Function generator

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Group 21

EN2091 - Laboratory Practice and Projects

Content

1.Abstract

This is the design of an analog function generator which generates sine, square, saw tooth and triangular waves. The output amplitude variable from 0V to 10V, and the output frequency variable from 20 Hz to 20000 Hz. It is able to drive a 50 Ω load without significant waveform distortion or amplitude reduction. This Function generator outputs a clean, noise-free waveform. Square pulse waveform has a variable pulse width (1% to 99%).

2.Introduction

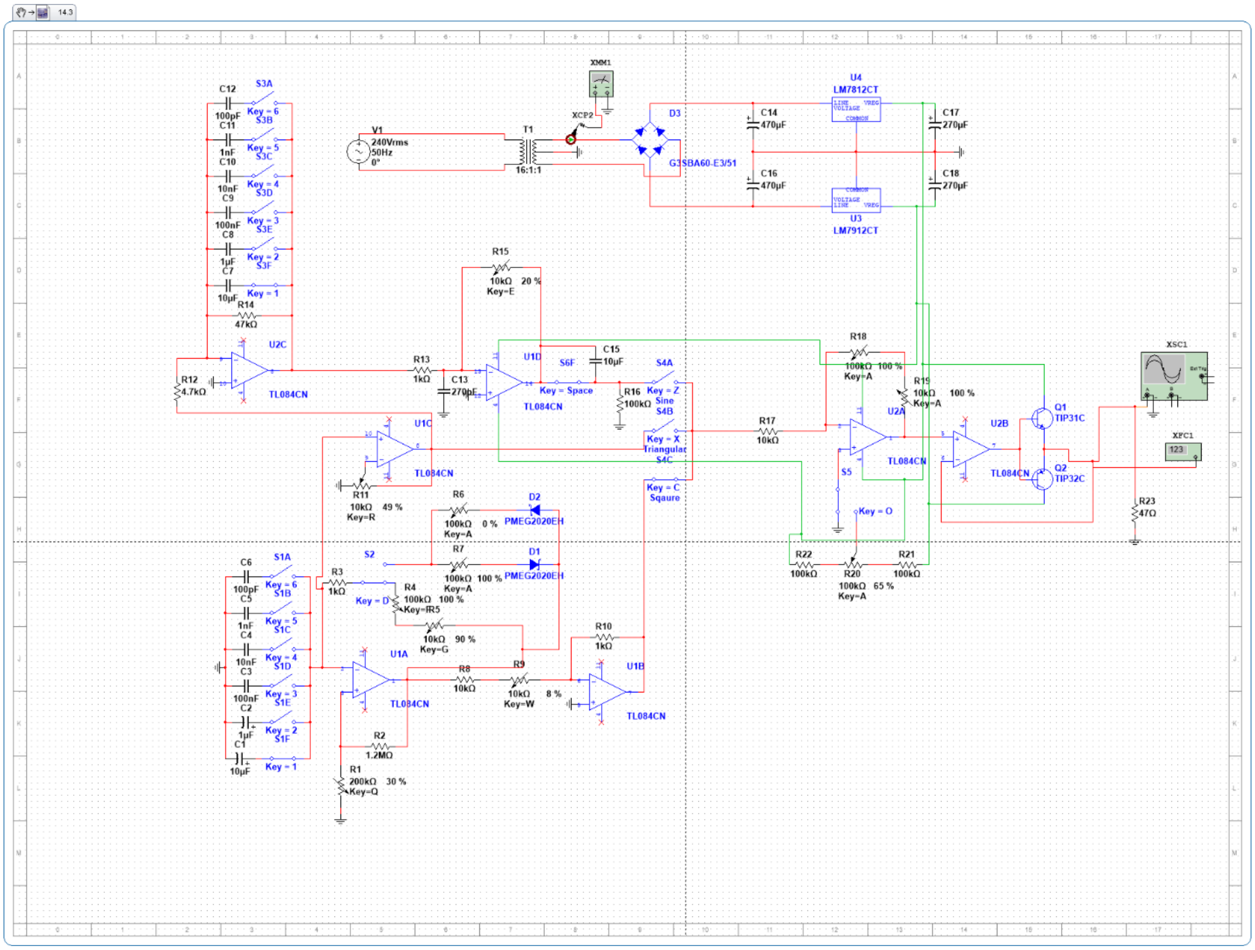
Function generators are extensively used to produce analog waveforms like sine waves, square waves, sawtooth waves, etc. Many applications, including phase locked loops, AM/FM generation, and sweep generation, are possible for it (PLLs). In the past, MAX038, XR2206, and NTE864 were some of the common analog integrated circuits (ICs). Nowadays, Direct Digital Synthesis (DDS) chips are used to mostly replace them (AD9850 DDS signal generator module).

The waveform frequency of function generators may often be changed precisely between a large range of values (0.1 Hz to 1 MHz). The amplitudes and average DC values of these signals can also be modified. It becomes crucial for some delicate applications that a function generator be able to produce a clear, noise-free waveform. This function generator is an analog circuit designed by using transistors and op-amps which can generate sine waves, square waves with variable duty cycle, sawtooth waves, and triangular waves.

3.Functionality description

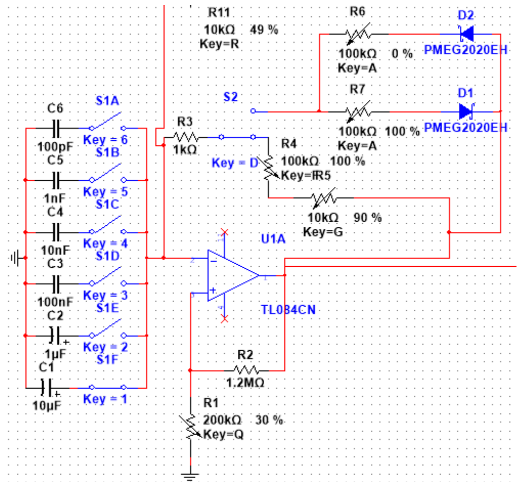
Switch 1 can be used to choose the desired waveform (square, triangle, sine). Then, using switch 2, we may decide whether to provide duty cycle or not (when choosing a triangle wave and 1% duty cycle, we will receive a sawtooth). Also, we may choose whether to provide an offset using switch 3 and the operating frequency range of the waveforms using screw 4. We can adjust the amplitude and frequency using screw 5, fine-tune the frequency using screw 6, and modify the duty cycle using screw 7 (up). You must tighten screw number 7 if you wish to adjust the offset as needed.

4. System model



Relaxation Oscillator

The relaxation oscillator is the basis of this design. A relaxation oscillator is basically a Schmitt Trigger that is made to oscillate in accordance with the charging discharging time of a series capacitor and resistor.



Opamp is connected to $+/-12V$, hence threshold voltages are $+/-12V * R1/(R1 + R2)$. The threshold is variable since R1 is a trimmer. If we assume the threshold value is adjusted to be $1V$. Initially the voltage across the capacitor is zero and the Opamp output rails to one of the supply voltages. Let's assume it rails to $+12V$. Then the voltage at pin 3 is $1V$ and Opamp output will be $+12V$ since $V_+>V_-$. current will pass through R3, R4, R5 and charges the capacitor according to the function $V_c(t)=12*(1-exp(-t/RC))$. When V_c goes just over $1V$, $V_+<V_-$ and the Opamp output will be changes to $-12V$. When $V_{out}=-12V$, $V_{thres}=-1V$. Now $V_-=+1V$ and $V_+=-1V$. The capacitor will discharge through R3, R4, R5 and reverse polarity until $V_-=-1V$, and Opamp will switch to $+12V$ again. This process continues forever, and we can adjust the frequency of this by adjusting the resistances R4, R5 and changing the capacitances.

The relaxation oscillator is now producing a square wave on the output pin and an approximate triangle wave on pin 2 at the same time. This triangular wave is actually follows an exponential curve, however making V_{thres} very low than the supply voltage well approximates the line as a straight line.

The relaxation oscillator U1A is the heart of the function generator. The power supply is achieved by a $2 * 15V$ center-tapped transformer that generates two equal and independent $15V$ sources. Bridge rectifier rectifies the current and two large capacitors filter it. Then the two voltage regulators clean the DC voltages set to +12V and -12V.

The switch S2 is used to select duty cycle / sawtooth mode. When selected we can get a duty cycle square wave from pin 1 and sawtooth wave from pin 2 that can be adjusted with POT R6, R7 (single POT is used in the actual circuit).

U1B is an inverting amplifier that attenuates the square wave to a more useful voltage since $12V$ is high at this point of the circuit. The attenuation is configured by the ratio of attached resistors and can be adjusted with the trimmer R9 when calibrating.

U1C is a non-inverting amplifier that is used to pick the triangular wave. Non-inverting configuration is used since it has high input impedance. We can adjust the gain with the trimmer R11 and U1C can be used as our triangular wave source.

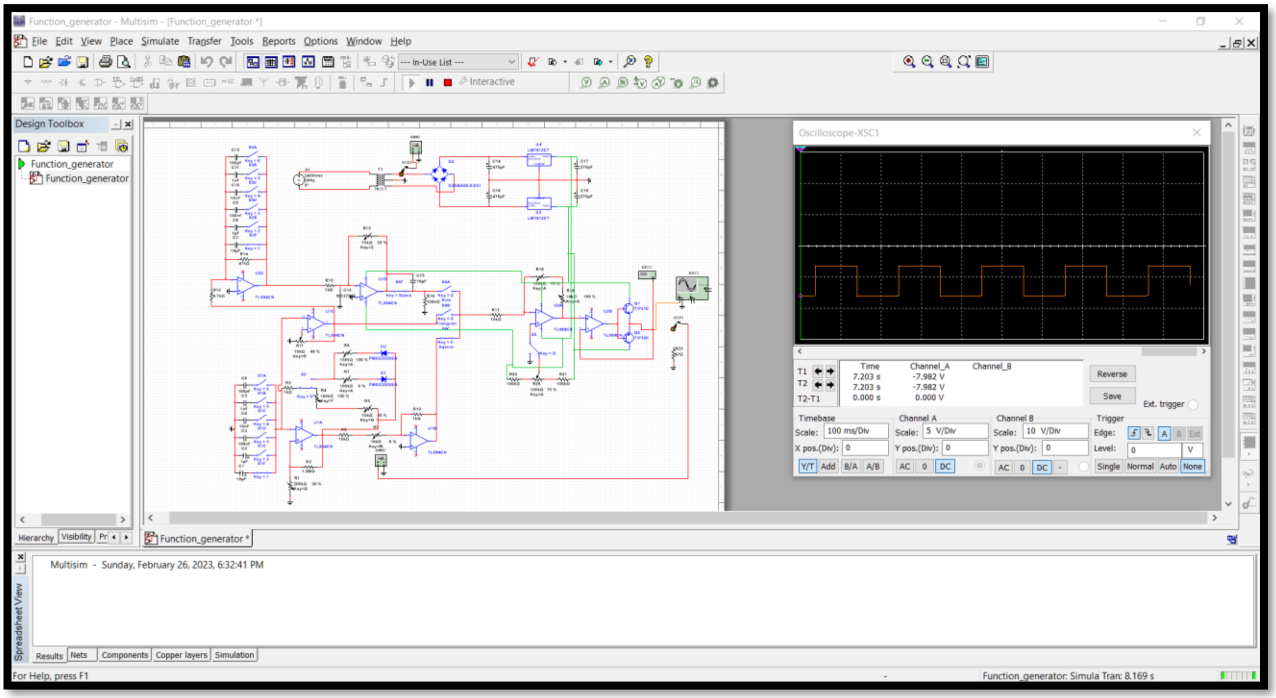
U2C is an integrating amplifier which converts the triangle wave into a series of parabolas that looks a lot like a sine wave. The results are a reasonable approximation for sine wave. The gain of this integrating Opamp is frequency dependent thus we use two deck capacitors to compensate the gain term to maintain a useful voltage. R14 is used to correct the drift that happens by integrating tiny inherent offsets in the Opamp.

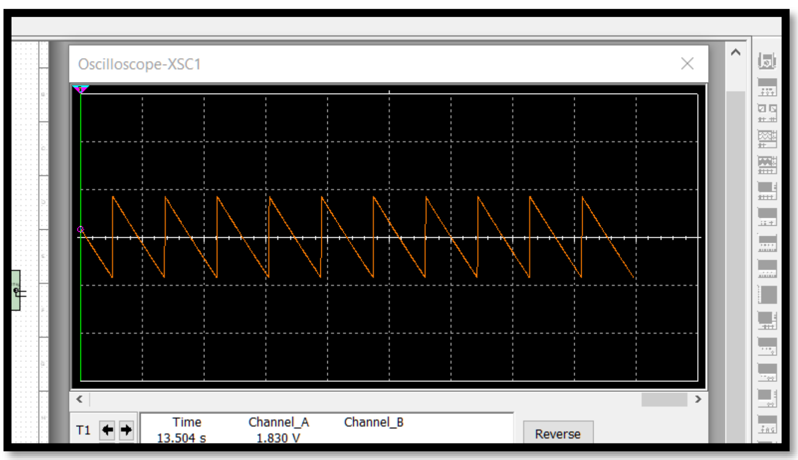
U1D is an inverting amplifier that is used for calibration. The low pass filter ($f_{3dB} = 600kHz$) is connected directly before eliminates some of the overtones to make the sine wave better. The high pass filter ($f_{3dB} = 0.1Hz$) directly after eliminates any offset reaming after drift correction.

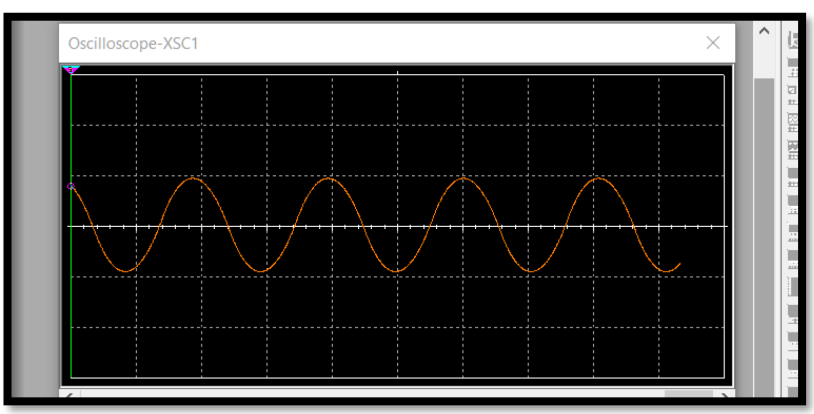
U2A is another inverting amplifier we adjust the gain with the variable resistors R18, R19. U2B is a unity gain amplifier that is driving the push-pull amplifier.

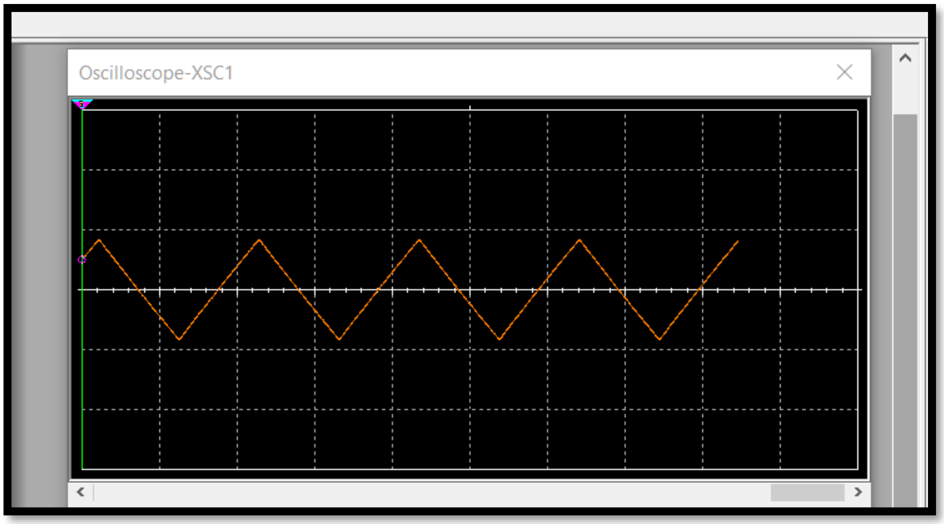
Offset mode can be selected with the switch S5 and can be adjusted with POT R20.

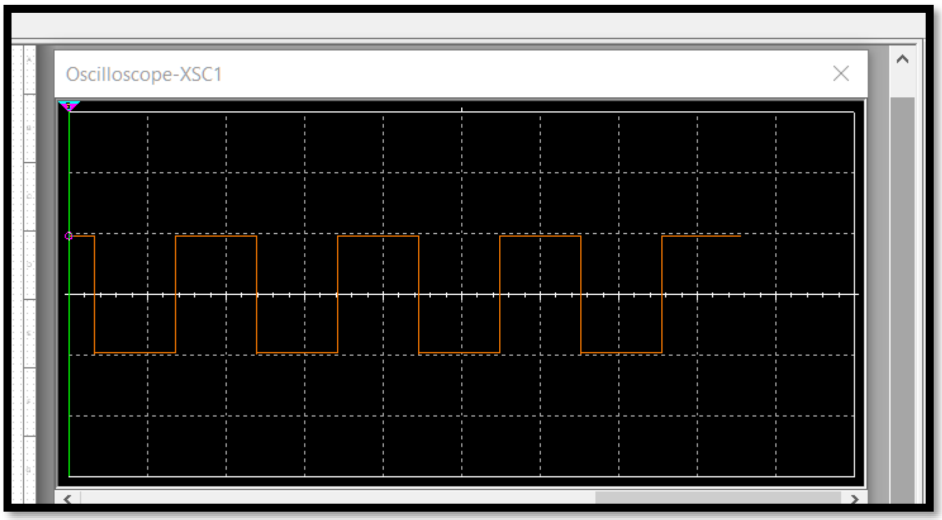
5. Simulation Results








Oscilloscope-XSC1


Oscilloscope-XSC1

6.Components

7.1 Opam TL084CN

The TL08x JFET-input operational amplifier family is designed to offer a wider selection than any previously developed operational amplifier family. Each of these JFET-input operational amplifiers incorporates well-matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit. The devices feature high slew rates, low input bias and offset currents, and low offset-voltage temperature coefficient. Offset adjustment and external compensation options are available within the TL08x family. Important characteristics are,

- Low Power Consumption
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- Low Total Harmonic Distortion . . . 0.003%
- High Input Impedance.
- Latch-Up-Free Operation.
- High Slew Rate 13 V/µs
- Common-Mode Input Voltage Range Includes VCC+

7.2Transistor TIP32C

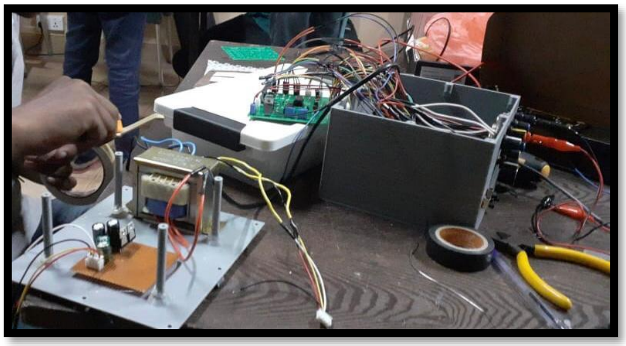
The TIP32C is a silicon Epitaxial-base PNP power transistor in Jedec TO-220 plastic package. It is intended for use in medium power linear and switching applications. The complementary NPN type is TIP31C.

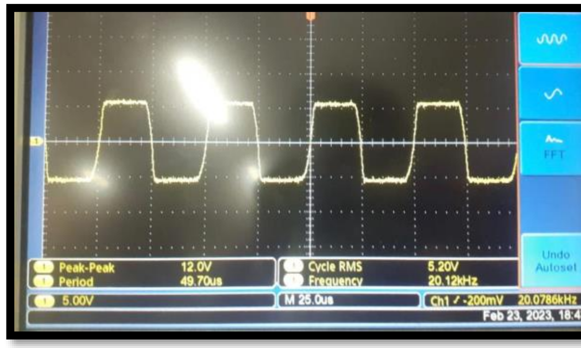
Symbol	Parameter	Value	Unit
V_{CBO}	Collector-base voltage ($I_E = 0$)	-100	V
V_{CEO}	Collector-emitter voltage ($I_B = 0$)	-100	V
V_{EBO}	Emitte-base voltage ($I_C = 0$)	-5	V
I_C	Collector current	-3	A
I_{CM}	Collector peak current ($t_P < 5ms$)	-5	A
I_B	Base current	-1	A
P_{TOT}	Total dissipation at $T_{case} = 25°C$ $T_{amb} = 25°C$	40 2	W W
T_{stg}	Storage temperature	-65 to 150	°C
T_J	Max. operating junction temperature	150	°C

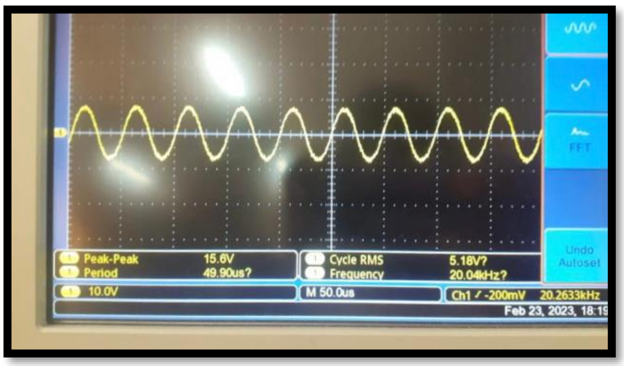
7.3 Shottky diode

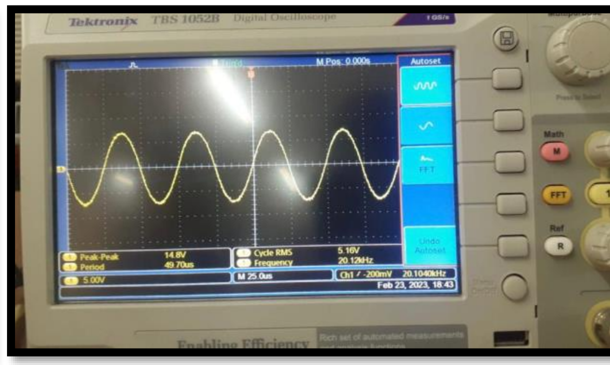
The schottky diode is a type of metal – semiconductor junction diode, which is also known as hot-carrier diode, low voltage diode or schottky barrier diode. The schottky diode is formed by the junction of a semiconductor with a metal. Schottky diode offers fast switching action and has a low forward voltage drop

7.Testing



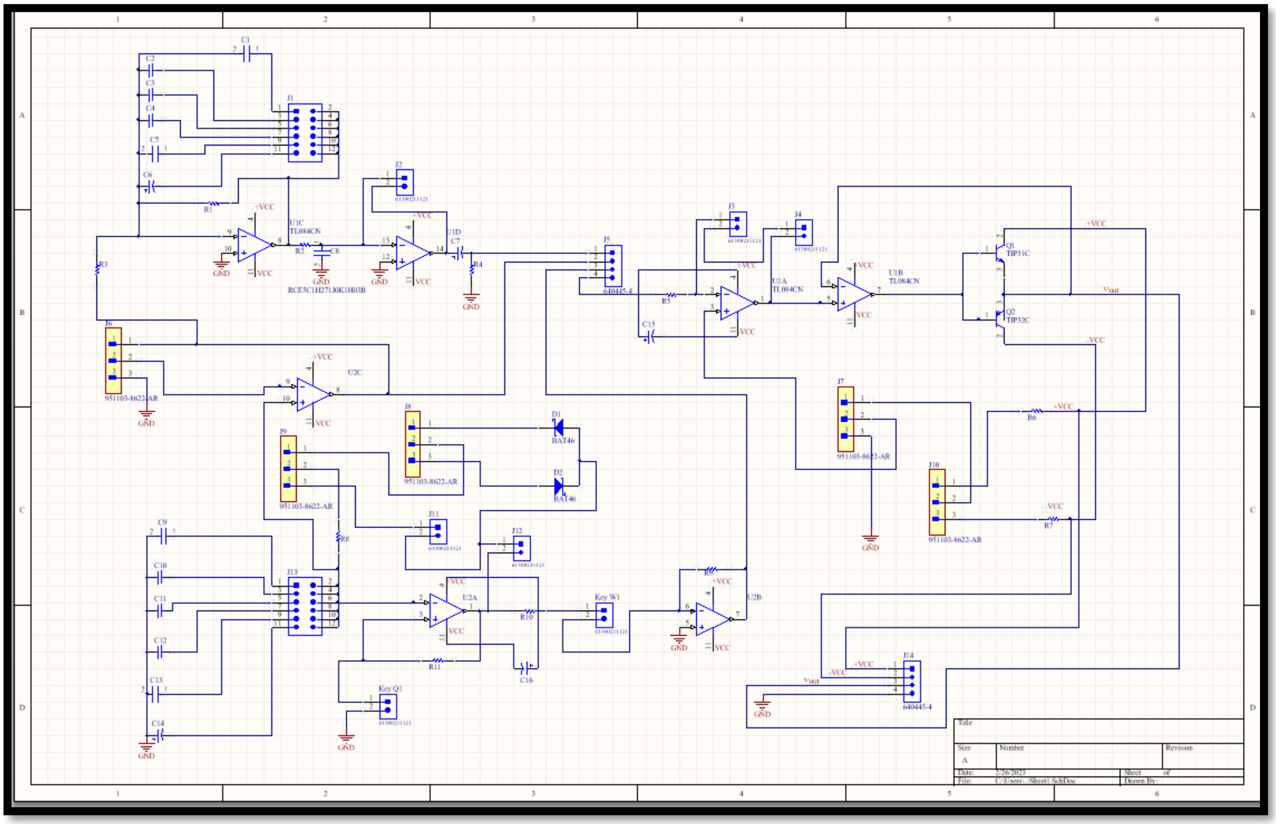




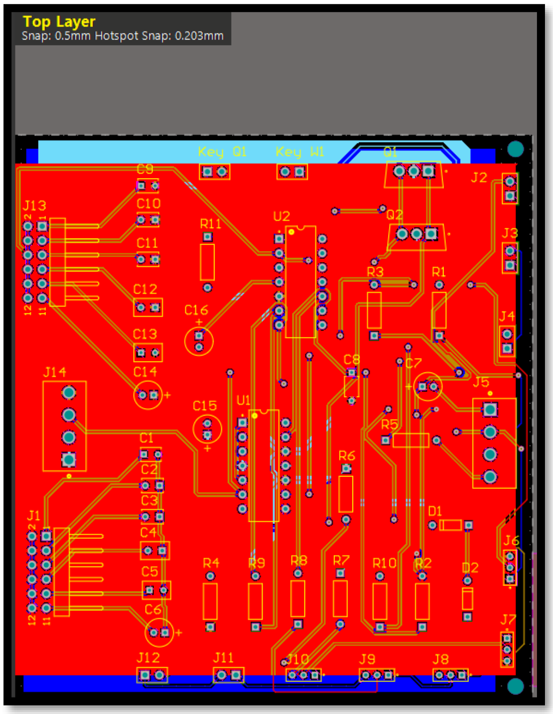


It turns out that testing the function generator is a little more difficult than it appears. We must ensure that it is calibrated and get the best components for the circuit because it gives distortions easily. As an instance, because the opam ic's slew rate was incorrect in the data sheets, we frequently had to import it again. It cannot be used at both high and low frequencies if the slew rate is insufficient.

8.Schematic



9.PCB design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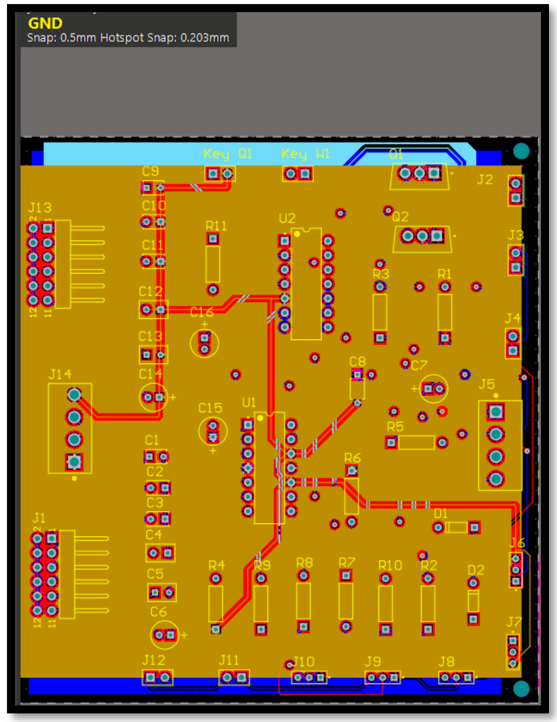
GND
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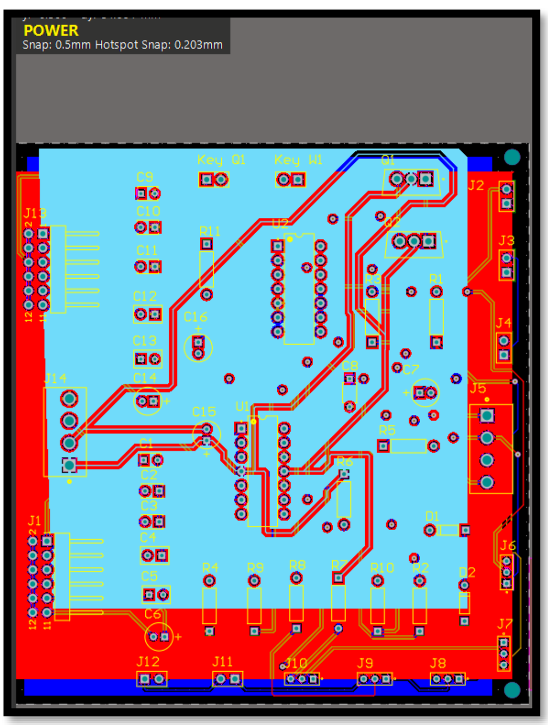
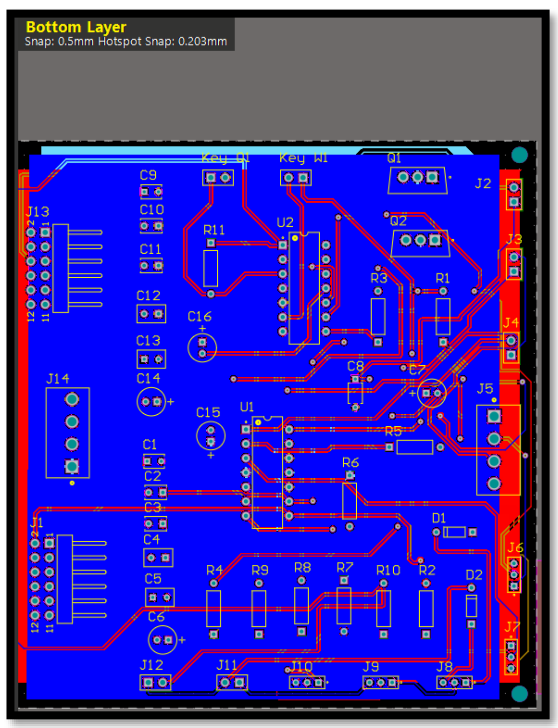
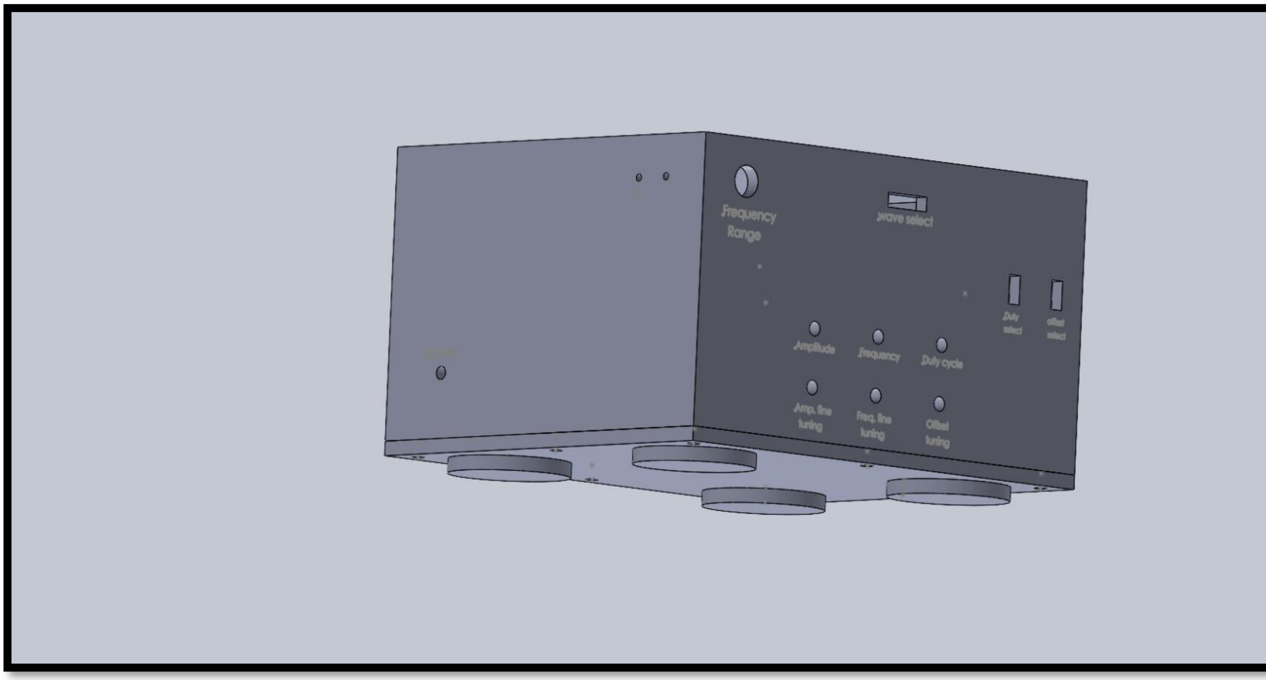
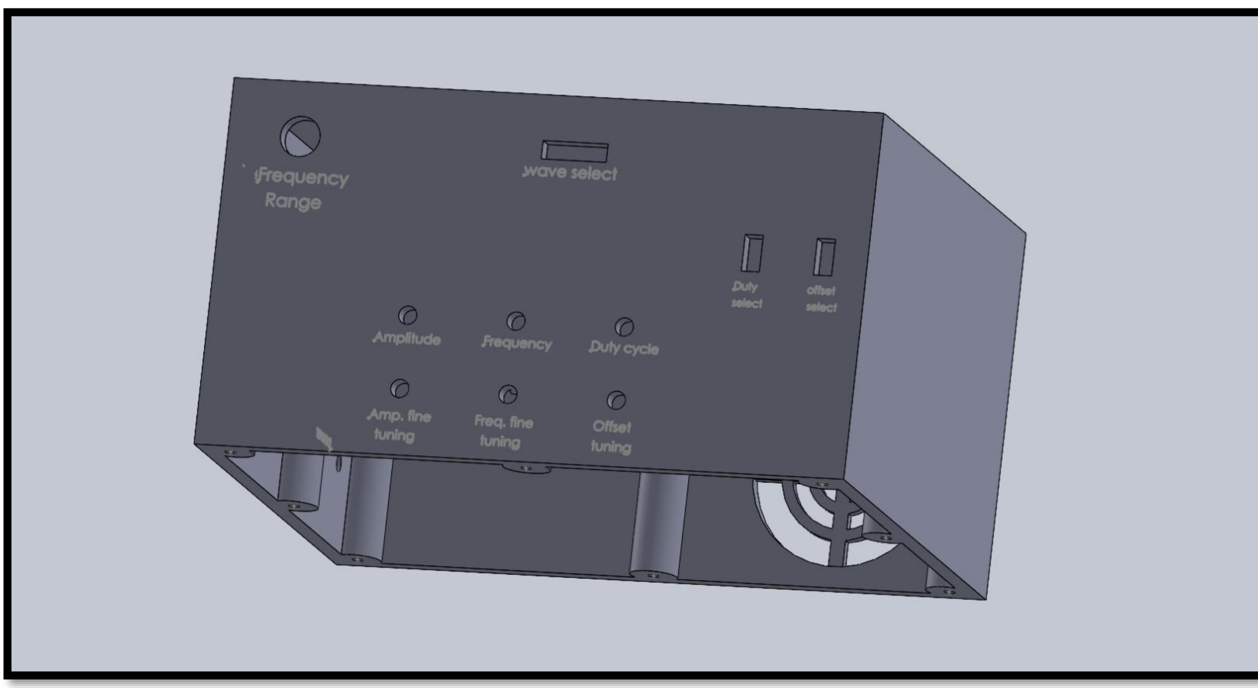

POWER
Snap: 0.5mm Hotspot Snap: 0.203mm


Bottom Layer
Snap: 0.5mm Hotspot Snap: 0.203mm

10.Enclosure Design





11.Individual contribution

Dhanomika A.P.N	200123H	- Alternative Circuits , Slide Show and report, schematic and PCB design, Soldering and Testing
Kurrshanth V	200331T	- Circuit designing and calculations , Simulations, Soldering and Testing, Slide show, Power supply
Gunatilake P.T.B.	200439G	- Enclosure design, Documentations, Circuit designing and Calculations , Soldering and Testing
Wijesiri H.D.K.G.	200728R	- PCB design and Schematic design, Enclosure design, Soldering and Testing,

12.Conclusion

It is possible to create a function generator solely using analog parts like resistors, opamps, and capacitors. With greater confidence, this design is capable of producing sine, square, sawtooth, and triangle waves. It is accurate enough to be used as a genuine function generator, with output amplitude variables ranging from 0 to 10 volts and output frequency variables ranging from 20 to 20000 Hz. It can generate a clean, noise-free waveform and drive a 50 load without experiencing substantial waveform distortion or amplitude reduction. The project has successfully met its stated requirements.

13.Future works

The project will cost less than 20,000 rupees, whereas a real function generator costs about $200. Hence, developing and marketing our own function generator locally and globally is considerably more affordable. By exporting this, we can make money that will assist us deal with Sri Lanka's economic difficulties. To sell this globally, we may either develop our own website and sell it there or utilize Ebay, AliExpress, or Amazon.

14.Acknowledgemnet

Our group members have taken efforts in this project. However, it would not have been possible without the kind support and help of many lecturers and instructors. I would like to convey my sincere thanks to all of them.

15.References

https://www.instructables.com/Function-Generator/

https://www.youtube.com/watch?v=gFSt21dXpb8

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