Mo Tu We Th Fr Sa Su

Assignment-2

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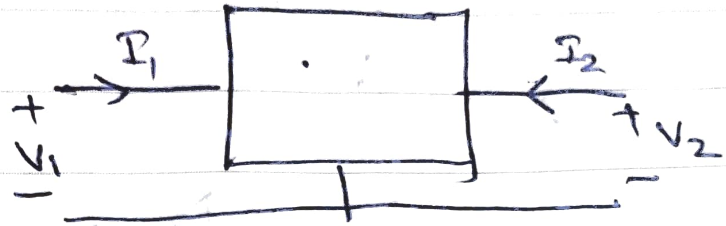
1) a) Given 3-terminal device:

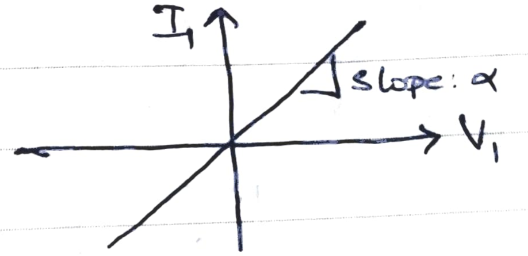


$I_1 = \alpha V_1$

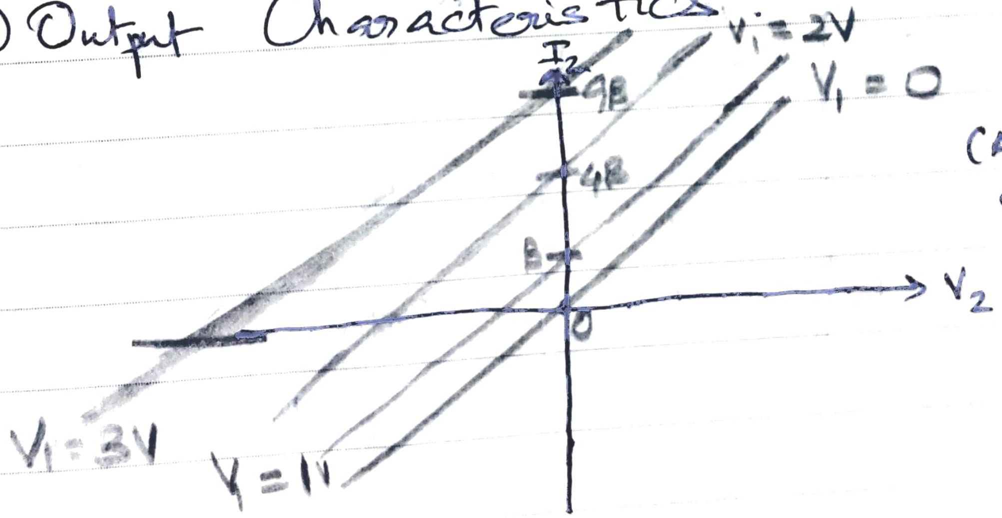
$I_2 = \beta V_1^2 + \gamma V_2$

α, β, γ are Constants

(i) Input characteristics:



(ii) Output Characteristics:



(Assuming $\alpha, \beta, \gamma > 0$)

1) b) By Tellengens theorem, we have
if $\sum_{k=1}^{N} V_k I_k \geq 0$, then system is Passive.

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$\Rightarrow V_1 I_1 + V_2 I_2 = V_1(\alpha V_1) + V_2(\beta V_1^2 + \gamma V_2)$

$= \alpha(V_1^2) + \beta V_1^2 V_2 + \gamma V_2^2$

$= V_1^2(\alpha + \beta V_2) + \gamma V_2^2$

$= \gamma V_2^2 + (\beta V_1^2) V_2 + V_1^2 \alpha$

The device is active ~~or~~ passive depending on the constants α, β, γ. By taking $\alpha, \beta, \gamma > 0$, for the device to be passive we want $\gamma V_2^2 + (\beta V_1^2) V_2 + V_1^2 \alpha > 0$

$\rightarrow$ This can be ensured by making $\Delta < 0 \Rightarrow (\beta V_1^2)^2 < 4\gamma V_1^2 \alpha$

i.e $\beta^2 V_1^2 < 4\gamma\alpha \Rightarrow V_1^2 < 4\gamma\alpha/\beta^2 \Rightarrow \frac{-2\sqrt{\gamma\alpha}}{\beta} < V_1 < \frac{2\sqrt{\gamma\alpha}}{\beta}$

Then the device is assured to be passive.

By changing the constants, it can be active in certain operating regions

1) c) The incremental y-parameters when the device is op. at (V_1, V_2) is

$$y = \begin{bmatrix} \partial I_1/\partial V_1 & \partial I_1/\partial V_2 \\ \partial I_2/\partial V_1 & \partial I_2/\partial V_2 \end{bmatrix} \qquad \begin{aligned} I_1 &= \alpha V_1 \\ I_2 &= \beta V_1^2 + \gamma V_2 \end{aligned}$$

$$\Rightarrow y = \begin{bmatrix} \alpha & 0 \\ 2\beta V_1 & \gamma \end{bmatrix}$$

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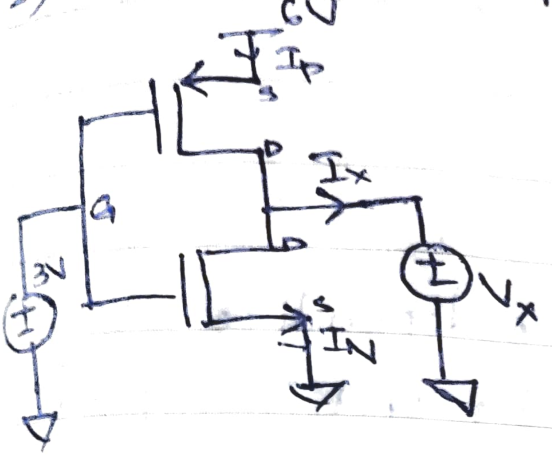
2) Given,



PMOS : $|V_{Tp}| = 1V$ $\mu_p C_{ox} = 100 \mu A V^{-2}$

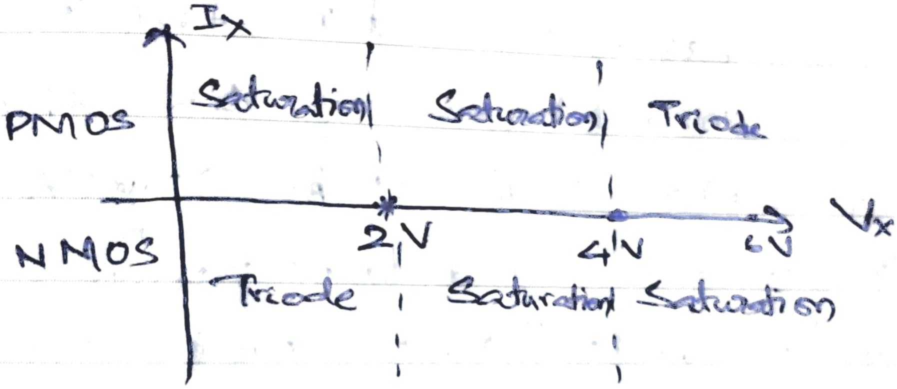
$W/L = 3$ $V_{SG} = 6-3 = 3V$

$V_{SD} = 6 - V_x$

NMOS : $|V_{Tn}| = 1V$ $\mu_n C_{ox} = 300 \mu A V^{-2}$

$W/L = 1$ $V_{GS} = 3V$

$V_{DS} = V_x$



Hence, we will find the triode and saturation currents.

NMOS :

- Saturation : $I_{DS}^{N} = \mu_N C_{ox} \frac{W}{2L} (V_{GS} - V_T)^2$

$$= \frac{300 \times 1}{2} (2)^2 = 600 \mu A$$

- Triode Region : $I_{DS}^{N} = \mu_N C_{ox} \frac{W}{L} \left[(V_{GS} - V_T) V_{DS} - \frac{V_{DS}^2}{2} \right]$

$$= 300 \times 1 \times \left[2 V_{DS} - \frac{V_{DS}^2}{2} \right]$$

$$= 150 \times V_x (4 - V_x)$$

PMOS :

- Saturation : $I_{SD}^{P} = \mu_P C_{ox} \frac{W}{2L} (V_{SG} - V_T)^2$

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$\Rightarrow I_{SD}^{P} = 100 \times \frac{3}{2} \times (2)^2 = 600 \mu A$

• Triode Region: $I_{SD}^{P} = \mu_p C_{ox} \frac{W}{L} \left[(V_{SG} - V_T) V_{SD} - \frac{V_{SD}^2}{2} \right]$

$\Rightarrow I_{SD}^{P} = 100 \times 3 \left[(2)(6 - V_x) - \frac{(6 - V_x)^2}{2} \right]$

$= 300 \times (6 - V_x) \times \left(2 - \left(\frac{6 - V_x}{2} \right) \right)$

$= 300 \times (6 - V_x) \times \left(\frac{4 - 6 + V_x}{2} \right)$

$= \cancel{300}^{150} \times (6 - V_x) \times \frac{(V_x - 2)}{\cancel{2}} = 150 (6 - V_x)(V_x - 2)$

Now, when

• $0 \leq V_x \leq 2V$: $I_x = I_{SD(sat)}^{P} - I_{DS(triode)}^{N}$

$\Rightarrow I_x = 600 \mu A - 150 \times V_x (4 - V_x)$

$= (600 - 600 V_x + 150 V_x^2) \mu A$

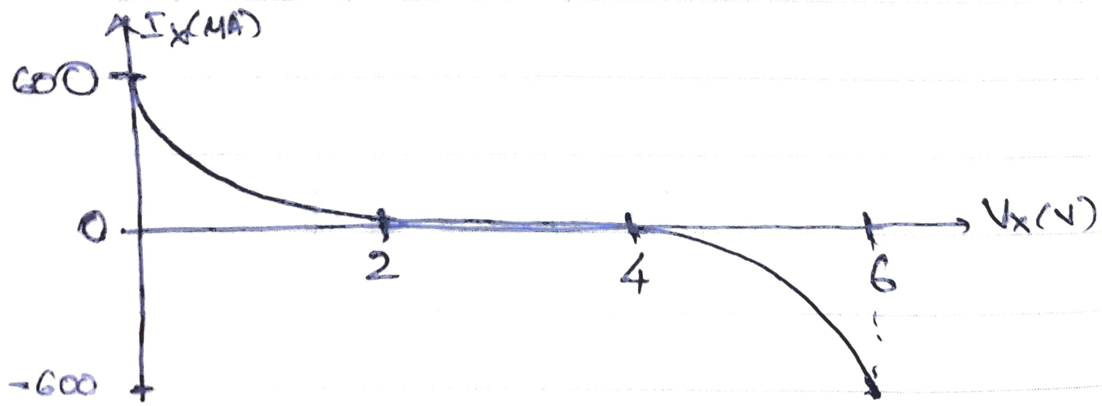
• $2V \leq V_x \leq 4V$: $I_x = I_{SD(sat)}^{P} - I_{DS(sat)}^{N}$

$= 600 \mu A - 600 \mu A = 0$

• $4V \leq V_x \leq 6V$: $I_x = I_{SD(Triode)}^{P} - I_{DS(sat)}^{N}$

$= 150 (6 - V_x)(V_x - 2) - 600 \mu A$

∴ Plot is :



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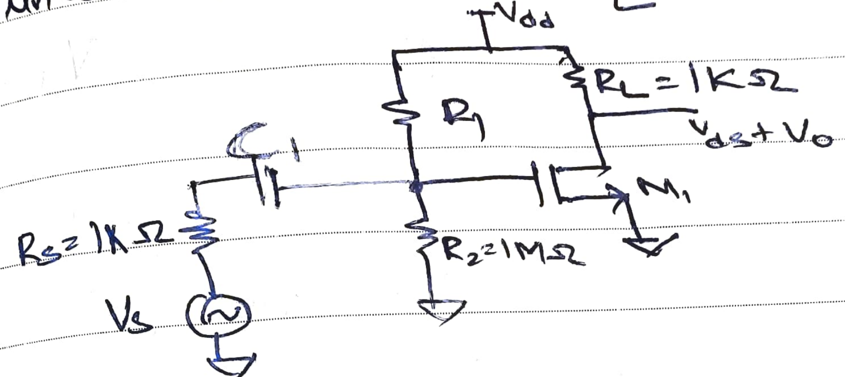
Given MOS parameters are

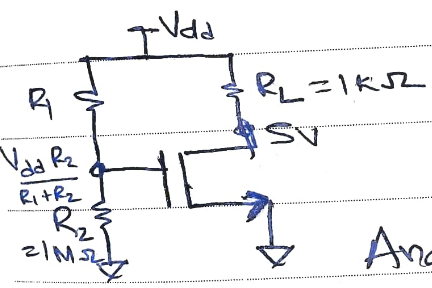
$\mu_n C_{ox} = 100 \mu A/V^2$, $\frac{W}{L} = 500$, $V_T = 1V$



We want R_1 and V_{DD} such that,

$* |Gain| = g_m R_L = \frac{V_o}{V_s} = 10$ $\quad * V_{DS}|_{@DC} = 5V$

For D.C operation,



$$\boxed{I_{DS} = \frac{V_{dd} - 5}{1k\Omega}}$$

$$V_{GS} = \frac{V_{dd} R_2}{R_1 + R_2}$$

$$\boxed{V_{GS} = \frac{V_{dd}\,(1M)}{R_1 + (1M)}}$$

And we have,

$$g_m (1K\Omega) = 10 \Rightarrow \boxed{g_m = 10m}$$

And taking saturation,

$$g_m = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_T)$$

$$\Rightarrow 10 \times 10^{-3} = 5 \times 10^{-2} (V_{GS} - 1)$$

$$\Rightarrow \boxed{V_{GS} = \frac{6}{5} V}$$

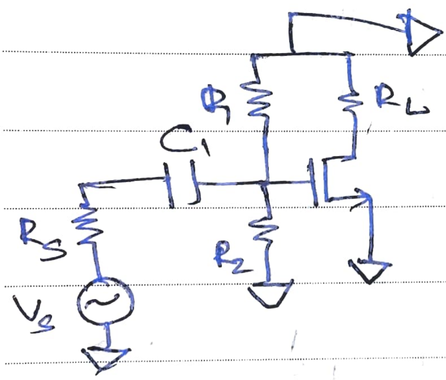
And, $I_{ds} = \mu_n C_{ox} \frac{W}{2L} (V_{GS} - V_T)^2$

$$\Rightarrow \frac{V_{dd}-5}{1K} = \frac{5\times10^{-2}}{2}\left(\frac{6}{5}-1\right)^2$$

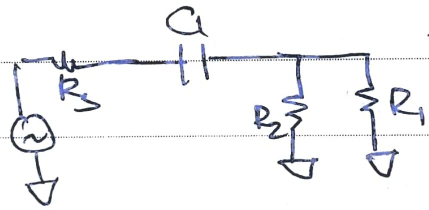
$$\Rightarrow V_{dd}-5 = 10^3 \times \frac{5}{2}\times 10^{-2} \times \frac{1}{25} = 1 \Rightarrow \boxed{V_{dd} = 6V}$$

Hence $\frac{6}{5} = \frac{6\,(1M)}{R_1+(1M)}$ $\Rightarrow R_1 + 1M = 5M$ $\Rightarrow \boxed{R_1 = 4M\,\Omega}$

(b) For the incremental picture,



For finding the time constant associated with capacitor, we have

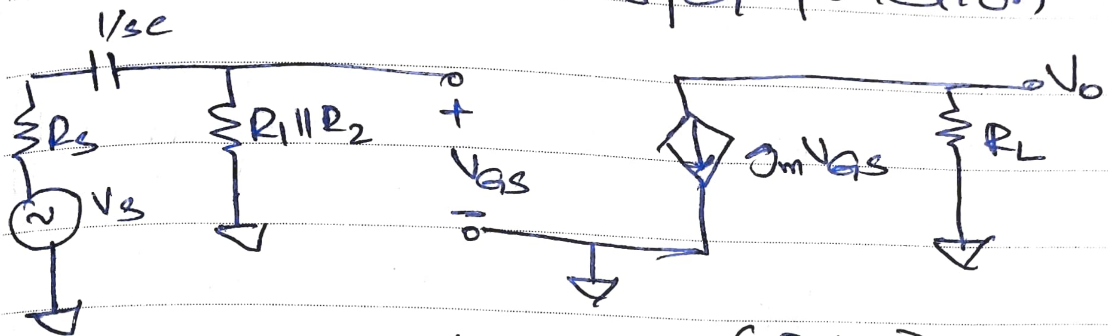


$$\Rightarrow R_{eff} = R_s + (R_1 \| R_2) = 1K + \frac{4M}{5} = 801\,k\Omega$$

And for maintaining large enough discharge time, we have, $R_{eff}C_1 >> \frac{1}{\omega_1}$, we can assume around 10 times greater. Then

$$\Rightarrow R_{eff}C_1 \approx 10\times\frac{1}{\omega_1} \Rightarrow C_1 \approx \frac{10}{(801K)} \times \frac{1}{2\pi(1K)} \approx 1.986nF$$

c) Incremental transfer function is

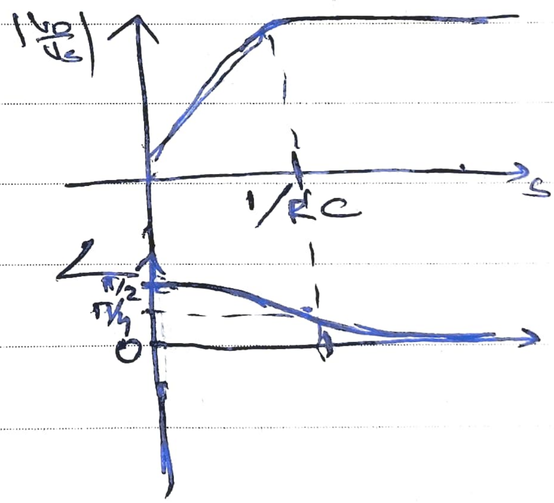


$$\Rightarrow V_{GS} = \frac{V_s\,(R_1 \| R_2)}{R_s + \frac{1}{sC} + (R_1 \| R_2)}$$

And $\quad V_o = -g_m V_{GS} R_L$

$$\Rightarrow \frac{V_o(s)}{V_s(s)} = \frac{-g_m R_L (R_1 \| R_2)}{R_s + (R_1 \| R_2) + \frac{1}{sC}}$$

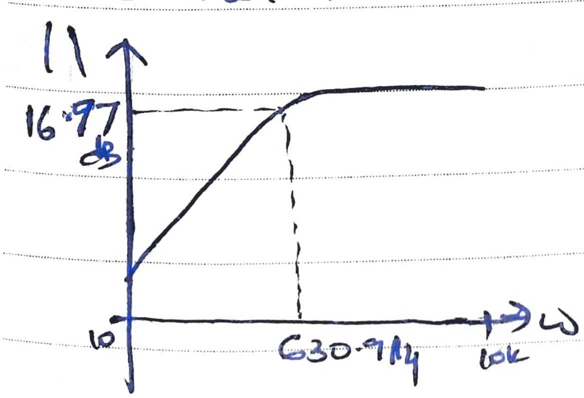
General T.F : $\dfrac{sCR}{1+sRC}$



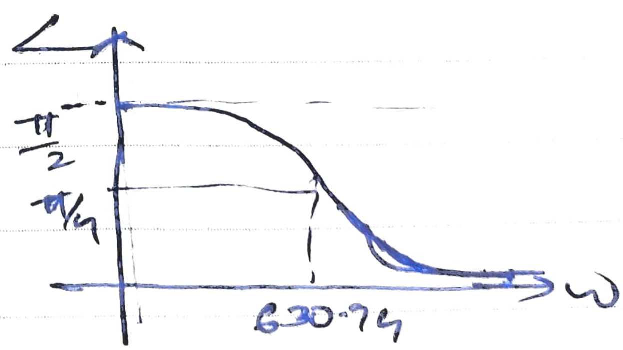
Substituting values give

$$\Rightarrow \frac{V_o}{V_s} = \frac{15.84\times 10^{-3}\,s}{1+s\,(\underbrace{1.585\times 10^{-3}}_{1/630.914})}$$

∴ Bode Plot :



Magnitude



Phase