TS5

$f_0 = 22KHz$ $\quad f_{s_1} = 17KHz \rightarrow \alpha(f_{s1}) = 16dB \quad \omega_{s1} = 17/22$

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

$\alpha_{MÁX} = 0{,}5dB$

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

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

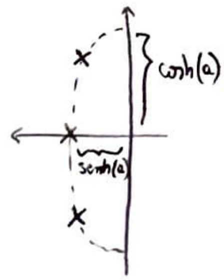
$\Omega_s = Q \cdot \frac{\omega_s^2-1}{\omega_s} \rightarrow \Omega_{s_1} = \overset{\text{se ignora}}{-2{,}606951872} \quad \Omega_{s2} = 5{,}126262626$

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

$\alpha_{MÍN} = 10\log\left(1+\varepsilon^2\cosh^2\left[n\cosh^{-1}(\Omega_s)\right]\right) \rightarrow \cancel{\alpha}\ \Omega_{s_1}: n=3 \ (\alpha = 26{,}866dB) \quad \Omega_{s2}: n=2\ (\alpha = 25{,}123dB) \Rightarrow n=3$

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

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



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

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

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

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

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

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

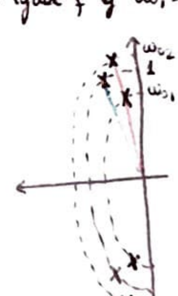
$\Rightarrow T(s) = \frac{s.a/Q}{s^2+s.\frac{a}{Q}+1} \cdot \frac{s^2.c/Q^2}{s^4+s^3\left(\frac{b}{Q}\right)+s^2\left(2+\frac{c}{Q^2}\right)+s\left(\frac{b}{Q}\right)+1} \rightsquigarrow \frac{a}{Q} = 0{,}1252912973 = b \quad \frac{c}{Q^2} = 0{,}04569779092$

Descomposición ~~de~~ en sos:

Polos: $-0{,}02813691233 \pm j\,0{,}9025322821 \rightarrow \omega_0 = 0{,}902970767 \quad q = 16{,}04601868$ → se cumple igual q y $\omega_{0_1} = \omega_{0_2}^{-1}$

$-0{,}03450873632 \pm j\,1{,}106917781 \rightarrow \omega_0 = 1{,}10745564 \quad q = 16{,}04601736$

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

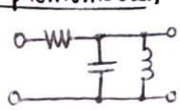


$\Rightarrow T(s) = \frac{s.0{,}125}{s^2+s.0{,}125+1} \cdot \frac{s.0{,}056}{s^2+s.0{,}056+0{,}815} \cdot \frac{s.0{,}069}{s^2+s.0{,}069+1{,}226} \cdot \underbrace{\frac{0{,}046}{0{,}056.0{,}069}}_{c/Q^2 \cdot \frac{1}{\omega_{01}/q_1 \cdot \omega_{02}/q_2}}$

$= 11{,}76605617$

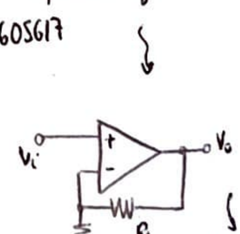
La transferencia transformada requiere de ganancia

Implementación



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

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



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

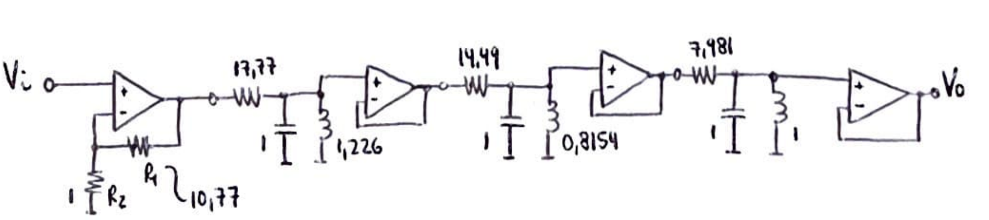
$\frac{R_1}{R_2} = 10{,}76605617 \rightarrow R_2 = 1$

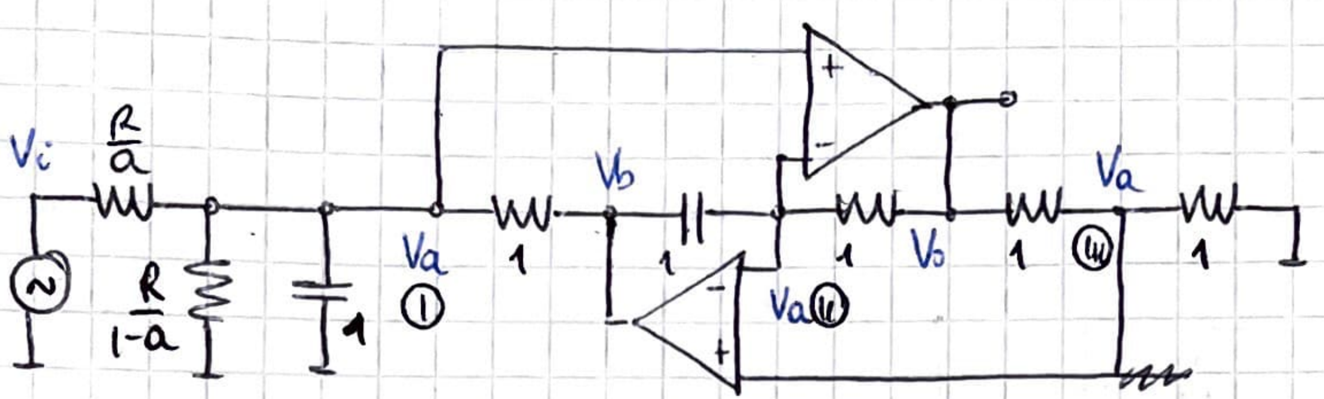
$R_1 = 10{,}76605617$

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

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

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





$$\begin{cases} \text{(I)} \quad V_a\left(\frac{a}{R}+\frac{1-a}{R}+S+1\right)=V_i\left(\frac{a}{R}\right)+V_b(1) \\ \text{(II)} \quad V_a\left(S+1\right)=V_b S+V_o(1) \\ \text{(III)} \quad V_a(1+1)=V_o(1) \end{cases}$$

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

$$\text{(III) y (II) en (I)} \Rightarrow \frac{V_o}{2}\left(\frac{1}{R}+S+1\right)=V_i\left(\frac{a}{R}\right)+V_o\left(\frac{S-1}{2S}\right)$$

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

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

$$\frac{V_o}{V_i}=\frac{2aS}{S+S^2R+R}=\frac{2a/RS}{S^2+\frac{S}{R}+1}=2a\cdot\frac{S/R}{S^2+S/R+1} \longrightarrow \omega_0=1,\ f=R$$

TS5

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

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

$\alpha_{MÁX} = 0{,}5dB$

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

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

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

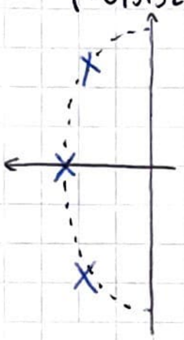
$\varepsilon^2 = 10^{\alpha_{MÁX}/10} - 1 = 0{,}1220184543 \quad \varepsilon = 0{,}3493114002$

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

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

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

$\omega_{0\,(cc)} = \cancel{1{,}0266263...}$ $1{,}068853465 \quad q = 1{,}706189477 \rightarrow \frac{\omega_0}{q} = 0{,}6264564865$



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

Transferencia pasabajos prototipo.

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

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

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

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

Polos: $-0{,}02409792021 + j0{,}7902938082$
$\quad$ " $\quad -j$ "
$-0{,}03854772844 + j1{,}264176778$
$\quad$ " $\quad -j$ "

$a/Q = 0{,}1252912973$
$b/Q = \nearrow$
$c/Q = 0{,}228489546$
$2 + c/Q = 2{,}228489546$

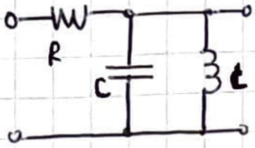
Descomposición en SOS:

$\cancel{\omega_0 = 0{,}790661124}$ $\quad \cancel{\omega_0 = 1{,}321641276}$
$\cancel{q = 1{,}64051735}$ $\quad \cancel{q = 1{,}714292034}$ $\rightarrow$ Hay algo mal.

$\omega_{0_1} = 0{,}790661124 \quad \omega_{0_2} = 1{,}264764347 \rightarrow$ Ahora sí $(\omega_{0_1} = 1/\omega_{02},\ q_1 = q_2)$
$q_1 = 16{,}4051735 \quad q_2 = 16{,}40517351$

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

$\cancel{\frac{s}{Q}\sqrt{c} \cdot k = \frac{\omega_0}{q}}$ $\quad \frac{\omega_0}{q} \cdot k = \frac{\sqrt{c}}{Q} \rightarrow k = \frac{\sqrt{c}/Q}{\omega_0/q} \rightarrow k_1 = 4{,}435459392 \quad k_2 = 2{,}772805319$



$Y_{11} = sC + 1/sL \qquad Y_R = G$

$$T(s) = \frac{G}{sC + 1/sL + G} = \frac{s \cdot G/C}{s^2 + s\frac{G}{C} + \frac{1}{LC}} = \frac{s/RC}{s^2 + s/RC + 1/LC} = \frac{s\,w_0/Q}{s^2 + s\,w_0/Q + w_0^2}$$

Si $C = 1 \rightarrow \frac{1}{LC} = w_0^2 \rightarrow L = \frac{1}{w_0^2} \qquad \frac{w_0}{Q} = \frac{1}{RC} \rightarrow \frac{w_0}{Q} = \frac{1}{R} \rightarrow R = \frac{Q}{w_0}$

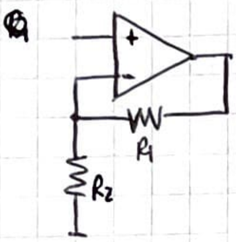
~~SOS1~~

~~SOS2~~

SOS1 $w_0 = 1,\ Q = 7{,}98140032 \qquad \rightarrow R = 7{,}98140032;\ L = 1;\ C = 1$

SOS2 $w_0 = 0{,}790661124,\ Q = 16{,}40517351, \quad k = 4{,}435459392 \rightarrow R = 20{,}74867856;\ L = 1{,}599628853;\ C = 1$

SOS3 $w_0 = 1{,}264764347,\ Q = 16{,}40517351, \quad k = 2{,}772805319 \rightarrow R = 12{,}97093292;\ L = 0{,}6251450128;\ C = 1$



$$V_i = V_o \cdot \frac{R_2}{R_1 + R_2} \rightarrow \frac{V_o}{V_i} = \frac{R_1 + R_2}{R_2} = 1 + \frac{R_1}{R_2} \rightsquigarrow R_2 = 1 \rightarrow \frac{V_o}{V_i} = 1 + R_1 \rightarrow R_1 = \frac{V_o}{V_i} - 1 = k - 1$$

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

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

SOS1: Buffer $(R_1 \rightarrow 0,\ R_2 \rightarrow \infty)$ → Desconectado

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

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

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

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