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Experiment No.5

Aim of the Experiment:

Study different analog circuits using op-amp

Tools used:

1. Voltage Source

2.Resistors

3.Capacitors

4.Op-amp(OP07)

Background Knowledge:

An Operational Amplifier is basically a three-terminal device which is made from transistors and resistors.

An op-amp is active component. Op-amp can be used for performing many mathematical operation like addition, subtraction, integration and differentiation.

One input is called the **Inverting Input**, marked with a negative sign, (–). The other input is called the **Non-inverting Input**, marked with a positive sign (+).The name given so because if input is given to inverting pin , output is opposite direction i.e., inverted. And if input is given to non-inverting pin, output is in same direction.

i. **DC Gain**

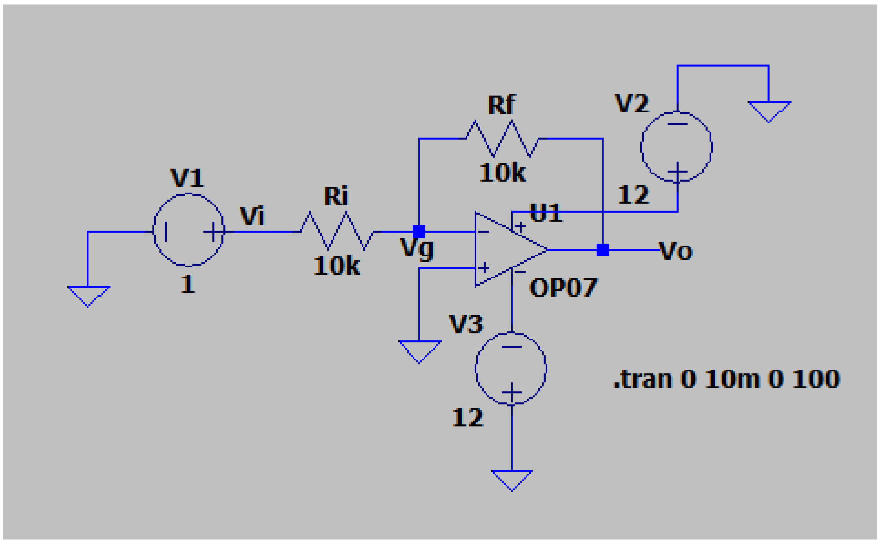
Brief knowledge:

In this ,op-amp in the inverting configuration is used.

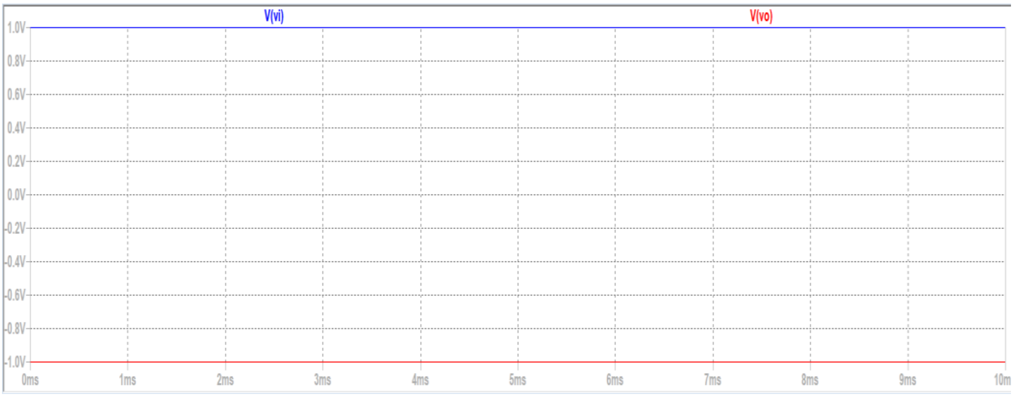
Vout=-(Rf/Ri).Vin

a.

Circuit



Graph:



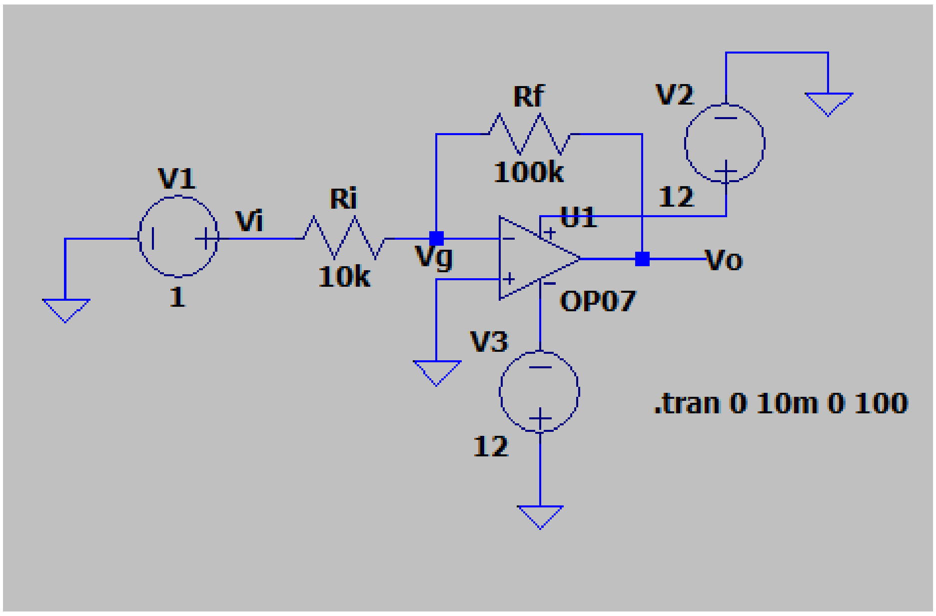
This graph shows that for equal value of Ri and Rf, we get output with equal magnitude and opposite sign. This is equal to the Vout that we can calculate from the formula i.e., Vout=-(Rf/Ri)Vin .

Measurement Table: Comparing Vout and Vout(Calculated)

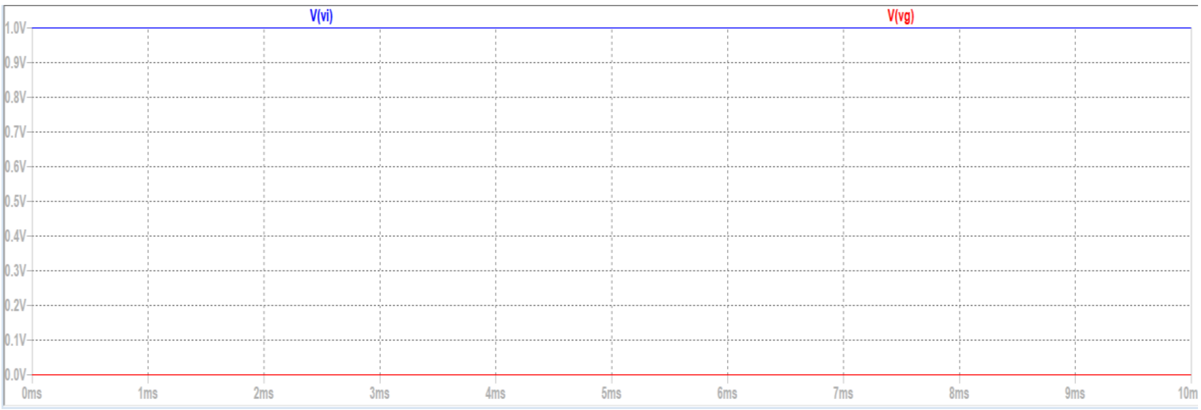
Serial No.	Ri(kΩ)	Rf(kΩ)	Vin(V)	Vout(V)	Vout(calculated)(V)
1	10	27	1	-2.7	-2.7
2	10	47	1	-4.7	-4.7
3	10	100	1	-10	-10

b. Virtual Ground

Circuit:



Graph:



From graph we can say that, pin 2 is at virtual ground compared to Vin because Vg i.e. voltage at pin 2 is 0V(from graph).

c. Input Resistance

i)Voltage across Ri= 1V

Ii=Vi/Ri=1/10k=0.1mA

Now,

Vin=1V

Rin=Vin/Ii=10k

Ω

ii) Vin=1V, Ri=1kΩ

Serial No.	Rf(Ω)	Vout(V)
1	10k	-10
2	27k	-11.05
3	47k	-11.06

4	100k	-11.06

If we gradually increase the value of Rf ,we get that the amplifier cease to be linear at Rf=11Ω.

The output voltage at which op-amp saturates is -11.06V.

Now,

Vin=2V,Ri=1kΩ

Serial No.	Rf(Ω)	Vout(V)
1	10k	-11.01
2	27k	-11.05
3	47k	-11.05
4	100k	-11.05

If we gradually increase the value of Rf ,we get that the amplifier cease to be linear at Rf=11Ω.

The output voltage at which op-amp saturates is -11.05V.

From this we can say that Saturation Voltage levels are always less than the power supply voltages.

ii. Non-inverting Amplifier

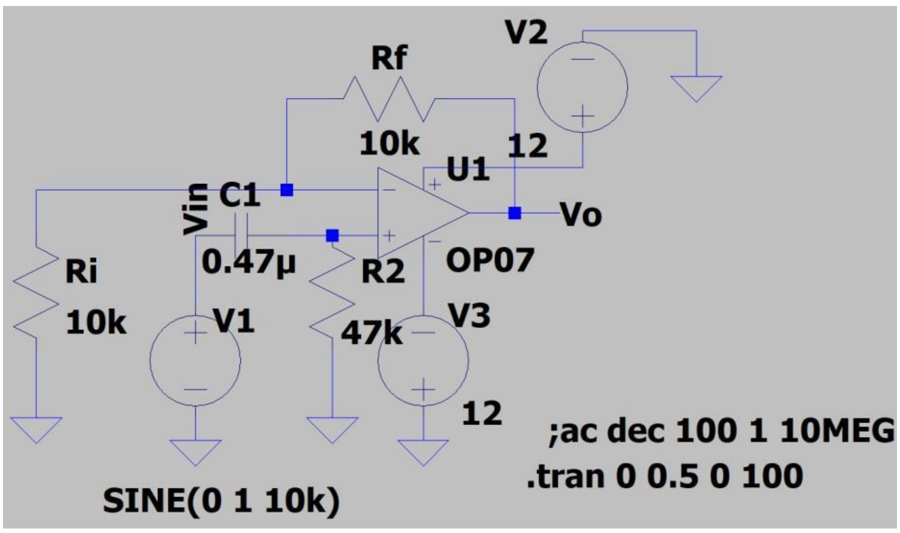
Brief knowledge:

Gain=1+Rf/Ri

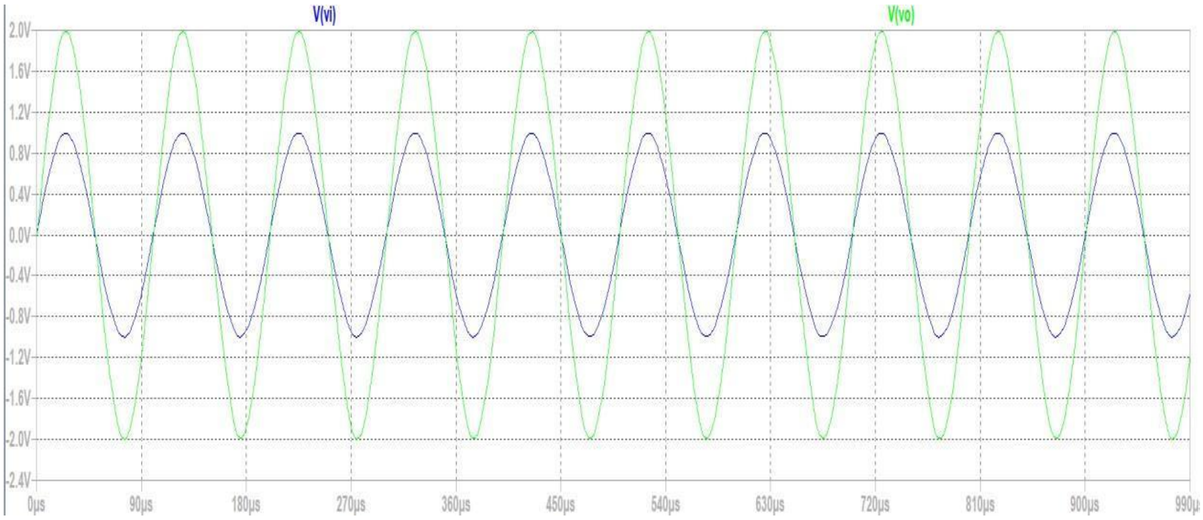
a.

Ri=10kΩ, Rf=10kΩ

Circuit:



Graph:



From graph gain(Vo/Vi) is 2.

Measurement Table:

Ri=10kΩ,Vip-p=2V

Serial No.	Rf(Ω)	Vop-p(V)	Gain	Gain(calculated)
1	27k	3.671	3.671	3.7
2	47k	5.54	5.54	5.7
3	100k	5.97	5.97	11

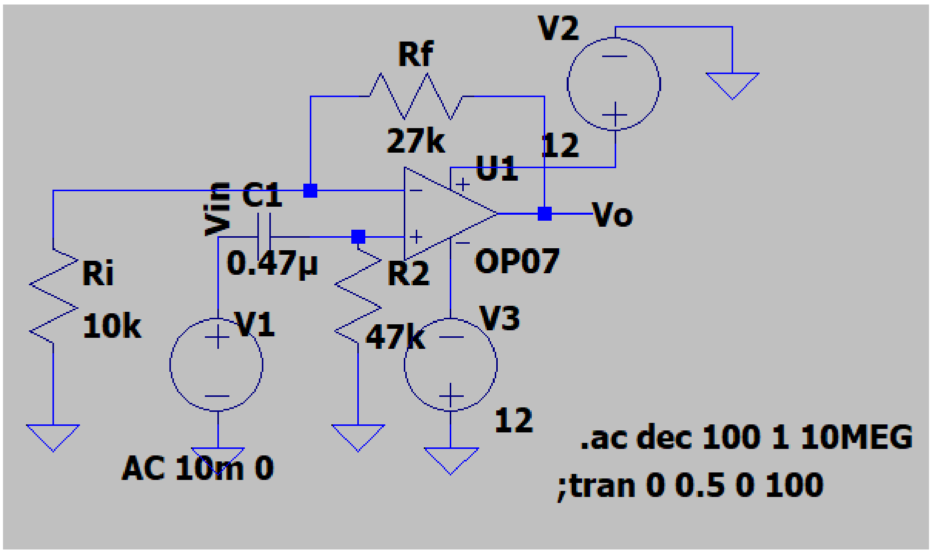
From oscilloscope we get do not get inverted output.

Reactance of capacitor=1/wc=33.87Ω

As reactance of capacitor is negligible with respect toR2, hence can be neglected for gain calculations.

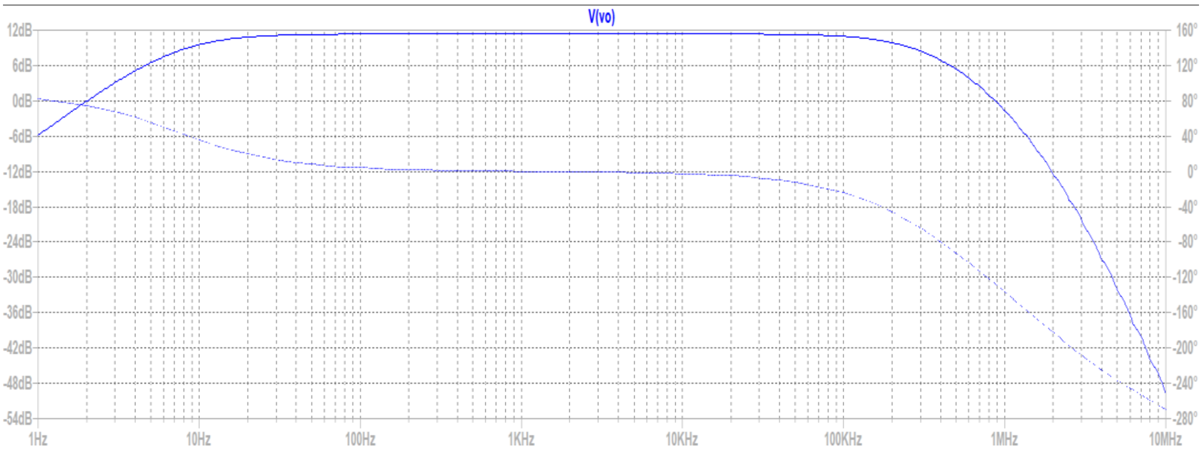
b. Frequency response

Circuit:

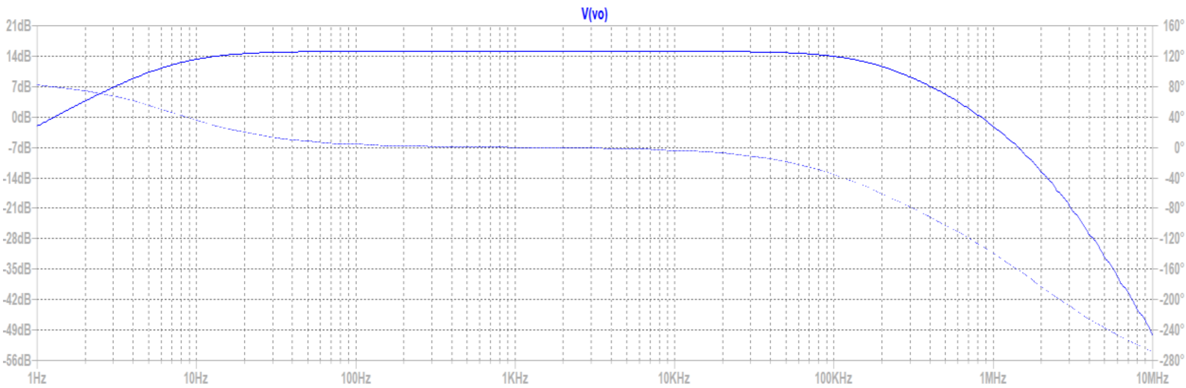


Graph:

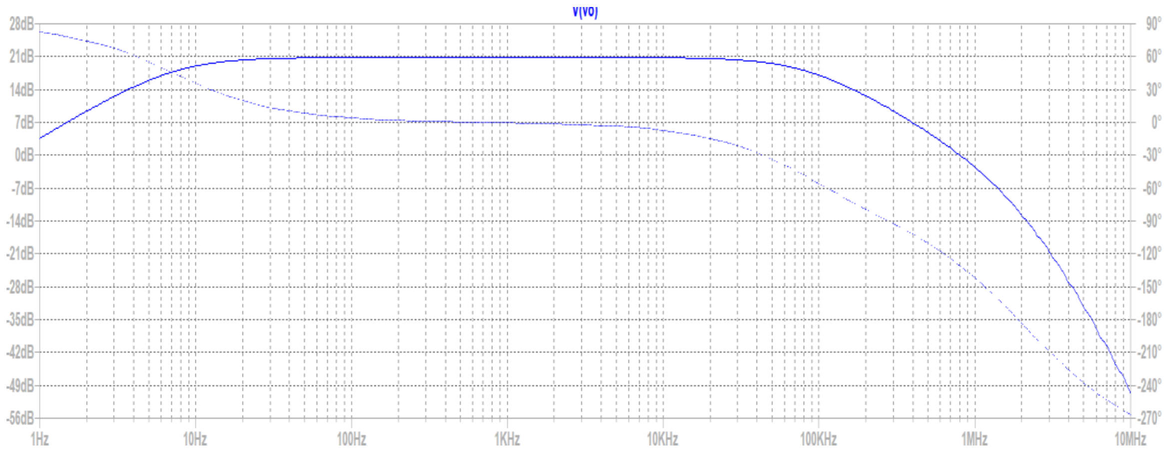
Rf=27kΩ



Rf=47kΩ



Rf=100kΩ



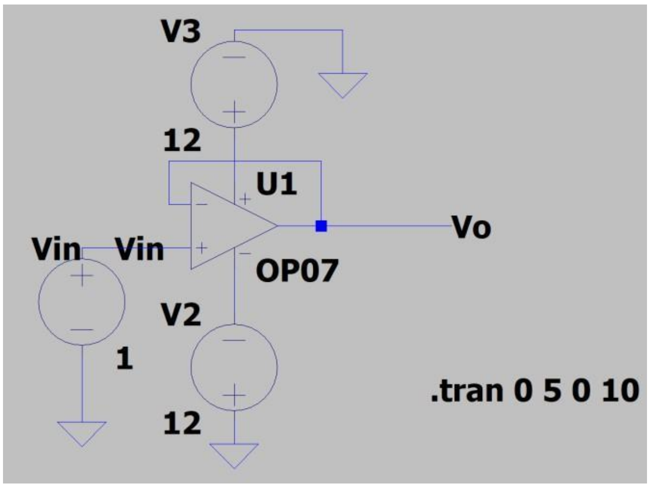
We can notice that the high gain circuit begins to roll off sooner than the lower gain circuit.

Measurement Table:

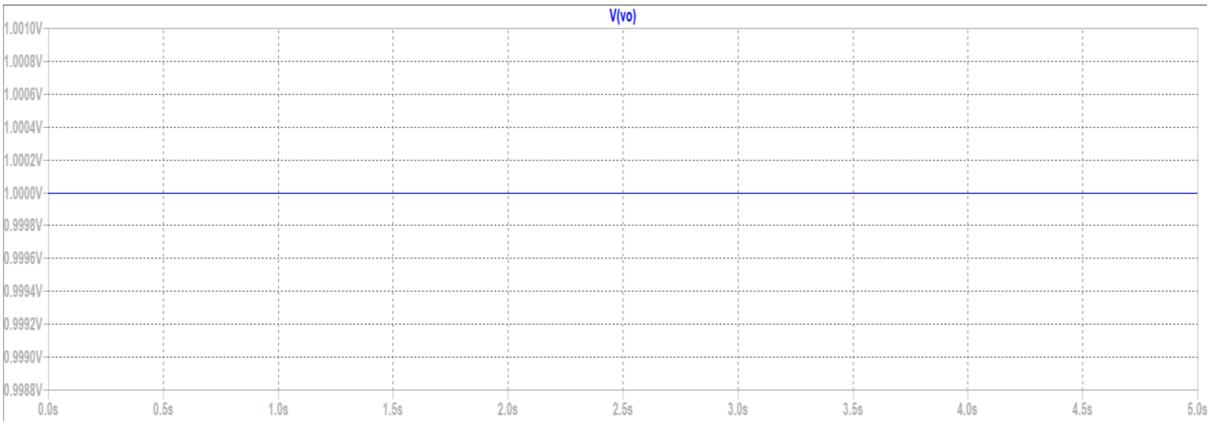
Serial No	Rf(Ω)	Bandwidth(HZ)	Gain (dB)	Af	Gain Bandwidth	B=Ri/(Rf+Ri)	Ao=Af/(1-BAf)
1	27k	298k	11.36	3.7	1109.47k	0.27	3700
2	47k	179k	15.112	5.7	1020k	0.1754	2280
3	100k	83.1k	20.835	11.0	914k	0.091	1100

iii. Voltage Follower

Circuit:

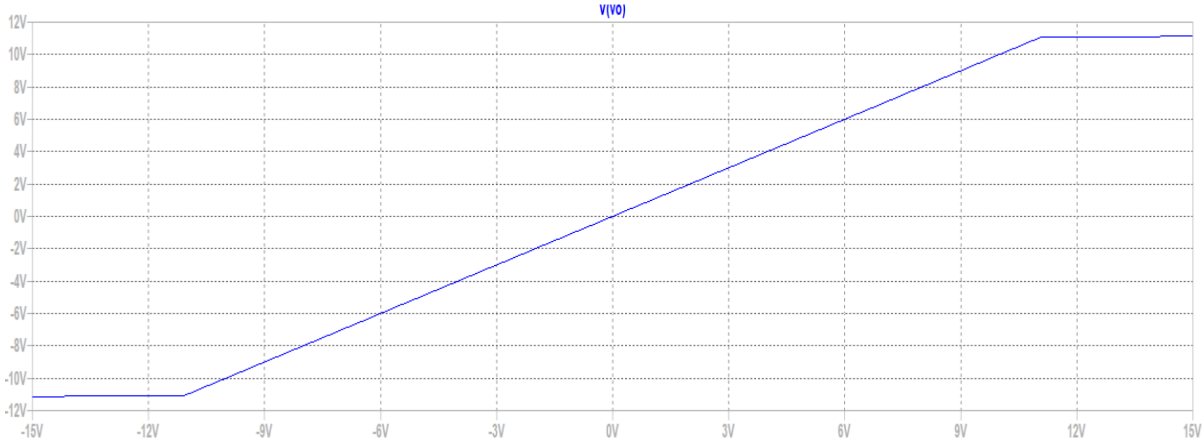


Inverting pin is at virtual ground w.r.t. Vin as voltage at inverting and non-inverting pin are equal.



Vout=1V

Therefore,Vout=Vin.

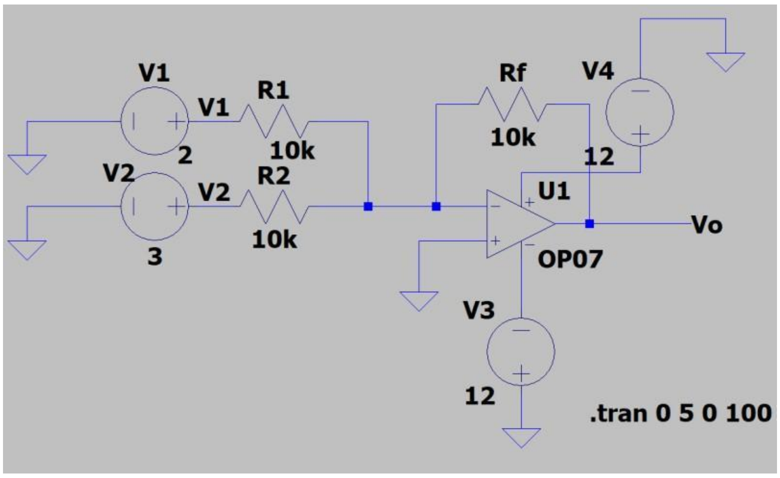


The maximum (+) and minimum(-) voltages where this stop being true are 11 V and -11V.

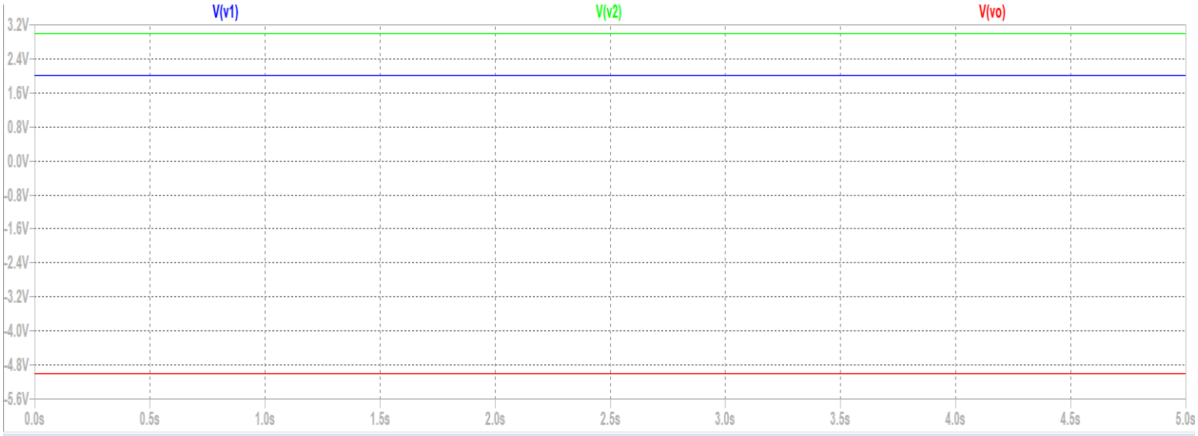
iv. Adder

a.

Circuit:



Output:



V1=2V

V2=3V

Vo=Vout(measured)=-5V

According to theory,

Vout=-Rf(V1/Ri+V2/Ri)

=-10000(2/10000+3/100000)

=-5V

Therefore,

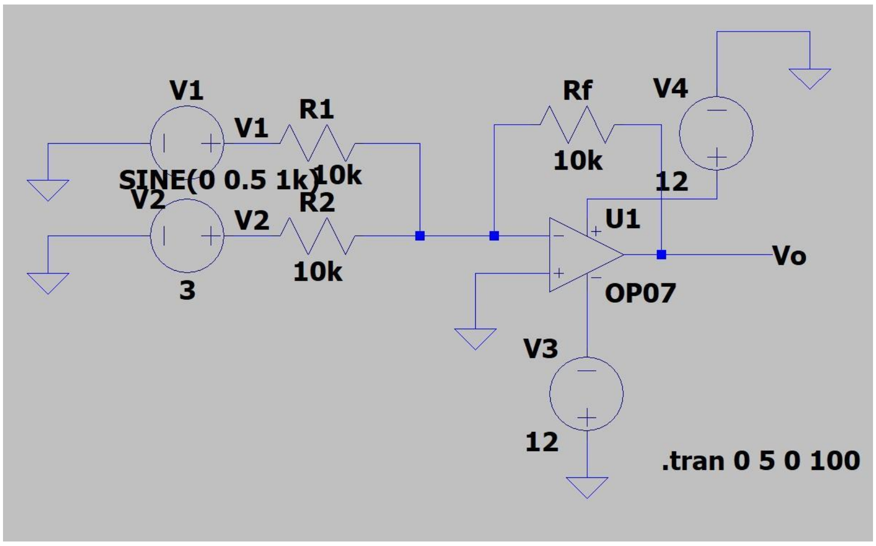
Vout(measured)=Vout(calculated)

b. Summing

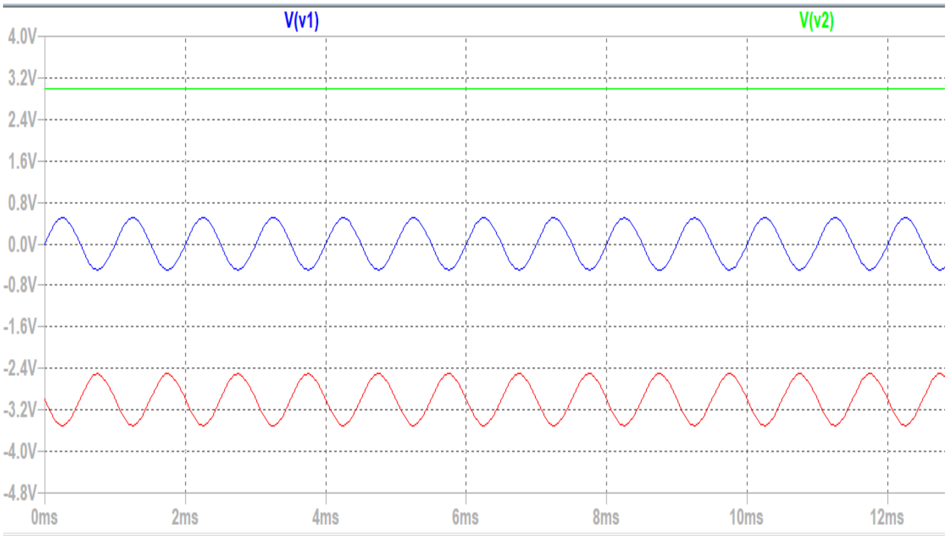
Amplifier V1=Vin

V2=Voffset=3V

Circuit:



Graph:

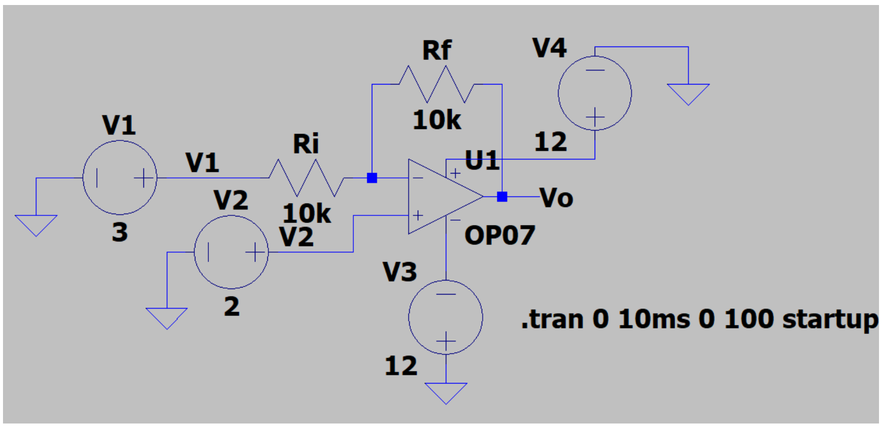


From graph we can see,Vout=-Vin+(-Voffset)

v. Superposition:

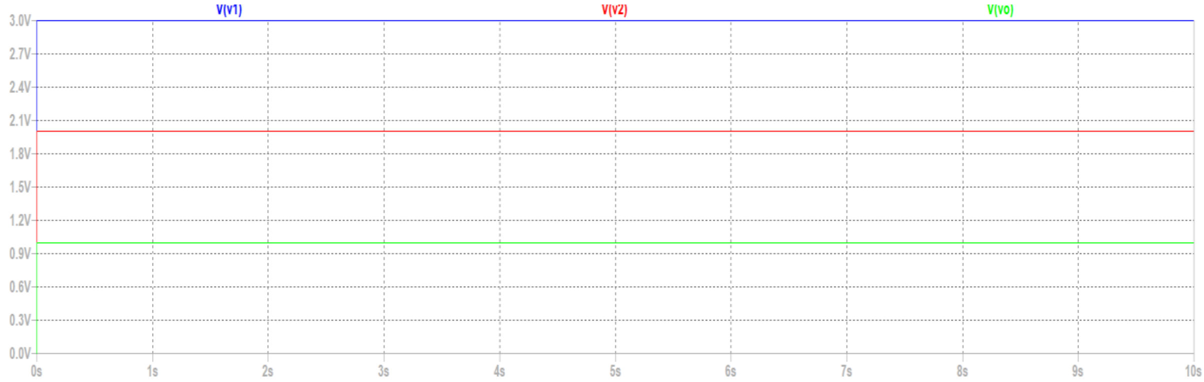
a. When input is provided simultaneously at both inverting and non-inverting terminals, the relation between Vout and the inputs can be obtained using Horowitz and Hill's golden rules. This can also be given by superposition theorem which implies that if Vout1(Vout2) is the response due to input V1(V2) acting alone ,i.e., with other input V2(V1) being Zeroed. Then response due to both inputs V1 and V2 acting simultaneously is Vout=Vout1 +Vout2.

Circuit:

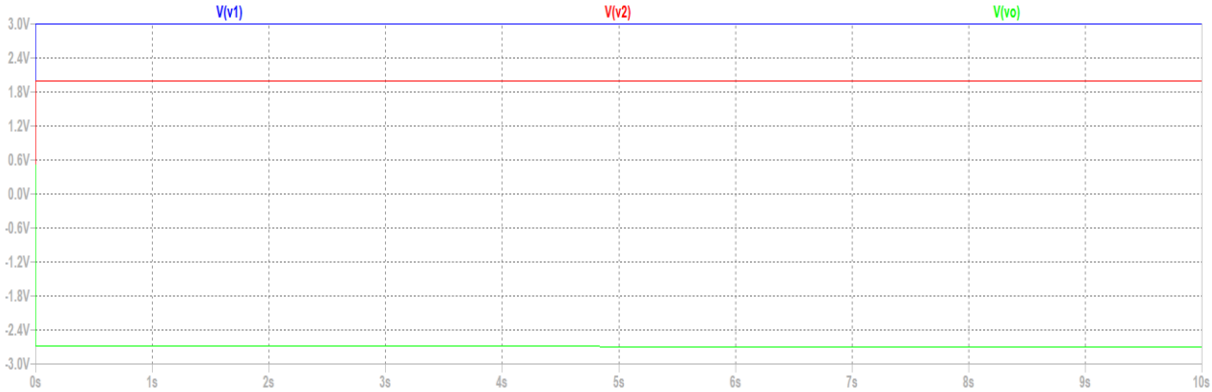


Graphs:

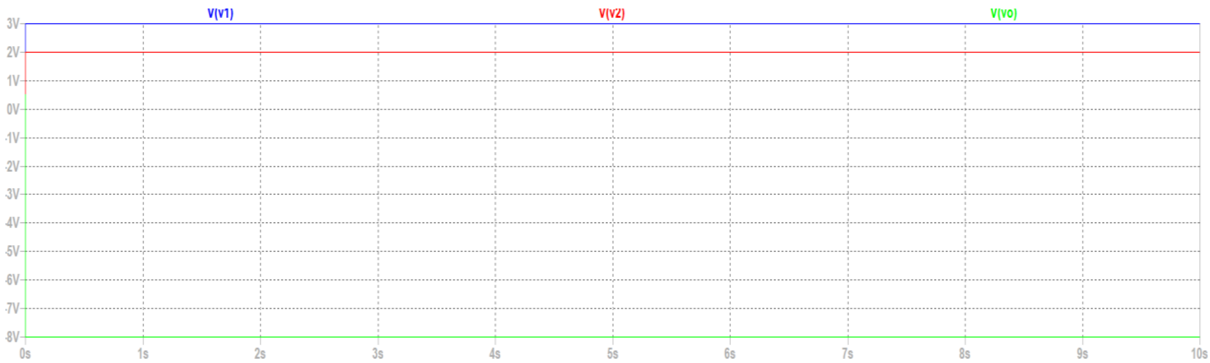
1)



2)



3)



Measurement Table:

Vout1=-(Rf/Ri).V1

Vout2=(1+Rf/Ri).V2

Vout(calculated)=Vout1+Vout2

Ri=10kΩ

Serial No.	Rf(Ω)	V1(V)	V2(v)	Vout(measure)(V)	Vout(calculated)(V)
1	10k	3	2	1	1

2	47k	3	2	-2.7	-2.7
3	100k	3	2	-8	-8

In each case ,Vout(measured)=Vout(Calculated)

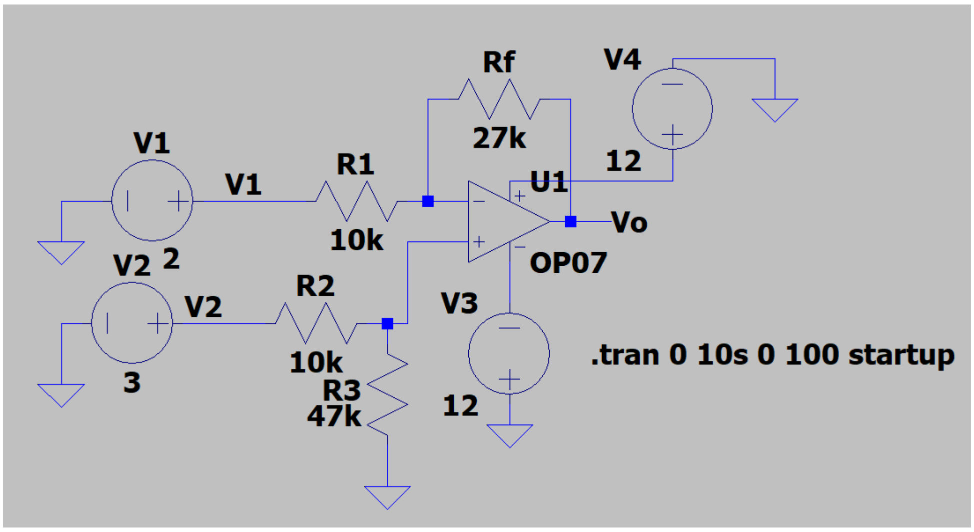
b. Differential Amplifier

Vout=V2*[R3/(R2+R3)](1+Rf/Ri)-V1*(Rf/Ri)

If,R2=R1 and R3=Rf

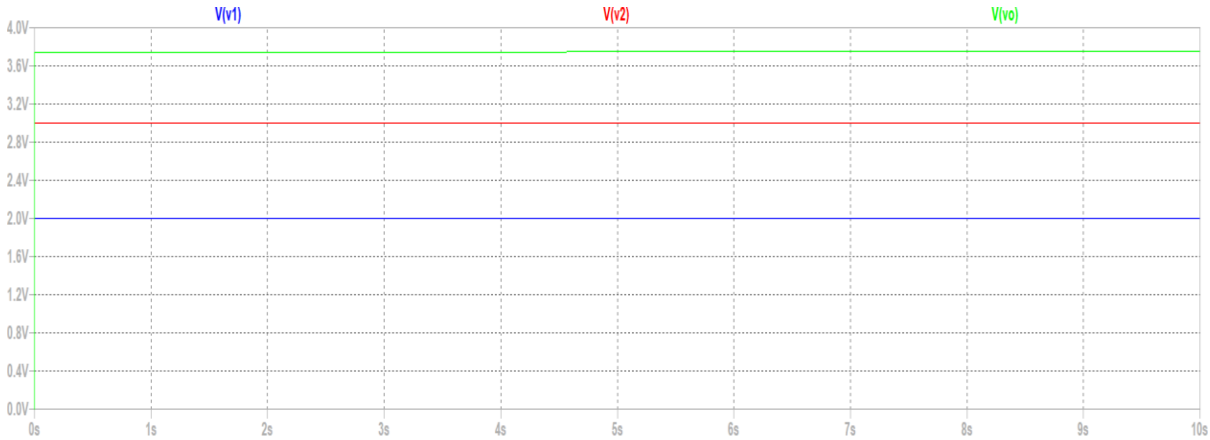
Vout=(Rf/R1)*(V2-V1)

Circuit:

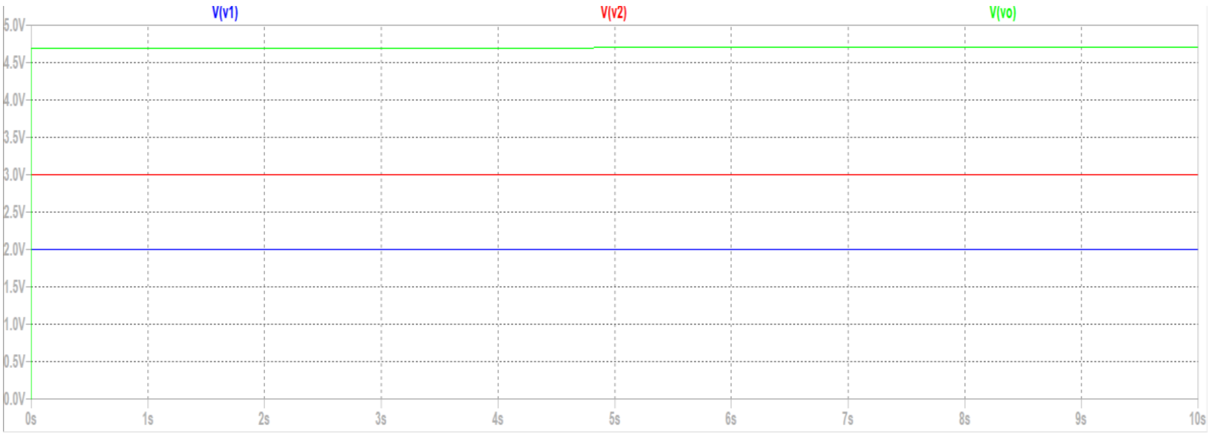


Graph:

1)



2)



Measurement Table:

R1(Ω)	R2(Ω)	R3(Ω)	Rf(Ω)	V1(V)	V2(V)	Vout(Measured)(V)	Vout(calculated)(V)
10k	10k	47k	27k	2	3	3.753	3.7526
10k	10k	47k	47k	2	3	4.706	4.7

There is negligible difference between Vout(Theoritical) and Vout(Measured)

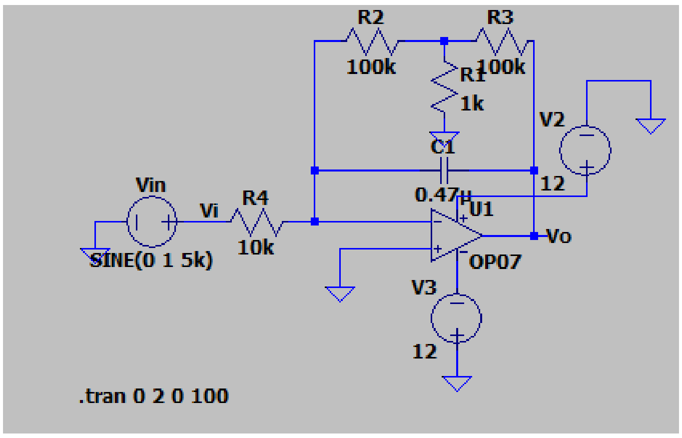
Vi. Integrator

Vout=-(1/RC)Vindt+const

1. Sine

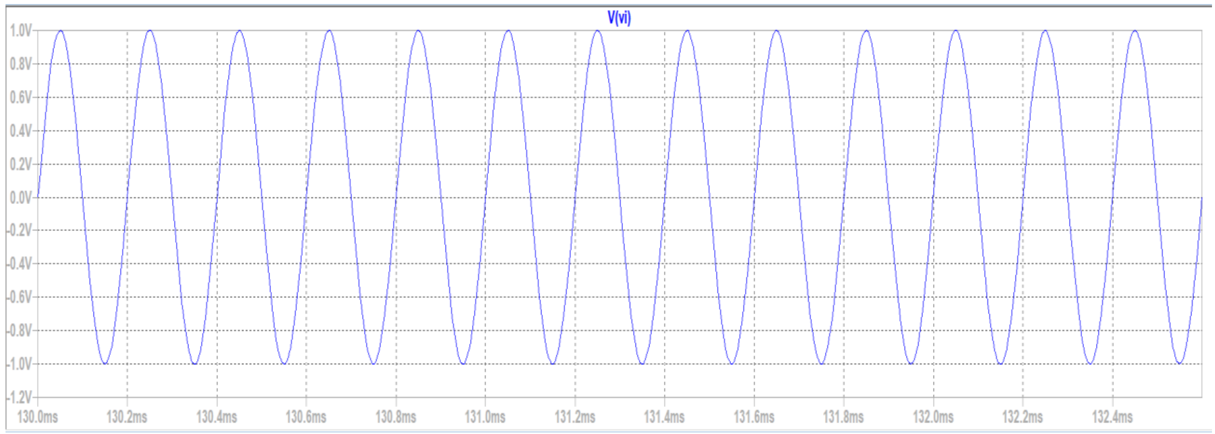
Wave

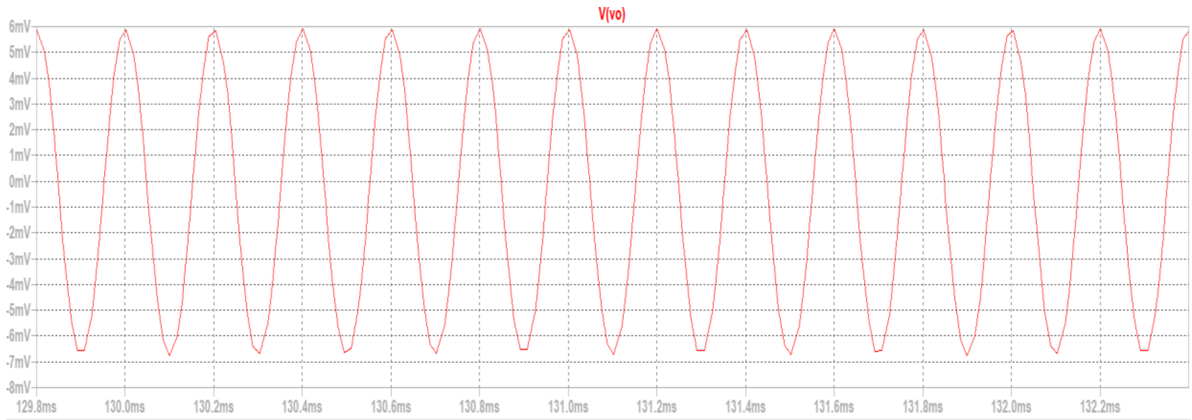
Circuit:



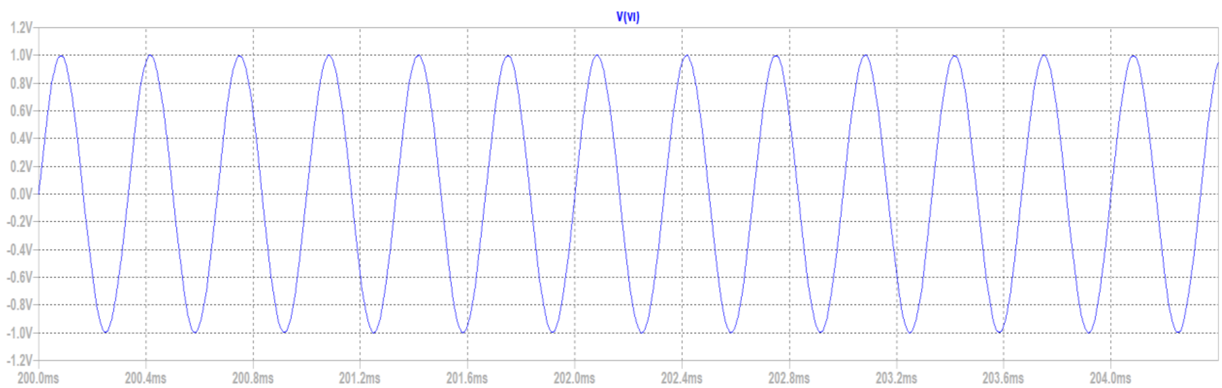
Graph:

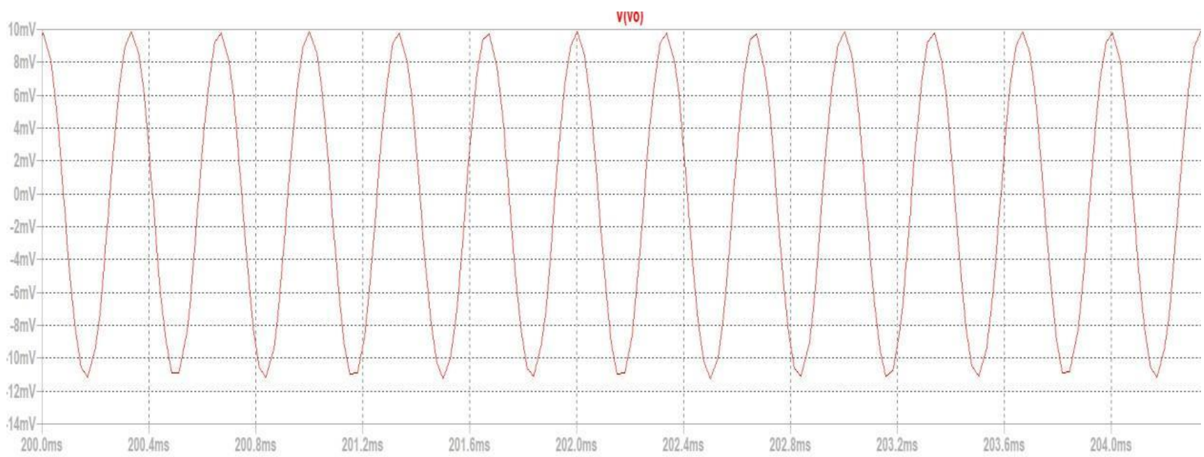
Frequency:5kHz, Vin=1V



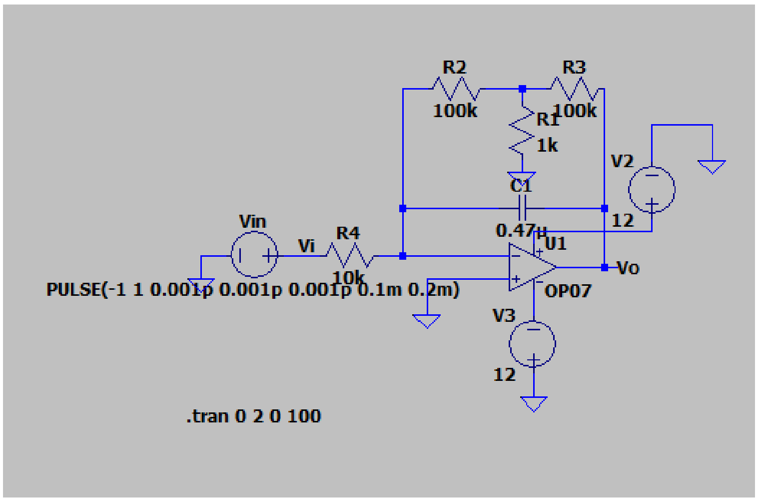


Frequency:3kHz, Vin=1V



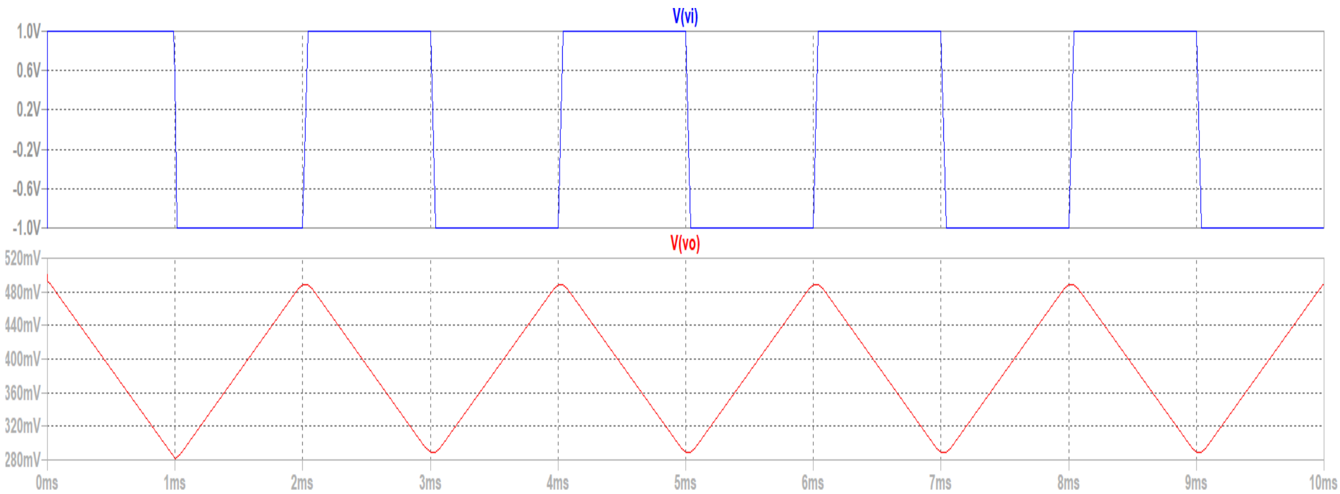


2. Square wave Circuit:

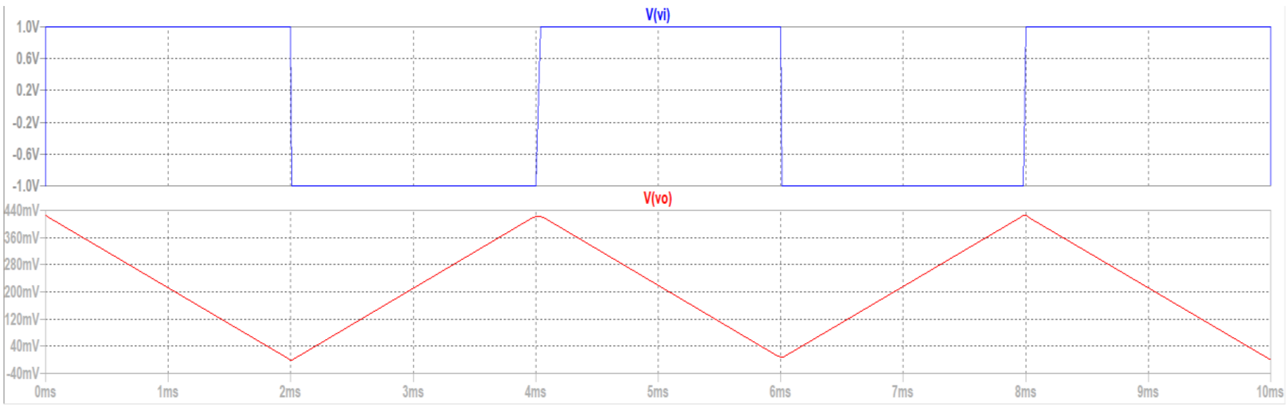


Graph:

Frequency:5kHz



Frequency:1kHz

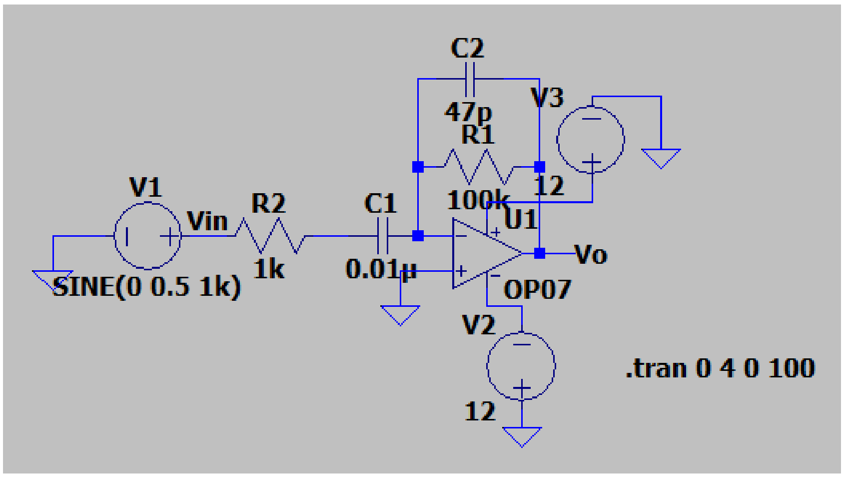


Vii. Differentiator

Vout=-(RC)(dVin/dt)

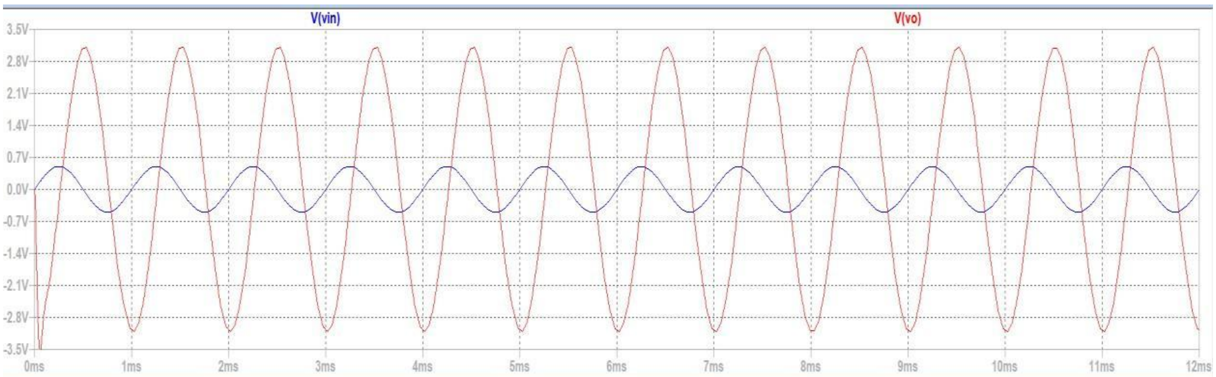
1. **Sine**

wave Circuit:

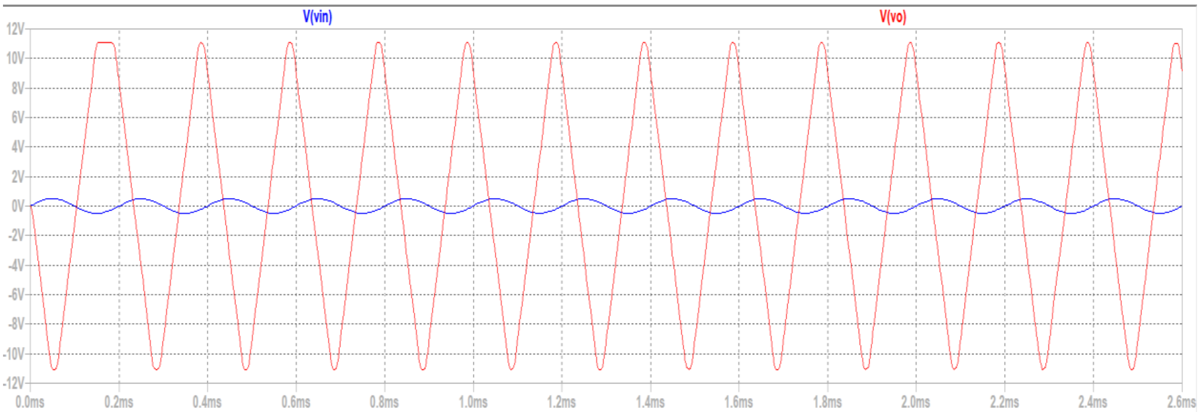


Graph:

Frequency: 1kHz



Frequency: 5kHz

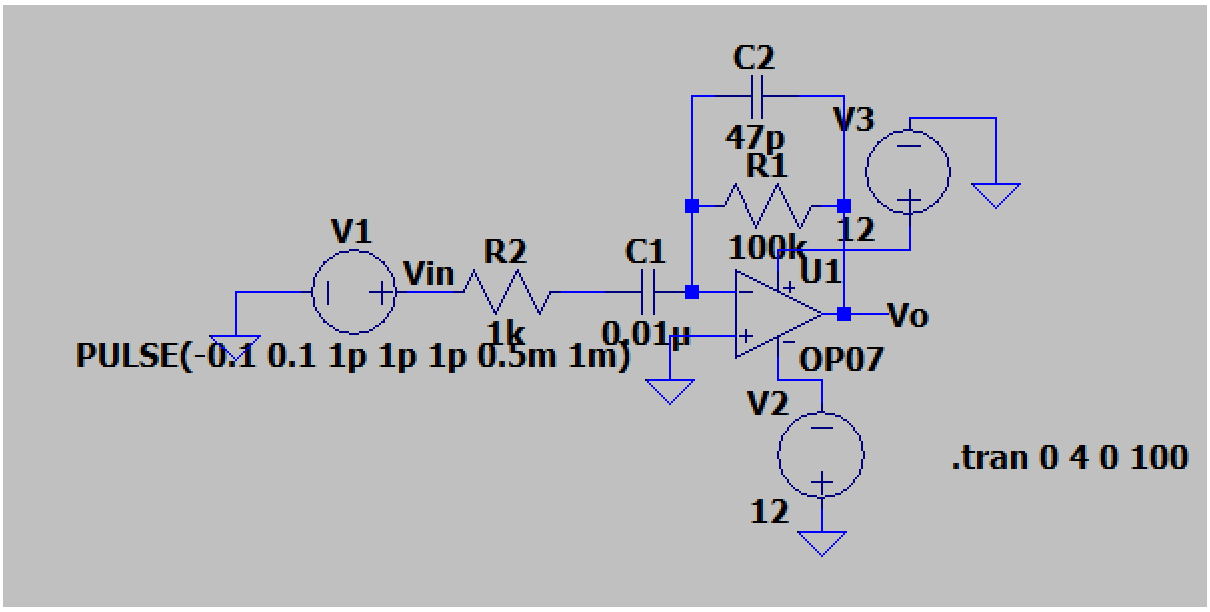


As, Vout=-(RC)(dVin/dt)

Vin is the sine wave. Hence we should get cosine wave at output with increase in amplitude with the factor of (RCw) according to formula. In output we get the same graph as expected from theory.(w is 2πf)

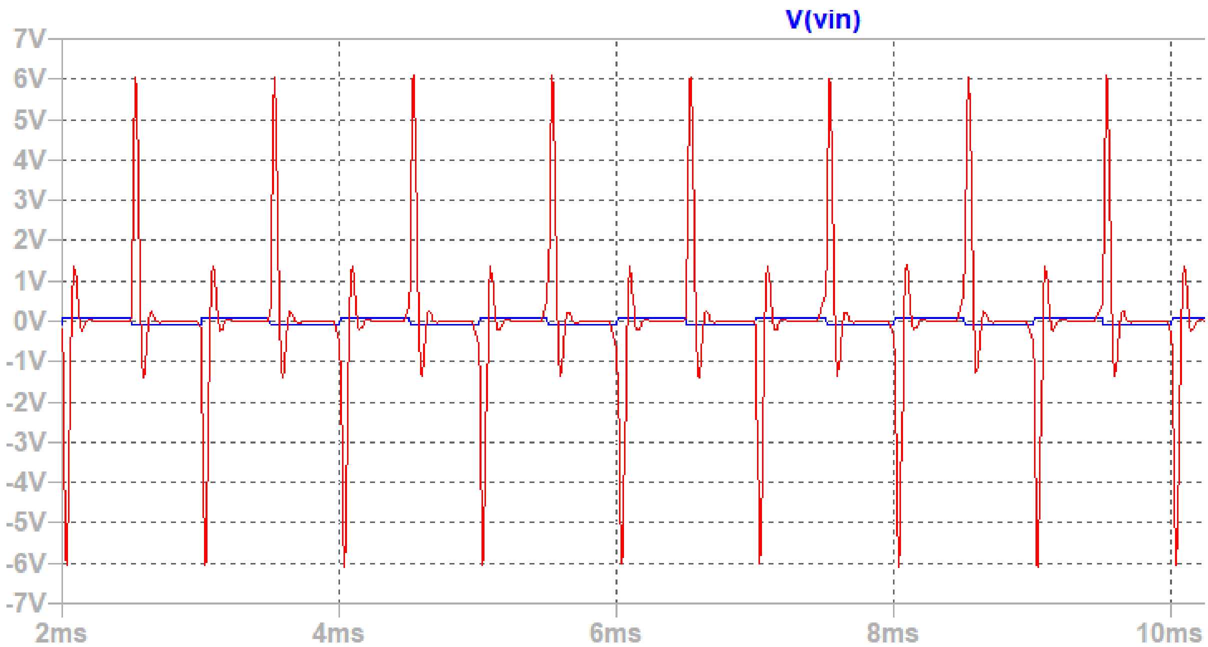
2. Square

Wave Circuit:



Graph:

Frequency: 1K



Note: From this we can say that if we increase the frequency i.e., decrease the time period then we will not get proper spikes.

As, $V_{out}=-(RC)(dV_{in}/dt)$

Vin is square wave, hence we should get spikes at time when direction of input voltage change. Other time we get zero output voltage. Graph with frequency 1kHz gives expected graph .

Conclusion:

Operational Amplifiers or Op-Amps, are like the one of the basic building blocks of Analogue Electronic Circuits. A variety of analogue circuits, amplifiers, can be designed using an Op-Amp. They can also be used to perform mathematical operations such as add, subtract, integration and differentiation.

Discussion:

In ideal op-amp input impedance is infinite and output impedance is zero. Practically input impedance is very large and output impedance is very small.

Virtual ground- the output voltage of the op-amp is A*(v1-v2). Where A is the open loop differential gain and v1,v2 are non-inverting and inverting terminal voltage.

Since value of A is around 10^5 to 10^6 if we want a output of 10V then v1-v2 is in micro volts so we assume it to be nearly zero because of which v1=v2.

So if we apply different input voltage on the two terminals then also v1=v2 which is called virtual ground.

Differential Amplifier –When we connect signals to both of inputs, inverting and non-inverting at the same time it produces another common type of operational amplifier circuit called a **Differential Amplifier**.

Then differential amplifier amplify the difference between two voltages making this type of operational amplifier circuit a **Subtractor.**

Integrator- The **Op-amp Integrator** is an operational amplifier circuit that performs the mathematical operation of **Integration.**

It acts as a integrator because of the capacitor in the feedback which forms a RC circuit. When we apply KCL on the circuit we get output voltage as the integration of the input voltage.

At low frequencies the reactance of the capacitor is "High" resulting in a high gain (R_f/X_c) and higher output voltage from the op-amp. At higher frequencies the reactance of the capacitor is much lower resulting in a lower gain and low output voltage from the Integrator amplifier.

The capacitor acts as a low pass filter.

Differentiator- This operational amplifier circuit performs the mathematical operation of **differentiation.**

As with the integrator circuit, we have a resistor and capacitor forming an RC Network across the operational amplifier and the reactance (Xc) of the capacitor plays a major role in the performance of a **Op-amp Differentiator**.

It acts as a differentiator because of the capacitor which forms a CR circuit. When we apply KCL on the circuit we get output voltage as the differentiation of the input voltage.

At low frequencies the reactance of the capacitor is "High" resulting in a low gain (Rf/Xc) and low output voltage from the op-amp. At higher frequencies the reactance of the capacitor is much lower resulting in a higher gain and higher output voltage from the differentiator amplifier.

The capacitor acts as a high pass filter.

Some of the advantages of using an op – amp :

• It has a smaller size.

• Its reliability is higher than conventional amplifier

• Reduced cost as compared to its discrete circuit parts.

• Less power consumption

• Easy to replace Same OP-AMP can be used for different applications.

Other applications :

● In analog and digital data transmission system differential amplifiers are used for noise cancellation.

● Differential Amplifiers are used for audio and video processing.

● They are also used as an automatic gain control circuit.

Source:LT spice