DEPARTMENT OF ELECTRONIC AND TELECOMMUNICATION

UNIVERSITY OF MORATUWA

EN2090 : LABORATORY PRACTICE II

ANALOG FUNCTION GENARATOR

Group 15

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Preparation of Analaog Fuction Genarator

Abstract

Numerous instrumentation engineers and researchers frequently manage analog electronic issues when moving toward sensitive estimations. Regardless of whether off-the-shelf measuring solutions exist, perception of the analog electronic of the measuring solutions is frequently a need. The function generator is also known as the signal generator is become the most used testing device. The function generator delivers an accurate calibrated range. This report talks about the overview of a signal generator, how to generate function using analog electronics, and changing its characteristics like waveform, modulation, frequency, and amplitude voltage.

Contents

1. INTRODUCTION

A function generator is an electronic device that is used for generating various types of electrical waveforms such as sine waves, square waves, triangular waves, Sawtooth waves over a frequency range. These waveforms can be either single-shot signals or repetitive signals. In addition to changing the type of waveform, the function generator is also capable of varying the waveform characteristics such as frequency, amplitude. Uses of the function generator,

- Sweep generation
- AM/FM generation
- Phase-Locked Loops

In addition to the above applications function generators are also used for repair, development, and test of electronic devices. Function generators are primarily used for working with analog circuits, related pulse generators are primarily used for working with digital circuits.

Most of the modern function generators are made using Digital components. The objective of this project is to build and implement a fully functional analog function generator which generates various waveforms with varying amplitude and frequencies.

In this report, we describe the different circuits used for the generation of noise-free waveforms and how potentiometers and transistors are used to change the frequencies and the amplitudes of the waveforms.

2. Electronic Design

2.1. Design Specifications

In this project, we will fulfill these **specifications**.

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 20000 Hz.
3. The amplitudes of the waves should be able to vary up to 20V peak-to-peak.
4. In the 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 50W load.
6. The function generator should be able to give a DC shift to the waves.

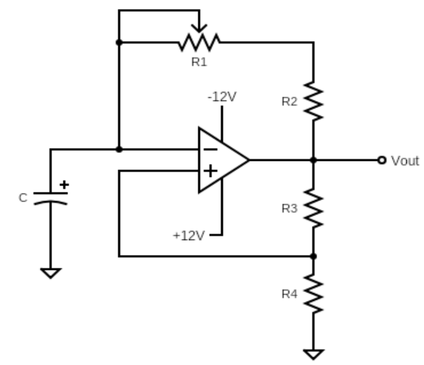
3. Wave Genaration

3.1. Square Wave

A square wave is a wave which is a non-sinusoidal periodic waveform. A square waveform can be represented as an infinite summation of sinusoidal waves.

Square wave generator can be constructed using the Schmitt trigger circuit. A Schmitt inverter is the inverse to that of its input. It uses a Schmitt trigger action that changes state between an upper and lower threshold level as the input voltage signal increases and decreases about the input terminal.

Figure 1. Schmitt Trigger



This simple square wave generator circuit consists of a single Schmitt inverter logic gate with a capacitor connected between its input terminal and ground and the positive feedback required for the circuit to oscillate being provided by the feedback resistor.

Let us take,

$$V_2 = Voltage\,at\,inverting\,terminal$$
$$V_1 = Voltage\,at\,the\,non-inverting\,terminal$$
$$Vid = differential\,voltage$$

When the charge across the capacitor is below Schmitt's lower threshold level it makes the input to the inverter at a logic "0" level resulting in a logic "1" output level (inverter principals).

At this stage,

$$V_2 = 0V$$
$$Therefore, V_{\mathrm{id}} = V_1$$

As Vid is positive, it will drive the Vout to the positive saturation voltage. (Since the capacitor does not have any charge at the initial stage, the gain is maximum)

At this time capacitor gets started charging and it will increase the voltage of the capacitor. Therefore, V2 gets an increase. After V2 getting a little higher than V1, it will give negative output and Vout will be switched from positive saturation voltage to negative saturation voltage.At this negative saturation voltage,V1 can be given as,

At this negative saturation voltage,V1can be given as

$$V_{\mathrm{id}} = -V_1 + V2$$
$$-V_1 = \frac{R4}{R4+R3}(-V_{\mathrm{saturation}})$$

Since V1 is negative, the capacitor starts to discharge through the resistor towards negative saturation voltage.

After reaching V2 slightly less than -V1, the output will again be switched to a positive saturation voltage. This process will happen again and again, and a square wave is generated.

Overall,

$$|V1| = \frac{R1}{R1+R2}|V_{\mathrm{saturation}}|$$

Let

$$R1 + R2 = R$$

We can write the product as,

$$T = 2RC \times \ln \frac{2R4+R3}{R4}$$
$$since\, f = \frac{1}{T}$$
$$= \frac{1}{2RC \times \ln \frac{2R4+R3}{R4}} \mathrm{Hz}$$

Since R4 and R3 are constants,

$$f \,\alpha\, \frac{1}{RC}$$

Therefore, by changing R and C values, we can change the frequency of the square waveform.The R2 is used to prevent the resulting resistance from becoming zero.

3.2. Trangular Wave

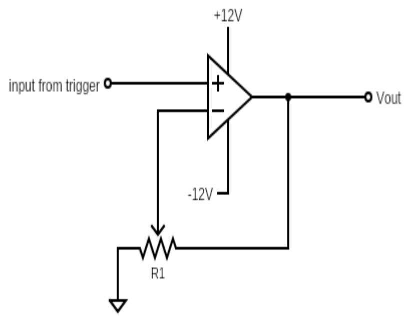
Method I

This method is based on passing the square waves through an integrator. This method has two main parts. Which are,

1. Square wave generator – which generates square waves.
2. Integrator – which converts square waves to triangular waves.

Method II When the capacitor charges and dis-

Figure 2. Triangular Wave Genaration



charges,theoretically the shape of the voltage across the capacitor is an exponential waveform. But practically,it will be triangular. So, we can use a capacitor as a triangular waveform generator.

we are using second method because easy to integrates with other circuits.

3.3. PWM Wave

PWM signal is used to get low-frequency signal by high-frequency source by switching the voltage between upper and lower levels, and output can be taken as the average of voltage over the period of switching between upper and lower level.

The PWM waves are generated by passing the triangular waves through a comparator.

3.4. Sawtooth Wave

A triangular waveform is a waveform that is linear,non-sinusoidal, triangular shape waveform. When the rise time and the fall time are equal, the waveform is named as a pure triangular waveform.

When the rising time and falling time are different the waveform named Sawtooth Waveform.The saw-

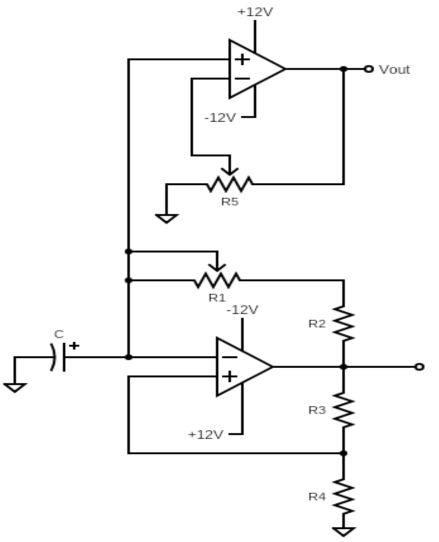
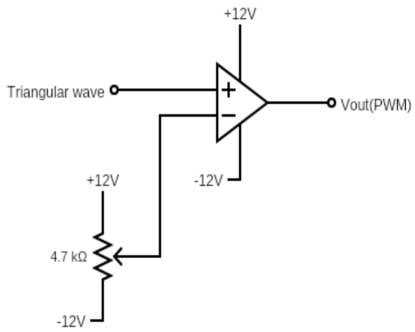


Figure 3. With Schmitt Trigger

Figure 4. Comparator PWM Genaration



tooth waveform can be generated using a cascade combination of a Schmitt trigger circuit and an integrator. The Schmitt trigger gives the output as a square wave. By feeding this output by an integrator we can generate triangle and sawtooth waveforms.In our circuit we use PWM as the input, by doing that we can adjust the rising/falling time by using PWM duty adjuster.

In this circuit, the non-inverting terminal of the integrating op-amp is given a dc voltage. The second op-amp integrates the Schmitt trigger output of the first op-amp and gives a saw-tooth waveform. By varying the dc voltage given to the non-inverting input of the integrator, we can change the rising and falling time of the saw-tooth waveform. When this dc voltage becomes zero, the output will be a triangular waveform. The frequency of the output voltage can be varied by varying R1 resistor and capacitor.

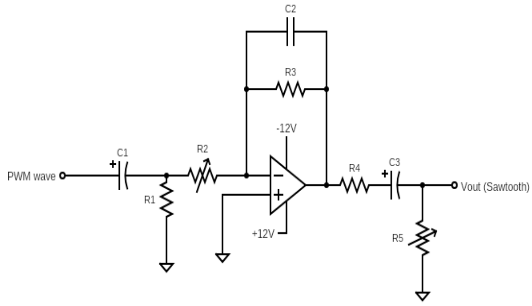


Figure 5. Intergrating PWM Wave

3.5. Sine Wave

There are many ways to create a sine wave. Such as Wien bridge oscillator, Phase-shift oscillator, Colpitts crystal oscillator, **Square waveform and filter**, Pulse-based sine wave generator.

We have chosen the square waveform and filter. From the Fourier series theory, a square wave can be thought of as sinusoidal waves. We can similarly think of triangular waves. So, we can obtain the sinusoidal waves by sending the amplified triangular waves through a low pass filter.

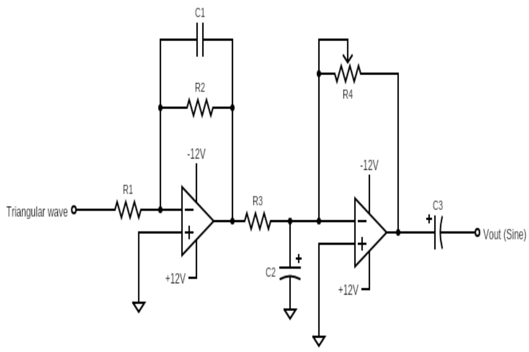


Figure 6. Sine Wave Genaration

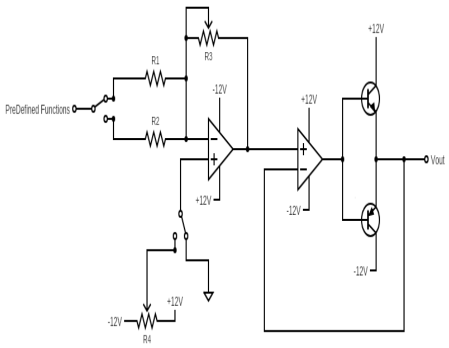


Figure 7. Output Circuit

4. Output Circuit

4.1. Summing Amplifier

Summing amplifier is used to give DC offsets and Changing Amplitude of the final output signal.

$$\begin{aligned} Gain &= \frac{Vout}{Vin} \\ &= \frac{Rf}{Rin} \end{aligned}$$

Rf is constant.So

$$\begin{aligned} when\, Rin &= 10k \\ Gain &= \frac{10k}{10k} \\ &= 1 \\ Also\, Rin &= 1k \\ Gain &= \frac{10k}{1k} \\ &= 10 \end{aligned}$$

By changing Voltage of non-inverting terminal, We can add DC offsets to the output circuit.

4.2. Push-Pull amplifier

A push-pull amplifier is an amplifier that has an output stage that coulddrive a current in both directions through the load. The output stage of a typical push-pull amplifier consists of two identical BJTs or MOSFETs one sourcing current through the load while the other one sinking the current from the load.

5. Power Supply

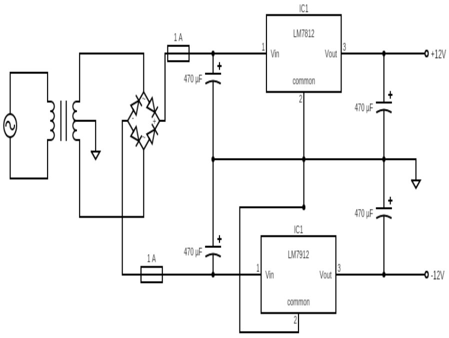


Figure 8. Power Supply Circuit

In this project power supply wants to give several outputs. They are DC outputs because electronic components need DC power. To complete our requirement, we must create +12V and -12V DC power supply. There were two options for this. They are, Using a rechargeable battery. Using the AC power supply. Considering these two options we are mostly thinking about the second option. Our product is laboratory equipment. And it must be work for a long time . If we choose a rechargeable battery it cannot withstand against those conditions.

We use a step-down transformer and plug its inputs to the main power supply through the fuse for the protection of the circuit. Then there is a diode bridge for the full-wave rectifier . Then use a smoothing capacitors and then use a regulation done by LM78712 and LM7912 regulators. Finally,there is another capacitors for further improving output voltage quality.

6. Component Selections

In this project we have use RC oscillator for making and changing frequiency of the wave. First we decided to use **variable resistor**. Then we realised that we need more resolution so we used **Multi turn variable resistors** for fine tuning. Also we used **Descrete set of capacitors** for make it more fine.

Op-amp selection The waveform generation and amplification is done by op-amp circuits. To meet the given specifications a suitable op-amp must be selected.The selected op-amp for this project is TL084. Which has higher GBP 1MHz and This low noise op-amp has a high slew rate of 13Vus.This is an important

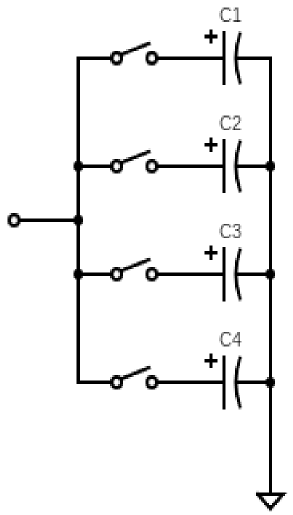


Figure 9. Capacitor set

factor in square wave generation.

$$\begin{aligned} maximum\,gain &= \frac{1\times 10^6}{2\times 10^4} \\ &= 50 \end{aligned}$$

Transistor selection The push-pull amplifier output stage is to drive a 50Ω load through the function generator. The maximum power and current which should be given across a 50W load by a 20V peak-to-peak wave can be calculated as follows.

$$\begin{aligned} maximum\,power &= \frac{10^2}{50} \\ &= 2W \\ maximum\,current &= \frac{10}{50} \\ &= 200mA \end{aligned}$$

So We selected TIP 31 and TIP 31 transistors.

In power supply circuit we choose LM7812 and LM7912 which has maximum output cuurent of 3A. In that case, we have used GBU6M/DGBU6A bridge rectifier.

We have used DPDT switches which has locking mechanisms on it for selecting options.

7. Simulations

Power Supply

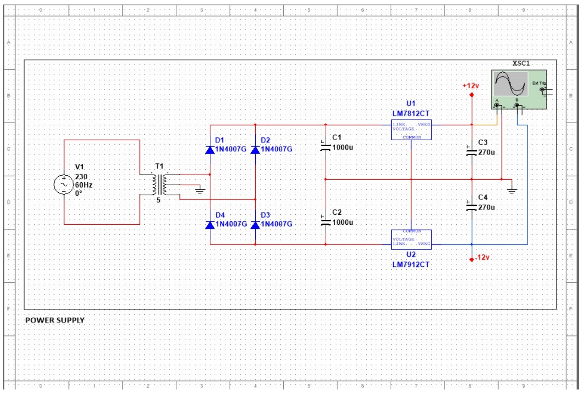


Figure 10. Power Supply Circuit

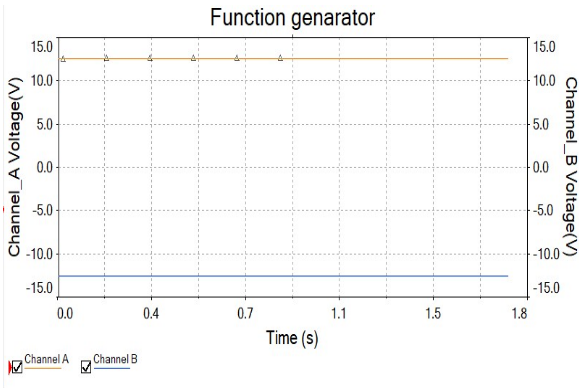


Figure 11. Output Results by Power Supply

Output Circuit
Main Circuit

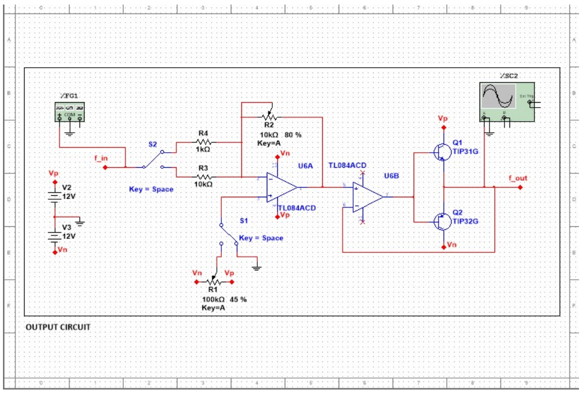


Figure 12. Output Circuit

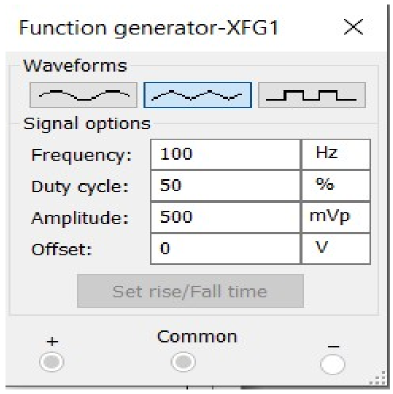


Figure 13. Input Signal for Output cct. Simulations

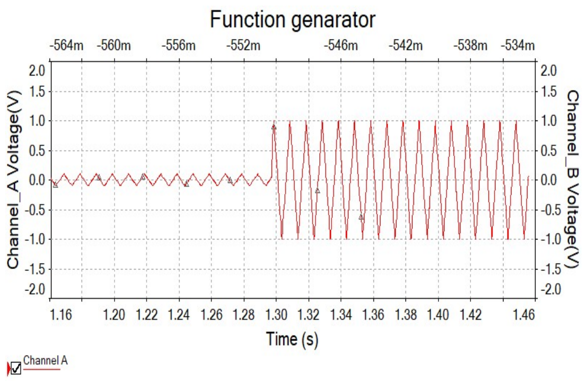


Figure 14. Amplitude Changing

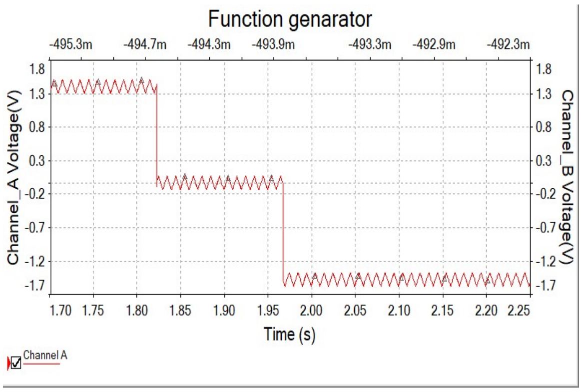


Figure 15. DC Offsets

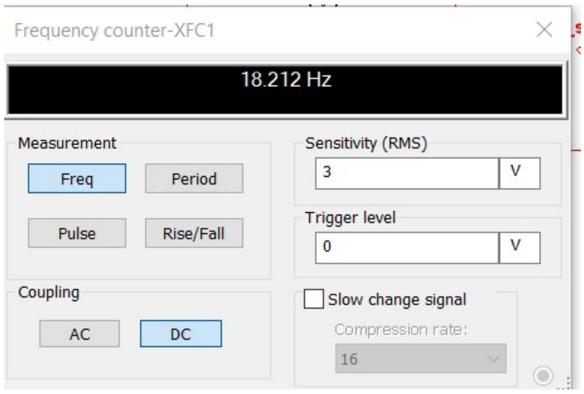


Figure 18. 20Hz

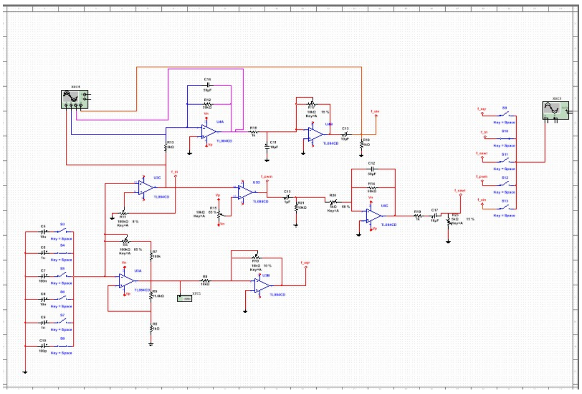


Figure 16. Main Circuit

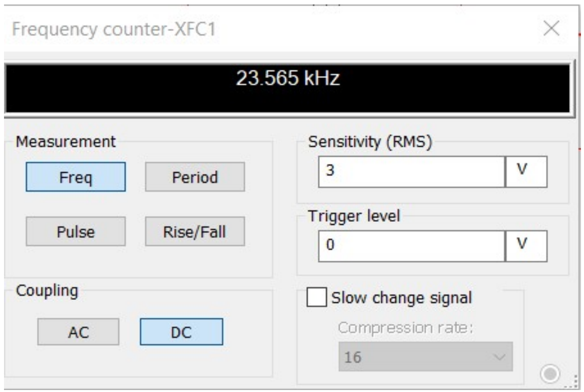


Figure 19. 20000Hz

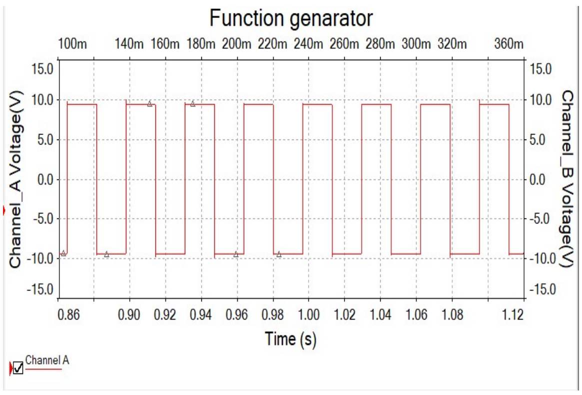


Figure 17. Square Wave

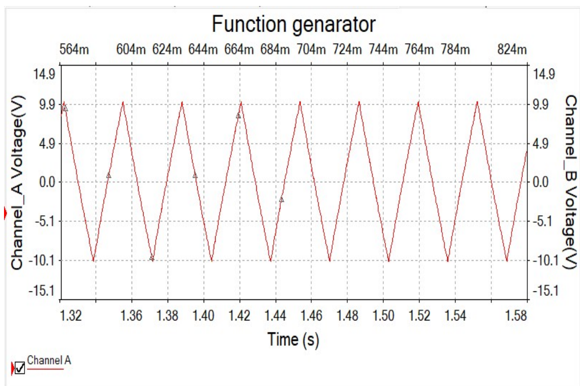


Figure 20. Triangular Wave

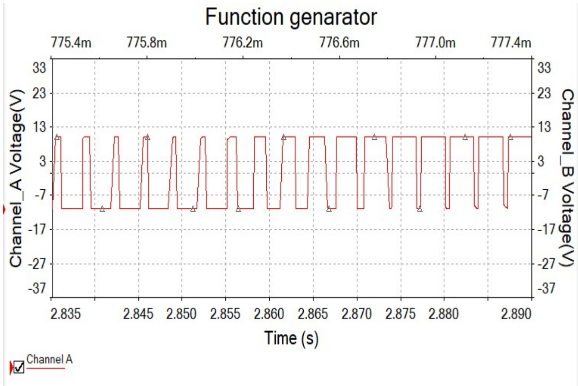


Figure 21. PWM Wave

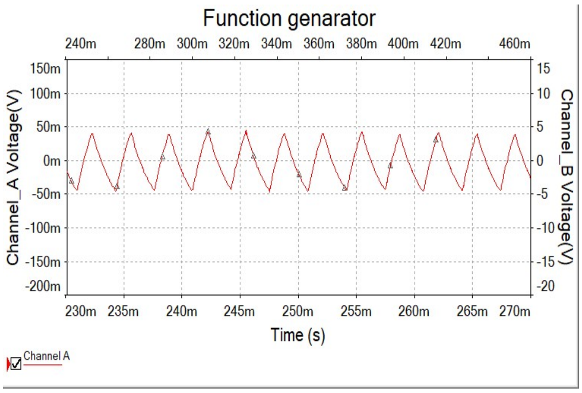


Figure 22. Sawtooth Wave

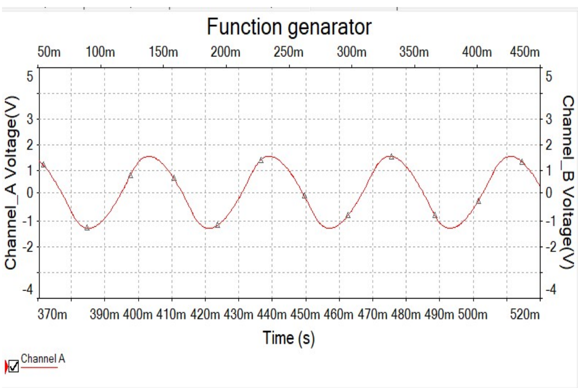


Figure 23. Sine Wave

8. PCB Designs

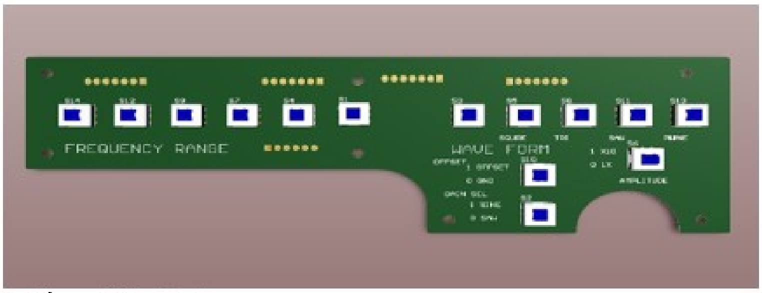


Figure: Button Panel

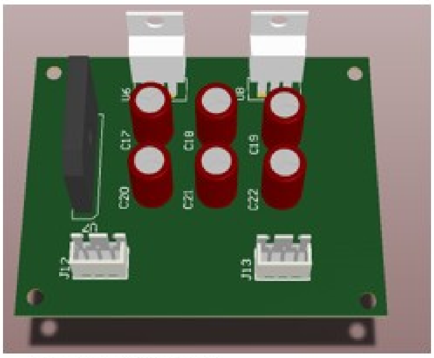


Figure: Power Supply

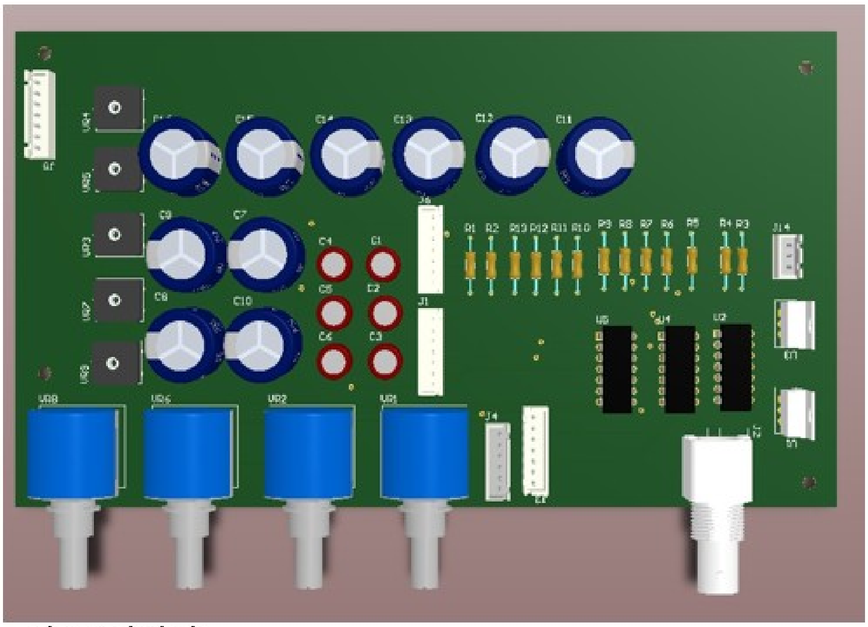
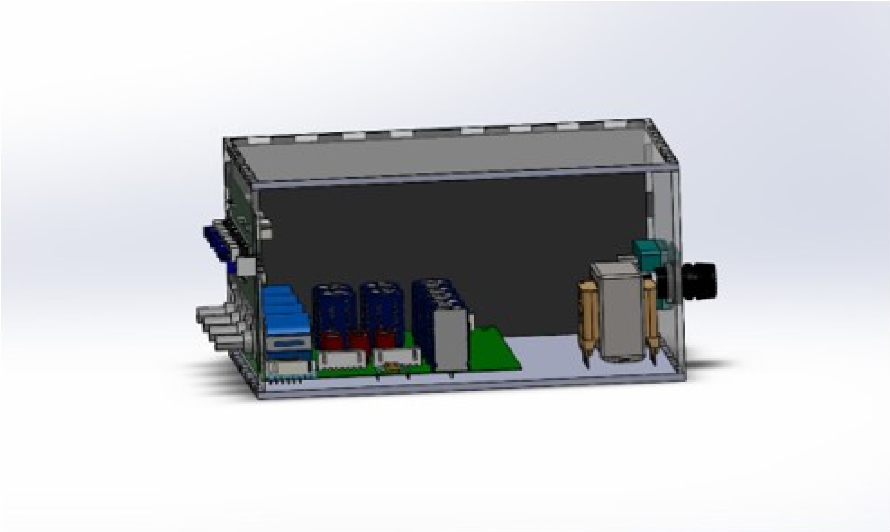
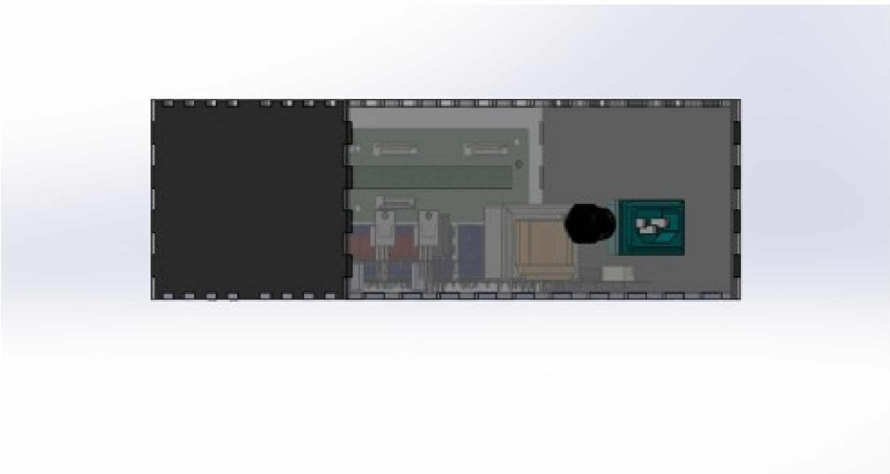


Figure: Main Circuit

9. Enclosure Design

(exploded view, isometric view of front and back)





10. Discussion

By using analog electronic components we can make waves. We can determine characteristics such as frequiency, Amplitude, DC offset,Wave shape and Duty Cycle.Using Op amp as the main block of the design, We could implement comparators, Inverters,amplifiers and Schmitt Trigger... etc.By combine them together and using several filters for joints we could make working function genarator at the end.

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