Digital Electronic Circuit
Homework 1

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Q1

a) If $V_{out} = 0,2V$, $V_{in} = 5V$

PMOS Region: $|V_{GS}| = 5V$, $|V_{TP}| = |0,95V|$, $|V_{DS}| = 4,8V$

$|V_{DS}| > |V_{GS}| - |V_{TP}|$ → This equation is correct, so PMOS is in saturation region.

NMOS Region:

$V_{GS} = 5V$, $V_{TN} = 0,7V$, $V_{DS} = 0,2V$

$V_{DS} < V_{GS} - V_{TN}$ → If it is true then NMOS is linear mode.

For $I_{DN} = I_{DP}$:

find W_N

$$\frac{1}{2} \cdot 156\mu \cdot \frac{W_N}{0,6\mu}\left(2(5-0,7)\cdot 0,2 - 0,2^2\right) = \frac{1}{2} \cdot 48\mu \cdot \frac{3,2\mu}{0,6\mu}(5-0,95)^2$$

$2,1mA = 218,4\, W_N$ $\quad W_N = 9,61\mu$

b) For $V_{in} = V_{out}$, V_M's value → $V_M = V_{in} = V_{out}$ } PMOS

$|V_{GS}| = 5V$, $|V_{TP}| = 0,95V$ $\quad V_{DS} = |V_M - 5| = |5 - V_M|$

Evaluated that it is in linear mode

$V_{GS} = V_M$ $\quad V_{TN} = 0,7V$, $V_{DS} = V_M$

$V_{GS} - V_{TN} < V_{DS}$ is true, so it is saturation } NMOS

$I_{DN} = I_{DP}$:

$$\frac{1}{2}\ 156\mu \frac{9,61\mu}{0,6}(V_M - 0,7)^2 = \frac{1}{2}\ 48\mu \frac{3,2\mu}{0,6\mu}\left(2(4,05)(5-V_M) - (5-V_M)^2\right)$$

$10,76\, V_M^2 - 15,564 - 10,716 = 0$, $V_M = 1,955V$

Assumption is true for pmos

c) $V_{in} = 0$ → There is not power consumption because NMOS off, no current

$V_{in} = 5$ → $P_S = V_{DD} \cdot I$

for: $I = I_P = I_N$, $I_D = \frac{1}{2}\ 48\mu \cdot \frac{3,2\mu}{0,6\mu}(5 - 0,95)^2$

$V_{DD} = 5V$ ⇒ Power consumption: $5V \times 2,1mA = 10,5mW$

Average " $= 10,5mW/2 = 5,25mW$

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d) $t_{PLH} = 0.69 \times R \times C$

$$R = \frac{1}{k_p \frac{W_1}{L}} \times \frac{1}{V_{DD} - |V_{tp}|} \times \left[\frac{2|V_{tp}|}{V_{DD} + |V_{tp}|} + \ln\left(\frac{3V_{DD} - 4|V_{tp}|}{V_{DD}} \right) \right]$$

$$= \frac{1}{48\mu \cdot \frac{3.2\mu}{0.6\mu}} \times \frac{1}{4.6} \times \left[\frac{1.9}{4.05} + \ln\left(\frac{11.2}{5} \right) \right] \approx 964.5\,(0.47 + 0.8) \approx 1224\,\Omega$$

$t_{PLH} = 0.69 \times 1224 \cdot 10pF \approx 8.44ns$