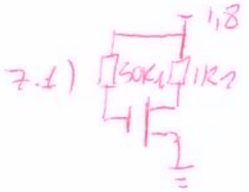
CAP7 (RAZAVI) 1, 5, 7, 9, 15, 17, 19, 23, 33, 38, 42, 44b, 44c, 48, 54, 56

Exercícios

7.1)



$\mu_n C_{ox} = 200 \cdot 10^{-6} A$
$\lambda = \emptyset$
$\frac{W}{L} = ?$
$V_{TH} = 0,4V$

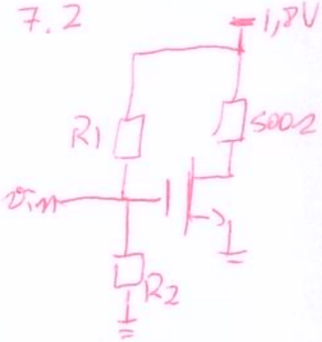
$V_{GS} = 1,8V$ pois $I_G = \emptyset$

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

$I_D = \frac{1}{2} 200 \cdot 10^{-6} \frac{W}{L} (1,8 - 0,4)^2$

- $I_D = 1,96 \cdot 10^{-4} \frac{W}{L}$
- $V_{DS} > V_{GS} - V_{TH} \rightarrow V_{DS} > 1,4V$
- $V_{DS} = 1,8 - 1000 I_D \Rightarrow 1,4 < 1,8 - 1,96 \cdot 10^{-4} \cdot 1000 \cdot \frac{W}{L} \Rightarrow \boxed{\frac{W}{L} < 2,0408}$

7.2



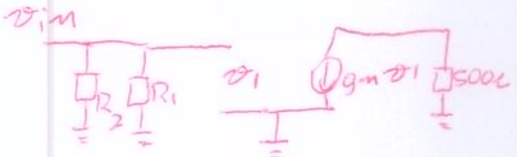
$\frac{W}{L} = \frac{20}{0,18}$
$R_{in} \geq 20k\Omega$
$I_D = 1mA$
$\lambda = \emptyset$
$V_{TH} = 0,4V$
$\mu_n C_{ox} = 200 \cdot 10^{-6} A$

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

$1 \cdot 10^{-3} = \frac{1}{2} 200 \cdot 10^{-6} \cdot \frac{20}{0,18} \cdot (V_{GS} - 0,4)^2$

$(V_{GS} - 0,4)^2 = \frac{1 \cdot 10^{-3}}{0,0111} \Rightarrow \boxed{V_{GS} = 0,7V} > V_{TH}$

- $V_{DS} = 1,8 - 500 \cdot 1 \cdot 10^{-3} \Rightarrow V_{DS} = 1,3V \geq \underbrace{V_{GS}}_{0,7} - \underbrace{V_{TH}}_{0,4} \Rightarrow SAT \Rightarrow OK$



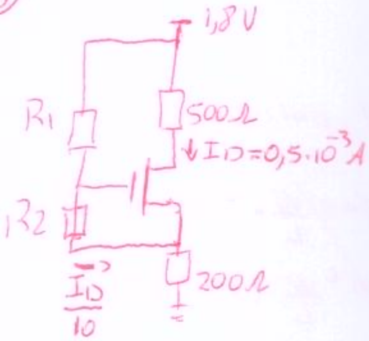
$\Rightarrow R_{in} = R_1 // R_2 \Rightarrow (R_1)^{-1} + (R_2)^{-1} \leq (20000)^{-1}$

$V_{GS} = V_{R2} \Rightarrow 0,7 = \frac{1,8}{R_1 + R_2} \cdot R_2 \Rightarrow 1,8 R_2 = 0,7 R_1 + 0,7 R_2 \Rightarrow \boxed{R_2 = 0,6364 R_1}$

$$R_2^{-1} + (0,6364 R_2)^{-1} \leq 20000^{-1} \rightarrow R_2 \geq 3,1429 \times 10^4 \Omega$$

$$Para\ R_2 = 32000 \rightarrow R_1 = 50282\Omega$$

(5)



R_1 e R_2?

$\frac{W}{L} = \frac{20}{0{,}18}$

$\mu n C_{ox} = 200 \cdot 10^{-6}$

$V_{TH} = 0{,}4 V$

$\lambda = \emptyset$

$I_D = 0{,}5 \cdot 10^{-3}$

$I_R = 0{,}5 \cdot 10^{-4} \rightarrow \frac{I_D}{10}$

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

$0{,}5 \cdot 10^{-3} = \frac{1}{2} 200 \cdot 10^{-6} \cdot \frac{20}{0{,}18} \cdot (V_{GS} - 0{,}4)^2$

$(V_{GS} - 0{,}4)^2 = 0{,}045 \Rightarrow \boxed{V_{GS} = 0{,}6121 V} > V_{TH}$

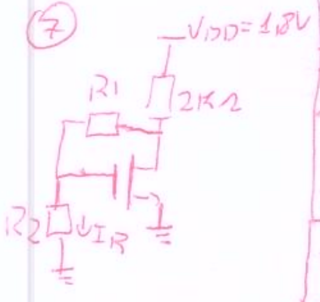
• $V_{DS} = 1{,}8 - (500 + 200) \cdot 0{,}5 \cdot 10^{-3} \Rightarrow V_{DS} = 1{,}55 V \geq V_{GS} - V_{TH}$ ↳ SAT ⇒ OK

• $V_{R2} = V_{GS} \Rightarrow R_2 = \frac{V_{R2}}{I_R} = \frac{V_{GS}}{I_R} \Rightarrow R_2 = \frac{0{,}6121}{0{,}5 \cdot 10^{-4}} \Rightarrow \boxed{R_2 = 1{,}2243 \cdot 10^4 \Omega}$

• $V_{R1} = 1{,}8 - V_{GS} - V_{200} = 1{,}8 - 0{,}6121 - 200 \cdot (\underbrace{I_D}_{0{,}5 \cdot 10^{-3}} + \frac{I_D}{10}) = 1{,}8 - 0{,}6121 - 200 \cdot 1{,}1 \cdot 0{,}5 \cdot 10^{-3}$

• $\boxed{V_{R1} = 1{,}1873 V} = R_1 \cdot 0{,}5 \cdot 10^{-4} \Rightarrow \boxed{R_1 = 2{,}1557 \cdot 10^{-4} \Omega}$

(7)



R_1 e R_2?

$I_D = 0{,}5 \cdot 10^{-3} A$

$\frac{W}{L} = \frac{50}{0{,}18}$

$I_R = \frac{I_D}{10} = 0{,}5 \cdot 10^{-4}$

$\mu n C_{ox} = 200 \cdot 10^{-6} A$

$\lambda = \emptyset$

$V_{TH} = 0{,}4 V$

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

$0{,}5 \cdot 10^{-3} = \frac{1}{2} 200 \cdot 10^{-6} \cdot \frac{50}{0{,}18} \cdot (V_{GS} - 0{,}4)^2$

$\boxed{V_{GS} = 0{,}5342 V} > V_{TH}$

$V_{DS} = 1{,}8 - 2000 \cdot 0{,}5 \cdot 10^{-3} \Rightarrow V_{DS} = 0{,}8V \geq V_{GS} - V_{TH}$ ↳ SAT ⇒ OK

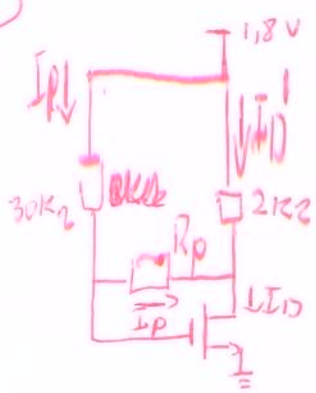
• $V_{GS} = V_{R2} = I_R R_2 \Rightarrow R_2 = \frac{V_{GS}}{I_R} = \frac{0{,}5342}{0{,}5 \cdot 10^{-4}} \Rightarrow \boxed{R_2 = 1{,}0683 \cdot 10^4 \Omega}$

• ~~$V_{R1} = 1{,}8 - 2000 I_D - R_2 \, I_R \, V_{GS} \Rightarrow V_{R1}$~~

• $V_{R1} = 1{,}8 - 2000 (\underbrace{I_D}_{0{,}5 \cdot 10^{-3}} + \underbrace{I_R}_{\frac{I_D}{10}}) - V_{GS} \Rightarrow$

$$\boxed{VR_1 = 0{,}1658V \rightarrow R_1 = \frac{VR_1}{IR_1} \rightarrow R_1 = 3316\Omega}$$

7-9



$R_p \to \infty \Rightarrow V_{GS} = V_{DS} + 100mV$ ↳ SAT

$\mu_n C_{ox} = 200 \cdot 10^{-6} A$

$V_{TH} = 0,4V$

$R_p < \infty \Rightarrow V_{GS} = V_{DS} + 50mV$

↳ SAT pq $V_{DS} = V_{GS} - 50 \cdot 10^{-3} \geq V_{GS} -$

$\frac{W}{L}$? ¿R_p?

• $R_p \leq 100\Omega$ $R_p \to \infty$

ID=.5unCox(W/L)(VGS-VTH)^2
IG=0 => VGS=1,8V

• $I_D = \frac{1}{2} \mu_n C_{ox} \cdot \frac{W}{L} (V_{GS} - V_{TH})^2$; $I_G = 0 \Rightarrow V_{GS} = 1,8V$

$I_D = \frac{1}{2} \cdot 200 \cdot 10^{-6} \cdot \frac{W}{L} (1,8 - 0,4)^2 \Rightarrow I_D = \frac{W}{L} \cdot 1,96 \cdot 10^{-4}$

• $V_{DS} = 1,8 - 2000 I_D$

$\underset{1,8}{V_{GS}} - 100 \cdot 10^{-3} = 1,8 - 2000 \cdot \frac{W}{L} \cdot 1,96 \cdot 10^{-4}$

$1,7 = 1,8 - 2 \cdot 1,96 \cdot 10^{-1} \frac{W}{L} \Rightarrow \boxed{\frac{W}{L} = 0,2551}$

- $R_p < \infty \Rightarrow V_{DS} = V_{GS} - \underbrace{5.10^{-2}}_{50\,mV}$

- $I_D' = \dfrac{1{,}8 - V_{DS}}{2000} \Rightarrow I_D' = \dfrac{1{,}8 - (V_{GS} - 5.10^{-2})}{2000} \Rightarrow I_D = \dfrac{1{,}8 - V_{GS} + 5.10^{-2}}{2.10^{3}}$

- $I_p = \dfrac{1{,}8 - V_{GS}}{30000} \Rightarrow I_p = \dfrac{1{,}8 - V_{GS}}{3.10^{4}}$

- $I_D = \frac{1}{2} \mu n C_{ox} \cdot \frac{W}{L} \cdot (V_{GS} - V_{TH})^2 \Rightarrow I_D = 2{,}551.10^{-5}(V_{GS} - 0{,}4)^2$

- $I_D = I_D' + I_p$

$$2{,}551.10^{-5}(V_{GS} - 0{,}4)^2 = \frac{1{,}8 - V_{GS} + 5.10^{-2}}{2.10^{3}} + \frac{1{,}8 - V_{GS}}{3.10^{4}}$$

$$2{,}551.10^{-5}.(V_{GS}^2 - 0{,}8V_{GS} + 0{,}16) = \frac{3.10^4(1{,}8 - V_{GS} + 5.10^{-2}) + 2.10^3(1{,}8 - V_{GS})}{6.10^7}$$

$$1{,}5306.10^3(V_{GS}^2 - 0{,}8V_{GS} + 0{,}16) = 5{,}4 10^4 - \underline{3.10^4}V_{GS} + 15.10^2 + 3{,}6.10^3 - \underline{2.10^3}V_{GS})$$

$$1{,}5306 V_{GS}^2.10^3 - 1{,}2245.10^3 V_{GS} + 244{,}898 = -3{,}2.10^4 V_{GS} + 5{,}91.10^4$$

$$1{,}5306.10^3 V_{GS}^2 + 3{,}0776.10^4 - 5{,}8855.10^4 = 0$$

~~$V_{GS} = 1{,}7852$~~

$$V_{GS} = \begin{cases} -21{,}8653 \\ \boxed{1{,}7586\,V} \end{cases}$$

~~$I_p = \frac{V_{GS} - V_{DS}}{1}$~~

$\Rightarrow I_D' = \dfrac{1{,}8 - V_{GS} + 50.10^{3}}{2000} \Rightarrow I_D' = 4{,}5705.10^{-5}$

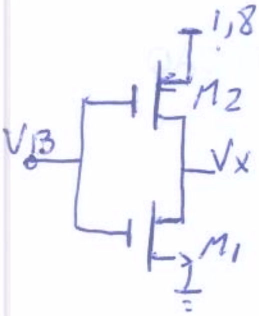
$\Rightarrow I_p = \dfrac{1{,}8 - V_{GS}}{30000} \Rightarrow I_p = 1{,}3804.10^{-6}$

$\Rightarrow I_D = 2{,}551.10^{-5}(V_{GS} - 0{,}4)^2 \Rightarrow I_D = 4{,}7086.10^{-5}$ → OK

$\Rightarrow I_D = I_D' + I_p \Rightarrow I_D = 4{,}7086.10^{-5}$

- $R_p = \dfrac{50.10^{-3}}{I_p} \Rightarrow \boxed{R_p = 3{,}6222.10^4\,\Omega}$

7,15



$\left(\frac{W}{L}\right)_1 = \frac{10}{0,18}$; $\left(\frac{W}{L}\right)_2 = \frac{30}{0,18}$; $\lambda = 0,1V^{-1}$; $V_x = 0,9$; V_B

$\mu_n C_{ox} = 200 \cdot 10^{-6}$
$\mu_p C_{ox} = 100 \cdot 10^{-6}$
$|V_{TH}| = 0,4$

$V_{GS1} = V_B$
$|V_{GS2}| = 1,8 - V_B$

$$\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_1 (V_{GS1} - V_{TH})^2 \cdot (1 + \lambda V_{DS1}) = \frac{1}{2}\mu_p C_{ox}\left(\frac{W}{L}\right)_2 (|V_{GS2}| - |V_{TH}|)^2 \cdot (1 + \lambda |V_{DS2}|)$$

$$200 \cdot 10^{-6} \cdot \frac{10}{0,18} \cdot (V_{GS1} - V_{TH})^2 \cdot (1 + \lambda \underbrace{V_{DS1}}_{V_x = 0,9}) = 100 \cdot 10^{-6} \cdot \frac{30}{0,18} \cdot (|V_{GS2}| - |V_{TH}|)^2 \cdot (1 + \lambda \underbrace{|V_{DS2}|}_{1,8 - V_x = 0,9})$$

$$2 \cdot (V_B - 0,4)^2 \cdot (1 + 0,1 \cdot 0,9) = 3 \cdot (\underbrace{1,8 - V_B - 0,4}_{1,4})^2 \cdot (1 + 0,1 \cdot 0,9)$$

$$2 \cdot (V_B^2 - 0,8 V_B + 0,16) = 3 \cdot (V_B^2 - 2,8 V_B + 1,96)$$

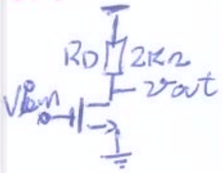
$$V_B^2 - 6,8 \cdot V_B + 6,2 = 0$$

$$V_B = \begin{cases} 5,8495 \Rightarrow V_{DS1} < 5,84 - 0,4 \Rightarrow \text{Triodo} \\ 0,9505 \Rightarrow V_{DS1} < 0,9505 - 0,4 \Rightarrow \text{Triodo} \end{cases}$$

$$V_B = \begin{cases} \cancel{5,8495} \Rightarrow \underbrace{V_{DS1}}_{0,9} < 5,84 - 0,4 \Rightarrow \text{Triodo} \\ 0,9505 \Rightarrow \begin{cases} \underbrace{0,9}_{V_{DS1}} > 0,9505 - 0,4 \Rightarrow SAT \Rightarrow OK \\ \underbrace{|V_{DS2}|}_{0,9} > \underbrace{(1,8 - 0,9505)}_{|V_{G2}|} - 0,4 \Rightarrow SAT \Rightarrow OK \end{cases} \end{cases}$$

$$\Rightarrow \boxed{V_B = 0,9505V}$$

7.17



$\boxed{\begin{array}{l} \lambda = 0 \\ I_D = 0{,}5\,mA \\ \frac{W}{L} = \frac{30}{0{,}18} \\ \mu_n C_{ox} = 200\cdot10^{-6} \\ V_{TH} = 0{,}4V \end{array}}$

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

$0{,}5\cdot10^{-3} = \frac{1}{2}\cdot 200\cdot10^{-6}\cdot\frac{30}{0{,}18}\cdot(V_{GS}-0{,}4)^2$

$(V_{GS}-0{,}4)^2 = 0{,}03 \Rightarrow \boxed{V_{GS} = 0{,}5732V}$

$\Rightarrow V_{DS} = 2000\cdot0{,}5\cdot10^{-3} \Rightarrow V_{DS} = 1V \geq 0{,}5732-0{,}4 \Rightarrow SAT \Rightarrow OK$

$\Rightarrow g_m = \frac{2I_D}{V_{GS}-V_{TH}} = \frac{2\cdot0{,}5\cdot10^{-3}}{0{,}5732-0{,}4} \Rightarrow \boxed{g_m = 5{,}7735\,mS}$

$\Rightarrow$ $v_1 = v_{in}$

$v_{out} = -g_m v_1\cdot2\cdot10^3 \Rightarrow A_v = -\overset{5{,}7735\cdot10^{-3}}{g_m}\cdot2\cdot10^3$

$\boxed{A_v = 11{,}5470}$

7.19 $A_v = 5$ $P \leq 1mW \Rightarrow 1{,}8\cdot I_D \leq 1mW \Rightarrow \boxed{I_D \leq 5{,}5556\cdot10^{-4}A}$

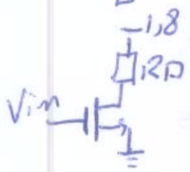
$\frac{W}{L} \leq \frac{200}{0{,}18}$

$\mu_n C_{ox} = 200\cdot10^{-6}\,\mu A/V^2$

$V_{TH} = 0{,}4V$

$A_v = -5$

↳ Ex 7.17

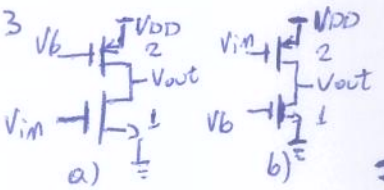


$A_v = -g_m R_D \Rightarrow -5 = -g_m\cdot R_D \Rightarrow -5 = -\sqrt{2\mu_n C_{ox}\frac{W}{L}\cdot I_D}\cdot R_D$

$R_D = \frac{5}{\sqrt{2\mu_n C_{ox}\frac{W}{L}I_D}} \Rightarrow$ Como $I_D \leq 5{,}556\cdot10^{-4}A$ e $\frac{W}{L} \leq \frac{200}{0.18} \Rightarrow R_D \geq \frac{5}{\sqrt{2\,200\cdot10^{-6}\cdot\frac{200}{0{,}18}\cdot5{,}55\ldots}}$

$\Rightarrow \boxed{R_D \geq 1{,}0062\cdot10^3\,\Omega}$

7.23



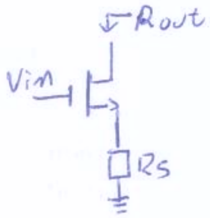
$\Rightarrow$ Para $I_{Da} = I_{Db}$ e $\left(\frac{W}{L}\right)_a = \left(\frac{W}{L}\right)_b$, as topologias são idênticas

$A_{va} = -g_{m1}(r_{o1}\|r_{o2})$ e $A_{vb} = -g_{m2}(r_{o1}\|r_{o2})$ → F.C. com fonte de corrente como carga

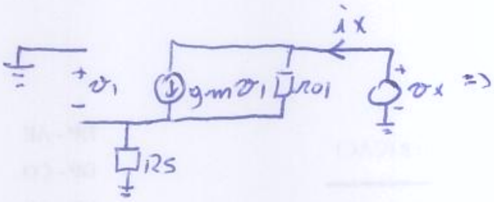
$\Rightarrow$ Como $g_{m1} > g_{m2}$ $(\mu_n C_{ox_a} > \mu_p C_{ox_b}) \Rightarrow A_{va} > A_{vb}$

∴ A topologia a deve ser utilizada para maximizar o gan

7.33 → Todos casos remetem ao seguinte caso:



⇒



⇒ $v_x = R_S i_x + (i_x - g_m v_1) r_{o1}$

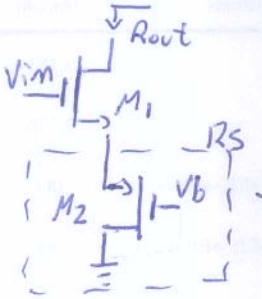
$v_1 = -R_S i_x$

$v_x = R_S i_x + (i_x + R_S i_x g_m) . r_{o1} \Rightarrow v_x = R_S i_x + (1 + R_S g_m) . i_x . r_{o1}$

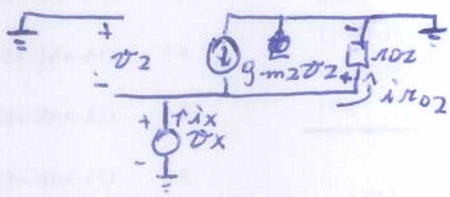
$v_x = i_x . [R_S + (1 + R_S g_m) r_{o1}] \Rightarrow R_{out} = \frac{v_x}{i_x} = R_S + r_{o1} + r_{o1} R_S g_m$

$$\boxed{R_{out} = r_o + R_S(1 + r_o g_m)}$$

a)



⇒



• $v_x = -v_2$
• $v_{r_{o2}} = v_x$
$\Rightarrow v_x = -v_2 = v_{r_{o2}}$

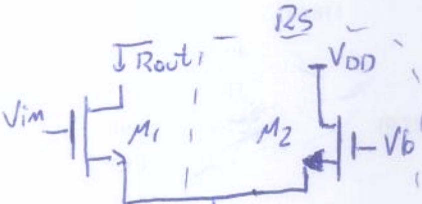
• $i_x = i_{r_{o2}} - g_{m2} v_2$

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

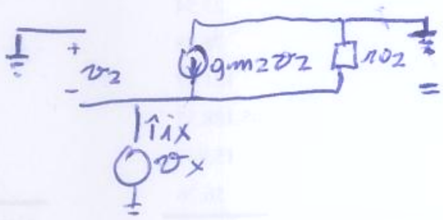
$i_x = \frac{v_x}{r_{o2}} + g_{m2} v_x \Rightarrow \frac{v_x}{i_x} = \frac{1}{\left(\frac{1}{r_{o2}} + g_{m2}\right)}$ $\Rightarrow \boxed{R_S = \frac{v_x}{i_x} = r_{o2} \| \frac{1}{g_{m2}}}$

$\therefore R_{out} = r_{o1} + \left(r_{o2} \| \frac{1}{g_{m2}}\right) . (1 + r_{o1} g_{m1})$

b)



⇒



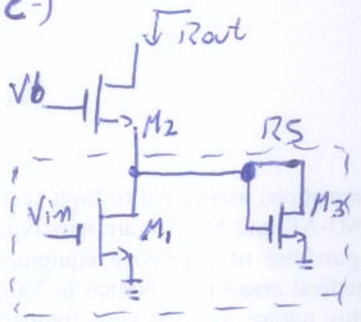
⇒ Idem ao a)

$$\boxed{R_S = r_{o2} \| \frac{1}{g_{m2}}}$$

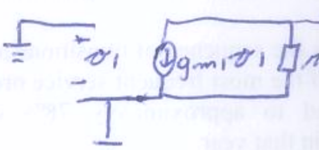
$\therefore R_{out} = r_{o1} + \left(r_{o2} \| \frac{1}{g_{m2}}\right) . (1 + r_{o1} g_{m1})$

c-)

obs: No modelo de pequenos sinais $V_b = V_{in} = \emptyset$, portanto, vou considerar $\boxed{R_{S_2} = R_{M1} // R_{M3}}$, ao invés de $R_{D_1} = R_{M2} // R_{M3}$

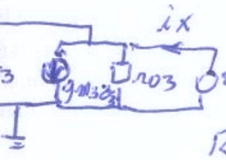


* R_{M1}



$\Rightarrow R_{M1} = r_{o1}$

* R_{M3}



$v_x = v_3$

$i_x = g_{m3} v_3 + \frac{v_3}{r_{o3}}$

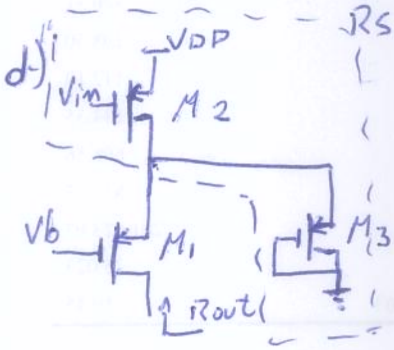
$i_x = v_3 \left(g_{m3} + \frac{1}{r_{o3}}\right)$

$R_{M3} = \left(\frac{1}{g_{m3}} // r_{o3}\right)$

* $R_{S2} = r_{o1} // r_{o3} // \frac{1}{g_{m3}}$

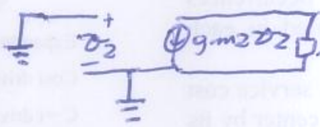
* $\boxed{R_{out} = r_{o2} + \left(r_{o1} // r_{o3} // \frac{1}{g_{m3}}\right) \cdot \left(1 + r_{o2} g_{m2}\right)}$

d-)



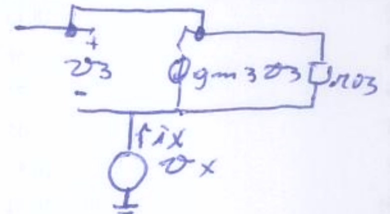
obs: ver obs 7.33-c $\Rightarrow R_S = R_{M2} // R_{M3}$

* R_{M2}



$\Rightarrow \boxed{R_{M2} = r_{o2}}$

* R_{M3} $\Rightarrow$ idem ao ~~[illegible]~~ 7.33a

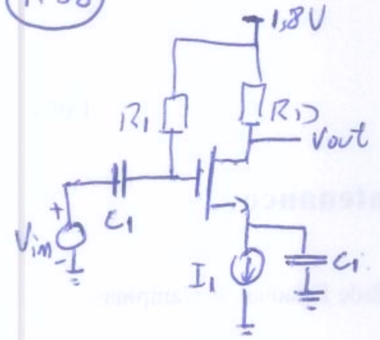


$\boxed{R_{M3} = r_{o3} // \frac{1}{g_{m3}}}$

$\Rightarrow R_S = \left(r_{o3} // \frac{1}{g_{m3}}\right) // r_{o2}$

$\Rightarrow \boxed{R_{out} = r_{o1} + \left(r_{o3} // \frac{1}{g_{m3}} // r_{o2}\right) \cdot \left(1 + r_{o1} g_{m1}\right)}$

7.38



$I_D = I_1 = 1\,mA$ $\lambda = \phi$ $V_{TH} = 0{,}4V$

$\mu_n C_{ox} = 200 \cdot 10^{-6}\, A/V^2$ $R_{D_{MAX}} = ?$

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

• Limite da Saturação

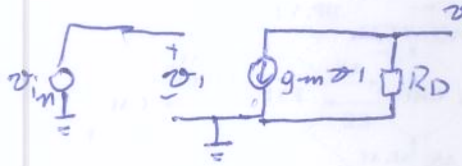
$V_{DS} \geq V_{GS} - V_{TH}$

$V_D - \cancel{V_S} = \underbrace{V_G}_{1{,}8V\,(I_G=\phi)} - \cancel{V_S} - \underbrace{V_{TH}}_{0{,}4} \Rightarrow \boxed{V_D = 1{,}4V}$

• ~~$I_D = \frac{V_D}{R_D} \Rightarrow 1 \cdot 10^{-3} = \frac{1{,}4}{R_D} \Rightarrow R_D$~~

• $I_D = \frac{1{,}8 - V_D}{R_D} \Rightarrow 1 \cdot 10^{-3} = \frac{1{,}8 - 1{,}4}{R_D} \Rightarrow \boxed{R_D = 400\,\Omega}_{M}$

b.) $A_v = -5$

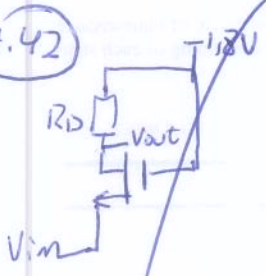


$v_{out} \Rightarrow A_v = \frac{v_{out}}{v_{in}} = -g_m R_D$

$5 = g_m \cdot 400 \Rightarrow \boxed{g_m = 0{,}0125\ S}$

$g_m = \sqrt{2\mu_n C_{ox}\frac{W}{L} I_D} \Rightarrow 0{,}0125 = \sqrt{2 \cdot \underbrace{\mu_n C_{ox}}_{200\cdot 10^{-6}} \cdot \frac{W}{L} \cdot 1 \cdot 10^{-3}} \Rightarrow \boxed{\frac{W}{L} = 390{,}625}$

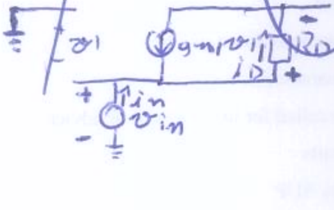
7.42



• $I_{D\,max}$? • $\mu_n C_{ox} = 200 \cdot 10^{-6}\, A/V^2$

• $R_{in} = 500\,\Omega$ • $\lambda = \phi$

• $R_{out} = 500\,\Omega$

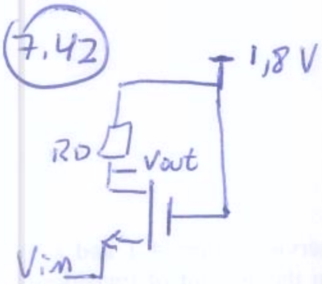


$v_{out} \Rightarrow v_1 = -v_{in}$

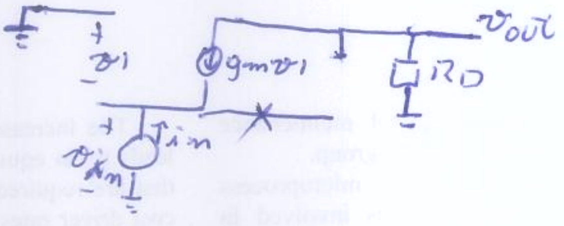
~~$v_{out} = R_D \cdot$~~

$v_{out} = v_{in} - v_{RD} = v_{in} - R_D i_d = v_{in} - R_D(i_{in} - g_m v_1)$

7.42



$\Rightarrow$



• A_v

$$\left.\begin{array}{l} v_1 = -v_{in} \\ v_{out} = -g_m v_1 \cdot R_D \end{array}\right\} \Rightarrow \boxed{A_v = \frac{v_{out}}{v_{in}} = g_m R_D}$$

• R_{in}

$$i_{in} = -g_m v_1 \Rightarrow R_{in} = \frac{v_{in}}{i_{in}} \Rightarrow R_{in} = \frac{1}{g_m}$$

• R_{out}

$$\rightarrow v_{in} = 0 \Rightarrow g_m v_1 = 0 \Rightarrow R_{out} = R_D$$

• $R_{in} = 50\,\Omega$ • $\mu_n C_{ox} = 200 \cdot 10^{-6}\ \mu A/V^2$

• $R_{out} = 500\,\Omega$ • $\lambda = 0$

• $R_D = R_{out} \Rightarrow \boxed{R_D = 500\,\Omega}$

• I_D máx

Limite da saturação $\Rightarrow$ saturação $\Rightarrow V_{DS} \geq V_{GS} - V_{TH} \Rightarrow V_D \geq V_G - 0{,}4$

$V_{TH} = 0{,}4$; $I_G = 0$

$$\Rightarrow (1{,}8 - 500 \cdot I_D) \geq (1{,}8 - 0{,}4) \Rightarrow I_D \leq \frac{0{,}4}{500} \Rightarrow \boxed{I_D \leq 8 \cdot 10^{-4} A}$$

b) $g_m = \sqrt{2\mu_n C_{ox} \frac{W}{L} I_D} \Rightarrow g_m = \sqrt{2 \cdot 200 \cdot 10^{-6} \cdot \frac{W}{L} \cdot 8 \cdot 10^{-4}}$

$I_D \to$ máximo

~~$A_v = 5 = g_m R_D \Rightarrow g_m = \frac{5}{400} \Rightarrow g_m = 0{,}0125$~~

$$R_{in} = \frac{1}{g_m} = 50\,\Omega \Rightarrow \boxed{g_m = 0{,}025}$$

$$\boxed{\frac{W}{L} = 1250}$$

$$\cancel{0{,}0125}\ 0{,}02 = \sqrt{2 \cdot 200 \cdot 10^{-6} \cdot \frac{W}{L} \cdot 8 \cdot 10^{-4}}$$

$\Downarrow$

$\frac{W}{L} = 1250$

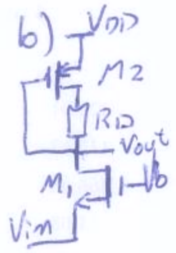
$\frac{W}{L} \to$ máx

$L \to$ limite saturação

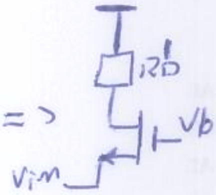
c) $A_v = g_m R_D = 1250 \cdot 500 \Rightarrow \boxed{A_v = 10}$

(7.44) $\lambda = 0$

b)



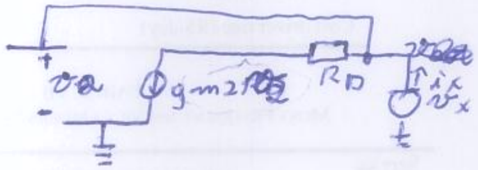
$\Rightarrow$



$\Rightarrow A_v = g_{m1} R'_D$

↳ ver $\boxed{7.42}$

* R'_D

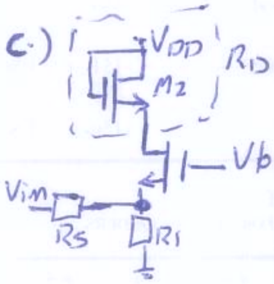


$v_2 = v_x$

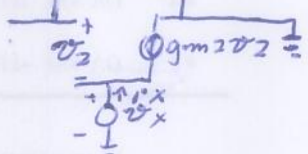
$i_x = g_{m2} v_2 \Rightarrow R'_D = \frac{1}{g_{m2}}$

$\therefore A_v = g_{m1} \cdot R'_D \Rightarrow \boxed{A_v = \frac{g_{m1}}{g_{m2}}}$

c.)

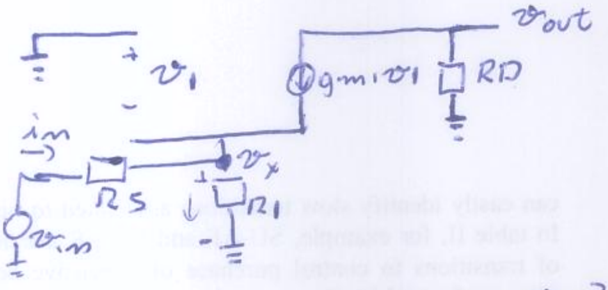


• R_D



$v_x = -v_2$

$i_x = -g_{m2} v_2 \Rightarrow R_D = \frac{1}{g_{m2}}$



$$v_{out} = -g_{m1} v_1 RD$$

$$v_x = -v_1 \Rightarrow v_{out} = g_{m1} v_x RD \Rightarrow \frac{v_{out}}{v_x} = g_{m1} RD \Rightarrow \frac{v_{out}}{v_x} = \frac{g_{m1}}{g_{m2}}$$

$$\cancel{v_i = v_x + RS\, i_{in} = v_x + RS\left(\frac{v_x}{R_1} \cdots\right)}$$

$$v_{in} = v_{RS} + v_x = RS\, i_{in} + v_x = RS \cdot \left(\frac{v_x}{R_1} + g_{m1} v_1\right) + v_x = RS\left(\frac{v_x}{R_1} + g_{m1} v_x\right) + v_x$$

$$v_{in} = RS\, v_x \cdot \left(\frac{1}{R_1} + g_{m1}\right) + v_x$$

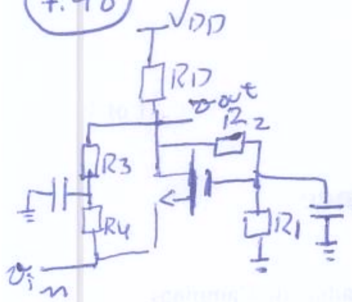
$$\cancel{\frac{v_x}{v_{in}} = \frac{1}{RS} \cdot \left(R_1 \| \frac{1}{g_{m1}}\right)} \Rightarrow v_{in} = v_x\left[RS \cdot \left(\frac{1}{R_1} + g_{m1}\right) + 1\right] \Rightarrow$$

$$\cancel{A_v = \frac{v_x}{v_{in}} \cdot \frac{v_{out}}{v_x} = \frac{1}{RS}\left(R_1 \| \frac{1}{g_{m1}}\right) \cdot g_{m1} RD}$$

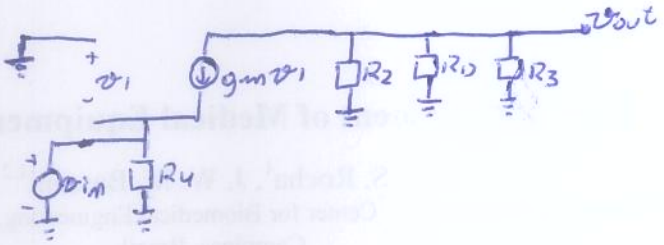
$$\Rightarrow \frac{v_x}{v_{in}} = \frac{1}{RS \cdot \left(\frac{1}{R_1} + g_{m1}\right) + 1} \cdot \frac{\left(\frac{1}{R_1} + g_{m1}\right)^{-1}}{\left(\frac{1}{R_1} + g_{m1}\right)^{-1}} \Rightarrow \frac{v_x}{v_{in}} = \frac{R_1 \| \frac{1}{g_{m1}}}{RS + R_1 \| \frac{1}{g_{m1}}}$$

$$\Rightarrow \boxed{A_v = \frac{v_x}{v_{in}} \cdot \frac{v_{out}}{v_x} = \frac{R_1 \| \frac{1}{g_{m1}}}{RS + R_1 \| \frac{1}{g_{m1}}} \cdot \frac{g_{m1}}{g_{m2}}}$$

(7.48)



$\Rightarrow$



$\Rightarrow v_{out} = -g_m v_1 \cdot (R_2 \| R_3 \| R_D)$

$\Rightarrow v_{in} = -v_1$

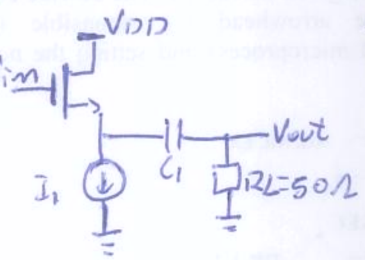
$$\boxed{\Rightarrow A_v = \frac{v_{out}}{v_{in}} = g_m (R_2 \| R_3 \| R_D)}$$

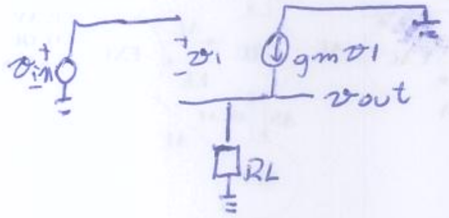
(7.54)

$A_v = 0{,}8$ $\quad \frac{W}{L}?$

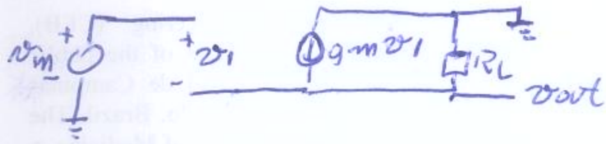
$P = 3mW$ $\quad \mu_n C_{ox} = 200 \cdot 10^{-6} A/V^2$

$\lambda = 0$





$\Rightarrow$



$v_{out} = g_m v_1 R_L$

$v_{in} = v_{out} + v_1$

$v_{in} = g_m v_1 R_L + v_1$

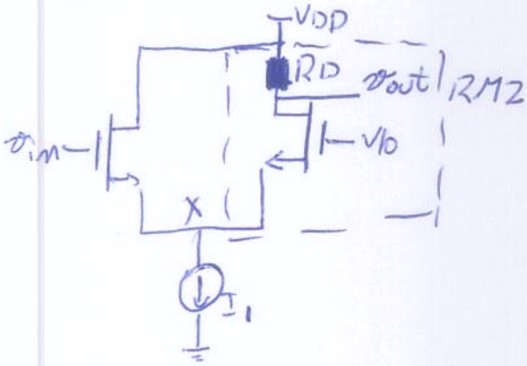
$v_{in} = v_1 (g_m R_L + 1)$

$$A_v = \frac{v_{out}}{v_{in}} = \frac{R_L g_m}{g_m R_L + 1} \quad \begin{matrix} \cdot g_m^{-1} \\ \cdot g_m^{-1} \end{matrix} \Rightarrow \boxed{A_v = \frac{R_L}{R_L + \frac{1}{g_m}}}$$

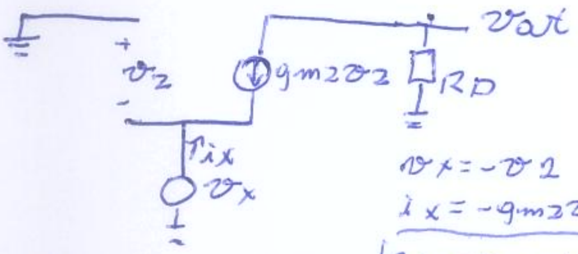
$$0{,}8 = \frac{50}{50 + \frac{1}{g_m}} \Rightarrow 50 \cdot 0{,}8 + 0{,}8 \cdot \frac{1}{g_m} = 50 \Rightarrow \boxed{g_m = 0{,}08S}$$

- $P = 1{,}8 I_D \Rightarrow 3 \cdot 10^{-3} = 1{,}8 \cdot I_D \Rightarrow \boxed{I_D = 1{,}6667 \cdot 10^{-3} A}$
- $g_m = \sqrt{2 \mu_n C_{ox} \frac{W}{L} I_D} \Rightarrow 0{,}08 = \sqrt{2 \cdot 200 \cdot 10^{-6} \cdot \frac{W}{L} \cdot 1{,}6667 \cdot 10^{-3}} \Rightarrow \boxed{\frac{W}{L} = 9600}$

(7.56) $X = \emptyset$



*RM2



$v_x = -v_2$

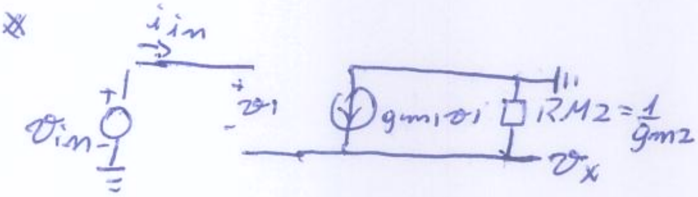
$i_x = -g_{m2} v_2$

$$\boxed{R_{M2} = \frac{v_x}{i_x} = \frac{1}{g_{m2}}}$$

$$v_{out} = -g_{m2} v_2 \cdot R_D$$

$$\boxed{\frac{v_{out}}{v_x} = g_{m2} R_D}$$

*



$$v_x = g_{m1} v_1 \cdot \frac{1}{g_{m2}}$$

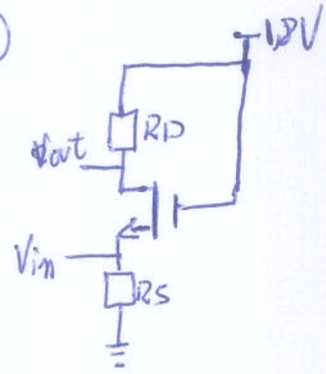
$$v_{in} = v_1 + g_{m1} v_1 \frac{1}{g_{m2}}$$

$$v_{in} = v_1\left(1 + \frac{g_{m1}}{g_{m2}}\right)$$

$$\frac{v_x}{v_{in}} = \frac{\frac{g_{m1}}{g_{m2}} \cdot g_{m1}^{-1}}{1 + \frac{g_{m1}}{g_{m2}} \cdot g_{m1}^{-1}} \Rightarrow \frac{v_x}{v_{in}} = \frac{\frac{1}{g_{m2}}}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}}$$

$$\rightarrow A_v = \frac{v_{out}}{v_x} \cdot \frac{v_x}{v_{in}} = \frac{\frac{1}{g_{m2}}}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}} \cdot g_{m2} R_D \Rightarrow \boxed{A_v = \frac{R_D}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}}}$$

(7.68)



$\lambda = 0$

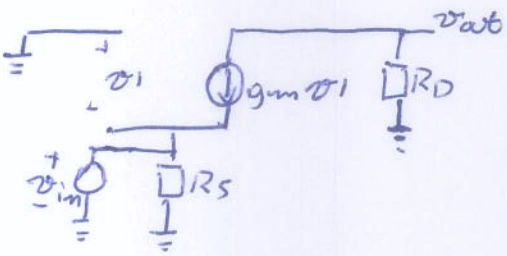
$A_v = 4$ $\qquad \mu_n C_{ox} = 200 \cdot 10^{-6}\,A/V^2$

$P = 2\,mW$

• $P = 1{,}8 I_D \Rightarrow I_D = \frac{P}{1{,}8} = \frac{2 \cdot 10^{-3}}{1{,}8} \Rightarrow \boxed{I_D = 1{,}1111 \cdot 10^{-3}\,A}$

• $V_{DS} = V_{GS} - \underbrace{V_{TH}}_{0{,}4V} + 0{,}1 \Rightarrow \boxed{V_{DS} = \underbrace{V_G}_{1{,}8V} - 0{,}3} \Rightarrow \boxed{V_D = 1{,}5V}$

• $V_D = 1{,}8 - R_D I_D \Rightarrow R_D = \frac{V_D - 1{,}8}{-I_D} = \frac{1{,}5 - 1{,}8}{-1{,}1111 \cdot 10^{-3}} \Rightarrow \boxed{R_D = 270\Omega}$ *



$v_{in} = -v_1$

$v_{out} = -g_m v_1 R_D$

$\boxed{A_v = \frac{v_{out}}{v_{in}} = g_m R_D}$

$4 = g_m \underbrace{R_D}_{270} \Rightarrow \boxed{g_m = 0{,}01485}$

• $\underbrace{g_m}_{0{,}0148} = \sqrt{2 \cdot \mu_n C_{ox} \frac{W}{L} I_D} = \sqrt{2 \cdot 200 \cdot 10^{-6} \cdot \frac{W}{L} \cdot 1{,}111 \cdot 10^{-3}} \Rightarrow$

$\Rightarrow \boxed{\frac{W}{L} = 493{,}8272}$ *

• $I_D = \frac{1}{2} \mu_n C_{ox} \cdot \frac{W}{L} \cdot (V_{GS} - V_{TH})^2 \Rightarrow 1{,}1111 \cdot 10^{-3} = \frac{1}{2} \cdot 200 \cdot 10^{-6} \cdot 493{,}8272 (V_{GS} - 0{,}4)^2$

$0{,}0494 (V_{GS} - 0{,}4)^2 = 1{,}1111 \cdot 10^{-3} \Rightarrow \boxed{V_{GS} = 0{,}55V}$

• $V_{RS} = 1{,}8 - V_{GS} \Rightarrow \boxed{V_{RS} = V_S = 1{,}25V}$

• $R_S = \frac{V_{RS}}{I_D} = \frac{1{,}25}{1{,}1111 \cdot 10^{-3}} \Rightarrow \boxed{R_S = 1125\Omega}$ *

• Resp:

$R_D = 270\Omega$

$R_S = 1125\Omega$

$\frac{W}{L} = 493{,}8272$