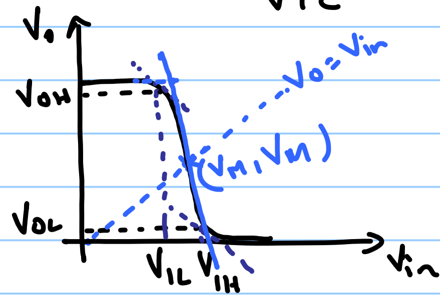
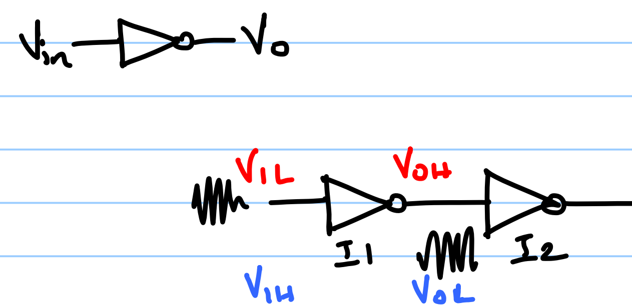
04/09/2019

EE5311

Module -3- The Inverter

Noise Margin



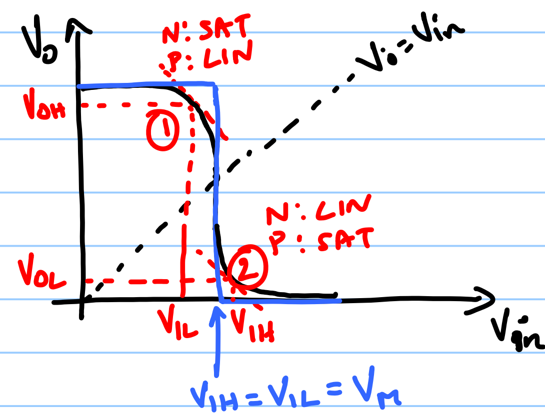


$NM_H = V_{OH} - V_{IH}$

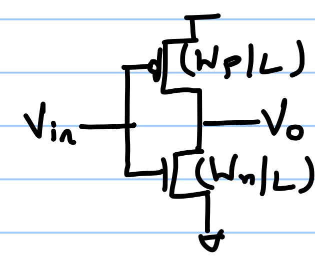
$NM_L = V_{IL} - V_{OL}$

Long Channel Inverters (ALL SCE = 0)

$$g = \left.\frac{dV_o}{dV_{in}}\right|_{V_{in}=V_o=V_M} \propto \frac{1}{(\lambda_n - \lambda_p)} \longrightarrow \frac{1}{2\lambda_n} \qquad (\lambda_p = -\lambda_n)$$



$$\frac{dV_o}{dV_{in}} = -1$$



	NMOS	PMOS
V_{GS}	V_{in}	$V_{in} - V_{DD}$
V_{DS}	V_o	$V_o - V_{DD}$

$$I_{Dsn} = \frac{1}{2} k_n' \frac{W_n}{L} (V_{in} - V_{Tn})^2 \qquad (\text{SAT})$$

$$I_{Dsp} = k_p' \frac{W_p}{L} (V_o - V_{DD}) \left(V_{in} - V_{DD} - V_{Tp} - \frac{(V_o - V_{DD})}{2} \right)$$

$$I_{Dsn} = - I_{Dsp}$$

$$\Rightarrow \quad \frac{1}{2} k_n' W_n (V_{in} - V_{Tn})^2 = - k_p' \frac{W_p}{L} (V_o - V_{DD}) \left(V_{in} - V_{DD} - V_{Tp} - \frac{(V_o - V_{DD})}{2} \right)$$

Diff wrt V_{in}

$$\Rightarrow \quad k_n' W_n (V_{in} - V_{Tn}) = - k_p' W_p \left[\left(\frac{dV_o}{dV_{in}} \right) \left(V_{in} - V_{DD} - V_{Tp} - \frac{(V_o - V_{DD})}{2} \right) + (V_o - V_{DD}) \left(1 - \frac{1}{2} \frac{dV_o}{dV_{in}} \right. \right.$$

Let $\quad - k_p' W_p / k_n' W_n = \gamma$

$$\Rightarrow \quad (V_{IL} - V_{Tn}) = r\left[(-1)\left(V_{IL} - V_{DD} - V_{Tp}\right) - \left(\frac{V_{OH} - V_{DD}}{2}\right)\right) + (V_{OH} - V_{DD})\left(\frac{3}{2}\right)\Big]$$

$$\therefore \quad V_{IL} = \frac{V_{Tn} + r\left(V_{DD} + V_{Tp} + 2(V_{OH} - V_{DD})\right)}{(1 + r)}$$

FOR V_{IH}

PMOS $\rightarrow$ SAT

NMOS $\rightarrow$ LIN

$$I_{DSp} = \frac{1}{2} K_p' \frac{W_p}{L} (V_{in} - V_{DD} - V_{Tp})^2$$

$$I_{DSn} = K_n' \frac{W_n}{L} V_0 \left[(V_{in} - V_{Tn}) - \frac{V_0}{2} \right]$$

$$\Rightarrow \quad I_{DSn} = -I_{DSp}$$

$$\Rightarrow \quad K_n' W_n V_0 \left[(V_{in} - V_{Tn}) - \frac{V_0}{2} \right] = -K_p' W_p (V_{in} - V_{DD} - V_{Tp})^2$$

$$\left(\frac{dV_0}{dV_{in}} = -1 \right) \quad \& \quad -K_p' W_p / K_n' W_n = \gamma$$

$$\Rightarrow \quad \frac{dV_0}{dV_{in}} \left[V_{in} - V_{Tn} - \frac{V_0}{2} \right] + V_0 \left[\left(1 - \frac{1}{2} \frac{dV_0}{dV_{in}} \right) \right] = \gamma (V_{in} - V_{DD} - V_{Tp}) \qquad \begin{matrix} V_{in} = V_{IH} \\ V_0 = V_{OL} \end{matrix}$$

$$\Rightarrow \quad (1+\gamma)V_{IH} = V_{Tn} + 2V_{OL} + \gamma(V_{DD}+V_{TP})$$

$$\Rightarrow \quad V_{IH} = \frac{V_{Tn} + 2V_{OL} + \gamma(V_{DD}+V_{TP})}{1+\gamma} = \frac{V_{Tn} + \gamma(V_{DD}+V_{TP}) + 2V_{OL}}{1+\gamma}$$

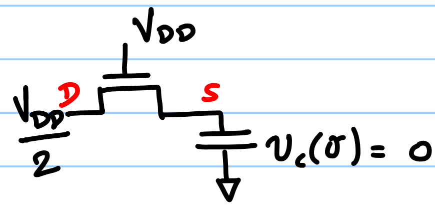
$$V_{IL} = \frac{V_{Tn} + \gamma\left(V_{DD}+V_{TP} + 2(V_{OH}-V_{DD})\right)}{(1+\gamma)} = \frac{V_{Tn} + \gamma(V_{DD}+V_{TP}) + 2\gamma(V_{OH}+V_{DD}}{1+\gamma}$$

$$\Delta V_{ILH} = V_{IH} - V_{IL} = \frac{2V_{OL} - 2\gamma(V_{OH}-V_{DD})}{(1+\gamma)}$$

Let $V_{OL} = V_{DD} - V_{OH}$

$$\Rightarrow \quad \Delta V_{ILH} = \frac{2V_{OL} + 2\gamma(V_{OL})}{(1+\gamma)} = 2V_{OL} \leftarrow$$

Pass Transistors

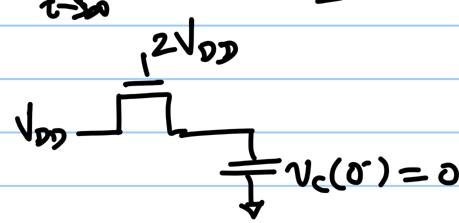


$\lim_{t\to\infty} V_s(t) = V_{DD} - V_{Tn}$ (I_{off} = SUB TH LEAKAGE = 0)

$V_{DD} - V_s \geq V_{Tn}$

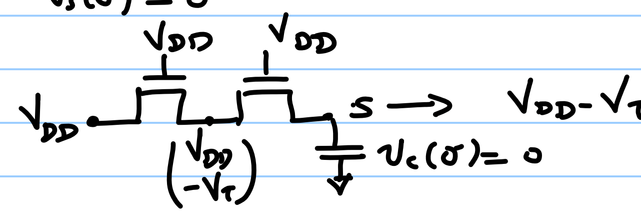
$\Rightarrow \quad V_s \leq V_{DD} - V_{Tn}$

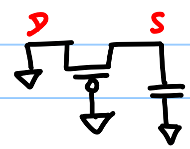
$\Rightarrow \quad \lim_{t\to\infty} V_s(t) = \frac{V_{DD}}{2}$



$\lim_{t\to\infty} V_s(t) = \min(V_G - V_T, V_D)$

$V_s(0^-) = 0$





$v_c(0^-) = V_{DD}$

$$V_{GS} - V_{Tp} \leq 0$$
$$-V_S - V_{Tp} \leq 0$$
$$\therefore -V_S \leq +V_{Tp}$$
$$\Rightarrow V_S \geq (V_{Tp})$$