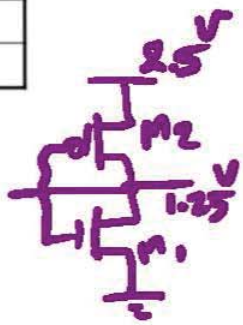
University of New Mexico
Department of Electrical and Computer Engineering

1. Design a CMOS inverter using 0.25um CMOS devices, such that $V_M=V_{DD}/2$. Assume that the NMOS and PMOS device parameters are given below and V_{DD}=2.5V and (W/L)n=1.5.

   - In our generic 0.25 micron CMOS process, using the process parameters from table a V_{DD} = 2.5V, and a minimum size NMOS device ($(W/L)_n$ of 1.5)

	V_{T0}(V)	$\gamma(V^{0.5})$	V_{DSAT}(V)	k'(A/V²)	$\lambda(V^{-1})$
NMOS	0.43	0.4	0.63	115 x 10^{-6}	0.06
PMOS	-0.4	-0.4	-0.8	-30 x 10^{-6}	-0.1



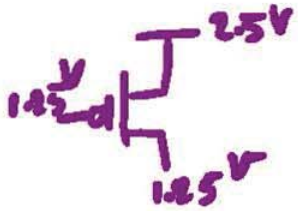
$I_{DS_1} = |I_{DS_2}|$

checking:

NMOS: $V_{min} = \min\{V_{DS}, V_{GS}-V_T, V_{DST_n}\}$

1.25 | 1.25−0.43 = 0.82 | 0.63 Vel. sat.

PMOS: $V_{min} = \min\{|V_{DS}|, |V_{GS}-V_T|, |V_{DST_p}|\}$



1.25 | 1.25−0.4 = 0.85 | 0.8 vel. sat.

$$K_n'\left(\frac{W}{L}\right)_n\left[(V_M - V_{tn})V_{DSAT_n} - \frac{V_{DSAT_n}^2}{2}\right](1+\lambda_n V_{DS})$$

$$= K_p'\left(\frac{W}{L}\right)_p\left[(V_{DD} - V_M - |V_{tp}|)|V_{DSAT_p}| - \frac{|V_{DSAT_p}|^2}{2}\right](1+|\lambda_p|(V_{DD}-V_{DS}))$$

$$\Rightarrow 115\ \frac{\mu A}{V^2} \times 1.5 \times \left[(1.25 - 0.43\ V) \times 0.63 - \frac{0.63^2}{2}\right](1+0.06\times 1.25)$$

$$= 30\ \frac{\mu A}{V^2}\left(\frac{W}{L}\right)_p\left[(2.5-1.25-0.4)\times 0.8 - \frac{0.8^2}{2}\right) + (1+0.1\times(2.5-1.25)\Big]$$

$$\Rightarrow \left(\frac{W}{L}\right)_p = 5.1$$

2. Estimate all static parameters of the inverter in problem 1, including V_{OL}, V_{OH}, V_M, V_{IL}, V_{IH}, NML, and NMH.

$$V_{OL} = 0\ V,\quad V_{OH} = 2.5\ V,\quad V_M = 1.25\ V$$

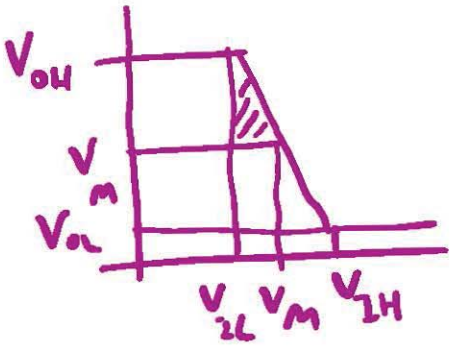
$$g = \frac{1}{I_D(V_M)} \frac{K_n'\left(\frac{W}{L}\right)_n V_{DSAT_n} + |K_p'\left(\frac{W}{L}\right)_p| V_{DSAT_p}|}{\lambda_n + |\lambda_p|}$$

$$I_D(V_M) = 115\ \frac{\mu A}{V^2} \times 1.5 \times \left[(1.25 - 0.43\ V) \times 0.63 - \frac{0.63^2}{2}\right](1+0.06\times 1.25)$$

$$= 59\ \mu A$$

$$\Rightarrow g = \frac{115\ \frac{\mu A}{V^2} \times 1.5 \times 0.63 + 30\ \frac{\mu A}{V^2} \times 5.1 \times 0.8}{59\ \mu A \times (0.06 + 0.1)}$$

$$\Rightarrow |g| = 24.48$$



$$|g| = \frac{V_{OH} - V_m}{V_m - V_{IL}}$$

$$\Rightarrow 24.48 = \frac{2.5 - 1.25}{1.25 - V_{IL}}$$

$$\Rightarrow \underline{V_{IL} = 1.199^{V}}$$

$$|g| = \frac{V_M - V_{OL}}{V_{IH} - V_M} \Rightarrow 24.48 = \frac{1.25 - 0}{V_{IH} - 1.25}$$

$$\Rightarrow \underline{V_{IH} = 1.301^{V}}$$

$$NMH = V_{OH} - V_{IH} = 2.5 - 1.301 = \underline{1.199^{V}}$$

$$NML = V_{IL} - V_{OL} = 1.199 - 0 = \underline{1.199^{V}}$$