

Homework 10

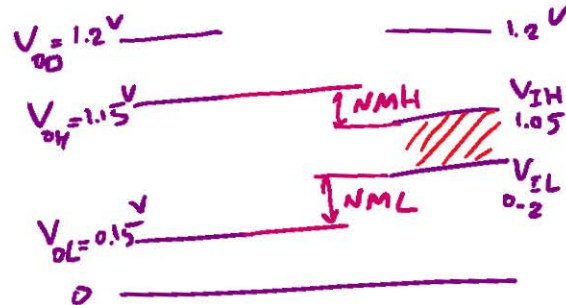
5.1)

$$NMH = V_{OH} - V_{IH} = 1.15V - 1.05V$$

$$\Rightarrow NMH = 0.1V$$

$$NML = V_{IL} - V_{OL} = 0.2V - 0.15V$$

$$\Rightarrow NML = 0.05V$$



5.3)

a-  $NMH = V_{OH} - V_{IH} \Rightarrow 100^{mV} = V_{OH} - 1.75V \Rightarrow V_{OH} = 1.85V$

b-  $NML = V_{IL} - V_{OL} \Rightarrow 75^{mV} = 0.3V - V_{OL} \Rightarrow V_{OL} = 0.225V$

5.7) Symmetric:  $V_m = V_{DD}/2 = \frac{1.2V}{2} = 0.6V$

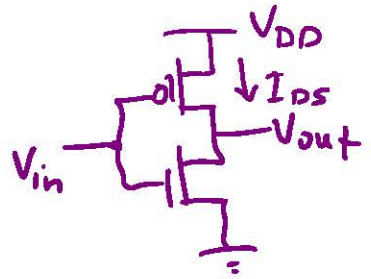
@  $V_m$ :  $\frac{K_n'}{2} \left(\frac{W}{L}\right)_n (V_m - V_{tn})^2 = \frac{K_p'}{2} \left(\frac{W}{L}\right)_p (V_{DD} - V_m - |V_{tp}|)^2$

$$\Rightarrow \mu_n C_{ox} \cdot W_n \left(\frac{V_{DD}}{2} - V_{tn}\right)^2 = \mu_p C_{ox} W_p \left(\frac{V_{DD}}{2} - |V_{tp}|\right)^2$$

$$\Rightarrow \left(\frac{V_{DD}}{2} - V_{tn}\right)^2 = \left(\frac{\mu_p}{\mu_n}\right) \left(\frac{W_p}{W_n}\right) \left(\frac{V_{DD}}{2} - |V_{tp}|\right)^2$$

$$\Rightarrow (0.6 - V_{tn})^2 = \left(\frac{540}{1530}\right) (4.6) (0.6 - 0.4)^2 \Rightarrow V_{tn} = 0.345V$$

5.9) NMOS  $\rightarrow$  linear  
 PMOS  $\rightarrow$  Saturation



PMOS:  $I_{D_s} = \frac{K'_p}{2} \left(\frac{W}{L}\right)_p (V_{DD} - V_{in} - |V_{Tp}|)^2$

$\Rightarrow 5^{\mu A} = \frac{25^{\mu A/V^2}}{2} \cdot 4 \cdot (2 - V_{in} - 0.6)^2$

$\Rightarrow V_{in} = 1.084 \text{ V}$

NMOS:  $I_{D_s} = K'_n \left(\frac{W}{L}\right)_n \left[ (V_{in} - V_{Tn}) V_{out} - \frac{V_{out}^2}{2} \right]$

$\Rightarrow 5^{\mu A} = 50^{\mu A/V^2} \cdot 2 \cdot \left[ (1.084 - 0.5) V_{out} - \frac{V_{out}^2}{2} \right]$

$\Rightarrow V_{out}^2 - 1.167 V_{out} + 0.1 = 0 \Rightarrow \left. \begin{aligned} V_{out} &= 0.093 \text{ V} \\ V_{out} &= 1.074 \text{ V} \end{aligned} \right\}$

check NMOS:  $V_{D_s} < V_{G_s} - V_T$   $\checkmark$  linear  
 $0.093 < 1.084 - 0.5$

check PMOS  $|V_{D_s}| > |V_{G_s}| - |V_{Tp}|$   $\checkmark$  Saturation  
 $2 - 0.093 > 2 - 1.084 - 0.6$   
 $1.907 > 0.316$

5.12) From the ITC,  $V_M \approx 0.8 \text{ V}$ ,  $I_{DD_{MAX}} = 500 \mu A$

At  $I_{DD_{MAX}}$ ,  $V_{in} = V_M$ , both NMOS and PMOS in Saturation.

PMOS:  $|I_{D_s}| = \frac{K'_p}{2} \left(\frac{W}{L}\right)_p (V_{DD} - V_M - |V_{Tp}|)^2$

$\Rightarrow 500^{\mu A} = \frac{70^{\mu A/V^2}}{2} \cdot 150 \cdot (1.5 - 0.8 - |V_{Tp}|)^2 \Rightarrow V_{Tp} = -0.39 \text{ V}$

5.15) Need to find  $V_M$  in each case:

$$a) V_{DD} = 1.5 \text{ V} \rightarrow \frac{K'_n}{2} \left(\frac{W}{L}\right)_n (V_M - V_{tn})^2 = \frac{K'_p}{2} \left(\frac{W}{L}\right)_p (V_{DD} - V_M - |V_{tp}|)^2$$

$$\Rightarrow \frac{200 \text{ MA/V}^2}{2} \cdot 2 \cdot (V_M - 0.4)^2 = \frac{100 \text{ MA/V}^2}{2} \cdot 3 \cdot (1.5 - V_M - 0.35)^2$$

$$\Rightarrow V_M = 0.748 \text{ V}$$

Back into the  $I_{DS}$  eq. :  $I_{DD_{MAX}} = \frac{200 \text{ MA/V}^2}{2} \cdot 2 \cdot (0.748 - 0.4)^2 \Rightarrow \underline{I_{DD_{MAX}} = 24.2 \text{ MA}}$

$$b) V_{DD} = 1.0 \text{ V} \rightarrow \frac{K'_n}{2} \left(\frac{W}{L}\right)_n (V_M - V_{tn})^2 = \frac{K'_p}{2} \left(\frac{W}{L}\right)_p (V_{DD} - V_M - |V_{tp}|)^2$$

$$\Rightarrow \frac{200 \text{ MA/V}^2}{2} \cdot 2 \cdot (V_M - 0.4)^2 = \frac{100 \text{ MA/V}^2}{2} \cdot 3 \cdot (1.0 - V_M - 0.35)^2$$

$$\Rightarrow V_M = 0.516 \text{ V}$$

Back into the  $I_{DS}$  eq. :  $I_{DD_{MAX}} = \frac{200 \text{ MA/V}^2}{2} \cdot 2 \cdot (0.516 - 0.4)^2 \Rightarrow \underline{I_{DD_{MAX}} = 2.69 \text{ MA}}$