TS5

$f_0 = 22\,KHz$ $\quad f_{s1} = 17\,KHz \rightarrow \alpha(f_{s1}) = 16\,dB \quad \omega_{s1} = 17/22$

$Q = 5$ $\quad f_{s2} = 36\,KHz \rightarrow \alpha(f_{s2}) = 24\,dB \quad \omega_{s2} = 36/22$

$\alpha_{MAX} = 0{,}5\,dB$

$f_1, f_2 ? \rightarrow \omega_1\omega_2 = 1 \wedge Q = \dfrac{\omega_0}{\omega_2-\omega_1} \Rightarrow \omega_1\omega_2 = Q(\omega_2-\omega_1) \rightarrow \omega_1(\omega_2+Q) = Q\omega_2 \rightarrow \omega_1 = \dfrac{\omega_2 Q}{\omega_2+Q} \rightarrow 1 = \dfrac{\omega_2^2 Q}{\omega_2+Q} \rightarrow \omega_2^2 Q - \omega_2 - Q = 0$

$\Rightarrow \omega_2 = \dfrac{1+\sqrt{101}}{10} \cong 1{,}104987562 \rightarrow \omega_1 = 0{,}9049875622$

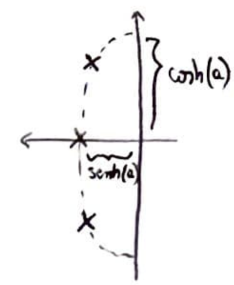
$\Omega_s = Q\cdot\dfrac{\omega_s^2-1}{\omega_s} \rightarrow \Omega_{s1} = \overset{\text{se ignora}}{-2{,}606951872} \quad \Omega_{s2} = 5{,}126262626$

$\varepsilon^2 = 10^{\alpha_{MAX}/10} - 1 = 0{,}1220184543 \rightarrow \varepsilon = 0{,}3493114002$

$\alpha_{MIN} = 10\log\left(1+\varepsilon^2\cosh^2\left[n\cosh^{-1}(\Omega_s)\right]\right) \rightarrow \cancel{\alpha}\ \Omega_{s1}: n=3 \quad (\alpha = 26{,}866\,dB) \quad \Omega_{s2}: n=2 \ (\alpha = 25{,}123\,dB) \Rightarrow n=3$

$a = \dfrac{1}{n}\,\mathrm{senh}^{-1}\left(\dfrac{1}{\varepsilon}\right) = 0{,}5913783794$

Polos: $\sigma_k = -\mathrm{senh}(a)\,\mathrm{sen}\left(\dfrac{2k-1}{2n}\pi\right) \quad \omega_k = \cosh(a)\cos\left(\dfrac{2k-1}{2n}\pi\right) \rightarrow \begin{cases} -0{,}3132282432 + j1{,}021927491 \\ -0{,}6264564863 \\ -0{,}3132282432 - j1{,}021927491 \end{cases}$



Comp. conj: $\omega_0 = \sqrt{\omega^2+\sigma^2} = 1{,}068853465 \quad q = \dfrac{\omega_0}{2\sigma} = 1{,}706189477$

$\omega_0/q = 0{,}6264564865 \quad \omega_0^2 = 1{,}14244773$

$T(\$) = \dfrac{0{,}626}{\$+0{,}626}\cdot\dfrac{1{,}142}{\$^2+0{,}626\,\$+1{,}142} = \dfrac{a}{\$+a}\cdot\dfrac{c}{\$^2+b\$+c} \Leftarrow$ Transferencia pasabajos prototipo

Transformación LP-BP $\quad$ Núcleo: $\Omega(\omega) = Q\,\dfrac{\omega^2+1}{\omega} \rightarrow \$(s) = Q\,\dfrac{s^2+1}{s}$

P.s: $\dfrac{a}{Q\frac{s^2+1}{s}+a} = \dfrac{s.a/Q}{s^2+s.\frac{a}{Q}+1}$

C.C: $\dfrac{c}{\left(Q\frac{s^2+1}{s}\right)^2+b\left(Q\frac{s^2+1}{s}\right)+c} = \dfrac{c}{\frac{Q^2}{s^2}(s^4+2s^2+1)+b.\frac{Q}{s}(s^2+1)+c} = \dfrac{c.s^2/Q^2}{s^4+s^3(b/Q)+s^2(2+c/Q^2)+s(b/Q)+1}$

$\Rightarrow T(s) = \dfrac{s.a/Q}{s^2+s.\frac{a}{Q}+1}\cdot\dfrac{s^2.c/Q^2}{s^4+s^3\left(\frac{b}{Q}\right)+s^2\left(2+\frac{c}{Q^2}\right)+s\left(\frac{b}{Q}\right)+1} \rightsquigarrow \dfrac{a}{Q} = 0{,}1252912973 = b \quad \dfrac{c}{Q^2} = 0{,}04569779092$

Descomposición ~~de~~ en sos:

Polos: $-0{,}02813691233 \pm j\,0{,}9025322821 \rightarrow \omega_0 = 0{,}902970767 \quad q = 16{,}04601868 \rightarrow$ se cumple igual q y $\omega_{01} = \omega_{02}^{-1}$

$-0{,}03450873632 \pm j\,1{,}106917781 \rightarrow \omega_0 = 1{,}107455564 \quad q = 16{,}04601736$

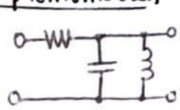
(Primera sección) $\rightarrow \omega_0 = 1 \quad q = \dfrac{Q}{a} = 7{,}981400317$

$\Rightarrow T(s) = \dfrac{s.0{,}125}{s^2+s.0{,}125+1}\cdot\dfrac{s.0{,}056}{s^2+s.0{,}056+0{,}815}\cdot\dfrac{s.0{,}069}{s^2+s.0{,}069+1{,}226}\cdot\overbrace{\dfrac{0{,}046}{0{,}056.0{,}069}}^{c/Q^2\cdot\frac{1}{\omega_{01}/q_1\cdot\omega_{02}/q_2}}$

$= 11{,}76605617$

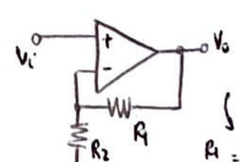
La transferencia transformada requiere de ganancia

Implementación



$T(s) = \dfrac{G}{sC+\frac{1}{sL}+G} = \dfrac{sLG}{s^2LC+1+sLG} = \dfrac{sG/C}{s^2+s\frac{G}{C}+\frac{1}{LC}}$

$C = 1 \rightarrow 1/L = \omega_0^2 \rightarrow L = 1/\omega_0^2 \quad 1/R = G = \omega_0/q \rightarrow R = q/\omega_0$



$V_o = V_i\cdot 1+\dfrac{R_1}{R_2}$

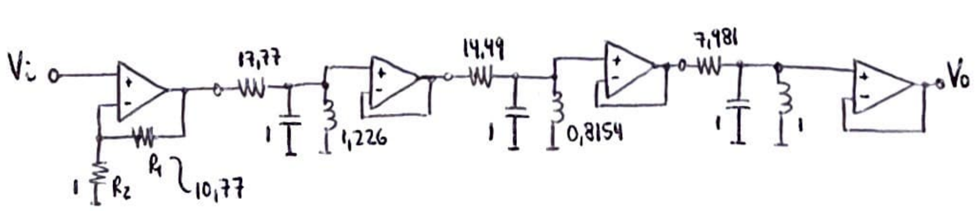
$\dfrac{R_1}{R_2} = 10{,}76605617 \rightarrow R_2 = 1$

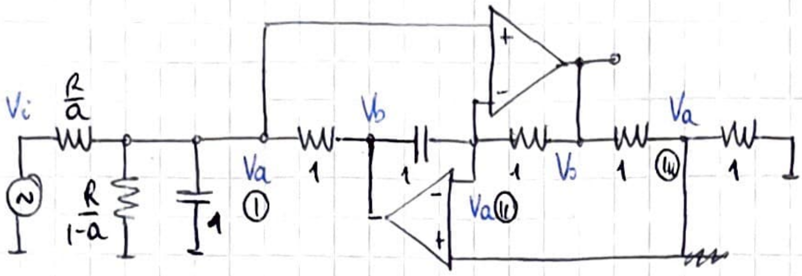
$R_1 = 10{,}76605617$

SOS1: $\{R = 17{,}77025267 \quad L = 1{,}226457826 \quad C = 1\}$

SOS2: $\{R = 14{,}4890846 \quad L = 0{,}815356206 \quad C = 1\}$

SOS3: $\{R = 7{,}981400317 \quad L = 1 \quad C = 1\}$





$$\begin{cases} \text{(I)} & V_a\left(\frac{a}{R}+\frac{1-a}{R}+s\cancel{C}+1\right)=V_i\left(\frac{a}{R}\right)+V_b(1) \\ \text{(II)} & V_a\left(s\cancel{C}+1\right)=V_b\,s\cancel{C}+V_o(1) \\ \text{(III)} & V_a(1+1)=V_o(1) \end{cases}$$

(III) $\Rightarrow V_a=\frac{V_o}{2} \rightsquigarrow$ en (II): $\cancel{V_o}\left(\frac{s\cancel{C}+1}{2}-1\right)=V_b\,s\cancel{C} \to V_b=V_o\left(\frac{s\cancel{C}-1}{2s\cancel{C}}\right) \Rightarrow V_b=V_o\left(\frac{s-1}{2s}\right)$

(III) y (II) en (I) $\Rightarrow$

$$\frac{V_o}{2}\left(\frac{1}{R}+s+1\right)=V_i\left(\frac{a}{R}\right)+V_o\left(\frac{s-1}{2s}\right)$$

$$\frac{V_o}{2}\left(\frac{1}{R}+s+\cancel{1}-\cancel{\frac{s}{s}}+\frac{1}{s}\right)=V_i\left(\frac{a}{R}\right)$$

$$\frac{V_o}{2}\left(\frac{s+s^2R+R}{s\cancel{R}}\right)=V_i\left(\frac{a}{\cancel{R}}\right)$$

$$\frac{V_o}{V_i}=\frac{2as}{s+s^2R+R}=\frac{2a/R\,s}{s^2+\frac{s}{R}+1}=2a\cdot\frac{s/R}{s^2+s/R+1} \to \omega_0=1,\ q=R$$

Esta celda posee $\omega_0=1$ para los valores de componentes propuestos, y se pueden variar q y la ganancia en la frecuencia central variando los valores de $\frac{R}{a}$ y $\frac{R}{1-a}$

Si planteo mantener ganancia unitaria en SOS2 y SOS3, y aplicar la ganancia total de la transferencia en SOS1, entonces $a_{SOS2}=a_{SOS3}=1/2$ (tal que $2a=1$)

Esto sí

Desnormalizado solo $\Omega_\omega=2\pi 22\,\text{KHz}\cdot\omega_{0\,SOS1}$

$\Rightarrow$ ~~SOS1:~~	~~$R=q=16{,}04601868$~~	~~$2a=11{,}76605617 \to a=5{,}883028085$~~
SOS2:	$R=q=16{,}04601868$	~~$a=1/2 \to R/a=32{,}09203736=R/(1-a)$~~
~~SOS3:~~	~~$R=q=7{,}981400317$~~	~~$a=1/2 \to R/a=15{,}96280063=R/(1-a)$~~

NO! a_{SOS1} es mayor a 1 $\to 1-a<0$ y $\frac{R}{a}>0 \to$ Imposible

$2a_1\cdot 2a_2\cdot 2a_3=k=11{,}76605617 \to a_1\cdot a_2\cdot a_3=\frac{k}{8}=1{,}470757021$

$\Rightarrow$ $0<a_1<1$ y $0<a_2<1 \wedge 0<a_3<1 \Rightarrow a_1\cdot a_2\cdot a_3<1 \to$ No se puede lograr la ganancia requerida únicamente con una cascada de estas secciones. $\to$ Utilizo nuevamente la etapa no inv.

$R_1=q_{SOS1}$ $\quad R_2=q_{SOS2}$ $\quad R_3=q_{SOS3}$ $\quad a_1=1/2=a_2=a_3$ $\quad \frac{R_1}{a_1}=\frac{R_1}{1-a_1}=2R_1$ $\quad \frac{R_2}{a_2}=\frac{R_2}{1-a_2}=2R_2$ $\quad \frac{R_3}{a_3}=\frac{R_3}{1-a_3}=2R_3$

$32{,}09203736 \longrightarrow =$ $\quad 15{,}96280063$

TS5

$f_0 = 22kHz$ $\quad f_{s1} = 17kHz \to \alpha(f_{s1}) = 16dB \to \omega_{s1} = 17/22$

$Q = 5$ $\quad f_{s2} = 36kHz \to \alpha(f_{s2}) = 24dB \to \omega_{s2} = 36/22$

$\alpha_{MAX} = 0{,}5dB$

$f_1, f_2? \to \omega_1\omega_2 = 1 \wedge Q = \frac{\omega_0}{\omega_2-\omega_1} \Rightarrow \omega_1\omega_2 = Q(\omega_2-\omega_1) \to \omega_1(\omega_2+Q) = \omega_2 Q \to \omega_1 = \frac{Q\omega_2}{\omega_2+Q}$

$1 = \omega_2 \cdot \frac{Q\omega_2}{\omega_2+Q} \to \omega_2 + Q = Q\omega_2^2 \to \omega_2^2 - \frac{\omega_2}{Q} - 1 = 0 \to \omega_2 = \frac{1+\sqrt{101}}{10} = 1{,}104987562 \to \omega_1 = 0{,}9049875622$

$\Omega_s = \frac{\omega_s^2-1}{\omega_s}Q \to \Omega_{s1} = \cancel{0{,}5243903743}$ $-2{,}606951872$ $\quad \Omega_{s2} = \cancel{1{,}025252525} = 5{,}126262626$

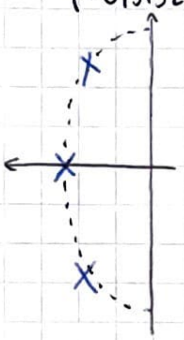
$\xi^2 = 10^{\alpha_{MAX}/10} - 1 = 0{,}1220184543$ $\quad \xi = 0{,}3493114002$

$\alpha_{MIN} = 10\log\left(1+\xi^2\cosh^2\left[n\cosh^{-1}(\Omega_s)\right]\right) \to \Omega_{s1}: n = 3 \ (\alpha = 26{,}866dB)$ $\quad \Omega_{s2}: n = 2 \ (\alpha = 25{,}123dB)$

$a = \frac{1}{n}\sinh^{-1}\left(\frac{1}{\xi}\right) = 0{,}5913783794$ $\quad \sigma_k = -\sinh(a)\cdot\sin\left(\frac{2k-1}{2n}\cdot\pi\right)$ $\quad \omega_k = \cosh(a)\cos\left(\frac{2k-1}{2n}\pi\right)$

Polos: $\begin{cases} -0{,}3132282432 + j1{,}021927491 \\ -0{,}6264564863 + j0 \\ -0{,}3132282432 - j1{,}021927491 \end{cases} \to T(\$) = \frac{0{,}626}{\$+0{,}626} \cdot \frac{1{,}142}{\$^2 + \$\cdot 0{,}626 + 1{,}142}$

$\omega_{0\,(cc)} = \cancel{1{,}0266...}$ $1{,}068853465$ $\quad Q = 1{,}706189477 \to \frac{\omega_0}{Q} = 0{,}6264564865$



$$T(\$) = \frac{a}{\$+a} \cdot \frac{c}{\$^2 + b\cdot\$ + c} \qquad \begin{cases} a = 0{,}6264564863 \\ b = a \\ c = 1{,}14244773 \end{cases}$$

Transferencia pasobajos prototipo.

Núcleo de trasf: $\Omega(\omega) = \frac{\omega^2+1}{\omega}Q \to \$(s) = \frac{s^2+1}{s}\cdot Q$

$$T(s) = \frac{a}{Q\cdot\frac{s^2+1}{s}+a} \cdot \frac{c}{\left(Q\frac{s^2+1}{s}\right)^2 + Q\frac{s^2+1}{s}\cdot b + c} \qquad \frac{s\cdot a/Q}{s^2 + s\cdot\frac{a}{Q} + 1}$$

$$\frac{s^2/Q^2\cdot c}{(s^2+1)^2 + \frac{s}{Q}(s^2+1)\cdot b + \frac{s^2}{Q^2}c} = \frac{s^2/Q^2\cdot c}{(s^4+2s^2+1) + (s^3\cdot b/Q + s\cdot b/Q) + s^2\cdot c/Q^2} = \frac{s^2/Q^2\cdot c}{s^4+s^3(b/Q)+s^2(2+c/Q)+s(b/Q)+1}$$

$$\Rightarrow T_{BP}(s) = \frac{s\cdot a/Q}{s^2+s\cdot a/Q+1} \cdot \frac{s^2/Q^2\cdot c}{s^4+s^3(b/Q)+s^2(2+c/Q)+s(b/Q)+1}$$

$a/Q = 0{,}1252912973$

$b/Q = \nearrow$

$c/Q = 0{,}228489546$

$2 + c/Q = 2{,}228489546$

Descomposición en SOS:

Polos: $-0{,}02409792021 + j0{,}7902938082$

$\quad$ " $-j$ "

$-0{,}0\,38547772844 + j1{,}264176778$

$\quad$ " $-j$ "

~~$\omega_0 = 0{,}790661124$~~ $\quad$ ~~$\omega_0 = 1{,}321641276$~~

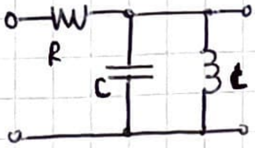
~~$Q = 1{,}64051735$~~ $\quad$ ~~$Q = 1{,}714292034$~~ $\to$ Hay algo mal.

$\omega_{01} = 0{,}790661124$ $\quad \omega_{02} = 1{,}264764347$ $\to$ Ahora sí $(\omega_{01} = 1/\omega_{02},\ Q_1 = Q_2)$

$Q_1 = 16{,}4051735$ $\quad Q_2 = 16{,}40517351$

$\frac{s^2}{Q^2}\cdot c = \left(\frac{s}{Q}\cdot\sqrt{c}\right)^2$ (Coeficiente de los ~~polos~~ ceros en los sos) $\to$ $k_1 = 0{,}2254557897$? No

$\cancel{\frac{s}{Q}\sqrt{c}\cdot k = \frac{\omega_0}{Q}}$ $\quad \frac{\omega_0}{Q}\cdot k = \frac{\sqrt{c}}{Q} \to k = \frac{(\sqrt{c}/Q)}{\omega_0/Q} \longrightarrow k_1 = 4{,}435459392$ $\quad k_2 = 2{,}772805319$



$Y_{11} = SC + 1/SL$ $\quad Y_R = G$

$$T(s) = \frac{G}{SC+1/SL+G} = \frac{S\cdot G/C}{S^2+S\frac{G}{C}+\frac{1}{LC}} = \frac{S/RC}{S^2+S/RC+1/LC} = \frac{S W_0/Q}{S^2+S W_0/Q+W_0^2}$$

Si $C=1 \to \frac{1}{LC}=W_0^2 \to L=\frac{1}{W_0^2}$ $\quad \frac{W_0}{Q}=\frac{1}{RC} \to \frac{W_0}{Q}=\frac{1}{R} \to R=\frac{Q}{W_0}$

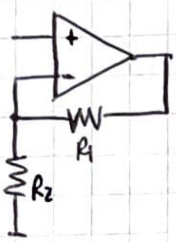
~~SOS1~~

~~SOS2~~

SOS1 $W_0=1$, $Q=7{,}98140032$ $\quad \to R=7{,}98140032;\ L=1;\ C=1$

SOS2 $W_0=0{,}790661124$, $Q=16{,}40517351$, $\quad k=4{,}435459392 \to R=20{,}74867856;\ L=1{,}599628853;\ C=1$

SOS3 $W_0=1{,}264764347$, $Q=16{,}40517351$, $\quad k=2{,}772805319 \to R=12{,}97093292;\ L=0{,}6251450128;\ C=1$



$V_i = V_0\cdot\frac{R_2}{R_1+R_2} \to \frac{V_0}{V_i}=\frac{R_1+R_2}{R_2}=1+\frac{R_1}{R_2} \rightsquigarrow R_2=1 \to \frac{V_0}{V_i}=1+R_1 \to R_1=\frac{V_0}{V_i}-1=k-1$

SOS2: $R_1=3{,}435459392$ $\quad R_2=1$

SOS3: $R_1=1{,}772805319$ $\quad R_2=1$

SOS1: Buffer $(R_1\to 0,\ R_2\to\infty)$, Desconectado.

$$\frac{C}{S^2+b\cdot S+C} \longrightarrow \frac{C}{\left(Q\frac{S^2+1}{S}\right)^2+b\cdot\left(Q\frac{S^2+1}{S}\right)+C} = \frac{C}{Q^2\frac{(S^4+2S^2+1)}{S^2}+b\cdot Q\frac{(S^2+1)}{S}+C}$$

$$=\frac{S^2/Q^2\cdot C}{(S^4+2S^2+1)+b\cdot Q\cdot\frac{S^2}{Q^2}\cdot\frac{(S^2+1)}{S}+\frac{S^2}{Q^2}\cdot C} = \frac{S^2/Q^2\cdot C}{(S^4+2S^2+1)+b\cdot\frac{S}{Q}(S^2+1)+S^2\frac{C}{Q^2}} = \frac{S^2/Q^2\cdot C}{S^4+S^3(b/Q)+S^2(2+C/Q^2)+S(b/Q)+1}$$

$$\frac{C}{\left(Q\frac{S^2+1}{S}\right)^2+b\left(Q\cdot\frac{S^2+1}{S}\right)+C} = \frac{C}{\frac{Q^2}{S^2}\cdot(S^4+2S^2+1)+b\cdot\frac{Q}{S}(S^2+1)+C} = \frac{\frac{S^2}{Q^2}\cdot C}{(S^4+2S^2+1)+\frac{S^2}{Q^2}\cdot\frac{Q}{S}(S^2+1)b+\frac{S^2}{Q^2}\cdot C}$$

$$=\frac{S^2\cdot\frac{C}{Q^2}}{(S^4+2S^2+1)+\frac{S}{Q}(S^2+1)\cdot b+S^2\frac{C}{Q^2}} = \frac{S^2\left(\frac{C}{Q^2}\right)}{S^4(1)+S^3\left(\frac{b}{Q}\right)+S^2\left(2+\frac{C}{Q^2}\right)+S\left(\frac{b}{Q}\right)+1}$$