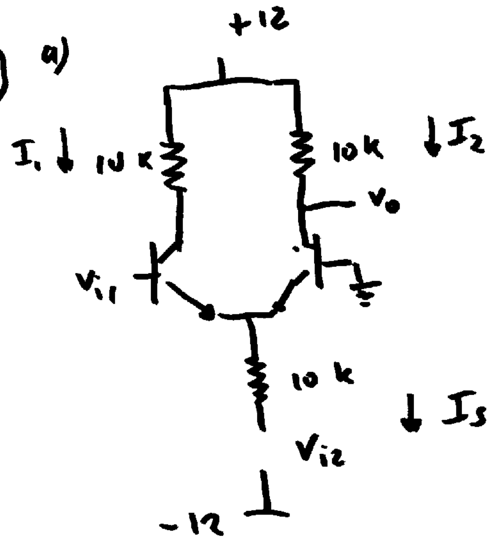
Solução Exame de Recurso Electrónica II

1/02/2007

① a)



$$I_S = \frac{-0.7-(-12)}{10} = 1.13 \text{ mA}$$

$$I_1 = I_2 = I_S/2 = 0.565 \text{ mA}$$

$$V_0 = 12 - 10k\Omega \times 0.565 \text{ mA}$$

$$= 6.35 \text{ V}$$

$$r_e = \frac{26 \text{ mV}}{0.565 \text{ mA}} = 46 \ \Omega$$

b) $$i_s = -\frac{v_{i2}}{10 \ k\Omega}$$

$$i_2 = \frac{i_s}{2} = -\frac{v_{i2}}{2 \times 10 \ k\Omega} , \quad v_o = -i_2 \cdot 10k\Omega$$

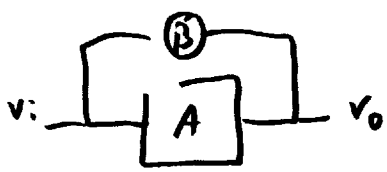
$$= +\frac{v_{i2}}{2}$$

$$\frac{v_o}{v_{i1}} = +\frac{10 \ k\Omega}{2 r_e} = +109$$

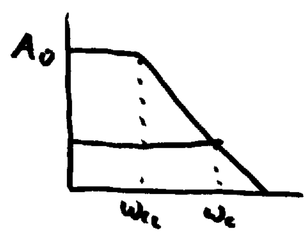
$$\boxed{v_o = +109 \ v_{i1} + \tfrac{1}{2} v_{i2}}$$

usando a regra de sobreposição.

②



$$\text{gain: } \frac{v_o}{v_i} = \frac{A_o}{1+A_o\beta}$$



$$\text{bandwidth : } \quad \omega_c = (1+A\beta)\,\omega_{co}$$

$$\text{gain-bandwidth} = \frac{A}{1+A\beta} \cdot (1+A\beta)\,\omega_{co} = A\,\omega_{co}$$

(constant, indep. de β)

Função de transferência do amplificador
(com um polo a ω_A)

$$A(\omega) = \frac{A_0}{1 + j\,\omega/\omega_A}$$

realimentação negativa

$$\frac{v_o}{v_i} = \frac{A(\omega)}{1 + A(\omega)\beta} = \frac{\dfrac{A_0}{1 + j\,\omega/\omega_A}}{1 + \dfrac{A_0}{1 + j\,\omega/\omega_A} \cdot \beta}$$

$$= \frac{A_0}{(1 + j\,\omega/\omega_A) + A_0\beta} = \frac{A_0}{(1 + A_0\beta) + j\dfrac{\omega}{\omega_A}}$$

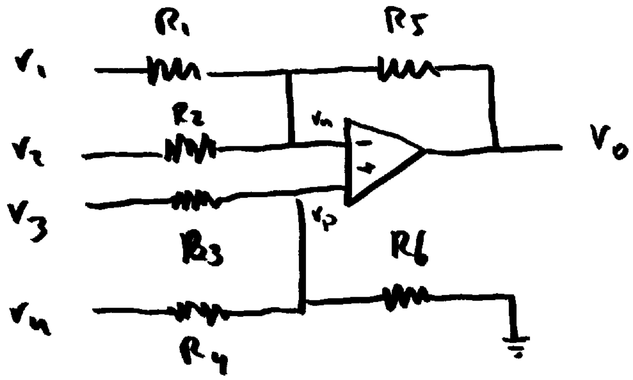
$$= \frac{A_0 / (1 + A_0\beta)}{1 + j\dfrac{\omega}{\omega_A(1 + A_0\beta)}} \leftarrow \frac{v_o}{v_i}(0\,\text{Hz}) = \frac{A_0}{(1 + A_0\beta)}$$

$$\omega_A(1 + A_0\beta) \rightarrow \omega_c = \omega_A(1 + A_0\beta)$$

produto $\dfrac{A_0}{1 + \cancel{A_0\beta}} \cdot \omega_A\,(\cancel{1 + A_0\beta}) = A_0\,\omega_A$

(independente do β)

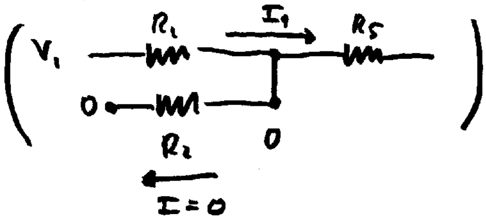
③ Sobre posição



ampop ideal

$$\frac{v_0}{v_1}\ (v_2 = v_3 = v_4 = 0) = -\frac{R_5}{R_1}$$

(nota: V_n = terra virt.)



$$\frac{v_0}{v_2}\ (v_1 = v_3 = v_4 = 0) = -\frac{R_5}{R_2}$$

$$\frac{v_0}{v_3}\ (v_1 = v_2 = v_4 = 0) \Rightarrow v_p = \frac{R_4 /\!/ R_6}{R_4 /\!/ R_6 + R_3}\, v_3$$

$$\frac{v_0}{v_p} = 1 + \frac{R_5}{R_1 /\!/ R_2}$$

$$\frac{v_0}{v_3} = \frac{v_0}{v_p}\cdot\frac{v_p}{v_3} = \left(1 + \frac{R_5}{R_1 /\!/ R_2}\right)\cdot\left(\frac{R_4 /\!/ R_6}{R_4 /\!/ R_6 + R_3}\right)$$

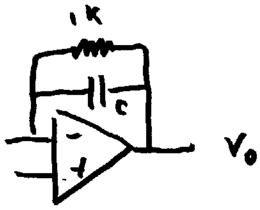
$$\frac{v_0}{v_4}\ (v_1 = v_2 = v_3 = 0) \Rightarrow = \left(1 + \frac{R_5}{R_1 /\!/ R_2}\right)\cdot\left(\frac{R_3 /\!/ R_6}{R_3 /\!/ R_6 + R_4}\right)$$

$$\sum :\quad v_0 = \frac{R_1 /\!/ R_2 + R_5}{R_1 /\!/ R_2}\left(\frac{R_3 /\!/ R_6}{R_3 /\!/ R_6 + R_4}\, v_4 + \frac{R_4 /\!/ R_6}{R_4 /\!/ R_6 + R_3}\, v_3\right)$$

$$-\left(\frac{R_5}{R_1}\, v_1 + \frac{R_5}{R_2}\, v_2\right)$$

b)

altas frequências



Efeito miller : $C_M = (1-A)C$

$$R_M = \frac{1\,k\Omega}{1-A}$$

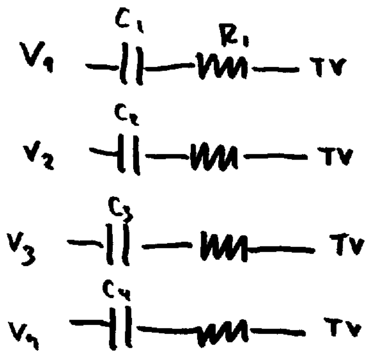
(dado que $A = \infty$, as outras resistências não tem importância!)

$$f_c = \frac{1}{2\pi R_M C_M} = \frac{1}{2\pi\,(1-A)C\,\frac{1k\Omega}{1-A}} = \frac{1}{2\pi\ 1k\Omega \cdot C}$$

$f_c = 100$ kHz : $\frac{1}{2\pi \cdot 1000 \cdot C} = 100 \cdot 10^3 \Rightarrow C = \frac{1}{2\pi} \cdot 10^{-8}$

$= 1.6$ nF

baixas frequências



(TV = terra virtual)

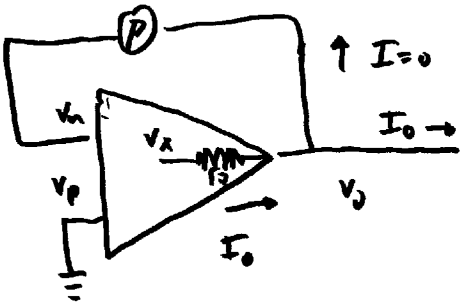
para a análise de V_1 consideramos todos os outros sinais $= 0$

Todos iguais :

$$f_c = \frac{1}{2\pi CR} = 10 \text{ Hz}$$

$$C = \frac{1}{2\pi \cdot 10 \cdot 1000} = 16\ \mu F$$

(4) Directamente copiado do sebenta. p.9 of ch. 3

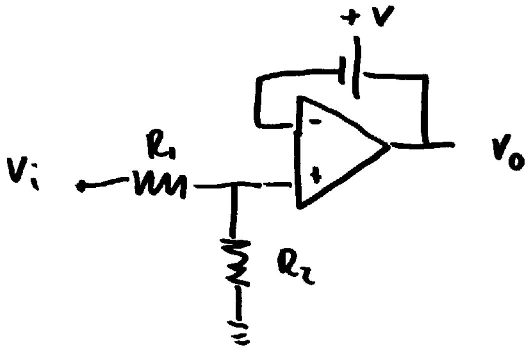


$$V_x = -AV_n$$
$$V_o = V_x - I_o r_o$$
$$V_n = \beta V_o$$

$$I_o = V_o \frac{1+A\beta}{r_o}$$

$$r_{out} = 1 \Big/ \frac{\partial I_o}{\partial V_o} = \frac{r_o}{1+A\beta}$$

(5) a)



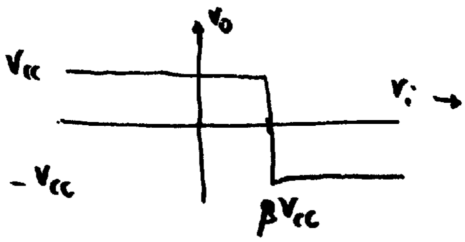
$$V_p = \frac{R_2}{R_1+R_2} V_i$$, ampop ideal : $V_n = V_p$:

$$V_n = \frac{R_2}{R_1+R_2} \cdot V_i$$, $V_o = V_n + 1 \text{ V}$:

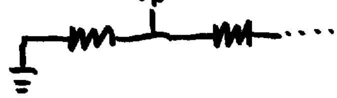
$$V_o = \frac{R_2}{R_1+R_2} \cdot V_i + 1 \text{ V}$$

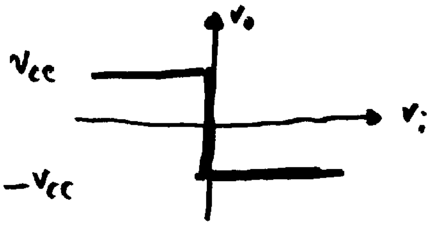
$$= \frac{1}{2} V_i + 1 \text{ V}$$

b) $V_o > 0$: $V_p = \frac{R_1}{R_1+R_2} V_{cc}$
$+V_{cc}$
$= \beta V_{cc}$

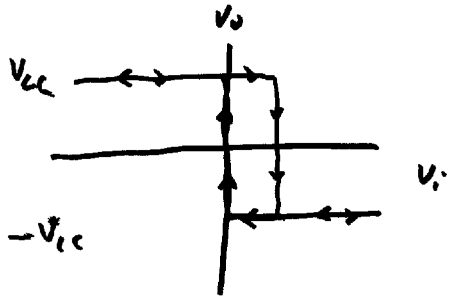


$v_0 < 0$: $v_p = 0$





total :



(hysterese)

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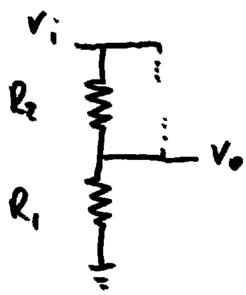
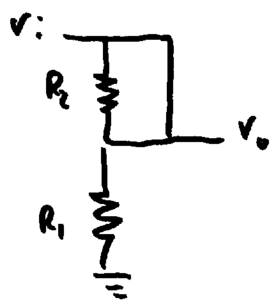
C : baixas frequencias, circuito aberto



$$\frac{V_0}{V_i} = \frac{R_1}{R_1+R_2} = \frac{0.1}{10.1} \approx 0$$

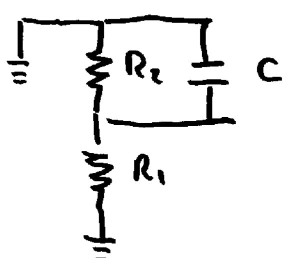
$$\phi = 0^\circ$$

altas frequencias : circuito curto



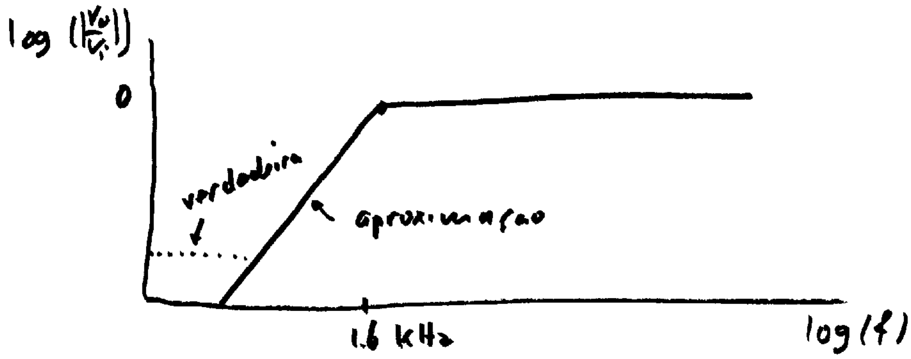
$$\frac{V_0}{V_i} = 1$$

f_c :



$$\frac{1}{2\pi\, C\, (R_1 /\!/ R_2)} \approx \frac{1}{2\pi R_1 C}$$

$$= 1.6 \text{ kHz}$$



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solução luxo :

$$\frac{v_o}{v_i} = \frac{R_1}{R_1 + R_2 /\!/ \frac{1}{j\omega C}} = \cdots\cdots = \cdots\cdots$$

$$= \frac{\frac{R_1}{R_1+R_2} + j\omega C\,(R_1/\!/R_2)}{1 + j\omega\,(R_1/\!/R_2)\,C}$$

$\rightarrow$ zero $\omega = \frac{1}{R_1/\!/R_2\, C} \cdot \frac{R_1}{R_1+R_2}$

$\rightarrow$ polo $\omega = \frac{1}{(R_1/\!/R_2)\,C}$

$$\omega = 0 \implies \frac{v_o}{v_i} = \frac{R_1}{R_1+R_2}, \quad \phi = 0^\circ$$

$$\omega = \infty \implies \frac{v_o}{v_i} = 1, \quad \phi = 0^\circ$$

entre o polo e o zero

$$\frac{v_o}{v_i} \approx \frac{j\omega C\; R_1/\!/R_2}{1 + 0}, \quad \text{fase} = +90^\circ$$

$$\frac{v_0}{v_i} = \frac{R_1}{R_1 + R_2 /\!/ \frac{1}{j\omega C}} = \frac{R_1}{R_1 + \frac{R_2 \frac{1}{j\omega C}}{R_2 + \frac{1}{j\omega C}}}$$

$$= \frac{R_1}{R_1 + \frac{R_2}{R_2 j\omega C + 1}} = \frac{R_1 (R_2 j\omega C + 1)}{R_1 (R_2 j\omega C + 1) + R_2}$$

$$= \frac{R_1 R_2 j\omega C + R_1}{R_1 R_2 j\omega C + R_1 + R_2}$$

$$= \frac{\frac{R_1 R_2}{R_1 + R_2} j\omega C + \frac{R_1}{R_1 + R_2}}{\frac{R_1 R_2}{R_1 + R_2} j\omega C + 1}$$

$$= \frac{j\omega C(R_1 /\!/ R_2) + \frac{R_1}{R_1 + R_2}}{1 + j\omega (R_1 /\!/ R_2) C}$$

anexo com os cálculos