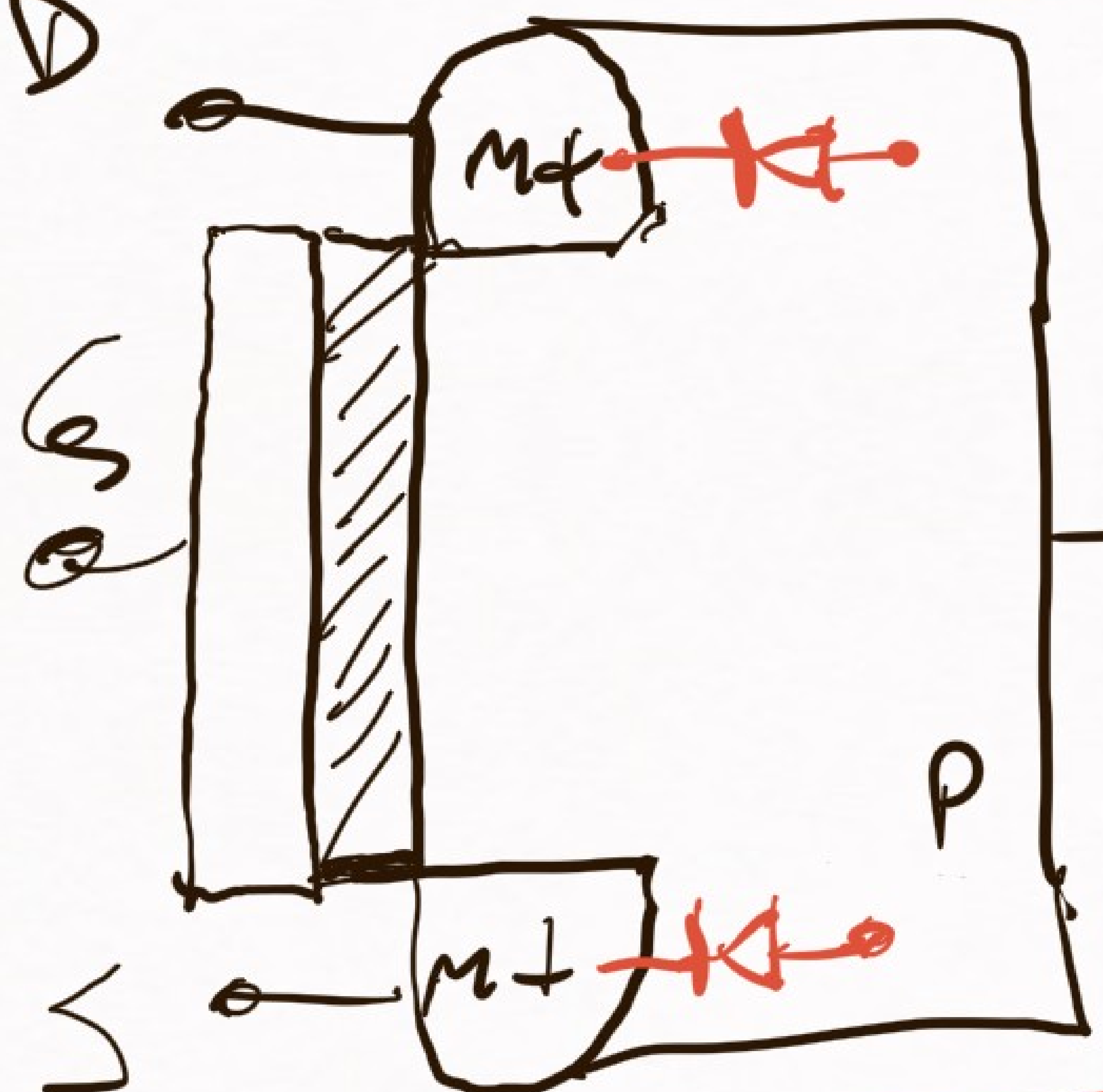
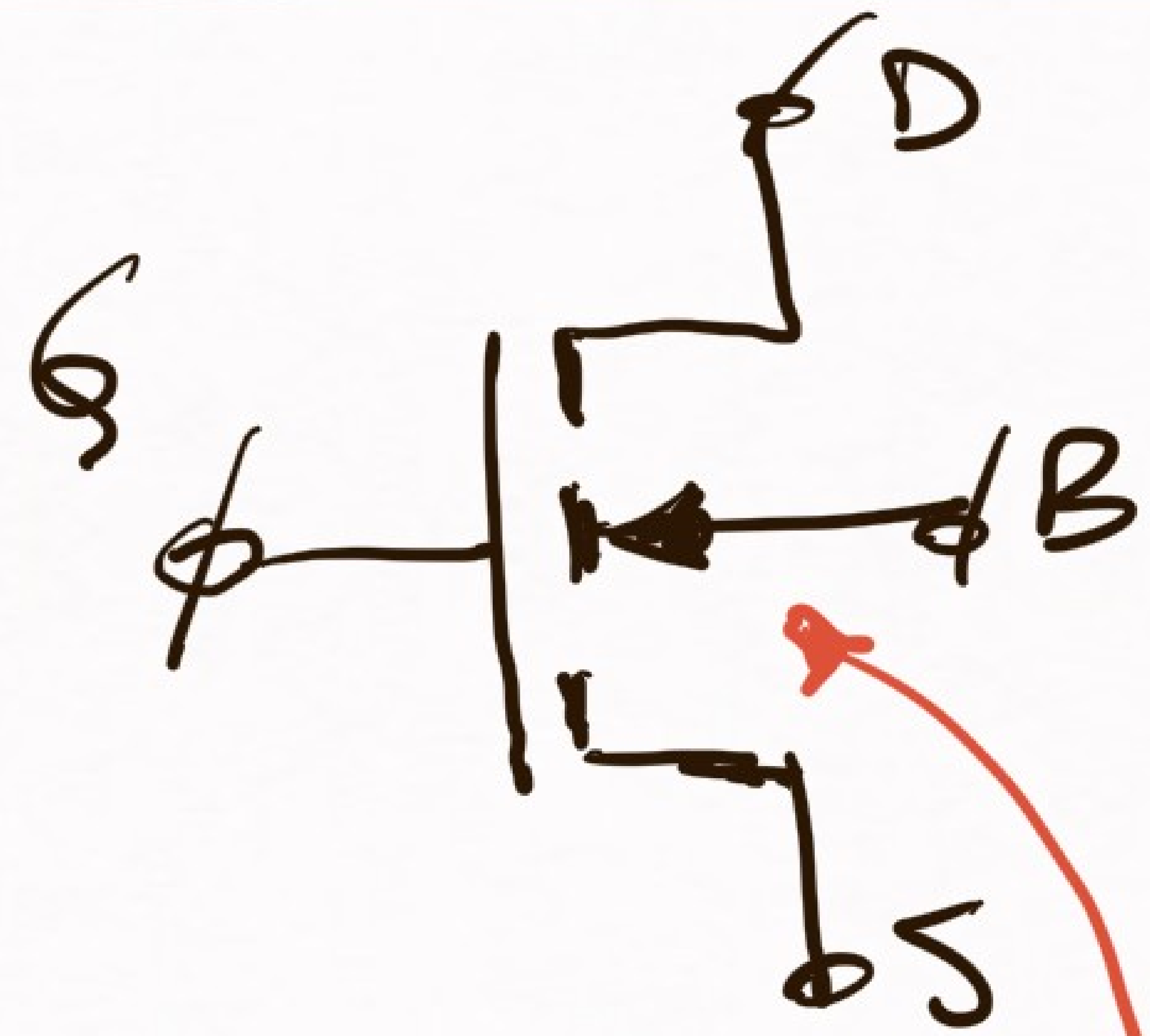
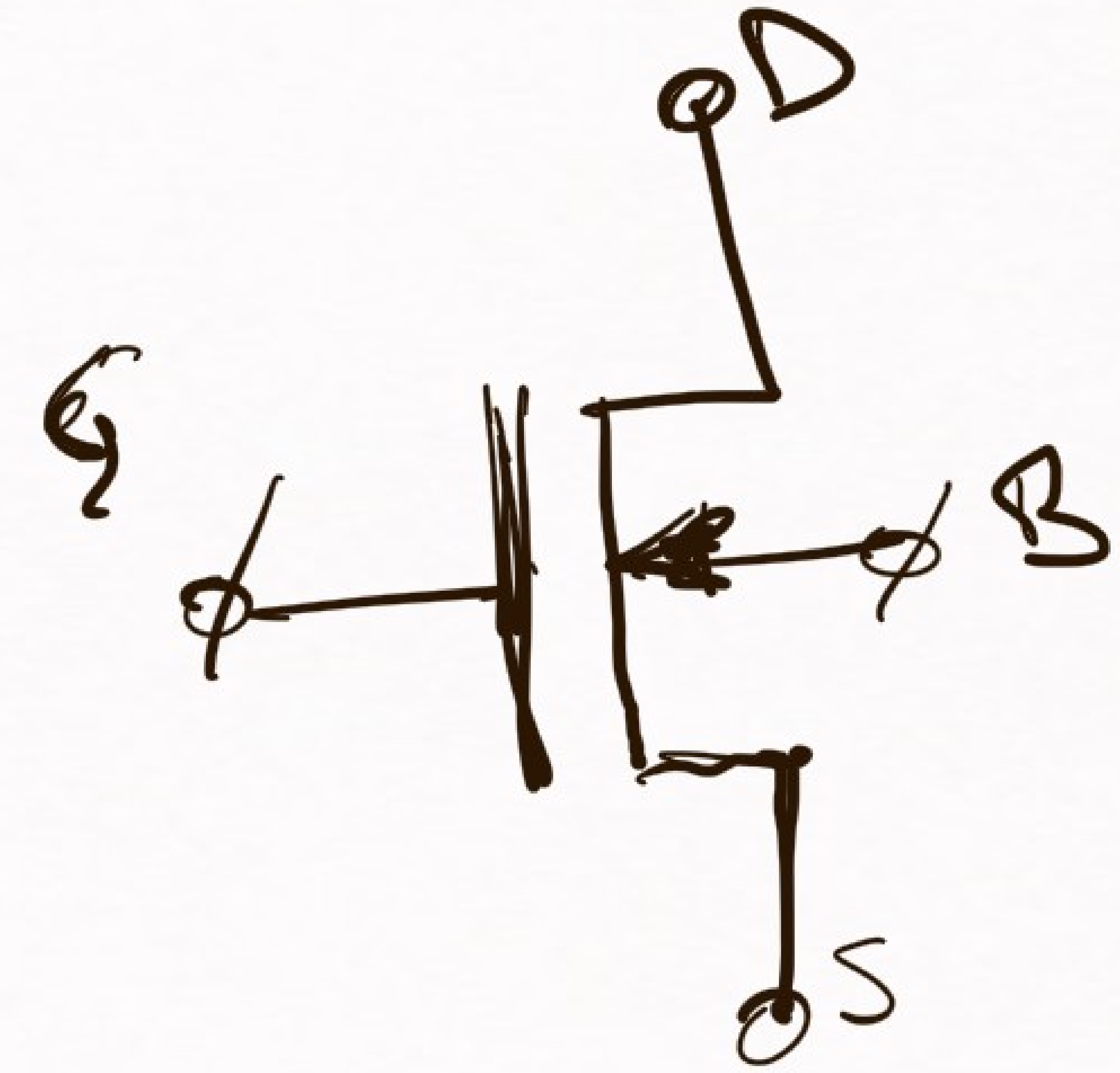
Simbolo de circuito del transistor n MOS

21/4/2021



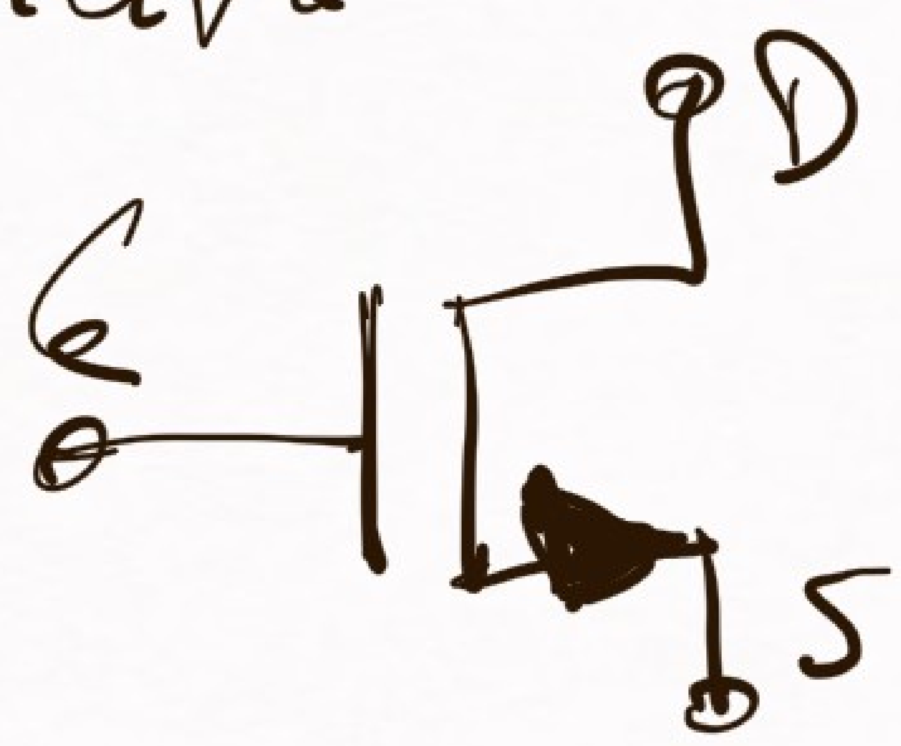




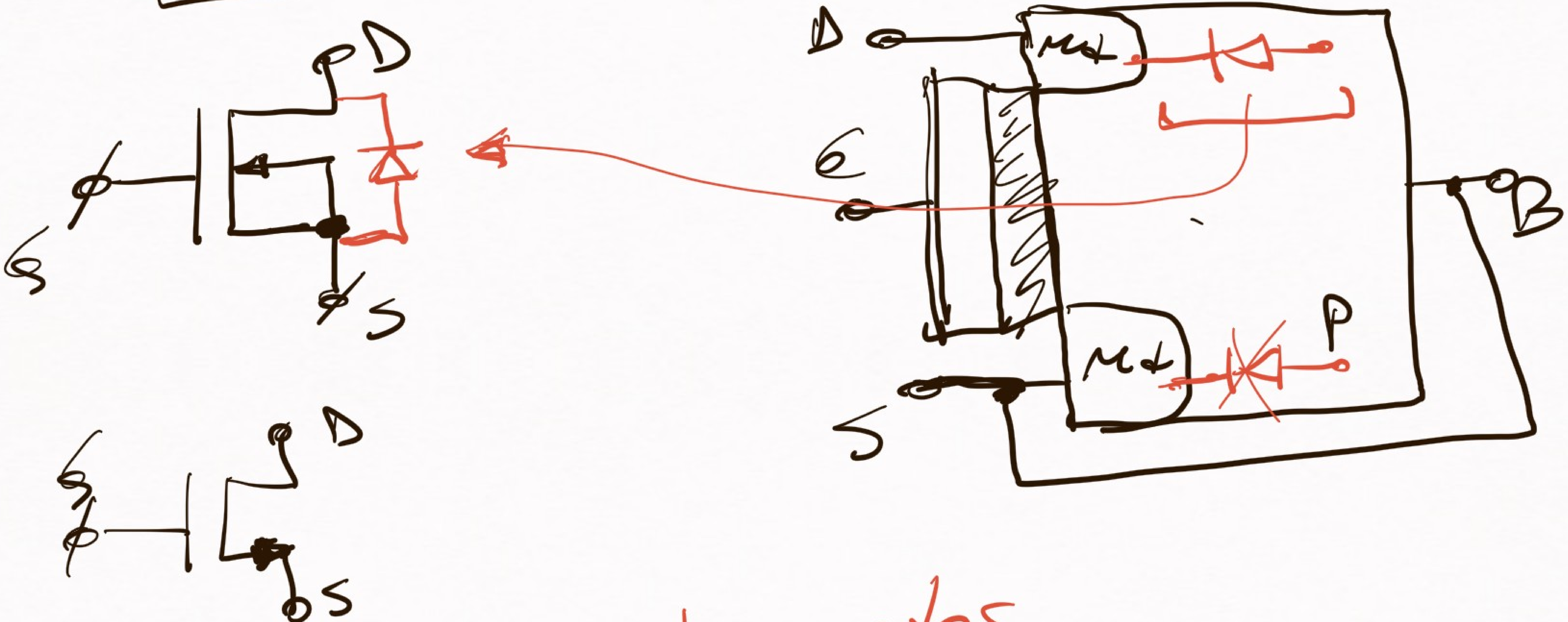
flecha apunta en el sentido directo de la juntura B-S (o equiv. B-D)

sin conexión explícita del sustrato

B:



Transistores nMOS discretos



Transistor MOS discretos

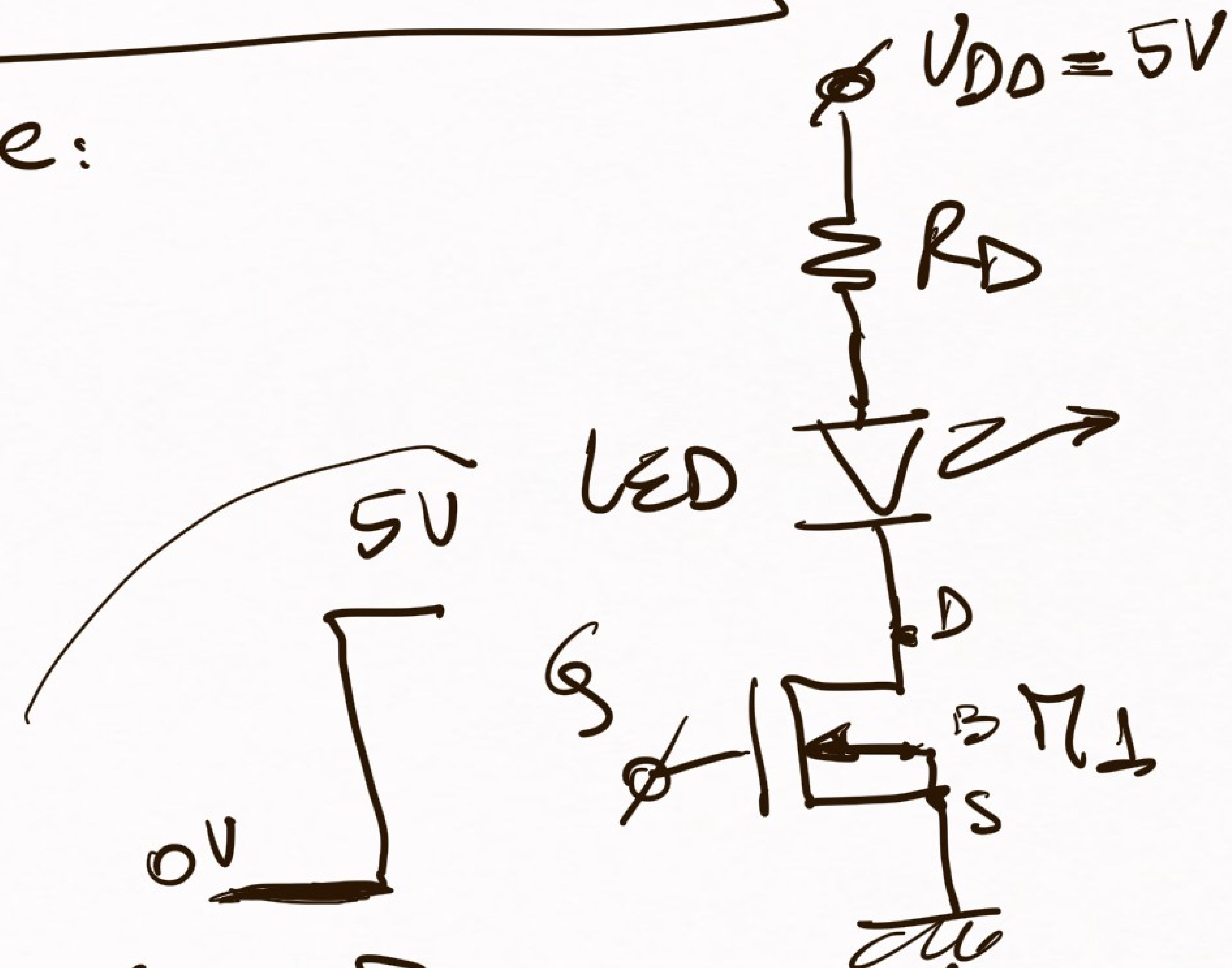
↳ ⊛ tienen 3 terminales

⊛ <u>No</u> son simétricos respecto a S, D

⊛ Tienen el diodo D-B en "antiparalelo"

Ejs. de análisis de circuitos con transistor nMOS.

1) Uso como llave:



M1: $V_{to} = 1.5V$

$\gamma = 0.3$

$\beta = 0.1 A/V^2$

LED: $V_{LED} = 1.4V$

- Diseñar R_D para que $I_{LED} = 10 mA$

1) $V_G = 0 \Rightarrow$ H M1 cortado $\Rightarrow I_D = 0$

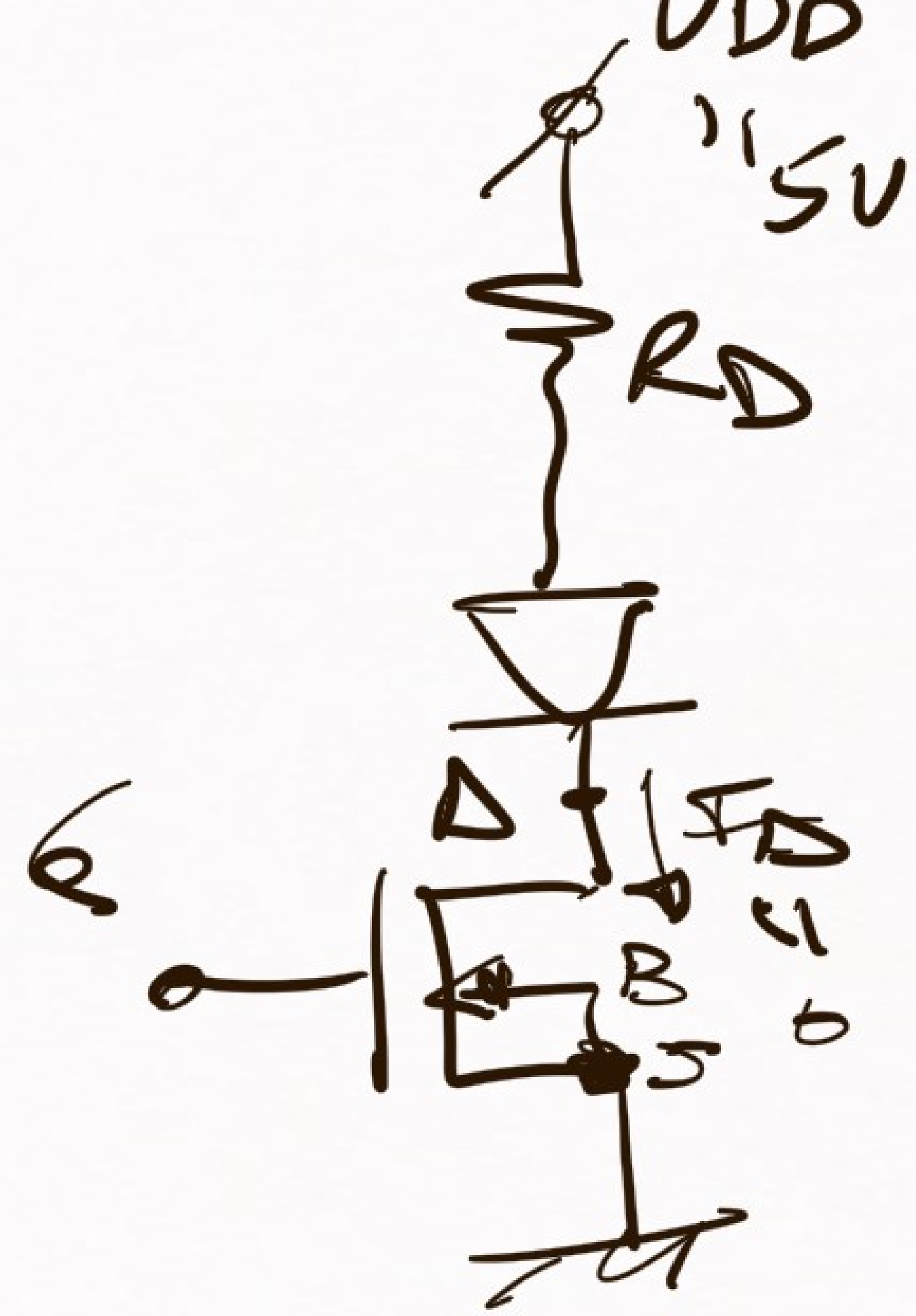
$\Rightarrow I_{LED} = 0 \rightarrow$ LED apagado

Verifico si la solución es coherente con la H de M1 cortado:

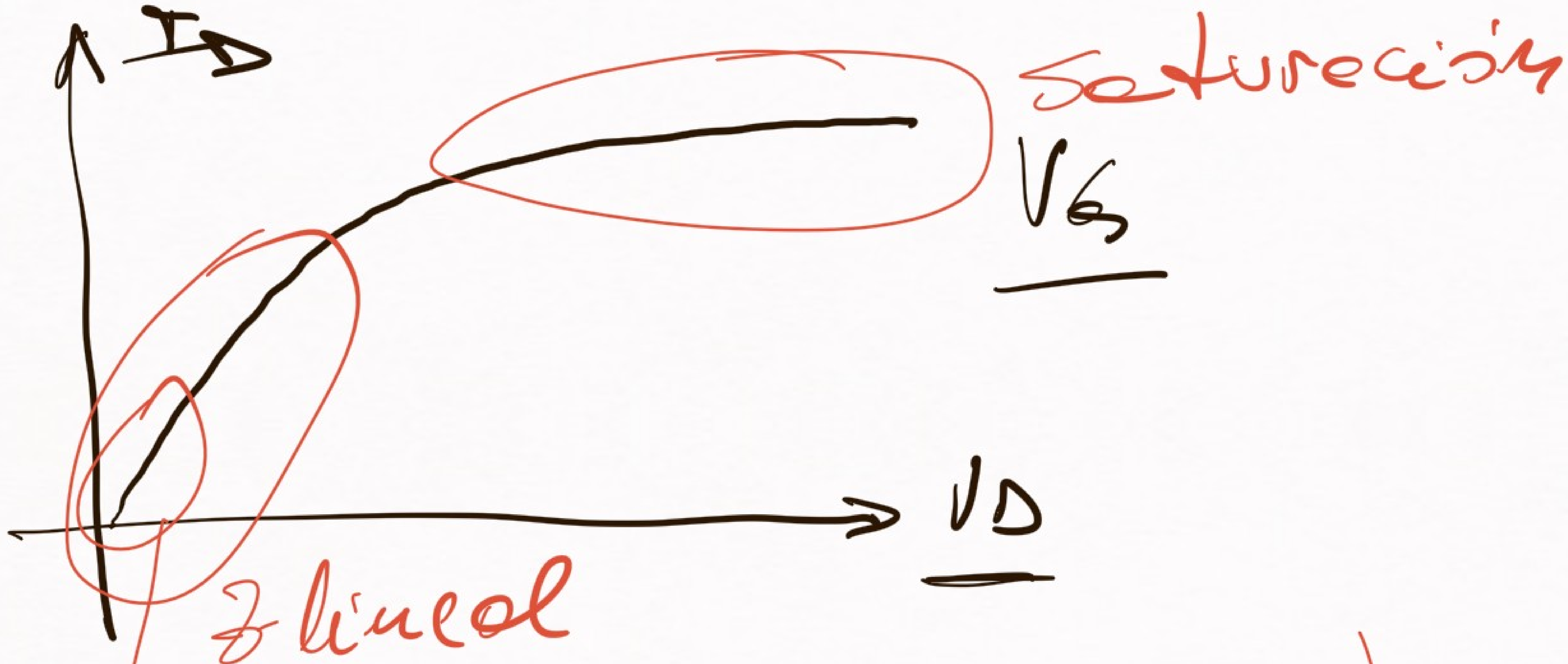
$$\left[V_S > V_P \;,\; V_D\,(\geq V_S) > V_P \right]$$

$$\underbrace{V_S}_{= V_{SB} = 0} \overset{?}{>} V_P = \frac{\overset{=0}{V_G} - V_{t0}}{(1+\delta)} = \frac{-1{,}5V}{1.3}$$

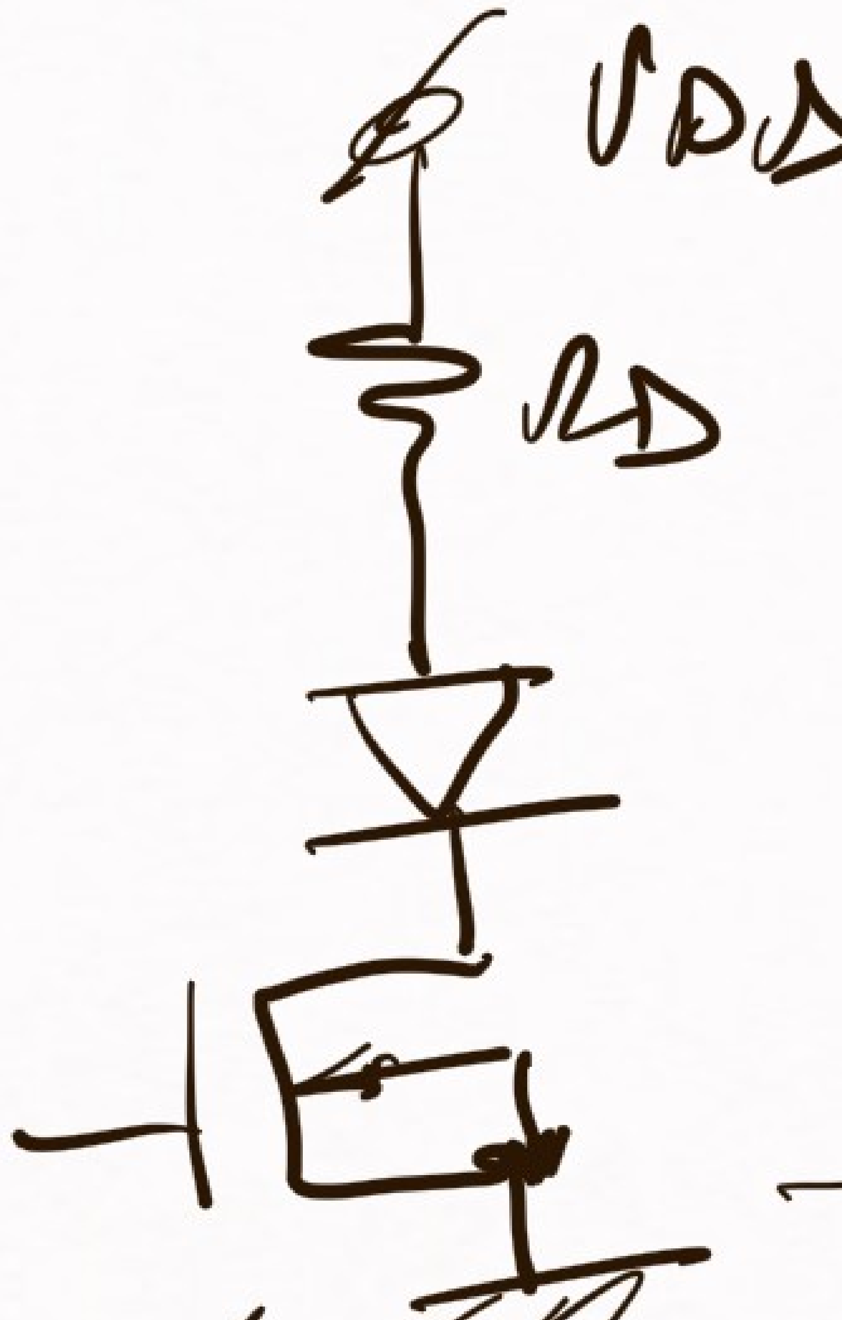
$$\underbrace{V_D}_{=5V} \overset{?}{>} V_P = -\frac{1{,}5V}{1.3}$$



2) $V_G = 5V$



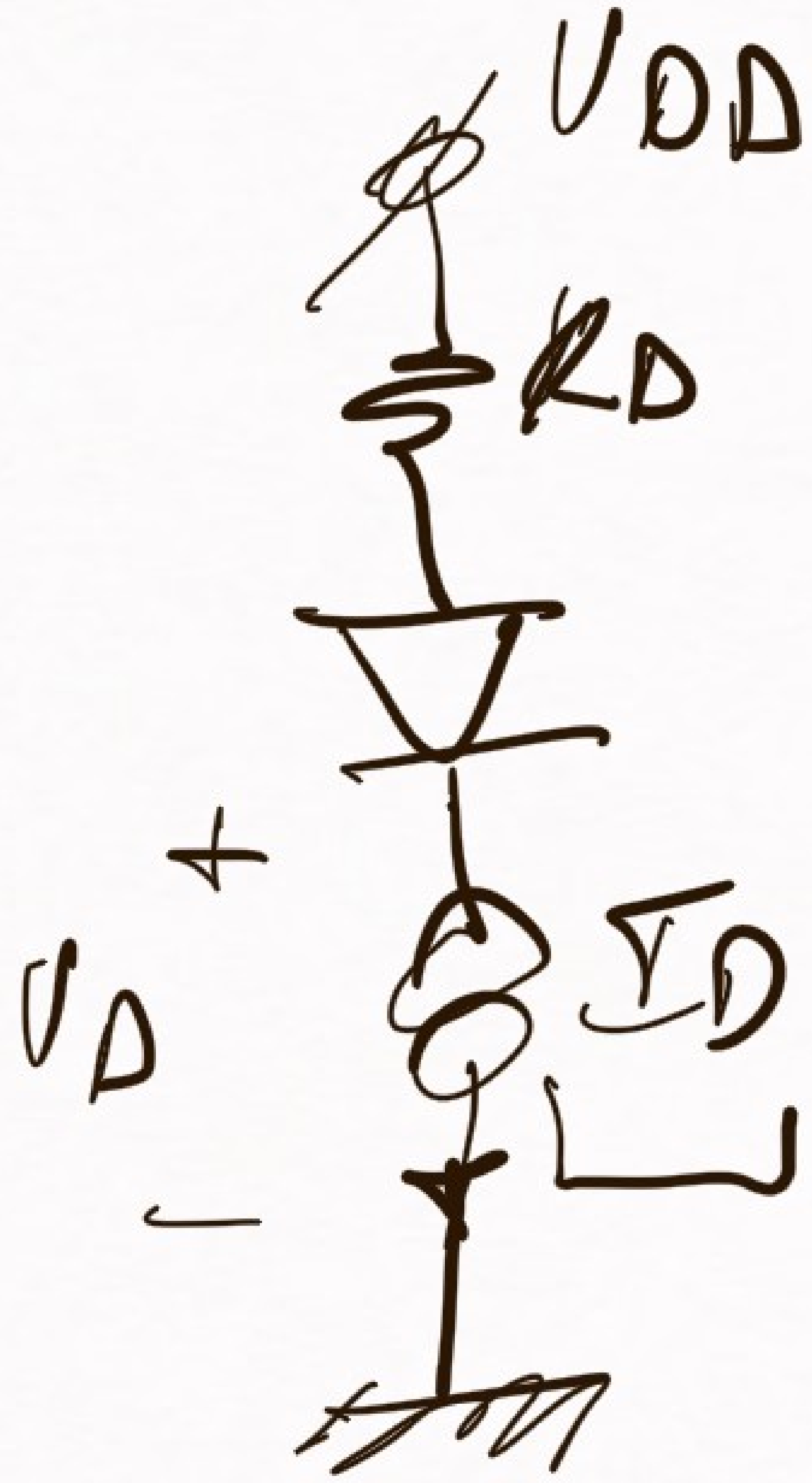
$\rightarrow r_l \sim R_{ON}(V_G, V_{to}, \beta)$



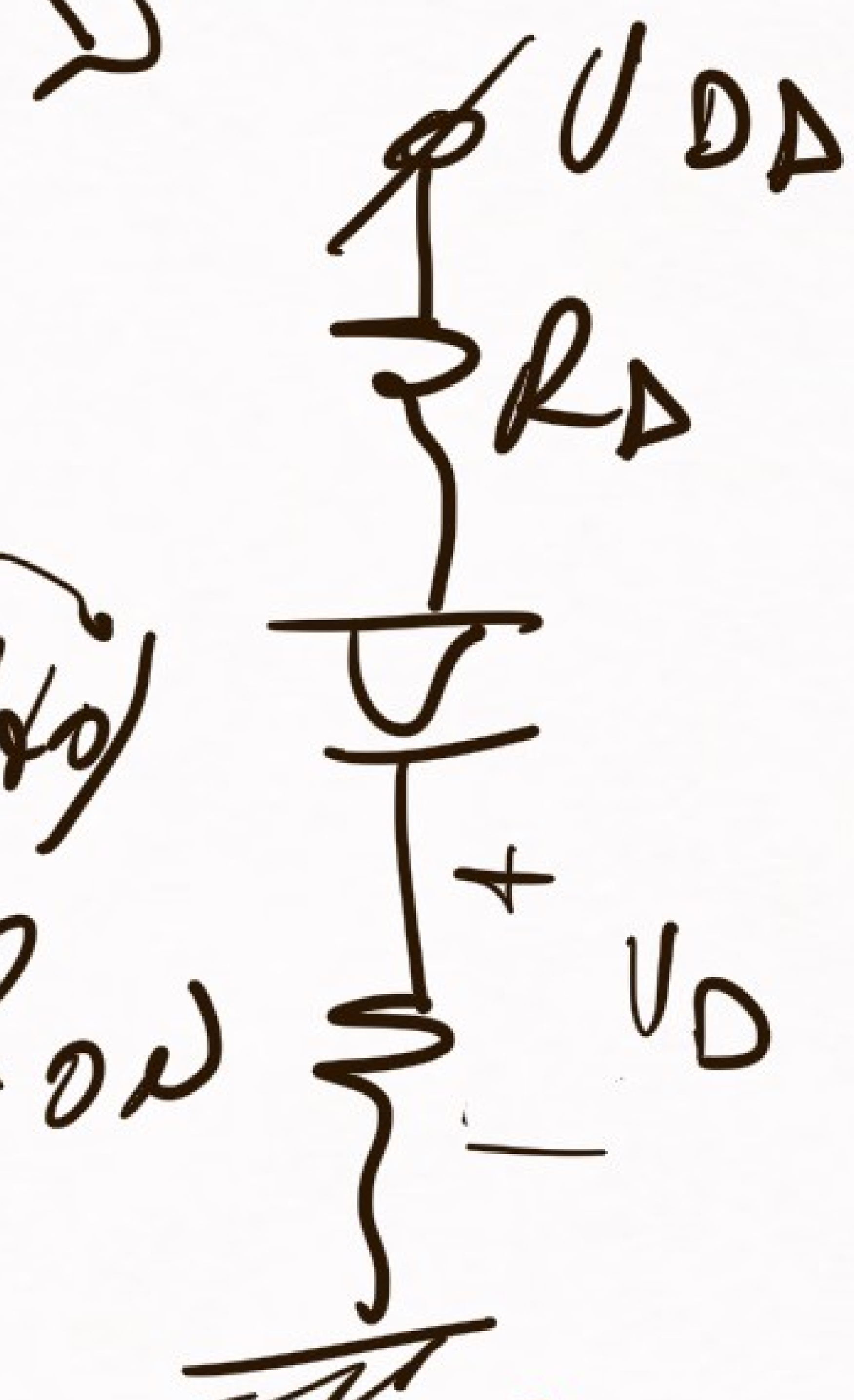
M_1 en z. lineal (y $V_D << V_P$)

M_1 sat.

Ajustar V_G



$I_D = f(\underbrace{V_G, V_{t0}, \beta, \delta}_{\text{dispersión}})$



$f(V_G, \beta, V_{t0}) = R_{ON}$

Si $R_{ON} << R_D$

$\Rightarrow I_{LED}$ fijada por R_D

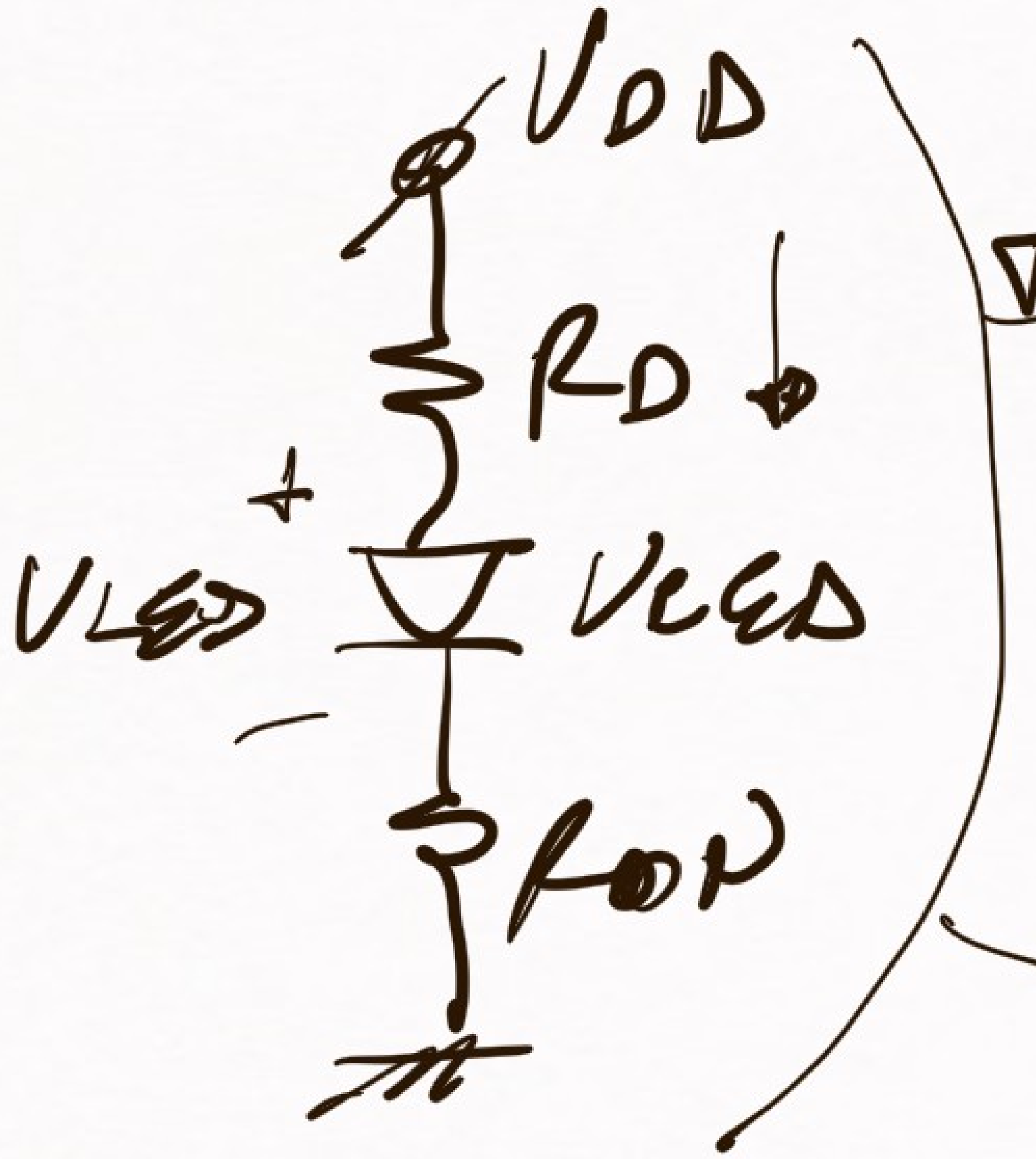
(H) M1 in zona lineal ∂ V_D / $V_D << V_P$

$\rightarrow V_S < V_P$

$V_D < V_P$

$\Downarrow$

$M_1 \longrightarrow R_{ON}$



$$R_{ON} = \frac{1}{\beta(V_G - V_{t0})} = \frac{1}{0.1 \cdot (5 - 1.5)} = 2.9\,\Omega$$

$$I_{LED} = \frac{\overset{5}{V_{DD}} - \overset{1.4}{V_{LED}}}{(R_D + R_{ON})} \cong \frac{V_{DD} - V_{LED}}{R_D}$$

$I_{LED} = 10\,mA$

$R_{ON} << R_D$

$\Rightarrow R_D + R_{ON} = 360\,\Omega \Rightarrow R_D = 357\,\Omega,\ R_D \cong 360\,\Omega$

Verifico si: $V_S < V_P$

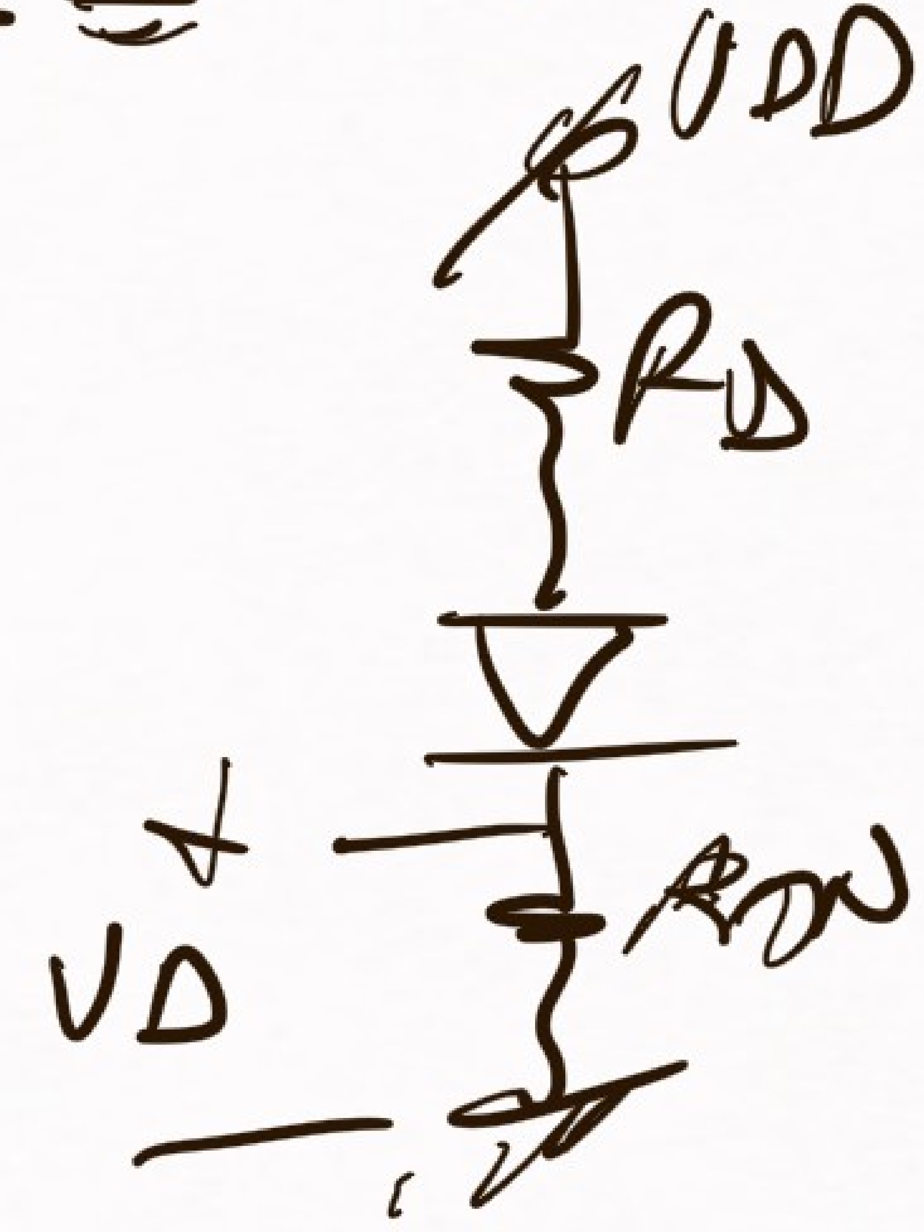
$$\left(V_D \cancel{<} V_P \right) \rightarrow V_D << V_P$$

$$V_S \overset{?}{<} V_P \iff \underbrace{V_G}_{=\,5V} > \underbrace{V_{to}}_{=\,1.5V} + (1+\delta)\underbrace{V_S}_{=\,0}$$

$$V_D \overset{?}{<<} V_P = \frac{V_G - V_{to}}{1+\delta} = \frac{5V - 1.5V}{1.3} = 2.7V$$

$$V_D = I_{LED} R_{ON} = 10mA \cdot 2.9\Omega =$$

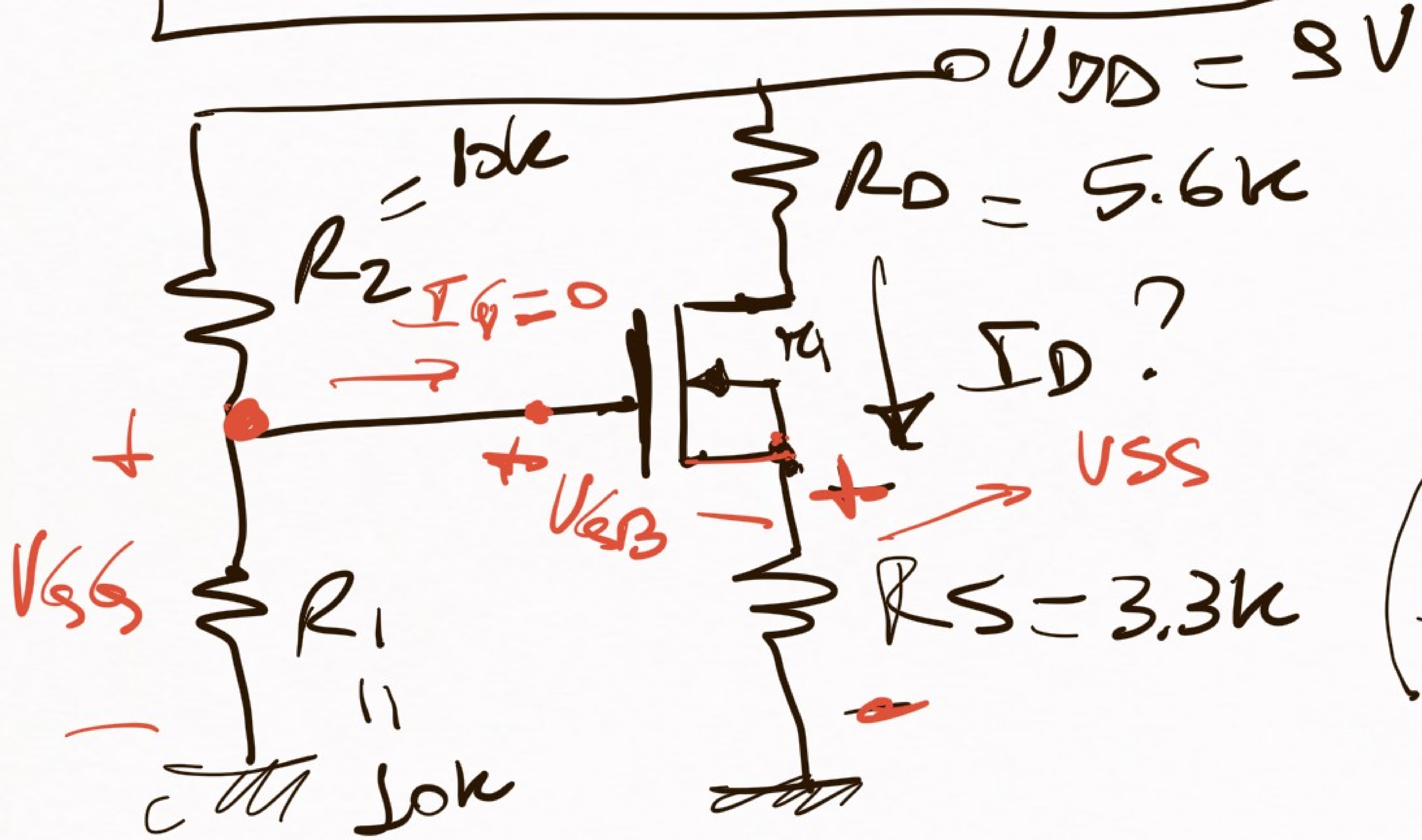
$$= \underline{\underline{29 mV}}$$



$$\boxed{v_s < v_p} \iff \boxed{v_b > v_{t0} + (1+f)\,v_s}$$

$$v_p = \frac{v_b - v_{t0}}{(1+f)}$$

Ej. en saturación:



M_1: $V_{to} = 1V$

$\delta \cong 0$

$\beta = 1 \, mA/V^2$

(H) M_1 en saturación.

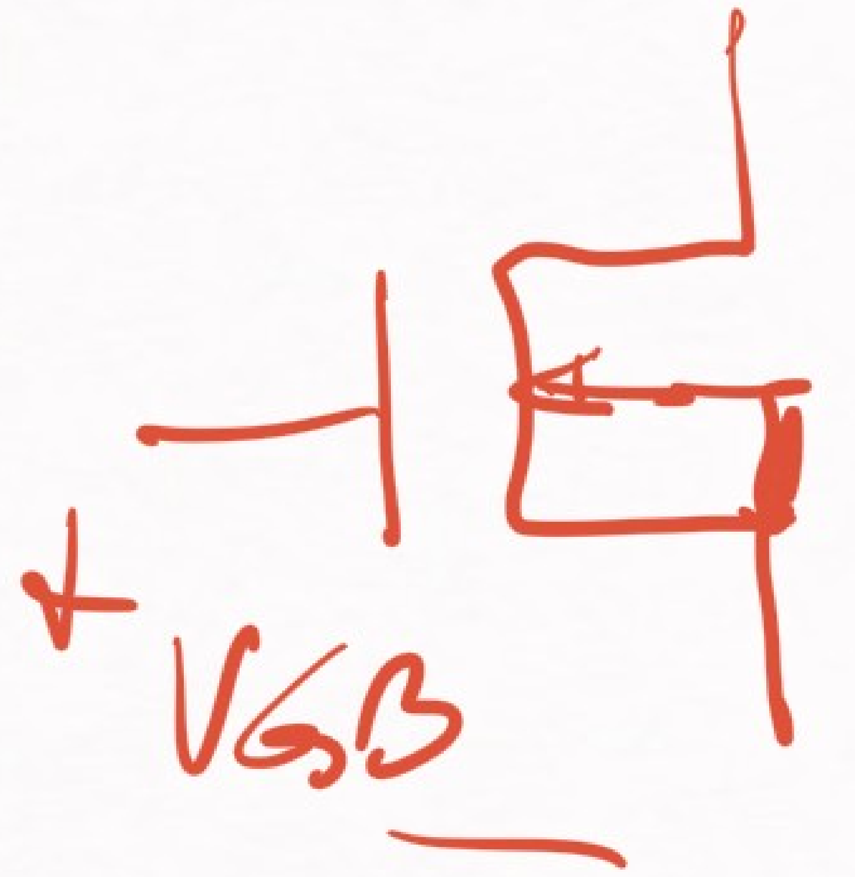
$$I_D = \frac{\beta}{2(1+\delta)}\left(\underbrace{V_G}_{=V_{GB}} - V_{to} - (1+\delta)\underbrace{V_S}_{=V_{SB}=0}\right)^2$$

$$I_D = \frac{\beta}{2(1+\delta)}\left(V_{GB} - V_{to}\right)^2$$

$$V_{GG} = \frac{R_1}{R_1 + R_2} \cdot V_{DD} = 4.5V$$

$$V_{SS} = I_D \cdot R_S$$

$$V_{GB} = V_{GG} - V_{SS} = V_{GG} - R_S \cdot I_D$$



saturación

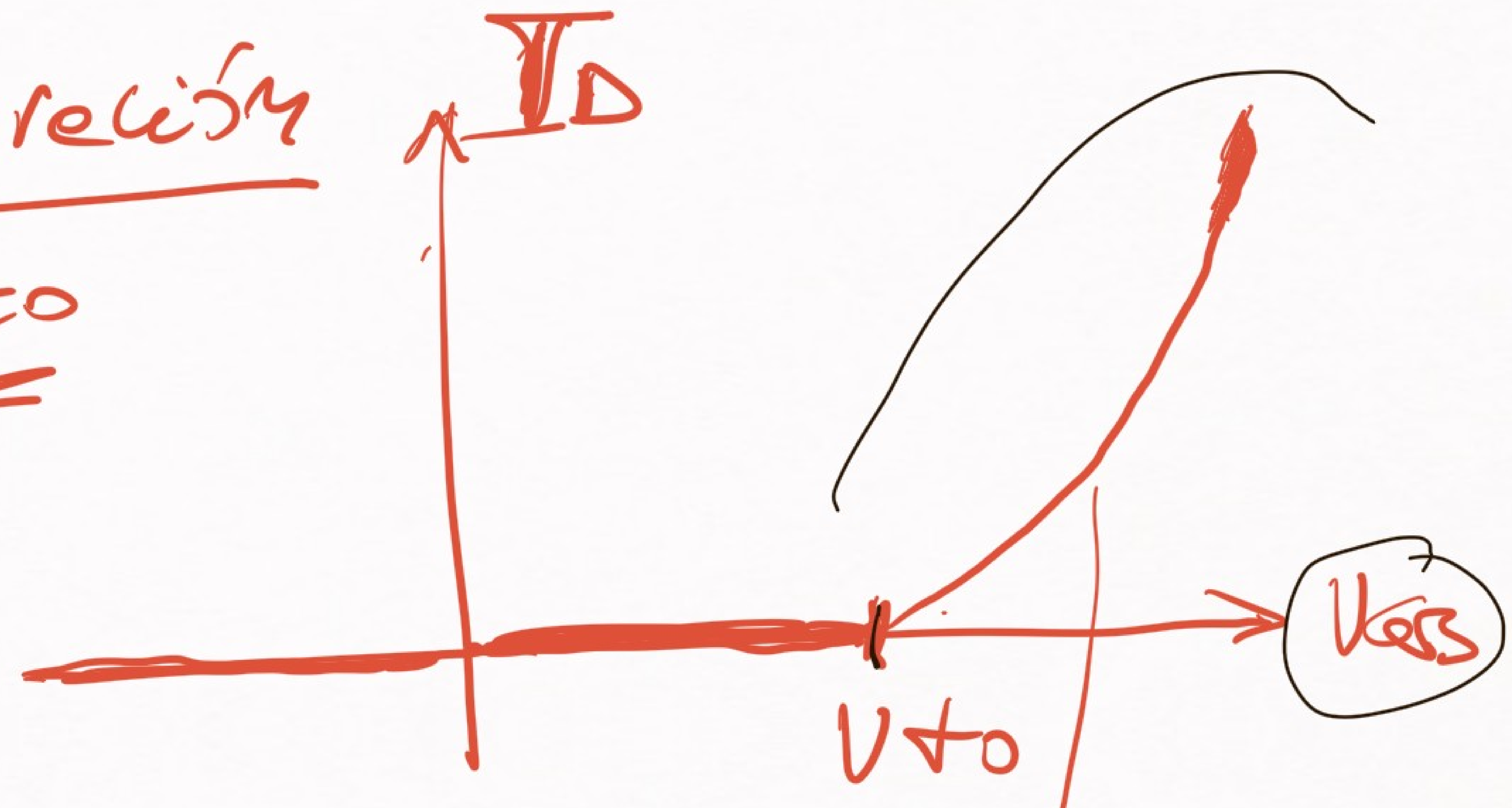
$V_{SB} = 0$

$V_S < V_P = \dfrac{V_{GB} - V_{to}}{1+\delta}$

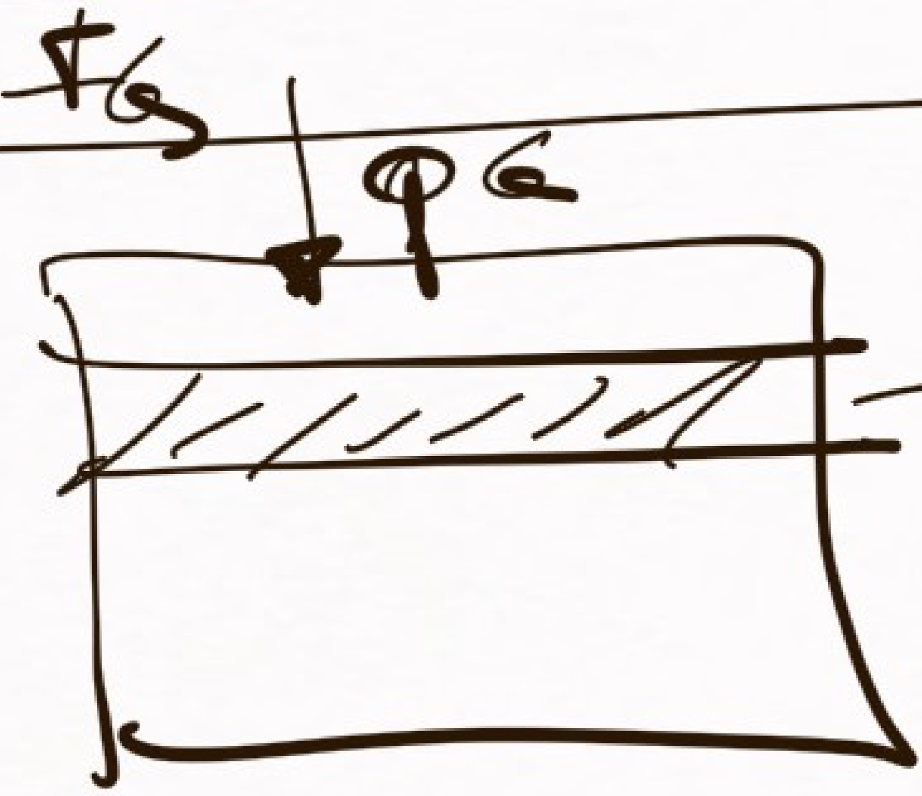
$V_S = 0$

$\Updownarrow$

$V_{GB} > V_{to}$



$I_D = \dfrac{\beta}{2(1+\delta)} \cdot (V_{GB} - V_{to})^2$



aislante

$I_{G_{DC}} = 0$

en continua

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

$$V_{GB} = V_{GG} - R_S \cdot \underbrace{I_D}$$

$$V_{GG} = V_{GB} + R_S I_D = V_{GB} + \frac{R_S\,\beta}{2(1+\delta)}\left(V_{GB} - V_{t0}\right)^2$$

→ Ec. de 2do grado en V_{GB}

(o ec. de 2do grado en I_D)

$$V_{GB} = \begin{cases} \boxed{2.18\,V} \\ \cancel{-0.79\,V} \end{cases}$$

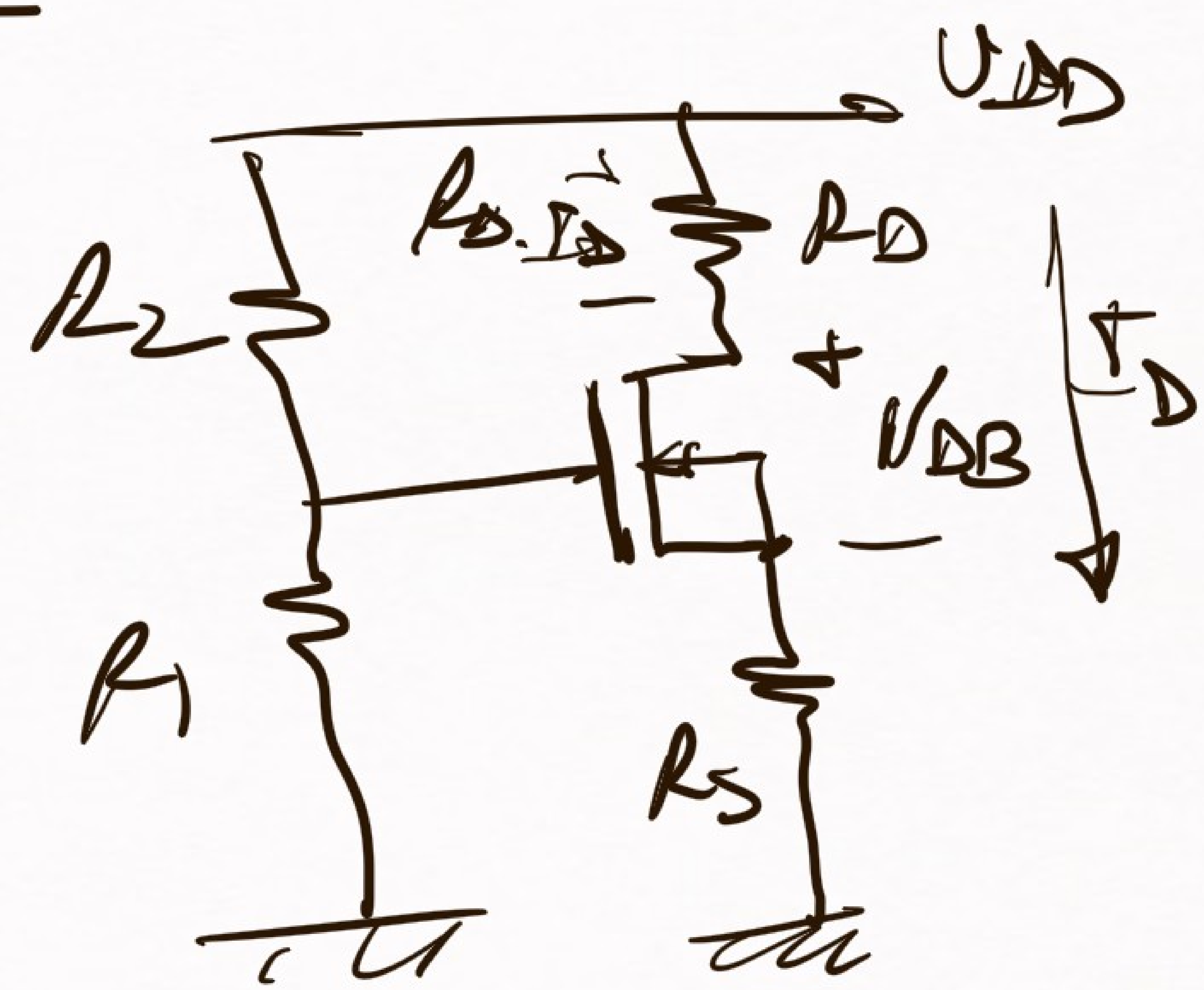
no cumple

$V_S < V_P \iff V_{GB} > \underbrace{V_{t0}}_{1V} + (1+\delta)\underbrace{V_S}_{0}$ ✓

Saturación $\Longleftrightarrow$ $V_S < V_P$

$V_D > V_P$

$$V_D > V_P = \frac{V_{GB} - V_{to}}{(1+\delta)} = \frac{2.18 - 1V}{1} = 1.18V$$



$$V_{DB} = V_{DD} - \underbrace{R_D \cdot I_D}_{=3.32V} - \underbrace{R_S \cdot I_D}_{=2.32V} = 2.26V$$

$$\boxed{I_D = \frac{\beta}{2(1+\delta)}\left(V_{GB} - V_{to}\right)^2 = \frac{1e-3}{2\cdot(1)}\left(2.18 - 1\right)^2 = 0.7 mA}$$