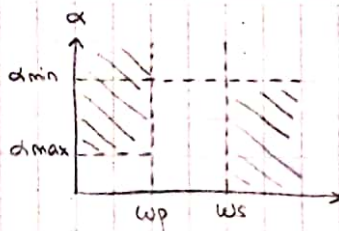


Tp2

3)



$$\alpha_{\min} = 48 \text{ dB}$$

$$\alpha_{\max} = 0,48 \text{ dB}$$

Chebyshev.

$$f_s = 9,6 \text{ kHz} \rightarrow \omega_s = 3$$

$$f_p = 3,2 \text{ kHz} \rightarrow \omega_p = 1$$

$$a. \quad \epsilon_1^2 = 10^{\alpha_{\max}/10} - 1$$

$$\epsilon_1^2 = 10^{0,4/10} - 1 = 0,096$$

$$\boxed{\epsilon_1 = 0,31}$$

$$\alpha_{\min} = 10 \log \left\{ 1 + \epsilon_1^2 \cosh^2 \left[n \cosh^{-1}(\omega_s) \right] \right\}$$

$$n=2: \alpha_{\min} = 14,6 \text{ dB}$$

$$n=3: \alpha_{\min} = 28,7 \text{ dB}$$

$$n=4: \alpha_{\min} = 45 \text{ dB}$$

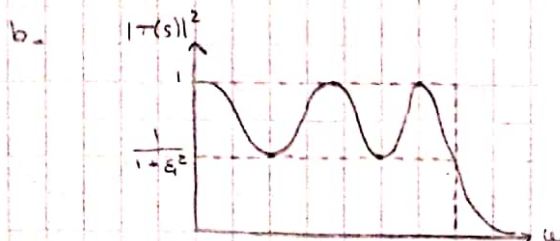
$$\boxed{n=5: \alpha_{\min} = 60,3 \text{ dB}}$$

$$\begin{aligned} c. \quad |T_c(j\omega)|^2 &= \frac{1}{1 + \epsilon_1^2 C_5^2(\omega)} = \frac{1}{1 + \epsilon_1^2 (16\omega^5 - 20\omega^3 + 5\omega)^2} \\ &= \frac{1}{1 + \epsilon_1^2 (256\omega^{10} + 400\omega^6 + 25\omega^2 - 640\omega^8 + 160\omega^6 - 200\omega^4)} \\ &= \frac{1}{\omega^{10} \epsilon_1^2 256 - \omega^8 \epsilon_1^2 640 + \omega^6 \epsilon_1^2 560 - \omega^4 \epsilon_1^2 200 + \omega^2 \epsilon_1^2 25 + 1} \\ &= \frac{1/\epsilon_1^2 256}{\omega^{10} - \omega^8 \cdot 2,5 + \omega^6 \cdot 2,187 - \omega^4 \cdot 0,781 + \omega^2 \cdot 0,097 + 0,04} \end{aligned}$$

$$|T_c(j\omega)|^2 \Big|_{\omega = s/j} = \frac{1/\epsilon_1^2 256}{-s^{10} + s^8 \cdot 2,5 - s^6 \cdot 2,187 - s^4 \cdot 0,781 - s^2 \cdot 0,097 + 0,04} = T(s)T(-s)$$

$$T(s) = \frac{1/\epsilon_1 16}{(s + 0,385)(s + 0,118 + j1,018)(s + 0,118 - j1,018)(s + 0,311 + j0,63)(s + 0,311 - j0,63)}$$

$$T(s) = \frac{0,385}{(s + 0,385)(s^2 + s \cdot 0,236 + 1,05)} \cdot \frac{1,05}{(s^2 + s \cdot 0,622 + 0,493)}$$



$$d. \quad T_{LP}(s) = -\frac{R_2}{R_4} \frac{R_3 / C C_2 R_2 R_4 R_5}{s^2 + s \cdot \frac{1}{C_1 R_4} \left(\frac{R_7}{R_6 + R_7} \right) \left(\frac{R_3}{R_1} + \frac{R_3}{R_2} + 1 \right) + \frac{R_3}{C C_2 R_2 R_4 R_5}}$$

$$SOS_1: \begin{cases} \omega_1 = 1 \\ \omega_{01} = 1,025 \\ Q_1 = 4,343 \end{cases}$$

$$SOS_2: \begin{cases} \omega_2 = 1 \\ \omega_{02} = 0,702 \\ Q_2 = 1,128 \end{cases}$$

$$\omega_c = \frac{R_2}{R_4}$$

$$\omega_c = 1$$

$$\begin{cases} C_1 = C_2 = C \\ R_1 = R_2 = R_3 \\ R_6 = R_7 \end{cases}$$

$$C = 1 \text{ m}$$

$$R_1 = R_2 = R_3 = 1 \text{ k}$$

$$R_6 = R_7 = 1 \text{ k}$$

$$\omega_{01}^2 = \frac{R_3}{C C_2 R_2 R_4 R_5}$$

$$\omega_{01}^2 = \frac{1}{C^2 R_4 R_5}$$

$$\omega_{01}^2 = 1,025^2 = \frac{1}{C^2 R_4 R_5}$$

$$R_5 = 149,4$$

$$\frac{\omega_{01}}{Q_1} = \frac{1}{C_1 R_4} \left(\frac{R_7}{R_6 + R_7} \right) \left(\frac{R_3}{R_1} + \frac{R_3}{R_2} + 1 \right)$$

$$\frac{\omega_{01}}{Q_1} = \frac{1}{2} \frac{1}{C R_4} \cdot 3$$

$$\frac{\omega_{01}}{Q_1} = \frac{1,025}{4,343} = \frac{3}{2} \frac{1}{C R_4}$$

$$0,157 \text{ m} = \frac{1}{R_4}$$

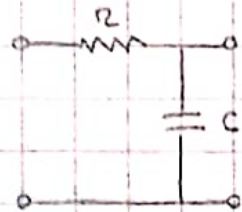
$$R_4 = 6369$$

$$\omega_{02}^2 = 0,702^2 = \frac{1}{C^2 R_u' R_s'}$$

$$R_s' = 842$$

$$\frac{\omega_{02}}{Q_2} = \frac{0,702}{1,128} = \frac{3}{2} \frac{1}{C R_u'}$$

$$R_u' = 2410$$



$$T(s) = \frac{1/C R}{s + 1/C R} = \frac{\omega_0}{s + \omega_0}$$

$$\omega_0 = \frac{1}{C R} = 0,385$$

$$C = 1 \text{ m}$$

$$R = 2597$$

Valores normalizados $\rightarrow R_2 = R_1$

$$R_1 = 1 \quad R_2 = 1 \quad R_3 = 1 \quad R_4 = 6,37 \quad R_5 = 0,149 \quad R_6 = R_7 = 1 \quad C = 1 \rightarrow \text{1er etapa}$$

$$R_1' = 1 \quad R_2' = 1 \quad R_3' = 1 \quad R_4' = 2,41 \quad R_5' = 0,842 \quad R_6' = R_7' = 1 \quad C = 1 \rightarrow \text{2da etapa}$$

$$R = 2,6 \quad C = 1 \rightarrow \text{3er etapa}$$