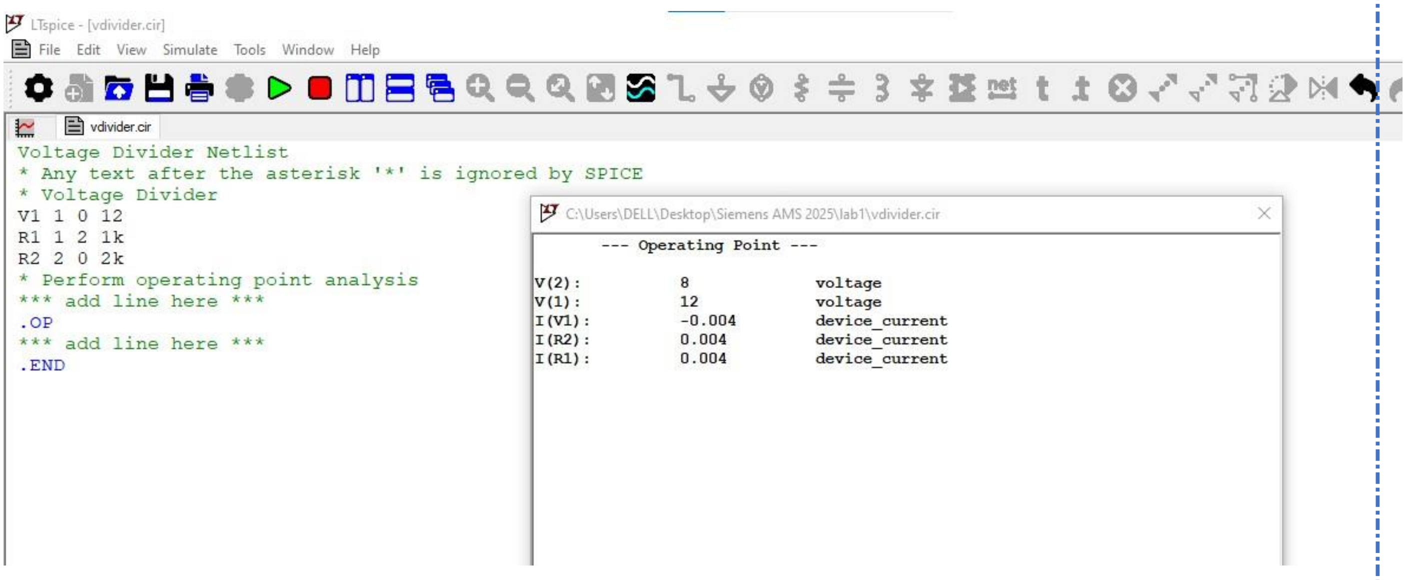
# lab 1

## Part 1 :

## Voltage divider

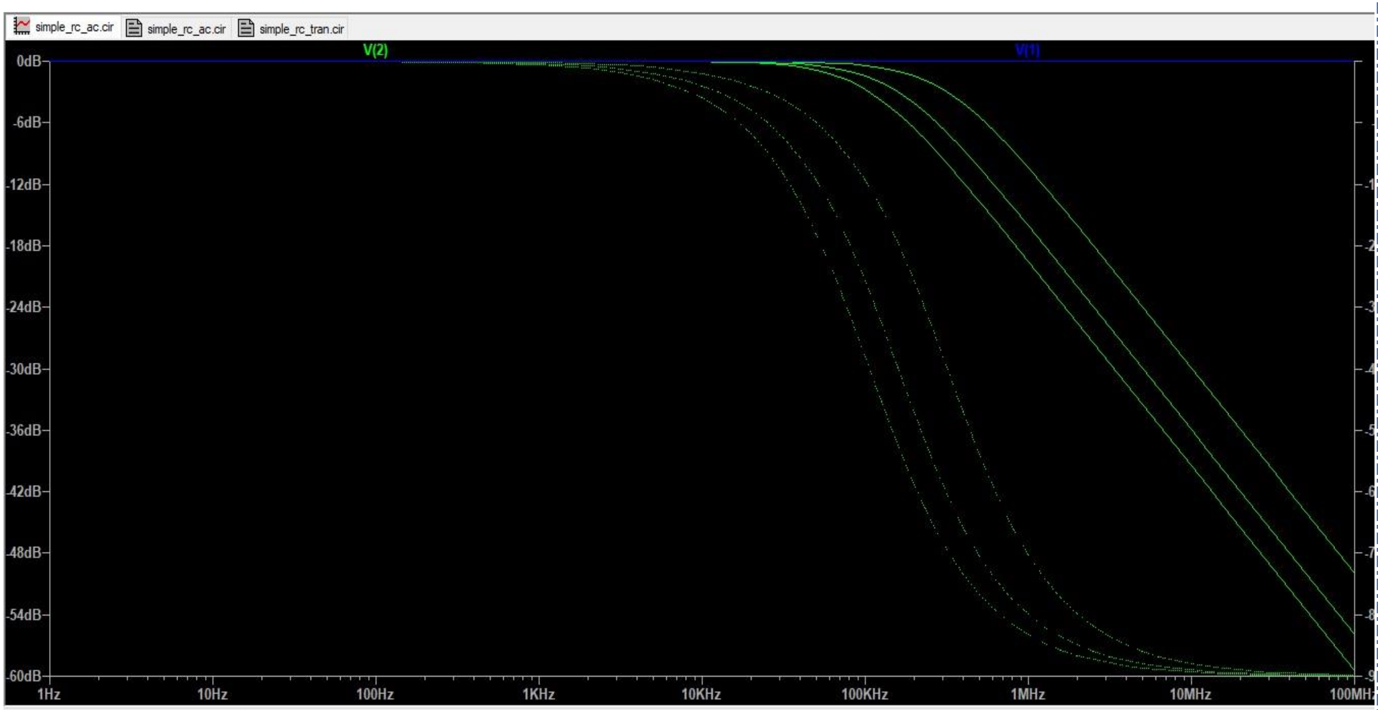


# AC

simple_rc_ac.cir | simple_rc_ac.cir

```
* Circuit Description
* RC low-pass filter with parametric sweep for CPAR

* Parameters
.PARAM CPAR=500p

* Signal sources
V1 1 0 AC 1

* Circuit elements
R1 1 2 1k
C1 2 0 {CPAR}

* Analysis request
* Run ac sweep from 1Hz to 100MEG with 10 pts per decade
.AC DEC 10 1 100MEG
* Use parametric sweep for CPAR: 500p:500p:1.5n
.STEP PARAM CPAR 500p 1.5n 500p
*.STEP PARAM CPAR LIST 500p 1n 1.5n

* Output request
.PRINT AC V(1) V(2)
.PLOT AC V(1) V(2)

* Measure the peak
.MEAS AC PEAK max mag(V(2))

* Measure bandwidth using PEAK/sqrt(2)
.MEAS AC BW WHEN mag(V(2))=PEAK/SQRT(2)

.END
```

```
LTspice 24.1.9 for Windows
Circuit: C:\Users\DELL\Desktop\Siemens AMS 2025\lab1\simple_rc_ac.cir
Start Time: Fri Jul 18 03:37:14 2025
solver = Normal
Maximum thread count: 8
tnom = 27
temp = 27
method = trap
.OP point found by inspection.
.step cpar=5e-10
.step cpar=1e-09
.step cpar=1.5e-09
Total elapsed time: 0.064 seconds.

Files loaded:
C:\Users\DELL\Desktop\Siemens AMS 2025\lab1\simple_rc_ac.cir


Measurement: peak
  step       MAX(mag(V(2)))      FROM  TO
     1       (-4.28633915609e-11dB,0Â°)     1      100000000
     2       (-1.71452601918e-10dB,0Â°)     1      100000000
     3       (-3.85768595401e-10dB,0Â°)     1      100000000

Measurement: bw
  step       mag(V(2))=PEAK/SQRT(2)
     1       318360.932452
     2       159171.763992
     3       106165.634071
```

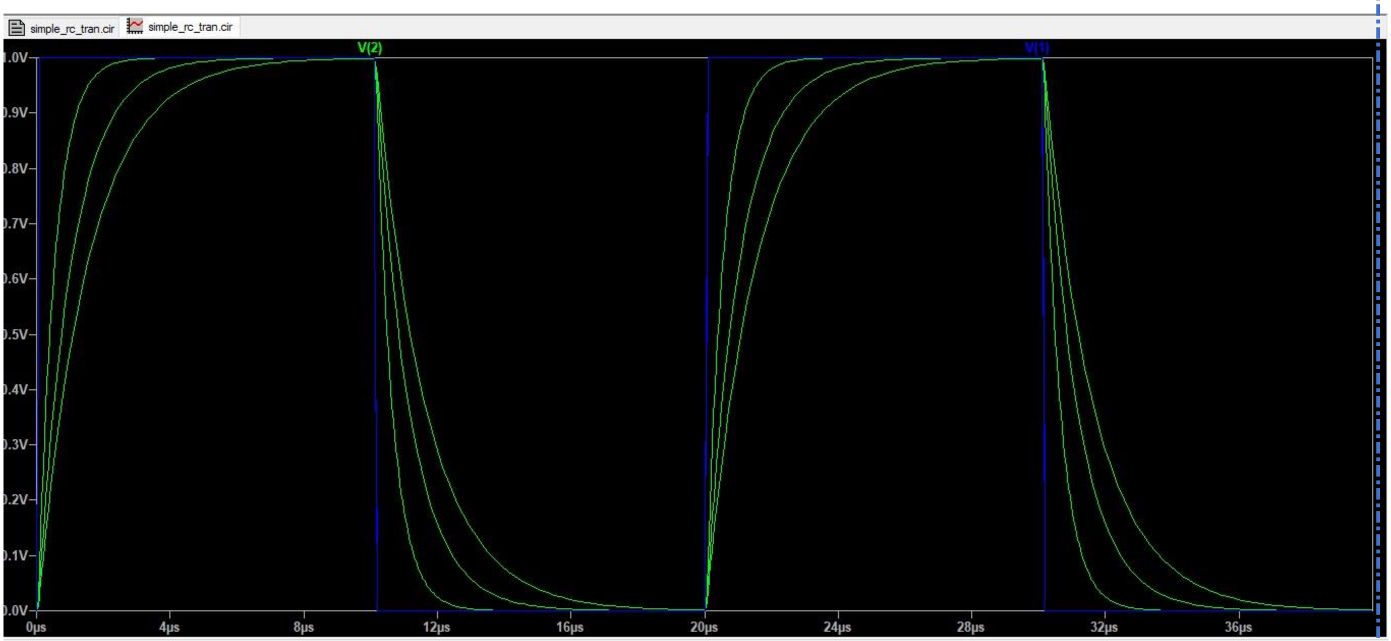


# Transient

```
Simple RC Circuit

* Circuit Description

* Parameters
*** add line here ***
.PARAM CPAR=500p
* Signal sources
V1 1 0 PULSE(0V 1V 0 100n 100n 10u 20u)

* Circuit elements
R1 1 2 1k
C1 2 0 {CPAR}

* Initial conditions
.IC V(2)=0
* Analysis request
* Run transient for 40us with 100ns step
*** add line here ***
.TRAN 100n 40u
* Use parametric sweep for CPAR: 500p:500p:1.5n
*** add line here ***
*.STEP PARAM CPAR 500p 1.5n 500p
.STEP PARAM CPAR LIST 500p 1n 1.5n
* Measure rise time from 10% to 90%
.MEAS TRAN TRISE
+ TRIG when v(2) = 0.1 CROSS = 1
+ TARG WHEN V(2) = 0.9 CROSS = 1
*** add line here ***
.PRINT TRAN V(1) V(2)
.PLOT TRAN V(1) V(2)
*** add line here ***
.END
```

SPICE Output Log: C:\Users\DELL\Desktop\Siemens AMS 2025\lab1\simple_rc_tran.log

```
LTspice 24.1.9 for Windows
Circuit: C:\Users\DELL\Desktop\Siemens AMS 2025\lab1\simple_rc_tran.cir
Start Time: Fri Jul 18 03:34:56 2025
solver = Normal
Maximum thread count: 8
tnom = 27
temp = 27
method = trap
.OP point found by inspection.
.step cpar=5e-10
.step cpar=1e-09
.step cpar=1.5e-09
Total elapsed time: 0.227 seconds.

Files loaded:
C:\Users\DELL\Desktop\Siemens AMS 2025\lab1\simple_rc_tran.cir


Measurement: trise
  step       trise FROM  TO
     1       1.09838514095e-06 1.03673538479e-07 1.20205867943e-06
     2       2.19830457284e-06 1.55908759936e-07 2.35421333277e-06
     3       3.2964401991e-06  2.08544980342e-07 3.50498517945e-06
```



# Part 2:

1-

OPAMP.cir OPAMP.cir

```
OPAMP CIRCUIT SIMULATION
*** opamp subcuircuit ***
.subckt opamp 1 2 3

* VCVS with gain 10000
Eopamp 1 0 4 0 1
Gp 0 4 2 3 0.6289              ; A0 = Gp * Rp
* redundant current sources to avoid errors
Iopen1 2 0 0A
Iopen2 3 0 0A

* Parameters
Rp 4 0 15.9k            ; dominant pole resistor
Cp 4 0 10n                    ; dominant pole capacitor

.ends opamp
```

Given : A0 = 10000 and UGF= 10MHz. fp=1KHz

RpCp = $\frac{1}{2*3.14*fp}$ = $\frac{1}{2*3.14*1000}$ =159.23 u

Assumed Rp =15.9 Kohm , Cp = 10nF

GP = A0/Rp = 0.6289

2-

```
*** Circuit ***
*V1 IN+ 0 DC 1V                    ; 1V DC input
Vsig IN+ 0 SIN(0 1 1k)      ; 1V amplitude, 1kHz frequency sine wave


Rin IN- 0 1k                      ; Input resistor
Rf IN- OUT 9k                      ; Feedback resistor
XOP OUT IN+ IN- opamp  ; Op-amp subcircuit

*** Transfer Function Analysis ***
*.TF V(OUT) V1

*** Transient Analysis ***
.TRAN 20u 2m 20u            ; Step = 20 us, Stop time = 2 ms

*** Probes ***
.PRINT TRAN V(IN+) V(OUT)
.PLOT TRAN V(IN+) V(OUT)

*** Measurement Commands ***
.MEAS TRAN Vsig_peak MAX V(IN+)
.MEAS TRAN Vout_peak MAX V(OUT)

.END
```

C:\Users\DELL\Desktop\Siemens AMS 2025\lab1\OPAMP.cir

```
      --- Transfer Function ---

transfer_function:             9.99001        transfer
V1#input_impedance:            1e+20          impedance
output_impedance_at_v(out):    0              impedance
```

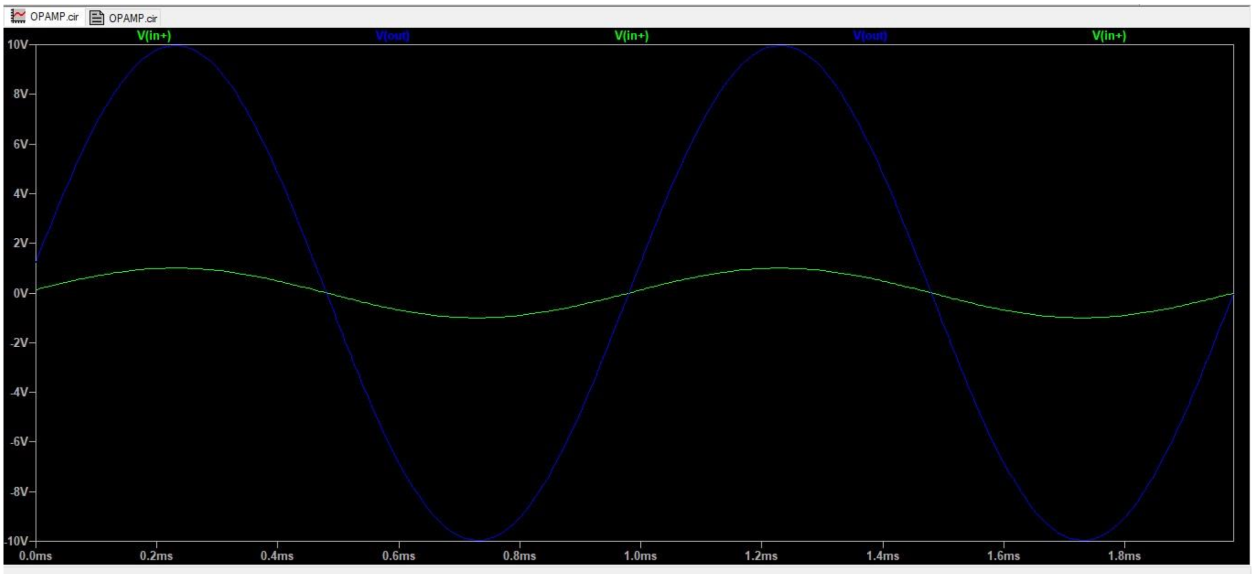
We can see that transfer function = $\frac{Vout}{Vsig}$ = 9.99 and the TF analatically =10

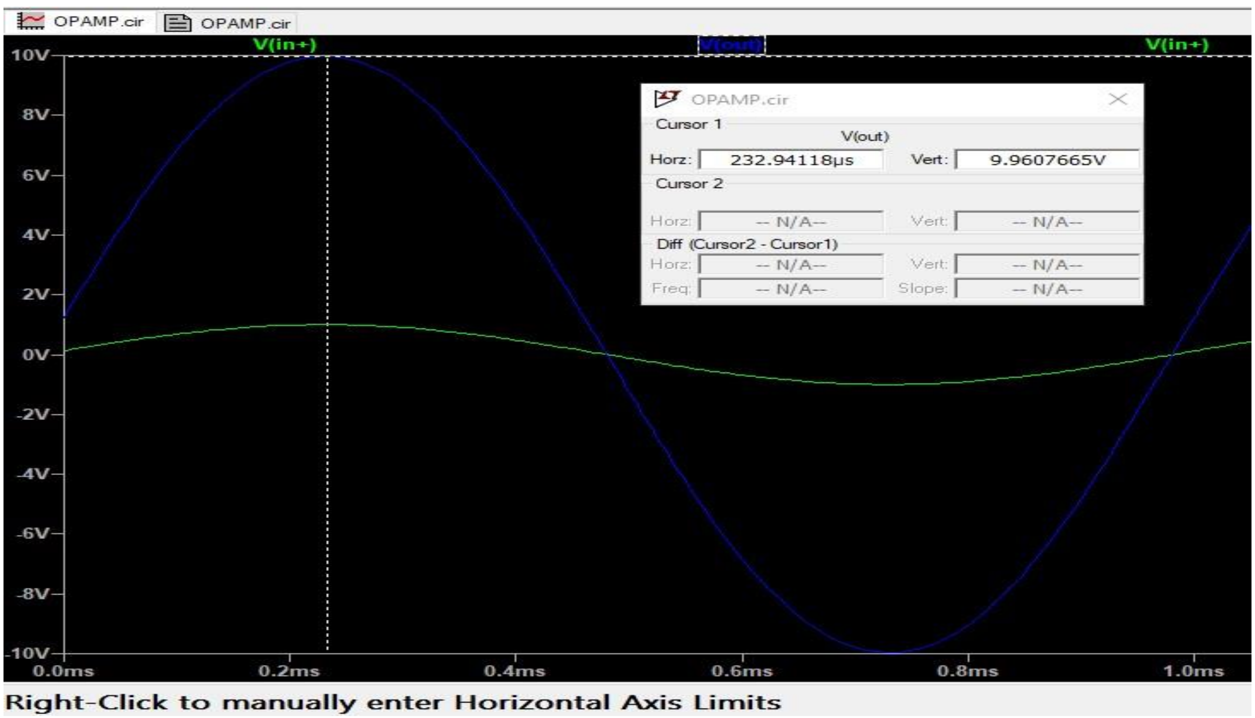
Very large input impedance(ideally infinity) and small output impedance(ideally 0) and that matches the predicted from the opamp analysis

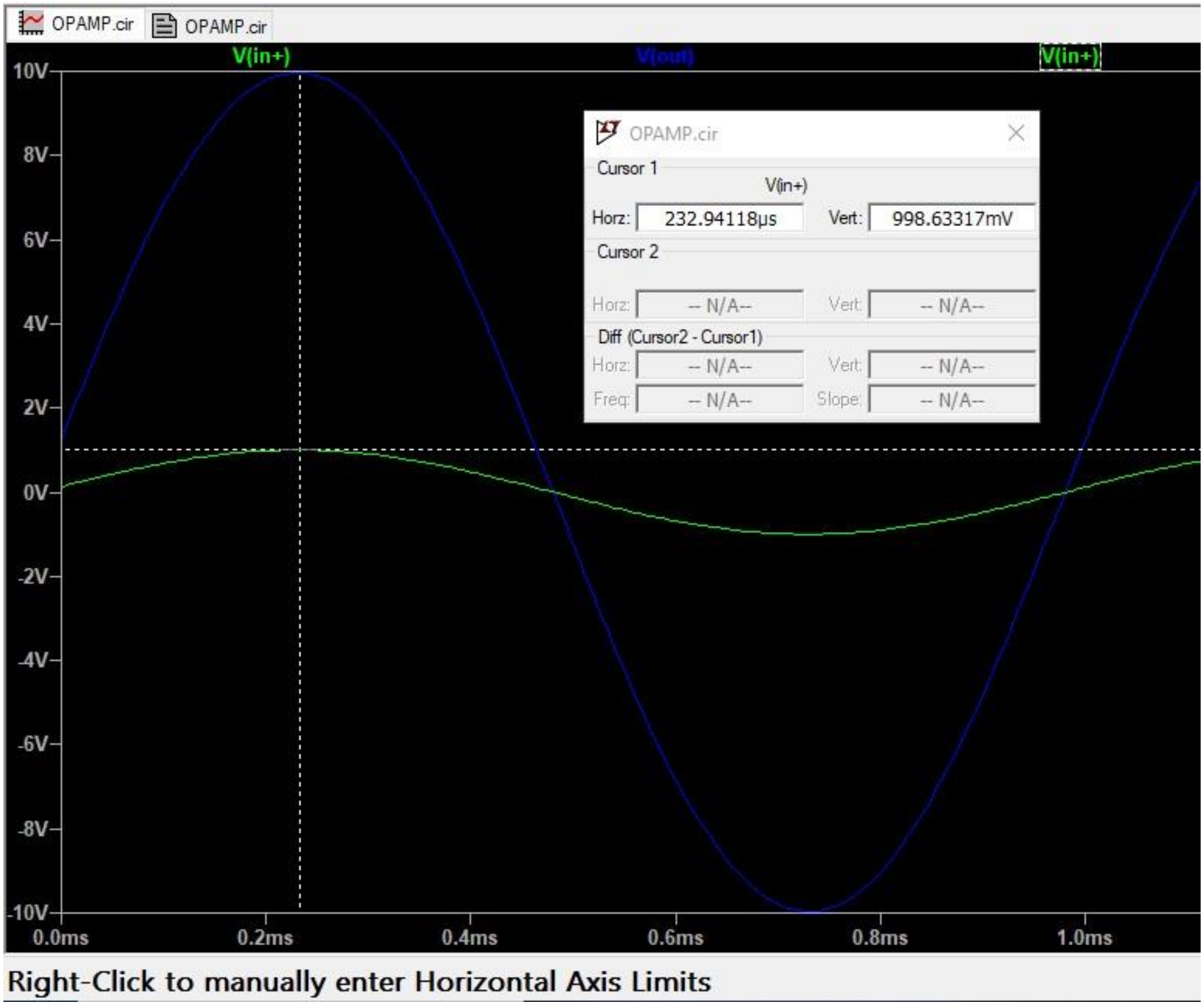
3-

```
*** Circuit ***
*V1 IN+ 0 DC 1V                    ; 1V DC input
Vsig IN+ 0 SIN(0 1 1k)      ; 1V amplitude, 1kHz frequency sine wave


Rin IN- 0 1k                    ; Input resistor
Rf IN- OUT 9k                    ; Feedback resistor
XOP OUT IN+ IN- opamp   ; Op-amp subcircuit

*** Transfer Function Analysis ***
*.TF V(OUT) V1

*** Transient Analysis ***
.TRAN 20u 2m 20u            ; Step = 20 us, Stop time = 2 ms

*** Probes ***
.PRINT TRAN V(IN+) V(OUT)
.PLOT TRAN V(IN+) V(OUT)


.END
```

```
LTspice 24.1.9 for Windows
Circuit: C:\Users\DELL\Desktop\Siemens AMS 2025\lab1\OPAMP.cir
Start Time: Mon Jul 21 19:55:05 2025
solver = Normal
Maximum thread count: 8
tnom = 27
temp = 27
method = trap
.OP point found by inspection.
Total elapsed time: 0.061 seconds.

Files loaded:
C:\Users\DELL\Desktop\Siemens AMS 2025\lab1\OPAMP.cir

vdiff_peak: MAX(V(VDIFF))=0.00141209574511 FROM 0 TO 0.00198
vsig_peak: MAX(V(IN+))=0.999020652352 FROM 0 TO 0.00198
vout_peak: MAX(V(OUT))=9.98029558502 FROM 0 TO 0.00198
```


OPAMP.cir
OPAMP.cir
V(in+)
V(out)
V(in+)
V(out)
V(in+)
10V
8V
6V
4V
2V
0V
-2V
-4V
-6V
-8V
-10V
0.0ms
0.2ms
0.4ms
0.6ms
0.8ms
1.0ms
1.2ms
1.4ms
1.6ms
1.8ms


OPAMP.cir
OPAMP.cir
V(in+)
V(out)
V(in+)
10V
8V
6V
4V
2V
0V
-2V
-4V
-6V
-8V
-10V
0.0ms
0.2ms
0.4ms
0.6ms
0.8ms
1.0ms
OPAMP.cir
Cursor 1
V(out)
Horz: 232.94118µs
Vert: 9.9607665V
Cursor 2
Horz: -- N/A--
Vert: -- N/A--
Diff (Cursor2 - Cursor1)
Horz: -- N/A--
Vert: -- N/A--
Freq: -- N/A--
Slope: -- N/A--
Right-Click to manually enter Horizontal Axis Limits




4- from the measured peaks of Vsig and Vout

Av= Vout / Vsig = $\frac{9.9802}{0.999}$ = 9.99

| Hand analysis | TF analysis | Transient analysis |
|---|---|---|
| Av = 1+ $\frac{9K}{1K}$ = 10 | From TF log<br>Av=9.9901 | Av=9.99 |

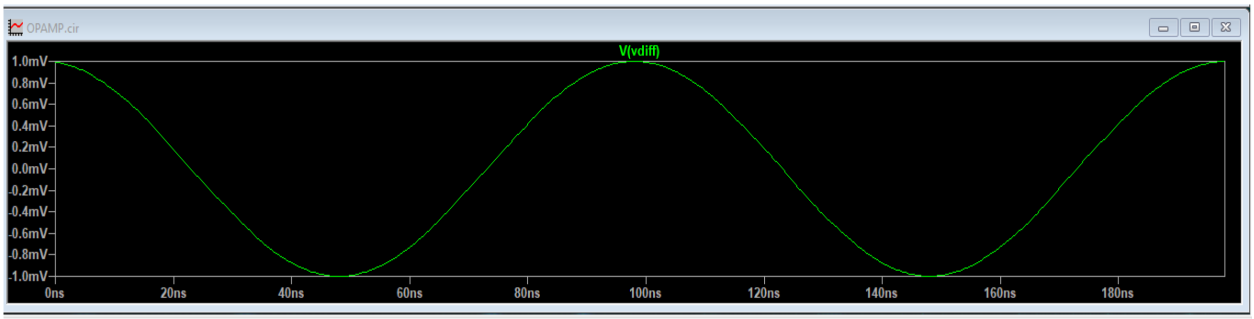
We can see that the analytical way gives the most accurate results although LTspice gives good results also for both TF analysis and Transient analysis

5- ⍰ At **1 kHz**, the op-amp has high gain → feedback works → differential input is **very small**.

⍰ At **10 MHz**, the op-amp can no longer amplify → feedback fails → differential input is **larger**

Differential voltage for frequency 1KHz

```
vdiff peak: MAX(V(VDIFF))=0.000999087070492 FROM 0 TO 1.98e-07
```




The amplitude of Vdiff = 1mV nearly .

**<u>Hand analysis:</u>**

At low frequency, the output is:

$$Vout = Av * Vsig = 10 * 1 = 10\ V$$

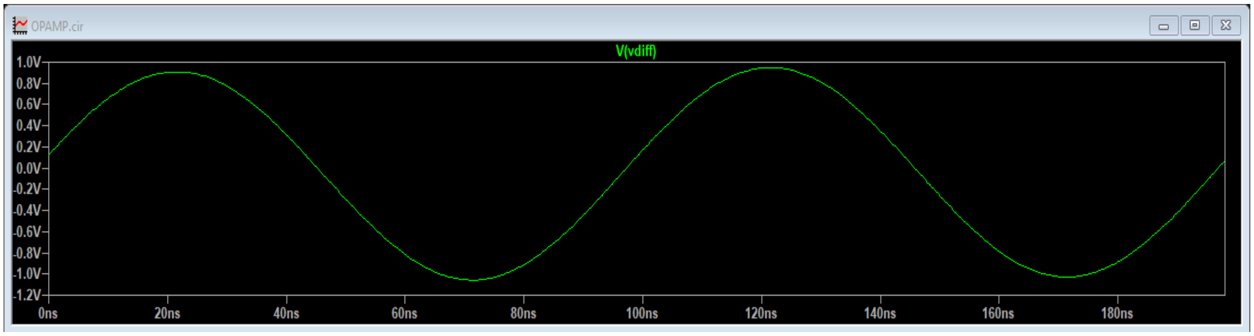
So The differential input voltage is approximately:

$$Vdiff = Vout / A0 = 10 / 10000 = 1mV$$

6-

Differential voltage for frequency 10MHz

```
vdiff_peak: MAX(V(VDIFF))=0.949425053546 FROM 0 TO 1.98e-07
vsig_peak: MAX(V(IN+))=0.999966450467 FROM 0 TO 1.98e-07
vout_peak: MAX(V(OUT))=1.72927891716 FROM 0 TO 1.98e-07
```




The amplitude of Vdiff = 1V  nearly .

**<u>Hand analysis:</u>**

At UGF, the op-amp's open-loop gain drops to 1 : A0(f=UGF) = 1

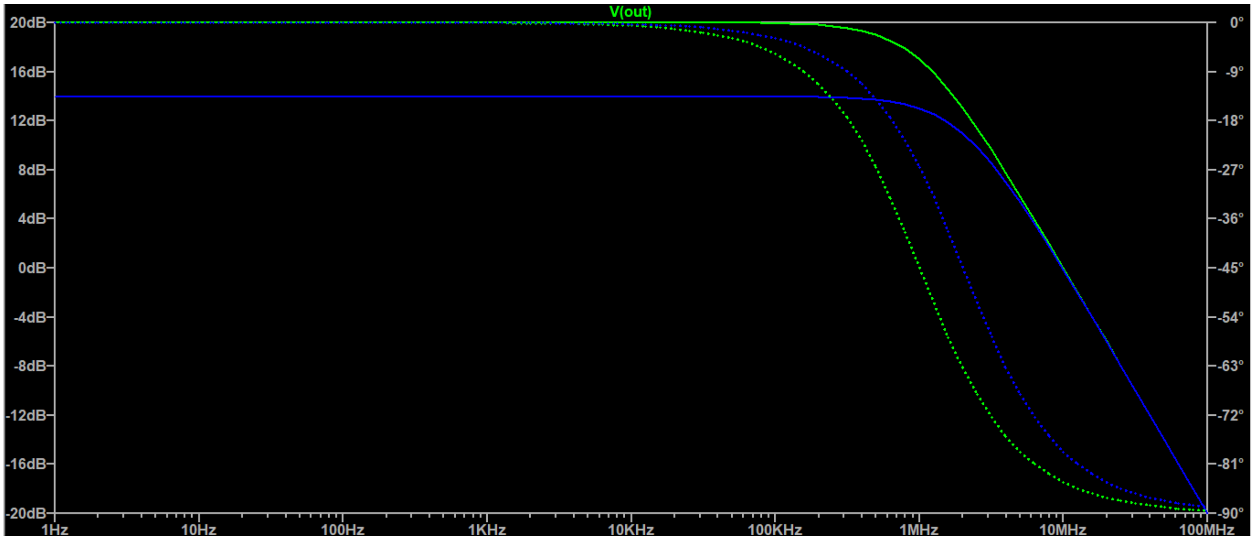
The feedback will not work properly and the differential voltage will be close in value to output voltage with very small gain ( nearly no gain ).

7- <u>Netlist :</u>

test.cir   test.cir

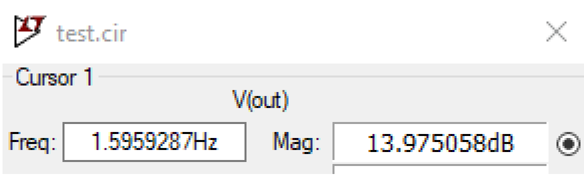
```
OPAMP CIRCUIT SIMULATION
*** opamp subcuircuit ***
.subckt opamp 1 2 3
* VCVS with gain 10000
Eopamp 1 0 4 0 1
Gp 0 4 2 3 0.6289                ; A0 = Gp * Rp
* redundant current sources to avoid errors
Iopen1 2 0 0A
Iopen2 3 0 0A

* Parameters
Rp 4 0 15.9k                     ; dominant pole resistor
Cp 4 0 10n                       ; dominant pole capacitor

.ends opamp

*** Circuit ***
* AC source for AC analysis
Vsig IN+ 0 AC 1
Rin IN- 0 1k                     ; Input resistor
Rf IN- OUT {R_feedback}          ; Feedback resistor, using a parameter for sweep
XOP OUT IN+ IN- opamp            ; Op-amp subcircuit

*** AC Analysis ***
.AC DEC 10 1 100Meg               ; Decade sweep, 10 points per decade, from 1Hz to 100MHz

*** Parametric Sweep ***
.STEP PARAM R_feedback LIST 9k 4k

*** Probes ***
.PRINT AC V(OUT)
.PLOT AC DB(V(OUT))
```

## Waveform :

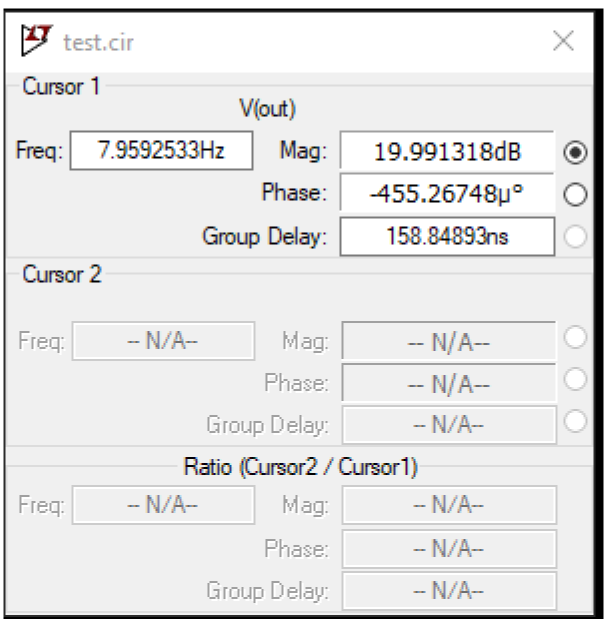



## GAIN

For the case RF = 4k : GAIN= 14dB

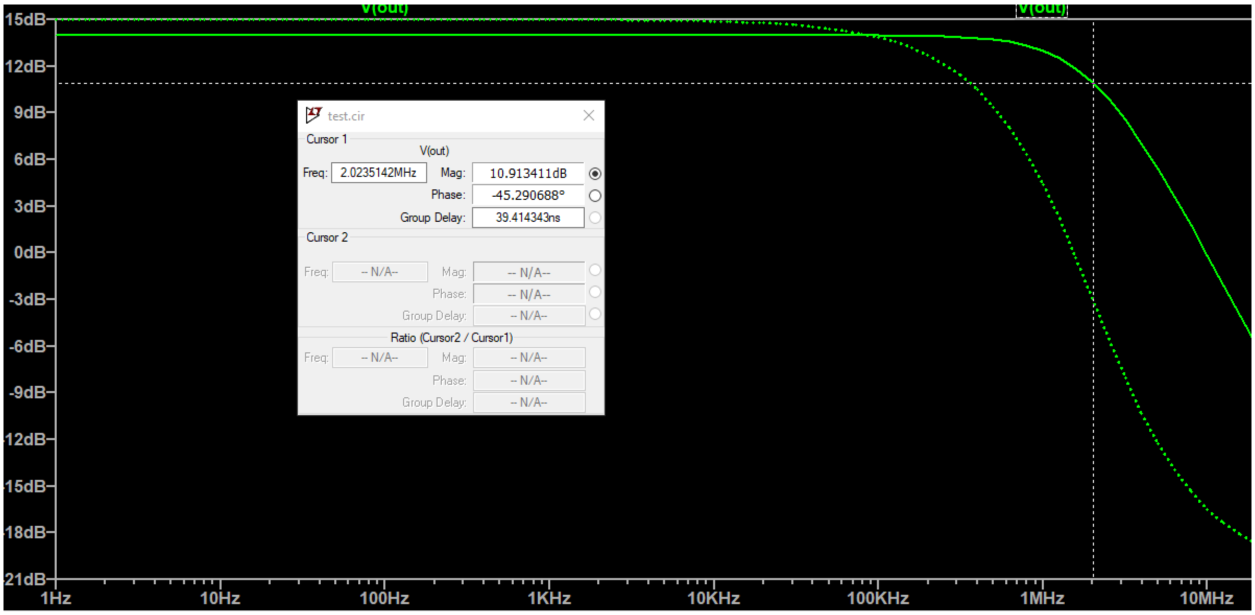



For the case RF = 9K : GAIN = 20dB

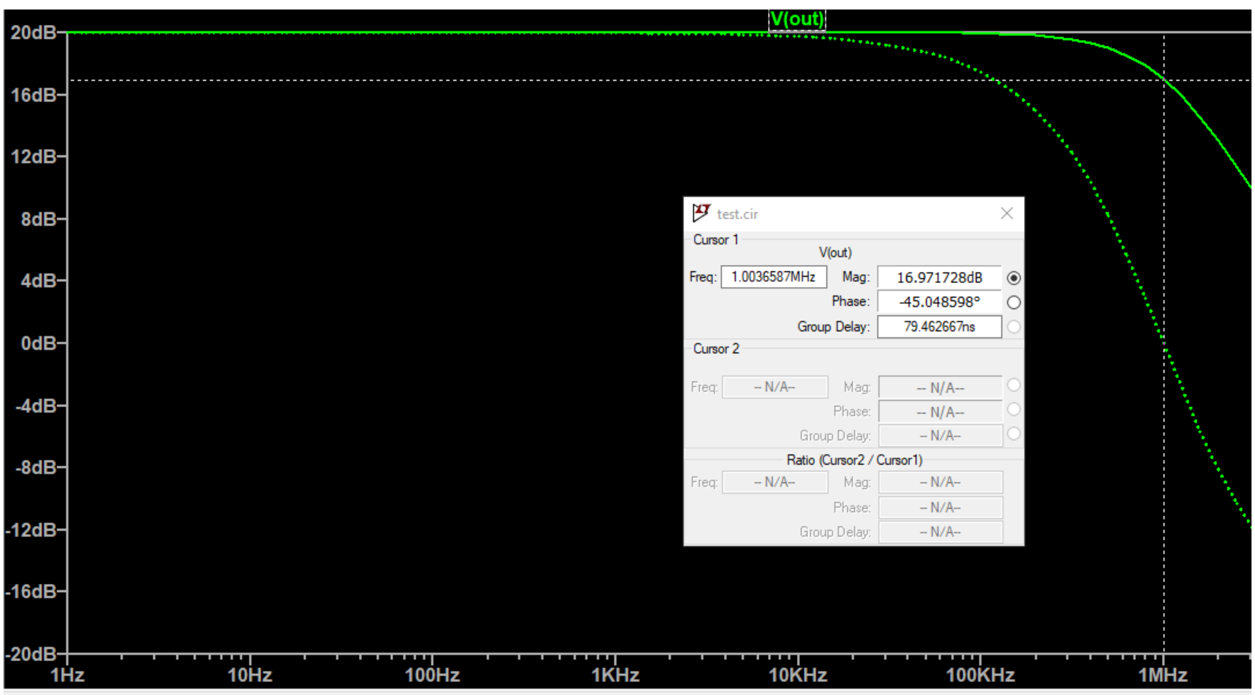


## 3dB Bandwidth

For the case RF = 4k : BW=  2MHz

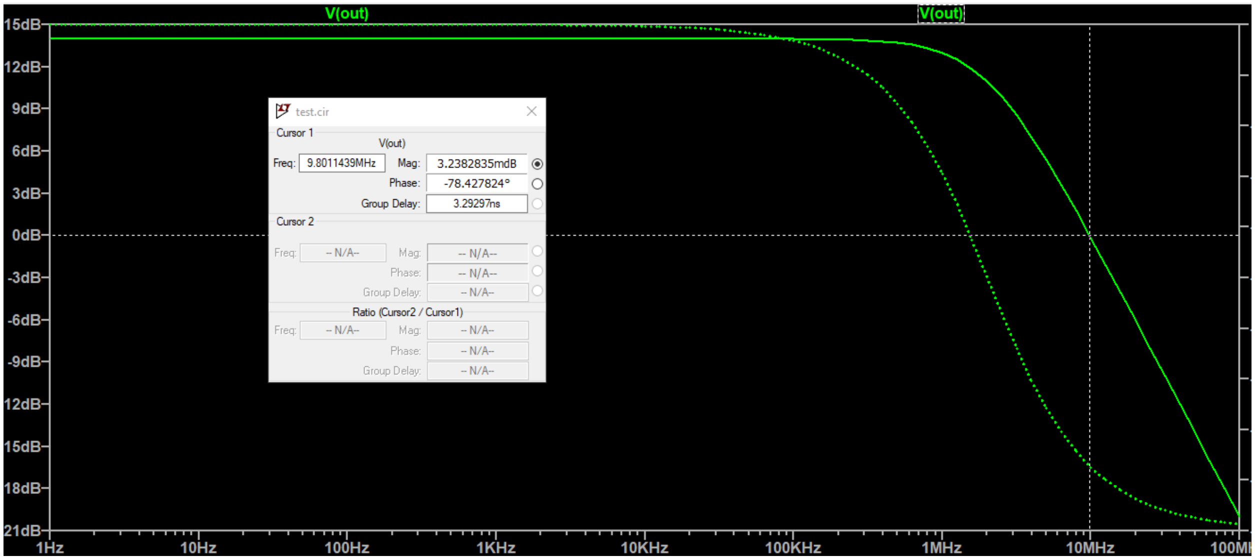



For the case RF = 9k : BW=  1MHz

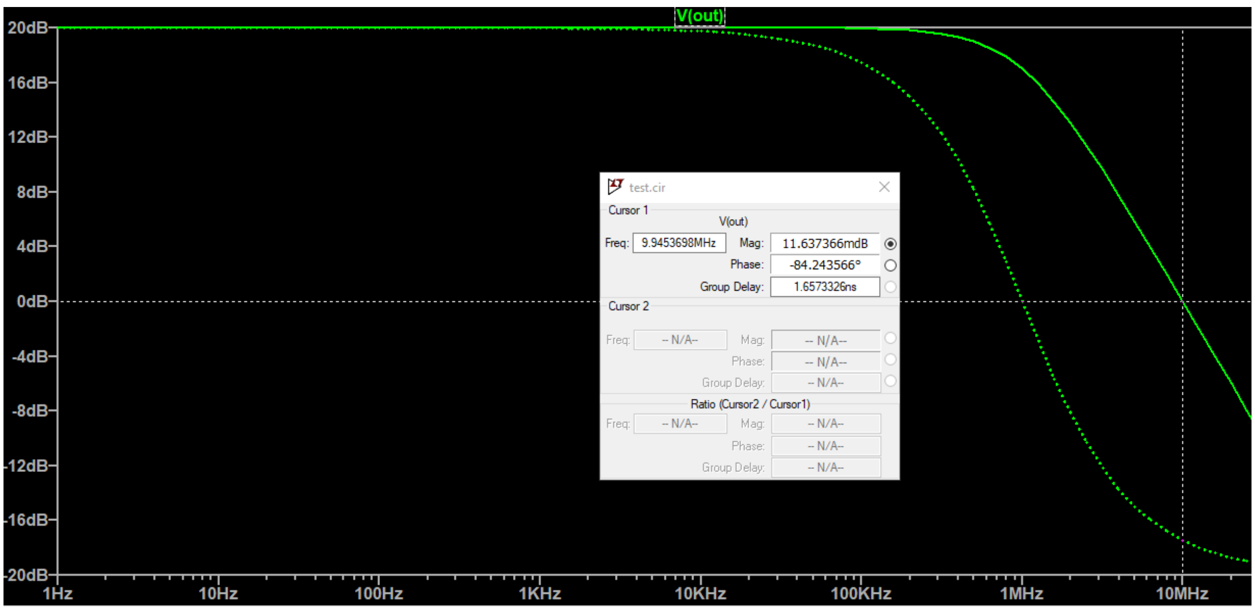


<u>Unity Gain Frequency :</u>

For the case RF = 4k : UGF=  9.85MHz (nearly)




For the case RF = 9k : UGF=  9.95MHz (nearly)



8- **AC Analysis**

There will be no clipping in the output because this is linear small-signal analysis that analyses the response with frequency , The simulator scales everything linearly and does not consider nonlinearities but we can achieve higher gain if the input amplitude increases .

**Transient Analysis**

you can see clipping in transient analysis if the output tries to go beyond the op-amp's output voltage limits (supply rails) because this is a time-domain simulation and applies real large voltages on the circuit

9- **DC Gain :**

Av =1+$\frac{Rf}{Rin}$

For RF = 9K : Av =20log( 1+ (9K/1K) ) = 20dB

For RF = 4K : Av =20log( 1+ (4K/1K) ) = 14dB

**Bandwidth:**

Bw=$\frac{UGF}{Av}$

For RF = 9K , UGF = 10MHz : BW= 10M / 10 = 1MHz

For RF = 4K , UGF = 10MHz : BW= 10M / 5 = 2MHz

**Unity Gain Frequency**:

Circuirt was designed for UGF = 10MHz so it is for the two cases

| Parameter | Hand Analysis | AC analysis |
|---|---|---|
| DC Gain | RF=4K ==> 14dB<br>RF=9K ==> 20dB | RF=4K ==> 13.975dB<br>RF=9K ==> 19.99dB |
| 3dB Bandwidth | RF=4K ==> 2MHz<br>RF=9K ==> 1MHz | RF=4K ==> 2MHz<br>RF=9K ==> 1MHz |
| UGF | RF=4K ==> 10MHz<br>RF=9K ==> 10MHz | RF=4K ==> 9.8MHz<br>RF=9K ==> 9.945MHz |

BONUS ( Non Inverting Summing Amplifier ) :

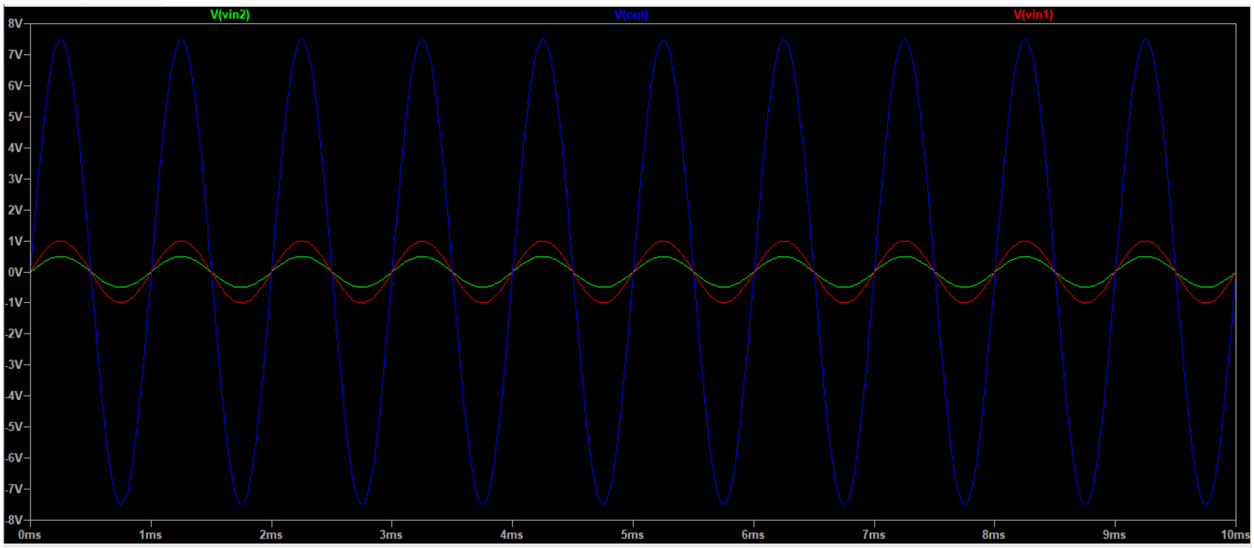
Netlist :

```
* === OPAMP BEHAVIORAL SUBCKT ===
.subckt opamp 1 2 3
Eopamp 1 0 4 0 1
Gp 0 4 2 3 0.6289
Iopen1 2 0 0A
Iopen2 3 0 0A
Rp 4 0 15.9k
Cp 4 0 10n
.ends opamp

* === SIGNAL SOURCES ===
V1 VIN1 0 SIN(0 1 1k)      ; 1V amplitude sine at 1kHz
V2 VIN2 0 SIN(0 0.5 1k)    ; 0.5V amplitude sine at 1kHz

* === SUMMING RESISTORS INTO NON-INVERTING INPUT ===
R1 VIN1 NPLUS 10k
R2 VIN2 NPLUS 10k

* === FEEDBACK NETWORK ON INVERTING INPUT ===
Rf NMIN OUT 9k
Rin NMIN 0 1k

* === OPAMP INSTANCE ===
XOP OUT NPLUS NMIN opamp

* === ANALYSIS ===
.TRAN 10u 10m
.PRINT TRAN V(VIN1) V(VIN2) V(OUT)

.MEAS TRAN VIN1_peak MAX V(VIN1)
.MEAS TRAN VIN2_peak MAX V(VIN2)
.MEAS TRAN VOUT_peak MAX V(OUT)
```

Measurement :

```
vin1_peak: MAX(V(VIN1))=0.999999701977 FROM 0 TO 0.01
vin2_peak: MAX(V(VIN2))=0.499999850988 FROM 0 TO 0.01
vout_peak: MAX(V(OUT))=7.49249172211 FROM 0 TO 0.01
```

Wave form :




Components :

1- Two AC sources at frequency 1KHz with amplitudes 1 , 0.5 Volts
2- Two summing resistors equal 10Kohm
3- Feedback resistor equals 9Kohm
4- Input resistor equals 1Kohm

**Analysis :**

Av = $1+\frac{9K}{1K}$ = 10

V+= $\frac{V1+V2}{2}$ (equal resistor weights)

Vout = Av * V+ = 10 * 0.75 = 7.5 V

Voltage gain = Vout / Vsig = $\frac{7.5}{1+0.5}$ = 5

TF Analysis :

We perform TF analysis on each source with the output and we find the results are identical and the voltage gain is near to the gain we obtained from Transient analysis

```
transfer_function:              4.995           transfer
V2#input_impedance:             20000           impedance
output_impedance_at_v(out):     0               impedance
```