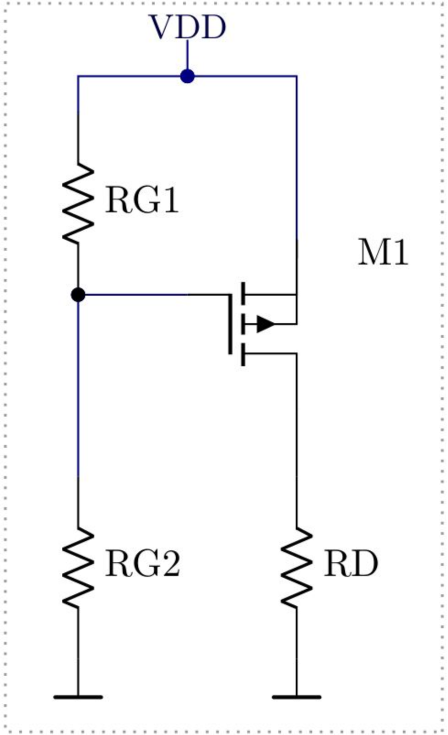
[86.03/66.25] Dispositivos Semiconductores
1er Cuatrimestre 2020

# Transistor MOS

1. Polarización
2. Modelo de Pequeña Señal

# Enunciado



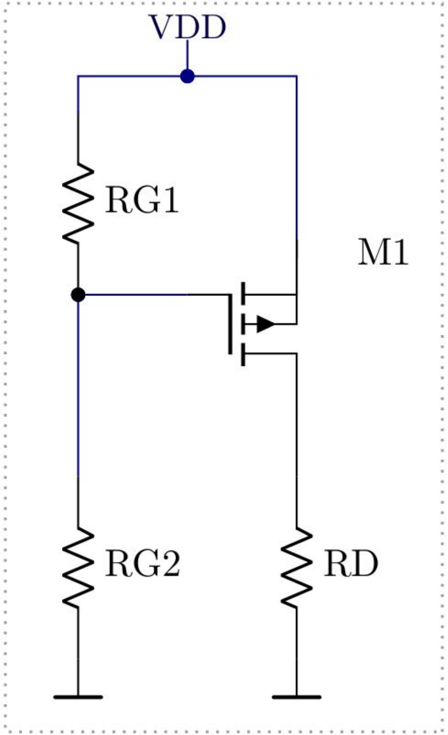

Para el circuito de la figura y los siguientes datos:

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

hallar

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

# Enunciado




Para el circuito de la figura y los siguientes datos:

- $|V_T| = 0.8$ 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
- $R_{G1} = 130\ k\Omega$, $R_{G2} = 370\ k\Omega$ $R_D = 18 k\Omega$, $V_{DD} = 5$ 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 $v_{gs}$

<u>Datos</u>

$|V_T| = 0.8$ 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

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

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

# 1. Polarización

**Datos**

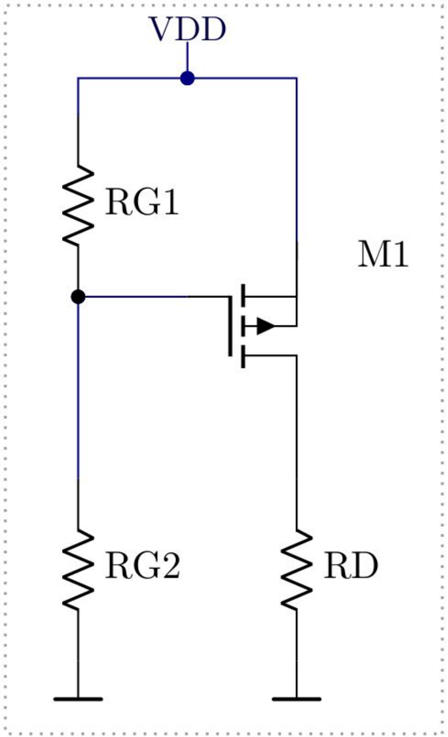
$|V_T| = 0.8$ V, $\mu_P C'_{ox} = 80$ μA/V$^2$

$W = 32$ μm, $L = 4$ μm

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

$R_{G1} = 130$ kΩ, $R_{G2} = 370$ kΩ

$R_D = 18$kΩ, $V_{DD} = 5$ V



# 1. Polarización

Datos

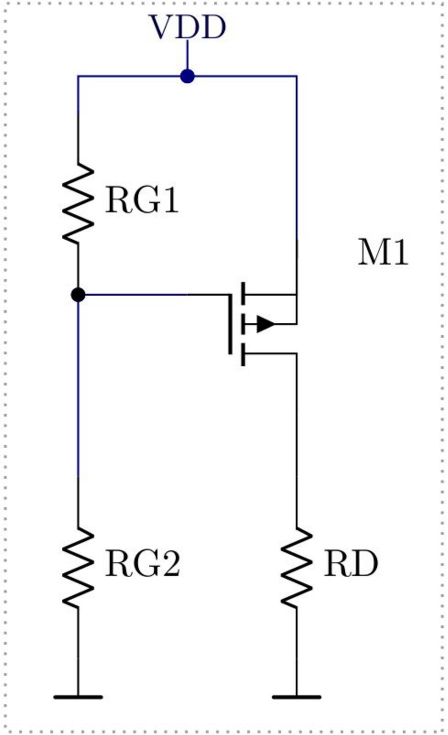
$|V_T| = 0.8$ V, $\mu_P C'_{ox} = 80\ \mu A/V^2$

W = 32 μm, L = 4 μm

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

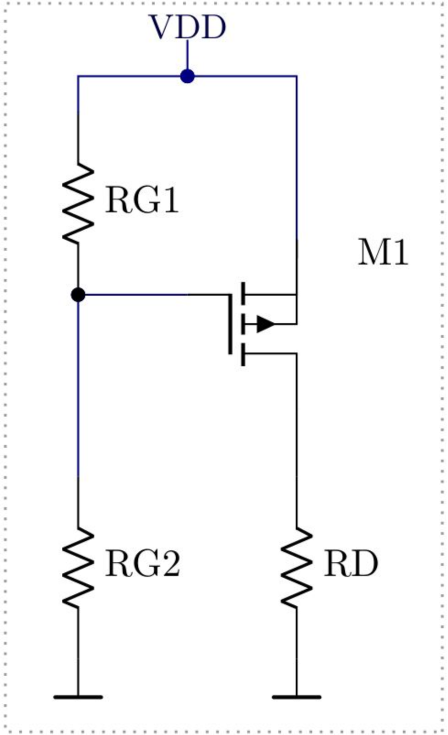
$R_{G1} = 130$ kΩ, $R_{G2} = 370$ kΩ

$R_D = 18$kΩ, $V_{DD} = 5$ V




Hallamos el k:

# 1. Polarización




Hallamos el k:

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

**Datos**

$|V_T| = 0.8$ 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

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

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

# 1. Polarización

**Datos**

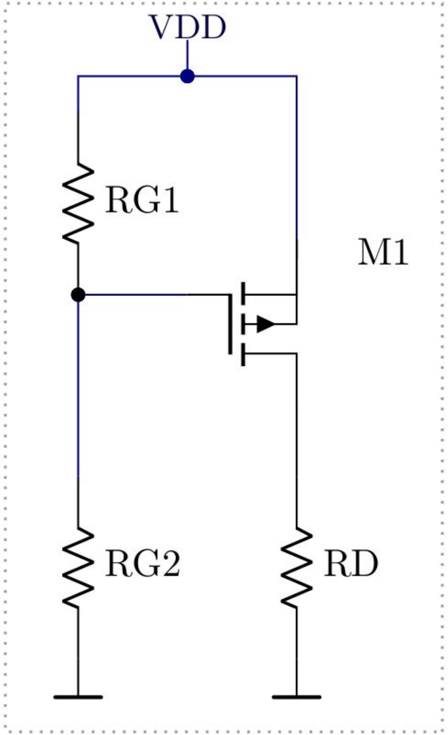
$|V_T| = 0.8$ V, $\mu_P C'_{ox} = 80\ \mu A/V^2$

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

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

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

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




Hallamos el k:

$$k = \frac{\mu_p C_{ox}}{2} \frac{W}{L} = \frac{80}{2} \frac{\mu A}{V^2} \frac{32\ \mu m}{4\ \mu m}$$

# 1. Polarización

Datos

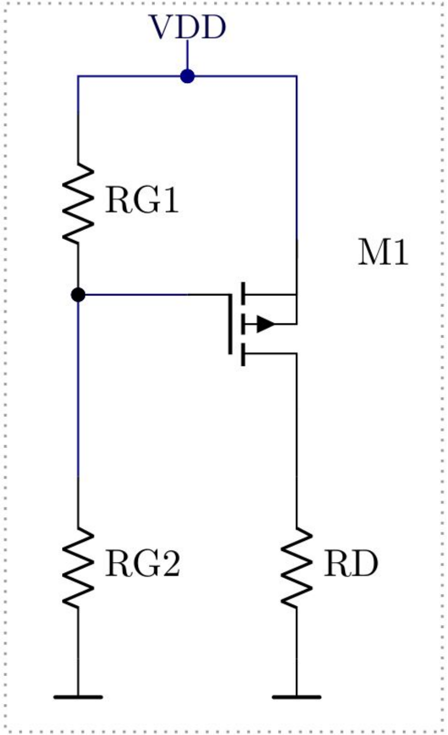
$|V_T| = 0.8$ V, $\mu_p C'_{ox} = 80\ \mu A/V^2$

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

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

$R_{G1} = 130$ kΩ, $R_{G2} = 370$ kΩ

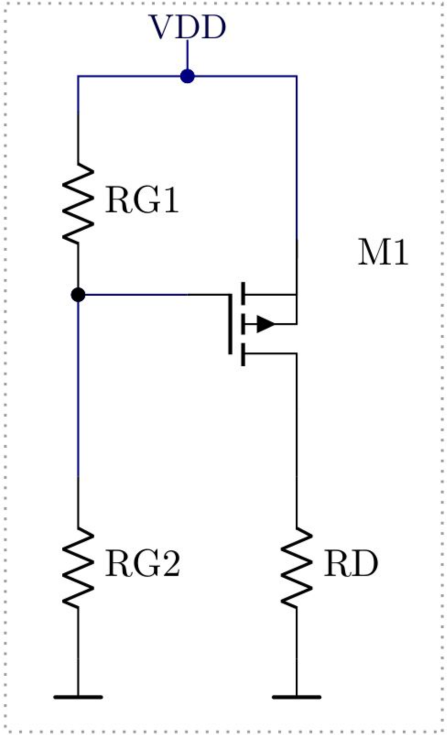
$R_D = 18$kΩ, $V_{DD} = 5$ V




Hallamos el k:

$$k = \frac{\mu_p C_{\text{ox}}}{2}\frac{W}{L} = \frac{80}{2}\frac{\mu\text{A}}{\text{V}^2}\frac{32\ \mu\text{m}}{4\ \mu\text{m}} = 320\ \frac{\mu\text{A}}{\text{V}^2}$$

# 1. Polarización




Hallamos el $V_T$:

**Datos**

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

W = 32 μm, L = 4 μm

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

$R_{G1} = 130$ kΩ, $R_{G2} = 370$ kΩ

$R_D = 18$kΩ, $V_{DD} = 5$ V

# 1. Polarización

**Datos**

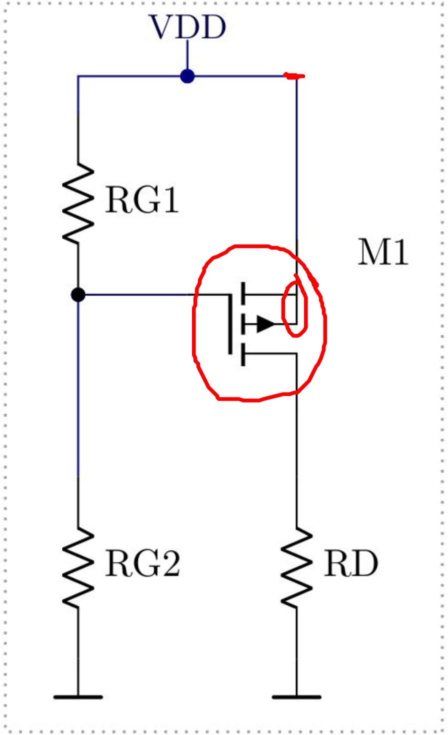
$|V_T| = 0.8$ V, $\mu_P C'_{ox} = 80$ μA/V$^2$

W = 32 μm, L = 4 μm

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

$R_{G1} = 130$ kΩ, $R_{G2} = 370$ kΩ

$R_D = 18$kΩ, $V_{DD} = 5$ V

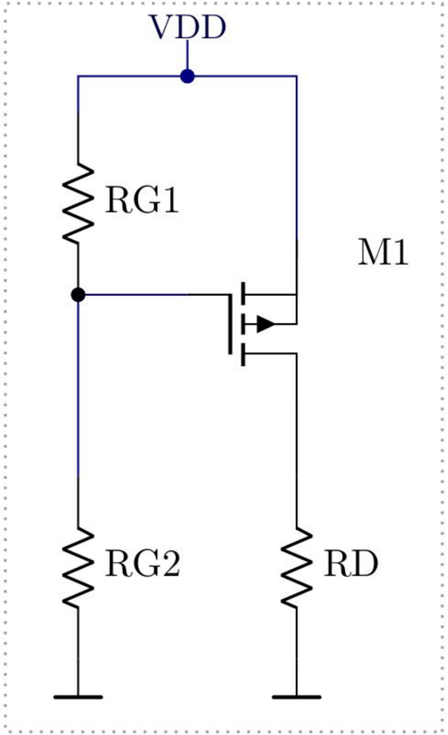



Hallamos el $V_T$:

- ¿El transistor MOS es canal P o canal N?

# 1. Polarización

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




Hallamos el $V_T$:

- ¿El transistor MOS es canal P o canal N?

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

# 1. Polarización

Datos

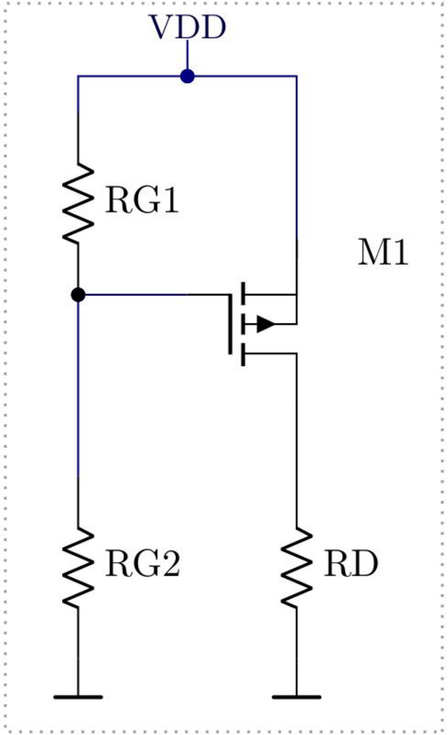
$|V_T| = 0.8$ V, $\mu_P C'_{ox} = 80\ \mu A/V^2$

W = 32 µm, L = 4 µm

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

$R_{G1} = 130$ kΩ, $R_{G2} = 370$ kΩ

$R_D = 18$kΩ, $V_{DD} = 5$ V




Hallamos el $V_T$:

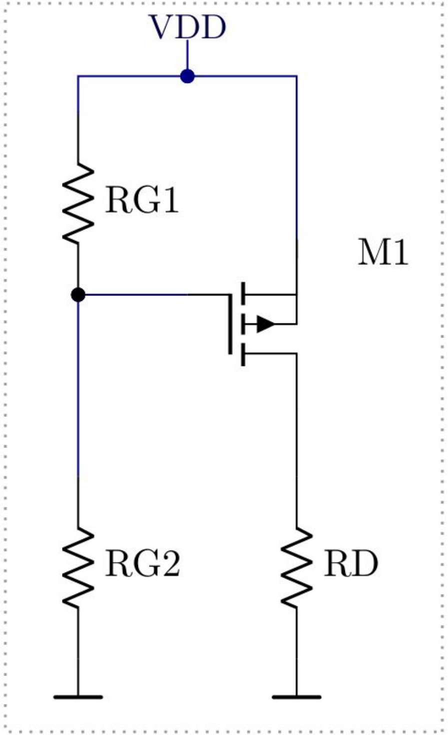
- ¿El transistor MOS es canal P o canal N?

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

- ¿$V_T$ = 0.8 V o $V_T$ = -0.8 V?, ¿porqué?

# 1. Polarización

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




Hallamos el $V_T$:

- ¿El transistor MOS es canal P o canal N?

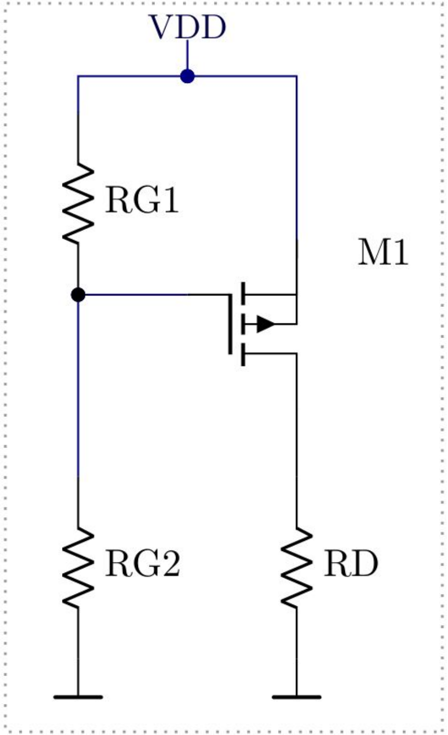
  Por su símbolo es canal P y por lo tanto el substrato es tipo N.

- ¿$V_T$ = 0.8 V o $V_T$ = -0.8 V?, ¿porqué?

  Primero supongo que no tengo inversión del canal en equilibrio, entonces me encuentro en acumulación o vaciamiento.

# 1. Polarización

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




Hallamos el $V_T$:

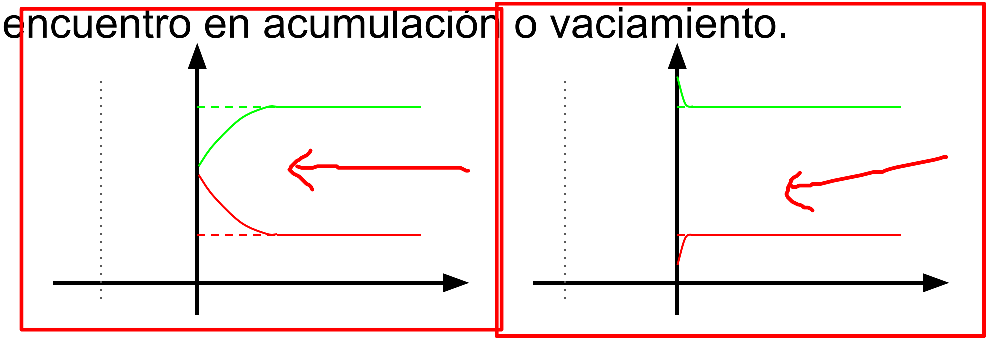
- ¿El transistor MOS es canal P o canal N?

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

- ¿$V_T$ = 0.8 V o $V_T$ = -0.8 V?, ¿porqué?

  Primero supongo que no tengo inversión del canal en equilibrio, entonces me encuentro en acumulación o vaciamiento.

  Recordemos:



# 1. Polarización

**Datos**

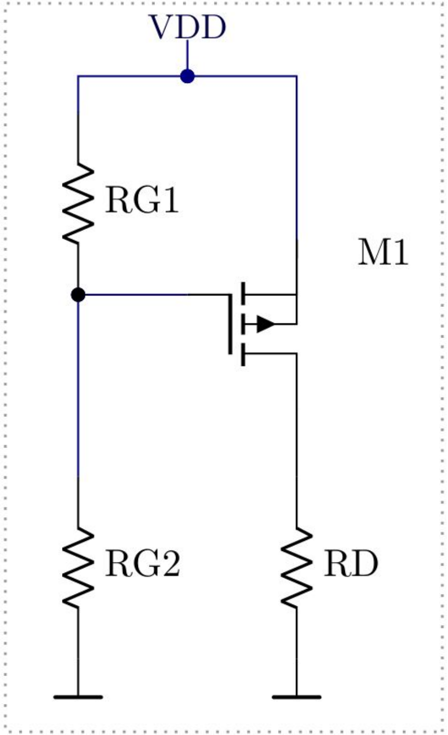
$|V_T| = 0.8$ V, $\mu_P C'_{ox} = 80\ \mu A/V^2$

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

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

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

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




Hallamos el $V_T$:

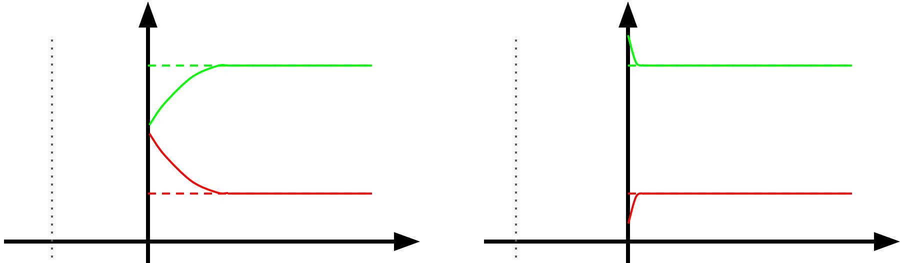
- ¿El transistor MOS es canal P o canal N?

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

- ¿$V_T$ = 0.8 V o $V_T$ = -0.8 V?, ¿porqué?

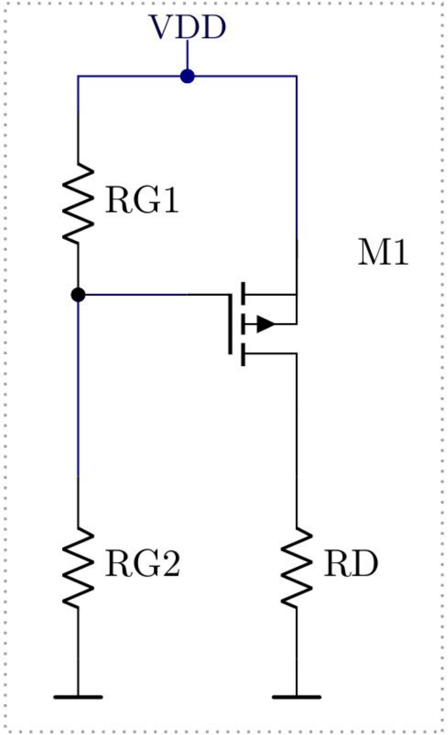
  Primero supongo que no tengo inversión del canal en equilibrio, entonces me encuentro en acumulación o vaciamiento.

  Recordemos:



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

# 1. Polarización




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

Hallamos el $V_T$:

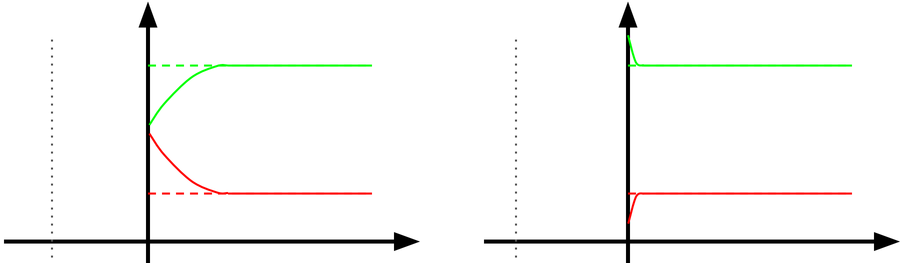
- ¿El transistor MOS es canal P o canal N?

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

- ¿$V_T$ = 0.8 V o $V_T$ = -0.8 V?, ¿porqué?

  Primero supongo que no tengo inversión del canal en equilibrio, entonces me encuentro en acumulación o vaciamiento.

  Recordemos:

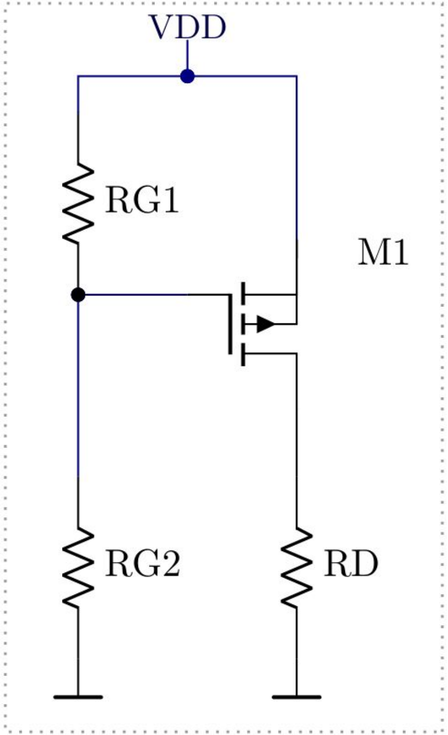


En ambos casos es necesario inyectar huecos en el substrato para llegar a inversión, entonces $V_T$ = -0.8 V

# 1. Polarización

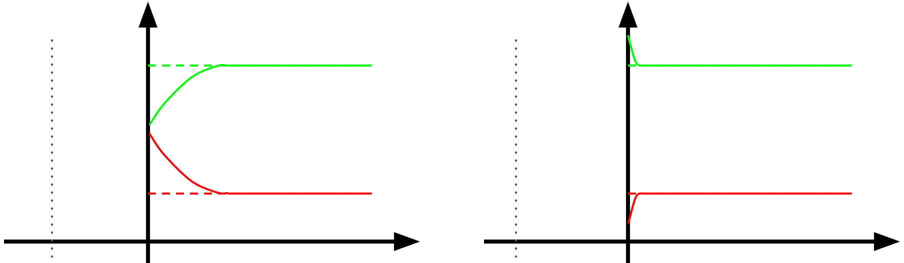
$V_T$ = -0.8 V, k = 320 μA/V$^2$

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




Hallamos el $V_T$:

- ¿El transistor MOS es canal P o canal N?
  Por su símbolo es canal P y por lo tanto el substrato es tipo N.
- ¿$V_T$ = 0.8 V o $V_T$ = -0.8 V?, ¿porqué?
  Primero supongo que no tengo inversión del canal en equilibrio, entonces me encuentro en acumulación o vaciamiento.
  Recordemos:



En ambos casos es necesario inyectar huecos en el substrato para llegar a inversión, entonces $V_T$ = -0.8 V

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V$^2$

Datos

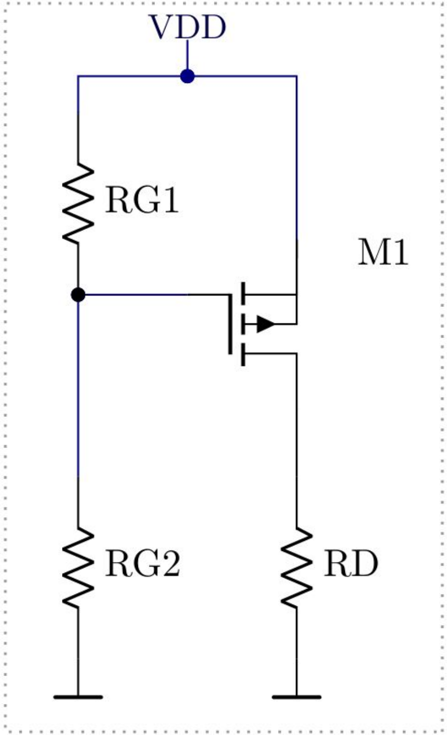
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 μA/V$^2$

W = 32 μm, L = 4 μm

λ = 0.02 V$^{-1}$, $\gamma^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V



# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/$V^2$

Datos

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

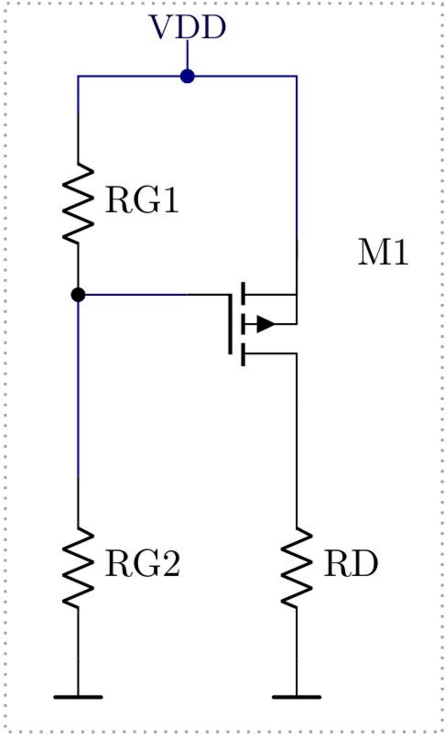
W = 32 μm, L = 4 μm

λ = 0.02 $V^{-1}$, $\gamma^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V

Ahora sí pasamos al circuito de polarización:



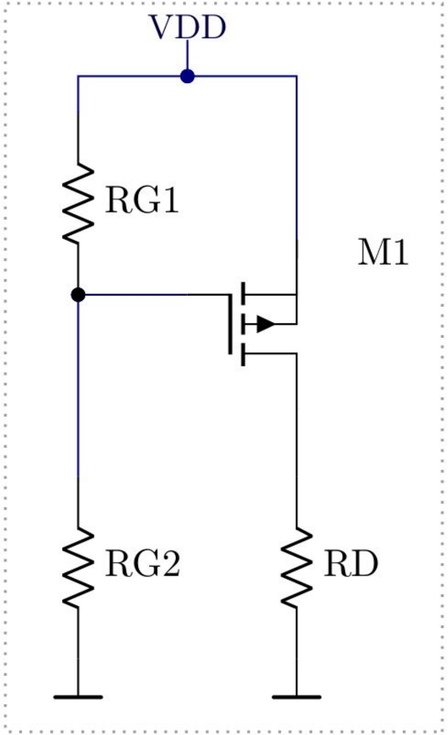
# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/$V^2$

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

Ahora sí pasamos al circuito de polarización:

- Fuentes de continua



# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/$V^2$

<u>Datos</u>

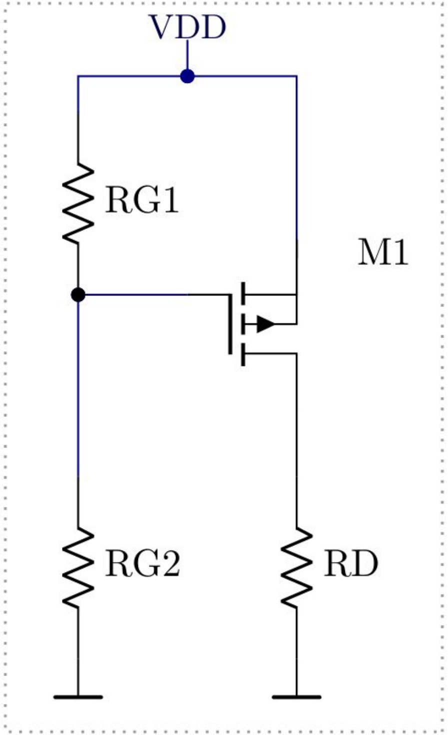
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 μA/$V^2$

W = 32 μm, L = 4 μm

λ = 0.02 $V^{-1}$, $\gamma^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V



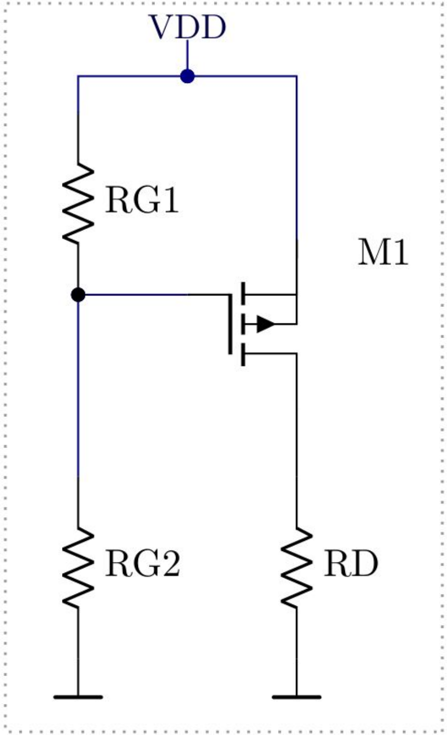

Ahora sí pasamos al circuito de polarización:

- Fuentes de continua
- Capacitores = Circuitos abiertos

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V$^2$

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



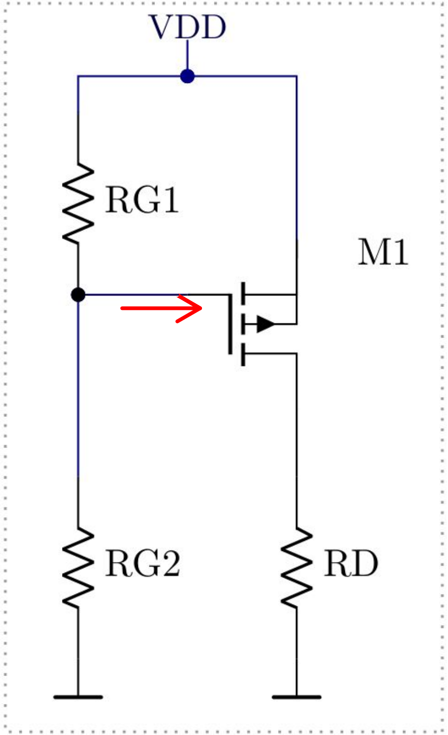

Ahora sí pasamos al circuito de polarización:

- Fuentes de continua
- Capacitores = Circuitos abiertos
- Modelo de “Gran Señal”

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V$^2$

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




Ahora sí pasamos al circuito de polarización:

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

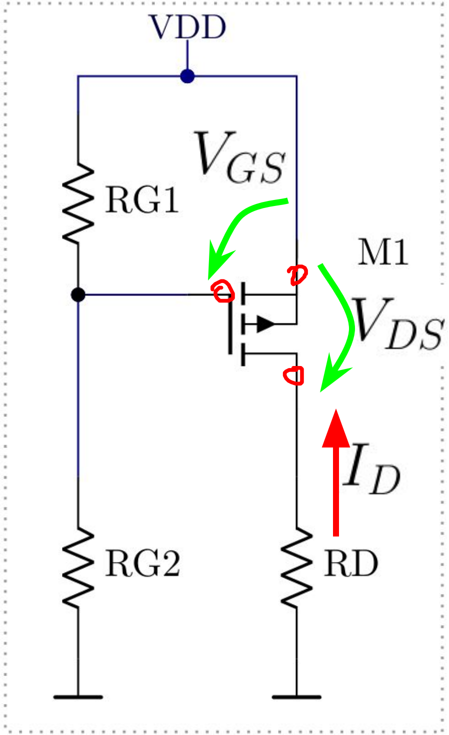
$$I_G = 0$$

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

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V$^2$

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




Ahora sí pasamos al circuito de polarización:

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

$$I_G = 0$$

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

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V$^2$

**Datos**

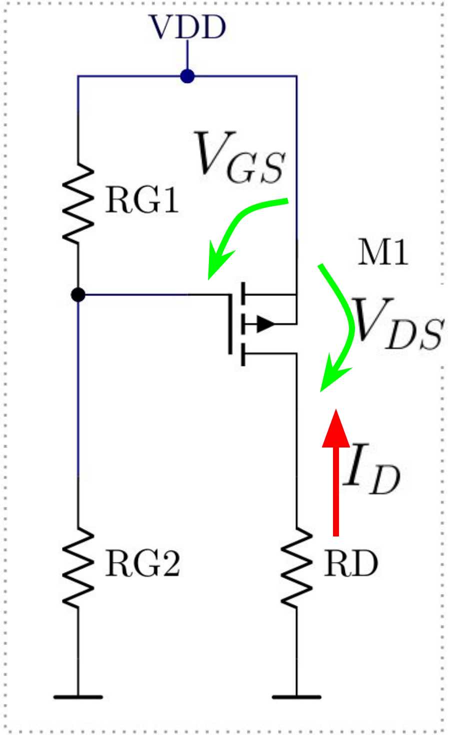
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 μA/V$^2$

W = 32 μm, L = 4 μm

λ = 0.02 V$^{-1}$, $\gamma^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V




Ahora sí pasamos al circuito de polarización:

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

$$I_G = 0$$

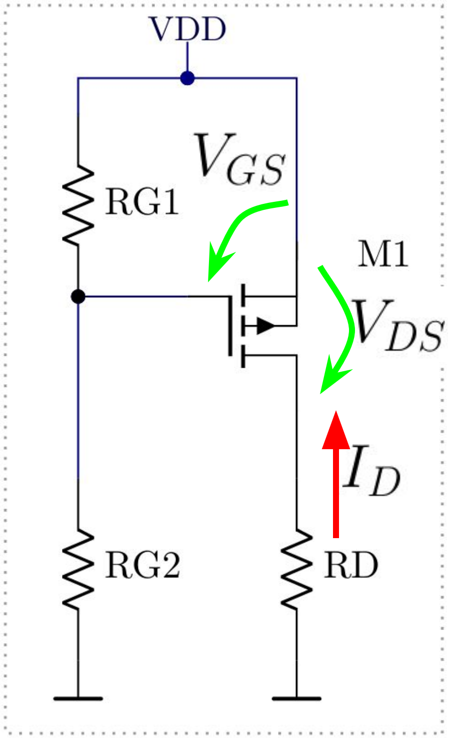
$$I_D = f(V_{GS}, V_{DS}, V_{BS})$$

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

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V$^2$

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




Ahora sí pasamos al circuito de polarización:

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

$$I_G = 0$$

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

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

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

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V$^2$

**Datos**

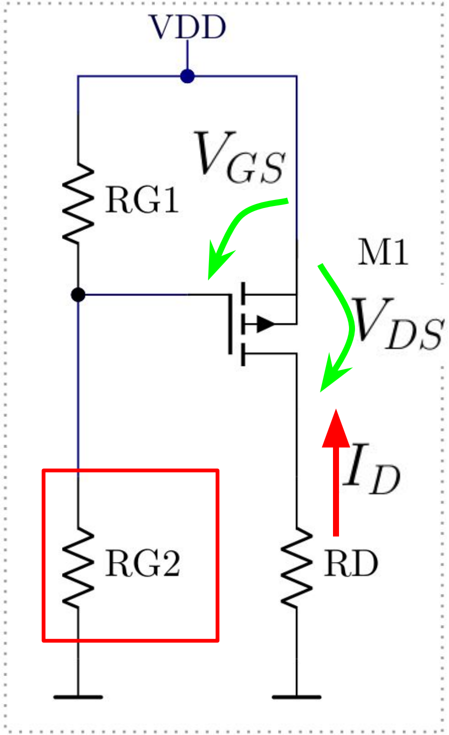
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 μA/V$^2$

W = 32 μm, L = 4 μm

λ = 0.02 V$^{-1}$, $\gamma^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V




Ahora sí pasamos al circuito de polarización:

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

$$I_G = 0$$

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

$$I_D = \begin{cases} 0 \\ -k(2( \ldots \\ -k(V \ldots \end{cases}$$

**Polarización: Debemos hallar "todas" las tensiones y corrientes de nuestro circuito: $V_{GS}$, $V_{DS}$ e $I_D$**

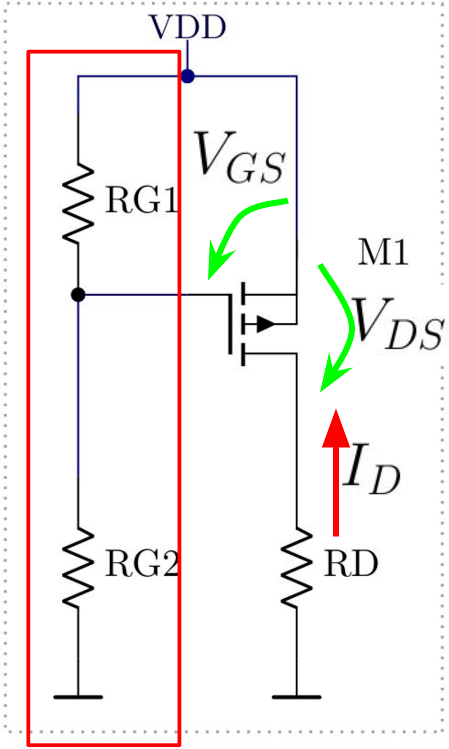
**y el régimen de operación del MOS**

# 1. Polarización

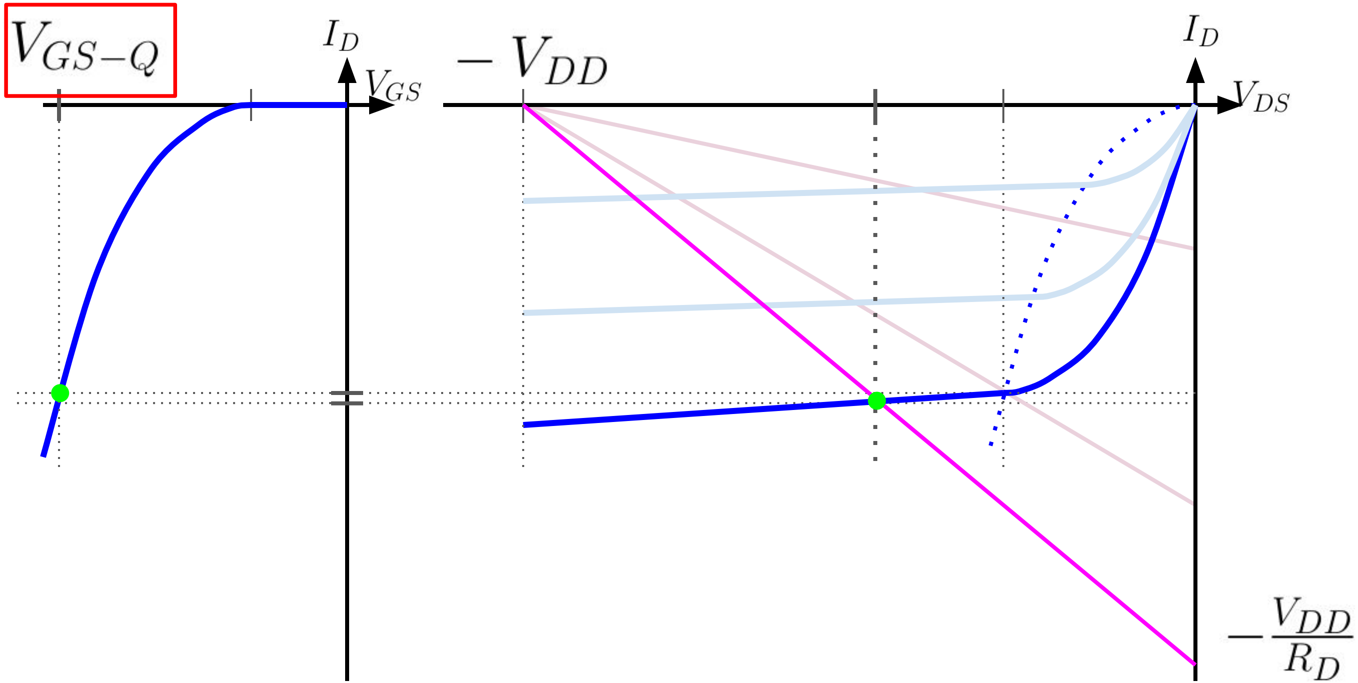
$V_T$ = -0.8 V, k = 320 μA/V²

Datos
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 μA/V²
W = 32 μm, L = 4 μm
λ = 0.02 $V^{-1}$, $\gamma^2$ = 0.5 V
$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ
$R_D$ = 18kΩ, $V_{DD}$ = 5 V

Mirando las curvas características del transistor:




**Transferencia** **Salida**



# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/$V^2$

<u>Datos</u>

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

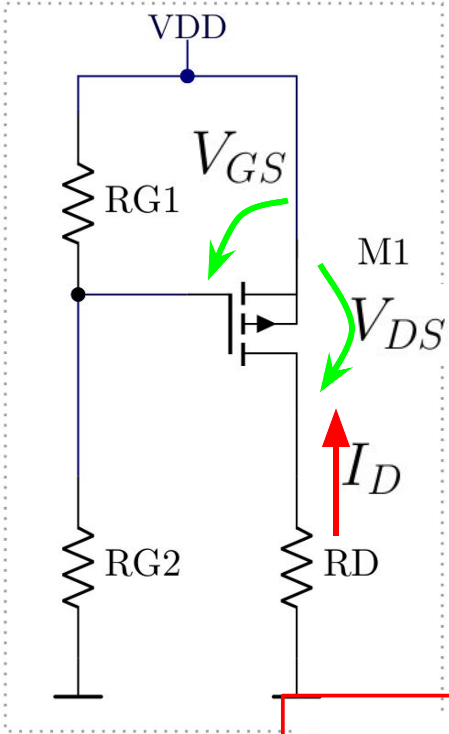
W = 32 μm, L = 4 μm

λ = 0.02 $V^{-1}$, $\gamma^2$ = 0.5 V

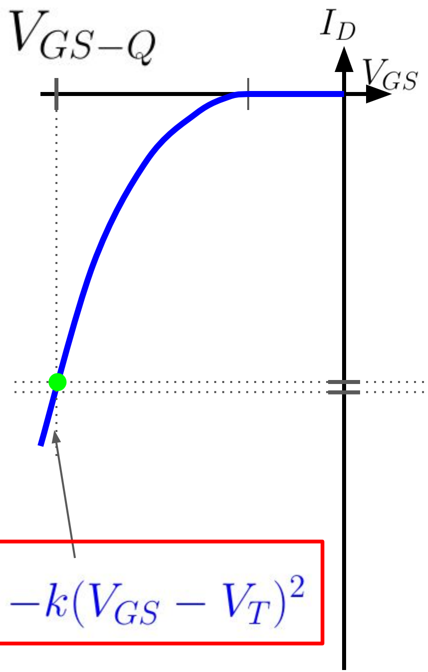
$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V

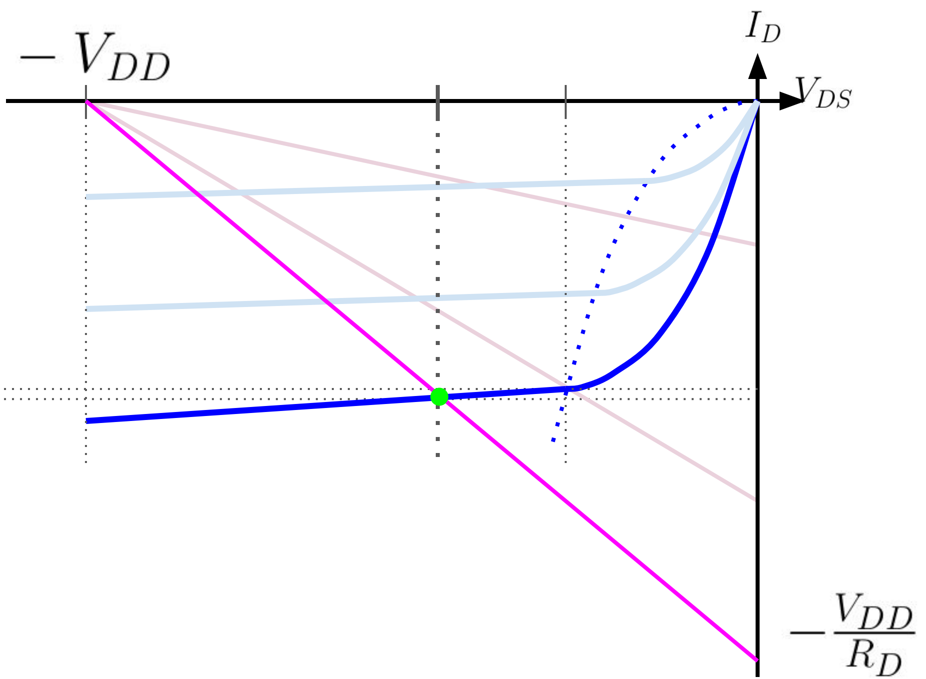
Mirando las curvas características del transistor:




**Transferencia**




**Salida**



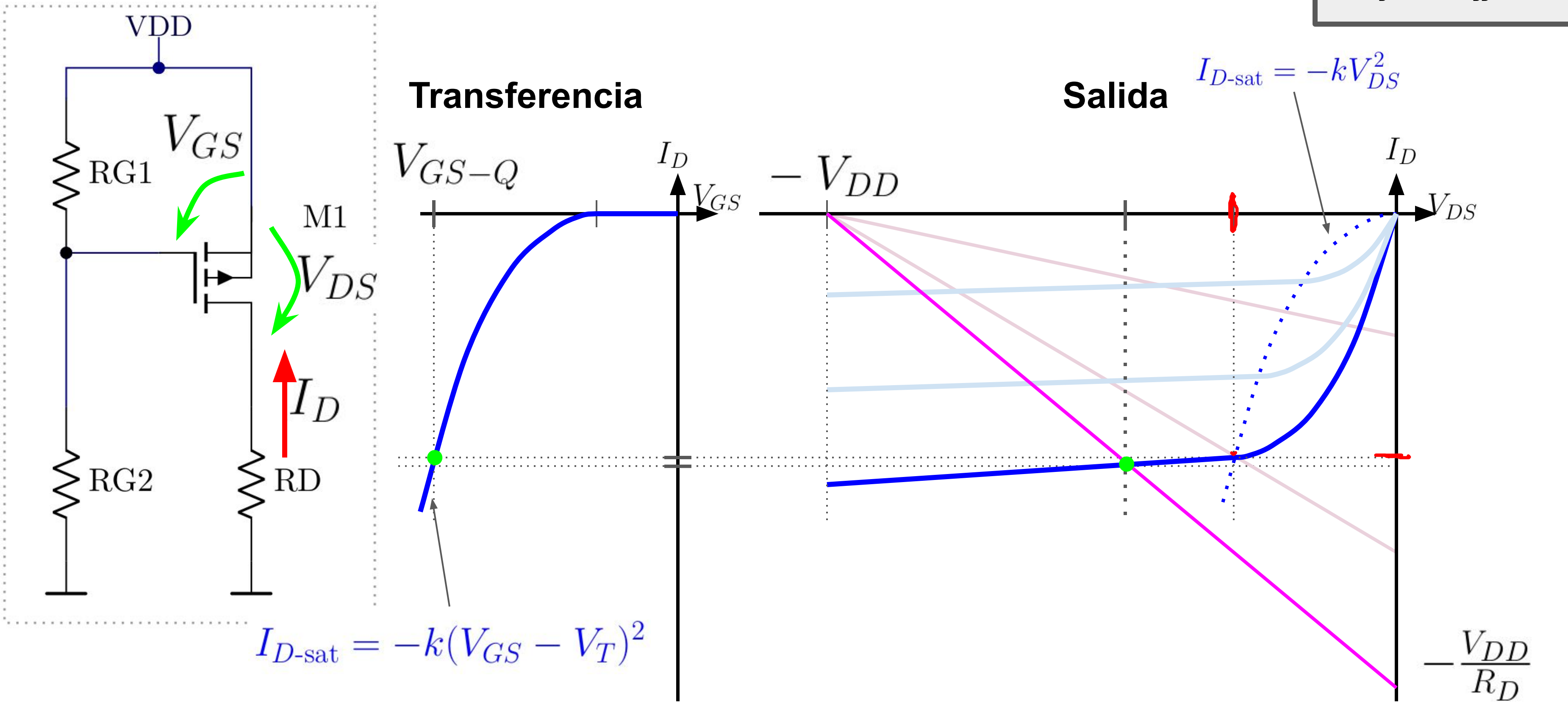

$$I_{D\text{-sat}} = -k(V_{GS} - V_T)^2$$

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V$^2$

<u>Datos</u>
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 μA/V$^2$
W = 32 μm, L = 4 μm
λ = 0.02 V$^{-1}$, γ$^2$ = 0.5 V
$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ
$R_D$ = 18kΩ, $V_{DD}$ = 5 V

Mirando las curvas características del transistor:



# 1. Polarización

$V_T = -0.8$ V, $k = 320$ μA/V$^2$

**Datos**

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

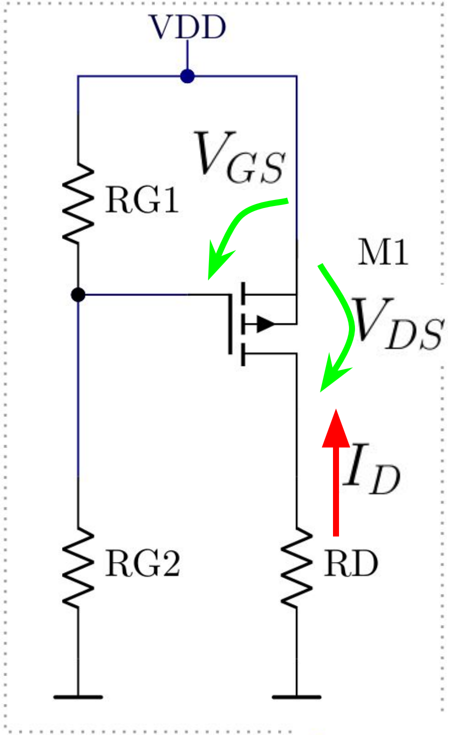
$W = 32$ μm, $L = 4$ μm

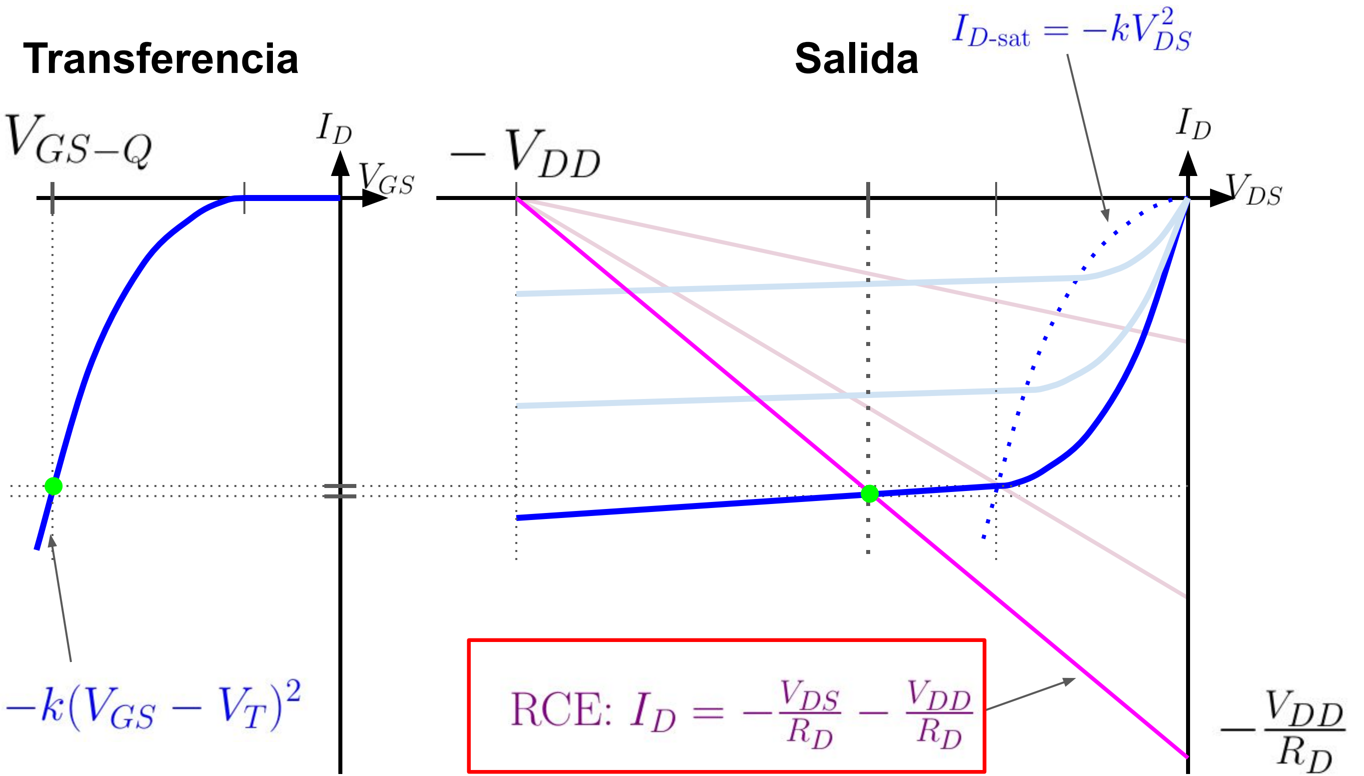
$\lambda = 0.02$ V$^{-1}$, $\gamma^2 = 0.5$ V

$R_{G1} = 130$ kΩ, $R_{G2} = 370$ kΩ

$R_D = 18$kΩ, $V_{DD} = 5$ V

Mirando las curvas características del transistor:



# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V$^2$

**Datos**

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

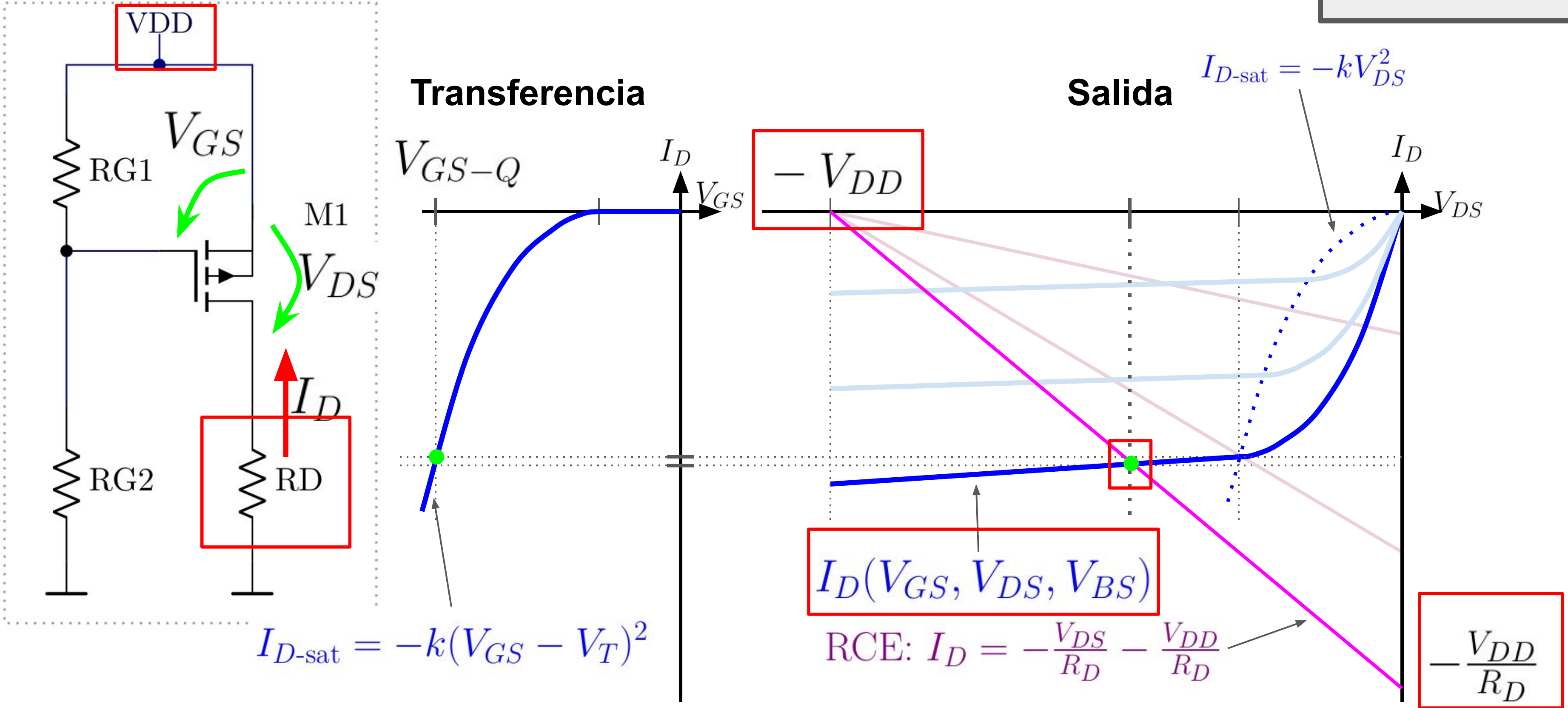
W = 32 μm, L = 4 μm

λ = 0.02 V$^{-1}$, $\gamma^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V

Mirando las curvas características del transistor:



# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/$V^2$

<u>Datos</u>

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

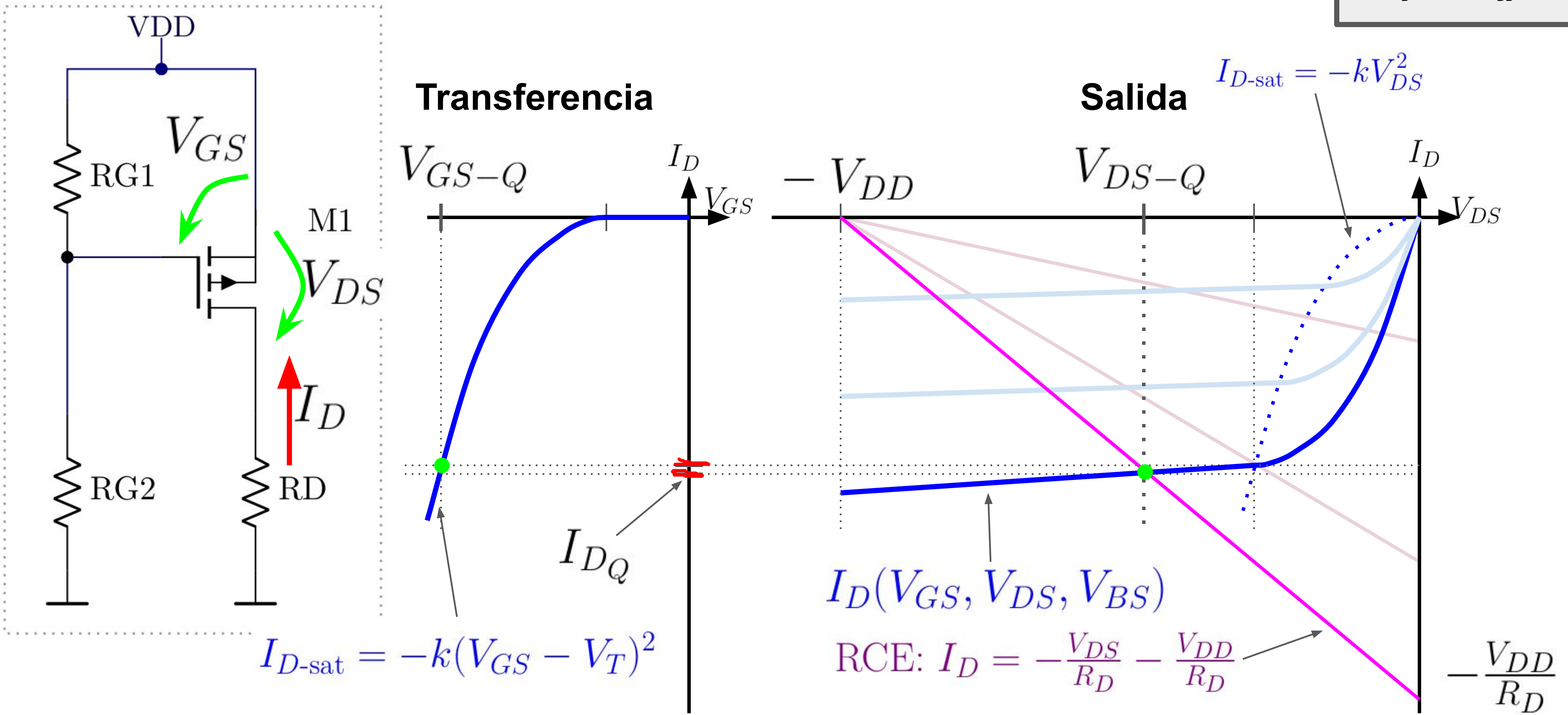
W = 32 μm, L = 4 μm

λ = 0.02 $V^{-1}$, $\gamma^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V

Mirando las curvas características del transistor:



# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/$V^2$

Datos

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

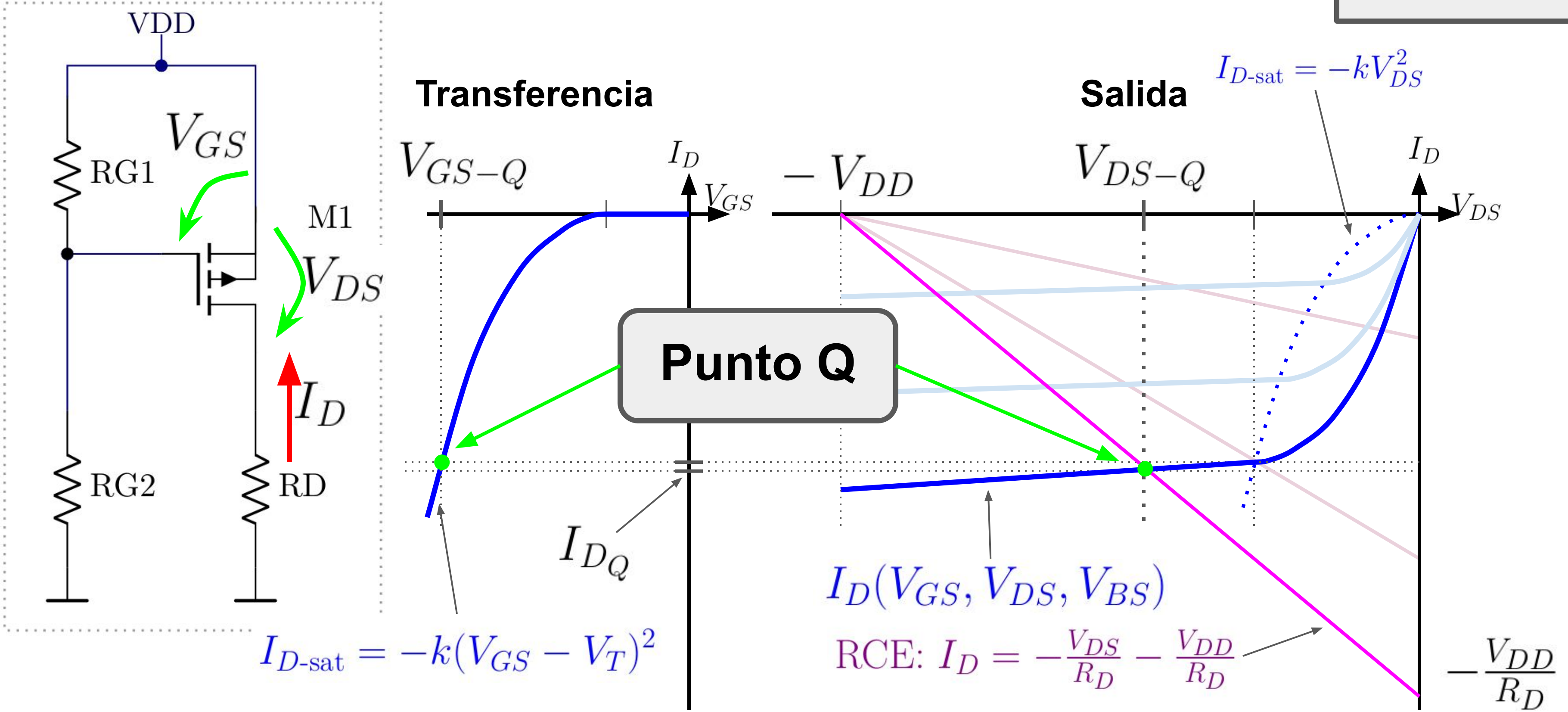
W = 32 μm, L = 4 μm

λ = 0.02 $V^{-1}$, $\gamma^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V

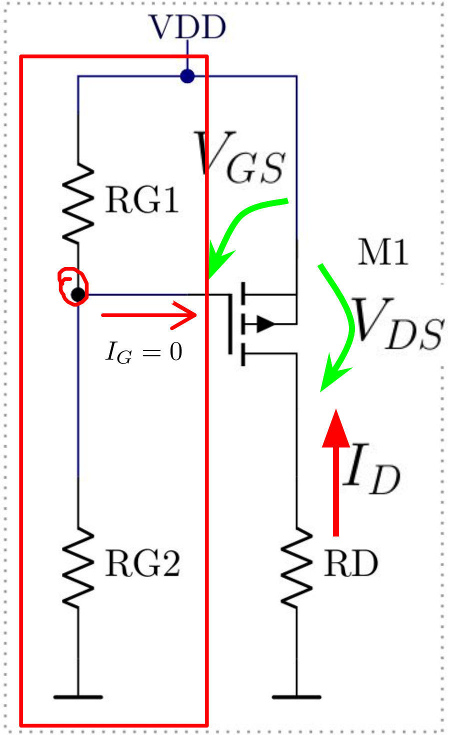
Mirando las curvas características del transistor:



# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/$V^2$

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




Hallamos $V_{GS}$:

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/$V^2$

Datos

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

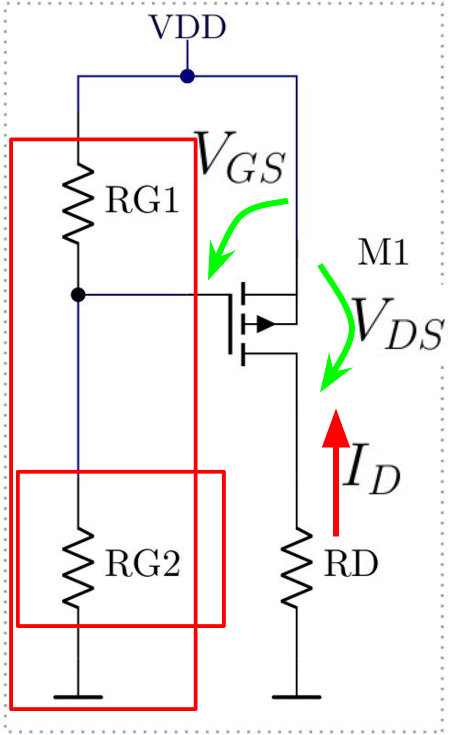
W = 32 μm, L = 4 μm

λ = 0.02 $V^{-1}$, $\gamma^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V

Hallamos $V_{GS}$:




- Empezamos por $V_G$:

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

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V$^2$

**Datos**

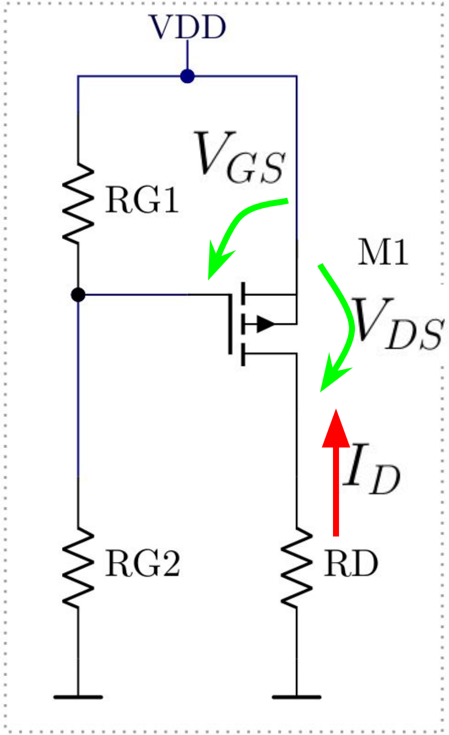
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 μA/V$^2$

W = 32 μm, L = 4 μm

λ = 0.02 V$^{-1}$, γ$^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V




Hallamos $V_{GS}$:

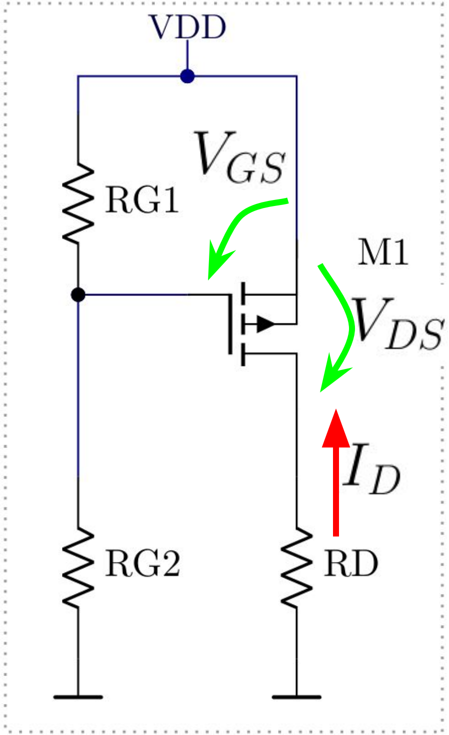
- Empezamos por $V_G$:

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

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V²

Datos
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 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




Hallamos $V_{GS}$:

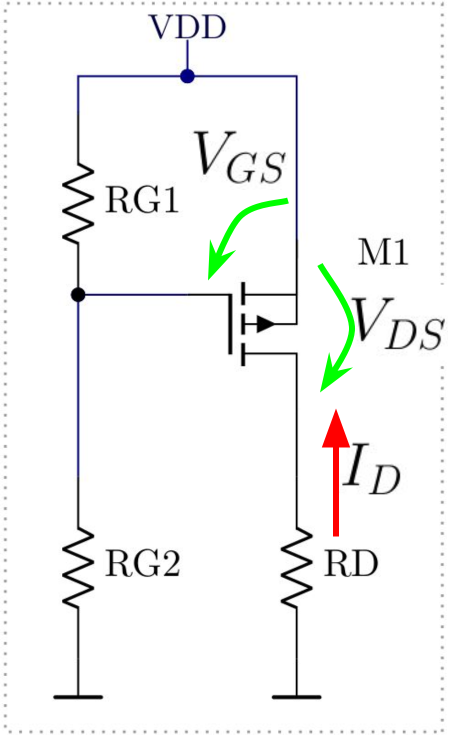
- Empezamos por $V_G$:

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

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/$V^2$

<u>Datos</u>
$|V_T|$ = 0.8 V, $\mu_p C'_{ox}$ = 80 μA/$V^2$
W = 32 μm, L = 4 μm
λ = 0.02 $V^{-1}$, $\gamma^2$ = 0.5 V
$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ
$R_D$ = 18kΩ, $V_{DD}$ = 5 V




Hallamos $V_{GS}$:

- Empezamos por $V_G$:

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

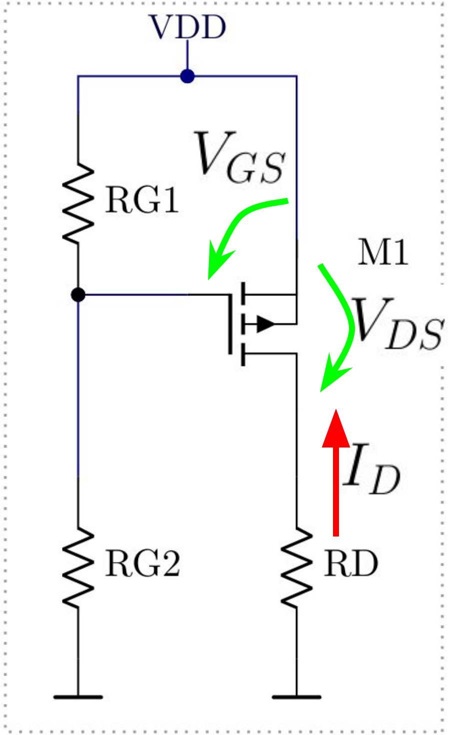
- Luego $V_{GS}$:

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

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V²

**Datos**
$|V_T|$ = 0.8 V, $\mu_p C'_{ox}$ = 80 μA/V²
W = 32 μm, L = 4 μm
λ = 0.02 $V^{-1}$, $\gamma^2$ = 0.5 V
$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ
$R_D$ = 18kΩ, $V_{DD}$ = 5 V




Hallamos $V_{GS}$:

- Empezamos por $V_G$:

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

- Luego $V_{GS}$:

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

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/$V^2$

Datos

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

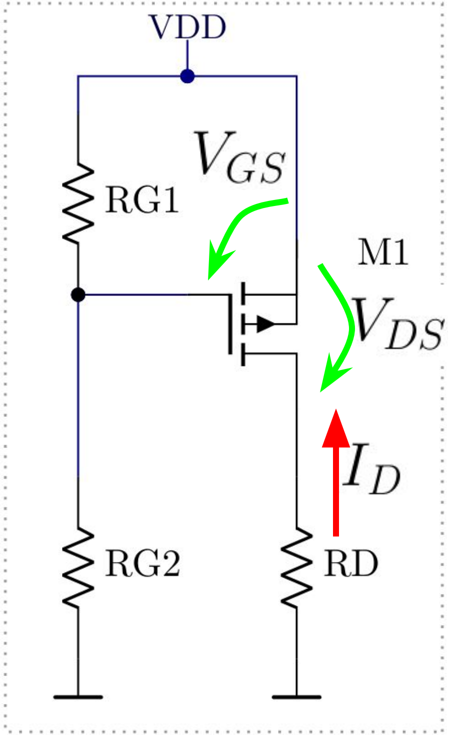
W = 32 μm, L = 4 μm

λ = 0.02 $V^{-1}$, $\gamma^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V

Hallamos $V_{DS}$ e $I_D$:



# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/$V^2$

Datos

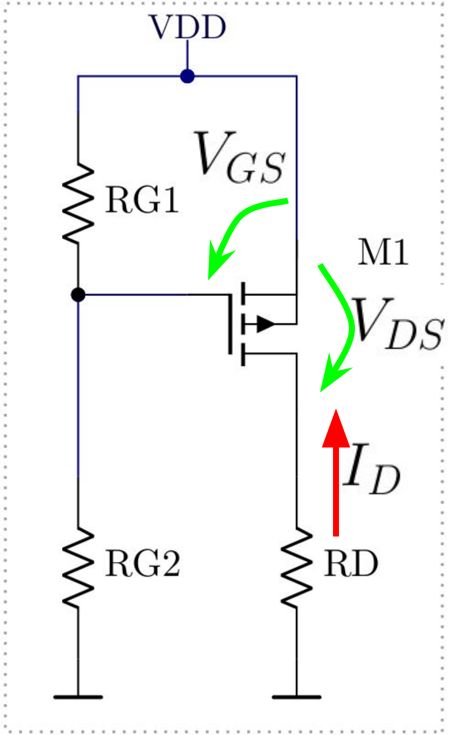
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 μA/$V^2$

W = 32 μm, L = 4 μm

λ = 0.02 $V^{-1}$, $\gamma^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V



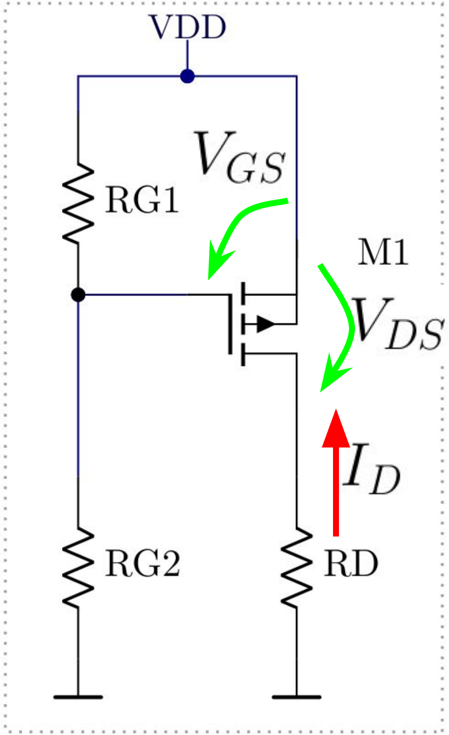

Hallamos $V_{DS}$ e $I_D$:

- Supongo SATURACIÓN entonces:

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V²

Datos
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 μA/V²
W = 32 μm, L = 4 μm
λ = 0.02 $V^{-1}$, $\gamma^2$ = 0.5 V
$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ
$R_D$ = 18kΩ, $V_{DD}$ = 5 V




Hallamos $V_{DS}$ e $I_D$:

- Supongo SATURACIÓN entonces:

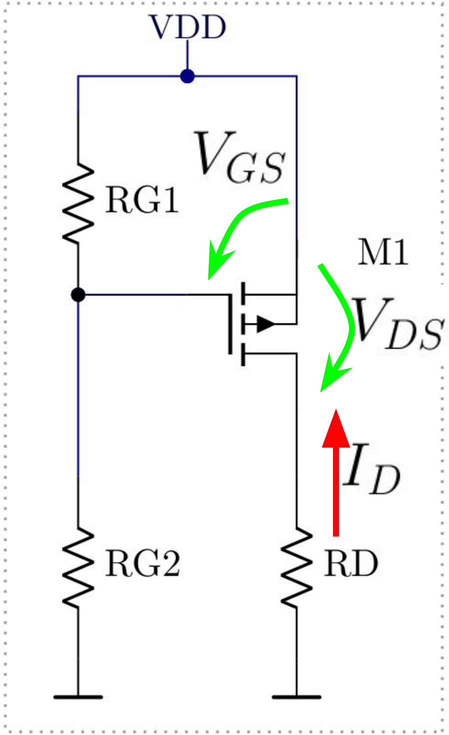
$$I_{D\text{-sat}} = -k(V_{GS} - V_T)^2$$

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

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/$V^2$

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




Hallamos $V_{DS}$ e $I_D$:

- Supongo SATURACIÓN entonces:

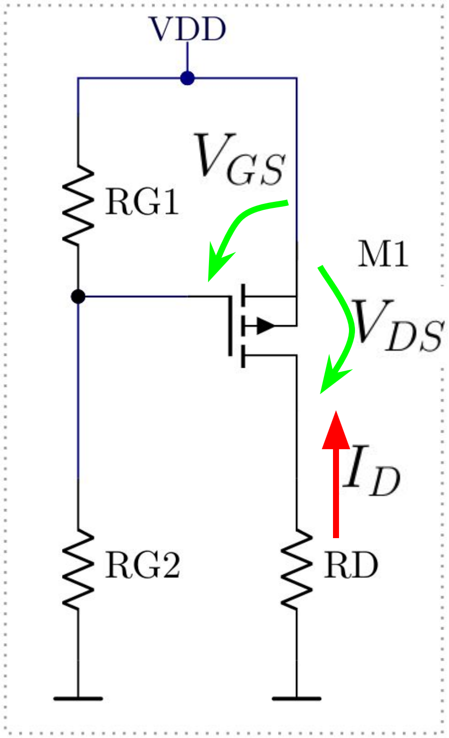
$$I_{D\text{-sat}} = -k(V_{GS} - V_T)^2$$
$$= -320\frac{\mu A}{\mathrm{V}^2}(0.5\,\mathrm{V})^2 = -80\mu A$$

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

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V$^2$

<u>Datos</u>
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 μA/V$^2$
W = 32 μm, L = 4 μm
λ = 0.02 V$^{-1}$, γ$^2$ = 0.5 V
$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ
$R_D$ = 18kΩ, $V_{DD}$ = 5 V




Hallamos $V_{DS}$ e $I_D$:

- Supongo SATURACIÓN entonces:

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

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

# 1. Polarización

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

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

**Datos**

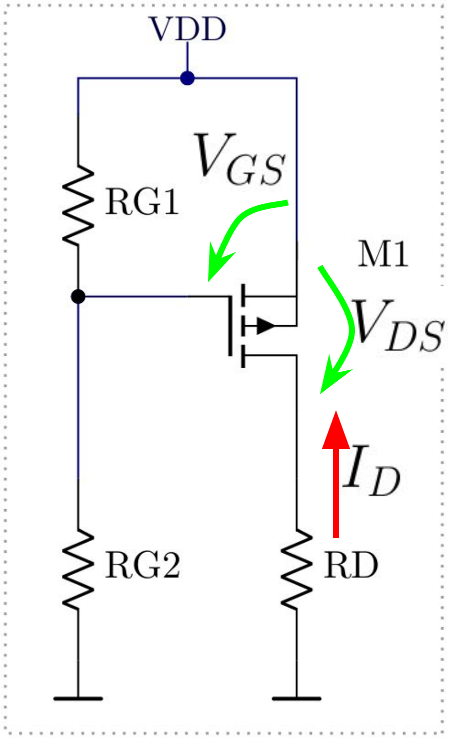
$|V_T| = 0.8\ V$, $\mu_p C'_{ox} = 80\ \mu A/V^2$

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

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

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

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



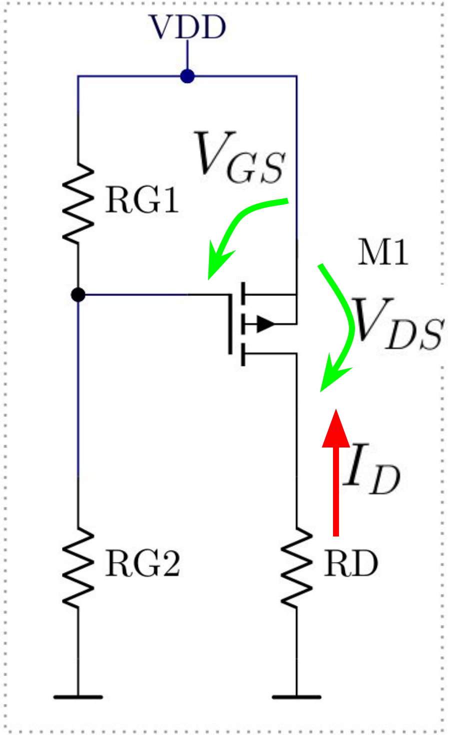

Hallamos $V_{DS}$ e $I_D$:

- Supongo SATURACIÓN entonces:

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

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

# 1. Polarización




$V_T$ = -0.8 V, k = 320 µA/V²
$I_{Dsat}$ = -80 µA, $V_{DS\text{-}sat}$ = 0.5V

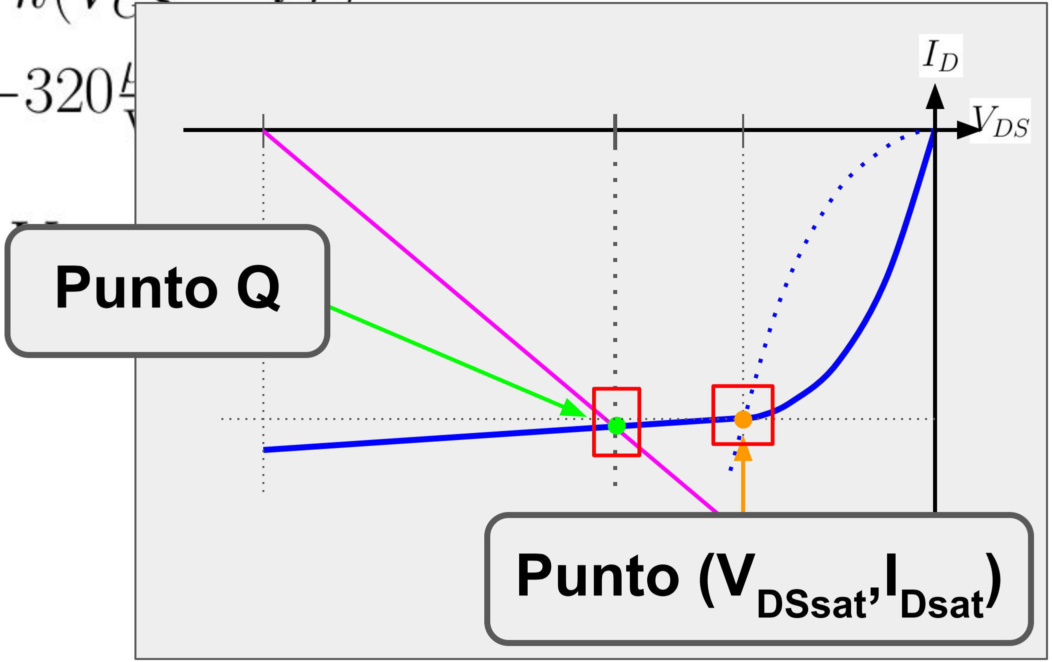
**Datos**
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 µA/V²
W = 32 µm, L = 4 µm
$\lambda$ = 0.02 $V^{-1}$, $\gamma^2$ = 0.5 V
$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ
$R_D$ = 18kΩ, $V_{DD}$ = 5 V

Hallamos $V_{DS}$ e $I_D$:

- Supongo SATURACIÓN entonces:

$$I_{D\text{-sat}} = -k(V_{GS} - V_T)^2$$
$$= -320$$

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



# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V$^2$

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

Datos

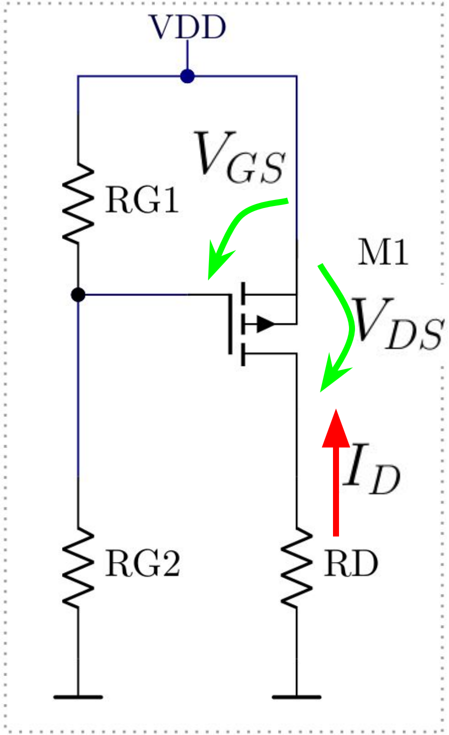
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 μA/V$^2$

W = 32 μm, L = 4 μm

λ = 0.02 V$^{-1}$, γ$^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V




Hallamos $V_{DS}$ e $I_D$:

- Supongo SATURACIÓN entonces:

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

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

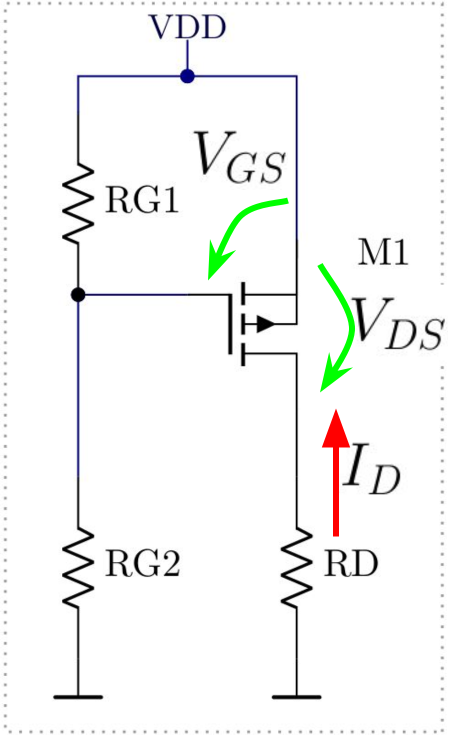
$$\begin{cases} I_D = I_{D\text{-sat}}\left[1 - \lambda(V_{DS} - V_{DS\text{-sat}})\right] \\ -I_D R_D - V_{DS} = V_{DD} \end{cases}$$

# 1. Polarización

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

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

Resolvemos nuestro problema:




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

- Por simulación
- Despejando
- Iterando

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V²

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

<u>Datos</u>

$|V_T|$ = 0.8 V, $\mu_p C'_{ox}$ = 80 μA/V²

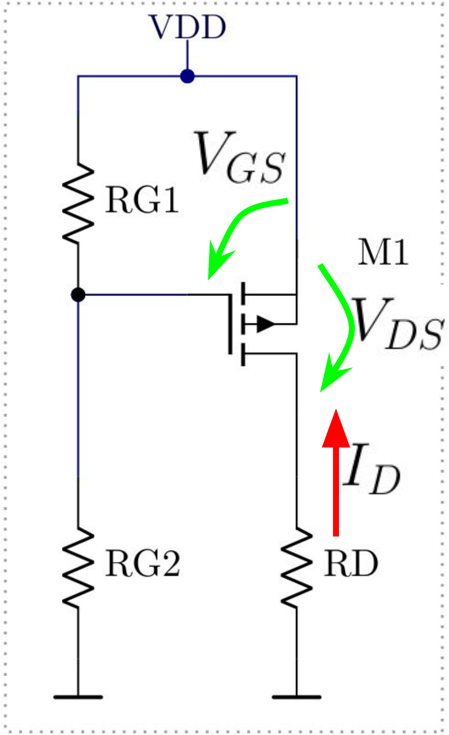
W = 32 μm, L = 4 μm

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

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

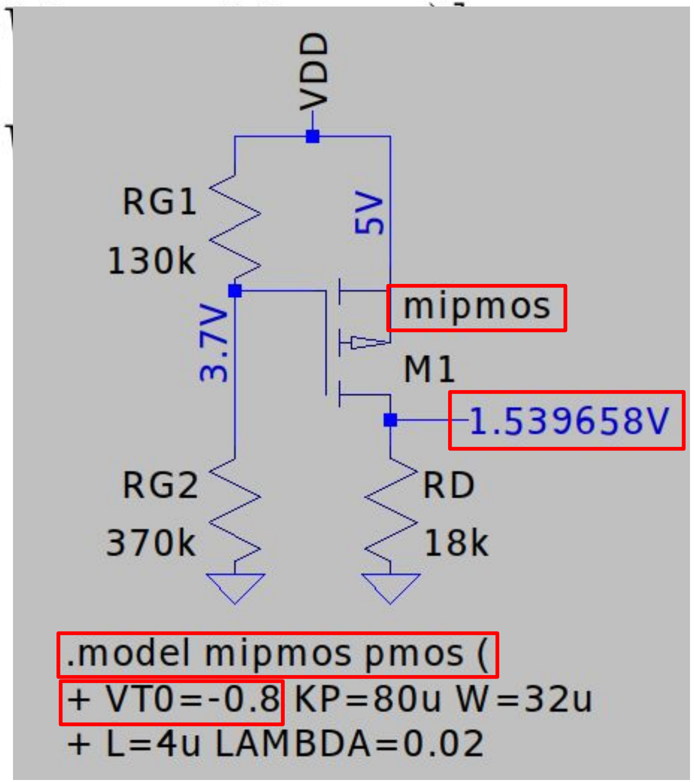
$R_D$ = 18kΩ, $V_{DD}$ = 5 V

Resolvemos nuestro problema:




$$\begin{cases} I_D = I_{D\text{-sat}}\left[1 - \lambda(\ldots\right. \\ -I_D R_D - V_{DS} = \ldots \end{cases}$$

- **Por simulación**
- Despejando
- Iterando

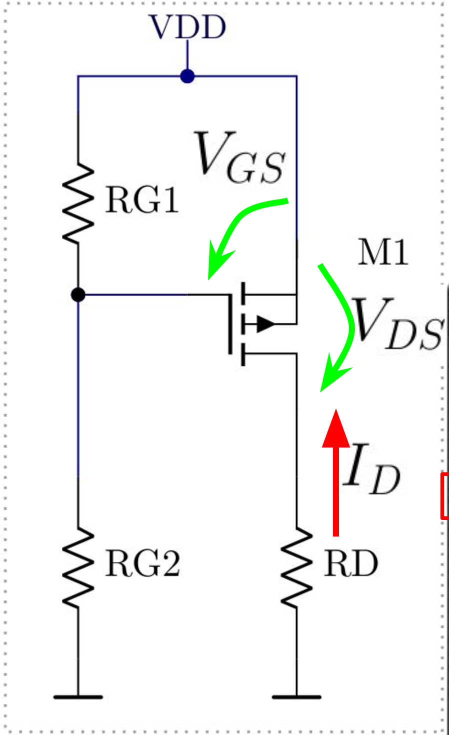


# 1. Polarización

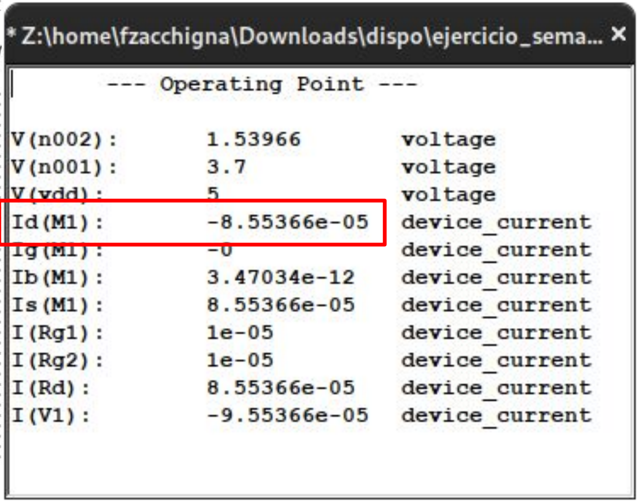
$V_T$ = -0.8 V, k = 320 μA/V$^2$
$I_{Dsat}$ = -80 μA, $V_{DS\text{-}sat}$ = 0.5V

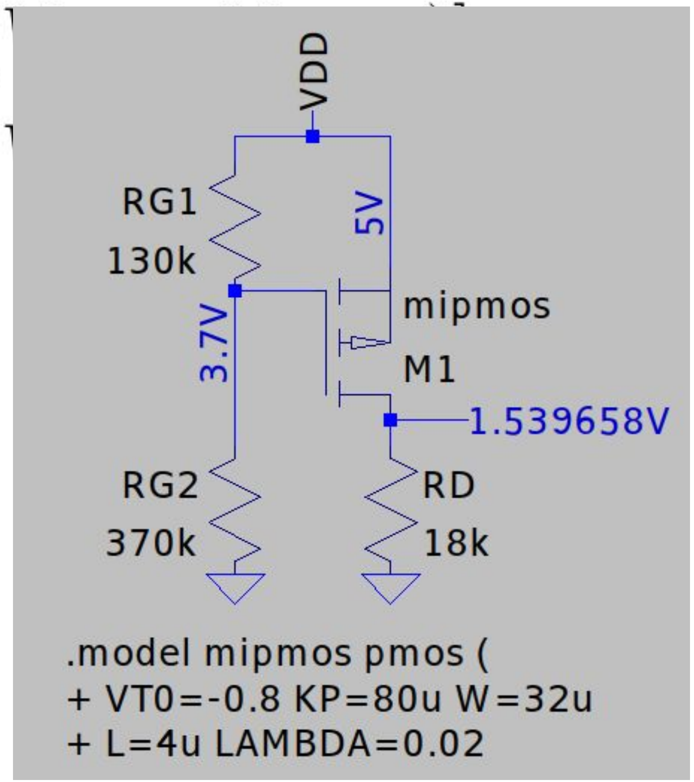
<u>Datos</u>
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 μA/V$^2$
W = 32 μm, L = 4 μm
λ = 0.02 V$^{-1}$, γ$^2$ = 0.5 V
$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ
$R_D$ = 18kΩ, $V_{DD}$ = 5 V

Resolvemos nuestro problema:




$$\begin{cases} I_D = I_{D\text{-sat}}\left[1 - \lambda( \right. \\ -I_D R_D - V_{DS} = \end{cases}$$



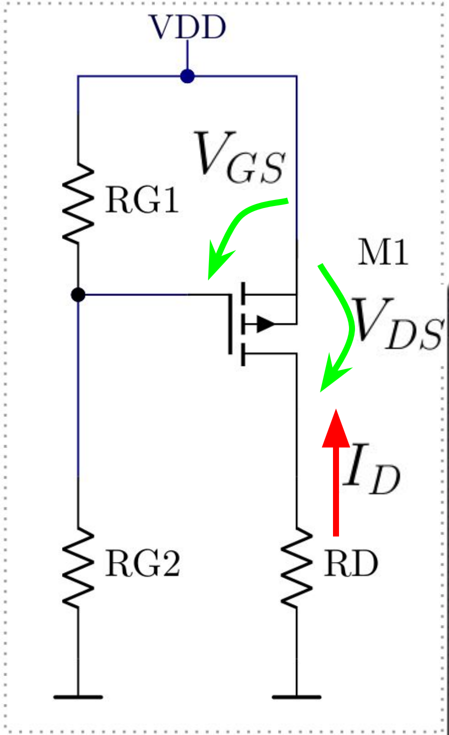



# 1. Polarización

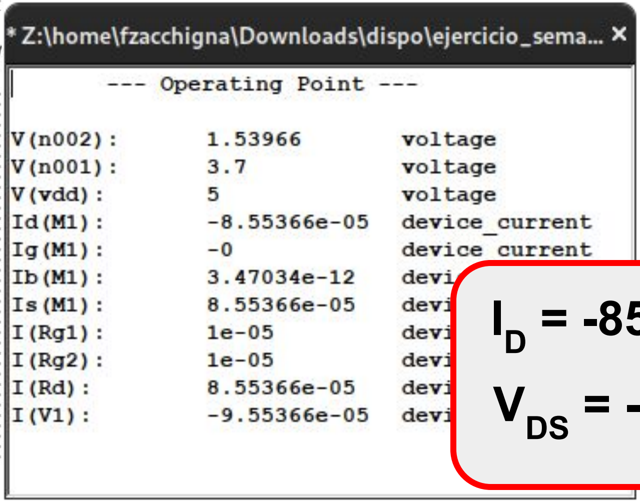
$V_T$ = -0.8 V, k = 320 µA/V$^2$
$I_{Dsat}$ = -80 µA, $V_{DS\text{-}sat}$ = 0.5V

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

Resolvemos nuestro problema:

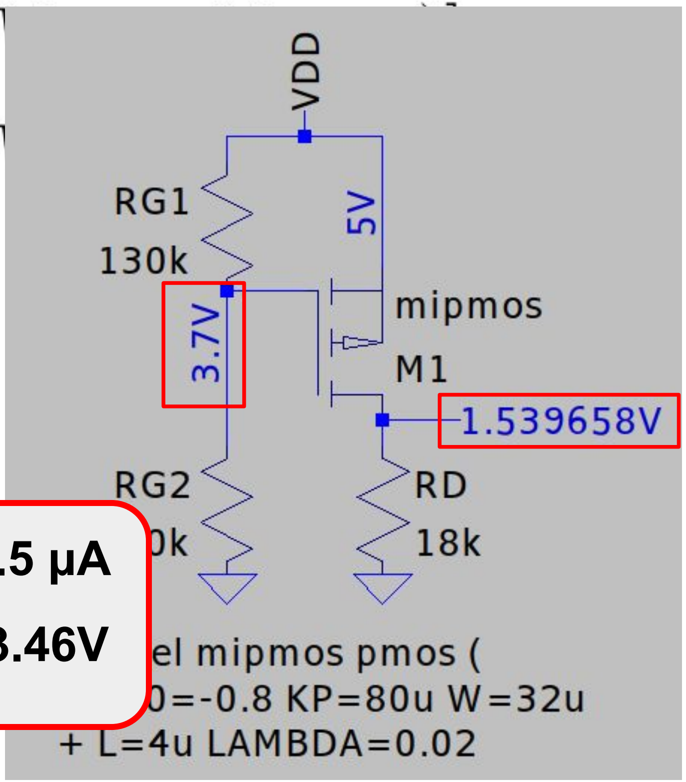



$$\begin{cases} I_D = I_{D\text{-sat}}\left[1 - \lambda( \right. \\ -I_D R_D - V_{DS} = \end{cases}$$


* Z:\home\fzacchigna\Downloads\dispo\ejercicio_sema...

--- Operating Point ---

| | | |
|---|---|---|
| V(n002): | 1.53966 | voltage |
| V(n001): | 3.7 | voltage |
| V(vdd): | 5 | voltage |
| Id(M1): | -8.55366e-05 | device_current |
| Ig(M1): | -0 | device_current |
| Ib(M1): | 3.47034e-12 | devi |
| Is(M1): | 8.55366e-05 | devi |
| I(Rg1): | 1e-05 | devi |
| I(Rg2): | 1e-05 | devi |
| I(Rd): | 8.55366e-05 | devi |
| I(V1): | -9.55366e-05 | devi |




**$I_D$ = -85.5 µA**

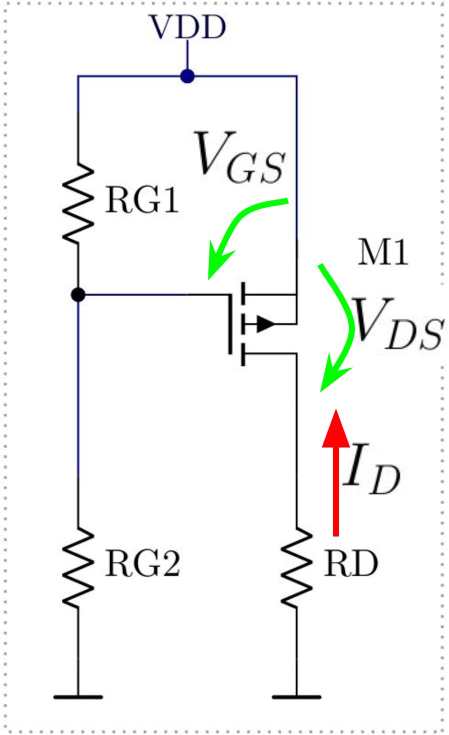
**$V_{DS}$ = -3.46V**

# 1. Polarización

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

<u>Datos</u>
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 μA/V$^2$
W = 32 μm, L = 4 μm
λ = 0.02 V$^{-1}$, γ$^2$ = 0.5 V
$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ
$R_D$ = 18kΩ, $V_{DD}$ = 5 V

Resolvemos nuestro problema:




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

- Por simulación
- **Despejando**
- Iterando

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

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/$V^2$

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

<u>Datos</u>

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

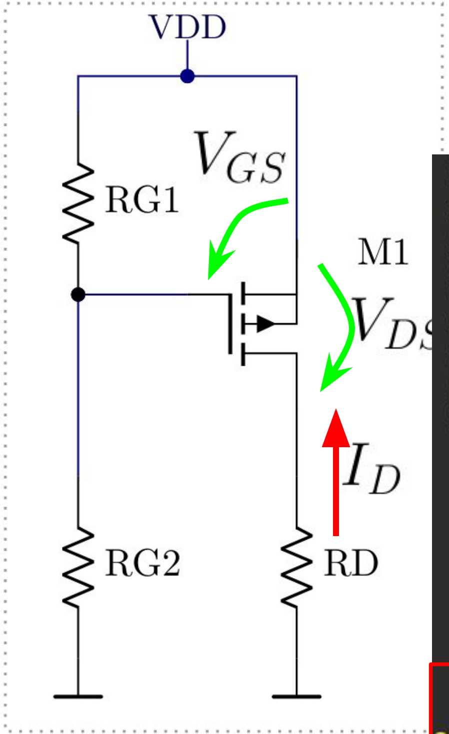
W = 32 μm, L = 4 μm

λ = 0.02 $V^{-1}$, $\gamma^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V

Resolvemos nuestro problema:




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

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

```
mupcox = 80e-6;
W = 32;
L = 4;

vdd = 5
rd = 18e3
lambda = 0.02
vt = -0.8;
vgs = -1.3;

k = mupcox/2*W/L

idsat = -k*(vgs-vt)^2
vdssat = vgs-vt


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

```
vds = -3.4743
id = -0.000084759
```

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/$V^2$

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

<u>Datos</u>

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

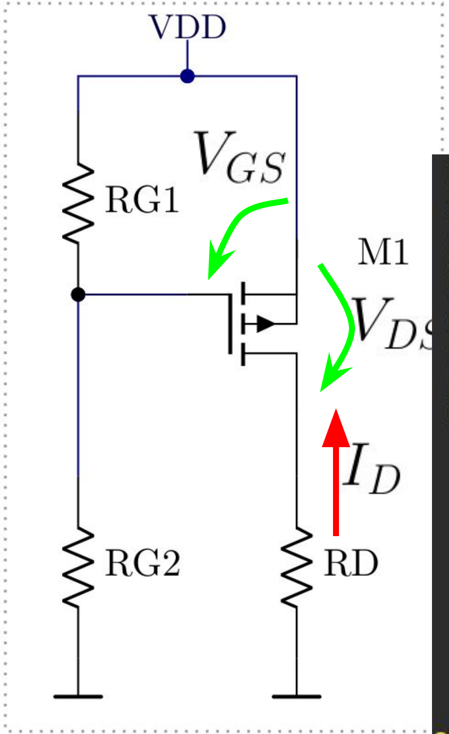
W = 32 μm, L = 4 μm

λ = 0.02 $V^{-1}$, $\gamma^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V

Resolvemos nuestro problema:




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

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

```
mupcox = 80e-6;
W = 32;
L = 4;

vdd = 5
rd = 18e3
lambda = 0.02
vt = -0.8;
vgs = -1.3;

k = mupcox/2*W/L

idsat = -k*(vgs-vt)^2
vdssat = vgs-vt


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

```
vds = -3.4743
id = -0.000084759
```

# 1. Polarización

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

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

<u>Datos</u>

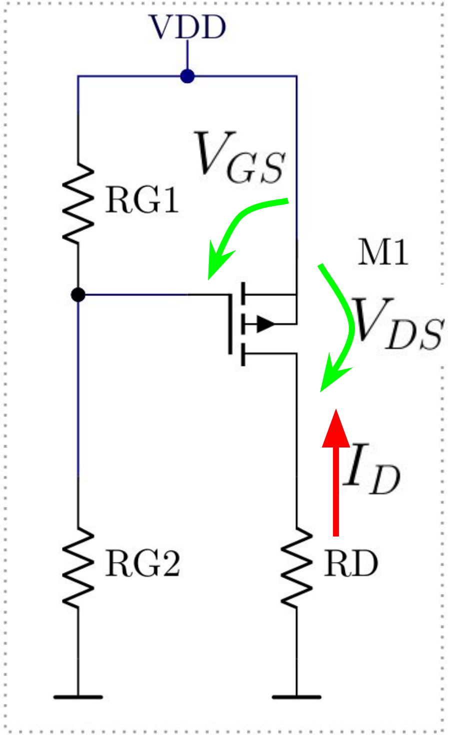
$|V_T| = 0.8$ V, $\mu_P C'_{ox} = 80\ \mu A/V^2$

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

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

$R_{G1} = 130$ kΩ, $R_{G2} = 370$ kΩ

$R_D = 18$kΩ, $V_{DD} = 5$ V




Resolvemos nuestro problema:

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

- Por simulación
- Despejando
- **Iterando**

# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V$^2$

**Datos**

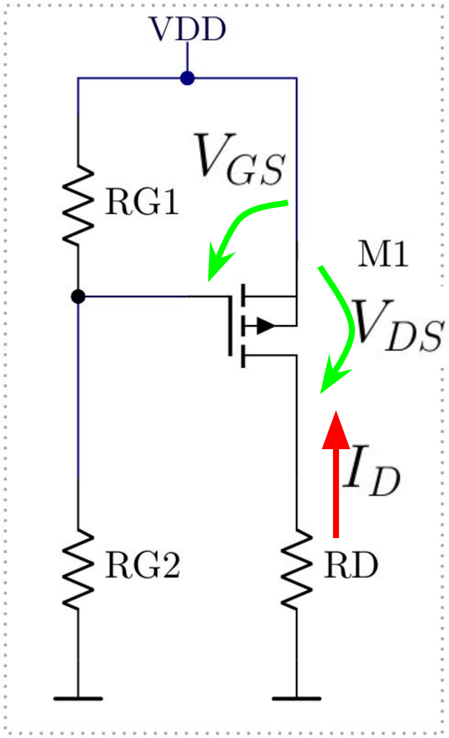
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 μA/V$^2$

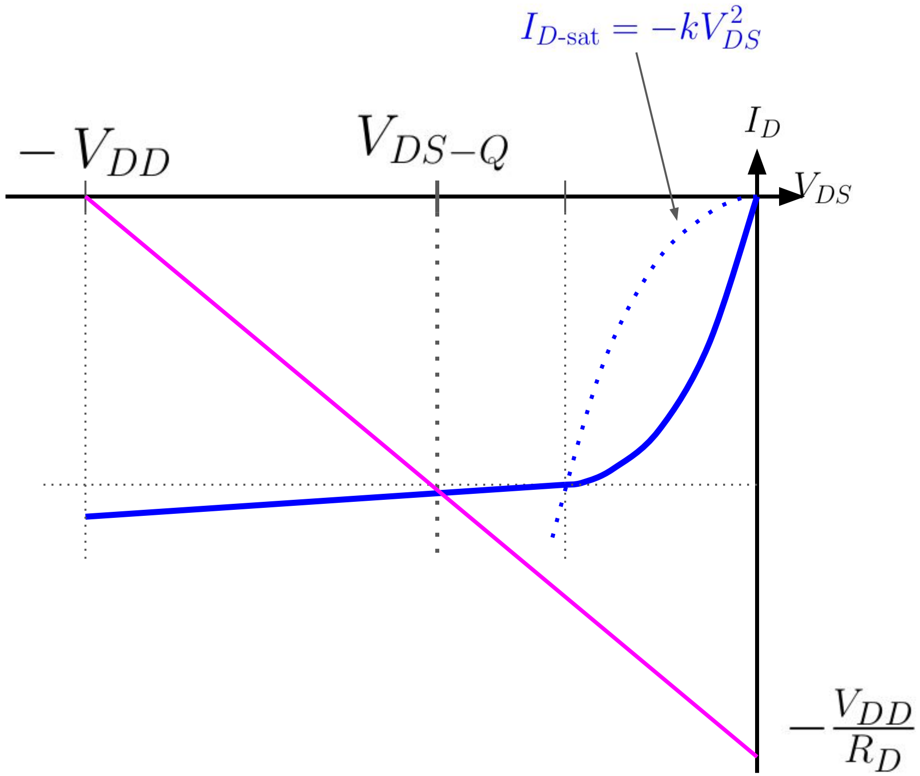
W = 32 μm, L = 4 μm

λ = 0.02 V$^{-1}$, $\gamma^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V



# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V$^2$

Datos

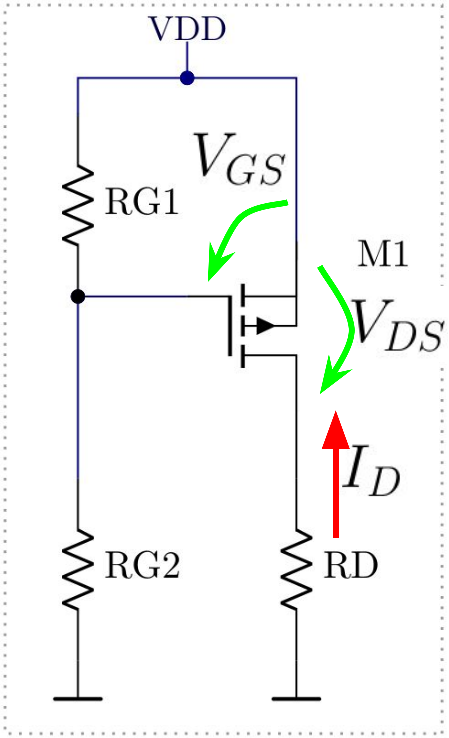
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 μA/V$^2$

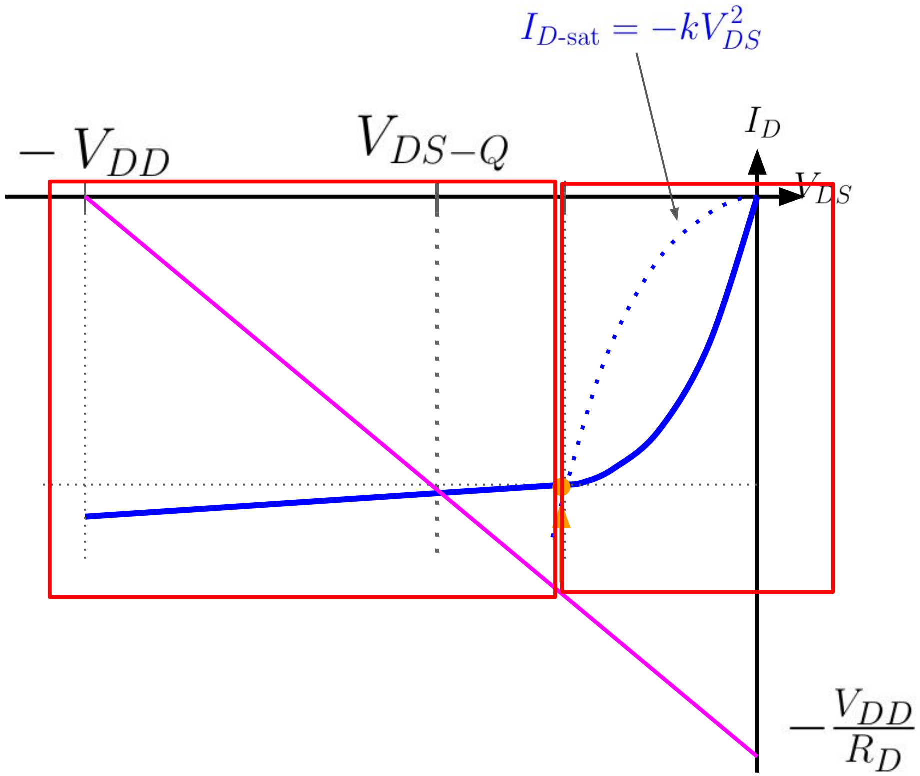
W = 32 μm, L = 4 μm

λ = 0.02 V$^{-1}$, γ$^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V



# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V$^2$

Datos

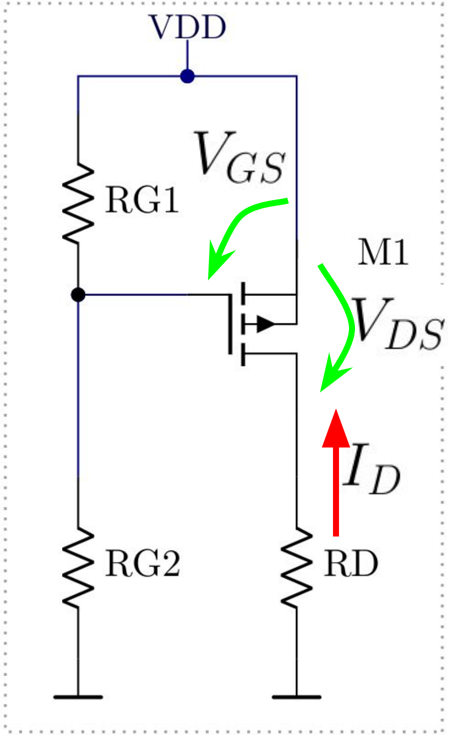
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 μA/V$^2$

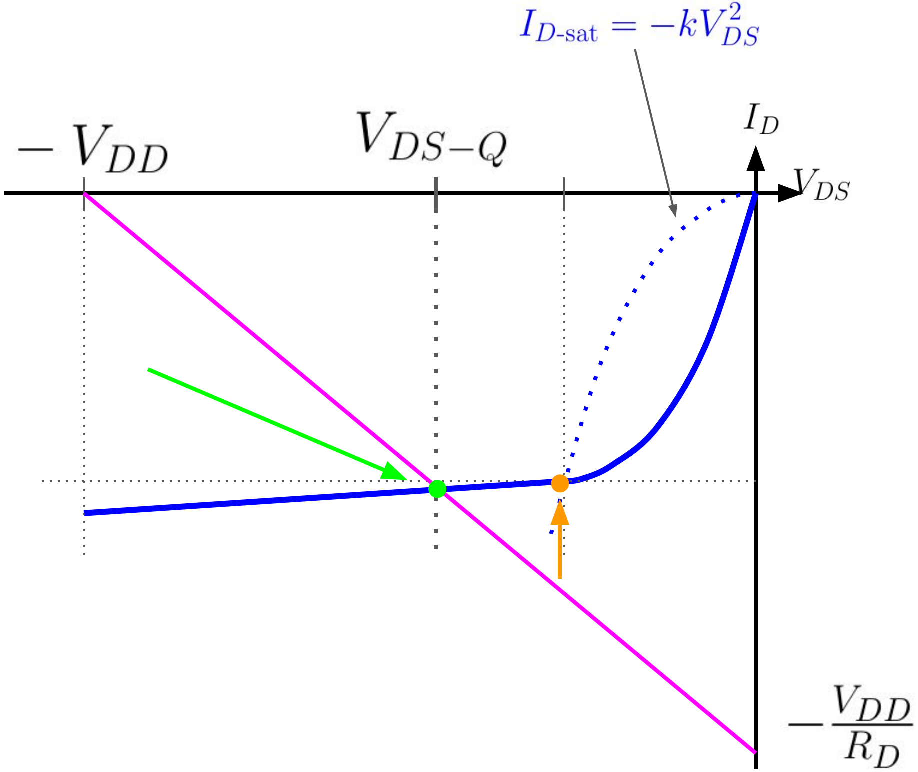
W = 32 μm, L = 4 μm

λ = 0.02 V$^{-1}$, $\gamma^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V



# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/$V^2$

Datos

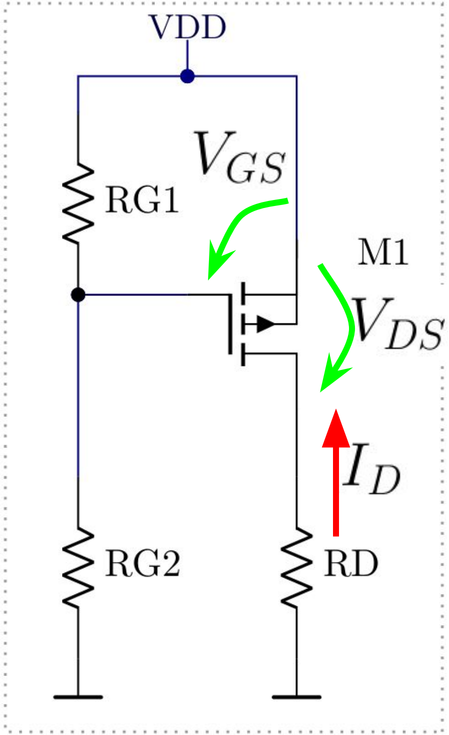
$|V_T|$ = 0.8 V, $\mu_p C'_{ox}$ = 80 μA/$V^2$

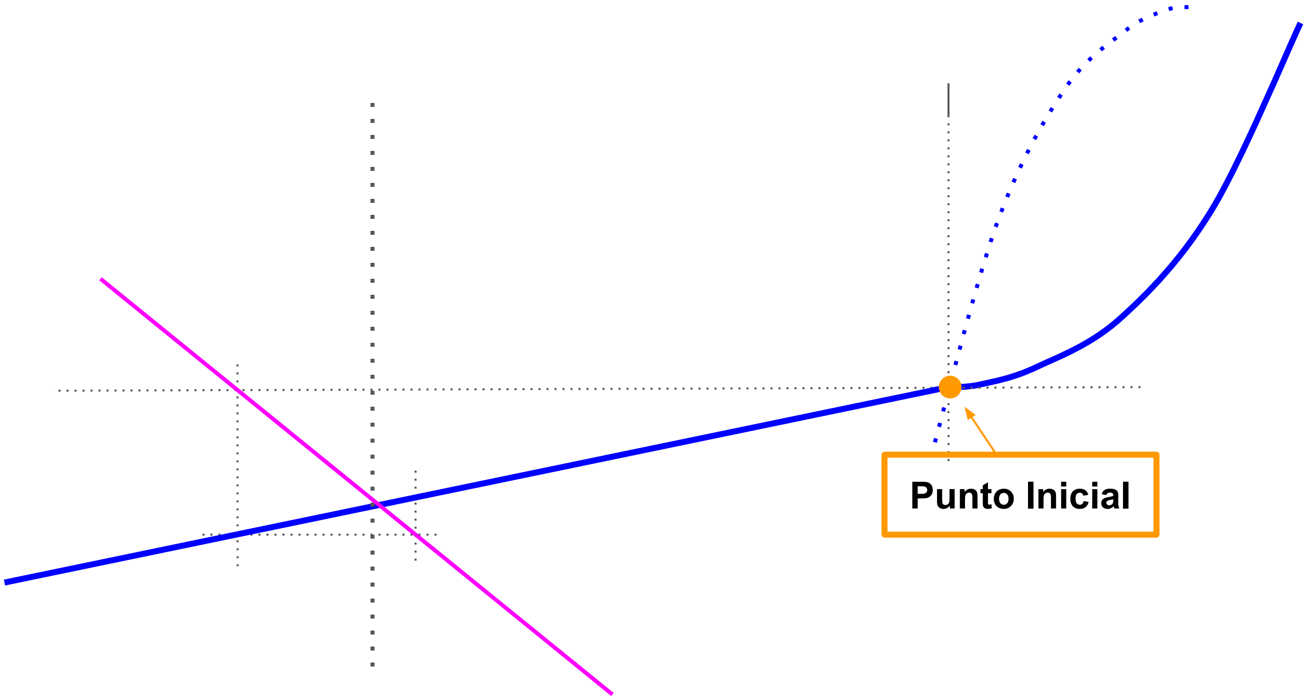
W = 32 μm, L = 4 μm

λ = 0.02 $V^{-1}$, $\gamma^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V

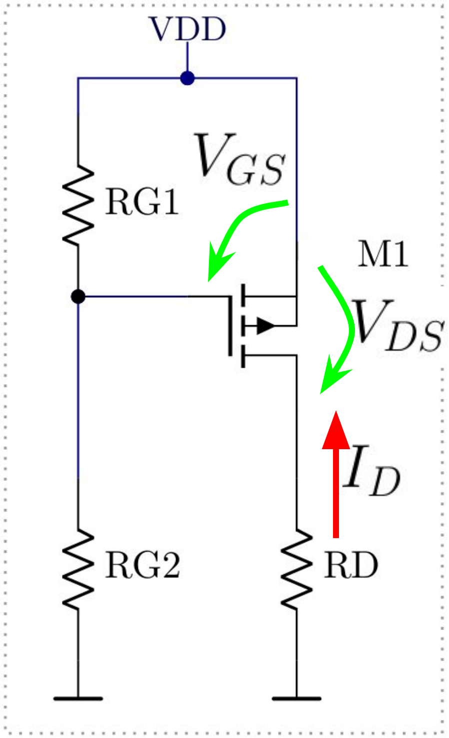


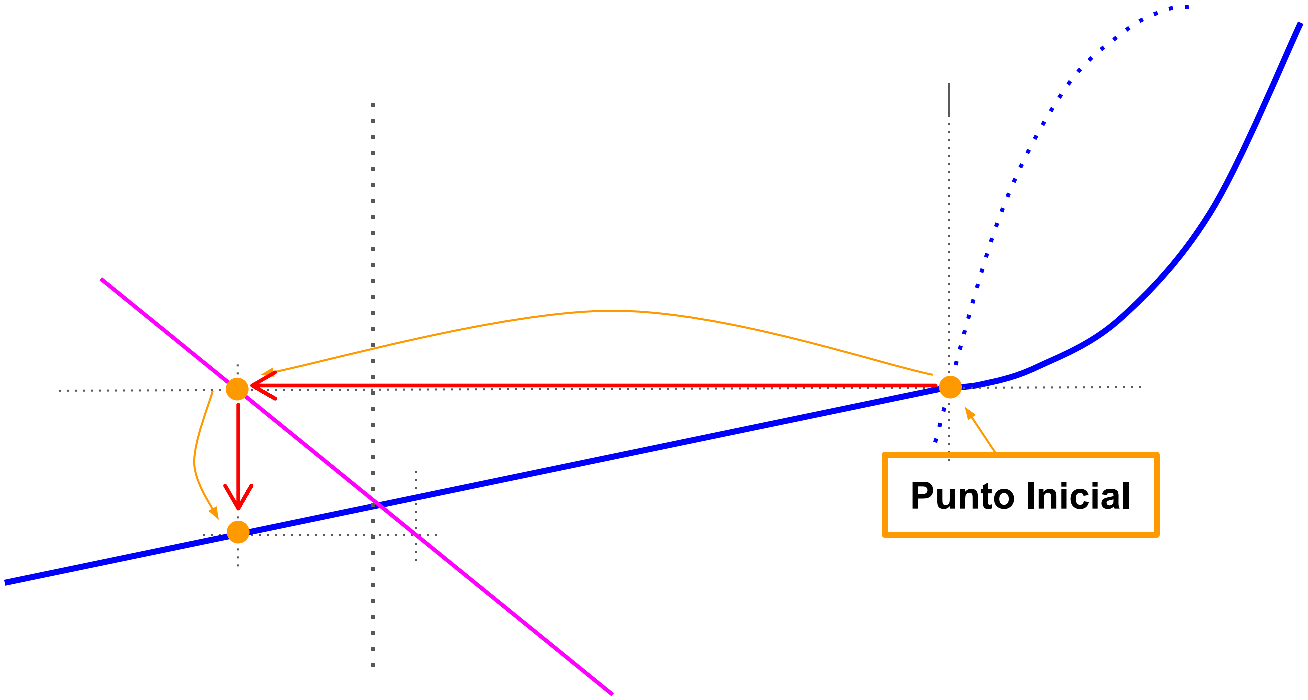



# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/$V^2$

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

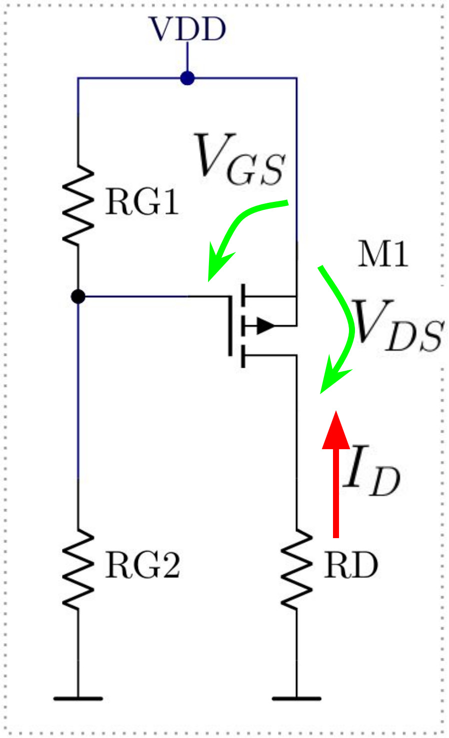


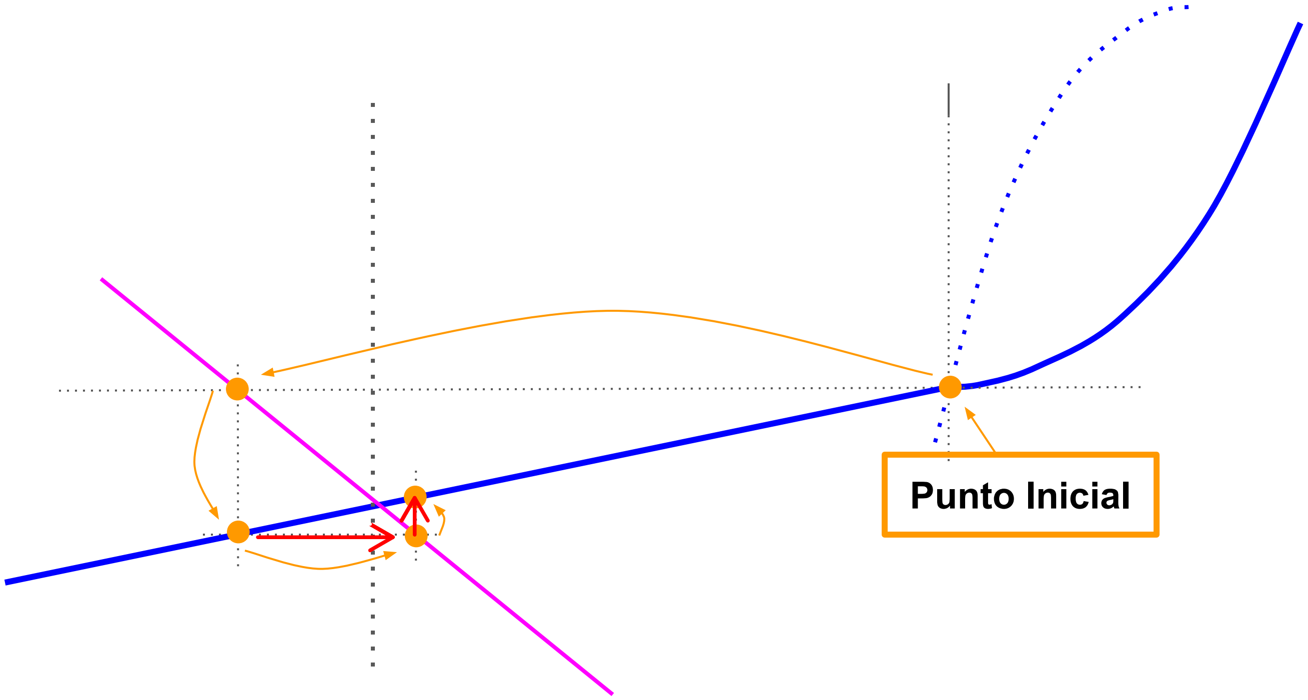



# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/$V^2$

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



# 1. Polarización

$V_T$ = -0.8 V, k = 320 μA/V$^2$

Datos

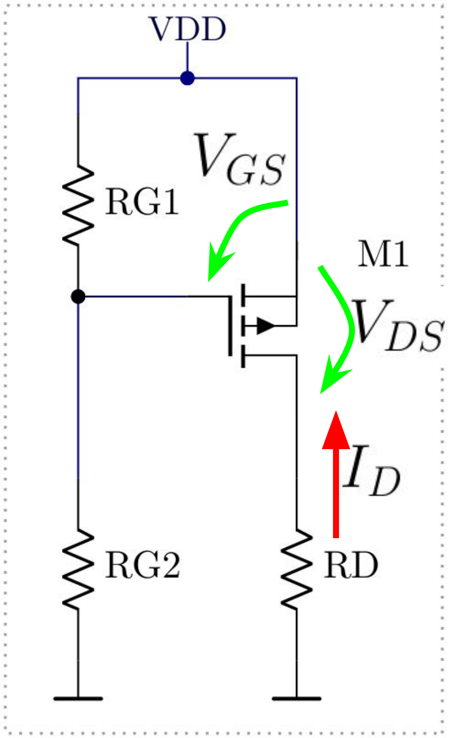
$|V_T|$ = 0.8 V, $\mu_p C'_{ox}$ = 80 μA/V$^2$

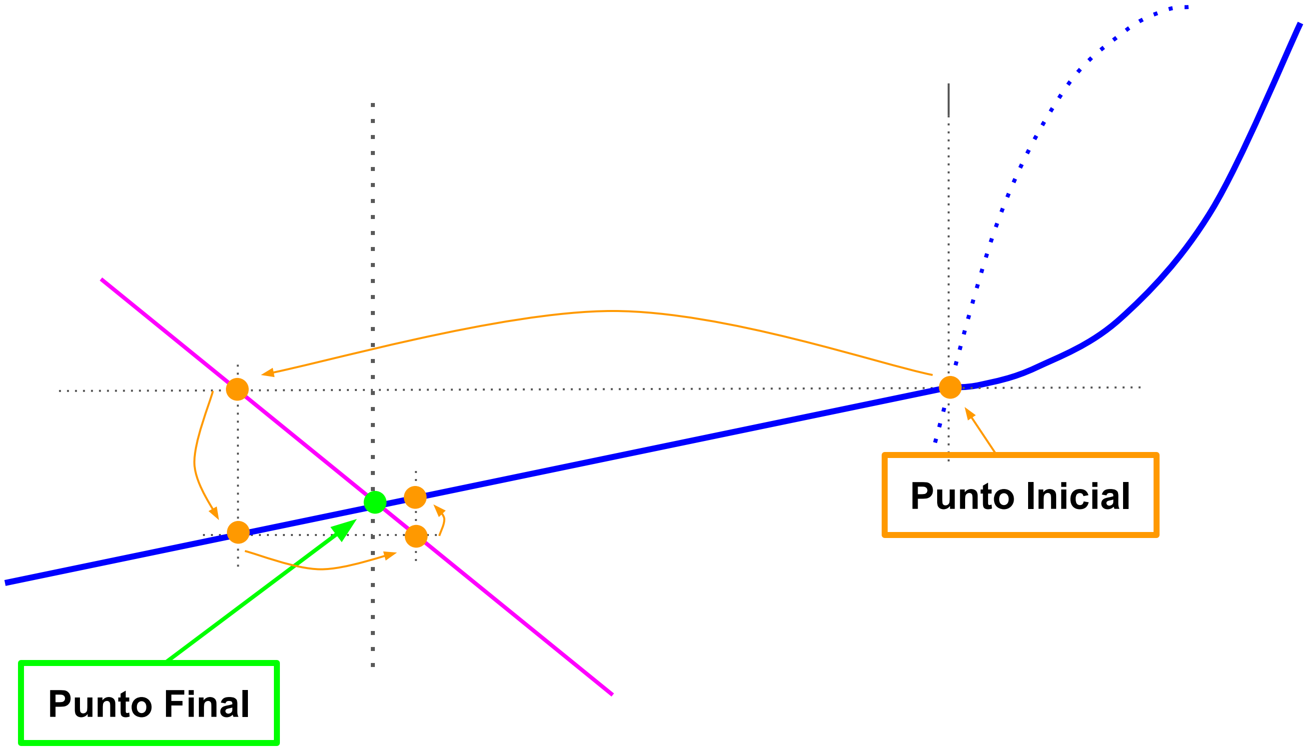
W = 32 μm, L = 4 μm

λ = 0.02 V$^{-1}$, $\gamma^2$ = 0.5 V

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V



# 1. Polarización

$V_T$ = -0.8 V, k = 320 µA/$V^2$

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

**Datos**

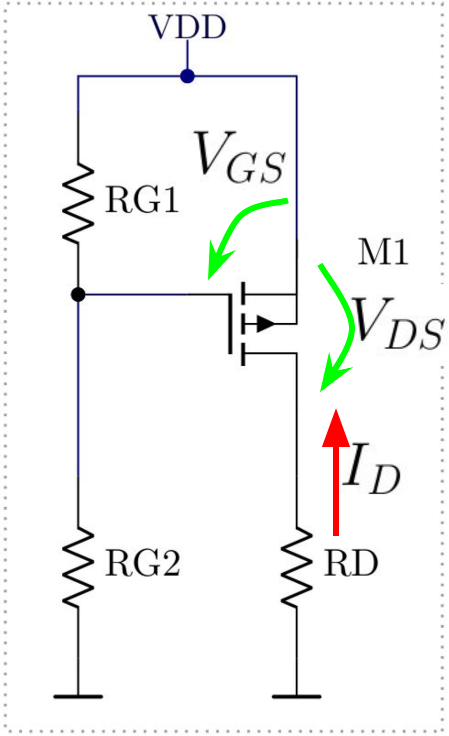
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 µA/$V^2$

W = 32 µm, L = 4 µm

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

$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ

$R_D$ = 18kΩ, $V_{DD}$ = 5 V




Resolvemos el sistema de ecuaciones:

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

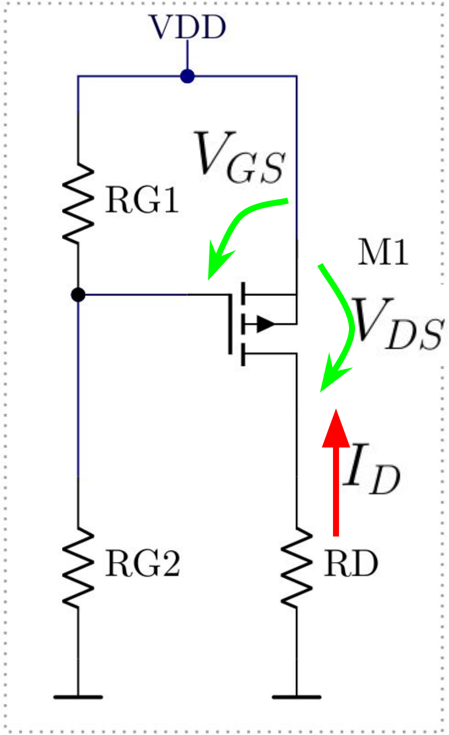
```
vds(1) = vdssat
id (1) = idsat

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

# 1. Polarización

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

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

Resolvemos el sistema de ecuaciones:




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

```
vds(1) = vdssat
id (1) = idsat

for i = 2:10
  vds(i) = -vdd-id(i-1
  id (i) = idsat*(1-la
end
[vds(:) id(:)]
```

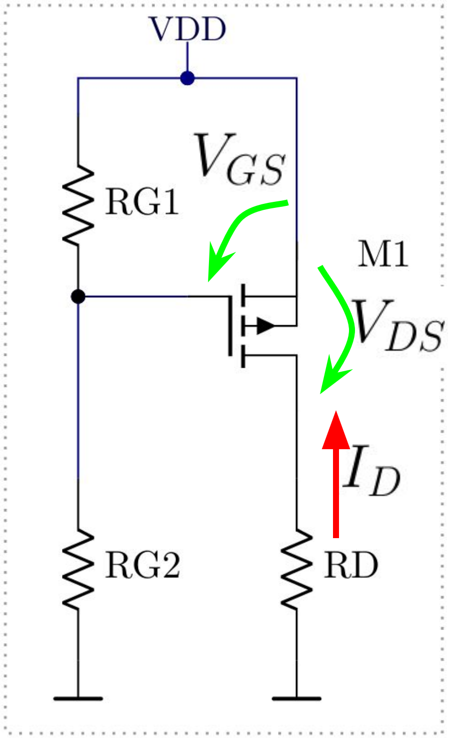
```
id = -0.000080000
ans =
   -0.500000000  -0.000080000
   -3.560000000  -0.000084896
   -3.471872000  -0.000084755
   -3.474410086  -0.000084759
   -3.474336990  -0.000084759
   -3.474339095  -0.000084759
   -3.474339034  -0.000084759
   -3.474339036  -0.000084759
   -3.474339036  -0.000084759
   -3.474339036  -0.000084759

octave:34>
```

# 1. Polarización

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

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

Resolvemos el sistema de ecuaciones:




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

```
vds(1) = vdssat
id (1) = idsat

for i = 2:10
  vds(i) = -vdd-id(i-1
  id (i) = idsat*(1-la
end
[vds(:) id(:)]
```

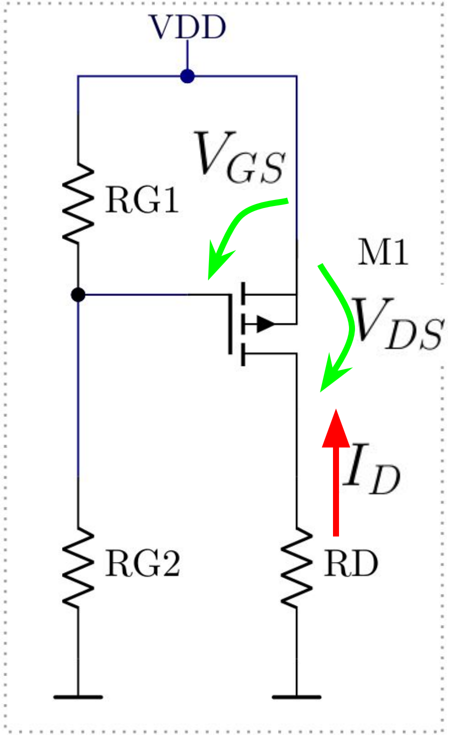
```
id = -0.000080000
ans =
   -0.500000000   -0.000080000
   -3.560000000   -0.000084896
   -3.471872000   -0.000084755
   -3.474410086   -0.000084759
   -3.474336990   -0.000084759
   -3.474339095   -0.000084759
   -3.474339034   -0.000084759
   -3.474339036   -0.000084759
   -3.474339036   -0.000084759
   -3.474339036   -0.000084759

octave:34>
```

# 1. Polarización

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

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

Resolvemos el sistema de ecuaciones:




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

```
vds(1) = vdssat
id (1) = idsat

for i = 2:10
  vds(i) = -vdd-id(i-1
  id (i) = idsat*(1-la
end
[vds(:) id(:)]
```

```
id = -0.000080000
ans =

  -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
  -3.474339036  -0.000084759

octave:34>
```

# 1. Polarización

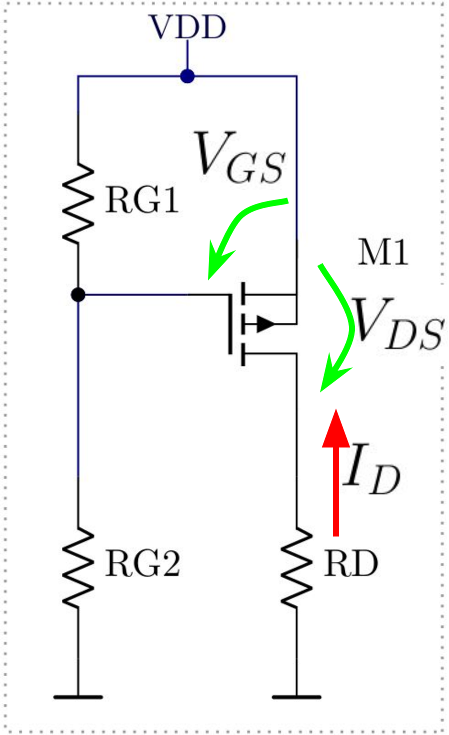
| Datos |
|---|
| $\|V_T\| = 0.8$ V, $\mu_p C'_{ox} = 80\ \mu A/V^2$ |
| W = 32 μm, L = 4 μm |
| $\lambda = 0.02\ V^{-1}$, $\gamma^2 = 0.5$ V |
| $R_{G1} = 130\ k\Omega$, $R_{G2} = 370\ k\Omega$ |
| $R_D = 18 k\Omega$, $V_{DD} = 5$ V |

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

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

Resolvemos el sistema de ecuaciones:

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




```
vds(1) = vdssat
id (1) = idsat

for i = 2:10
  vds(i) = -vdd-id(i-1
  id (i) = idsat*(1-la
end
[vds(:) id(:)]
```

```
id = -0.000080000
ans =
  -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
  -3.474339036  -0.000084759

octave:34>
```

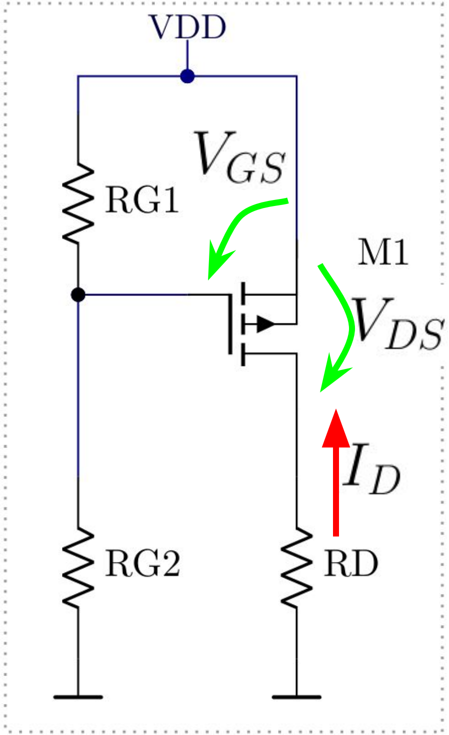
# 1. Polarización

**$V_{GS}$ = -1.3 V**
**$I_D$ = -85.5 µA**
**$V_{DS}$ = -3.46V**

$V_T$ = -0.8 V, k = 320 µA/V²
$I_{Dsat}$ = -80 µA, $V_{DS\text{-}sat}$ = -0.5V

Datos
$|V_T|$ = 0.8 V, $\mu_P C'_{ox}$ = 80 µA/V²
W = 32 µm, L = 4 µm
$\lambda$ = 0.02 $V^{-1}$, $\gamma^2$ = 0.5 V
$R_{G1}$ = 130 kΩ, $R_{G2}$ = 370 kΩ
$R_D$ = 18kΩ, $V_{DD}$ = 5 V

Resolvemos el sistema de ecuaciones:




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

- Por simulación
- Despejando
- Iterando

**El resultado es aproximadamente el mismo:**
**$I_D$ = -85 µA, $V_{DS}$ = -3.46 V**

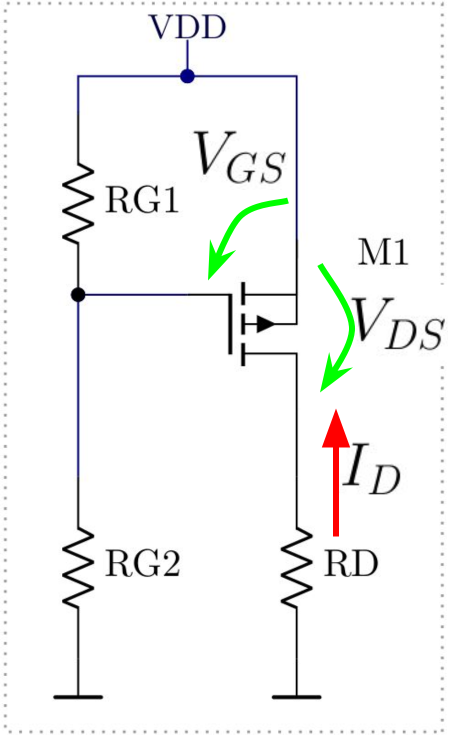
# 1. Polarización

**$V_{GS}$ = -1.3 V**
**$I_D$ = -85.5 μA**
**$V_{DS}$ = -3.46V**

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

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

Resolvemos el sistema de ecuaciones:




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

- Por simulación
- Despejando
- Iterando

**El resultado es aproximadamente el mismo:**
**$I_D$ = -85 μA, $V_{DS}$ = -3.46 V**

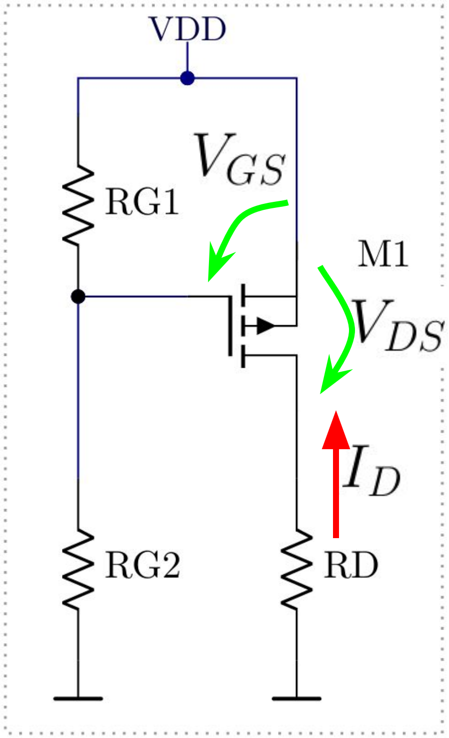
**Antes de terminar con la polarización debemos verificar que efectivamente estamos en SAT: $V_{DS} < V_{DSsat}$ (canal P)**

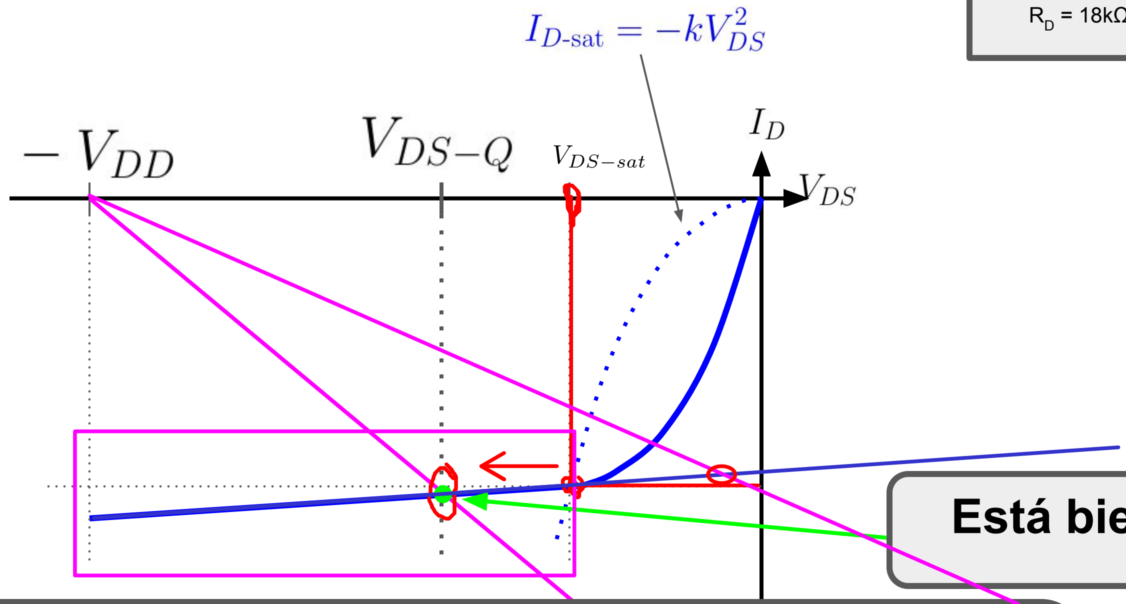
# 1. Polarización

$V_{GS}$ = -1.3 V
$I_D$ = -85.5 μA
$V_{DS}$ = -3.46V

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

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




**Está bien!**

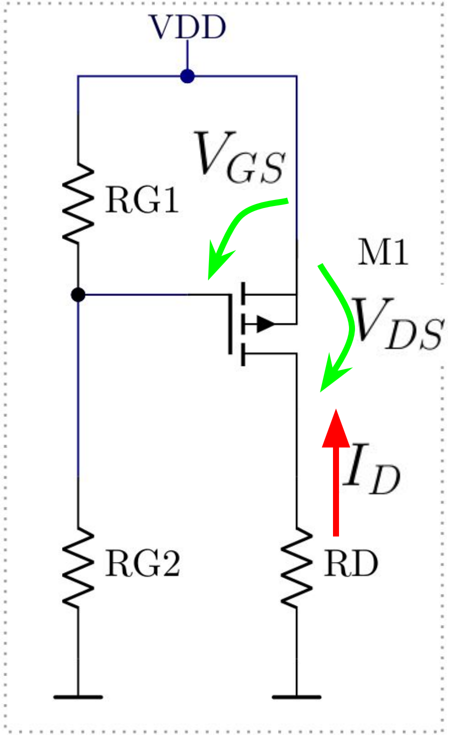
**Antes de terminar con la polarización debemos verificar que efectivamente estamos en SAT: $V_{DS}<V_{DSsat}$ (canal P)**

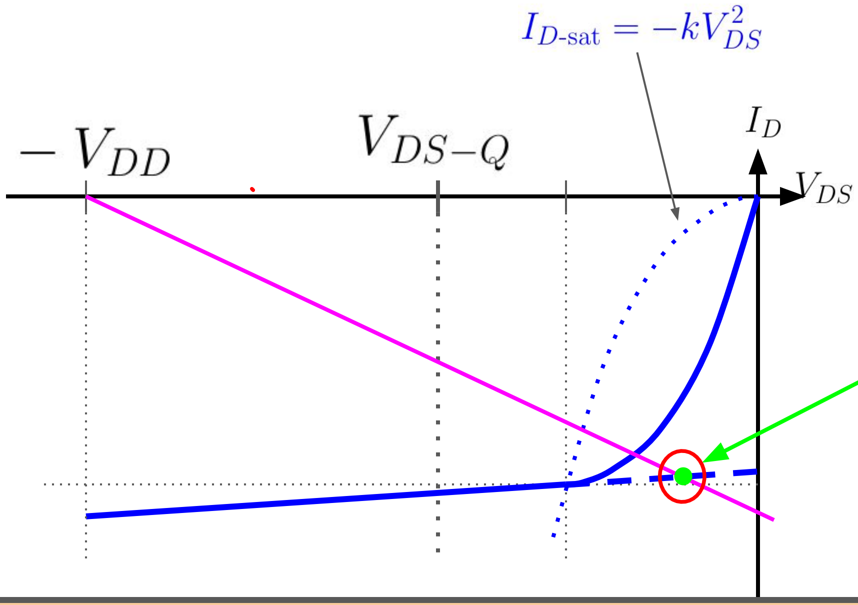
# 1. Polarización

**$V_{GS}$ = -1.3 V**
**$I_D$ = -85.5 µA**
**$V_{DS}$ = -3.46V**

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

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




**Está mal!**

**No está sobre la curva del transistor!!**

**Antes de terminar con la polarización debemos verificar que efectivamente estamos en SAT: $V_{DS}$<$V_{DSsat}$ (canal P)**