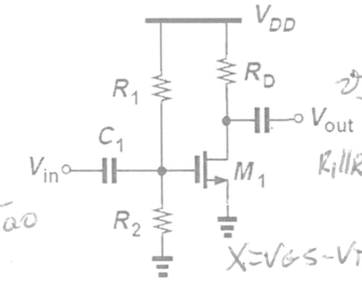
EE-530: - Eletrônica Básica I
Prova 2
Nome:________________________ **RA:**____________

obs: Prova sem consulta. Pode usar calculadora. Respostas a lápis serão corrigidas, mas não aceito reclamação da correção das mesmas.

1) Dados V_{DD}=18V, $\mu_n C_{ox}$=100 μA/V^2, λ=0, V_{TH}=0,5V, W/L=10/0,18 e Zin=10MΩ. 35
Projete um amplificador fonte comum com ganho de tensão igual a -5 de modo a obter a máxima excursão simétrica de saída.



v_{in} $R_1 // R_2$; $+v_1$ $g_m v_1$ R_D $-v_{out}$

$\to v_{in} = v_1$

$v_{out} = -g_m R_D v_1$

$\boxed{A_v = -g_m R_D}$

$\to \boxed{Z_{in} = R_1 // R_2}$

$\to$ Max. excursão

$X = V_{GS} - V_{TH}$

$\mu_n C_{ox} \frac{W}{L} = K$

- $V_{DS} = \frac{V_{DD} + (V_{GS} - V_{TH})}{2}$ (1) $\Rightarrow V_{DS} = \frac{V_{DD} + X}{2}$
- $V_{DS} = V_{DD} - R_D I_D$ (2) $\Rightarrow V_{DS} = V_{DD} - R_D I_D$
- $I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})^2$ (3) $\Rightarrow I_D = \frac{1}{2} K \cdot X^2$
- $|A_v| = g_m \cdot R_D \Rightarrow R_D = \frac{|A_v|}{g_m}$ (4) $\Rightarrow R_D = |A_v| / g_m$
- $g_m = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})$ (5) $\Rightarrow g_m = K \cdot X$
- (5) $\to$ (4) $\Rightarrow \boxed{R_D = \frac{|A_v|}{K X}}$ (6)
- (1) = (2) $\Rightarrow \frac{V_{DD} + X}{2} = V_{DD} - R_D I_D \overset{(3)}{\Rightarrow} \frac{V_{DD} + X}{2} = V_{DD} - R_D \frac{1}{2} K X^2$

$\overset{(4)}{\Rightarrow} \frac{V_{DD} + X}{2} = V_{DD} - \frac{|A_v|}{\cancel{K X}} \cdot \frac{\cancel{K} X^2}{2} \Rightarrow V_{DD} + X = 2 V_{DD} - \frac{2 |A_v| \cdot X}{2}$

$X (1 + |A_v|) = V_{DD} \Rightarrow X = \frac{V_{DD}}{1 + |A_v|} = \frac{18}{1 + 5} \Rightarrow \boxed{X = 3 \, V}$

$\Downarrow$

$V_{GS} - V_{TH} = 3 \Rightarrow \boxed{V_{GS} = 3{,}5 \, V}$

- (3) $\Rightarrow I_D = \frac{1}{2} \cdot 100 \cdot 10^{-6} \cdot \frac{10}{0{,}18} \cdot X^2 \Rightarrow I_D = 5{,}5556 \cdot 10^{-3} \cdot 3^2 \Rightarrow \boxed{I_D = 25 \, mA}$
- (5) $\Rightarrow g_m = 100 \cdot 10^{-6} \cdot \frac{10}{0{,}18} \cdot X \Rightarrow \boxed{g_m = 16{,}7 \, mS}$
- (4) $\Rightarrow R_D = \frac{|A_v| \to 5}{g_m} \Rightarrow \boxed{R_D = 300 \, \Omega}$
- $\begin{cases} Z_{in} = R_1 // R_2 \Rightarrow \frac{1}{10 \cdot 10^6} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow \frac{R_1 R_2}{R_1 + R_2} = 10 \cdot 10^6 \Rightarrow \boxed{R_1 + R_2 = \frac{R_1 \cdot R_2}{10 \cdot 10^6}} \\ V_{GS} = \frac{R_2}{R_1 + R_2} \cdot V_{DD} \Rightarrow 3{,}5 = \frac{R_2 \cdot 18}{R_1 + R_2} \Rightarrow 3{,}5 = \frac{\cancel{R_2} \, 18}{\frac{R_1 \cdot \cancel{R_2}}{10 \cdot 10^6}} \end{cases}$

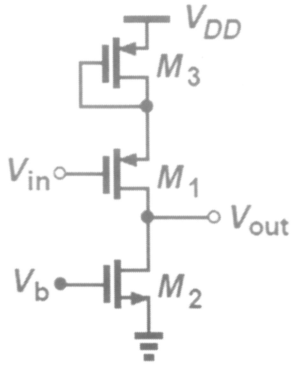
$\Rightarrow \boxed{R_2 = 12{,}4 \, M\Omega}$

$\Rightarrow \boxed{R_1 = 51{,}4 \, M\Omega}$

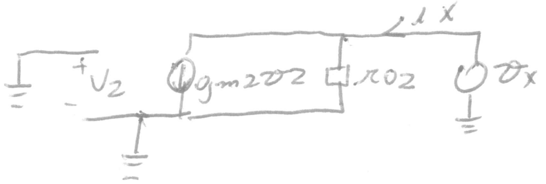
2) Se $\lambda \neq 0$, determine o ganho e as impedâncias de entrada e saída do circuito abaixo. 10'

$\lambda_1 = \emptyset$

λ_2 e $\lambda_3 \neq \emptyset$



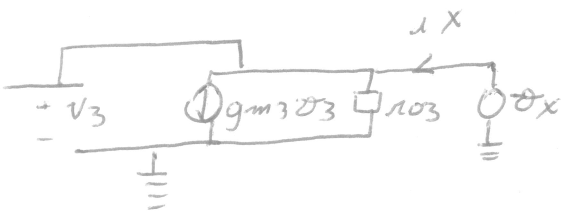
• Z_{M2}



$v_2 = 0 \Rightarrow g_{m2} v_2 = \emptyset$

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

• Z_{M3}



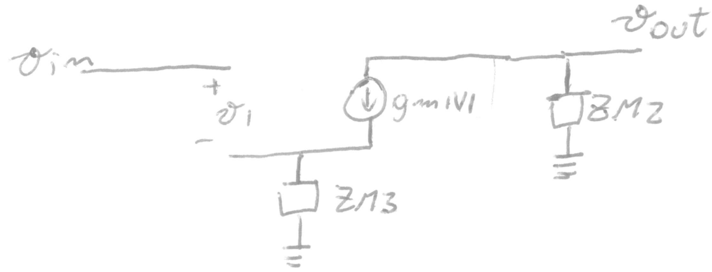
$v_x = v_3$

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

$i_x = v_3 \cdot (r_{o3}^{-1} + g_{m3})$

$Z_{M3} = \frac{v_x}{i_x} = \frac{1}{\frac{1}{r_{o3}} + g_{m3}} \Rightarrow \boxed{Z_{M3} = r_{o3} // 1/g_{m3}}$

•



• $v_{out} = -g_{m1} v_1 Z_{M2}$

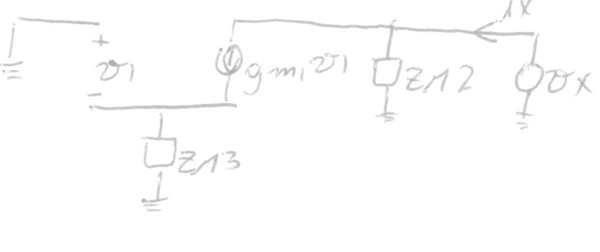
• $v_{in} = v_1 + g_{m1} v_1 \cdot Z_{M3}$
$= v_1 (1 + g_{m1} Z_{M3})$

$A_v = \frac{-g_{m1} Z_{M2}}{1 + g_{m1} Z_{M3}} \frac{\cdot g_{m1}^{-1}}{\cdot g_{m1}^{-1}} \Rightarrow \boxed{A_v = \frac{-Z_{M2}}{\frac{1}{g_{m1}} + Z_{M3}}} = \boxed{\frac{-r_{o2}}{\frac{1}{g_{m1}} + r_{o3} // 1/g_{m3}}}$

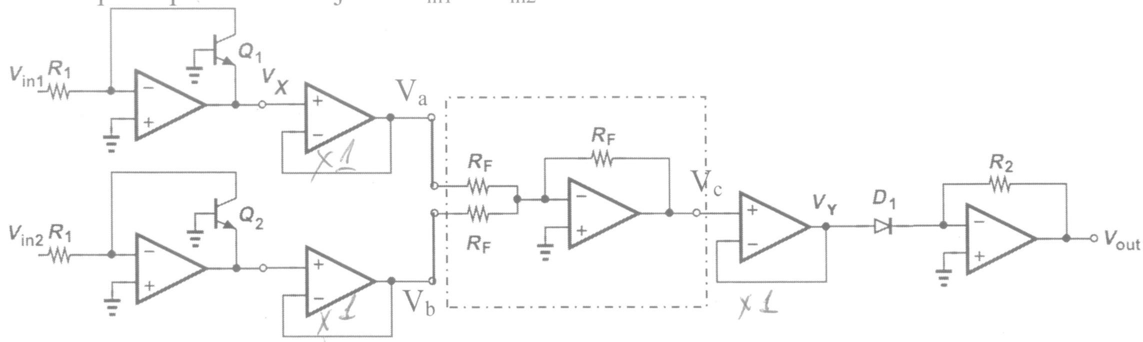
• $Z_{in} = \infty$

• $Z_{out} \Rightarrow v_{in} = \emptyset \Rightarrow v_1 = \emptyset \Rightarrow g_{m1} v_1 = \emptyset \Rightarrow \boxed{Z_{out} = Z_{M2}}$

$\boxed{Z_{out} = r_{o2}}$



3) a)Determine V_X em função de V_{in1} ($V_A=\infty$).
b) Determine V_{out} em função de V_Y. Considere o diodo como não ideal (modelo exponencial).
c) Determine V_c em função de V_a e V_b
d) Dado $I_{QS1}= I_{QS2}=10^{-8}$ A, $I_{DS1}=10^{-12}$ A e $R_1=10000\Omega$, calcule o valor de R_2, para que a saída seja ~ $-V_{in1} \times V_{in2}$.



a)

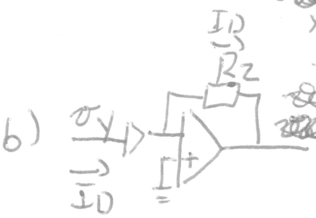

$I_{C_1} = I_{SQ_1}\cdot\exp\left(\frac{V_{BE}}{V_T}\right)$

$I_{R_1} = \frac{v_{in}}{R_1}$

$v_X = -V_{BE}$

$I_{R1} = I_{C1} \Rightarrow \frac{v_{in}}{R_1} = I_{SQ_1}\exp\left(-\frac{V_X}{V_T}\right) \Rightarrow \exp\left(-\frac{V_X}{V_T}\right) = \frac{v_{in}}{R_1 I_{SQ_1}}$

$\boxed{v_X = -V_T \ln\left(\frac{v_{in}}{R_1 I_{SQ_1}}\right)}$

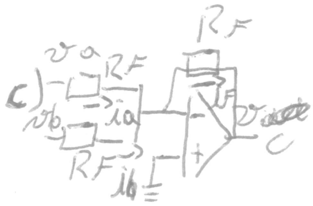
b)


$I_D = I_{DS1}\exp\frac{V_D}{V_T}$

$I_D = -\frac{v_{out}}{R_2}$

$V_Y = V_D$

$\boxed{v_{out} = -R_2 I_{DS1}\exp\left(\frac{V_Y}{V_T}\right)}$

c)


- $i_F = \frac{v_c}{R_F}$
- $i_a = \frac{v_a}{R_F}$
- $i_b = \frac{v_b}{R_F}$
- $i_F = i_a + i_b$

$-\frac{v_c}{R_F} = \frac{v_a}{R_F} + \frac{v_b}{R_F} \Rightarrow \boxed{v_c = -(v_a+v_b)}$

d) $V_Y = -(V_a+V_b) = -\left[-V_T\ln\left(\frac{v_{in1}}{R_1 I_{SQ_1}}\right) - V_T\ln\left(\frac{v_{in2}}{R_1 I_{SQ2}}\right)\right] = V_T\ln\left(\frac{v_{in1}}{R_1 I_{SQ_1}}\cdot\frac{v_{in2}}{R_2 I_{SQ2}}\right)$

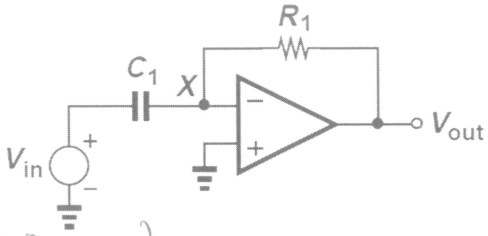
$v_{out} = -R_2 I_{DS1}\exp\left(\frac{V_Y}{V_T}\right) = -R_2 I_{DS1}\cdot\exp\left[\ln\left(\frac{v_{in1}}{R_1 I_{QS1}}\cdot\frac{v_{in2}}{R_1 I_{QS2}}\right)\right]$

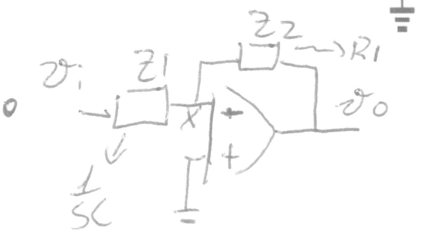
$v_{out} = -R_2\cdot 10^{-12}\,\frac{v_{in1}\cdot v_{in2}}{10^4 10^{-8}\cdot 10^4\cdot 10^{-8}} \Rightarrow R_2 = \frac{10^{-8}}{10^{-12}} \Rightarrow \boxed{R_2 = 10^4\,\Omega}$

10''

4) a) Determine $V_{out}(s)$em função de $V_{in}(s)$um diferenciador inversor. Considere $A_0=\infty$. 2''

b) Determine $V_{out}(s)$em função de $V_{in}(s)$ de um diferenciador inversor. Considere $A_0<\infty$. 8''





a) $\Rightarrow \frac{v_i}{Z_1} = \frac{-v_o}{Z_2} \Rightarrow v_o = \frac{-Z_2}{Z_1} v_{in}$

$\Rightarrow V_o(s) = \frac{-R_1}{1/SC} \cdot V_{in}(s) \Rightarrow \boxed{V_o(s) = -R_1 C S V_{in}(s)}$

b) $v_o = (v_+ - v_-) \cdot A_0 \Rightarrow v_o = (0 - v_x) \cdot A_0 \Rightarrow \boxed{v_o = -v_x A_0}$

$\frac{v_i - v_x}{Z_1} = \frac{v_x - v_o}{Z_2} \Rightarrow v_i Z_2 - v_x Z_2 = v_x Z_1 - v_o Z_1$

$v_i Z_2 = \underbrace{v_x}_{-\frac{v_o}{A_0}} (Z_2 + Z_1) - v_o Z_1 \Rightarrow v_i Z_2 = -v_o \left(Z_1 + \frac{Z_2 + Z_1}{A_0} \right)$

$\Rightarrow v_o = \frac{-Z_2}{Z_1 + \frac{Z_2 + Z_1}{A_0}} v_1$

$\Rightarrow V_o(s) = \frac{-R_1}{\frac{1}{SC} + \frac{R_1 + \frac{1}{SC}}{A_0}} \Rightarrow V_o(s) = \frac{-R_1}{\frac{1}{SC} + \frac{\frac{R_1 SC + 1}{SC}}{A_0}} = \frac{-R_1}{\frac{A_0 + \cancel{SC} \cdot \frac{RCS+1}{\cancel{SC}}}{A_0 SC}}$

$$\boxed{V_o(s) = \frac{-R_1 C S \cdot A_0}{A_0 + RCS + 1} = \frac{-R_1 C S}{1 + \frac{R_1 CS}{A_0} + \frac{1}{A_0}}}$$