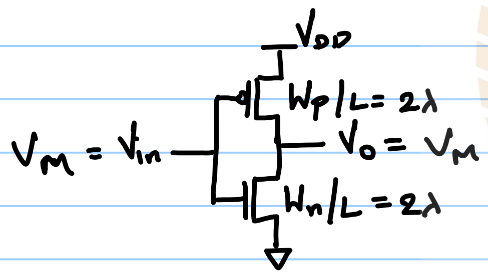
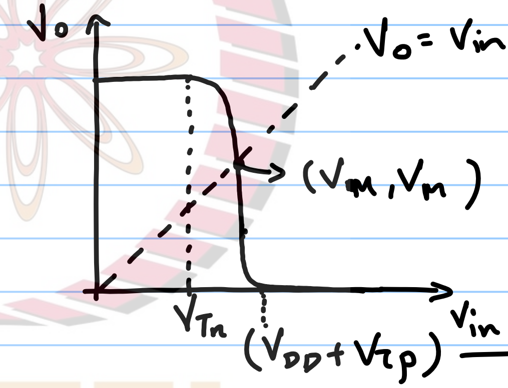
29/08/2019

EE5311

MODULE-3 - THE INVERTER

LONG CHANNEL





$(V_{DD}+V_{Tp}) \longrightarrow (V_{DD}-|V_{Tp}|)$

$V_{Tn} \le V_M \le V_{DD}+V_{Tp}$

$\Rightarrow V_M - V_{Tn} > 0$

$(V_M - V_{DD} - V_{Tp}) < 0$

ASSUMPTION:

BOTH N & P ARE IN SATURATION

	NMOS	PMOS
V_{GS}	V_M	$V_M - V_{DD}$
V_{DS}	V_M	$V_M - V_{DD}$

$I_{Dsn} = \frac{1}{2} K_n'(W_n/L)\,(V_M - V_{Tn})^2$

$I_{Dsp} = \frac{1}{2} K_p'(W_p/L)\,(V_M - V_{DD} - V_{Tp})^2$

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

$$\Rightarrow \quad k_n' W_n (V_M - V_{Tn})^2 = -k_p' W_p (V_M - V_{DD} - V_{Tp})^2$$

$$\sqrt{x^2} = |x|$$

$$r = \frac{-k_p' W_p}{k_n' W_n} = \frac{|k_p'| W_p}{k_n' W_n} > 0$$

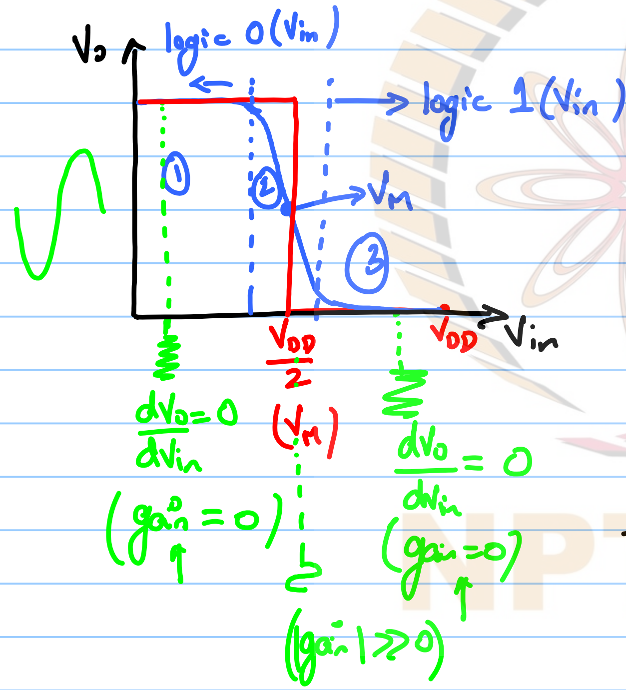
$$\therefore \quad (V_M - V_{Tn})^2 = r\,(V_M - V_{DD} - V_{Tp})^2$$

$$\underbrace{(V_M - V_{Tn})}_{+ve} = \pm\sqrt{r}\,\underbrace{(V_M - V_{DD} - V_{Tp})}_{-ve}$$

$$\therefore \quad V_M - V_{Tn} = -\sqrt{r}\,(V_M - V_{DD} - V_{Tp})$$

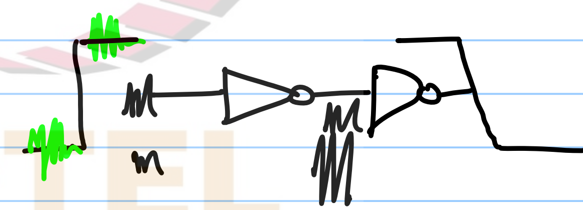
$$\Rightarrow \quad V_M = \frac{V_{Tn} + \sqrt{r}\,(V_{DD} + V_{Tp})}{1 + \sqrt{r}}$$

NOISE MARGIN ANALYSIS

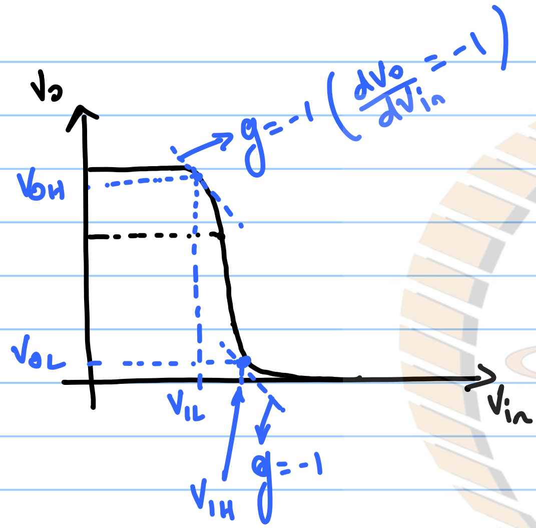


$V_{in} < V_M \Rightarrow V_{in}$ is logic 0 $\Rightarrow V_o =$ logic 1

$V_{in} > V_M \Rightarrow$ " " " 1 $\Rightarrow V_o =$ " 0



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

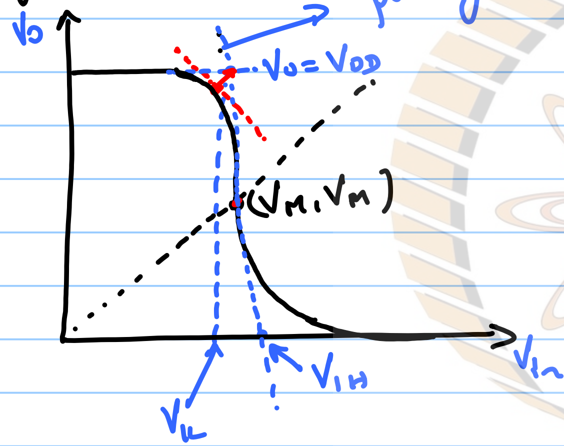


if $V_{in} > V_{IH} \Rightarrow$ input is logic 1
$V_{in} < V_{IL} \Rightarrow$ " " " 0

$V_{IL} \le V_{in} \le V_{IH}$?

$\Rightarrow$ V_o WILL BE Logic 0/1 depending on NOISE (gain is very high)

Finding V_{IL} & V_{IH} :



passing through (V_M, V_M) with slope $g = \frac{dV_o}{dV_{in}}\Big|_{V_{in}=V_M}$

Find $\frac{dV_o}{dV_{in}} = g$ @ $V_{in} = V_o = V_M$

V_{in} near V_M

$$I'_{DSn} = K'_n \frac{W_n}{L} V_{DSATn}\left[(V_{in}-V_{Tn}) - \frac{V_{DSATn}}{2}\right]$$

$$I'_{DSp} = K'_p \frac{W_p}{L} V_{DSATp}\left[(V_{in}-V_{DD}-V_{Tp}) - \frac{V_{DSATp}}{2}\right]$$

$$\frac{dV_o}{dV_{in}} = g \Big|_{V_{in}=V_o=V_M}$$

$I_{DSn} = I'_{DSn}(1+\lambda_n V_o)$

$I_{DSp} = I'_{DSp}(1+\lambda_p(V_o - V_{DD}))$

$g = dV_o / dV_{in} \big|_{V_{in}=V_o=V_M}$

$g =$

$$g = -\frac{1}{I_D(V_M)}\frac{k_n V_{DSATn} + k_p V_{DSATp}}{\lambda_n - \lambda_p}$$

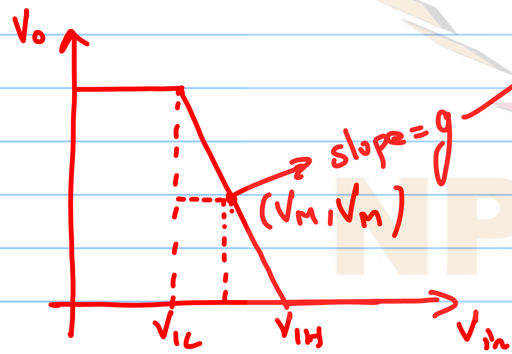
$$g \approx \frac{1+r}{(V_M - V_{Tn} - V_{DSATn}/2)(\lambda_n - \lambda_p)}$$

$$r = \frac{k_p V_{DSATp}}{k_n V_{DSATn}}$$

$$g \propto \frac{1}{(\lambda_n - \lambda_p)}$$

$$\lambda_p = -\lambda_n$$

$$g \propto \frac{1}{2\lambda_n}$$



$$g = \frac{-V_M}{V_{IH} - V_M}$$

$$\therefore V_{IH} = V_M - \frac{V_M}{g}. \quad > V_M$$

$$g = \frac{V_M - V_{DD}}{V_M - V_{IL}} \Rightarrow V_{IL} = V_M - \frac{(V_M - V_{DD})}{g}.$$