$\boxed{\text{TP1}}$ Cheby

$\omega_c = 3000\pi$ $\omega_s = 9000\pi$

$\Omega\omega = 3000\pi$

$\omega_s = 3$

$\omega_c = 1$

$\alpha_{MAX} = 0,5\,dB$ $\alpha_{min} = 16\,dB$

$$\xi^2 = 10^{\frac{0,5}{10}} - 1 \simeq 0,122$$

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

$n = 1 \rightarrow 3,22\,dB$

$n = 2 \rightarrow 15,59\,dB$

$n = 3 \rightarrow 30,78\,dB$

$n = 3$

$$C_{3(\omega)} = 2\omega \cdot C_{n-1}(\omega) - C_{n-2}(\omega)$$

$2\omega \cdot (2\omega^2 - 1) - \omega$

$$C_{3(\omega)} = 4\omega^3 - 3\omega$$

entonces

$$\frac{1}{1+\xi^2 \cdot C_{3(\omega)}^{\ 2}} = \frac{1}{1+\xi^2 \cdot (16\omega^6 - 24\omega^4 + 9\omega^2)} = \frac{\frac{1}{16\cdot\xi^2}}{\omega^6 - \frac{3}{2}\omega^4 + \frac{9}{16}\omega^2 + \frac{1}{16\xi^2}}$$

Pasando a dominio S

$$|T_{(s)}|^2 = |T_{(j\omega)}|^2\Big|_{\omega=\frac{s}{j}} = \frac{\frac{1}{16\xi^2}}{\frac{s^6}{j^6} - \frac{3}{2}\cdot\frac{s^4}{j^4} + \frac{9}{16}\frac{s^2}{j^2} + \frac{1}{16\xi^2}}$$

$j^6 = -1$

$j^4 = 1$

$j^2 = -1$

$$|T_{(s)}|^2 = \frac{1/16\xi^2}{-s^6 - \frac{3}{2}s^4 - \frac{9}{16}s^2 + 1/16\xi^2}$$

esto se implementaría con un 2do orden y 1er orden

$$T_{(s)} = K\cdot\frac{A}{s+A}\cdot\frac{C}{s^2+Bs+C}$$

Formando en conjunto un 3er orden

$$T_{(s)} = D\cdot\frac{G}{s^3+s^2\cdot E+s\cdot F+G}$$

entonces

$$T_{(s)}\cdot T_{(-s)} = \frac{D\cdot G}{-s^3+s^2E-sF+G}\cdot\frac{D\cdot G}{s^3+s^2E+sF+G}$$

$$T_{(s)} \cdot T_{(-s)} = \frac{D^2 \cdot G^2}{-S^6 - S^4 F \cdot 2 + S^4 E^2 + 2 \cdot S^2 E G - S^2 F^2 + G^2}$$

$$T_{(s)} \cdot T_{(-s)} = \frac{D^2 \quad G^2}{S^6 \cdot (-1) + S^4 \cdot (E^2 - 2F) + S^2 (2 \cdot E \cdot G - F^2) + G^2}$$

Igualando a expresión de Cheby

$$\frac{D^2 \quad G^2}{S^6 \cdot (-1) + S^4 \cdot (E^2 - 2F) + S^2 (2 \cdot E \cdot G - F^2) + G^2} = \frac{\frac{1}{16 \xi^2}}{S^6 (-1) + S^4 \left(-\frac{3}{2}\right) + S^2 \left(-\frac{9}{16}\right) + \frac{1}{16 \xi^2}}$$

$$\begin{cases} G^2 = \frac{1}{16 \xi^2} \quad , D^2 = 1 \\ E^2 - 2F = -\frac{3}{2} \quad \text{I} \\ 2EG - F^2 = -\frac{9}{16} \quad \text{II} \end{cases}$$

$$G = \frac{1}{4 \xi} \simeq 0{,}7157$$

$$\text{I} \quad \left(E^2 + \frac{3}{2}\right) \frac{1}{2} = F \rightarrow F^2 = \left(\frac{E^2}{2} + \frac{3}{4}\right)^2$$

$$F^2 = \frac{E^4}{4} + \frac{\cancel{2} E^2}{\cancel{2}} \cdot \frac{3}{4} + \frac{9}{16}$$

II

$$2 \cdot E \cdot G - \frac{E^4}{4} - E^2 \cdot \frac{3}{4} - \frac{9}{16} = -\frac{9}{16}$$

$$E^4 \left(-\frac{1}{4}\right) + E^2 \left(-\frac{3}{4}\right) + 2 \cdot E \cdot \frac{1}{4 \xi} = 0$$

$$E^3 \left(-\frac{1}{4}\right) + E \left(-\frac{3}{4}\right) + \frac{1}{2 \xi} = 0$$

(con CALC)

$E_1 = 1{,}252912973$

E_2, E_3 $\not\in$ conv.

$F = 1{,}534895458$

con estos valores. Factorizo para hallar los 2 filtros 2do y 1er orden a utilizar

$$T_{(s)} = K \cdot \frac{A}{S+A} \frac{C}{S^2+BS+C} = \frac{K \cdot A \cdot C}{S^3+BS^2+CS+S^2A+BAS+CA}$$

$$T_{(s)} = \frac{K \cdot A \cdot C}{S^3+S^2(B+A)+S(AB+C)+AC} = \frac{G}{S^3+S^2E+SF+G}$$

$$\begin{cases} A \cdot C = G \ \text{I}, \quad k=1 \\ B+A = E \ \text{II} \\ AB+C = F \ \text{III} \end{cases}$$

I $C = \frac{G}{A}$ → III

II $B = E - A$

$$A \cdot (E-A) + \frac{G}{A} = F$$

$$-A^2+EA+\frac{G}{A} = F \qquad -A^3+EA^2-F \cdot A+G=0$$

con G, F y E en calcu...

$A_1 = 0{,}6264564863$

A_2 y A_3 $\not\in$

$B = 0{,}6264564863$ B=A

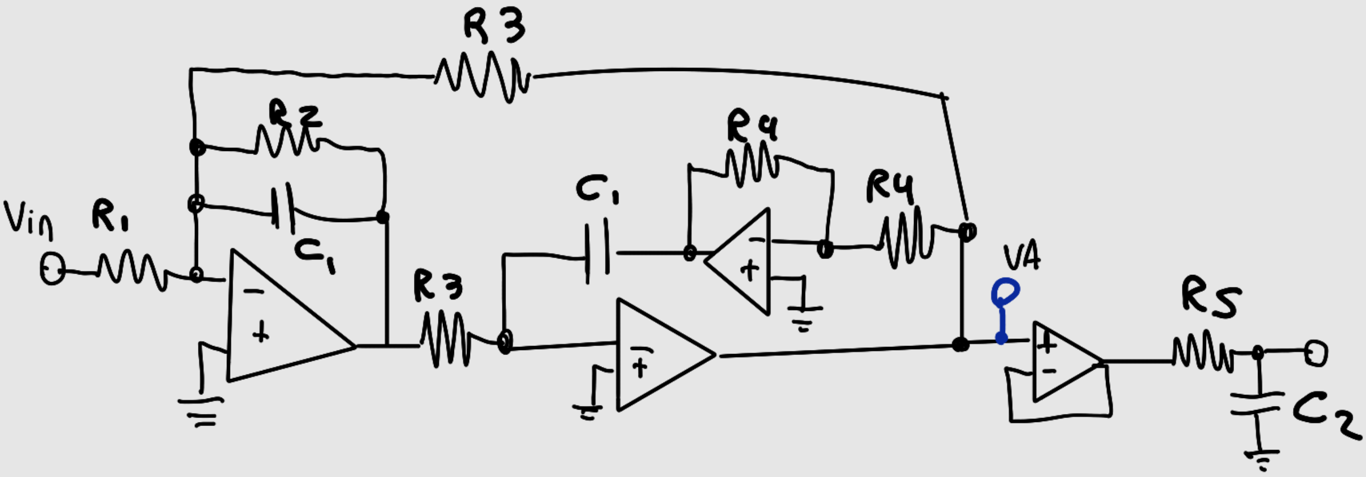
$C = 1{,}142447729$

Finalmente, se llega a...

$$T_{(s)} = \overbrace{\frac{0{,}6264565}{s + 0{,}6264565}}^{T_{2(s)}} \cdot \overbrace{\frac{1{,}14245}{s^2 + s \cdot 0{,}6264565 + 1{,}14245}}^{T_{1(s)}}$$

$$T_{(s)} = \frac{0{,}71569}{s^3 + s^2 \cdot 1{,}252913 + s \cdot 1{,}5349 + 0{,}71569}$$

Un circuito posible podría ser



Donde $\frac{V_a}{V_{in}}$ se podía obtener como:

$$\frac{V_{a(s)}}{V_{in(s)}} = T_{1(s)} = -\frac{G_1}{G_3} \cdot \frac{\left(\frac{G_3}{C_1}\right)^2}{s^2 + s \cdot \frac{G_2}{C_1} + \left(\frac{G_3}{C_1}\right)^2}, \quad K_1 = -\frac{G_1}{G_3}$$

$$\omega_{o_1} = \frac{G_3}{C_1}$$

$$Q_1 = \frac{G_3}{G_2}$$

Dejamos todo en función de C_1

$$\underset{\mathrm{I}}{\omega_{o_1} \cdot C_1' = G_3'}, \quad \underset{\mathrm{II}}{G_2' = \frac{\omega_{o_1} \cdot C_1'}{Q_1}}, \quad \underset{\mathrm{III}}{-G_1' = K_1 \cdot \omega_{o_1} \cdot C_1'}$$

NOTA: Tomamos $K_1 = K_2 = -1$ para que entre sí se anulen

Por el lado de $T_{2(s)}$ ..

$$\frac{V_o}{V_a} = T_{2(s)} = \frac{\frac{1}{R_5C_2}}{S + \underbrace{\frac{1}{R_5C_2}}_{\omega_{o_2}}} = \frac{0{,}6264565}{S + 0{,}6264565}$$

donde

$$G_5' = \omega_{o_2} \cdot C_2' \quad \text{IV}$$

PARA DESNORMALIZAR, sé que

$$\Omega_\omega = 3000\pi$$

Elijo C_1 y C_2 utilizables... $C_1 = C_2 = 100nF$

Desnormalizo ω_o

$$T_{1(s)} = \frac{1{,}14245}{S^2 + S \cdot 0{,}6264565 + 1{,}14245} \rightarrow T_{1(s)} = \frac{101{,}48 \cdot 10^6 \frac{1}{s^2}}{S^2 + S \cdot 5{,}904 \cdot 10^3 \frac{1}{s} + 101{,}48 \cdot 10^6}$$

$$T_{2(s)} = \frac{5{,}904 \cdot 10^3 \frac{1}{s}}{S + 5{,}904 \cdot 10^3 \frac{1}{s}}$$

Retomando ecuaciones I - IV.

$$G_3 = \sqrt{101{,}48 \cdot 10^6} \cdot 100nF = 1{,}007 \cdot 10^{-3} \rightarrow \boxed{R_3 = 992{,}68\,\Omega}$$

$$G_2 = 5{,}904 \cdot 10^3 \tfrac{1}{s} \cdot 100nF = 590{,}42 \cdot 10^{-6} \rightarrow \boxed{R_2 = 1{,}69\,k\Omega}$$

$$G_1 = k \cdot G_3 = G_3 \rightarrow \boxed{R_1 = 992{,}68}$$

$$G_4 = G_1 \quad \boxed{R_4 = 992{,}68}$$

$$G_5 = 5{,}904 \cdot 10^3 \cdot 100nF \rightarrow \boxed{R_5 = 1{,}69k}$$

Con R_2 y R_5 tendríamos un error $\simeq$ 10% .

Probamos otros valores de C_1 y C_2 . .

$\boxed{C_1 = C_2 = 5{,}6\,nF}$

$R_1 = R_3 = R_5 = 17{,}72\,k\Omega$

$R_2 = R_5 = 30{,}17\,k\Omega$

$\boxed{R_{1n} = R_{3n} = R_{5n} = 18\,k\Omega}$

$\boxed{R_{2n} = R_{5n} = 33\,k\Omega}$