Assignment #3

Course: Your Cource
Cource ID: The Code of Cource
Professor: Your Instructor

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Question

Consider the pseudo-NMOS inverter shown in Fig. 1, with transistor parameters given in Table 1.
(a) Find V_{OL} and V_{OH}.
(b) Find the switching threshold V_M.
(c) If the same transistors are used to build a static CMOS inverter, i.e. the gate of PMOS is connected to V_{in} instead of GND, what is the new switching threshold V_M?

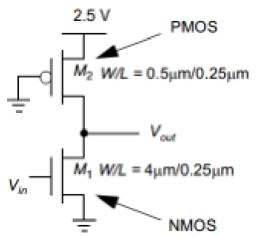

Fig. 1 Pseudo-NMOS inverter

Table 1 Transistor parameters

	k' (A/V^2)	V_{T0} (V)	γ (V$^{0.5}$)	V_{DSAT} (V)	λ (V^{-1})
NMOS	115 x 10^{-6}	0.43	0.4	0.6	0.06
PMOS	-30 x 10^{-6}	-0.4	-0.4	-1	-0.1

Answer.

(a)

Let $V_{in} = 0\,V$.
Then M_1 is off, and M_2 is on.

$$\Rightarrow \qquad V_{OH} = V_{Out} = V_{DD} = 2.5\,V$$

Let $V_{in} = V_{OH} = 2.5\,V$.
Then both M_1 and M_2 are on. The drain current of each transistor can be expressed as:

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$$\begin{cases} I_{D1} = k'_n(W/L)_n(V_{GTn}V_{Out} - \frac{1}{2}V_{Out}^2)(1+\lambda_n V_{Out}) \\ I_{D2} = k'_p(W/L)_p(V_{GTp}V_{DSATp} - \frac{1}{2}V_{DSATp}^2)(1+\lambda_p(V_{Out} - V_{DD})) \end{cases}$$

According to Kirchoff Current Law, $I_{D1} + I_{D2} = 0$.
Given: $k'_n = 115 \times 10^{-6}\,A/V^2$, $k'_p = -30 \times 10^{-6}\,A/V^2$, $(W/L)_n = 8$, $(W/L)_p = 2$, $V_{GTn} = V_{in} - V_{T0n} = 2.07\,V$, $V_{GTp} = 0\,V - 2.5\,V - V_{T0p} = -2.1\,V$, $V_{DSATp} = -1\,V$, $\lambda_n = 0.06\,V^{-1}$, $\lambda_p = -0.1\,V^{-1}$.
Solve these equations, we have: $V_{Out} = 0.0634\,V$. Then:

$$V_{OL} = V_{Out} = 0.0634\,V$$

(b)

The drain current of each transistor can be expressed as:

$$\begin{cases} I_{D1} = k'_n(W/L)_n(V_{GTn}V_{DSATn} - \frac{1}{2}V_{DSATn}^2)(1+\lambda_n V_M) \\ I_{D2} = k'_p(W/L)_p(V_{GTp}V_{DSATp} - \frac{1}{2}V_{DSATp}^2)(1+\lambda_p(V_M - V_{DD})) \end{cases}$$

According to Kirchoff Current Law, $I_{D1} + I_{D2} = 0$.
Given: $k'_n = 115 \times 10^{-6}\,A/V^2$, $k'_p = -30 \times 10^{-6}\,A/V^2$, $(W/L)_n = 8$, $(W/L)_p = 2$, $V_{GTn} = V_M - V_{T0n}$, $V_{GTp} = 0\,V - V_{DD} - V_{T0p} = -2.1\,V$, $V_{DSATn} = 0.6\,V$, $V_{DSATp} = -1\,V$, $\lambda_n = 0.06\,V^{-1}$, $\lambda_p = -0.1\,V^{-1}$.
Solve these equations, we have:

$$V_M = 0.921\,V$$

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(c)

The drain current of each transistor can be expressed as:

$$\begin{cases} I_{D1} = k'_n(W/L)_n(V_{GTn}V_{DSATn} - \frac{1}{2}V_{DSATn}^2)(1+\lambda_n V_M) \\ I_{D2} = k'_p(W/L)_p(V_{GTp}V_{DSATp} - \frac{1}{2}V_{DSATp}^2)(1+\lambda_p(V_M - V_{DD})) \end{cases}$$

According to Kirchoff Current Law, $I_{D1} + I_{D2} = 0$.
Given: $k'_n = 115 \times 10^{-6}\,A/V^2$, $k'_p = -30 \times 10^{-6}\,A/V^2$, $(W/L)_n = 8$, $(W/L)_p = 2$, $V_{GTn} = V_M - V_{T0n}$, $V_{GTp} = V_M - V_{DD} - V_{T0p}$, $V_{T0n} = 0.43\,V$, $V_{T0p} = -0.4\,V$, $V_{DSATn} = 0.6\,V$, $V_{DSATp} = -1\,V$, $\lambda_n = 0.06\,V^{-1}$, $\lambda_p = -0.1\,V^{-1}$.
Solve these equations, we have:

$$V_M = 0.824\,V$$

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asdfghjkl [Datta, 2017]

References

[Datta, 2017] Datta, D., editor (2017). *LaTeX in 24 Hours*. Springer International Publishing, Stuttgart, 1 edition.