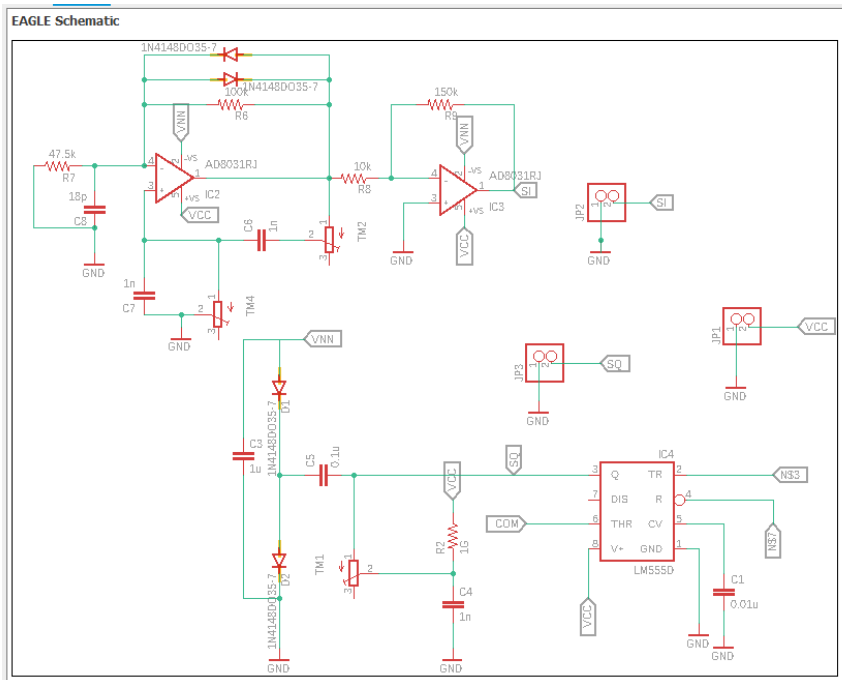
Signal Generator

Objective: Designing a Signal Generator capable of producing Sine wave and Square wave using 555 timer IC.

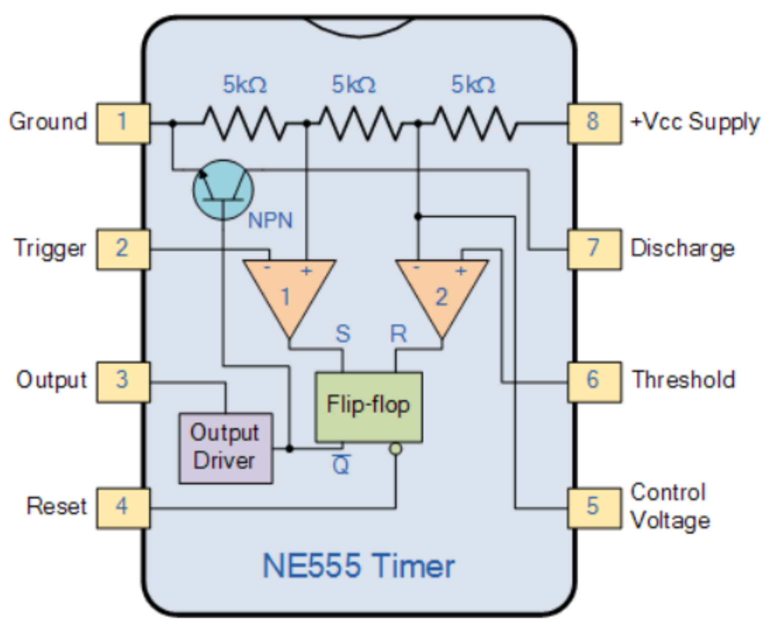
List of components used :

Name	Quantity
1N4148	4
LT1413A	1
AD3080	1
NE555	1
1G ohm	1
47,5K ohm	1
100k ohm	2
10K ohm	1
18pF	1
1nF	3
0.01uF	1
1uF	2

Eagle Schematic :


EAGLE Schematic
1N4148DO35-7
100k
R6
VNN
47.5k
R7
AD8031RJ
IC2
18p
C8
VCC
GND
C6
1n
TM2
10k
R8
150k
R9
IC3
SI
GND
VCC
JP2
1n
C7
TM4
VNN
D1
C3
1u
C5
0.1u
JP3
SQ
JP1
IC4
Q
TR
DIS
R
THR
CV
V+
LM555D
COM
N$3
N$7
R2
1G
C4
TM1
D2
C1
0.01u

555 timer IC :


5kΩ
5kΩ
5kΩ
Ground
1
8
+Vcc Supply
NPN
Trigger
2
7
Discharge
1
2
S
R
Output
3
Flip-flop
6
Threshold
Output Driver
Q̄
Reset
4
5
Control Voltage
NE555 Timer

The 555 timer is an integrated circuit (IC) that contains various functional blocks, including comparators, flip-flops, a voltage divider network, and an output driver. It is designed to provide precise timing and oscillator functions in electronic circuits.

The main concept of the circuit revolves around the concept of oscillators, An oscillator is a device or circuit that generates an electronic signal or waveform with a repetitive pattern. The primary purpose of an oscillator is to produce a stable and predictable frequency or timing reference.

There are different modes of operation for an oscillator , those are as follows :

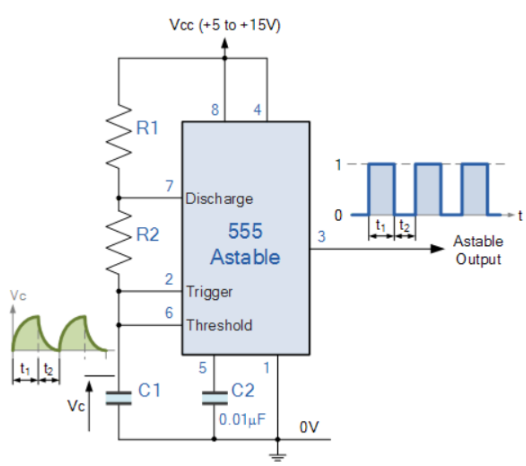
- Monostable Mode : Monostable mode, also known as a "one-shot" mode, is a mode in which the oscillator produces a single output pulse of a specific duration in response to an input trigger signal. Once triggered, the oscillator output transitions from a stable state to an unstable state for the specified pulse width and then returns to the stable state. Monostable oscillators are used in applications such as time-delay circuits, pulse stretching, and debouncing.

- Bistable Mode : Bistable mode refers to the operation of an oscillator in which it has two stable states and remains in either state until triggered to transition to the other state. This mode is often associated with flip-flops and latches, where external signals cause the output to toggle between the stable states. Bistable oscillators are utilized in applications such as digital memory elements, electronic switches, and sequential logic circuits.

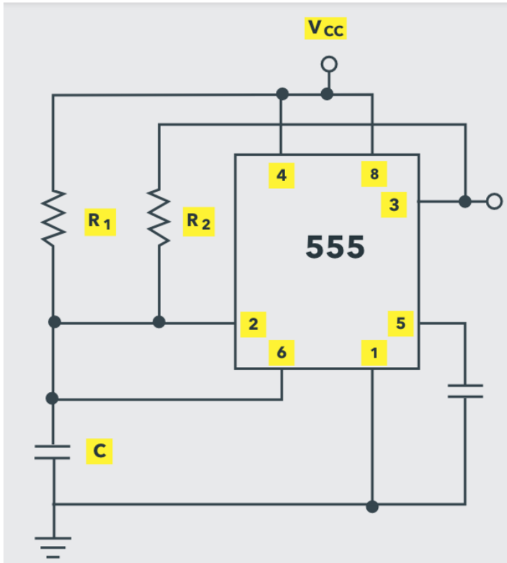
- Astable Mode : Astable mode refers to the operation of an oscillator where the output waveform is continuously oscillating between two states without any stable state. This mode is characterized by a repetitive waveform with a specific frequency and duty cycle. The output can be a square wave or a pulse waveform. Astable multivibrators based on ICs like the 555 timer often operate in this mode and find applications in timing circuits, pulse generators, and clock dividers

For our use, the 555 timer will act in the Astable Mode of operation oscillating between Vcc and 0 v.

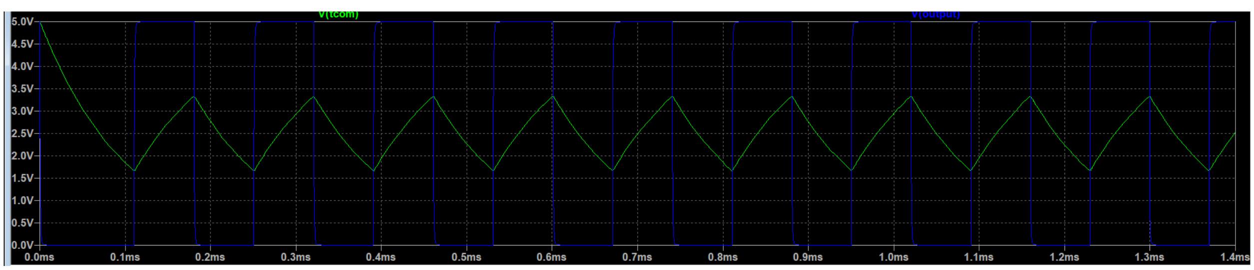
Since we need to produce a square wave we need to produce a wave with an assured 50% Duty Cycle. The basic Astable Multivibrator circuit with a 555 timer is as shown. In this circuit the charging of the capacitor takes place through R1 and R2 and discharging only through R2 as such the rising and falling curves have different time constant and such that



the time for charging and discharging is different .This is reflected in our produced square wave, which does not have a 50% Duty Cycle. As a result, we improve on this design by changing the circuit so that it only uses only one resistor to discharge.



In this circuit, the capacitor C charges and discharges through R2 only. When Pin 3’s output is High C starts charging up and it discharges when the output is low. When the circuit starts, the output gets high in the form of an impulse due to which there is a very sudden increase in the voltage across the capacitor, this peak is never reached by the capacitor again.



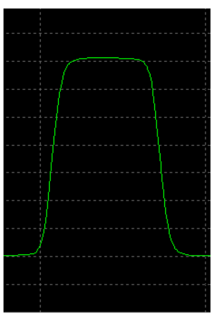
This diagram shows the initial peak mentioned.

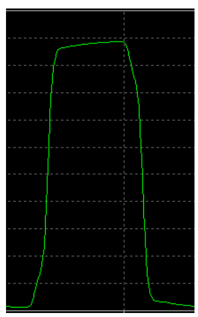
Time period Of the square wave :

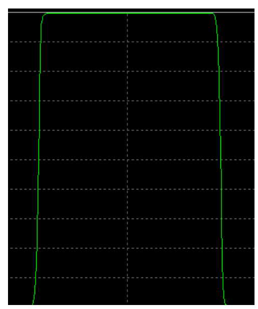
$$f = \frac{1}{0.693(2R_2).C} \text{ Hz}$$

The connection through R1 resistor is there to make sure that the capacitor is initially charged to Vcc, and in order to make sure that it doesn't interfere with the further operation of the circuit and wave formation. It should be quite high as compared to R2. In our circuit therefore we have chosen the value of R1 as 1 G ohm.

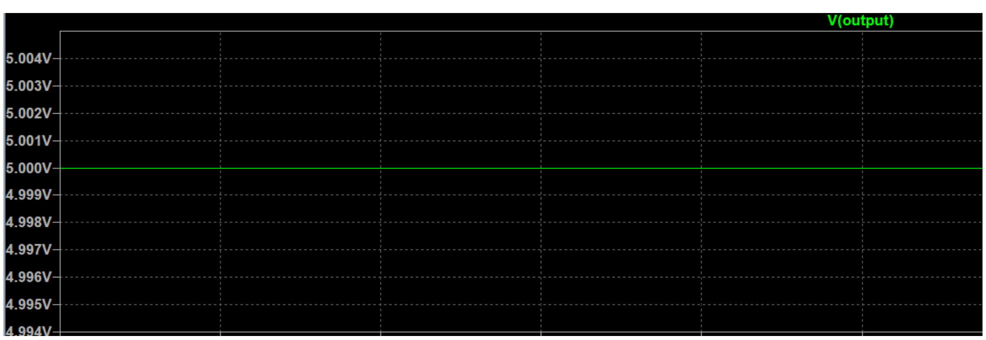
We can also see from the equation that by changing the value of R2, we can change the frequency of the square wave. While the equation implies that we can vary R2 as high or low as we want, this is not the case in practice. The Waveform exhibits distortion at extremely low R2 values.


1 ohm


100 ohm

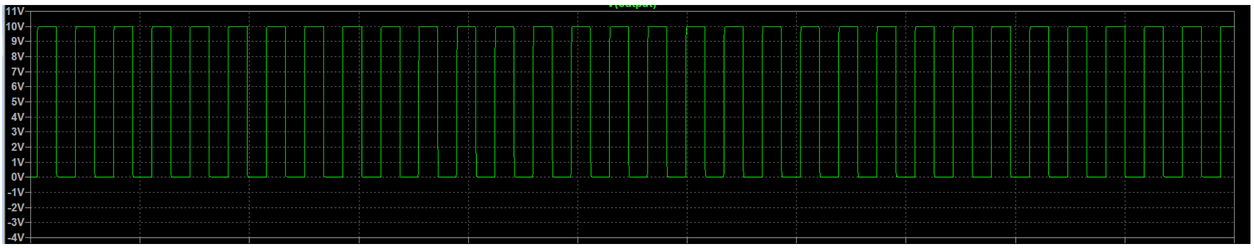

1K ohm

The deviation is pretty clear to see. On the other hand if we tremendously increase the value of R2 such that R2>= R1, the result is as shown.



This is the output for when R2 = R1 = 1G.

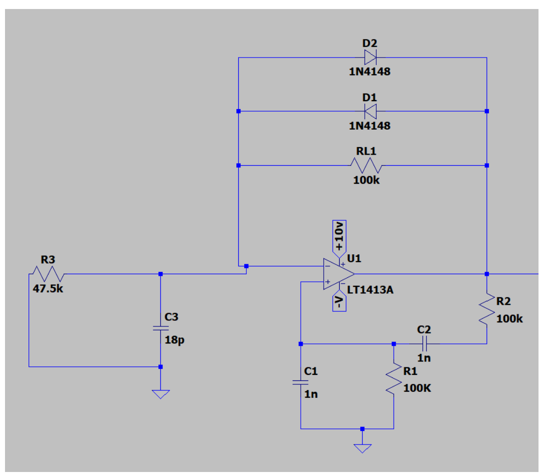
There the value of R2 can be varied using a potentiometer to vary the frequency. The safe limit of varying seems to be from 250 ohm to 0.1G ohm, which, with the value used as 1nF, gives us a band-width of approximately **10 Hz to 2.8 MHz** for the square wave.



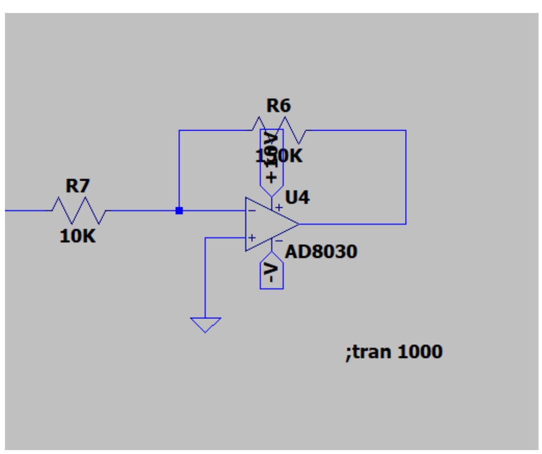
For producing the Sine-wave, we used the classical Wein Bridge circuit with some slight modifications in order to get sine waves of suitable amplitude.

This circuit consists of the mainly two parts :

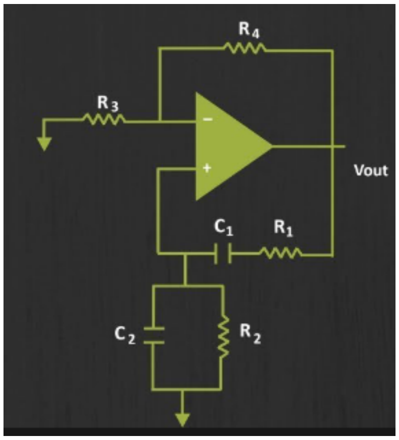
- **Oscillator**



- **Amplifier.**

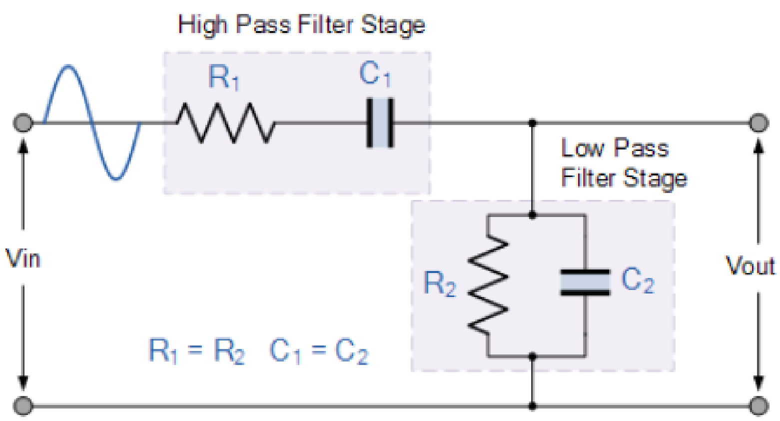


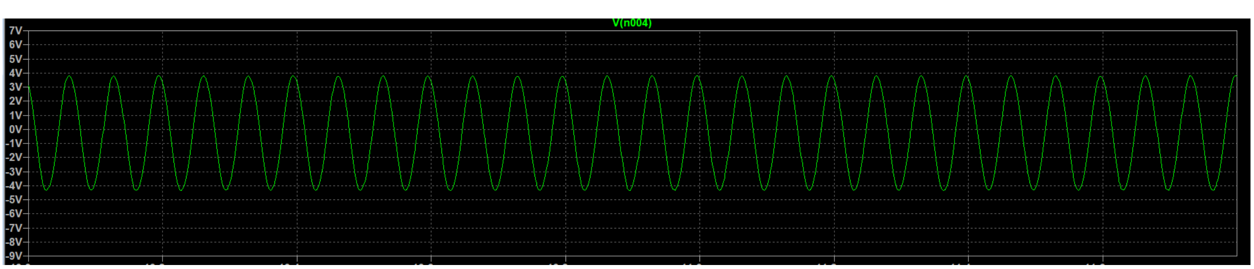
The Wien bridge oscillator is a type of electronic oscillator that generates sine waves. It can generate a large range of frequencies.



Here the op-amp is used in a non-inverting configuration with R3 and R4 giving the Open -loop gain as 1 + R4/R3.

The feedback network consists of R1,C1,R2,C2 respectively. This circuit being an oscillator works on the principle of positive feedback.





The feedback consisting of R1,C1,R2 and C2 ultimately performs as a Band-pass Filter allowing a certain set of frequencies to pass through. Among that band-width of frequency there exists a certain frequency for which the pass shift of the above circuitous zero and the gain is ⅓.

From Calculations it can be shown for a given value of R1,C1,R2,C2 the resonant frequency is given as :

$$f = \frac{1}{2\pi\sqrt{R_1C_1R_2C_2}}$$

In the special case of R1 = R2 = R and C1 = C2 =C, we have :

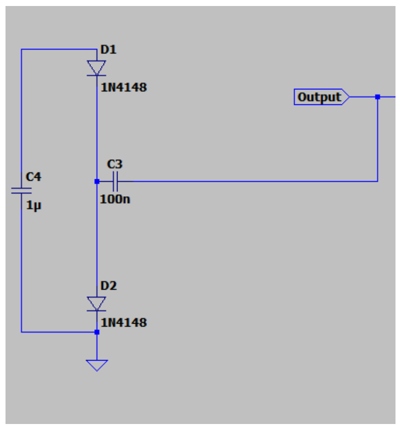
$$f_r = \frac{1}{2\pi RC}$$

The purpose of anti-parallel diodes in our Wien bridge oscillator is to provide non-linear feedback. For stable oscillator operation, the closed-loop gain must be 1. If it is greater than 1, the oscillations will increase with time. If it is less than 1, the oscillations will decay.

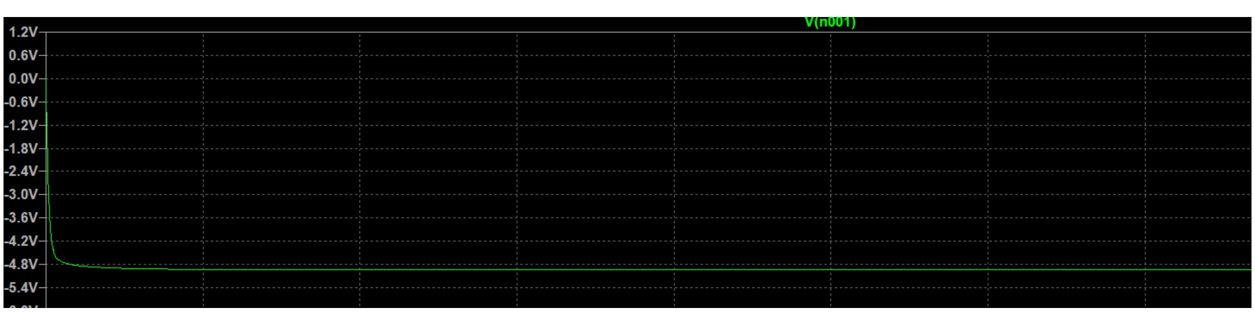
By using a non-linear feedback element, as the signal increases in amplitude, the gain decreases. If the signal decreases in amplitude, the gain increases. This permits there to be a level for the signal where the gain is exactly 1, and the oscillator is stable.

Diodes have an exponential/logarithmic voltage/current relationship. Although their use to automatically adjust gain in a Wien bridge oscillator leads to some distortion of the output so that it is not exactly sinusoidal, in practice, the distortion is often small enough for the purposes at hand. If not, another method of gain regulation is needed, or a different oscillator topology.

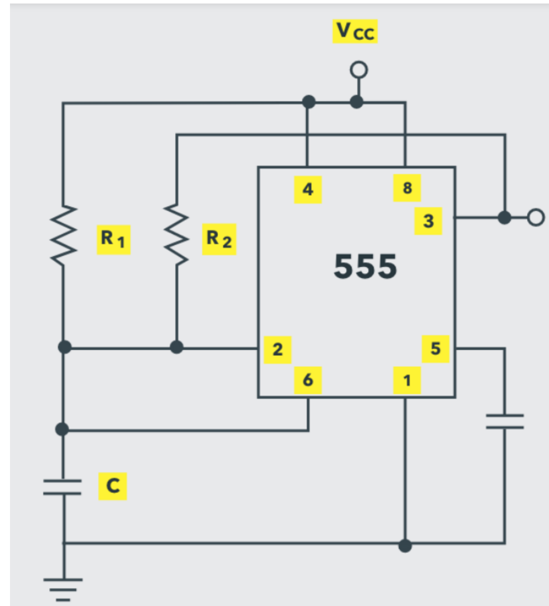
For the operational amplifiers used, we needed +ve and -ve voltages in order to feed the supply rails. In my complete circuit I have taken advantage of the square produced by 555 timer to produce negative voltage and feed it to the op-amp. The output of the 555 timer is connected to the given circuit as shown :



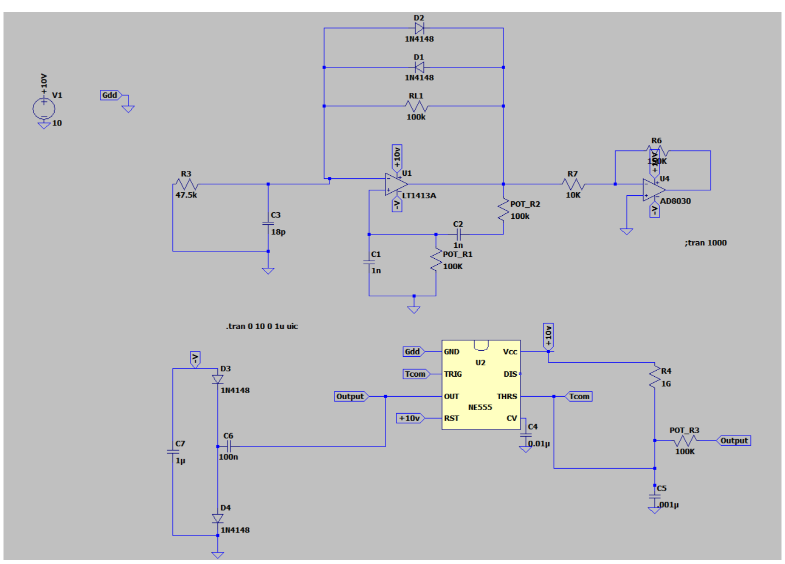
When there is a positive peak at output current flows through C3 ,D2 to the ground while charging up C3. During this time, D1 remains reverse-biased. When the output falls down to 0 V, the current direction will change and now it will start flowing from C4 ➡ D1 ➡ C3 and forward. During this C3 discharges while C4 starts charging and hence building voltage across it. The voltage across C4 will be negative with respect to ground.



<u>Challenge faced</u> : For the proper production of negative voltage by the 555 timer, we should lower the resistance of R2 to around less than 100K ohms, even 10k ohms will also work, but doing so will affect the frequency of the square wave. But if this is not done, the negative voltage produced will not be ideal and there would be high distortion in the sine wave produced. Therefore, during the use and production of sine waves, the square wave's is compromised to a certain extent. This is one of the limitations of the circuit.



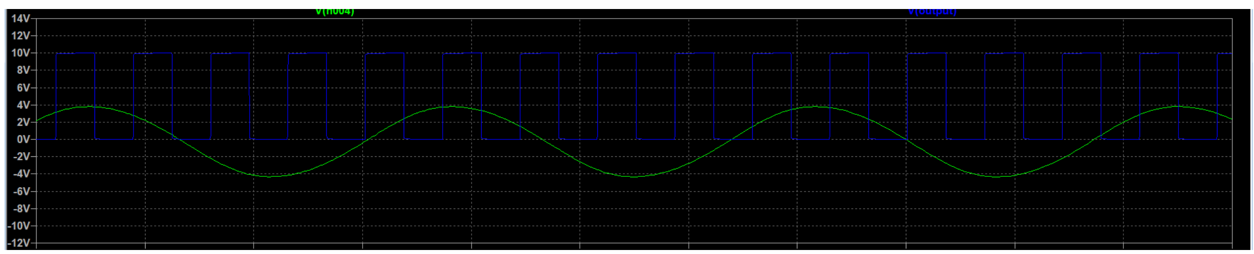
Frequency Control :



In the circuit diagram, there are three resistances which are marked as POT_Rx. These are actually potentiometers to be used in the PCB which control the frequency of the waves.

POT_R3 is responsible for controlling the frequency of square waves produced.

POT_R1 and POT_R2 are responsible for controlling the frequency of the sine wave produced from the diode-stabilized wien bridge circuit. But the most symmetric sine wave is produced and then resistance by POT_r1 and POT_R2 is the same.



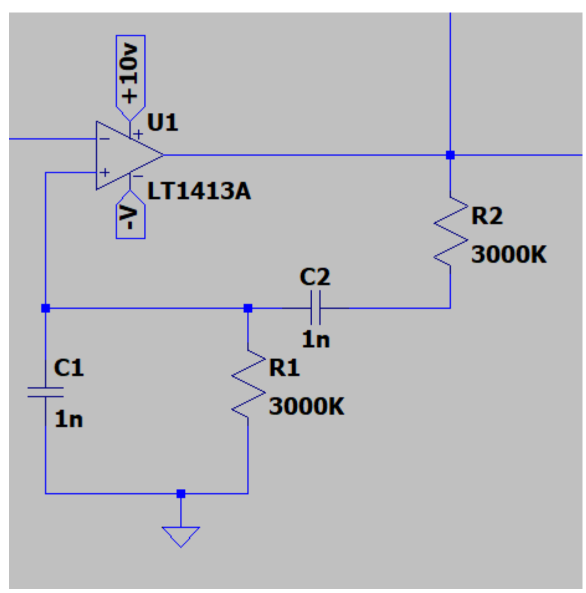
<u>Bandwidth</u>:

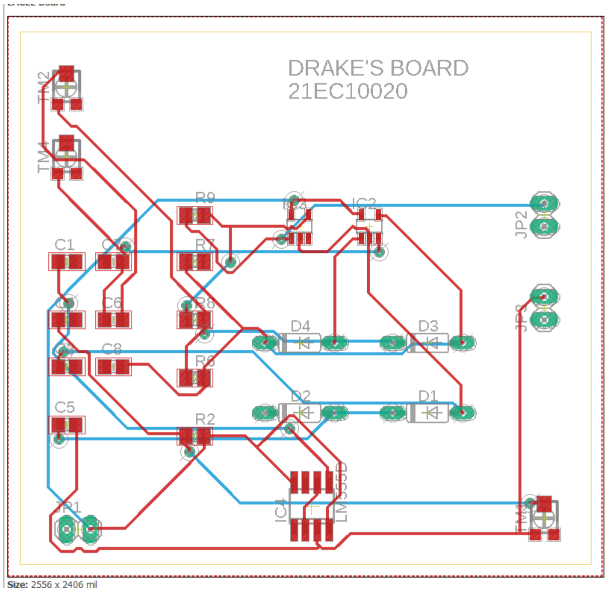
A mentioned earlier the band-width limitation for square wave is :

10 Hz to 2.8 MHz

While testing for the limitations for sine wave's frequency, the safe limit for varying R1's and R2's values simultaneously gives the safe range of 1k ohm to 3M ohm, which in turn translates to a bandwidth of about :

50Hz to 1.6 MHz.





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