EHB 322-E - HW-2

a) Operation Regions

PMOS: $|V_{GS} - V_T| = |(0-5) - (-0,95)| = 4,05V \rightarrow V_{satp}$

$|V_{DS}| = |5 - 0,2| = 4,8V$

since $|V_{GS} - V_T| \leq |V_{DS}| \rightarrow$ Saturation

$4.05 \leq 4,8$

NMOS: $|V_{GS} - V_T| = |(5-0) - (0,7)| = 4,3 \rightarrow V_{satn}$

$|V_{DS}| = |0,2 - 0| = 0,2$

since $|V_{GS} - V_T| \geq |V_{DS}| \rightarrow$ Linear

$4,3 \geq 0,2$

By using current equations, we can find desired W_N value.

$$I_n = I_p$$

$$\frac{B_n}{2}\left[2(V_{GSn} - V_{Tn})V_{DSn} - V_{DSn}^2\right] = \frac{B_p}{2}\left[V_{GSp} - V_{Tp}\right]^2$$

$$k_n' \cdot \frac{W_n}{L_n} \cdot \left[2(4,3)0,2 - (0,2)^2\right] = k_p' \cdot \frac{W_p}{L_p}\left[-4,05\right]^2$$

$$156.10^{-6} \cdot W_n (1,68) = 48.10^{-6} \cdot 3,2.10^{-6} \cdot (16,4025)$$

$$W_n = \frac{16,4025 \cdot 48.10^{-6} \cdot 3,2.10^{-6}}{156.10^{-6} \cdot 1,68}$$

$$W_n = 9,61.10^{-6} m \rightarrow \boxed{9,61 \mu m}$$

b) $V_{in} = V_{out} = V_M$

Operation Regions

PMOS: $|V_{GS} - V_{Tp}| = 4,05\,V$

$|V_{DS}| = |5 - V_{out}| = |5 - V_M|$ $\rightarrow$ $4,05 \geq |5 - V_M|$ Linear

NMOS: $|V_{GS} - V_{Tn}| = |V_M - 0,7|$

$|V_{DS}| = |V_M|$ $\rightarrow$ $V_M - 0,7 < V_M$ Saturation

$$I_n = I_p$$

$$\frac{\beta_n}{2}(V_{GS} - V_{Tn})^2 = \frac{\beta_p}{2}\left[2(V_{GSp} - V_{Tp})V_{DS} - V_{DS}^2\right]$$

$$\frac{156.10^{-6} \cdot 9,61.10^{-6}}{48.10^{-6} \cdot 3,2.10^{-6}}(V_M - 0,7)^2 = 2.(-4,05)(V_M - 5) - (V_M - 5)^2$$

$$9,76.(V_M^2 - 1,4V_M + 0,49) = 40,5 - 8,1V_M - 25 + 10V_M - V_M^2$$

$$10,76V_M^2 - 15,564V_M - 10,716 = 0$$

Root 1 $\rightarrow$ 1,955 $\longrightarrow$ $\boxed{V_M = 1,955\,V}$

Root 2 $\rightarrow$ $-0,509$

c) $V_{in} = 0 \rightarrow$ NMOS is off, no current flowing

$P_S = 0$

(we could use I_p or $I_n \rightarrow I_p = I_n$)

$V_{in} = 5 \rightarrow P_S = V \cdot I = 5 \cdot \left[\frac{\beta_p}{2} (V_{GS} - V_T)^2 \right]$

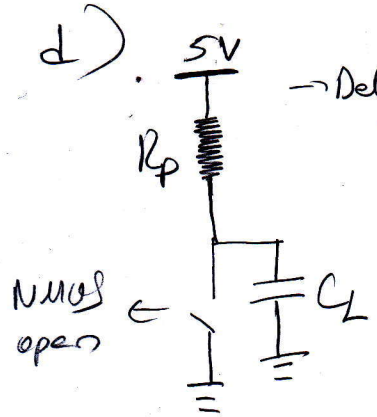
→ PMOS in saturation mode bcs of the 0 V input

$$5 \cdot \left[\frac{48 \cdot 10^{-6} \cdot 3,2 \cdot 10^{-6}}{2 \cdot 0,6 \cdot 10^{-6}} \left((0-5) - (-0,85) \right)^2 \right]$$

$$= 5 \cdot 128 \cdot 10^{-6} \cdot 16,4$$

$$= 10497 \cdot 10^{-6} W = \boxed{10,49 \text{ mW}}$$

d).



→ Delay Model $t_{PLH} = 0,69 \cdot R_p \cdot C_L$

$C_L = 10 \cdot 10^{-12} F$

$$R_p = \frac{1}{2K_p} \cdot \frac{1}{(V_{DD} - |V_{TP}|)} \cdot \left[\frac{2|V_{TP}|}{(V_{DD} - |V_{TP}|)} + \ln \frac{3V_{DD} - 4|V_{TP}|}{V_{DD}} \right]$$

$$K_p = \frac{1}{2} \mu_p \cdot c_{ox} \cdot \frac{W_p}{L_p}$$

$$R_p = \underbrace{\frac{0,6 \cdot 10^{-6}}{48 \cdot 10^{-6} \cdot 3,2 \cdot 10^{-6}}}_{964} \underbrace{\frac{1}{4,05} \cdot \left[0,46 + \underbrace{\ln 2,24}_{0,8} \right]}_{1,26}$$

$R_p = 1215,2 \Omega$

$t_{PLH} = 0,69 \cdot R_p \cdot C_L = 0,69 \cdot 10 \cdot 10^{-12} \cdot 1215,2 = 8384 \cdot 10^{-12}$

$= \boxed{8,3 \text{ ns}}$