VLSI Design - Lecture 6
16 Aug 2022

$$I_{dn} + I_{dp} = 0 \qquad r = \frac{k_p V_{DSATp}}{k_n V_{DSATn}}$$

$$V_{IN} - V_{Tn} - \frac{V_{DSATn}}{2} + r\left(V_{IN} - V_{DD} - V_{Tp} - \frac{V_{DSATp}}{2}\right) = 0$$

$$V_M = \frac{V_{Tn} + \frac{V_{DSATn}}{2} + r\left(V_{DD} + V_{Tp} + \frac{V_{DSATp}}{2}\right)}{1+r}$$

For $V_M = V_{DD}/2$ $\quad r - ?$ $\quad 1.45$ $\qquad \frac{(W/L)_p}{(W/L)_n} = 3.5$

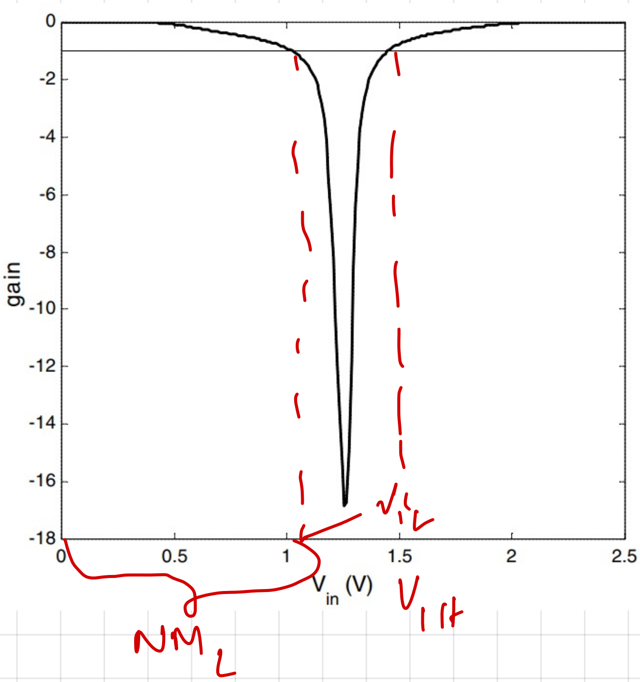
$L_p = L_n = 0.25\,\mu m$

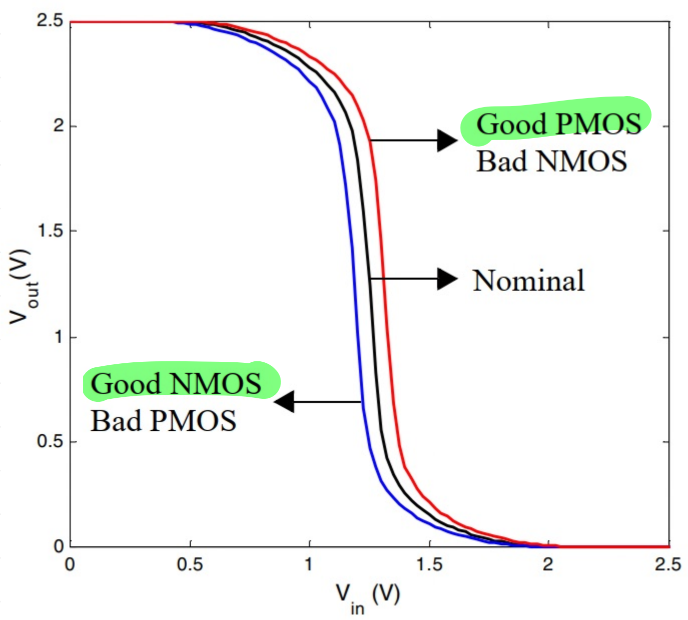
$W_n = 0.25\,\mu m$

$W_p = 3.5 \times 0.25\,\mu m$

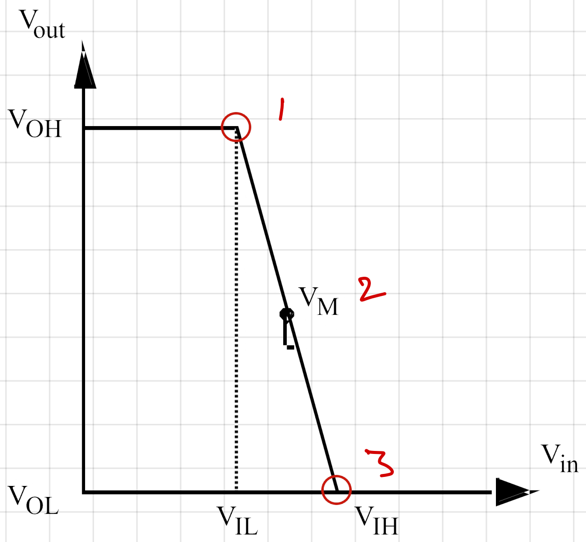
$$g = \frac{dV_{out}}{dV_{in}} = -\frac{1}{I_D(V_M)} \frac{k_n V_{DSATn} + k_p V_{DSATp}}{\lambda_n - \lambda_p}$$

$$= -\frac{1+r}{\left(V_M - V_{Tn} - \frac{V_{DSATn}}{2}\right)(\lambda_n - \lambda_p)}$$





Noise Margins



Piecewise linear approx.

$V_{IH} = ?$ 2 & 3

$$g = \frac{V_M - \cancel{V_{OL}}^{\to 0}}{V_M - V_{IH}}$$

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

$$= 1.25 + \frac{1.25}{30} = 1.29$$

$$V_{IL} = V_M + \frac{V_{DD} - V_M}{g}$$

$$= 1.21$$

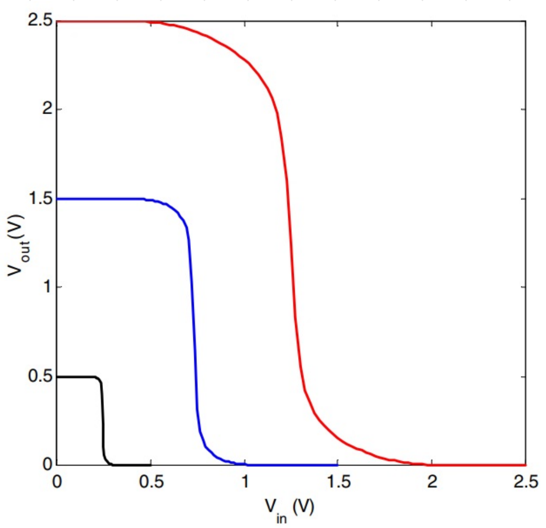
$V_{DD} = 1.8$

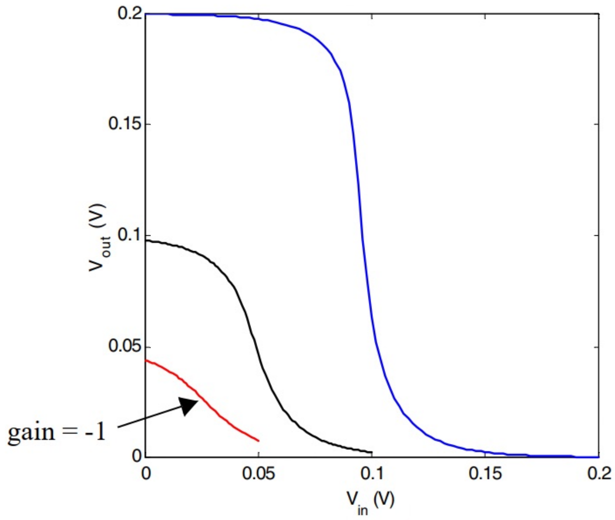
$V_m = 0.9$

$NM_L = 1.21$

$NM_H = 1.21$

$$g = -\frac{1+g}{\left(V_M - V_{Tn} - \frac{V_{DSATn}}{2}\right)(\lambda_n - \lambda_p)}$$



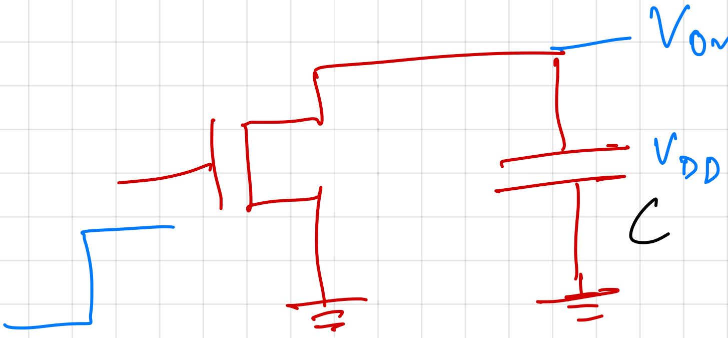


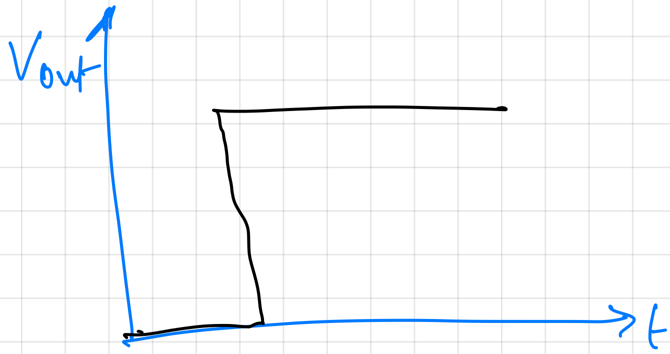
$$V_{DD,min} = V_{Tn} + |V_{Tp}|$$

$V_{Tn} = 0.43$

$V_{Tp} = -0.4$

Dynamic Performance





$$t_{PHL} = 0.69\, RC$$

↳ R fixed ?

$$R = \frac{V_{DS}}{I_{DS}}$$

R_{VDD} $\quad$ $R_{VDD/2}$

$$R_{eq} = \frac{1}{2}\left[\frac{V_{DD}}{I_{DSAT}(1+\lambda V_{DD})} + \frac{V_{DD}/2}{I_{DSAT}(1+\lambda V_{DD}/2)}\right]$$

$$= \frac{1}{2}\frac{V_{DD}}{I_{DSAT}}\left[1 - \lambda V_{DD} + \frac{1}{2} - \lambda\frac{V_{DD}}{4}\right]$$

$$= \frac{3V_{DD}}{4I_{DSAT}}\left[1 - \frac{5}{4}\times\frac{2}{3}\lambda V_{DD}\right] \qquad R_{eqp} = 31\,k\Omega$$

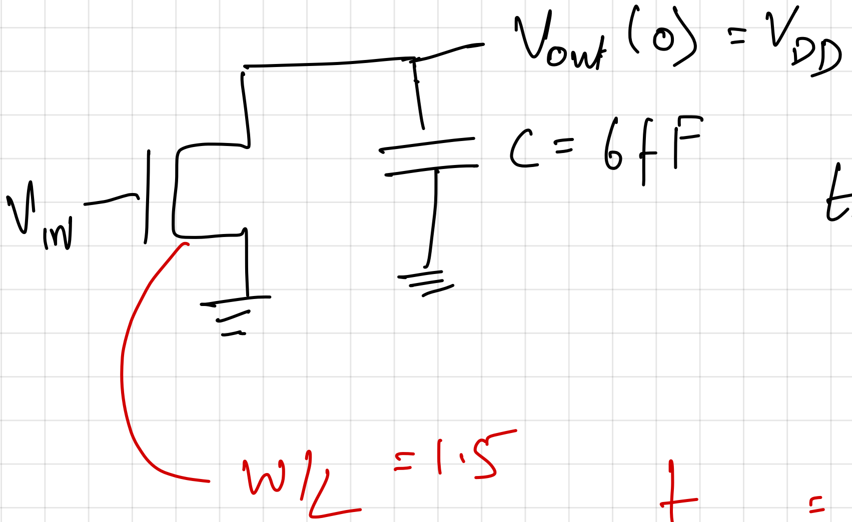
0.06

$$R_{eq,n} = \frac{3V_{DD}}{4I_{DSAT}}\left[1 - \frac{5}{6}\lambda V_{DD}\right] = 13\,k\Omega$$

$$\frac{W}{L} = 1$$

↳ $115 \times 1\left[2.5 - 0.43 - \frac{0.63}{2}\right]0.63$

$= 127\ uA$

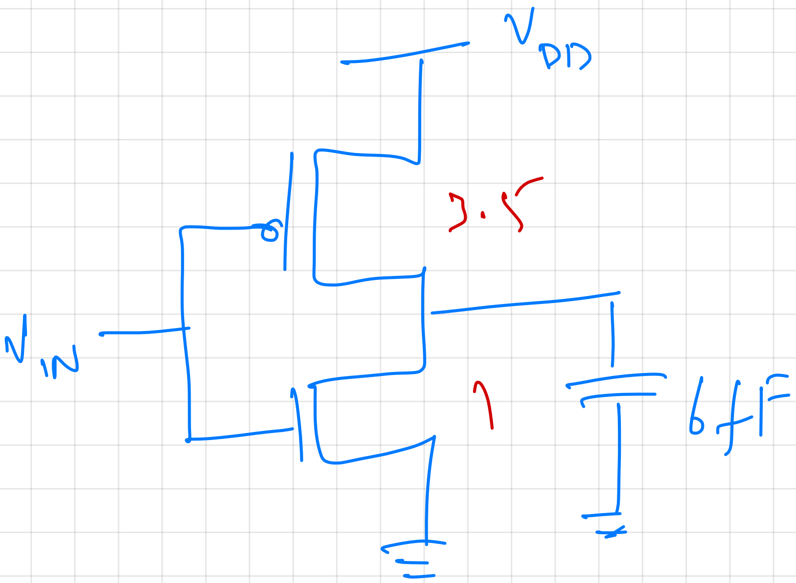


$$t_{PHL} = 0.69 \times 13k\Omega \times 6fF$$

$$= 54\ ps$$

$$t_{PHL} = 0.69 \times \frac{13k\Omega}{1.5} \times 6fF$$

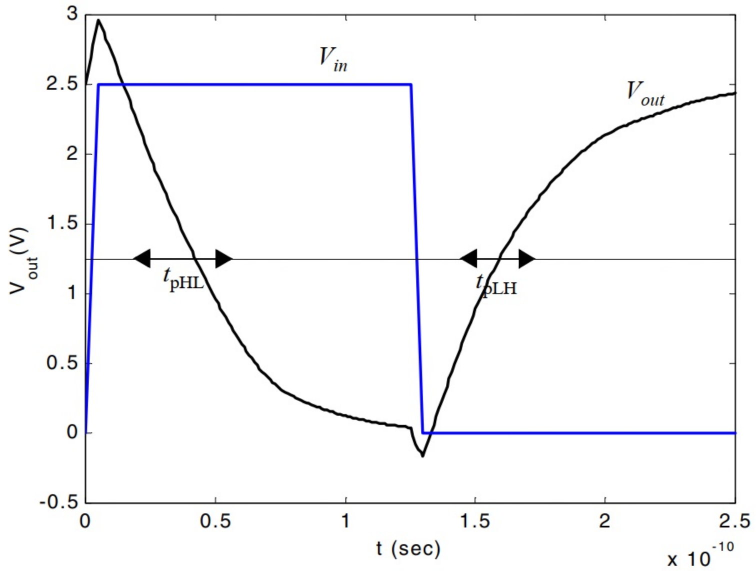
$$= 36\ ps$$



$$t_{PLH} = 0.69 \times \frac{31}{1.5} \times 6fF$$

$$= 85.$$

$$t_p = (t_{PHL} + t_{PLH})/2$$



V_{in}
V_{out}
t_{pHL}
t_{pLH}
V_{out}(V)
t (sec)
x 10^{-10}
3
2.5
2
1.5
1
0.5
0
-0.5
0
0.5
1
1.5
2
2.5