21ECE1039

SAHIL YADAV

VLSI Circuit Design EC401 Assignment-1

Q:1 for the configuration shown in fig1, determine small-signal resistance R_x and R_y assum $\lambda \neq 0$

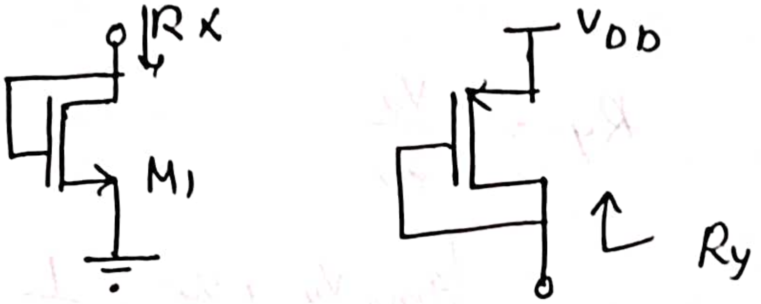
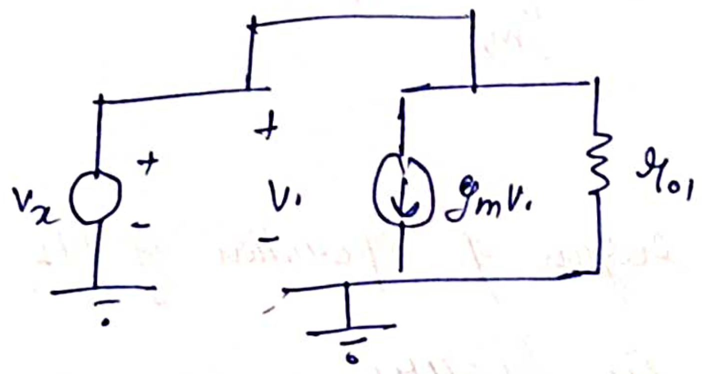


fig 1

Small signal model for (R_x,) NMOS

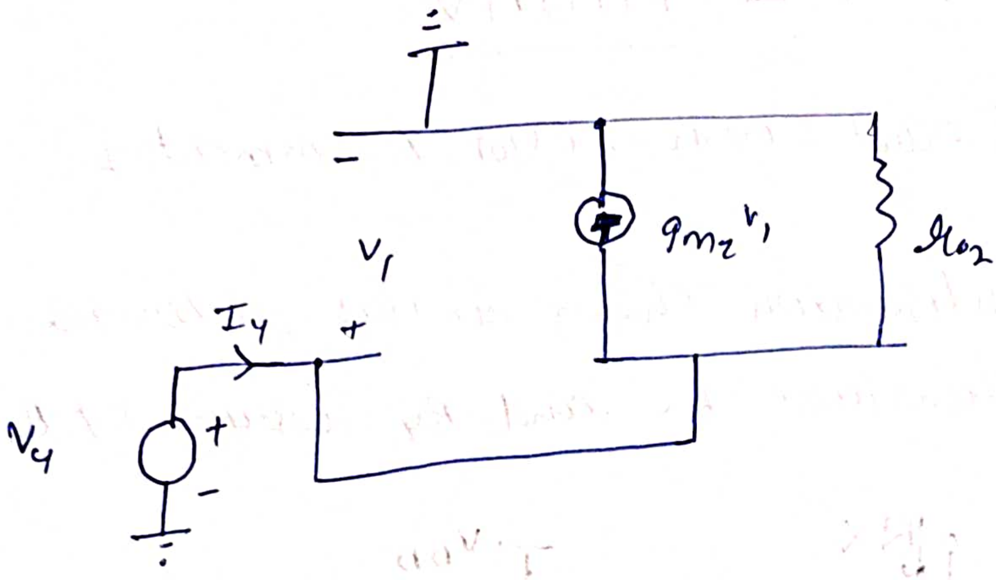


$$R_x = \frac{V_x}{i_x}$$

$$= \left(g_{m_1} V_x + \frac{V_x}{r_{o1}}\right) \frac{1}{i_x}$$

$$= \frac{1}{g_{m_1}} \parallel r_{o1}$$

Small signal model for PMOS (R_y)



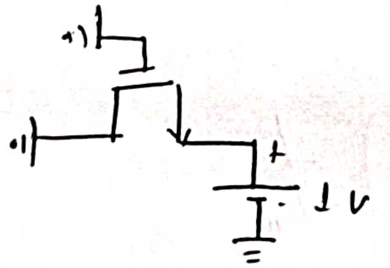
$$R_y = \frac{V_y}{I_y}$$

$$= \left(g_{m2} V_y + \frac{V_y}{r_{o1}}\right)\frac{1}{i_y}$$

$$= \frac{1}{g_{m2}} \parallel r_{o2}$$

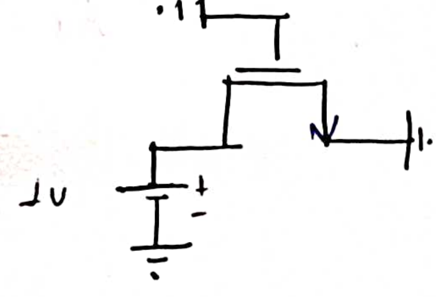
Q: 2 Determine the region of operation of M_1 in each of circuit shown in figure.

(a)



$V_{GS} = 0$
$V_{GS} < V_{TH}$] OFF

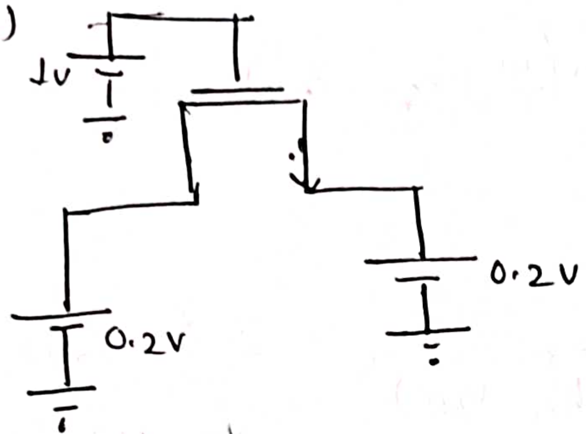
(b)



$V_S = 0$
$V_G = 0$
$V_D = 1$

$V_{GS} = 0 \Rightarrow$ OFF

(c)

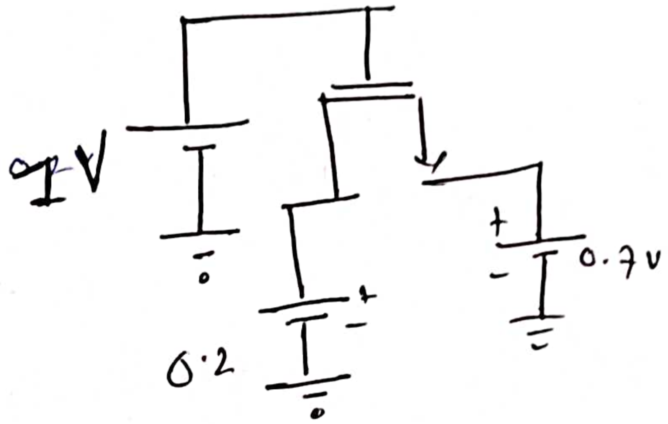


<u>Linear</u> $\quad V_{GS} = 0.8 \quad V_{DS} = 0$

$V_{GS} > V_{TH}$

$V_{DS} < V_{GS} - V_{th}$

(d)



$V_G = 1V$

$V_S = 0.7 \quad V_D = 0.2V$

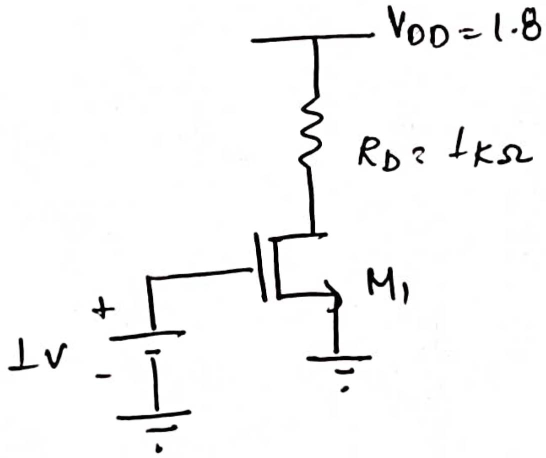
$V_{GS} = 0.3 \quad V_{DS} = -0.5V$

$V_{th} = 0.6V$

$V_{DS} < V_{GS} - V_{th}$

Linear

Q:3



$\lambda = 0 \quad V_{th} = 0.4V$

$\mu_n C_{ox} = 100\,\mu \frac{A}{V^2}$

<u>Ans</u> M_1 is at Edge of Saturation when

$V_{DS} = V_{GS} - V_{th}$

$V_{DS} = (1 - 0.4)\,V = 0.6\,V$

By KCL $\quad I_{D1} = I_{RD} = \dfrac{V_{DD} - V_{DS}}{R_D} = \dfrac{1.2V}{1k\Omega} = 1.2mA$

$$\therefore \quad I_D = 1.2mA = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS}-V_{TH})^2$$

$$\Rightarrow \quad \frac{W}{L} = \frac{2I_D}{\mu_n C_{ox}(V_{GS}-V_{TH})^2} = \frac{2(1.2mA)}{200\frac{\mu A}{V^2}(1-0.4)^2_V}$$

$$\left(\frac{W}{L}\right) \simeq 66$$

Q:4 Calculate the bias current M1 in Fig 4 if $\lambda = 0$. If $R_D = 1k\Omega$ Assuming $\frac{W}{L} = \frac{10}{0.18}$

$\lambda = 0.1 V^{-1}$ and $V_{DD} = 1.8V$, calculate the Drain current of M1 in Fig 4

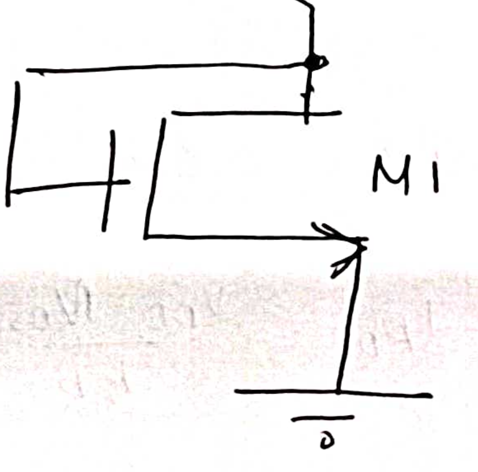
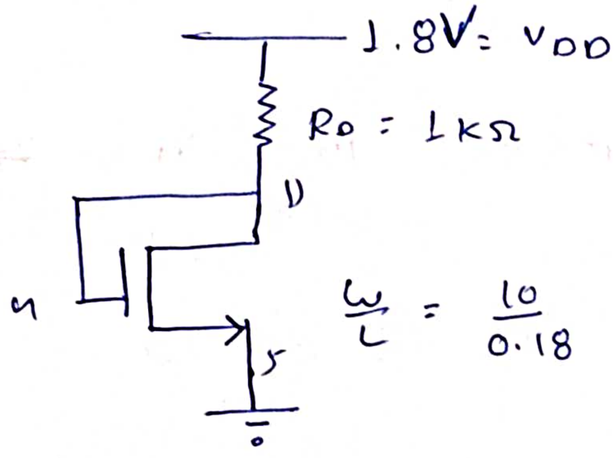


fig 4

Ans (4)



Case I $\lambda = 0$

~~Assumption~~ mos is in Saturation $[V_{GS} - V_{th} < V_{DS}]$

$\therefore$ Since $V_{GS} = V_{DS}$ so always

$$V_{DS} > V_{GS} - V_{th} \Rightarrow V_{DS} > V_{DS} - V_{th}$$

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} \left[(V_{GS} - V_{th})^2 \right] (1 + \cancel{\lambda}^{\,0} V_{DS})$$

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} \left[(V_{GS} - V_{th})^2 \right]$$

$$V_{GS} = V_{DS}$$

$$I_D = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L}\right) \left[(V_{DS} - V_{th})^2 \right] \quad -(1)$$

$$V_{DS} = V_{DD} - I_D R_D$$

$$V_{DS} = 1.8 - I_D (1 \times 10^3) \quad -(2)$$

Puting values of parameter in Eq^n ①

$$I_D = \frac{1}{2}\, 100\times10^{-6}\, \frac{10}{0.18}\left(V_{DS} - \cancel{I_D R_D}\, V_{th}\right)^2$$

After puting Eq^n ② in Eq ①

we get

$$\left(\frac{1}{2}\mu_n C_{ox}\frac{W}{L}R_D^2\right)I_D^2 - \left(\mu_n C_{ox}\frac{W}{L}R_D\,(V_{DD}-V_{th})+1\right)I_D$$

$$+\frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{DD}-V_{th})^2 = 0$$

After Solving this Quadratic Eq^n we get

$$I_D = \frac{\left(\mu_n C_{ox}\frac{W}{L}R_D(V_{DD}-V_{th})+1\right) \pm \sqrt{\left(\mu_n C_{ox}\frac{W}{L}R_D(V_{DD}-V_{th})+1\right)^2 - 4\left(\frac{1}{2}\mu_n C_{ox}\frac{W}{L}R_D(V_{DD}-V_{th}\right.}}{2\left(\frac{1}{2}\mu_n C_{ox}\frac{W}{L}R_D^2\right)}$$

$$\Rightarrow \frac{\mu_n C_{ox}\frac{W}{L}R_D(V_{DD}-V_{th})+1 \pm \sqrt{\left(\mu_n C_{ox}\frac{W}{L}R_D(V_{DD}-V_{th})+1\right)^2 - \mu_n C_{ox}\frac{W}{L}R_D\,(V_{DD}-V_{th}}}{\mu_n C_{ox}\frac{W}{L}R_D^2}$$

Case II $\lambda = 0.1 V^{-1}$

Since M_1 is Diode-Connected it operate in saturation

By KCL $\Rightarrow$ $\frac{V_{DD} - V_G}{R_D} = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L}\right) (V_G - V_{th})^2 (1 + \lambda V_G)$

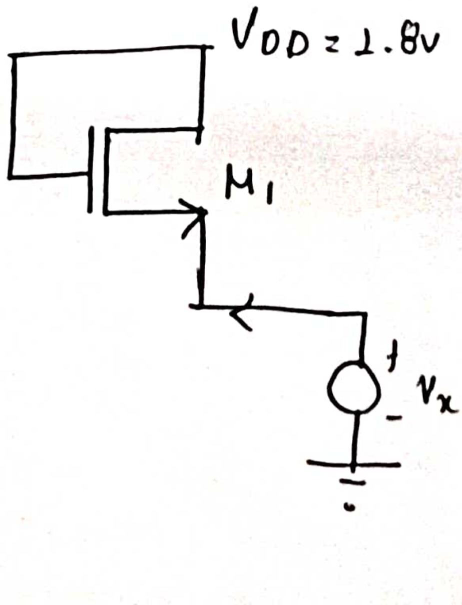
By Solving above eqn we get

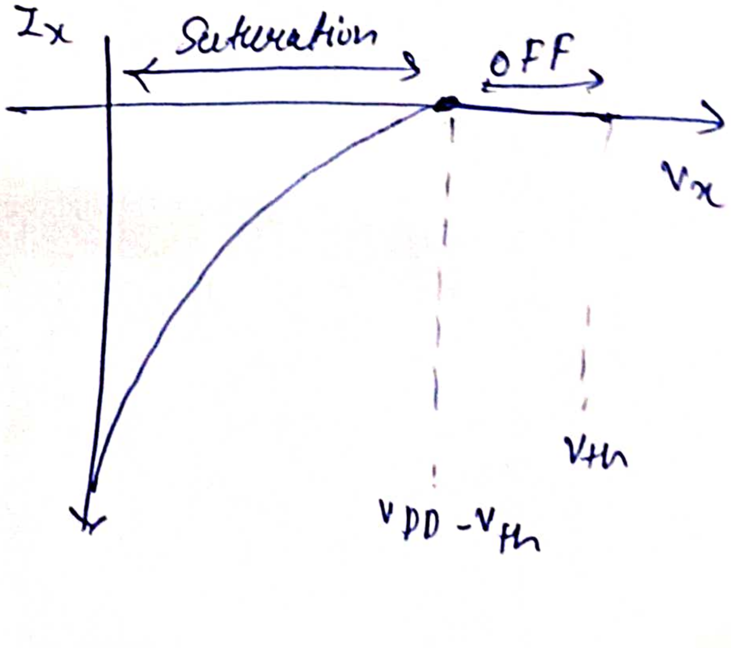
$V_G = 0.807 V$

$I_D = \frac{V_{DD} - V_G}{R_D} \simeq 1 mA$

Q:5 Sketch I_x as a function of V_x for the circuit shown in fig 5 Assume V_x goes from 0 to $V_{DD} = 1.8$) Also $\lambda = 0$, Determine at what value of V_x the device changes its region ~~from~~ of operation.

(a)





(b)