Department of Electronic and Telecommunication

University Of Moratuwa

EN-2091 Laboratory Practice and Project

Analog **F**unction **G**enerator

Group:- 25

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Abstract

The construction of an analog function generator that can produce sine, sawtooth, and square waves (with changeable duty cycle), as well as waves with variable amplitude, frequency, and a DC shift, is thoroughly described in this report. The frequencies can be changed from 20 Hz to 20 kHz, and the amplitudes can be changed from 0 V to 10 V. Op-amps, resistors, and capacitors were mostly used in this project.

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1.Introduction

Analog waveforms (such as sine waves, square waves, sawtooth waves, etc.) are frequently produced by function generators for usage in a variety of applications, including phase locked loops, AM/FM production, and sweep generation (PLLs).

For this project, we were required to construct an analog function generator that performs all the essential functions of a function generator used in a lab. These are the major capabilities of the function generator: generation of Sine, Saw-tooth, Triangle, Square (PWM) with configurable amplitude and frequency and a DC shift to the waveforms. Op-amps, transistors, resistors, capacitors, and potentiometers were the sole components used in our project to construct the function generator. In this report, we discuss the various waveform production circuits and how capacitors and potentiometers are utilized to modify the amplitudes, frequencies, and DC shift levels.

Figure 1.1 Implemented Function Generator

2.Functional Description

Most of the parameters that were given at the outset of the project to build an analogue function generator were ones that we were able to meet. Without any distortion or noise, all the necessary wave forms—sine, saw-tooth, triangle, square, and PWM—were produced. Overall, the resulting waveforms' frequencies could fluctuate between 20 Hz and 20 kHz. For the majority of the frequencies, the duty cycle of the PWM could be changed between 1% and 99%. The device could also drive a 50 resistor without causing any distortion to the waveform it generated.

2.1 Waveforms

The following waveforms were asked to be produced by the device:

- sine wave
- saw-tooth wave
- triangular wave
- Square wave (PWM wave)

Within the specified frequency and amplitude ranges, this generator created all of the desired waveforms successfully and without any distortion.

2.2 Amplitude

For every waveform, an amplitude of 10 V was required. This device meets the aforementioned requirement and has the additional ability to alter the amplitude.

2.3 Minimum Load

This device could operate with all waveforms within the specified frequency range and drive the necessary 50 load.

2.4 Frequency Range

By changing the capacitor and potentiometer we can change the frequency. To get the required frequency range that is 20Hz to 20KHz we use a capacitor set. So all waveforms we were able to change their frequency range 20Hz-20KHz region.

3.System Model

3.1 Design Specification

For this project our function generator is fulfil with following specifications.

1. The function generator should be able to generate sin, triangular, saw-tooth, square and pulse with modulations waves.
2. The frequencies of the waves vary from 20Hz to 20000Hz.
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 can give a DC shift to the waves.

3.2 Waveform Generation

According to the given specifications, four functions should be generated namely, sine wave, triangular wave, saw-tooth wave, square wave. Since these wave forms have mathematical relationships between them, we were able to reduce the complexity of the wave generation by using a one wave to generate another wave.

3.2.1 Triangular and Saw-tooth wave generation

The triangular and saw-tooth wave is generated using a cascade combination of a Schmitt trigger circuit and an integrator. The circuit used to generate the triangular wave is shown in Figure.

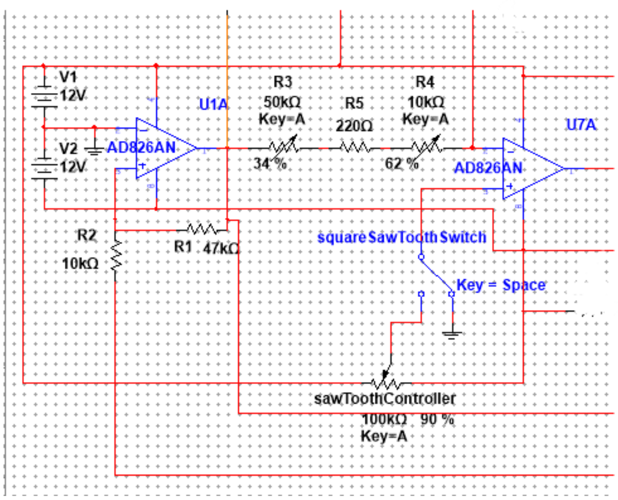


Figure 3.1 Triangular waveform generation

The output of the Schmitt trigger alternates between positive and negative direct current levels. By changing the value of the resistor R1, we can change the frequency of this oscillation. The integrator receives the Schmitt trigger's output and connect this output signal to the inverting terminal of the integrator and non-inverting terminal is connected to the ground. Then we can get the triangular waveform as the output of the integrator circuit.

Concept we used here:-

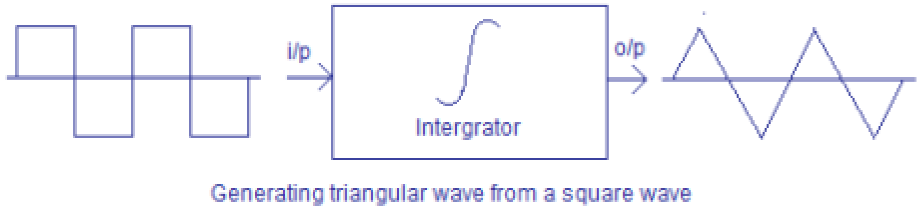


Figure 3.2 Concept to generate triangular waveform

To generate saw-tooth waveform we connect the non-inverting terminal of the integrator to a DC voltage value. To do that we use the potentiometer.

By changing the switch to the sawtooth controller side we can get the saw-tooth waveform as the output. The rise time and the fall time of the sawtooth wave can be varied by varying the dc voltage given to the non-inverting input of the integrator.. The frequency of the output can be varied by varying R4 and C1.

3.2.2 Square Wave Generation

After getting the output of the integrator that is a triangular wave goes through a unity gain amplifier and non-inverting terminal of that Op-Amp is connected to the DC voltage value by applying a potentiometer to that terminal. By doing this, we can give the triangular waveform a DC shift. The amplifier's output is then passed through a buffer circuit. We want to segregate the input side from the output side, which is why we should employ a buffer. So, the prior intended signals will be affected if the subsequent component of the circuit draws a significant quantity of current. We employ a buffer to separate the two sides because of this. The signal then passes through a comparator circuit. The waveform that oscillates between +12V and -12V is then obtained. It is a square wave, however it has a 12V amplitude. As a result, we wish to lower its amplitude to match the level we gave the triangular waveform. An inverting di-amplifier circuit is used to do it. After that circuit, the square waveform is obtained.

Since in the previous we use a circuit to give a DC shift to the triangular waveform. By doing this we can vary the duty cycle of the square waveform. Full circuit of this process in the Figure 3.4.

Trinagular/Saw-tooth Waveform

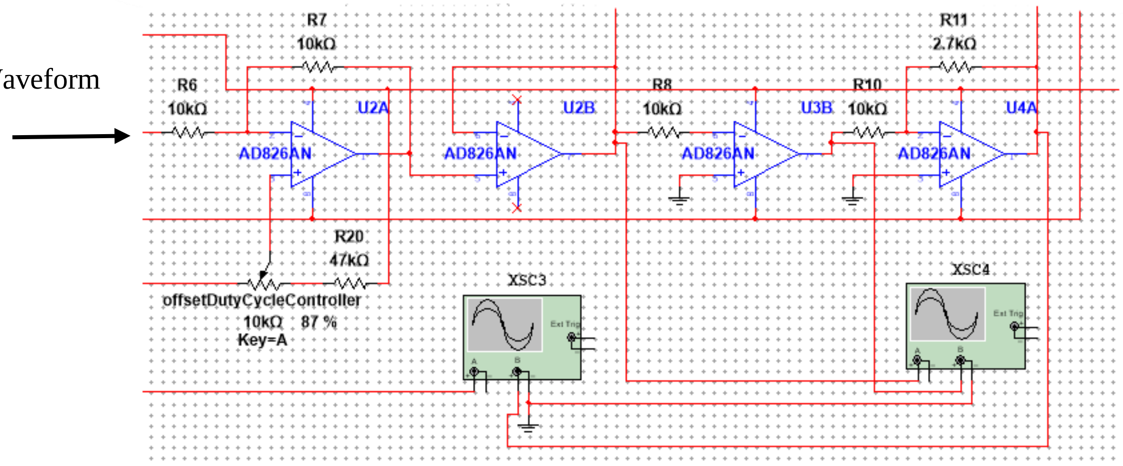


Figure 3.3 Full circuit to implement square waveform

Following figure 3.5 is the circuit used to give a DC shift to the triangular/sawtooth waveform to generate PWM signal the square waveform.

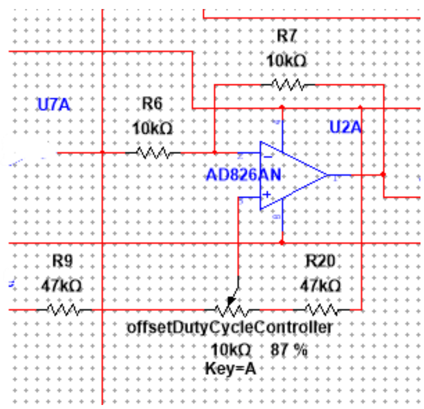


Figure 3.4 PWM waveform generating circuit

We can change the duty cycle of the PWM signal by varying offset duty cycle controller. In this circuit we add two more 47Kohm resistors to besides to the offset duty cycle controller. The reason is to add these resistors, we only want to shift the triangular waveform within 5V range. To set that range we add suitable resistors to both of sides. And we can change the frequency of the square wave signal by changing the frequency of the triangular signal.

Concept of varying the duty cycle of the square wave pulse.

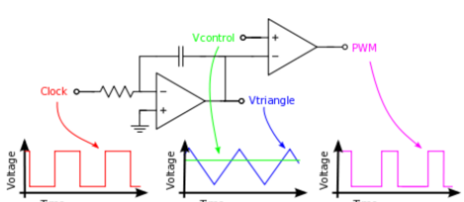


Figure 3.5 varying the duty cycle of PWM wave.

3.2.3 Sin Waveform Generation.

In our case we design the sin waveform by integrating the triangular waveform. Following figure 2.7 is the circuit used to generate the sin waveform.

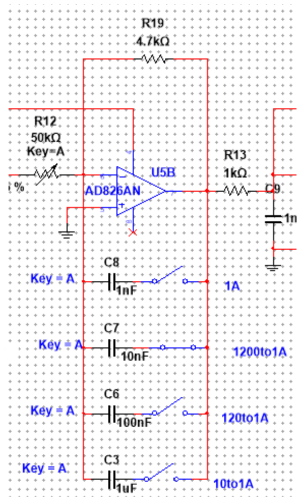


Figure 3.6 Sin wave generation

Here we use four capacitors to change the frequency of the sin wave

3.3 Calculations and Component Selection

It is necessary to choose the most suitable components for the circuitry in order to meet the requirements. Calculations and the component datasheets are used to achieve this.

Op Amp Selection

In the process of component selection, we selected following Op-Amps initially.

Op Amp	**Slew rate v/µs (Data Sheet Value)**	**Practical Slew rate v/µs**
TL072	13	0.5
NE5535	9	3
AD826	300	20

Because we are using a comparator to make the square wave, there should be high slew rate values for a better function generation. Our calculated value of slew rate of the Op-Amp is 300. Therefore, AD826 Op-Amps are selected for the circuit.

A dual, high-speed voltage feedback op amp is the AD826. Applications requiring unity gain stability and high output drive capability, like buffering and cable driving, are perfect fits for its use. The AD826 is helpful in many high-speed applications due to its 50 MHz bandwidth and 300 V/s slew rate.

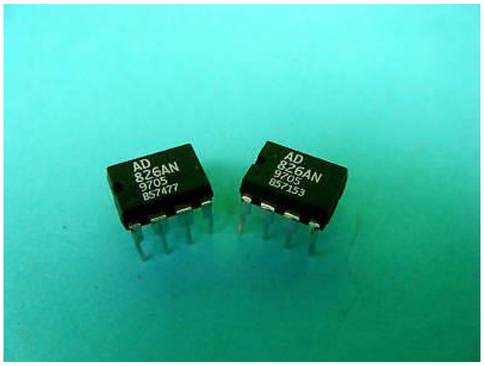
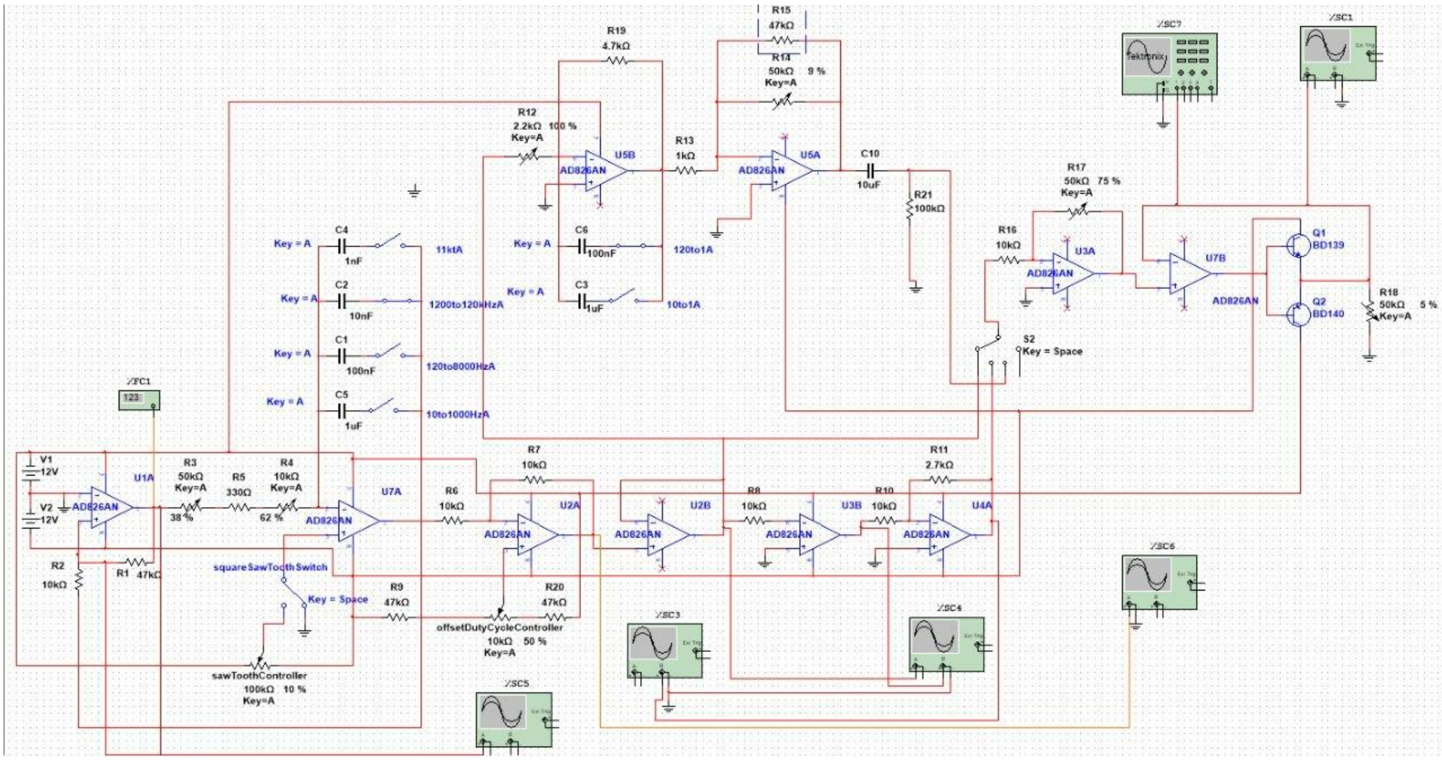


Figure 3.7 AD826 Op-Amp

4.Schematic



5 PCB Designing and Soldering

When the circuits in protoboards have been tested, Altium software is used to design PCBs. All of the tested circuits were integrated into two distinct circuits for PCB design one for main functionality circuit and other for the power supply circuit. The output files for the designs were created, and the PCB printing files were delivered to China. The designed schematics and layouts are depicted in Figures 5.1, 5.2, 5.3, and 5.4.

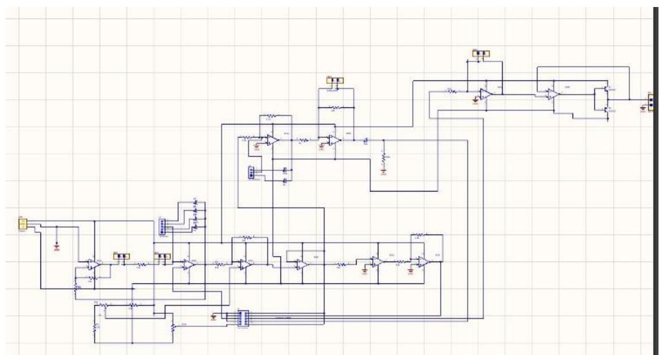


Figure 5.1: Main circuit schematic

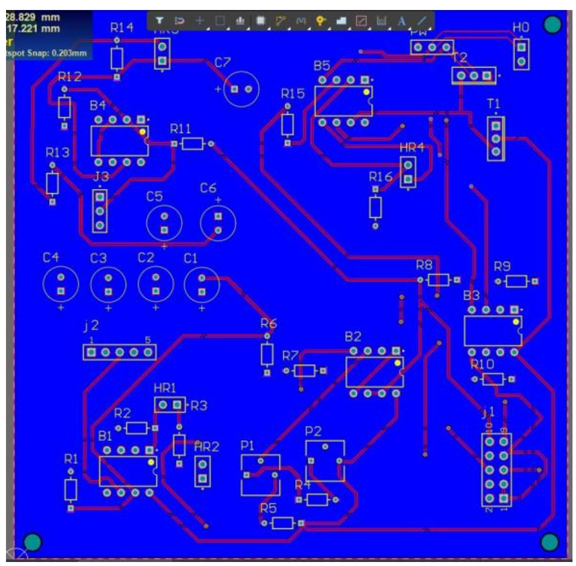


Figure 5.2: Main PCB layout

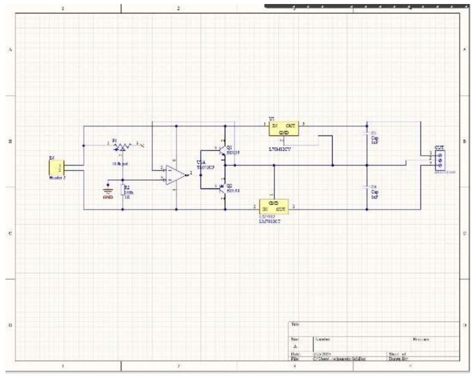


Figure 5.3: Power Circuit schematic

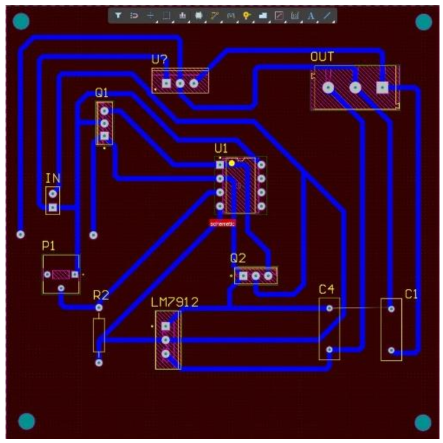


Figure 5.4: Power Circuit schematic

Once the components have been inserted, the designed PCBs are soldered. To adjust the frequency amplitude, dc offset, PWM duty cycle, and switch between waves, potentiometers and rotary switches are employed. Male headers are used to connect them to the Boards. Figure 6.1 and 6.2 shows the final output of the main PCB and power supply circuit after soldered.

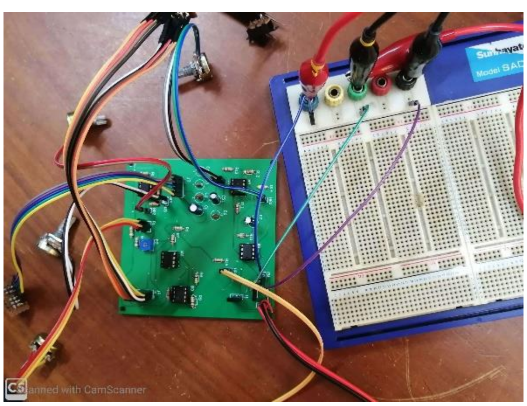


Figure 5.5 Main PCB

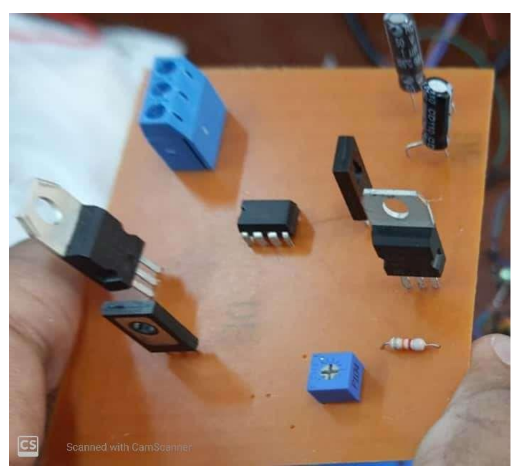


Figure 5.6 Power Supply circuit PCB

6 Enclosure Design

The enclosure was designing using Solidworks software and we design it using 3D printing. Here following figure 8.1 and 8.2 shows the sollidworks file of our enclosure.

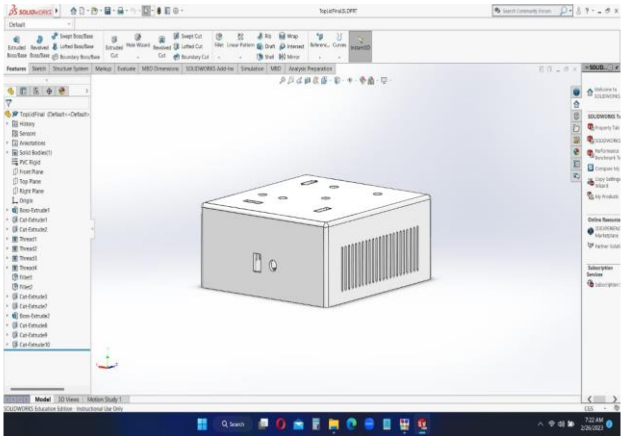


Figure 6.1

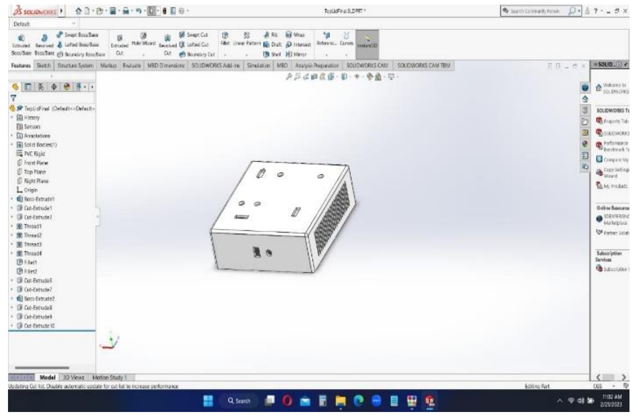
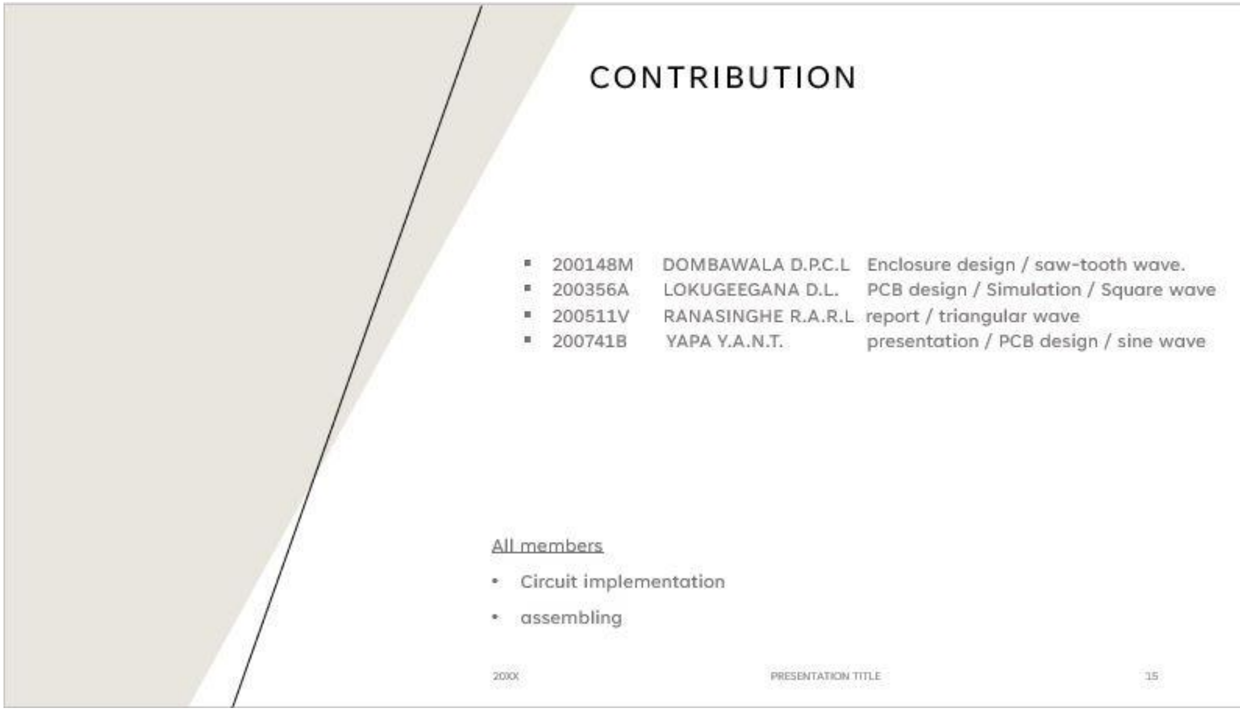


Figure 6.2

Figure 6.3 After printing the enclosure

7 Individual Contribution



8 Simulation Result

Printed circuit boards were designed after the circuits were tested and simulated (PCB). The simulation tool is Multisim by National Instruments (NI). Using NI Multisim, Figure 4.1 depicts the simulation of the triangular waveform.

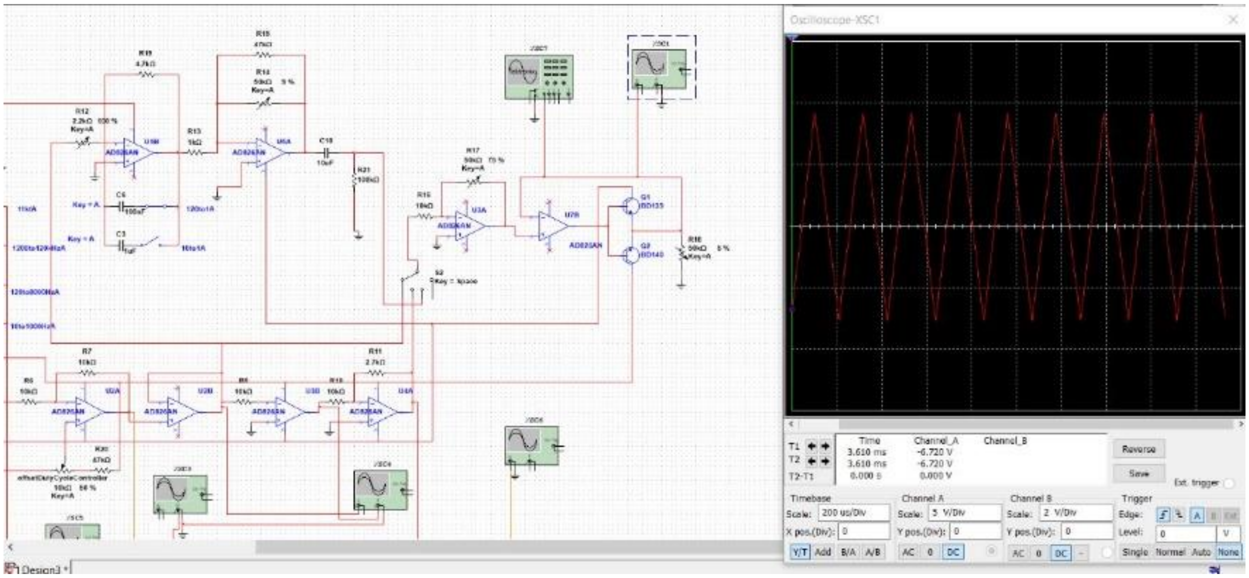


Figure 8.1 triangular waveform

Figure 4.2 depicts the simulation of the saw-tooth waveform.

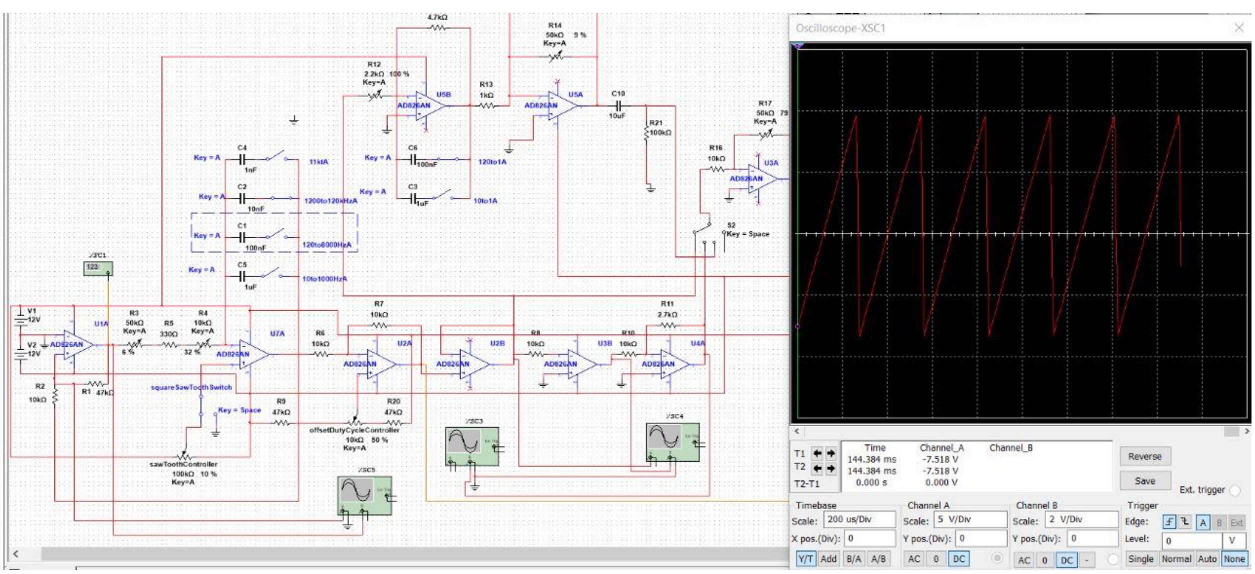


Figure 8.2 saw-tooth waveform

Figure 4.3 depicts the simulation of the sin waveform.

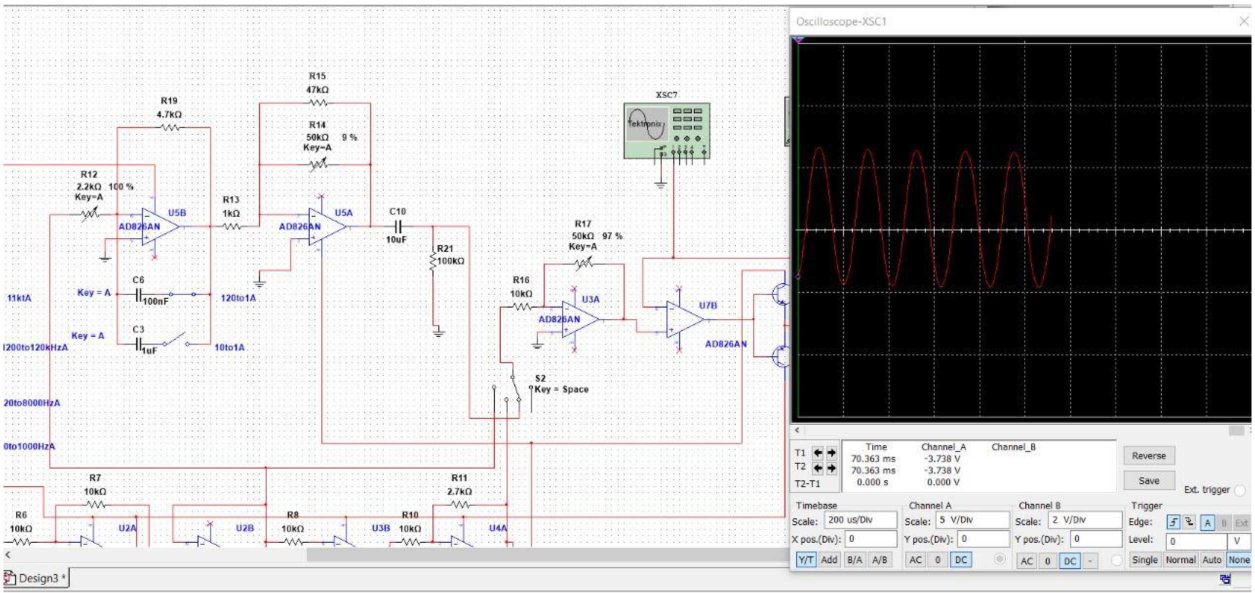


Figure 8.3 sin waveform

Figure 4.4 depicts the simulation of the square(PWM) waveform.

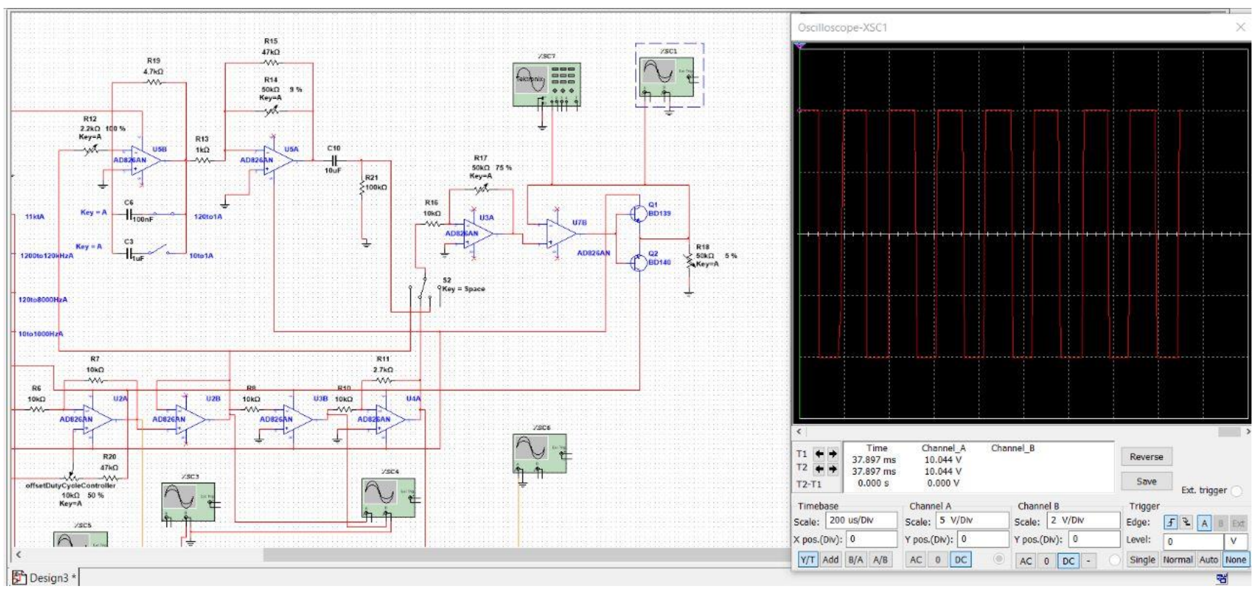
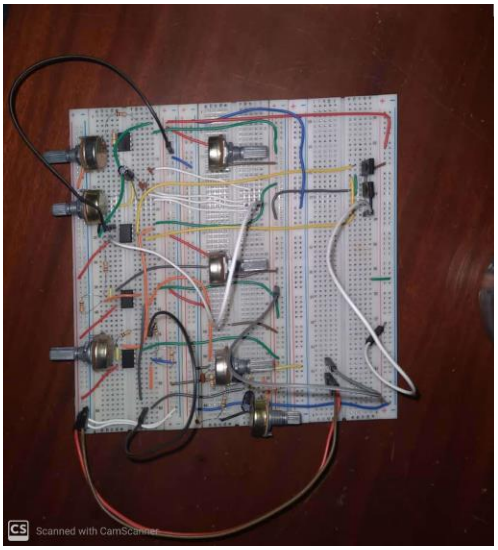
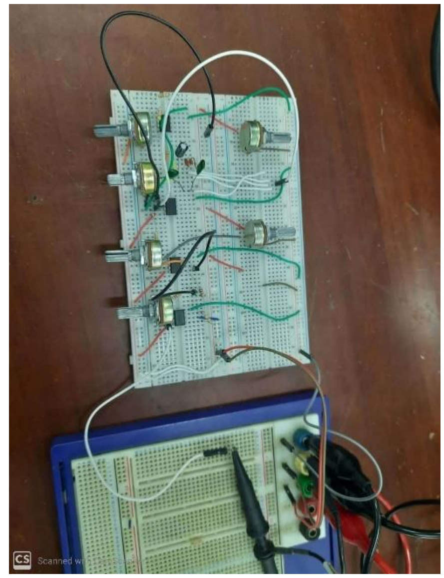


Figure 8.4 square (PWM) waveform

Here is the main circuit we implement in the lab to generate all waves and change their frequencies amplitudes and vary the duty cycle.



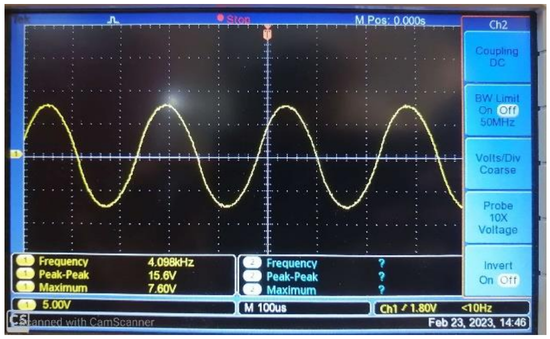


Following figures shows the result we obtained during the lab testing.

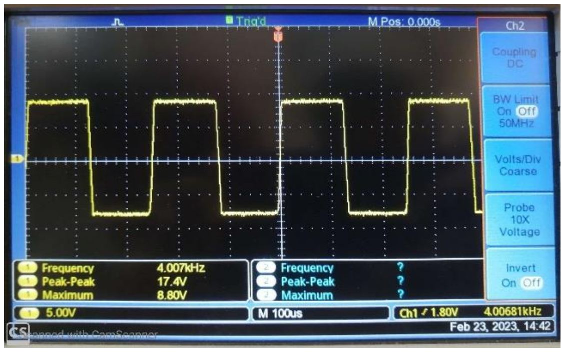
- Triangular waveform generation: -

- Saw-tooth waveform generation: -

- Sin Waveform generation: -



- Square waveform Generation: -



- Square waveform by changing the duty cycle of that signal: -

9 Conclusion and Future Works

In this project, we were able to construct an analog function generator that can generate various waveforms including sine, sawtooth, triangular, and square waves with changeable duty cycle. The device can also generate waves with variable amplitude, frequency, and a DC shift. The frequencies of the generated waveforms can be changed from 20 Hz to 20 kHz, and the amplitudes can be changed from 0 V to 10 V. The main components used in this project are op-amps, resistors, and capacitors

The constructed function generator fulfills all the design specifications given at the task of the project, including generating all the required waveforms within the specified frequency and amplitude ranges. Moreover, the device can drive any load resistor more than 50ohm without causing any distortion to the waveform it generates.

In conclusion, this project was successful in constructing an analog function generator that can perform all the essential functions of a function generator used in a laboratory. The device can be utilized for a variety of applications in electrical and electronic engineering, including phase locked loops, AM/FM production, and sweep generation (PLLs). Further improvements can be made to the device to enhance its performance and capabilities.

In future we could improve the frequency range of the waves also with higher amplitudes. Further we could improve to have device protection technics.

Bibliography

Op-Amp: -

- TL072cp - https://www.alldatasheet.com/datasheet-pdf/pdf/28775/TI/TL072.html
- Ne5535 - https://www.alldatasheet.com/datasheet-pdf/pdf/168624/PHILIPS/NE5535.html
- Ad826 - https://www.alldatasheet.com/datasheet-pdf/pdf/48429/AD/AD826.html

Transistor

- Bd140 - https://www.alldatasheet.com/datasheet-pdf/pdf/2921/MOTOROLA/BD140.html
- Bd139- https://www.alldatasheet.com/datasheet-pdf/pdf/2920/MOTOROLA/BD139.html

Voltage regulator

- 7812 - https://www.alldatasheet.com/datasheet-pdf/pdf/4475/MOTOROLA/7812.html
- 7912 - https://www.alldatasheet.com/datasheet-pdf/pdf/131205/ETC1/7912.html