Department of Electronic and Telecommunication Engineering

University of Moratuwa

EN2090 Laboratory Practice - II

Project Report

FUNCTION GENERATOR

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Abstract

Most of the electronics applications require various wave forms. From finding the characteristics of OPAMPs and diodes to testing the inner workings of the audio amplifier these wave forms are used. This report discusses about an analog function generator which can produce sine, square, triangular and saw tooth wave forms at the range of 20Hz to 20000Hz in frequency where the output voltage varies from -5v to 10v.

Contents

1 Introduction

Analog function generator is an electronic device implemented using the basic elements such as OPAMPs, transistor and analogue components.Function generators are used for many application such as testing and design of electronic devices, etc. This reports presents the design and physical implementation of an analogue function generator. First, the methodology used to implement the requirements is presented. In this part the implementations with circuit diagrams and the principles are discussed. Next the results are described. For each wave forms the output through the oscilloscope are presented and in the final section the results and the possible further improvements are discussed.

2 Methodology

2.1 Waveform Generation

2.1.1 Square Wave and PWM

An astable mutivibrator circuit is used in the generation process of the square wave where a Schmitt trigger is combined with a capacitor. The Schmitt trigger action changes the state between an upper and a lower threshold level as the input voltage signal increase and decrease about the input terminal. When the charge across the capacitor is higher than the Schmitt trigger higher threshold level since the voltage of the positive terminal is higher than the negative terminal, the output result to be logic “0” and vice versa. The period of the square wave changes with the RC value, a potentiometer is used as R to change the frequency.
The PWM signal is generated by sending the triangular waveform, generated at the capacitor, through a comparator circuit. The duty cycle of the PWM signal is changed by varying the reference voltage of the comparator. A precision rectifier circuit is used to rectify the square and PWM waveforms.

Following equation is used to determine the period(T) of the square/triangle wave output of the astable multivibrator circuit.

$$\beta = \frac{R_1}{R_1 + R_2}$$

$$T = 2RC\, ln(\frac{1+\beta}{1-\beta})$$

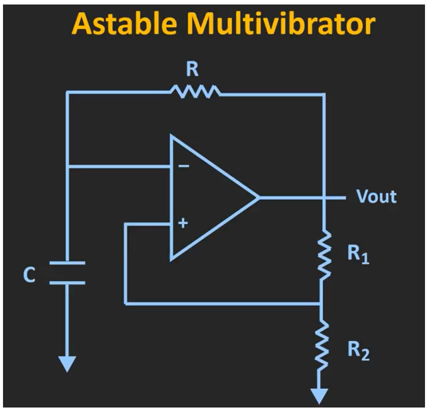

Figure 1: Astable Multivibrator Circuit

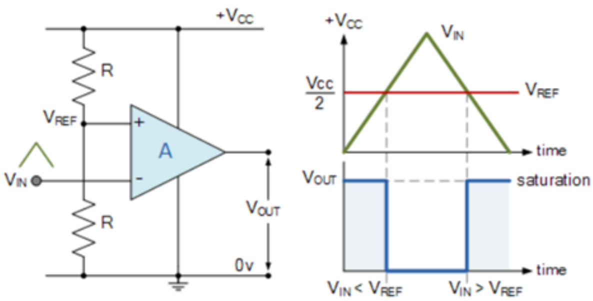

Figure 2: PWM signal genaration

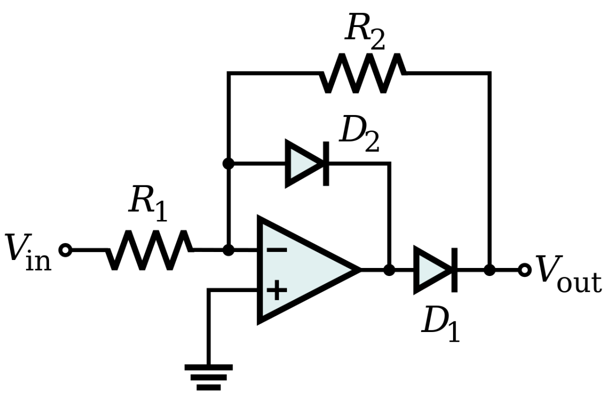

Figure 3: Precision rectifier circuit

2.1.2 Triangle Wave

Triangular wave is extracted in between the capacitor and the potentiometer where the triangular wave is generated as a result of the charging and discharging of the capacitor.

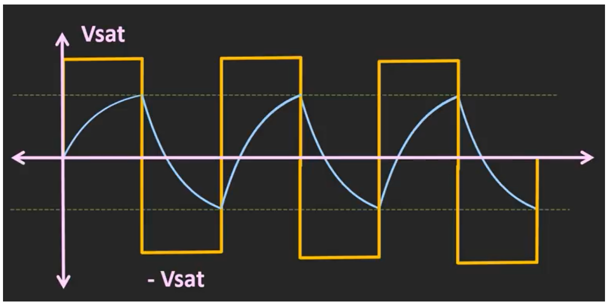

Figure 4: Square and triangular pulse generation

2.1.3 Sine Wave

The Sine Wave generation was done by low-pass filtering the traingle wave obtained from the relaxation oscillator. 3rd order RC passive filters were used for this purpose. As the filter output was frequncy dependent we implemented 4 filters with different resistor and capacitor values. The cut off frequency of each of the filters was obtained theoretically using the following equation,

$$f_c = \frac{1}{2\pi(R_1C_1R_2C_2R_3C_3)^{\frac{1}{3}}}$$

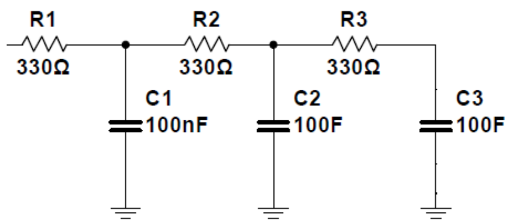

Figure 5: 3^{rd} order RC lowpass filter

	Frequency Range
Filter 1	80 Hz - 400 kHz
Filter 2	400 Hz - 2 kHz
Filter 3	2 kHz - 8 kHz
Filter 4	8 kHz - 20 kHz

Table 1: Filters with their frequncy ranges

2.1.4 Sawtooth Wave

In order to produce the sawtooth waveform, the magnitude should instantly come to zero from the peak value. To implement this a capacitor can be short circuited but using this the capacitor won't charge initially. By using a transistor we can find an optimal solution. Here the transistor is in cut-off region to be charged. When capacitor is charged up to required saturation level, a momentary positive pulse is applied at the base of the transistor to send it into saturation. In saturation $V_{CE} = 0$, so capacitor is short circuited and discharges quickly to zero. The positive pulses are given as a PWM signal with a very small duty cycle.

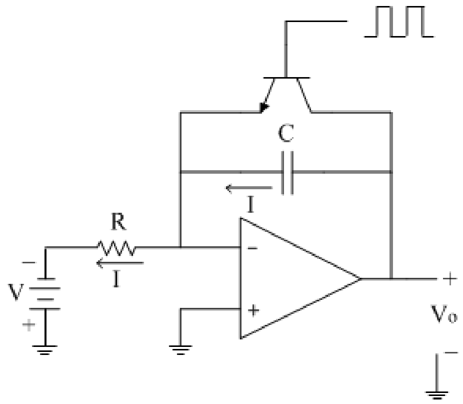

Figure 6: Square and triangular pulse generation

2.2 Output Stage

According to the given specifications the function generator must be able to drive 50Ω load. In general an OPAMP can provide only upto 100mA current which is not enough to drive a 50Ω load at 10V pk-pk. In order to accomplish this task we used an OPAMP buffer circuit containing transistor push-pull stage. The maximum current required is about 200mA (10V/50Ω). For this we are using 2N2222A NPN and 2N2907A transistors which can support upto 800mA I_C current.

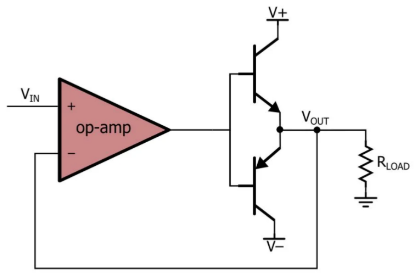

Figure 7: Buffer Circuit (using OPAMPS and push-pull stage

2.3 Power Supply

The power supply will take input AC voltages in the range of 7 - 24 V (rms) and output a dual voltage of ±9V. This dual voltages are used to operate all the components including the OPAMPs. A rectifier bridge (KBP307) and positive and negative voltage regulators were used for this purpose (LM7809 LM7909).

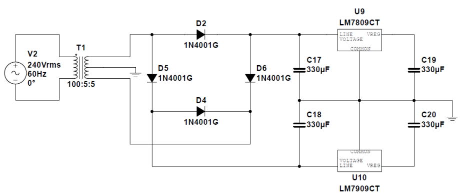

Figure 8: ±9V power supply

2.4 Circuit Block Diagram

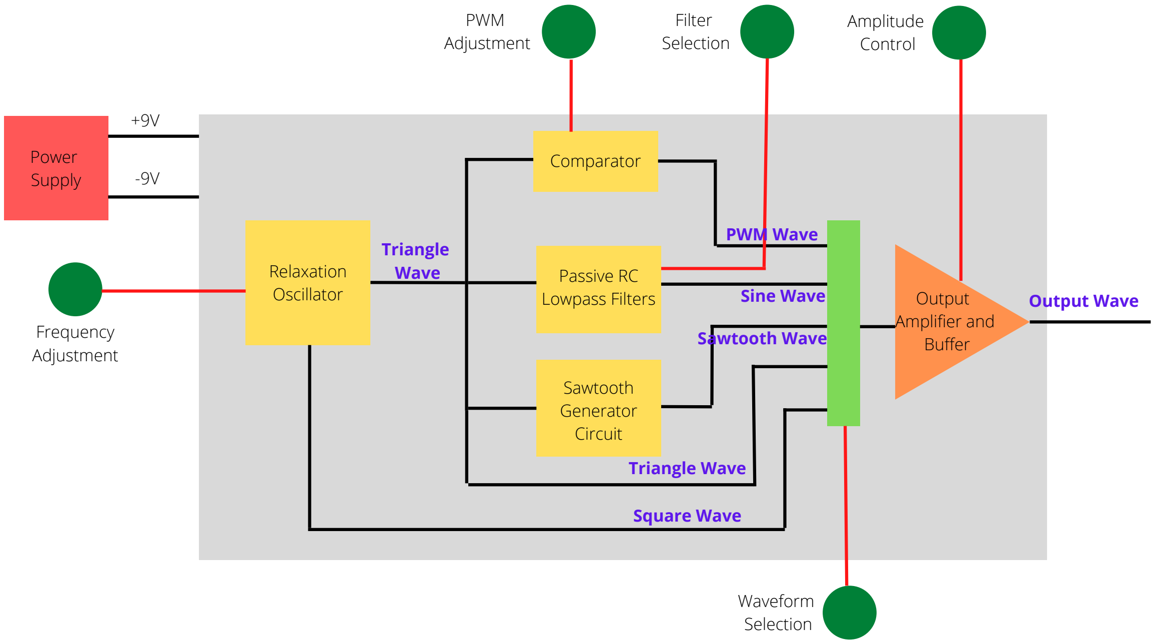

Figure 9: Circuit Block Diagram

2.5 Component Selection

Following are the main components used in the implementation of the analogue function generator.

- TL084CN Quad-OPAMP
- AD826AN Dual-OPAMP
- 2N2222A, 2N2907A, 2N3904 transistors
- resistors, potentiometers, capacitors, etc.

TL084CN

TL084CN is a 14-pin Quad Operational Amplifier by Texas Instruments. It has a slew rate of 20 $V/\mu s$ and a unity gain bandwidth of 5.25MHz. All the signal generation tasks were carried out using 2 of these OPAMPs. This OPAMPs able to produce both low (40Hz) and high (20kHz) frequency signals with sufficient accuracy.

AD826AN

AD826AN is an 8-pin Dual Operational Amplifier by Analog Devices. Is has a very high slew rate of 350$V\mu s$ and a unity gain bandwidth of 40-50MHz. This OPAMP was used in the output stage as a non-inverting amplifier and a buffer before the transistor push-pull stage.

3 Results

After testing the following results could be obtained relating to different modules in the function generator circuits.

3.1 Square and PWM wave

We used two capacitors ($10nF$ and $0.33\mu F$) to achieve lower and higher frequencies respectively in the relaxation oscillator. The PWM control is done using the OPAMP comparator. The following images show rectified square waveforms with different PWM values.

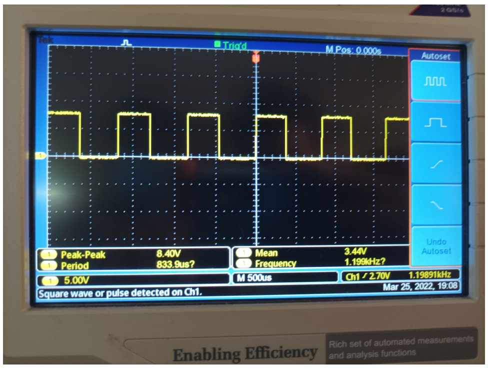

Figure 10: 1kHz Square Wave Signal

Figure 11: 16kHz Square Wave Signal

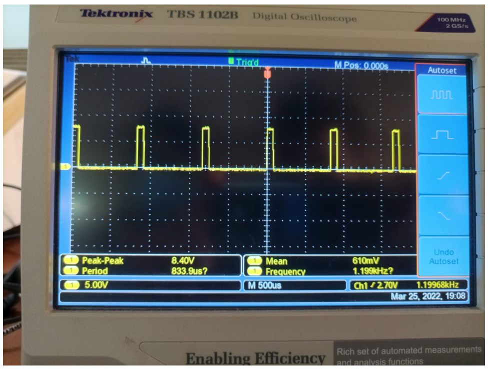

Figure 12: PWM control of square wave

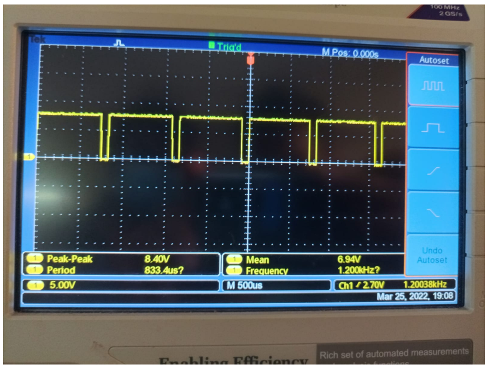

Figure 13: PWM control of square wave

Triangle Wave

The triangle waveform is obtained as the voltage across the capacitor from the relaxation oscillator.

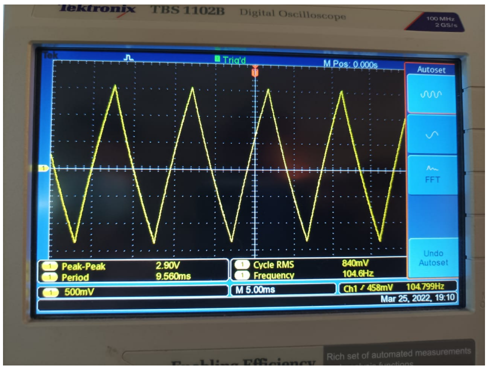

Figure 14: 100Hz triangle waveform

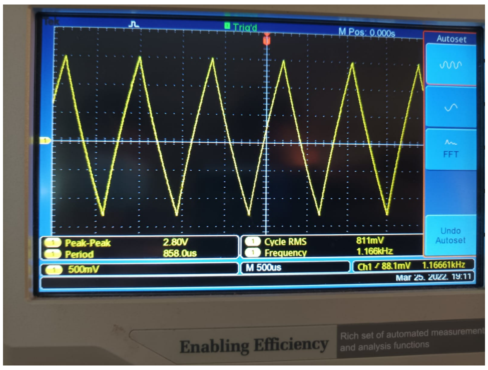

Figure 15: 1kHz triangle waveform

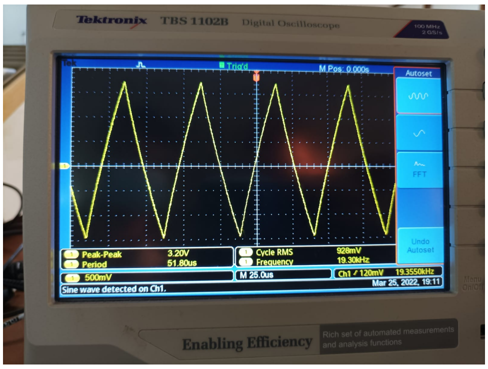

Figure 16: 20kHz triangle waveform

Sine Wave

The sine wave is obtained after the triangle waveform is filtered from the low pass filters. From the four filters we used the accurate wave forms could be obtained.

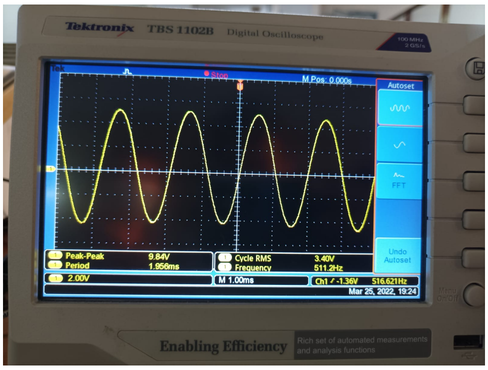

Figure 17: 500Hz sine waveform

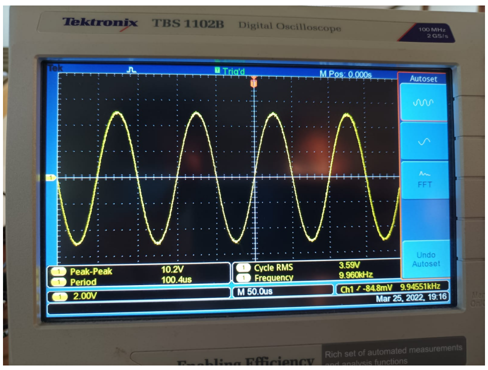

Figure 18: 10kHz sine waveform

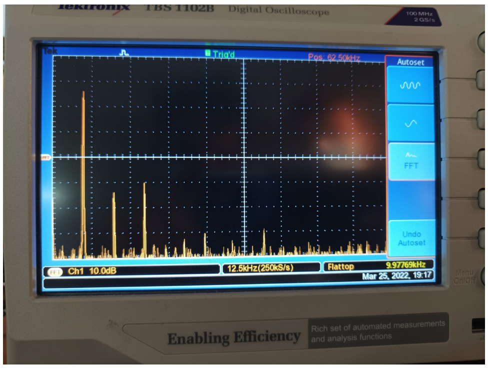

Figure 19: Frequency spectrum of 10kHz sine waveform

4 Discussion

Following are some of the issues we encountered when designing the analogue function generator. We were able to fix some these issues.

Shape of the Triangle Waveform

The triangle wave which was obtained as the capacitor voltage of the relaxation oscillator, was not exactly triangular in shape. At closer inspection it is possible to see a curve similar to that of a capacitor charging and discharging. This could have been avoided by integrating the square wave, using an **OPAMP integrator** circuit instead. But we decided not to implement it because, the waveform was very nearly triangular.

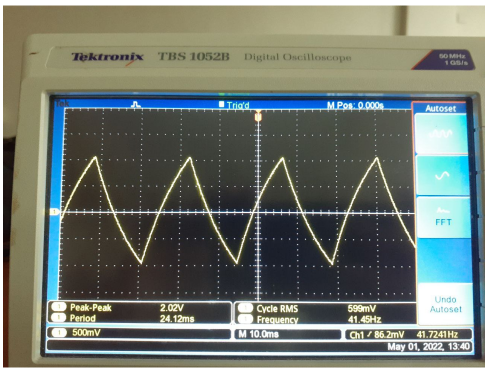

Figure 20: 1Distored triangle wave

Amplitude reduction of Sine and Sawtooth functions when increasing frequency

This is another issue that could not be completely resolved in our design. As the frequency is increased, the amplitude of both sine and sawtooth wave reduced dramatically. This happened in each waveform due to the following reason;

- **Sine wave** - Once the frequency was increased past the cutoff frequency of the filter, the gain reduction caused the amplitude of the waveform to drop.

- **Sawtooth Wave** - RC circuit in the OPAMP integrator in the sawtooth generator circuit gave a frequency dependent output. Therefore, as the frequency was increased it caused the amplitude to drop.

The method currently used to overcome this issue is to, increase the amplitude at the output stage to counter balance the amplitude reduction resulted by frequency change.

5 Member Contribution

Member	Contribution
190234E Hewasura G.I.	Squre and Triangle Wave Genration, Enclosure Design
190250A Jayabawan T.	Sawtooth Generator Circuit, PCB Design
190262L Jayasinghe D.R.	Power Supply, Output amplifer, PCB Design
190274B Jayawardhane L.H.T.V.	Sine Wave Generation, Soldering

6 References

1. https://www.electronics-notes.com/articles/test-methods/signal-generators/function-generator.php
2. https://www.electronics-tutorials.ws/filter/second-order-filters.html
3. https://www.elprocus.com/what-is-a-square-wave-ger
4. https://www.electronics-tutorial.net/analog-integrated-circuits/multivibrators/sawtooth-waveform-generator
5. https://www.allaboutcircuits.com/technical-articles/how-to-buffer-an-op-amp-output-fo
6. https://en.wikipedia.org/wiki/Precision_rectifier

7 Appendices

7.1 Appendix I - PCB Layout

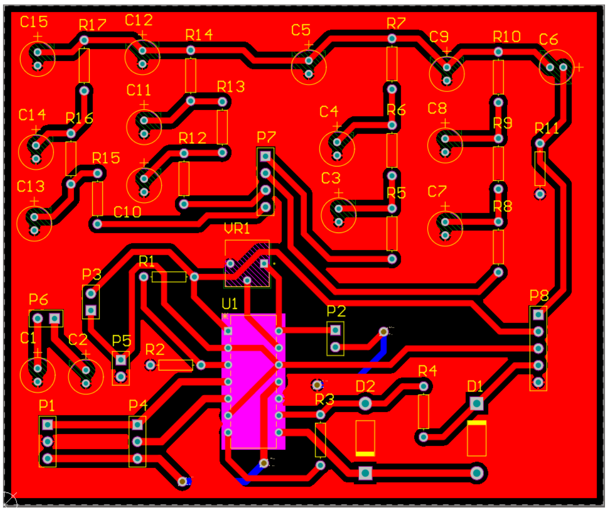

Figure 21: PCB 1 - Triangle, Square, Sine Wave generation

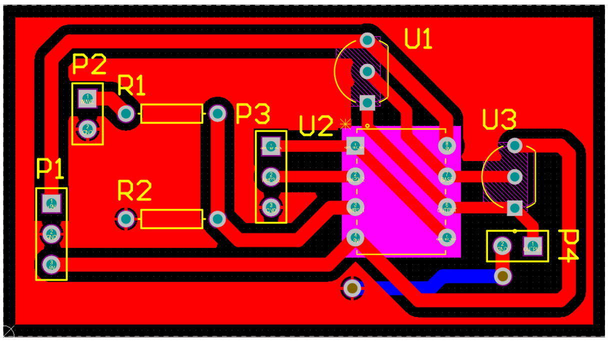

Figure 22: PCB 2 - Output Stage

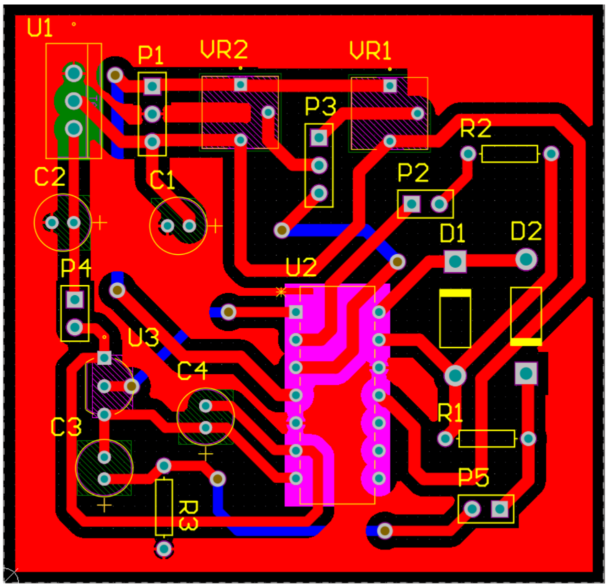

Figure 23: PCB 3 - Sawtooth Wave Generation

8 Appendix II - Enclosure

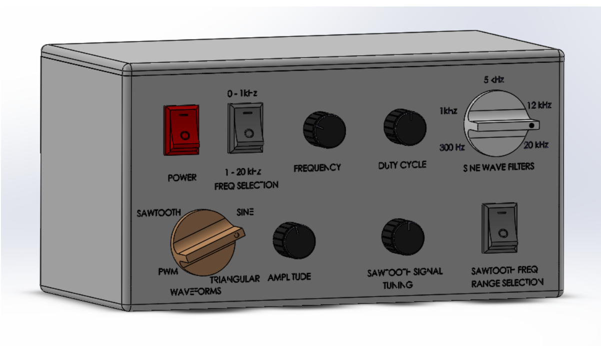

Figure 24: Enclosure - View 1

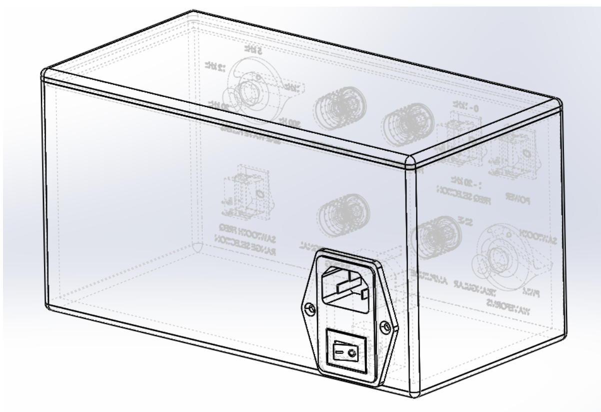

Figure 25: Enclosure - View 2

9 Appendix III - Datasheet

Analogue Function Generator - Datasheet

Features

- 5 output functions
- Adjustable frequency from 40Hz to 20kHz
- Amplitude can be adjusted within ±7V
- Can drive small loads

Description

Analogue Function Generator is designed completely using analogue electronic components and it is capable of producing the following output functions.

- Triangle Wave
- Square Wave (50% duty)
- Square Wave PWM (variable duty cycle)
- Sine Wave
- Sawtooth Wave

The device can output these waveforms with minimum distortion approximately within a range of 40Hz - 20kHz. It is possible to adjust the amplitude of each of the waveforms within a range about of ±7V. The fuction generator can be used for multiple electronics and communications applications such as testing equipments, analyse Audio Systems, etc.

Specifications

Power Supply

Input		
Min. Input Voltage	7	V AC rms
Max. Input Voltage	24	V AC rms
Typ. Input Voltage	9 - 15	V AC rms

Output		
Output Voltage	±9	V DC
Max. Output Current	1.5	A

Function Generator Output

Output Frequency Ranges

Function	Min. Frequency	Max. Frequency
Triangle	41 Hz	30 kHz
Square (50% Duty)	44 Hz	20 kHz
Square Wave (PWM)	44 Hz	22 kHz
Sine Wave	80 Hz	20 kHz
Sawtooth Wave	110 Hz	10 kHz

PWM Duty Cycle Range

Frequency Range	Duty Cycle
40 - 1 kHz	1.6% - 98.5%
1 - 10 kHz	2% - 97%
10 - 20 kHz	4% - 95%

Sine Filter Selection

	Frequency Range
Filter 1	44 Hz - 400 Hz
Filter 2	400 Hz - 2 kHz
Filter 3	2 kHz - 10 kHz
Filter 4	10 kHz - 20 kHz