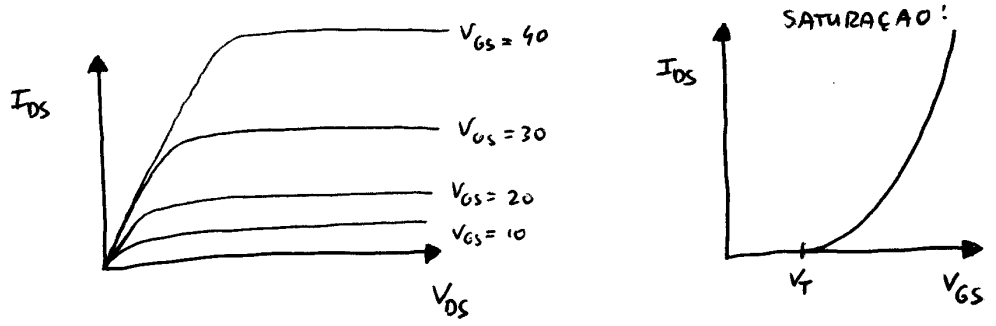
① saturação : $V_{DS} \geq V_{GS} - V_T$

② satur. : $I_{DS} = \frac{1}{2} \mu_N C_{ox} \frac{W}{L} (V_{GS} - V_T)^2$

③ linear : $I_{DS} = \mu_N C_{ox} \frac{W}{L} (V_{GS} - V_T) V_{DS}$



1a : $R_D = ?$ $\quad V_D = \pm 1\,V \Rightarrow$ polarização $V_D = 0\,V$

$I_D = 0.1\,mA \Rightarrow R_D = \frac{V_{DD} - V_D}{I_D} = 50\,k\Omega$

$R_S = ?$: $V_S = ?$: saturação : $I_{DS} = \frac{1}{2} \mu_N C_{ox} \frac{W}{L} (V_{GS} - V_T)^2$

$$0.1\,mA = \frac{1}{2}\, 0.4\,mA\, (V_G - V_S - V_T)^2$$

$$0.5 = (V_S + V_T)^2$$

$$V_S = -1 - \sqrt{0.5} = -1.7\,V$$

$$R_S = \frac{V_S - V_{SS}}{0.1\,mA} = 33\,k\Omega$$

$R_G = 10\,M\Omega$ (escolha)

verifique se temos saturação : $V_{DS} \geq V_{GS} - V_T$?

$V_D = 0\,V$ $\quad 0 - (-1.7) \geq 0 - (-1.7) - 1$ ✓

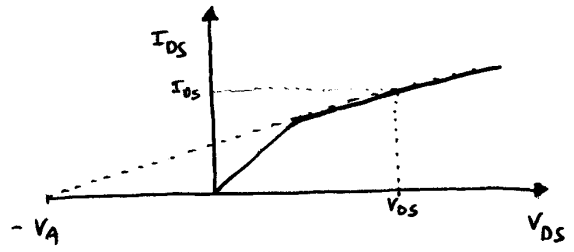
mínimo $V_D = -1\,V$ $\quad -1 - (-1.7) \geq 0 - (-1.7) - 1$ ✓

1b : ④ $g_m \equiv \frac{\partial I_{DS}}{\partial V_{GS}}$, em saturação (veja eq. ②) :

$$g_m = \frac{1}{2} \mu_N C_{ox} \frac{W}{L} 2 (V_{GS} - V_T) = \frac{2 I_{DS}}{(V_{GS} - V_T)}$$

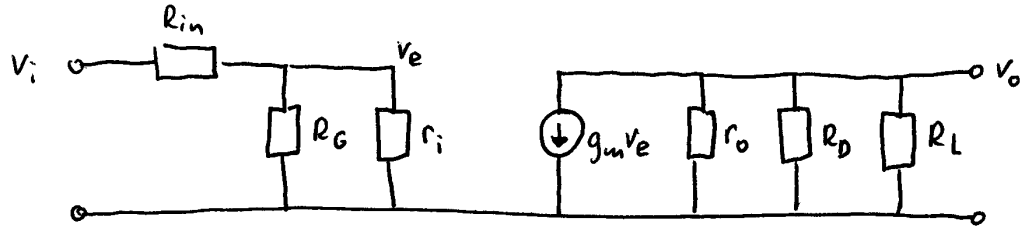
$$g_m = \frac{2 I_{DS}}{(V_{GS} - V_T)} = \frac{2 \cdot 0.1\ mA}{1.7\ V - 1V} = 2.85\ 10^{-3}\ A/V$$

⑤ $\frac{1}{r_o} \equiv \frac{\partial I_{DS}}{\partial V_{DS}}$



$$\frac{1}{r_o} = \frac{I_{DS}}{V_{DS} + V_A} = \frac{0.1\ mA}{1.7\ V + 40\ V} \Rightarrow r_o = 417\ k\Omega$$

1c: modelo pequenos sinais

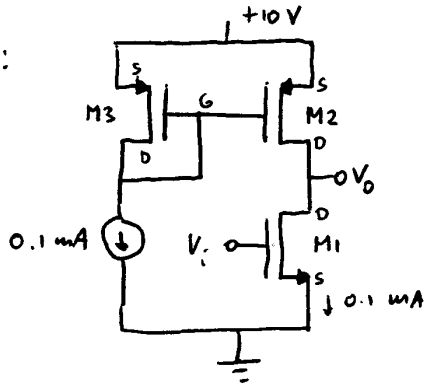


$$V_e = \frac{R_G // r_i}{R_G // r_i + R_{in}} \cdot V_i$$

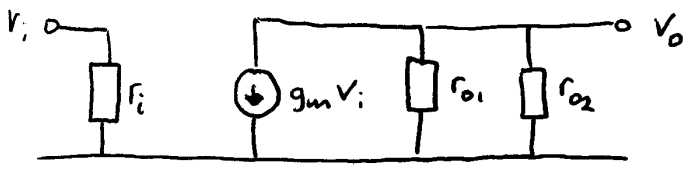
$$V_o = g_m V_e (r_o // R_D // R_L) V_i = g_m \frac{R_G // r_i}{R_G // r_i + R_{in}} (r_o // R_D // R_L) V_i$$

$$\Rightarrow \frac{V_o}{V_i} = 2.85\ 10^{-3} \cdot \frac{5M}{5M + 1M} (417k // 50k // 40k) = 50\ V/V$$

2:



modelo pequenos sinais:



M3: $V_{SG} = V_{SD} \Rightarrow$

$V_{SD} > V_{SG} - |V_T|$ sempre $\Rightarrow$ saturação

$$g_m = \frac{2 I_{DS}}{V_{GS} - V_T} = \frac{2 \cdot 0.1\,mA}{-1\,V} = -2 \cdot 10^{-4}\ A/V$$

$$r_{o1} = \frac{V_{DS} + V_A}{0.1\,mA} \approx \frac{V_A}{0.1\,mA} = \frac{100\,V}{0.1\,mA} = 1\,M\Omega$$

$$r_{o2} = r_{o1} = 1\,M\Omega$$

$$\frac{v_o}{v_i} = g_m (r_{o1} \| r_{o2}) = (-2 \cdot 10^{-4}\ A/V) \cdot (500\,k\Omega) = -100\ V/V$$

2b: M2: saturação quando $V_{SD2} \geq V_{SG2} - |V_{T2}|$

$$10 - V_{D2} \geq 10 - V_{G2} - |V_{T2}|$$

$$V_{D2} \leq V_{G2} + 1\,V \qquad V_G = 0$$

$$V_{D2} \leq 1\,V$$

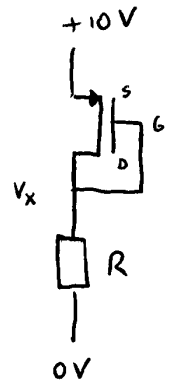
M1: saturação quando $V_{DS1} \geq V_{GS1} - V_T$

$$V_{D1} \geq V_{G1} - 1\,V$$

$$V_{D1} \geq -1\,V$$

$$v_o = V_{O1} = V_{D2} \Rightarrow -1\,V < V_o < 1\,V$$

2c:



(I): $I_{SD} = \frac{1}{2} \mu_p C_{ox} \frac{W}{L} (V_{SG} - |V_T|)^2$

$$I_{SD} = \frac{1}{2} \cdot 10\,(mA/V^2) \cdot \frac{100\,\mu m}{10\,\mu m} \cdot (10 - V_x - 1)^2$$

$$= 50 \cdot (9 - V_x)^2\,mA = 0.1\,mA$$

(II) $I_{SD} = \frac{V_x}{R} \Rightarrow V_x \sim 9\,V$

$$R = \frac{V_x}{I_{SD}} = \frac{9\,V}{0.1\,mA} = 90\,k\Omega$$