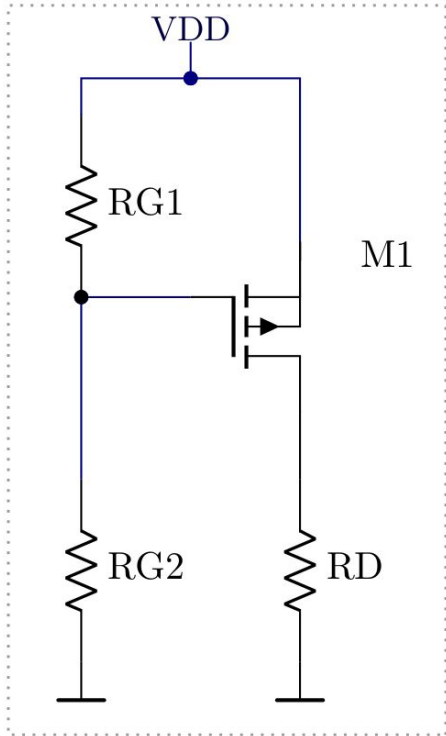


[86.03/66.25] Dispositivos Semiconductores
1er Cuatrimestre 2020

Transistor MOS

1. Polarización
2. Modelo de Pequeña Señal

Enunciado



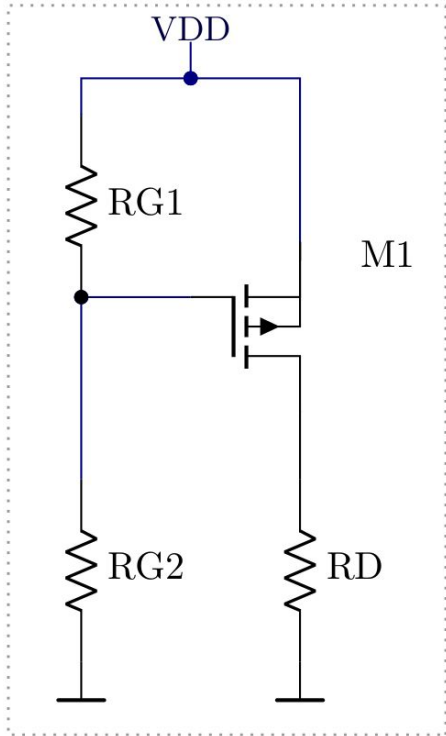
Para el circuito de la figura y los siguientes datos:

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

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

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La polarización la calculamos

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

$$I_D = -85.5 \text{ } \mu\text{A}$$

$$V_{DS} = -3.46 \text{ V}$$

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

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

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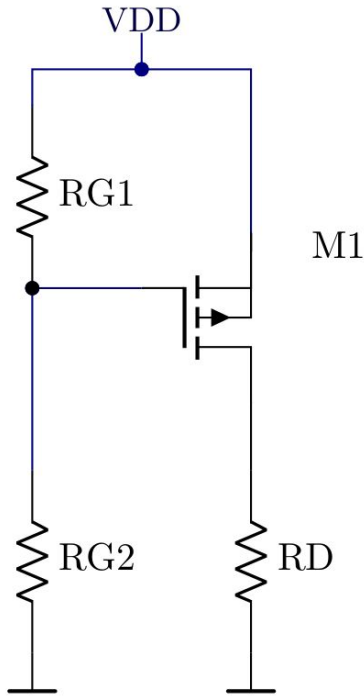
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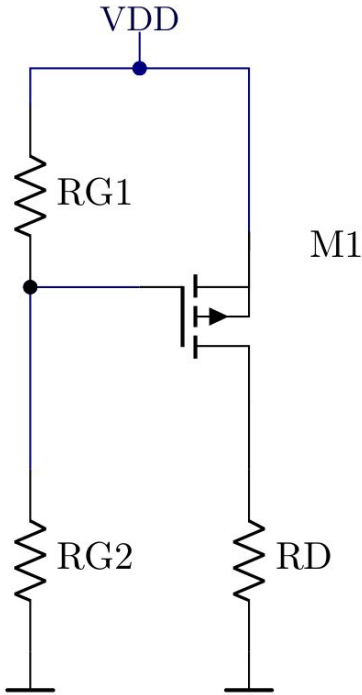
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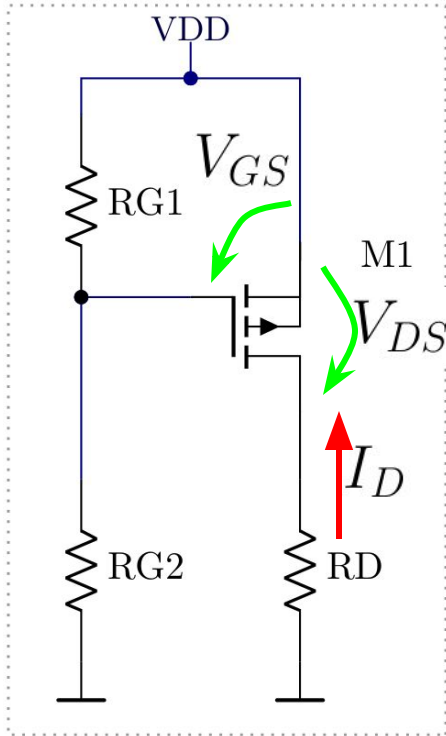
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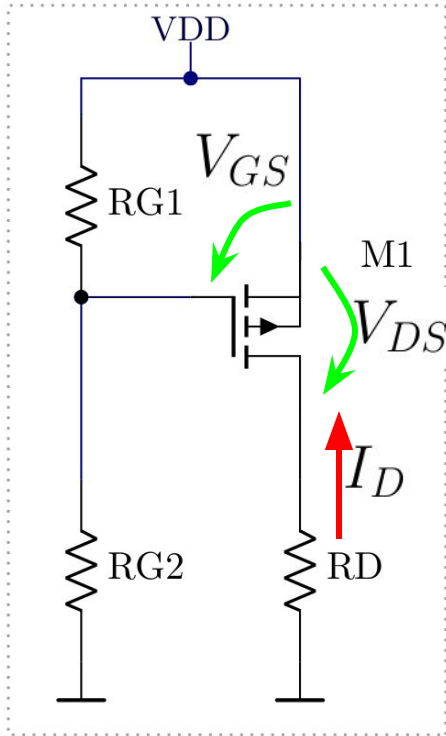
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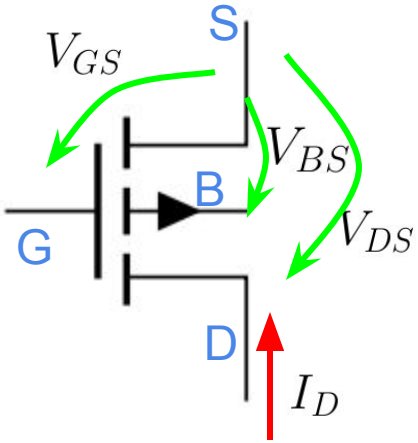
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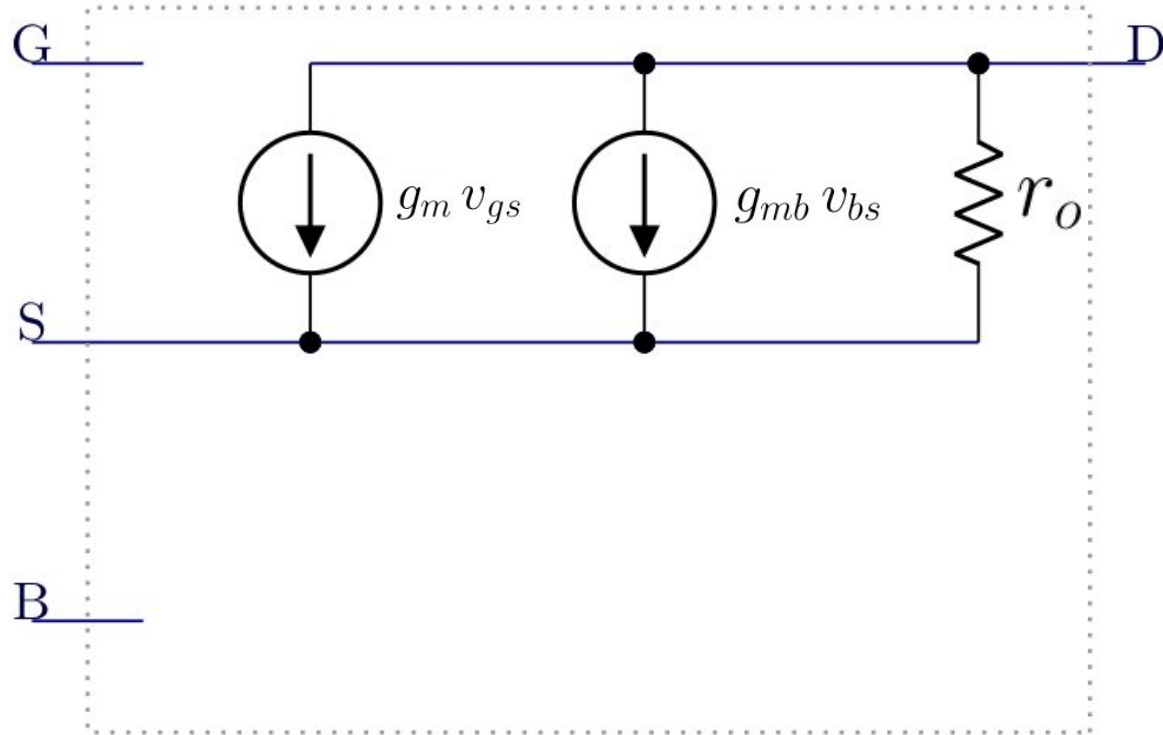
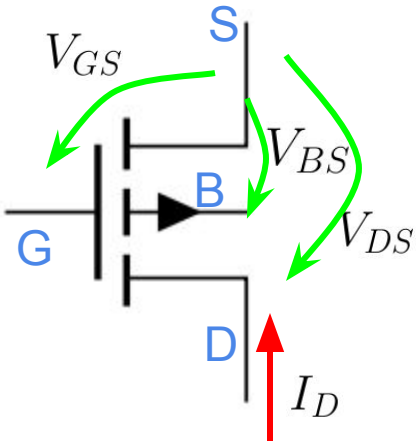
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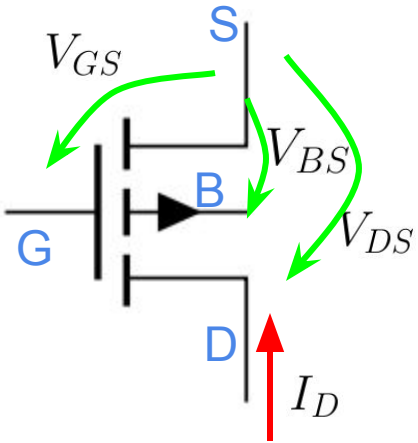
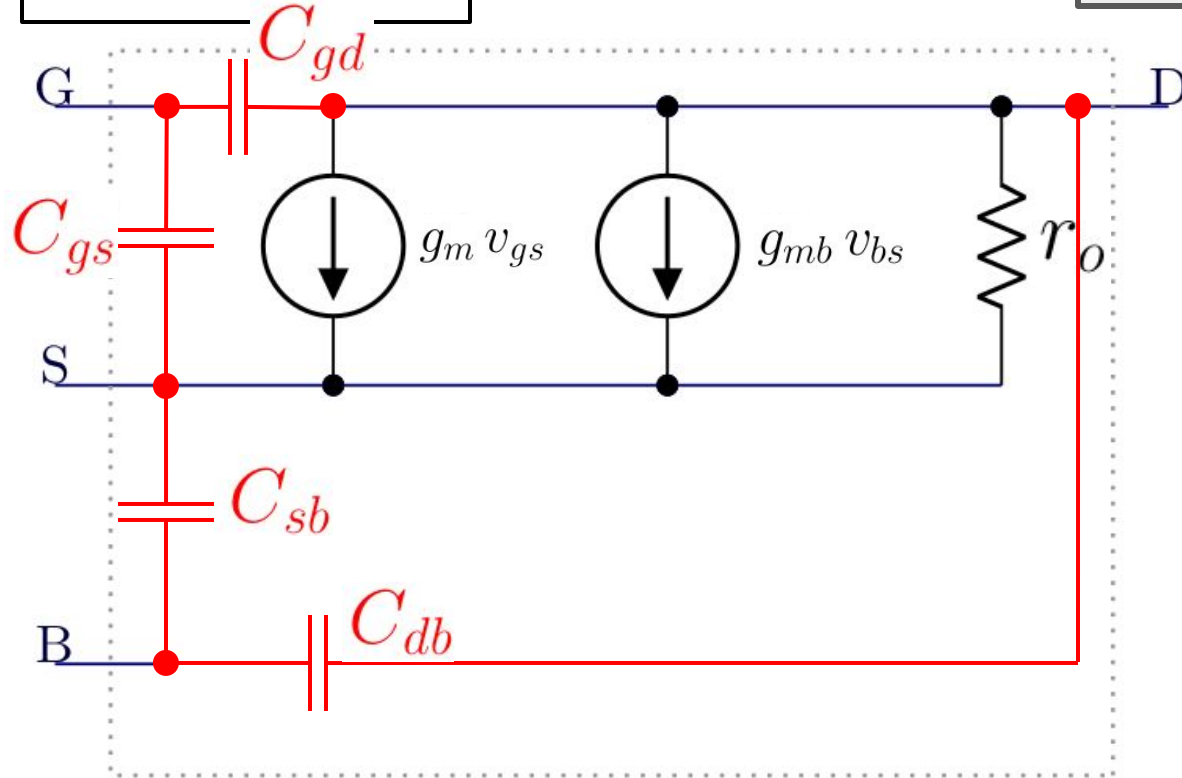
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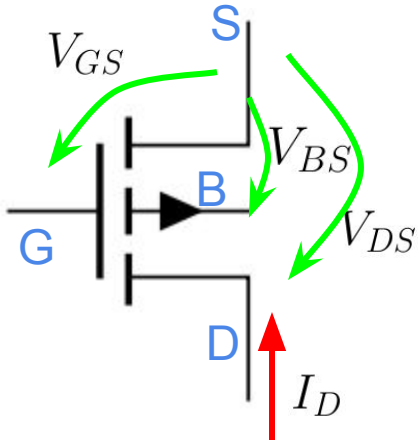
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$$g_m$$

$$g_{mb}$$

$$g_o$$

Para frecuencias altas

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$$C_{gs}$$

$$C_{sb}$$

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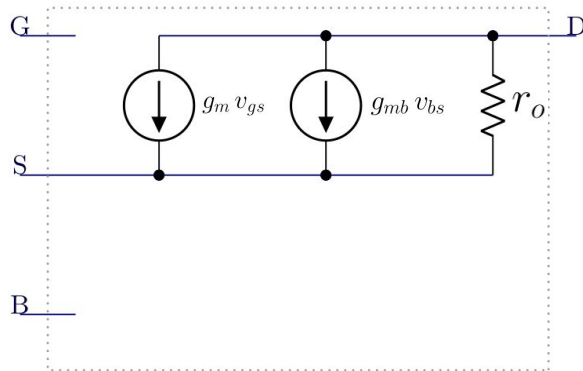
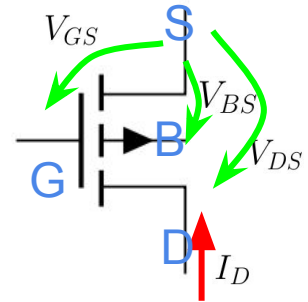
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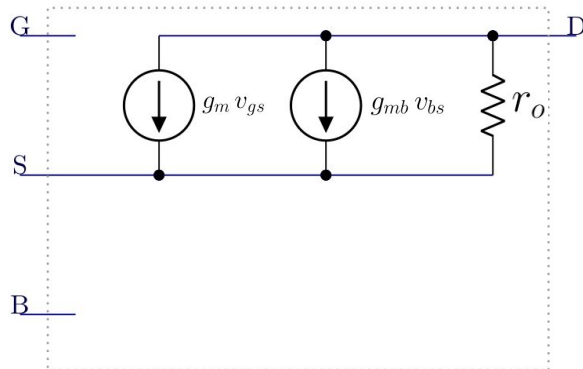
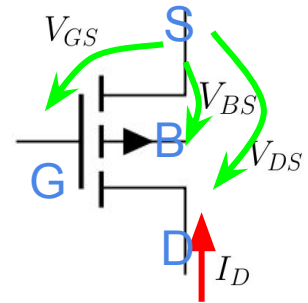
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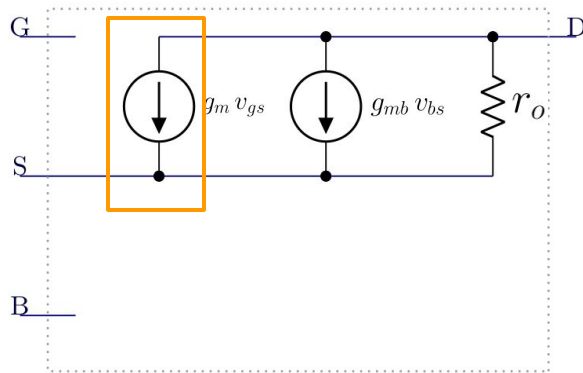
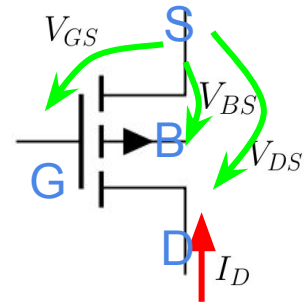
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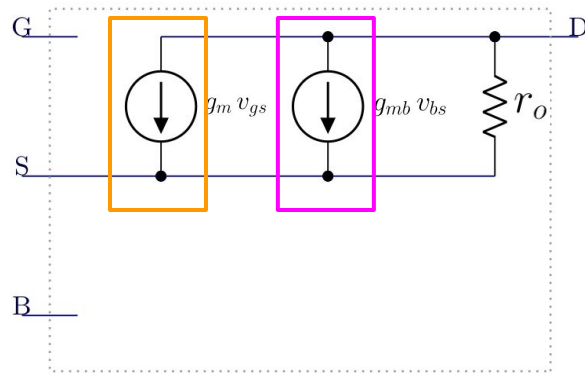
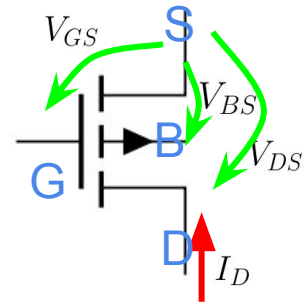
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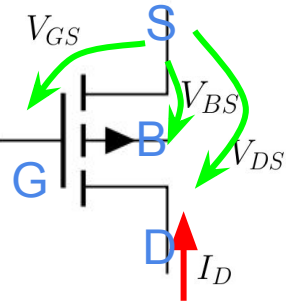
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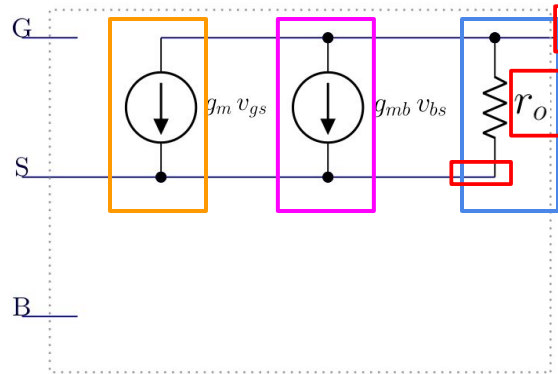


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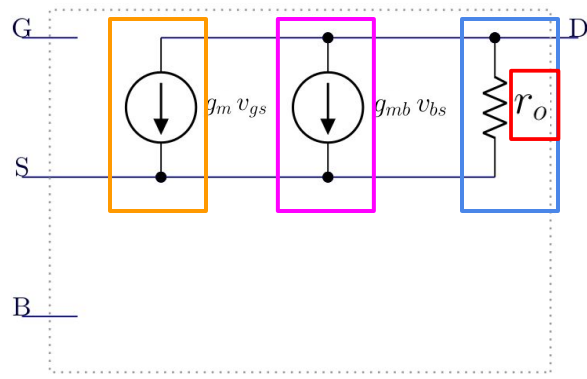
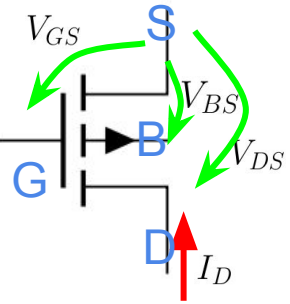
$$I_D = -k (V_{GS} - V_T)^2 [1 - \lambda(V_{DS} - V_{DS-sat})]$$

$$g_m = \left. \frac{\partial I_D}{\partial V_{GS}} \right|_Q$$

$$g_{mb} = \left. \frac{\partial I_D}{\partial V_{BS}} \right|_Q$$

$$g_o = \left. \frac{\partial I_D}{\partial V_{DS}} \right|_Q$$

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



2. Mod. de Pequeña Señal

Para frecuencias bajas/medias

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

$$I_D = -85.5 \text{ } \mu\text{A}$$

$$V_{DS} = -3.46 \text{ V}$$

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

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

Datos

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

$$W = 32 \text{ } \mu\text{m}, L = 4 \text{ } \mu\text{m}$$

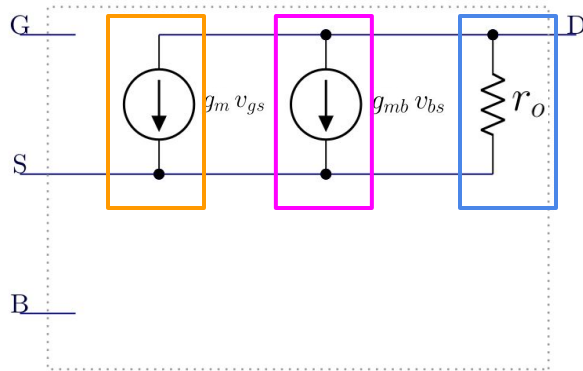
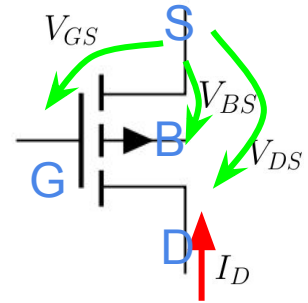
$$\lambda = 0.02 \text{ V}^{-1}, \gamma^2 = 0.5 \text{ V}$$

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

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

$$I_D = -k (V_{GS} - V_T)^2 [1 - \lambda(V_{DS} - V_{DS\text{-sat}})]$$

$$g_m = \left. \frac{\partial I_D}{\partial V_{GS}} \right|_Q$$



2. Mod. de Pequeña Señal

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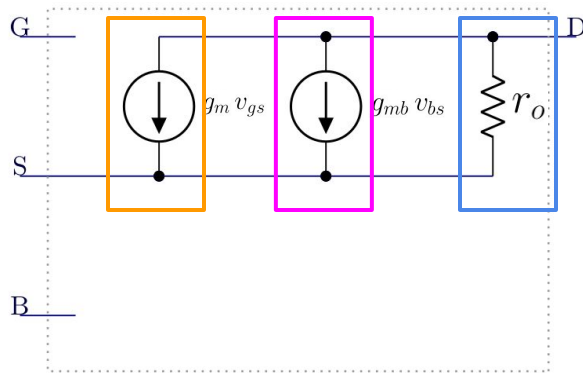
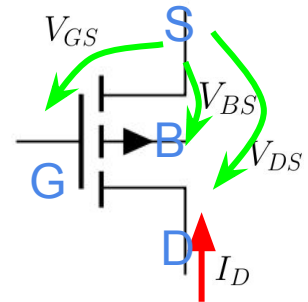
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$$g_m = \left. \frac{\partial I_D}{\partial V_{GS}} \right|_Q$$

$$g_m = -2k (V_{GS} - V_T) [1 - \lambda(V_{DS} - V_{DS\text{-sat}})]$$



2. Mod. de Pequeña Señal

Para frecuencias bajas/medias

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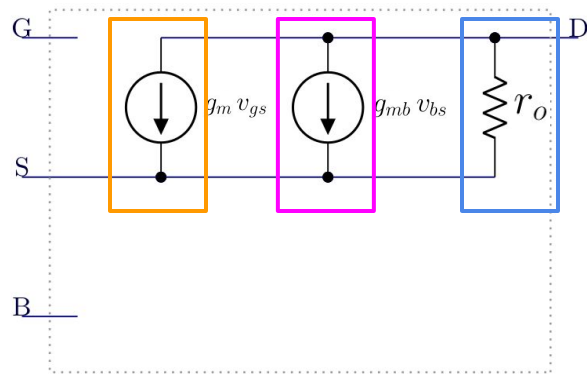
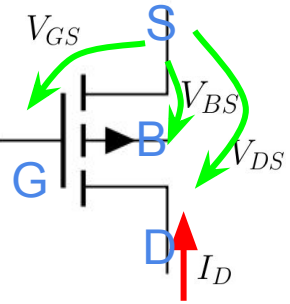
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$$g_m = \left. \frac{\partial I_D}{\partial V_{GS}} \right|_Q$$

$$g_m = -2k \underbrace{(V_{GS} - V_T)}_{-\sqrt{\frac{-I_{D\text{-sat}}}{k}}} [1 - \lambda(V_{DS} - V_{DS\text{-sat}})]$$



2. Mod. de Pequeña Señal

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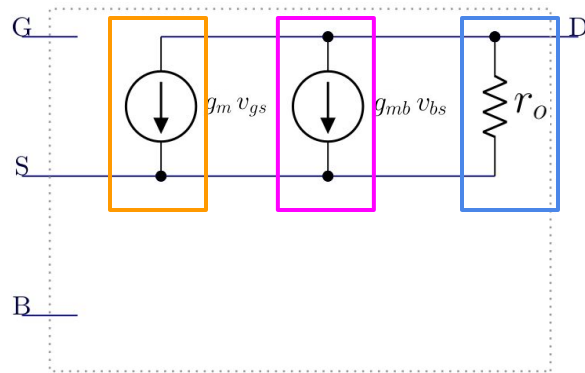
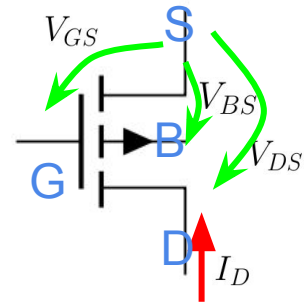
$$R_D = 18 \text{ k}\Omega, V_{DD} = 5 \text{ V}$$

$$I_D = -k (V_{GS} - V_T)^2 [1 - \lambda(V_{DS} - V_{DS\text{-sat}})]$$

$$g_m = \left. \frac{\partial I_D}{\partial V_{GS}} \right|_Q$$

$$g_m = -2k \underbrace{(V_{GS} - V_T)}_{-\sqrt{\frac{-I_{D\text{-sat}}}{k}}} [1 - \lambda(V_{DS} - V_{DS\text{-sat}})]$$

$$g_m = 2\sqrt{-k I_{D\text{-sat}}} [1 - \lambda(V_{DS} - V_{DS\text{-sat}})]$$



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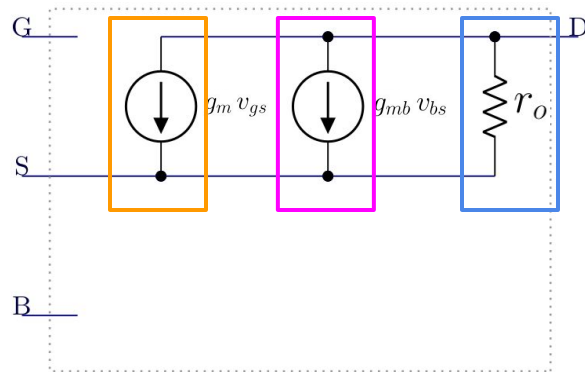
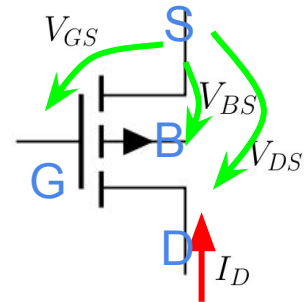
$$I_D = -k (V_{GS} - V_T)^2 [1 - \lambda(V_{DS} - V_{DS\text{-sat}})]$$

$$g_m = \left. \frac{\partial I_D}{\partial V_{GS}} \right|_Q$$

$$g_m = -2k \underbrace{(V_{GS} - V_T)}_{-\sqrt{\frac{-I_{D\text{-sat}}}{k}}} [1 - \lambda(V_{DS} - V_{DS\text{-sat}})]$$

$$g_m = 2\sqrt{-k I_{D\text{-sat}}} [1 - \lambda(V_{DS} - V_{DS\text{-sat}})]$$

$$g_m \approx 2\sqrt{-k I_{D\text{-sat}}}$$



2. Mod. de Pequeña Señal

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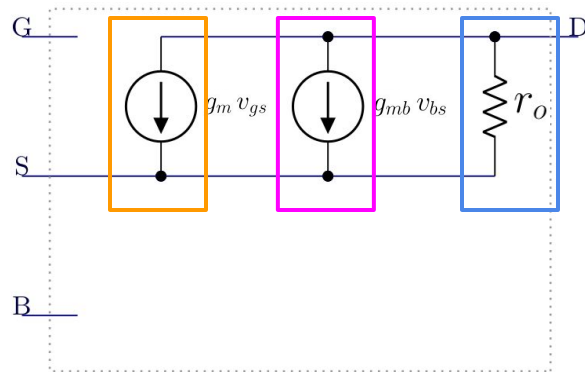
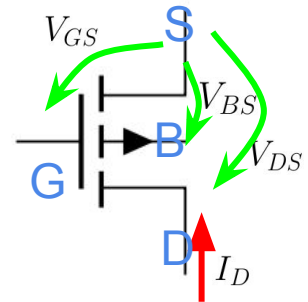
$$I_D = -k (V_{GS} - V_T)^2 [1 - \lambda(V_{DS} - V_{DS\text{-sat}})]$$

$$g_m = \left. \frac{\partial I_D}{\partial V_{GS}} \right|_Q$$

$$g_m = -2k \underbrace{(V_{GS} - V_T)}_{-\sqrt{\frac{-I_{D\text{-sat}}}{k}}} [1 - \lambda(V_{DS} - V_{DS\text{-sat}})]$$

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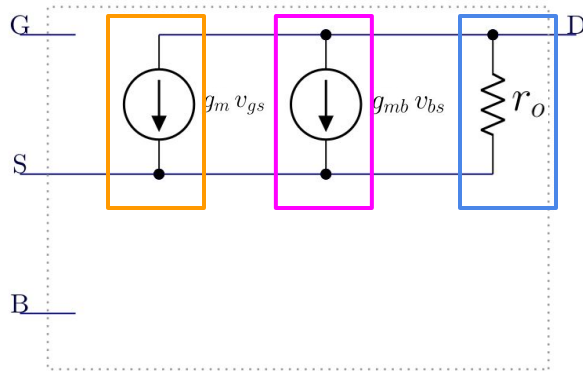
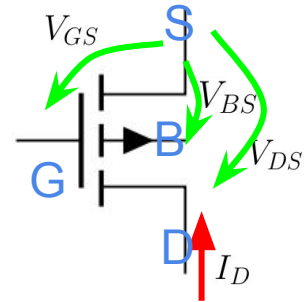
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$$g_{mb} = \left. \frac{\partial I_D}{\partial V_{BS}} \right|_Q$$



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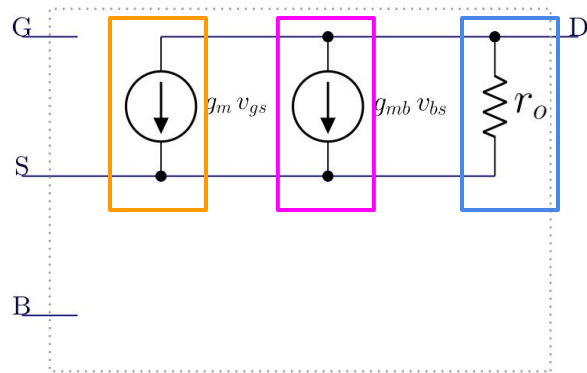
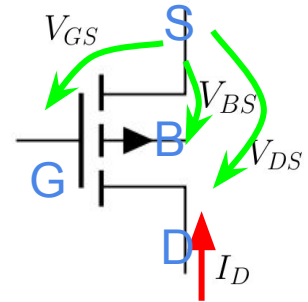
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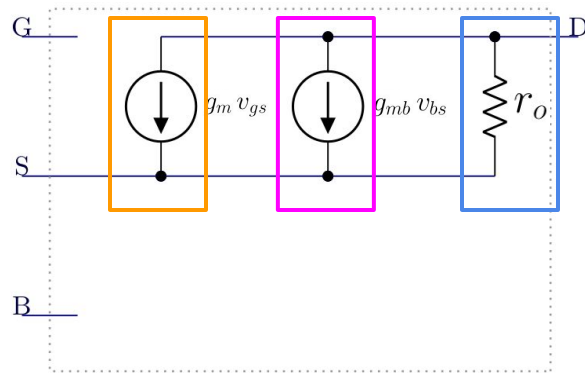
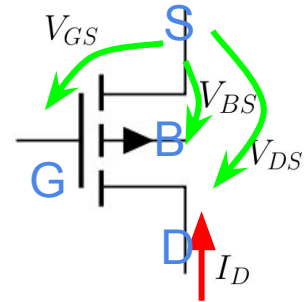
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$$V_T = V_{T0} - \gamma(\sqrt{2\phi_n + V_{BS}} - \sqrt{2\phi_N})$$

$$\frac{\partial V_T}{\partial V_{BS}} = -\frac{\gamma}{2} \frac{1}{\sqrt{2\phi_n + V_{BS}}}$$



2. Mod. de Pequeña Señal

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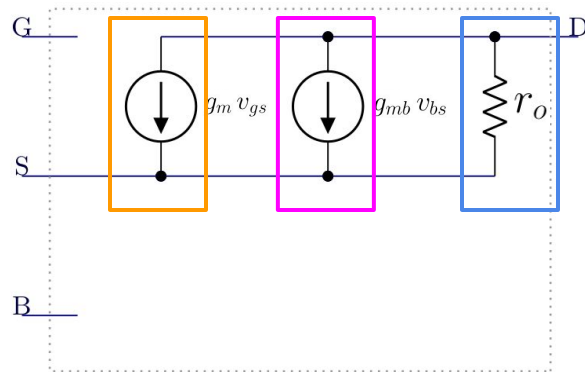
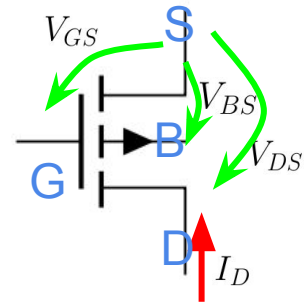
$$g_{mb} = \left. \frac{\partial I_D}{\partial V_{BS}} \right|_Q$$

$$g_{mb} = \underbrace{-2k (V_{GS} - V_T) [1 - \lambda(V_{DS} - V_{DS-sat})]}_{g_m} \left(-\frac{\partial V_T}{\partial V_{BS}} \right) \Big|_Q$$

$$V_T = V_{T0} - \gamma (\sqrt{2\phi_n + V_{BS}} - \sqrt{2\phi_N})$$

$$\frac{\partial V_T}{\partial V_{BS}} = -\frac{\gamma}{2} \frac{1}{\sqrt{2\phi_n + V_{BS}}}$$

$$g_{mb} = g_m \frac{\gamma}{\sqrt{2\phi_n + V_{BS}}}$$



2. Mod. de Pequeña Señal

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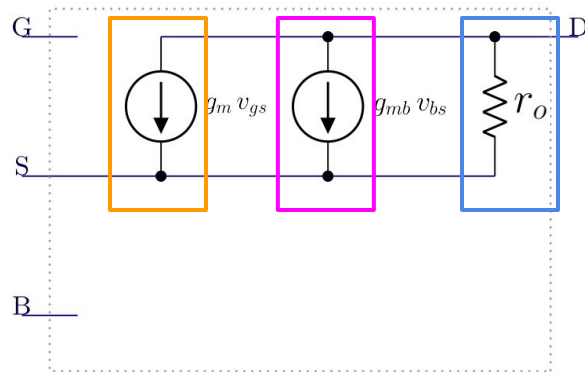
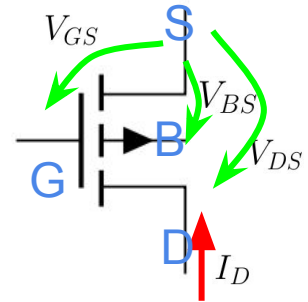
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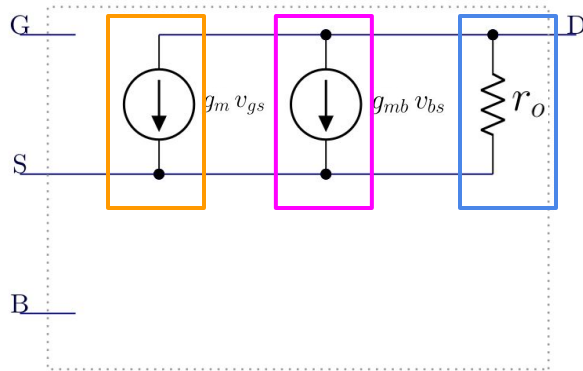
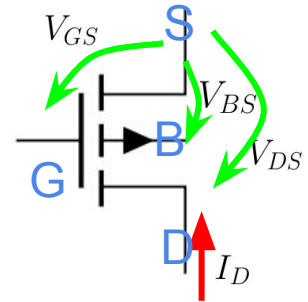
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$$V_{DS} = -3.46 \text{ V}$$

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

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

Datos

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

$$W = 32 \text{ } \mu\text{m}, L = 4 \text{ } \mu\text{m}$$

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

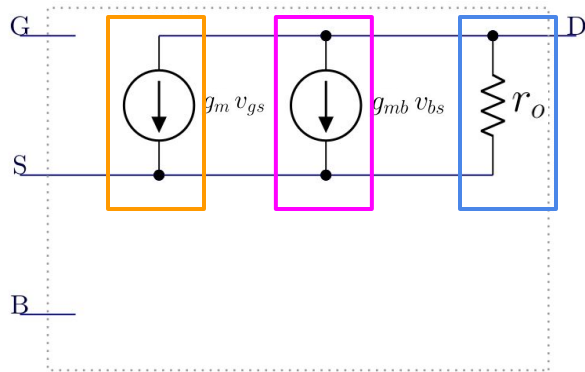
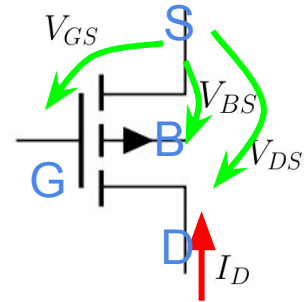
$$R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$$

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

$$I_D = -k (V_{GS} - V_T)^2 [1 - \lambda(V_{DS} - V_{DS\text{-sat}})]$$

$$g_o = \left. \frac{\partial I_D}{\partial V_{DS}} \right|_Q$$

$$g_o = -k (V_{GS} - V_T)^2 (-\lambda)$$



2. Mod. de Pequeña Señal

Para frecuencias bajas/medias

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

$$I_D = -85.5 \text{ } \mu\text{A}$$

$$V_{DS} = -3.46 \text{ V}$$

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

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

Datos

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

$$W = 32 \text{ } \mu\text{m}, L = 4 \text{ } \mu\text{m}$$

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

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

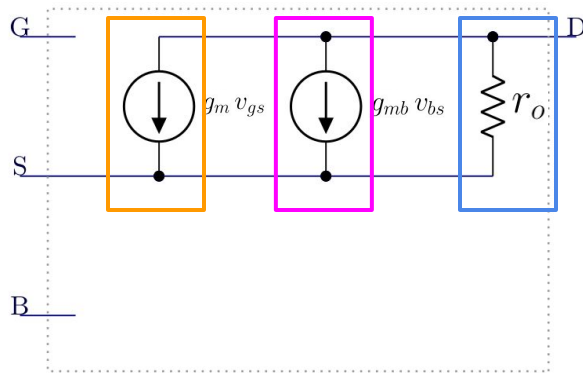
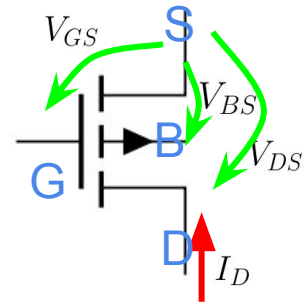
$$R_D = 18 \text{ k}\Omega, V_{DD} = 5 \text{ V}$$

$$I_D = -k (V_{GS} - V_T)^2 [1 - \lambda(V_{DS} - V_{DS\text{-sat}})]$$

$$g_o = \left. \frac{\partial I_D}{\partial V_{DS}} \right|_Q$$

$$g_o = -k (V_{GS} - V_T)^2 (-\lambda)$$

$$g_o = -\lambda I_{D\text{-sat}}$$



2. Mod. de Pequeña Señal

Para frecuencias bajas/medias

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

$$I_D = -85.5 \text{ } \mu\text{A}$$

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

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

Datos

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

$$W = 32 \text{ } \mu\text{m}, L = 4 \text{ } \mu\text{m}$$

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

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

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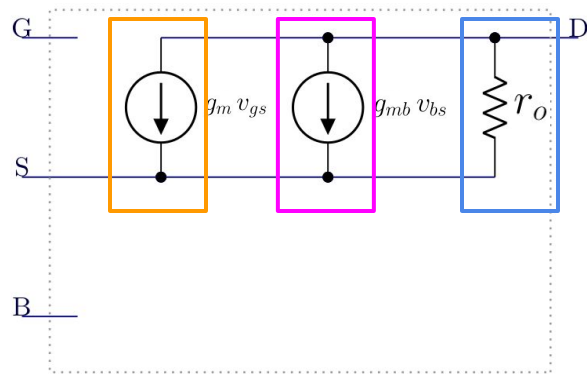
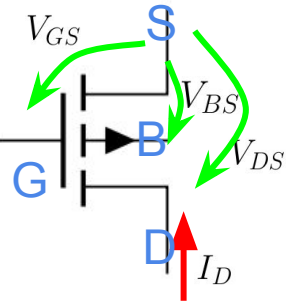
$$I_D = -k (V_{GS} - V_T)^2 [1 - \lambda(V_{DS} - V_{DS\text{-sat}})]$$

$$g_o = \left. \frac{\partial I_D}{\partial V_{DS}} \right|_Q$$

$$g_0 = -k (V_{GS} - V_T)^2 (-\lambda)$$

$$g_0 = -\lambda I_{D\text{-sat}}$$

$$r_0 = \frac{1}{g_0}$$



2. Mod. de Pequeña Señal

Para frecuencias bajas/medias

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

$$I_D = -85.5 \text{ } \mu\text{A}$$

$$V_{DS} = -3.46 \text{ V}$$

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

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

Datos

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

$$W = 32 \text{ } \mu\text{m}, L = 4 \text{ } \mu\text{m}$$

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

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

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

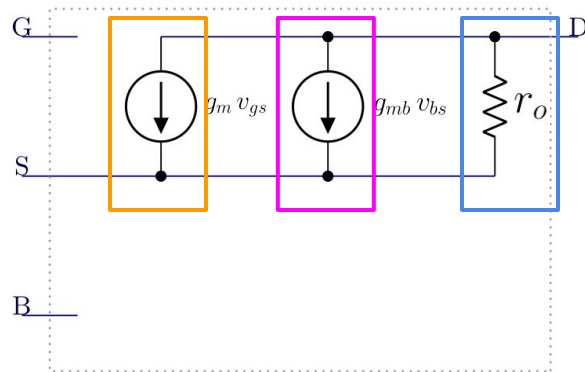
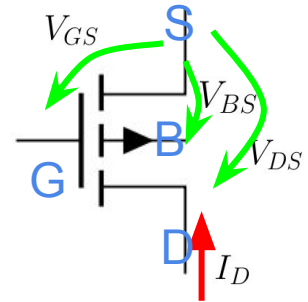
$$I_D = -k (V_{GS} - V_T)^2 [1 - \lambda(V_{DS} - V_{DS\text{-sat}})]$$

$$g_o = \left. \frac{\partial I_D}{\partial V_{DS}} \right|_Q$$

$$g_o = -k (V_{GS} - V_T)^2 (-\lambda)$$

$$g_o = -\lambda I_{D\text{-sat}}$$

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



2. Mod. de Pequeña Señal

Para frecuencias bajas/medias

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

$$I_D = -85.5 \text{ } \mu\text{A}$$

$$V_{DS} = -3.46 \text{ V}$$

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

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

Datos

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

$$W = 32 \text{ } \mu\text{m}, L = 4 \text{ } \mu\text{m}$$

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

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

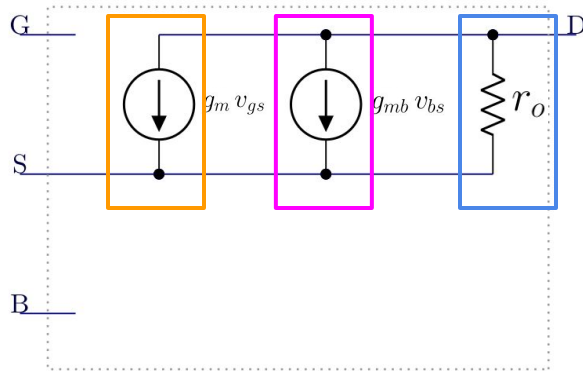
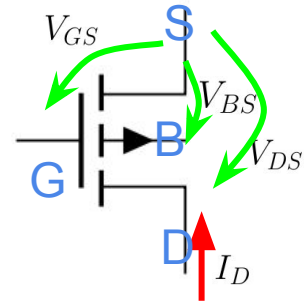
$$R_D = 18 \text{ k}\Omega, V_{DD} = 5 \text{ V}$$

$$g_m = \left. \frac{\partial I_D}{\partial V_{GS}} \right|_Q = 2 \sqrt{-k I_{D\text{-sat}}} [1 - \cancel{\lambda} (V_{DS} - V_{DS\text{-sat}})]$$

$$\approx 2 \sqrt{-k I_{D\text{-sat}}}$$

$$g_{mb} = \left. \frac{\partial I_D}{\partial V_{BS}} \right|_Q = g_m \frac{\gamma}{\sqrt{2\phi_n + V_{BS}}}$$

$$g_o = \left. \frac{\partial I_D}{\partial V_{DS}} \right|_Q = -\lambda I_{D\text{-sat}}$$



2. Mod. de Pequeña Señal

Para frecuencias bajas/medias

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

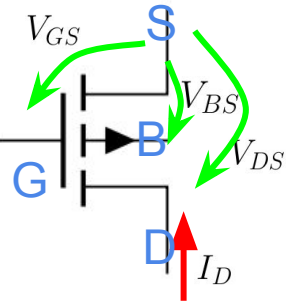
$$I_D = -85.5 \text{ } \mu\text{A}$$

$$V_{DS} = -3.46 \text{ V}$$

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

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

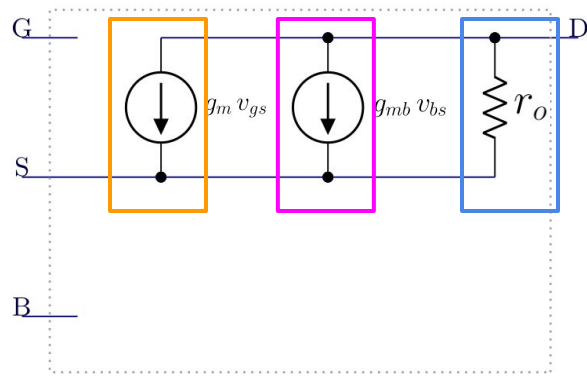
Datos
$ V_T = 0.8 \text{ V}, \mu_P C'_{ox} = 80 \text{ } \mu\text{A/V}^2$
$W = 32 \text{ } \mu\text{m}, L = 4 \text{ } \mu\text{m}$
$\lambda = 0.02 \text{ V}^{-1}, \gamma^2 = 0.5 \text{ V}$
$R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$
$R_D = 18 \text{ k}\Omega, V_{DD} = 5 \text{ V}$



$$g_m = \left. \frac{\partial I_D}{\partial V_{GS}} \right|_Q = 2 \sqrt{-k I_{D\text{-sat}}} [1 - \lambda(V_{DS} - V_{DS\text{-sat}})]$$

$$= 339 \text{ } \mu\text{A/V}$$

$$\approx 2 \sqrt{-k I_{D\text{-sat}}} = 320 \text{ } \mu\text{A/V}$$



$$g_{mb} = \left. \frac{\partial I_D}{\partial V_{BS}} \right|_Q = g_m \frac{\gamma}{\sqrt{2\phi_n + V_{BS}}} = 293 \text{ } \mu\text{A/V}$$

$$g_o = \left. \frac{\partial I_D}{\partial V_{DS}} \right|_Q = -\lambda I_{D\text{-sat}} = 1.6 \text{ } \mu\text{A/V} \rightarrow r_o = 625 \text{ k}\Omega$$

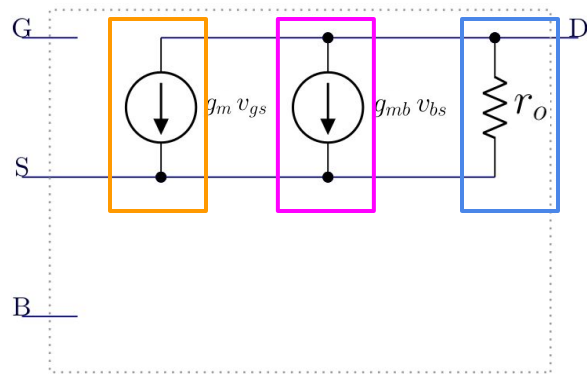
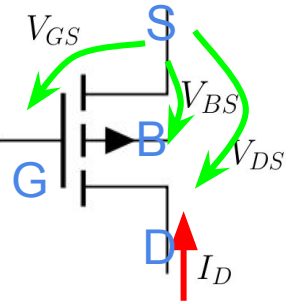
2. Mod. de Pequeña Señal

Para frecuencias bajas/medias

$$\begin{aligned} V_{GS} &= -1.3 \text{ V} \\ I_D &= -85.5 \mu\text{A} \\ V_{DS} &= -3.46 \text{ V} \end{aligned}$$

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

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



$$\begin{aligned} g_m &= \left. \frac{\partial I_D}{\partial V_{GS}} \right|_Q = 2 \sqrt{-k I_{D\text{-sat}}} [1 - \lambda(V_{DS} - V_{DS\text{-sat}})] \\ &= 339 \mu\text{A/V} \end{aligned}$$

$$\approx 2 \sqrt{-k I_{D\text{-sat}}} = 320 \mu\text{A/V}$$

No tengo los datos, así que tomo $N_D = 10^{15} \text{ cm}^{-3}$ Tal que $\phi_n = 279.9 \text{ mV}$

$$g_{mb} = \left. \frac{\partial I_D}{\partial V_{BS}} \right|_Q = g_m \frac{\gamma}{\sqrt{2\phi_n + V_{BS}}} = 293 \mu\text{A/V}$$

$$g_o = \left. \frac{\partial I_D}{\partial V_{DS}} \right|_Q = -\lambda I_{D\text{-sat}} = 1.6 \mu\text{A/V} \rightarrow r_o = 625 \text{ k}\Omega$$

2. Mod. de Pequeña Señal

Para frecuencias altas

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

$$I_D = -85.5 \text{ } \mu\text{A}$$

$$V_{DS} = -3.46 \text{ V}$$

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

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

Datos

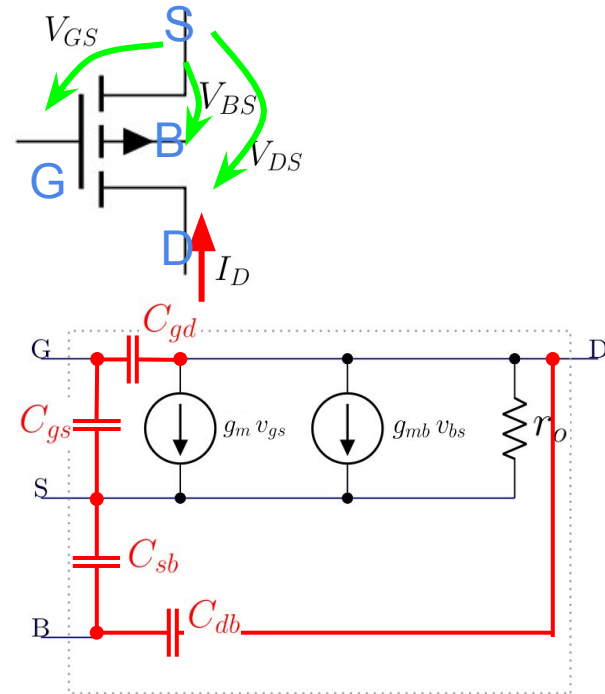
$$|V_T| = 0.8 \text{ V}, \mu_P C'_{\text{ox}} = 80 \text{ } \mu\text{A/V}^2$$

$$W = 32 \text{ } \mu\text{m}, L = 4 \text{ } \mu\text{m}$$

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

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

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



2. Mod. de Pequeña Señal

Para frecuencias altas

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

$$I_D = -85.5 \text{ } \mu\text{A}$$

$$V_{DS} = -3.46 \text{ V}$$

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

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

Datos

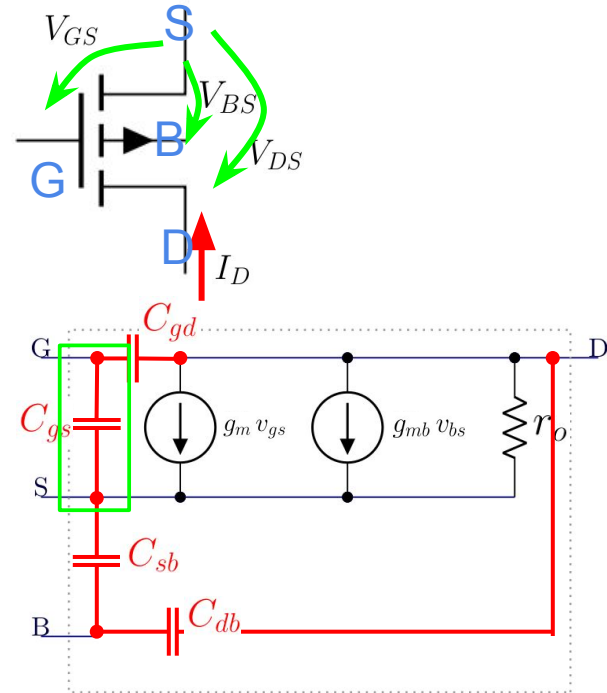
$$|V_T| = 0.8 \text{ V}, \mu_P C'_{ox} = 80 \text{ } \mu\text{A/V}^2$$

$$W = 32 \text{ } \mu\text{m}, L = 4 \text{ } \mu\text{m}$$

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

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

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



$$C_{gs} = \left. \frac{\partial Q}{\partial V_{GS}} \right|_Q$$

$$C_{gd} = \left. \frac{\partial Q}{\partial V_{GD}} \right|_Q$$

$$C_{db} = \left. \frac{\partial Q}{\partial V_{DB}} \right|_Q$$

$$C_{sb} = \left. \frac{\partial Q}{\partial V_{SB}} \right|_Q$$

2. Mod. de Pequeña Señal

Para frecuencias altas

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

$$I_D = -85.5 \text{ } \mu\text{A}$$

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$$I_{Dsat} = -80 \text{ } \mu\text{A}, V_{DSsat} = -0.5 \text{ V}$$

Datos

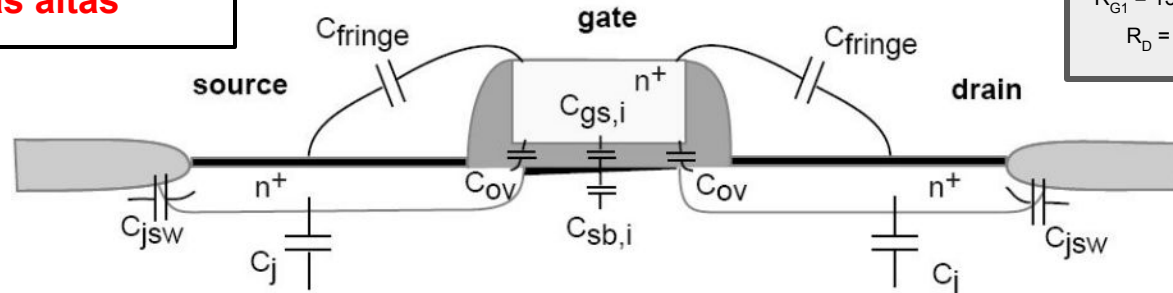
$$|V_T| = 0.8 \text{ V}, \mu_P C'_{ox} = 80 \text{ } \mu\text{A/V}^2$$

$$W = 32 \text{ } \mu\text{m}, L = 4 \text{ } \mu\text{m}$$

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

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

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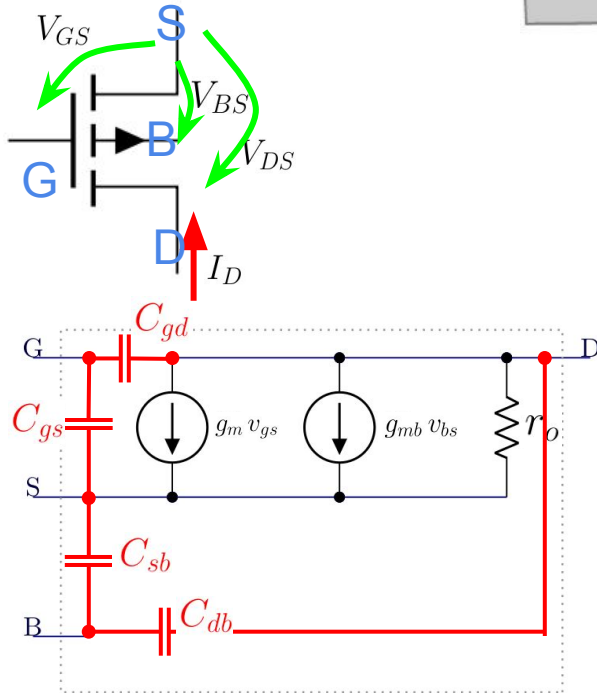


$$C_{gs} = \left. \frac{\partial Q}{\partial V_{GS}} \right|_Q$$

$$C_{gd} = \left. \frac{\partial Q}{\partial V_{GD}} \right|_Q$$

$$C_{db} = \left. \frac{\partial Q}{\partial V_{DB}} \right|_Q$$

$$C_{sb} = \left. \frac{\partial Q}{\partial V_{SB}} \right|_Q$$



2. Mod. de Pequeña Señal

Para frecuencias altas

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

$$I_D = -85.5 \text{ } \mu\text{A}$$

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

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

Datos

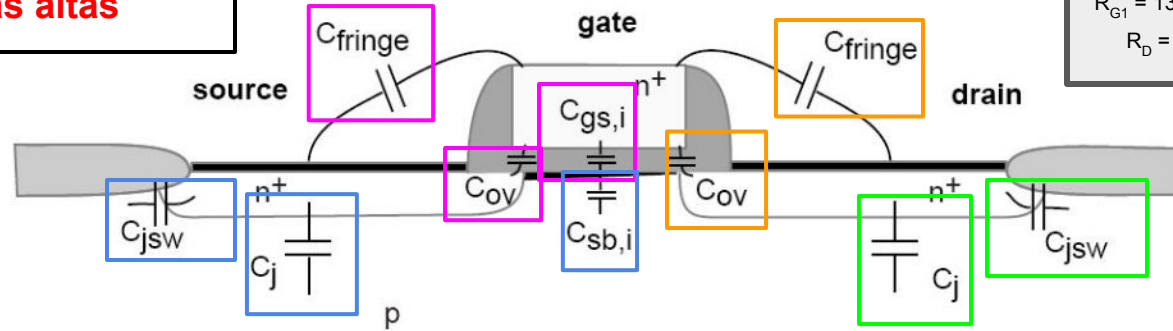
$$|V_T| = 0.8 \text{ V}, \mu_P C'_{ox} = 80 \text{ } \mu\text{A/V}^2$$

$$W = 32 \text{ } \mu\text{m}, L = 4 \text{ } \mu\text{m}$$

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

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

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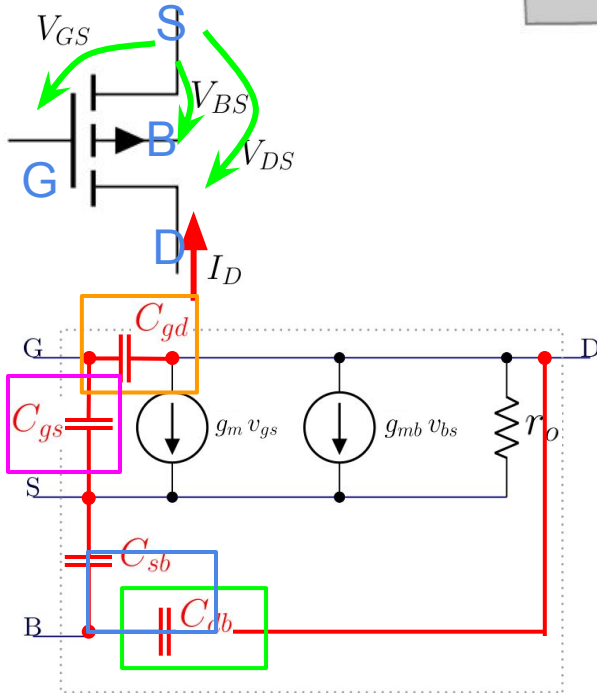


$$C_{gs} = \left. \frac{\partial Q}{\partial V_{GS}} \right|_Q$$

$$C_{gd} = \left. \frac{\partial Q}{\partial V_{GD}} \right|_Q$$

$$C_{db} = \left. \frac{\partial Q}{\partial V_{DB}} \right|_Q$$

$$C_{sb} = \left. \frac{\partial Q}{\partial V_{SB}} \right|_Q$$



2. Mod. de Pequeña Señal

Para frecuencias altas

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

$$I_D = -85.5 \text{ } \mu\text{A}$$

$$V_{DS} = -3.46 \text{ V}$$

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

$$I_{Dsat} = -80 \text{ } \mu\text{A}, V_{DSsat} = -0.5 \text{ V}$$

Datos

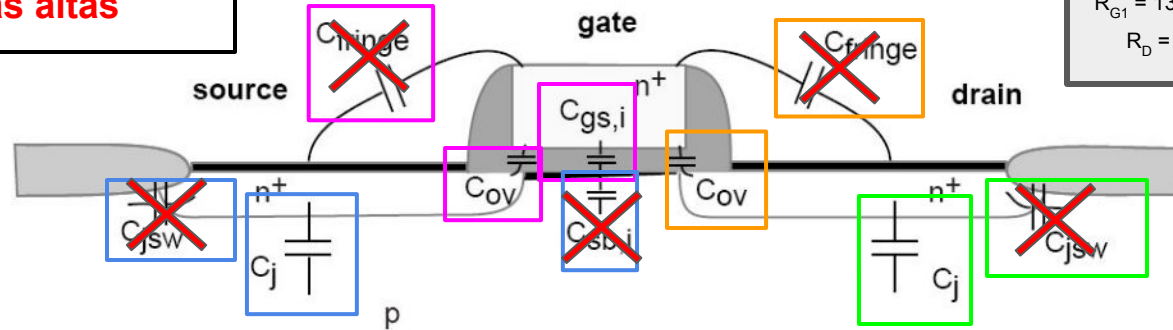
$$|V_T| = 0.8 \text{ V}, \mu_P C'_{ox} = 80 \text{ } \mu\text{A/V}^2$$

$$W = 32 \text{ } \mu\text{m}, L = 4 \text{ } \mu\text{m}$$

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

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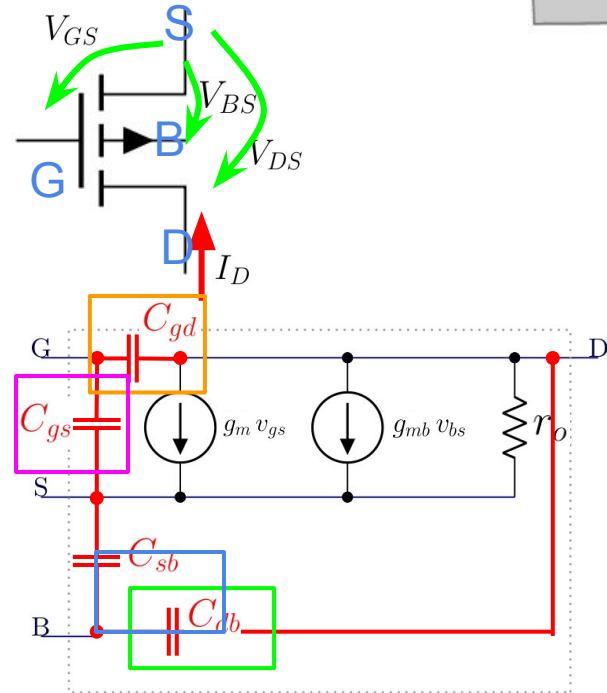


$$C_{gs} = \left. \frac{\partial Q}{\partial V_{GS}} \right|_Q$$

$$C_{gd} = \left. \frac{\partial Q}{\partial V_{GD}} \right|_Q$$

$$C_{db} = \left. \frac{\partial Q}{\partial V_{DB}} \right|_Q$$

$$C_{sb} = \left. \frac{\partial Q}{\partial V_{SB}} \right|_Q$$



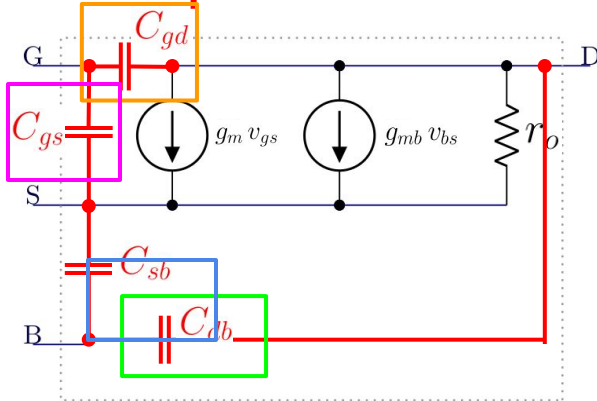
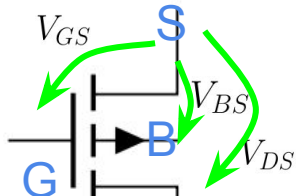
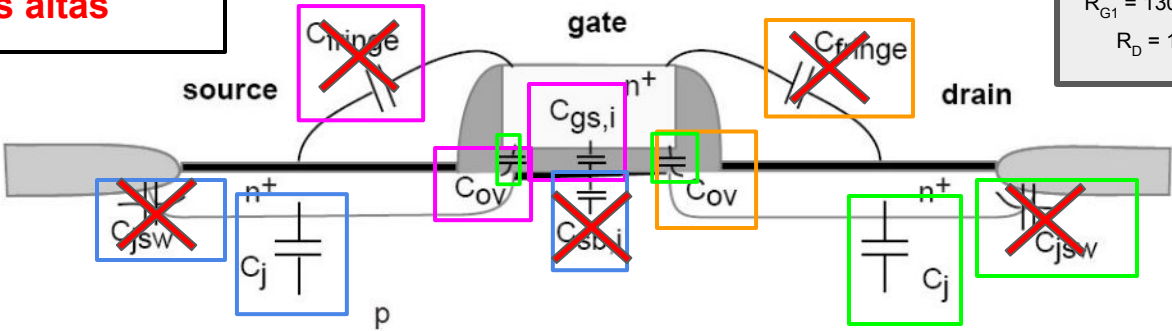
2. Mod. de Pequeña Señal

Para frecuencias altas

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

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

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



$$C_{gs} = \left. \frac{\partial Q}{\partial V_{GS}} \right|_Q = \frac{2}{3} W L C'_{ox} + W C_{ov}$$

$$C_{gd} = \left. \frac{\partial Q}{\partial V_{GD}} \right|_Q = W C_{ov}$$

$$C_{db} = \left. \frac{\partial Q}{\partial V_{DB}} \right|_Q = C'_j A_S$$

$$C_{sb} = \left. \frac{\partial Q}{\partial V_{SB}} \right|_Q = C'_j A_D$$

2. Mod. de Pequeña Señal

Para frecuencias altas

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

$$I_D = -85.5 \text{ } \mu\text{A}$$

$$V_{DS} = -3.46 \text{ V}$$

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

$$I_{Dsat} = -80 \text{ } \mu\text{A}, V_{DSsat} = -0.5 \text{ V}$$

Datos

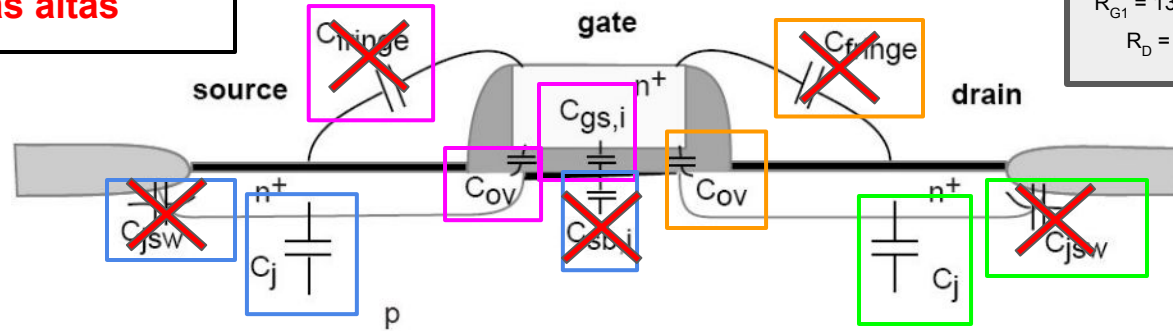
$$|V_T| = 0.8 \text{ V}, \mu_P C'_{ox} = 80 \text{ } \mu\text{A/V}^2$$

$$W = 32 \text{ } \mu\text{m}, L = 4 \text{ } \mu\text{m}$$

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

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

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

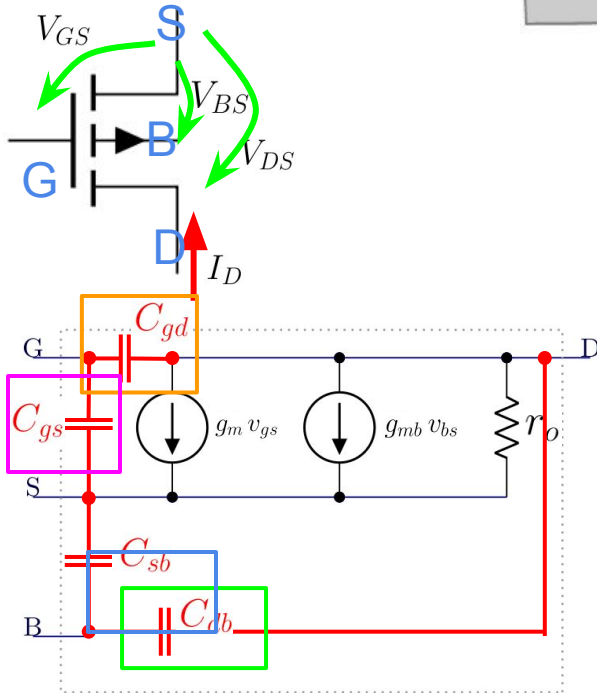


$$C_{gs} = \frac{\partial Q}{\partial V_{GS}} \Big|_Q = \frac{2}{3} W L C'_{ox} + W C'_{ov}$$

$$C_{gd} = \frac{\partial Q}{\partial V_{GD}} \Big|_Q = W C'_{ov}$$

$$C_{db} = \frac{\partial Q}{\partial V_{DB}} \Big|_Q = C'_j A_S$$

$$C_{sb} = \frac{\partial Q}{\partial V_{SB}} \Big|_Q = C'_j A_D$$



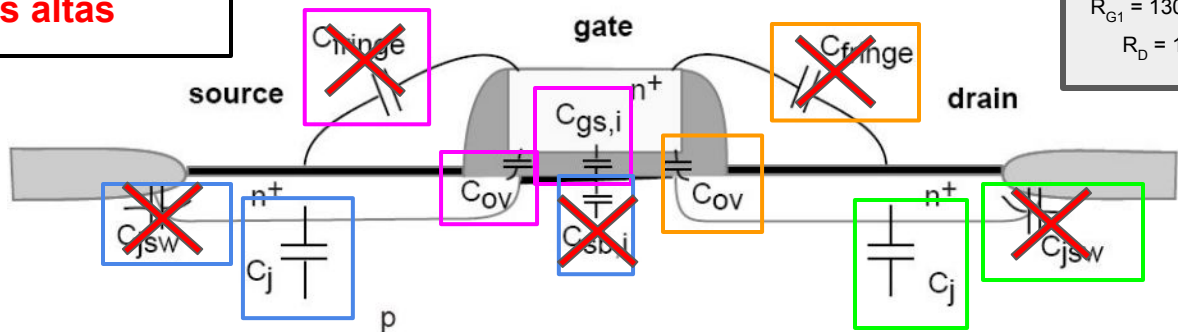
2. Mod. de Pequeña Señal

Para frecuencias altas

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

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

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

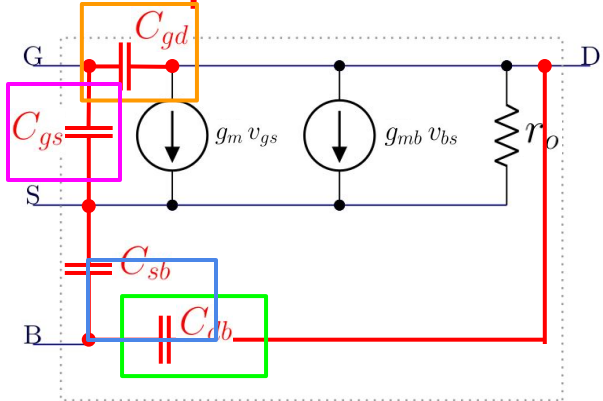
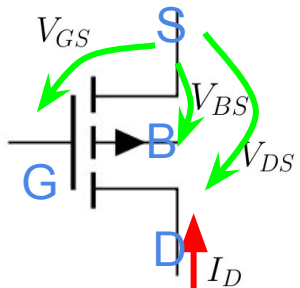


$$C_{gs} = \frac{\partial Q}{\partial V_{GS}} \Big|_Q = \frac{2}{3} W L C'_{ox} + W C'_{ov}$$

$$C_{gd} = \frac{\partial Q}{\partial V_{GD}} \Big|_Q = W C'_{ov}$$

$$C_{db} = \frac{\partial Q}{\partial V_{DB}} \Big|_Q = C'_j A_j$$

$$C_{sb} = \frac{\partial Q}{\partial V_{SB}} \Big|_Q = C'_j A_j$$



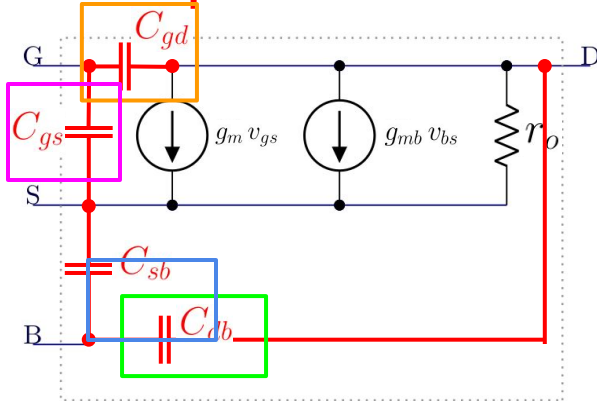
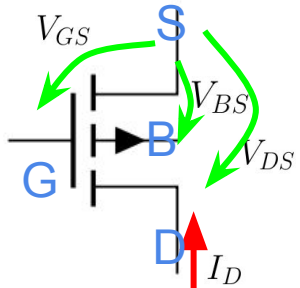
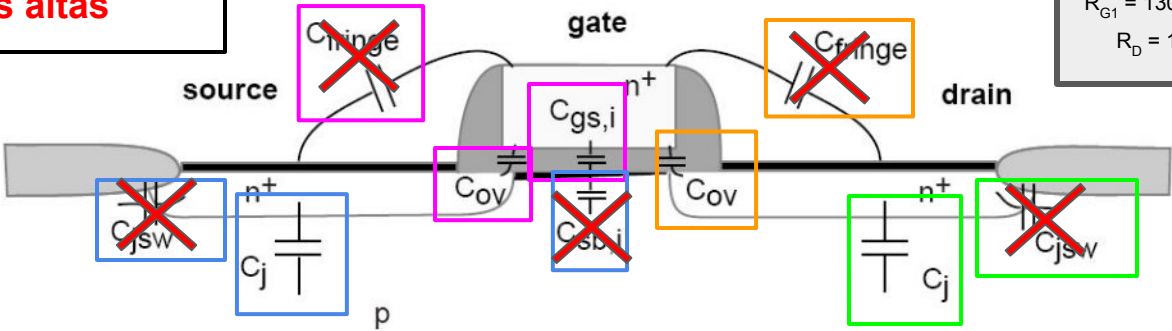
2. Mod. de Pequeña Señal

Para frecuencias altas

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

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

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



$$C_{gs} = \left. \frac{\partial Q}{\partial V_{GS}} \right|_Q = \frac{2}{3} W L C'_{ox} + W C'_{ov}$$

$$C_{gd} = \left. \frac{\partial Q}{\partial V_{GD}} \right|_Q = W C'_{ov}$$

$$C_{db} = \left. \frac{\partial Q}{\partial V_{DB}} \right|_Q = C'_j A_j$$

$$C_{sb} = \left. \frac{\partial Q}{\partial V_{SB}} \right|_Q = C'_j A_j$$

2. Mod. de Pequeña Señal

Para frecuencias altas

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

$$I_D = -85.5 \mu\text{A}$$

$$V_{DS} = -3.46 \text{ V}$$

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

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

Datos

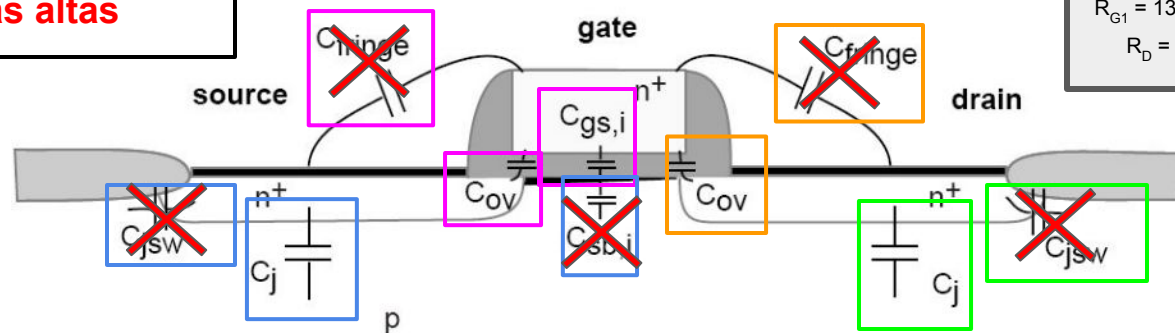
$$|V_T| = 0.8 \text{ V}, \mu_P C'_{\text{ox}} = 80 \mu\text{A}/\text{V}^2$$

$$W = 32 \mu\text{m}, L = 4 \mu\text{m}$$

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

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

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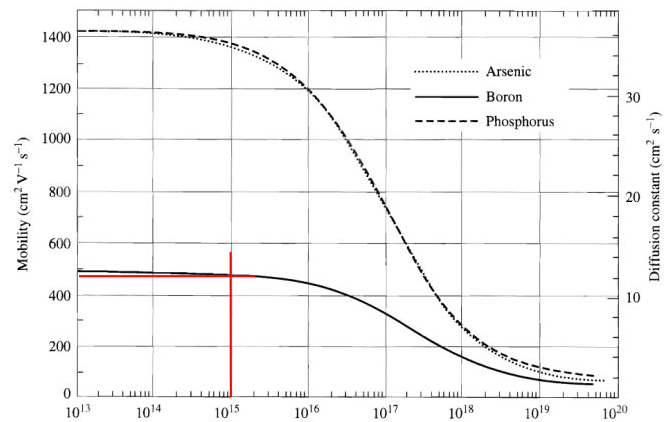
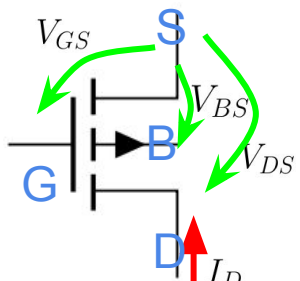


$$C_{gs} = \left. \frac{\partial Q}{\partial V_{GS}} \right|_Q = \frac{2}{3} W L C'_{\text{ox}} + W C'_{\text{ov}}$$

$$C_{gd} = \left. \frac{\partial Q}{\partial V_{GD}} \right|_Q = W C'_{\text{ov}}$$

$$C_{db} = \left. \frac{\partial Q}{\partial V_{DB}} \right|_Q = C'_j A_{\text{db}}$$

$$C_{sb} = \left. \frac{\partial Q}{\partial V_{SB}} \right|_Q = C'_j A_{\text{sb}}$$



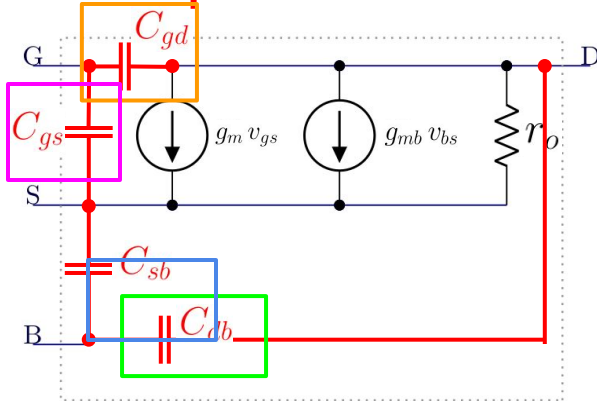
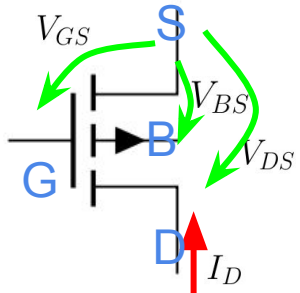
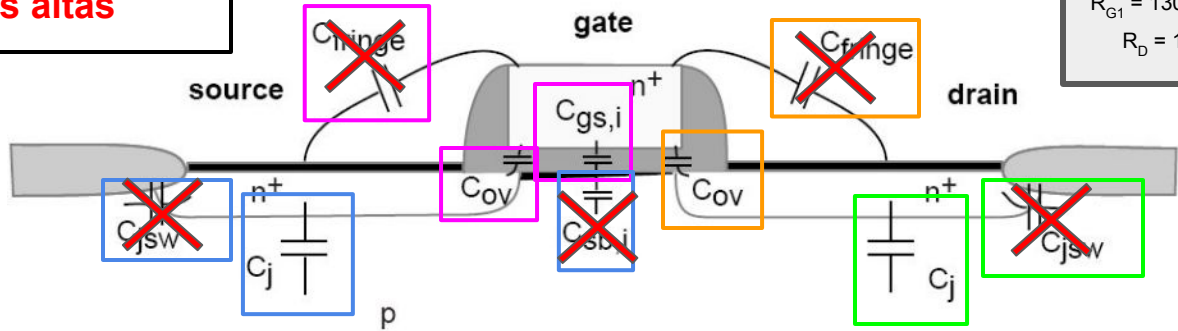
2. Mod. de Pequeña Señal

Para frecuencias altas

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

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

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

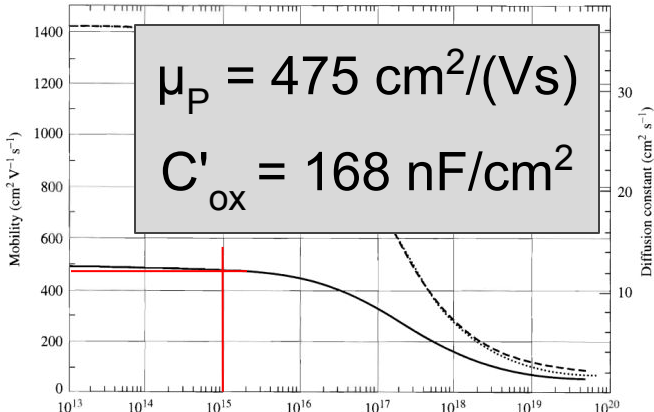


$$C_{gs} = \frac{\partial Q}{\partial V_{GS}} \Big|_Q = \frac{2}{3} W L C'_{ox} + W C'_{ov}$$

$$C_{gd} = \frac{\partial Q}{\partial V_{GD}} \Big|_Q = W C'_{ov}$$

$$C_{db} = \frac{\partial Q}{\partial V_{DB}} \Big|_Q = C'_j A_{db}$$

$$C_{sb} = \frac{\partial Q}{\partial V_{SB}} \Big|_Q = C'_j A_{sb}$$



2. Mod. de Pequeña Señal

Para frecuencias altas

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$$I_D = -85.5 \text{ } \mu\text{A}$$

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$$I_{Dsat} = -80 \text{ } \mu\text{A}, V_{DSsat} = -0.5 \text{ V}$$

Datos

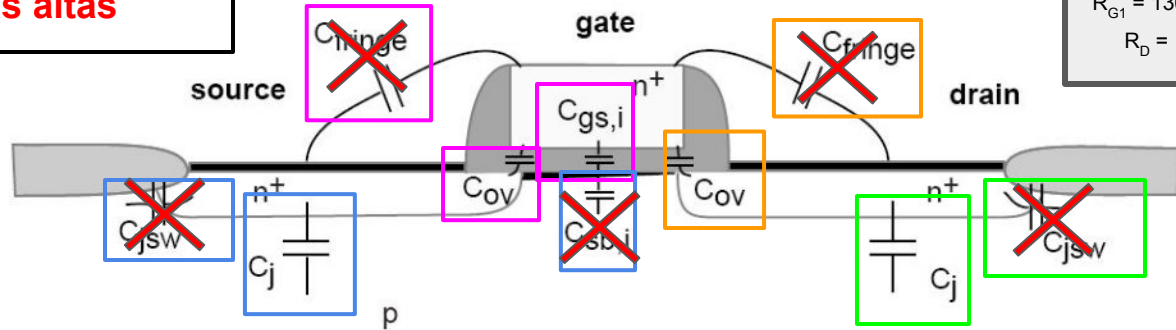
$$|V_T| = 0.8 \text{ V}, \mu_P C'_{ox} = 80 \text{ } \mu\text{A/V}^2$$

$$W = 32 \text{ } \mu\text{m}, L = 4 \text{ } \mu\text{m}$$

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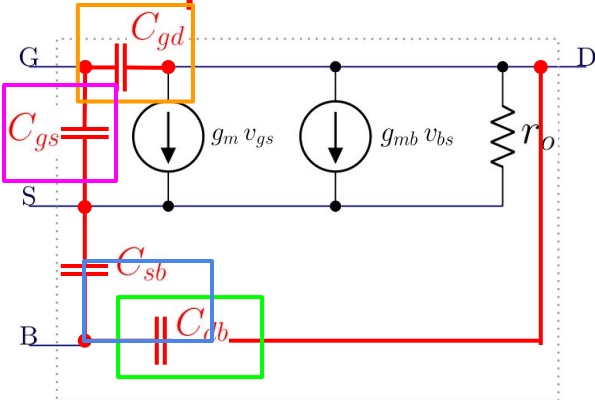
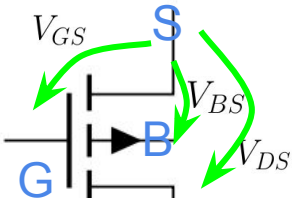
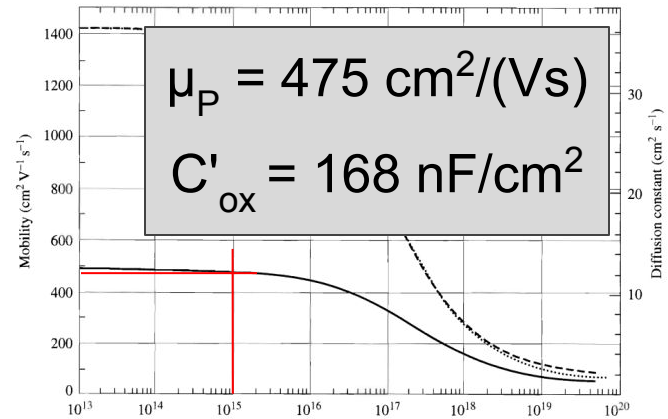


$$C_{gs} = \frac{\partial Q}{\partial V_{GS}} \Big|_Q = \frac{2}{3} W L C'_{ox} + W C'_{ov} = 1.4372 \times 10^{-17} \text{ F}$$

$$C_{gd} = \frac{\partial Q}{\partial V_{GD}} \Big|_Q = W C'_{ov}$$

$$C_{db} = \frac{\partial Q}{\partial V_{DB}} \Big|_Q = C'_j A_j$$

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2. Mod. de Pequeña Señal

Para frecuencias altas

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$$g_m = 320 \text{ } \mu\text{A/V}, g_{mb} = 293 \text{ } \mu\text{A/V}$$

$$r_o = 625 \text{ k}\Omega, r_{gs} = 4 \times 10^{11} \text{ } \mu\text{F}$$

Datos

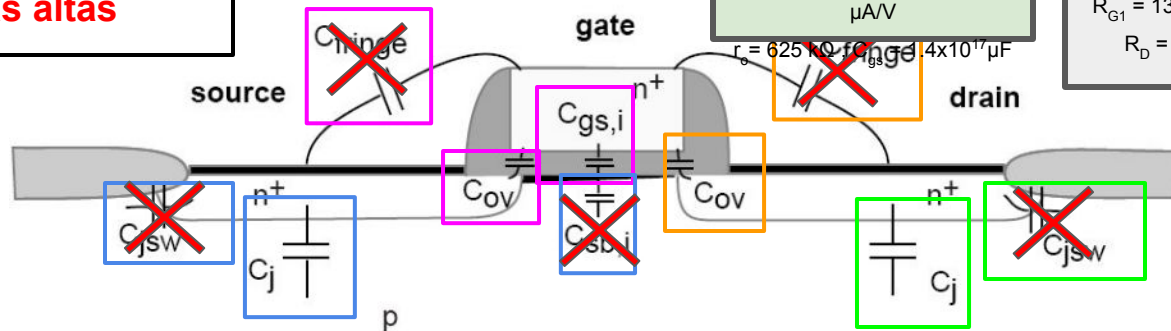
$$|V_T| = 0.8 \text{ V}, \mu_P C'_{ox} = 80 \text{ } \mu\text{A/V}^2$$

$$W = 32 \text{ } \mu\text{m}, L = 4 \text{ } \mu\text{m}$$

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

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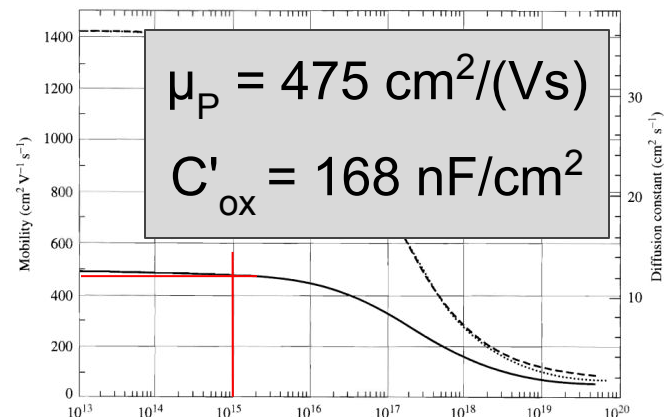
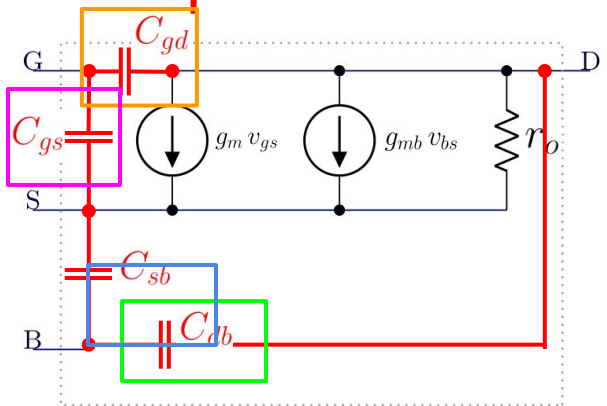
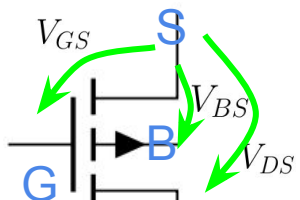


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$$g_m = 320 \text{ } \mu\text{A/V}, g_{mb} = 293 \text{ } \mu\text{A/V}$$

$$r_o = 625 \text{ k}\Omega, C_{gs} = 1.4 \times 10^{-11} \text{ } \mu\text{F}$$

Datos

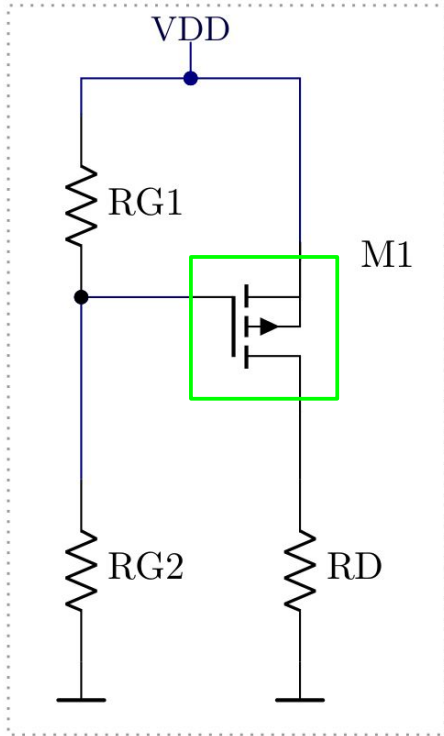
$$|V_T| = 0.8 \text{ V}, \mu_P C'_{ox} = 80 \text{ } \mu\text{A/V}^2$$

$$W = 32 \text{ } \mu\text{m}, L = 4 \text{ } \mu\text{m}$$

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

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

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



¿Para qué se utiliza el Modelo e Pequeña Señal?

El MPS *modela* mediante elementos **lineales** el comportamiento del transistor alrededor del punto de trabajo. Si trabajamos en su rango de validez, nos liberamos de las ecuaciones no lineales de I_D y V_{GS} y es más fácil resolver el circuito.

2. Mod. de Pequeña Señal

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

$$I_D = -85.5 \text{ } \mu\text{A}$$

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Datos

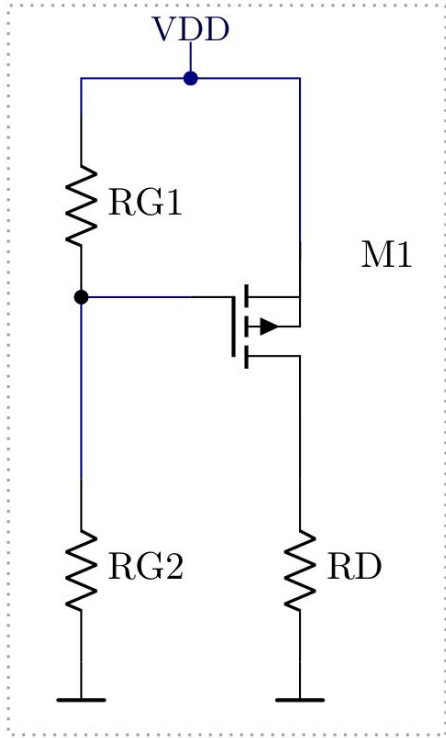
$$|V_T| = 0.8 \text{ V}, \mu_P C'_{ox} = 80 \text{ } \mu\text{A/V}^2$$

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

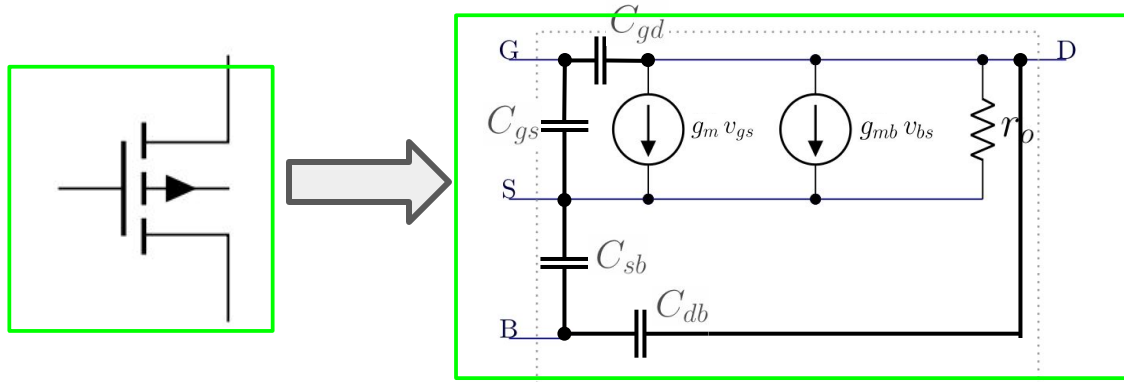
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$$r_o = 625 \text{ k}\Omega, C_{gs} = 1.4 \times 10^{-17} \text{ } \mu\text{F}$$

Datos

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

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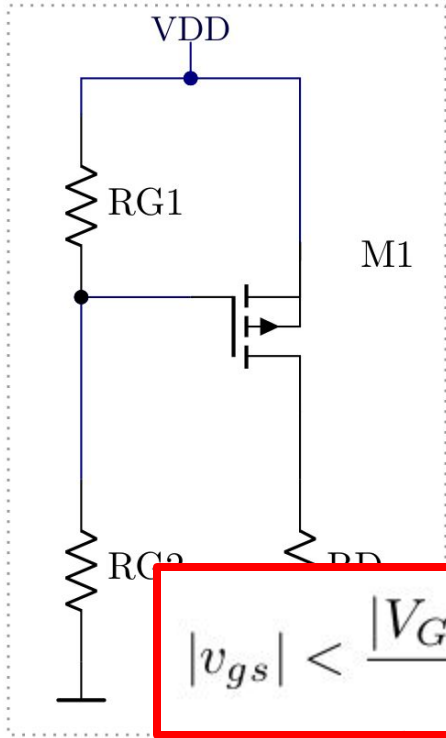
$$\lambda = 0.02 \text{ V}^{-1}, \gamma^2 = 0.5 \text{ V}$$

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

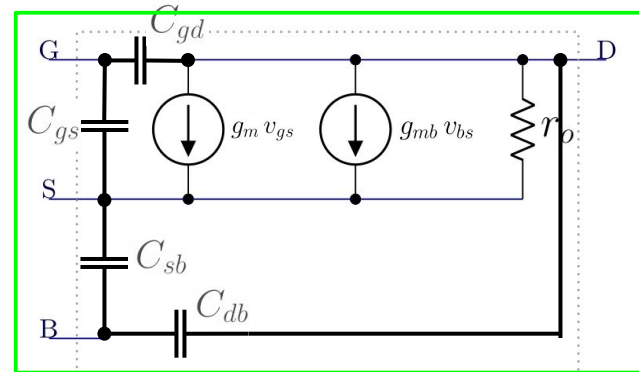
$$R_D = 18 \text{ k}\Omega, V_{DD} = 5 \text{ V}$$

¿Para qué se utiliza el Modelo e Pequeña Señal?

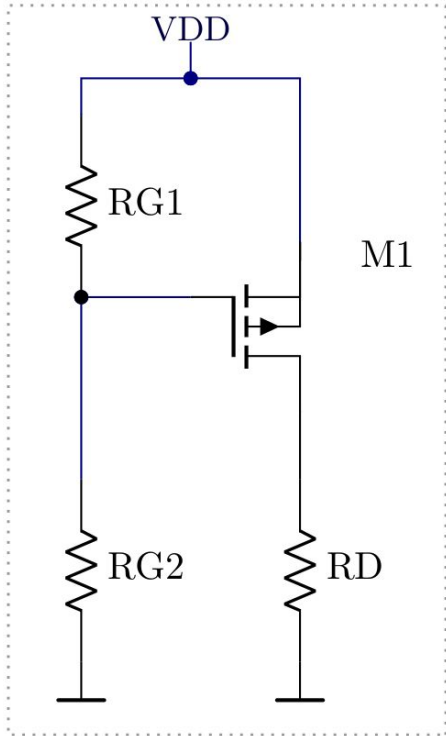
El MPS *modela* mediante elementos lineales el comportamiento del transistor alrededor del punto de trabajo. Si trabajamos en su **rango de validez**, nos liberamos de las ecuaciones no lineales de I_D y V_{GS} y es más fácil resolver el circuito.



$$|v_{gs}| < \frac{|V_{GS} - V_T|}{5}$$



Enunciado



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

$$I_D = -85.5 \text{ } \mu\text{A}$$

$$V_{DS} = -3.46 \text{ V}$$

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

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Datos

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

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

Para el circuito de la figura y los siguientes datos:

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

hallar

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

3. Circuito de Peq. Señal

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

$$I_D = -85.5 \text{ } \mu\text{A}$$

$$V_{DS} = -3.46 \text{ V}$$

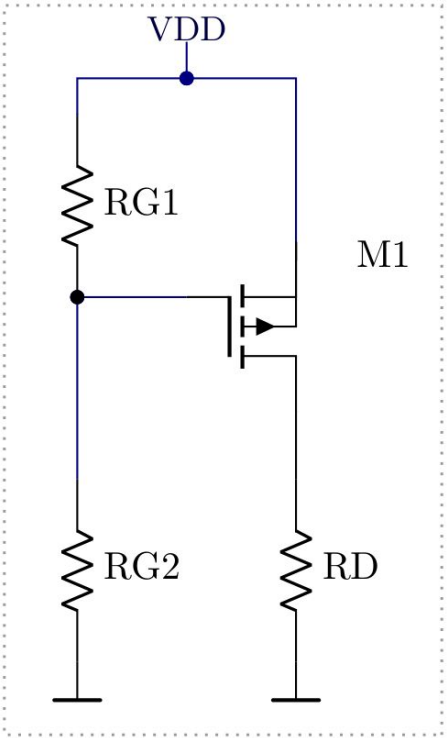
$$V_T = -0.8 \text{ V}, k = 320 \text{ } \mu\text{A/V}^2$$

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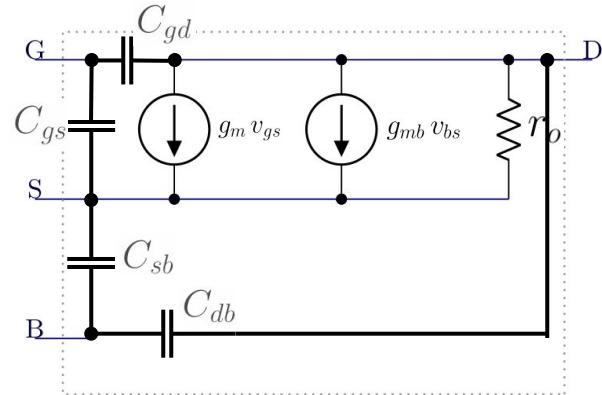
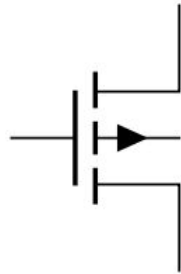
$$g_m = 320 \text{ } \mu\text{A/V}, g_{mb} = 293 \text{ } \mu\text{A/V}$$

$$r_o = 625 \text{ k}\Omega, C_{gs} = 1.4 \times 10^{-11} \text{ } \mu\text{F}$$

Datos
$ V_T = 0.8 \text{ V}, \mu_P C'_{ox} = 80 \text{ } \mu\text{A/V}^2$
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$R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$
$R_D = 18 \text{ k}\Omega, V_{DD} = 5 \text{ V}$



Simplificamos el modelo de pequeña señal



3. Circuito de Peq. Señal

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

$$I_D = -85.5 \text{ } \mu\text{A}$$

$$V_{DS} = -3.46 \text{ V}$$

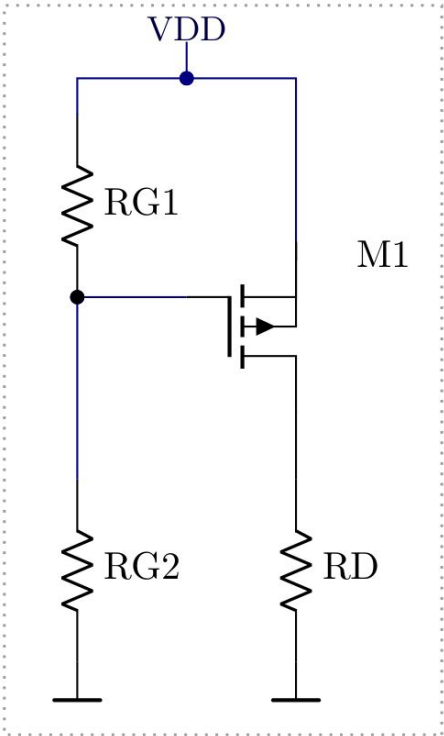
$$V_T = -0.8 \text{ V}, k = 320 \text{ } \mu\text{A/V}^2$$

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

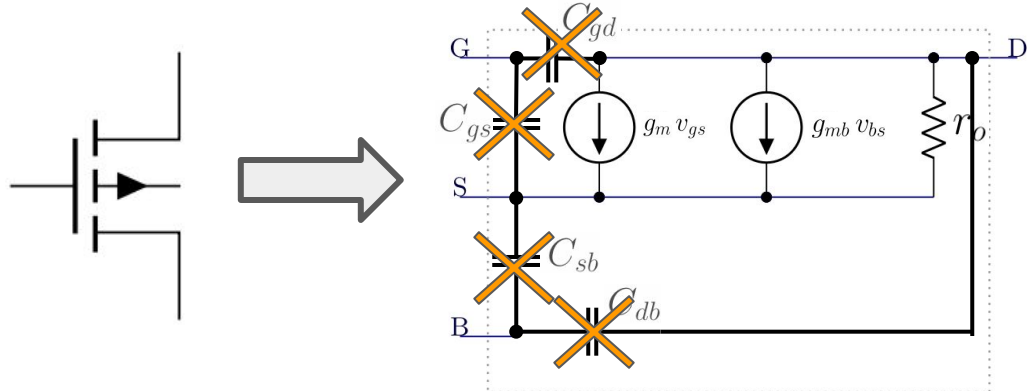
$$g_m = 320 \text{ } \mu\text{A/V}, g_{mb} = 293 \text{ } \mu\text{A/V}$$

$$r_o = 625 \text{ k}\Omega, C_{gs} = 1.4 \times 10^{-17} \text{ } \mu\text{F}$$

Datos
$ V_T = 0.8 \text{ V}, \mu_P C'_{ox} = 80 \text{ } \mu\text{A/V}^2$
$W = 32 \text{ } \mu\text{m}, L = 4 \text{ } \mu\text{m}$
$\lambda = 0.02 \text{ V}^{-1}, \gamma^2 = 0.5 \text{ V}$
$R_{G1} = 130 \text{ k}\Omega, R_{G2} = 370 \text{ k}\Omega$
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Simplificamos el modelo de pequeña señal



Se puede considerar frecuencias bajas o medias.

Enunciado:
 3. La variación de corriente de Drain al variar 1 mV la v_{gs}

3. Circuito de Peq. Señal

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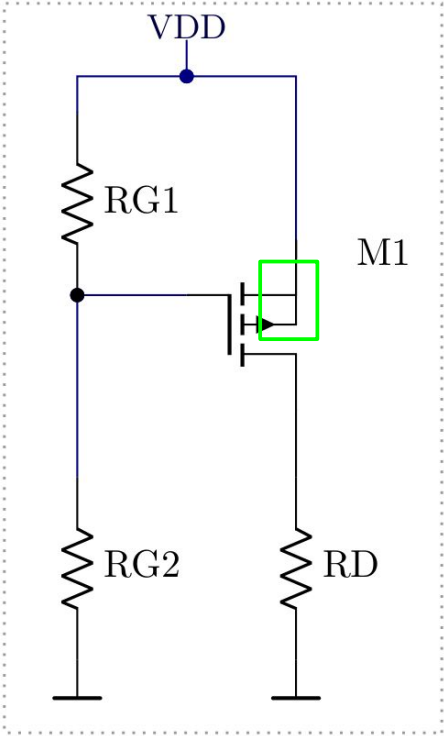
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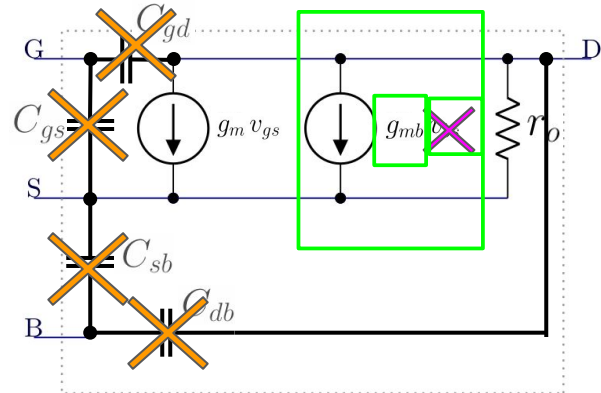
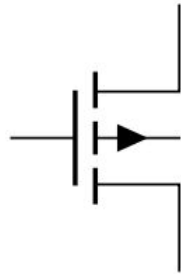
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Simplificamos el modelo de pequeña señal



Se puede considerar frecuencias bajas o medias.

B y S cortocircuitados

3. Circuito de Peq. Señal

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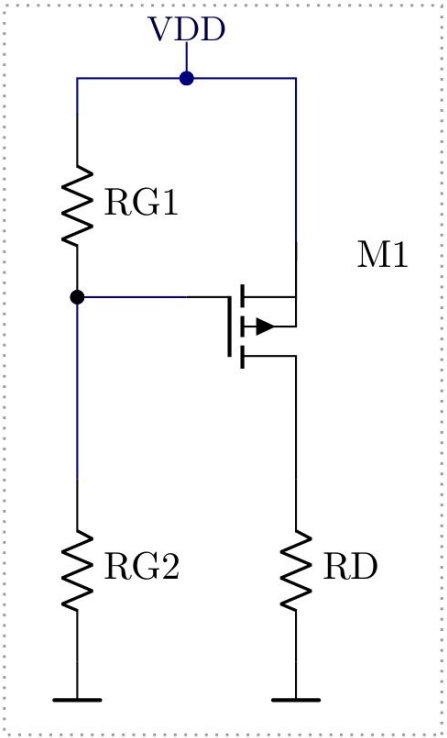
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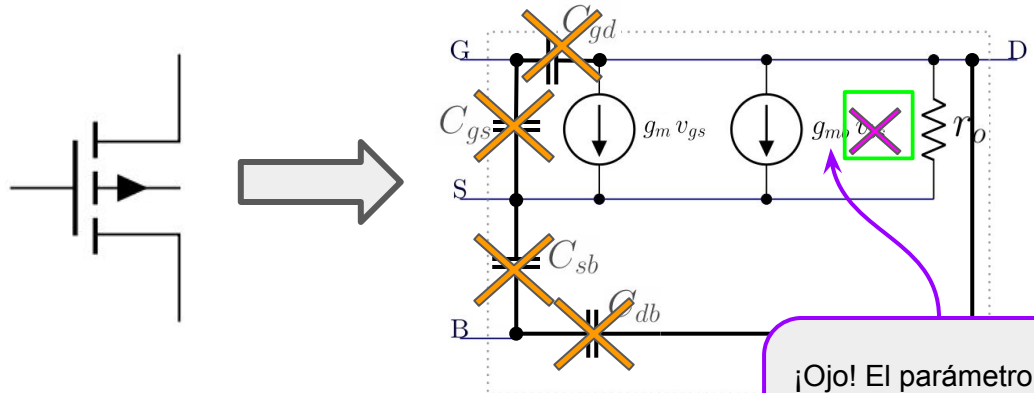
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Simplificamos el modelo de pequeña señal



Se puede considerar frecuencias bajas

¡Ojo! El parámetro g_{mb} y la fuente controlada siguen estando, aunque $V_{BS}=0$

B y S cortocircuitados

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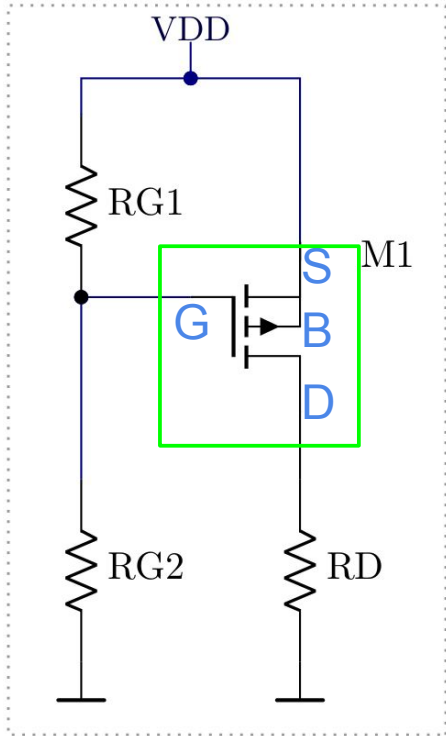
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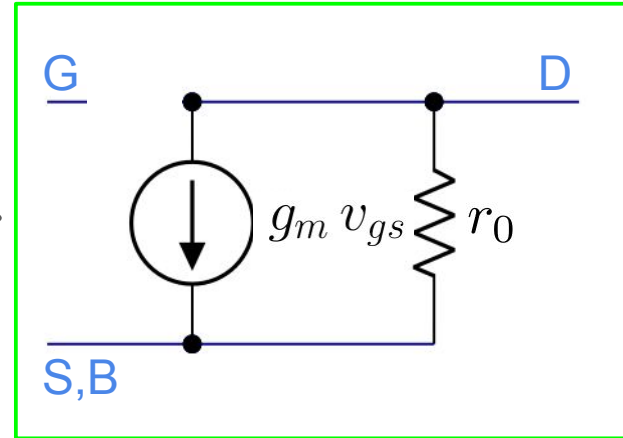
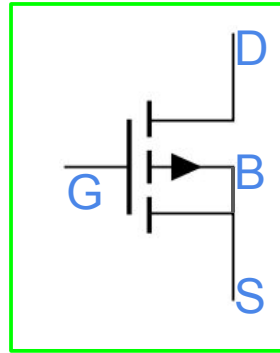
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Simplificamos el modelo de pequeña señal



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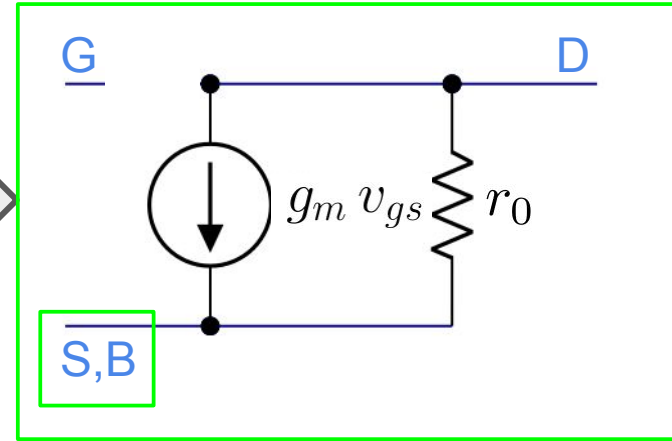
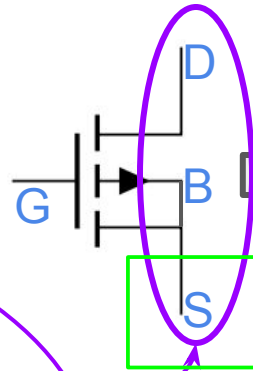
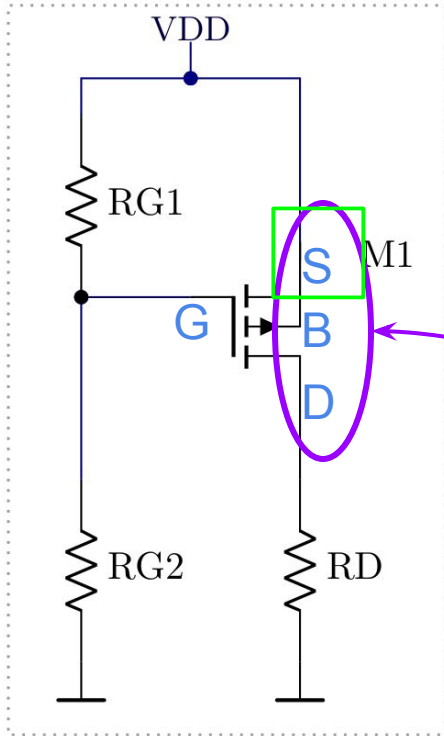
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Simplificamos el modelo de pequeña señal



¡Ojo! Están al revés

3. Circuito de Peq. Señal

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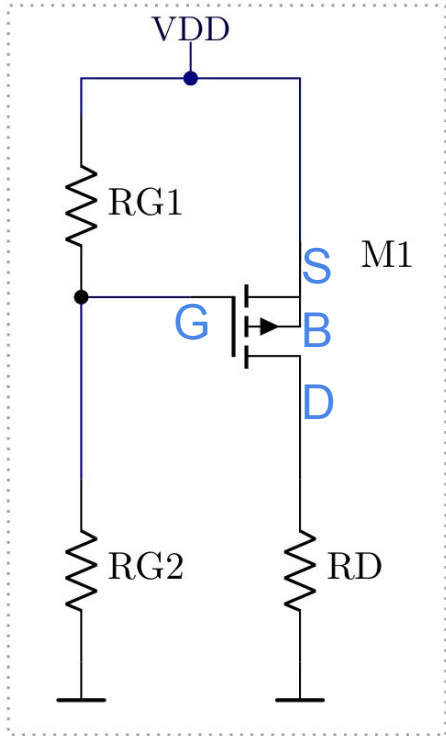
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Ahora sí pasamos al circuito de pequeña señal:



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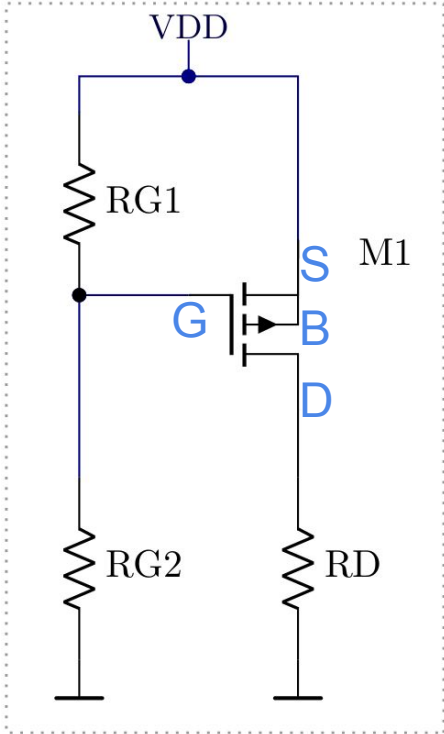
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Ahora sí pasamos al circuito de pequeña señal:

- Dejamos las fuentes de señal

3. Circuito de Peq. Señal

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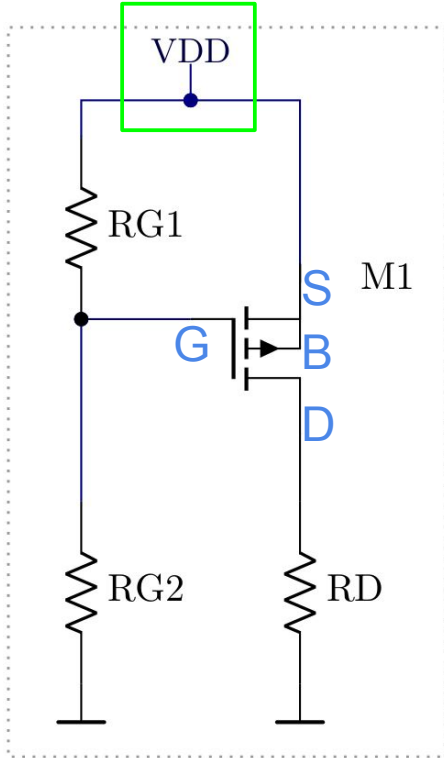
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Ahora sí pasamos al circuito de pequeña señal:

- Dejamos las fuentes de señal
- Pasivamos las fuentes de continua

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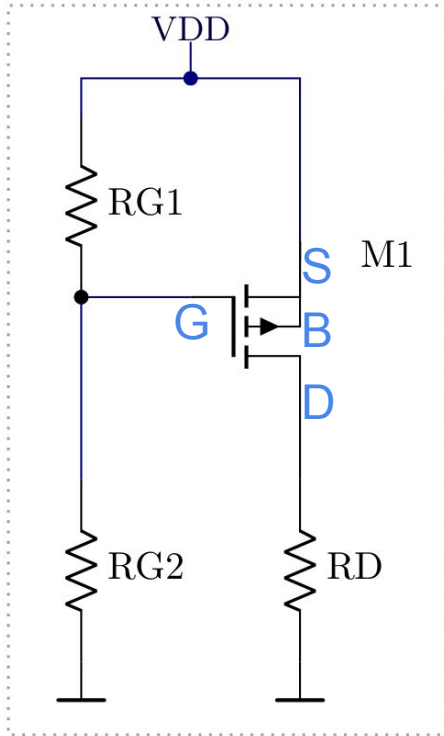
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Ahora sí pasamos al circuito de pequeña señal:

- Dejamos las fuentes de señal
- Pasivamos las fuentes de continua
- Capacitores = Circuitos cerrados

3. Circuito de Peq. Señal

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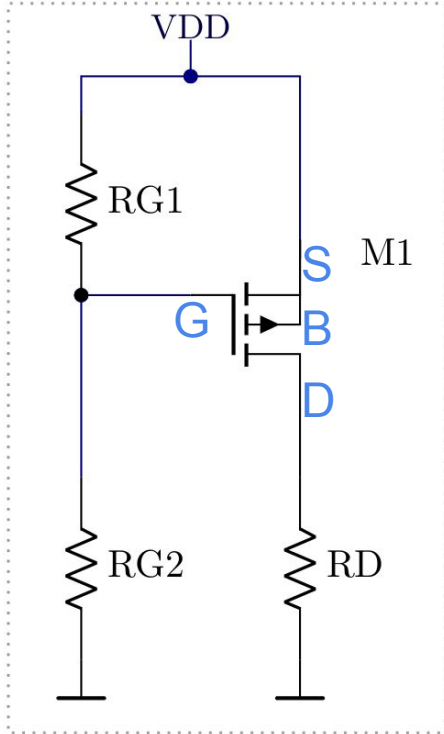
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Ahora sí pasamos al circuito de pequeña señal:

- Dejamos las fuentes de señal
- Pasivamos las fuentes de continua
- Capacitores = Circuitos cerrados
- Utilizamos el modelo de pequeña señal

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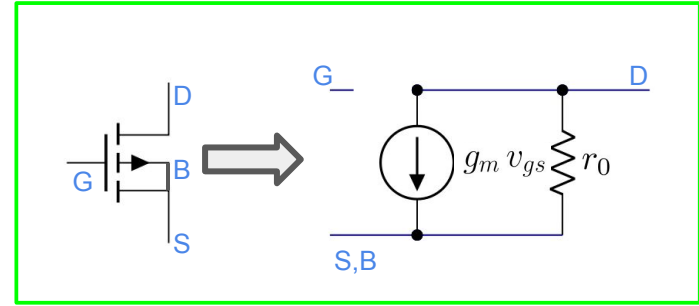
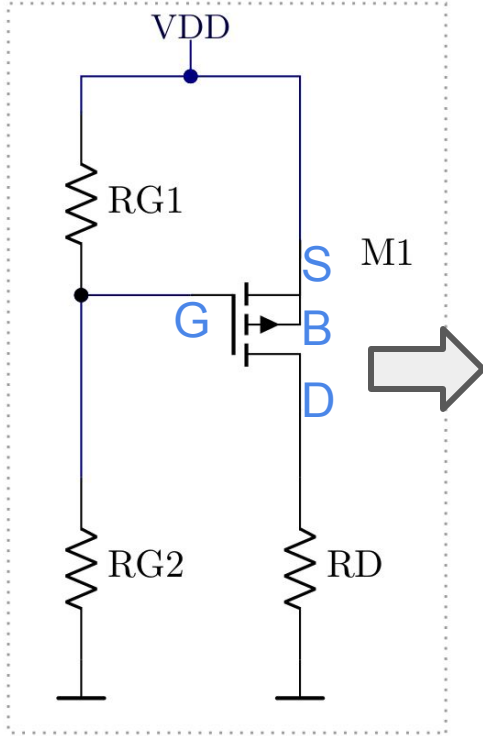
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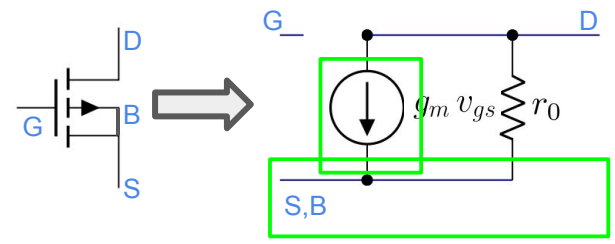
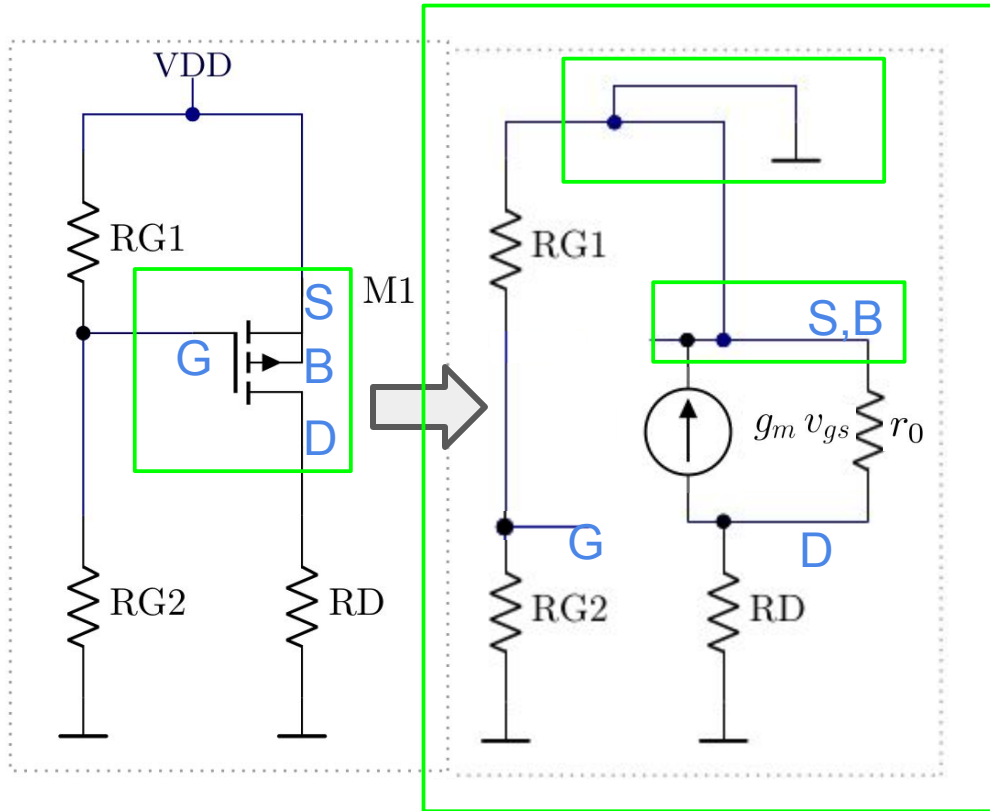
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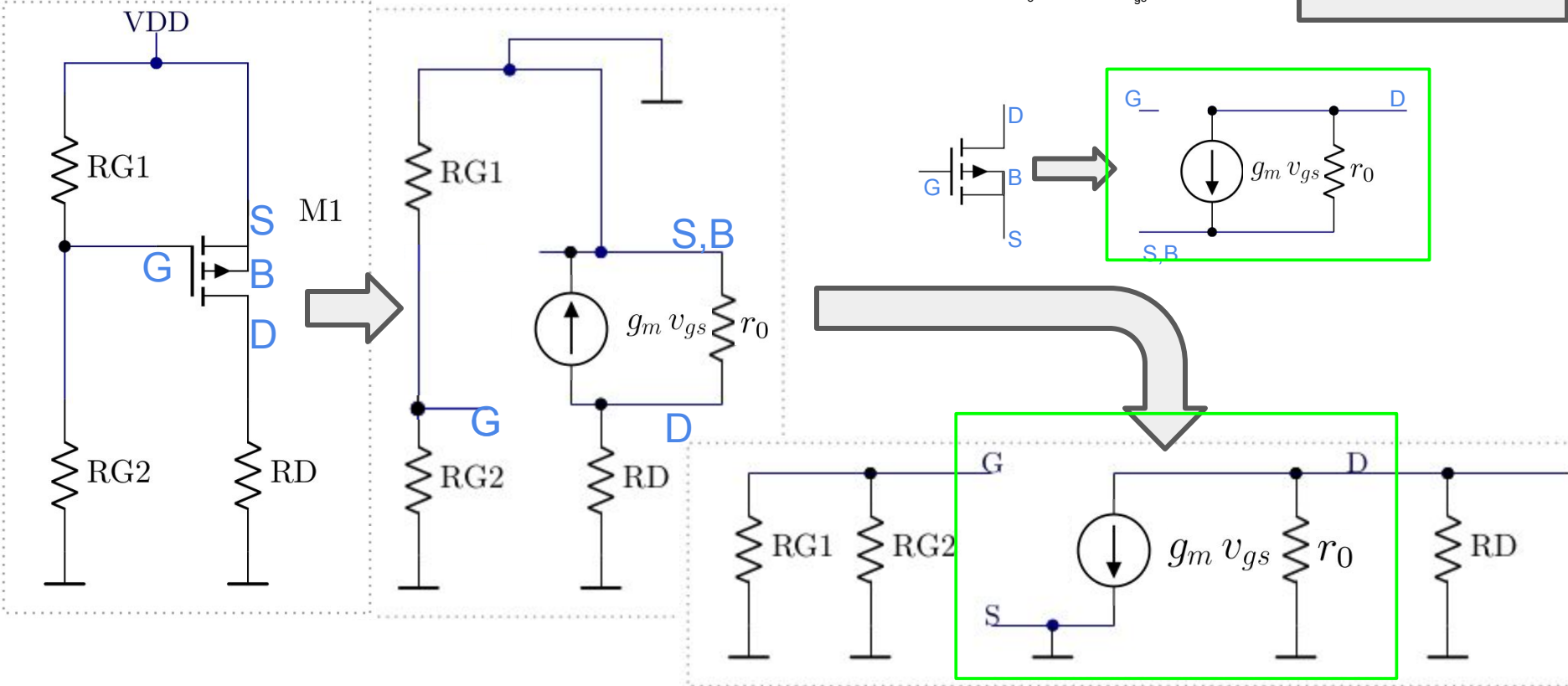
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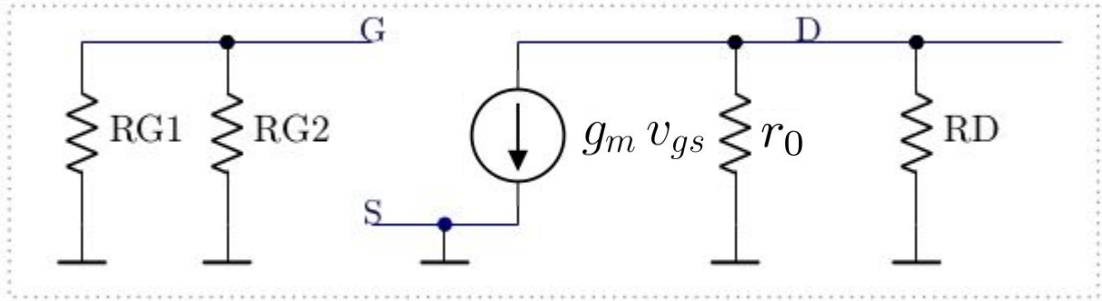
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La variación de corriente de Drain al variar 1 mV la v_{gs}



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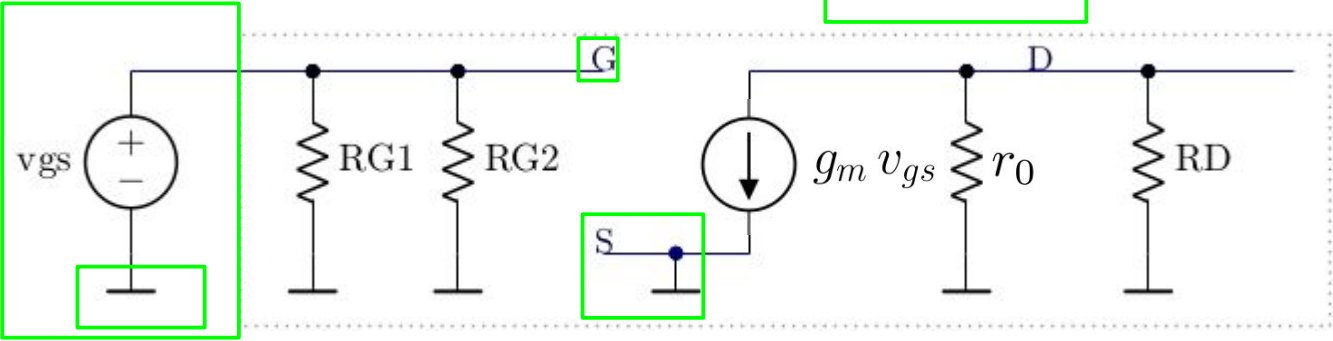
$$\begin{aligned} g_m &= 320 \text{ } \mu\text{A/V}, g_{mb} = 293 \\ &\text{ } \mu\text{A/V} \end{aligned}$$

$$r_o = 625 \text{ k}\Omega, C_{gs} = 1.4 \times 10^{-17} \text{ } \mu\text{F}$$

Datos

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

La variación de corriente de Drain al variar 1 mV la v_{gs}



3. Circuito de Peq. Señal

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

$$I_D = -85.5 \text{ } \mu\text{A}$$

$$V_{DS} = -3.46 \text{ V}$$

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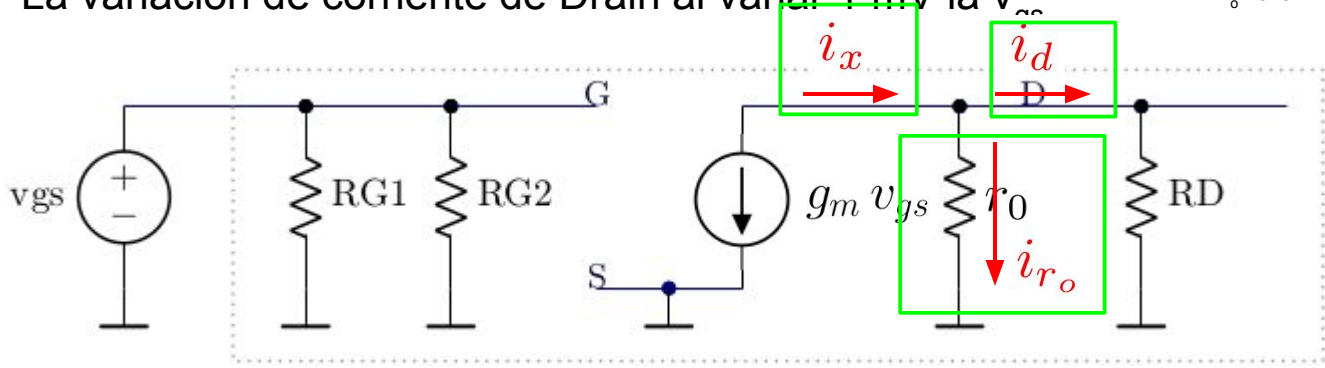
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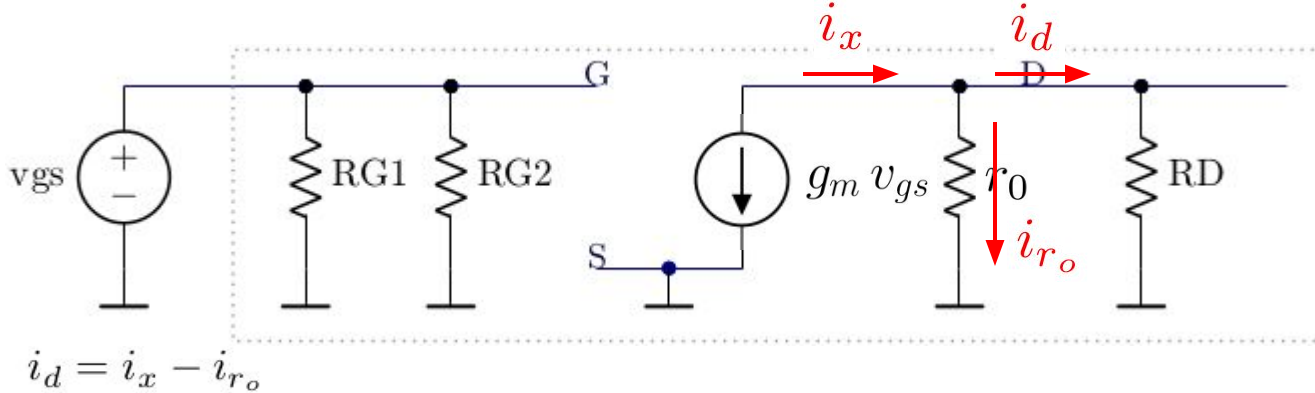
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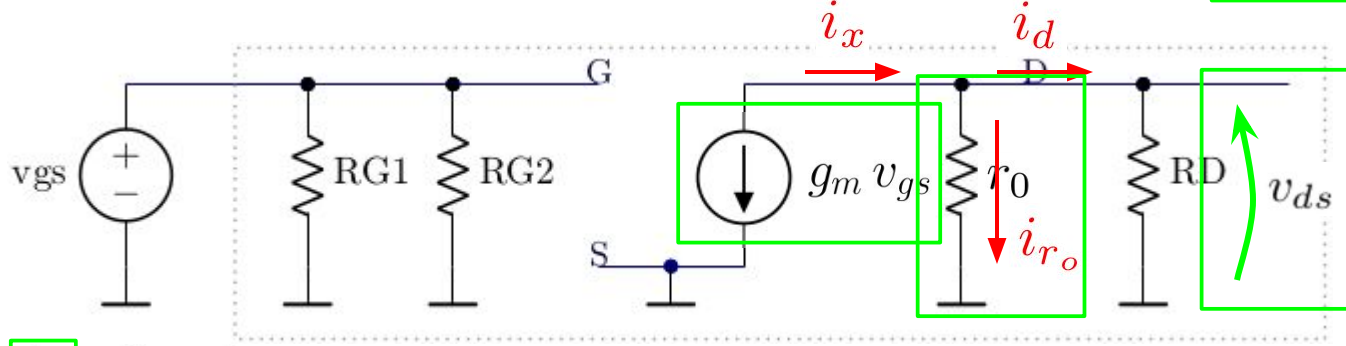
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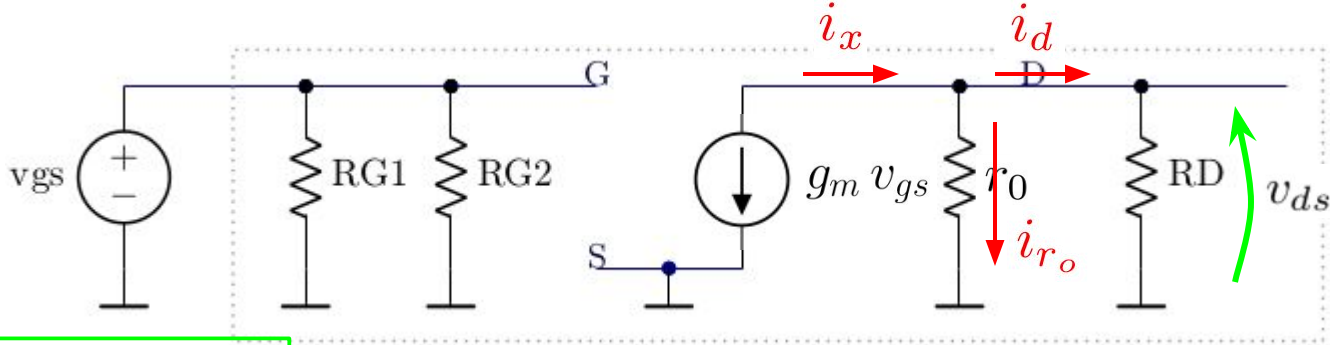
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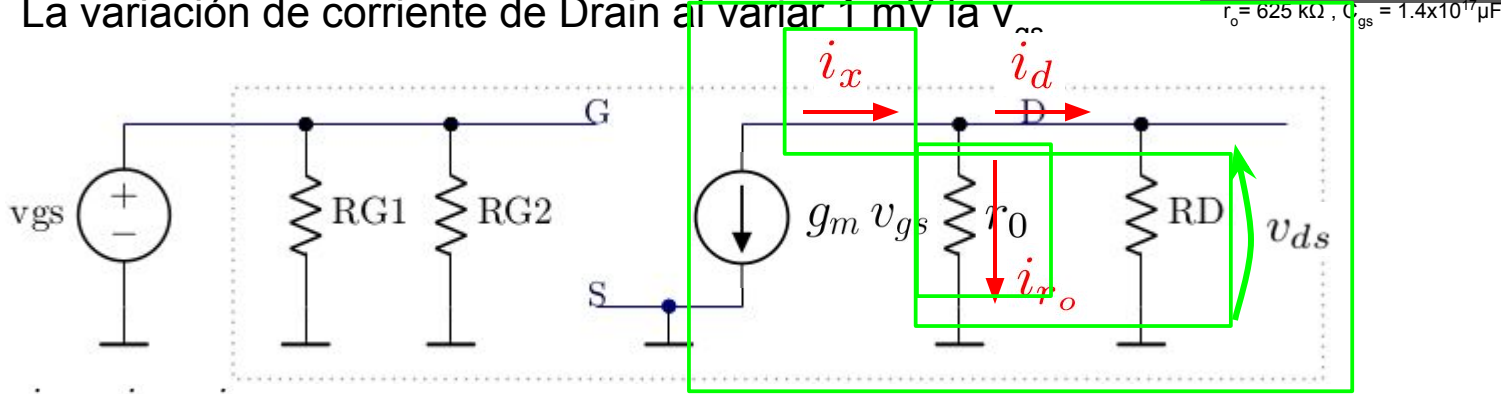
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$$v_{ds} \approx -g_m v_{gs} R_D \cdot 1.03 = -5.76 \text{ mV}$$

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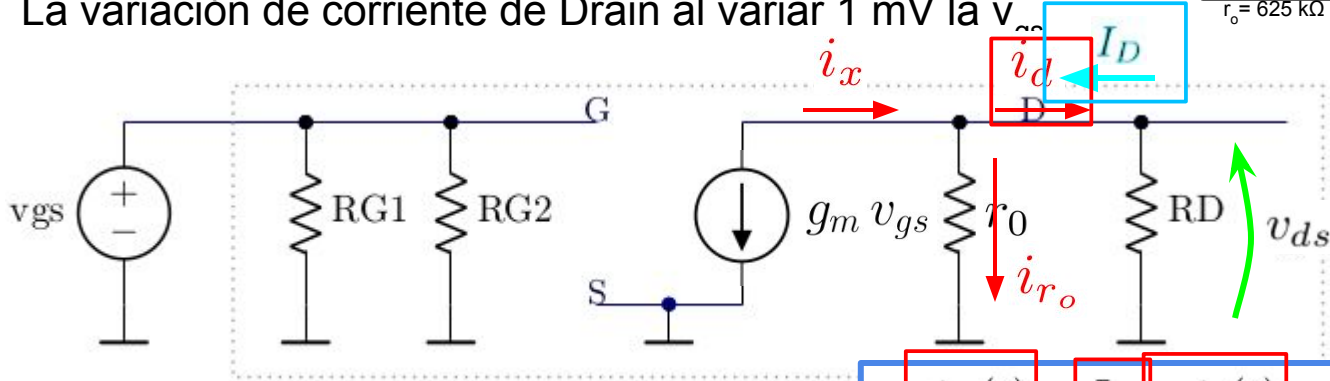
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$$v_{DS}(t) = V_{DS} + v_{ds}(t) = -(3.46 + 0.00576 u(t)) \text{ V}$$

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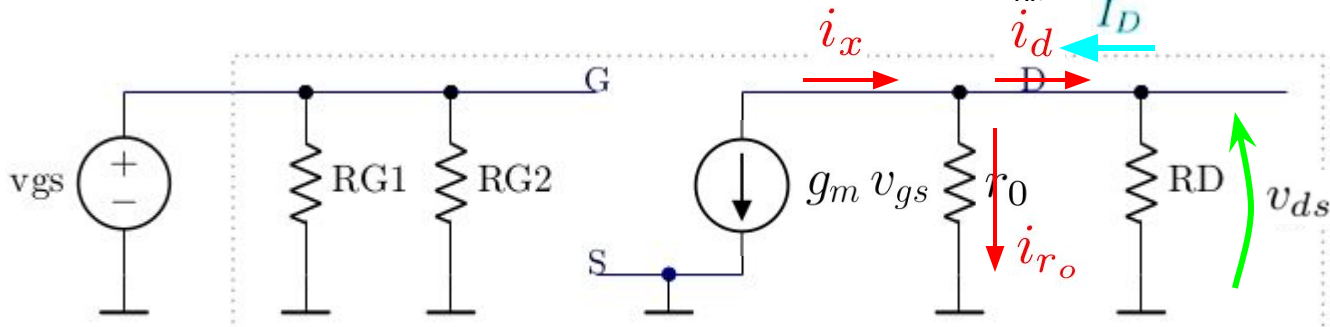
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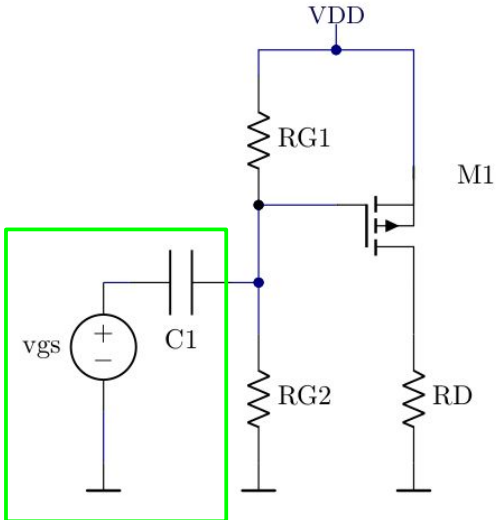
$$v_{DS}(t) = V_{DS} + v_{ds}(t) = -(3.46 + 0.00576 u(t)) \text{ V}$$

Recordemos que solo vale cuando ...

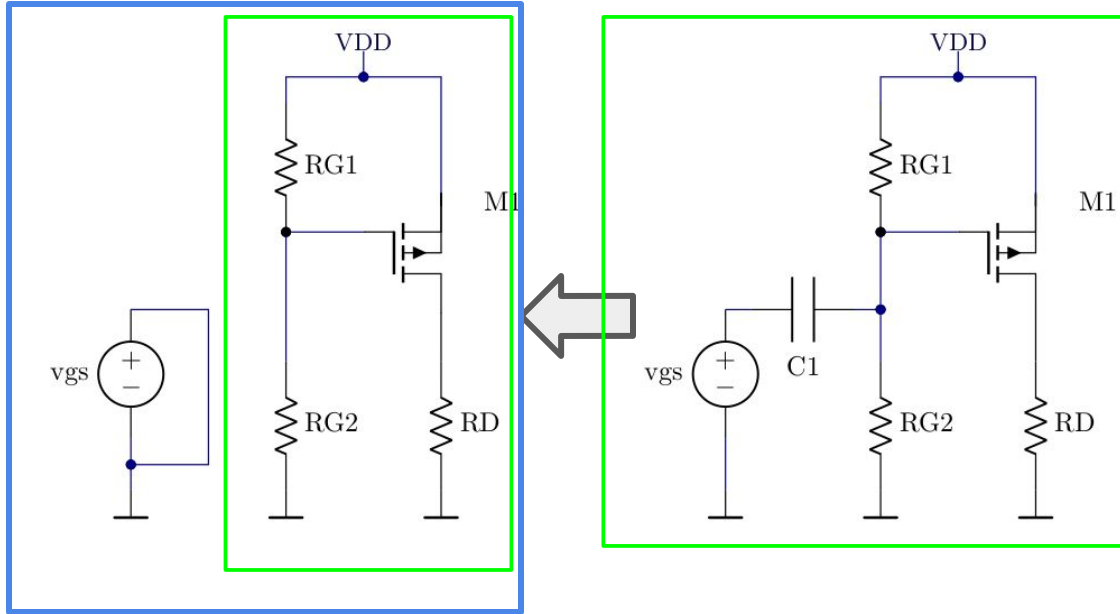
$$|v_{gs}| < \frac{|V_{GS} - V_T|}{5}$$

4. Extra: Como conseguir la variación de 1 mV sobre v_{gs}

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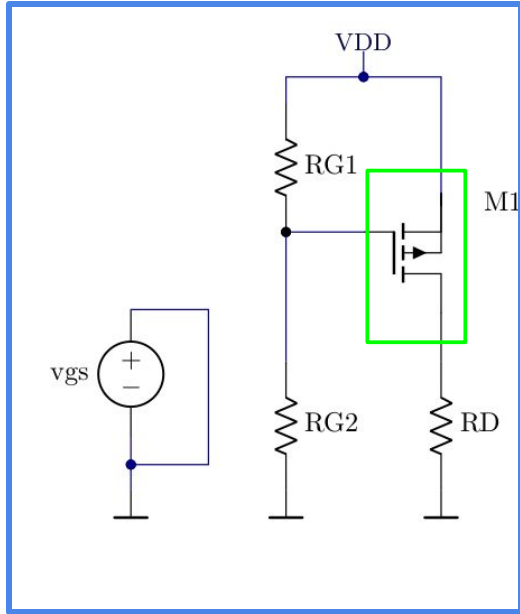


4. Extra: Como conseguir la variación de 1 mV sobre v_{gs}

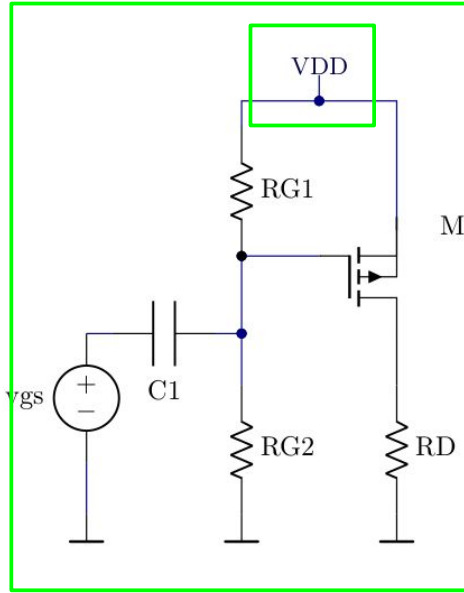


POLARIZACIÓN

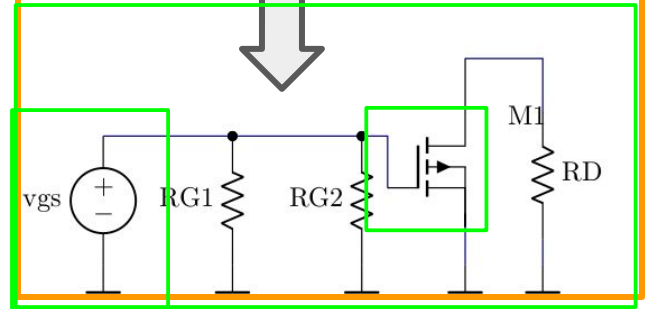
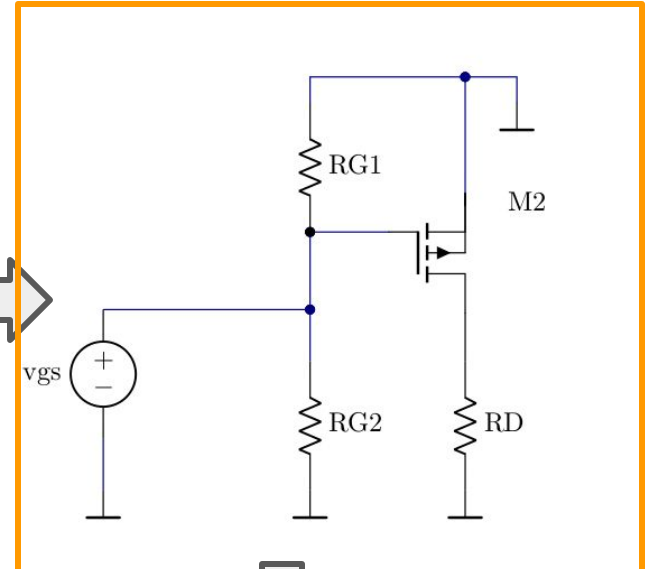
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POLARIZACIÓN



PEQUEÑA SEÑAL



5. Extra: Simulación

LTspice XVII - sim_circuito.raw

File View Plot Settings Simulation Tools Window Help

sim_circuito.asc sim_circuito.raw

```

.model mi_pmos pmos(
+VT0=-0.8 KP=80u W=32 L=4
+lambda=0.02 gamma=0.7071)
V1 vdd 5
V2 PULSE(0 1m 1u 1f 1f 1)
R3 130k
R2 370k
R1 18k
C1 10µ
C2 1µ
C3 1µ
M1 mi_pmos
S
D 1.539658V

```

`.tran 0 10u 0`

V(D,S)

Cursor	Horz	Vert
Cursor 1	492.12598ns	-3.4603V
Cursor 2	5µs	-3.46632V
Diff (Cursor2 - Cursor1)	4.507874µs	-5.980849mV
Freq	221.83406KHz	Slope: -1326.7

Id(M1)

Cursor	Horz	Vert
Cursor 1	492.12598ns	-85.536551µA
Cursor 2	5µs	-85.204283µA
Diff (Cursor2 - Cursor1)	4.507874µs	332.26774nA
Freq	221.83406KHz	Slope: 0.0737083

10µs

x = 5.30µs y = -3.465493V

5. Extra: Simulación

LTspice XVII - sim_circuito.raw

File View Plot Settings Simulation Tools

sim_circuito.asc sim_circuito.raw

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$$v_{DS}(t) = V_{DS} + v_{ds}(t) = -(3.46 + 0.00576 u(t)) \text{V}$$

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

$I_D = -85.5 \mu\text{A}$

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`.model mi_pmos pmos(+VT0=-0.8 KP=80u W=32 L=4 +lambda=0.02 gamma=0.7071)`

`.tran 0 10u 0`

`PULSE(0 1m 1u 1f 1f 1)`

`V1 5`

`V2 3.7V`

`R1 18k`

`R2 370k`

`R3 130k`

`C1 10µ`

`M1 mi_pmos`

`D 1.539658V`

`S 3.7V`

`vdd 5V`

`x = 5.30µs y = -3.465493V`

V(D,S)

Cursor 1	V(D,S)
Horz:	492.12598ns
Vert:	-3.46034
Cursor 2	V(D,S)
Horz:	5µs
Vert:	-3.46632
Diff (Cursor2 - Cursor1)	
Horz:	4.507874µs
Vert:	-5.980849
Freq:	221.83406KHz
Slope:	-1326.7

Id(M1)

Cursor 1	Id(M1)
Horz:	492.12598ns
Vert:	-85.536551µA
Cursor 2	Id(M1)
Horz:	5µs
Vert:	-85.204283µA
Diff (Cursor2 - Cursor1)	
Horz:	4.507874µs
Vert:	332.26774nA
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FIN