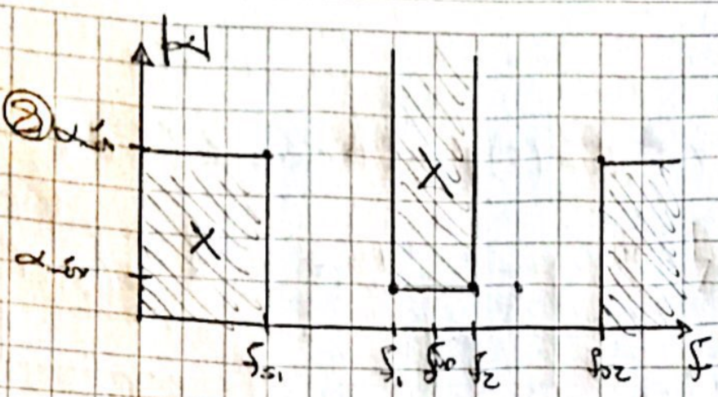


$$\left.\begin{array}{l} f_1 = 1{,}6\,KHz \\ f_2 = 2{,}5\,KHz \end{array}\right\} \Rightarrow f_0 = \sqrt{f_1 \cdot f_2} = 2\,KHz$$

$$Q = \frac{f_0}{f_2 - f_1} = 2{,}22$$

$f_{s1} = 1{,}25\,KHz \rightarrow \alpha_{MIN} = 20\,dB$

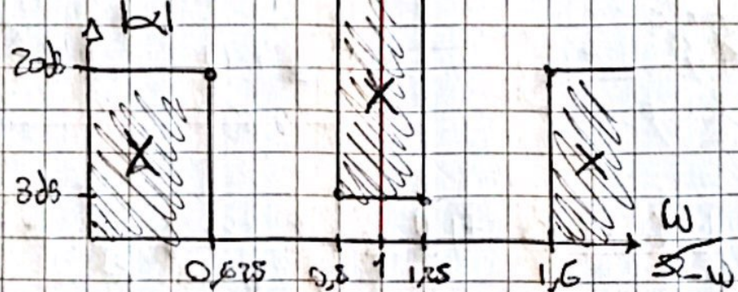
$f_{s2} = 3{,}2\,KHz$

$\alpha_{max} = 3\,dB$ y $|H(w_0)| = 20\,dB$

$$W_0 = 2\pi \cdot 2K = 4\pi\,K\,rad/s \cong 12{,}56\,Krad/s$$

Plantilla Normalizada:

$\Omega_W = w/w_0$



Como Ambos piden 20dB, a simple vista salta que la pollera derecha es mas exigente. Por las dudas hacemos los calculos $\rightarrow \Omega_{s1} = 2{,}1645$

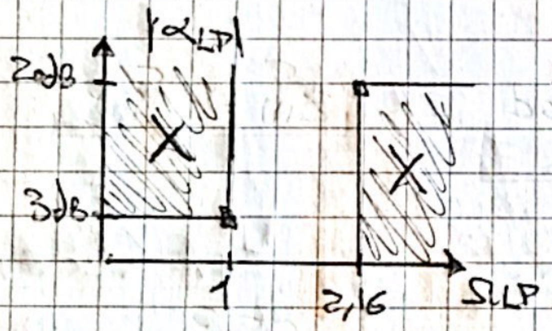
$\Omega_{s2} = 2{,}1645$

$$\varepsilon^2 = 10^{\alpha/10} - 1 = 0{,}99 \approx 1$$

$\varepsilon \approx 1 \rightarrow$ Butterworth!

Al Final No era evidente.

Plantilla Pasabajos



Para Máxima Planicidad:

$$\alpha_{MIN} = 10 \log\left(1 + \varepsilon^2\, \Omega_s^{2N}\right)$$

$$\Downarrow$$

$$N \geq 2{,}98 \Longrightarrow N = 3$$

sigue!

Butterworth N=3 $\rightarrow |T(\Omega)|^2 = \frac{1}{1+\Omega^6}\Bigg|_{\Omega=\bar{s}/j} = \frac{1}{1-\bar{s}^6} = T(\bar{s})\cdot T(-\bar{s})$

$$\frac{1}{1-\bar{s}^6} = \frac{1}{a+b\bar{s}+c\bar{s}^2+\bar{s}^3}\cdot\frac{1}{a-b\bar{s}+c\bar{s}^2-\bar{s}^3}$$

sabemos que

$\boxed{a=1}$

$c^2-2b=0$ $\Rightarrow$ por ser de la misma forma $\Rightarrow \boxed{c=b} \Rightarrow c^2-2c=0$

$2c-b^2=0$

$\cancel{c=0} \vee c=2$

$$\boxed{T(\bar{s}) = \frac{1}{\bar{s}^3+2\bar{s}^2+2\bar{s}+1}}$$

En espacio LP.

$$\longrightarrow \boxed{T(\bar{s}) = \frac{1}{\bar{s}+1}\cdot\frac{1}{\bar{s}^2+\bar{s}+1}}$$

$$T(s) = T(\bar{s})\Big|_{\bar{s}=Q\frac{(s^2+1)}{s}} = \frac{s\,1/Q}{s^2+s\,1/Q+1}\cdot\frac{1}{\frac{Q^2(s^4+2s^2+1)}{s^2}+\frac{Q(s^2+1)s}{s^2}+\frac{s^2}{s^2}}$$

$$T_1(s) = \frac{s\,1/Q}{s^2+s\,1/Q+1}$$

$$T_2(s) = \frac{s^2\,1/Q^2}{(s^4+2s^2+1)+1/Q\cdot(s^3+s)+1/Q^2\cdot s^2} = \frac{s^2\,1/Q^2}{s^4+1/Q\,s^3+(2+1/Q^2)s^2+1/Q\,s+1}$$

$$\boxed{T_2(s) = \frac{s^2\cdot 0{,}202}{s^4+s^3\cdot 0{,}45+s^2\cdot 2{,}202+s\cdot 0{,}45+1}} \longrightarrow$$

$P_1 = -0{,}09 + j0{,}817$
$P_1^* = -0{,}09 - j0{,}817$

$P_2 = -0{,}134 + j1{,}207$

$P_2^* = -0{,}134 - j1{,}207$.

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Podemos expresar la $T_2(s) = T_{21}(s) \cdot T_{22}(s)$,

$$\boxed{T_{21}(s) = K \frac{s\frac{\omega_{01}}{Q_1}}{s^2 + s\frac{\omega_{01}}{Q_1} + \omega_{01}^2}}$$

Con $\omega_{01}^2 = 0{,}09^2 + 0{,}817^2 = 0{,}675$

$\omega_{01} = 0{,}821 \Rightarrow Q_1 = \frac{0{,}821}{2 \cdot 0{,}09} = 4{,}56$

$$\boxed{T_{22}(s) = K \frac{s\frac{\omega_{02}}{Q_2}}{s^2 + s\frac{\omega_{02}}{Q_2} + \omega_{02}^2}}$$

Con $\omega_{02}^2 = 0{,}134^2 + 1{,}207^2 = 1{,}474$

$\omega_{02} = 1{,}214 \Rightarrow Q_2 = \frac{1{,}214}{2 \cdot 0{,}134} = 4{,}53$

sabemos que $K^2 \cdot \frac{\omega_{02}}{Q_2} \cdot \frac{\omega_{01}}{Q_1} = 1/Q^2$

Nota $Q_1 \simeq Q_2$

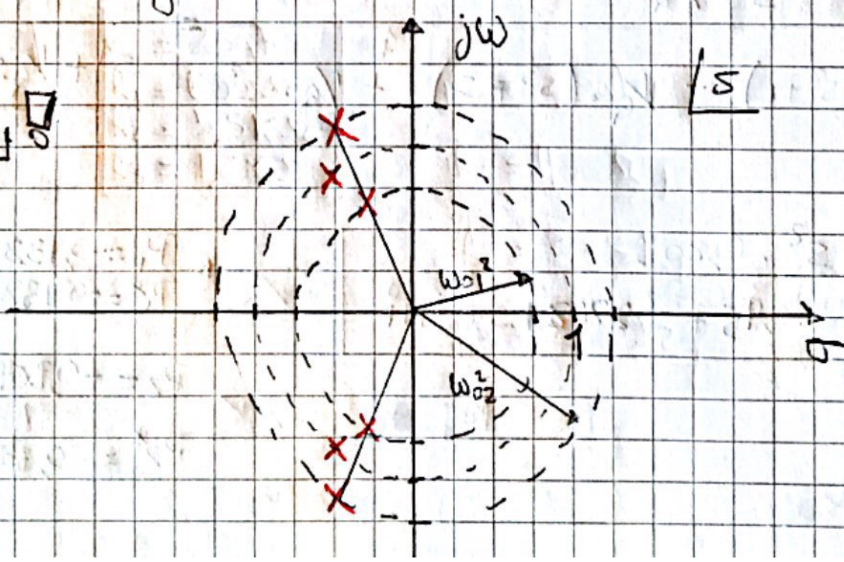
$$K^2 = \frac{1}{Q^2} \cdot \frac{Q_2\, Q_1}{\omega_{01}\, \omega_{02}} = 4{,}17 \rightarrow K = 2{,}04$$

Transferencia Pasa Banda Normalizada

$$\boxed{T(s) = \frac{s\,1/Q}{s^2 + s\,1/Q + 1} \cdot \frac{s\frac{\omega_{01}}{Q_1} \cdot K}{s^2 + s\frac{\omega_{01}}{Q_1} + \omega_{01}^2} \cdot \frac{s\frac{\omega_{02}^2}{Q_2^2} \cdot K}{s^2 + s\frac{\omega_{02}}{Q_2} + \omega_{02}^2}}$$

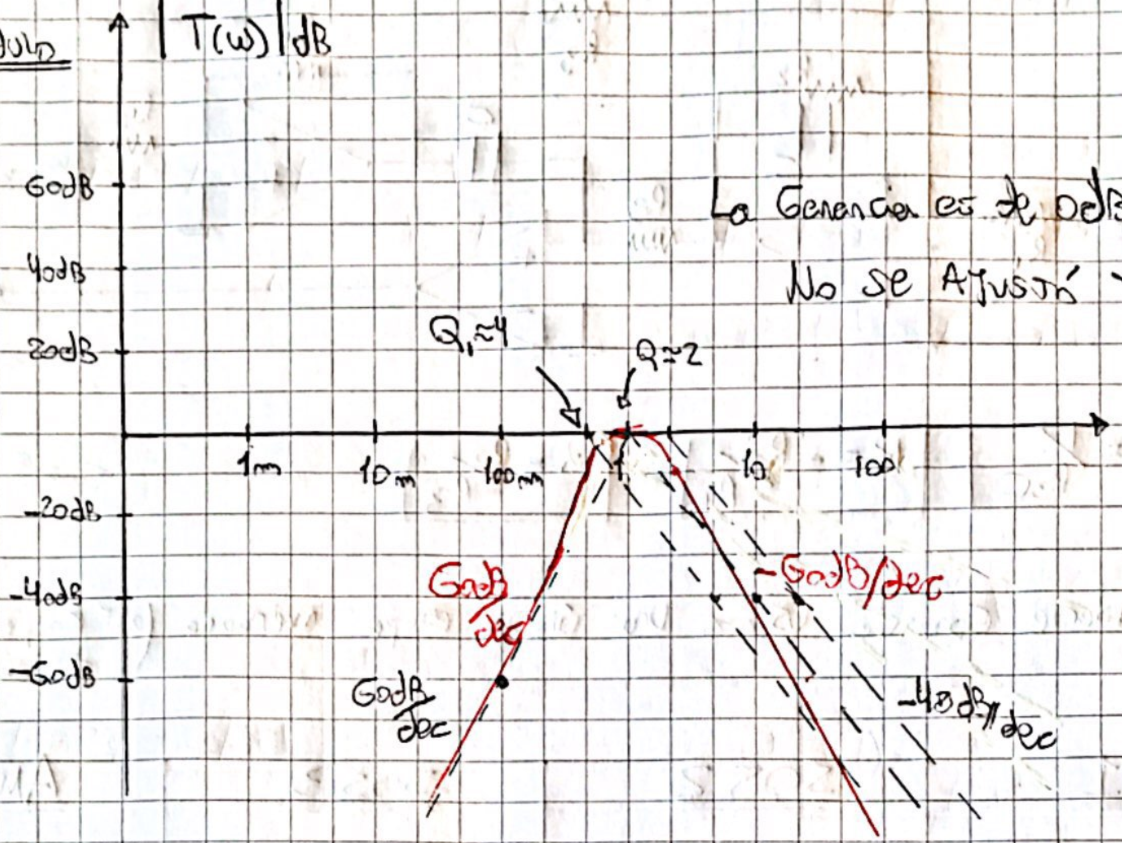
Diagrama de Polos y Ceros Normalizado

$Q_1 = Q_2 > Q$!



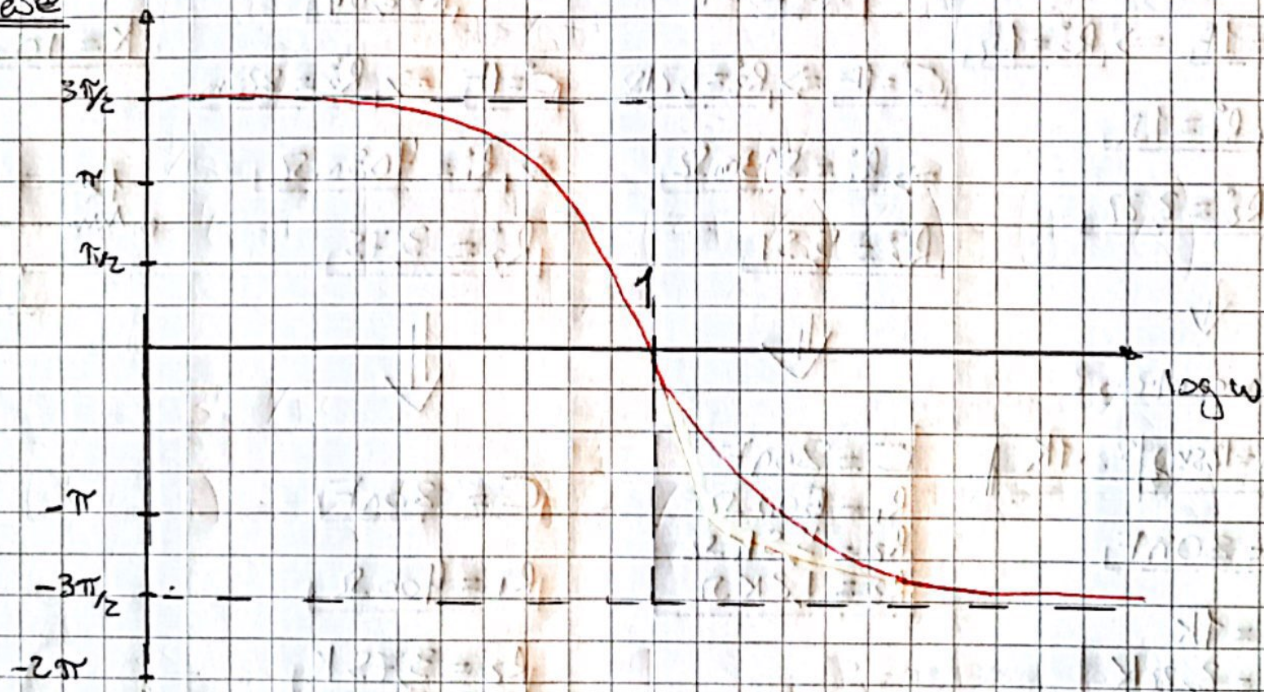
Transferencia en Módulo y Fase (Bode)

Módulo

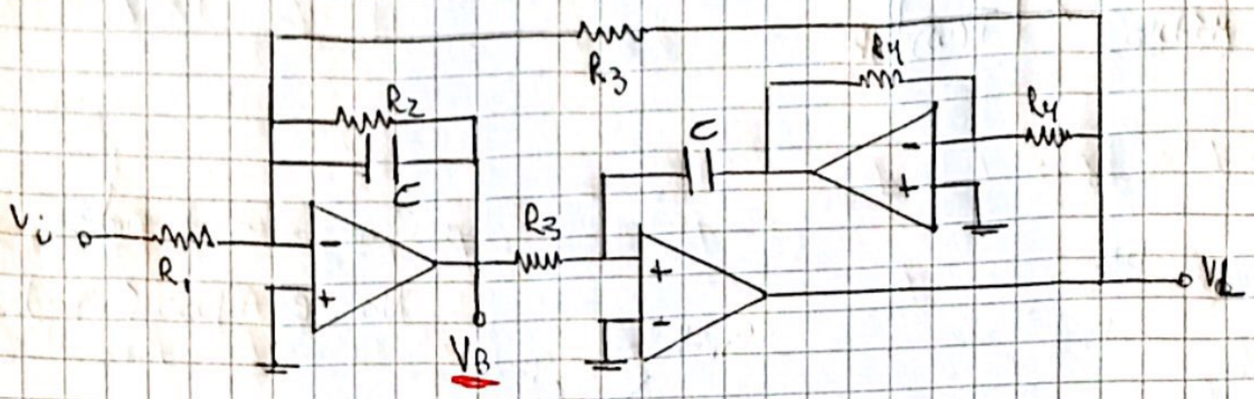


La Ganancia es de 0dB porque No se Ajustó Todavía

Fase



Nos Piden usar Ackerberg-Mossberg:



$\boxed{W_0 = \frac{1}{R_3 C}}$ $\boxed{K = -\frac{R_3}{R_1}}$ $\boxed{Q = \frac{R_2}{R_3}}$

Para Darle Ganancia Usamos Una Última etapa inversora (así compensamos el desfasaje)

SOS 1

$W_0 = 1$ $Q = 2,22$

$K = 1$

$C^* = 1F \Rightarrow R_3^* = 1\Omega$

$\Rightarrow R_1^* = 1\Omega$

y $R_2^* = 2,22$

$\Downarrow$

Desnormalizo:

$\Omega_w = 12{,}5\,\text{krad/s}$ $\Omega_z = 1K$

$C = 80nF$

$R_1 = 1K$
$R_2 = 2,22K$
$R_3 = 1K$

SOS 2

$W_0 = 0,821$ $Q = 4,56$

$K = 2,04$

$C^* = 1F \Rightarrow R_3^* = 1,218$

$\Rightarrow R_1^* = 593m\Omega$

$R_2^* = 5,51$

$\Downarrow$

$C = 80nF$
$R_1 = 600\,\Omega$
$R_2 = 5,5K\Omega$
$R_3 = 1,2K\Omega$

SOS 3

$W_0 = 1,214$ $Q = 4,56$

$K = 2,04$

$C^* = 1F \Rightarrow R_3^* = 823m$

$\Rightarrow R_1^* = 403m\Omega$

$R_2^* = 3,75$

$\Downarrow$

$C = 80nF$

$R_1 = 400\,\Omega$

$R_2 = 3,75K$

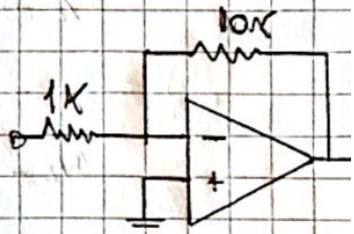
$R_3 = 820\,\Omega$

AMP inversor

Necesitamos 20dB.

$\Downarrow$

$K = 10$



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Al momento de simular me doy cuenta de que hay problemas en la ganancia. En particular, la variable de diseño $K = H\,\omega_0/Q$. Por ende, tengo que ajustar los valores. También voy a incorporar los 20dB que necesito en la 1er etapa, y saco la 4ta.

SOS1

$C = 80nF$
$R_2 = 2{,}22K$
$R_3 = 4K$

$K = 10 \cdot 1/2{,}22$

$K = 4{,}5$

$\Downarrow$

$R_1 = 222\,\Omega$

SOS2

$C = 80nF$
$R_2 = 5{,}5K$
$R_3 = 1{,}2K$

$K = \overset{H}{\widetilde{2{,}04}} \cdot \frac{0{,}821}{4{,}56}$

$K = 0{,}367$

$\Downarrow$

$R_1 = 3{,}2K$

SOS3

$C = 80nF$
$R_2 = 3{,}75K$
$R_3 = 820\,\Omega$

$K = 2{,}04 \cdot \frac{1{,}214}{4{,}56}$

$K = 0{,}543$

$\Downarrow$

$R_1 = 1{,}5K$

Ahora la simulación da bien!

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