

$$\omega_0 = 2\pi \cdot 22 \text{ kHz} = 44000\pi \text{ Hz}$$

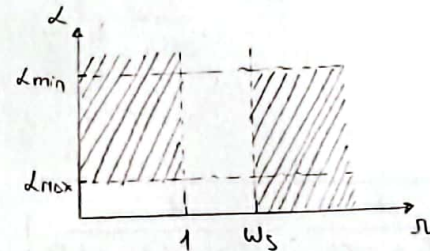
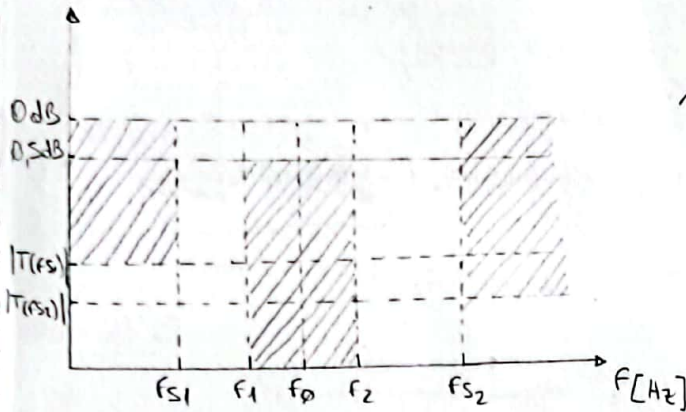
$$Q = 5$$

Approx cheby con ripple de 0,5 dB

$$|T(f_{S1})| = -16 \text{ dB} \quad \text{para } f_{S1} = 17 \text{ kHz}$$

$$|T(f_{S2})| = -24 \text{ dB} \quad \text{para } f_{S2} = 36 \text{ kHz}$$

TSS



$$\omega_{S1} = \frac{17 \text{ kHz}}{22 \text{ kHz}} = \frac{17}{22} = 0,77$$

$$\omega_{S2} = \frac{36 \text{ kHz}}{22 \text{ kHz}} = \frac{18}{11} = 1,63$$

$$\Omega_{S1,2} = \frac{Q(\omega_{S1,2}^2 - 1)}{\omega_{S1,2}} \quad \begin{cases} \Omega_{S1} = -2,6 \\ \Omega_{S2} = 5,1 \end{cases}$$

BUSCO el más exigente

$$\alpha_{min} = 10 \log [1 + \epsilon^2 C_n^2(\Omega_{Sn})]$$

$$\bullet \omega_{S1} = 0,77 ; \Omega_{S1} = -2,6$$

$$n=1 \rightarrow \alpha(\Omega_{S1}) = 2,61$$

$$n=2 \rightarrow \alpha(\Omega_{S1}) = 13,04$$

$$n=3 \rightarrow \alpha(\Omega_{S1}) = 26,79$$

$\Rightarrow \boxed{n=3}$   $\therefore \omega_{S1}$  y  $\Omega_{S1}$  es el más exigente.

$$\bullet \omega_{S2} = 1,63 ; \Omega_{S2} = 5,1$$

$$n=1 \rightarrow \alpha(\Omega_{S2}) = 6,12$$

$$n=2 \rightarrow \alpha(\Omega_{S2}) = 25,03$$

$$\epsilon^2 = 10^{0,5/10} - 1 = 0,122 \rightarrow \epsilon = 0,349$$

$$C_3(\omega) = 4\omega^3 - 3\omega \Rightarrow |T_f(j\omega)|^2 = \frac{1}{1 + \epsilon^2(4\omega^3 - 3\omega)^2} = \frac{1}{1 + \epsilon^2(16\omega^6 - 24\omega^4 + 9\omega^2)} = \frac{2}{\omega^6 - b\omega^4 + c\omega^2 + 2}$$

$$|T(j\omega)|^2 \Big|_{\omega = \frac{s}{j}} = \frac{2}{-s^6 - bs^4 - cs^2 + 2} = \frac{2}{\underbrace{s^3 + \beta s^2 + \gamma s + \alpha}_{T(s)} \underbrace{-s^3 + \beta s^2 - \gamma s + \alpha}_{T(-s)}}$$

$$\begin{cases} a = \frac{1}{16\epsilon^2} \\ b = 3/2 \\ c = 9/16 \end{cases}$$

$$\Rightarrow \frac{1/16\epsilon^2}{s^6 - \frac{3}{2}s^4 - \frac{9}{16}s^2 + \frac{1}{16\epsilon^2}} = \frac{2}{s^3 + \beta s^2 + \gamma s + \alpha} \frac{2}{-s^3 + \beta s^2 - \gamma s + \alpha}$$

$$\alpha^2 = \frac{1}{16\epsilon^2} \Rightarrow \boxed{\alpha = \frac{1}{4\epsilon}}$$

$$-\gamma + \beta^2 - \gamma = \frac{3}{2}$$

$$-2\gamma + \beta^2 = -\frac{3}{2}$$

$$\gamma = \left(-\frac{3}{2} - \beta^2\right) \left(-\frac{1}{2}\right)$$

$$\gamma = \frac{3}{4} + \frac{\beta^2}{2}$$

$$\gamma^2 = \left(\frac{3}{4} + \frac{\beta^2}{2}\right)^2$$

$$\beta\alpha - \gamma^2 + \beta\alpha = -\frac{9}{16}$$

$$2\beta\alpha - \gamma^2 = -\frac{9}{16}$$

$$\frac{\beta}{2\epsilon} - \gamma^2 = -\frac{9}{16}$$

$$\therefore \boxed{\gamma = 1,53}$$

$$\frac{\beta^4}{4} + \frac{3}{4}\beta^2 + \frac{9}{16}$$

$$\frac{\beta}{2\epsilon} - \frac{\beta^4}{4} - \frac{3}{4}\beta^2 - \frac{9}{16} = -\frac{9}{16}$$

$$-\frac{\beta^4}{4} - \frac{3}{4}\beta^2 + \frac{\beta}{2\epsilon}$$

$$\boxed{\beta_1 = 1,25}$$

$$\beta_2 = 0$$

$$\beta_3 = 0$$

$$\beta_4 = 0$$

$$T(s) = \frac{1/4E}{s^3 + 1,2s^2 + 1,53s + \frac{1}{4E}}$$

$$s_1 = -0,6287$$

$$s_2 = -0,31 + j1,02$$

$$s_3 = -0,31 - j1,02$$

$$(s - (-0,31 + j1,02))(s - (-0,31 - j1,02))$$

$$(s + 0,31 - j1,02)(s + 0,31 + j1,02)$$

$$s^2 + 0,31s + j1,02 + 0,31s + 0,0961 + j0,3162 - j1,02$$

$$-j0,3162 + 1,0404$$

$$s^2 + 0,62s + 1,14$$

$$\therefore T(s) = \frac{1}{s + 0,63} \cdot \frac{1}{s^2 + 0,62s + 1,14}$$

Transformo LP → BP

$$T_{BP}(s) = T_{LP}\left(\frac{s}{Q}\right) \quad Q = \frac{s^2 + 1}{s}$$

$$T_{BP}(s) = \frac{0,63}{\frac{s^2 + 1}{s} + 0,63} \cdot \frac{1,14}{\left(\frac{s^2 + 1}{s}\right)^2 + 0,62 \frac{s^2 + 1}{s} + 1,14} =$$

$$= \frac{0,63s}{s^2 + 1 + 0,63s} \cdot \frac{1,14}{\frac{Q^2 s^4 + 2Q^2 s^2 + Q^2}{s^2} + \frac{0,62 s^2 Q + 0,62 Q}{s} + 1,14}$$

$$= \frac{0,63s}{s^2 + 0,63s + 1} \cdot \frac{1,14}{\frac{Q^2 s^4 + 2Q^2 s^2 + Q^2 + 0,62 s^3 Q + 0,62 s Q + 1,14 s^2}{s^2}}$$

$$= \frac{s \cdot \frac{0,63}{Q}}{s^2 + s \cdot \frac{0,63}{Q} + 1} \cdot \frac{1,14 s^2}{Q^2 s^4 + 0,62 s^3 Q + s^2(2Q^2 + 1,14) + s \cdot 0,62 Q + Q^2}$$

$$= \frac{s \cdot \frac{0,63}{Q}}{s^2 + s \cdot \frac{0,63}{Q} + 1} \cdot \frac{s^2 \cdot \frac{1,14}{Q^2}}{s^4 + s^3 \frac{0,62}{Q} + s^2(2 + \frac{1,14}{Q^2}) + s \cdot \frac{0,62}{Q} + 1} \quad ; Q = s$$

$$T_{BP}(s) = \frac{s \cdot 0,126}{s^2 + s \cdot 0,126 + 1} \cdot \frac{s^2 \cdot 0,0456}{s^4 + s^3 \cdot 0,124 + s^2 \cdot 2,0456 + s \cdot 0,124 + 1}$$

Factorizo en SOS

$$\begin{cases} \omega_1 \omega_2 - \omega_0^2 = 0 \\ \omega_2 - \omega_1 - \omega_0/Q = 0 \end{cases} \quad \text{con } \omega_0 = 1, Q = s$$

$$\omega_2 - \omega_1 = \frac{1}{s} \Rightarrow \omega_2 = \frac{1}{s} + \omega_1$$

$$\omega_1 \cdot \left(\frac{1}{s} + \omega_1\right) = 1$$

$$\omega_1^2 + \frac{1}{s} \omega_1 - 1 = 0$$

$$\boxed{\omega_2 = 1,104}$$

$$\omega_{11} = 0,904 \Rightarrow \boxed{\omega_1 = 0,904}$$

$$s^4 + s^3 \cdot 0,124 + s^2 \cdot 2,0456 + s \cdot 0,124 + 1$$

$$s_1 = -0,028 + j0,902$$

$$s_2 = -0,028 - j0,902$$

$$s_3 = -0,034 + j1,11$$

$$s_4 = -0,034 - j1,11$$



$$Q^2 = \frac{Q}{a} \left[ \left( \frac{2Q}{a} + \frac{b}{2aQ} \right) \pm \sqrt{\left( \frac{2Q}{a} + \frac{b}{2aQ} \right)^2 - 1} \right] \quad \text{donde } Q = 5$$

$$a = 0,62$$

$$b = 1,14$$

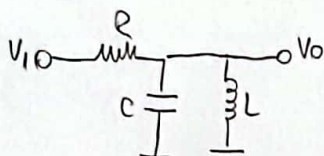
$$|Q = 16,21| \Rightarrow Q = Q_1 = Q_2$$

$$T_{BP}(s) = \underbrace{\frac{S \cdot 0,126}{s^2 + S \cdot 0,126 + 1}}_{\text{Sección 1}} \underbrace{\frac{S \cdot k_1 \cdot \frac{0,904}{16,21}}{s^2 + S \cdot \frac{0,904}{16,21} + 0,904^2}}_{\text{Sección 2}} \underbrace{\frac{S \cdot k_2 \cdot \frac{1,104}{16,21}}{s^2 + S \cdot \frac{1,104}{16,21} + 1,104^2}}_{\text{Sección 3}}$$

Sección 1

$$\omega_0 = 1$$

$$Q = 7,94$$



$$\frac{V_0}{V_1} = \frac{s/Rc}{s^2 + s/Rc + 1/LC} \quad \begin{cases} \omega_0^2 = \frac{1}{LC} = 1 \\ \frac{\omega_0}{Q} = \frac{1}{RC} = 0,126 \end{cases}$$

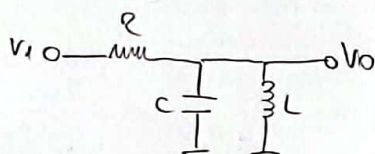
$$\Delta \text{donde } |C=1|$$

$$\Rightarrow |L=1|, |R=7,94|$$

Sección 2

$$\omega_0 = 0,904$$

$$Q = 16,21$$



$$\begin{cases} \omega_0^2 = \frac{1}{LC} = 0,904^2 \\ \frac{\omega_0}{Q} = \frac{1}{RC} = \frac{0,904}{16,21} \end{cases}$$

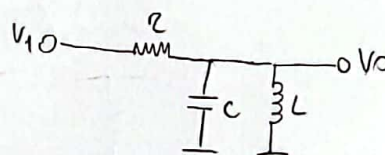
$$\Delta \text{donde } |C=1|$$

$$\Rightarrow |L=1,22|, |R=17,93|$$

Sección 3

$$\omega_0 = 1,104$$

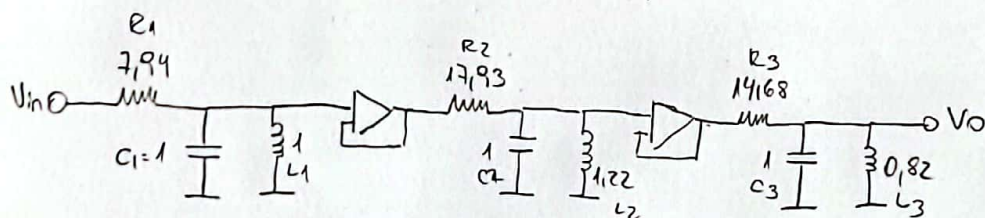
$$Q = 16,21$$



$$\begin{cases} \omega_0^2 = \frac{1}{LC} = 1,104^2 \\ \frac{\omega_0}{Q} = \frac{1}{RC} = \frac{1,104}{16,21} \end{cases}$$

$$\Delta \text{donde } |C=1|$$

$$\Rightarrow |L=0,82|, |R=14,68|$$



Desnormalizo:

$$\Omega R = 1k\Omega$$

$$\Omega \omega = 2\pi \cdot 22kHz$$

$$R = R_{norm} \cdot \Omega R$$

$$C = \frac{C_{norm}}{\Omega R \cdot \Omega \omega}$$

$$L = L_{norm} \cdot \frac{\Omega R}{\Omega \omega}$$

$$R_1 = 7,94 \cdot 1kHz$$

$$|R_1 = 7940\Omega|$$

$$C_1 = 1 \cdot \frac{1}{1kHz \cdot 2\pi \cdot 22kHz}$$

$$|C_1 = 7,23nF|$$

$$|L_1 = 7,23mH|$$

$$|R_2 = 17930\Omega|$$

$$|C_2 = 7,23nF|$$

$$|L_2 = 8,82mH|$$

$$|R_3 = 14630\Omega|$$

$$|C_3 = 7,23nF|$$

$$|L_3 = 5,93mH|$$