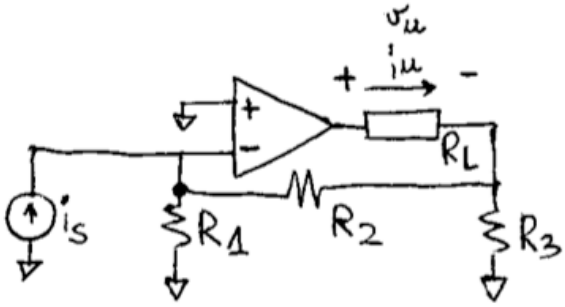
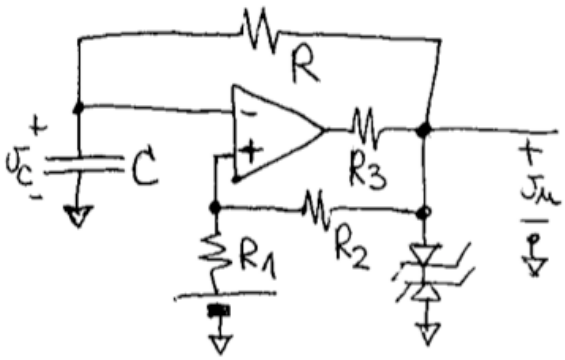
Esame di Elettronica
Corso di Laurea in Ingegneria delle Telecomunicazioni
4 luglio 2017

1. Sia dato il circuito mostrato nella figura a lato, dove l'amplificatore ha resistenza di ingresso Rin = 1MΩ, resistenza di uscita Rout=50Ω, amplificazione di tensione Av=100. Si calcolino la resistenza d'ingresso e di uscita del circuito reazionato. (Dati: RL=100 Ω, R1=R2=R3=1 KΩ).



Punteggio es. 1: 6/30

2. Sia dato il circuito mostrato a lato. Ricavare periodo dell'onda rettangolare ottenuta in uscita e duty cycle, giustificando il procedimento. Disegnare l'andamento della tensione sul condensatore e all'uscita del circuito nel tempo, sullo stesso asse dei tempi (R=2KΩ, C = 47 nF, R1=R2=R3=5KΩ, Vz=6V, VR=2V)



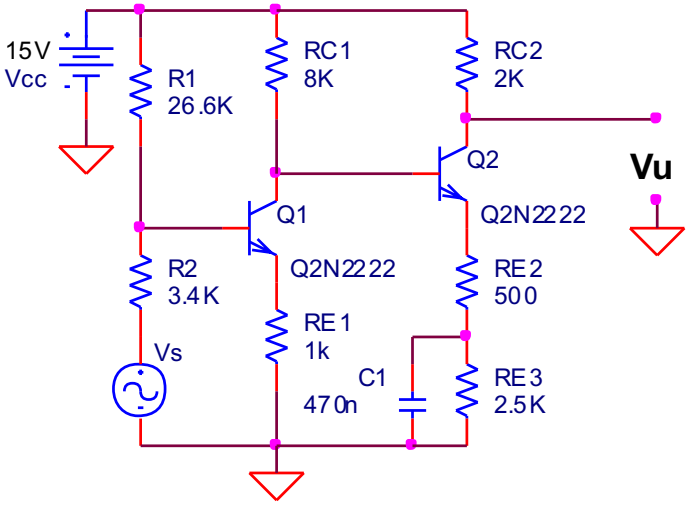
Punteggio es. 2 6/30

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
- i limiti di banda superiore e inferiore.

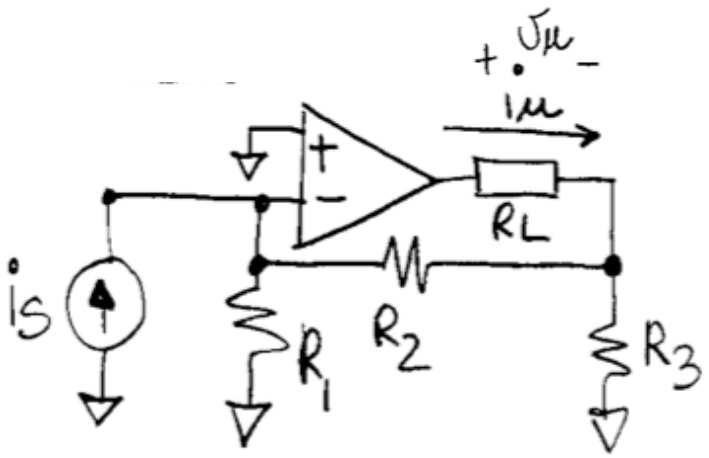
Fare le seguenti ipotesi semplificative:

– hoe = 0 e hre = 0 in Q1 e Q2
– Q2 completamente resistivo



Punteggio totale esercizio 3: 15/30

Esercizio 1



$R_1 = R_2 = R_3 = 1K\Omega$

$R_L = 100\,\Omega$

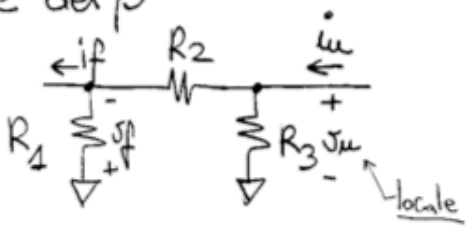
$R_{in} = 1M\Omega$

$R_{out} = 50\Omega$

$A_V = 100$

Prelievo di corrente, inserzione di corrente

Rete del β



$i_f = \beta i_\mu + \frac{v_f}{R_{o\beta}}$

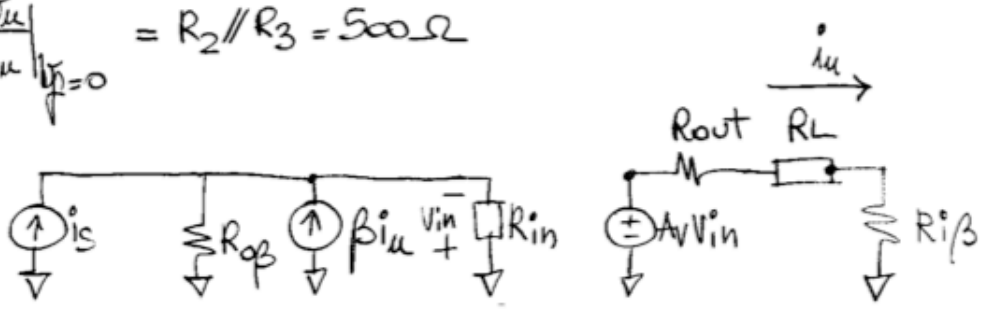
$v_\mu = R_{i\beta} i_\mu + \cancel{K_1 v_f}$

$$\beta = \left.\frac{i_f}{i_\mu}\right|_{v_f=0} = \frac{R_3}{R_2+R_3} = \frac{1}{2}$$

$$R_{o\beta} = \left.\frac{v_f}{i_f}\right|_{i_\mu=0} = R_1 /\!/ (R_2+R_3) = 667\,\Omega$$

$$R_{i\beta} = \left.\frac{v_\mu}{i_\mu}\right|_{v_f=0} = R_2 /\!/ R_3 = 500\,\Omega$$

Ae:

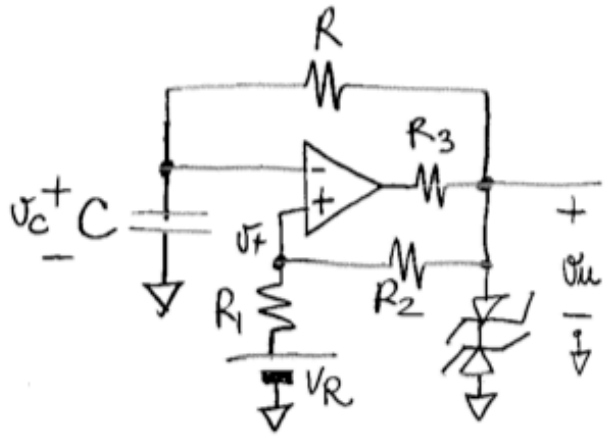


$$A_e = \left.\frac{i_\mu}{i_s}\right|_{\beta=0} = -\frac{(R_{o\beta} /\!/ R_{in})A_V}{R_{out}+R_L+R_{i\beta}} = -102.6 \rightarrow (1-\beta A_e) = 52.3$$

$$R_{IF} = \frac{R_{o\beta}}{1-\beta A_e} = \frac{667}{52.3} = \underline{12.8\,\Omega}$$

$$R_{oF} = (R_{out}+R_{i\beta})\left(1-\beta A_e\Big|_{R_L=0}\right) = \underline{= 33.85\,K\Omega}$$

Esercizio n. 2



$R = 2k\Omega$
$C = 47nF$
$R_1 = R_2 = R_3 = 5K\Omega$
$V_Z = 6V$
$V_R = 2V$

Se $v_u = +V_0 = (V_Z + V_\gamma) = 6.7\,V$

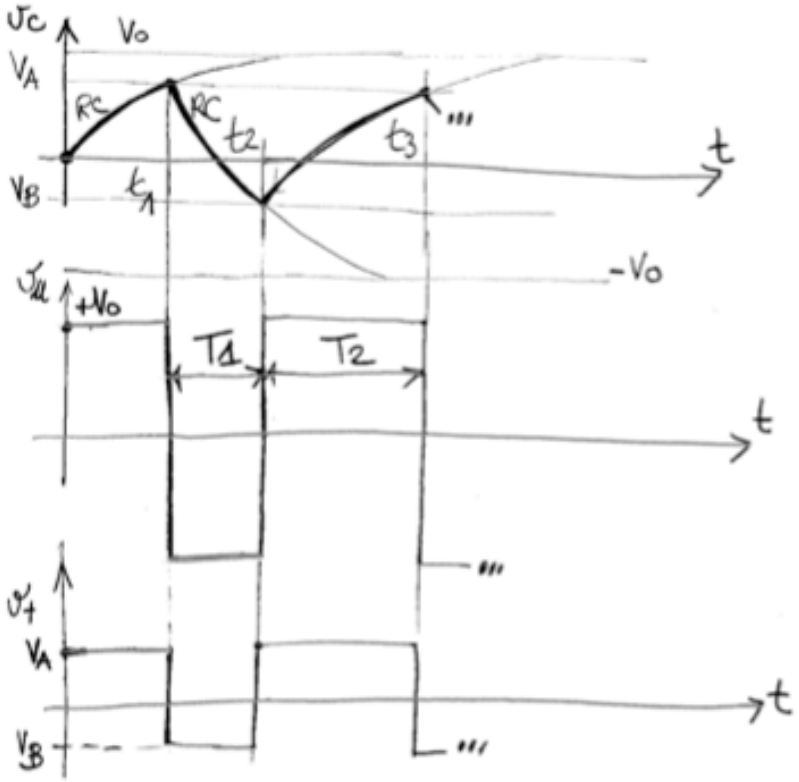
$$v_+ = v_u \frac{R_1}{R_1+R_2} + V_R \frac{R_2}{R_1+R_2} = 4.35\,V = V_A$$

Se $v_u = -V_0 = -6.7\,V$

$$v_+ = v_u \frac{R_1}{R_1+R_2} + V_R \frac{R_2}{R_1+R_2} = -2.35\,V = V_B$$

le costanti di tempo e gli asintoti di carica e scarica di C sono uguali

$\tau = RC = 94\mu s \qquad \pm V_0 = \pm 6.7\,V$



poniamo che per $t=0$ $v_C=0$ $v_{out}=+V_0$

Scarica $t_1 < t < t_2$

$$v_C(t) = V_A + (-V_0 - V_A)\left(1 - e^{-\frac{t-t_1}{RC}}\right)$$

$$v_C(t_2) = V_B$$

$$\hookrightarrow V_B = \cancel{V_A} - V_0 - \cancel{V_A} + (V_0 + V_A)e^{-T_1/RC} \qquad [T_1 = t_2 - t_1]$$

$$T_1 = RC \ln \frac{V_0 + V_A}{V_0 + V_B} = 88\ \mu s$$

Carica $t_2 < t < t_3$

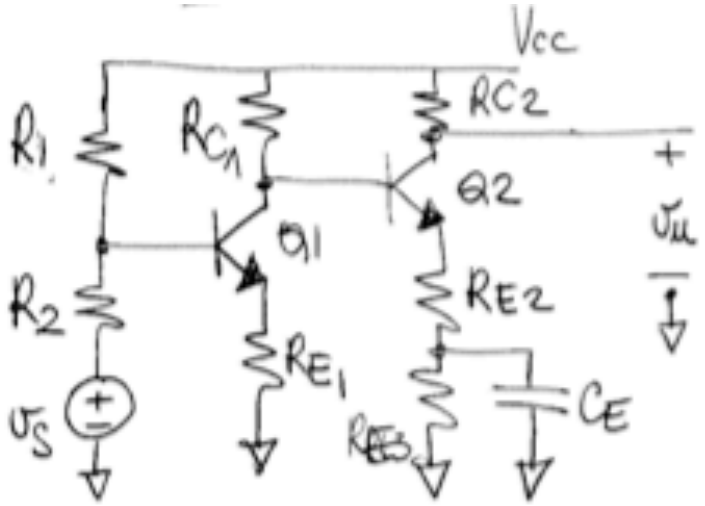
$$v_C(t) = V_B + (V_0 - V_B)\left(1 - e^{-\frac{t-t_2}{RC}}\right)$$

$$v_C(t_3) = V_A$$

$$\hookrightarrow V_A = \cancel{V_B} + V_0 - \cancel{V_B} - (V_0 - V_B)e^{-T_2/RC} \qquad [T_2 = t_3 - t_2]$$

$$T_2 = RC \ln\left(\frac{V_0 - V_B}{V_0 - V_A}\right) = 124\ \mu s \rightarrow T = T_1 + T_2 = 212\ \mu s \quad \delta = \frac{t_2}{T} = 0{,}58$$

Esercizio 3



$R_2 = 34\,k\Omega$
$R_1 = 26.6\,k$
$R_{E1} = 1\,k\Omega$
$R_{C1} = 8\,k\Omega$
$R_{E2} + R_{E3} = 3\,k\Omega$
$R_{C2} = 2\,k\Omega$
$R_{E2} = 500\,\Omega$
$R_{E3} = 2{,}5\,k\Omega$

Punto di Riposo

Hp (R_1, R_2) partitore pesante

$$V_{B_1} = \frac{R_2}{R_1+R_2} V_{CC} = 1.7\,V \rightarrow V_{E_1} = V_{B_1} - V_\gamma = 1\,V$$

$$I_{E_1} = \frac{V_{E1}}{R_{E_1}} = 1\,mA \rightarrow h_{FE_1} = 140$$

$$I_{B1} = \frac{I_{E1}}{h_{FE_1}} \ll \frac{V_{CC}}{R_1+R_2}$$ Hp partitore pesante VERIFICATA

Hp. $I_{B_2} \ll I_{C_1}$

$$V_{C_1} = V_{CC} - R_{C_1} I_{C_1} = 15 - 8 = 7\,V = V_{B2}$$

$$V_{E_2} = V_{B_2} - V_\gamma = 6.3\,V$$

$$I_{C_2} = \frac{V_{E2}}{R_{E_2}+R_{E3}} = \frac{6.3}{3} = 2.1\,mA$$

$$I_{B2} = \frac{I_{C2}}{h_{FE_2}} \ll I_{C_1}$$ Hp VERIFICATA

$$V_{C_2} = V_{CC} - R_{C_2} I_{C_2} = 15 - 2 \cdot 2.1 = 10.9\,V$$

Punto di Riposo

Q_1 : $I_{C_1} = 1\,mA$

$V_{CE_1} = 6\,V$

$h_{fe} = 175$

$h_{ie} = 5\,k\Omega$

$r_b = 450\,\Omega$

$f_T = 90\,MHz$

$C_\mu = 4.5\,pF$

$C_\pi = \frac{g_m}{2\pi f_T} - C_\mu = 63.5\,pF$

Q_2 : $I_{C_2} = 2.1\,mA$

$V_{CE_2} = 4.6\,V$

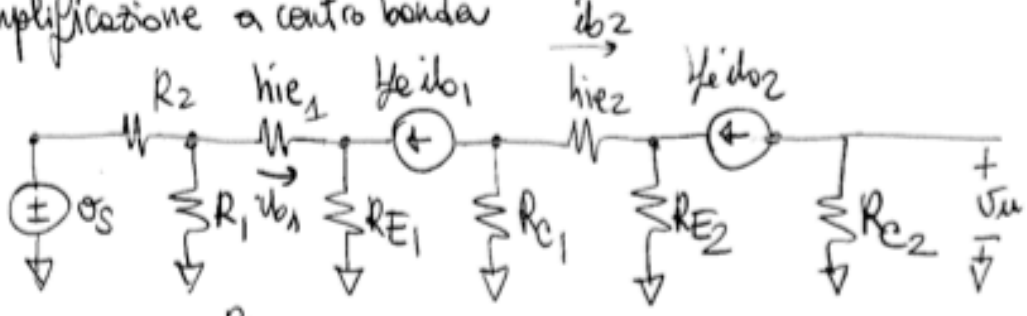
$h_{fe} \cup 175$

$r_{\pi_2} = \frac{h_{fe} V_T}{I_{C_2}} = 2166$

$h_{ie_2} = r_{\pi_2} + r_b = 2616\,\Omega$

$f_T = 140\,MHz$

Amplificazione a centro banda



$$i_{b_1} = \frac{v_s \frac{R_1}{R_1+R_2}}{R_1 /\!/ R_2 + h_{ie_1} + (h_{fe_1}+1) R_{E_1}}$$

$$i_{b_2} = - \frac{h_{fe} i_{b_1} R_{C_1}}{R_{C_1} + h_{ie_2} + R_{E_2}(h_{fe_2}+1)}$$

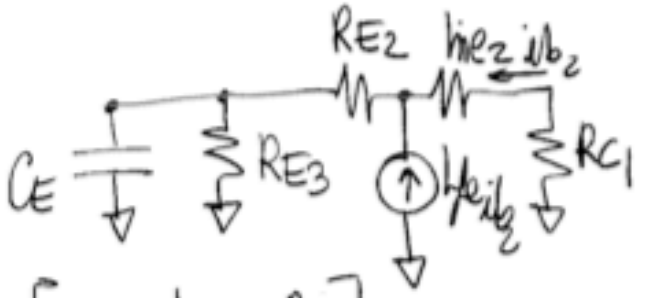
$$v_u = - h_{fe_2} i_{b_2} R_{C_2}$$

$$A_{V_{CB}} = \frac{v_u}{v_s} = h_{fe_2} R_{C_2} \frac{h_{fe_1} R_{C_1}}{R_{C_1} + h_{ie_2} + R_{E_2}(h_{fe_2}+1)} \cdot \frac{1}{R_1 /\!/ R_2 + h_{ie_1} + (h_{fe_1}+1) R_{E_1}} \cdot \frac{R_1}{R_1+R_2}$$

$$A_{V_{CB}} = 175 \cdot 2 \cdot \frac{175 \cdot 8}{8 + 2.616 + 0.5(176)} \cdot \frac{1}{3 + 5 + 176} \cdot \frac{26.6}{30} = 24$$

Limite inferiore di banda

R_{VCE_1}

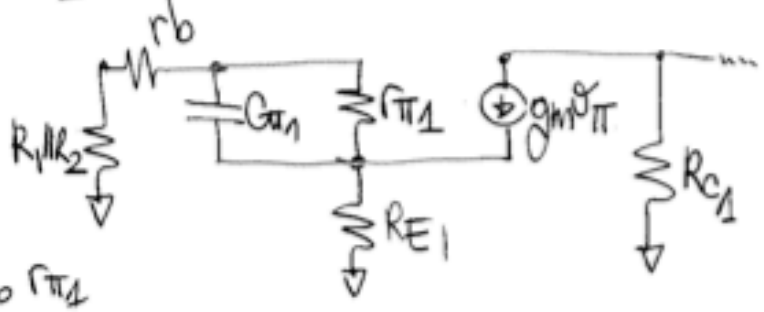


$$R_{VCE} = R_{E3} \,/\!/ \left[R_{E2} + \frac{h_{ie2} + R_{C1}}{h_{fe2}+1} \right] = \underline{457\,\Omega}$$

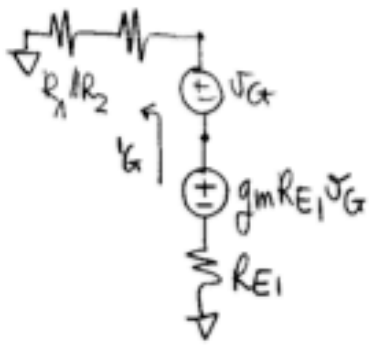
$$f_L = \frac{1}{2\pi R_{VCE} C_E} = \frac{1}{6.28 \cdot 457 \cdot 47 \cdot 10^{-9}} = \underline{742\,Hz}$$

Limite superiore di BANDA

$R_{VC\pi_1}$



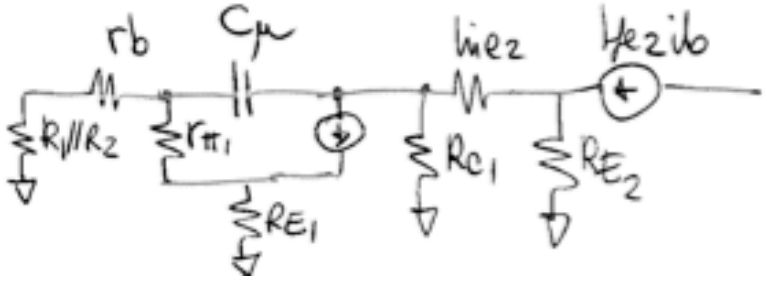
tolgo r_{π_1}



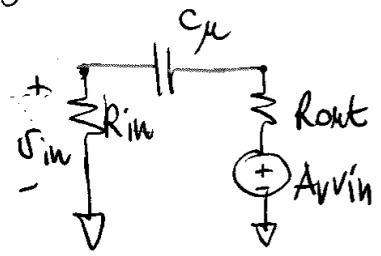
$$i_G = \frac{v_G (1 + g_m R_{E1})}{R_{E1} + R_1 \,/\!/\, R_2 + r_b}$$

$$R_{C\pi_1} = r_{\pi_1} \,/\!/ \left[\frac{R_{E1} + R_1 \,/\!/\, R_2 + r_b}{1 + g_m R_{E1}} \right] = \underline{107.4\,\Omega}$$

$R_{VC\mu_1}$:



Ridisegnamo il circuito come



$$R_{in} = \left(r_b + R_1 /\!/ R_2\right) /\!/ \left(r_{\pi_1} + (\beta_e + 1) R_{E1}\right) =$$

$$R_{in} = 3.39\ K\Omega$$

$$R_{out} = R_{C_1} /\!/ \left[h_{ie_2} + R_{E_2}(\beta_e + 1)\right] = 7.7 K\Omega$$

$$A_V = -\frac{\beta_{e_1} R_{out}}{r_\pi + R_{E_1}(\beta_{e_1} + 1)} = -\frac{176 \cdot 7{,}7}{2.17 + 176} = 7.6$$

$$R_{V C_\mu} = R_{in}(1 - A_V) + R_{out} = 3{,}39 \cdot 8.6 + 7{,}7 = \underline{36.85 K\Omega}$$

$$f_H = \frac{1}{2\pi} \frac{1}{R_{V C_\mu} C_\mu + R_{V C_\pi} C_\pi} = \frac{1}{6{,}28\left[36.85 \cdot 10^3 \cdot 4{,}5 \cdot 10^{-12} + 107.4 \cdot 6{,}35 p 10^{-12}\right]} = 922 KHz$$