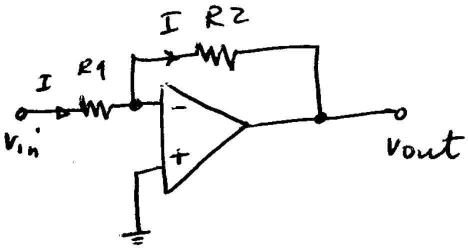
ELECTRÓNICA I - TESTE 04.01.2001 SOLUÇÃO

1.a) $A = \infty$, $R_{in} = \infty$ logo OPAMP IDEAL



$$v_- = v_+ = 0$$

$$I = \frac{v_{in}}{R1}$$

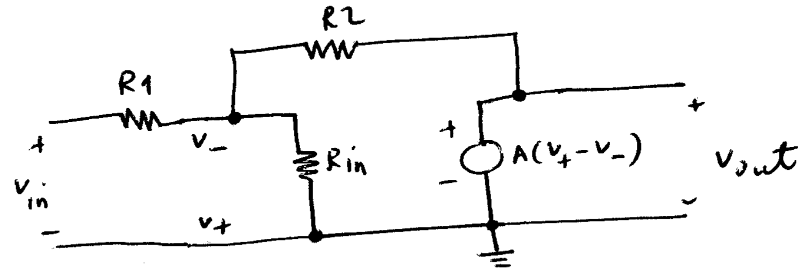
$$V_{out} = -R2\, I$$

logo $\boxed{V_{out} = -\frac{R2}{R_1} v_{in}}$

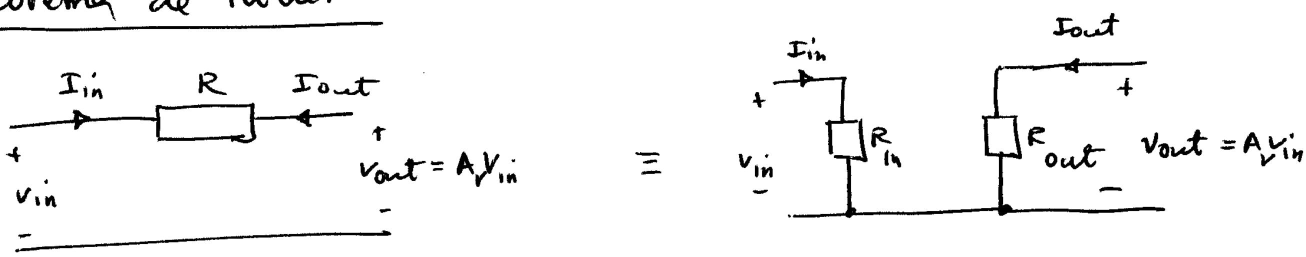
$R1 = 10\,k\Omega$, $R2 = 100\,k\Omega$, $v_{in} = 0.1\,V$

$$V_{out} = -\frac{100 \times 10^3}{10 \times 10^3} \times 0.1 = -1\,V$$

1 b)



teorema de Miller

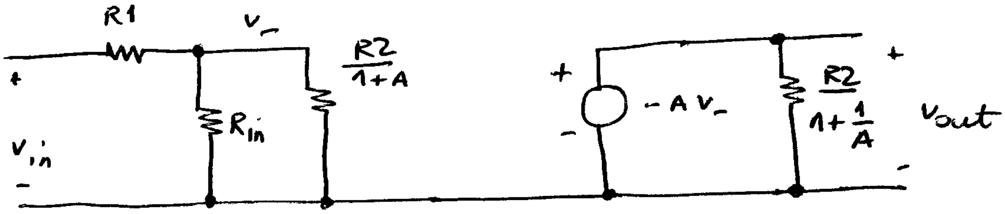


$$I_{in} = \frac{v_{in} - V_{out}}{R} = \frac{(1 - A_v)}{R} v_{in} \qquad I_{in} = \frac{V_{in}}{R1}$$

$$I_{out} = \frac{V_{out} - v_{in}}{R} = \frac{1 - \frac{1}{A_v}}{R} V_{out} \qquad I_{out} = \frac{V_{out}}{R2}$$

logo $\boxed{R_{in} = \frac{R}{1 - A_v}}$ e $\boxed{R_{out} = \frac{R}{1 - \frac{1}{A_v}}}$

circuito equivalente: $V_{out} = -A\,v_-$ logo $A_v = -A$



$$v_- = \frac{R_{eq}}{R_1 + R_{eq}}\, v_{in} \quad \text{com} \quad R_{eq} = R_{in} \parallel \frac{R2}{1+A} = \frac{R_{in} \times \frac{R2}{1+A}}{R_{in} + \frac{R2}{1+A}}$$

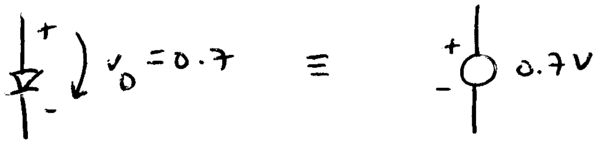
$$V_{out} = -A\,v_-$$

substituindo $$R_{eq} = \frac{1\times10^3 \times \frac{100\times10^3}{1+100}}{1\times10^3 + \frac{100\times10^3}{1+100}} = 497.5\ \Omega$$

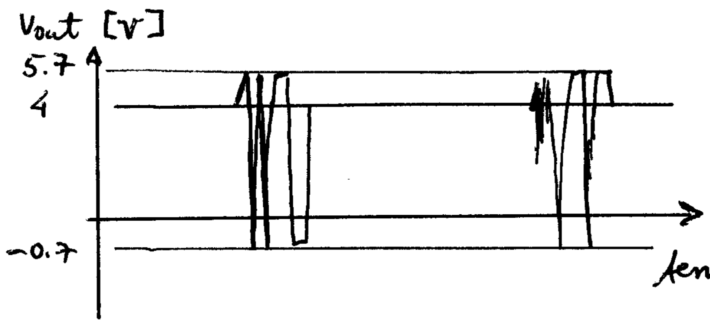
$$v_- = \frac{497.5}{10\times10^3 + 497.5} \times 0.1 = 4.74\ \text{mV}$$

$$V_{out} = -100 \times 4.74\times10^{-3} = -474\ \text{mV} = -0.474\ \text{V}$$

2) sempre que a tensão de entrada v_i permitir que o diodo entre em condução, este apresenta nos seus terminais uma queda de tensão $V_D \simeq 0.7$ V:



diodo directamente polarizado



3a) $V(2) = 10\ V$

$V(1) = V(3)$ porque não passa corrente na resistência R_G

logo basta apenas encontrar $V(3)$.

Pela lei de Ohm

$$I_D = \frac{V_{DD} - V(3)}{R_D}$$

mas, assumindo que o transistor está a funcionar na zona de saturação

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

$$I_D = \frac{1}{2} \mu C_{ox} \frac{W}{L} (V(3) - V_T)^2$$

Substituindo

$$\frac{V_{DD} - V(3)}{R_D} = \frac{1}{2} \mu C_{ox} \frac{W}{L} (V(3) - V_T)^2$$

introduzindo a variável $\boxed{\alpha = \frac{1}{2} \mu C_{ox} \frac{W}{L} R_D}$ vem

$$V_{DD} - V(3) = \alpha V(3)^2 - 2 \alpha V_T V(3) + \alpha V_T^2$$

agrupando

$$\alpha V(3)^2 + (-2\alpha V_T + 1) V(3) + (\alpha V_T^2 - V_{DD}) = 0$$

$$V(3) = \frac{(2\alpha V_T - 1) \pm \sqrt{(1 - 2\alpha V_T)^2 - 4\alpha(\alpha V_T^2 - V_{DD})}}{2\alpha}$$

Substituindo

$$\alpha = 0.5 \times 45 \times 10^{-6} \times 44 \times 8 \times 10^3 = 7.92\ [V^{-1}]$$

$$(2 \alpha V_T - 1) = 2 \times 7.92 \times 1 - 1 = 14.84$$

$$(\alpha V_T^2 - V_{DD}) = 7.92 \times 1^2 - 10 = -2.08$$

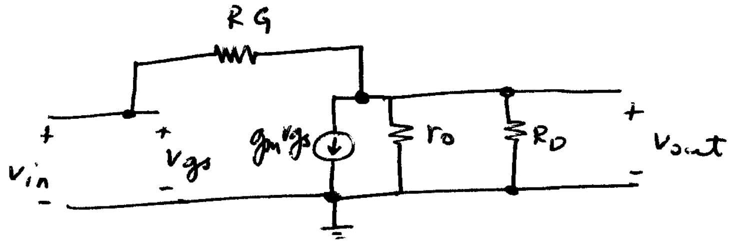
logo

$$v(3) = \frac{14.84 \pm \sqrt{14.84^2 + 4 \times 7.92 \times 2.08}}{2 \times 7.92}$$

$$v(3) = \frac{14.84 \pm 16.91}{15.84} \quad \begin{cases} \boxed{2.00\ V} \\ \cancel{-0.13\ V} \end{cases}$$

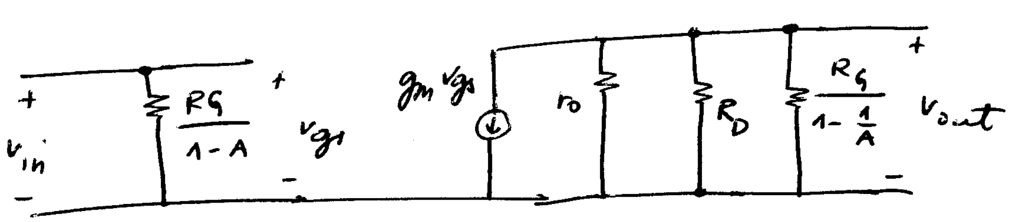
IMPOSSIVEL

3b) modelo de pequeno sinal



NÃO esquecer:
- fontes de tensão independentes são curto circuitos para sinais!
- fontes de corrente independentes são circuitos abertos para sinais!

modelo equivalente (aplicando o teorema de Miller <u>ignorando</u> a corrente que passa em RG porque é desprezável)



com $A = -g_m (r_o \| R_D)$ [porquê?]

mas $g_m = \frac{\partial I_D}{\partial v_{gs}} = \frac{2 I_D}{V_{GS} - V_T}$

e $\frac{1}{r_o} = \frac{\partial I_D}{\partial v_{DS}} \simeq \lambda I_D$

sussti tuindo $\qquad I_D = \frac{1}{2}\mu C_{ox}\frac{W}{L}(v(3)-V_T)^2 = 1\,mA$

$$g_m = \frac{2\times10^{-3}}{2-1} = 2\times10^{-3}\ A/V$$

$$r_o = \frac{1}{0.02\times10^{-3}} = 50\ k\Omega$$

$$A = -g_m\,(r_o \parallel R_D) = -\cancel{2}\times\cancel{10^{-3}}\ \frac{\cancel{50\times10^3}\times 8\times\cancel{10^3}}{50\times10^3+8\times10^3}$$

$$A = -13.8$$

$$\frac{R_G}{1-\frac{1}{A}} = \frac{1\times10^6}{1+\frac{1}{13.8}} \cong 1\ M\Omega$$

$$\frac{R_G}{1-A} = \frac{1\times10^6}{1+13.8} \cong 68\ k\Omega$$

Cálculo de $A_V = \frac{v_{out}}{v_{in}}$

$$v_{out} = -g_m\left(r_o \parallel R_D \parallel \frac{R_G}{1-\frac{1}{A}}\right)v_{gs}$$

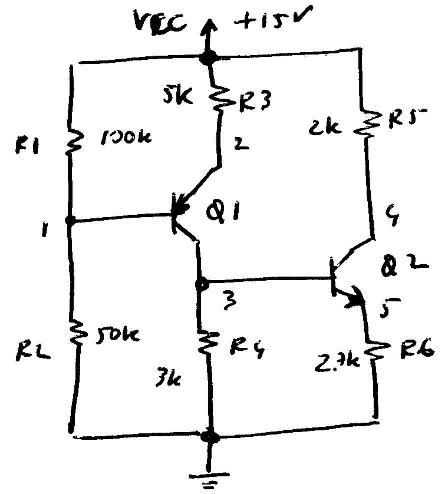
$$\frac{v_{out}}{v_{gs}} = -2\times10^{-3}\left(50\times10^3 \parallel 8\times10^3 \parallel 1\times10^6\right) \cong -13.8$$

logo $\boxed{A_V = \frac{v_{out}}{v_{in}} \cong -13.8}$

c) $R_{in} = \frac{v_{in}}{i_{in}} = \frac{R_G}{1-A} = 68\ k\Omega$

d) $R_{out} = \frac{v_{out}}{i_{out}} = r_o \parallel R_D \parallel \frac{R_G}{1-\frac{1}{A}} \cong r_o \parallel R_D = 6.9\ k\Omega$

4) Ignorando a corrente na base I_B dos transistores



divisor de tensão:

$$V(1) = \frac{R2\,V_{cc}}{R1+R2} = \frac{50k \times 15}{150k} = 5V$$

Assumindo que Q1 está a funcionar e que $|V_{BE}| = 0.7V$

temos $V(2) = V(1) + 0.7V = 5.7V$

logo $I(R3) = \frac{V_{cc} - V(2)}{R3} = \frac{15 - 5.7}{5k} = 1.86mA$

mas $I(R3) = I(R4)$

logo $V(3) = R4 * I(R4) = 3k \times 1.86 mA$

$V(3) = 5.58V$ [NOTA: Q1 está saturado]

Assumindo que Q2 está a funcionar

$V(5) = V(3) - 0.7V = 5.58 - 0.7 = 4.88V$

logo $I(R6) = \frac{V(5)}{R6} = \frac{4.88}{2.7k} = 1.8 mA$

Finalmente $V(4) = V_{cc} - R5 \times I(R5)$

$= 15 - 2k \times 1.8 mA$

$= 11.4V$

| Solução |

$V(1) = 5V$

$V(2) = 5.7V$

$V(3) = 5.58V$

$V(4) = 11.4V$

$V(5) = 4.88V$