Educate Elevate Enlighten

JSS Mahavidyapeetha
JSS Science And Technology University
(Established Under JSS Science and Technology University Act No. 43 of 2013)
(Formerly Known as SJCE)

JSS SCIENCE AND TECHNOLOGY UNIVERSITY MYSURU

Report on Event 4 of Lab Component

CMOS VLSI Circuits (EC630)

Covering the course objective

CO 4: Design, Demonstrate and validate the analog and digital CMOS circuits using Cadence tool / Electric tool, document and give an effective presentation.

Title: Part – B Analog Circuits

Name: Mohamed Farhan Fazal

Roll No: 27

USN: 01JST18EC055

Division: A

Submitted to

Prof. Halesh M. R
Assistant Professor, Dept. of ECE

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
2021

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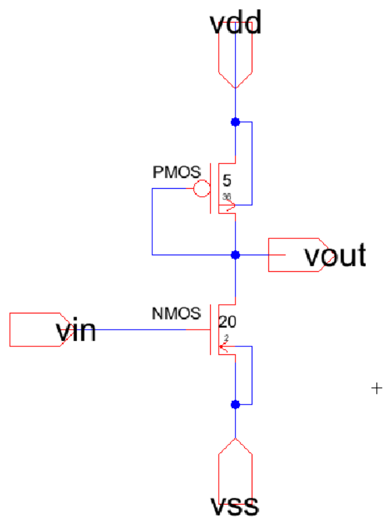
**All design calculations at the end

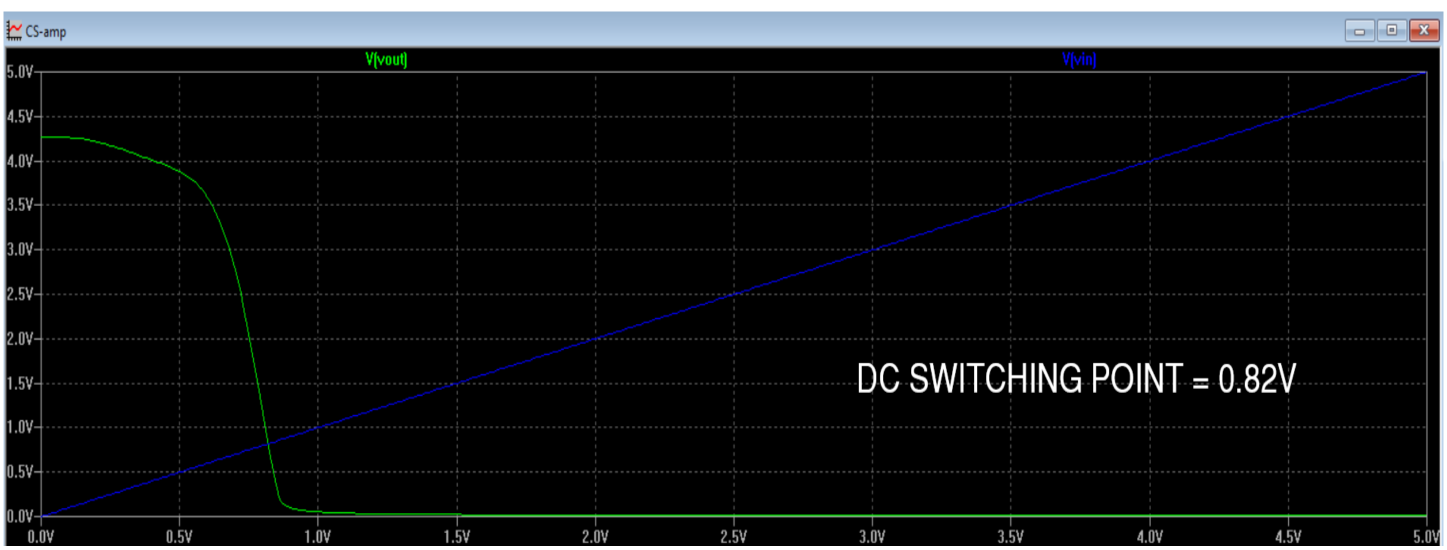
COMMON SOURCE AMPLIFIER

SCHEMATIC

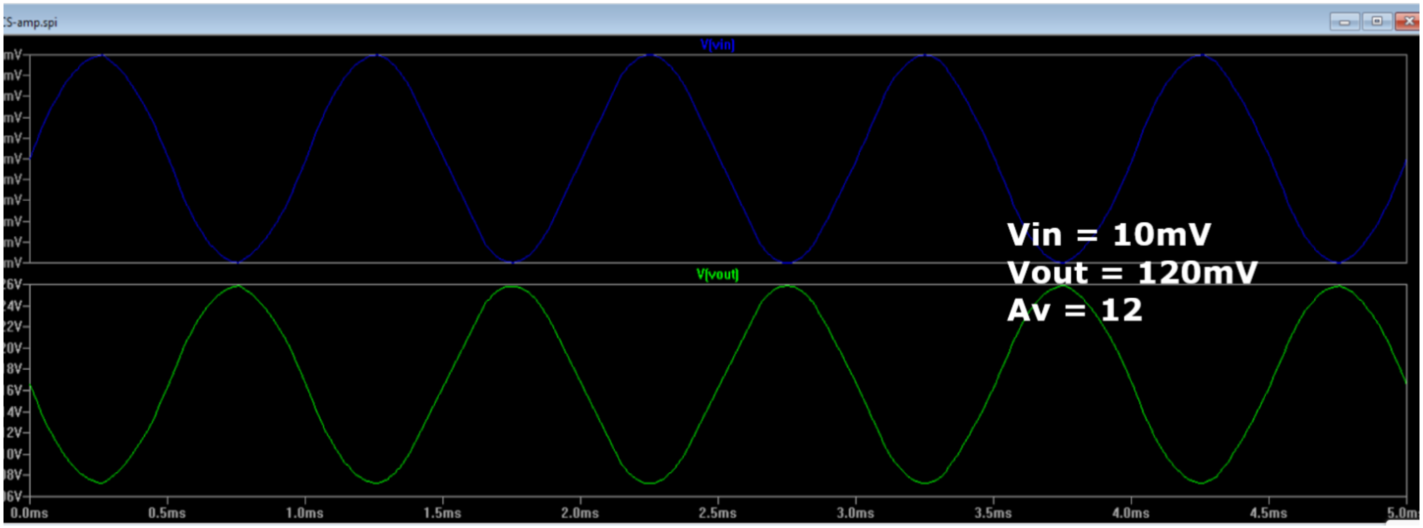


SCHEMATIC RESULT ANALYSIS

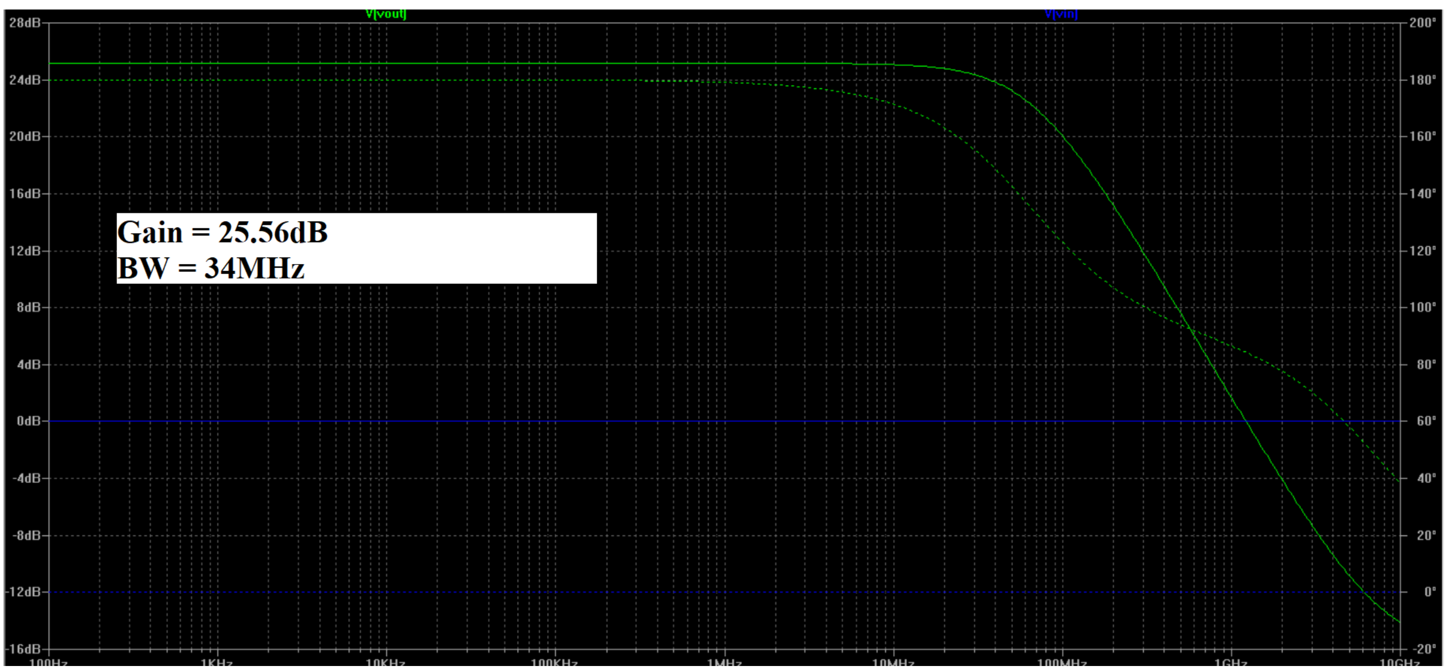
DC ANALYSIS



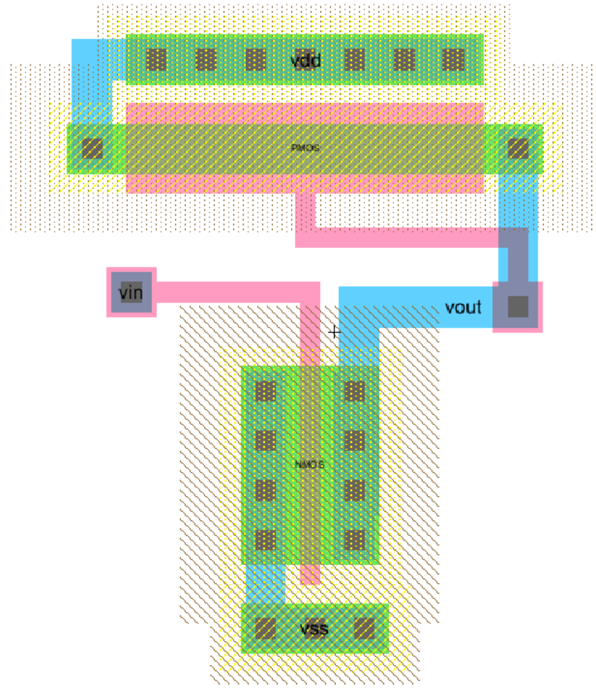
TRANSIENT ANALYSIS



AC ANALYSIS

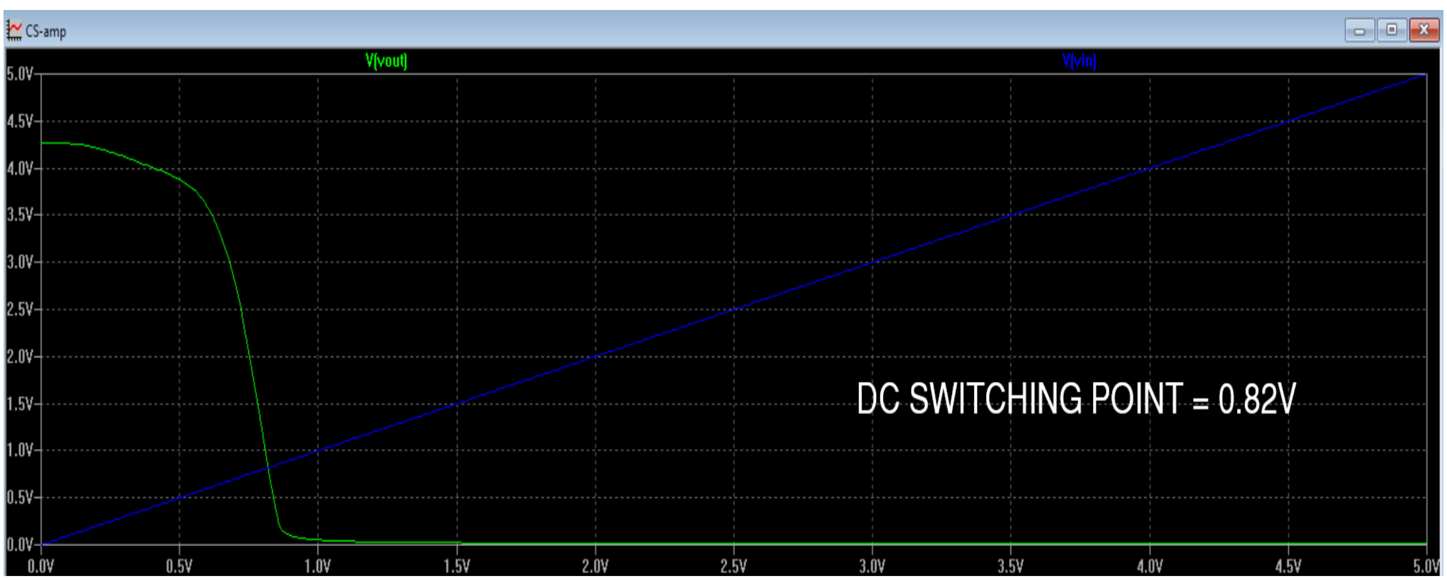


LAYOUT

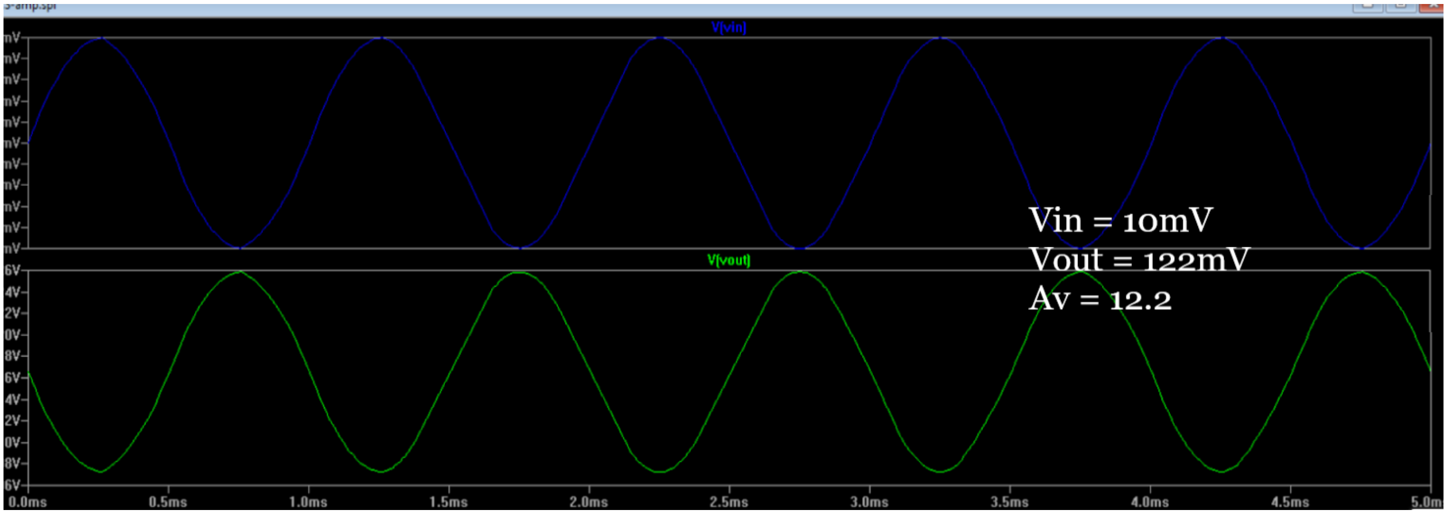


LAYOUT RESULT ANALYSIS

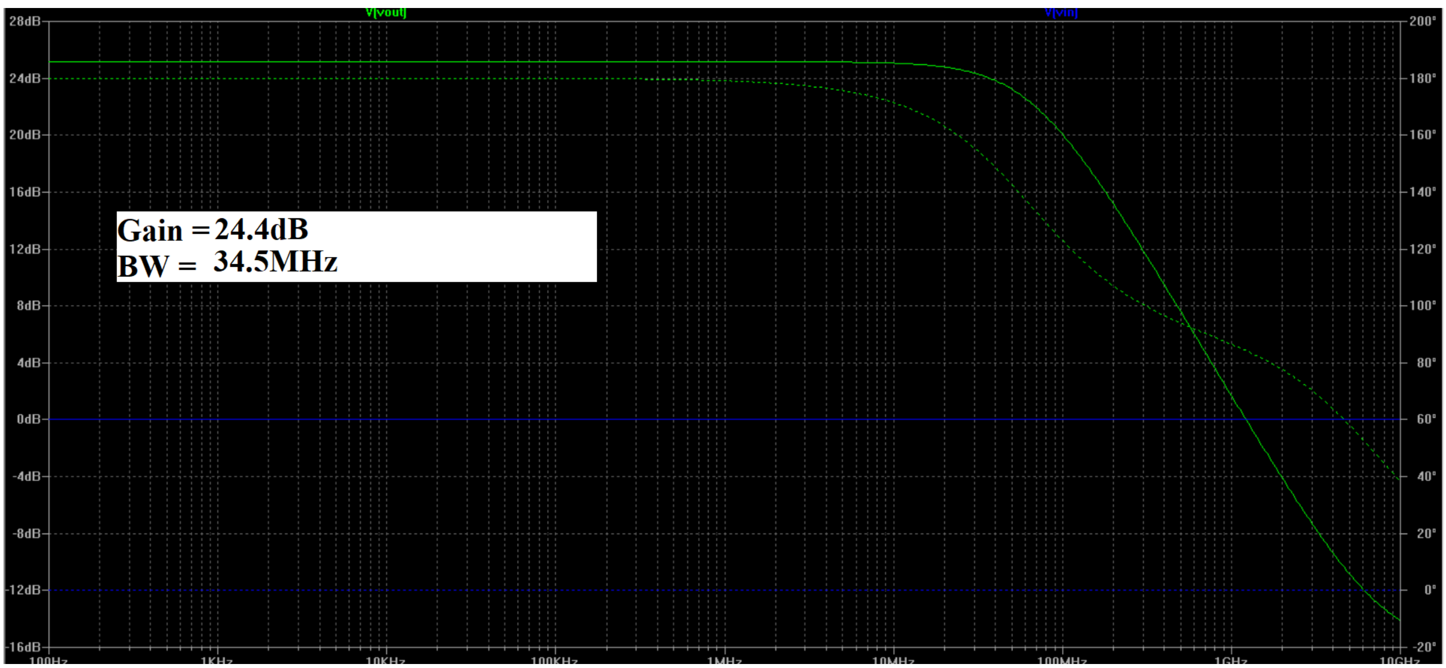
DC ANALYSIS



TRANSIENT ANALYSIS



AC ANALYSIS



INFERENCE

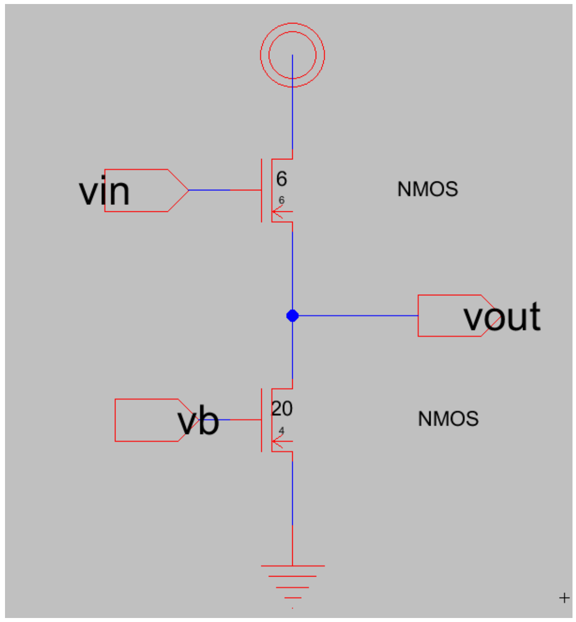
Designed Gain	12
Designed Gain in db	21.589
Number of transistors	2
$(W/L)_1$	5/36

$(W/L)_2$	20/2

Parameter	**Schematic**	**Layout**
DC Switching Point	0.82V	0.82V
Gain from transient analysis	12	12.2
Gain from AC analysis	25.56db	24.4db
Bandwidth	34MHz	34.5MHz

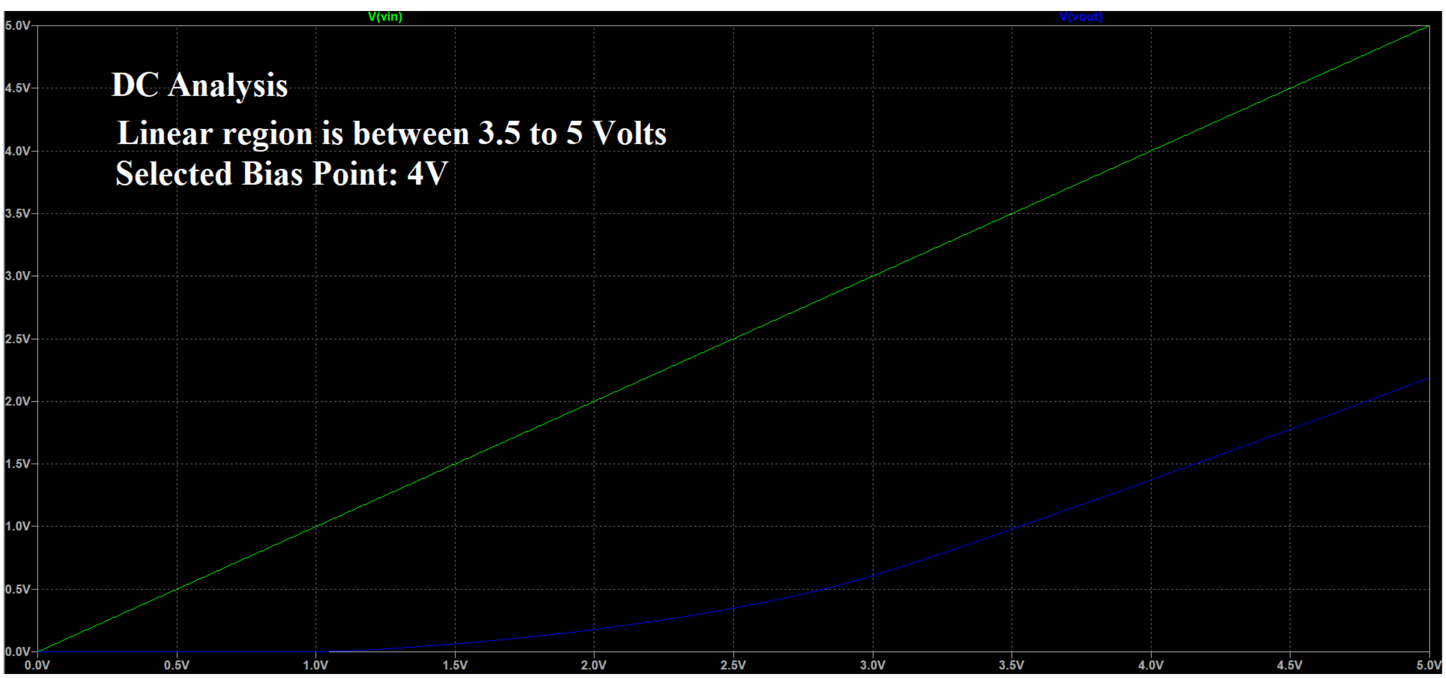
COMMON DRAIN AMPLIFIER

SCHEMATIC



SCHEMATIC RESULT ANALYSIS

DC ANALYSIS



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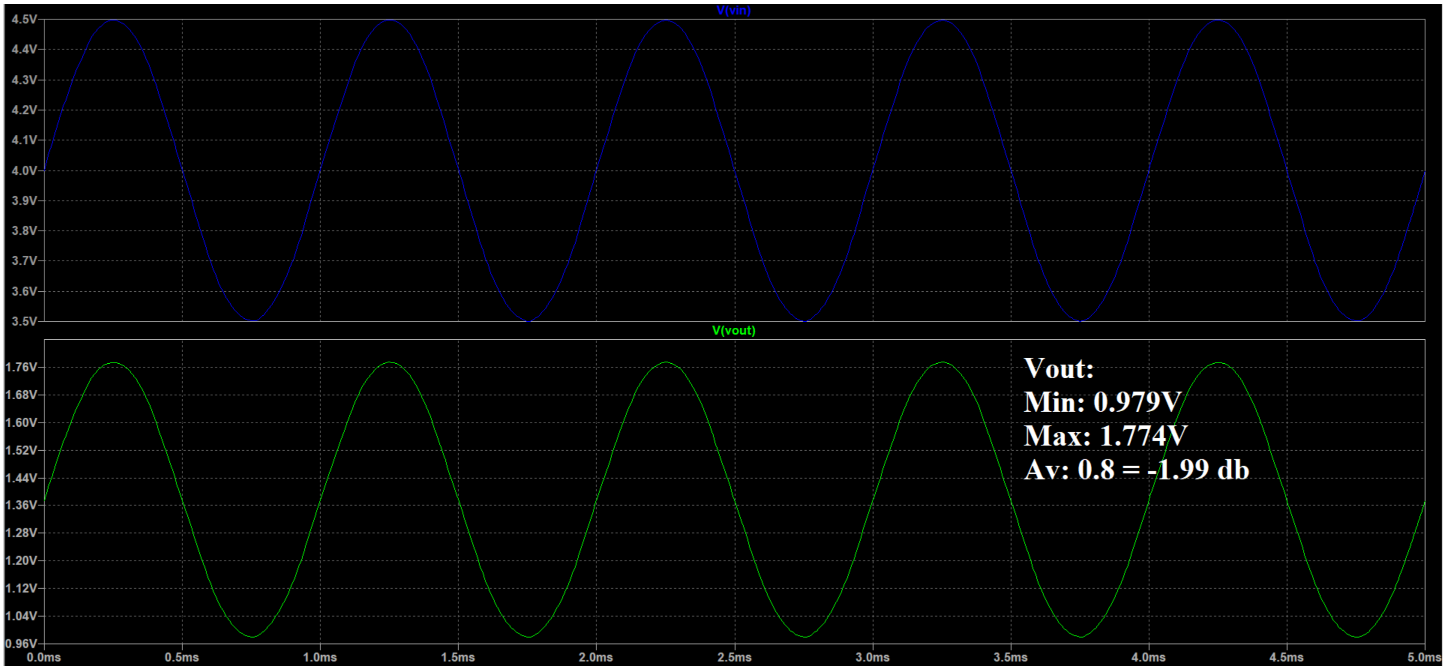
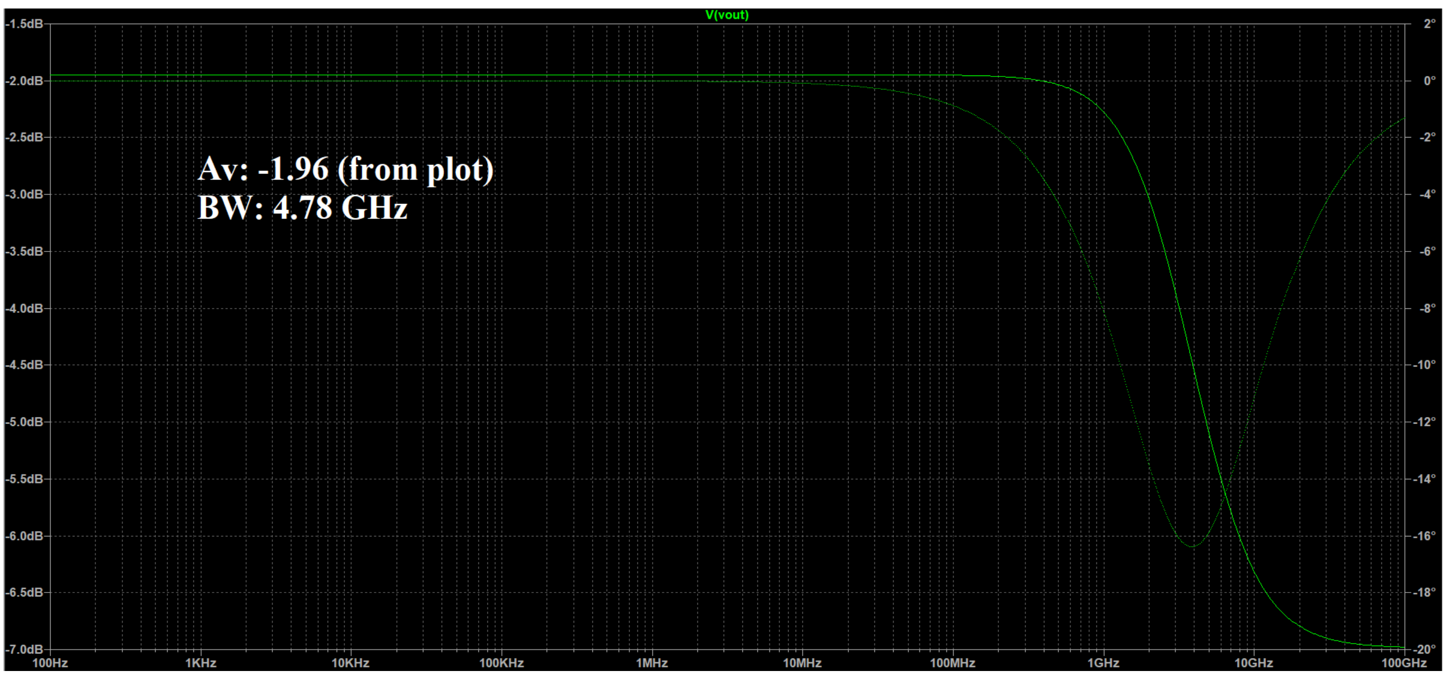
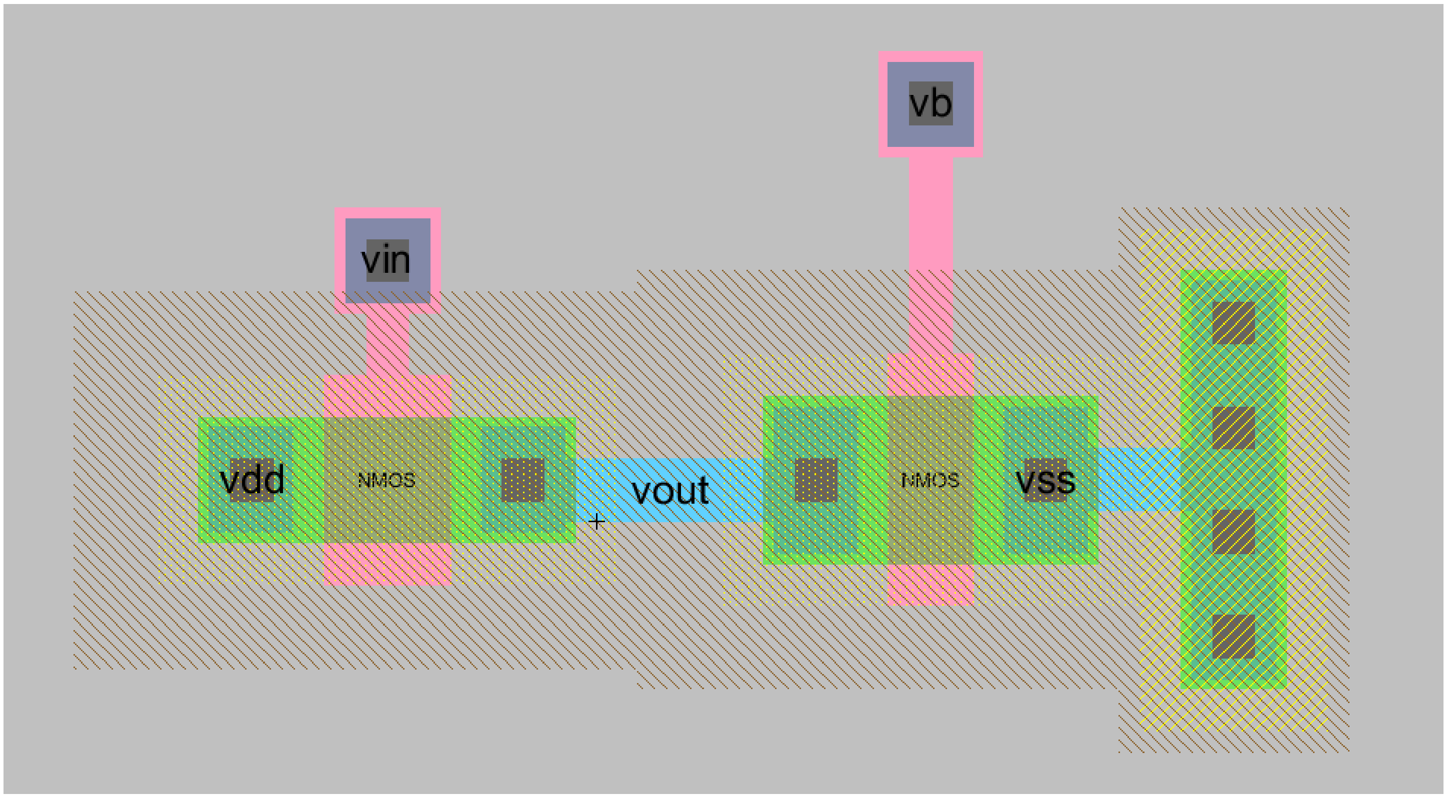


AC ANALYSIS

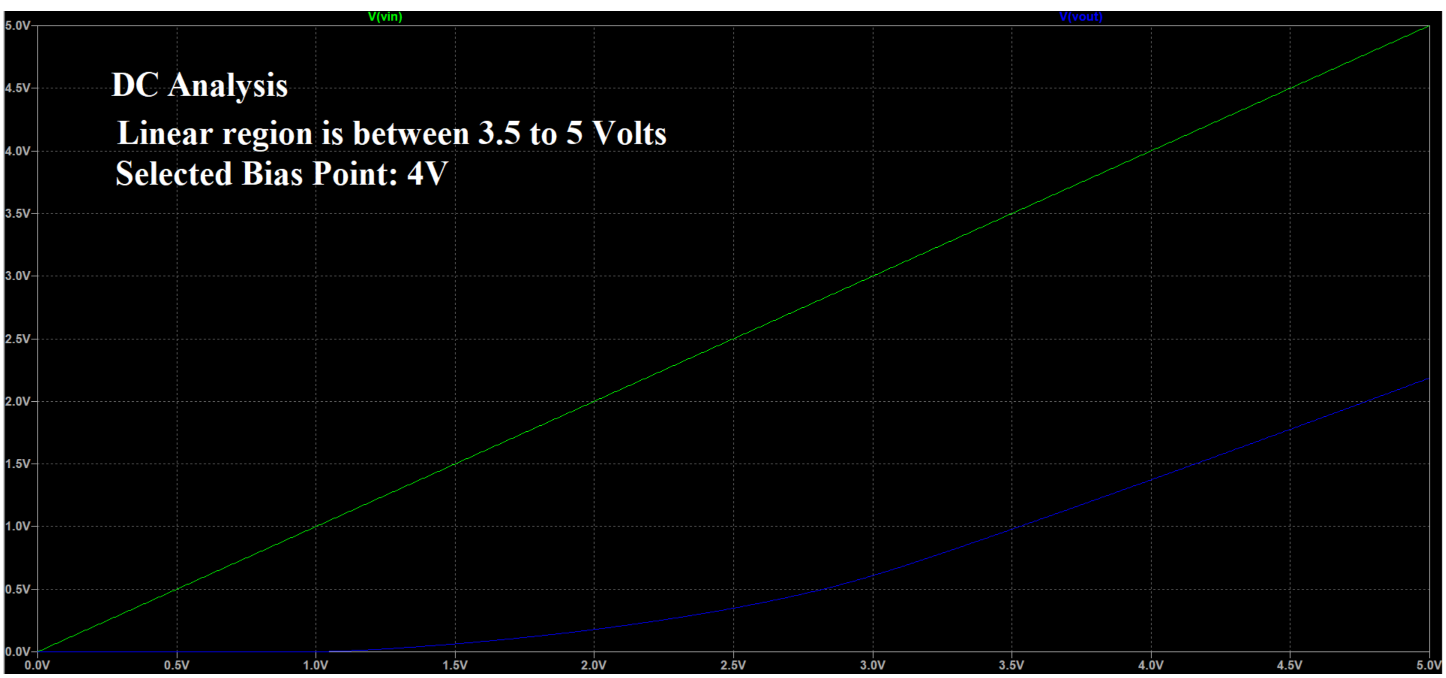


LAYOUT



LAYOUT RESULT ANALYSIS

DC ANALYSIS



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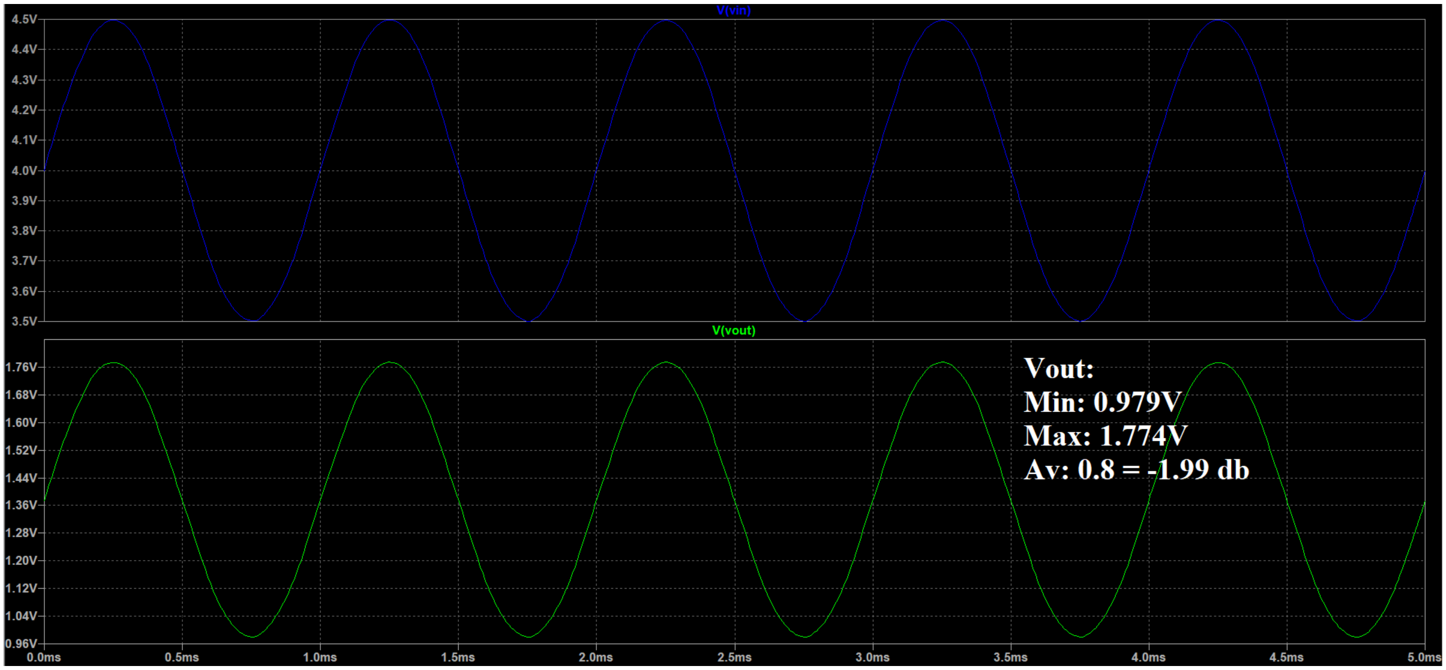
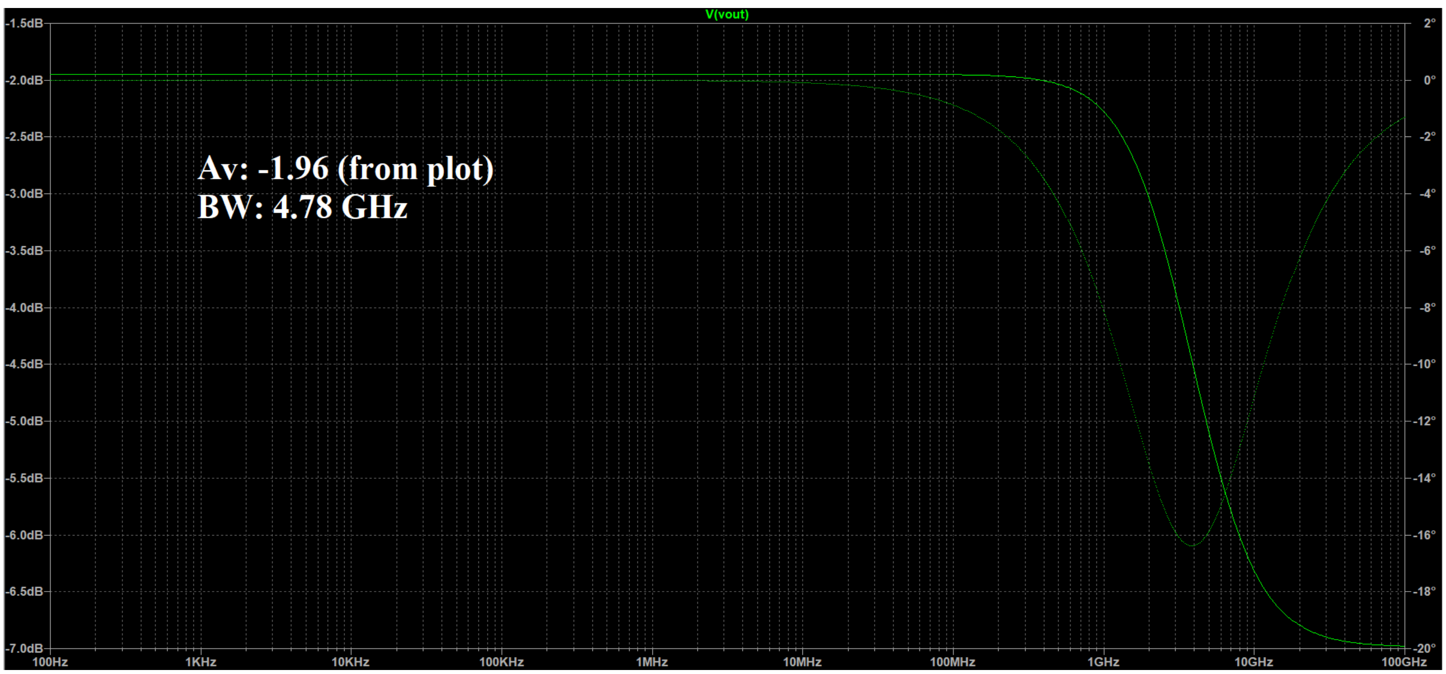


AC ANALYSIS



INFERENCE

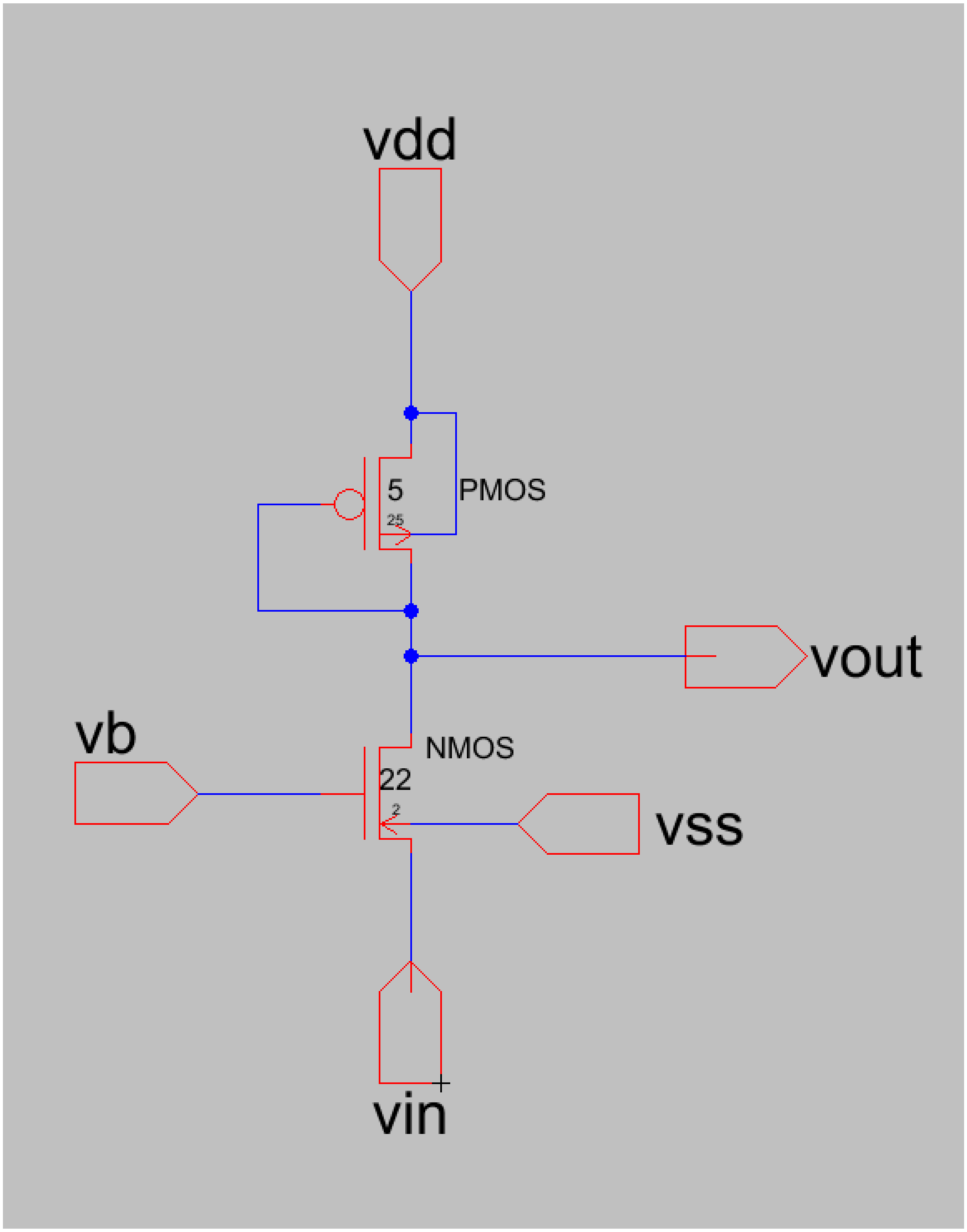
Designed Drain Current	0.35 mA
Obtained Gain	0.84
Number of transistors	2

$(W/L)_1$	6:6
$(W/L)_2$	2/1

Parameter	**Schematic**	**Layout**
DC Switching Point	.8v	.8v
Gain from transient analysis	1	0.9
Gain from AC analysis	-1.5db	-1.5db
Bandwidth	4.78Ghz	4.78Ghz

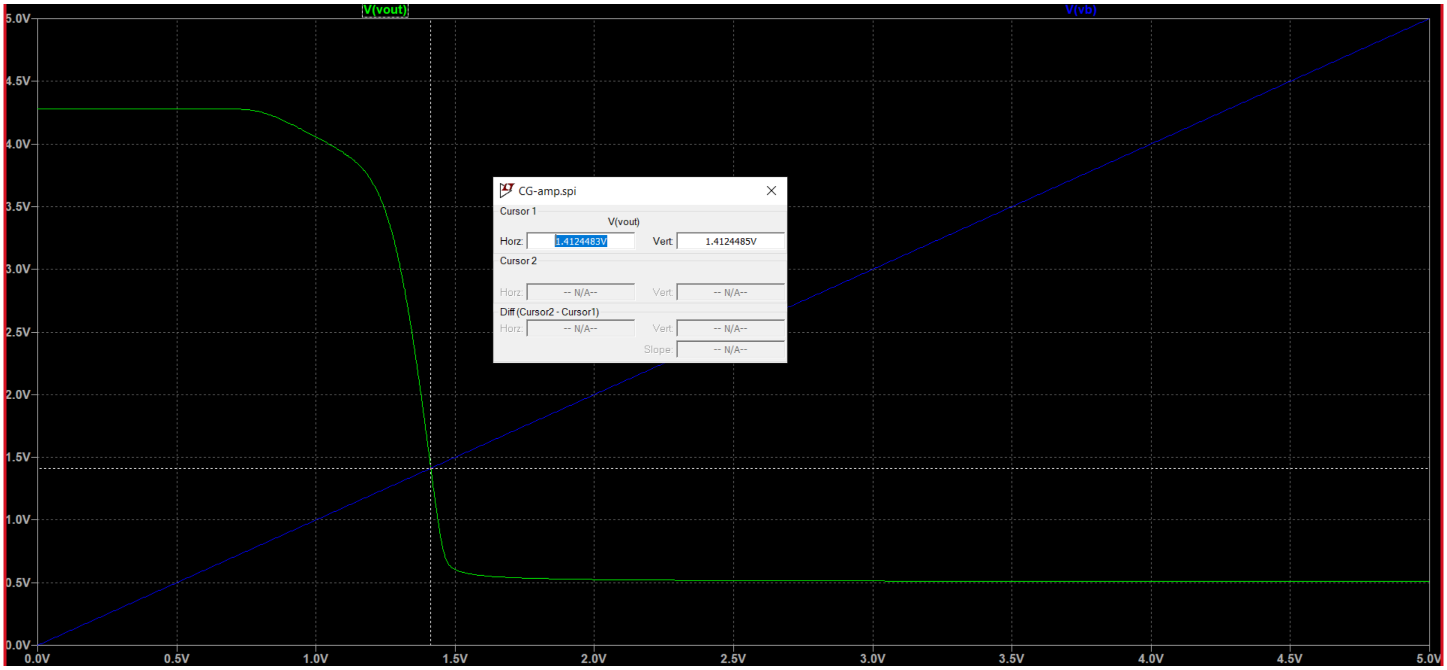
COMMON GATE AMPLIFIER

SCHEMATIC



SCHEMATIC RESULT ANALYSIS

DC ANALYSIS



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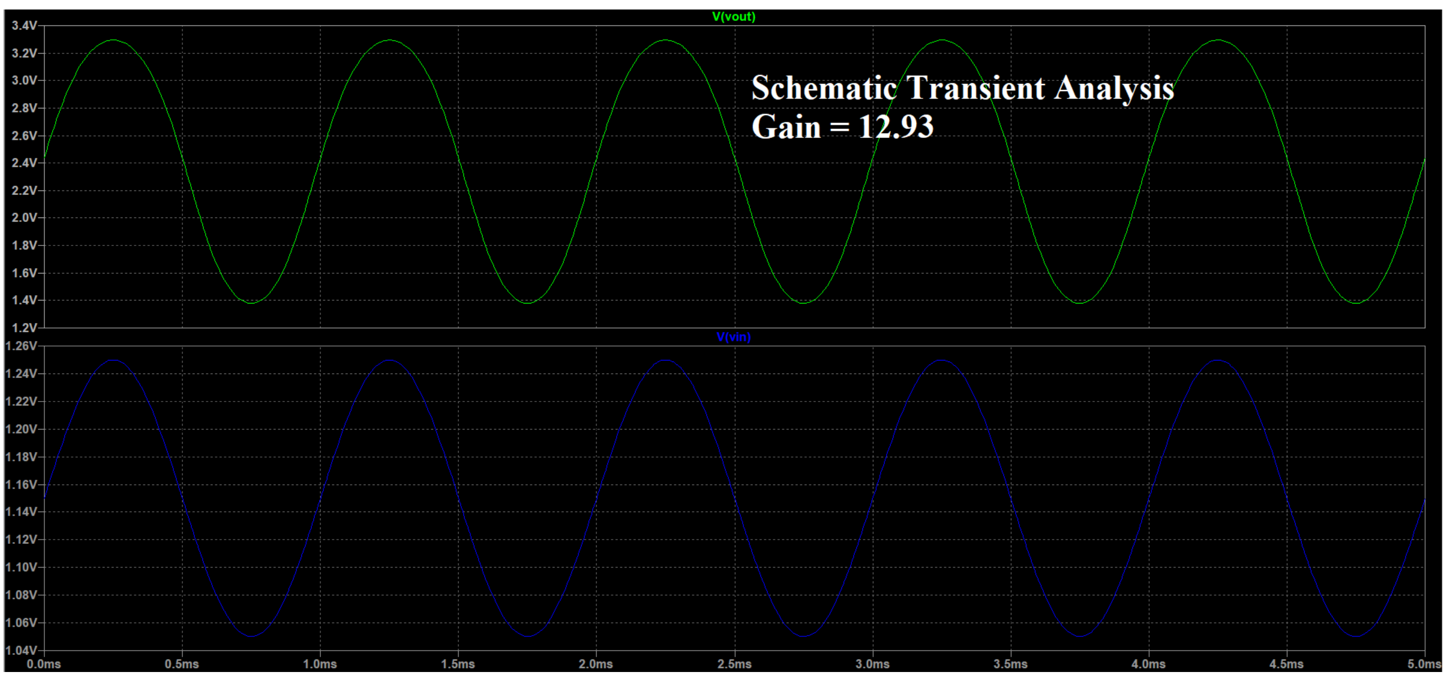

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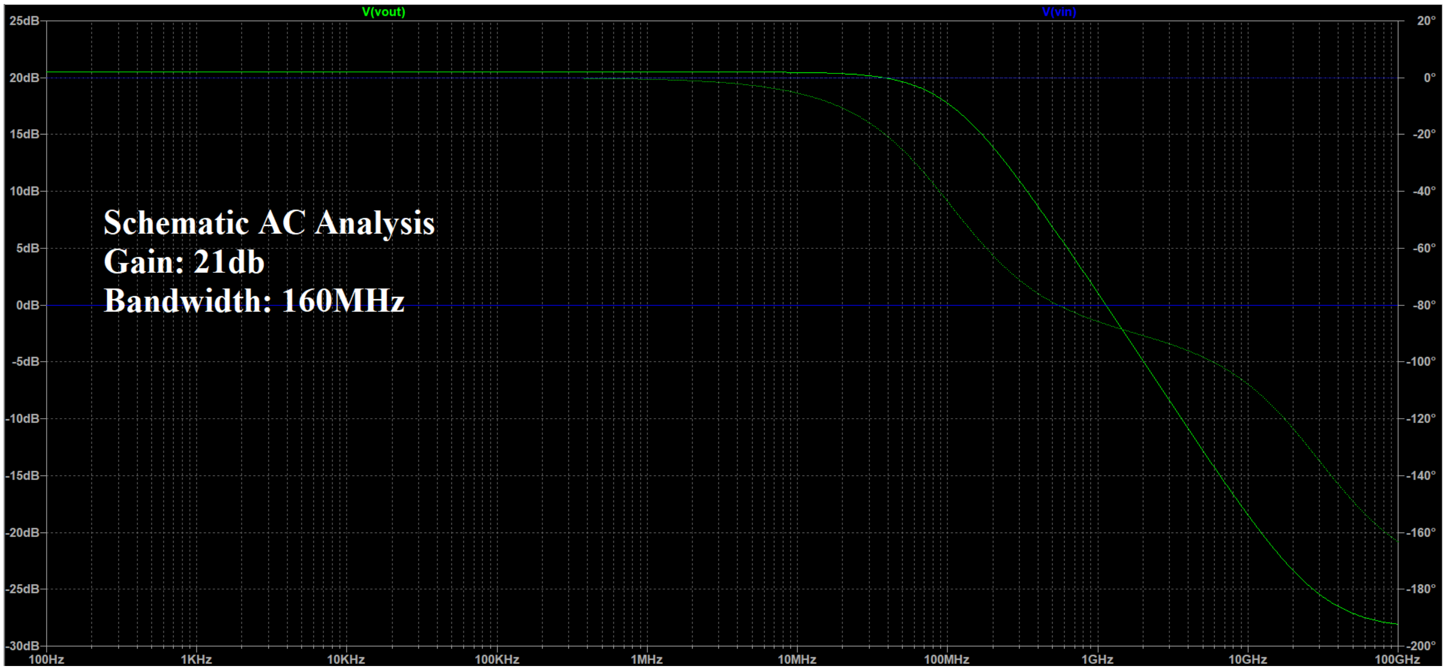
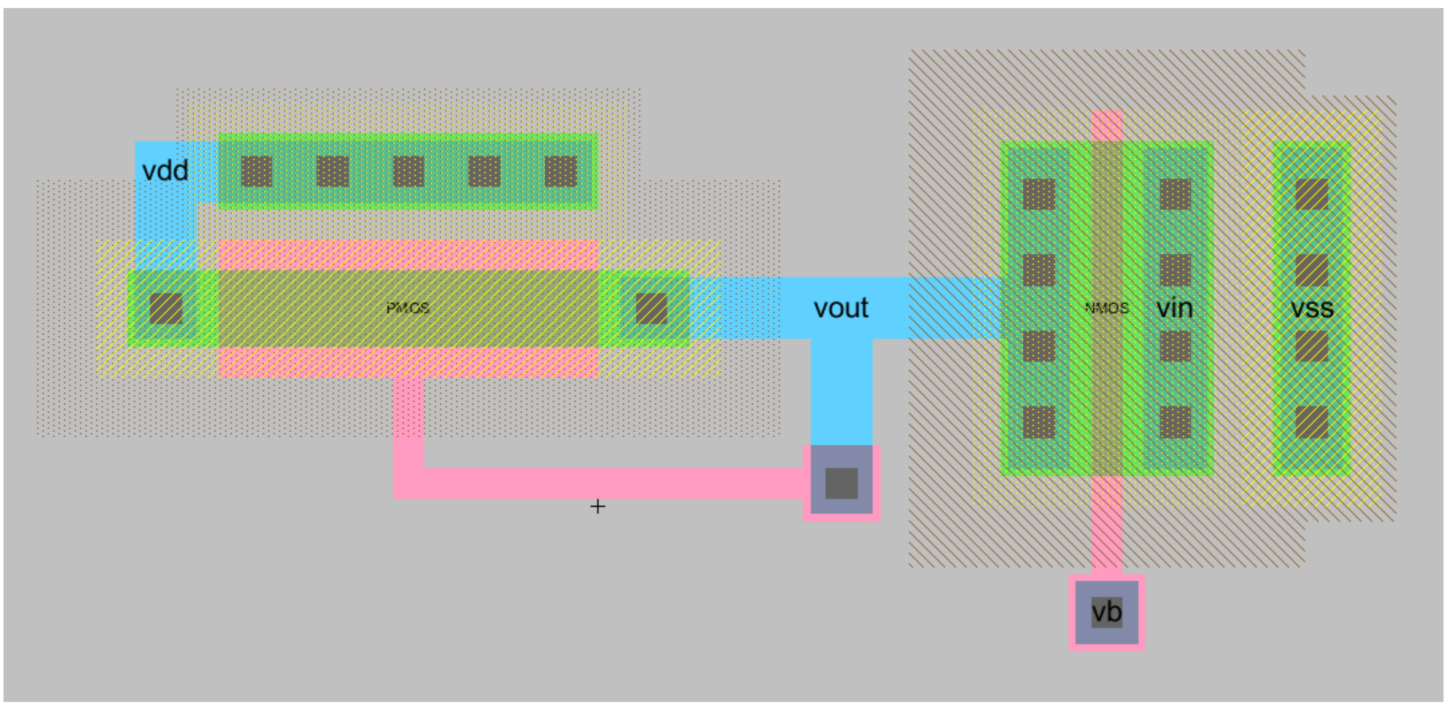
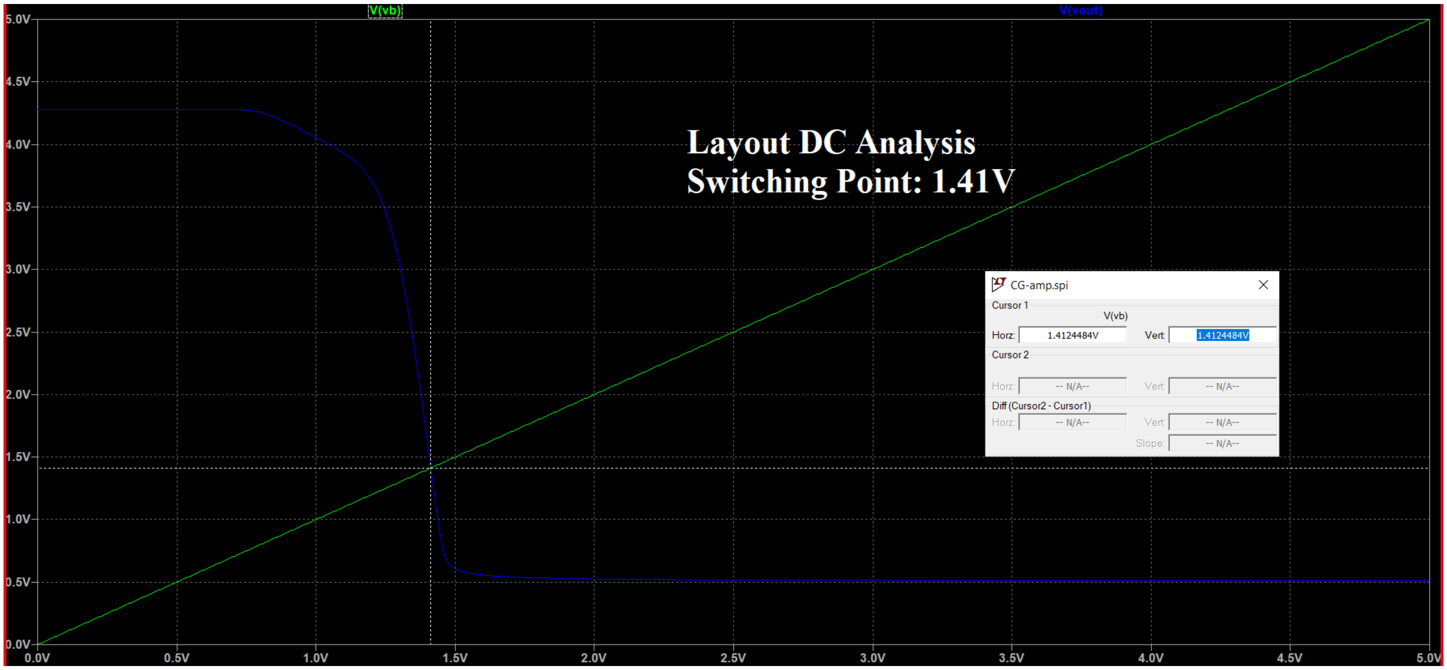


LAYOUT



LAYOUT RESULT ANALYSIS

DC ANALYSIS



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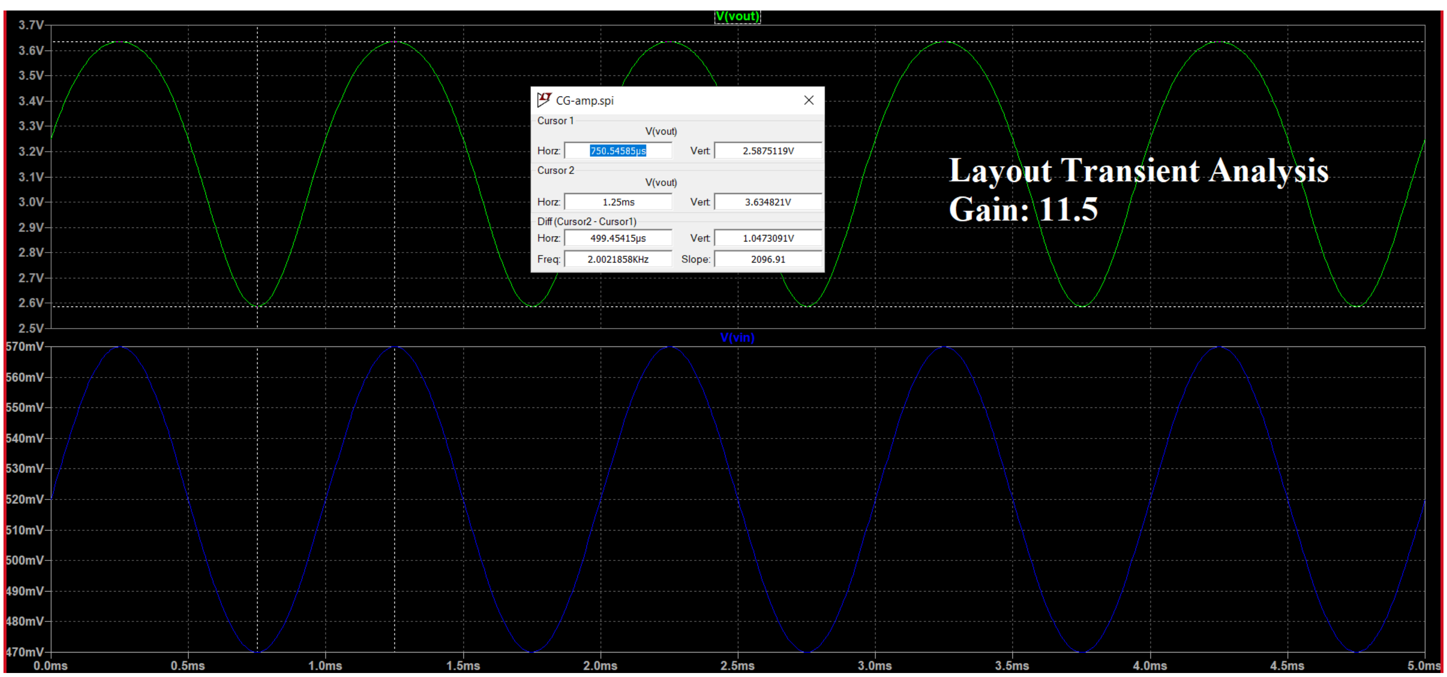
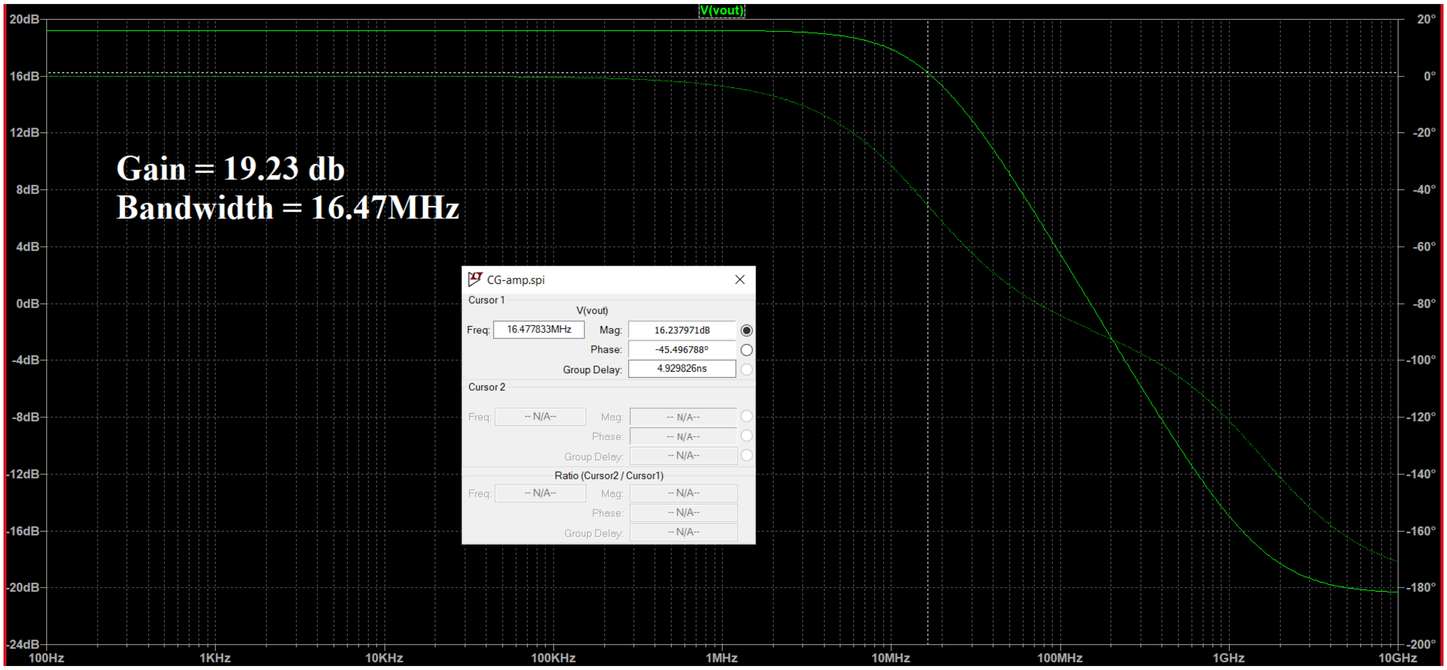


AC ANALYSIS



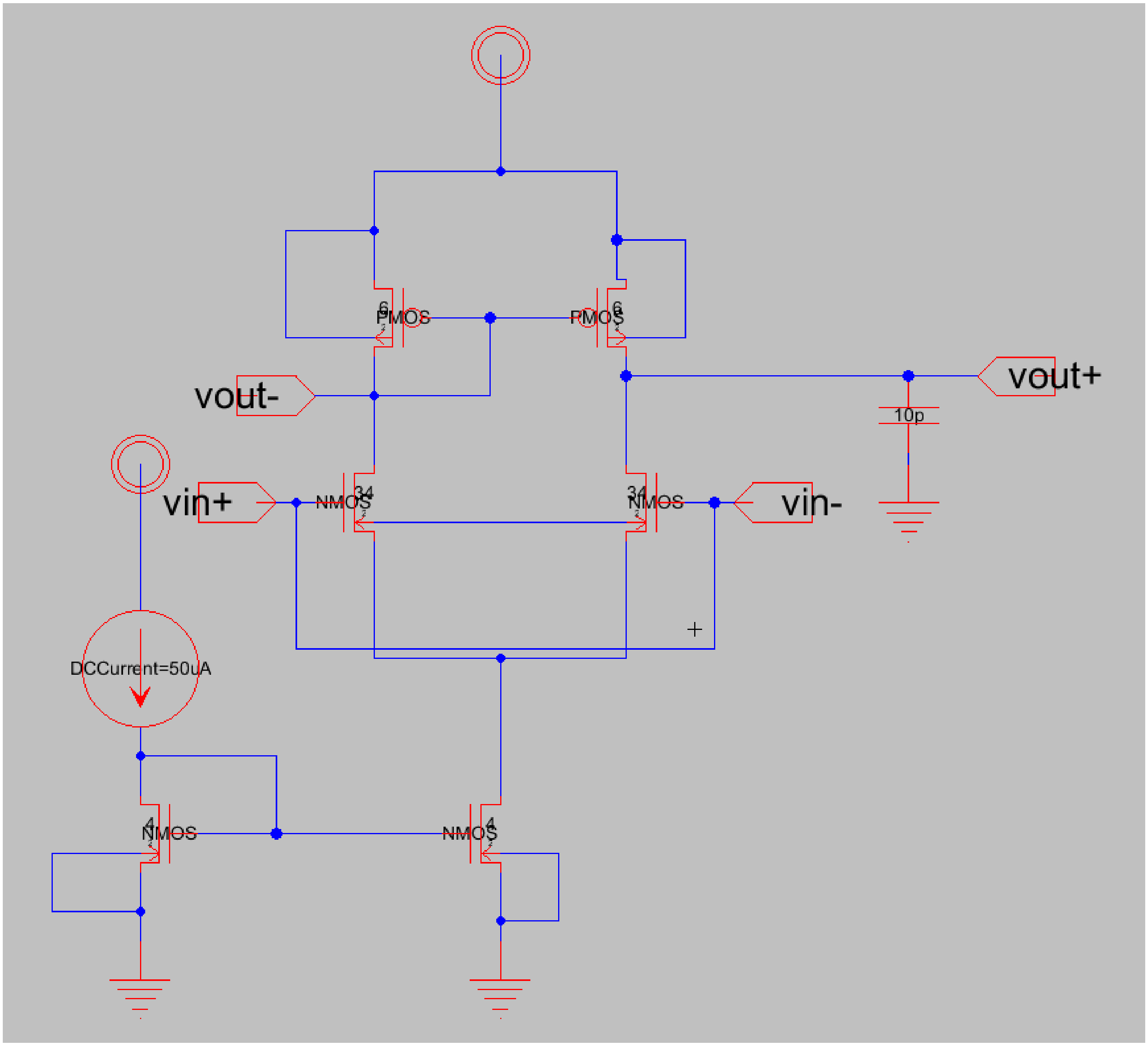
INFERENCE

Designed Gain	13
Designed Gain in db	22.27db
Number of transistors	2
$(W/L)_1$	11/1
$(W/L)_2$	5/25

Parameter	Schematic	Layout
DC Switching Point	1.42	1.41
Gain from transient analysis	12.97	11.55
Gain from AC analysis	22.25 db	21.25 db
Bandwidth	160 MHz	16.4 MHz

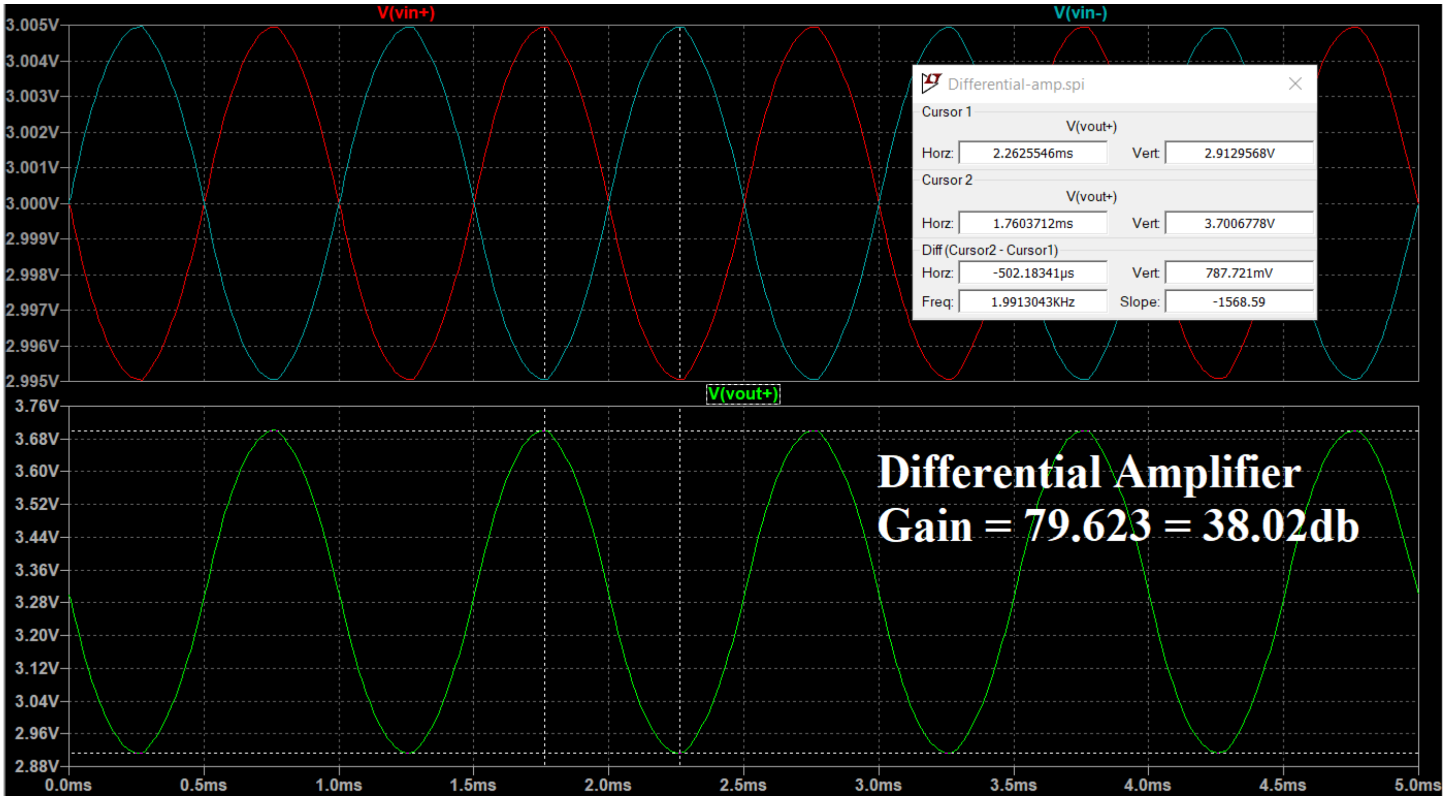
DIFFERENTIAL AMPLIFIER

SCHEMATIC



SCHEMATIC RESULT ANALYSIS

TRANSIENT ANALYSIS



AC ANALYSIS

INFERENCE

Designed Gain	100
Designed Gain in db	40 db
Number of transistors	6
$(W/L)_1 = (W/L)_2$	17/1
$(W/L)_3 = (W/L)_4$	6/2
$(W/L)_5 = (W/L)_8$	4/2

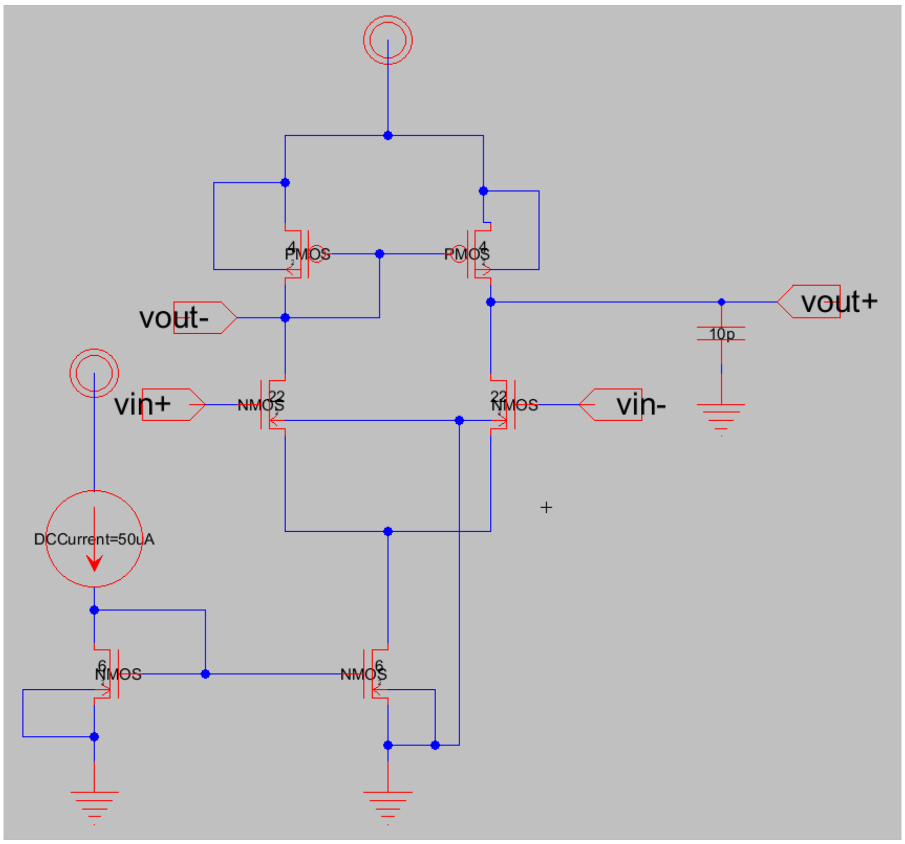
TEST QUESTION

QUESTION

Design an Operational Amplifier for a gain of 35db and simulate the same using electric tool.

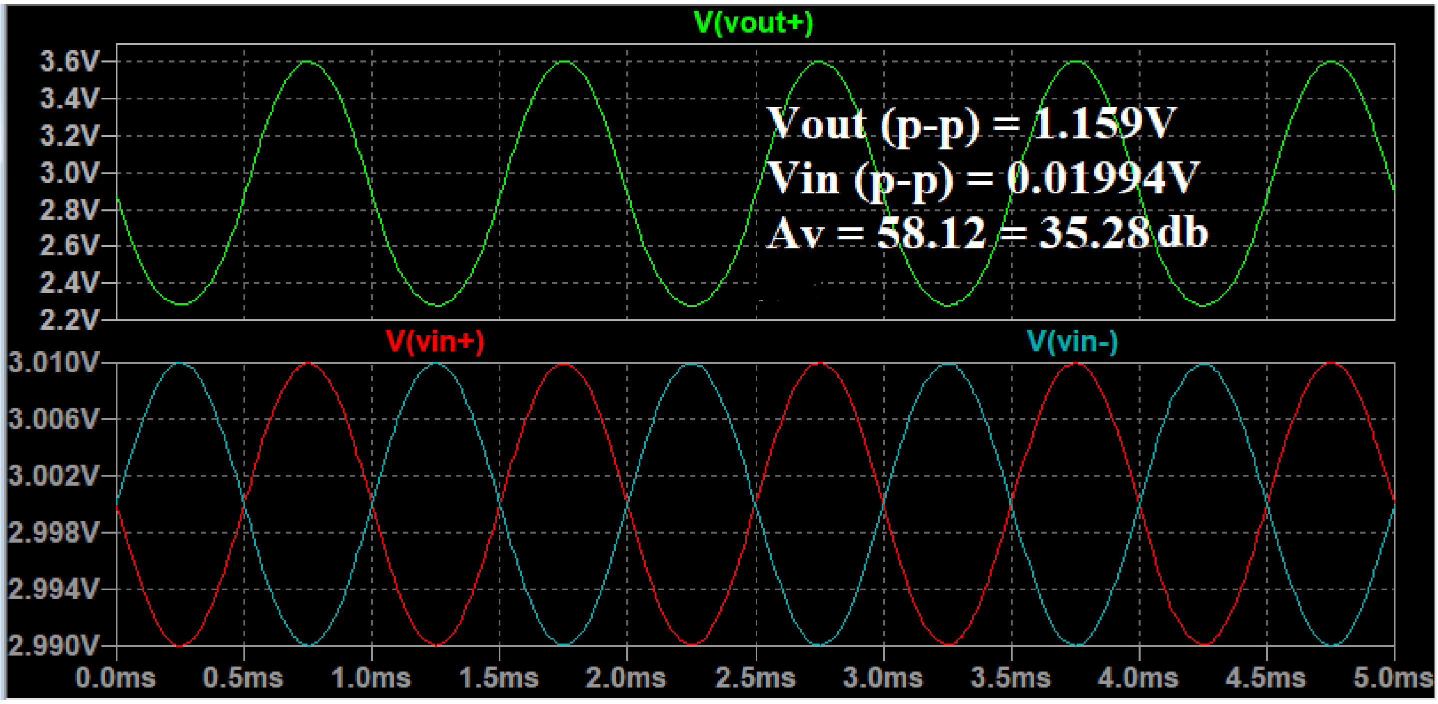
Given gain: **35db**

SCHEMATIC

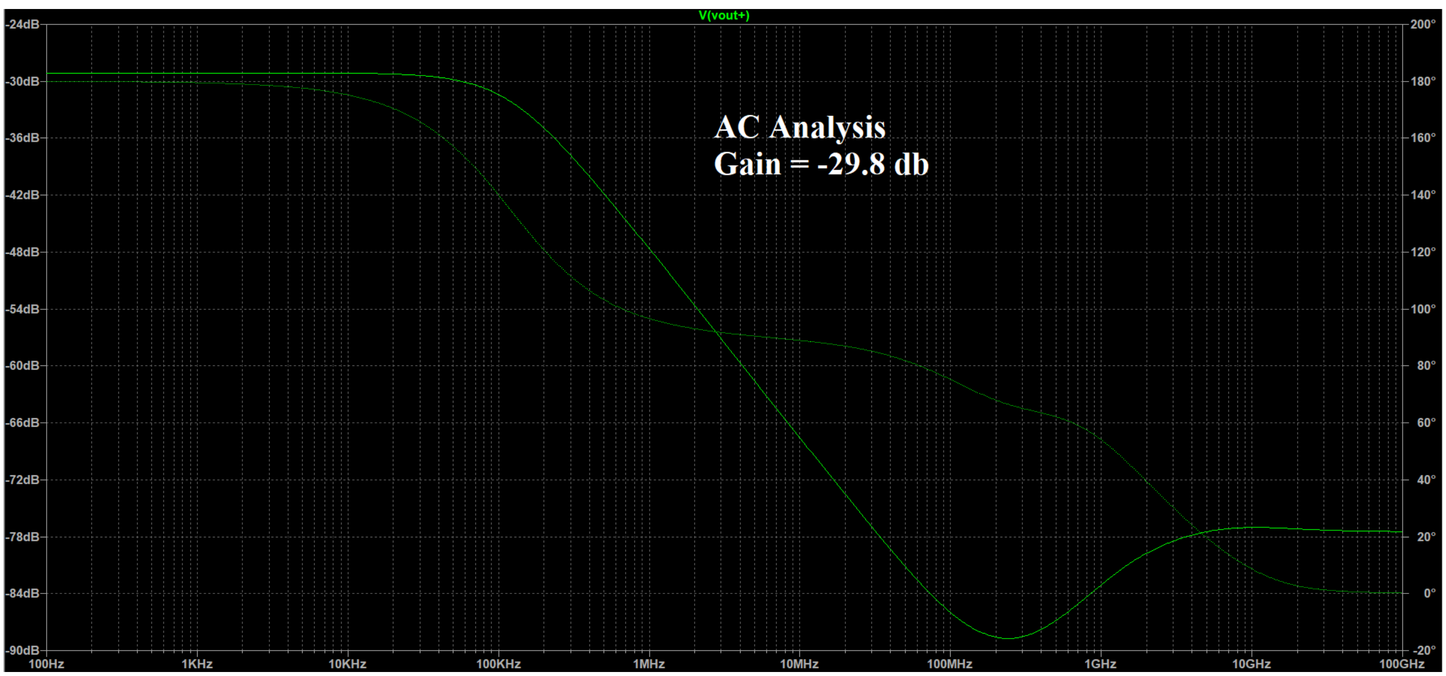


SCHEMATIC RESULT ANALYSIS

TRANSIENT ANALYSIS



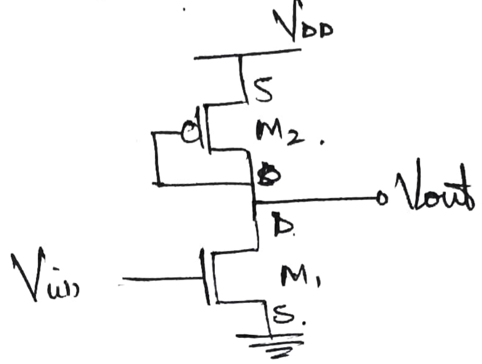
AC ANALYSIS



INFERENCE

Designed Gain	56.23
Designed Gain in db	35 db
Number of transistors	6
$(W/L)_1 \ = \ (W/L)_2$	11.1 ~ 12
$(W/L)_3 \ = \ (W/L)_4$	1.57 ~ 2
$(W/L)_5 \ = \ (W/L)_8$	2.43 ~ 3
Obtained Gain	58.12
Obtained Gain in db	35.28

Common Source Amplifier:



$A_{v1} = -g_{m1} \underline{\underline{R_d}}$
M_2

$R_d \approx \frac{1}{g_{m2}}$

$$A_{v1} = -\left(\frac{g_{m1}}{g_{m2}}\right) = -\left(\frac{\sqrt{2\mu_n C_{ox}(W/L)_1 I_{D1}}}{\sqrt{2\mu_p C_{ox}(W/L)_2 I_{D2}}}\right)$$

$\mu_n = 2\mu_p$

$$A_{v1} = -\left(\frac{\sqrt{2\cancel{\mu_p}\times 2\,\cancel{C_{ox}}\,(W/L)_1\,\cancel{I_{D1}}}}{\sqrt{\cancel{2\mu_p}\,\cancel{C_{ox}}\,(W/L)_2\,\cancel{I_{D2}}}}\right) = -\left(\frac{2\,(W/L)_1}{(W/L)_2}\right)^{1/2}$$

$$(A_{v1})^2 = -\frac{2\,(W/L)_1}{(W/L)_2} \qquad \frac{(W/L)_1}{(W/L)_2} = \underline{\underline{\frac{(A_{v1})^2}{2}}}$$

For a gain of $\underline{\underline{8}}$.
$A_{v1} = \underline{\underline{8}}$.

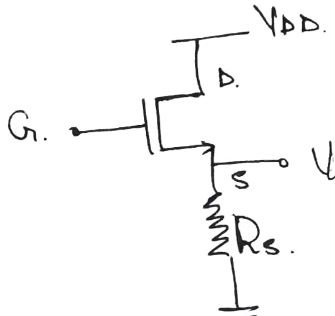
Taking $(W/L)_1 = \frac{6}{1}$

Min width of PMOS $= \underline{\underline{2}}$.
We take $\underline{\underline{3}}$.

$$\frac{(W/L)_1}{(W/L)_2} = \frac{6}{(W/L)_2} = \frac{8\times 8}{2}$$

$$(W/L)_2 = \frac{6\times\cancel{2}}{8\times\cancel{8}\,4} = \frac{3\cancel{6}}{8\times\cancel{4}\,2} = \underline{\underline{\frac{3}{16}}}$$

Common Drain Amplifier:



$$A_V = \frac{g_m r_o}{1 + (g_m + g_{mb}) r_o}$$

$g_m \rightarrow$ Transconductance

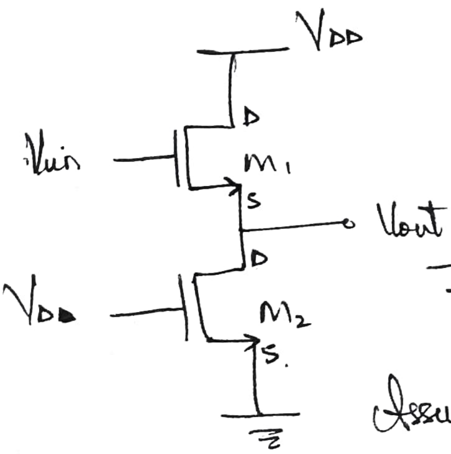
$g_{mb} \rightarrow$ body transconductance

$$A_V \approx \frac{g_m}{g_m + g_{mb}}$$

Input $Z \rightarrow$ very high.

O/P $Z \rightarrow$ low

* Used to prevent loading effect.



$\rightarrow M_1$ is in saturation.

$\therefore$ Constant Current.

$$I_{D1} = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L}\right)_1 (V_{GS} - V_{tn})^2$$

$$I_{D1} = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L}\right)_1 (V_{DD} - V_{out} - V_{tn})^2$$

Assuming $I_{D1} = 0.5mA$ $V_{in} = 0.5V$

$V_{th} = \underline{0.7}$

$$\left(\frac{W}{L}\right)_1 = 1 = \frac{6}{6}.$$

$$C_{ox} = \frac{\varepsilon_o \varepsilon_{ox}}{t_{ox}} = \frac{3.9 \times 8.854 \times 10^{-12}}{1.39 \times 10^{-8}}$$

$V_{th} = \underline{0.6696V}$.

$C_{ox} = 2.484 \times 10^{-3} F$ $\quad \mu_n = 458.43 = \underline{0.045843 mm^2}$

$$I_{D_1} = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L}\right)_1 (V_{DD} - V_{out} - V_{tn})^2.$$

$$(V_{DD} - V_{out} - V_{tn}) = \sqrt{\frac{2 I_{D_1}}{\mu_n C_{ox} \left(\frac{W}{L}\right)_1}}$$

$$V_{out} = V_{DD} - V_{tn} - \sqrt{\frac{2 I_{D_1}}{\mu_n C_{ox} \left(\frac{W}{L}\right)_1}}$$

$$\underline{\underline{V_{out} = 1.3366\ V.}}$$

M_2 also in saturation $\therefore$ $V_{DS} = V_{gs} - V_t$

$$V_{DS_2} = V_b - V_{th} = \underline{\underline{V_{out}}}$$

$$I_{D_2} = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L}\right)_2 (V_{out})^2$$

$$\left(\frac{W}{L}\right)_2 = \underline{\underline{4.920}} = \underline{\underline{5}}$$

$$W_2 = 20.$$

$$\underline{\underline{L_2 = 4.}}$$

For a drain Current of $I_{DS} = \underline{\underline{0.35 mA}}$.

$V_{in} = 0.5 V$. $V_{th} = 0.7V$.

$C_{ox} = 2.484 \times 10^{-3} F$ $\mu_n = 0.045843 mm^2$.

$$\left(\frac{W}{L}\right)_1 = \frac{6}{6} = 1$$

(1) $V_{out} = V_{DD} - V_{th} - \sqrt{\frac{2 I_{DS}}{\mu_n C_{ox} \left(\frac{W}{L}\right)_1}}$

$$V_{out} = 5 - 0.7 - \sqrt{\frac{2 \times 0.35 \times 10^{-3}}{0.045843 \times 2.484 \times 10^{-3} \times 1}}$$

$$\boxed{V_{out} = 1.8206 V.}$$

(2) $\left(\frac{W}{L}\right)_2 = \frac{2 I_{DS}}{\mu_n C_{ox} (V_{out})^2} = \frac{2 \times 0.35 \times 10^{-3}}{\mu_n C_{ox} (1.82)^2}$

$$\left(\frac{W}{L}\right)_2 = 1.85 = \frac{37}{20} \approx \frac{19}{10} \approx \boxed{\frac{4}{2}.}$$

$\underline{\underline{V_{in} = 1}}$

$V_{out} = 1.774 - 0.979 \cdot$ ~~0.8 = -1.99 dB.~~

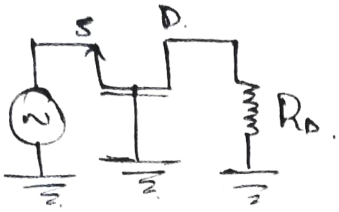
$A_v = \frac{V_{out}}{V_{in}} = 0.8 = \underline{\underline{-1.99 dB}}$.

From AC-analysis. (plot).

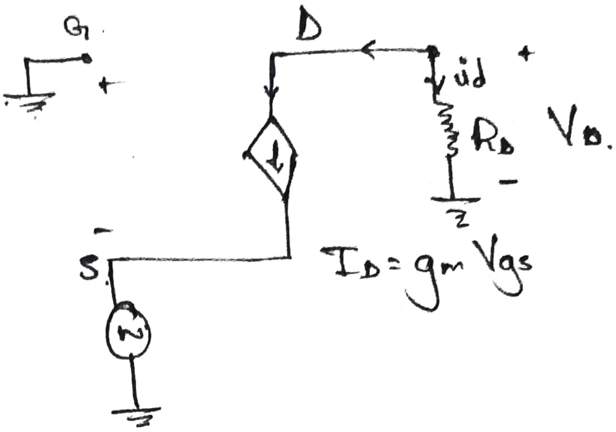
$A_v = -1.95 dB$.

$BW = \underline{\underline{4.78 GHz}}$.

Common Gate Amplifier.



AC GND



$I_D = g_m V_{gs}$

- Low input Impedance
- High o/p — " —.
- LNA

$$I_o + I_D = 0.$$

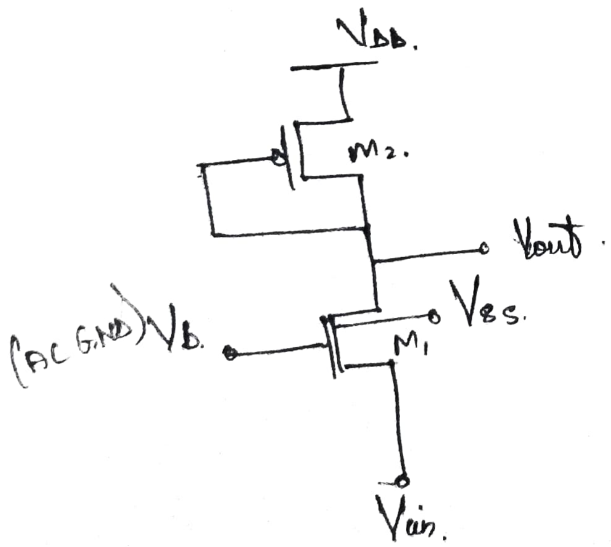
$$I_o = \frac{V_o}{R_D} = -I_d = -g_m V_{gs}.$$

$$V_{gs} = -V_{in}$$

$$\frac{V_o}{R_D} = -g_m(-V_{in}).$$

$$\frac{V_o}{V_{in}} = g_m R_D.$$ ∴ No change in phase.

$$R_D \approx \frac{1}{g_{m2}}.$$



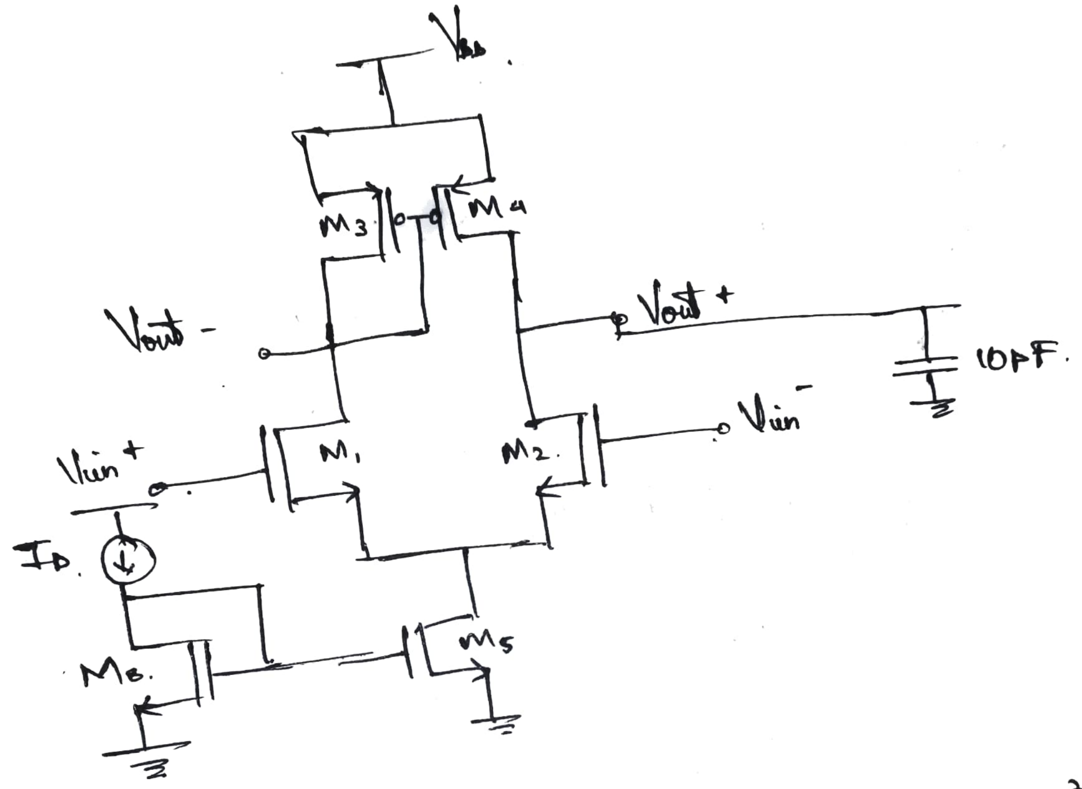
$$A_V = \frac{g_{m1}}{g_{m2}}.$$

$$A_{V1}^2 = \left(\frac{2\,(W/L)_1}{(W/L)_2}\right).$$

Taking $\left(\frac{W}{L}\right)_1 = \frac{6}{1}$

$\left(\frac{W}{L}\right)_2 = \frac{3}{16}.$

Differential Amplifier.



$\mu_n = 0.095843\ \mu m^2$ $\quad$ $\mu_p = 0.021201661\ mm^2$.

$C_{ox} = 2.484 \times 10^{-3}$ F

$\rightarrow V_{DD} = 5$. $\quad$ GBP = 5 $\quad$ $C_L = 10pF$ $\quad$ ICMR+ = 4V.

— " — — = 1.5V.

Slew Rate = 5V/μs.

(1) $q = CV$ $\quad$ $\frac{dv}{dt} \times C = \frac{dq}{dt}$.

$I_D = C_L \times$ Slew Rate

$= 10 \times 10^{-12} \times 5 \times 10^{6}$. $= 50 \times 10^{-6}$ A $= 50\mu A$.

(2) Finding V_x (M_1).

$V_{ds} > V_{gs} - V_{t}$ ⋮ $V_d - \cancel{V_s} > V_g - \cancel{V_s} - V_{t}$.

$V_d > V_g - V_{t}$.

$V_d = V_x$

$V_g = ICMR+ = \underline{4}$.

$V_{tn} = \underline{0.7}$.

$V_x > V_g - V_{t}$.

$V_x > 4 - 0.7 = \underline{3.3\,V}$.

$V_x = \underline{3.3\,V}$.

(3) **Find $M_3 - M_4$ Ratios.**

$V_{TP} = 0.9214\,V$.

$V_{ds_3} = V_{dd} - V_x = 5 - 3.3\,V = \underline{1.7\,V}$.

$V_{ds_3} = \underline{1.7\,V}$.

$$I_3 = \frac{\mu_p C_{ox}}{2}\left(\frac{W}{L}\right)_3 (V_{gs} - V_{tp})^2.$$

$$\left(\frac{W}{L}\right)_3 = \left(\frac{W}{L}\right)_4 = \frac{2 I_3}{\mu_p C_{ox}(V_s - V_g - V_{tp})^2}$$

$$= \frac{2 \times 25 \times 10^{-6}}{\mu_p C_{ox}(5 - 3.3 - 0.9214)^2} = \underline{1.86} = \left(\frac{W}{L}\right)_3 = \left(\frac{W}{L}\right)_4.$$

(4) **Find $M_1 - M_2$ Ratios.**

$$GBP = DC^{*} P_1 = \frac{g_{m_1}}{2\pi C_L} = 5 \times 10^6$$

$$g_{m_1} = 5 \times 10^6 \times 2 \times \pi \times 10 \times 10^{-12} = \underline{314\,\mu}$$

$$g_{m_1} = \sqrt{2 I_D \mu_n C_{ox}\left(\frac{W}{L}\right)},$$

$$\left(\frac{W}{L}\right)_1 = \frac{(g_{m_1})^2}{2 I_D \mu_n C_{ox}} = 17.35 = \underline{\frac{18}{1}}$$

(5) Finding M_5 & M_8.

$V_{in+} = ICMR-$

$V_{in+} > V_{gs_1} + V_{DS5}$.

& V_{gs_1} Can be obtained from

$$I_D = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_1 (V_{gs_1} - V_{th})^2.$$

$$V_{gs_1} = \left(\frac{2 I_D}{\mu_n C_{ox} (W/L)_1}\right)^{1/2} + V_{thn}.$$

$$V_{gs_1} = \left[\frac{2 \times 25 \times 10^{-6}}{\mu_n C_{ox} (18)}\right]^{1/2} + 0.7 = \underline{0.85V}.$$

Now, $1.5 > V_{gs_1} + V_{DS5}$.

$$V_{ds5} < 1.5 - V_{gs_1} = 1.5 - 0.85.$$

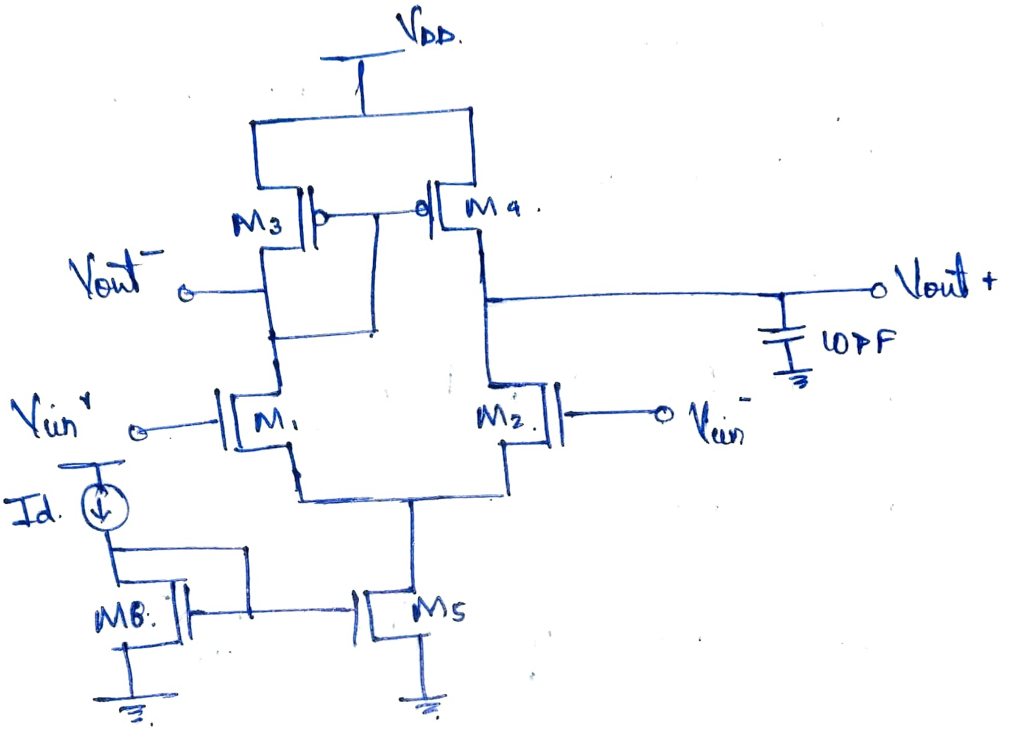
$$V_{ds5} = 0.64\underline{V}.$$

$$I_0 = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_5 (V_{gs} - V_t)^2$$

$$\left(\frac{W}{L}\right)_5 = \frac{2 I_0}{\mu_n C_{ox} (V_{ds5})^2} = 2.14 \approx \underline{3}.$$

Opamp for a gain of 35dB. (Differential)

$A_v = 35dB = 56.23$



Given Parameters:

$A_v = 35dB$. Selecting GBP of 4 MHz.

$\mu_n = 0.045843 mm^2$. $\mu_p = 0.02120661 mm^2$

$C_{ox} = 2.484 \times 10^{-3} F$

Selecting Parameters: $V_{DD} = 5$. $C_L = 10pF$ ICMR+ = 4V.

ICMR − = 1.5 V.

$V_{tn} = 0.7V$. $V_{tp} = 0.9214 V$.

Slew Rate = $5V/\mu s$.

① Finding I_D

$I_D = C_L \times$ Slew Rate.

$= 10 \times 10^{-12} \times 5 \times 10^{6} = 50 \times 10^{-6} = 50\mu A$.

(2) Finding V_x at M_1

$V_{ds} > V_{gs} - V_t \qquad V_d = V_x$

$V_d - V_s > V_g - V_s - V_t$

ICMR+ : $V_g = \underline{4}$

$V_d > V_g - V_t$

$V_x > V_g - V_t$

$V_x = 4 - 0.7 = \underline{3.3V}$

(3) Find $M_3 - M_4$ Ratios

$V_{ds3} = V_{dd} - V_x = 5 - 3.3 = \underline{1.7V}$

$$I_3 = \frac{\mu_p C_{ox}}{2}\left(\frac{W}{L}\right)_3 (V_{gs} - V_{tp})^2$$

$$\left(\frac{W}{L}\right)_3 = \left(\frac{W}{L}\right)_4 = \frac{2 I_3}{\mu_p C_{ox} (V_s - V_g - V_{tp})^2}$$

$$\left(\frac{W}{L}\right)_3 = \left(\frac{W}{L}\right)_4 = 1.57 \approx \boxed{2}$$

(4) Find $M_1 - M_2$ Ratios:

$$GBP = 4MHz = \frac{g_{m1}}{2\pi C_L} \qquad g_{m1} = 4\times10^6 \times 2\pi \times 10\times10^{-12}$$

$$g_{m1} = 2.514\times10^{-4}\ \mho$$

$$\left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_2 = \frac{(g_{m1})^2}{2 I_D \mu_n C_{ox}} = 11.1 \approx \boxed{12}$$

(8) Finding M_5 & M_8 Ratios.

$V_{in+} > V_{gs1} + V_{DS5}$. At V_{in+} = ICMR -

V_{gs1} can be found from

$$I_D = \frac{\mu_n C_{ox}}{2} \left(\frac{W}{L}\right)_1 (V_{gs1} - V_{th})^2.$$

$$V_{gs1} = \left[\frac{2 I_D}{\mu_n C_{ox} \left(\frac{W}{L}\right)_1}\right]^{1/2} + V_{th}.$$

$$= \left[\frac{2 \times 25 \times 10^{-6}}{\mu_n C_{ox} (12)}\right]^{1/2} + 0.7. = \underline{\underline{0.89}}.$$

$$1.5 > V_{gs1} + V_{ds5}.$$

$$V_{ds5} < 1.5 - 0.89 = \underline{\underline{0.6V}}.$$

$$I_D = \frac{\mu_n C_{ox}}{2} \left(\frac{W}{L}\right)_5 (V_{gs} - V_t)^2.$$

$$\left(\frac{W}{L}\right)_5 = \frac{2 I_D}{\mu_n C_{ox} (V_{ds5})^2} = 2.43 \approx \boxed{3.}$$