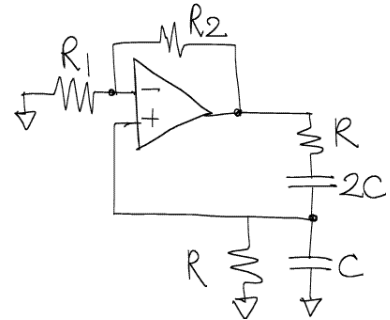


Esame di Elettronica - Corso di Laurea in Ingegneria delle Telecomunicazioni
6 febbraio 2018

1. Si consideri un amplificatore con amplificazione di tensione in continua $A_{v0}=1000$, $R_{in} = 100 \text{ K}\Omega$, $R_{out} = 100 \Omega$, un polo a frequenza $f_p = 100 \text{ Hz}$. Inoltre sia $R_s = 2 \text{ K}\Omega$ la resistenza del generatore di segnale e $R_L = 100 \Omega$ la resistenza del carico. Si reazioni il circuito in modo da ottenere una resistenza di ingresso compresa tra $1 \text{ M}\Omega$ e $2 \text{ M}\Omega$ e una resistenza di uscita maggiore di $100 \text{ K}\Omega$.

2. Sia dato l'oscillatore a lato. Verificare il criterio di Barkhausen all'innescio e calcolare l'eventuale frequenza di oscillazione. Sia $R=1 \text{ K}\Omega$, $C = 100 \text{ nF}$, $R_1=10 \text{ K}\Omega$, $R_2=20 \text{ K}\Omega$.



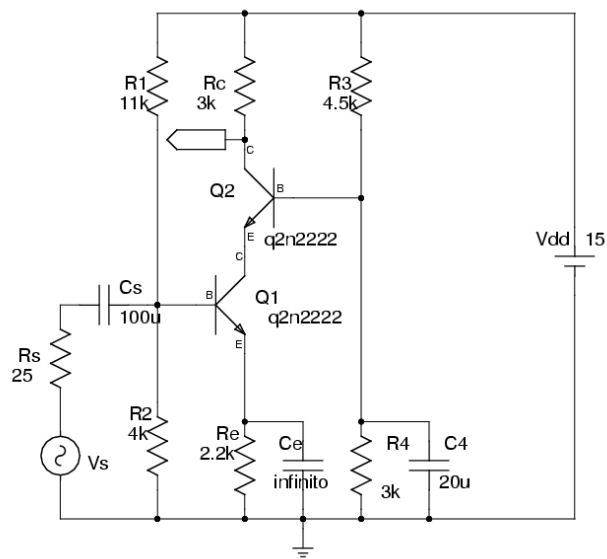
3.

Con riferimento al circuito mostrato a lato, calcolare:

- il punto di riposo dei due transistori Q1 e Q2 e i parametri del circuito di piccolo segnale
- la funzione di trasferimento a centro banda
- il limite superiore di banda

Assunzioni semplificative:

- considerare $h_{oe} = 0$ per i due transistori.

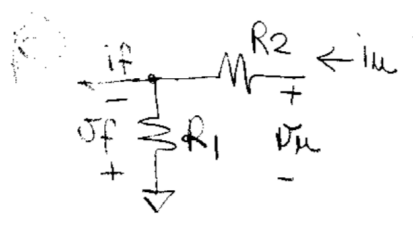
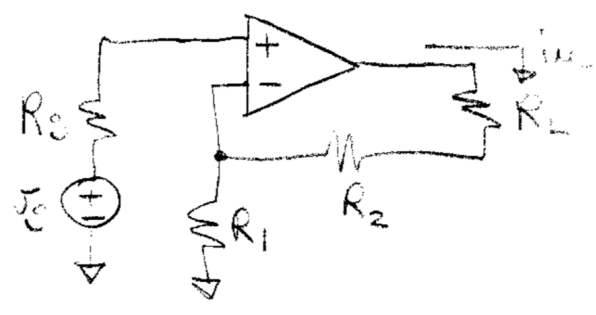


1.

$f_c = 100 \text{ Hz}$
 $f_{10} = 1000$
 $R_{in} = 100 \text{ k}\Omega$
 $R_{out} = 100 \Omega$
 $R_L = 100 \Omega$
 $R_s = 2 \text{ k}\Omega$

$1 \text{ M}\Omega < R_{IF} < 2 \text{ M}\Omega$
 $R_{OF} > 100 \text{ k}\Omega$

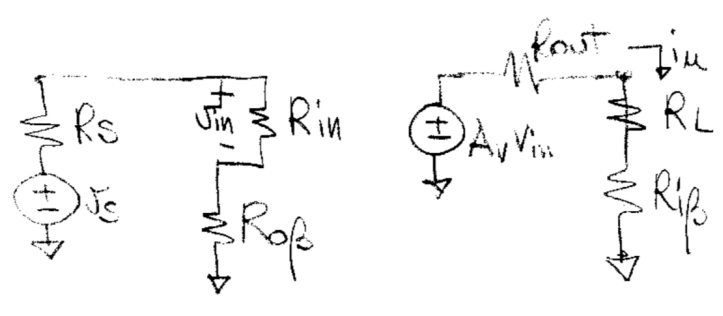
È necessaria una reazione con prelievo di corrente e inserzione di tensione



$$v_u = \beta i_u + R_o \beta i_f$$

$$i_u = R_i \beta i_u + R_i i_f$$

$$\beta \equiv \left. \frac{v_u}{i_u} \right|_{i_f=0} = -R_1 \quad R_o \beta = \left. \frac{v_u}{i_f} \right|_{i_u=0} = R_1 \quad R_i \beta = \left. \frac{v_u}{i_u} \right|_{i_f=0} = R_1 + R_2$$



$$A_e = \frac{R_{in}}{R_{in} + R_s + R_{of}} A_v \frac{1}{R_{out} + R_L + R_i \beta}$$

$$R_{IF} = (R_{in} + R_o \beta) (1 - \beta A_e |_{R_s=0})$$

$$R_{OF} = (R_{out} + R_i \beta) (1 - \beta A_e |_{R_L=0})$$

possiamo scegliere $1 - \beta A_{te}|_{R_S=0} = 10$ e $R_{o\beta} < R_{in} = 100 \text{ K}\Omega$
 in modo da soddisfare la condizione su R_{IF} .

inoltre $R_{i\beta} > 10 \text{ K}\Omega$ per soddisfare la condizione su R_{OF}

Poniamo

$$1 - \beta A_{te}|_{R_S=0} = 10 \Rightarrow -\beta A|_{R_S=0} = 9$$

$$R_1 \frac{R_{in}}{R_{in} + R_S + R_{o\beta}} A_V \frac{1}{R_{out} + R_L + R_{i\beta}} = 9$$

$\begin{matrix} \swarrow 100 \text{ K} \\ R_{in} \\ \uparrow \\ R_1 \end{matrix} \quad \begin{matrix} \uparrow \\ 100 \end{matrix} \quad \begin{matrix} \uparrow \\ 100 \end{matrix} \quad \begin{matrix} \uparrow \\ 100 \end{matrix} \quad \begin{matrix} \uparrow \\ R_1 + R_2 \end{matrix}$

poniamo $R_1 = 1 \text{ K}\Omega$

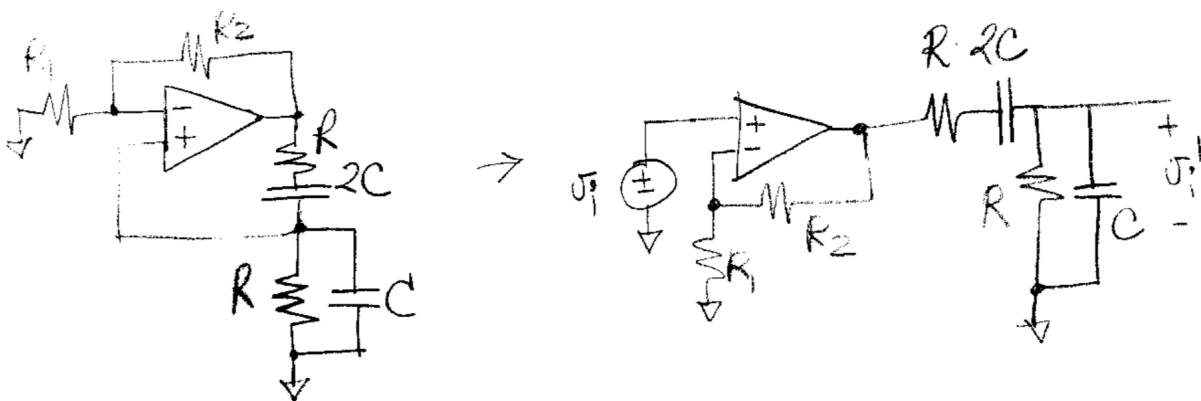
$$\frac{100}{101} \cdot 1000 \cdot \frac{1}{1.2 + R_2} = 9$$

$$1.2 + R_2 = \frac{100000}{101 \cdot 9} \Rightarrow R_2 = 108.8 \text{ K}\Omega$$

$$\text{ricalcoliamo } R_{IF} = (10^5 + 10^3) \left(1 + \frac{R_1 R_{in}}{R_{in} + R_S + R_{o\beta}} A_V \frac{1}{110000} \right) = 1.01 \text{ M}\Omega$$

$$R_{OF} = (100 + 109800) \left(1 + \frac{R_1 R_{in}}{R_{in} + R_S + R_{o\beta}} A_V \frac{1}{R_{out} + R_{o\beta}} \right) = 1.08 \text{ M}\Omega$$

2.



$$\beta A_e = \frac{R_1 + R_2}{R_1} \cdot \frac{\frac{R}{RCs+1}}{\frac{R}{RCs+1} + R + \frac{1}{2Cs}} = \frac{R_1 + R_2}{R_1} \cdot \frac{RCs}{2RCs + (2RCs+1)(RCs+1)}$$

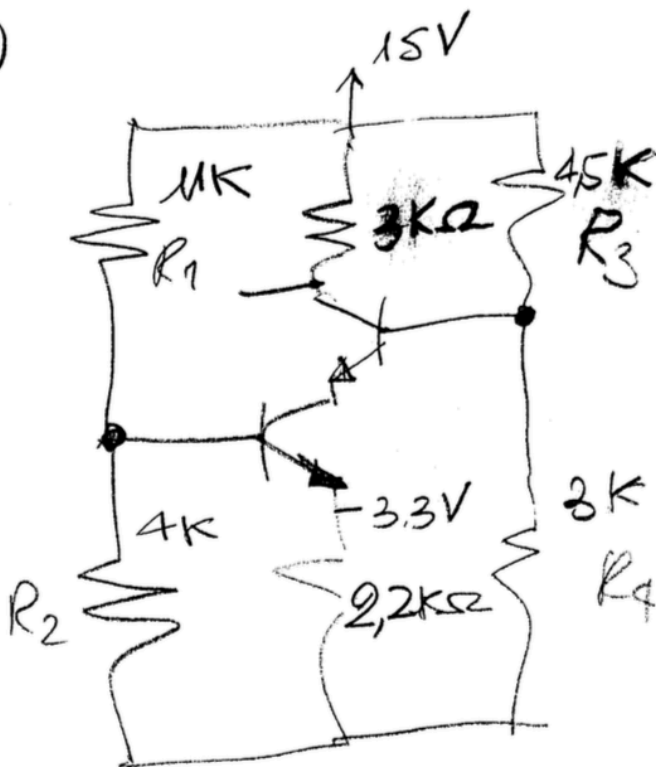
$$= \frac{R_1 + R_2}{R_1} \cdot \frac{J\omega 2RC}{1 + 5J\omega RC - 2\omega^2 R^2 C^2}$$

$$\angle \beta A_e = 0 \rightarrow \omega_0 = \frac{1}{\sqrt{2} RC} \rightarrow 7.07 \text{ Krad/s}$$

$$\beta A(\omega_0) = \frac{R_1 + R_2}{R_1} \cdot \frac{8}{5} = \frac{10+20}{10} \cdot \frac{2}{5} = 1.2 > 1$$

3.

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$$I_{R_2} = \frac{V_{CC}}{R_1 + R_2} = 1 \text{ mA}$$

$$I_{R_3} = \frac{V_{CC}}{R_3 + R_4} = 2 \text{ mA}$$

$$V_{B1} = \frac{R_2}{R_1 + R_2} = 4V \rightarrow V_{E1} = V_{B1} - V_{BE} = 3.3V$$

$$I_{E1} = \frac{V_{E1}}{R_E} = 1.5mA \Rightarrow h_{FE} = 150 \Rightarrow I_B = 10\mu A \ll I_{R12} \quad I_B \ll I_{R34}$$

$$V_{B2} = \frac{R_4}{R_4 + R_{23}} = 6V \rightarrow V_{E2} = V_{B2} - V_{BE} = 5.3V$$

$$V_{C2} = V_{CC} - R_{C2} I_{C2} = 10.5V \rightarrow V_{CB2} = 4.5V$$

$$V_{CB1} = 13V$$

$$g_{m1} = 57.8mS = g_{m2} = \frac{I_C}{V_E} \quad r_b = 450\Omega$$

$$h_{ie1} = 450 + \frac{h_{FE}}{g_{m1}} = 3471\Omega = h_{ie2}; \quad r_{\pi1} = r_{\pi2} = \frac{V_T}{I_E} = 33K\Omega$$

$$f_{T1} = f_{T2} \approx 120MHz; \quad C_{\mu1} = 7pF; \quad C_{\mu2} = 5pF \Rightarrow C_{\pi1} = 70pF; \quad C_{\pi2} = 72pF$$

A_{CB}



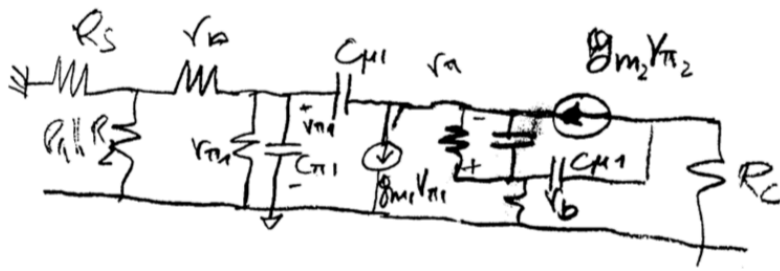
$$i_{b1} = \frac{R_1 \parallel R_2}{R_1 \parallel R_2 + h_{ie1}} \cdot \frac{V_s}{R_1 \parallel R_2 \parallel h_{ie1} + R_s}$$

$$i_{b2} = \frac{h_{fe1} i_{b1}}{1 + h_{fe2}}$$

$$V_o = \frac{-R_C h_{fe2}}{1 + h_{fe2}} h_{fe1} i_{b2}$$

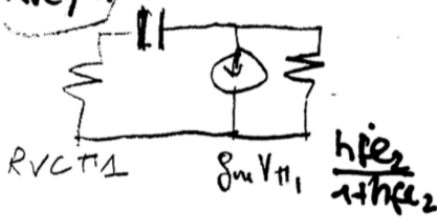
$$= \frac{-R_C h_{fe2} h_{fe1}}{1 + h_{fe2}} \cdot \frac{R_1 \parallel R_2}{R_1 \parallel R_2 + h_{ie1}} \cdot \frac{V_s}{R_1 \parallel R_2 \parallel h_{ie1} + R_s}$$

$$= -148$$



$$R_{VC\pi 1} = r_{\pi 1} \parallel (r_b + R_1 \parallel R_2 \parallel R_S) = 420,3 \Omega$$

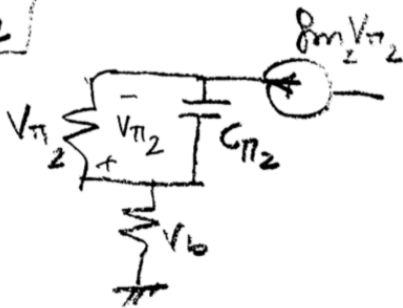
$R_{VC\mu 1}$



$$R_{VC\mu 1} = R_{VC\pi 1} \left(1 + \frac{g_{m1} h_{ie1}}{\omega C_{\mu 1}} \right) + \frac{h_{ie2}}{\omega C_{\mu 1}}$$

$$= 898 \Omega$$

$R_{VC\pi 2}$



$$R_{VC\pi 2} = r_{\pi 2} \parallel \frac{1}{g_{m2}} = 17 \Omega$$

$R_{VC\mu 2}$

$$R_{VC\mu 2} = R_C + r_b = 3450 \Omega$$

$$f_H = \frac{1}{2\pi} \left(\frac{1}{R_{VC\pi 1} C_{\pi 1} + R_{VC\mu 1} C_{\mu 1} + R_{VC\pi 2} C_{\pi 2} + R_{VC\mu 2} C_{\mu 2}} \right) = 3,02 \text{ MHz}$$

