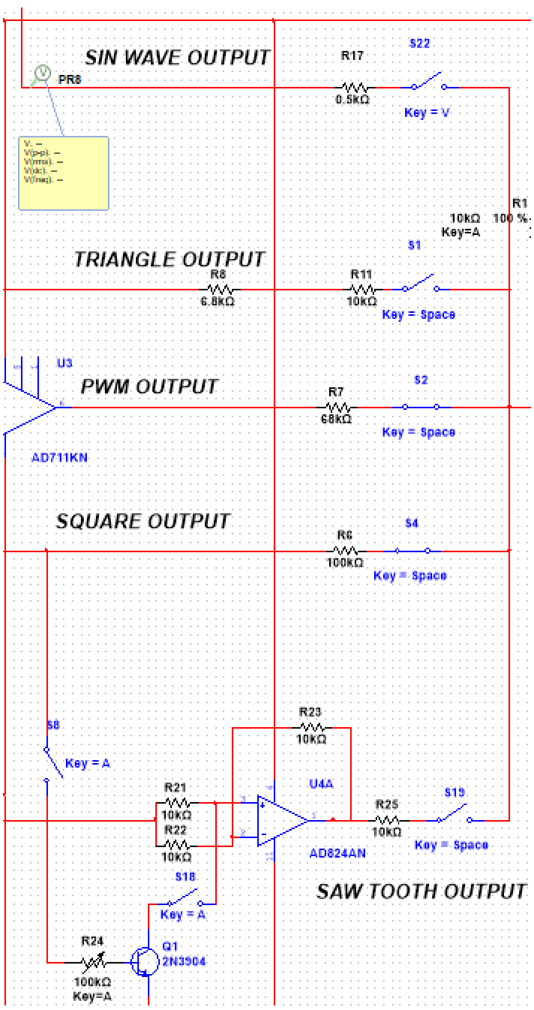
7. Lower Power Op Amp: Utility Sine Wave | Analog Devices
8. Waveform Generator using Op Amp 741 - IC Applications and HDL Simulation Lab | vikramlearning.com
9. Increase Amplifier Output Drive Using a Push-Pull Amplifier Stage | Analog Devices
10. Analog Function Generator : 13 Steps (with Pictures) - Instructables

12 Appendices

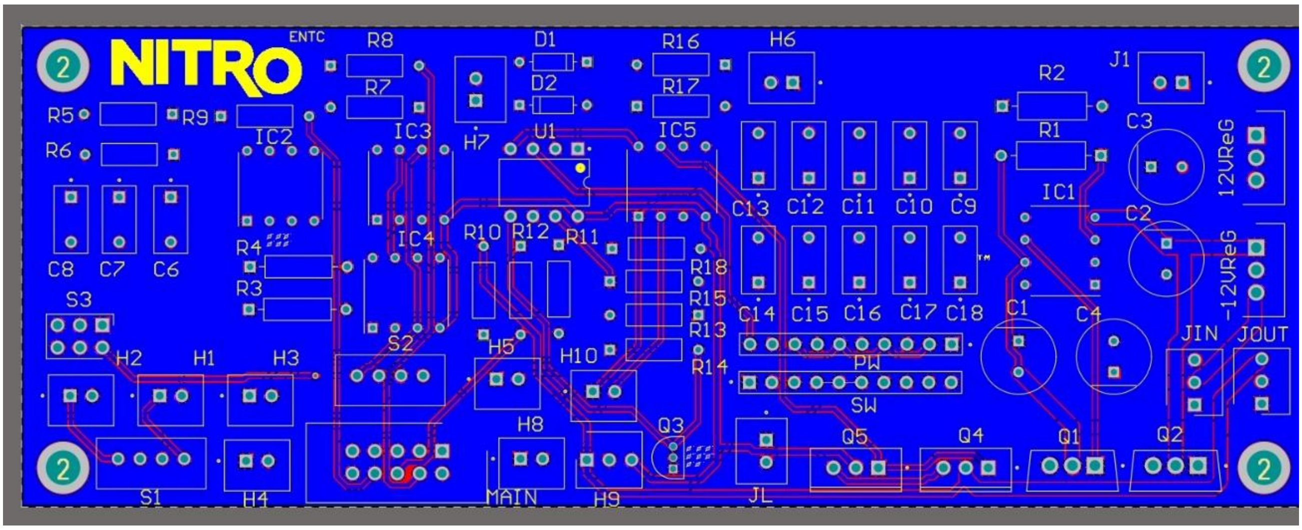
12.1 Schematic Design



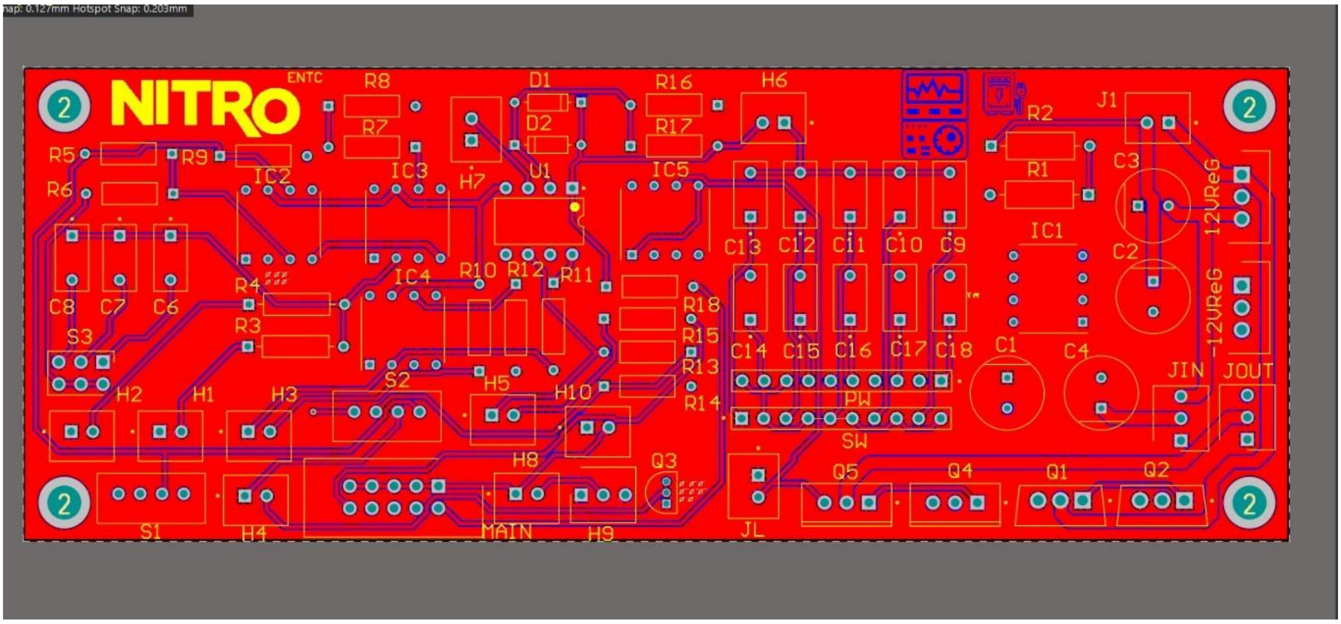


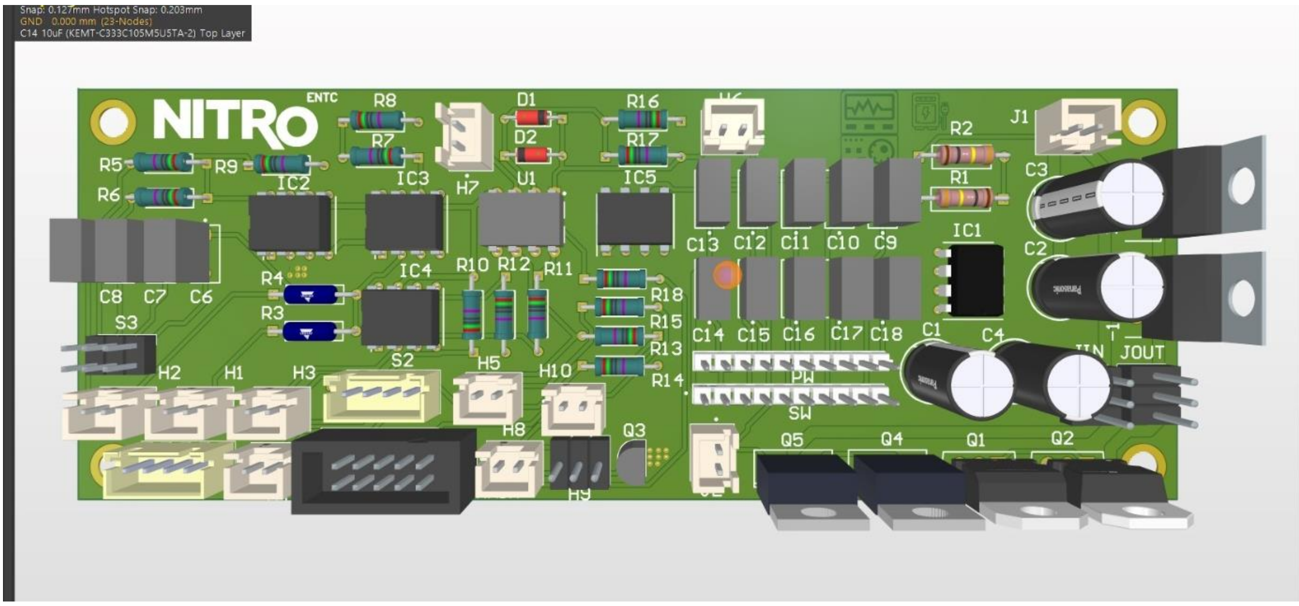
12.2 PCB Design

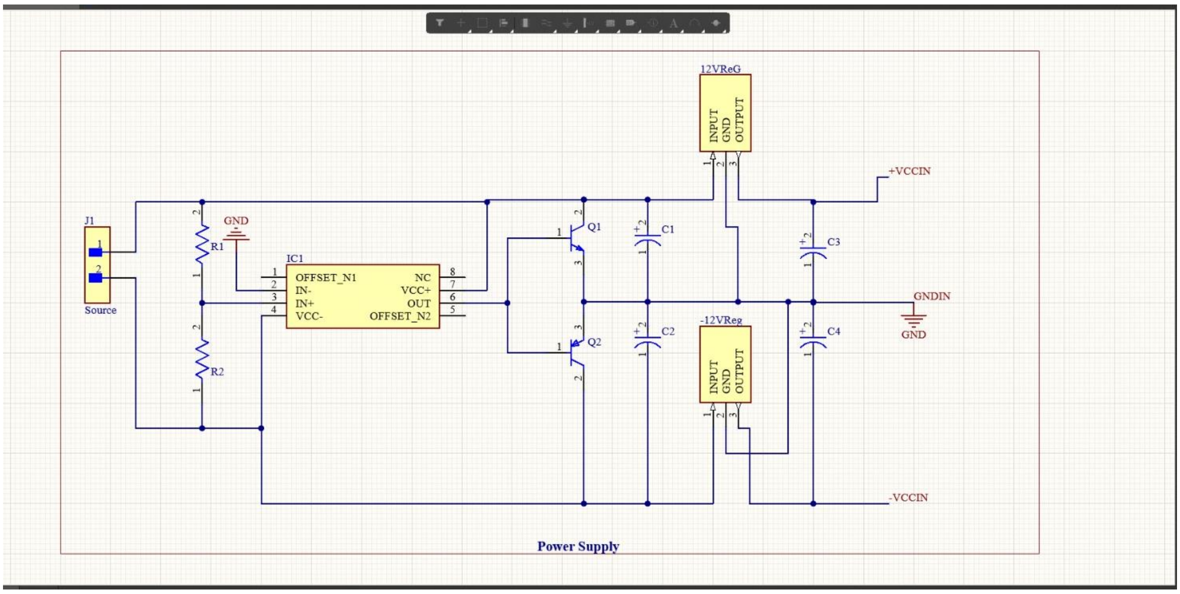
Bottom Layer

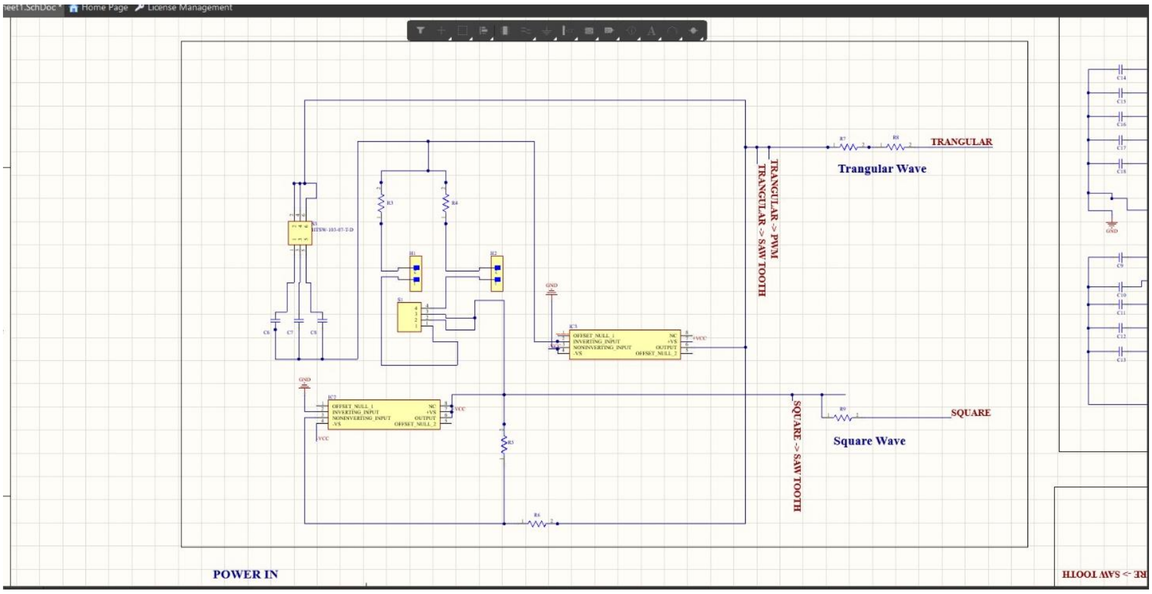


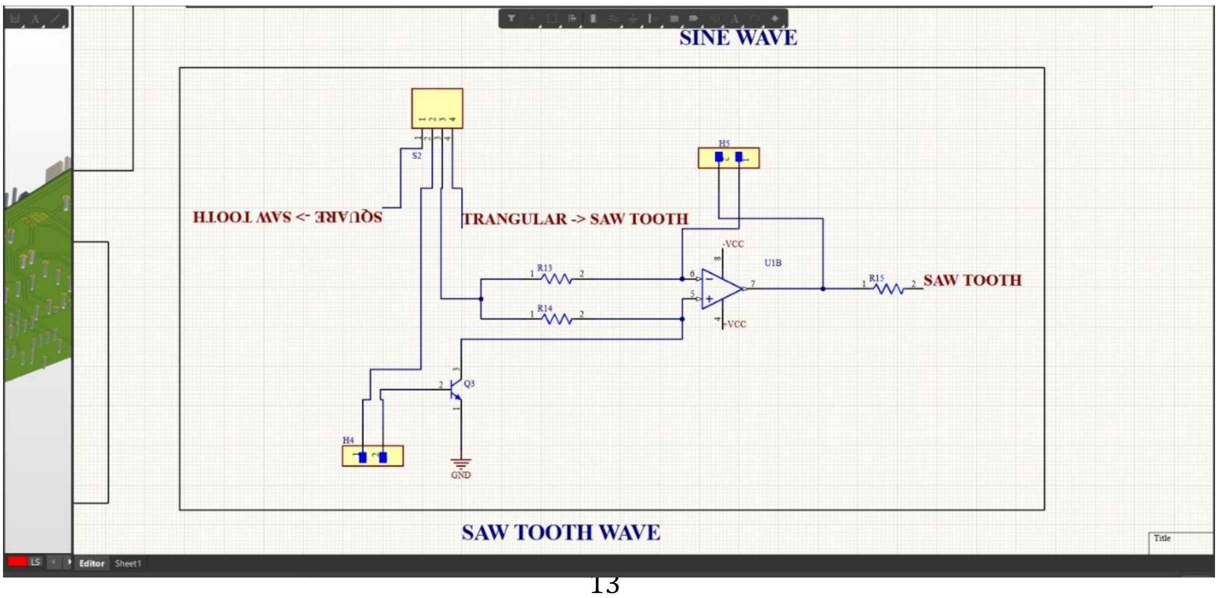
Top Layer



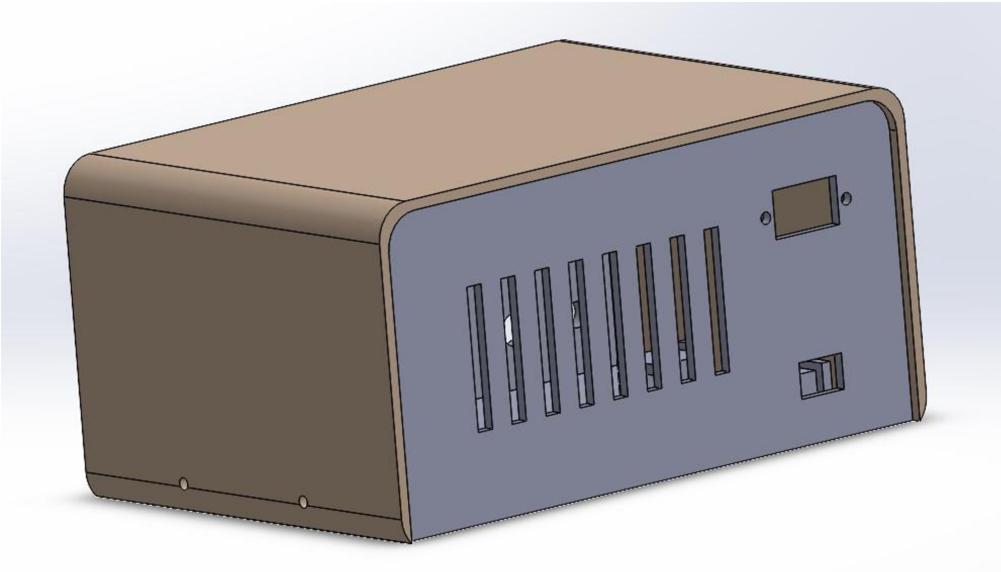


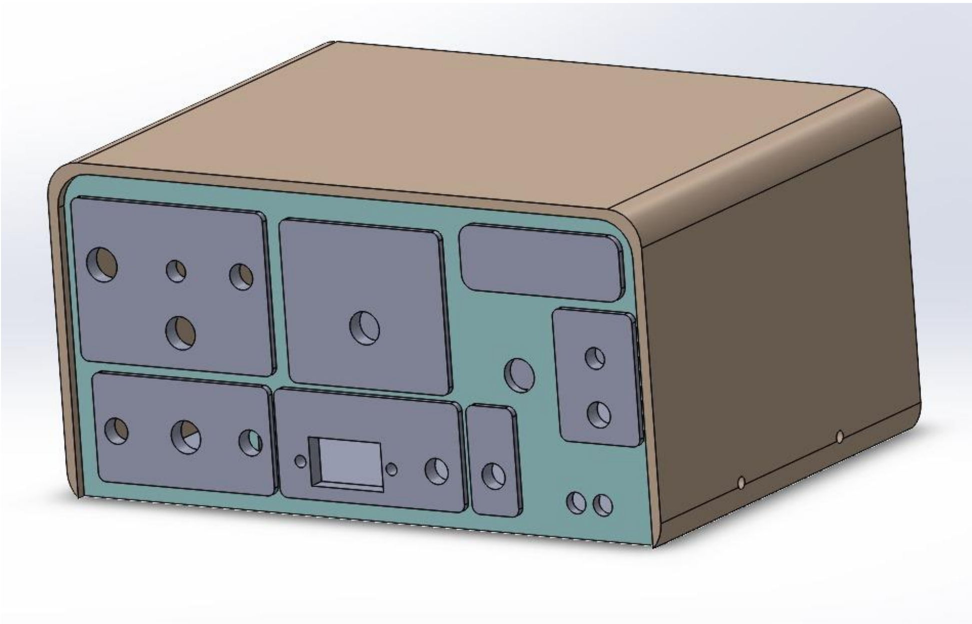

12VReG
INPUT GND OUTPUT
+VCCIN
J1
Source
GND
R1
IC1
OFFSET_N1
IN-
IN+
VCC-
NC
VCC+
OUT
OFFSET_N2
Q1
C1
C3
GNDIN
GND
Q2
C2
-12VReg
C4
R2
-VCCIN
Power Supply

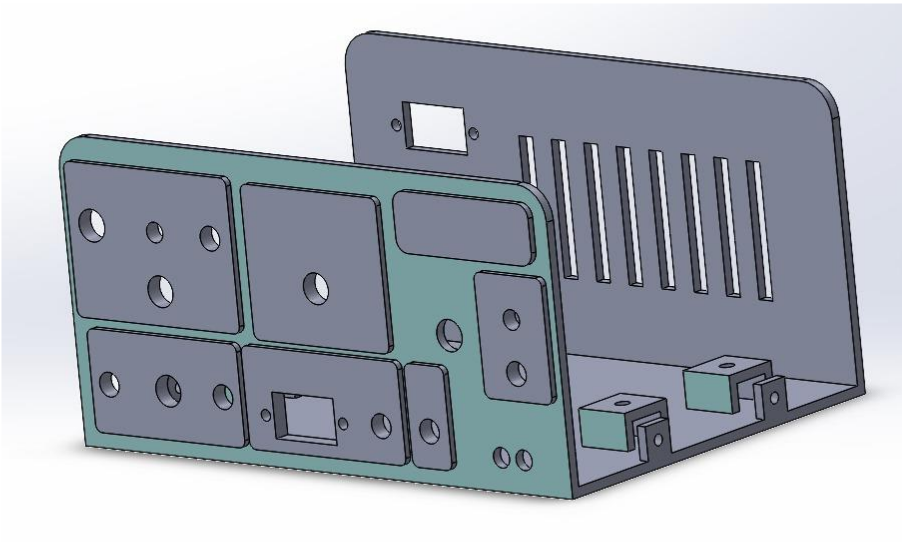

TRANGULAR
Trangular Wave
TRANGULAR -> PWM
TRANGULAR -> SAW TOOTH
SQUARE
Square Wave
SQUARE -> SAW TOOTH
POWER IN


SINE WAVE
S2
H5
SQUARE -> SAW TOOTH
TRANGULAR -> SAW TOOTH
-VCC
U1B
R13
R14
R15
SAW TOOTH
Q3
H4
GND
SAW TOOTH WAVE

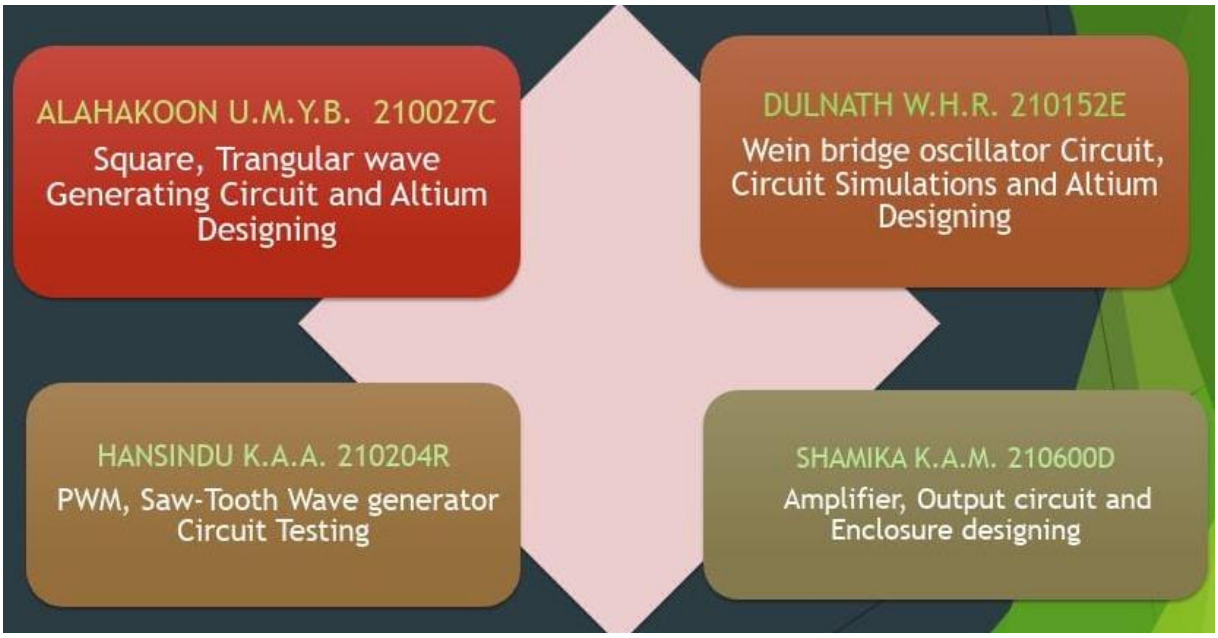
12.3 Enclosure Design







12.4 Team Members & Task Allocation



12.5 Bill of Quantities

Component	Quantity	Price Rs/=
AD711LN IC	3	6300
Ad712JNZ	1	2200
TL072CP IC	3	270
Potentiometers	7	2460
Switches	7	720
TIP31c	2	30
TIP32c	2	24
2N3904	1	6
Capacitors, resistors, diodes and JST wires		1500
3D Printing	-	5200
PCB Design Cost	-	3900
TOTAL		22 610/=


FREQ RANGE
FUNCTION
FUNCTION GENERATOR
AMPL
OFFSET
HIGH FREQ
LOWFREQ
DUTY
OUTPUT
CAP SELECTION
SAWTOOTH CHANGING