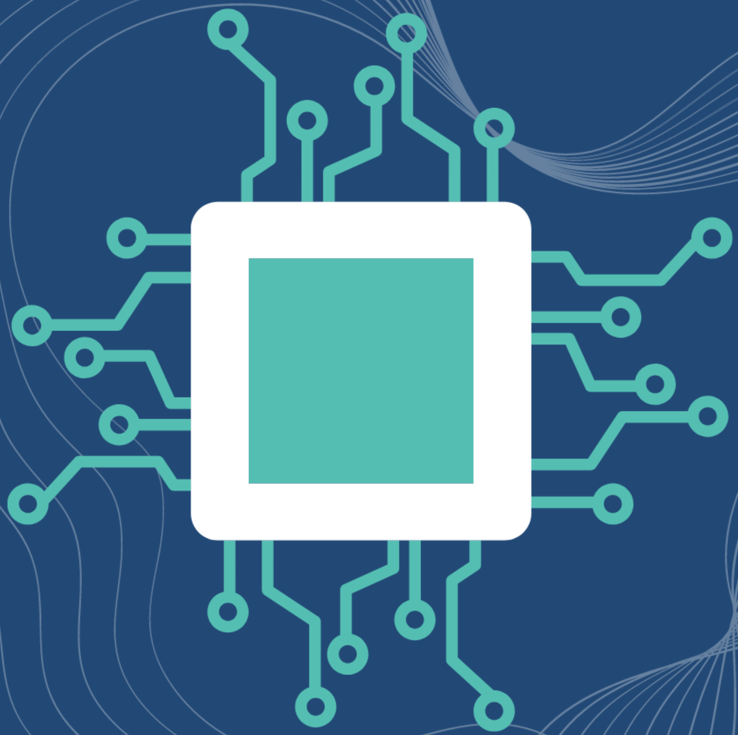
PROJECT REPORT

Designing a function generator by operational amplifier



EEE 208(S)

ELECTRONIC CIRCUITS II LABORATORY

BANGLADESH UNIVERSITY OF ENGINEERING & TECHNOLOGY

ELECTRICAL AND ELECTRONICS ENGINEERING

Report Title

Designing a function generator by operational amplifiers

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Problem statement

A function generator is a device to generate different types of wave, mainly sinusoidal, square, triangular and sawtooth waves.

Using different circuit configuration and properties of the op amp, a suitable Function Generator will be designed and displayed in this project.

1. Using PSPICE, suitable circuits for the desired Function Generator will be designed.
2. Secondly, the outcomes and operations will be verified by running the simulation and operating the generator by changing circuit parameters manually.
3. Thirdly, a few examples of new waves generated by the superposition of these waves will be constructed to show the usage of that device.
4. Finally, a few example circuits, also mainly consisting of basic op amp circuits, will be powered by this function generator and the output should be verified theoretically to show the accuracy of this device.

Introduction

A function generator is an electronic test instrument that generates different types of electrical waveforms over a wide range of frequencies. Some of the most common waveforms produced by the function generator are the sine wave, square wave, triangular wave and sawtooth shapes.

Function generators are used in a wide variety of applications, including:

- Testing and debugging electronic circuits
- Analyzing the performance of electronic components
- Creating training signals for electronic systems
- Generating audio signals for musical applications
- Generating waveforms for scientific experiments

There are two main types of function generators:

- Arbitrary waveform generators (AWGs) can generate any waveform that can be mathematically described. This makes them very versatile, but they can also be more expensive than other types of function generators.
- Standard function generators generate a limited set of waveforms, such as sine waves, square waves, and triangular waves. They are less versatile than AWGs, but they are also less expensive.

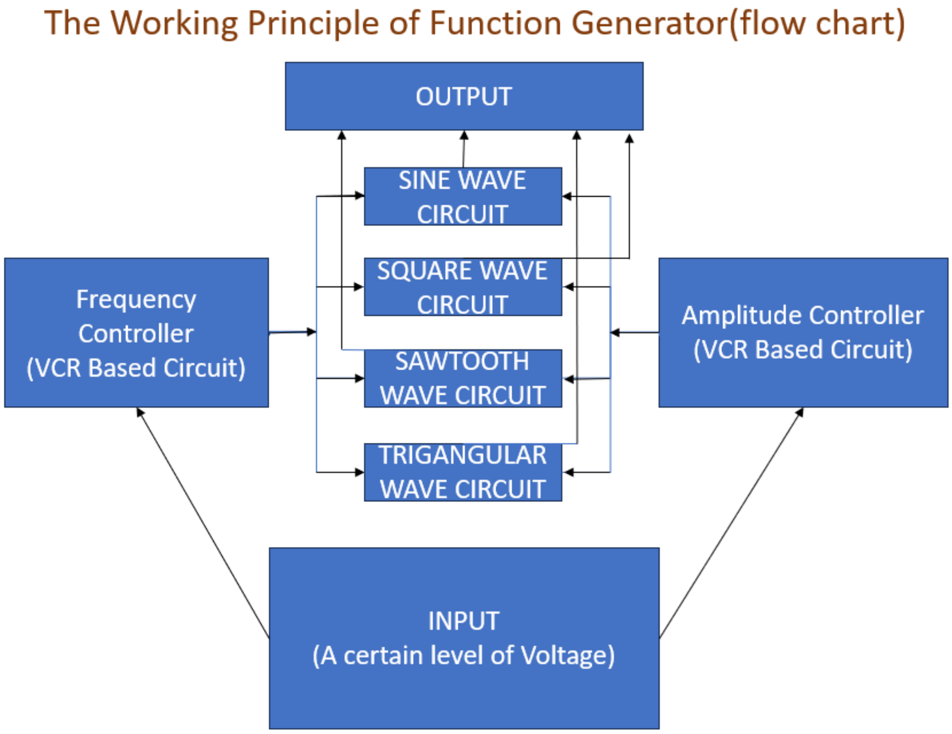
The function generator in our project is a standard function generator. It can generate sine waves, square waves, triangular waves and sawtooth waves. The amplitude and frequency can be adjusted.

Here are some additional things to know about function generators:

- The output voltage of a function generator is typically in the range of millivolts to volts.
- The frequency range of a function generator can be from a few hertz to several kilohertz.
- The waveform accuracy of a function generator depends on the model and price.

Proposed design

The basic idea of this project is illustrated by a flow chart which is given below: -



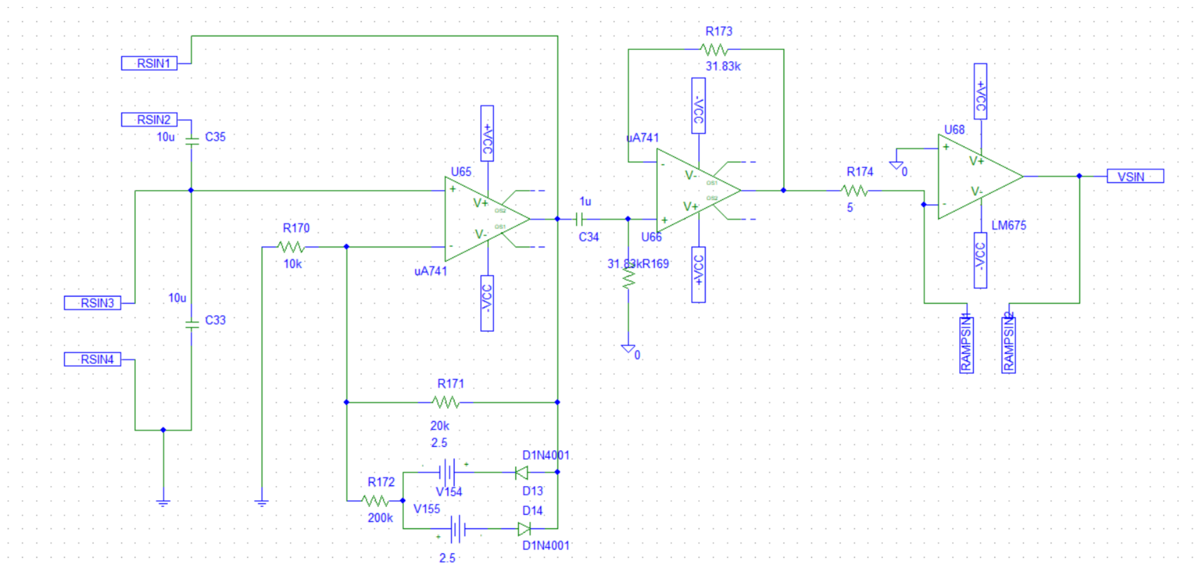
Oscillator circuits built with operational amplifiers will be used to generate the signals. Comparators, high pass filters etc. built with op-amps will be used for making the output signal more precise. Desired frequency and amplitude of the output signal can be obtained by using voltage controlled resistors. Adder circuits built with op amps will be used to superimpose two of the output signals.

Circuit diagrams with explanation

The circuit is designed for 4 different wave shape generation. So here we used four different circuit to generate those basic wave shapes. Here we used different circuits to maintain perfection, independency and less noise.

Sine wave generator

Here we used the modified version of Wien bridge oscillator.

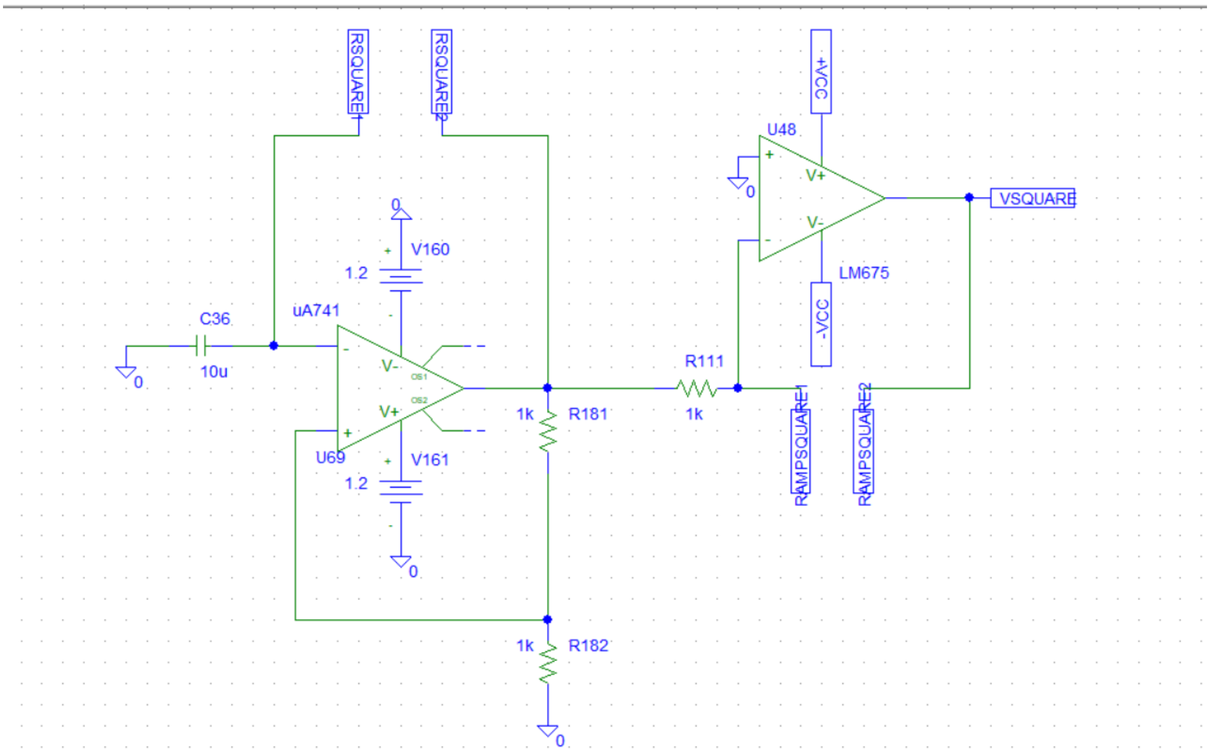


Here we controlled the frequency by changing the resistance of (RSIN1, RSIN2) and (RSIN3, RSIN4) points. Here we used parallel diode-based model to stabilize the voltage gain over the time. Then we used a 20db high pass filter to cancel out the unexpected DC offset voltage from the sine wave. Then we used LM675 a power amplifier to control the o/p voltage. We used LM675 because it has a high rated current (about 3A) which is more than enough for a function generator. We know that the frequency of the output of Wien bridge oscillator depends on the product of the resistances and capacitances of the series and parallel branches connected with positive terminal of the op amp ua741. We have kept both the capacitors fixed.

Here the frequency $f = \frac{1}{2\pi * 10u * \sqrt{(RSIN1,RSIN2)(RSIN3,RSIN4)}}$ and amplitude is controlled by feedback resistor of LM675.

Square Wave Generator

Here we used a free-running or multi vibrator as a square wave generator. Resistor R181 and R182 form a voltage divider to feed back a fraction of the output to the (+) input. Resistor (RSQUARE1, RSQUARE2) provides a feedback path to the (-) input.



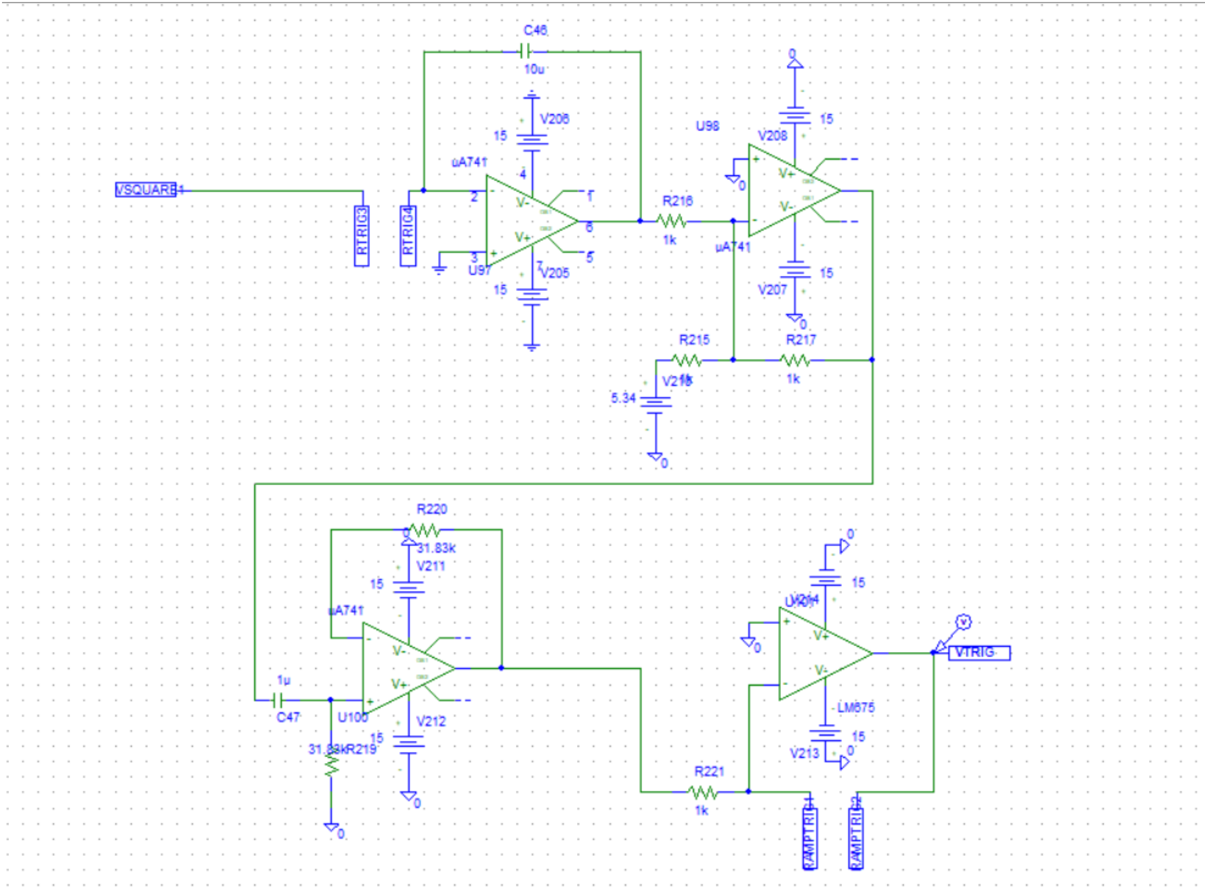
When output voltage reaches saturation voltage, current flows through (RSQUARE1, RSQUARE2) to charge the capacitor C36. As long as the capacitor voltage is less than voltage of + terminal, the output voltage remains at positive saturation voltage. When capacitor voltage charges to a value slightly greater than voltage of + terminal of op amp, the (-) input goes positive with respect to + input. This switches output from positive saturation voltage to negative saturation voltage. Now current discharges the capacitor to 0V.

Here we control the frequency by changing the resistance value at the point (RSQUARE1, RSQUARE2) by using a VCR. Here we used LM675 a power amplifier to maintain thee gain of the square wave.

B=$\frac{R162}{R161+R162}$; $f = 2 * \ (\mathrm{RSQUARE1}, \mathrm{RSQUARE2}) * 10\mathrm{u}\ \ln(\frac{1+\mathrm{B}}{1-\mathrm{B}})$

Triangular Wave Generator

Here we used a basic circuit to generate bipolar triangular wave.

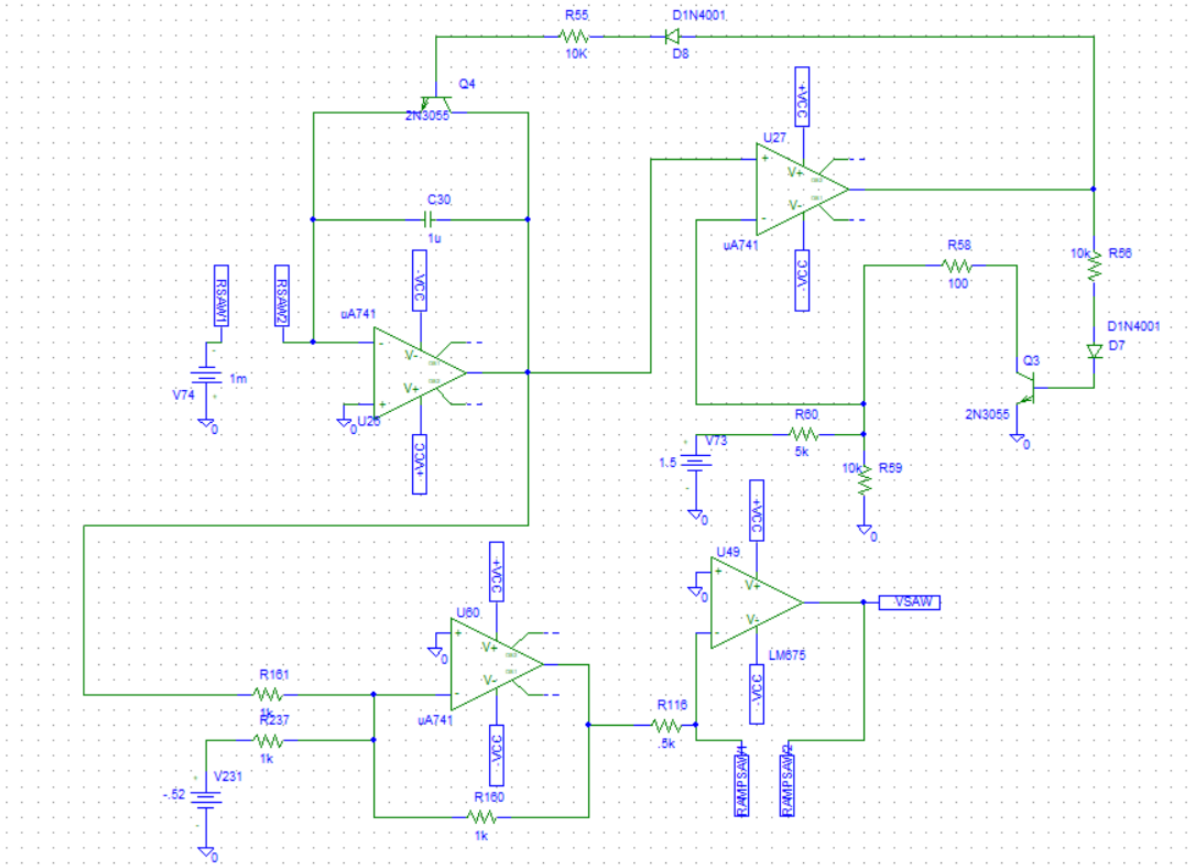


Here we simply integrate a square wave to generate a triangular wave. After that we added a inverting adder circuit to maintain zero reference voltage. The value is set for a certain capacitor value. Then by passing the wave through a high pass filter and a power amplifier we generate our desired triangular wave. Here the calculations are done to make the triangular wave very precise. The frequency is controlled by the point (RTRIG3, RTRIG4). And amplitude of output voltage is determined by feedback resistor of LM675.

B=$\frac{R162}{R161+R162}$; $f = 2 * (\mathrm{RTRIG3}, \mathrm{RTRIG4}) * 10\mathrm{u} \ln(\frac{1+\mathrm{B}}{1-\mathrm{B}})$

Sawtooth Wave generator

Here we used a low parts count sawtooth wave generator. Op-amp U26 is a ramp generator. Since V74 is negative, ramp voltage can only go up. The ramp voltage is monitored by the + input of comparator U27. If ramp voltage is below the voltage of (-)ve terminal of U27 (reference voltage) , the comparator’s output is negative. Diodes protect the transistors against excessive reverse bias. When ramp voltage rises to just exceed reference voltage, the output voltage of comparator goes to positive saturation. This forward biases transistor Q4 into saturation. The saturated transistor acts as a short circuit across the integrating capacitor C30. C30 discharges quickly through Q4 to essentially 0V. When output voltage of comparator goes positive, it turns Q3 to short circuit. As C discharges toward 0V, it drives the ramp voltage rapidly toward 0V. The ramp voltage drops below reference voltage, causing output voltage of comparator to go negative and turn off Q4. C30 begins charging linearly, and generation of new sawtooth wave begins.



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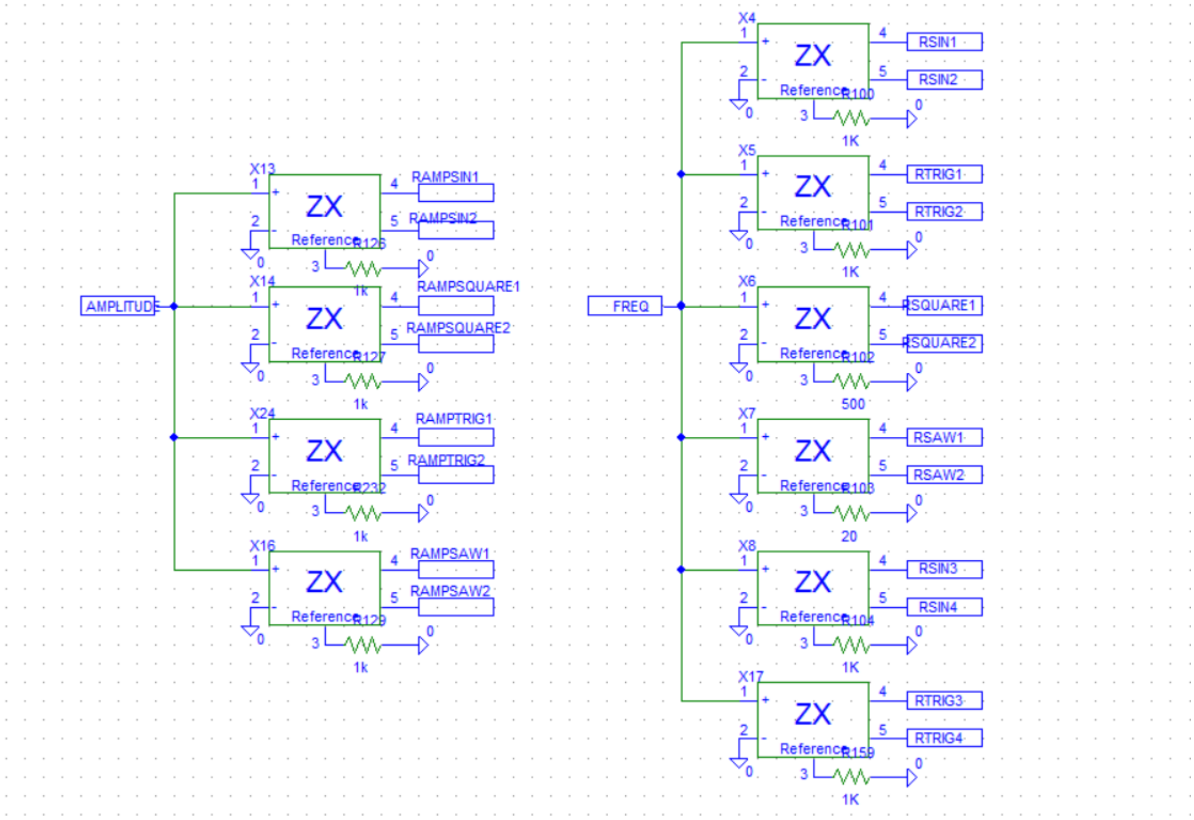
Here the frequency of the circuit is controlled by changing the resistance between (RSAW1, RSAW2) by using VCR. Then we used an inverting adder to maintain zero reference voltage and a power amplifier to generate the sawtooth wave of desired amplitude. We maintain the output voltage gain by changing the resistance between (RAMPSAW1, RAMPSAW2). The frequency is $f = \frac{0.001}{(RSAW1,RSAW2)*1u}$ and Vo= (Rf) of LM675.

Amplitude and frequency control

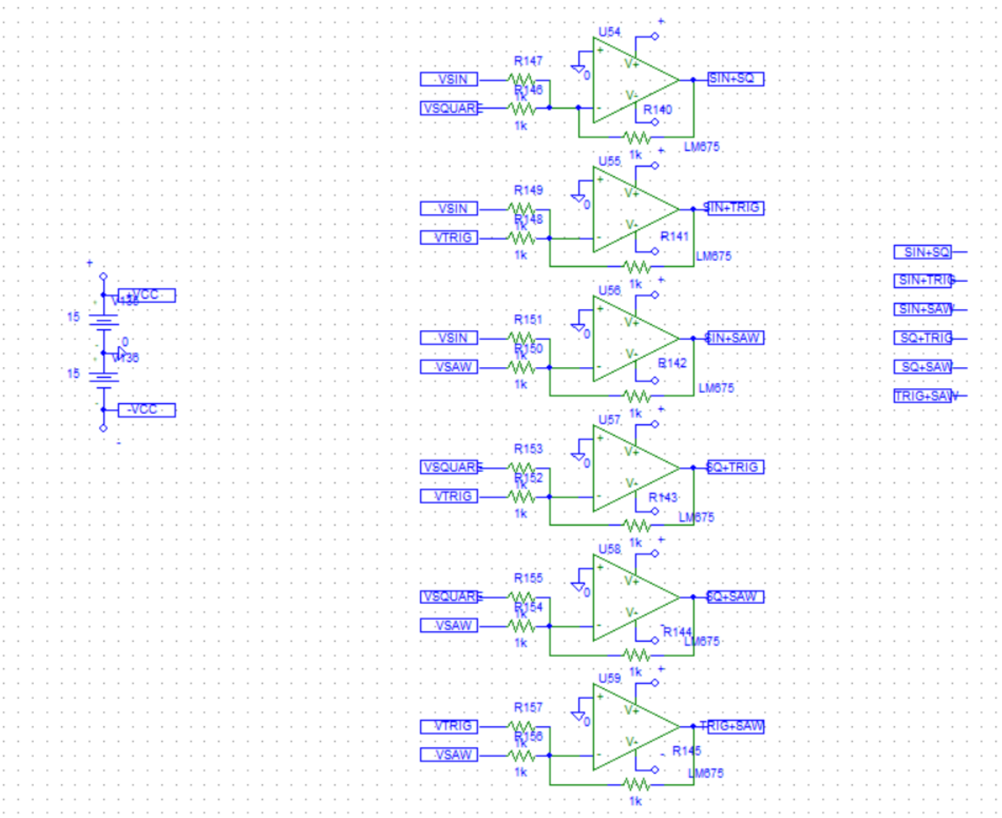
VCR (Voltage Controlled Resistor)



VCR is a kind of digital potentiometer. Its resistance can be controlled by applying variable voltage. We used this because we have to change the value of resistances of several circuits simultaneously. This can be a great option. Analog potentiometer cannot be controlled this much easily and accurately. Here we used four VCR to maintain the output voltage level and 6 VCR to maintain the frequency of the whole system.

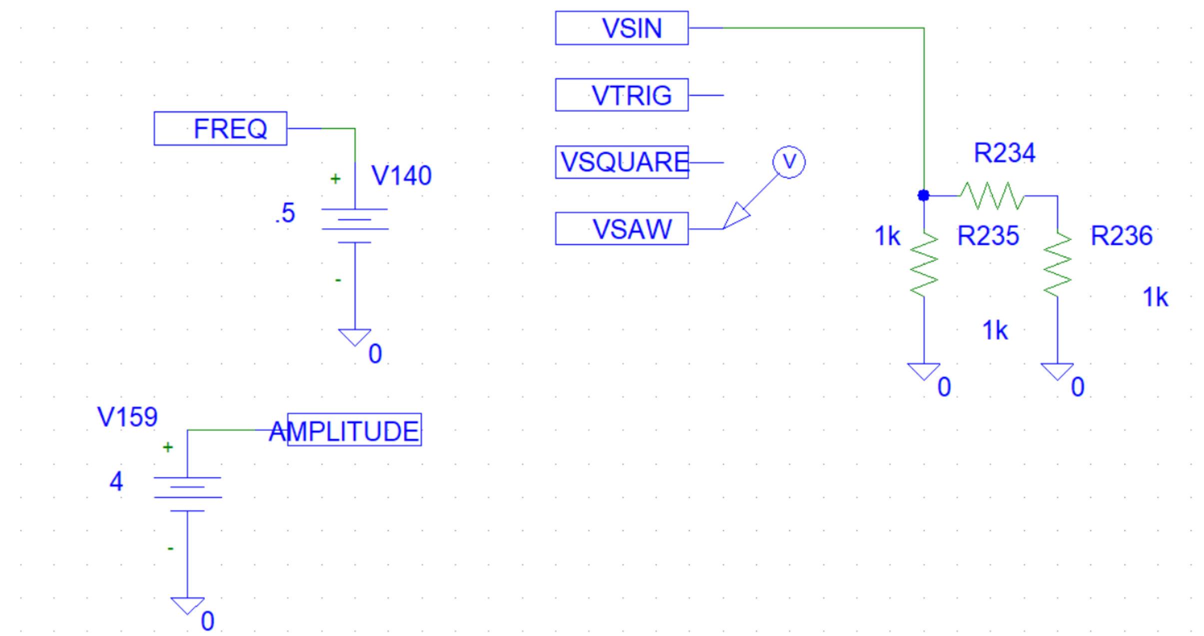
Superposition of waves

After generating basic waves ,now we can superimpose two waves as well as three or four waves to generate different level of waves. We are using inverting adder circuit by using LM675 power amplifier.



Output interface: -

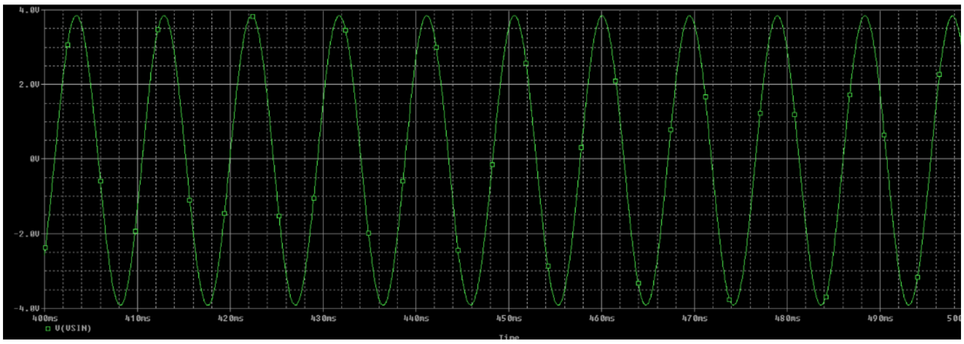
Here V140 control the system frequency and V159 controls the amplitude of the system. The off-page connectors are the output terminals of the function generator.



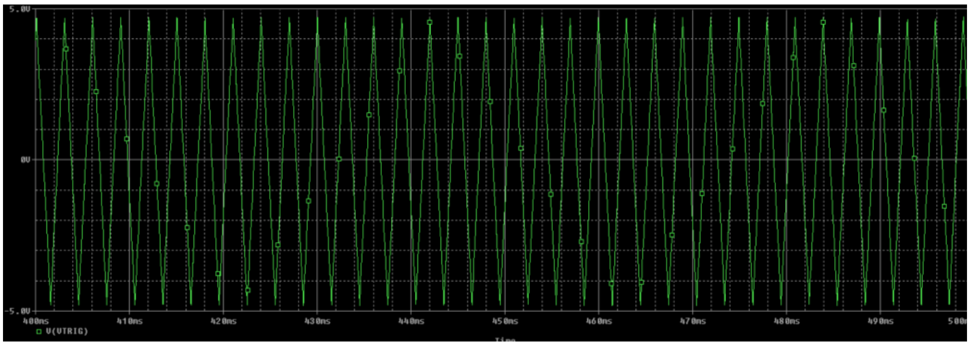
Outputs

When frequency control voltage is 0.15V and amplitude control voltage is 4V, then then outputs without any load are: -

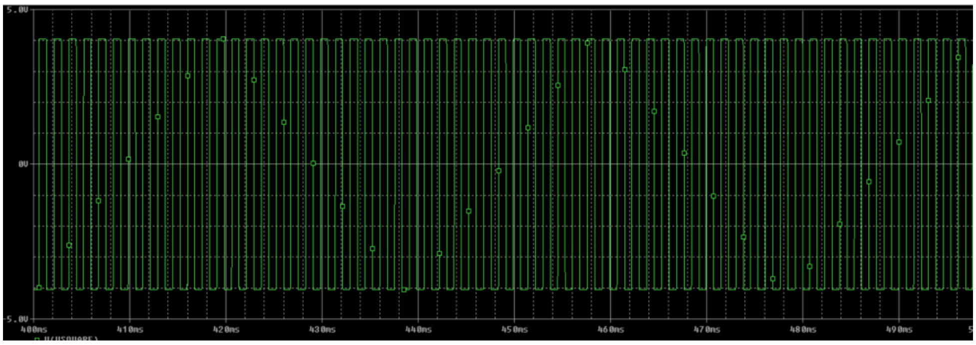
Sine



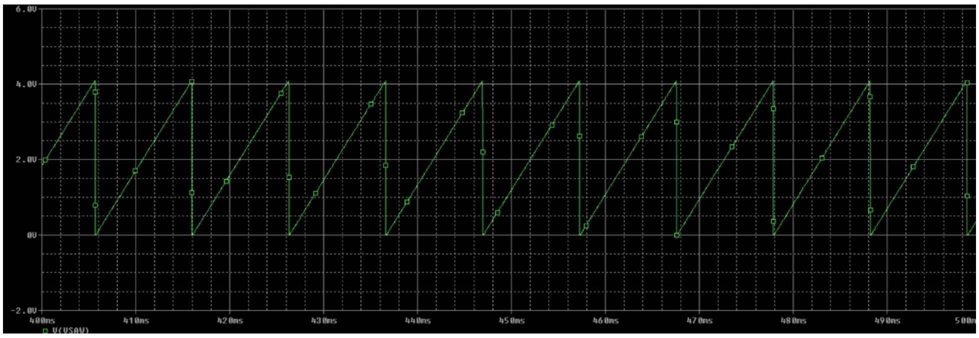
Triangular



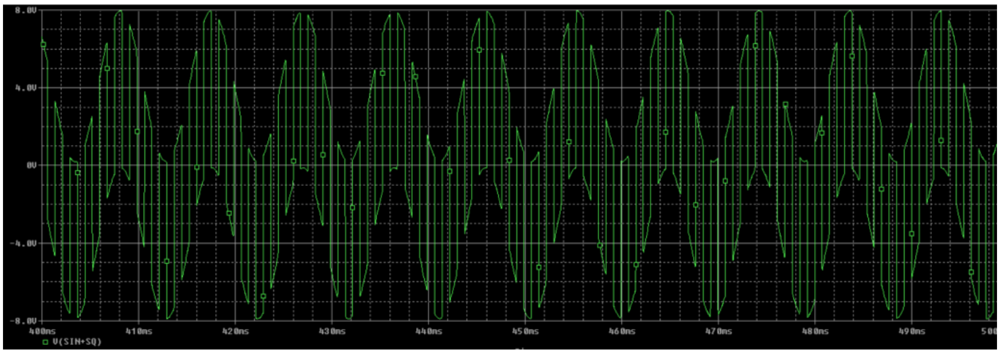
Square



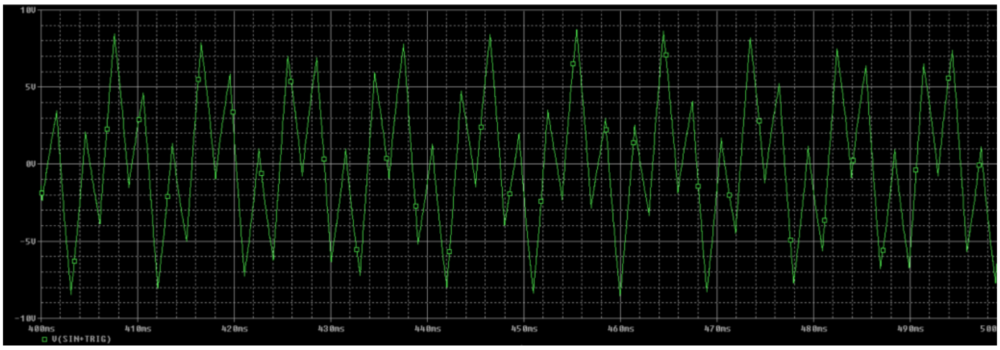
Sawtooth



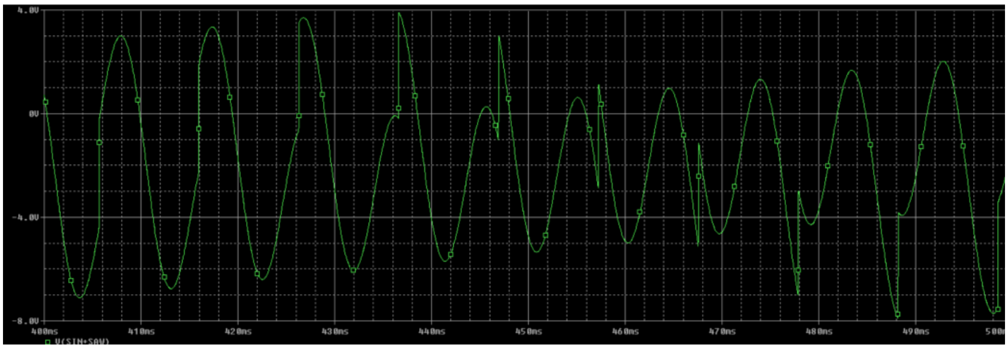
Square + Sine



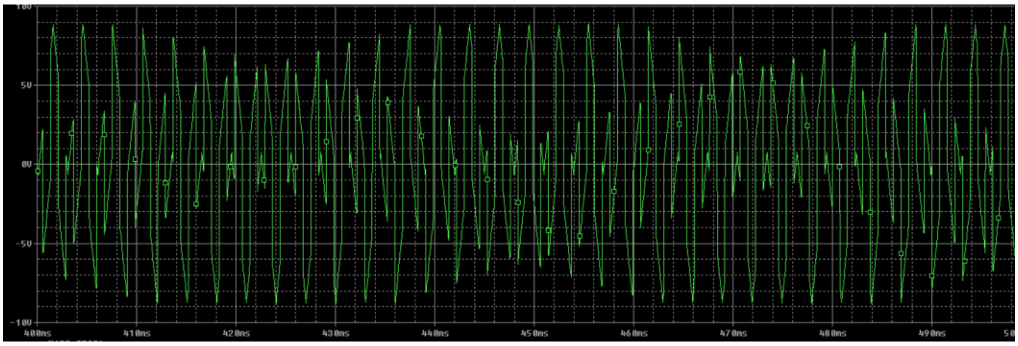
Sine+ Triangular



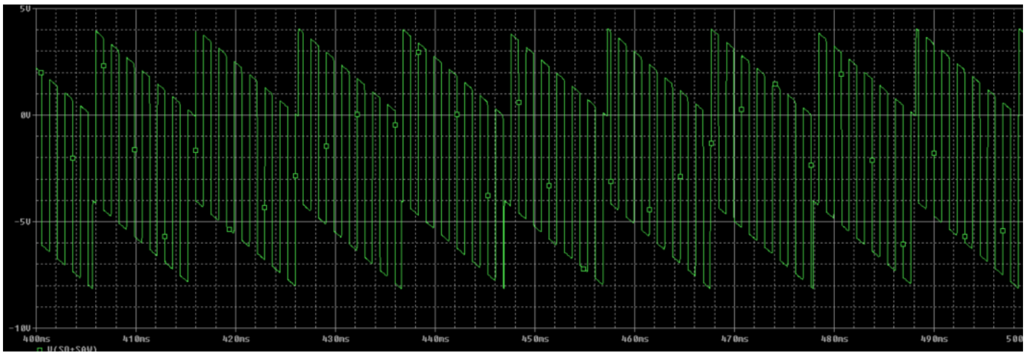
Sine + Sawtooth



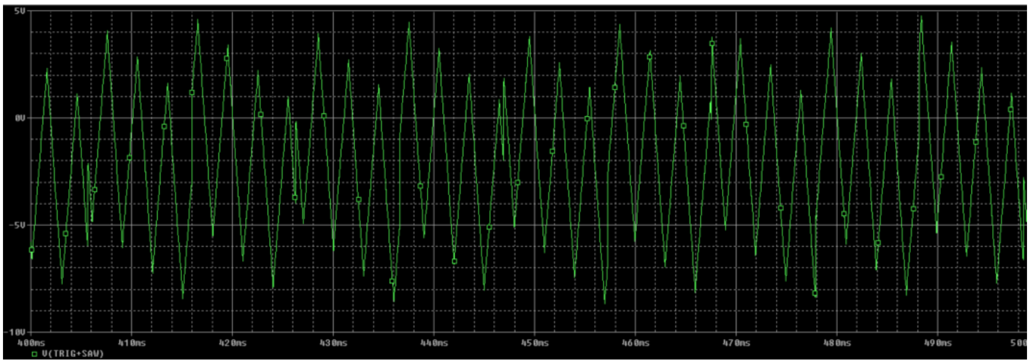
Square+ Triangular



Square + Sawtooth



Triangular+ Sawtooth

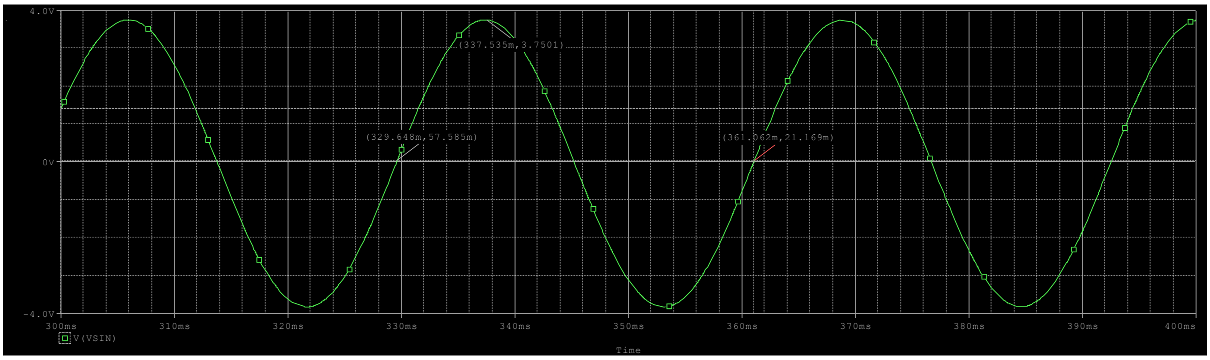


Here amplitude is close to 4V and frequency is 650Hz.

Test cases

1. **Generating a sine wave of 8V p-p and 32Hz frequency**

   $f = \frac{1}{2\pi * 10u * \sqrt{(\mathrm{RSIN1,RSIN2})(\mathrm{RSIN3,RSIN4})}}$, Here ($\mathrm{RSIN1, RSIN2}$)= ($\mathrm{RSIN3, RSIN4}$)=0.5K ohm; Rf= 4k ohm

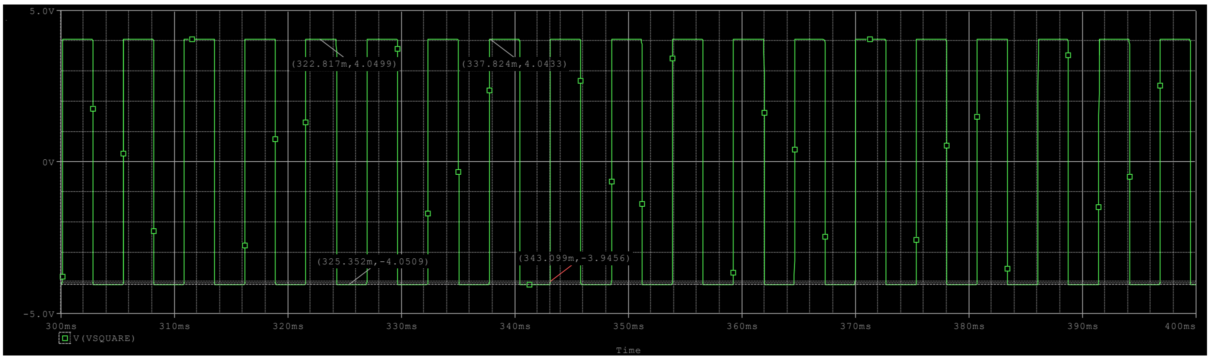


From simulation we can see that the output matches theoretical calculation.

2. **Generating a square wave of 8V p-p and 180Hz frequency**

B=$\frac{R162}{R161+R162}$; $f = 2 * \text{ (RSQUARE1, RSQUARE2)} * 10\text{u}\ \ln(\frac{1+\text{B}}{1-\text{B}})$

Here, $(\text{RSQUARE1}, \text{RSQUARE2}) = 0.25\text{K ohm}$; Rf =4K ohm

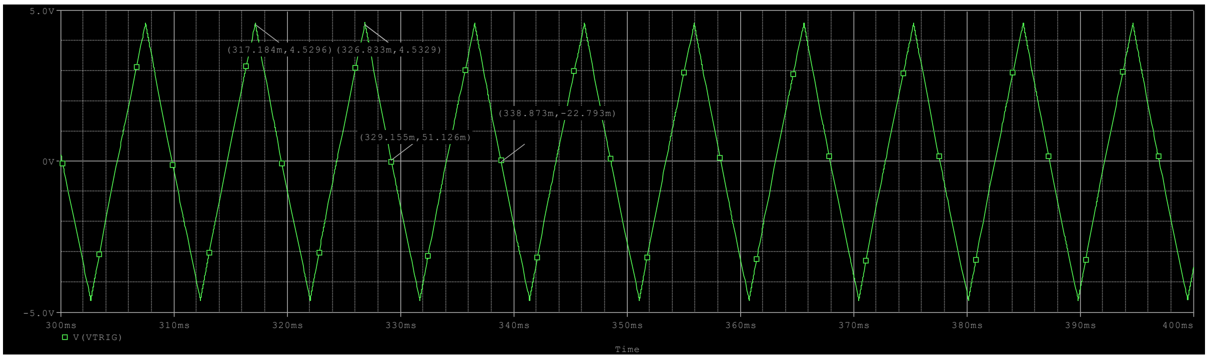


From simulation we can see that the output matches theoretical calculation.

3. **Generating a triangular wave of 8V p-p and 90Hz frequency**

B=$\frac{R162}{R161+R162}$; $f = 2 * \text{(RTRIG3, RTRIG4)} \ * 10\text{u}\ \ln(\frac{1+\text{B}}{1-\text{B}})$

Here, (RTRIG3, RTRIG4)= 0.5K ohm, Rf=4Kohm

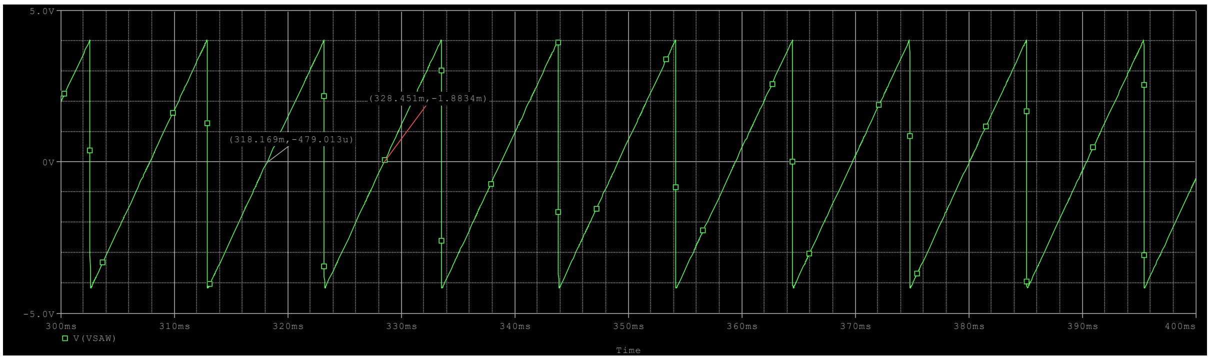


From simulation we can see that the output matches theoretical calculation.

4. **Generating a sawtooth wave of 8V p-p and 100Hz frequency**

$\text{f} = \frac{0.001}{\text{(RSAW1,RSAW2)}*1\text{u}}$

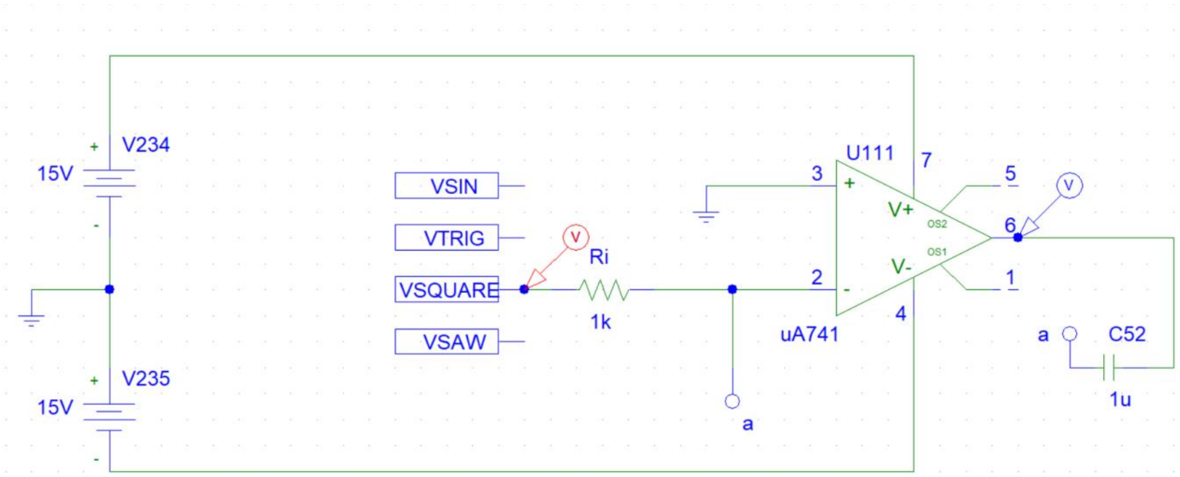
Here, $(\text{RSAW1}, \text{RSAW2}) = 10 ohm\ , Rf\ = 4Kohm$

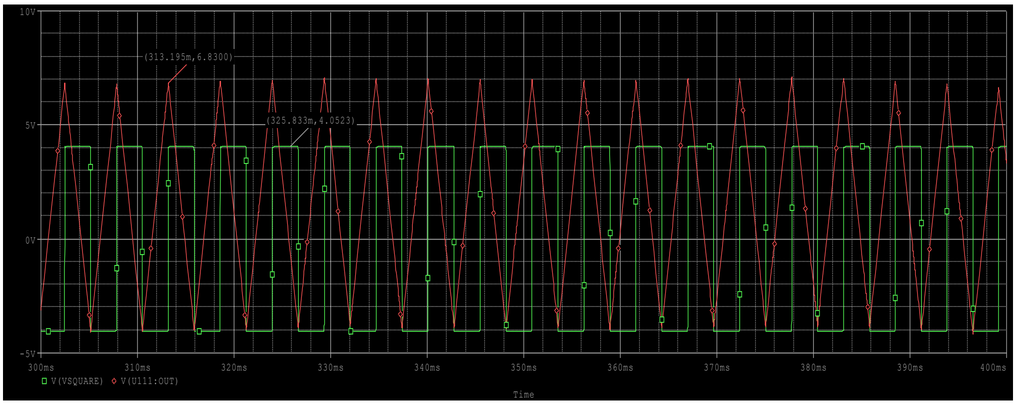


From simulation we can see that the output matches theoretical calculation.

5. Using the generated signals as input of inverting integrator

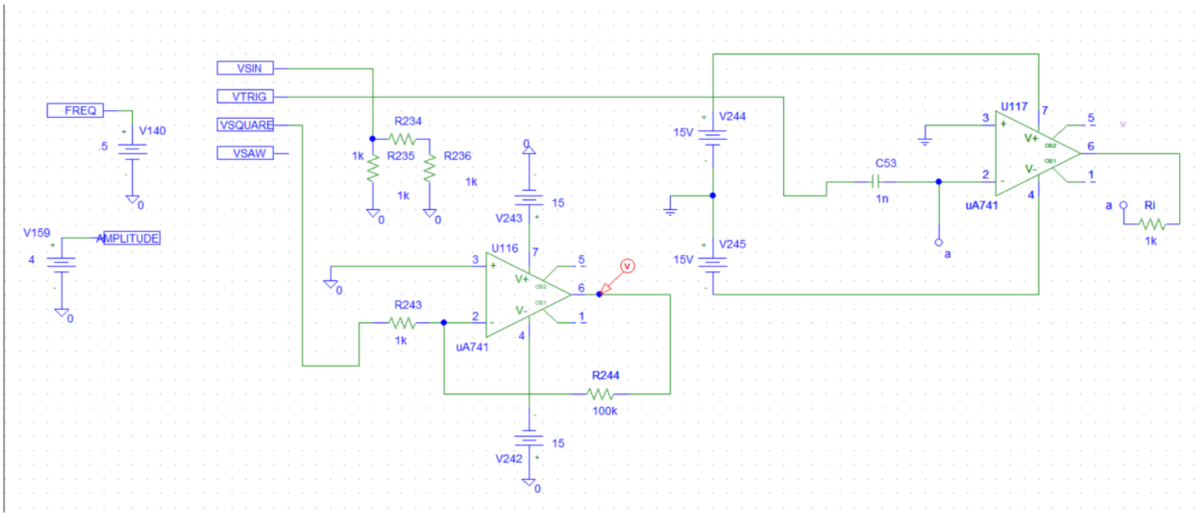
Output:

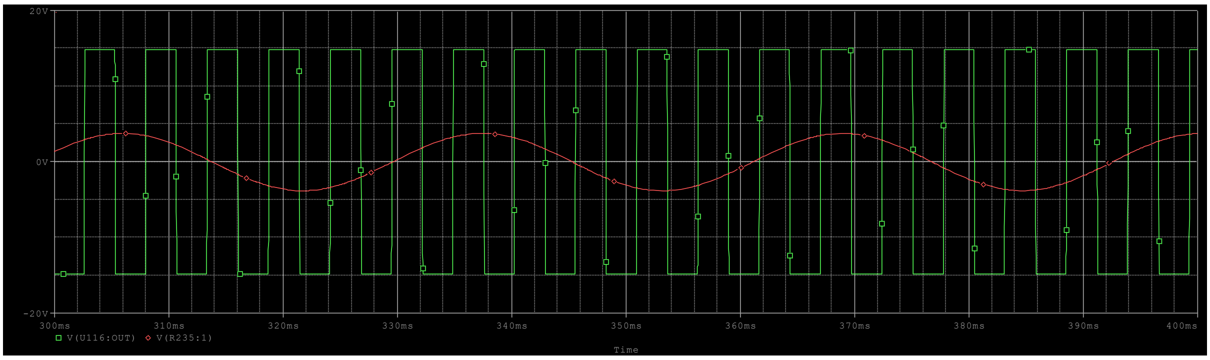




As the input of the integrator is our generated square wave, the output should be $\frac{1}{1000*1u}\int_0^{0.00025} 4dt$ = 10V amplitude triangular wave. Here we have got triangular wave with DC offset as output.

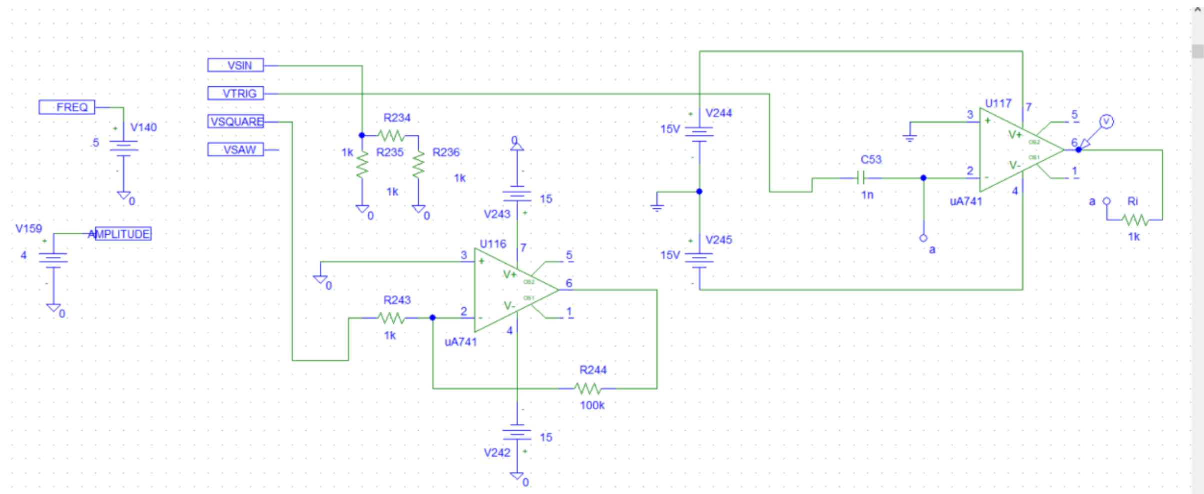
6. Using the generated signals as input of inverting amplifier

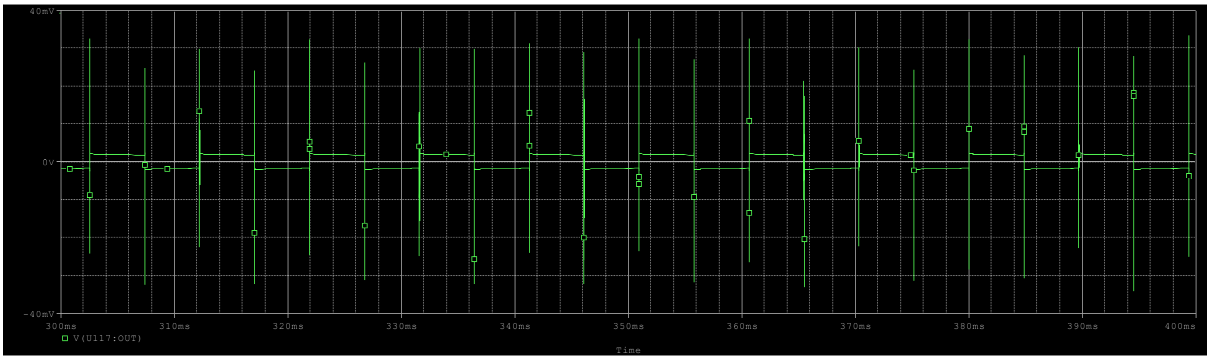




Here we used our generated square wave as input of an inverting amplifier. The gain is 100 hence the output is saturated.

7. Using the generated signals as input of inverting differentiator



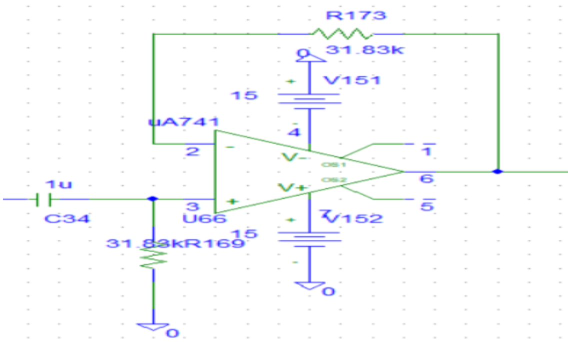


Here we used our generated triangular wave as input of an inverting differentiator. We get really low amplitude square wave, as RC is low in the differentiator.

Rationale behind certain choices

LM675 power operational amplifier: We have used LM675 in the amplitude control stage of every circuit. It is because LM675 has a current capability of 3A, which is much higher than other widely used op-amps like uA741 (20mA).

High-Pass Filter: Here we used 20dB high pass filter to minimize the DC offset from our oscillating output. Because the DC offset changes the reference voltage over the time at the end the graph shifts from zero reference voltage. The circuit diagram is given: -



Choosing capacitor: Here we choose a capacitor of the value about 10uF. We could choose a smaller value of capacitor to maintain large frequency range but small value capacitor has a problem of oscillating too slowly. Where high value capacitor lowers down the range of resonating frequency range. So 10uF maintains a wide range of frequency as well as small starting oscillation time.

Transistor 2N3055: The 2N3055 is a power bipolar transistor designed to handle high power loads in the range of 100 V, and **15 amps**.

List of components

Sl no.	Component name	numbers
1	UA741	9
2	LM675	10
3	VCR	10
4	Capacitors	7
5	Resistors	52
6	DC voltage source	11
7	2N3055	2
8	Diodes	4

Discussion

Advantages: The basic difference or the most advantageous difference of this function generator is that it has 4 basic output terminals. So, user can use 4 terminals at a time and can generate different types of waveshapes. The second basic advantage is the output current rating. As it has 3A current rating so we can use it for several electronics circuit as well as for power electronics circuits. The maximum output voltage limit is about 24V peak to peak.

Limitations: This is a low frequency range function generator. That means the range of the frequency of the function generator is 30Hz-300KHz. At the high frequency the amplitude does not maintain linear relationship and distortion may occur. The frequency control in not linear with the input voltage. Initially the frequency changes very rapidly, later it started changing slowly. Rather the system takes a few seconds to start up and generating wave.

Our main focus in this project was to create the main 4 signals as less distorted as we can with the minimum amount of component. A big challenge in this project was to tackle convergence error in simulation in PSPICE. That is why test cases have to be very limited as PSPICE has much limitation as a software .Real life function generators have digital ATmega328p to control waveform which cannot be simulated in PSPICE.