SIMULATION RESULTS OF DIFFERENTIAL AMPLIFIER WITH ACTIVE LOAD

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PROJECT TITLE : Design and Simulation of differential Amplifier with active load using cmos 180nm technology in LTSpice

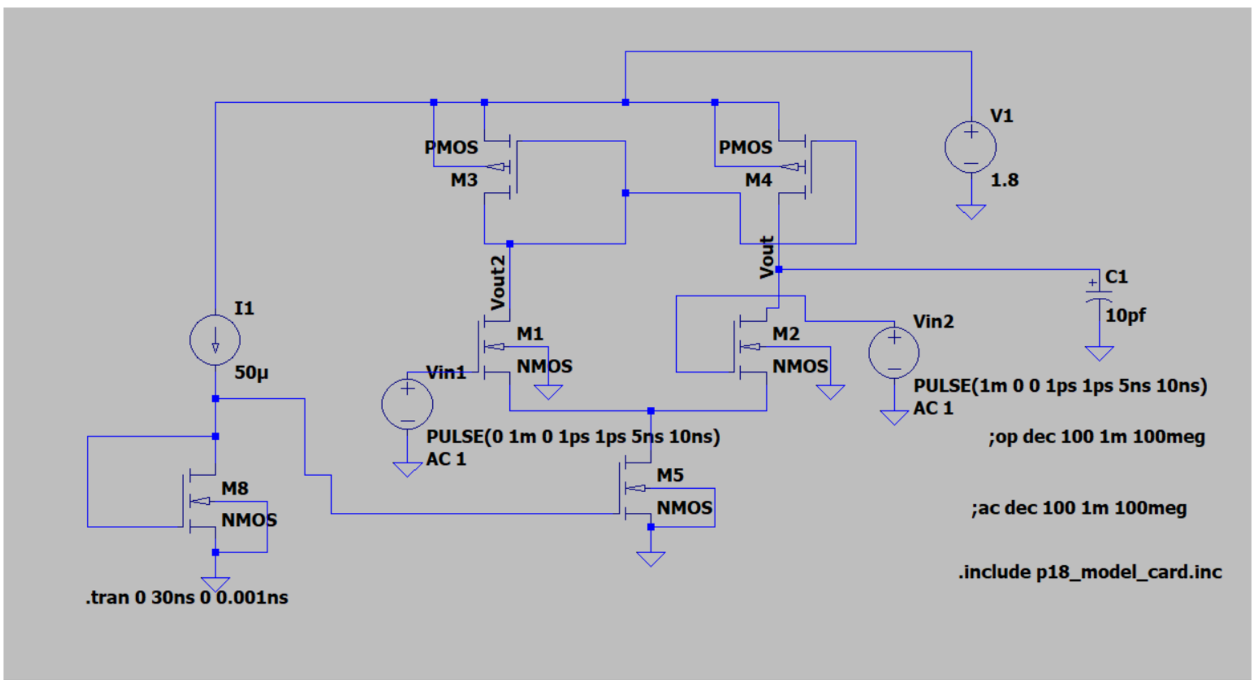
DESIGN SPECIFICATIONS :

Vd = 1.8v
Gain> = 40db
Cl = 10pf
ICMR(max)= 1.6v
ICMR(min) = 0.8v
Slew-Rate = 5V/us
Gain Band Width Product= 5Mhz

CALCULATIONS :

With the above specifications I have calculated all the design parameters. I later simulated the circuit in LTSpice And calculated all the parameters like gain-band-product, Differential AC gain,Slewrate,Common mode gain.

CIRCUIT DIAGRAM :



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DIFFERENTIAL AMPLIFIER WITH ACTIVE LOAD

(180 nm TECHNOLOGY)

DESIGN SPECIFICATIONS :

$V_{DD} = 1.8V$

$A_V \geq 40dB$

$C_L = 10pF$

ICMR (MAX) = 1.6V

ICMR (MIN) = 0.8V

SLEW-RATE = 5V/µsec

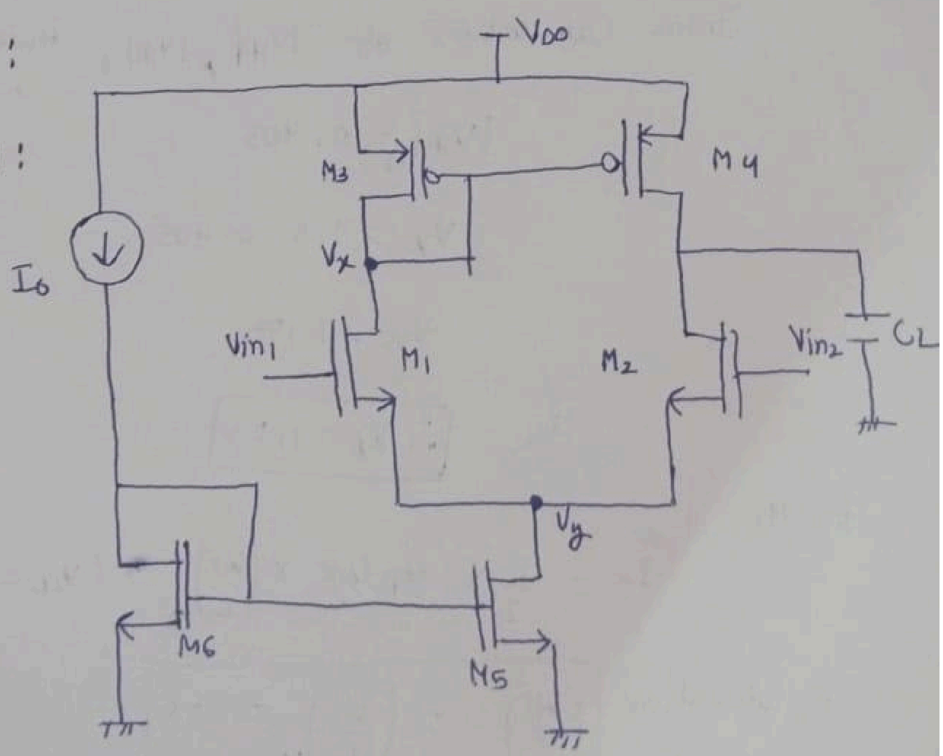
GAIN-BAND WIDTH PRODUCT = 5 megHz

$M_1, M_2 \rightarrow$ Matched

$M_3, M_4 \rightarrow$ Matched

CALCULATIONS :

CIRCUIT DIAGRAM :



① Calculation of I_0

$$\text{slew rate} = \frac{dV_o}{dt} = \frac{I_o}{C_L}$$

$$I_o = C_L \times \text{slew-rate}$$

$$I_o = 10pf \times 5V/\mu s$$

$$\boxed{I_D = 50\mu A}$$

② Calculation of $\left(\frac{W}{L}\right)_3$ and $\left(\frac{W}{L}\right)_4$

ICMR (Max) = 1.6V

$$V_{DS3} > V_{GS3} - |V_{TP}|_3$$

$$V_D > V_G - |V_{TP}|_3$$

$$V_x > (V_{in})_{max} - |V_{TP}|_3$$

From Calculations of $|V_{TP}|$, $|V_{TN}|$, $\mu_n C_{ox}$, $\mu_p C_{ox}$

$$|V_{TP}|_n = 0.405$$

$$V_x > 1.6 - 0.405$$

$$V_x > 1.195$$

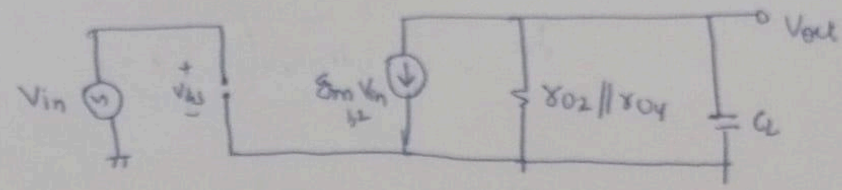
$$\boxed{\therefore V_x = 1.2V}$$

For M_3,

$$\frac{I_D}{2} = \frac{1}{2} \times \mu_p C_{ox} \times \left(\frac{W}{L}\right)_3 \times (V_{DD} - V_x - |V_{TP}|)^2$$

By Calculation we get $\boxed{\left(\frac{W}{L}\right)_3 = \left(\frac{W}{L}\right)_4 = 28}$

③ Calculation of M_1, M_2 from Gain-Bandwidth product :-
parameters



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$$\frac{V_{out}}{V_{in}} = \frac{-g_{m1,2}\,(r_{o2} \| r_{o4})}{1 + sC_L\,(r_{o2} \| r_{o4})}$$

$$\text{DC gain} = g_{m1,2}\,(r_{o2} \| r_{o4})$$

$$\text{3-dB cutoff frequency} = \frac{1}{2\pi \times (r_{o2} \| r_{o4}) \times C_L}$$

$$GBP = g_{m1,2}\,(r_{o2} \| r_{o4}) \frac{1}{2\pi \times (r_{o2} \| r_{o4}) \times C_L}$$

$$GBP = \frac{g_{m1,2}}{2\pi \times C_L}$$

Given $GBP = 5MHz$

$$5 \times 10^6 = \frac{g_{m1,2}}{2 \times 3.1416 \times 10 \times 10^{-12}}$$

$$\boxed{g_{m1,2} = 314.6\mu}$$

$$I_D = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_{1,2}(V_{GS}-V_T)^2$$

$$g_m = \sqrt{2\mu_n C_{ox}\left(\frac{W}{L}\right)_{1,2} \times I_d}$$

$$\left(\frac{W}{L}\right)_{1,2} = \frac{g_{m1,2}^2}{2 I_D \mu_n C_{ox}}$$

$$\left(\frac{W}{L}\right)_{1,2} \simeq 9.2952$$

Taking $\boxed{\left(\frac{W}{L}\right)_{1,2} \simeq 10}$

④ Calculating the Value of $\left(\frac{W}{L}\right)_5$ ~~of~~ M_5 :-

$$ICMR\,(min) = 0.8V$$

$$V_{gs1} < V_{min(ICMR)} - V_{y}$$

$$V_y < V_{min}(VICMR) - V_{gs1}$$

$$\frac{1}{2}\mu_n(V_{gs1} - V_{Tn1})^2 C_{ox} = \frac{I_{D0}}{2}$$

$$V_y = V_{GS5} - V_T$$

$$\boxed{V_{gs1} = 0.5135\,V}$$

$$I_{D5} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_5 (V_y)$$

$$\boxed{V_y < 0.2865}$$

$$\boxed{\therefore \left(\frac{W}{L}\right)_5 \simeq 6}$$

$$I_{D5} = 50\mu A$$

⑥ Calculating $\left(\frac{W}{L}\right)_6$:-

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By Current Mirroring

$$\frac{I_1}{I_0} = \frac{\left(\frac{W}{L}\right)_5}{\left(\frac{W}{L}\right)_6} = 1$$

$$\boxed{\left(\frac{W}{L}\right)_5 = \left(\frac{W}{L}\right)_6 = 56}$$

DESIGN PARAMATERS :-

$\left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_2 = 10$ $\quad W_1 = W_2 = 10\,\mu m$

$L_1 = L_2 = 1\,\mu m$

$\left(\frac{W}{L}\right)_3 = \left(\frac{W}{L}\right)_4 = 28$ $\quad W_1 = W_2 = 28\,\mu m$

$L_1 = L_2 = 1\,\mu m$

$\left(\frac{W}{L}\right)_5 = \left(\frac{W}{L}\right)_6 = 6$ $\quad W_5 = W_6 = 6\mu$

$L_6 = L_5 = 1\mu$

RESULT OBTAINED :

① DC operating point - given in fig for $(V_{in})_{cm} = 0.8V$
$= ICMR_{min}$

② DC operating point - given in fig for $(V_{in})_{cm} = 1.6V$
$= ICMR_{max}$

3) Differential - AC gain = 44.5 dB

V_{in1} = 1V (DC) + AC (1) → 0 phase

V_{in2} = 1V (DC) + AC (1) → 180 phase

4) Common Mode gain = 0.0096605

5) Unity - Gain Bandwidth product = 10.1 MHz

6) Slew - Rate obtained = 5.9 V/μs

<u>SIMULATION RESULTS :</u>

The following figures shows the results of the simulations obtained in LTSpice.

1) <u>DC Operating Point</u> : following image shows the dc operating point when Vin(cm)=0.8v (DC)

Semiconductor Device Operating Points:

--- BSIM3 MOSFETS ---

Name:	m1	m2	m5	m8	m3
Model:	nmos	nmos	nmos	nmos	pmos
Id:	2.27e-05	2.27e-05	4.53e-05	5.00e-05	-2.27e-05
Vgs:	6.06e-01	6.06e-01	6.84e-01	6.84e-01	-5.81e-01
Vds:	1.03e+00	1.03e+00	1.94e-01	6.84e-01	-5.81e-01
Vbs:	-1.94e-01	-1.94e-01	0.00e+00	0.00e+00	0.00e+00
Vth:	4.66e-01	4.66e-01	4.07e-01	4.04e-01	-4.20e-01
Vdsat:	1.21e-01	1.21e-01	2.10e-01	2.12e-01	-1.42e-01
Gm:	3.08e-04	3.08e-04	2.95e-04	3.58e-04	2.54e-04
Gds:	5.59e-07	5.59e-07	6.37e-05	2.93e-06	3.05e-06
Gmb	8.03e-05	8.03e-05	1.73e-04	4.89e-04	8.03e-05
Cbd:	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cbs:	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cgsov:	7.02e-15	7.02e-15	4.21e-15	4.21e-15	1.92e-14
Cgdov:	6.97e-15	6.97e-15	4.18e-15	4.18e-15	1.93e-14
Cgbov:	9.78e-19	9.78e-19	9.78e-19	9.78e-19	9.60e-19
dQgdVgb:	8.07e-14	8.07e-14	5.09e-14	4.93e-14	2.23e-13
dQgdVdb:	-6.97e-15	-6.97e-15	-6.40e-15	-4.05e-15	-1.89e-14
dQgdVsb:	-6.94e-14	-6.94e-14	-5.22e-14	-7.51e-14	-1.96e-13
dQddVgb:	-3.39e-14	-3.39e-14	-2.21e-14	-2.06e-14	-9.38e-14
dQddVdb:	6.97e-15	6.97e-15	6.35e-15	4.11e-15	1.91e-14
dQddVsb:	3.47e-14	3.47e-14	2.70e-14	4.00e-14	9.89e-14
dQbdVgb:	-1.29e-14	-1.29e-14	-6.62e-15	-8.03e-15	-3.53e-14
dQbdVdb:	-2.51e-18	-2.51e-18	-2.12e-15	2.04e-18	-5.41e-18
dQbdVsb:	-6.89e-15	-6.89e-15	-6.12e-15	-9.17e-15	-2.14e-14

Name:	m4
Model:	pmos
Id:	-2.27e-05
Vgs:	-5.81e-01
Vds:	-5.81e-01
Vbs:	0.00e+00
Vth:	-4.20e-01
Vdsat:	-1.42e-01
Gm:	2.54e-04
Gds:	3.05e-06
Gmb	8.03e-05
Cbd:	0.00e+00
Cbs:	0.00e+00
Cgsov:	1.92e-14
Cgdov:	1.93e-14
Cgbov:	9.60e-19
dQgdVgb:	2.23e-13
dQgdVdb:	-1.89e-14
dQgdVsb:	-1.96e-13
dQddVgb:	-9.38e-14
dQddVdb:	1.91e-14
dQddVsb:	9.89e-14
dQbdVgb:	-3.53e-14
dQbdVdb:	-5.41e-18
dQbdVsb:	-2.14e-14

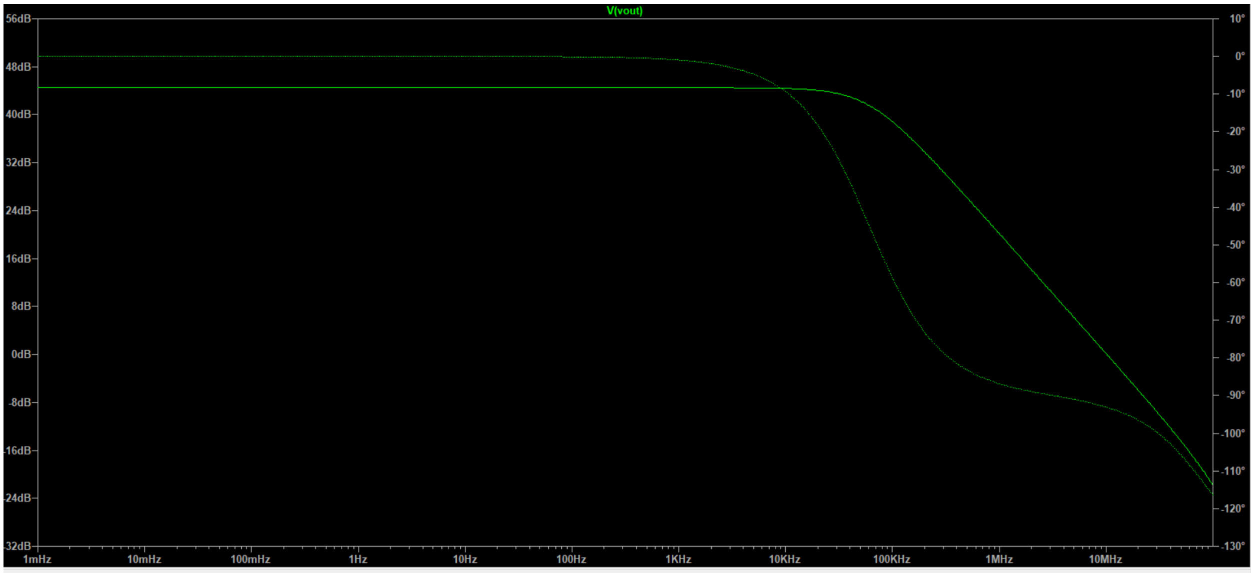
2) DC Operating Point when Vin(cm)=1.6v (DC)

--- BSIM3 MOSFETS ---

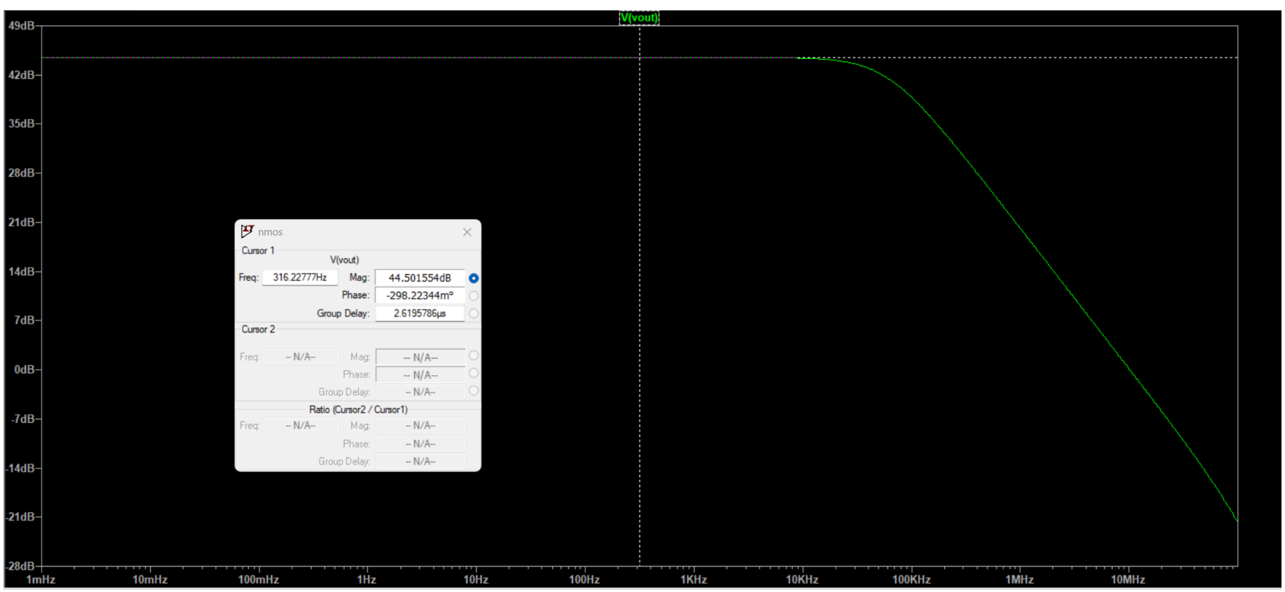
Name:	m1	m2	m5	m8	m3
Model:	nmos	nmos	nmos	nmos	pmos
Id:	2.52e-05	2.52e-05	5.04e-05	5.00e-05	-2.52e-05
Vgs:	7.66e-01	7.66e-01	6.84e-01	6.84e-01	-5.90e-01
Vds:	3.76e-01	3.76e-01	8.34e-01	6.84e-01	-5.90e-01
Vbs:	-8.34e-01	-8.34e-01	0.00e+00	0.00e+00	0.00e+00
Vth:	6.29e-01	6.29e-01	4.03e-01	4.04e-01	-4.20e-01
Vdsat:	1.33e-01	1.33e-01	2.12e-01	2.12e-01	-1.49e-01
Gm:	3.34e-04	3.34e-04	3.60e-04	3.58e-04	2.70e-04
Gds:	1.33e-06	1.33e-06	2.74e-06	2.93e-06	3.31e-06
Gmb	7.18e-05	7.18e-05	5.78e-04	4.89e-04	8.53e-05
Cbd:	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cbs:	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cgsov:	7.02e-15	7.02e-15	4.21e-15	4.21e-15	1.92e-14
Cgdov:	6.97e-15	6.97e-15	4.18e-15	4.18e-15	1.93e-14
Cgbov:	9.78e-19	9.78e-19	9.78e-19	9.78e-19	9.60e-19
dQgdVgb:	7.94e-14	7.94e-14	4.93e-14	4.93e-14	2.23e-13
dQgdVdb:	-7.07e-15	-7.07e-15	-4.04e-15	-4.05e-15	-1.89e-14
dQgdVsb:	-6.87e-14	-6.87e-14	-8.21e-14	-7.51e-14	-1.96e-13
dQddVgb:	-3.41e-14	-3.41e-14	-2.06e-14	-2.06e-14	-9.40e-14
dQddVdb:	7.05e-15	7.05e-15	4.10e-15	4.11e-15	1.91e-14
dQddVsb:	3.32e-14	3.32e-14	4.40e-14	4.00e-14	9.92e-14
dQbdVgb:	-1.12e-14	-1.12e-14	-8.04e-15	-8.03e-15	-3.52e-14
dQbdVdb:	-6.74e-17	-6.74e-17	1.12e-17	2.04e-18	-7.15e-18
dQbdVsb:	-4.69e-15	-4.69e-15	-1.01e-14	-9.17e-15	-2.15e-14

Name:	m4
Model:	pmos
Id:	-2.52e-05
Vgs:	-5.90e-01
Vds:	-5.90e-01
Vbs:	0.00e+00
Vth:	-4.20e-01
Vdsat:	-1.49e-01
Gm:	2.70e-04
Gds:	3.31e-06
Gmb	8.53e-05
Cbd:	0.00e+00
Cbs:	0.00e+00
Cgsov:	1.92e-14
Cgdov:	1.93e-14
Cgbov:	9.60e-19
dQgdVgb:	2.23e-13
dQgdVdb:	-1.89e-14
dQgdVsb:	-1.96e-13
dQddVgb:	-9.40e-14
dQddVdb:	1.91e-14
dQddVsb:	9.92e-14

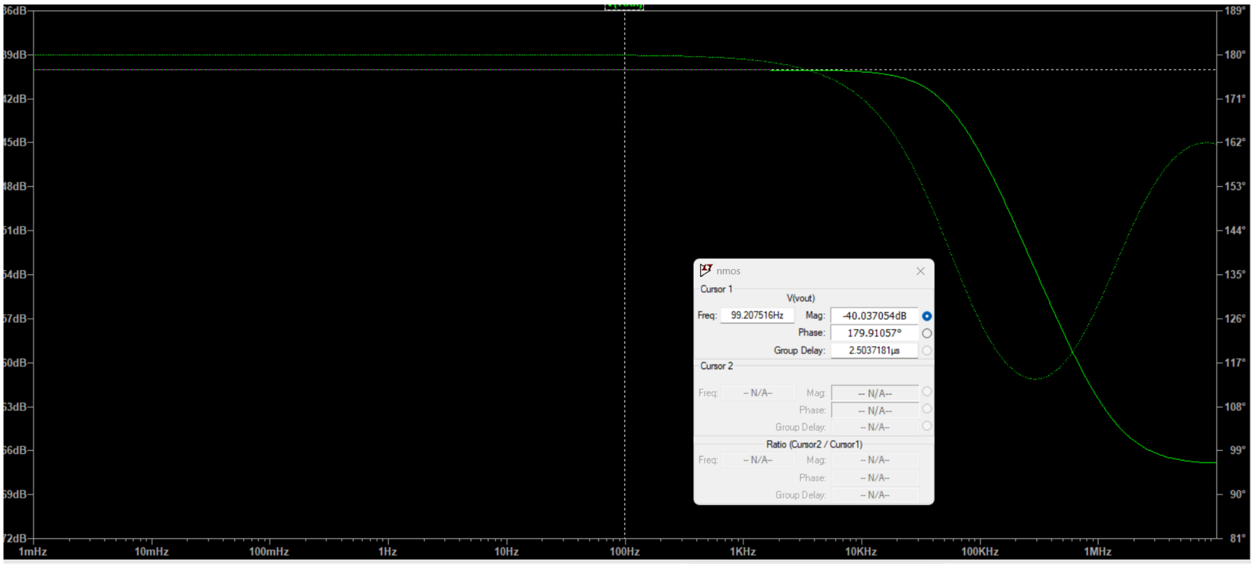
3) AC gain plot Gain Obtained=44.5 db



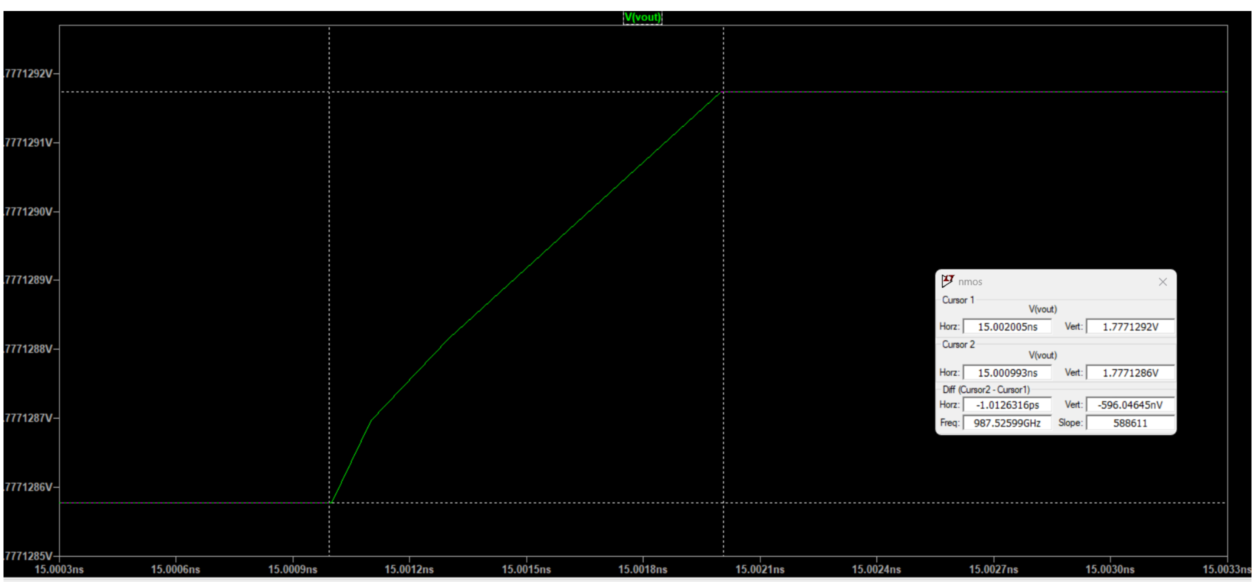
4) AC Gain Calculation :



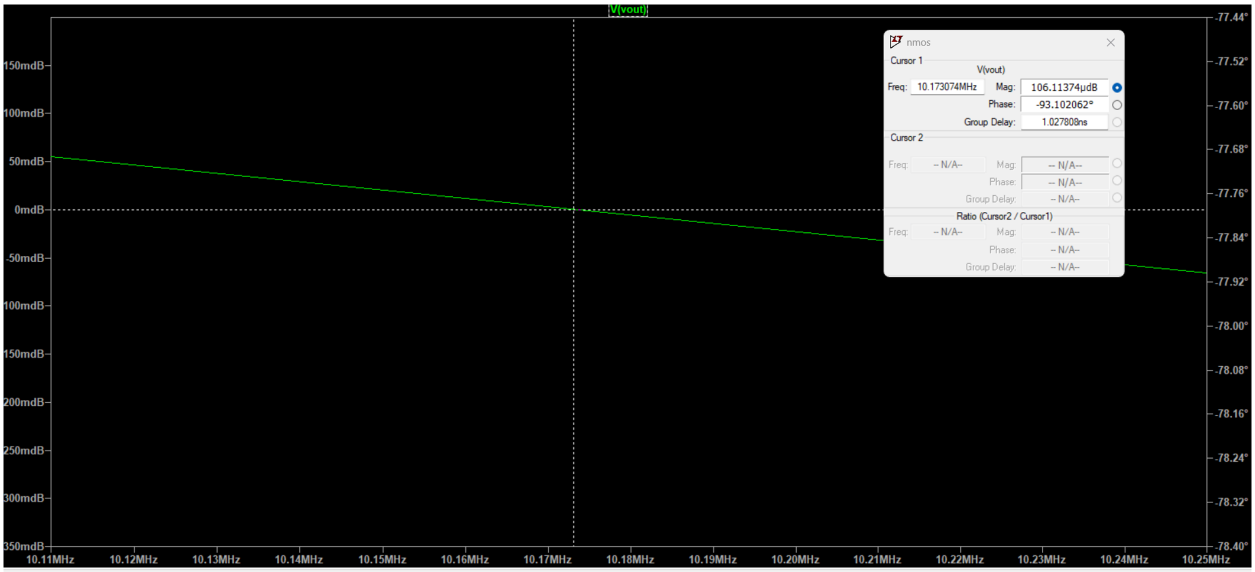
5) Common Mode Gain Plot :
Value obtained = 0.009



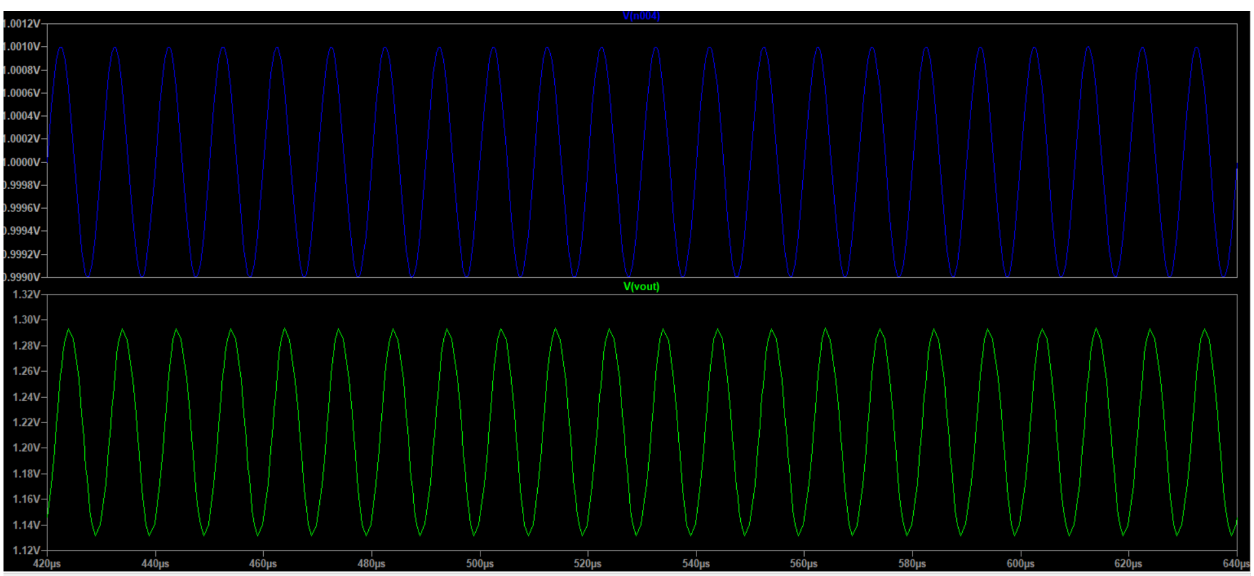
6) Slew Rate Obtained = 5.9 V/us



8) Unity Gain Bandwidth Frequency : 10.1Mhz



9) Transient Analysis Result : (with differential Voltage)



OBTAINED RESULT SPECIFICATIONS :

RESULT OBTAINED :

1. DC operating point - given in fig for $(V_{in})_{cm} = 0.8V = ICMR_{min}$
2. DC operating point - given in fig for $(V_{in})_{cm} = 1.6V = ICMR_{max}$
3. Differential - AC gain = 44.5 dB

V_{in1} = 1V (DC) + AC (1) → 0 phase

V_{in2} = 1V (DC) + AC (1) → 180 phase

4. Common Mode gain = 0.0096605
5. Unity - Gain Bandwidth product = 10.1 MHz
6. Slew - Rate obtained = 5.9 V/μs