End Sem Exam

Q.1

(a) As $\lambda = 0, \eta = 0$

$$R_{out} = R_D = 500\Omega$$

(b) For saturation, $V_{DS} \geq V_{GS} - V_{th}$

[As current is maximum when the transistor operates in saturation]

$$V_{DS} \geq V_{DD} - V_{th} \geq 1.4V$$

$$\therefore I_{D max} = \frac{V_{DD} - V_{DS}}{R_D} = \frac{(1.8 - 1.4)V}{.5K}$$

$$= .8 \text{ mA}$$

(c) The input impedance $= 50\Omega = \frac{1}{g_m}$

$$\therefore g_m = \frac{1}{50}$$

$$g_m = \sqrt{2 \times \mu C_{ox} (W/L) I_D}$$

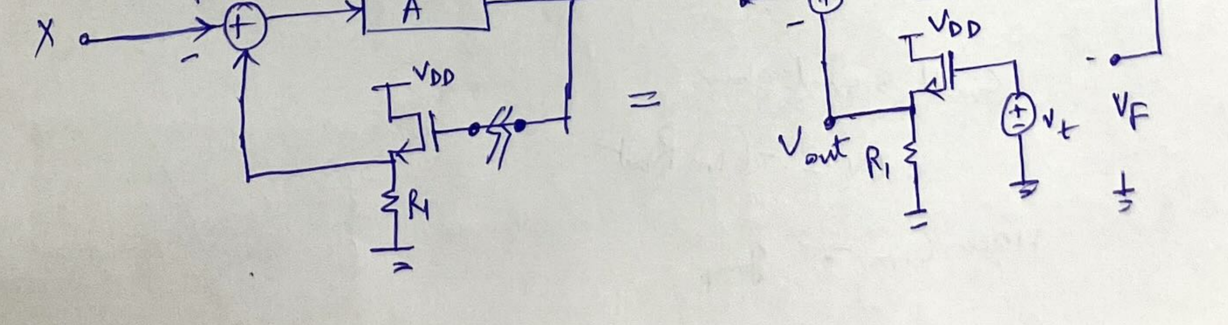
$$\text{or } W/L = \frac{g_m^2}{2 \mu C_{ox} (I_D)} = \frac{1 \times 10^6 \times 10^3}{50 \times 50 \times 2 \times 200 \times 0.8}$$

$$= \frac{10^4}{8} = 1250$$

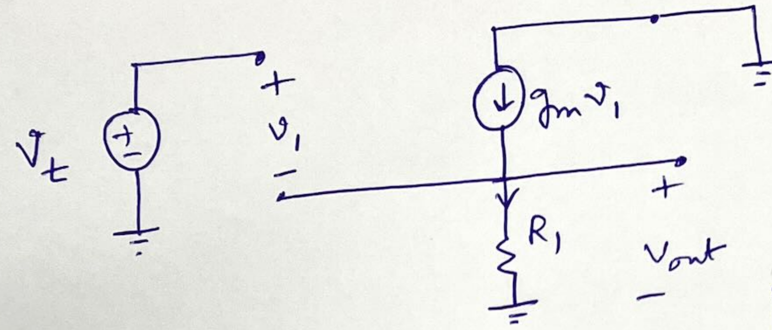
(d) Voltage gain $= g_m R_D = \frac{1 \times 500}{50} = 10$

of this common gate Amplifier

Q.2 (a) After setting the main ac i/p to zero, breaking the loop and injecting a test signal, the ckt. in fig. 2 will look as follows —



As $\lambda = 0$, $\gamma = 0$, the gain of the source-follower stage can bee found using



Using KCL,

$$g_m v_1 = \frac{V_{out}}{R_1}$$

$$\boxed{\text{or } v_1 = \frac{v_{out}}{g_m R_1}}$$

Using KVL, $v_t = v_1 + v_{out}$

$$= \frac{v_{out}}{g_m R_1} + V_{out}$$

$$= V_{out}\left(1 + \frac{1}{g_m R_1}\right)$$

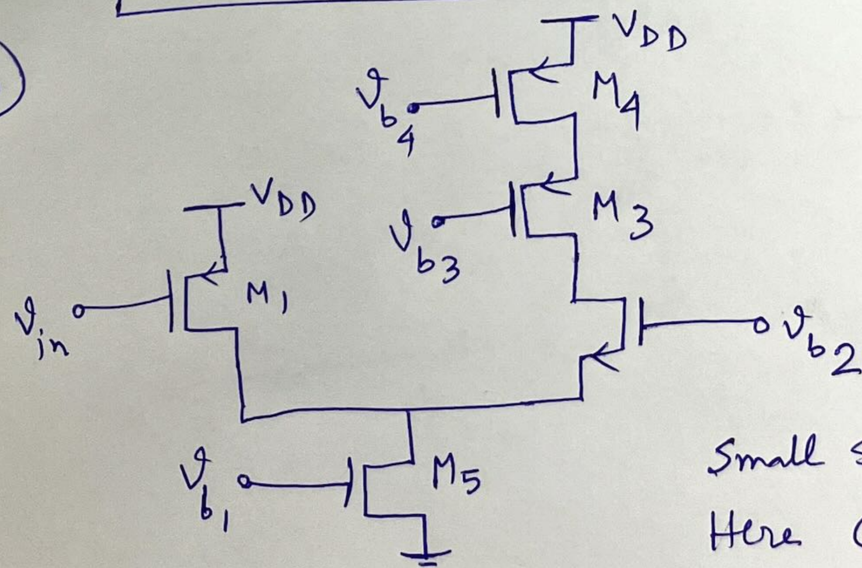
$$= V_{out}\left(\frac{g_m R_1 + 1}{g_m R_1}\right)$$

$$\therefore V_{out} = v_t\left(\frac{g_m R_1}{g_m R_1 + 1}\right)$$

$$\text{or } V_F = -A\left(\frac{g_m R_1}{1 + g_m R_1}\right) v_t$$

$$\boxed{\text{or } -\frac{V_F}{V_t} = \text{loop gain} = +\frac{A\, g_m R_1}{1 + g_m R_1}}$$

(b)

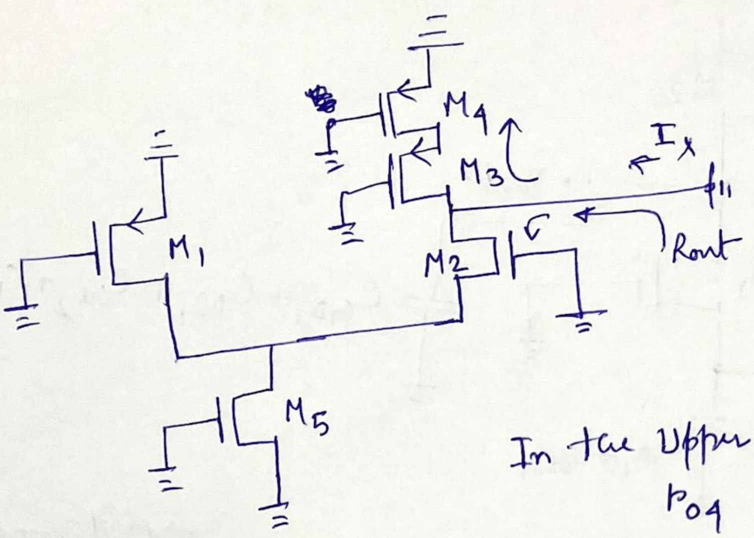


$$\boxed{\begin{array}{l}\text{given } \lambda \neq 0 \\ \gamma = 0\end{array}}$$

Small signal gain $A_v = -G_M R_{out}$

Here $G_m \simeq g_{m1}$

For Rout, the circuit will appear as



In the upper half M_3 is degenerated by r_{o4}

$$\therefore\ R_{out,upper} = \left\{ (1+g_{m3}r_{o3})r_{o4} + r_{o3} \right\}$$

In the lower half, M_2 is degenerated by $(r_{o5} \| r_{o1})$

$$\therefore\ R_{out,lower} = \left[\left\{ (1+g_{m2}r_{o2})(r_{o5}\|r_{o1}) \right\} + r_{o2} \right]$$

$$\simeq (g_{m2}r_{o2})(r_{o5}\|r_{o1})$$

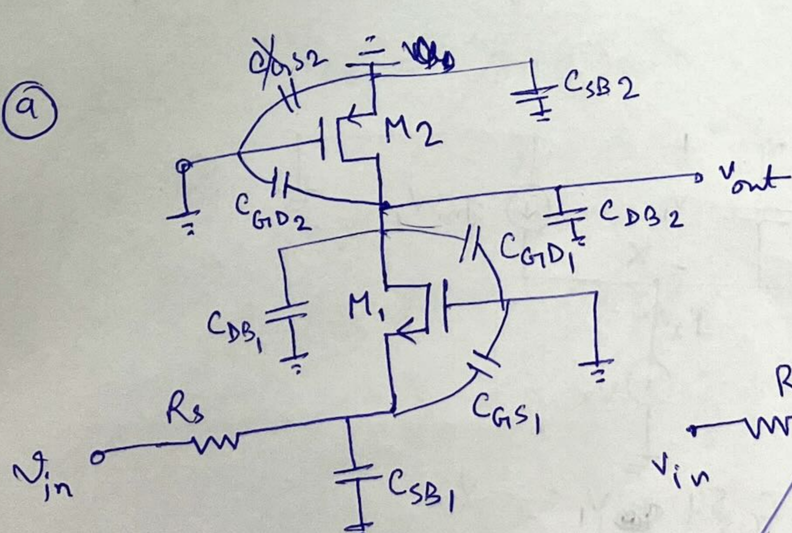
$$R_{out} = R_{out,upper} \| R_{out\,lower}$$

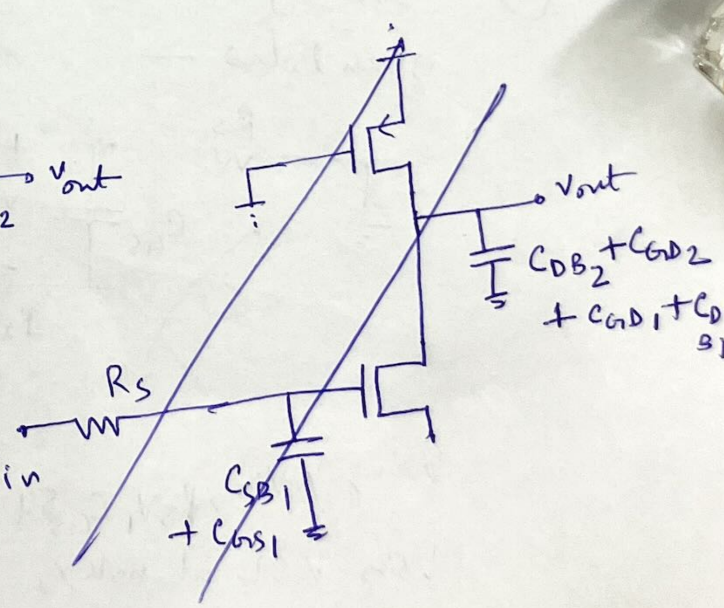
$$= (g_{m3}r_{o3}r_{o4}) \| \left[(g_{m2}r_{o2})(r_{o5}\|r_{o1}) \right]$$

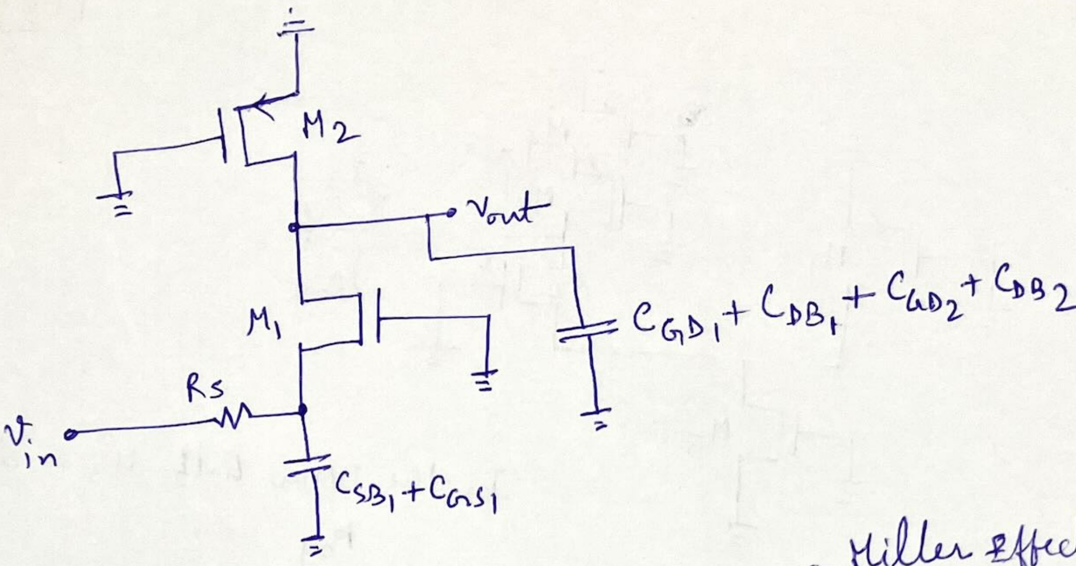
$$\therefore\ A_v = -g_{m1}\left[(g_{m3}r_{o3}r_{o4}) \| \left[(g_{m2}r_{o2})(r_{o5}\|r_{o1}) \right] \right]$$

Q. 3

(a)







There is no capacitor which experiences Miller Effect.

There are two nodes with two poles

$$\omega_{p_{in}} = \frac{1}{\left(R_S \,||\, \frac{1}{g_{m1}}\right)\left(C_{SB1} + C_{GS1}\right)}$$

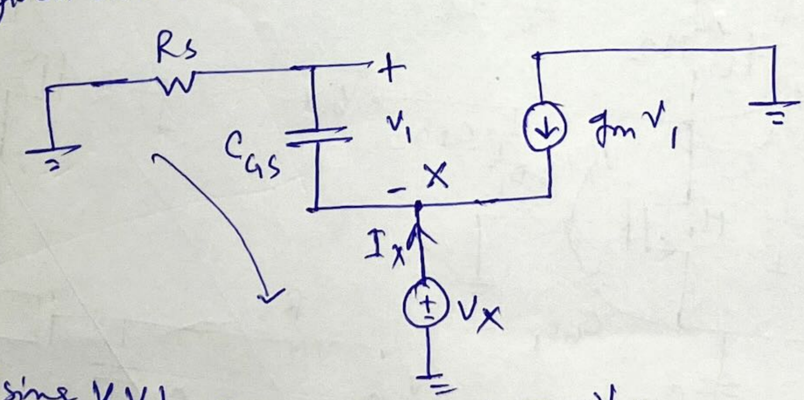
[As $\lambda = 0$, $\gamma = 0$ for M_1
$\lambda \neq 0$, $\gamma = 0$ for M_2
and $g_m r_o >> 1$]

$$\omega_{p_{out}} = \frac{1}{r_{o2}\left(C_{GD1} + C_{DB1} + C_{GD2} + C_{DB2}\right)}$$

(4) (a) To operate in deep triode region, the NMOS should have $V_{GS} > V_{TH}$ but $V_{DS} << 2(V_{GS} - V_{TH})$

(b) The equivalent circuit to find out the o/p impedance is given below —

189.2
199.2

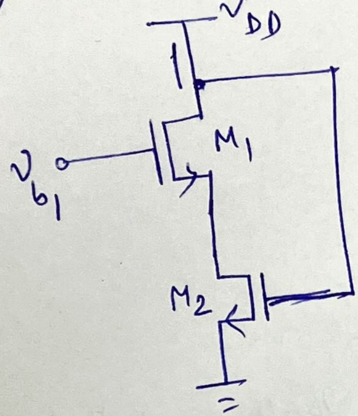


Using KVL, $R_S V_1 C_{GS} s + V_1 = -V_X$

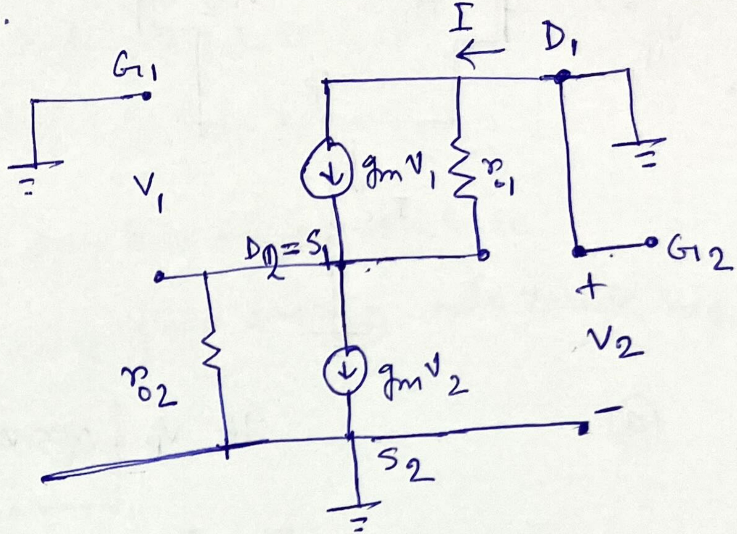
Using KCL at node X, $V_1 C_{GS} s + g_m V_1 = -I_X$

$$\boxed{\therefore\ Z_{out} = \frac{V_X}{I_X} = \frac{R_S C_{GS} S + 1}{g_m + C_{GS} S}}$$

(c)



$\Rightarrow$



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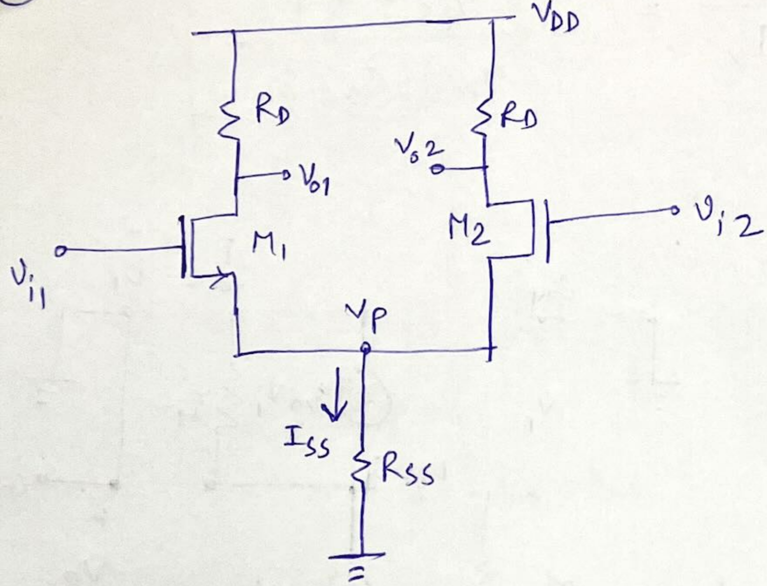


(a) If $V_P = 0.5\,V$, $I_{SS} = \frac{V_P - 0}{R_{SS}} = \frac{0.5\,V}{0.5K} = 1\,mA$

$\therefore\ I_{D_1} = I_{D_2} = 0.5\,mA$

$$V_{GS_1} = V_{GS2} = \sqrt{\frac{2 I_{D1}}{\mu_n C_{ox}(W/L)}} + V_{TH}$$

$$= \sqrt{\frac{2 \times 0.5\,mA}{50\,\mu A/V^2 \left(\frac{25}{0.5}\right)}} + 0.6$$

$$= 1.23\,V$$

$$\boxed{\therefore\ V_{in,CM} = V_{GS_1} + 0.5\,V = 1.73\,V}$$

(b) $g_m = \sqrt{2\mu_n C_{ox}\left(\frac{W}{L}\right) I_{D_1}} = \sqrt{2(50)\,\mu A/V^2 \times \left(\frac{25}{0.5}\right) \times 0.5\,mA}$

$= 10^{-3} \times 1.582\ \mho$

For gain $= 4 = R_D\, g_m$

$R_D = \frac{4}{g_m} = \frac{4 \times 10^3}{1.582} = 2.528\,K\Omega$

or $4 = \frac{g_m R_D}{1 + 2 g_m R_{SS}}$

Solving,

$R_D = 6.528\,K\Omega$

(c) $V_{DS} = V_{DD} - I_D R_D = 3 - 0.5\,mA \times 2.528\,K\Omega$

$= (3 - 1.2640)\,V = 1.736\,V$

~~V_{DS} should be $\geq V_{GS} - V_{TH}$ for saturation~~

V_{DS} should be $\geq V_{GS} - V_{th}$ to stay in saturation.

Therefore $V_{GS} \leq V_{DS} + V_{th}$

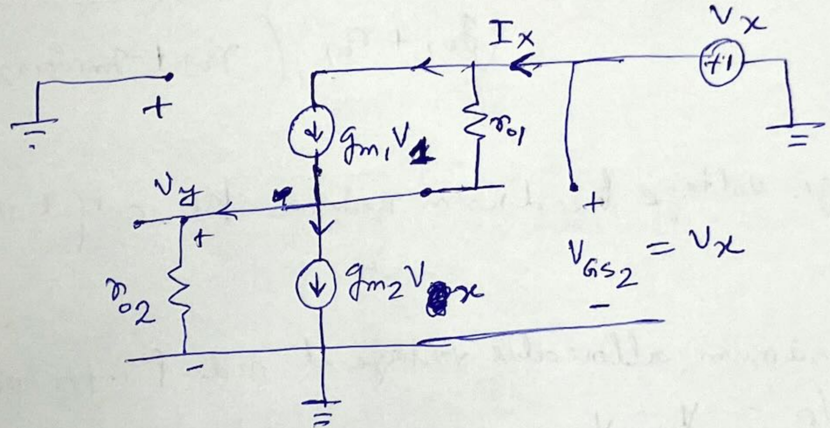
$$\leq (1.736 + 0.6)\,V$$

V_{GS} should be $\leq 2.336\ V$

$V_{in,CM} = 1.73\,V$ has been used which is $(2.336 - 1.73)\,V$ away from entering into triode region

$$\boxed{= 0.606\ V\ \text{away}}$$

6 a



$I_x = g_{m2} V_x + \dfrac{V_y}{r_{o2}}$ [Using KCL] — 1

Again, $I_x = g_{m1}(-V_y) + \cancel{(V_x - V_y)}/r_{o1}$ — 2

$I_x = -g_{m1}V_y + (V_x - V_y)/r_{01}$

or $V_y = (V_x - r_{01} I_x)/(1 + g_{m1} r_{01})$

Puting V_y in 1, we get

$$I_x = g_{m2} V_x + \frac{1}{r_{o2}}\left(\frac{V_x \cancel{r_{o1}} - I_x r_{01}}{1 + g_{m1} r_{01}}\right)$$

Solving for V_x/I_X, we get

$R_{out} = [(1+g_{m1}r_{01})r_{02}+r_{01}]/[g_{m2}r_{02}(1+g_{m1}r_{01})]$

(b) Disadvantage: Large voltage headroom reduces the output voltage swing

(c) Minimum allowable voltage at node P to operate all MOS in sat

$$V_P = V_N - V_{TH}$$

$$= V_{GS0} + V_{GS1} - V_{TH}$$

$$= (V_{GS0} - V_{TH}) + (V_{GS1} - V_{TH}) + V_{TH}$$

= Two ~~threshold~~ overdrive voltage + one threshold voltage