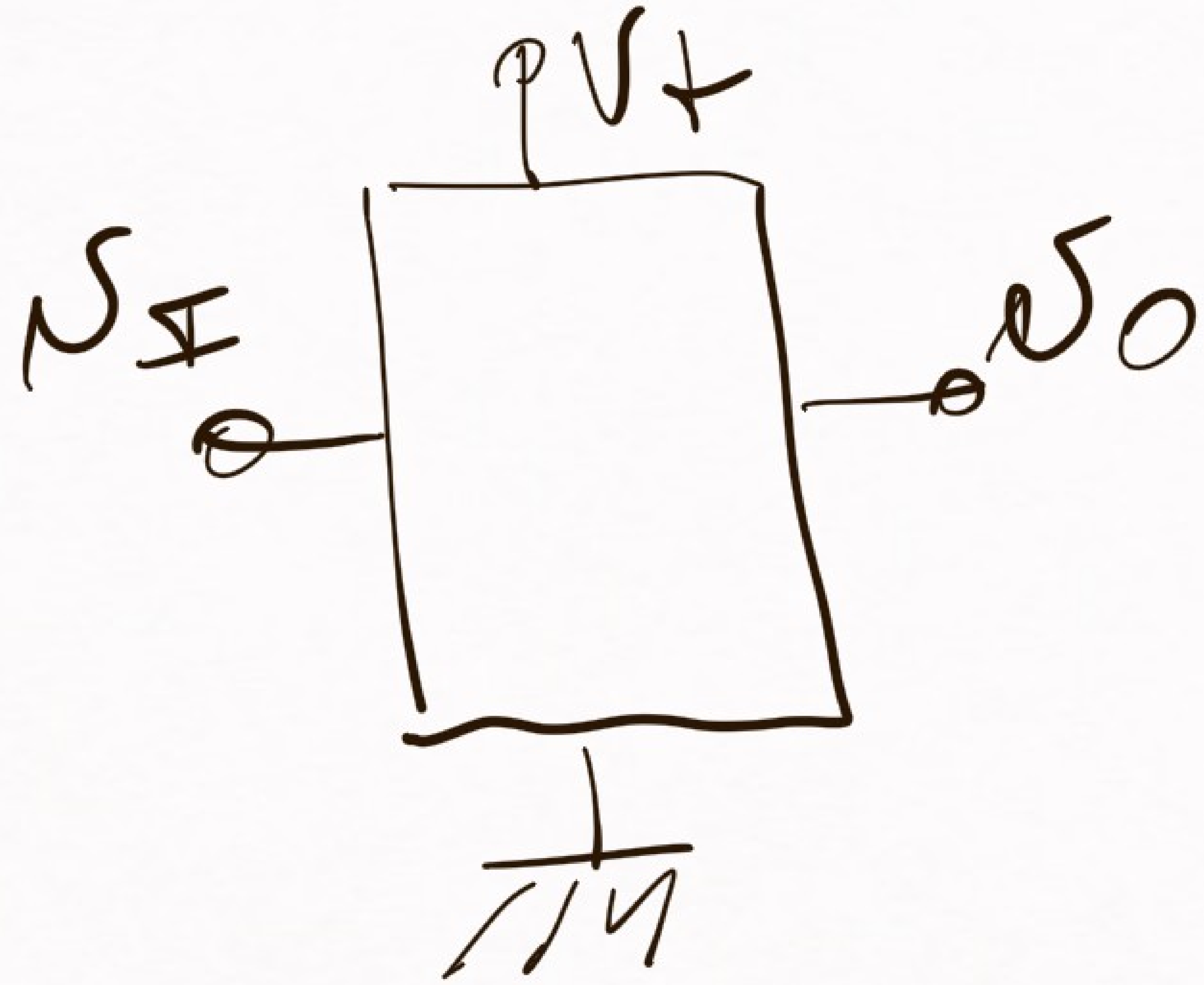
Modelo de peq. señal

13/5/20



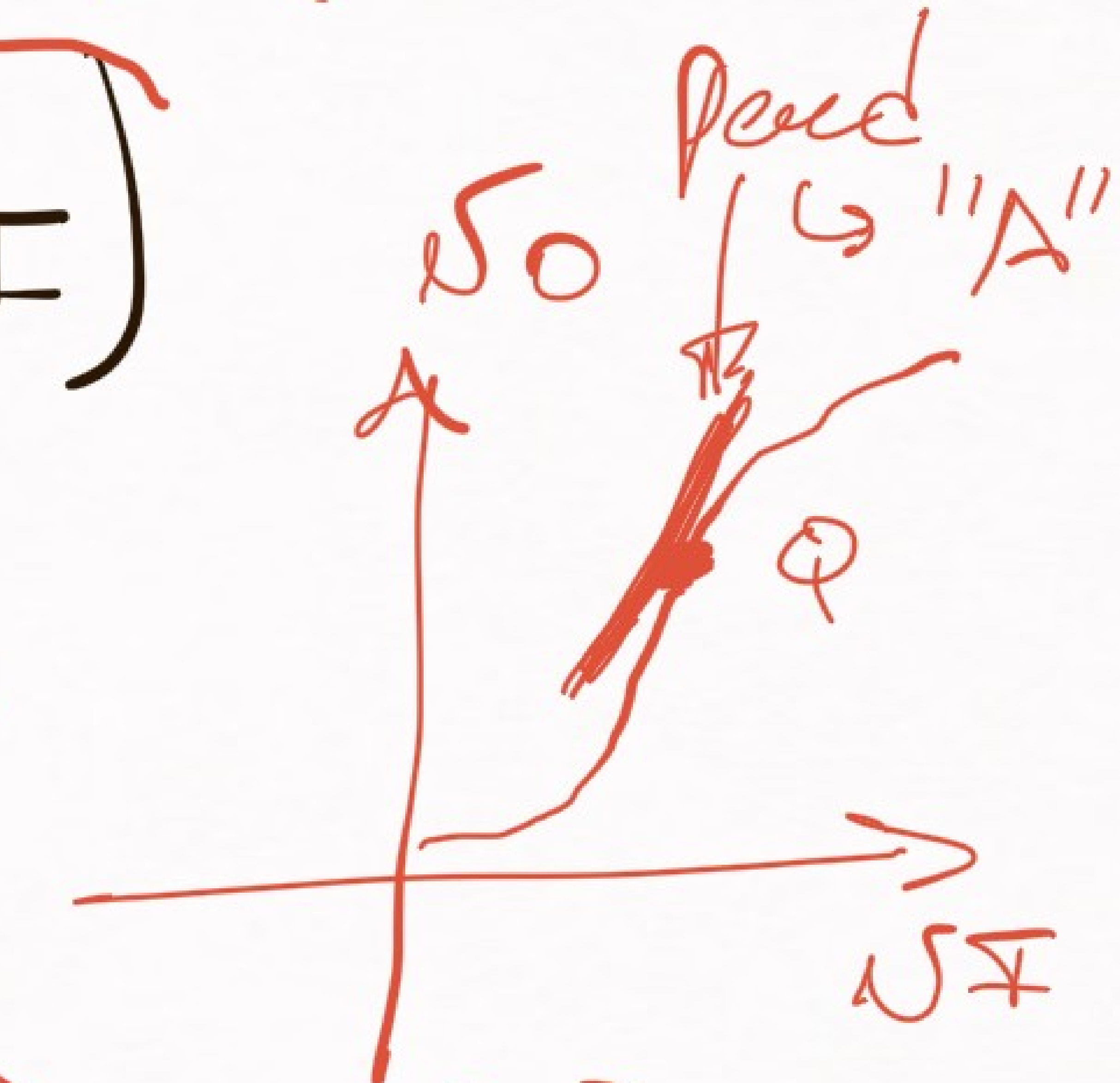
$v_O(v_I)$ ⟶ no lineal

⟹ Desarrollo de Taylor en torno a Q ($v_I = V_I$, $v_O = V_O$)

$$v_O \cong \underbrace{v_O(V_I)}_{\substack{V_O \\ \text{(salida de DC)}}} + \underbrace{\left.\frac{d v_O}{d v_I}\right|_{v_I = V_I}}_{= \text{"A"}} \cdot \overbrace{(v_I - V_I)}^{= v_i \text{ (entrada AC)}}$$

$A(V_I)$, $A(Q)$

$$\boxed{v_O \cong V_O + A \cdot v_i}$$



Aplicación del modelo de peq. señal

$\left(v_O = V_O + A(V_I) \cdot v_i \right)$

SALIDA =

1) Componente DC. (Primer paso es un análisis DC)

$\rightarrow$ $\underline{\underline{V_O}}$

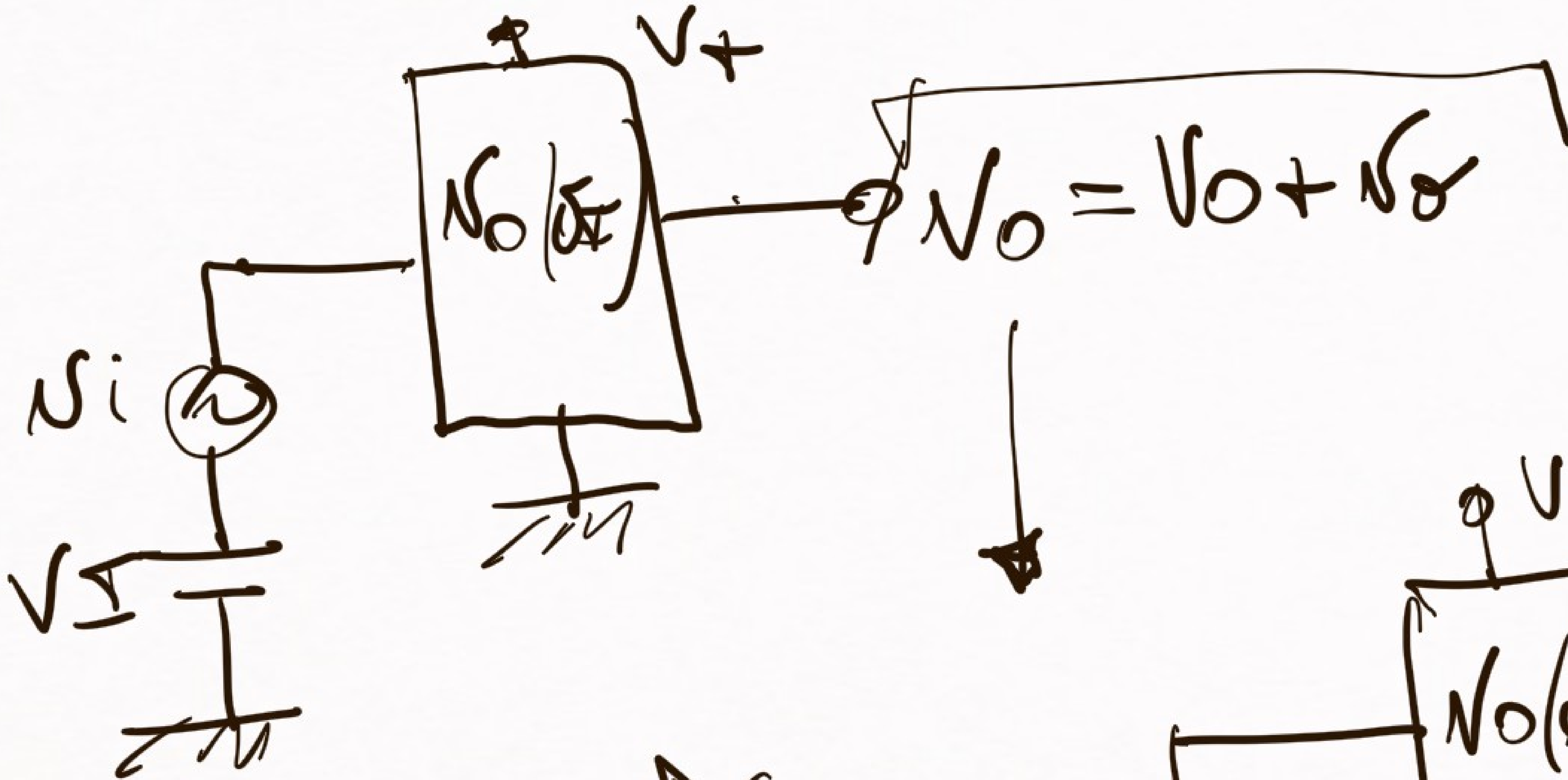
$\Rightarrow$ fuente indeps de AC = 0, C: circ. abierto
L: corto circuito

2) Calcular parámetros del modelo de peq. señal: $A(V_I)$

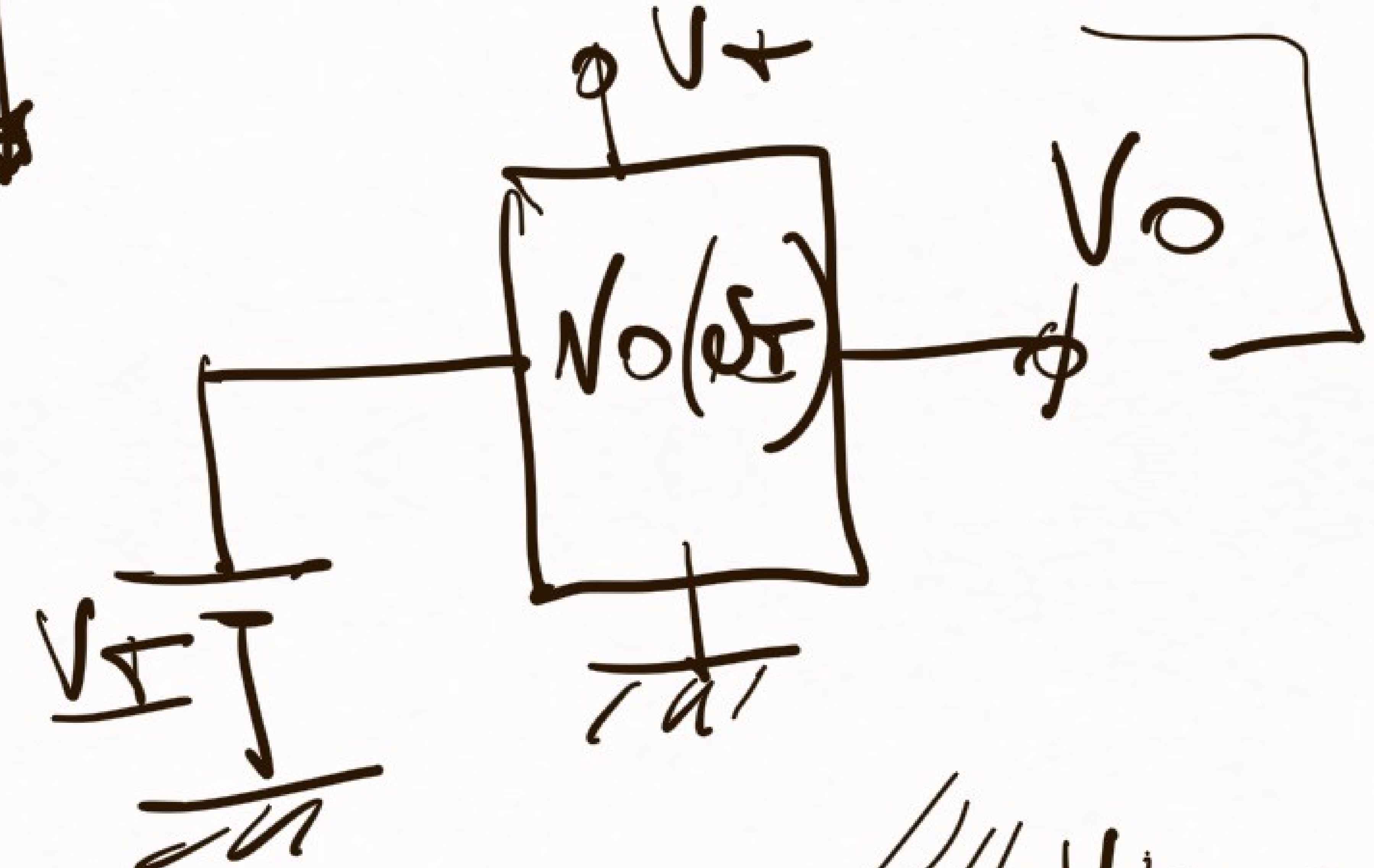
3) Componente AC (análisis AC): $A \cdot v_i$

$\rightarrow$ Fuentes DC puestas en 0:

$V_I = 0$, $V_+ = 0$.

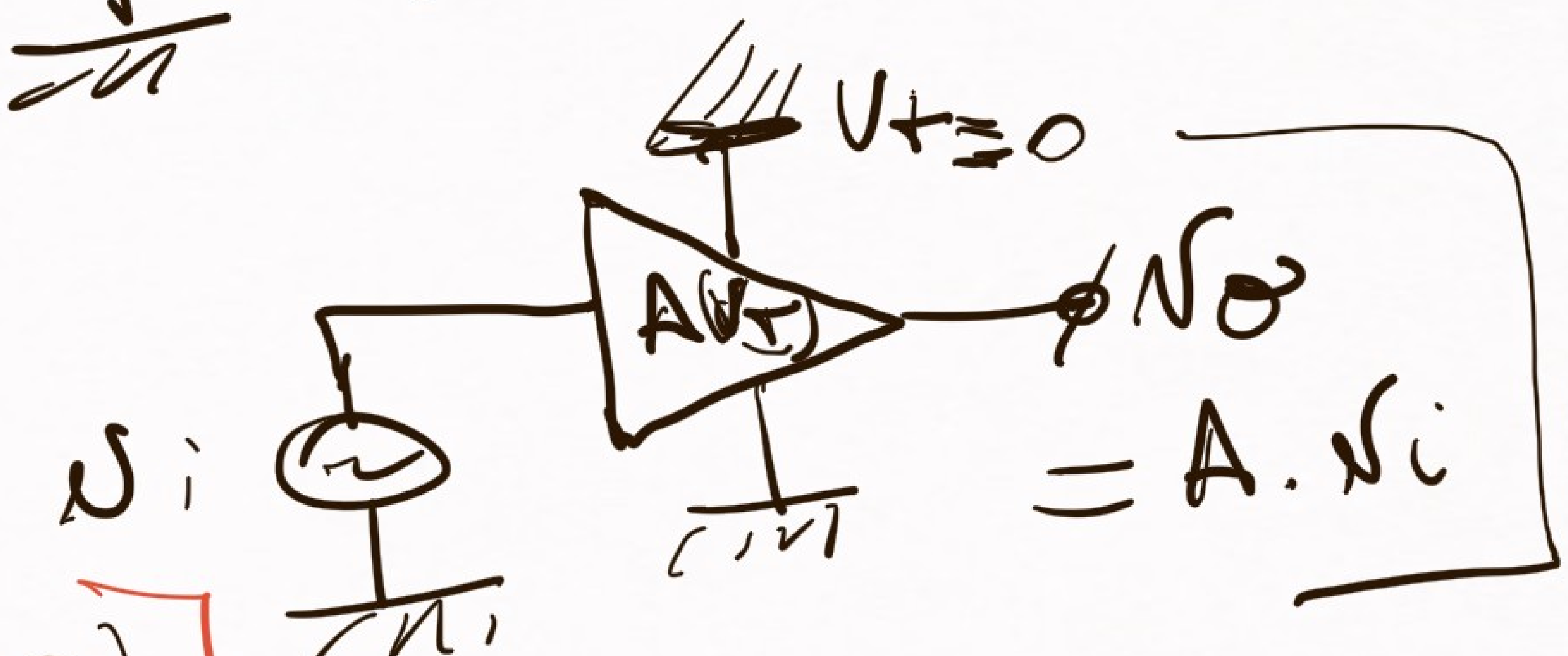


DC:
(vi = 0)



+

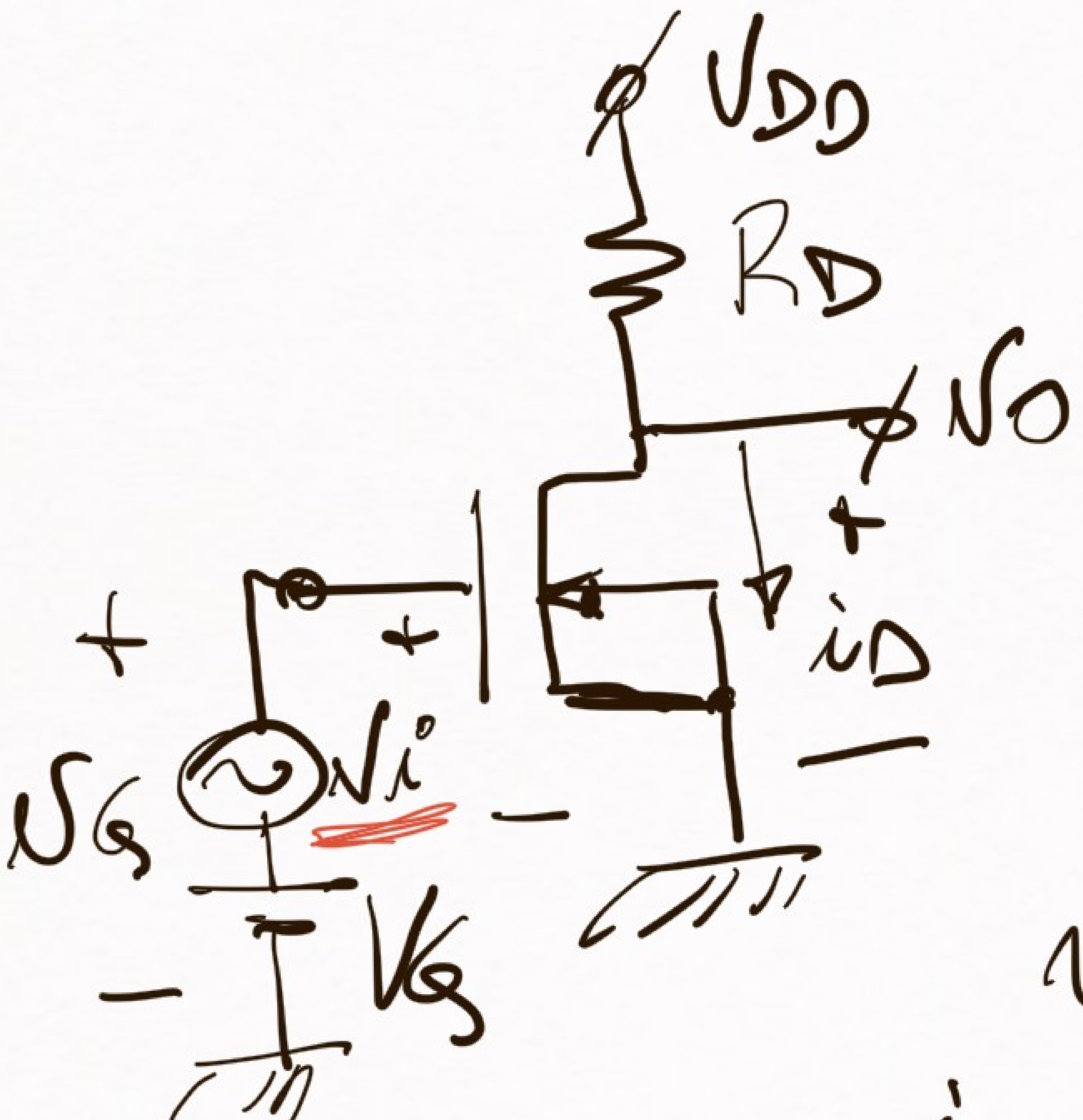
AC
(VI = 0, V+ = 0)
"Modelo de peq. señal"



1) linealización del tr. MOS en caso
$\underline{V_{SB} = 0}$
2) Modelo de peq. señal frcl. del tr. MOS.
3) Ej. de aplic. del modelo de peq. señal a una amp. con transistor MOS

Ej. Tr. MOS como amplificador

Configuración source común



(H) Tensiones y R_D tales que el Tr. opere en saturación.

$$v_O = V_{DD} - R_D \cdot i_D$$

$$i_D = \underbrace{\frac{\beta}{2(1+\delta)}\left(v_G - V_{to}\right)^2}_{\text{despreciando efecto de modulación de largo de canal}}$$

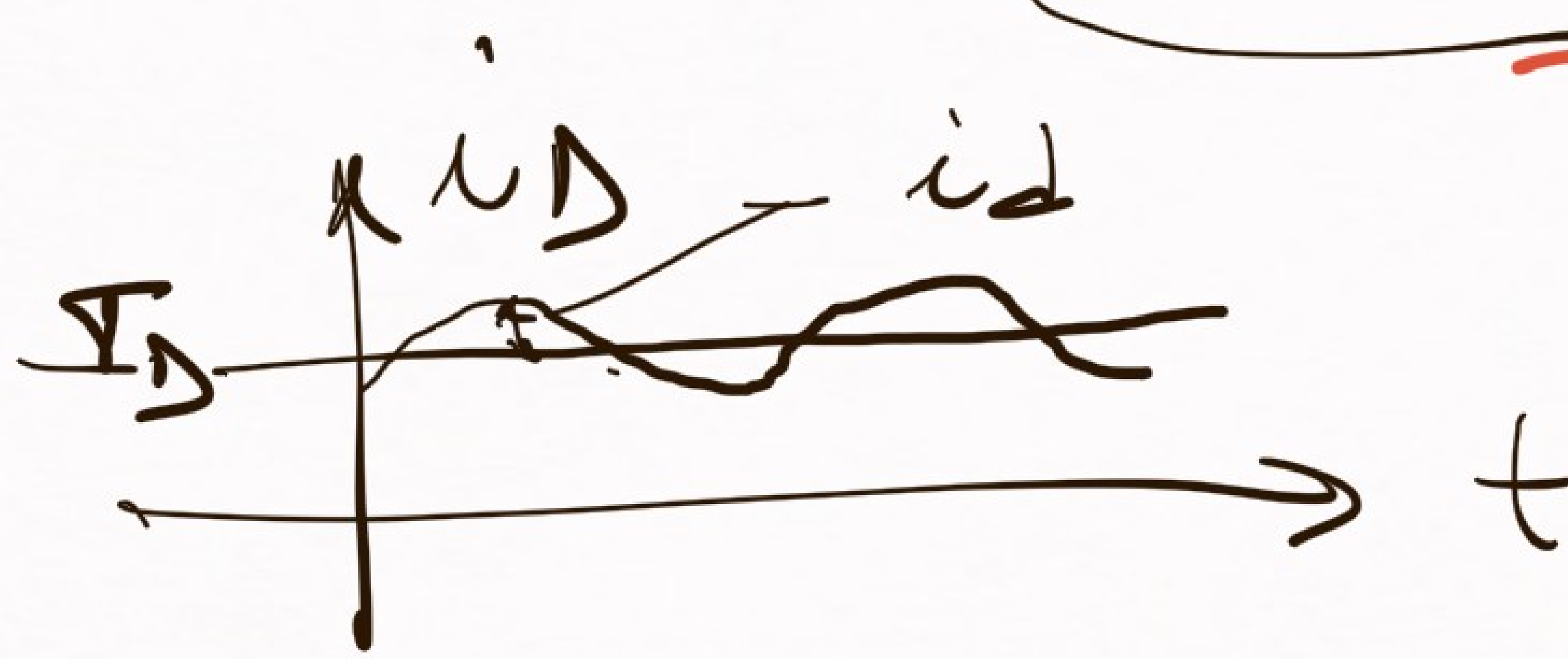
Linealizamos $i_D(v_G)$

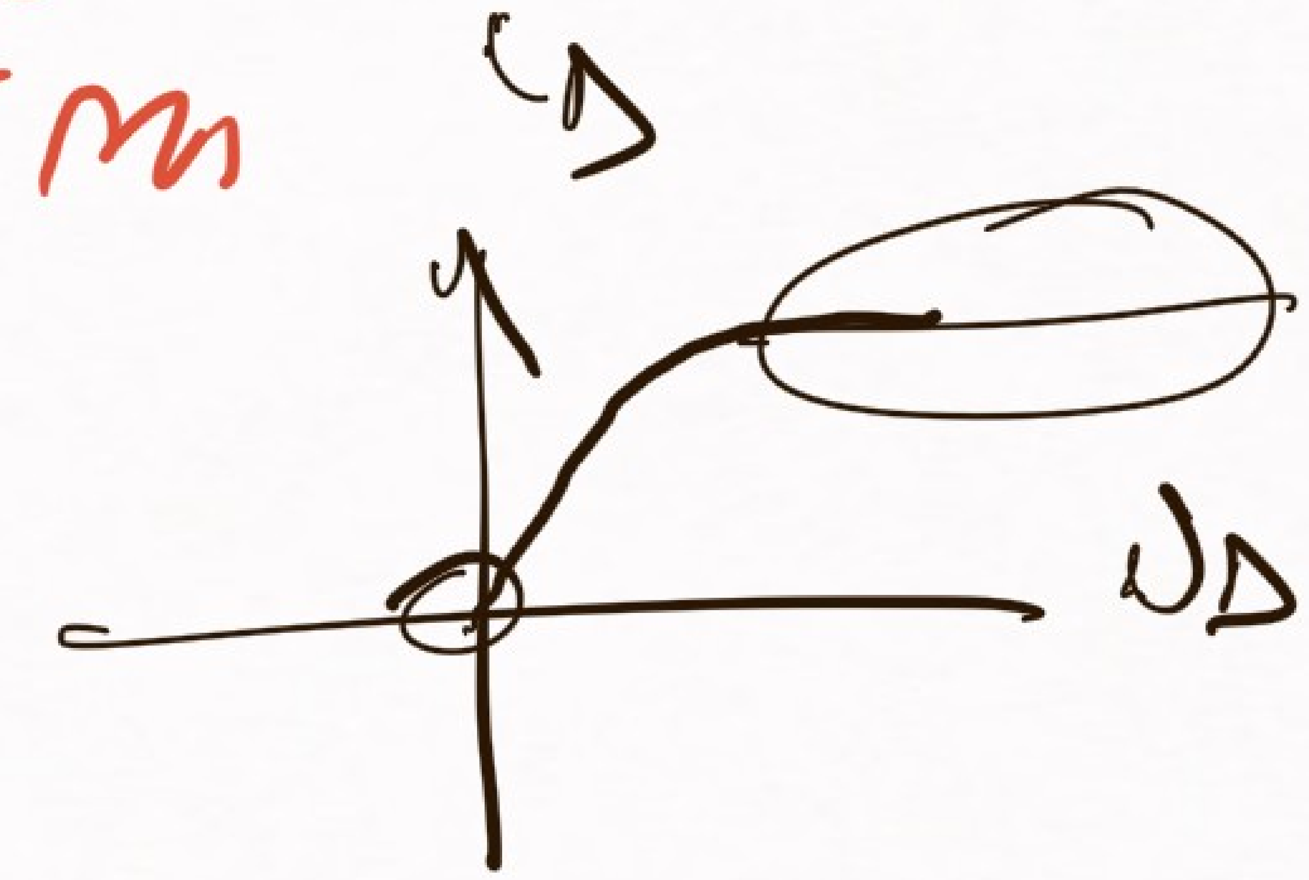
$$\underbrace{i_D}_{\text{total}} = \overbrace{I_D}^{DC} + \overbrace{\underbrace{\frac{\partial i_D}{\partial v_G}\Big|_{V_G}}_{g_m} \cdot \underbrace{(v_G - V_G)}_{v_g = v_i}}^{\rightarrow\, i_d}$$

$$i_D = \frac{\beta}{2(1+\delta)}(v_G - V_{T0})^2$$

$g_m \rightarrow$ transconductancia de fete

$$\Rightarrow \frac{\partial i_D}{\partial v_G}\Big|_{V_G} = \frac{\beta}{(1+\delta)}(V_G - V_{T0}) = \sqrt{\frac{2\beta \cdot I_D}{(1+\delta)}} = g_m$$



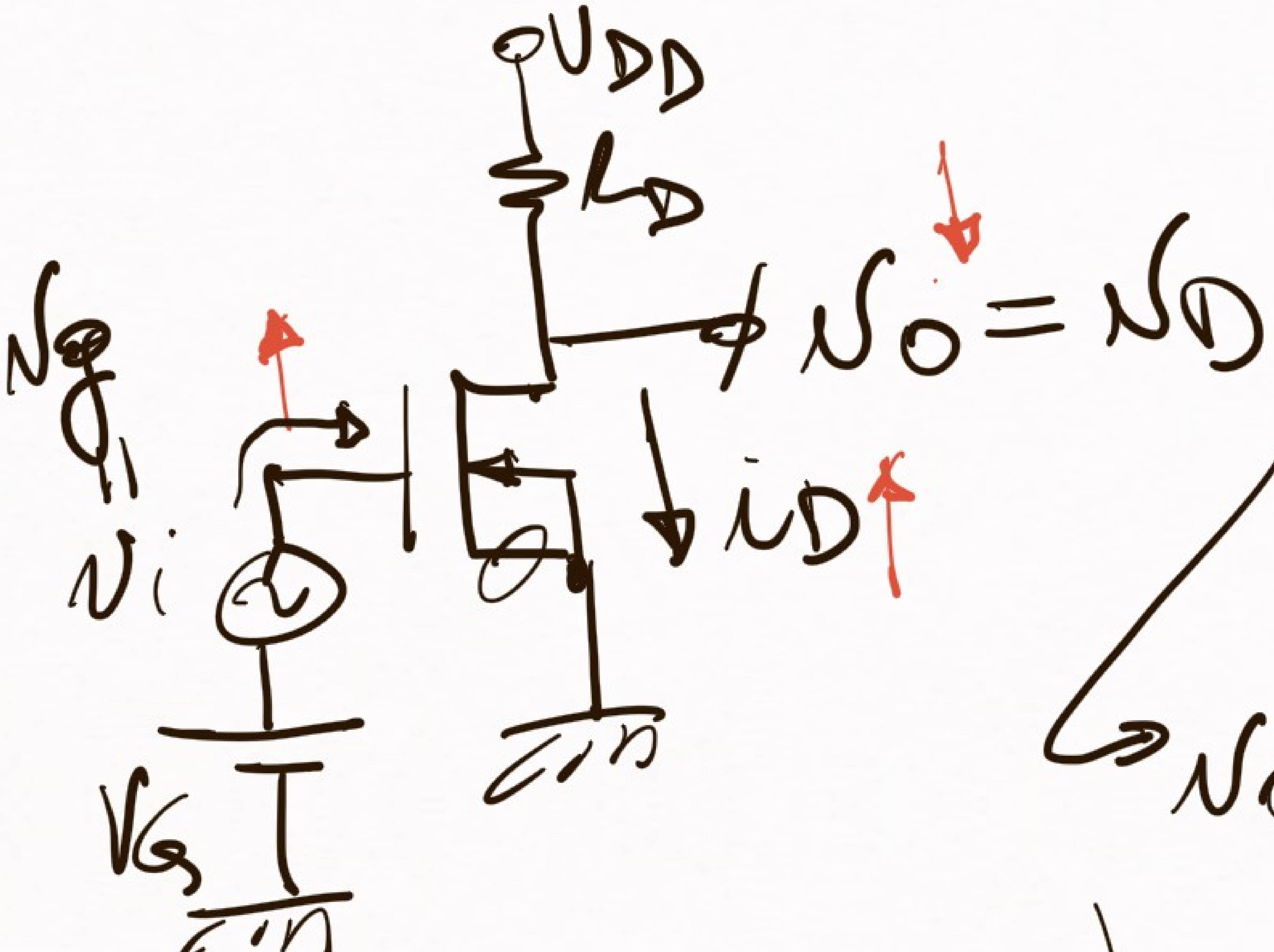


$$g_{m1} = \frac{\beta}{(1+\delta)} \left(V_G - V_{t0} \right)$$

$$i_D = \frac{\beta}{2(1+\delta)} \left(V_G - V_{t0} \right)^2$$

DC

$$I_D = \frac{\beta}{2(1+\delta)} \left(V_G - V_{t0} \right)^2 \Rightarrow \left(V_G - V_{t0} \right) = \sqrt{\frac{2 \cdot (1+\delta) I_D}{\beta}}$$

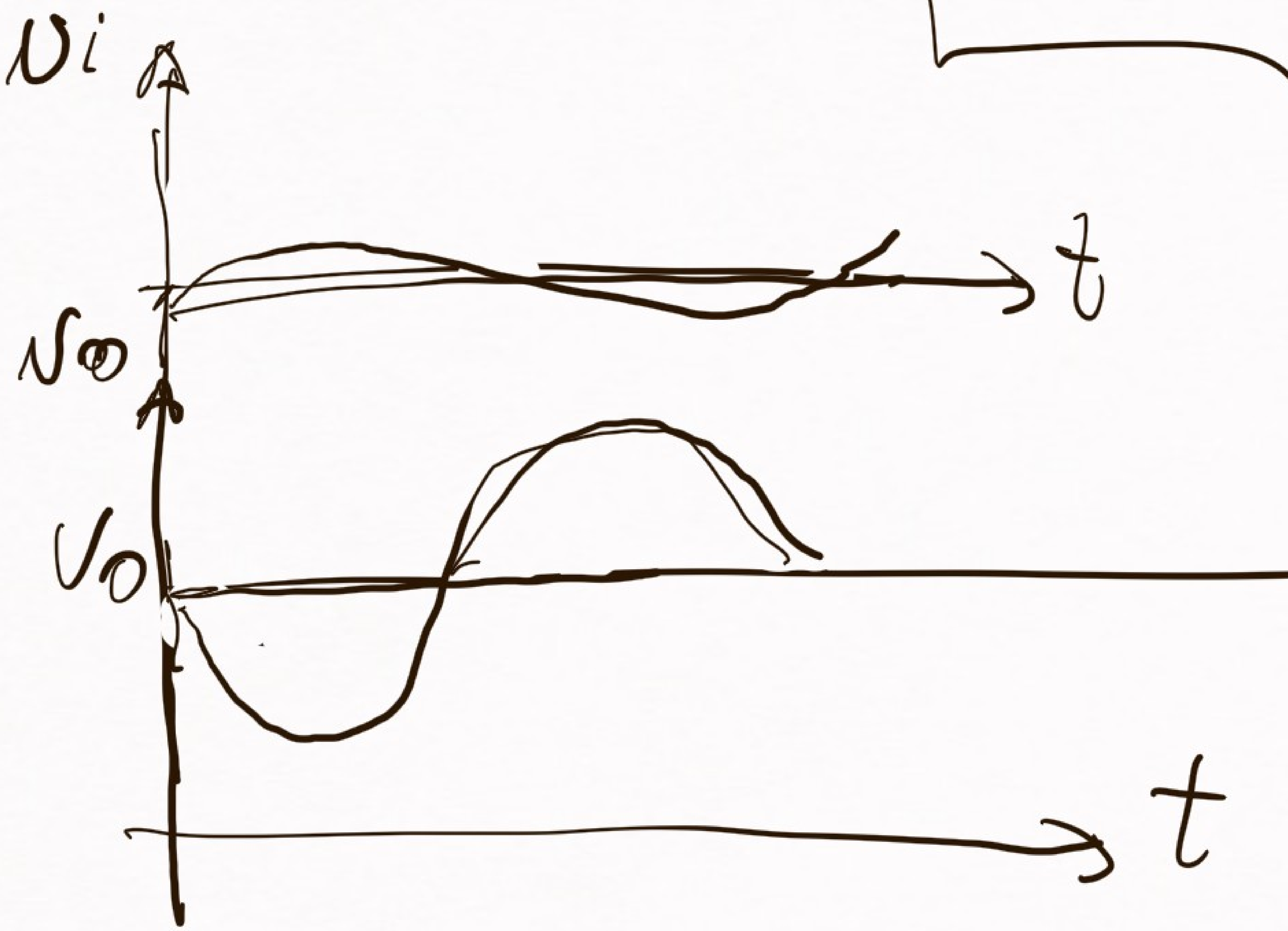


$$\begin{cases} v_O = V_{DD} - R_D \cdot i_D \\ i_D \cong I_D + g_m \cdot v_i \end{cases}$$

gonorcie

$$v_O \cong \underbrace{V_{DD} - R_D \cdot I_D}_{= V_O} \underbrace{- R_D \cdot g_m \cdot v_i}_{v_o}$$

$$V_O + v_o$$



$$\boxed{v_O = V_O \underbrace{- g_m \cdot R_D}_{\uparrow\ \text{ganancia}} \, v_i}$$

<u>Ej:</u> $R_D = 1.8k$, $\boxed{I_D = 1 mA}$

$\beta = 2 mA/V^2$, $\delta = 0.5$, $V_{t0} = 1V$

$$\Rightarrow g_m = \sqrt{\frac{2\beta I_D}{(1+\delta)}} = 1.6 \ mS \quad (mA/V)$$

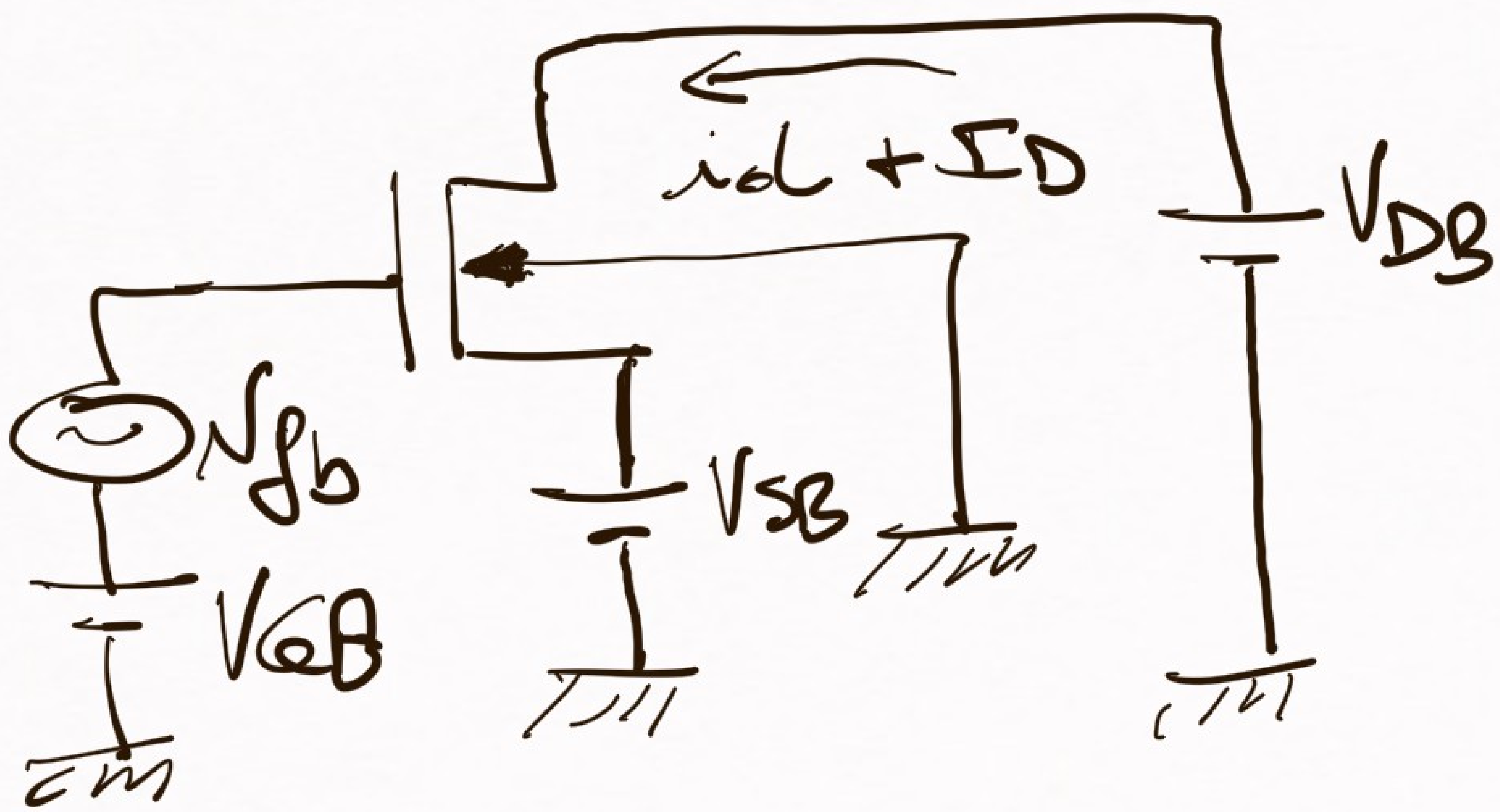
$$mS \rightarrow A/V$$

$$= 1.6 \times 10^{-3} \ S$$

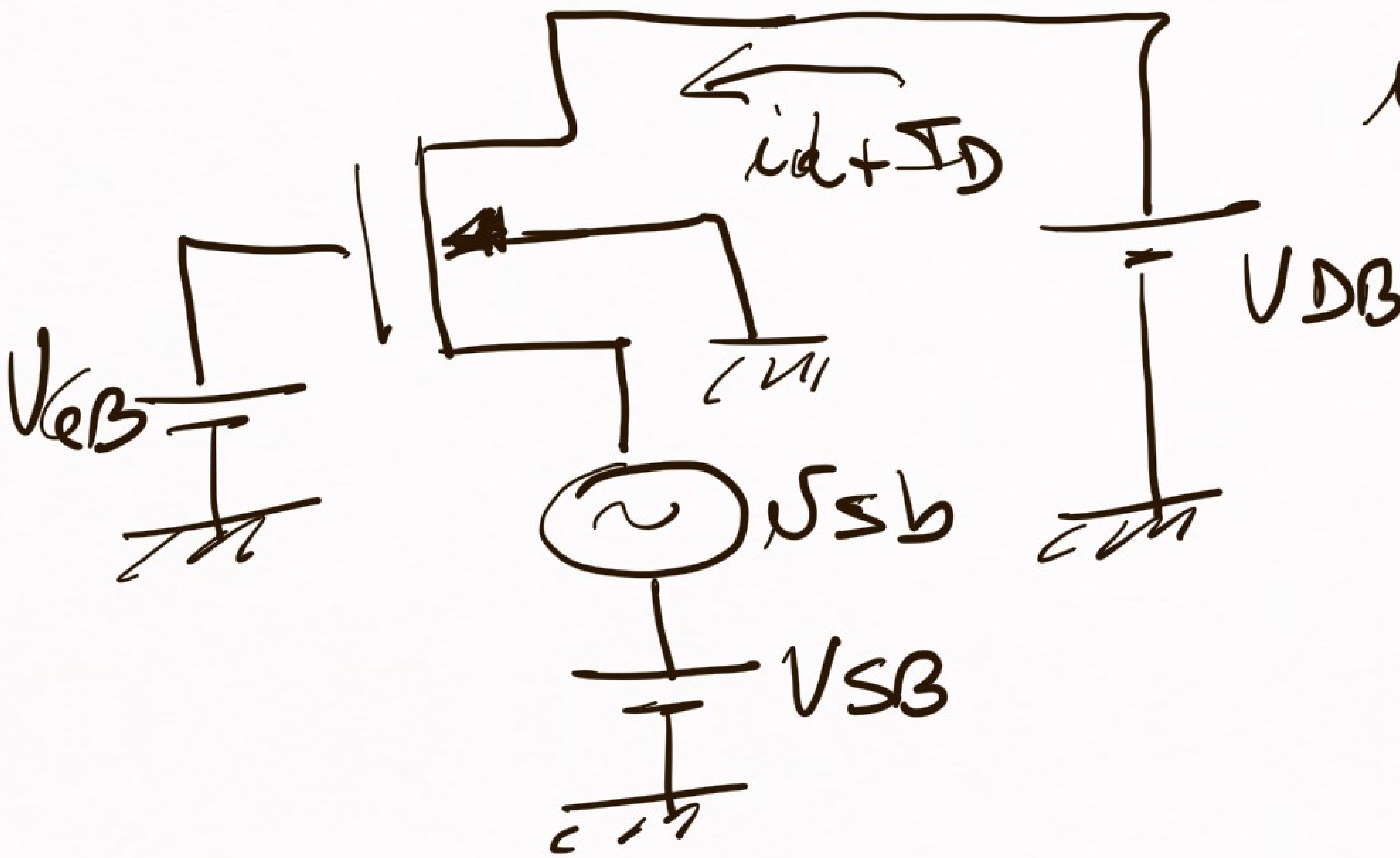
$$\Rightarrow \text{Ganancia} = -g_m \cdot R_D = \underline{-2.9 \ V/V}$$

Modelo de pequeña señal y baja frecuencia del transistor MOS

Referido al sustrato

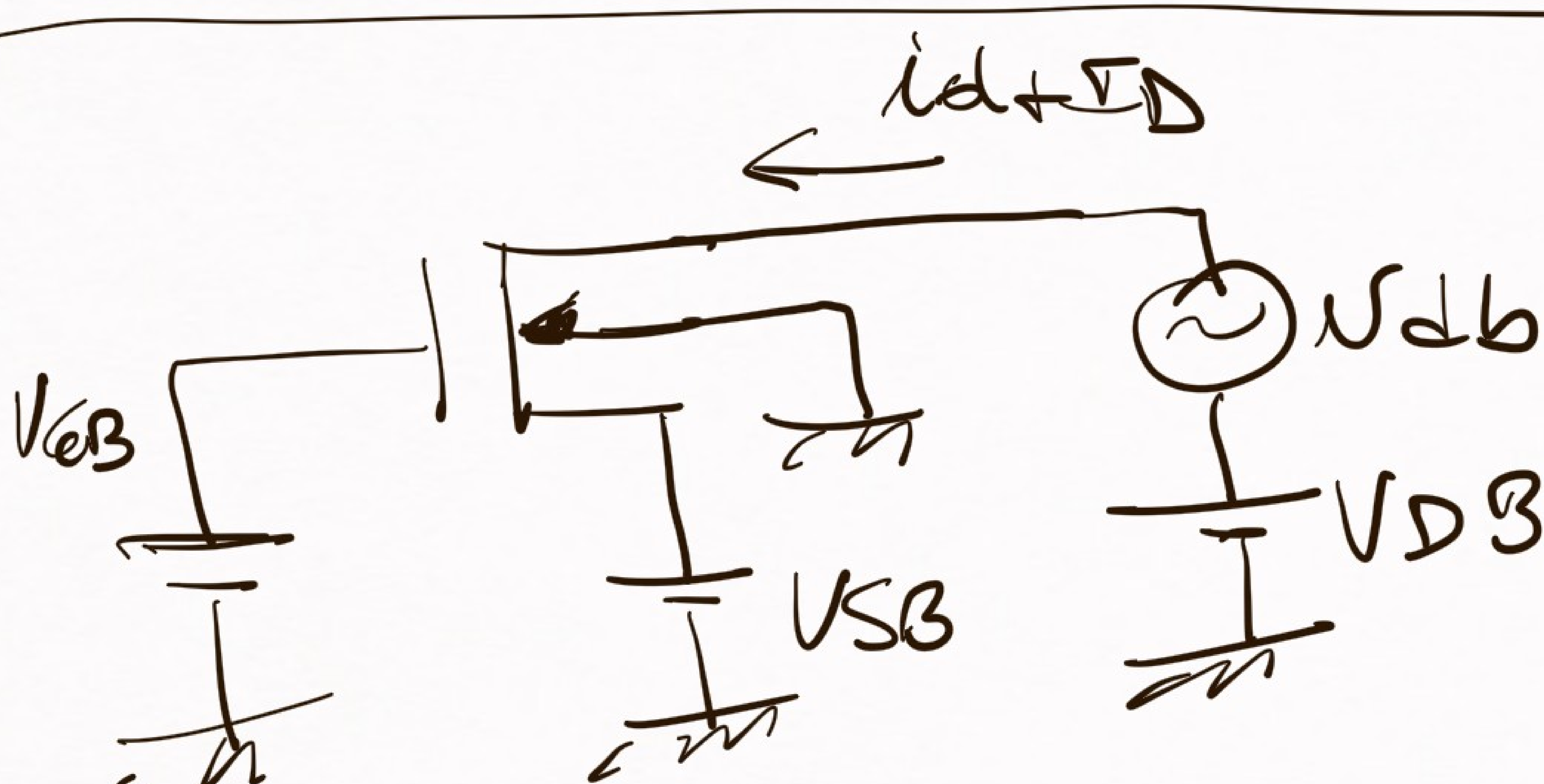


$$i_d = \overbrace{\left.\frac{\partial i_D}{\partial v_{GB}}\right|_{V_{GB},V_{SB},V_{DB}}}^{= g_m} \cdot v_{gb}$$



$$i_d = \left.\frac{\partial i_D}{\partial v_{SB}}\right|_{V_{GB},\, V_{SB},\, V_{DB}} \cdot v_{sb}$$

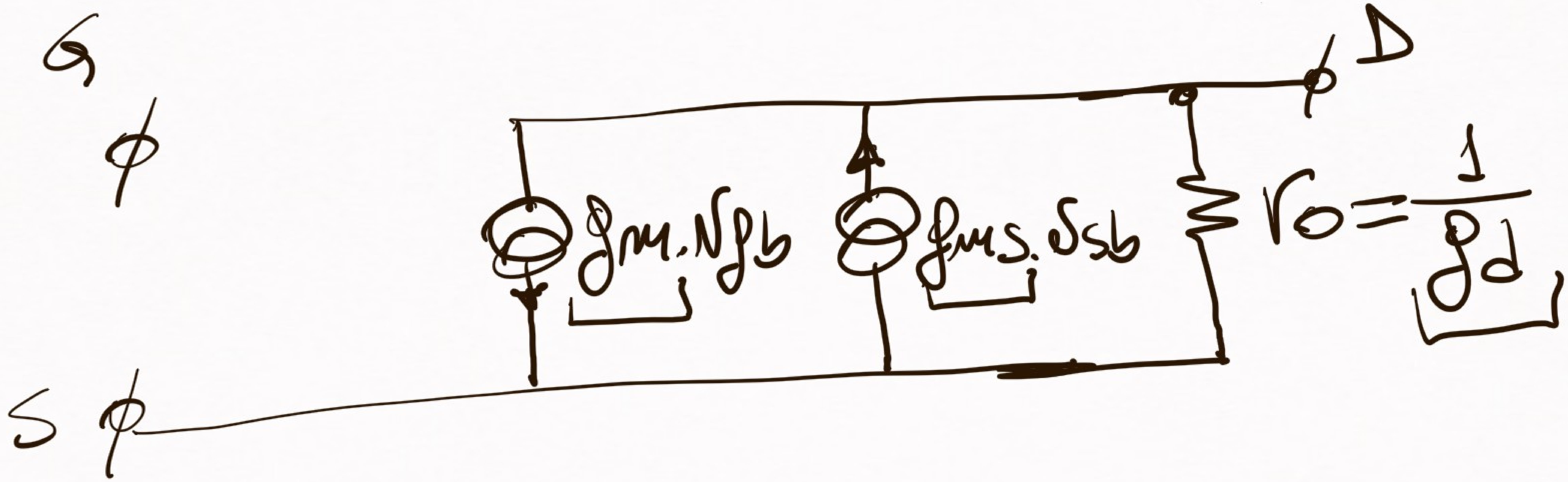
$$-g_{ms}$$



$$i_d = \left.\frac{\partial i_D}{\partial v_{DB}}\right|_{V_{GB},\, V_{SB},\, V_{DB}} \cdot v_{db}$$

$$g_d = \frac{1}{r_o}$$

⇒ Modelo de peq. señal y baja frec referido al sustrato:



$$\left[i_D = \frac{\beta}{2(1+\delta)} \left(v_{GB} - V_{t0} - (1+\delta) v_{SB} \right)^2 \left(1 + \frac{v_{DB}}{V_A} \right) \right]$$

$$g_m = \frac{\partial i_D}{\partial v_{GB}} = \sqrt{\frac{2\beta}{(1+\delta)} \cdot I_D}$$

$$g_{ms} = \frac{-\partial i_D}{\partial v_{SB}} =$$

$$\frac{\partial i_D}{\partial v_{GB}} = \frac{\beta}{\cancel{2}(1+\delta)} \cdot \cancel{2}\left(v_{GB} - V_{t0} - (1+\delta)\, v_{SB}\right)\left(1 + \frac{v_{DB}}{V_A}\right)$$

$$\boxed{\left(v_{GB} - V_{t0} - (1+\delta)\, v_{SB}\right)}$$

$$i_D = \frac{\beta}{2(1+\delta)} \cdot \left(v_{GB} - V_{t0} - (1+\delta)\, v_{SB}\right)^2 \cdot \left(1 + \frac{v_{DB}}{V_A}\right)$$

$$\left(V_{GB} - V_{t0} - (1+\delta)\, V_{SB}\right) = \sqrt{\frac{2(1+\delta)}{\beta\left(1 + \frac{V_{DB}}{V_A}\right)} \cdot I_D}$$

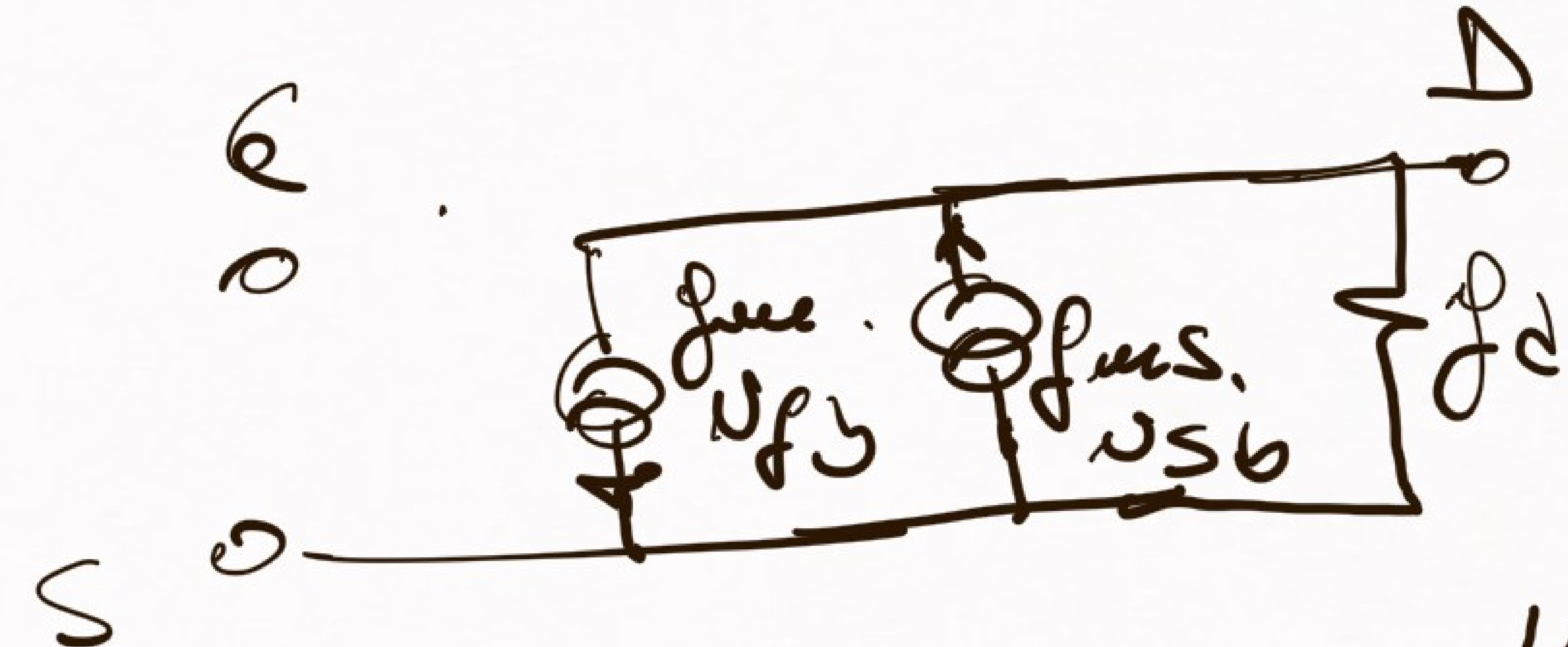
$$\frac{\partial i_D}{\partial v_{GB}} = \frac{\beta}{(1+\delta)}\sqrt{\frac{2(1+\delta)}{\beta\left(1+\frac{v_{DB}}{V_A}\right)}\cdot I_D}\cdot\left(1+\frac{v_{DB}}{V_A}\right)$$

$$= \sqrt{\frac{\beta 2}{(1+\delta)}\cdot I_D\cdot\cancel{\left(1+\frac{v_{DB}}{V_A}\right)}}$$

$$\frac{\partial i_D}{\partial v_{GB}} = \boxed{g_m = \sqrt{\frac{2\beta}{(1+\delta)} I_D}}$$

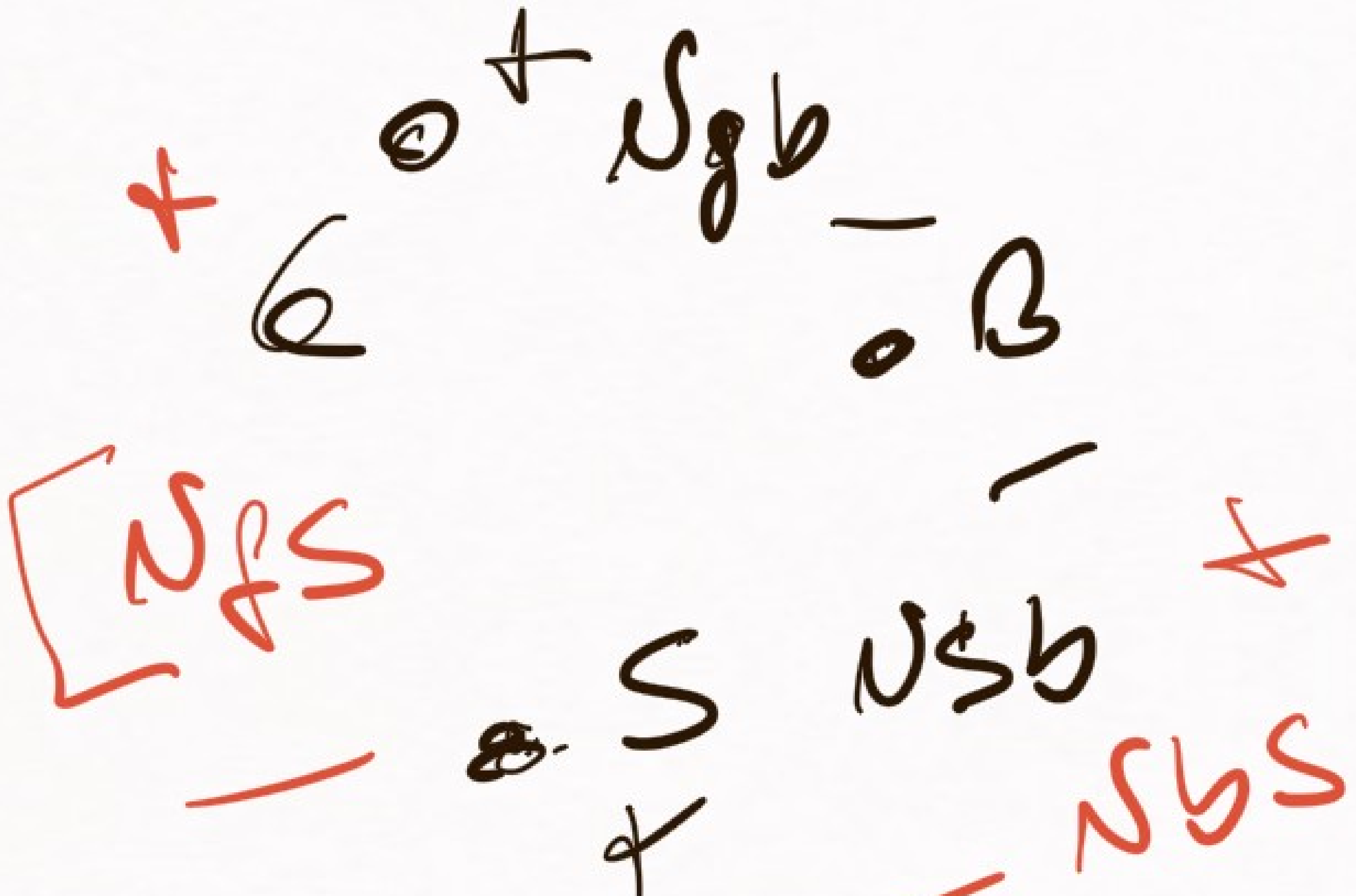
$$g_{ms} = -\frac{\partial i_D}{\partial v_{SB}} = -\left(-(1+\delta)\right) \underbrace{\frac{\beta}{(1+\delta)} \left(V_{GB} - V_{T0} - (1+\delta) V_{SB}\right)}_{= g_m}$$

$$\Longrightarrow \boxed{g_{ms} = (1+\delta) \cdot g_m}$$



$$\boxed{g_d = \frac{\partial i_D}{\partial v_{DB}} \cong \frac{I_D}{V_A}}$$

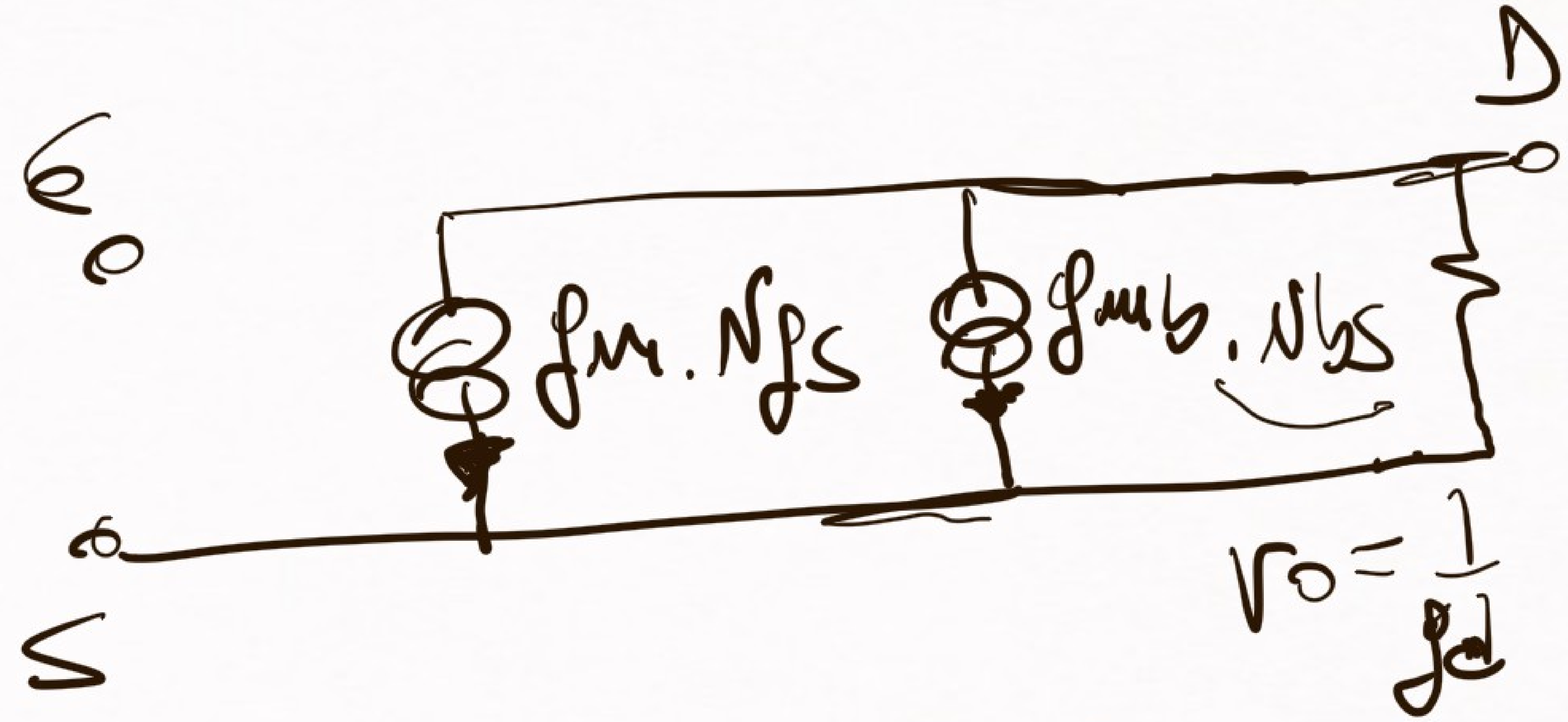
Modelo referido a la source



$$v_{gb} = v_{gs} - v_{bs}$$

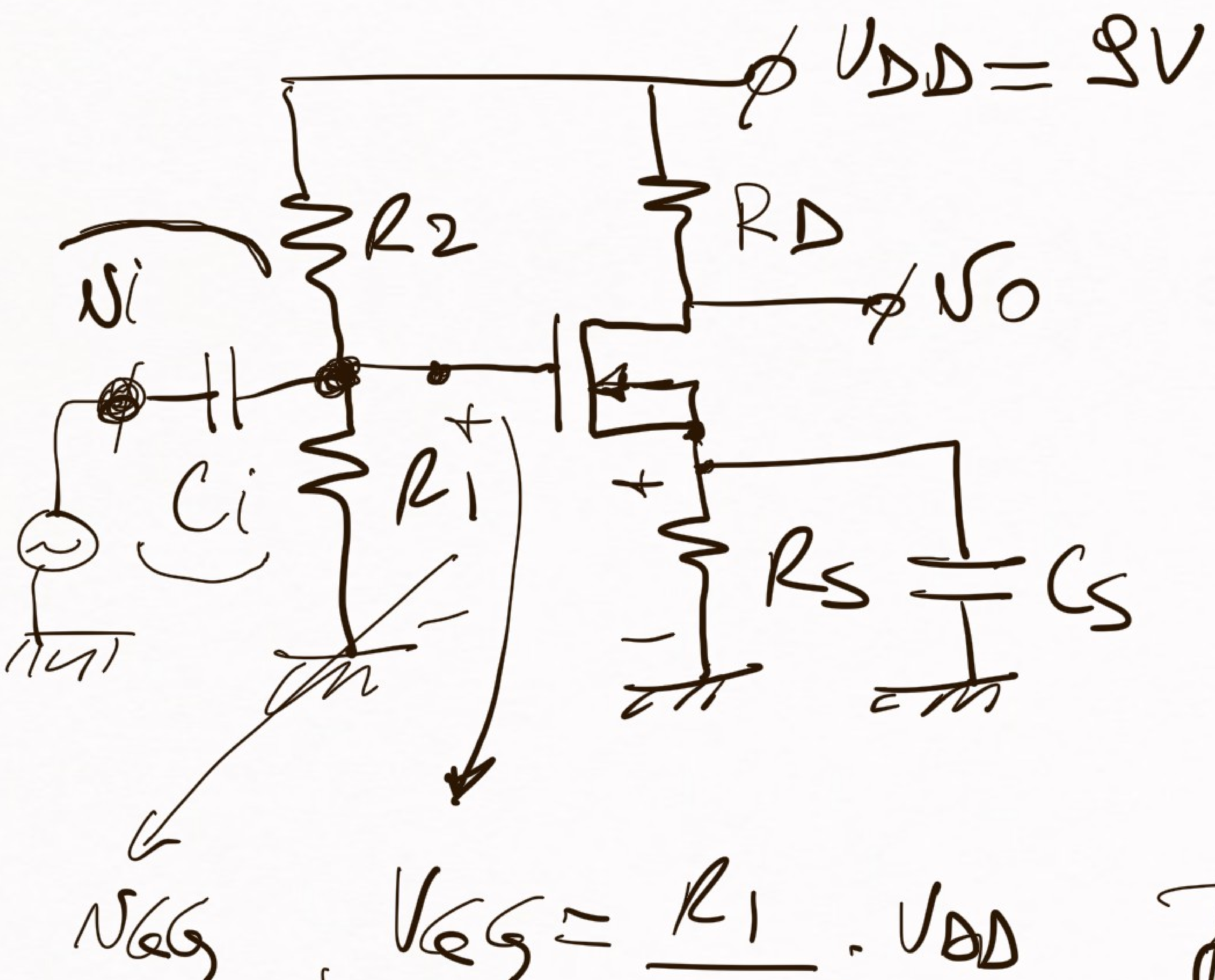
$$v_{sb} = -v_{bs}$$

$$v_{db} = v_{ds} - v_{bs}$$

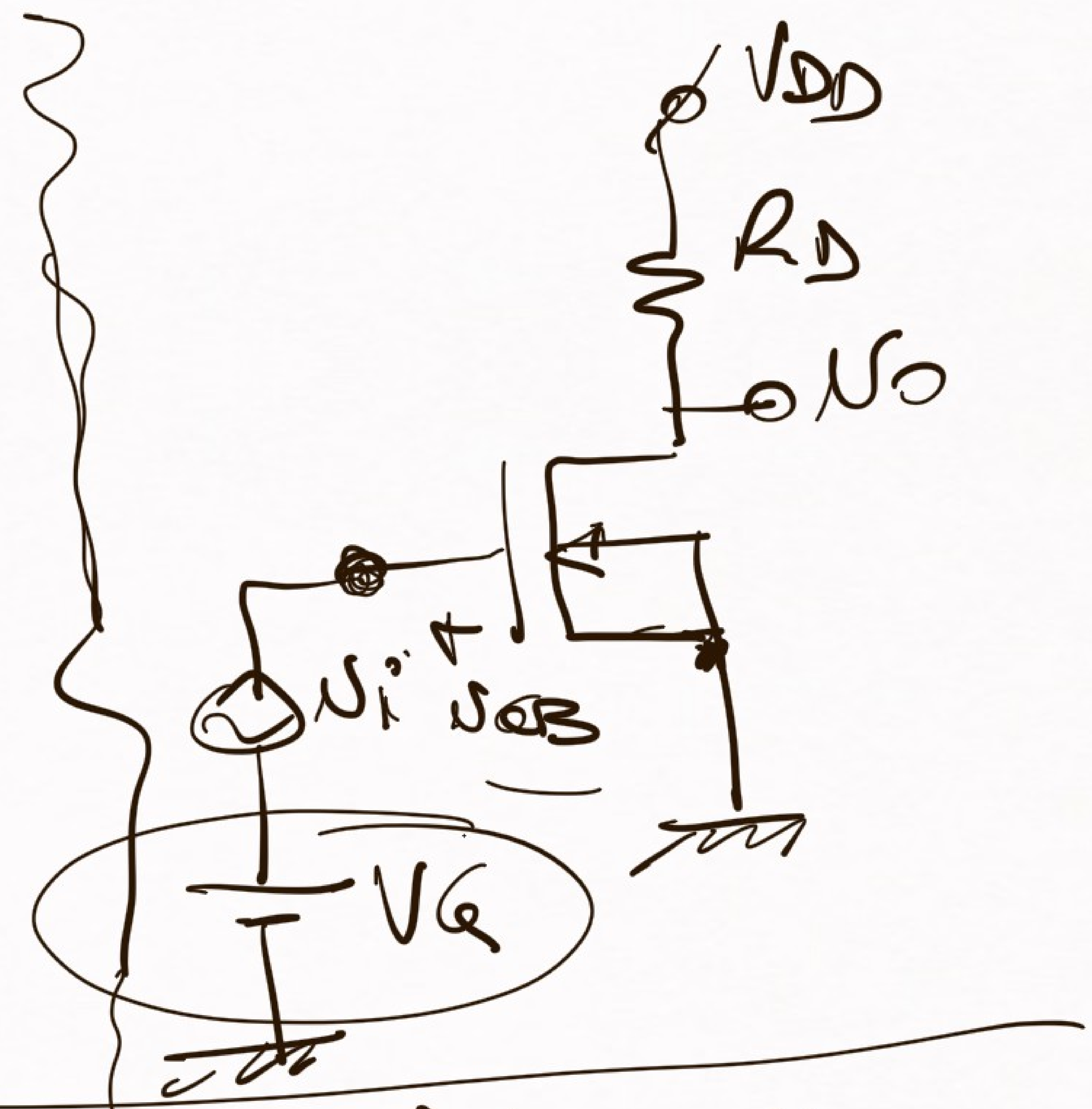


$$\boxed{g_{mb}} = (g_{ms} - g_m) = (1+\delta)g_m - g_m = \boxed{\delta \cdot g_m}$$

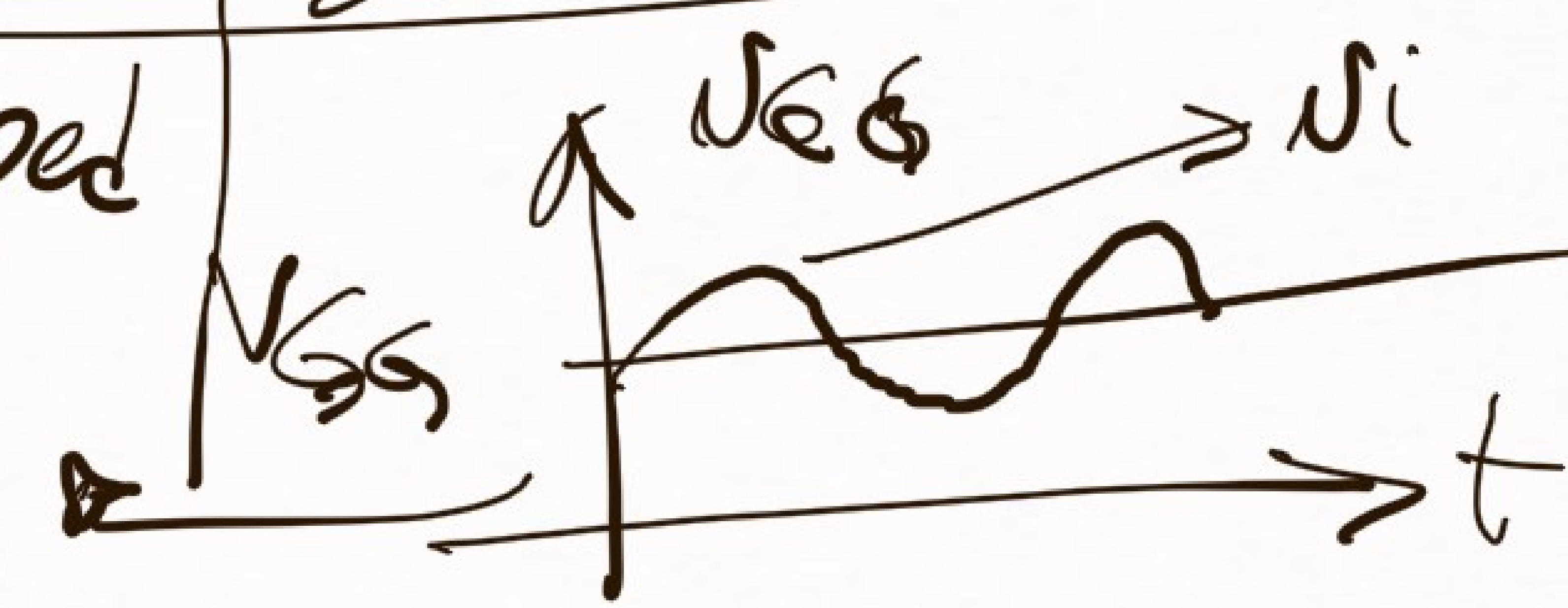
Ej. aplicación de modelo de peq. señal.

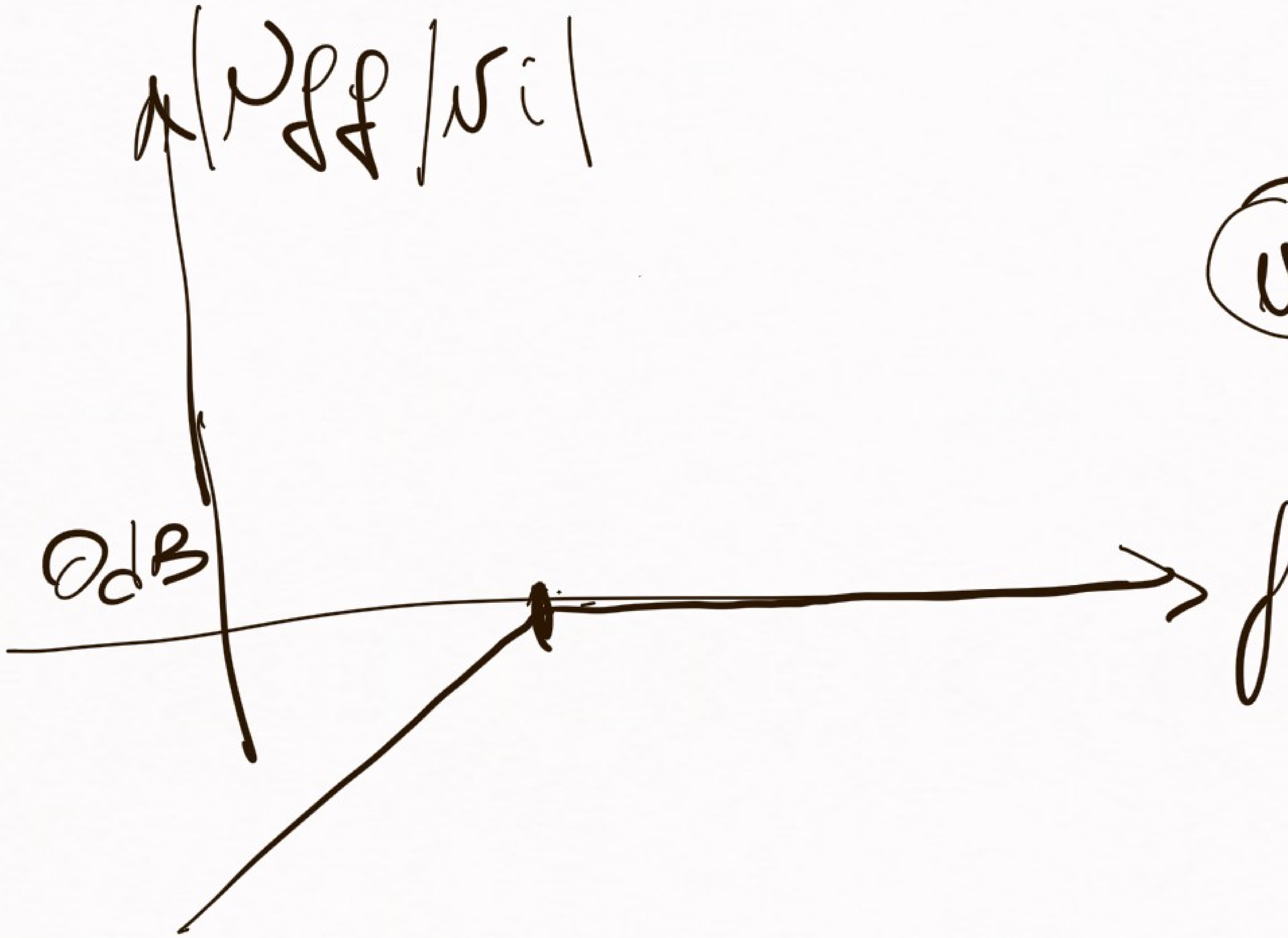


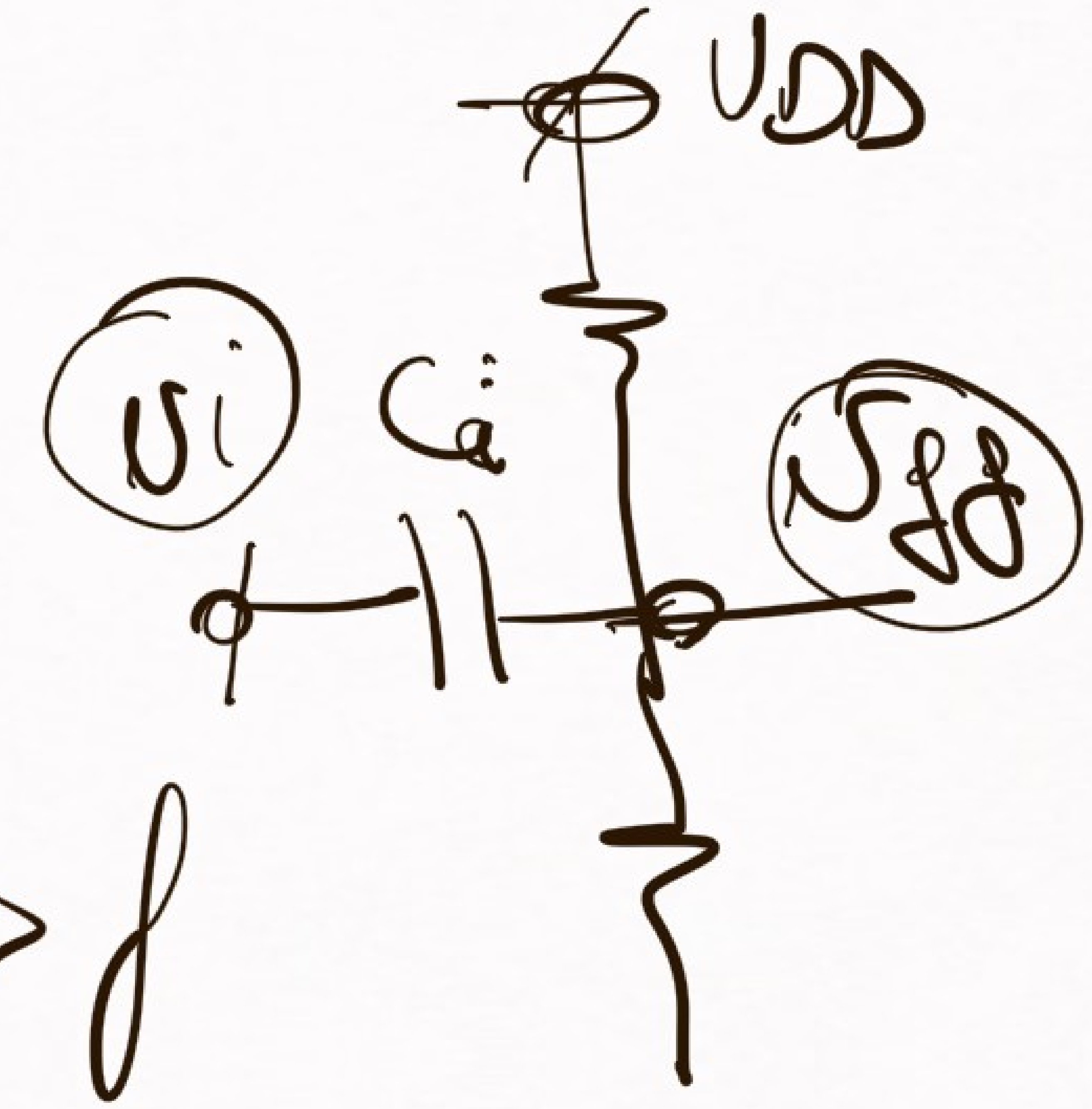
$$V_{GG} = \frac{R_1}{R_1+R_2} \cdot V_{DD}$$

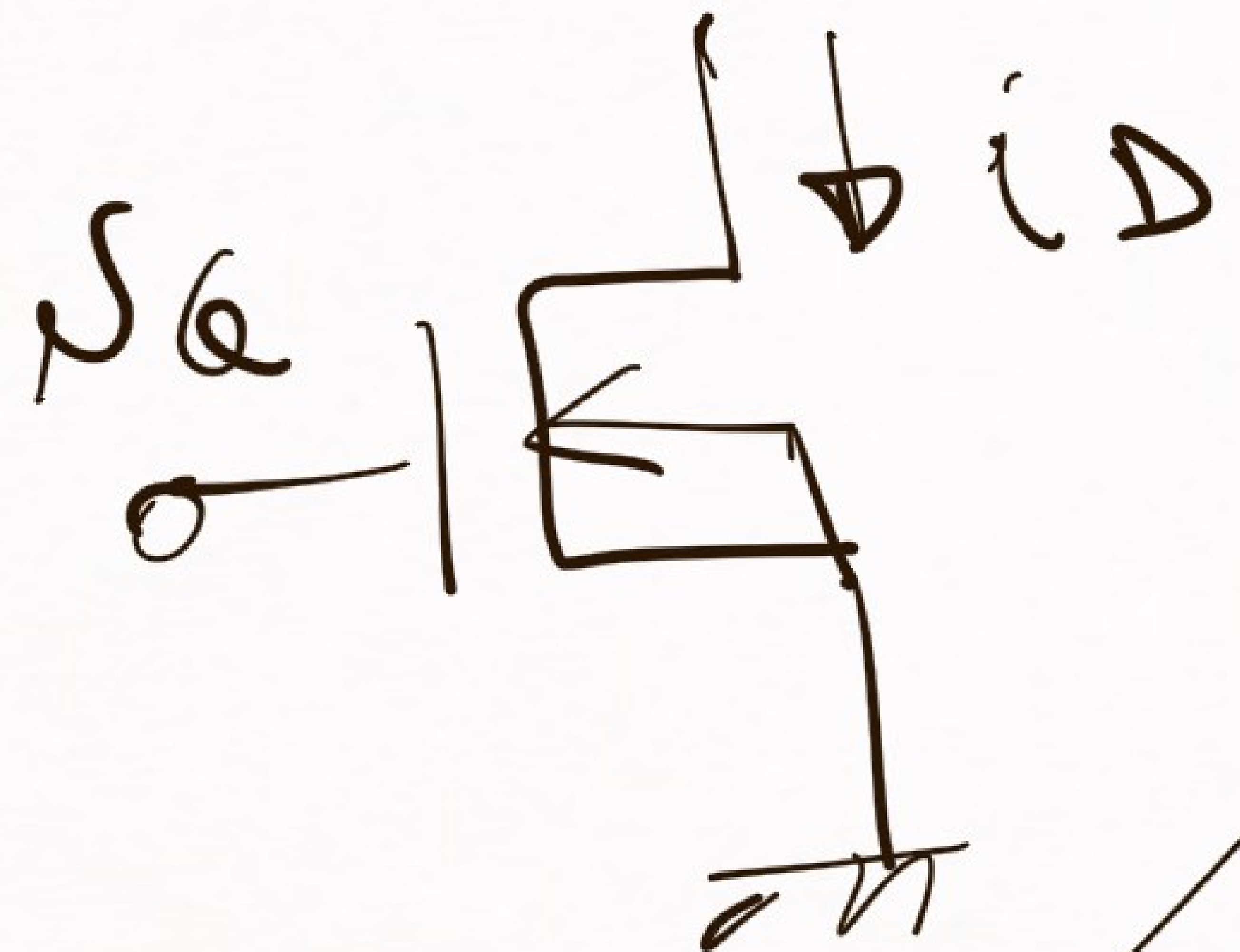


f/ imped de Ci despr.

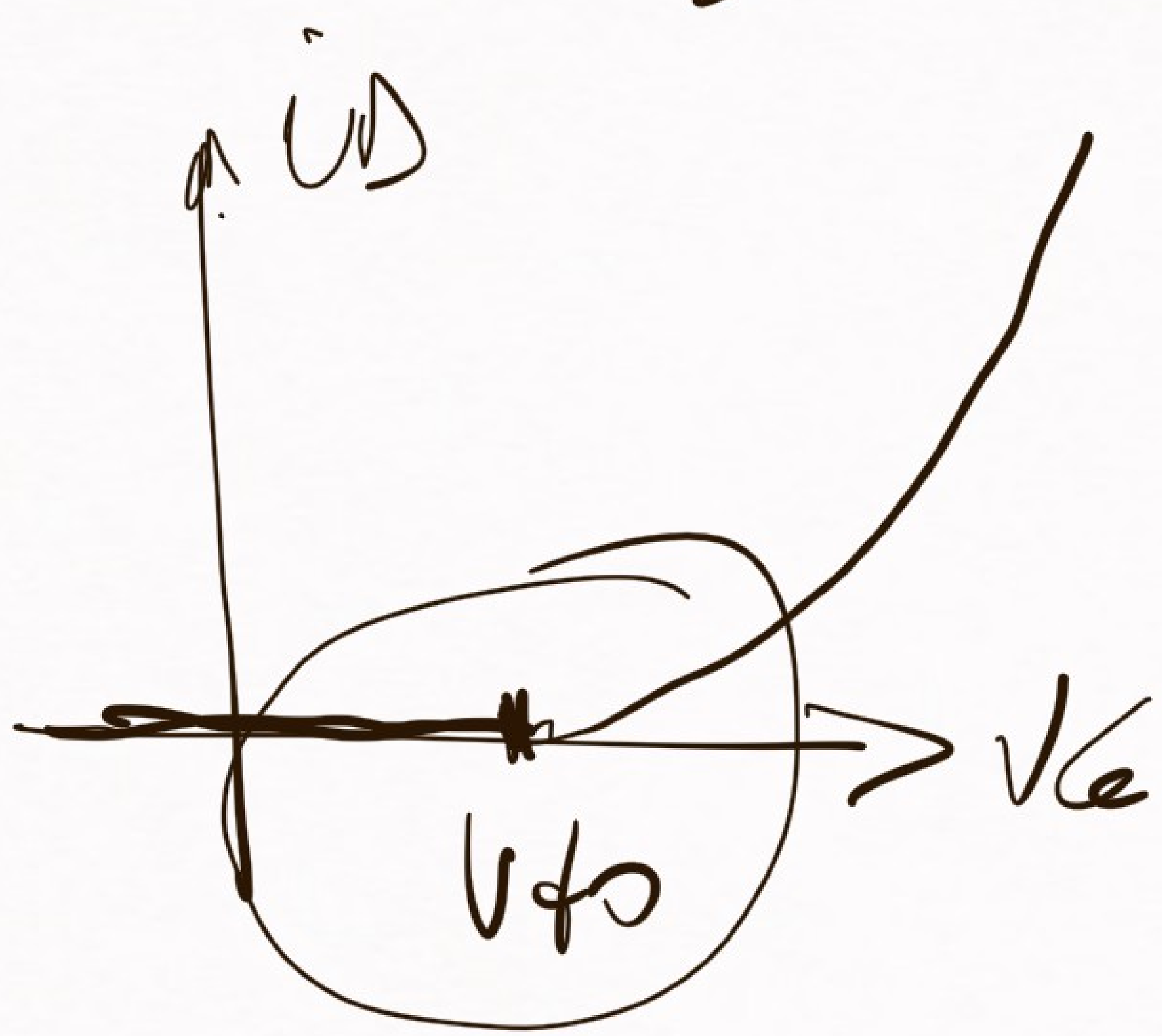


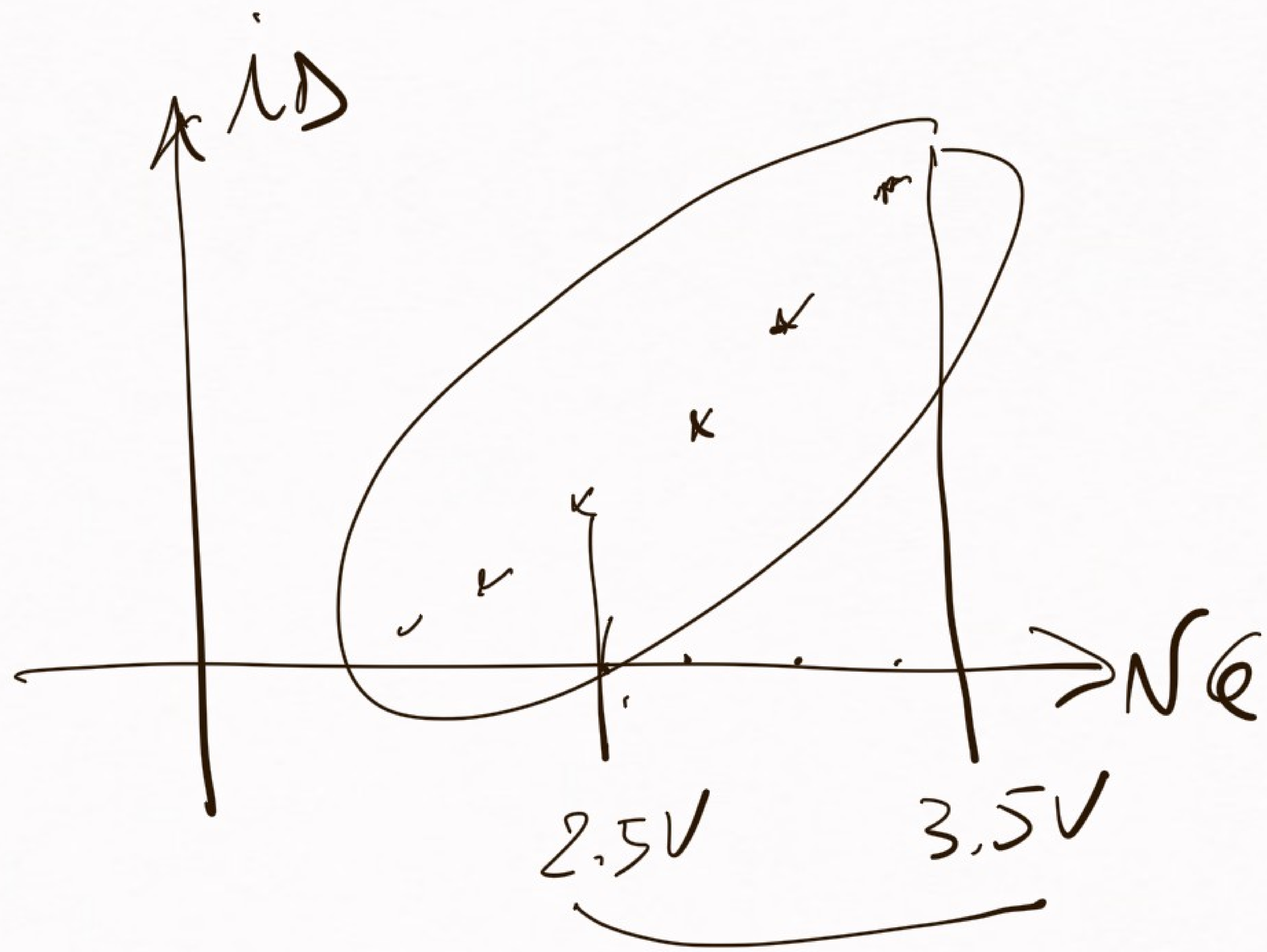

|vdd/vi|
0dB
f


VDD
vi
Ci
vdd



$$i_D = \frac{\beta}{2(1+\delta)}\left(v_G - V_{t0}\right)^2$$





$$\sqrt{i_D} = \sqrt{\frac{\beta}{2(1+\delta)}}\left(v_G - V_{t0}\right)$$