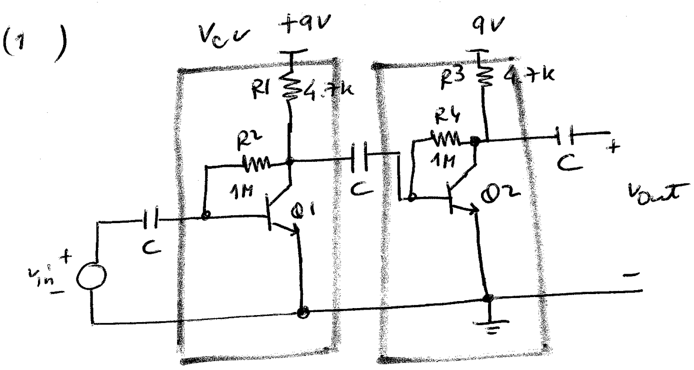
ELECTRÓNICA 1 - AULA 10

AMPLIFICADORES COM DOIS ANDARES

(1)



$\beta = 250$

(1a) Ponto de funcionamento dos transistores

Assumindo que a corrente na base I_B é desprezável

temos $V_{BE1} = V_{CE1} = 0.7V$

$V_{BE2} = V_{CE2} = 0.7V$

Notar que os dois andares estão isolados para sinais DC — logo os pontos de polarização são independentes

Para o 1º andar tem-se

$$I_{C1} = \frac{V_{CC} - V_{CE1}}{R1} = \frac{9 - 0.7}{4.7 \times 10^3} = 1.766 \text{ mA}$$

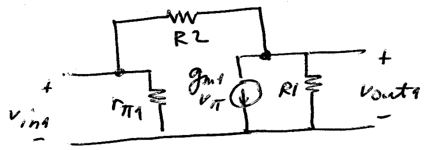
logo o ponto de funcionamento dos transistores é

$(V_{CE1}, I_{C1}) = (0.7V, 1.766 mA)$

$(V_{CE2}, I_{C2}) = (0.7V, 1.766 mA)$

porque os dois andares são iguais!

(1b) Modelo de pequeno sinal para o 1º andar (o 2º andar é igual)

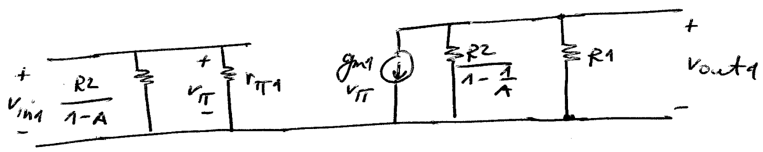


com $\frac{1}{r_\pi} = \frac{I_B}{V_T} = \frac{1}{\beta}\frac{I_C}{V_T}$

logo $r_\pi = \beta \frac{V_T}{I_C} = 250 \times \frac{25\times10^{-3}}{1.766\times10^{-3}} = 3540\,\Omega$

$$g_{m1} = \frac{\partial I_C}{\partial v_{BE}} = \frac{I_C}{V_T} = \frac{\times10^{-3}}{\times10^{-3}} = 0.07\ A/V$$

Aplicando o teorema de Miller (assumindo que a corrente através de R2 é desprezável) vem



com $A = -g_{m1} R1 = -0.07 \times 4.7\times10^{3} = -332$

logo

$$\frac{R2}{1-A} = \frac{1\times10^{6}}{1+332} = 3\,k\Omega$$

$$\frac{R2}{1-\frac{1}{A}} = \frac{1\times10^{6}}{1+\frac{1}{332}} = 1\,M\Omega$$

Tem-se

$$R_{in1} = \frac{v_{in1}}{i_{in1}} = r_{\pi 1} \,\|\, \frac{R2}{1-A} = 3\times10^{3} \,\|\, 3.54\times10^{3} = 1.62\,k\Omega$$

$$R_{out1} = \frac{v_{out1}}{i_{out1}} = R1 \,\|\, \frac{R2}{1-\frac{1}{A}} \approx R1 = 4.7\,k\Omega$$

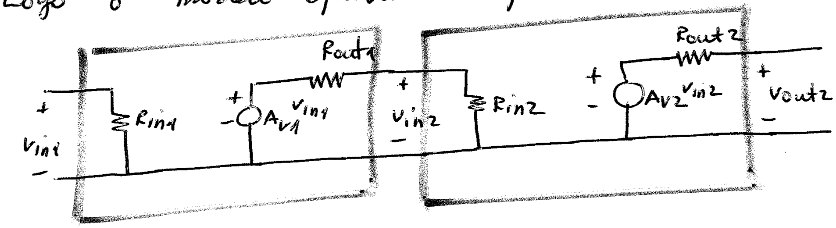
$$A_{v_1} = \frac{v_{out1}}{v_{in1}} = -g_{m1} \times \left(R_1 \parallel \frac{R_2}{1-\frac{1}{A}}\right)$$

$$= -0.07 \times (4.7\times10^3 \parallel 1\times10^6)$$

$$\simeq -0.07 \times 4.7\times10^3$$

$$\simeq -332$$

Logo o modelo equivalente para os dois andares é



logo

$R_{in} = R_{in1} = 1.62\ k\Omega$

$R_{out} = R_{out2} = 4.7\ k\Omega$

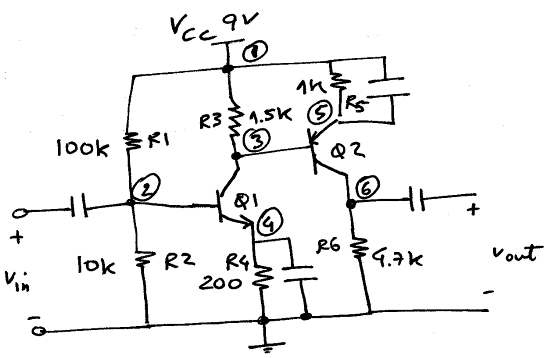
$$A_V = \frac{V_{out2}}{V_{in1}} = \frac{V_{out2}}{V_{in2}} \times \frac{V_{in2}}{V_{in1}}$$

$$= A_{V2} \times A_{V1} \times \frac{R_{in2}}{R_{in2} + R_{out1}}$$

$$= -332 \times (-332) \times \frac{1.62\times10^3}{1.62\times10^3 + 4.7\times10^3}$$

$$= +28\,254$$

(2)



(a) ponto de polarização

Por simplicidade vai-se <u>admitir</u> que se pode desprezar as correntes na base dos transistores, isto é, $I_{B1} \cong I_{B2} \cong 0$

$$V(2) = \frac{R2}{R1+R2} V_{cc} = \frac{10 \times 10^3}{10 \times 10^3 + 100 \times 10^3} \times 9 = 0.8V$$

logo

$$V(4) = V(2) - 0.7V = 0.8 - 0.7 = 0.1V$$

logo

$$IE1 = \frac{V(4)}{R4} = \frac{0.1}{200} = 0.5\,mA$$

logo

$$V(3) = V_{cc} - R3 \times Ic1$$
$$= 9 - 1.5 \times 10^3 \times 0.5 \times 10^{-3}$$
$$= 8.25V$$

logo

$$V(5) = V(3) + 0.7V = 8.25 + 0.7 = 8.95V$$

logo

$$IE2 = \frac{Vcc - V(5)}{R5} = \frac{9 - 8.95}{1 \times 10^3} = 50\mu A$$

logo

$$V(6) = R6 \times Ic2 = 4.7 \times 10^3 \times 50 \times 10^{-6} = 0.235V$$

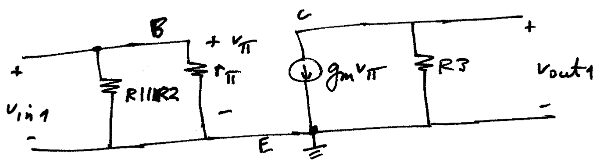
logo $(V_{CE1}, I_{C1}) = (8.15V, 0.5mA)$

$(V_{CE2}, I_{C2}) = (-8.715V, 50\mu A)$

(b) modelo de pequeno sinal para o 1° andar

$r_\pi = \beta \dfrac{V_T}{I_C} = 5k$

$g_m = \dfrac{I_C}{V_T} = 0.02\ A/V$

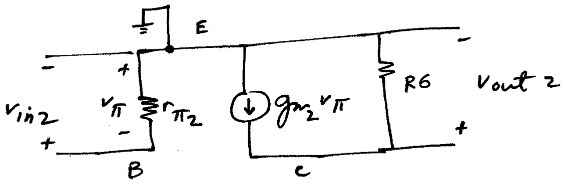


$R_{in1} = \dfrac{v_{in1}}{i_{in1}} = (R_1 \| R_2) \| r_\pi = 9k \| 5k = 3.2\,k\Omega$

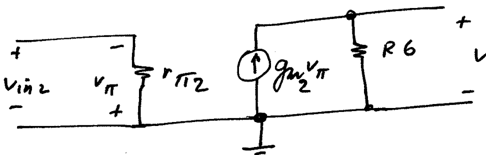
$R_{out1} = \dfrac{v_{out1}}{i_{out1}} = R3 = 1.5\,k\Omega$

$A_{V1} = \dfrac{v_{out1}}{v_{in1}} = -g_m R3 = -0.02 \times 1.5 \times 10^3 = -30$

(c) modelo de pequeno sinal para o 2° andar



circuito equivalente



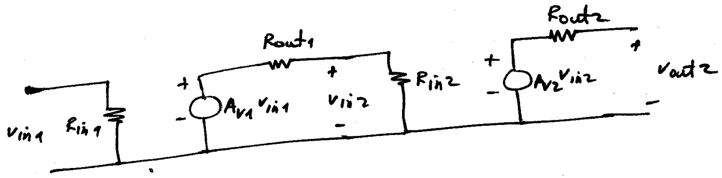
logo

$R_{out2} = R6 = 4.7\,k\Omega$

$R_{in2} = r_{\pi 2} = \beta \dfrac{V_T}{I_{C2}} = 100 \times \dfrac{25mV}{50\mu A} = 50\,k\Omega$

$A_{V2} = -g_{m2} R6 = -\dfrac{50\mu A}{25mV} \times 4.7\,k\Omega = -9.4$

(d) circuito equivalente para os dois andares



logo $R_{in} = R_{in1} = 3.2\ k\Omega$

$R_{out} = R_{out2} = 4.7\ k\Omega$

$$A_v = \frac{v_{out2}}{v_{in1}} = \frac{v_{out2}}{v_{in2}} \times \frac{v_{in2}}{v_{in1}} = A_{v2} \times \frac{R_{in2}}{R_{in2} + R_{out1}} \times A_{v1}$$

$$= -30 \times \frac{50k}{50k + 1.5k} \times (-9.4)$$

$$= +274$$