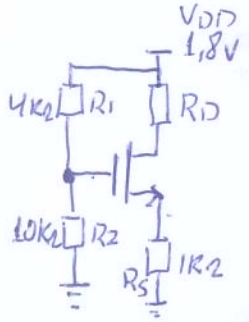
Exercícios - Aula 10-A

* Exemplo 7.1



- $V_G = \frac{V_{DD}}{R_1+R_2} \cdot R_2 \Rightarrow \boxed{V_G = 1,2857\,V}$

$$\begin{cases} \bullet\ V_{GS} = V_G - R_S I_D \Rightarrow V_{GS} = 1,2857 - 1000 I_D \\ \bullet\ I_D = \frac{1}{2} \underbrace{\mu_n C_{ox}}_{100.10^{-6}} \frac{W}{L}_{5/0,18} (V_{GS} - V_{TH})^2 \Rightarrow I_D = 1,3889.10^{-3} (V_{GS} - V_{TH}) \end{cases}$$

($V_{TH} = 0,5\,V$)

$$\Rightarrow V_{GS} = 1,2857 - 1000\left[1,3889.10^{-3} \cdot (V_{GS}^2 - 2.V_{GS}.V_{TH} + V_{TH}^2)\right]$$

$$\rightarrow V_{GS} = 1,2857 - 1,3889.V_{GS}^2 + 2.1,3889 V_{GS}.0,5 + 0,5^2.1,3889$$

$$2,3889.V_{GS}^2 - 1,3889 V_{GS} - 0,9385 = 0$$

$$\boxed{V_{GS} = 0,9816\,V} \qquad V_{GS} = \cancel{-0,4002}$$

$$\rightarrow 0,9816 = 1,2857 - 1000 I_D \Rightarrow \boxed{I_D = 0,3041\,mA}$$

$\Rightarrow$ Saturação

$$V_{DS} \geq V_{GS} - V_{TH} \Rightarrow 1,8 - R_D I_D - R_S I_D > 0,4816$$

($V_{GS} = 0,9816$; $V_{TH} = 0,5$; $I_D \rightarrow 0,3041\,mA$)

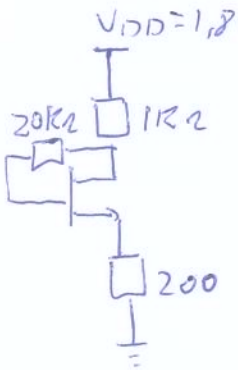
$$-(R_D + R_S).I_D \geq 0,4816 - 1,8$$

$$R_D + R_S \leq \frac{1,3184}{0,3041.10^{-3}}$$

($R_S = 1K\Omega$)

$$\boxed{R_D \leq 3,3352.10^3\,\Omega}$$

* Exemplo 7.3



- $I_G = 0 \Rightarrow V_{DS} = V_{GS}$
- $V_{DS} = V_{GS} = 1,8 - 1000 I_D - 200 I_D$

$$\begin{cases} V_{GS} = 1,8 - 1200 I_D \\ I_D = \frac{1}{2} \cdot \underbrace{\mu_n C_{ox}}_{100.10^{-6}} \cdot \underbrace{\frac{W}{L}}_{\frac{0,5}{0,18}} \cdot \underbrace{(V_{GS} - V_{TH})^2}_{0,5} \end{cases}$$

$$V_{GS} = 1,8 - 1200 \cdot \left[1,389.10^{-3} \cdot (V_{GS} - 0,5)^2 \right]$$

$$V_{GS} = 1,8 - 1,667 (V_{GS}^2 - 2 V_{GS} \cdot 0,5 + 0,5^2)$$

$$1,667 V_{GS}^2 - 1,667 V_{GS} + V_{GS} - 1,8 + 0,25 \cdot 1,667 = \emptyset$$

$$1,667 V_{GS}^2 - 0,6667 V_{GS} - 1,3833$$

$$\boxed{V_{GS} = 1,1327 V} \qquad V_{GS} = \cancel{-0,7327}$$

$$I_D = \frac{V_{GS} - 1,8}{-1200} \Rightarrow \boxed{I_D = 5,5608.10^{-4} A}$$

- $I_D = \frac{I_D}{2} = 278 \mu A$

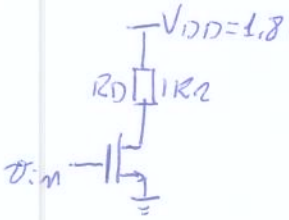
$$(V_{GS} - V_{TH})^2 = \frac{I_D}{\frac{1}{2} \mu_n C_{ox} \cdot \frac{W}{L}} \xrightarrow{\rightarrow 278.10^{-6}} (V_{GS} - V_{TH})^2 = 0,2002$$

$$V_{GS} - 0,5 = 0,4474 \Rightarrow \boxed{V_{GS} = 0,9474}$$

- $V_{GS} = 1,8 - R_D I_D - 200 I_D \Rightarrow R_D = \frac{1,8 - 200 I_D - V_{GS}}{I_D}$

$$\boxed{R_D = 2,8664.10^3 \Omega}$$

※ Exemplo 7.4



- $I_D = 1.10^{-3} A$
- $\mu_n C_{ox} = 100.10^{-6} A/V^2$
- $V_{TH} = 0,5$
- $\lambda = 0$
- $\frac{W}{L} = \frac{10}{0,18}$

$$I_D = \frac{1}{2}\mu_n C_{ox}\cdot\frac{W}{L}(V_{GS}-V_{TH})^2$$

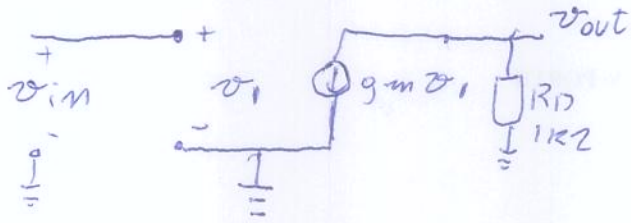
$1.10^{-3} = 2,77\cdot 10^{-3}(V_{GS}-V_{TH})^2$

$(V_{GS}-V_{TH})^2 = 0,36 \Rightarrow V_{GS}-0,5 = 0,6 \Rightarrow \boxed{V_{GS} = 1,1V}$

- $V_{DS} = 1,8 - R_D I_D \Rightarrow V_{DS} = 0,8V$

$V_{DS} > V_{GS}-V_{TH} \Rightarrow$ saturação

- $g_m = \mu_n C_{ox}\frac{W}{L}.(V_{GS}-V_{TH}) \Rightarrow g_m = 3,33.10^{-3} S$

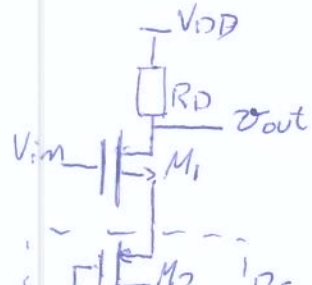


$v_{in} = v_1$

$v_{out} = -g_m v_1 R_D$

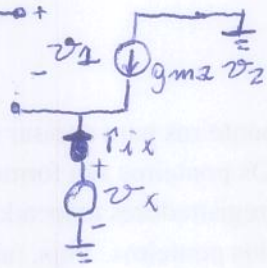
$A_v = \frac{v_{out}}{v_{in}} = -g_m R_D \Rightarrow \boxed{A_v = 3,33}$

※ Exemplo 7.8



$\Rightarrow$ Fonte comum com degeneração $\Rightarrow \boxed{A_v = \frac{-R_D}{\frac{1}{g_m}+R_S}}$ (1)

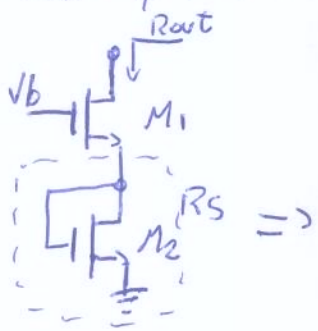
$\Rightarrow$



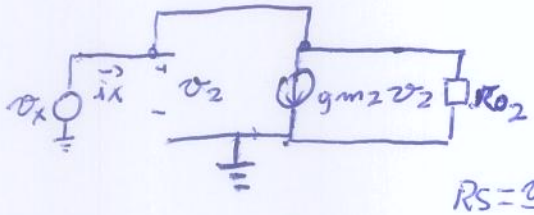
$\Rightarrow R_S = \frac{v_x}{i_x} = \frac{-v_2}{-g_{m2}v_2} \Rightarrow \boxed{R_S = \frac{1}{g_{m2}}}$ (2)

(2) x (1) $\Rightarrow A_v = \dfrac{-R_D}{\frac{1}{g_{m1}}+\frac{1}{g_{m2}}}$

✻ Exemplo 7.9



$$R_{out} = r_{o1} + g_{m1} r_{o1} \cdot R_S + R_S \quad (1)$$



$$v_x = v_2$$

$$i_x = g_{m2} v_2 + \frac{v_2}{r_{o2}}$$

$$R_S = \frac{v_x}{i_x} = \left(g_{m2} + \frac{1}{r_{o2}}\right)^{-1} \Rightarrow \boxed{R_S = r_{o2} \,//\, 1/g_{m2}} \quad (2)$$

$$R_{out} = r_{o1} + g_{m1} r_{o1} \cdot \left(r_{o2} \,//\, 1/g_{m2}\right) + \underbrace{\left(r_{o2} \,//\, \frac{1}{g_{m2}}\right)}_{\sim \frac{1}{g_{m2}}}$$

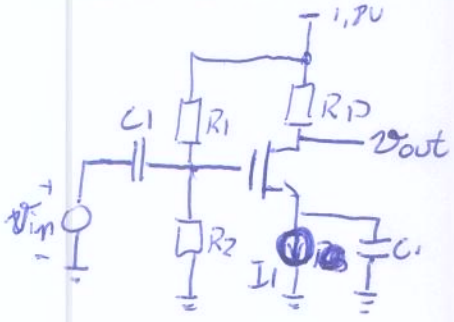
$$R_{out} \tilde{=} r_{o1} \cdot \left(1 + g_{m1} \cdot \frac{1}{g_{m2}}\right) + \frac{1}{g_{m2}}$$

$$M_1 = M_2 \Rightarrow \boxed{R_{out} \tilde{=} 2 r_{o1} + \frac{1}{g_m}}$$

$$\Downarrow$$

$$\boxed{R_{out} \tilde{=} 2 r_{o1}}$$

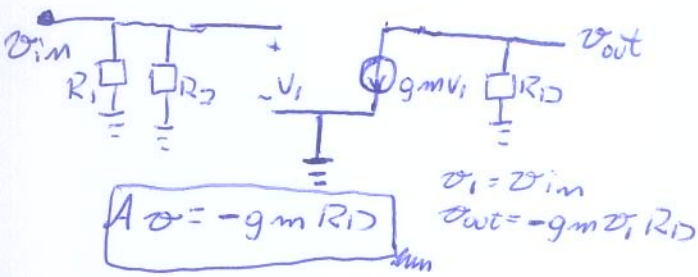
✱ Exercício 7.37 RAZAVI



$I_1 = 1mA$
$R_D = 500\Omega$
$A_v = 5$

$\Leftrightarrow$

$\frac{W}{L}$?



$A_v = -g_m R_D$

$v_i = v_{in}$

$v_{out} = -g_m v_i R_D$

a) $|A_v| = 5 \Rightarrow -5 = -g_m \cdot R_D \Rightarrow R_D = 500\Omega \Rightarrow g_m = 10^{-2} S$

$g_m = \sqrt{2 . \underbrace{\mu_n C_{ox}}_{200.10^{-6}} . \frac{W}{L} . \underbrace{I_D}_{I_1 = 1mA}} \Rightarrow 10^{-2} = \sqrt{2 \, 200.10^{-6} \frac{W}{L} . 1.10^{-3}}$

~~$10^{-4} = 400.10^{-9} \frac{W}{L} \Rightarrow \frac{W}{L} = 250$~~

b) • $I_D = \frac{1}{2} \underbrace{\mu_n C_{ox}}_{200.10^{-6}} . \underbrace{\frac{W}{L}}_{250} . (V_{GS} - \underbrace{V_{TH}}_{0,4})^2 \Rightarrow 1.10^{-3} = \frac{1}{2} . 200.10^{-6} . 250 (V_{GS} - 0,4)^2$

$(V_{GS} - 0,4)^2 = 0,04 \Rightarrow V_{GS} = 0,6V$

• $V_{DS} = V_{GS} - V_{TH} + 0,2 \Rightarrow V_{DS} = 0,6 - 0,4 + 0,2 \Rightarrow V_{DS} = 0,4V$

• $V_D = V_{DD} - R_D I_D = 1,8 - 500.1.10^{-3} \Rightarrow V_D = 1,3V$

• $V_S = V_D - V_{DS} \Rightarrow V_S = 0,9V$

• $V_G = V_{GS} + V_S \Rightarrow V_G = 1,5V$

• $I_{R1} = I_{R2} = \underbrace{0,1.10^{-3}}_{I \text{ maxima}} = \frac{V_G}{R_2} \Rightarrow R_2 = \frac{V_G}{0,1.10^{-3}} \Rightarrow R_2 = 1,5.10^4 \Omega$

• $I_{R1} = \frac{V_{DD} - V_G}{R_1} \Rightarrow R_1 = \frac{1,8 - 1,5}{0,1.10^{-3}} \Rightarrow R_1 = 3.10^3 \Omega$

c) $\frac{W'}{L} = 2 . \frac{W}{L} \xrightarrow{g_m \propto \sqrt{\frac{W}{L}}} g_m' = \sqrt{2} g_m \Rightarrow g_m' = 1,4142.10^{-2} S$

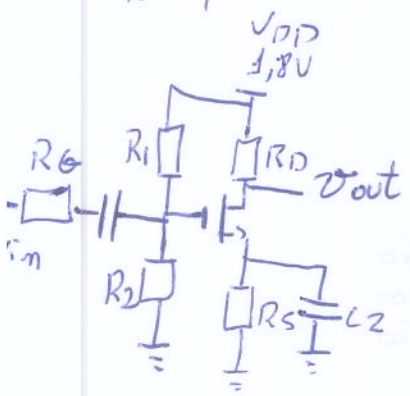
• $I_D = \frac{1}{2} . \mu_n C_{ox} . \underbrace{\frac{W'}{L}}_{500} . (V_{GS}' - V_{TH})^2 \Rightarrow V_{GS}' = 0,5414V$

• $V_G' = V_G = 1,5V \Rightarrow V_G' = V_{GS}' + V_S' \Rightarrow V_S' = V_G' - V_{GS}' \Rightarrow V_S' = 0,9586V$

• $V_D' = V_D \Rightarrow V_{DS}' = V_D' - V_S' \Rightarrow V_{DS}' = 0,3414$

• $V_{DS}' \geq V_G' - V_{TH} \Rightarrow 0,3414 \geq 0,5414 - 0,4 \Rightarrow$ OK (SATURAÇÃO)

* Exemplo 7.11 modificado => a resolução do livro está errada.



$A_v = 1$
$z_{in} = 50k\Omega$
$\mu_n C_{ox} = 100.10^{-6} A/V^2$
$V_{TH} = 0,5V$
$\lambda = 0$
$V_{RS} = 0,4V$
$P = 5.10^{-3}$

- $I_{DD} = \frac{P}{V_{DD}} = \frac{5.10^{-3}}{1,8} \Rightarrow \boxed{I_{DD} = 2,7778 mA}$

- $I_{DD} = I_{R1} + I_D$

$\Rightarrow \boxed{I_{R1} = I_{DD} - I_D}$ (1)

$\boxed{I_{R1} << I_D}$

↳ maior parte da potência no transistor

$$\begin{cases} I_{R1} = \frac{V_{DD}}{R_1+R_2} = \frac{1,8}{R_1+R_2} \Rightarrow R_1+R_2 = \frac{1,8}{I_{R1}} \Rightarrow \boxed{R_1 = \frac{1,8}{I_{R1}} - R_2} \\ R_{in} = 50.10^3 = R_1 // R_2 \Rightarrow \frac{R_1 R_2}{R_1+R_2} = 50.10^3 \rightarrow \frac{\left(\frac{1,8}{I_{R1}} - R_2\right) R_2}{\frac{1,8}{I_{R1}} - R_2 + R_2} = 50.10^3 \end{cases}$$

$$-R_2^2 + \frac{1,8}{I_{R1}} R_2 = 50.10^3 \cdot \frac{1,8}{I_{R1}} \Rightarrow R_2^2 - \frac{1,8 R_2}{I_{R1}} + 50.10^3 \cdot \frac{1,8}{I_{R1}} = 0$$

$\Rightarrow \boxed{I_{R1} R_2^2 - 1,8 R_2 + 90.10^3 = 0}$ (2)

$\Delta = (-1,8)^2 - 4 I_{R1} \cdot 90.10^3$

$\Delta = 3,24 - 360.10^3 I_{R1}$

$\Delta \geq 0 \Rightarrow 3,24 - 360.10^3 I_{R1} \geq 0 \Rightarrow \boxed{I_{R1} \leq 9.10^{-6} A}$ (3)

=> Considerando (1) e (3), escolho

$\boxed{I_{R1} = 7,77.10^{-6} A}$
$\boxed{I_D = 2,77.10^{-3} A}$ (4)

(4) → (2) $7,77.10^{-6} R_2^2 - 1,8 R_2 + 90.10^3 = 0$ → $R_2 = 1,5836.10^5 \Omega$ ou $R_2 = 0,7307.10^5 \Omega$

- $R_2 = 0,7307.10^5$

$\Rightarrow V_G = R_2 . I_{R1} = 0,7307.10^5 . 7,77.10^{-6} \Rightarrow V_G = 0,5683$

$V_S = 0,4 V \Rightarrow V_{GS} = V_G - V_S = 0,5683 - 0,4 \Rightarrow \boxed{V_{GS} = 0,1683}$ ✗

$V_{GS} < V_{TH}$

↳ Corte

- $R_2 = 1,5836 \cdot 10^5$

$V_G = 1,5836 \cdot 10^5 \cdot 7,77 \cdot 10^{-6} \Rightarrow V_G = 1,2317\,V$

$V_S = 0,4 \Rightarrow V_{GS} = 0,8317$

$\hookrightarrow V_{GS} \geq V_{TH} \Rightarrow OK$

- $R_1 = \frac{1,8}{I_{R1}} - R_2 \Rightarrow R_1 = \frac{1,8}{7,77 \cdot 10^5} - 1,5836 \cdot 10^5 \Rightarrow R_1 = 7,3069 \cdot 10^4$

- $R_S = \frac{V_S}{I_D} = \frac{0,4}{2,77 \cdot 10^{-3}} \Rightarrow R_S = 144,4043\,\Omega$

- $V_D = 1,8 - R_D I_D \Rightarrow V_D = 1,8 - 2,77 \cdot 10^{-3} R_D$

- $V_{DS} = V_D - V_S = 1,8 - 2,77 \cdot 10^{-3} R_D - 0,4 \Rightarrow V_{DS} = 1,4 - 2,77 \cdot 10^{-3} R_D$

- $V_{DS} \geq V_{GS} - V_{TH} \Rightarrow 1,4 - 2,77 \cdot 10^{-3} R_D \geq 0,8317 - 0,5$

SATURAÇÃO $\Rightarrow R_D \leq 385,6679\,\Omega$ (5)

- ~~$A_{vol} = 5 = g_m$~~
- $g_m = \frac{2 I_D}{V_{GS} - V_{TH}} = \frac{2 \cdot 2,77 \cdot 10^{-3}}{0,8317 - 0,5} \Rightarrow g_m = 0,01617\,S$

(7)

$$A_v = \frac{R_1 // R_2}{R_G + R_1 // R_2} \cdot \frac{R_D}{\frac{1}{g_m} + R_S} \Rightarrow 1 = \frac{4{,}99 \cdot 10^4}{R_G + 4{,}99 \cdot 10^4} \cdot \frac{R_D}{204{,}2780}$$

$$R_G + 4{,}99 \cdot 10^4 = 244{,}7584\, R_D$$

$$R_G = 244{,}7584\, R_D - 4{,}99 \cdot 10^4$$

$$R_G \geq 0 \Rightarrow 244{,}7584 R_D - 4{,}99 \cdot 10^4 \geq 0$$

$$\boxed{R_D \geq 204{,}2780} \quad (6)$$

De (5) e (6) $204{,}2780 \leq R_D \leq 385{,}6679$

~~• Escolho $R_D = 204{,}2904$~~

~~$\Rightarrow R_G = 244{,}7584 R_D - 4{,}99 \cdot 10^4 \Rightarrow$~~

• Escolho $\boxed{R_D = 204{,}2780\,\Omega \Rightarrow R_G = 0\,\Omega}$

↳ não modifica z_{in}

• Falta calcular $\frac{W}{L}$

$$\Rightarrow I_D = \frac{1}{2} \underbrace{\mu_n C_{ox}}_{100 \cdot 10^{-6}} \frac{W}{L} (V_{GS} - V_{TH})^2 \Rightarrow \boxed{\frac{W}{L} = 503{,}5224}$$

$I_D = 2{,}77 \cdot 10^{-3}$; $V_{GS} = 0{,}8317$; $V_{TH} = 0{,}5$

obs: O máximo ganho é dado para $I_{R1} = 9 \cdot 10^{-6}$ => $R_2 = 100K\Omega$

$I_D = 2{,}7688 \cdot 10^{-3}$ $R_1 = 100K\Omega$

$R_S = 144{,}4669\Omega$

$V_G = \frac{1{,}8}{2} = 0{,}9V$

$V_S = 0{,}4V$

$V_{GS} = 0{,}5V \geq V_{TH}$

↳ fronteira do corte

$V_{DS} = 1{,}8 - 2{,}7688 \cdot 10^{-3} R_D$

$V_{DS} \geq V_{GS} - V_{TH}$ => $R_D \leq$ ~~613,9800~~ $650{,}1011$

($V_{GS} - V_{TH} = \emptyset$)

=> $g_m \to \infty$

$A_{v_{máx}}$ => $R_G = \emptyset$ => $A_{v_{máx}} = \frac{R_D}{\frac{1}{g_m} + R_S}$ ($\frac{1}{g_m} \to \emptyset$) => $A_{v_{max}} = \frac{R_D}{144{,}4669}$ ($R_D \to 650{,}1011$) => $\boxed{A_{v_{máx}} = 4{,}5}$

O ganho não pode ser 5, como está no livro