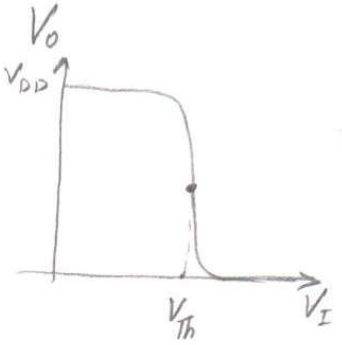
4/15/2018

Homework 1 Solution

10 B

Problem # 1

a)



b) $$I_{SD}|_P = I_{DS}|_N$$

$$\frac{K_P}{2}\left(V_{SG}|_P - |V_{TP}|\right)^2 = \frac{K_n}{2}\left(V_{GS}|_N - V_{TN}\right)^2$$

$$\sqrt{K_P}\left(V_{DD} - V_{Th} - |V_{TP}|\right) = \sqrt{K_n}\left(V_{Th} - V_{TN}\right)$$

$$V_{Th} = \frac{\sqrt{\frac{K_P}{K_n}}\left(V_{DD} - |V_{TP}|\right) + V_{TN}}{1 + \sqrt{\frac{K_P}{K_n}}}$$

$$K_P = K_P'\left(\frac{W_P}{L_P}\right) \qquad K_n = K_n'\left(\frac{W_n}{L_n}\right) \qquad , \quad V_{TN} = |V_{TP}| = V_T$$

$$V_{Th} = \frac{\sqrt{\frac{W_P}{W_n}}\left(V_{DD}\right) + V_T\left(1 - \sqrt{\frac{W_P}{W_n}}\right)}{1 + \sqrt{\frac{W_P}{W_n}}}$$

c) $V_{Th} = \frac{V_{DD}}{2}$, M_1 & M_2 are in Sat.

d)

$V_T = 0$

ω_p \ ω_n	1	4	16
1	2.5	5/3	1
4	10/3	2.5	
16	4		2.5

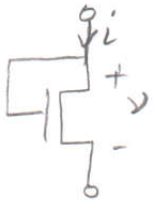
$V_T = 1$

ω_p \ ω_n	1	4	16
1	2.5	2	1.6
4	3	2.5	
16	3.4		2.5

problem #2

a) $V_G = V_D$

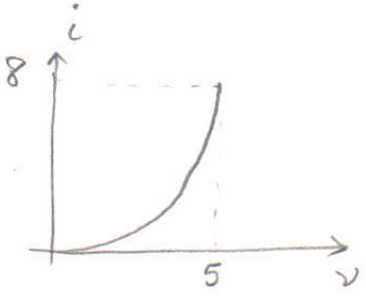
$V_{DS} > V_{GS} - V_T \longrightarrow$ Saturation



b) $i = \frac{K}{2}(V_{GS} - V_T)^2$

$i = \frac{K}{2}(v - V_T)^2$

c)



Problem # 3

a) For M_1 $\quad V_D = V_G \longrightarrow V_{DS} > V_{GS} - V_T \longrightarrow$ Saturation

b) $I_{ref} = \frac{K_1}{2}(V_{GS_1} - V_T)^2 \qquad I_o = \frac{K_2}{2}(V_{GS_2} - V_T)^2$

$V_{GS_1} = V_{GS_2}$

$$\frac{I_o}{I_{ref}} = \frac{(W_2/L_2)}{(W_1/L_1)}$$

c) $10 = \frac{10}{2}(V_{GS_1} - 0.5)^2$

$V_{GS_1} = 1.914\ V$

d) $I_o = I_{ref}\ \frac{(W_2/L_2)}{(W_1/L_2)} = 10 \times \left(\frac{20}{10}\right) = 20\ mA$

e) $V_{GS_2} = V_{GS_1} = 1.914\ V$

$V_o > V_{GS_2} - V_T$

$V_o > 1.414\ V \qquad V_{o_{min}} = 1.414\ V$

Problem # 4

$V_G = 0$ assume Sat. region

$$I_D = \frac{K_n}{2}\left(\frac{W}{L}\right)\left(-V_S - V_T\right)^2$$

$$0.4 = \frac{0.1}{2}\left(\frac{32}{1}\right)\left(V_S + 0.7\right)^2$$

$\boxed{V_S = -1.2V}$

$V_S = -0.2V \rightarrow$ ✗

$$V_S - V_{SS} = I_D R_S$$

$\boxed{R_S = 3.25K\Omega}$

For Sat. $V_{DS} > V_{GS} - V_T$ $\quad V_{GS} > V_T$

$V_D = 0.5V$

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

$$\boxed{R_D = \frac{V_{DD} - V_D}{I_D} = 5K\Omega}$$

Problem # 5

$I_{D_2} = I_{D_1}$ (both in Sat.)

$$\frac{K_n}{2}\left(V_2 - V_o - V_T\right)^2 = \frac{K_n}{2}\left(V_1 - V_T\right)^2$$

$$\sqrt{\frac{W_2}{L_2}}\left(V_2 - V_o - V_T\right) = \sqrt{\frac{W_1}{L_1}}\left(V_1 - V_T\right)$$

$$\boxed{V_o = \frac{\left(V_2 - V_T\right)\sqrt{\frac{W_2}{L_2}} - \left(V_1 - V_T\right)\sqrt{\frac{W_1}{L_1}}}{\sqrt{\frac{W_2}{L_2}}}}$$