EECS Laboratory 5

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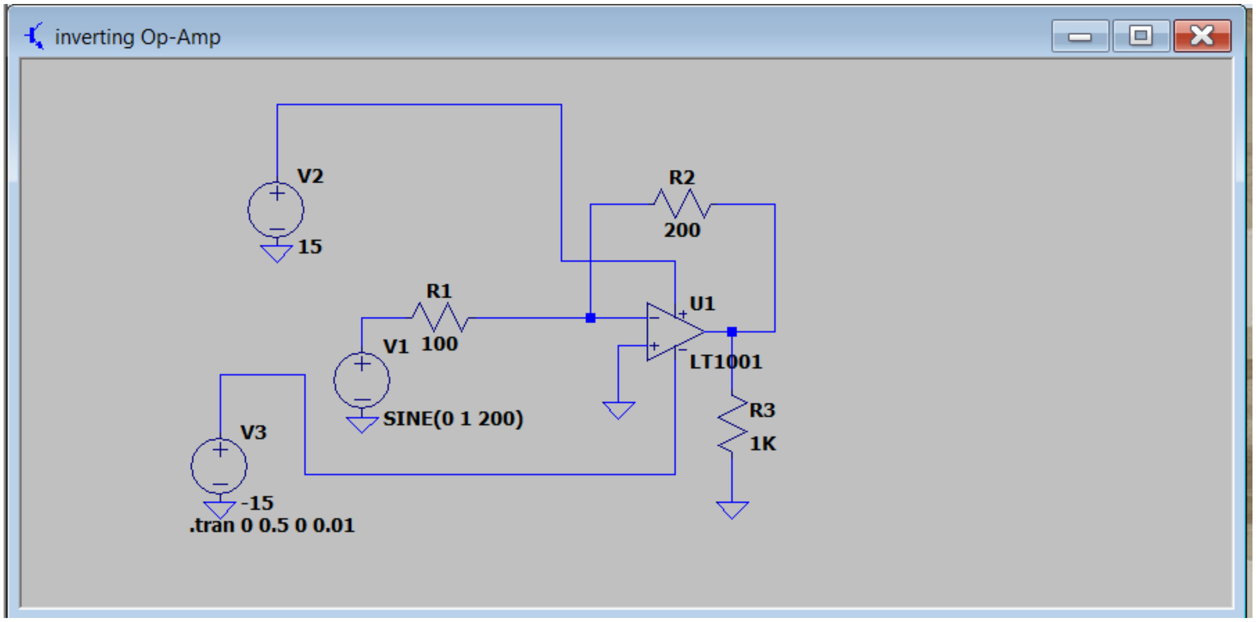
1) INVERTING AMPLIFIER USING OP-AMP

Circuit Diagram :

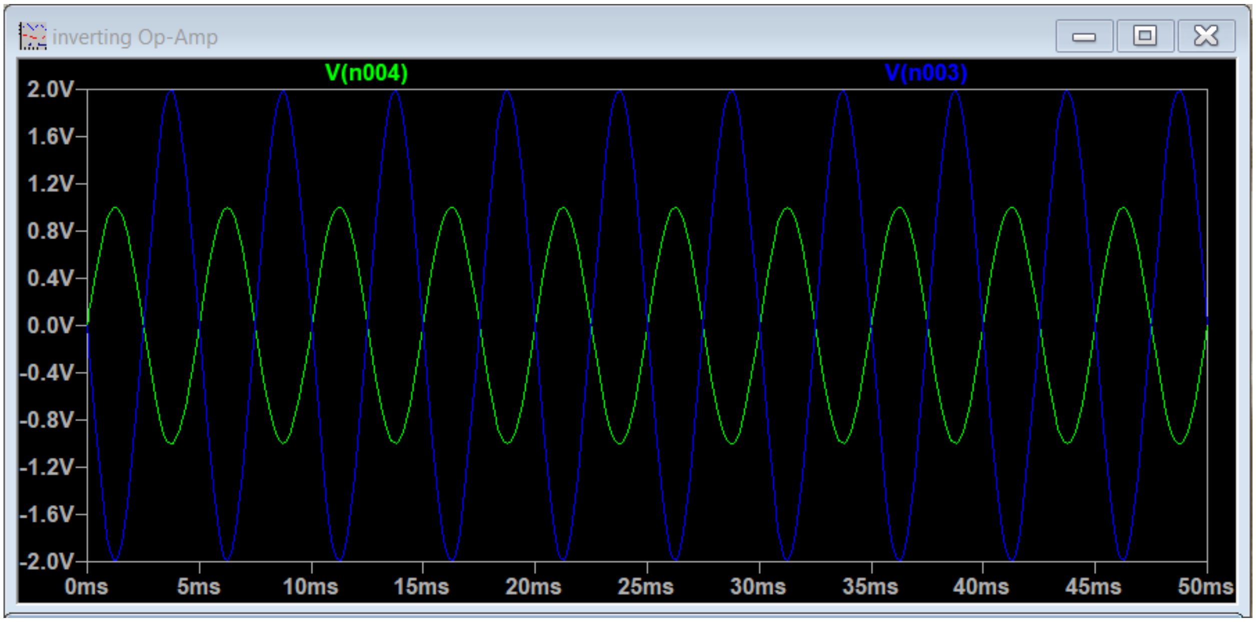


V_A	V_{out} (in V)
1	2
3	6
5	6.18
7	6.18
9	6.18

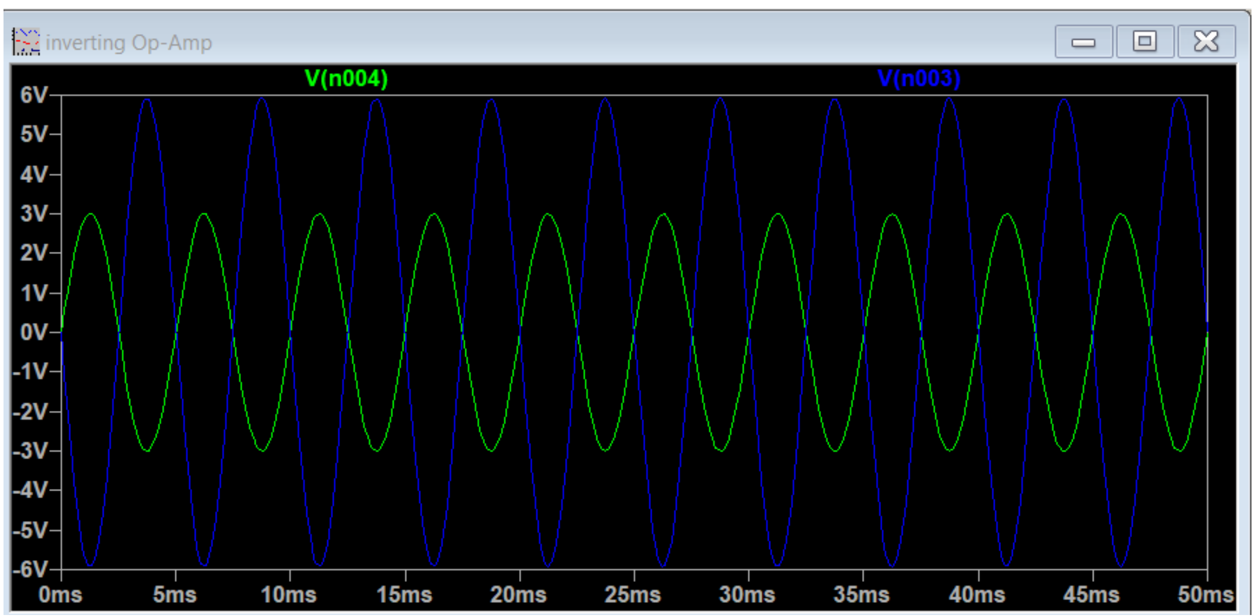
1. V_{out} for each of the cases will simply be

$V_{out} = V_A$ x gain
Gain = R_f/R_1 = 2 in our case

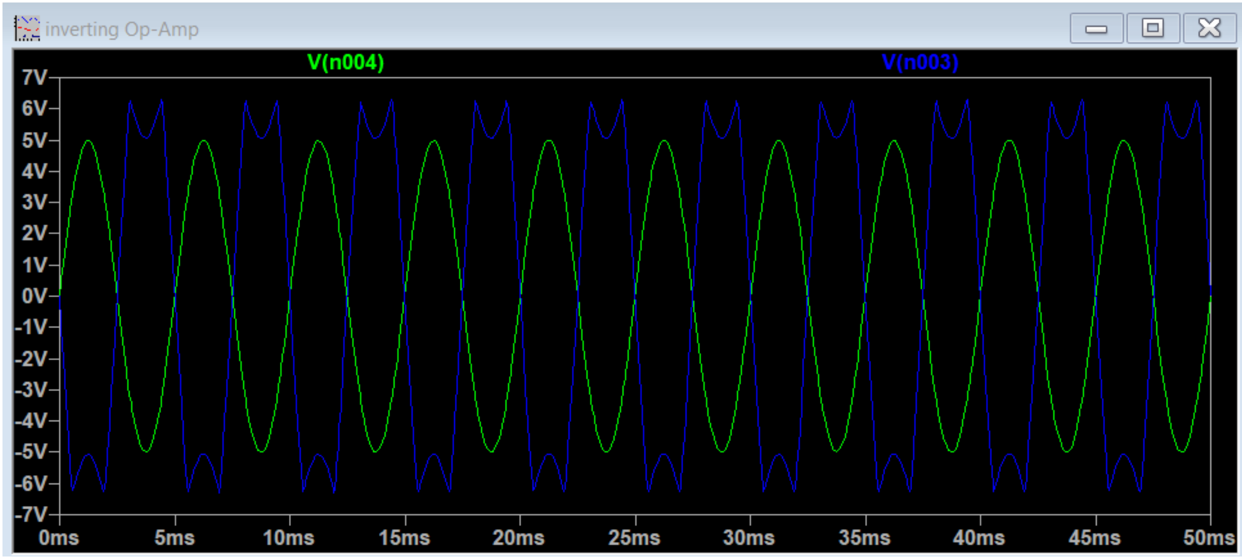
2. For V_A =1V



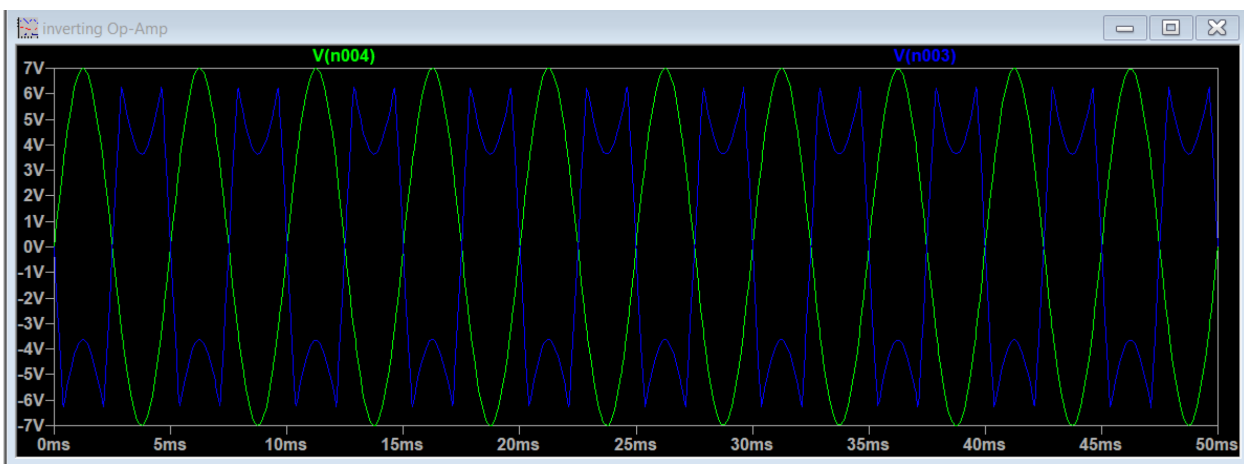
V_A = 3V



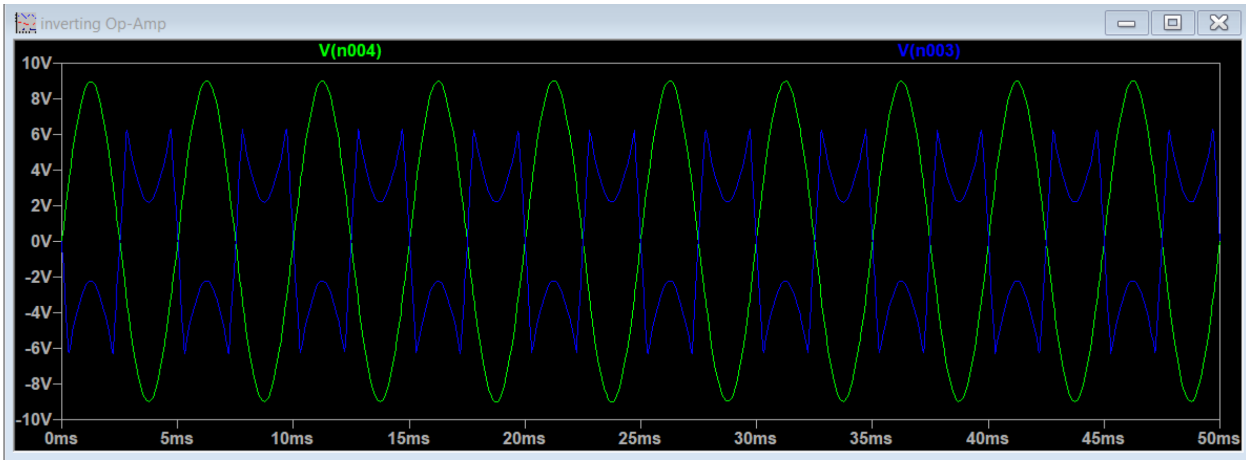
$V_A = 5V$


inverting Op-Amp
V(n004)
V(n003)
7V
6V
5V
4V
3V
2V
1V
0V
-1V
-2V
-3V
-4V
-5V
-6V
-7V
0ms
5ms
10ms
15ms
20ms
25ms
30ms
35ms
40ms
45ms
50ms

$V_A = 7V$


inverting Op-Amp
V(n004)
V(n003)
7V
6V
5V
4V
3V
2V
1V
0V
-1V
-2V
-3V
-4V
-5V
-6V
-7V
0ms
5ms
10ms
15ms
20ms
25ms
30ms
35ms
40ms
45ms
50ms

$V_A = 9V$



The output waveforms obtained after the V_A mark of 5V seem to saturate and clipped to give the same output.

Clipping in op-amp occurs when the output of the op-amp is greater then the power supply (Vcc & -Vee) that's why open loop configuration is not used in op-amp as open loop gain is very high which saturates the output (i.e clips the output waveform).

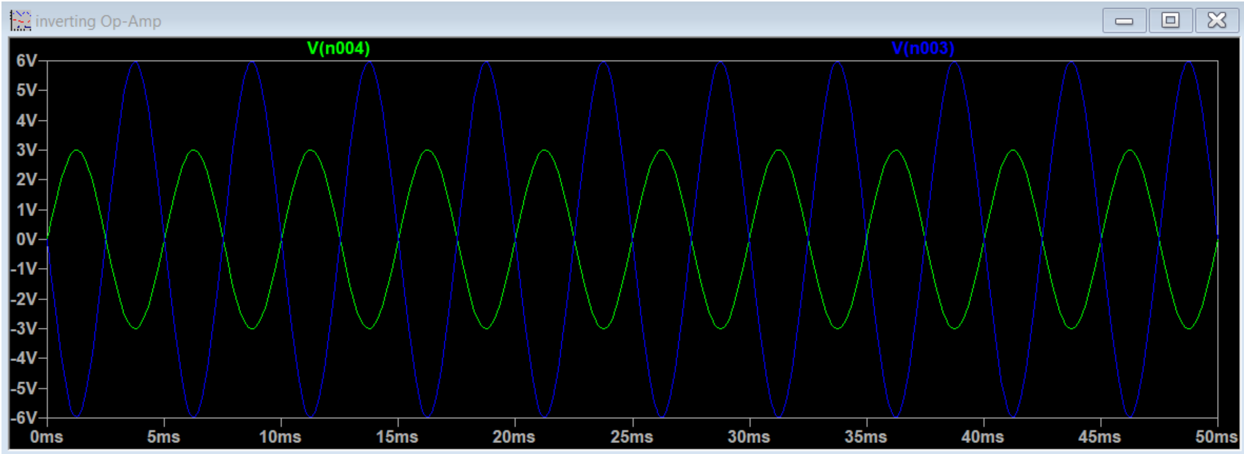
3. After 10 % increase in Rf, R1

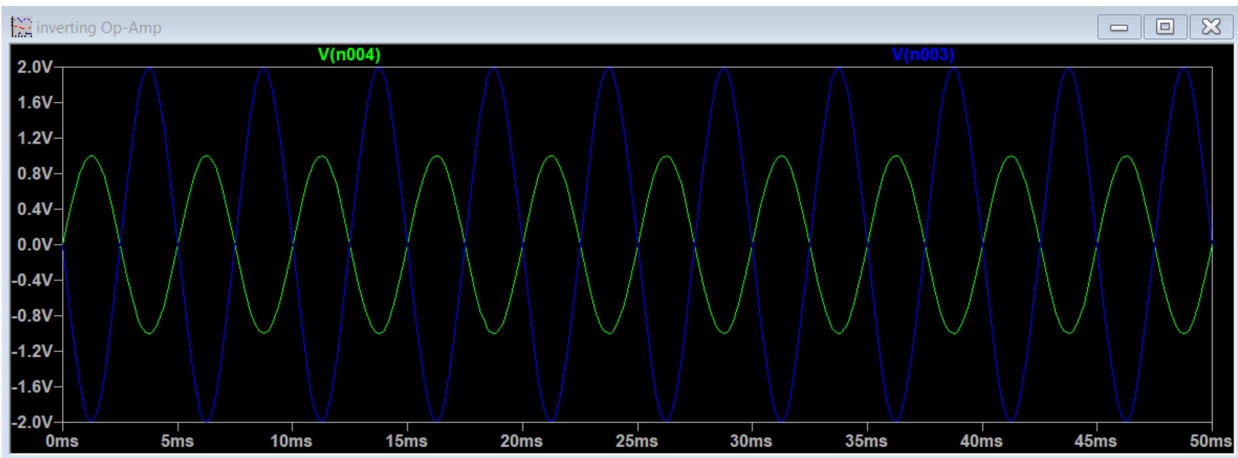
New R_f = 220 ohms ; R_1 = 110 ohms

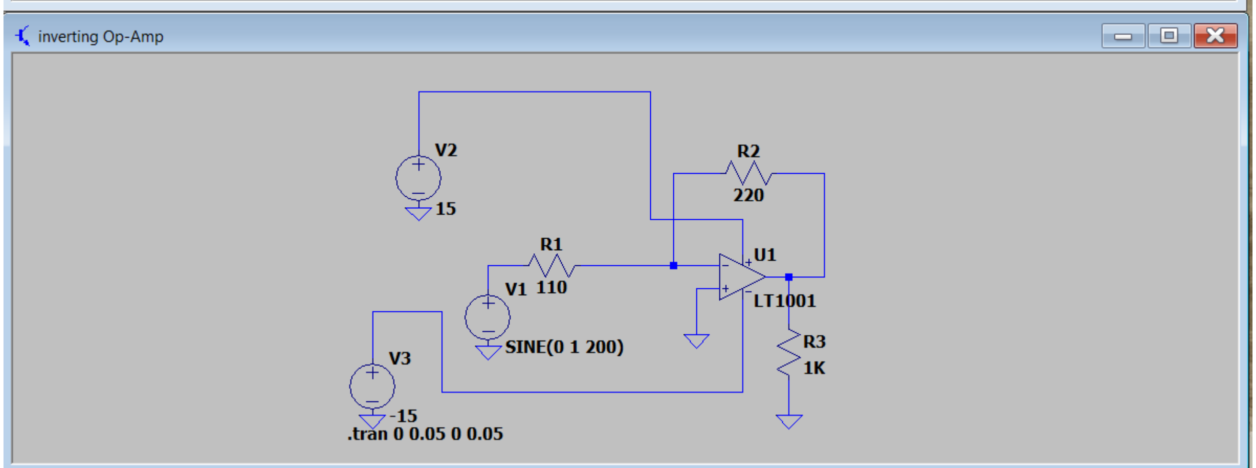
The gain after 10% variation Gain = R_f/R_1 = 2

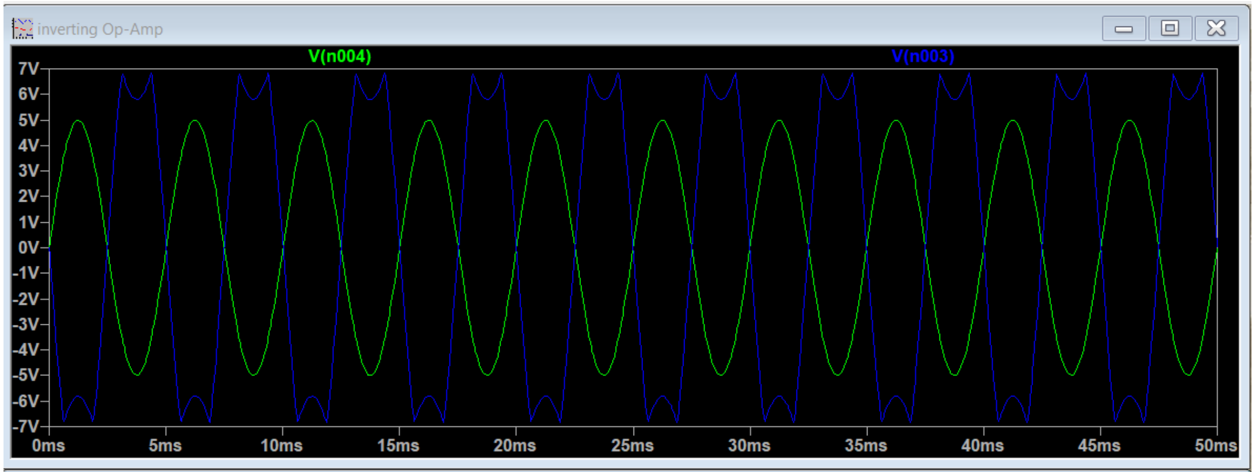
Since the gain is the same, the resultant output waveforms don't show much change from our original obtained waveforms.

The waveforms are shown below:

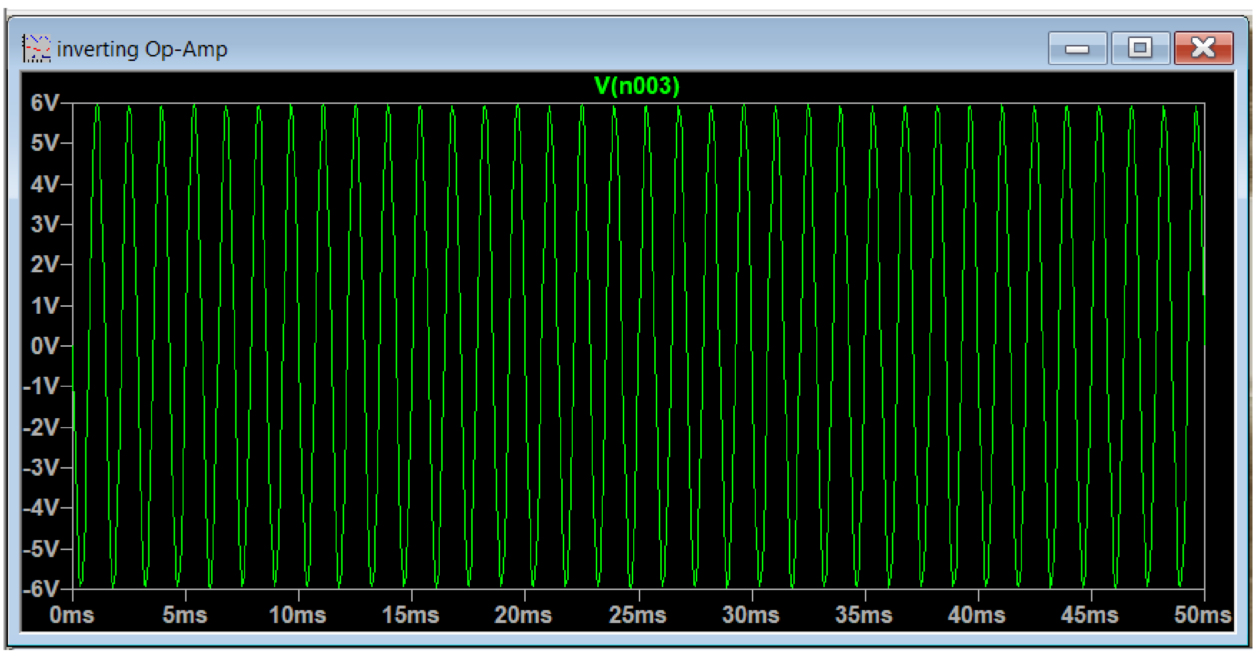

inverting Op-Amp
V(n004)
V(n003)
6V
5V
4V
3V
2V
1V
0V
-1V
-2V
-3V
-4V
-5V
-6V
0ms
5ms
10ms
15ms
20ms
25ms
30ms
35ms
40ms
45ms
50ms


inverting Op-Amp
V(n004)
V(n003)
2.0V
1.6V
1.2V
0.8V
0.4V
0.0V
-0.4V
-0.8V
-1.2V
-1.6V
-2.0V
0ms
5ms
10ms
15ms
20ms
25ms
30ms
35ms
40ms
45ms
50ms

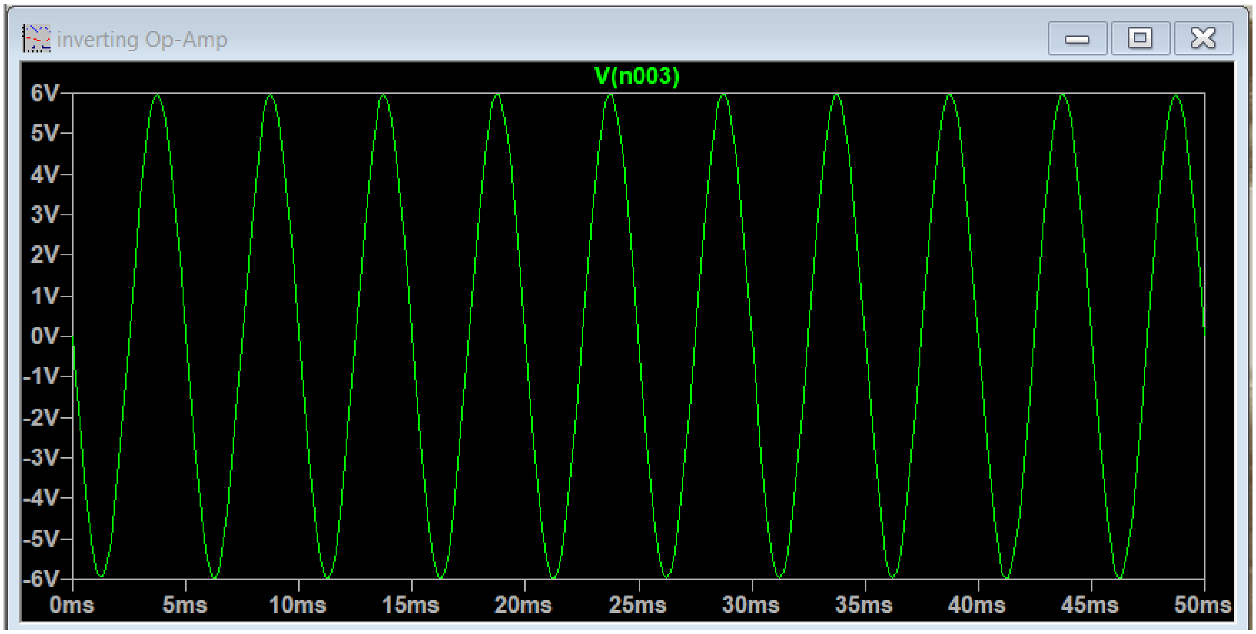

inverting Op-Amp
V2
15
R2
220
R1
110
V1
SINE(0 1 200)
U1
LT1001
R3
1K
V3
-15
.tran 0 0.05 0 0.05



4. The following waveform is obtained after changing frequency to 700 Hz



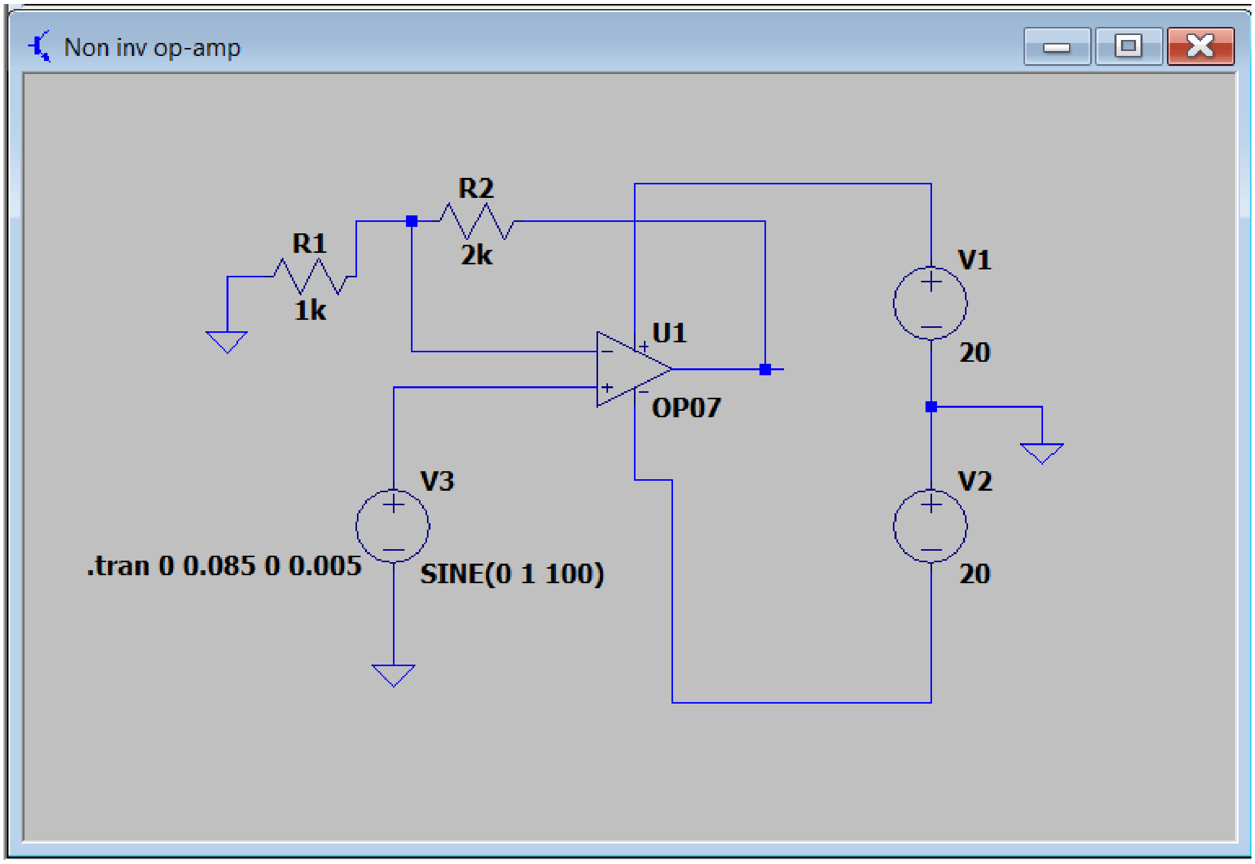
The earlier waveform for 200Hz is shown below



As can be seen, changing the frequency does not affect the magnitude of V_{out}

2) NON INVERTING AMPLIFIER USING OP-AMP

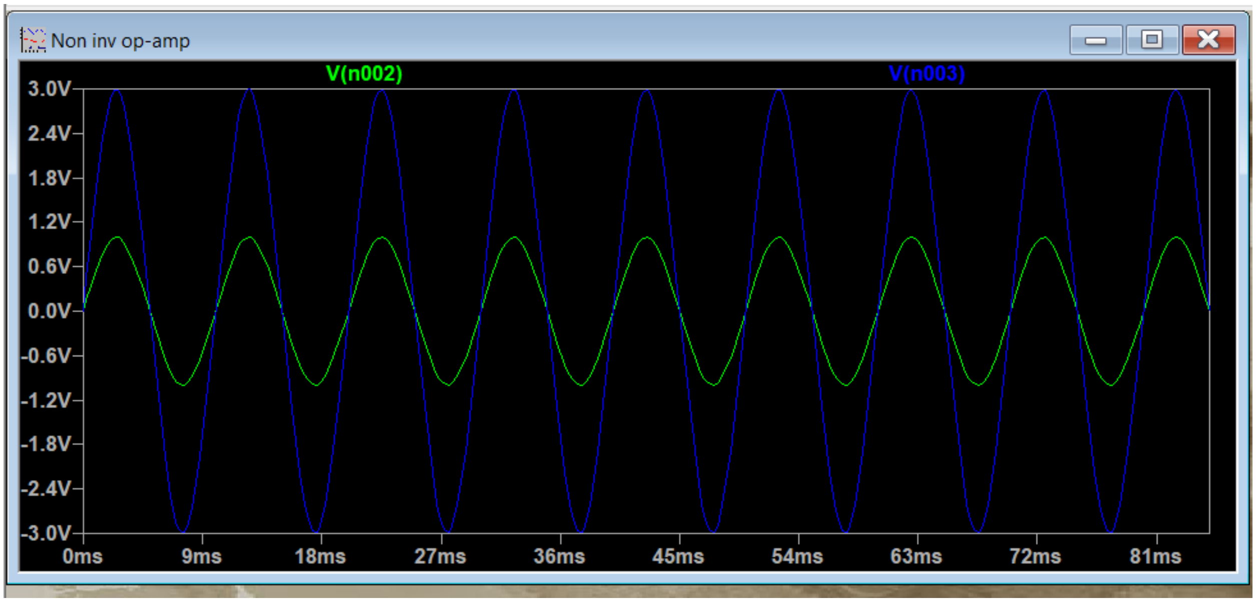
Circuit diagram:

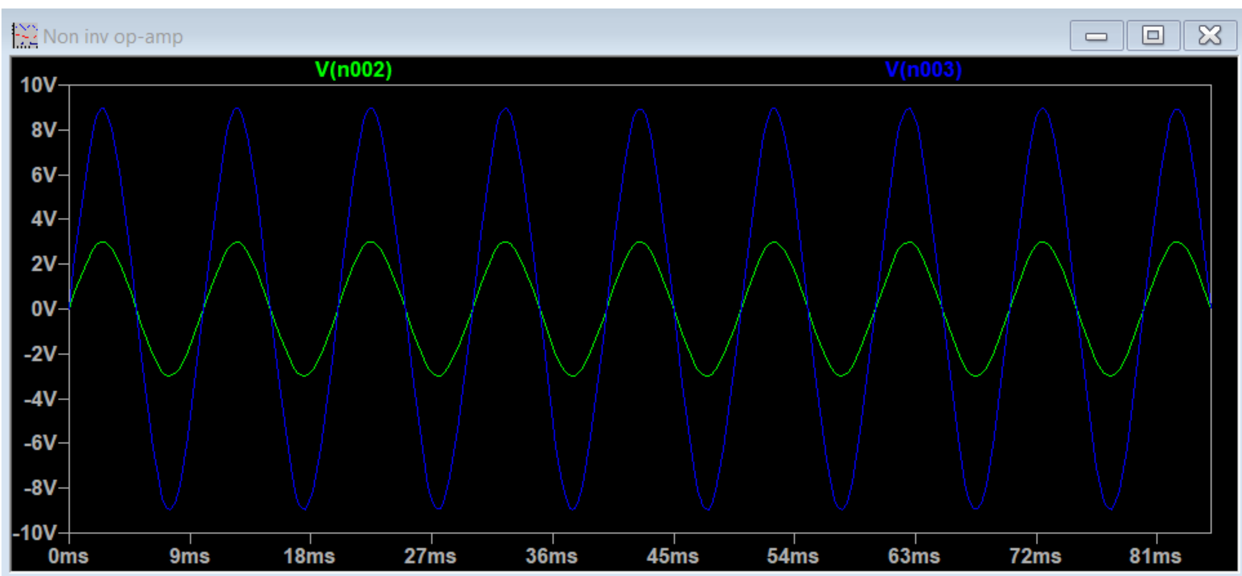


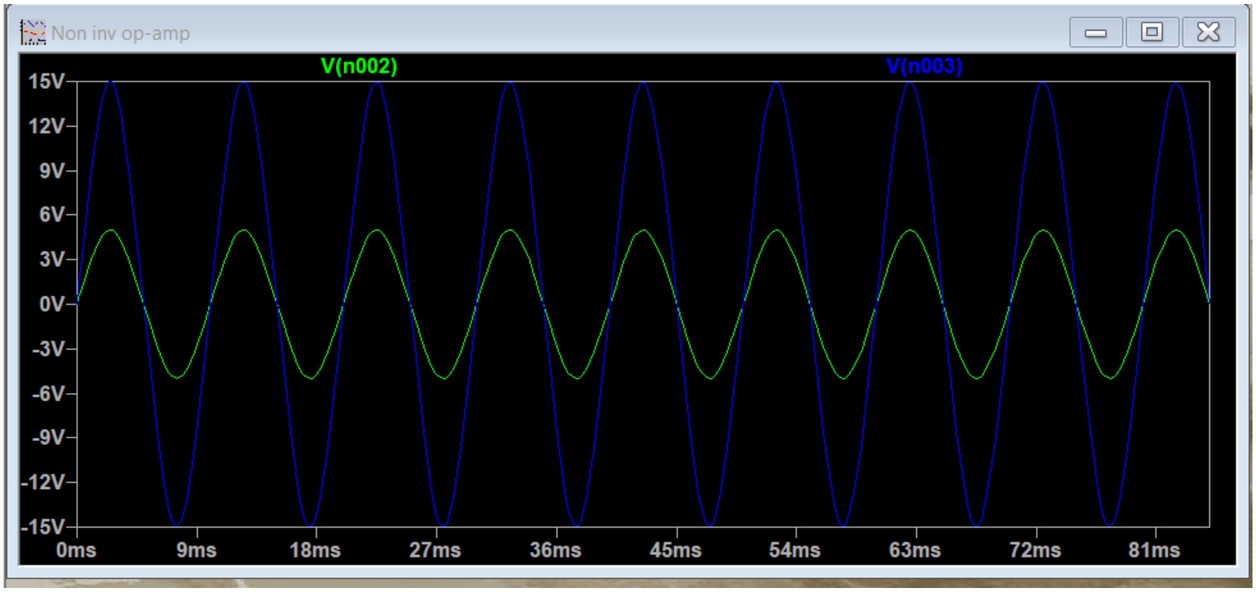
1.

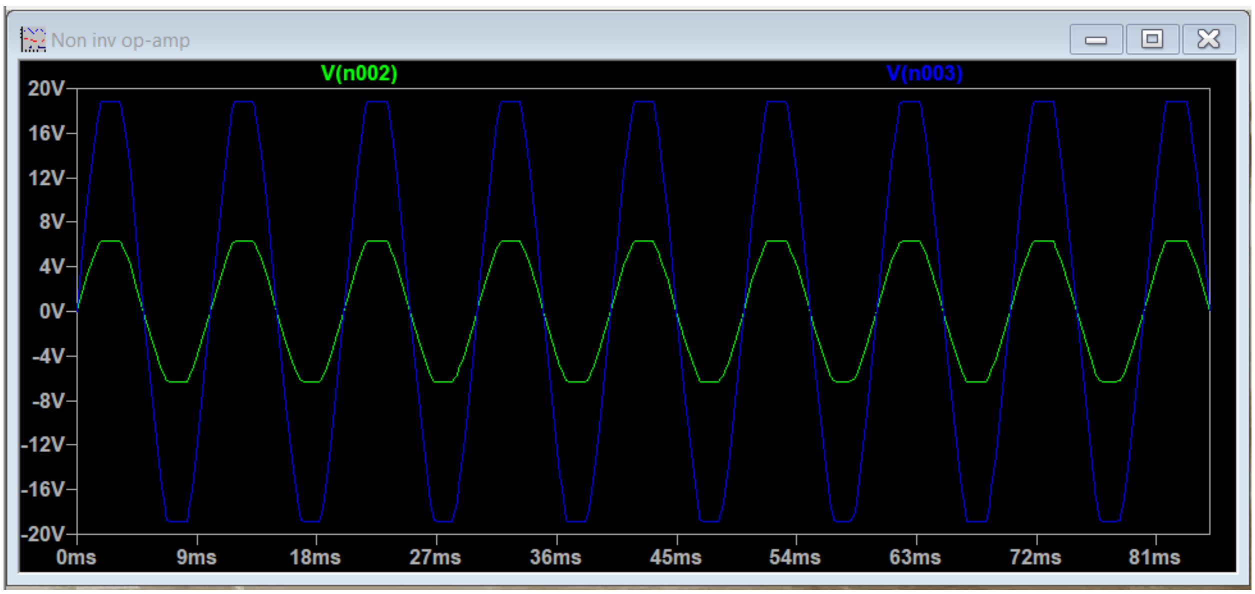
V_A	V_{out} (in V)
1	3
3	9
5	15
7	18.9
9	18.9

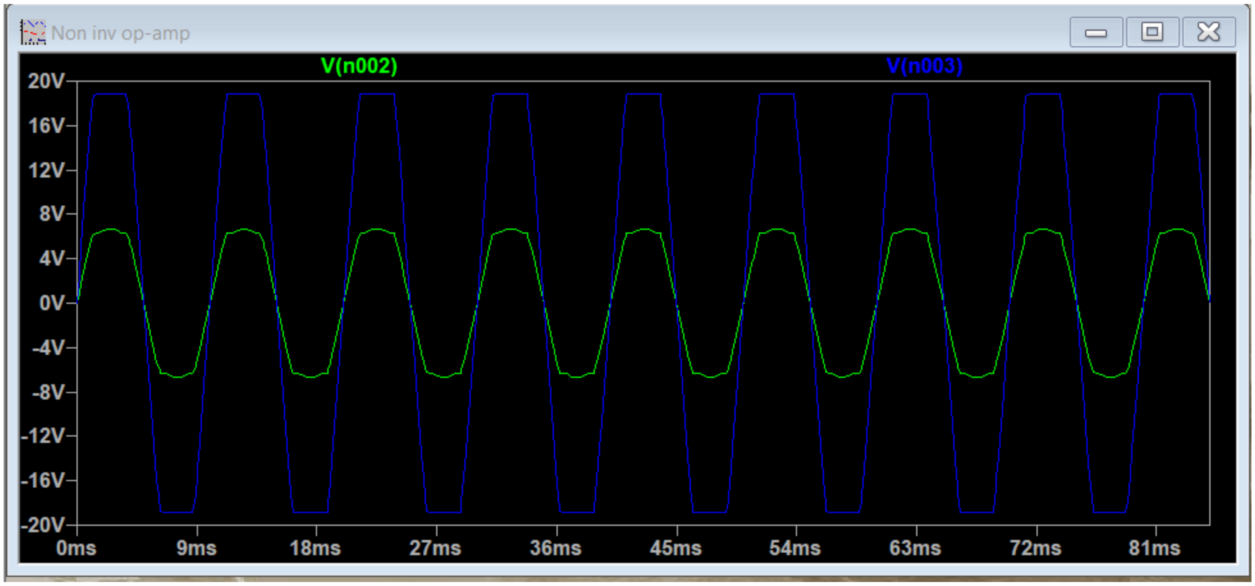
2.


Non inv op-amp
V(n002)
V(n003)
3.0V
2.4V
1.8V
1.2V
0.6V
0.0V
-0.6V
-1.2V
-1.8V
-2.4V
-3.0V
0ms
9ms
18ms
27ms
36ms
45ms
54ms
63ms
72ms
81ms


Non inv op-amp
V(n002)
V(n003)
10V
8V
6V
4V
2V
0V
-2V
-4V
-6V
-8V
-10V
0ms
9ms
18ms
27ms
36ms
45ms
54ms
63ms
72ms
81ms


Non inv op-amp
V(n002)
V(n003)
15V
12V
9V
6V
3V
0V
-3V
-6V
-9V
-12V
-15V
0ms
9ms
18ms
27ms
36ms
45ms
54ms
63ms
72ms
81ms


Non inv op-amp
V(n002)
V(n003)
20V
16V
12V
8V
4V
0V
-4V
-8V
-12V
-16V
-20V
0ms
9ms
18ms
27ms
36ms
45ms
54ms
63ms
72ms
81ms



Just like the case of the inverting amplifier, we observe some amount of clipping in the output waveform after a certain value of input voltage, in this case above 7V .

Clipping in op-amp occurs when the output of the op-amp is greater then the power supply (Vcc & -Vee) that's why open loop configuration is not used in op-amp as open loop gain is very high which saturates the output (i.e clips the output waveform). Hence we observe the waveforms like above.

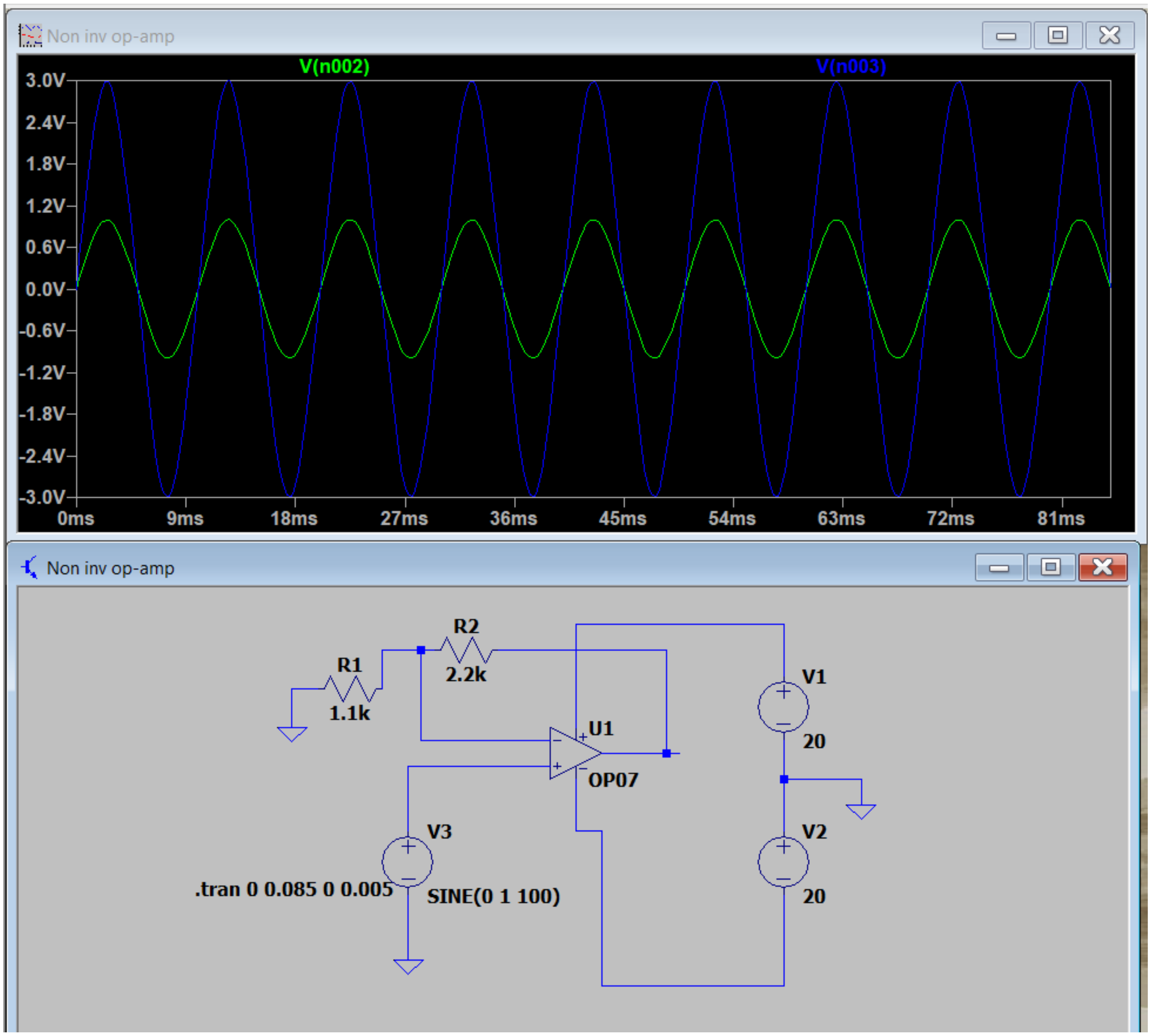
If there is a 10% increase in the values of R_f and R_1 , the new values are :

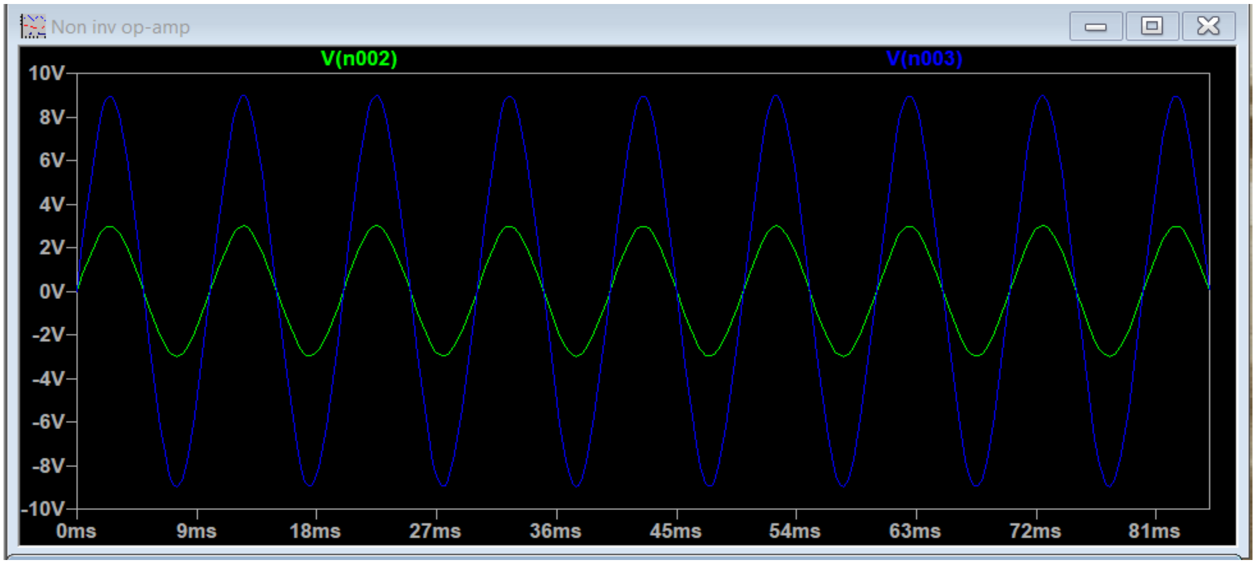
R_f = 2200 ohms and R_1 = 1100 ohms

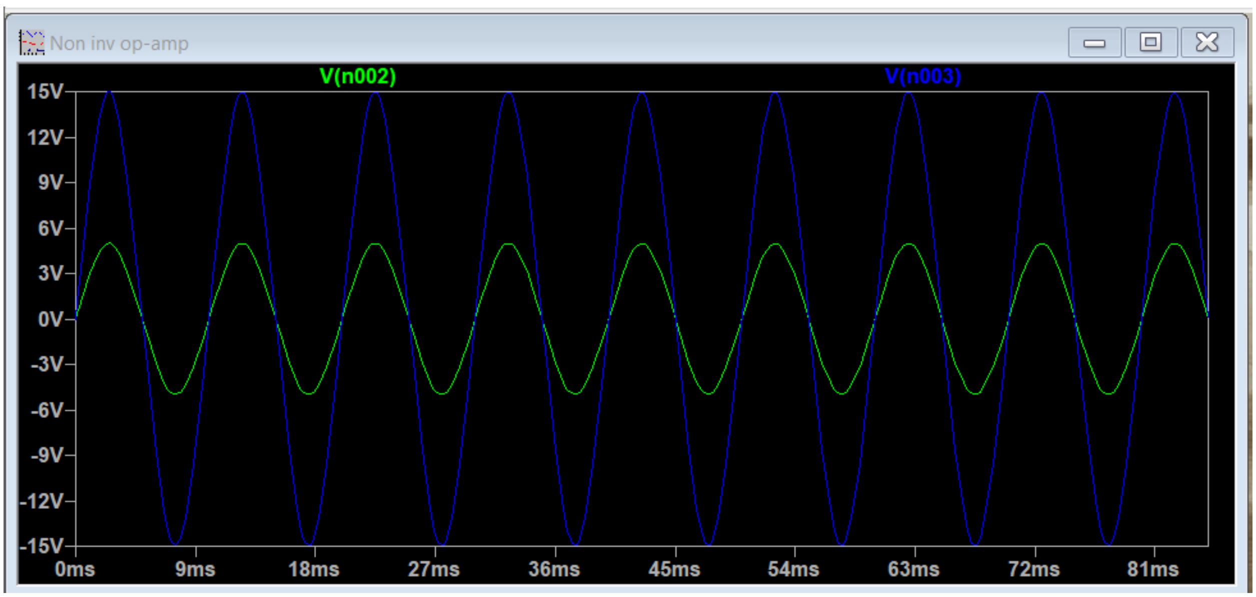
The gain, G= 1 + 2200/1100 = 3

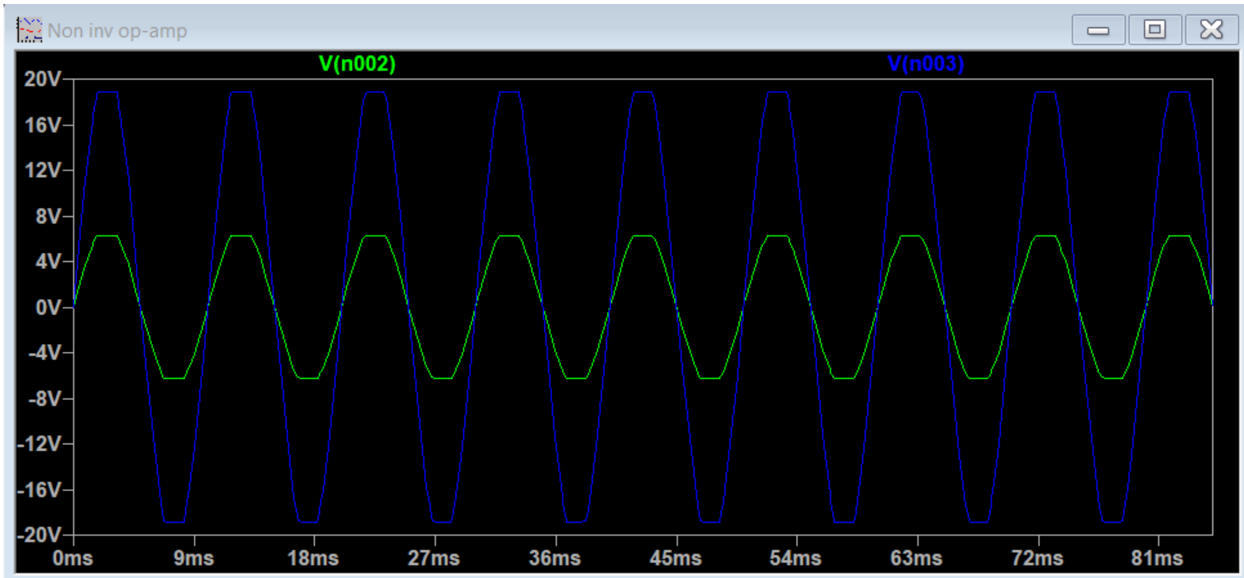
Since the gain remains the same, we don't observe any change in the maximum magnitude of the output waveforms.

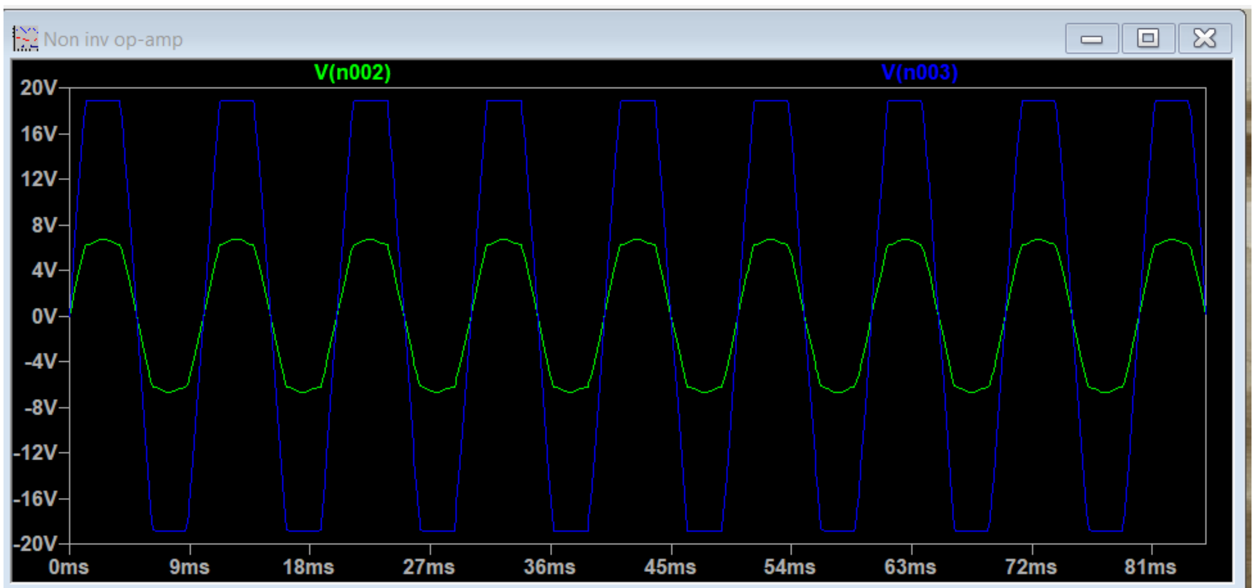
The waveforms for the new values of Rf and R1 are plotted below.


Non inv op-amp
V(n002)
V(n003)
3.0V
2.4V
1.8V
1.2V
0.6V
0.0V
-0.6V
-1.2V
-1.8V
-2.4V
-3.0V
0ms
9ms
18ms
27ms
36ms
45ms
54ms
63ms
72ms
81ms
Non inv op-amp
R2
2.2k
R1
1.1k
U1
OP07
V1
20
V2
20
V3
SINE(0 1 100)
.tran 0 0.085 0 0.005


Non inv op-amp
V(n002)
V(n003)
10V
8V
6V
4V
2V
0V
-2V
-4V
-6V
-8V
-10V
0ms
9ms
18ms
27ms
36ms
45ms
54ms
63ms
72ms
81ms

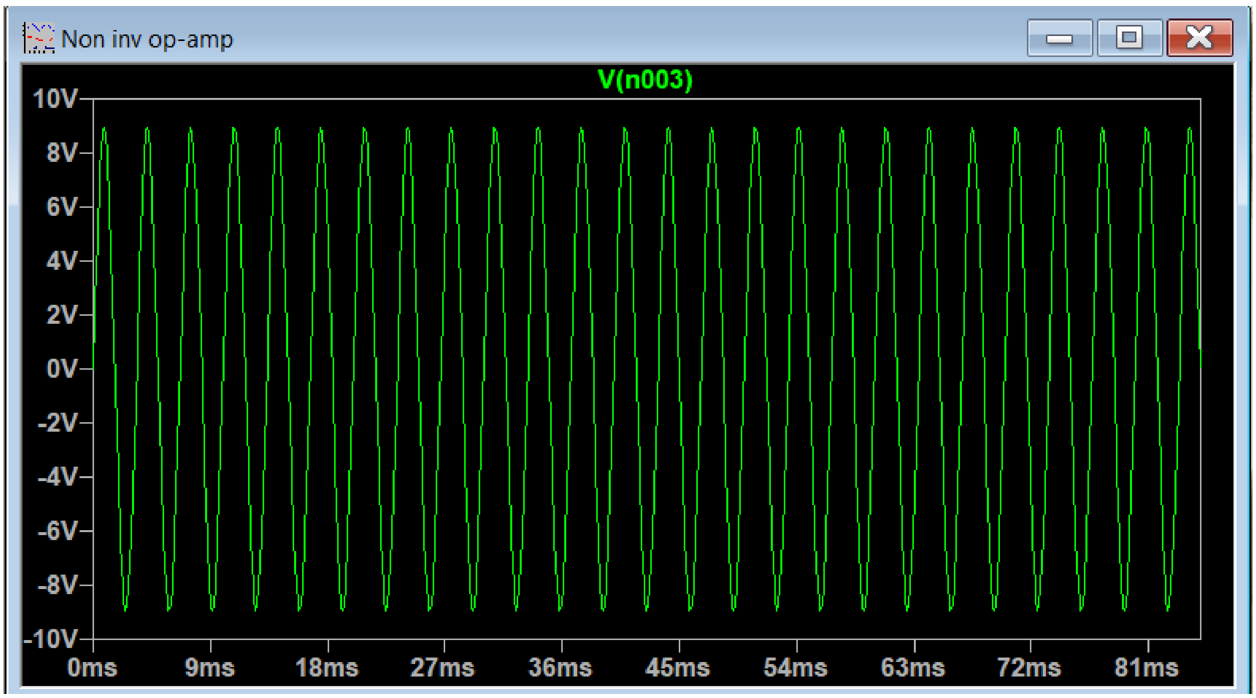

Non inv op-amp
V(n002)
V(n003)
15V
12V
9V
6V
3V
0V
-3V
-6V
-9V
-12V
-15V
0ms
9ms
18ms
27ms
36ms
45ms
54ms
63ms
72ms
81ms


Non inv op-amp
V(n002)
V(n003)
20V
16V
12V
8V
4V
0V
-4V
-8V
-12V
-16V
-20V
0ms
9ms
18ms
27ms
36ms
45ms
54ms
63ms
72ms
81ms


Non inv op-amp
V(n002)
V(n003)
20V
16V
12V
8V
4V
0V
-4V
-8V
-12V
-16V
-20V
0ms
9ms
18ms
27ms
36ms
45ms
54ms
63ms
72ms
81ms

4.

Changing the frequency of the source only compresses the waveform, it doesn't alter the magnitude of the V_{out} as shown below.



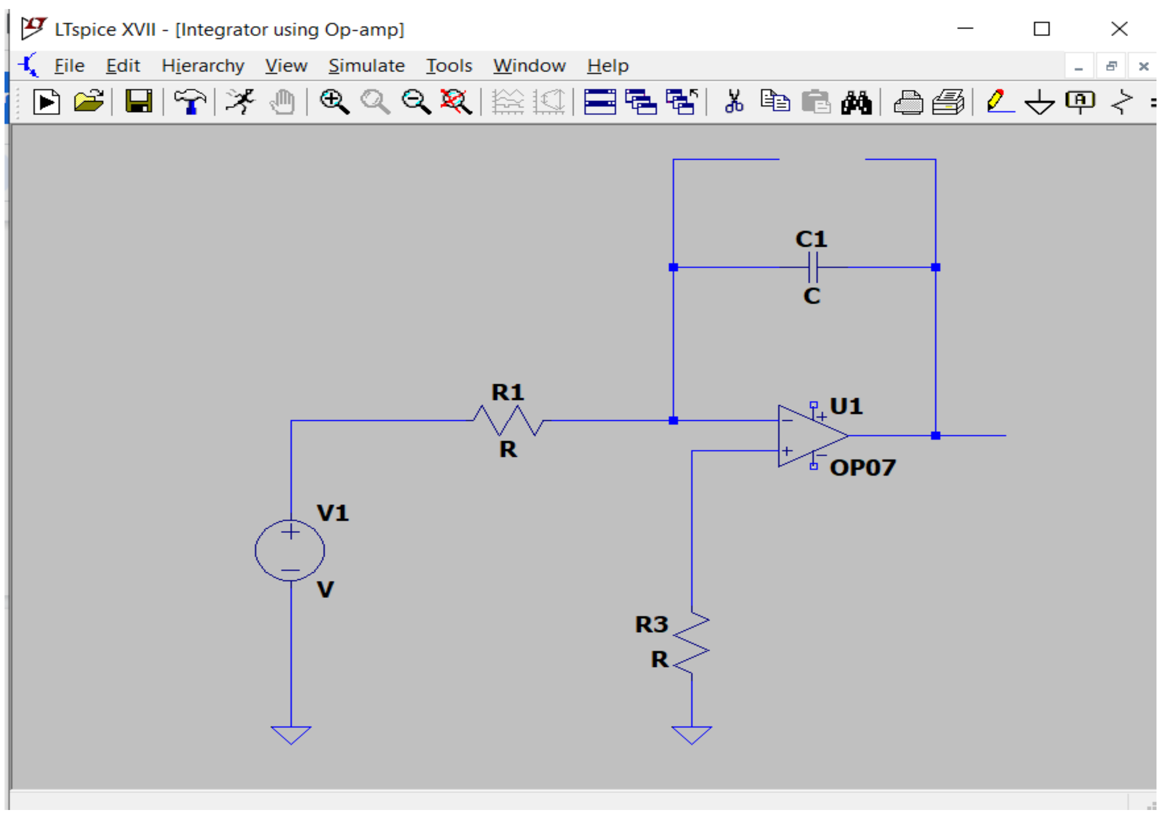
Compared to the original output waveforms, the magnitude doesn't change, a slight compression is observed.

3) ACTIVE INTEGRATOR USING OP-AMP

i) Without R_F resistor

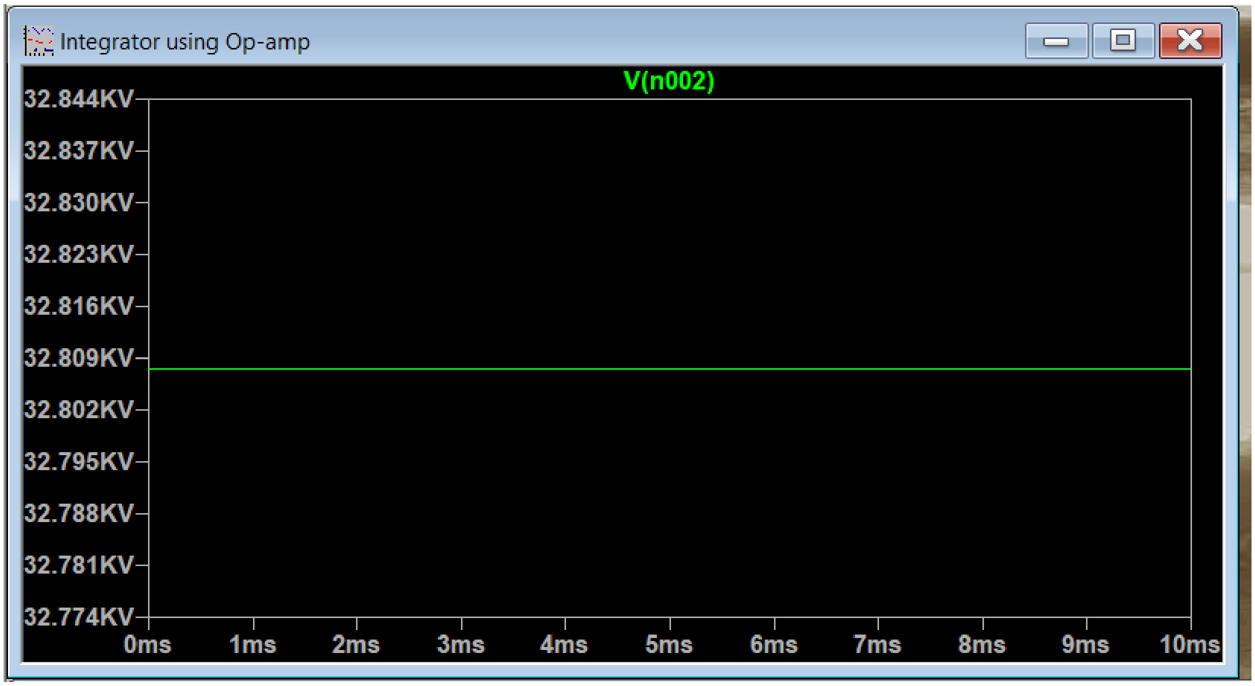
S.no	V_{in}	R	C	V_{out}
1	5 sin(wt)	10k ohms	0.01uF	32.81 KV
2	5 sin(wt)	10k ohms	0.1uF	32.81KV
3	5 sin(wt)	10k ohms	1uF	32.81KV
4	5 sin(wt)	10k ohms	10uF	32.81KV
5	5 sin(wt)	10k ohms	100uF	36.9KV

Circuit :



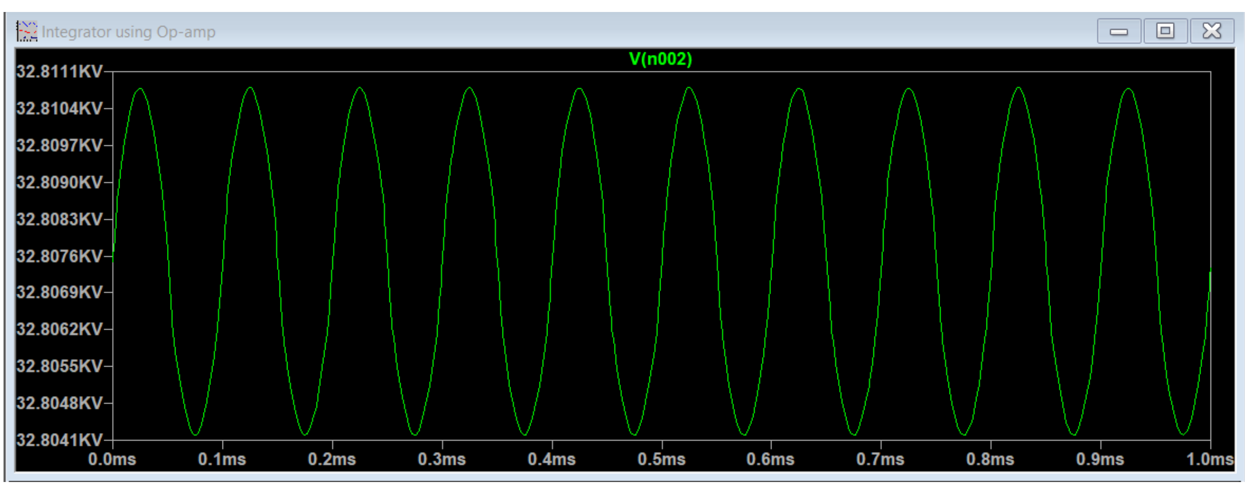
1. At 0 frequency, following output is obtained:

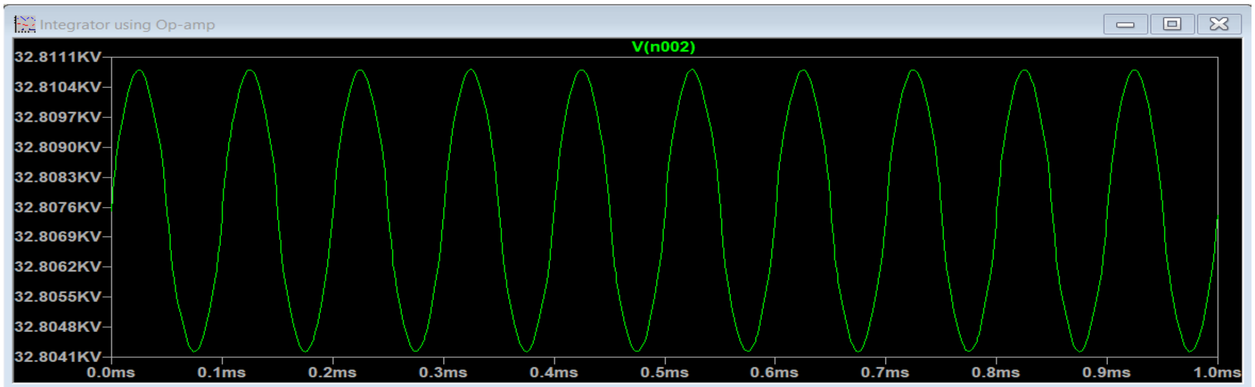
Constant DC output voltage is obtained with magnitude = 32.81KV

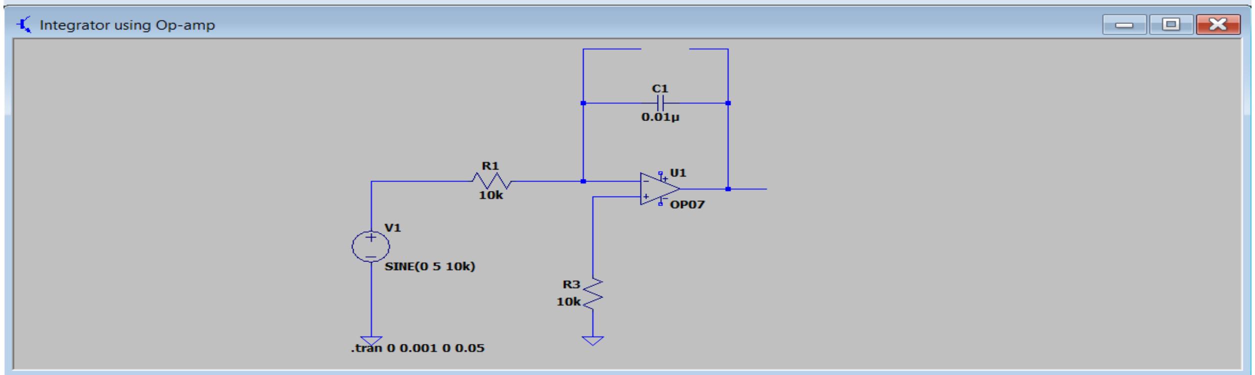


2.

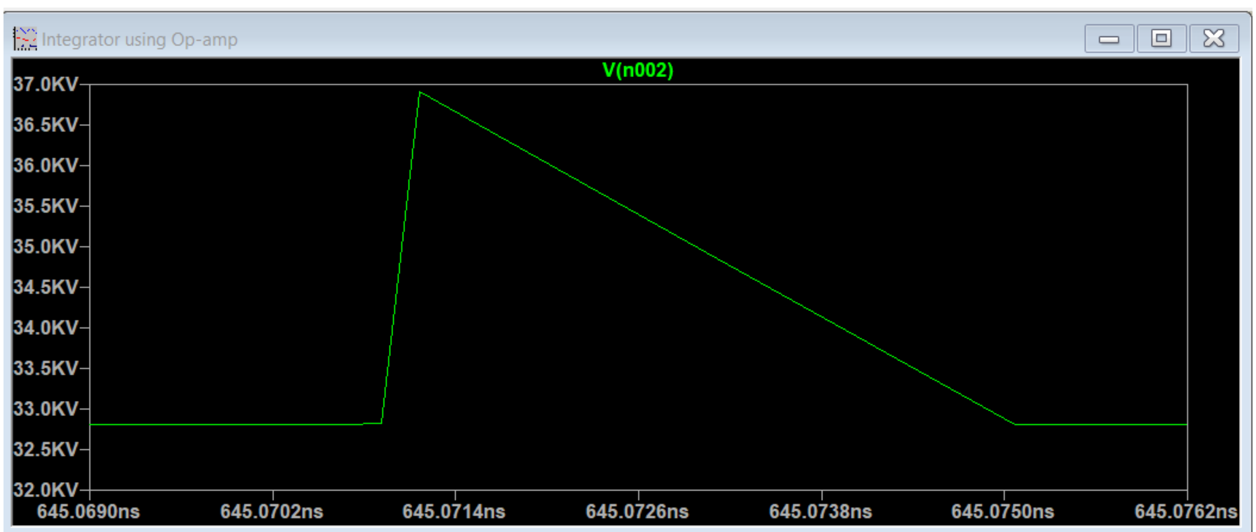
Until 10uF, changing the value of capacitance, does not produce significant change in the output waveforms, as shown below for each of the cases the output voltage saturates at 32.81KV.







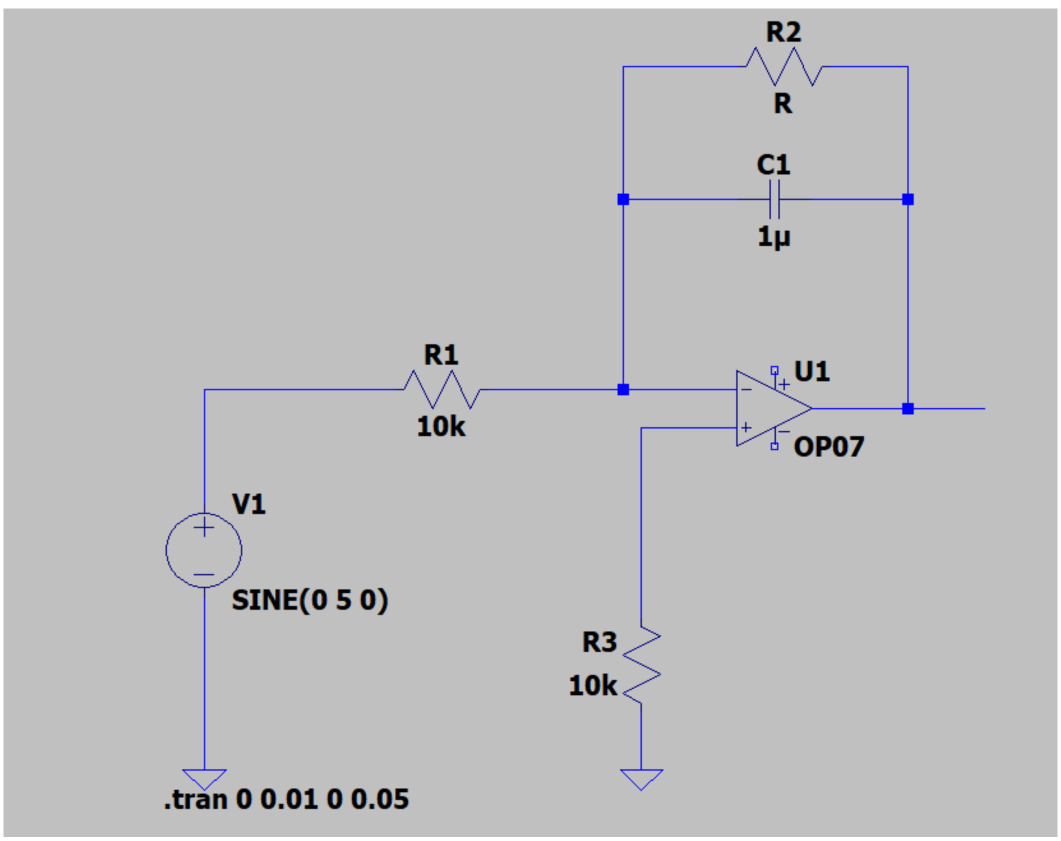
However, when the capacitance is above 100uF, we observe a change in the output waveform and voltage as shown below.
Some amount of decoherence, distortion and clipping takes place.



ii) With R_F resistor

S.no	V_{in}	R	C	R_F	V_{out}
1	5 sin(wt)	10k ohms	0.01uF	10 ohms	3.274V
2	5 sin(wt)	10k ohms	0.1uF	100 ohms	3.274V
3	5 sin(wt)	10k ohms	1uF	1k ohm	3.274V
4	5 sin(wt)	10k ohms	10uF	10k ohm	3.274V
5	5 sin(wt)	10k ohms	100uF	100k ohm	3.354V

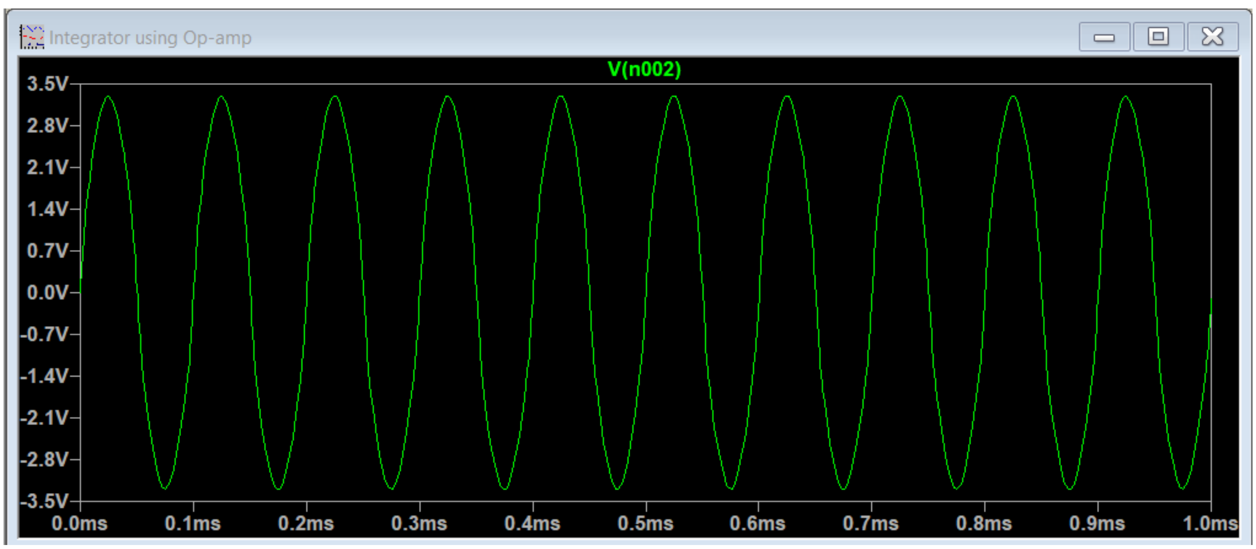
Circuit Diagram



1. What will be the response of the circuit at zero frequency?

1.49 mV (constant valued output voltage).

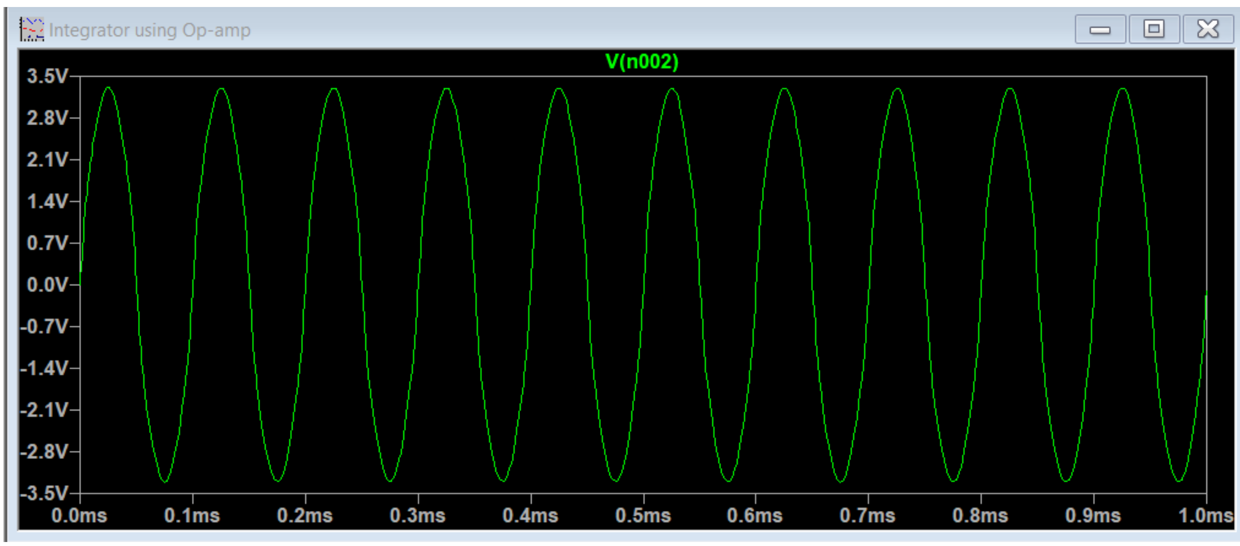
2. What is the impact of the capacitor value on the output voltage?



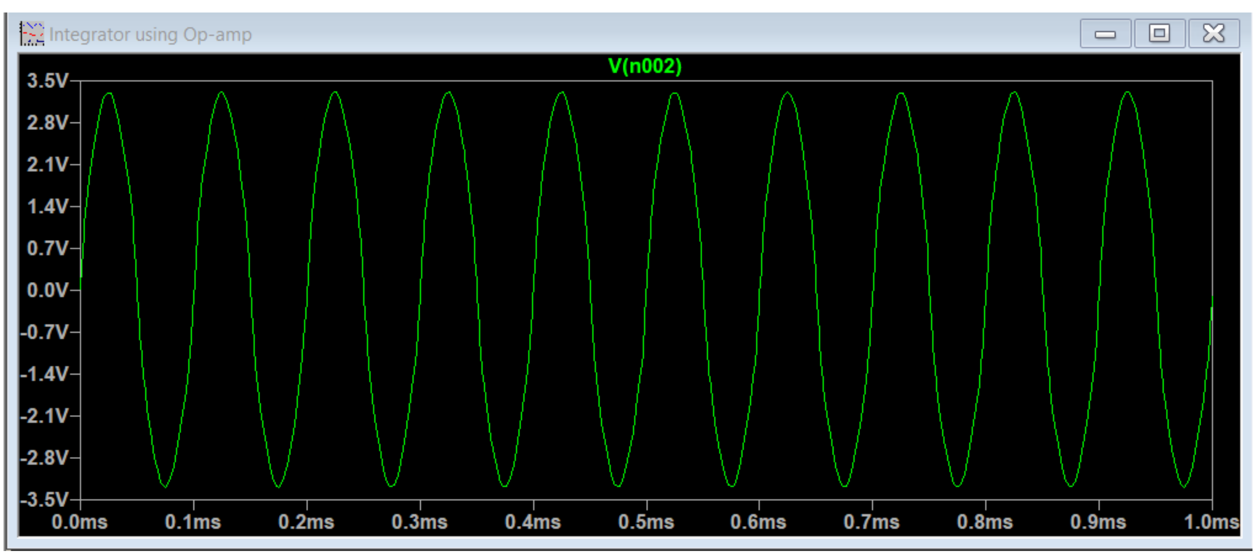
For the same R_F , changing capacitor value does not affect V_{out}

3. How does feedback resistor RF impact the output voltage?

Until the R_F value goes to 100 ohms, for all the values below it, we obtain the following output waveform. This is because a drastic change in the output voltage happens only with a combined change in the product of R_F and C. Once the cut-off frequency is exceeded, we see a change in waveforms.



For the last case :

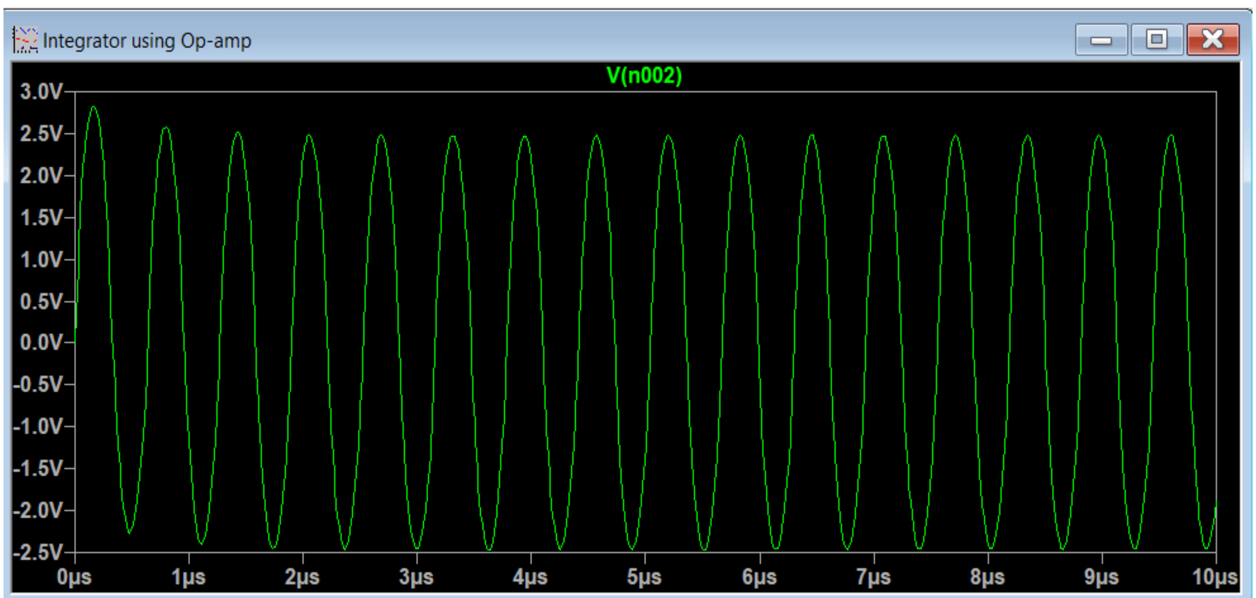


4. For ω ≪ ωH and ω ≫ ωH cases, draw the frequency response graph and justify your
answers in response to frequency ωH.

$\omega_H = 1/(R_F C)$

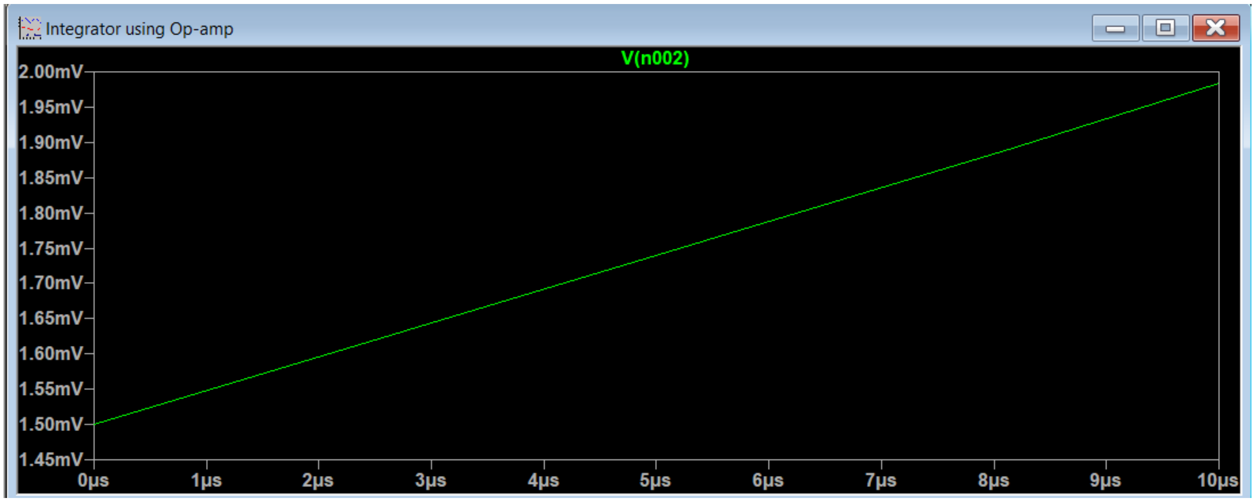
So for our case, let's take R_F = 10 ohms and C = 1u
Then $\omega_H = 10^5$ rad/sec

For ω ≫ ωH , let's take $\omega=10^7$ rad/sec
The frequency response is:



For ω << ωH , let's take ω=10 rad/sec
The following is the output

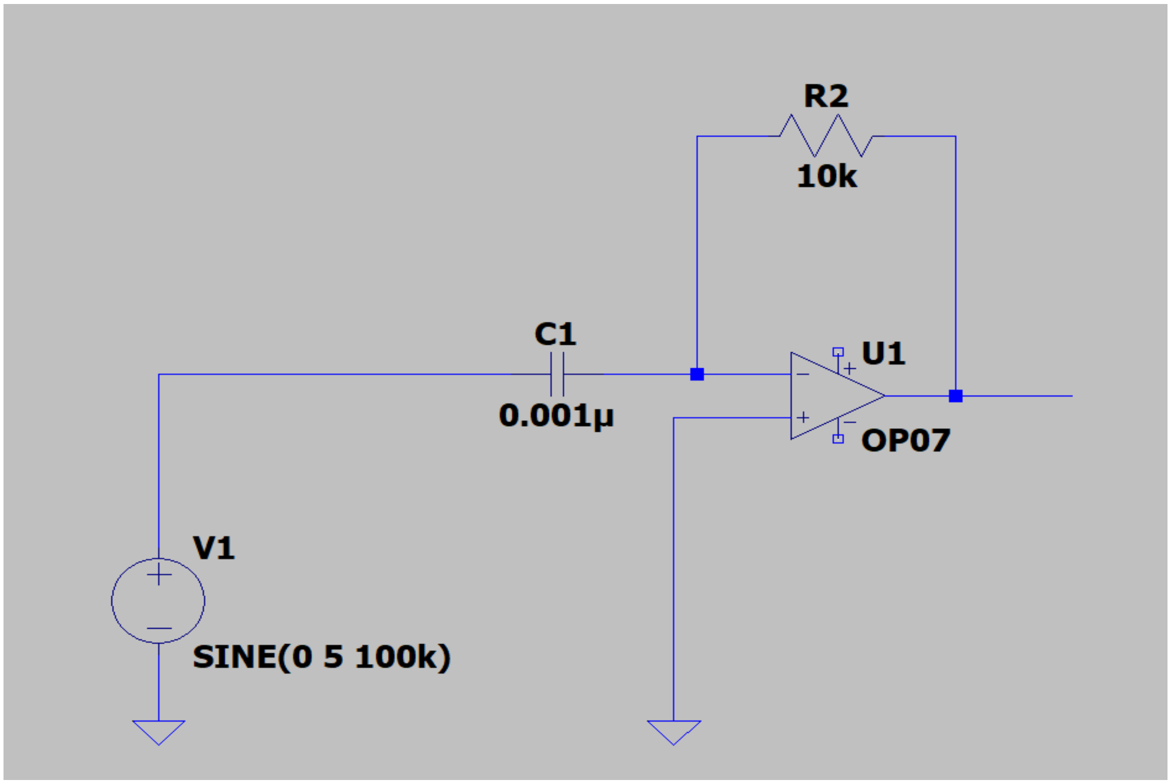
At a frequency lesser than the cut-off frequency, the absolute voltage gain becomes similar to the case of an inverting amplifier.



At ω ≪ ωH the absolute voltage gain becomes -RF/R , while ω ≫ ωH the gain decreases at a rate of 20dB per decade. At a frequency lesser than the cut-off frequency, the voltage gain becomes similar to the case of an inverting amplifier.

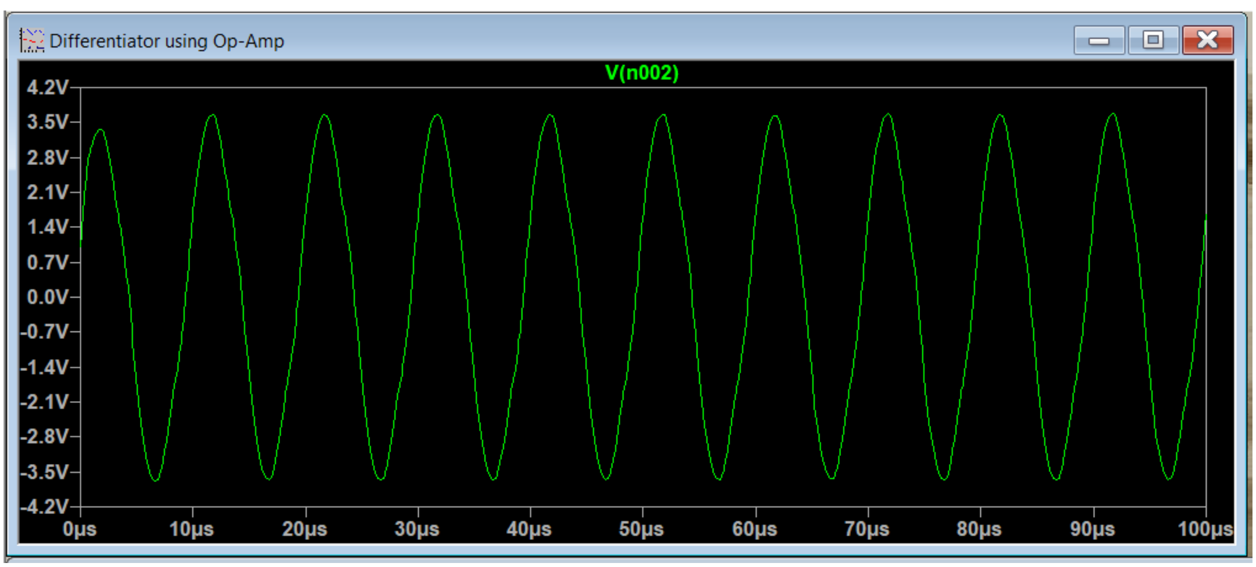
4) ACTIVE DIFFERENTIATOR USING OP-AMP

S.no	V_{in}	R	C	V_{out}
1	5 sin(wt)	10k ohms	0.001uF	3.65V
2	5 sin(wt)	10k ohms	0.01uF	5.22V
3	5 sin(wt)	10k ohms	0.1uF	5.76V
4	5 sin(wt)	10k ohms	1uF	5.76V
5	5 sin(wt)	10k ohms	10uF	5.76V
6	5 sin(wt)	10k ohms	100uF	5.76V
7	5 sin(wt)	10k ohms	1000uF	5.76V

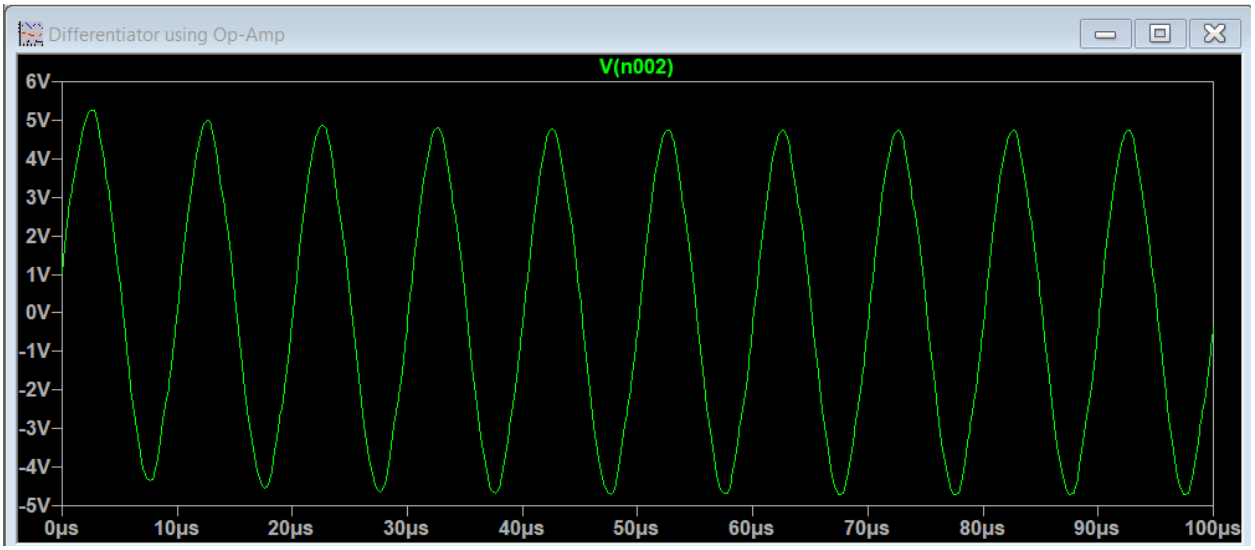


The following are the output waveforms obtained

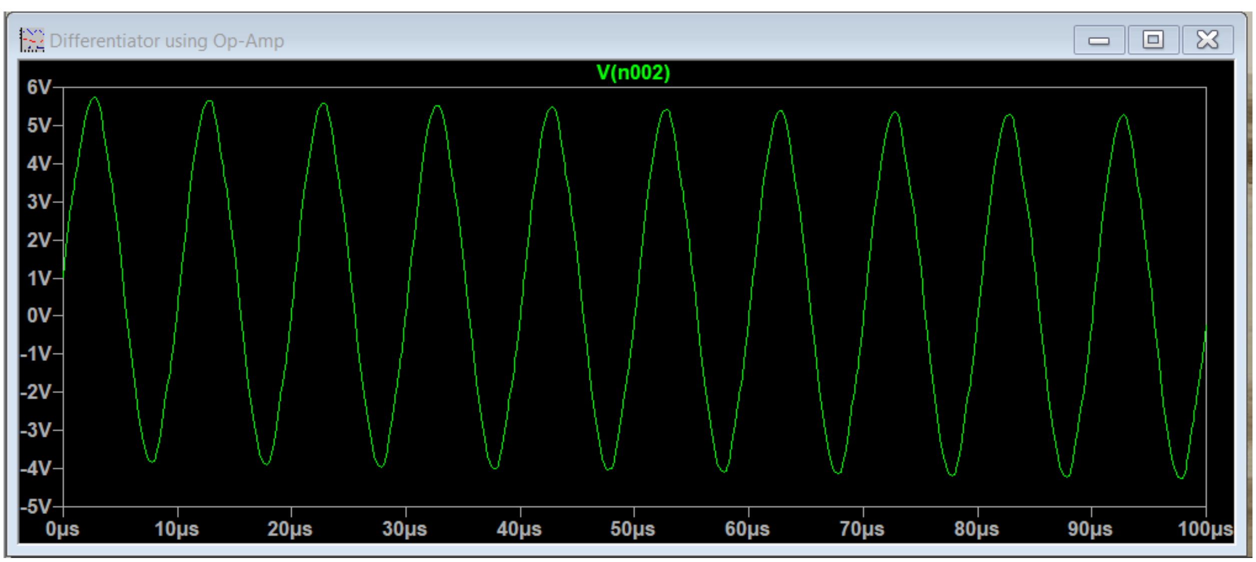
1)
For 0.001uF



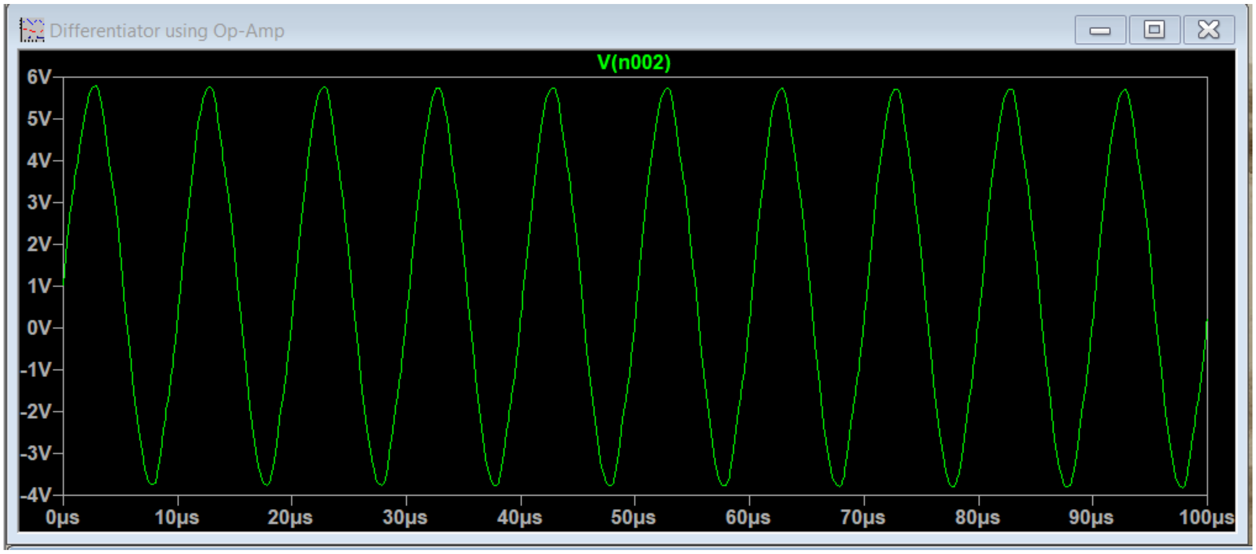
For 0.01uF



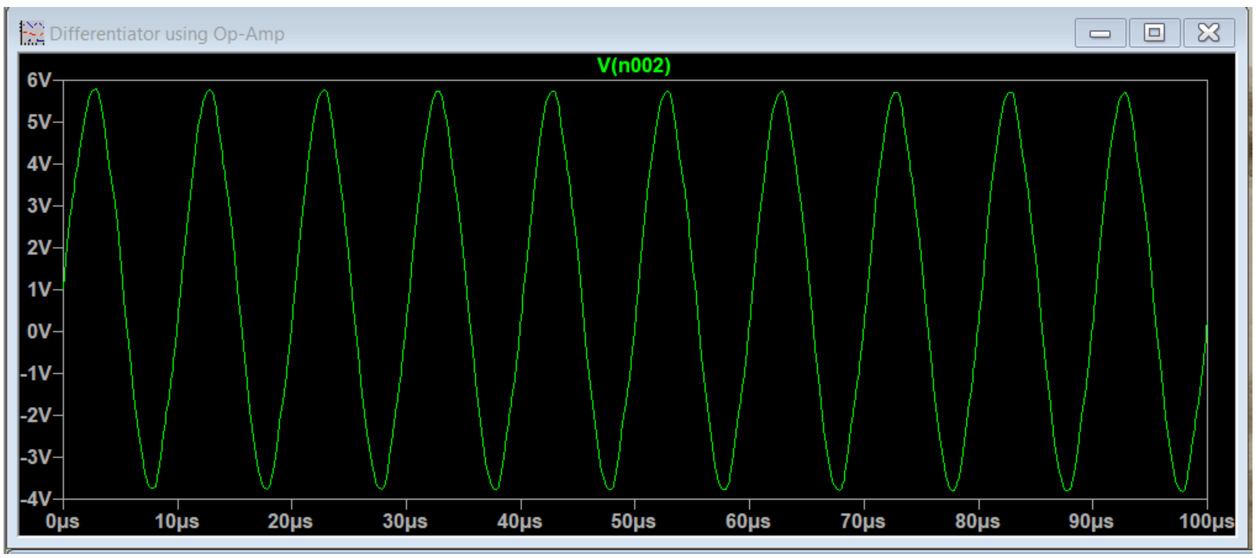
For 0.1uF



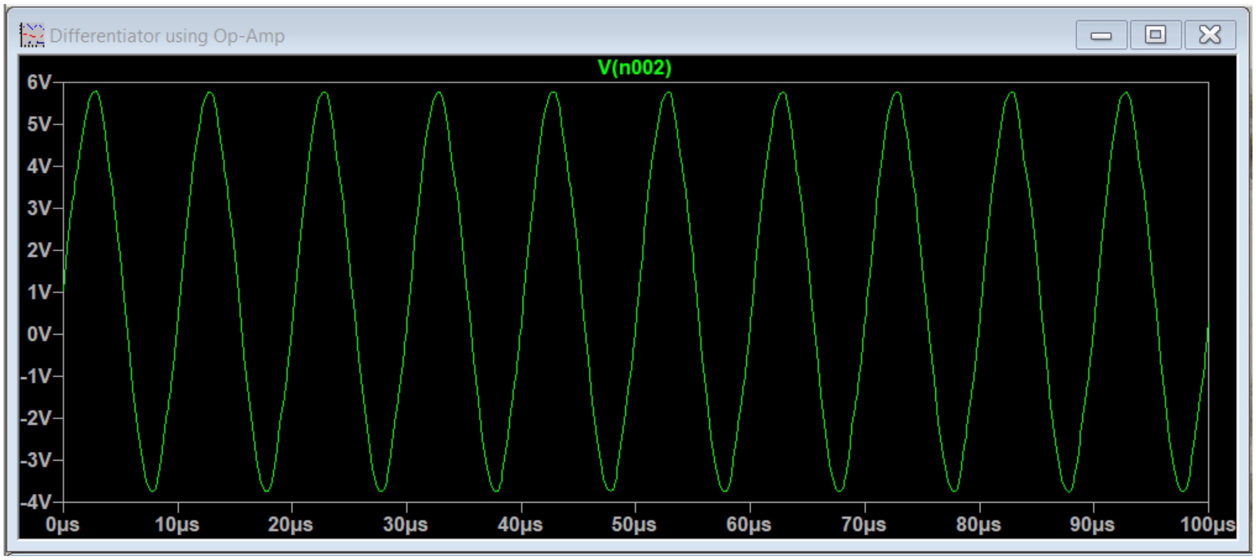
For 1uF



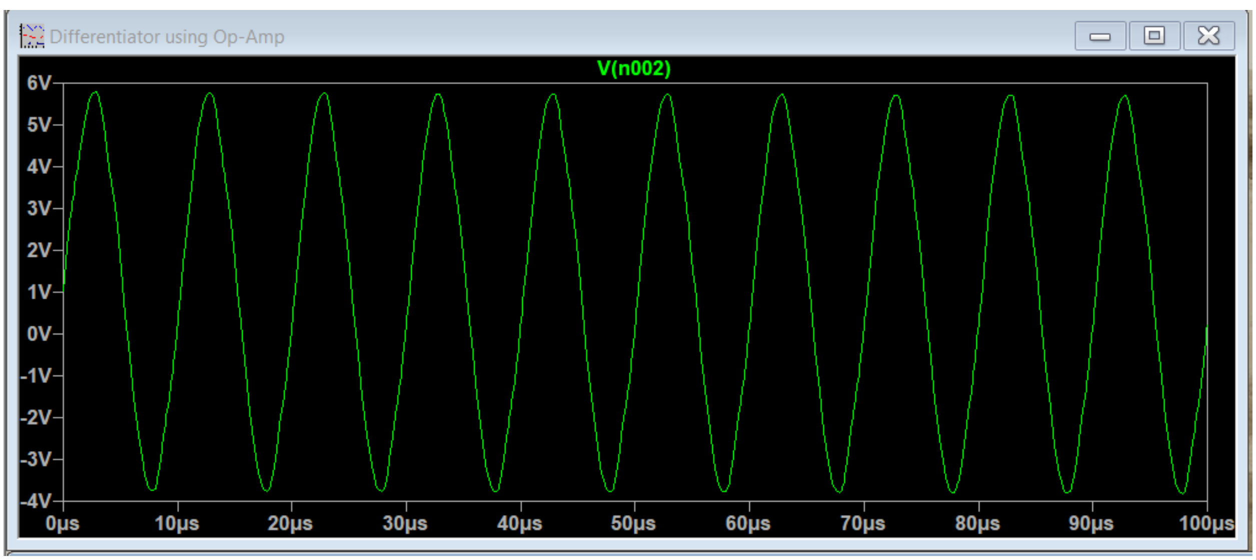
For 10uF



For 100uF



For 1000uF



When input is a pulse:

We see constant DC output voltage.

So when the input pulse is a sinusoid, we see the corresponding output voltage waveforms to also resemble sinusoids.

As the integrator is sensitive to DC drifts, the differentiator is sensitive to high frequency noise.

The differentiator thus is a great way to search for transients, but will add noise. However, an integrator will decrease noise.

So, as seen from the output waveforms this transfer function clearly reflects that at higher frequencies the gain of any differentiator will be high while being low at lower frequencies.