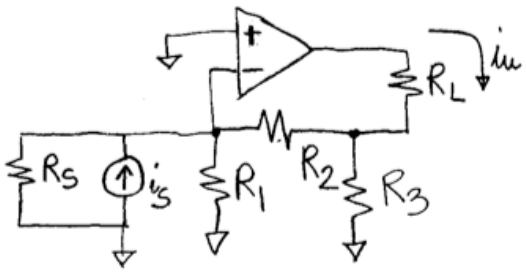
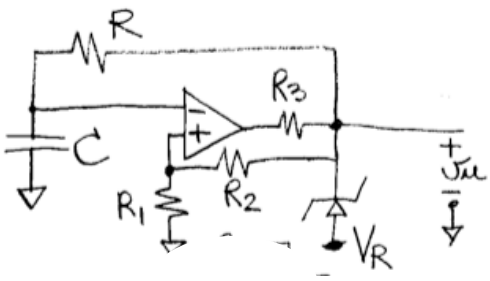
Esame di Elettronica - Corso di Laurea in Ingegneria delle Telecomunicazioni
18 luglio 2012

1. Si consideri il circuito a lato. R_s = 1 KΩ è la resistenza del generatore di segnale, R_L = 100 Ω è il carico. Si calcoli la resistenza di ingresso, la resistenza di uscita, la funzione del trasferimento i_u/i_s e il limite superiore di banda del circuito completo. L'amplificatore nello schema ha amplificazione di tensione $A_{vo}=10^4$, R_{in} = 200 KΩ, R_{out} = 300 Ω, un polo a frequenza f_p = 100 Hz. Inoltre si consideri R_1 = 10 KΩ, R_2 = 20 KΩ, R_3 = 30 KΩ.



2. Sia dato il circuito mostrato a lato. Ricavare la forma d'onda o Disegnare e quotare correttamente l'andamento della tension tempo, sullo stesso asse dei tempi (R = 10 KΩ, C = 47 nF, R_1 V).

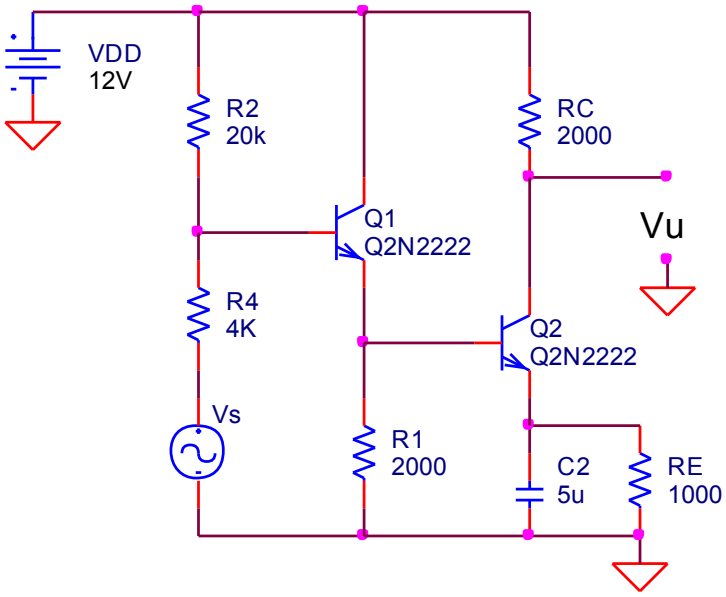


3.

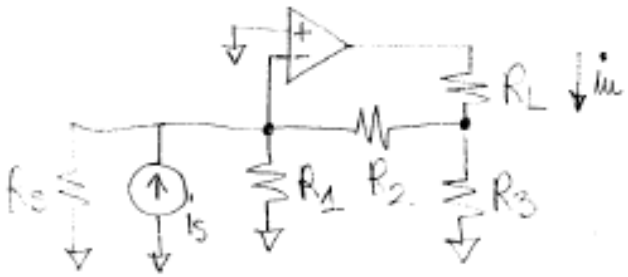
Con riferimento al circuito mostrato a lato, calcolare:

- 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

Considerare Q1 completamente resistivo

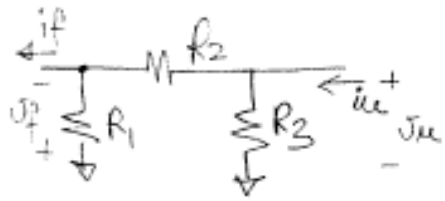


Es. 1



$R_1 = 10K\Omega$
$R_2 = 20K\Omega$
$R_3 = 30K\Omega$

rete × β



$$i_f = f\, i_u + \frac{V_f}{R_{of}}$$

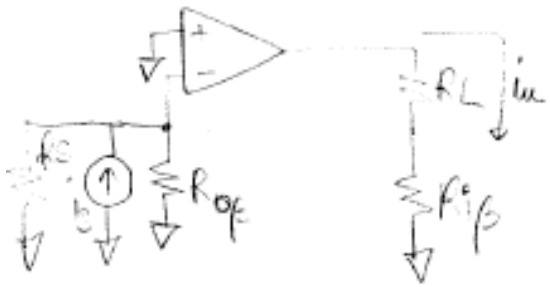
$$V_{iu} = f_{i\beta}\, i_u + f \cdot V_f$$

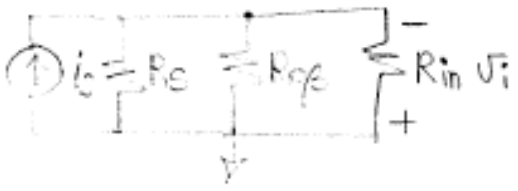
$$f = \left.\frac{i_f}{i_u}\right|_{V_f=0} = \frac{R_3}{R_2+R_3} = 0{,}6$$

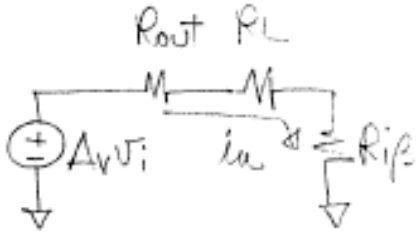
$$R_{o\beta} = \left.\frac{V_f}{i_f}\right|_{i_u=0} = R_1 /\!/ (R_2+R_3) = 8{,}3K\Omega$$

$$R_{i\beta} = \left.\frac{V_{iu}}{i_u}\right|_{V_f=0} = R_2 /\!/ R_3 = 12K\Omega$$

Ae







$$V_i = -i_s \left(R_S /\!/ R_{o\beta} /\!/ R_{in}\right)$$

$$i_u = \frac{A_v\, V_i}{R_{out} + R_L + R_{i\beta}}$$

$$A_e = \left.\frac{i_u}{i_s}\right|_{\beta=0} = -\frac{A_v(R_s /\!/ R_{o\beta} /\!/ R_{in})}{R_{out} + R_L + R_{i\beta}} = -716.9$$

$$\left[A_e|_{R_s\to\infty} = -645 \right.$$
$$\left. A_e|_{R_L=0} = -722,7 \right]$$

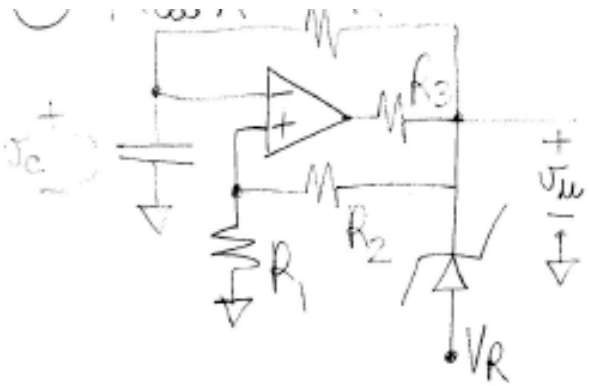
$$R_{IF} = \frac{(R_{o\beta} /\!/ R_{in})}{1 - \beta A_e|_{R_s\to\infty}} = 2,07\ \Omega$$

$$R_{OF} = (R_{i\beta} + R_{out})\left(1 - \beta A_e|_{R_L=0}\right) = 5,35\ M\Omega$$

$$A_F = \frac{i_u}{i_s} = \frac{A_e}{1 - \beta A_e} = -1,66$$

$$f_{-1} = f_p(1 - \beta A_e) = 43,1\ KHz$$

Es. 2

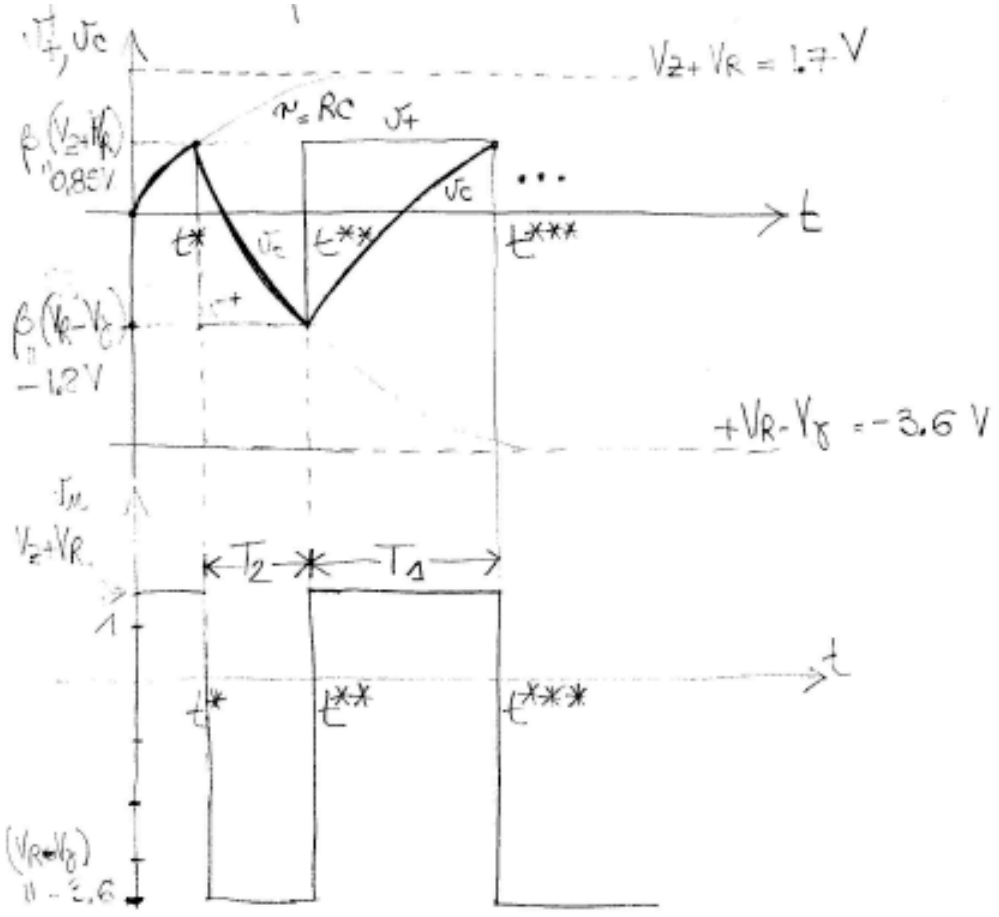


$V_R = -3V$
$V_Z = 4,7V$

scrite: ALTA $V_u = V_R + V_Z$, $V_+ = \frac{R_1}{R_1+R_2}(V_R+V_Z) = \beta(V_R+V_Z)$

BASSA $V_u = V_R - V_\gamma$, $V_+ = \frac{R_1}{R_1+R_2}(V_R-V_\gamma) = \beta(V_R-V_\gamma)$

poniamo che per $t=0$ $V_c = 0 = V_-$



Calcolo di T_1

$$\beta(V_z+V_R) = v_c(t^{***}) = \beta(V_R - V_\gamma) + \left[(V_z+V_R) - \beta(V_R - V_\gamma)\right]\left[1 - e^{-\frac{T_1}{RC}}\right]$$

$$\beta(V_z+V_R) = (V_z+V_R) - \left[V_z + (1-\beta)V_R + \beta V_\gamma\right] e^{-T_1/RC}$$

$$(V_z+V_R)(1-\beta) = \left[V_z + (1-\beta)V_R + \beta V_\gamma\right] e^{-T_1/RC}$$

$$T_1 = RC \ln\left[\frac{V_z + (1-\beta)V_R + \beta V_\gamma}{(V_z+V_R)(1-\beta)}\right] = 6{,}652 \times 10^{-4}\ s$$

calcolo di T_2

$$\beta(V_R - V_\gamma) = v_c(t^{**}) = \beta(V_z + V_R) + \left[V_R - V_\gamma - \beta(V_z + V_R)\right]\left[1 - e^{-\frac{T_2}{RC}}\right]$$

$$\beta(V_R - V_\gamma) = V_R - V_\gamma - \left[V_R(1-\beta) - V_\gamma - \beta V_z\right] e^{-T_2/RC}$$

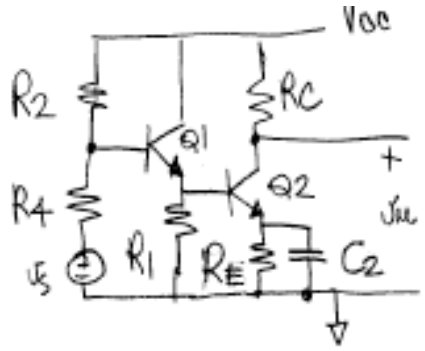
$$(1-\beta)(V_R - V_\gamma) = \left(V_R(1-\beta) - V_\gamma - \beta V_z\right) e^{-T_2/RC}$$

$$T_2 = RC \ln\left[\frac{V_R(1-\beta) - V_\gamma - \beta V_z}{(1-\beta)(V_R - V_\gamma)}\right] = 4{,}254 \times 10^{-4}\ s$$

T_2 $\qquad \delta = \frac{T_1}{T} = 0{,}61$

$T = 1{,}09\ ms$

Es. 3



$V_{B1} = \frac{R_4}{R_4+R_2} V_{CC} = \frac{4}{24} \times 12 = 2V$ (approssimazione di partitore pesante)

$V_{E1} = V_{B1} - V_{BEON} = 1,3V$

$I_{C1} = \frac{V_{E1}}{R_1} = \frac{1,3}{2000} = 0,65\ mA$ (approssimazione $I_{B2} \ll I_{C1}$)

$V_{CE_1} = V_{CC} - V_{E1} = 10.7V$

$V_{E2} = V_{E_1} - V_{BEON} = 0,6V$

$I_{E2} = \frac{V_{E2}}{RE} = 0,6\ mA \cup I_{C2}$ $\quad V_{CE2} = V_{CC} - I_{C_2} R_C - V_{E2} =$

$= 12 - 0,6 \cdot 2 - 0.6 = 10.2\ V$

$h_{FE_1} \cong h_{FE_2} = 140$

$I_{B1} = \frac{I_{C1}}{h_{FE_1}} \ll \frac{V_{CC}}{R_2+R_4} = \frac{12}{24 \cdot 10^3} = 0,5mA$

$\uparrow 4,3\mu A$

$I_{B2} = \frac{I_{C2}}{h_{FE_2}} \ll I_{C_1} = 0,65mA$

$\uparrow 4,3\mu A$

$r_{bb} = 450\Omega$ (valore a 1mA) $\quad h_{fe_1} = h_{fe_2} \cong h_{fe@1mA} = 175$

$r_{T_1} = \frac{h_{fe_1} V_T}{I_{C_1}} = \frac{175 \cdot 25.9}{0,65} = 6973\Omega \quad g_{m1} = \frac{I_{C_1}}{V_T} = 25 \cdot 10^{-3} \Omega^{-1}$

$h_{ie_1} = r_{bb} + r_{T_1} = 7423\Omega$

$r_{\pi_2} = \frac{h_{fe_2} V_T}{I_{C_2}} = \frac{175 \cdot 25{,}9}{0{,}6} = 7554$ $\quad h_{ie_2} = r_{\pi_2} + r_{bb'} = 8004\,\Omega$

$g_{m_2} = \frac{I_{C_2}}{V_T} = 23 \cdot 10^{-3}\,\Omega^{-1}$

V_A dalle caratteristiche a 1mA $\quad V_A = \frac{I_C}{h_{oe}} = \frac{1\,mA}{20 \cdot 10^{-6}\,\Omega} = 50\,V$

$\frac{1}{h_{oe_1}} = \frac{V_A}{I_{C_1}} = \frac{50}{0{,}65 \cdot 10^{-3}} = 76{,}9\,K\Omega$

$\frac{1}{h_{oe_2}} = \frac{V_A}{I_{C_2}} = \frac{50}{0{,}6 \cdot 10^{-3}} = 83{,}3\,K\Omega$

possiamo trascurare $\frac{1}{h_{oe_1}} \gg R_1$, $\frac{1}{h_{oe_2}} \gg R_E, R_C$

$V_{CB_1} = 10V \quad C_{\mu_1} = 4pF \quad f_{T_1} = 70\,MHz$

$f_{T_1} = \frac{g_{m_1}}{2\pi (C_{\mu_1} + C_{\pi_1})} \rightarrow C_{\pi_1} = \frac{g_{m_1}}{2\pi f_{T_1}} - C_{\mu_1} = \frac{I_{C_1}}{V_T 2\pi f_T} - C_{\mu_1}$

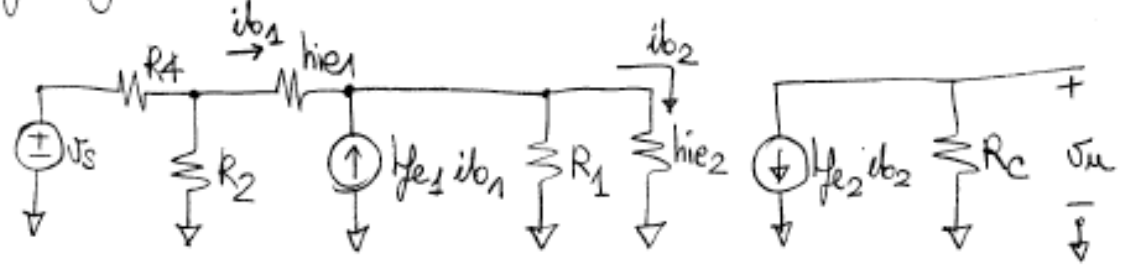
$= \frac{0{,}65 \cdot 10^{-3}}{25{,}9 \cdot 10^{-3} \cdot 6{,}28 \cdot 70 \cdot 10^6} - 4 \cdot 10^{-12}$

$= (57{,}1 - 4)\,10^{-12} = \underline{53{,}1\,pF}$

$V_{CB_2} = 9{,}5V \quad C_{\mu_2} = 4pF \quad f_{T_2} = 70\,MHz$

$C_{\pi_2} = \frac{g_{m_2}}{2\pi f_{T_2}} - C_{\mu_2} = \frac{0{,}7 \cdot 10^{-3}}{25{,}9 \cdot 10^{-3} \cdot 6{,}28 \cdot 70 \cdot 10^6} - 4 \cdot 10^{-12} = 48{,}7\,pF$

guadagno a centrobanda



$$i_{b_1} = v_S \cdot \frac{R_2}{R_2+R_4} \cdot \frac{1}{R_2 /\!/ R_4 + h_{ie_1} + (R_1 /\!/ h_{ie_2})(h_{fe_1}+1)} =$$

$$i_{b_2} = i_{b_1} (h_{fe_1}+1) \frac{R_1}{R_1+h_{ie_2}}$$

$$v_u = - h_{fe_2} R_C i_{b_2}$$

$$A_f = \frac{v_u}{v_S} = \underset{\uparrow \; 175}{- h_{fe_2}} R_C (h_{fe_1}+1) \frac{R_1}{R_1+h_{ie_2}} \cdot \frac{R_2}{R_2+R_4} \cdot \frac{1}{R_2 /\!/ R_4 + h_{ie_1} + (R_1 /\!/ h_{ie_2})(h_{fe_1}+1)}$$

$$= -175 \cdot 2000 \cdot 176 \cdot \frac{2000}{2000+8004} \cdot \frac{20}{20+4} \cdot \frac{1}{\frac{80000}{24} + 7423 + 1600 \cdot 176}$$

$$= -35.1$$

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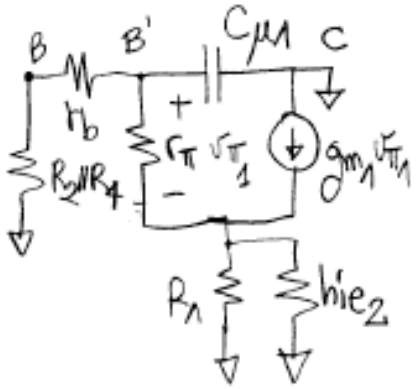
limite superiore di banda

$R_{V\mu_1}$

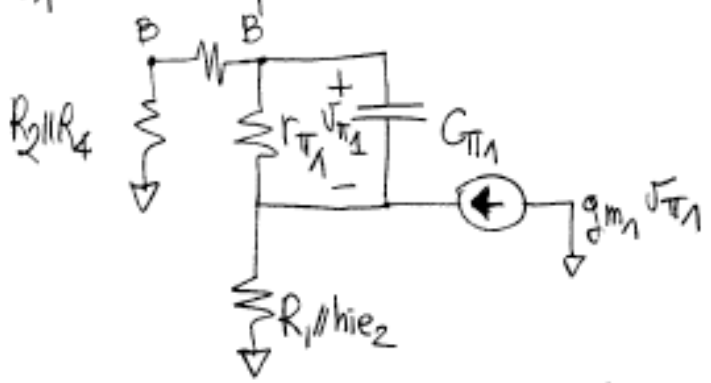


$$R_{V\mu_1} = \left[r_{\pi_1} + (1 + g_{m_1} r_{\pi_1})(R_1 /\!/ h_{ie_2}) \right] /\!/ (r_b + R_2 /\!/ R_4)$$

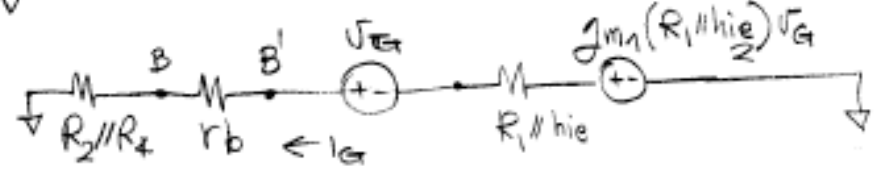
$$= [6973 + 176 \cdot 1600] /\!/ [450 + 3333] =$$

$$= 288573 /\!/ 3783 = 3734\ \Omega$$

$R_{V\pi_1}$



rimuovo r_{π_1}



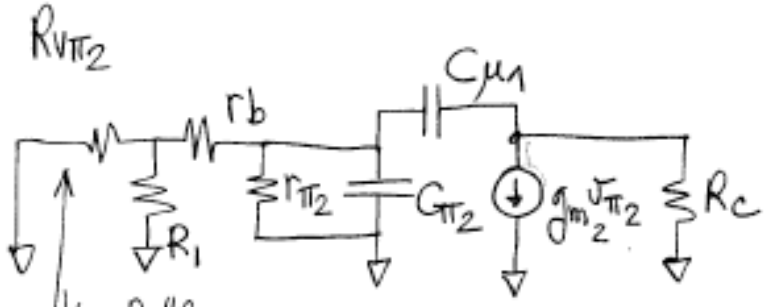
$$i_G = \frac{v_G\left(1 + g_{m_1}(R_1 // hie_2)\right)}{R_2 // R_4 + r_b + R_1 // hie_2}$$

$$R_{V\pi_1} = \underset{6973}{r_{\pi_1}} // \left[\frac{\overset{3333}{R_2 // R_4} + \overset{450}{r_b} + \overset{1600}{R_1 // hie_2}}{1 + g_{m_1}(R_1 // hie_2)}\right] = r_{\pi_1} // \left[\frac{5383}{1+40}\right] =$$

$g_{m_1} \to 25\cdot10^{-3}$, $R_1 // hie_2 \to 1600$

$= 6973 // 131{,}3 = 128{,}9\ \Omega$

$R_{V\pi_2}$



$$R_{V\pi_2} = \underset{7554}{r_{\pi_2}} // \underbrace{\left[\overset{450}{r_b} + R_1 // \overbrace{\left(\frac{hie_1 + R_2 // R_4}{h_{fe_1} + 1}\right)}^{61.1}\right]}_{508} = 476{,}9\ \Omega$$

$$R_{V\mu_2} = R_{V\pi_2}(1 + g_{m_2} R_C) + R_C = 476{,}9\,(1+46) + 2000 = 24{,}4\ K\Omega$$

$$f_H = \frac{1}{2\pi\left[R_{V\pi_1} C_{\pi_1} + R_{V\mu_1} C_{\mu_1} + R_{V\pi_2} C_{\pi_2} + R_{V\mu_1} C_{\mu_1}\right]} = 1.08\ MHz$$