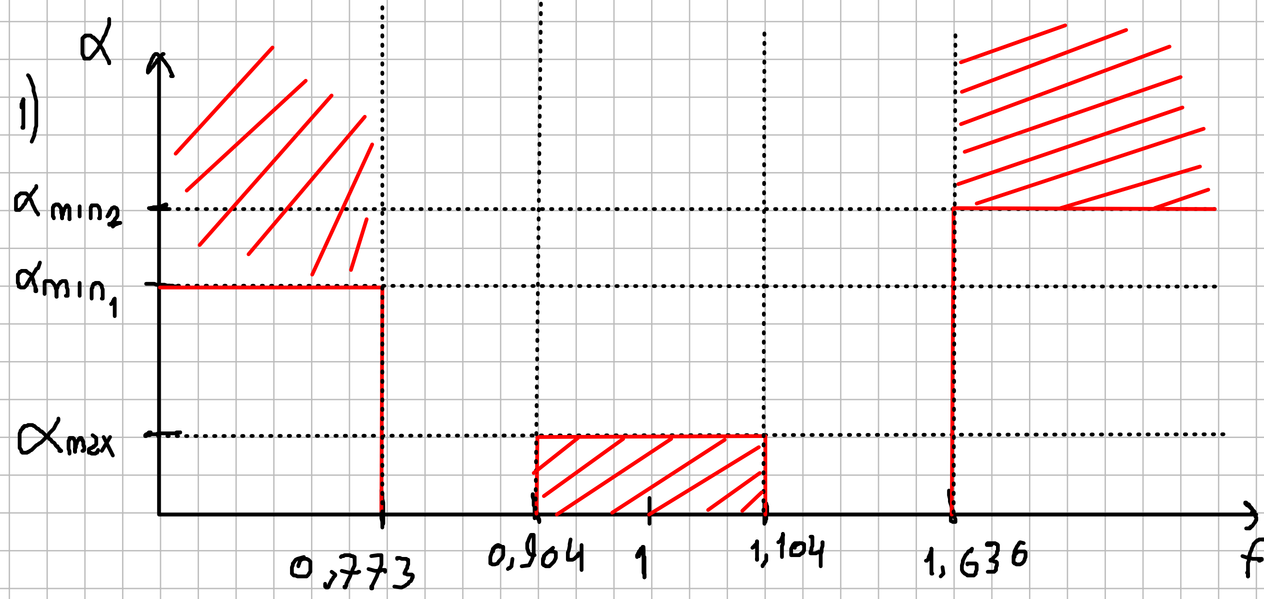
1)



$\alpha_{max} = 0{,}5\,dB \qquad \alpha_{min_1} = 16\,dB \qquad \alpha_{min_2} = 24\,dB$

$\Omega_w = W_0 = 2\pi \cdot f_0 = 2\pi \cdot 22\,kHz$

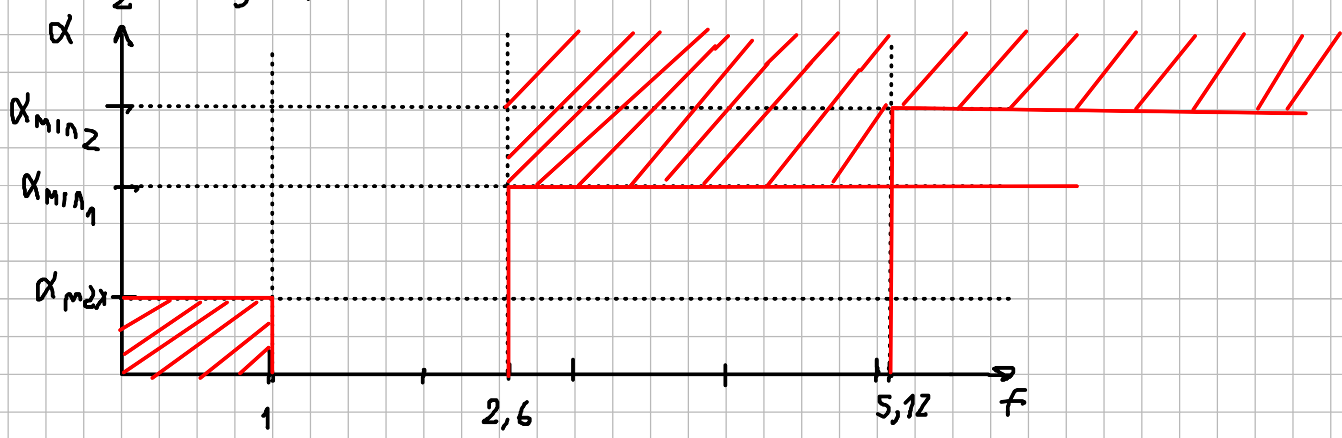
$$\left\{ \begin{array}{l} W_1 \cdot W_2 = W_0^2 \\ W_2 - W_1 = \dfrac{W_0}{Q} \end{array} \right\} \rightarrow \begin{array}{ll} W_1 = 125\,k\frac{r}{s} & f_1 = 19{,}9\,kHz \\ W_2 = 152742\,r/s & f_2 = 24{,}3\,kHz \end{array}$$

Plantilla prototipo pasabajos

$$\Omega_s = Q\,\frac{\omega_s^2 - 1}{\omega_s}$$

$\Omega_{s_1} = 2{,}6$

$\Omega_{s_2} = 5{,}12$



$\alpha_{min} = \alpha_{min1} = 16dB$

$\alpha_{max} = 0{,}5 dB$

$\Omega_s = 2{,}6$

$$\xi^2 = 10^{\alpha_{max}/10} - 1 = 122 \cdot 10^{-3}$$

Ω_s

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

$n = 1 \longrightarrow \alpha_{min} = 2{,}6 dB$

$n = 2 \longrightarrow \alpha_{min} = 13{,}03 dB$

$n = 3 \longrightarrow \alpha_{min} = 26{,}79 dB$

$\boxed{n = 3}$

$$C_0(\omega) = 1$$
$$C_1(\omega) = \omega$$
$$C_n(\omega) = 2\omega \cdot C_{n-1} - C_{n-2}$$
$$C_2(\omega) = 2\omega^2 - 1$$
$$C_3(\omega) = 4\omega^3 - 2\omega - \omega = 4\omega^3 - 3\omega$$

$$\frac{1}{1 + \xi^2 C_3^2(\omega)} = \left.\frac{1}{1 + \xi^2 \cdot (4\omega^3 - 3\omega)^2}\right|_{\omega = \frac{s}{j}} = \frac{1}{1 + \xi^2 (4 \cdot s^3 \cdot j + 3 s j)^2}$$

$$= \frac{1}{1 + \xi^2 \left(16 s^6 (-1) - 24 s^4 - 9 s^2\right)}$$

$$= \frac{\frac{1}{\xi^2}}{-16s^6 - 24s^4 - 9s^2 + \frac{1}{\xi^2}}$$

$$= \frac{\frac{1}{16\xi^2}}{-s^6 - \frac{3}{2}s^4 - \frac{9}{16}s^2 + \frac{1}{\xi^2 \cdot 16}}$$

$$= \frac{c^2}{(s^3 + as^2 + bs + c)(-s^3 + as^2 - bs + c)}$$

$$c = \sqrt{\frac{1}{16\xi^2}} = \frac{1}{4\xi}$$

1) $a^2 - 2b = -\frac{3}{2} \longrightarrow \frac{a^2}{2} + \frac{3}{4} = b$ (3)

2) $2 \cdot a \cdot c - b^2 = -\frac{9}{16}$

(3) en (2) $\longrightarrow$

$$2 \cdot a \cdot c - \left(\frac{a^2}{2} + \frac{3}{4}\right)^2 = -\frac{9}{16}$$

$$2 \cdot a \cdot c - \frac{a^4}{4} - \frac{3}{4}a^2 - \cancel{\frac{9}{16}} = -\cancel{\frac{9}{16}}$$

$a_1 = 1,2529$ ✓ $\longrightarrow b = 1,535$

$a_2 = 0$ ✗

$a_3 = -0,626 + 2,64j$ ✗

$$T(s) = \frac{c}{s^3 + b s^2 + a s + c}$$

$$T(s) = \frac{0,716}{s^3 + 1,2532 \cdot s^2 + 1,535 \cdot s + 0,716}$$

$$T(s) = \frac{0,716}{(s+0,627)(s+0,313-1,02j)(s+0,313+1,02j)}$$

$$T(s) = \frac{0,716}{(s+0,627)(s^2+0,626s+1,068^2)}$$

$$\boxed{T(s) = \frac{0,627}{s+0,627} \quad \frac{1,068^2}{s^2+0,626 \cdot s+1,068^2}}$$

$$S = \frac{\$ + 1}{\$} \cdot Q$$

$$T(\$)= \frac{0,627}{Q\cdot\frac{s^2+1}{s}+0,627} \quad \frac{1,068^2}{\left(Q\cdot\frac{s^2+1}{s}\right)^2+0,626\cdot\left(Q\cdot\frac{s^2+1}{s}\right)+1,068^2}$$

$$T(s)= \frac{\frac{0,627}{5}\cdot s}{s^2+s\cdot\frac{0,627}{5}+1}\cdot\frac{1,068^2}{\left(Q\cdot\frac{s^2+1}{s}\right)^2+0,626\cdot\left(Q\cdot\frac{s^2+1}{s}\right)+1,068^2}$$

$$\frac{1,068^2}{\left(Q\cdot\frac{s^2+1}{s}\right)^2+0,626\cdot\left(Q\cdot\frac{s^2+1}{s}\right)+1,068^2}=\frac{1,068^2}{\frac{Q^2}{s^2}(s^4+2s+1)+\frac{0,626\cdot Q}{s}(s^2+1)+1,068^2}$$

$$=\frac{1,068\cdot s^2}{Q^2s^4+Q^2\cdot 2\cdot s^2+Q^2\cdot\quad+0,626\cdot Q\cdot s^3+0,626\cdot Q\cdot s+1,068^2\cdot s^2}$$

$$=\frac{\frac{1,068}{Q^2}s^2}{s^4+s^3\left(\frac{0,626}{Q}\right)+s^2\left(2+\frac{1,068^2}{Q^2}\right)+s\,\frac{0,626\cdot}{Q}+1}$$

$$=\frac{\frac{1,068}{Q^2}s^2}{(s+0,0281-0,903j)(s+0,0281+0,903j)(s+0,0345-1,107j)(s+0,0345+1,107j)}$$

$$= \frac{\dfrac{1{,}068}{Q^2} \cdot s^2}{(s^2 + 0{,}0562s + 0{,}9034^2)(s^2 + 0{,}069 \cdot s + 1{,}1075^2)}$$

0,04272

$$= \frac{K_1 \cdot 0{,}0562 \cdot s}{(s^2 + 0{,}0562 \cdot s + 0{,}9034^2)} \cdot \frac{K_2 \; 0{,}069 \cdot s}{(s^2 + 0{,}069 \cdot s + 1{,}1075^2)}$$

$$K_1 \cdot K_2 \cdot (0{,}0562)(0{,}069) = 0{,}0472$$

$$K_1 \cdot K_2 = 12{,}178 \approx 12$$

$$K_1 = 3$$

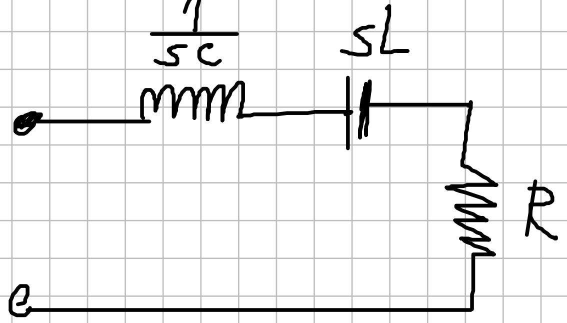
$$K_2 = 4$$

$$\boxed{T_{23P}(s) = \frac{\dfrac{0{,}627}{5} \cdot s}{s^2 + s \cdot \dfrac{0{,}627}{5} + 1} \cdot \frac{3 \cdot 0{,}0562 \cdot s}{(s^2 + 0{,}0562 \cdot s + 0{,}9034^2)} \cdot \frac{4 \; 0{,}069 \, s}{(s^2 + 0{,}069 \cdot s + 1{,}1075^2)}}$$

Bonus #1

No se puede implementar con circuitos pasivos porque no dan ganancia

Pero puedo implementar uno con circuitos seguidores con ganancia

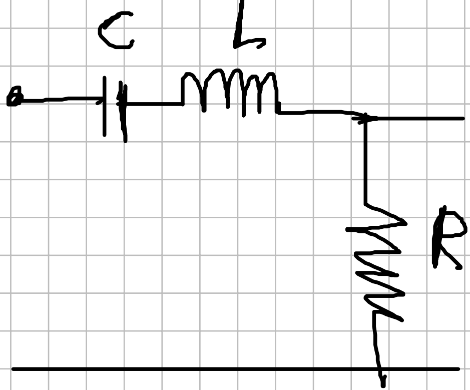


$$T(s) = \frac{R}{\frac{1}{sC} + R + sL}$$

$$T(s) = \frac{sCR}{1 + sCR + s^2 LC}$$

$$T(s) = \frac{s\,\frac{R}{L}}{s^2 + s\frac{R}{L} + \frac{1}{LC}}$$

$$\frac{\frac{0{,}627}{5}\cdot s}{s^2 + s\cdot\frac{0{,}627}{5} + 1} = \frac{s\cdot \frac{R_1}{L_1'}}{s^2 + s\cdot\frac{R_1}{L_1'} + \frac{1}{L_1' C_1'}}$$



$L_1 = 10$ mHy

$$\frac{1}{\Omega_\omega^2 L_1 C_1} = 1 \qquad C_1 = \frac{1}{1\cdot \Omega_\omega^2 L_1} = 5{,}234\ \text{nF}$$

$$\frac{R_1}{L_1'} = \frac{0{,}627}{5} \rightarrow R_1 = \frac{0{,}627}{5}\cdot L_1 \cdot \Omega_\omega = 173{,}34\,\Omega$$

$$L_2 = 10\,\text{mHY}$$

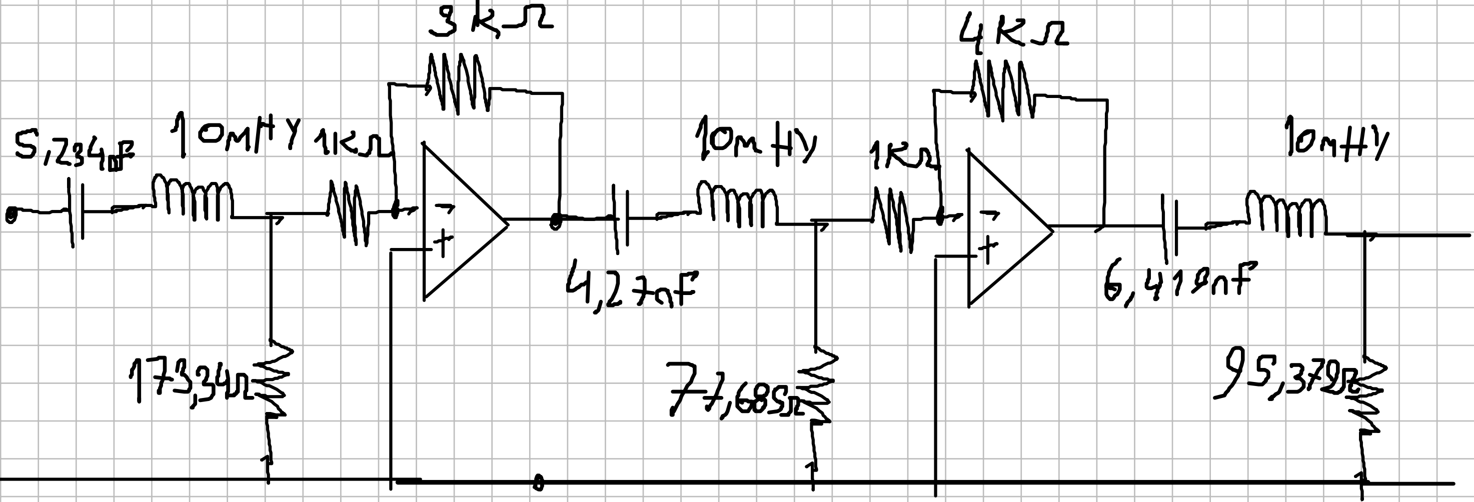
$$C_2 = \frac{1}{0{,}9034^2\, L_2\, \Omega_\omega^2} = 6{,}412\,\text{nF}$$

$$R_2 = 0{,}0562 \cdot L_1 \cdot \Omega_\omega = 77{,}685\,\Omega$$

$$L_3 = 10\,\text{mHY}$$

$$C_2 = \frac{1}{1{,}1075^2\, L_2\, \Omega_\omega^2} = 4{,}267\,\text{nF}$$

$$R_3 = 0{,}069 \cdot L_3 \cdot \Omega_\omega = 95{,}379\,\Omega$$



Bonus #2

$$\boxed{T(s) = \frac{0,627}{s+0,627} \quad \frac{1,068^2}{s^2+0,626\cdot s+1,068^2}}$$

$$s = \frac{1}{\$}$$

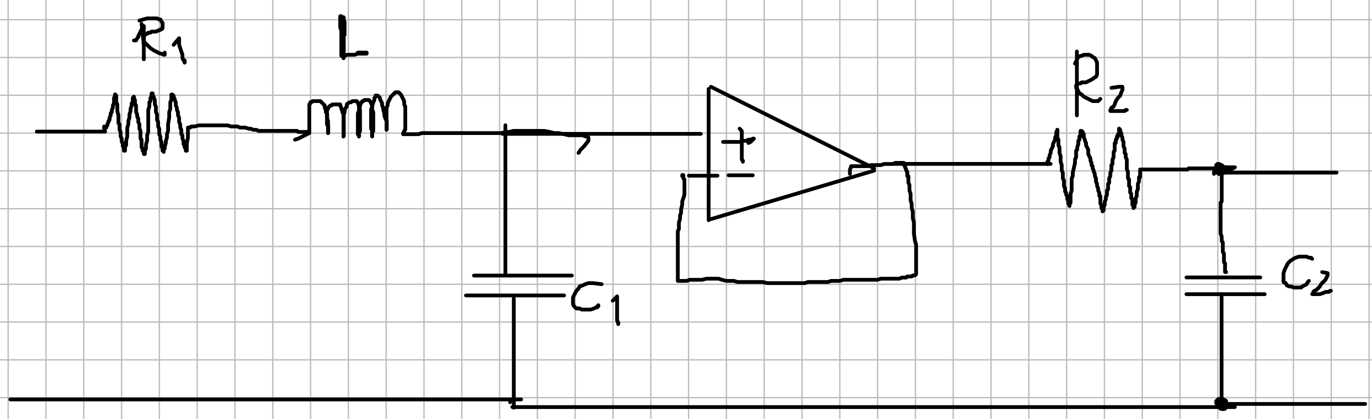
$$T(s) = \frac{0,627}{\frac{1}{s}+0,627} \cdot \frac{1,068^2}{\frac{1}{s^2}+0,626\cdot\frac{1}{s}+1,068^2}$$

$$T(s) = \frac{0,627\cdot s}{1+0,627\cdot s} \quad \frac{1,068^2\cdot s^2}{1,068^2\cdot s^2+0,626\cdot s+1}$$

$$T(s) = \frac{s}{s+\frac{1}{0,627}} \cdot \frac{s^2}{s^2+\frac{0,626}{1,068^2}\cdot s+\frac{1}{1,068^2}}$$

Bonus #3

$$T(s) = \frac{0{,}627}{s+0{,}627} \cdot \frac{1{,}068^2}{s^2+0{,}626\cdot s+1{,}068^2}$$



$$T(s) = \frac{\frac{1}{R_2C_2'}}{s+\frac{1}{R_2C_2'}} \cdot \frac{\frac{1}{L'C_1'}}{s^2+s\cdot\frac{R_1}{L'}+\frac{1}{L'C_1'}}$$

$\Omega_\omega = 2\pi \cdot 22\,kHz \qquad C = 10\,nF = C_2$

$$\frac{1}{R_2C_2'} = 0{,}627 \qquad C_2' = C_2 \cdot \Omega_\omega$$

$$R_2 = \frac{1}{0{,}627 \cdot C_2 \Omega_\omega} = 1153{,}79\,\Omega$$

$$L = 1\,mH_y \rightarrow \quad 1{,}068^2 = \frac{1}{L' \cdot C'} \rightarrow C_1 = \frac{1}{1{,}068^2 \cdot L \cdot \Omega_\omega^2}$$

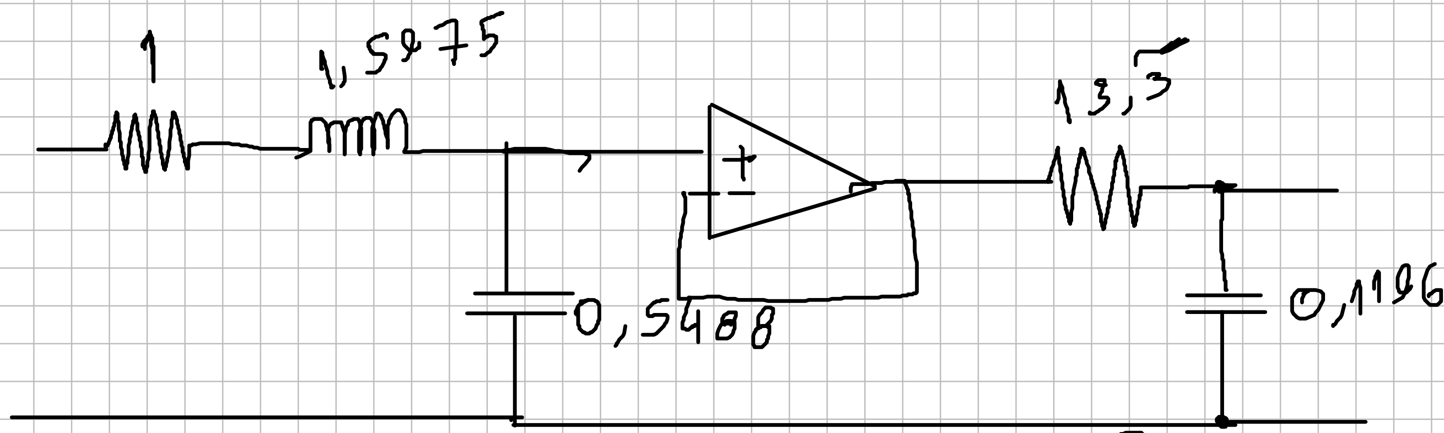
$C_1 = 45{,}88\,nF$

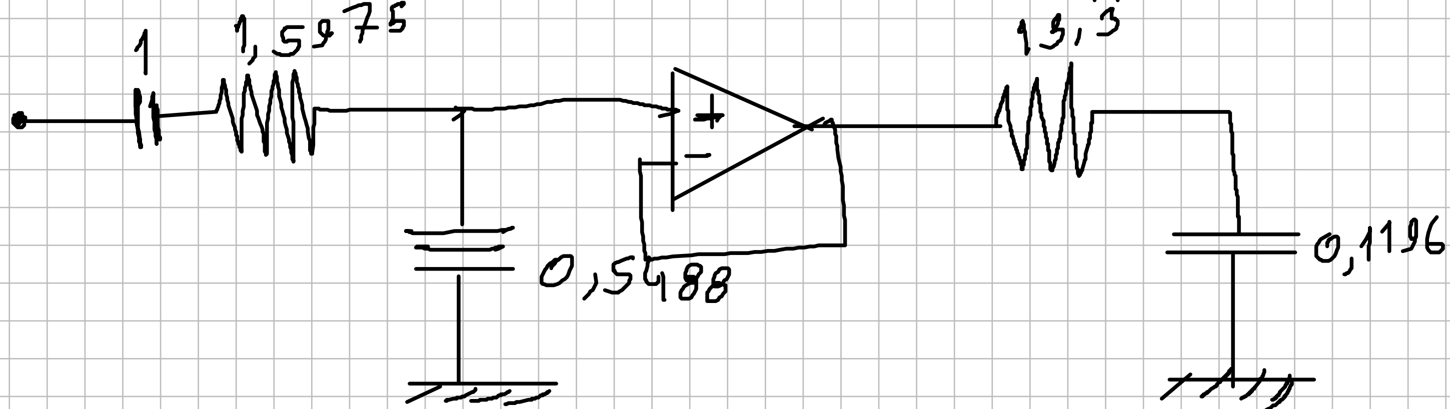
$$\frac{R_1}{L'} = 0,626$$

$$R_1 = 0,626 \cdot 1mHy \cdot \Omega_\omega = 86,53\,\Omega$$

Aplicando Bruton

$$\Omega_z = 86,53\,\Omega$$





$$0,5488 = \frac{C_{23}}{\omega_c} \rightarrow C_B = 0,5488\,\omega_c$$

$$\Omega_\omega = \omega_c = 2\pi \cdot 22K$$

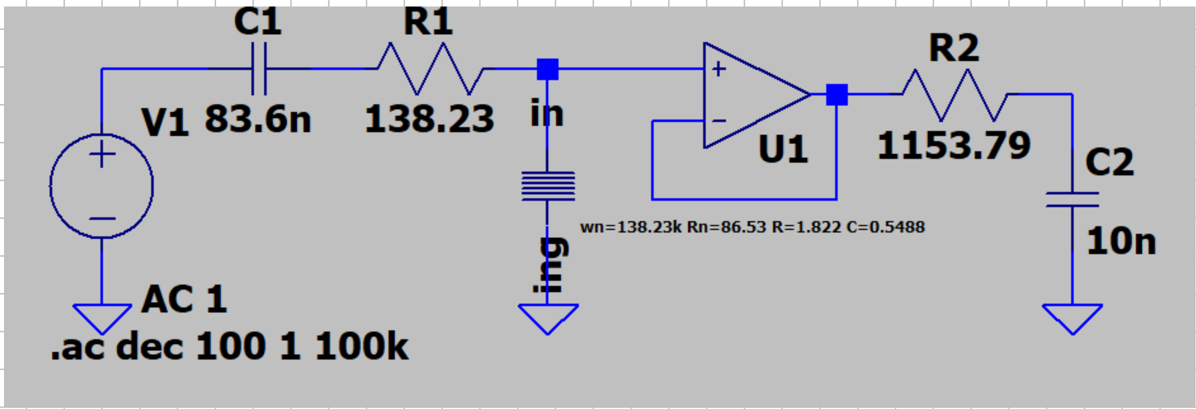
$$C_{B} = 0,5488 \rightarrow R_B = \frac{1}{\omega_c \cdot C}$$

$$R_B = 1,822$$

$$D_{normalizado} = 0,54875 = C_B^2 \cdot R_B$$

$$D_{desnormalizado} = 331,898f \left[\frac{A \cdot s^2}{V}\right]$$

Circuito desnormalizado



Verifica con este otro circuito