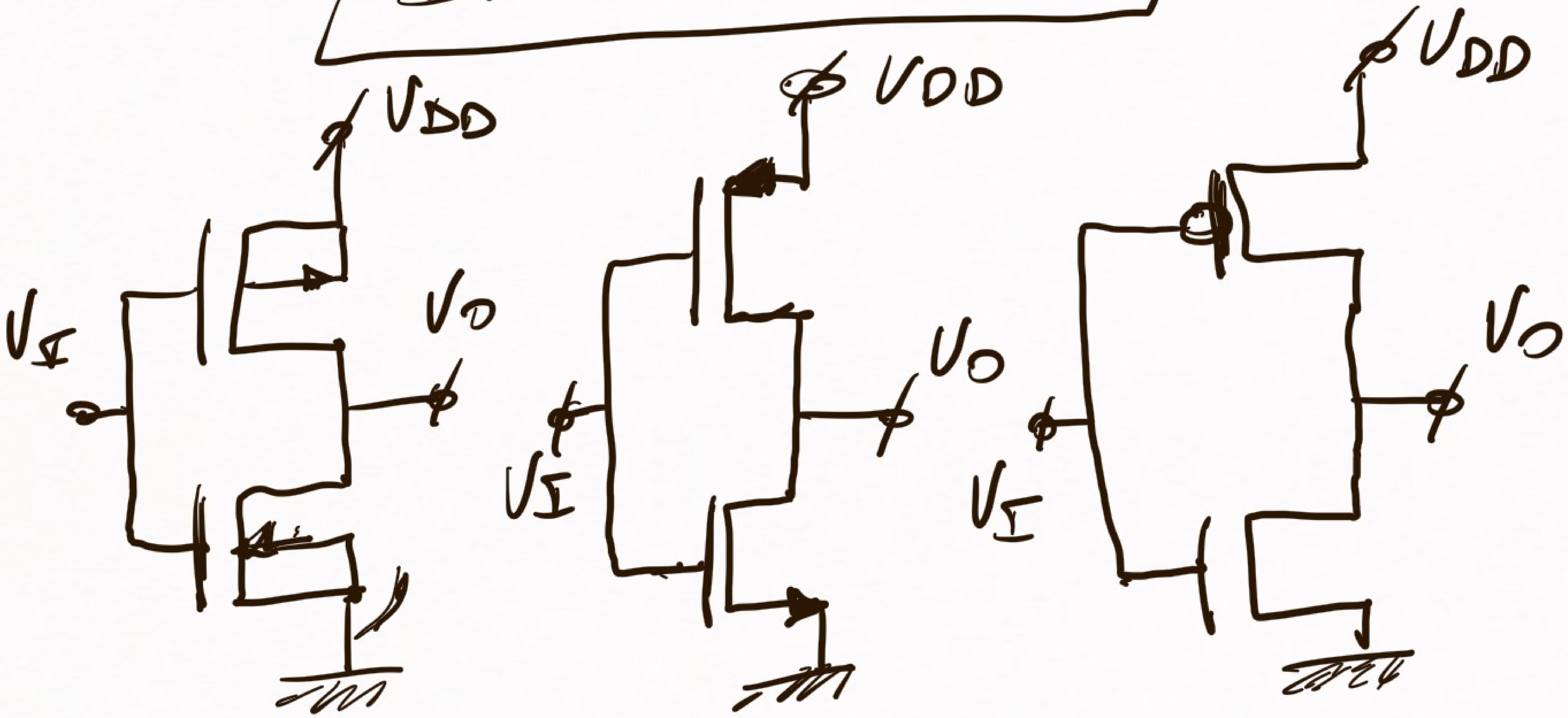
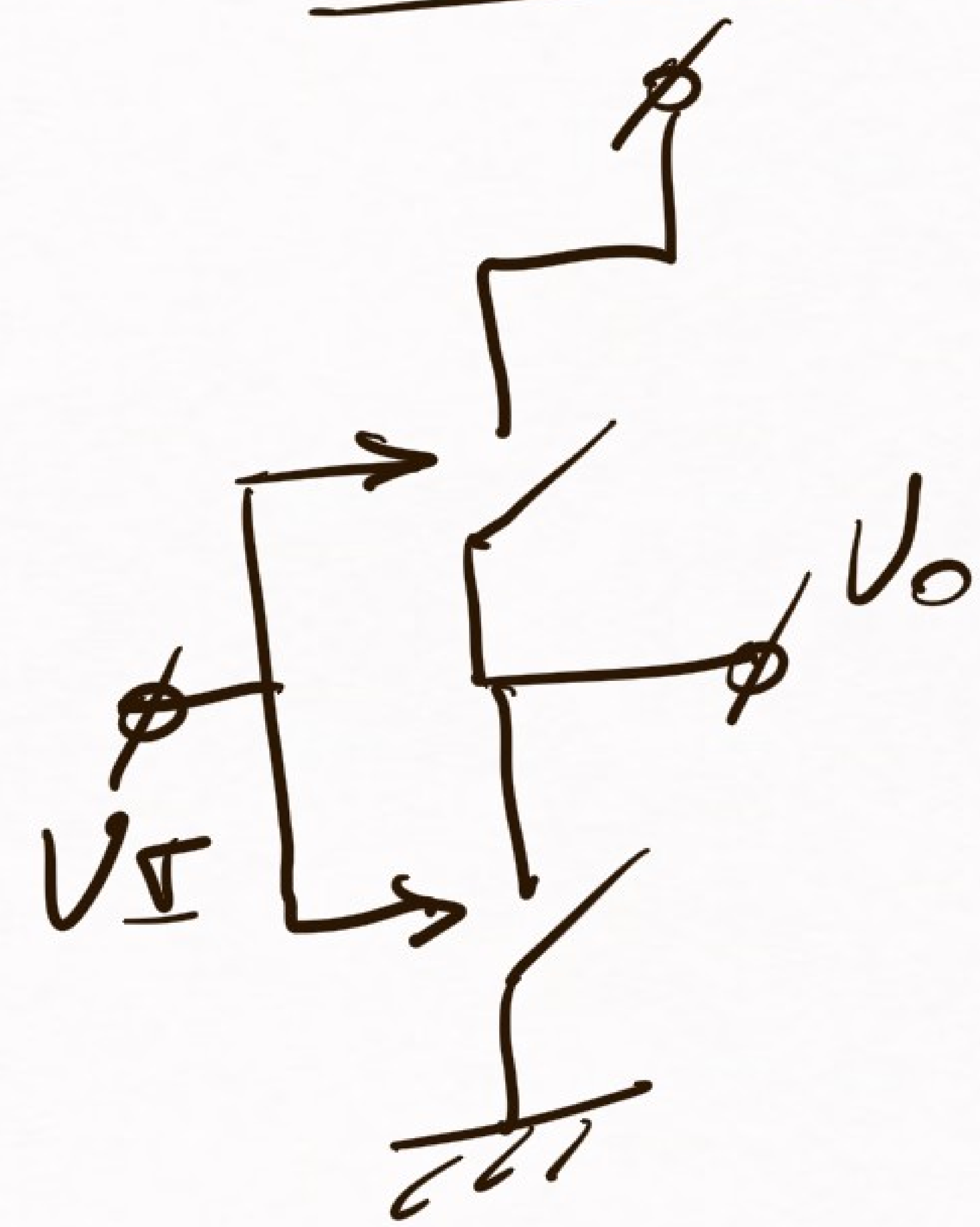
INVERSOR CMOS

2/6/2021



idea básica



Idea básica:

$V_I = 0 \Rightarrow$ nMOS OFF, pMOS ON $\rightarrow V_O = V_{DD}$

$V_I = V_{DD} \Rightarrow$ nMOS ON, pMOS OFF $\Rightarrow V_O = 0$

Propiedades fundamentales del inversor CMOS

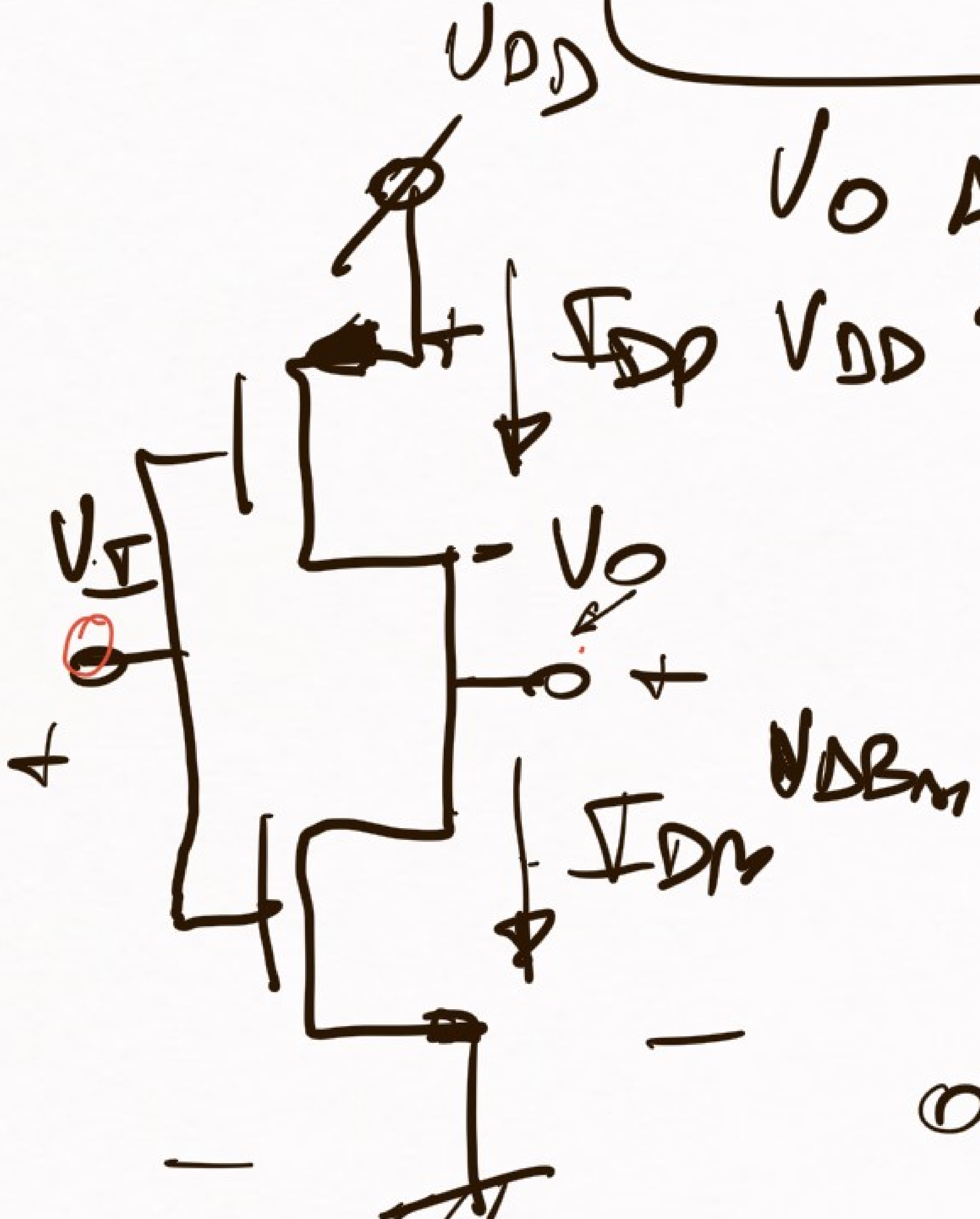
1) $V_{OH} = V_{DD}$
$V_{OL} = 0$ } independiente del tamaño (W, L) de los transistores.

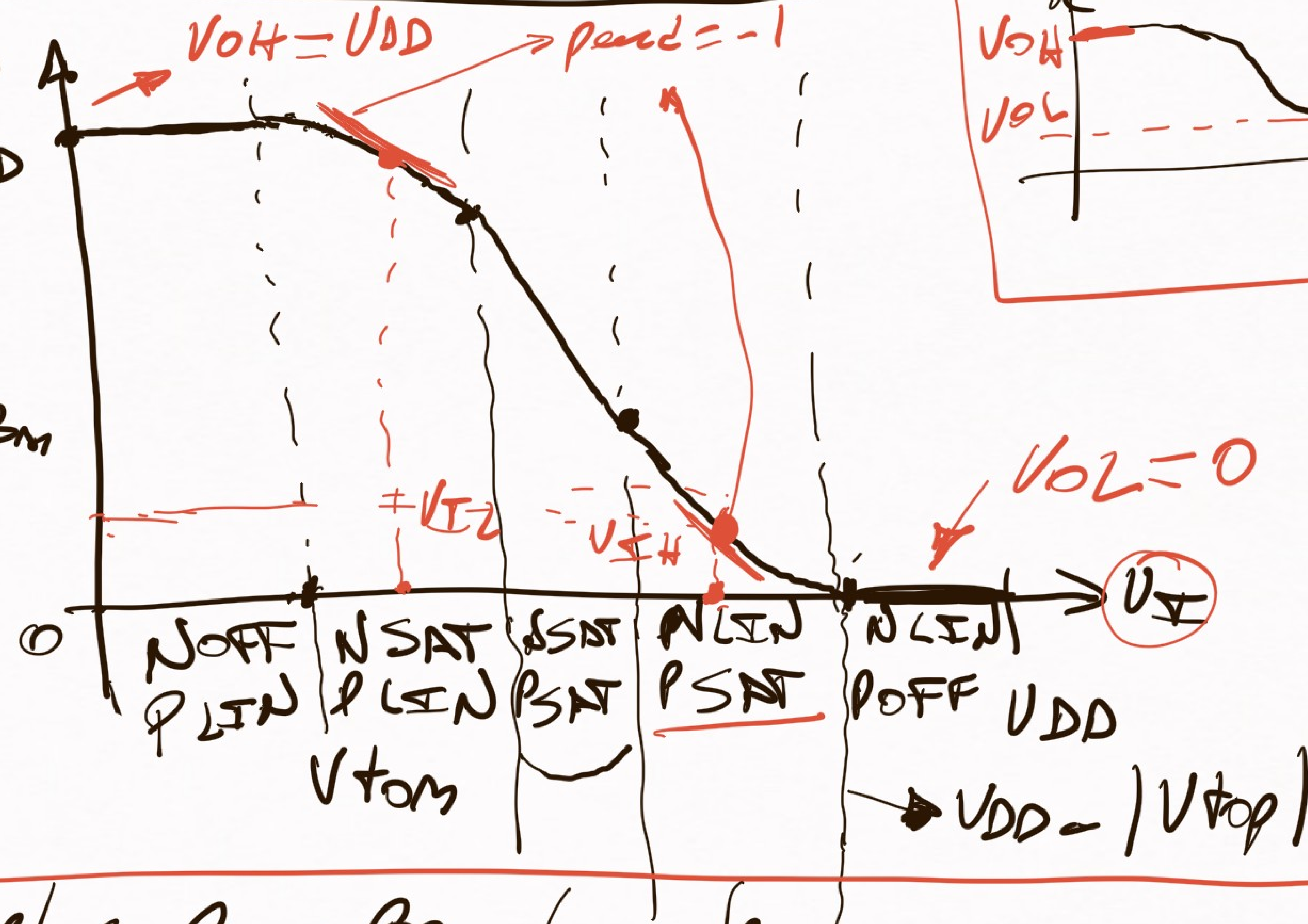
2) Se puede diseñar para tener una característica simétrica ($V_C = V_{DD}/2$)
$\Rightarrow$ amplios márgenes de ruido.

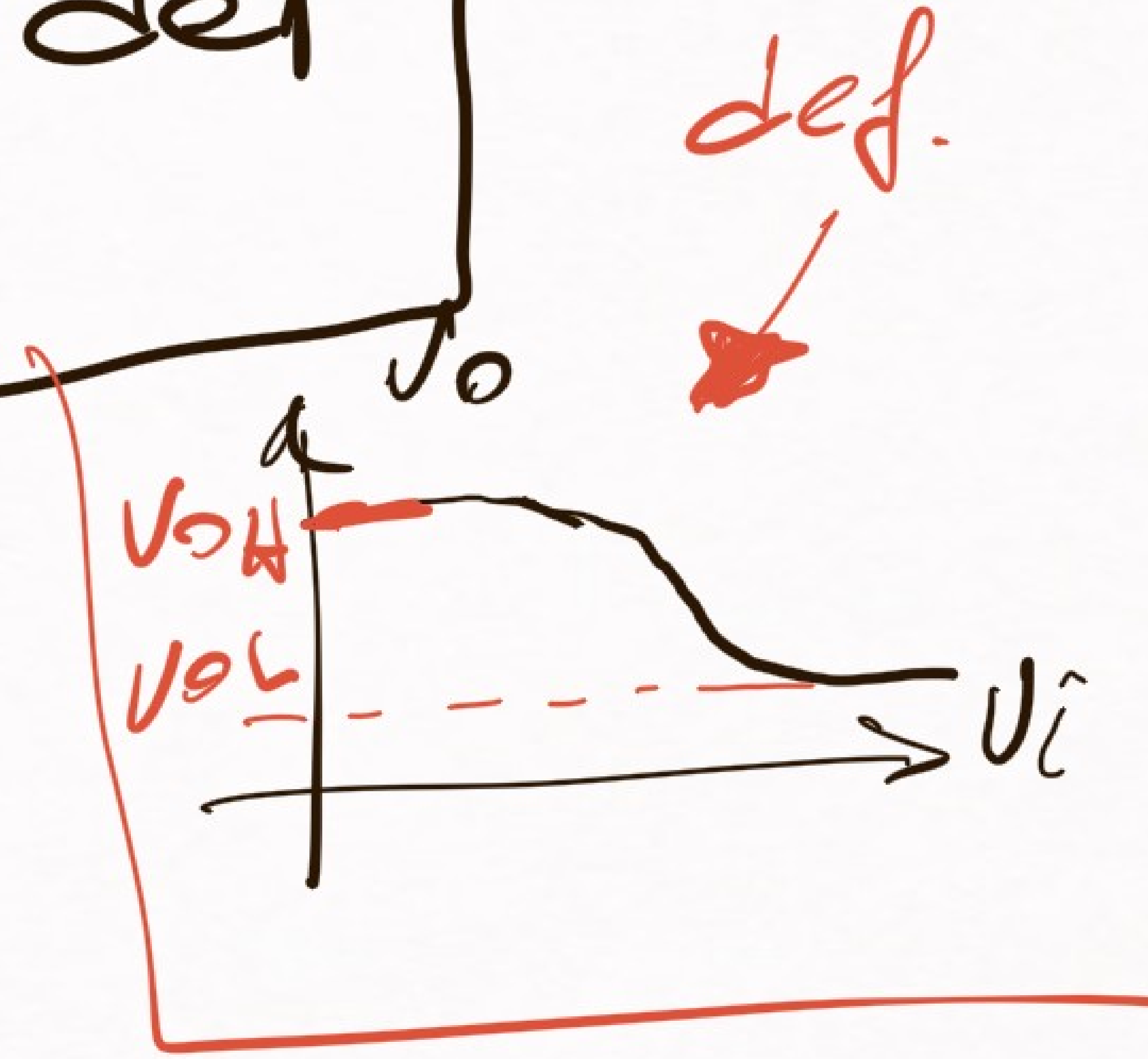
3) Idealmente el consumo estático es nulo

4) $R_i = \infty \Rightarrow$ característica estática independiente de cuántas compuertas se conectan a la salida

Característica estática del inversor CMOS





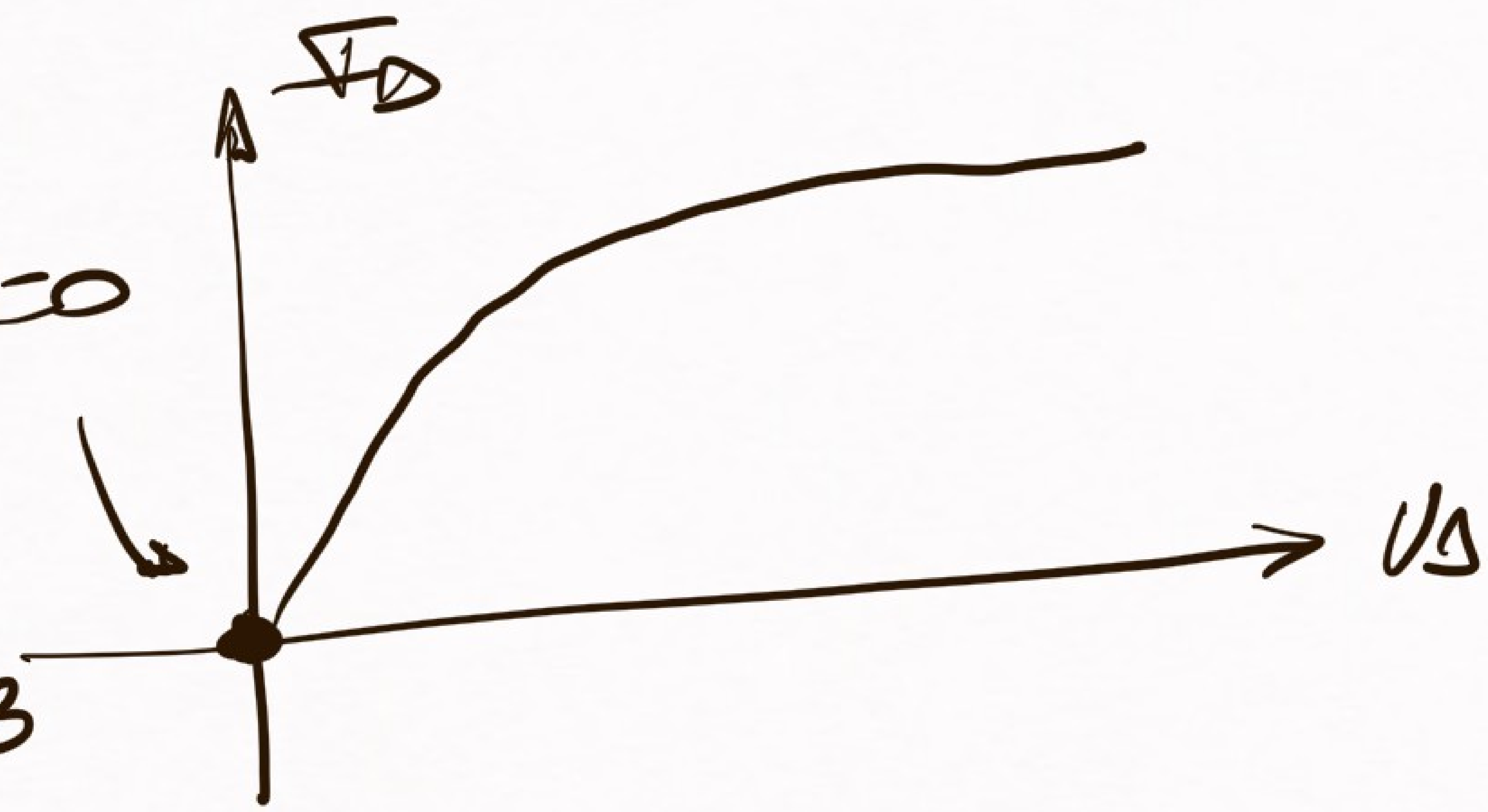


$I_{Dn} = I_{Dp}$

Si $V_{ton} = |V_{top}|$ y $\beta_n = \beta_p$, $\lambda_n = \lambda_p$

$\Rightarrow$ característica es simétrica respecto a $V_o = V_I$

y $V_C = V_{DD}/2$



$I_D = 0$

$\Downarrow$

$V_{DB} = 0$

N OFF

$\Updownarrow$

$\underbrace{V_{SB}}_{=0} > V_P = \dfrac{V_{GB} - V_{tom}}{1+\delta}$

$\Updownarrow$

$\underbrace{V_{GB}}_{= V_I} < V_{tom}$

N SAT:

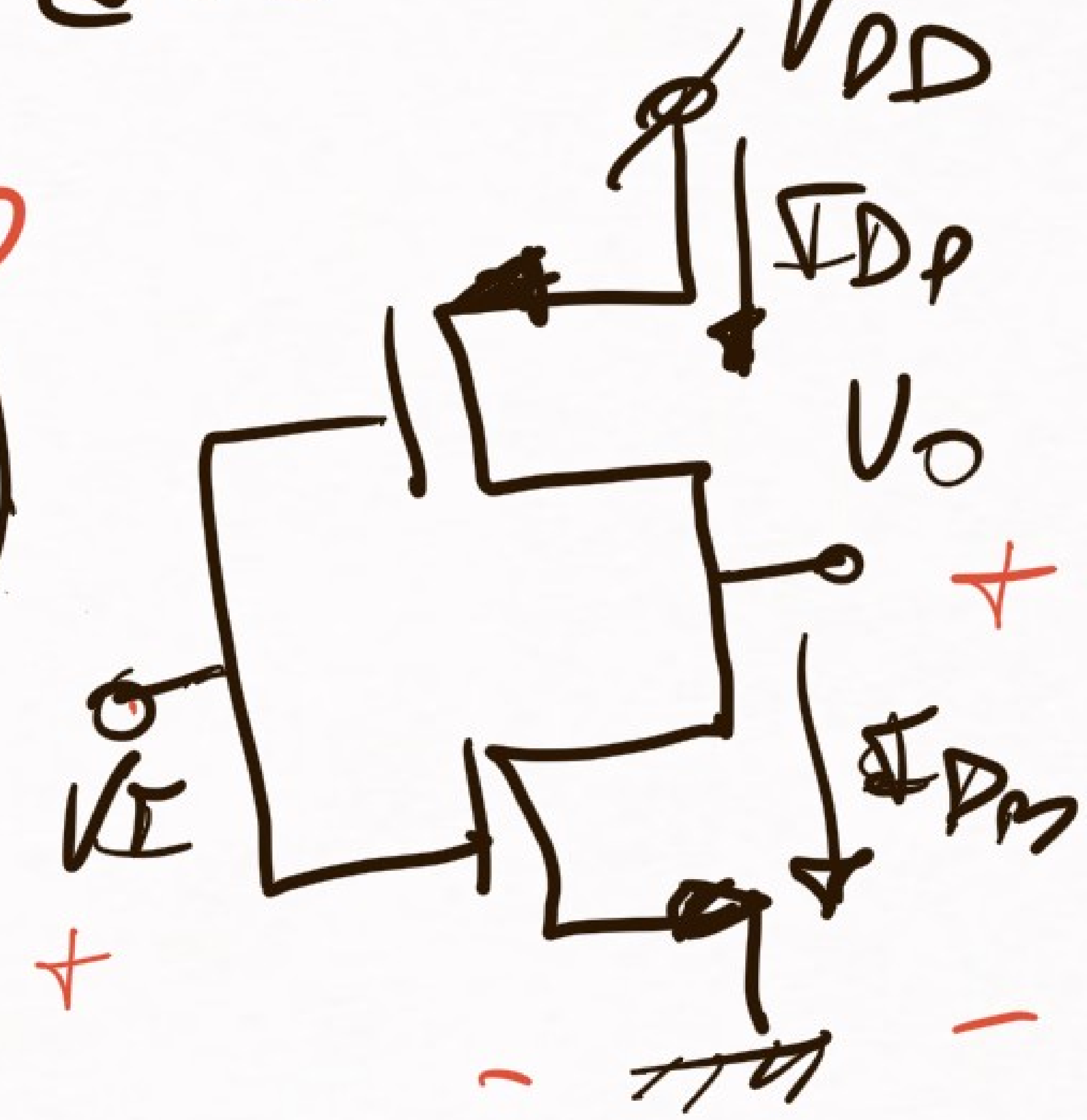
$$\begin{cases} V_{SB} < V_P \iff \underbrace{V_{GB}}_{= V_I} > V_{tom} \\ V_{DB} > V_P \iff \underbrace{V_O}_{= V_{DD}} > V_P = \dfrac{\overbrace{V_{GB} - V_{tom}}^{\text{pequeño}}}{(1+\delta)} \end{cases}$$

Determinación de V_{IH}

⇒ Zona en que P saturado y N en zona lineal.

Caso simplificado si hay simetría:
$$\begin{cases} V_{ton} = |V_{top}| = V_{to} \\ \beta_n = \beta_p = \beta \\ \lambda_n = \lambda_p = 0 \end{cases}$$

⇒ $V_O = f(V_I)$ y determinar $V_I \,/\, \dfrac{dV_O}{dV_I} = -1$



$$\boxed{I_{DN} = I_{DP}}$$

$$I_{DN} = \beta\left(\left(\overset{V_I}{V_G} - V_{to}\right)\left(\overset{V_O}{V_D} - \overset{0}{V_S}\right) - \frac{1}{2}\left(\overset{V_O^2}{V_D^2} - \overset{0}{V_S^2}\right)\right)$$

$$I_{DP} = \frac{\beta}{2}\left(\underset{(V_{DD} - V_I)}{V_{SG}} - V_{to}\right)^2$$

$I_{DM} = I_{DP}$

$$\Rightarrow \cancel{\beta}\left((V_I - V_{to}).V_o - \frac{1}{2}V_o^2\right) = \frac{\cancel{\beta}}{2}\left(V_{DD} - V_I - V_{to}\right)^2 \quad \text{I}$$

A $V_o = f(V_I)$ y derivo y hallo V_I / $dV_o/dV_I = -1$

B Derivar I a ambos lados de la igualdad respecto a V_I.

$$V_o + (\underbrace{V_I}_{V_{IH}} - V_{to})\underbrace{\frac{dV_o}{dV_I}}_{=-1} - V_o.\underbrace{\frac{dV_o}{dV_I}}_{=-1} = -(V_{DD} - \underbrace{V_I}_{V_{IH}} - V_{to})$$

$V_I = V_{IH}$ / $\frac{dV_o}{dV_I} = -1 \Rightarrow V_o\Big|_{e\,V_I = V_{IH}} = V_{IH} - \frac{V_{DD}}{2}$

$\Rightarrow$ sustituimos en I

$$\Rightarrow \boxed{V_{IH} = \frac{1}{8}(5V_{DD} - 2V_{to})}$$

Analogamente (o por simetria)

$$\Rightarrow \underline{V_{IL} = \frac{1}{8}(3V_{DD} + 2V_{to})}$$

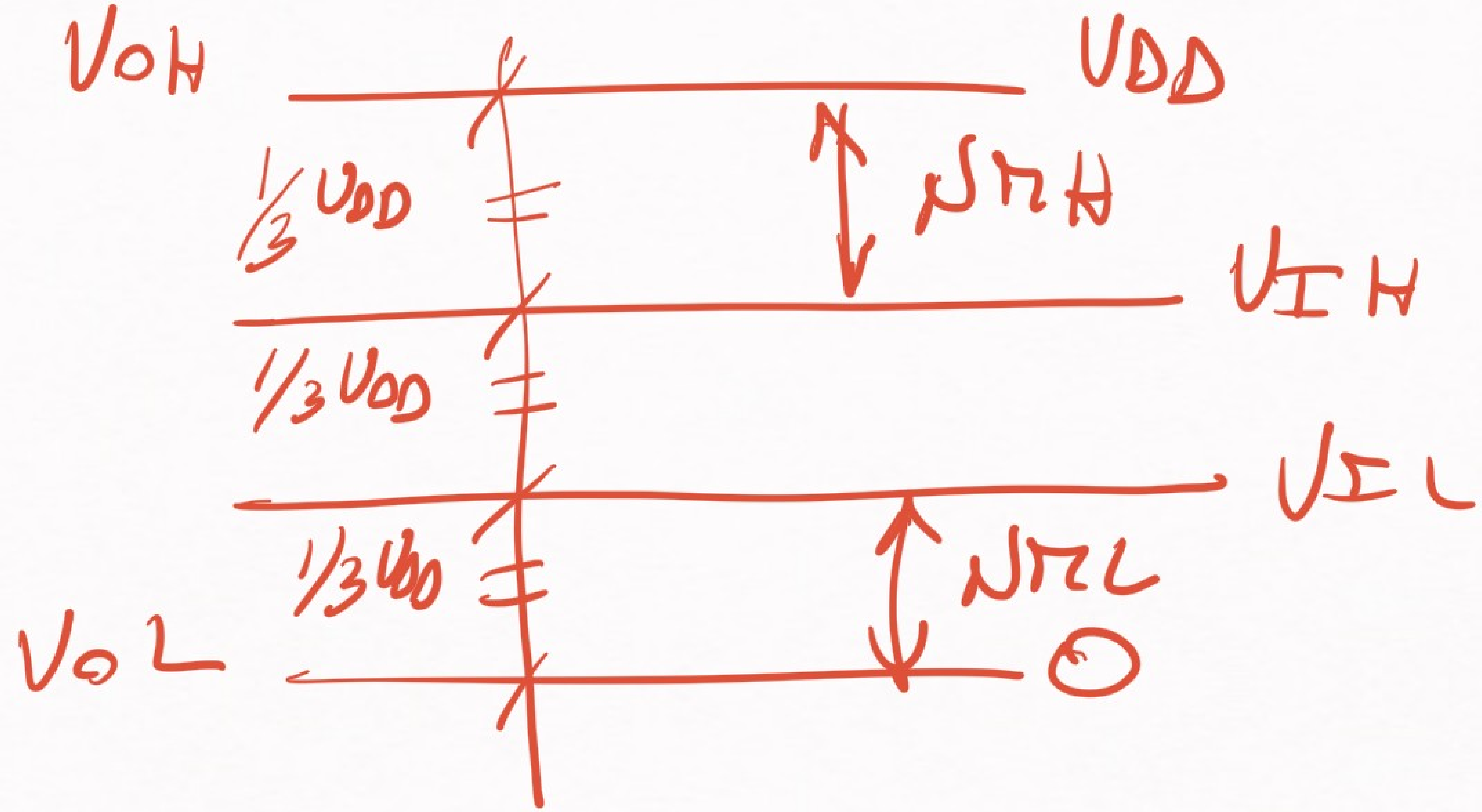
$$\Rightarrow NM_H = \underbrace{V_{OH}}_{=V_{DD}} - V_{IH} = \underline{\frac{1}{8}(3V_{DD} + 2V_{to})}$$

$$\Rightarrow NM_L = V_{IL} - \overbrace{V_{OL}}^{=0} = V_{IL} = \underline{\frac{1}{8}(3V_{DD} + 2V_{to})}$$

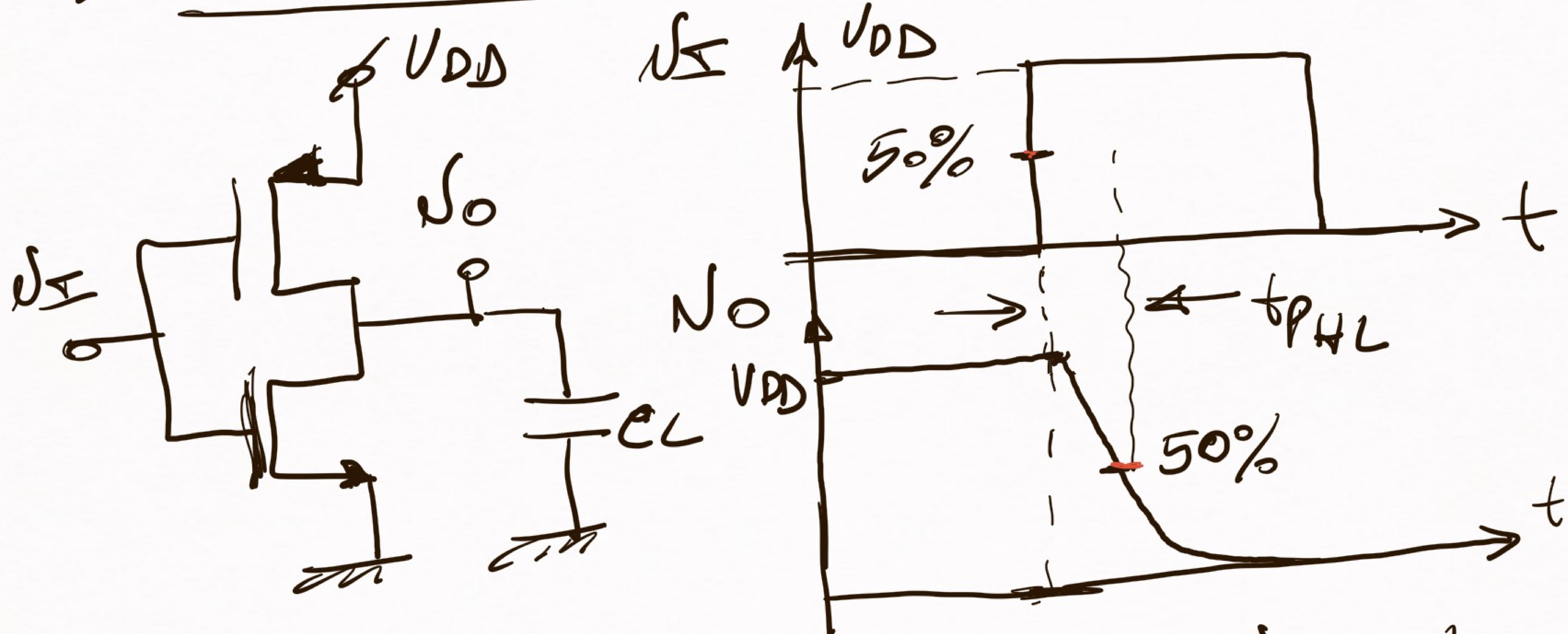
__Ej:__ $V_{DD} = 5V$, $V_{to} = 1V \Rightarrow V_{IL} = NM_L = NM_H = \underline{2.1V}$

$V_{IH} = 2.9V \; (= 5V - 2.1V)$ // $\boxed{\underline{\text{Usual}}: NM_L = NM_H = \frac{1}{3} V_{DD}}$

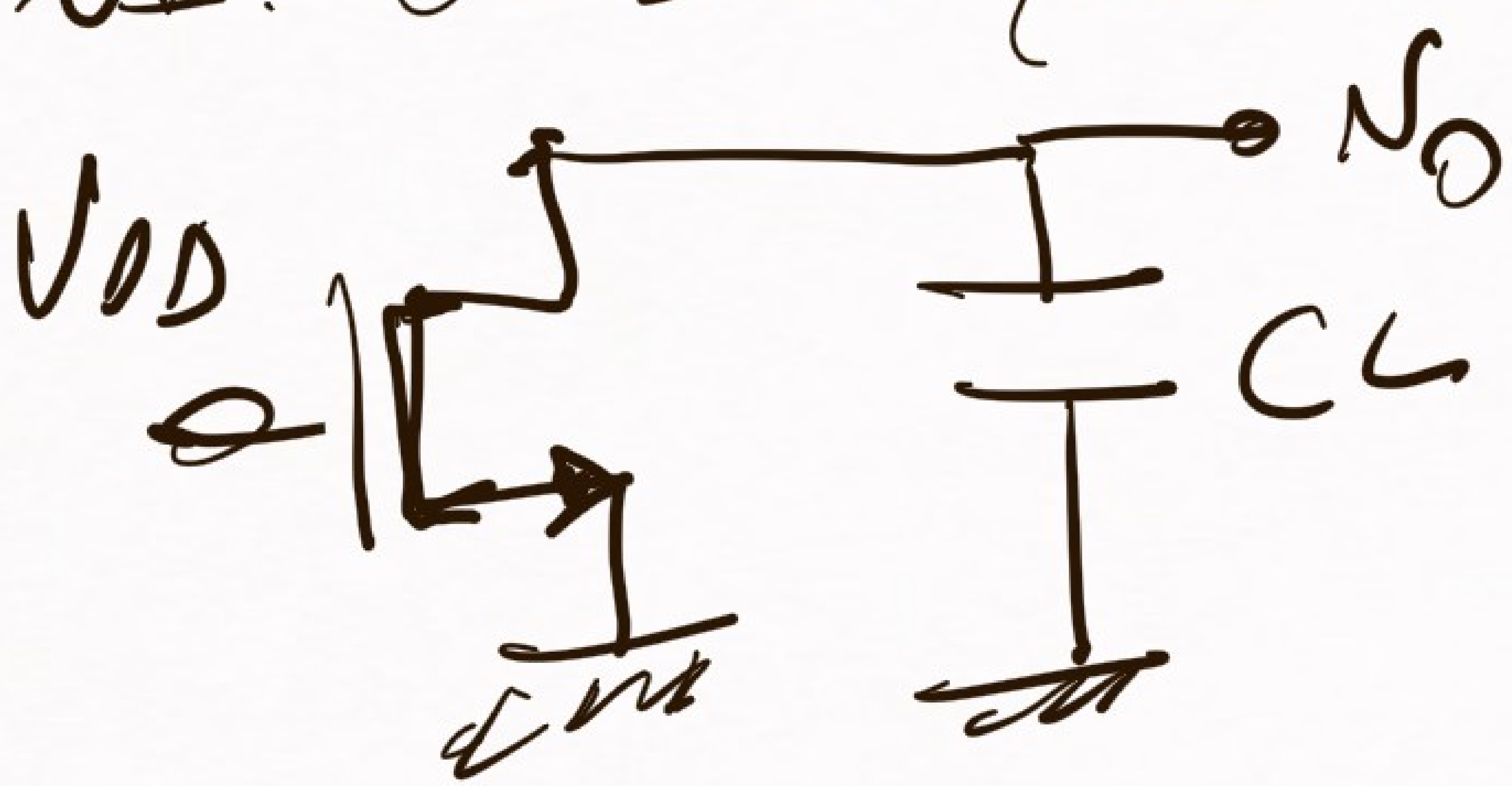
Used:



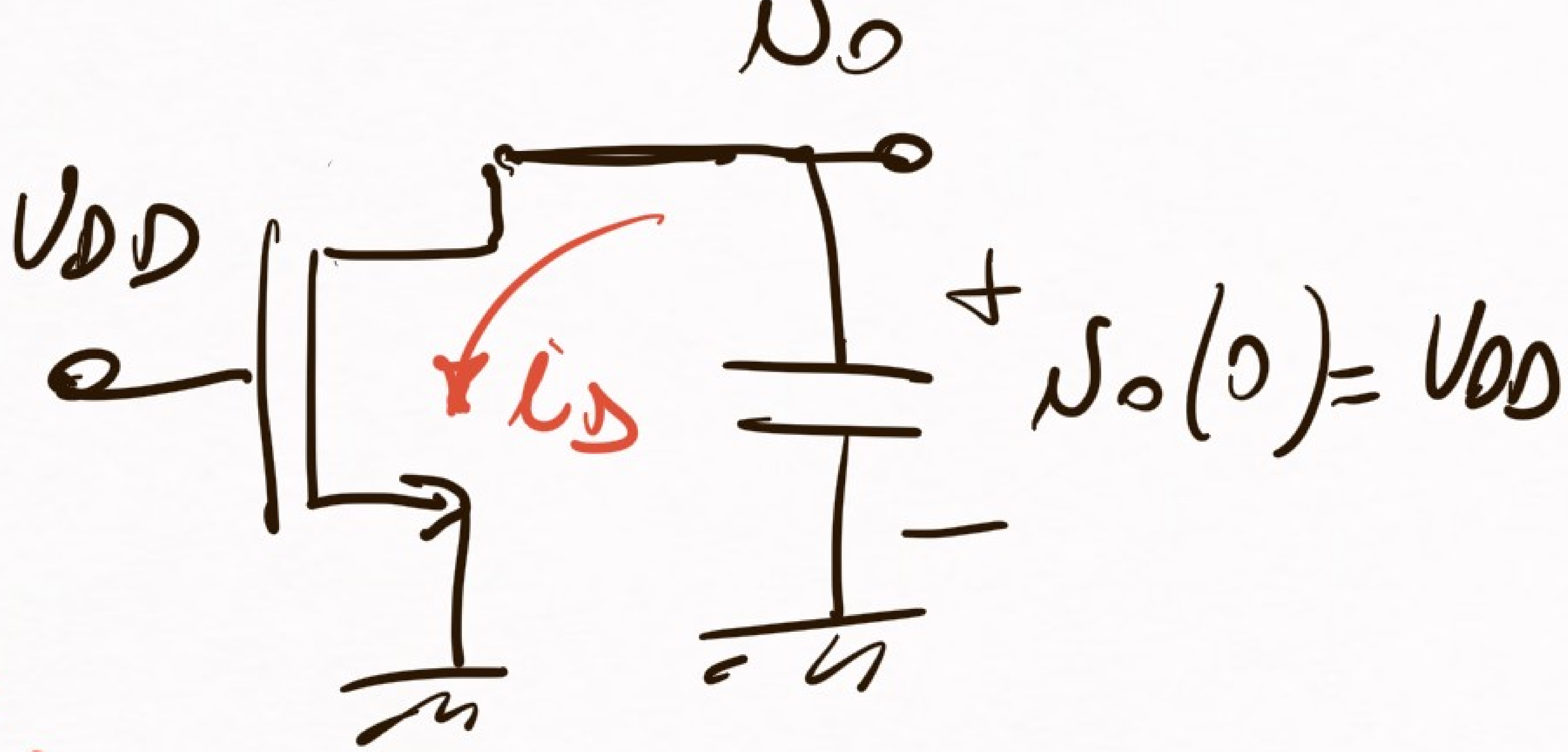
2) Velocidad, tiempo de Propagación

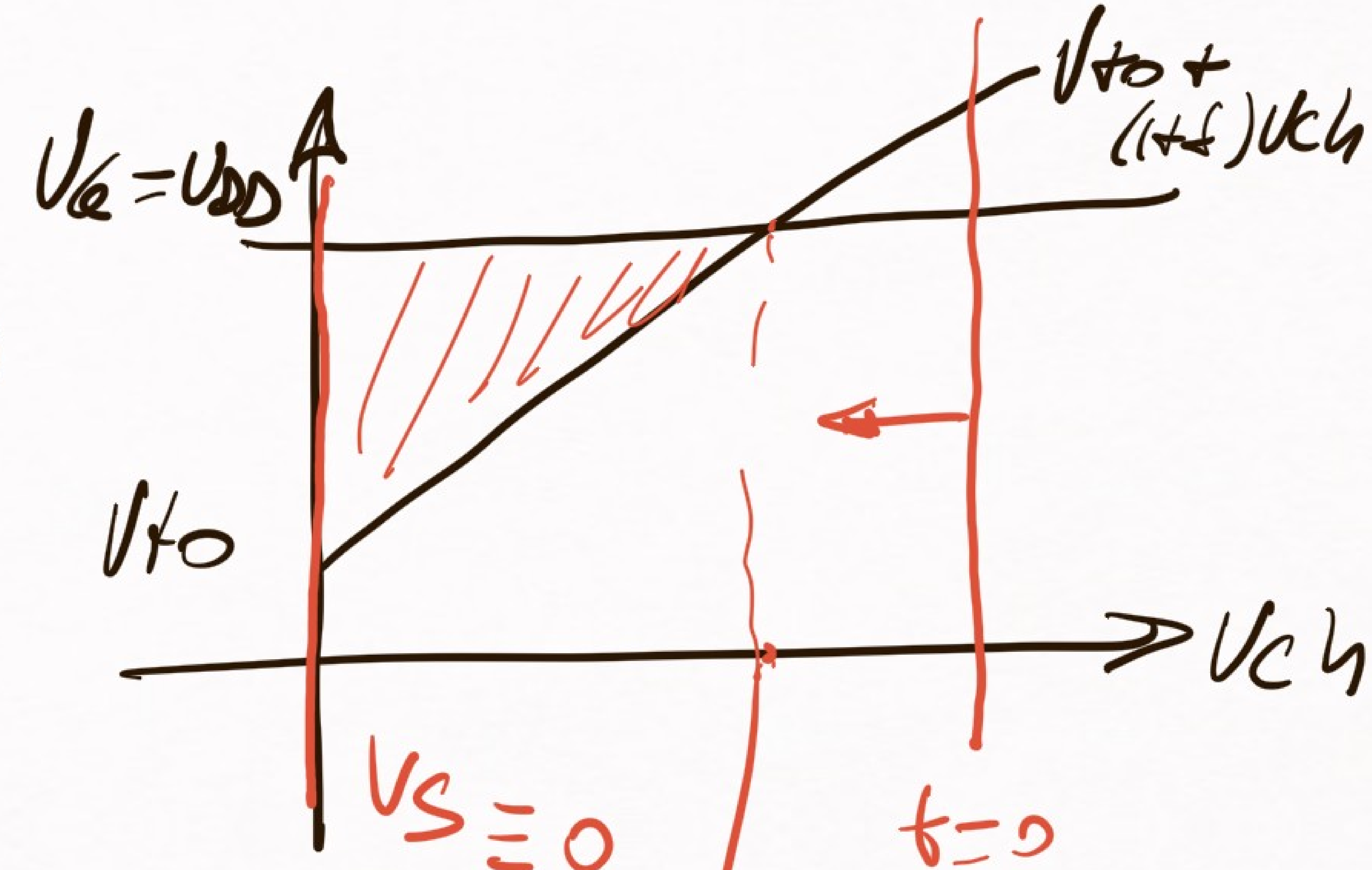


$v_I: 0 \rightarrow V_{DD}$ ($v_I = V_{DD}$) $\Longrightarrow$ p OFF, N conduce



$v_O(t=0) = V_{DD}$





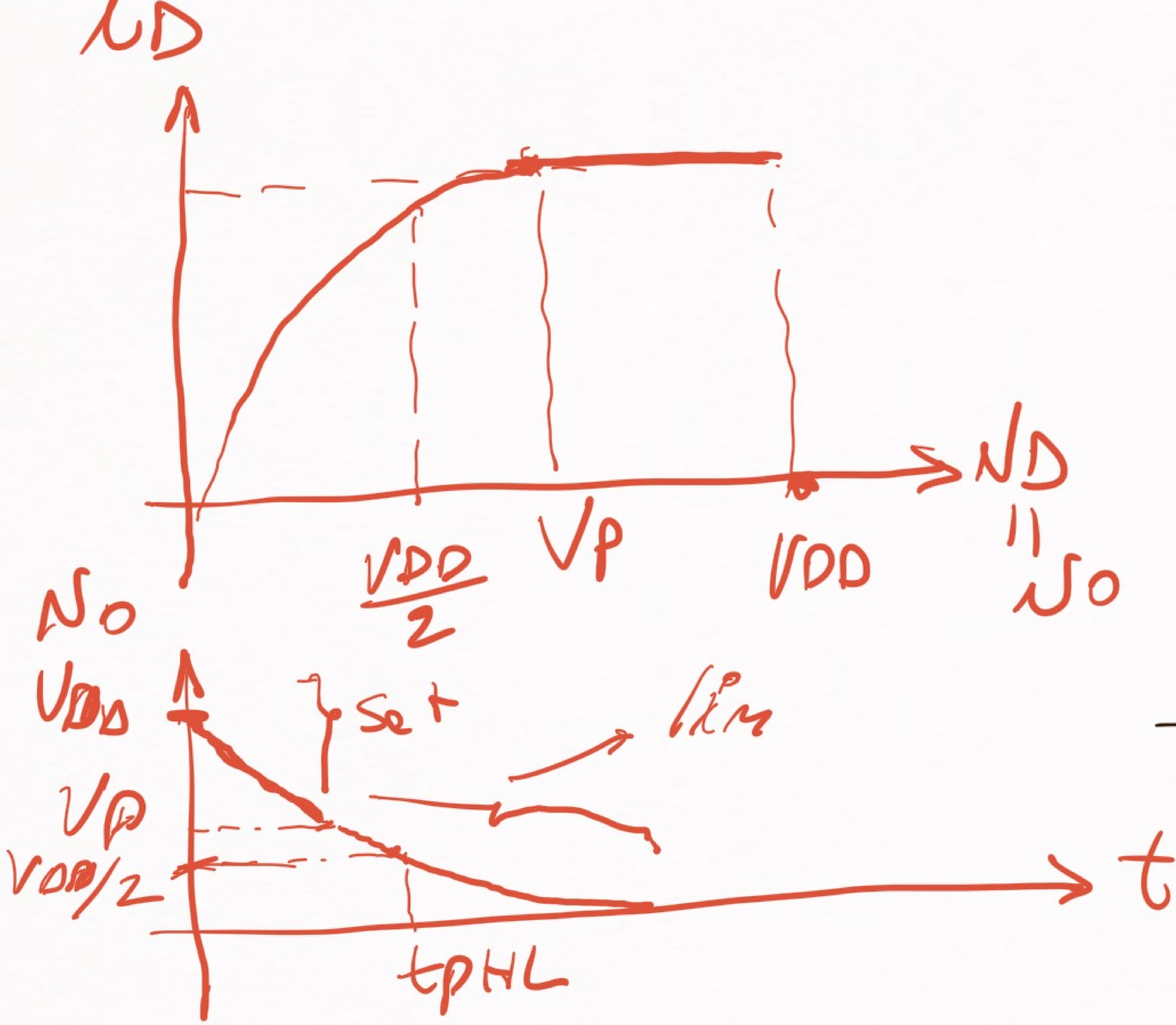
$t = 0$

$V_D = V_{DD}$

$\Downarrow$

$\underline{\text{in sat}}$

$$V_P = \frac{V_G - V_{t0}}{(1+\delta)}$$



$\longrightarrow$

$$t_{pHL} = f\left(\mu \cdot C_{ox} \cdot \frac{W}{L},\ C_L,\ V_{DD},\ V_{t0},\ \delta\right)$$

$$\Rightarrow t_{pHL} = f\left(\mu \cdot C_{ox} \frac{W}{L},\ V_{TO},\ \gamma,\ C_L,\ V_{DD}\right)$$

$\gamma = 0$

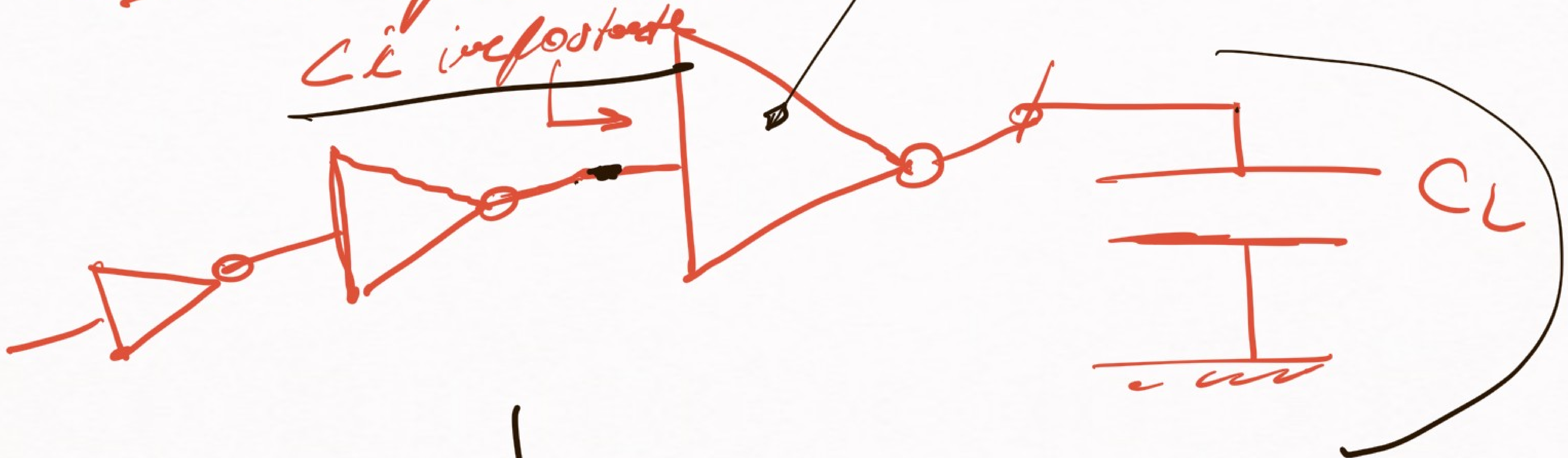
Si $V_{TO} = \frac{1}{5} V_{DD}$ (relación aprox. usual en muchas tecnologías)

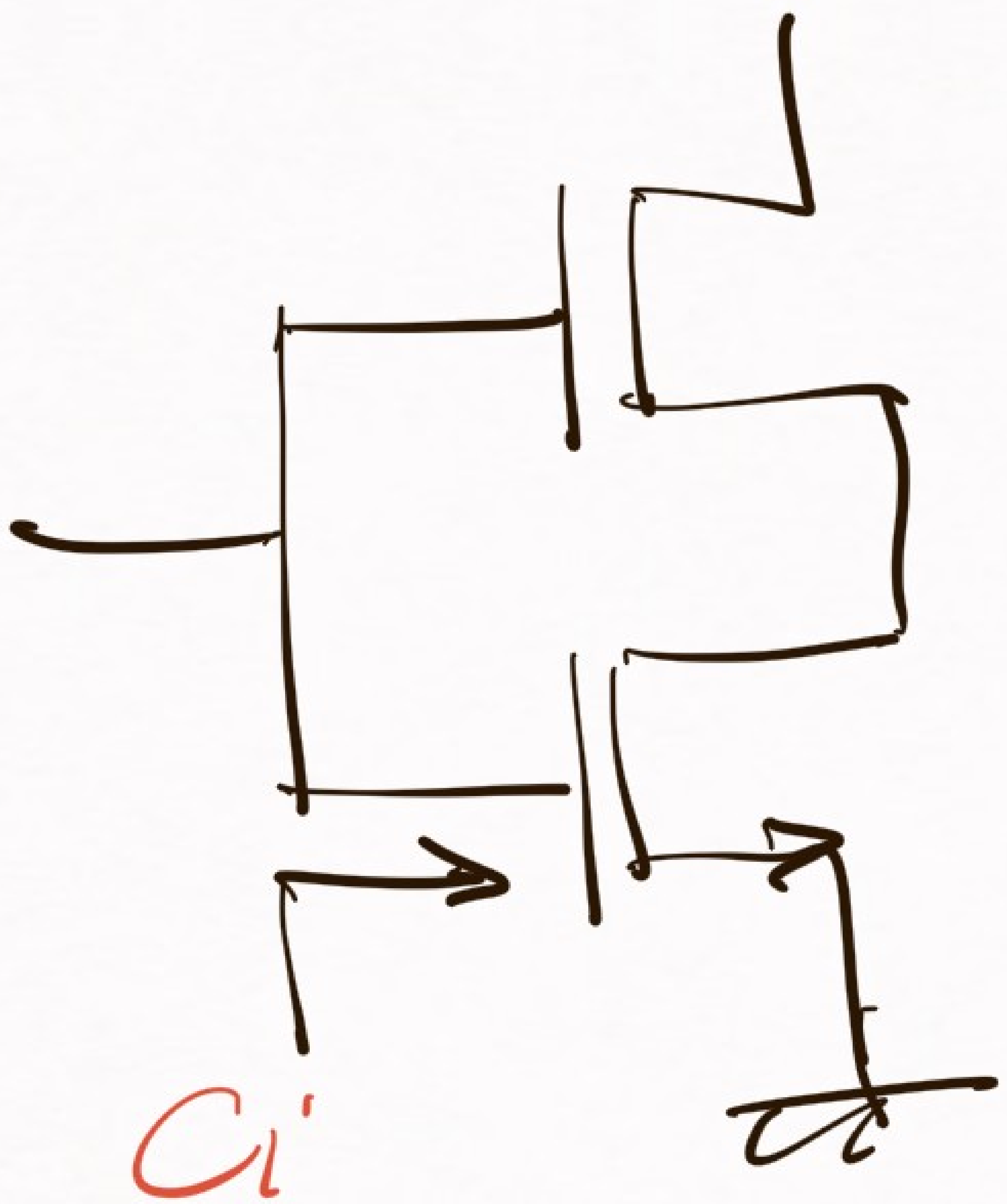
$$\boxed{t_{pHL} \cong \frac{1.6 \cdot C_L}{\underbrace{\mu_n C_{ox} \cdot \left(\frac{W}{L}\right)_n}_{\beta_n} \cdot V_{DD}}}$$

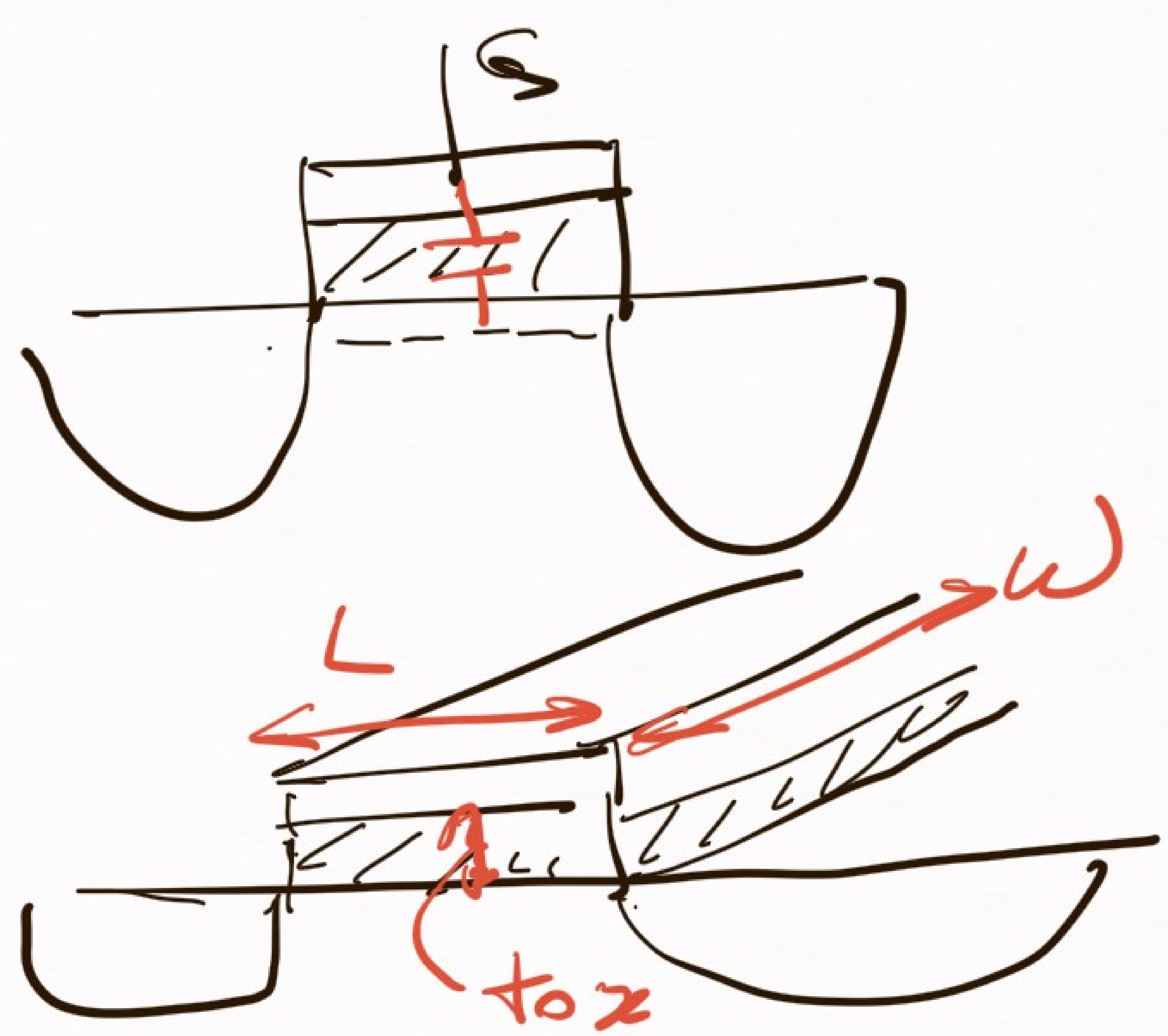
$t_{pHL} \propto C_L$ || $t_{pHL} \propto \frac{1}{V_{DD}}$ || $t_{pHL} \propto \frac{1}{\left(\frac{W}{L}\right)_n}$

$\left(\frac{W}{L}\right)\uparrow \Rightarrow I_{on}\uparrow \Rightarrow t_{pHL}\downarrow$ pero $\Rightarrow$ sube C_L de las etapas anteriores

⇒ Compromiso:







$$C_i \propto W \cdot L \cdot \underbrace{C'_{ox}}_{\frac{\varepsilon_{ox}}{t_{ox}}}$$