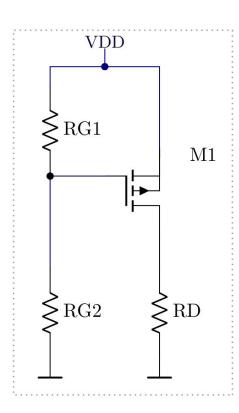
[86.03/66.25] Dispositivos Semiconductores 1er Cuatrimestre 2020

Transistor MOS

- 1. Polarización
- 2. Modelo de Pequeña Señal

Enunciado



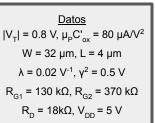
Para el circuito de la figura y los siguientes datos:

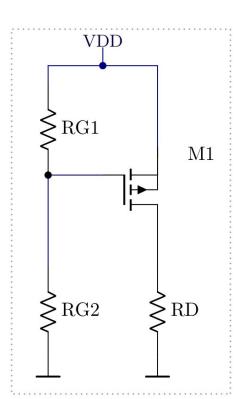
- $|V_T| = 0.8 \text{ V}, \, \mu_P C'_{OX} = 80 \, \mu \text{A/V}^2$
- W = 32 μ m, L = 4 μ m, λ = 0.02 V^{-1} , γ^2 = 0.5 V
- $R_{G1} = 130 \text{ k}\Omega$, $R_{G2} = 370 \text{ k}\Omega$ $R_{D} = 18 \text{k}\Omega$, $V_{DD} = 5 \text{ V}$

hallar

- El punto de polarización
- 2. El modelo de pequeña señal
- 3. La variación de corriente de Drain al variar 1 mV la v_{qs}

Enunciado



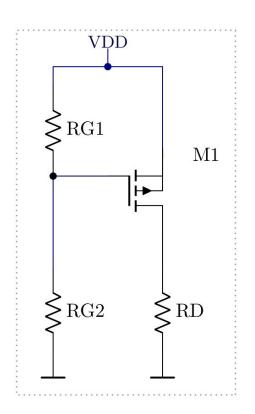


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hallar

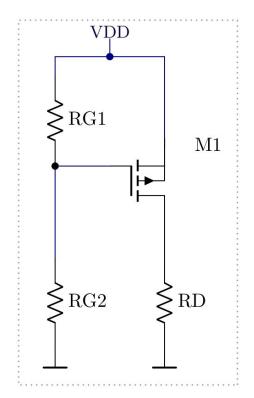
- El punto de polarización
- 2. El modelo de pequeña señal
- 3. La variación de corriente de Drain al variar 1 mV la $v_{\rm gs}$



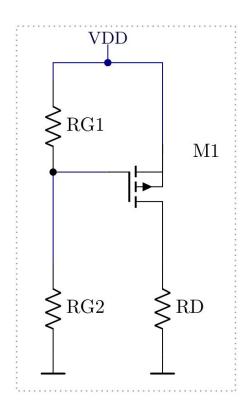
$\begin{aligned} & \underline{Datos} \\ |V_T| &= 0.8 \text{ V}, \ \mu_P C'_{ox} = 80 \ \mu A / V^2 \\ & W &= 32 \ \mu m, \ L = 4 \ \mu m \\ & \lambda = 0.02 \ V^{-1}, \ \gamma^2 = 0.5 \ V \\ & R_{G1} &= 130 \ k\Omega, \ R_{G2} = 370 \ k\Omega \end{aligned}$

 $R_{D} = 18k\Omega, V_{DD} = 5 V$

Hallamos el k:



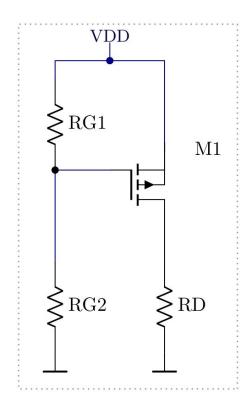
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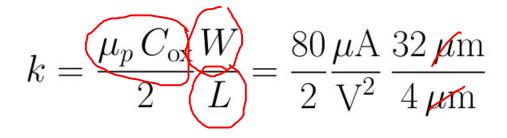
Hallamos el k:

$$k = \frac{\mu_p C_{\text{ox}} W}{2}$$

$\begin{aligned} & \underline{Datos} \\ |V_T| &= 0.8 \text{ V}, \ \mu_P \text{C'}_{ox} = 80 \ \mu \text{A/V}^2 \\ & \text{W} = 32 \ \mu \text{m}, \ \text{L} = 4 \ \mu \text{m} \\ & \lambda = 0.02 \ \text{V}^{-1}, \ \gamma^2 = 0.5 \ \text{V} \\ & \text{R}_{G1} = 130 \ \text{k}\Omega, \ \text{R}_{G2} = 370 \ \text{k}\Omega \\ & \text{R}_D = 18 \text{k}\Omega, \ \text{V}_{DD} = 5 \ \text{V} \end{aligned}$



Hallamos el k:

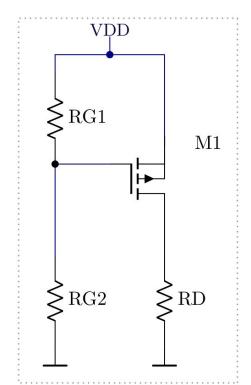


Datos

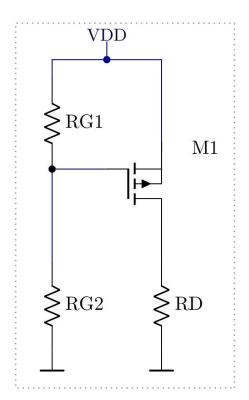
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Hallamos el k:



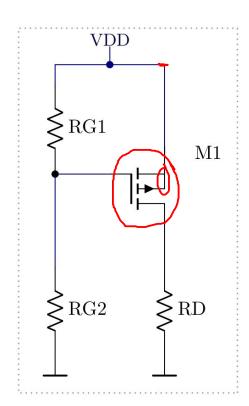
$$k = \frac{\mu_p C_{\text{ox}} W}{2} \frac{W}{L} = \frac{80 \, \mu \text{A}}{2} \frac{32 \, \mu \text{m}}{V^2} = 320 \, \frac{\mu \text{A}}{V^2}$$



Hallamos el V_T :

$\begin{aligned} & \underline{Datos} \\ |V_T| &= 0.8 \text{ V}, \ \mu_P C'_{ox} = 80 \ \mu \text{A/V}^2 \\ & W = 32 \ \mu \text{m}, \ L = 4 \ \mu \text{m} \\ & \lambda = 0.02 \ V^{-1}, \ \gamma^2 = 0.5 \ V \\ & R_{\text{G1}} = 130 \ k\Omega, \ R_{\text{G2}} = 370 \ k\Omega \end{aligned}$

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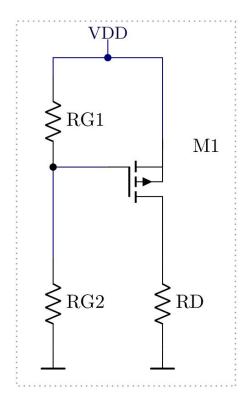


Hallamos el V_T :

¿El transistor MOS es canal P o canal N?

$\begin{aligned} & \underline{\text{Datos}} \\ |\text{V}_{\text{T}}| &= 0.8 \text{ V}, \, \mu_{\text{P}} \text{C'}_{\text{ox}} = 80 \,\, \mu\text{A/V}^2 \\ & \text{W} &= 32 \,\, \mu\text{m}, \, \text{L} = 4 \,\, \mu\text{m} \\ & \lambda = 0.02 \,\, \text{V}^{-1}, \,\, \text{Y}^2 = 0.5 \,\, \text{V} \\ & \text{R}_{\text{G1}} = 130 \,\, \text{k}\Omega, \, \text{R}_{\text{G2}} = 370 \,\, \text{k}\Omega \end{aligned}$

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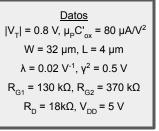


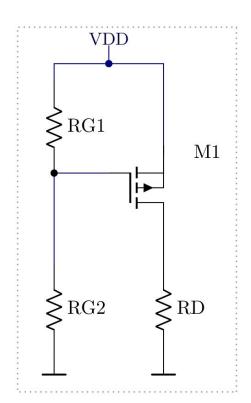
Hallamos el V_⊤:

¿El transistor MOS es canal P o canal N?

Por su símbolo es canal P y por lo tanto el substrato es tipo N.

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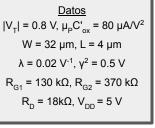


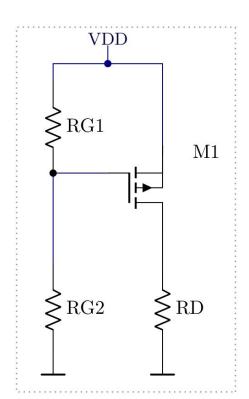


Hallamos el V_⊤:

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- $V_T = 0.8 \text{ V o } V_T = -0.8 \text{ V?}$, ¿porqué?

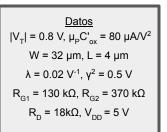


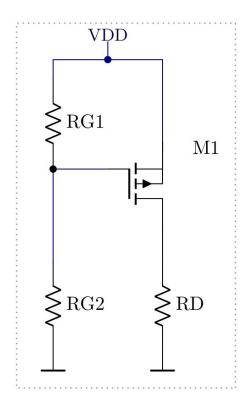


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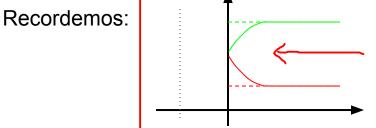




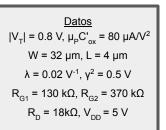
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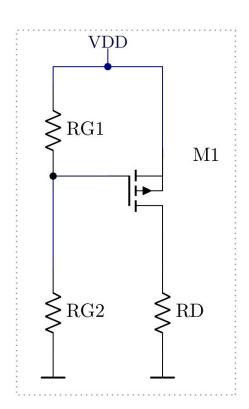
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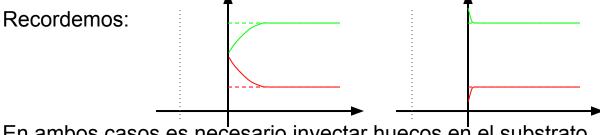




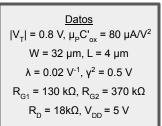


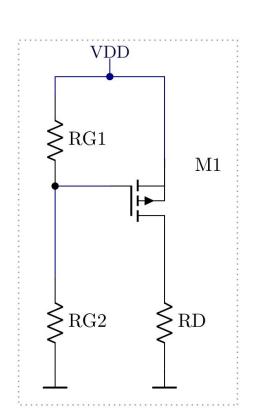
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En ambos casos es necesario inyectar huecos en el substrato para llegar a inversión

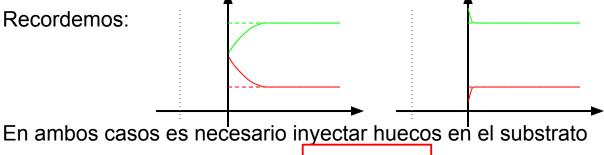




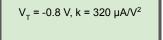
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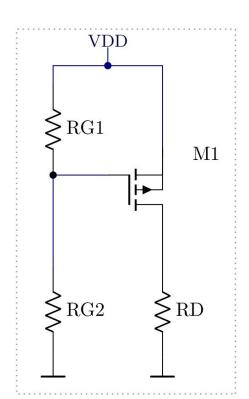
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para llegar a inversión, entonces $V_T = -0.8 \text{ V}$

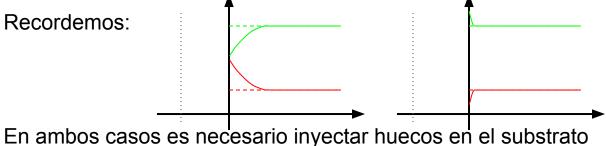


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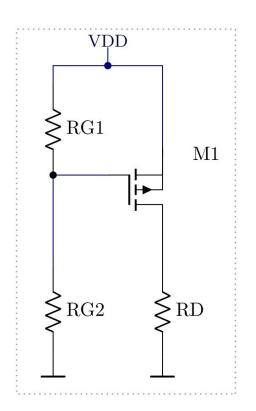


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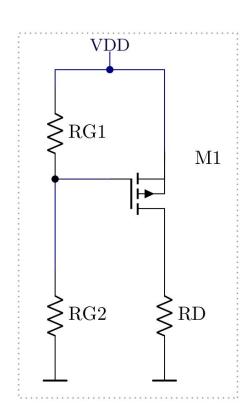
 $V_T = -0.8 \text{ V}, k = 320 \mu\text{A/V}^2$

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Ahora sí pasamos al circuito de polarización:

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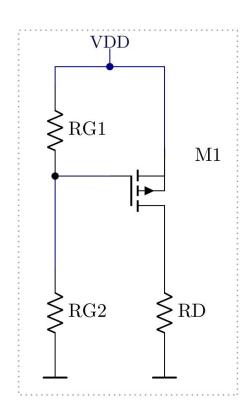


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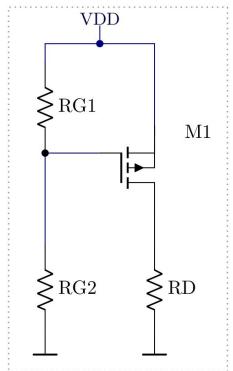
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Fuentes de continua

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- Fuentes de continua
- Capacitores = Circuitos abiertos

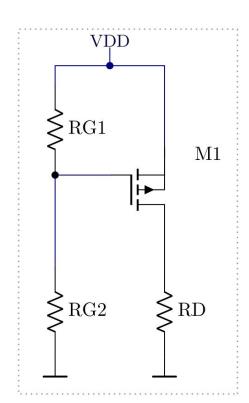


 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ } \mu\text{A/V}^2$

Ahora sí pasamos al circuito de polarización:

- Fuentes de continua
- Capacitores = Circuitos abiertos
- Modelo de "Gran Señal"

$$\begin{split} &\frac{Datos}{|V_T|} = 0.8 \text{ V}, \ \mu_P \text{C'}_{ox} = 80 \ \mu \text{A/V}^2 \\ &\text{W} = 32 \ \mu \text{m}, \ \text{L} = 4 \ \mu \text{m} \\ &\lambda = 0.02 \ \text{V}^{-1}, \ \gamma^2 = 0.5 \ \text{V} \\ &\text{R}_{G1} = 130 \ \text{k}\Omega, \ \text{R}_{G2} = 370 \ \text{k}\Omega \\ &\text{R}_D = 18 \text{k}\Omega, \ \text{V}_{DD} = 5 \ \text{V} \end{split}$$



 $V_T = -0.8 \text{ V}, k = 320 \mu\text{A/V}^2$

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Ahora sí pasamos al circuito de polarización:

- Fuentes de continua
- ullet Capacitores = Circuitos abiertos $_{
 earlow}I_G=1$
- Modelo de "Gran Señal"

VDD RG1 M1RD

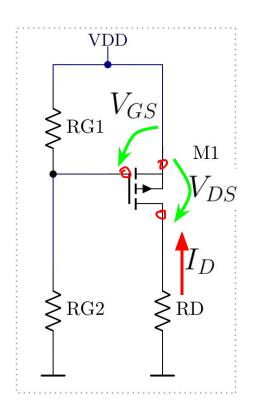
 $I_D = f(V_{GS}, V_{DS}, V_{BS})$

 $V_T = -0.8 \text{ V}, k = 320 \text{ }\mu\text{A/V}^2$

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Ahora sí pasamos al circuito de polarización:

- Fuentes de continua
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- ullet Modelo de "Gran Señal" $\begin{cases} \longleftarrow I_D = f(V_{GS}, V_{DS}, V_{BS}) \end{cases}$



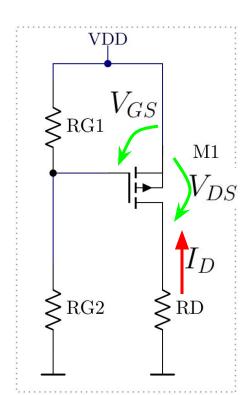
 V_{τ} = -0.8 V, k = 320 μ A/V²

Datos $|V_T| = 0.8 \text{ V}, \ \mu_P \text{C'}_{ox} = 80 \ \mu\text{A/V}^2$ $W = 32 \mu m, L = 4 \mu m$ $\lambda = 0.02 \text{ V}^{-1}, \, \gamma^2 = 0.5 \text{ V}$ $R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$ $R_{D} = 18k\Omega, V_{DD} = 5 V$

Ahora sí pasamos al circuito de polarización:

- Fuentes de continua
- Capacitores = Circuitos abiertos $I_G=0$ Modelo de "Gran Señal" $I_D=f(V_{GS},V_{DS},V_{BS})$

$$I_{D} = \begin{cases} 0 & \text{corte} \\ -k(2(V_{GS} - V_{T}) - V_{DS})V_{DS} & \text{triodo} \\ \underbrace{-k(V_{GS} - V_{T})^{2}}_{I_{D\text{-sat}}} [1 - \lambda(V_{DS} - V_{DS\text{-sat}})] & \text{saturación} \end{cases}$$



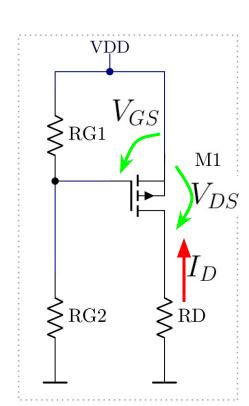
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Ahora sí pasamos al circuito de polarización:

- Fuentes de continua
- ullet Modelo de "Gran Señal" $\begin{cases} \longleftarrow I_D = f(V_{GS}, V_{DS}, V_{BS}) \end{cases}$

$$I_D = \begin{cases} 0 & \text{corte} \\ -k(2(V_{GS} - V_T) - V_{DS})V_{DS} & \text{triodo} \\ -k(V_{GS} + V_T)^2[1 - \lambda(V_{DS} - V_{DS\text{-sat}})] & \text{saturación} \end{cases}$$
$$V_T(V_{BS}) = V_{FB} - 2\phi_n - \gamma\sqrt{2\phi_n + V_{BS}}$$



 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ }\mu\text{A}/\text{V}^2$

 $\begin{aligned} & \underline{Datos} \\ |V_T| &= 0.8 \text{ V}, \ \mu_P C'_{ox} = 80 \ \mu A/V^2 \\ & W &= 32 \ \mu m, \ L = 4 \ \mu m \\ & \lambda = 0.02 \ V^{-1}, \ \gamma^2 = 0.5 \ V \\ & R_{G1} &= 130 \ k\Omega, \ R_{G2} = 370 \ k\Omega \\ & R_D &= 18k\Omega, \ V_{DD} = 5 \ V \end{aligned}$

Ahora sí pasamos al circuito de polarización:

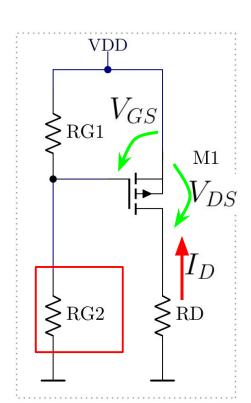
- Fuentes de continua
- Capacitores = Circuitos abiertos $_{\nearrow}I_{G}=0$
- Modelo de "Gran Señal" $I_D = f(V_{GG}, V_{DG}, V_{BS})$

 $I_D = \begin{cases} 0 \\ -k(2) \\ -k(V_0) \end{cases}$

Polarización: Debemos hallar "todas" las tensiones y corrientes de nuestro circuito:

{ss}, V{DS} e I_D

y el régimen de operación del MOS



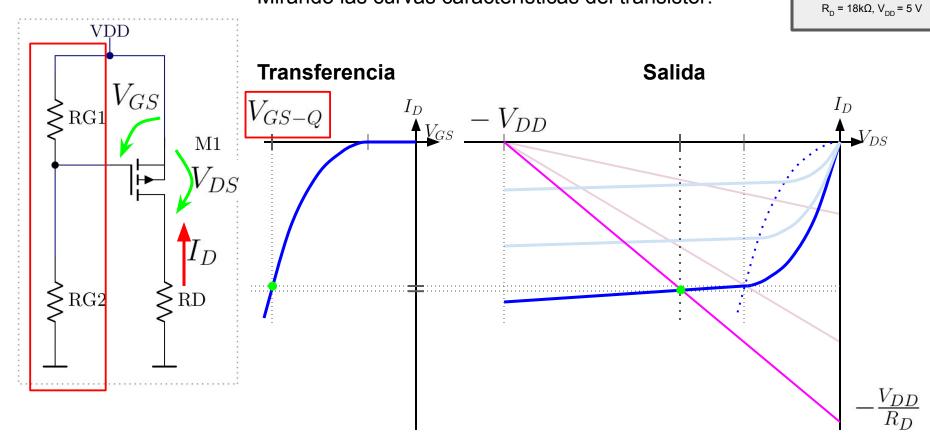
 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ }\mu\text{A}/\text{V}^2$

 $|V_T| = 0.8 \text{ V}, \mu_P C'_{ox} = 80 \mu A/V^2$

W = 32 μm, L = 4 μm

Datos

 $λ = 0.02 \text{ V}^{-1}, \ γ^2 = 0.5 \text{ V}$ $R_{G1} = 130 \text{ k}Ω, \ R_{G2} = 370 \text{ k}Ω$



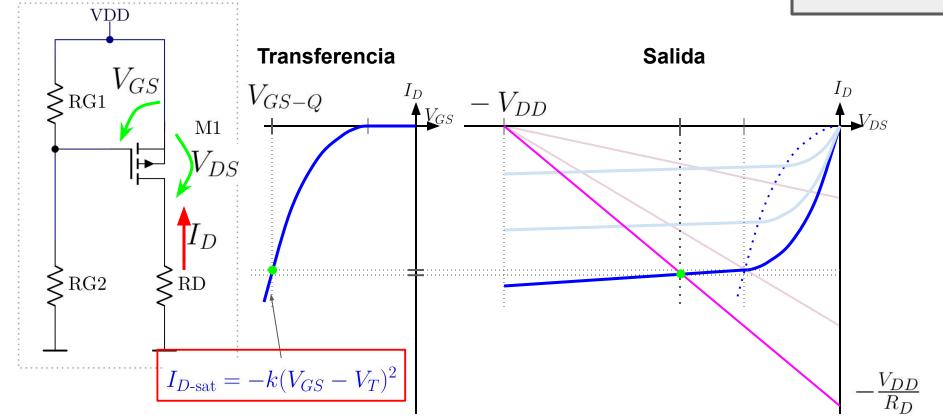
 $V_{T} = -0.8 \text{ V}, \text{ k} = 320 \text{ } \mu\text{A/V}^{2}$

 $|V_T| = 0.8 \text{ V}, \ \mu_P C'_{OX} = 80 \ \mu\text{A/V}^2$ $W = 32 \mu m, L = 4 \mu m$

 $R_{D} = 18k\Omega, V_{DD} = 5 V$

Datos

 $\lambda = 0.02 \text{ V}^{-1}, \, \gamma^2 = 0.5 \text{ V}$ $R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$

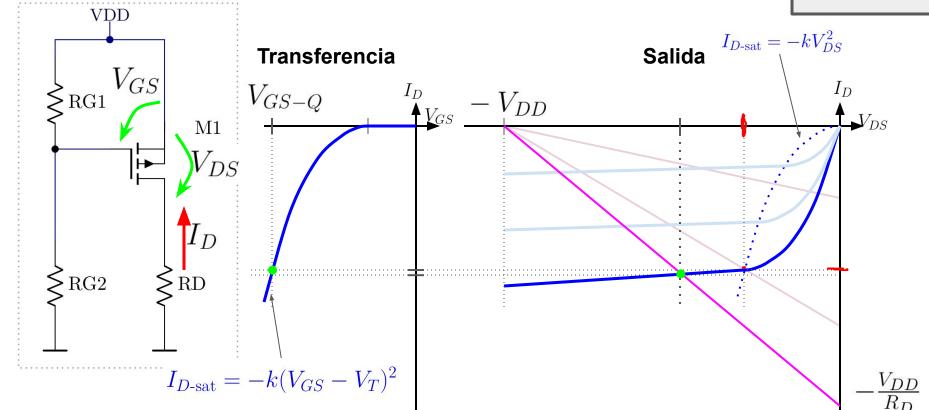


 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ }\mu\text{A/V}^2$

 $W = 32 \ \mu m, \ L = 4 \ \mu m$ $\lambda = 0.02 \ V^{\text{-1}}, \ \gamma^2 = 0.5 \ V$ $R_{\text{G1}} = 130 \ k\Omega, \ R_{\text{G2}} = 370 \ k\Omega$

 $R_{D} = 18k\Omega, V_{DD} = 5 V$

 $|V_T| = 0.8 \text{ V}, \mu_P C'_{ox} = 80 \mu A/V^2$

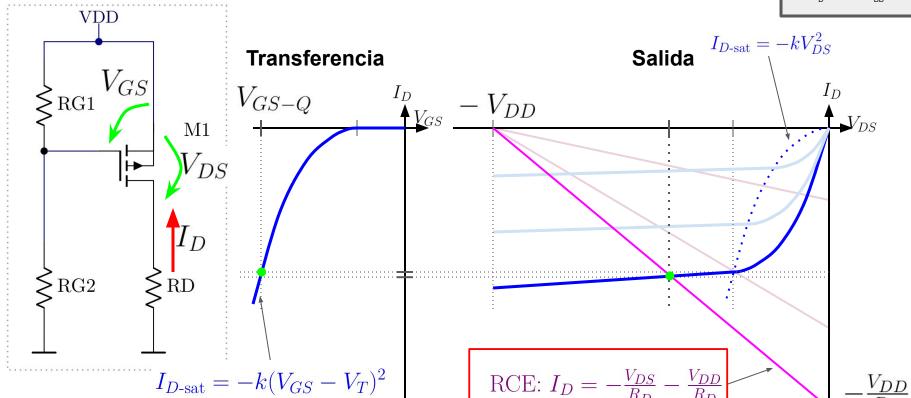


 $V_{T} = -0.8 \text{ V}, \text{ k} = 320 \text{ }\mu\text{A/V}^{2}$

Mirando las curvas características del transistor:

W = 32 μ m, L = 4 μ m λ = 0.02 V⁻¹, γ ² = 0.5 V R_{G1} = 130 $k\Omega$, R_{G2} = 370 $k\Omega$ R_{D} = 18 $k\Omega$, V_{DD} = 5 V

 $|V_T| = 0.8 \text{ V}, \mu_P C'_{ox} = 80 \mu A/V^2$

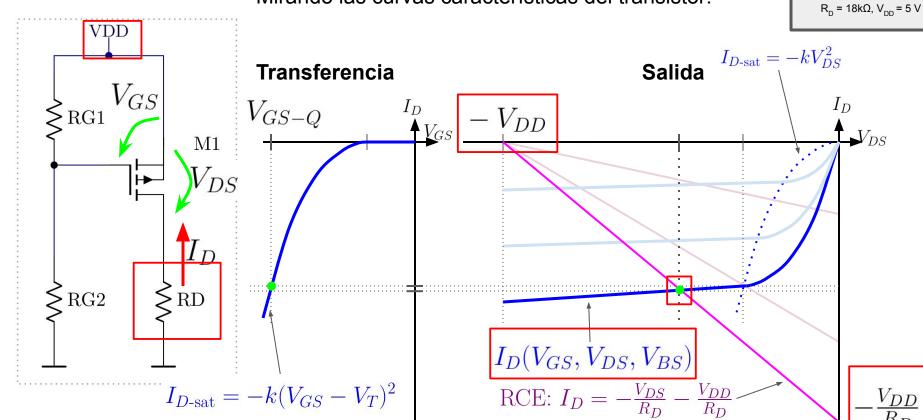


 $V_T = -0.8 \text{ V}, k = 320 \mu\text{A/V}^2$

 $|V_T| = 0.8 \text{ V}, \, \mu_P C'_{OX} = 80 \, \mu \text{A/V}^2$ $W = 32 \mu m, L = 4 \mu m$ $\lambda = 0.02 \text{ V}^{-1}, \, \gamma^2 = 0.5 \text{ V}$

Datos

 $R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$



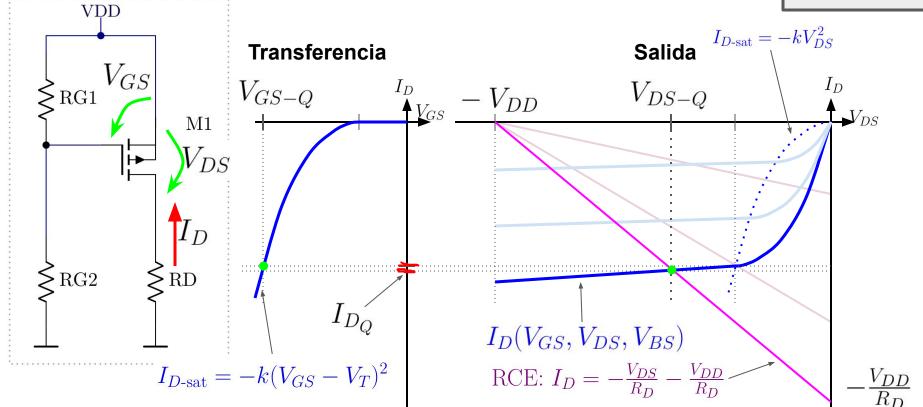
 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ } \mu\text{A/V}^2$

Mirando las curvas características del transistor:

 $λ = 0.02 \text{ V}^{-1}$ $γ^2 = 0.5 \text{ V}$ $R_{G1} = 130 \text{ k}Ω, R_{G2} = 370 \text{ k}Ω$ $R_D = 18 \text{k}Ω, V_{DD} = 5 \text{ V}$

 $|V_T| = 0.8 \text{ V}, \mu_P C'_{ox} = 80 \mu \text{A/V}^2$

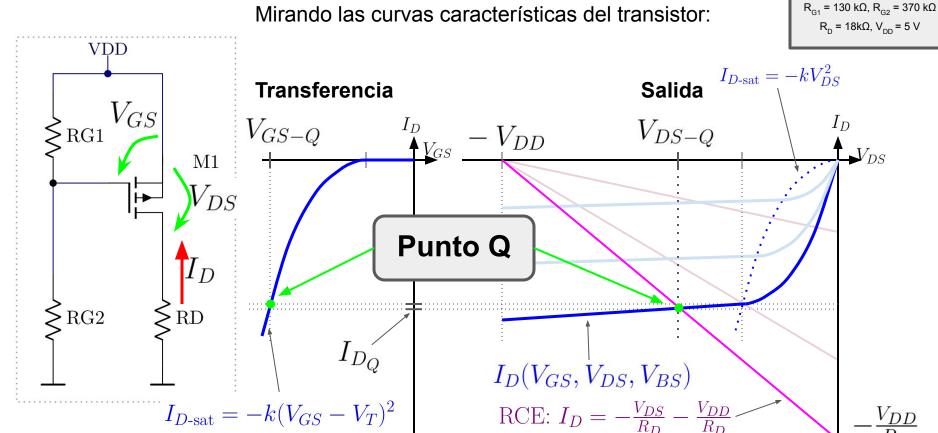
 $W = 32 \mu m$, L = 4 μm



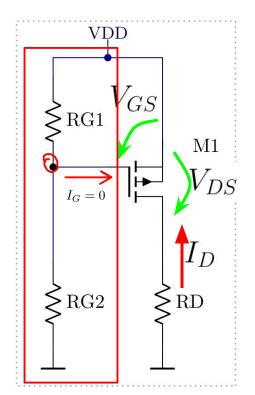
 $V_{T} = -0.8 \text{ V}, \text{ k} = 320 \text{ } \mu\text{A/V}^{2}$

Datos $|V_T| = 0.8 \text{ V}, \, \mu_P C'_{OX} = 80 \, \mu \text{A/V}^2$

> $W = 32 \mu m, L = 4 \mu m$ $\lambda = 0.02 \text{ V}^{-1}, \, \gamma^2 = 0.5 \text{ V}$

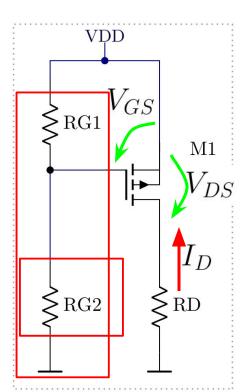


Hallamos V_{GS}:



 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ } \mu\text{A/V}^2$

 $\begin{aligned} & \underline{Datos} \\ |V_T| &= 0.8 \text{ V}, \ \mu_P \text{C'}_{ox} = 80 \ \mu \text{A/V}^2 \\ & \text{W} = 32 \ \mu \text{m}, \ L = 4 \ \mu \text{m} \\ & \lambda = 0.02 \ \text{V'}^1, \ \gamma^2 = 0.5 \ \text{V} \\ & \text{R}_{G1} = 130 \ \text{k}\Omega, \ \text{R}_{G2} = 370 \ \text{k}\Omega \\ & \text{R}_D = 18 \text{k}\Omega, \ \text{V}_{DD} = 5 \ \text{V} \end{aligned}$



Hallamos V_{GS}:

Empezamos por V_G:

$$V_G = V_{DD} \frac{R_{G2}}{R_{G1} + R_{G2}}$$

 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ } \mu\text{A/V}^2$

$$\begin{split} &\frac{Datos}{|V_T|} = 0.8 \ V, \ \mu_P C'_{ox} = 80 \ \mu A / V^2 \\ &V = 32 \ \mu m, \ L = 4 \ \mu m \\ &\lambda = 0.02 \ V^{-1}, \ \gamma^2 = 0.5 \ V \\ &R_{G1} = 130 \ k\Omega, \ R_{G2} = 370 \ k\Omega \\ &R_D = 18 k\Omega, \ V_{DD} = 5 \ V \end{split}$$

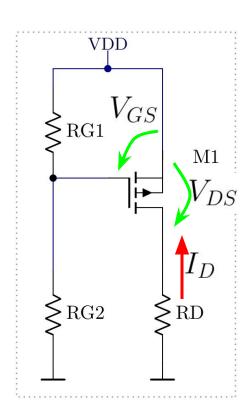
 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ } \mu\text{A/V}^2$

 $\begin{aligned} & \underline{Datos} \\ |V_T| &= 0.8 \text{ V}, \ \mu_p \text{C'}_{ox} = 80 \ \mu \text{A/V}^2 \\ & \text{W} = 32 \ \mu \text{m}, \ L = 4 \ \mu \text{m} \\ & \lambda = 0.02 \ \text{V}^{-1}, \ \gamma^2 = 0.5 \ \text{V} \\ & \text{R}_{\text{G1}} = 130 \ \text{k}\Omega, \ \text{R}_{\text{G2}} = 370 \ \text{k}\Omega \\ & \text{R}_{\text{D}} = 18 \text{k}\Omega, \ \text{V}_{\text{DD}} = 5 \ \text{V} \end{aligned}$

Hallamos V_{GS}:

Empezamos por V_G:

$$V_G = V_{DD} \frac{R_{G2}}{R_{G1} + R_{G2}} = 5 V \frac{370}{370 + 130}$$



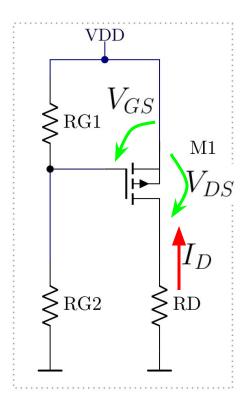
 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ }\mu\text{A/V}^2$

 $\begin{aligned} & \underline{Datos} \\ |V_T| &= 0.8 \text{ V}, \ \mu_P C'_{ox} = 80 \ \mu A/V^2 \\ & W &= 32 \ \mu m, \ L = 4 \ \mu m \\ & \lambda = 0.02 \ V^{-1}, \ \gamma^2 = 0.5 \ V \\ & R_{G1} &= 130 \ k\Omega, \ R_{G2} = 370 \ k\Omega \\ & R_D &= 18k\Omega, \ V_{DD} = 5 \ V \end{aligned}$



Empezamos por V_G:

$$V_G = V_{DD} \frac{R_{G2}}{R_{G1} + R_{G2}} = 5 \text{ V} \frac{370}{370 + 130} = 3.7 \text{ V}$$



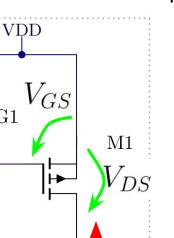
 $V_{T} = -0.8 \text{ V}, \text{ k} = 320 \text{ } \mu\text{A/V}^{2}$

Datos $|V_T| = 0.8 \text{ V}, \ \mu_P \text{C'}_{OX} = 80 \ \mu\text{A/V}^2$

 $W = 32 \mu m, L = 4 \mu m$ $\lambda = 0.02 \text{ V}^{-1}, \, \gamma^2 = 0.5 \text{ V}$

 $R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$

 $R_D = 18k\Omega$, $V_{DD} = 5 V$



Hallamos V_{GS}:

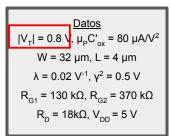
Empezamos por V_G:

$$V_G = V_{DD} \frac{R_{G2}}{R_{G1} + R_{G2}} = 5 \text{ V} \frac{370}{370 + 130} = 3.7 \text{ V}$$

Luego V_{GS}:

$$V_{GS} = V_G - V_S$$

 $V_T = -0.8 \text{ V}, k = 320 \text{ } \mu\text{A/V}^2$



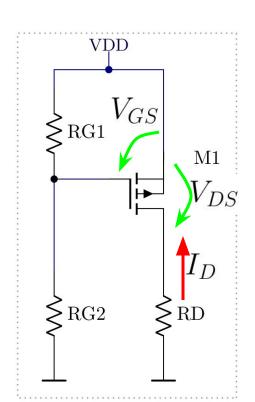
Hallamos V_{GS}:

Empezamos por V_G:

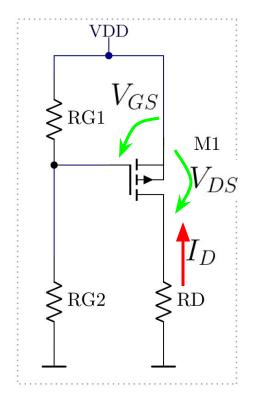
$$V_G = V_{DD} \frac{R_{G2}}{R_{G1} + R_{G2}} = 5 \text{ V} \frac{370}{370 + 130} = 3.7 \text{ V}$$

Luego V_{GS}:

$$V_{GS} = V_G - V_S = 3.7 \,\text{V} - 5 \,\text{V} = -1.3 \,\text{V}$$



Hallamos V_{DS} e I_{D} :

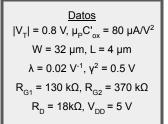


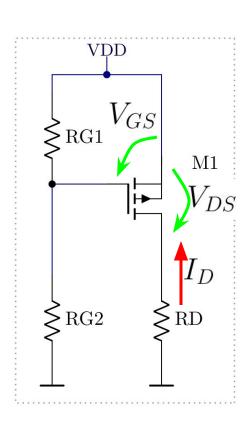
 $V_T = -0.8 \text{ V}, k = 320 \text{ } \mu\text{A/V}^2$

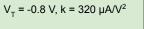
 $\begin{aligned} & \underline{Datos} \\ |V_T| &= 0.8 \text{ V}, \ \mu_P C'_{ox} = 80 \ \mu\text{A/V}^2 \\ & W &= 32 \ \mu\text{m}, \ L = 4 \ \mu\text{m} \\ & \lambda = 0.02 \ V^{-1}, \ \gamma^2 = 0.5 \ V \\ & R_{G1} &= 130 \ k\Omega, \ R_{G2} = 370 \ k\Omega \\ & R_D &= 18k\Omega, \ V_{DD} = 5 \ V \end{aligned}$

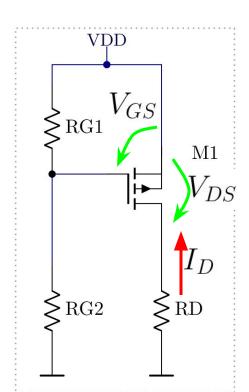
 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ } \mu\text{A/V}^2$

Hallamos V_{DS} e I_D:









Hallamos V_{DS} e I_{D} :

Supongo SATURACIÓN entonces:

$$I_{D\text{-sat}} = -k(V_{GS} - V_T)^2$$

$$V_{DS\text{-sat}} = V_{GS} - V_T$$

Datos $|V_T| = 0.8 \text{ V}, \ \mu_P \text{C'}_{OX} = 80 \ \mu\text{A/V}^2$ $W = 32 \mu m, L = 4 \mu m$ $\lambda = 0.02 \text{ V}^{-1}, \, \gamma^2 = 0.5 \text{ V}$ $R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$ $R_{D} = 18k\Omega, V_{DD} = 5 V$

 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ } \mu\text{A/V}^2$

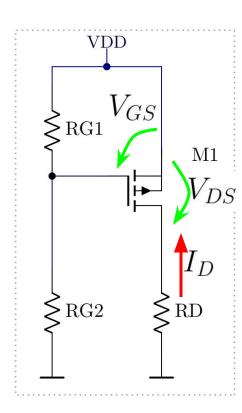
 $|V_T| = 0.8 \text{ V}, \mu_P \text{C}'_{ox} = 80 \text{ μA/V}^2$ W = 32 μm, L = 4 μm $\lambda = 0.02 \text{ V}^{-1}, \gamma^2 = 0.5 \text{ V}$ $R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$ $R_D = 18\text{k}\Omega, V_{DD} = 5 \text{ V}$

Hallamos V_{DS} e I_{D} :

$$I_{D\text{-sat}} = -k(V_{GS} - V_T)^2$$

= $-320 \frac{\mu A}{V^2} (0.5 \text{ V})^2 = -80 \mu A$

$$V_{DS\text{-sat}} = V_{GS} - V_T$$



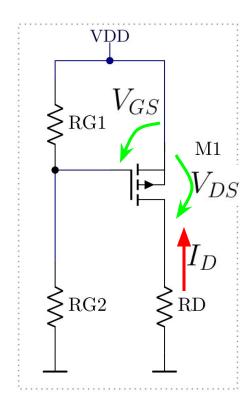
 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ } \mu\text{A/V}^2$

 $\begin{aligned} & \underline{\text{Datos}} \\ |V_{\text{T}}| &= 0.8 \text{ V}, \ \mu_{\text{P}} \text{C'}_{\text{ox}} = 80 \ \mu\text{A/V}^2 \\ & \text{W} = 32 \ \mu\text{m}, \ \text{L} = 4 \ \mu\text{m} \\ & \lambda = 0.02 \ \text{V}^{-1}, \ \gamma^2 = 0.5 \ \text{V} \\ & \text{R}_{\text{G1}} = 130 \ \text{k}\Omega, \ \text{R}_{\text{G2}} = 370 \ \text{k}\Omega \\ & \text{R}_{\text{D}} = 18 \text{k}\Omega, \ \text{V}_{\text{DD}} = 5 \ \text{V} \end{aligned}$

Hallamos V_{DS} e I_D:

$$I_{D-\text{sat}} = -k(V_{GS} - V_T)^2$$
$$= -320 \frac{\mu A}{V^2} (0.5 \text{ V})^2 = -80 \mu A$$

$$V_{DS\text{-sat}} = V_{GS} - V_T = -0.5 \text{ V}$$



 $V_T = 0.8 \text{ V, k} = 320 \mu \Lambda \Lambda^2$ $I_{Dsat} = -80 \mu A, V_{DS-sat} = 0.5 \text{V}$

$$\begin{split} &\frac{Datos}{|V_T|} = 0.8 \text{ V}, \, \mu_P \text{C'}_{ox} = 80 \,\, \mu \text{A/V}^2 \\ &\text{W} = 32 \,\, \mu \text{m}, \, \text{L} = 4 \,\, \mu \text{m} \\ &\text{\lambda} = 0.02 \,\, \text{V}^{-1}, \, \gamma^2 = 0.5 \,\, \text{V} \\ &\text{R}_{\text{G1}} = 130 \,\, \text{k}\Omega, \, \text{R}_{\text{G2}} = 370 \,\, \text{k}\Omega \end{split}$$

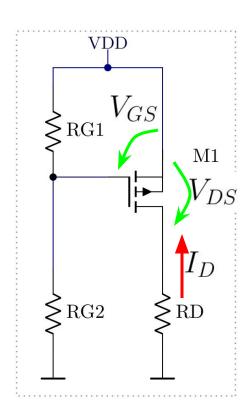
 $R_{D} = 18k\Omega, V_{DD} = 5 V$

Hallamos V_{DS} e I_{D} :

$$I_{D\text{-sat}} = -k(V_{GS} - V_T)^2$$

= $-320 \frac{\mu A}{V^2} (0.5 \text{ V})^2 = -80 \mu A$

$$V_{DS\text{-sat}} = V_{GS} - V_T = -0.5 \,\text{V}$$



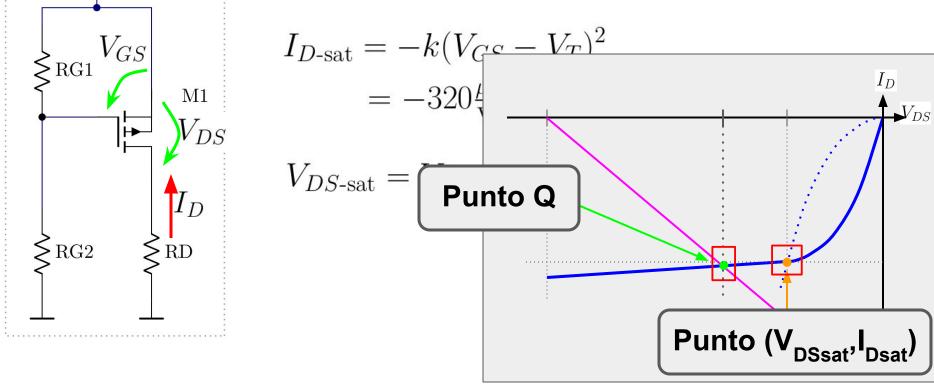
VDD

 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ } \mu\text{A/V}^2$ $I_{Dsat} = -80 \text{ } \mu\text{A}, \text{ } V_{DS-sat} = 0.5 \text{V}$

 $|V_T|$ = 0.8 V, $μ_p C'_{ox}$ = 80 μA/V² W = 32 μm, L = 4 μm λ = 0.02 V⁻¹, γ² = 0.5 V R_{G1} = 130 kΩ, R_{G2} = 370 kΩ R_D = 18kΩ, V_{DD} = 5 V

Datos

Hallamos V_{DS} e I_{D} :



Datos $|V_T| = 0.8 \text{ V}, \ \mu_P C'_{OX} = 80 \ \mu \text{A/V}^2$ $W = 32 \mu m, L = 4 \mu m$ $\lambda = 0.02 \text{ V}^{-1}, \, \gamma^2 = 0.5 \text{ V}$ $R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$ $R_D = 18k\Omega, V_{DD} = 5 V$

Hallamos V_{DS} e I_{D} :

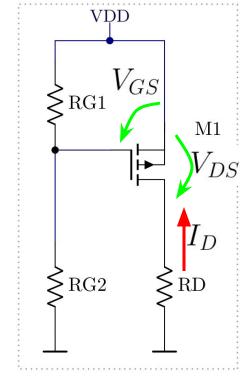
Supongo SATURACIÓN entonces:

$$I_{D\text{-sat}} = -k(V_{GS} - V_T)^2$$

= $-320 \frac{\mu A}{V^2} (0.5 \text{ V})^2 = -80 \mu A$

$$V_{DS\text{-sat}} = V_{GS} - V_T = -0.5 \,\text{V}$$

 $I_D = I_{D\text{-sat}} \left[1 - \lambda (V_{DS} - V_{DS\text{-sat}}) \right]$ $I_D R_D - V_{DS} = V_{DD}$



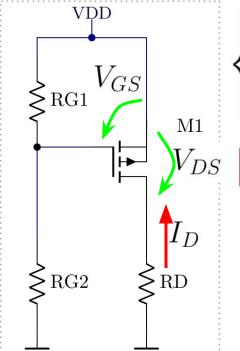
 V_{τ} = -0.8 V, k = 320 μ A/V²

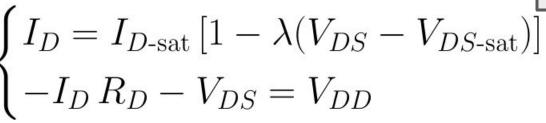
Datos

 $|V_T| = 0.8 \text{ V}, \ \mu_P \text{C'}_{ox} = 80 \ \mu \text{A/V}^2$ $W = 32 \mu m, L = 4 \mu m$

 $\lambda = 0.02 \text{ V}^{-1}, \, \gamma^2 = 0.5 \text{ V}$

 $R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$ $R_{D} = 18k\Omega, V_{DD} = 5 V$

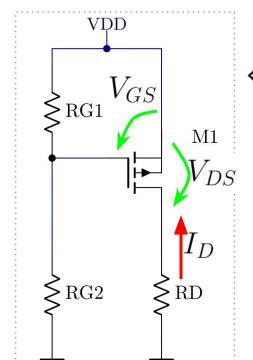




- Por simulación
- Despejando
- Iterando

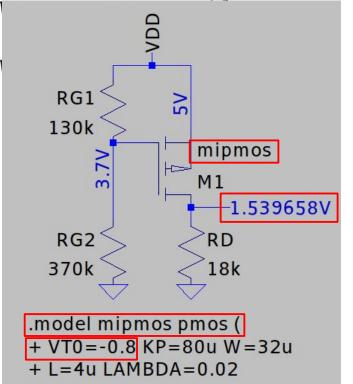
 $V_T = -0.8 \text{ V, k} = 320 \text{ } \mu\text{A/V}^2$ $I_{Dsat} = -80 \text{ } \mu\text{A, V}_{DS-sat} = 0.5 \text{V}$

$$\begin{split} &\frac{Datos}{|V_T|} = 0.8 \text{ V}, \ \mu_P \text{C'}_{ox} = 80 \ \mu \text{A/V}^2 \\ &\text{W} = 32 \ \mu \text{m}, \ \text{L} = 4 \ \mu \text{m} \\ &\lambda = 0.02 \ \text{V}^{-1}, \ \gamma^2 = 0.5 \ \text{V} \\ &\text{R}_{G1} = 130 \ \text{k}\Omega, \ \text{R}_{G2} = 370 \ \text{k}\Omega \\ &\text{R}_D = 18 \text{k}\Omega, \ \text{V}_{DD} = 5 \ \text{V} \end{split}$$



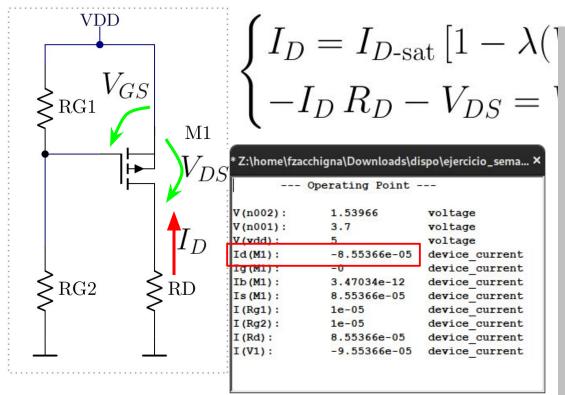
$$\begin{cases} I_D = I_{D\text{-sat}} [1 - \lambda()] \\ -I_D R_D - V_{DS} = 0 \end{cases}$$

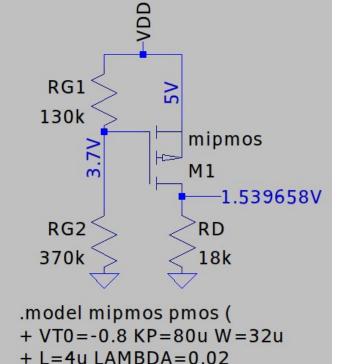
- Por simulación
- Despejando
- Iterando



 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ }\mu\text{A/V}^2$ $I_{Deat} = -80 \text{ }\mu\text{A}, V_{DS-sat} = 0.5 \text{V}$

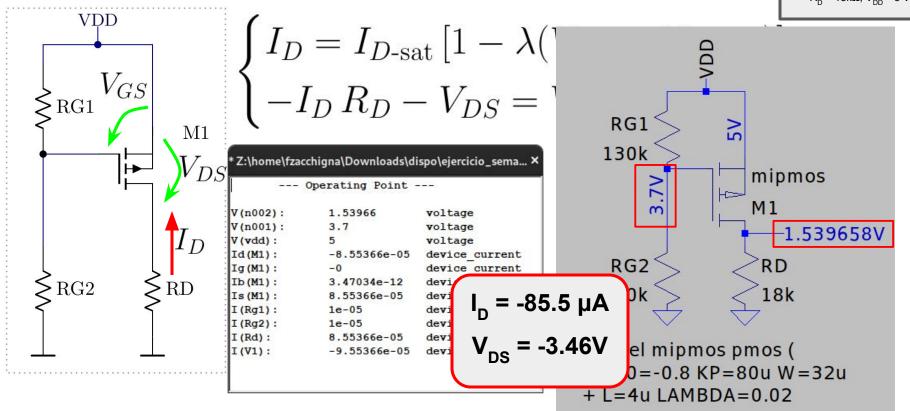
 $\begin{aligned} & \underline{Datos} \\ |V_T| &= 0.8 \text{ V, } \mu_P \text{C'}_{ox} = 80 \text{ } \mu \text{A/V}^2 \\ & \text{W} = 32 \text{ } \mu \text{m, } \text{L} = 4 \text{ } \mu \text{m} \\ & \lambda = 0.02 \text{ V}^{-1}, \text{ } \gamma^2 = 0.5 \text{ V} \\ & \text{R}_{G1} = 130 \text{ } k\Omega, \text{R}_{G2} = 370 \text{ } k\Omega \\ & \text{R}_D = 18 \text{k}\Omega, \text{V}_{DD} = 5 \text{ V} \end{aligned}$





 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ } \mu\text{A/V}^2$ $I_{Dsat} = -80 \text{ } \mu\text{A}, \text{ } V_{DS-sat} = 0.5 \text{V}$

$$\begin{split} &\frac{Datos}{|V_T|} = 0.8 \text{ V}, \ \mu_P \text{C'}_{ox} = 80 \ \mu \text{A/V}^2 \\ &\text{W} = 32 \ \mu \text{m}, \ \text{L} = 4 \ \mu \text{m} \\ &\lambda = 0.02 \ \text{V'}^1, \ \gamma^2 = 0.5 \ \text{V} \\ &\text{R}_{G1} = 130 \ \text{k}\Omega, \ \text{R}_{G2} = 370 \ \text{k}\Omega \\ &\text{R}_D = 18 \text{k}\Omega, \ \text{V}_{DD} = 5 \ \text{V} \end{split}$$



 V_{τ} = -0.8 V, k = 320 μ A/V² $I_{Dsat} = -80 \mu A, V_{DS-sat} = 0.5 V$

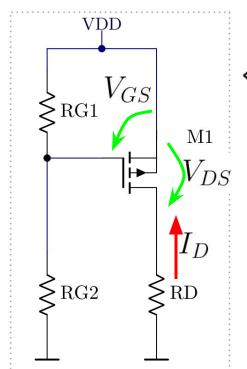
Datos $|V_T| = 0.8 \text{ V}, \ \mu_P \text{C'}_{ox} = 80 \ \mu \text{A/V}^2$

 $W = 32 \mu m, L = 4 \mu m$

 $\lambda = 0.02 \text{ V}^{-1}, \, \gamma^2 = 0.5 \text{ V}$

 $R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$

 $R_D = 18k\Omega, V_{DD} = 5 V$



$$\begin{bmatrix} I_D = I_{D\text{-sat}} \left[1 - \lambda (V_{DS} - V_{DS\text{-sat}}) \right] \leftarrow \\ -I_D R_D - V_{DS} = V_{DD} \end{bmatrix}$$

- Por simulación
- Despejando
- Iterando

$$V_{DS} = \frac{\frac{V_{DD}}{R_D I_{D-\text{sat}} \lambda} + \frac{1}{\lambda} + V_{DS}}{1 - \frac{1}{R_D I_{D-\text{sat}} \lambda}}$$

 $V_{\tau} = -0.8 \text{ V}, k = 320 \mu\text{A/V}^2$ $I_{Dsat} = -80 \mu A, V_{DS-sat} = 0.5 V$

Datos $|V_T| = 0.8 \text{ V}, \, \mu_D C'_{OV} = 80 \, \mu \text{A/V}^2$

 $W = 32 \mu m, L = 4 \mu m$

 $\lambda = 0.02 \text{ V}^{-1}, \, \gamma^2 = 0.5 \text{ V}$ $R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$

 $R_{D} = 18k\Omega, V_{DD} = 5 V$

Resolvemos nuestro problema:

```
VDD
                       I_D = I_{D\text{-sat}} \left[ 1 - \lambda (V_{DS} - V_{DS\text{-sat}}) \right]
                       mupcox = 80e-6;
                    10 \text{ vt} = -0.8:
                     9 \text{ vgs} = -1.3;
                     7 k = mupcox/2*W/L
                     5 idsat = -k*(vgs-vt)^2
                     4 vdssat = vgs-vt
                     1 vds = (vdd/(rd*idsat*lambda)+1/lambda+vdssat)/ ...
                                 (1-1/(rd*idsat*lambda))
```

1 id = idsat*(1-lambda*(vds-vdssat))

$$\frac{1}{-\frac{1}{R_D I_{D-\text{sat}} \lambda}} + \frac{1}{\lambda} + V_{DS-\text{sat}}$$

vds = -3.4743id = -0.000084759

 $V_{\tau} = -0.8 \text{ V}, k = 320 \mu\text{A/V}^2$ $I_{Dsat} = -80 \mu A, V_{DS-sat} = 0.5 V$

Datos $|V_T| = 0.8 \text{ V}, \, \mu_D C'_{OV} = 80 \, \mu \text{A/V}^2$

 $W = 32 \mu m, L = 4 \mu m$

 $\lambda = 0.02 \text{ V}^{-1}, \, \gamma^2 = 0.5 \text{ V}$

 $R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$

 $R_{D} = 18k\Omega, V_{DD} = 5 V$

1 vds = (vdd/(rd*idsat*lambda)+1/lambda+vdssat)/...

(1-1/(rd*idsat*lambda))

1 id = idsat*(1-lambda*(vds-vdssat))

Resolvemos nuestro problema:

```
VDD
                        I_D = I_{D\text{-sat}} \left[ 1 - \lambda (V_{DS} - V_{DS\text{-sat}}) \right]
                        mupcox = 80e-6;
                     10 \text{ vt} = -0.8:
                      9 \text{ vgs} = -1.3;
                      7 k = mupcox/2*W/L
                      5 idsat = -k*(vgs-vt)^2
                      4 vdssat = vgs-vt
```

vds = -3.4743id = -0.000084759

 $V_T = -0.8 \text{ V, k} = 320 \text{ }\mu\text{A/V}^2$ $V_{Dsat} = -80 \text{ }\mu\text{A, V}_{DS-sat} = 0.5 \text{ V}$

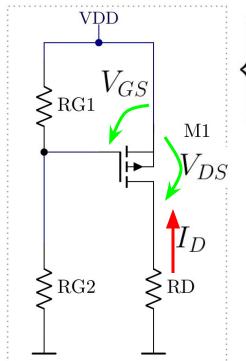
 $|V_T| = 0.8 \text{ V}, \mu_P C'_{ox} = 80 \ \mu \text{A/V}^2$

W = 32 μm, L = 4 μm

 $\lambda = 0.02 \text{ V}^{-1}, \text{ y}^2 = 0.5 \text{ V}$

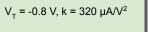
 $R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$

 $R_D = 18k\Omega, V_{DD} = 5 V$

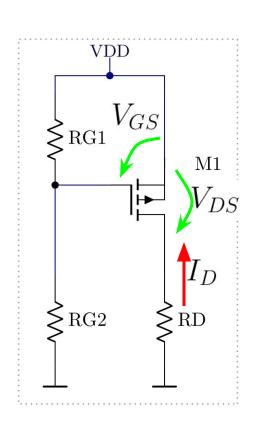


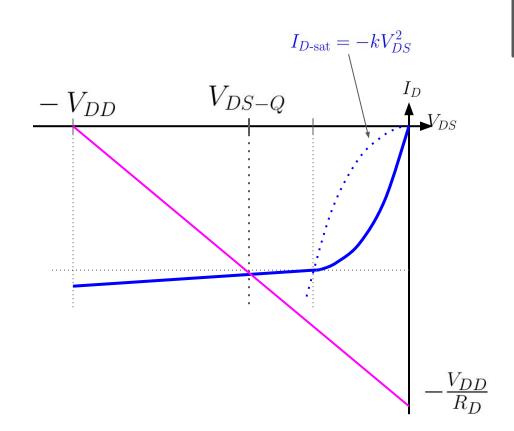
$$\begin{cases} I_{D} = I_{D\text{-sat}} \left[1 - \lambda (V_{DS} - V_{DS\text{-sat}}) \right] \\ -I_{D} R_{D} - V_{DS} = V_{DD} \end{cases}$$

- Por simulación
- Despejando
- Iterando



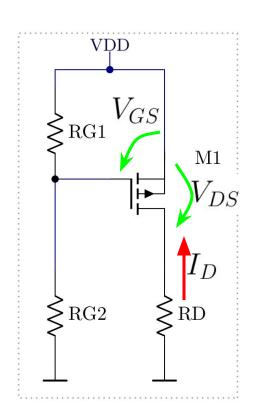
$\begin{aligned} & \underline{\text{Datos}} \\ |V_{\text{T}}| &= 0.8 \text{ V, } \mu_{\text{P}} \text{C'}_{\text{ox}} = 80 \text{ } \mu \text{A/V}^2 \\ & \text{W} = 32 \text{ } \mu \text{m, L} = 4 \text{ } \mu \text{m} \\ & \lambda = 0.02 \text{ V}^{-1}, \text{ } \gamma^2 = 0.5 \text{ V} \\ & \text{R}_{\text{G1}} = 130 \text{ } \text{k} \Omega, \text{ R}_{\text{G2}} = 370 \text{ } \text{k} \Omega \\ & \text{R}_{\text{D}} = 18 \text{k} \Omega, \text{ V}_{\text{DD}} = 5 \text{ V} \end{aligned}$

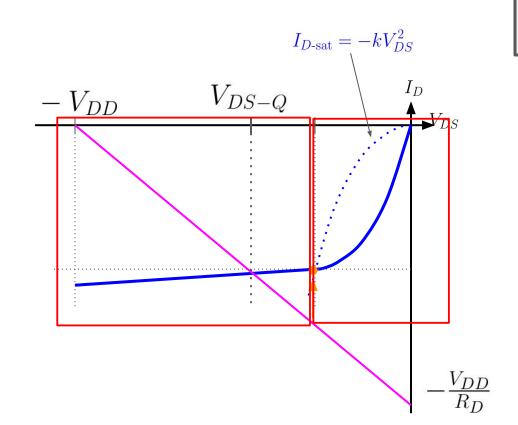




 $V_T = -0.8 \text{ V, k} = 320 \ \mu\text{A/V}^2$

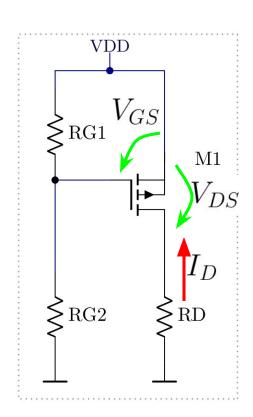
$\begin{aligned} & \underline{Datos} \\ |V_T| &= 0.8 \text{ V}, \ \mu_P \text{C'}_{ox} = 80 \ \mu \text{A/V}^2 \\ & \text{W} = 32 \ \mu \text{m}, \ L = 4 \ \mu \text{m} \\ & \lambda = 0.02 \ \text{V'}^1, \ \gamma^2 = 0.5 \ \text{V} \\ & \text{R}_{G1} = 130 \ \text{k}\Omega, \ \text{R}_{G2} = 370 \ \text{k}\Omega \\ & \text{R}_D = 18 \text{k}\Omega, \ \text{V}_{DD} = 5 \ \text{V} \end{aligned}$

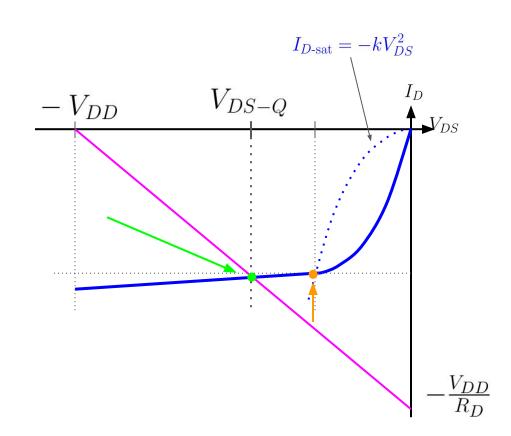


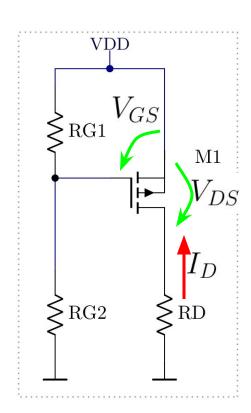


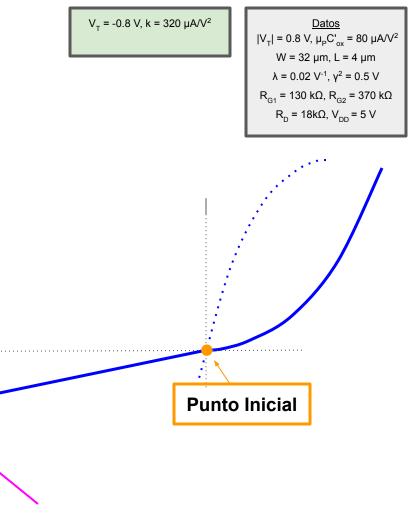
 $V_T = -0.8 \text{ V, k} = 320 \ \mu\text{A/V}^2$

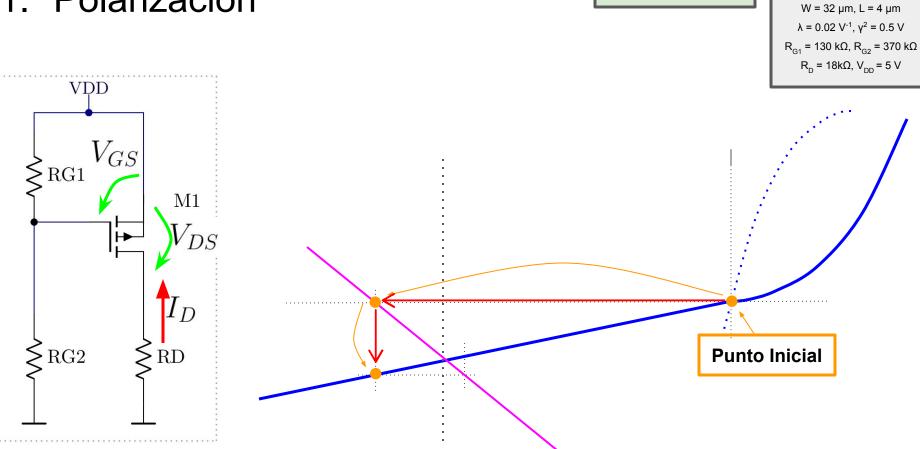
$\begin{aligned} & \underline{Datos} \\ |V_T| &= 0.8 \text{ V}, \ \mu_P \text{C'}_{ox} = 80 \ \mu \text{A/V}^2 \\ & \text{W} = 32 \ \mu \text{m}, \ L = 4 \ \mu \text{m} \\ & \lambda = 0.02 \ \text{V'}^1, \ \gamma^2 = 0.5 \ \text{V} \\ & \text{R}_{G1} = 130 \ \text{k}\Omega, \ \text{R}_{G2} = 370 \ \text{k}\Omega \\ & \text{R}_D = 18 \text{k}\Omega, \ \text{V}_{DD} = 5 \ \text{V} \end{aligned}$





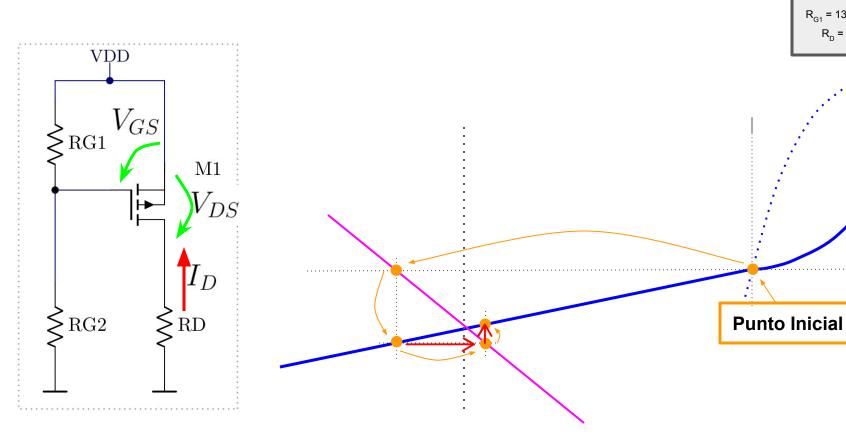






 $V_T = -0.8 \text{ V, k} = 320 \ \mu\text{A/V}^2$

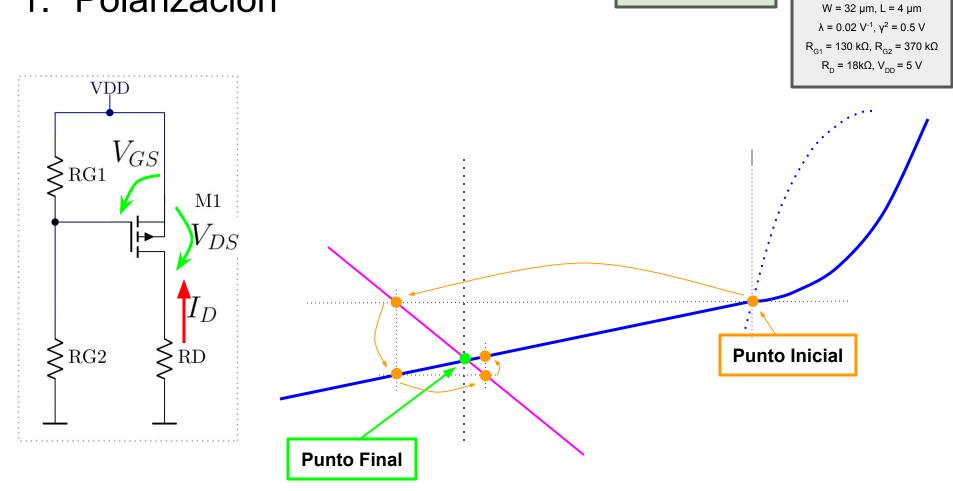
 $|V_T| = 0.8 \text{ V}, \mu_P \text{C'}_{ox} = 80 \mu \text{A/V}^2$



<u>Datos</u>

 $V_T = -0.8 \text{ V, k} = 320 \ \mu\text{A/V}^2$

 $|V_{T}| = 0.8 \text{ V}, \mu_{P}C_{ox}^{-} = 80 \text{ } \mu\text{A/V}^{2}$ $W = 32 \text{ } \mu\text{m}, \text{ } L = 4 \text{ } \mu\text{m}$ $\lambda = 0.02 \text{ V}^{-1}, \text{ } \gamma^{2} = 0.5 \text{ V}$ $R_{G1} = 130 \text{ } k\Omega, R_{G2} = 370 \text{ } k\Omega$ $R_{D} = 18k\Omega, V_{DD} = 5 \text{ V}$



 $V_{T} = -0.8 \text{ V}, k = 320 \mu\text{A/V}^{2}$

 $|V_T| = 0.8 \text{ V}, \mu_P \text{C'}_{ox} = 80 \mu \text{A/V}^2$

 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ }\mu\text{A/V}^2$ $I_{Deat} = -80 \text{ }\mu\text{A}, V_{DS-sat} = -0.5 \text{V}$
$$\begin{split} \frac{Datos}{|V_T|} &= 0.8 \text{ V}, \ \mu_P \text{C'}_{ox} = 80 \ \mu\text{A/V}^2 \\ W &= 32 \ \mu\text{m}, \ L = 4 \ \mu\text{m} \\ \lambda &= 0.02 \ V^{-1}, \ \gamma^2 = 0.5 \ V \\ R_{G1} &= 130 \ \text{k}\Omega, \ R_{G2} = 370 \ \text{k}\Omega \\ R_D &= 18 \text{k}\Omega, \ V_{DD} = 5 \ V \end{split}$$

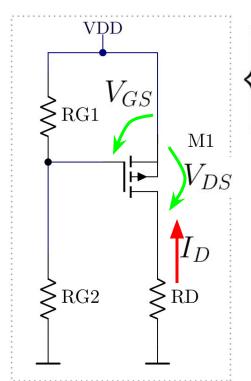
```
VDD
         M1
```

```
\begin{cases} I_{D} = I_{D\text{-sat}} [1 - \lambda (V_{DS} - V_{DS\text{-sat}})] \\ -I_{D} R_{D} - V_{DS} = V_{DD} \end{cases}
```

```
5  vds(1) = vdssat
4  id (1) = idsat
3
2  for i = 2:10
     vds(i) = -vdd-id(i-1)*rd;
     id (i) = idsat*(1-lambda*(vds(i)-vdssat));
1  end
2  [vds(:) id(:)]
3
```

 $V_{\tau} = -0.8 \text{ V}, k = 320 \mu\text{A/V}^2$ $I_{Dsat} = -80 \mu A, V_{DS-sat} = -0.5 V$

Datos $|V_T| = 0.8 \text{ V}, \ \mu_D C'_{OV} = 80 \ \mu\text{A/V}^2$ $W = 32 \mu m, L = 4 \mu m$ $\lambda = 0.02 \text{ V}^{-1}$. $v^2 = 0.5 \text{ V}$ $R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$ $R_{D} = 18k\Omega, V_{DD} = 5 V$

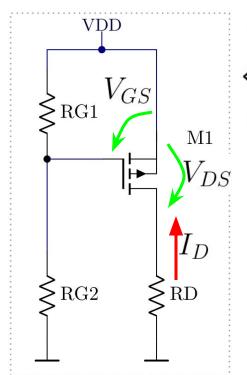


```
\begin{cases} I_D = I_{D\text{-sat}} \left[1 - \lambda (V_{DS} - V_{DS\text{-sat}})\right] \\ -I_D R_D - V_{DS} = V_{\text{ans}} \end{cases}
    5 \text{ vds}(1) = \text{vdssat}
        id (1) = idsat
    2 \text{ for } i = 2:10
           vds(i) = -vdd-id(i-1)
            id(i) = idsat*(1-la)
     1 end
        [vds(:) id(:)]
```

```
-0.500000000
                 -0.000080000
  -3.560000000
                 -0.000084896
  -3.471872000
                 -0.000084755
  -3.474410086
                 -0.000084759
  -3.474336990
                 -0.000084759
  -3.474339095
                 -0.000084759
  -3.474339034
                 -0.000084759
  -3.474339036
                 -0.000084759
  -3.474339036
                 -0.000084759
                 -0.000084759
  -3.474339036
octave:34>
```

 $V_{\tau} = -0.8 \text{ V}, k = 320 \mu\text{A/V}^2$ $I_{Dsat} = -80 \mu A, V_{DS-sat} = -0.5 V$

Datos $|V_T| = 0.8 \text{ V}, \ \mu_D C'_{OV} = 80 \ \mu\text{A/V}^2$ $W = 32 \mu m, L = 4 \mu m$ $\lambda = 0.02 \text{ V}^{-1}$. $v^2 = 0.5 \text{ V}$ $R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$ $R_{D} = 18k\Omega, V_{DD} = 5 V$

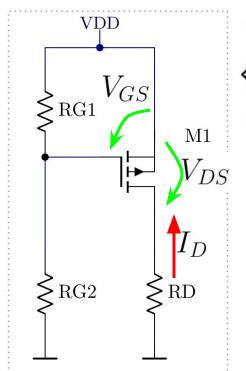


```
\begin{cases} I_D = I_{D\text{-sat}} \left[ 1 - \lambda (V_{DS} - V_{DS\text{-sat}}) \right] \\ -I_D R_D - V_{DS} = V_{\text{ans}} = \end{cases}
     5 \text{ vds}(1) = \text{vdssat}
        id(1) = idsat
    2 \text{ for } i = 2:10
           vds(i) = -vdd-id(i-1)
            id(i) = idsat*(1-la)
     1 end
        [vds(:) id(:)]
```

```
-0.500000000
                 -0.000080000
  -3.560000000
                 -0.000084896
  -3.471872000
                 -0.000084755
  -3.474410086
                 -0.000084759
  -3.474336990
                 -0.000084759
  -3.474339095
                 -0.000084759
  -3.474339034
                 -0.000084759
  -3.474339036
                 -0.000084759
                 -0.000084759
  -3.474339036
  -3.474339036
                 -0.000084759
octave:34>
```

 $V_{\tau} = -0.8 \text{ V}, k = 320 \mu\text{A/V}^2$ $I_{Dsat} = -80 \mu A, V_{DS-sat} = -0.5 V$

Datos $|V_T| = 0.8 \text{ V}, \ \mu_D C'_{OV} = 80 \ \mu\text{A/V}^2$ $W = 32 \mu m, L = 4 \mu m$ $\lambda = 0.02 \text{ V}^{-1}$. $v^2 = 0.5 \text{ V}$ $R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$ $R_{D} = 18k\Omega, V_{DD} = 5 V$

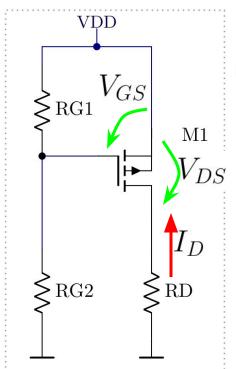


```
\begin{cases} I_D = I_{D\text{-sat}} \left[1 - \lambda (V_{DS} - V_{DS\text{-sat}})\right] \\ -I_D R_D - V_{DS} = V_{\text{ans}} \end{cases}
    5 \text{ vds}(1) = \text{vdssat}
        id(1) = idsat
    2 \text{ for } i = 2:10
           vds(i) = -vdd-id(i-1)
            id(i) = idsat*(1-la)
     1 end
        [vds(:) id(:)]
```

```
-0.500000000
                 -0.000080000
  -3.560000000
                 -0.000084896
  -3.471872000
                 -0.000084755
  -3.474410086
                 -0.000084759
  -3.474336990
                 -0.000084759
  -3.474339095
                 -0.000084759
  -3.474339034
                 -0.000084759
  -3.474339036
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  -3.474339036
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  -3.474339036
octave:34>
```

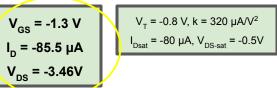
 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ }\mu\text{A}/\text{V}^2$ $I_{Deat} = -80 \text{ }\mu\text{A}, \text{ V}_{DS-eat} = -0.5 \text{V}$ $\begin{aligned} & \underline{Datos} \\ |V_T| &= 0.8 \text{ V}, \ \mu_P C'_{ox} = 80 \ \mu \text{A/V}^2 \\ & W &= 32 \ \mu \text{m}, \ L = 4 \ \mu \text{m} \\ & \lambda = 0.02 \ V^{-1}, \ V^2 = 0.5 \ \text{V} \\ & R_{G1} &= 130 \ k\Omega, \ R_{G2} = 370 \ k\Omega \\ & R_D &= 18k\Omega, \ V_{DD} = 5 \ \text{V} \end{aligned}$

Resolvemos el sistema de ecuaciones:



```
-\lambda(V_{DS}-V_{DS\text{-sat}})
                            -0.500000000
                                            -0.000080000
                            -3.560000000
                                            -0.000084896
5 vds(1)
                            -3.471872000
         = vdssat
                                            -0.000084755
  id(1) = idsat
                             -3.474410086
                                            -0.000084759
                             -3.474336990
                                            -0.000084759
2 \text{ for } i = 2:10
                             -3.474339095
                                            -0.000084759
    vds(i) = -vdd-id(i-1)
                             -3.474339034
                                            -0.000084759
    id (i) = idsat*(1-la)
                             -3.474339036
                                            -0.000084759
1 end
                             -3.474339036
                                            -0.000084759
  [vds(:) id(:)]
                                            -0.000084759
                             -3.474339036
```

octave:34>



 $\begin{aligned} & \underline{Datos} \\ |V_T| &= 0.8 \text{ V}, \ \mu_P \text{C'}_{ox} = 80 \ \mu \text{A/V}^2 \\ & W &= 32 \ \mu \text{m}, \ L = 4 \ \mu \text{m} \\ & \lambda = 0.02 \ \text{V}^{-1}, \ \gamma^2 = 0.5 \ \text{V} \\ & R_{G1} &= 130 \ \text{k}\Omega, \ R_{G2} = 370 \ \text{k}\Omega \\ & R_D &= 18 \text{k}\Omega, \ V_{DD} = 5 \ \text{V} \end{aligned}$

Resolvemos el sistema de ecuaciones:

$$V_{GS}$$
 V_{GS}
 V_{DS}
 V_{DS}
 V_{DS}
 V_{DS}

$$\begin{cases} I_{D} = I_{D\text{-sat}} \left[1 - \lambda (V_{DS} - V_{DS\text{-sat}}) \right] \\ -I_{D} R_{D} - V_{DS} = V_{DD} \end{cases}$$

- Por simulación
- Despejando
- Iterando

El resultado es

aproximadamente el mismo:

$$I_D = -85 \mu A, V_{DS} = -3.46 V$$

 $V_{GS} = -1.3 \text{ V}$ $I_{D} = -85.5 \,\mu\text{A}$

 $V_{ps} = -3.46V$

Ш

 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ }\mu\text{A}/\text{V}^2$ $I_{Dsat} = -80 \text{ }\mu\text{A}, \text{ }V_{DS-sat} = -0.5 \text{V}$

 $\frac{Datos}{|V_T|} = 0.8 \text{ V}, \ \mu_P \text{C'}_{ox} = 80 \ \mu\text{A/V}^2$

W = 32 μm, L = 4 μm $\lambda = 0.02 \text{ V}^{-1}$, $\gamma^2 = 0.5 \text{ V}$ $R_{G1} = 130 \text{ k}\Omega$, $R_{G2} = 370 \text{ k}\Omega$

 $R_{D} = 18k\Omega, V_{DD} = 5 V$

Resolvemos el sistema de ecuaciones:

$$V_{GS}$$
 V_{GS}
 V_{DS}
 V_{DS}
 V_{DS}
 V_{DS}

- $\begin{cases} I_{D} = I_{D\text{-sat}} \left[1 \lambda (V_{DS} V_{DS\text{-sat}}) \right] \\ -I_{D} R_{D} V_{DS} = V_{DD} \end{cases}$
 - Por simulación
 - Despejando
 - Iterando

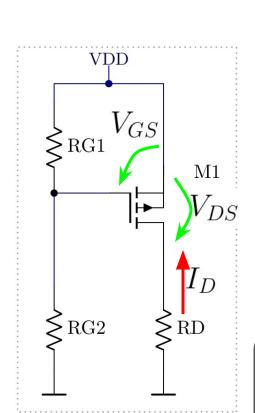
aproximadamente el mismo:

El resultado es

 $I_D = -85 \mu A, V_{DS} = -3.46 V$

Antes de terminar con la polarización debemos verificar que efectivamente estamos en SAT:

V_{DS}<V_{DSsat} (canal P)



 $V_{GS} = -1.3 \text{ V}$ $I_{D} = -85.5 \text{ } \mu\text{A}$ $V_{DS} = -3.46 \text{ V}$

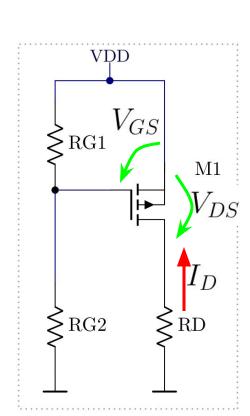
 $-V_{DD}$

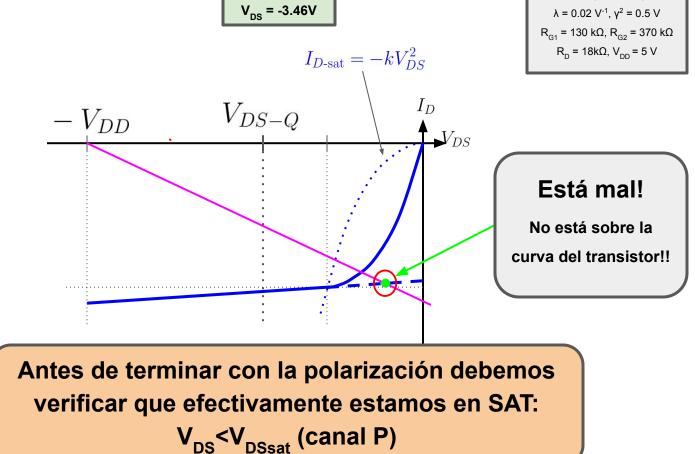
 $V_T = -0.8 \text{ V}, \text{ k} = 320 \text{ }\mu\text{A}/\text{V}^2$ $I_{Dsat} = -80 \text{ }\mu\text{A}, \text{ }V_{DS-sat} = -0.5\text{V}$

 $I_{D\text{-sat}} = -kV_{DS}^2$

 $\begin{aligned} & \underline{Datos} \\ |V_T| &= 0.8 \text{ V}, \ \mu_P \text{C'}_{ox} = 80 \ \mu \text{A/V}^2 \\ & W = 32 \ \mu \text{m}, \ L = 4 \ \mu \text{m} \\ & \lambda = 0.02 \ \text{V}^{-1}, \ \gamma^2 = 0.5 \ \text{V} \\ & R_{G1} = 130 \ \text{k}\Omega, \ R_{G2} = 370 \ \text{k}\Omega \\ & R_D = 18 \text{k}\Omega, \ V_{DD} = 5 \ \text{V} \end{aligned}$







 $V_{GS} = -1.3 \text{ V}$

 $I_{D} = -85.5 \, \mu A$

 $V_T = -0.8 \text{ V}, k = 320 \mu\text{A/V}^2$

 $I_{Dsat} = -80 \mu A, V_{DS-sat} = -0.5 V$

 $|V_T| = 0.8 \text{ V}, \ \mu_D C'_{OV} = 80 \ \mu \text{A/V}^2$

 $W = 32 \mu m, L = 4 \mu m$