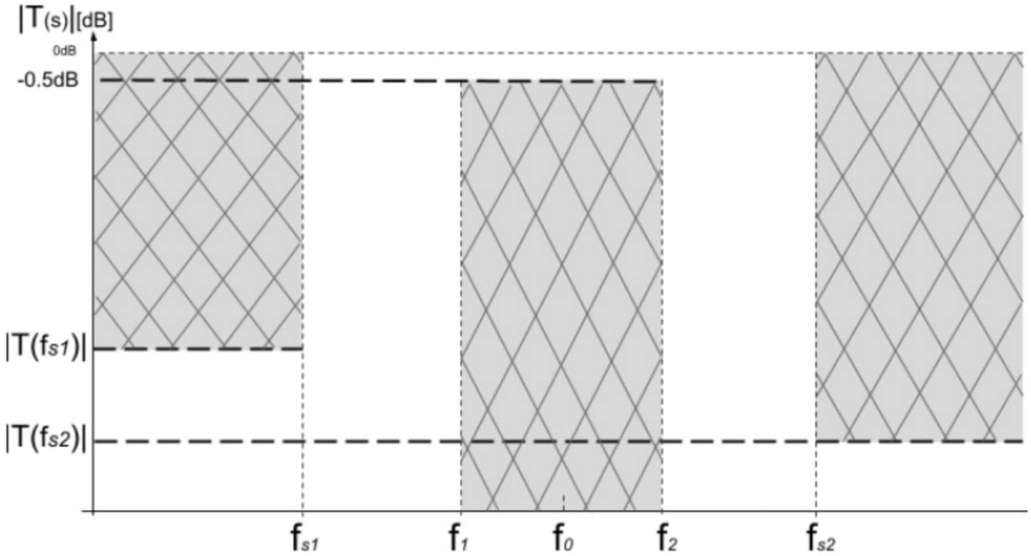
Consigna del ejercicio

Se pide diseñar un filtro pasabanda que cumpla con la siguiente plantilla:

- $\omega_0 = 2\pi\ 22\ \text{kHz}$
- $Q = 5$
- Aproximación Chebyshev con ripple de 0,5 dB

También se sabe que la transferencia del filtro debe ser:

- $|T(f_{S1})| = -16\ dB$ para $f_{S1} = 17\ kHz$
- $|T(f_{S2})| = -24\ dB$ para $f_{S2} = 36\ kHz$



Consignas de la actividad:

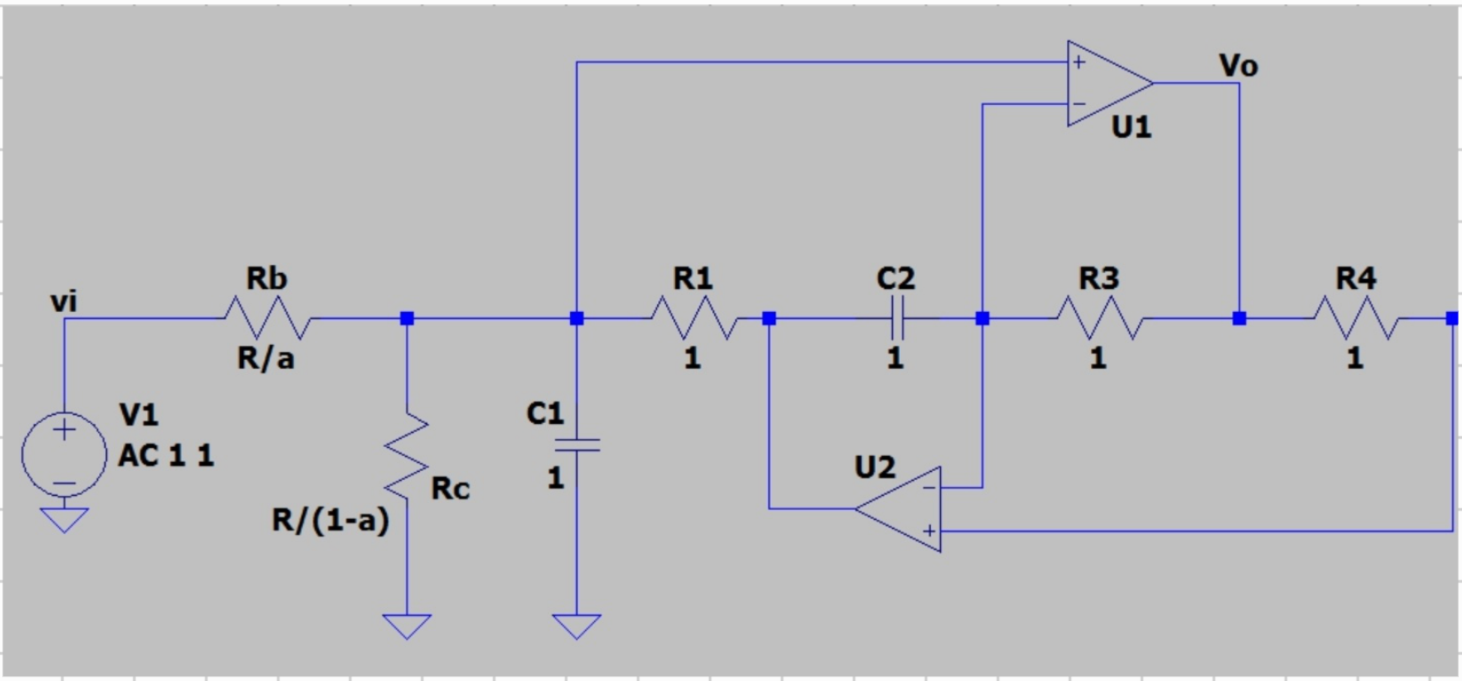
👉 Obtener la plantilla de diseño pasabanda normalizada

👉 Obtener la función transferencia normalizada del prototipo pasabajo que satisfaga el requerimiento del filtro pasabanda.

👉 Obtener la transferencia pasabanda normalizada

👉 Implementar mediante secciones pasivas separadas por seguidores de tensión activos.

👉 Activar las redes pasivas mediante la red propuesta aquí debajo y comprobar mediante simulación el comportamiento deseado.



Desarrollo:

Obtengo frecuencias normalizadas: ($\Omega_0 = w_0$)

$w_0 = 2\pi \cdot 22\,kHz \longrightarrow w_{0_n} = 1$

$f_{S1} = 17\,kHz \longrightarrow w_{S1_n} = 0{,}7727$

$f_{S2} = 36\,kHz \longrightarrow w_{S2_n} = 1{,}636$

$Q = 5 \longrightarrow Q = \frac{w_0}{Bw} \Rightarrow Bw = 2\pi \cdot 4400\,Hz$

$$\left.\begin{array}{l} w_{p2} - w_{p1} = Bw \\ w_0 = \sqrt{w_{p2} \cdot w_{p1}} \end{array}\right\} \begin{array}{l} w_{p2} = Bw + \frac{w_0^2}{w_{p2}} \\ w_{p2}^2 - w_{p2} Bw - w_0^2 = 0 \end{array}$$

$w_{p2} = 24309{,}72\,Hz \cdot 2\pi$

$w_{p1} = 19909{,}72\,Hz \cdot 2\pi$

$\omega_{p2n} = 1,1049$

$\omega_{p1n} = 0,9049$

plantilla pasa bandas

$\omega_{0n} = 1$

$\omega_{s1n} = 0,7727$

$\omega_{s2n} = 1,636$

$\omega_{p2n} = 1,1049$

$\omega_{p1n} = 0,9049$

plantilla pasa bajos

1

$\Omega_{pn} = 1 \longrightarrow 0,5\,dB$

$\Omega_{sn} = 2,607 \longrightarrow 16\,dB$

2

$\Omega_{pn} = 1 \longrightarrow 0,5\,dB$

$\Omega_{sn} = 1,6363 \longrightarrow 24\,dB$

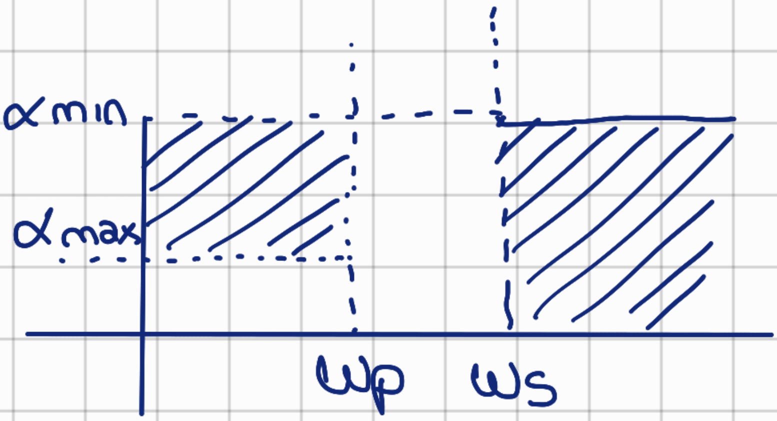
filtro Lp

$\omega_p = 1$

$\omega_s = 2,607$

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

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



$$\varepsilon^2 = 10^{\alpha max/10} - 1 \longrightarrow \varepsilon^2 = 0{,}122$$

$$\alpha max = 10 \, Log \, (1 + \varepsilon^2)$$

$$\alpha min = 10 \, Log \left[1 + \varepsilon^2 \cosh^2 (n \cosh^{-1} (w_0)) \right]$$

$n = 3$

Obtengo Cn:

$$C_n(w) = 2w \; C_{n-1}(w) - C_{n-2}(w)$$

$$C_1(w) = 2w \cdot w - 1 = 2w^2 - 1$$

$$C_2(w) = 2w(2w^2 - 1) - w = 4w^3 - 3w$$

$$|T(jw)|^2 = \frac{1}{1 + (\varepsilon \, C_n)^2}$$

$$|T_c(jw)|^2 = \frac{1}{1 + (\varepsilon \, (4w^3 - 3w))^2}$$

$$|T_c(jw)|^2 = \frac{1}{1 + \varepsilon^2 (4w^3 - 3w)(4w^3 - 3w)}$$

$$|T_c(jw)|^2 = \frac{1}{1 + \varepsilon^2 \left[16w^6 - 12w^4 - 12w^4 + 9w^2 \right]}$$

$$|T_c(jw)|^2 = \frac{1}{w^6\, 16.\varepsilon^2 - w^4\, 24.\varepsilon^2 + w^2\, 4\varepsilon^2 + 1}$$

$$|T_c(jw)|^2 = \frac{\frac{1}{16\varepsilon^2}}{w^6 - w^4 \frac{24\varepsilon^2}{16\varepsilon^2} + w^2 \frac{4\varepsilon^2}{16\varepsilon^2} + \frac{1}{16\varepsilon^2}}$$

$$|T_c(jw)|^2 = \frac{\frac{1}{16\varepsilon^2}}{w^6 - w^4\, 1{,}5 + w^2\, 0{,}5625 + 0{,}5122}$$

$$jw = s \rightarrow w = \frac{s}{j}$$

$$|T_c(jw)|^2 = \frac{0{,}5122}{-s^6 - s^4\, 1{,}5 - s^2\, 0{,}5625 + 0{,}5122}$$

resuelvo con python los polos

$$\text{polos} = \left[-0{,}3132 \pm 1{,}0219j \;;\; 0{,}3132 \pm 1{,}0219j \;;\; -0{,}62 \;;\; 0{,}62 \right]$$

descarto los polos en el plano derecho

$$\text{polos} = \left[-0{,}3132 \pm 1{,}0219j \;;\; -0{,}62 \right]$$

$$T(\$) = \frac{\sqrt{0{,}5122}}{(\$-(-0{,}3132 \pm 1{,}0219j))(\$+0{,}62)}$$

$$T(\$) = \frac{0{,}7156}{\$^3+\$^2\,1{,}2529+\$\,1{,}5348+0{,}7156}$$

Transforma a pasa bandas

$$\$ \rightarrow Q \cdot \frac{\$'^2+1}{\$'}$$

$$T(\$') = \frac{0{,}7156}{\left(Q\,\frac{\$'^2+1}{\$'}\right)^3+\left(Q\,\frac{\$'^2+1}{\$'}\right)^2 1{,}2529+\left(Q\,\frac{\$'^2+1}{\$'}\right)1{,}5348+0{,}7156}$$

$$T(\$') = \frac{0{,}7156}{\frac{Q^3}{\$'^3}\left[(\$^6+3\$^4+3\$^2+1)+(\$^4+2\$^2+1)\frac{1{,}2529}{Q}\$+(\$^2+1)\frac{1{,}5348}{Q^2}\$^2+\frac{\$^3\,0{,}7156}{Q^3}\right.}$$

$$(\$'^2+1)(\$'^2+1)(\$^2+1)$$
$$(\$^4+2\$^2+1)(\$^2+1)$$
$$\$^6+2\$^4+\$^2+\$^4+2\$^2+1$$
$$\$^6+3\$^4+3\$^2+1$$

$$T(\$) = \frac{\$'^3\;0{,}7156/Q^3}{\$^6+\$^5\frac{1{,}2529}{Q}+\$^4\left(3+\frac{1{,}5348}{Q^2}\right)+\$^3\left(\frac{2{,}5058}{Q}+\frac{0{,}7156}{Q^3}\right)+\$^2\left(3+\frac{1{,}5348}{Q^2}\right.}$$

$$\overline{\qquad\qquad\qquad\qquad} \quad \text{Con } Q = 5$$

$$+ s\,\frac{1{,}2529}{Q} + 1$$

$$T(s) = \frac{s^3 \; 5{,}7248 \cdot 10^{-3}}{s^6 + s^5 0{,}25058 + s^4 3{,}061 + s^3 0{,}5068 + s^2 3{,}061 + s\,0{,}25058 + 1}$$

Obtengo polos con python:

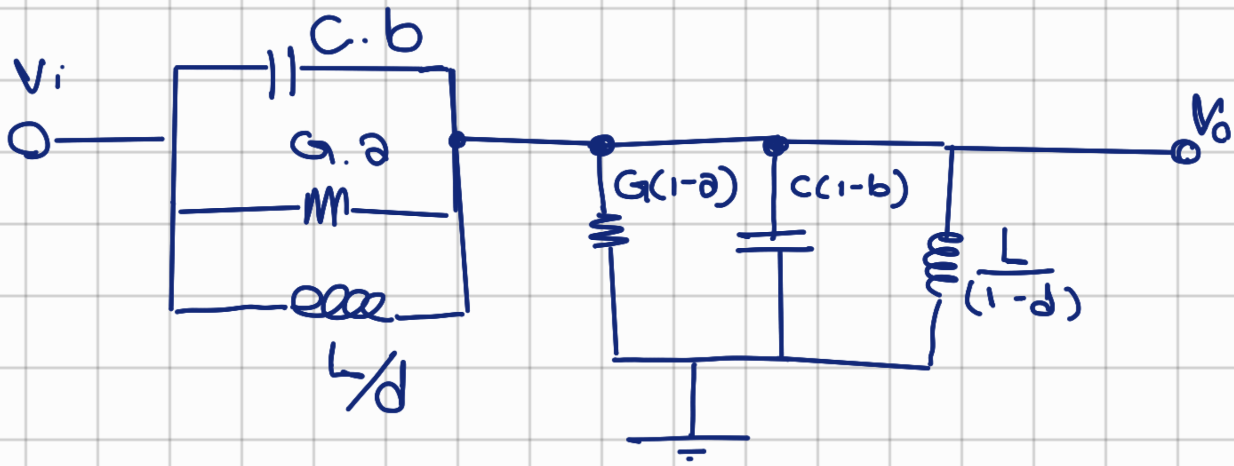
$$\text{Polos} = \left\{ -0{,}0347 \pm 1{,}106j \;;\; -0{,}0622 \pm 0{,}998j \;;\; -0{,}028 \pm 0{,}903j \right\}$$

$$T(s) = k \, \frac{s\,0{,}0694}{s^2 + s\,0{,}0694 + 1{,}224} \cdot \frac{s\,0{,}124}{s^2 + s\,0{,}124 + 0{,}998} \cdot \frac{s\,0{,}056}{s^2 + s\,0{,}056 + 0{,}816}$$

$$k = 11{,}87$$

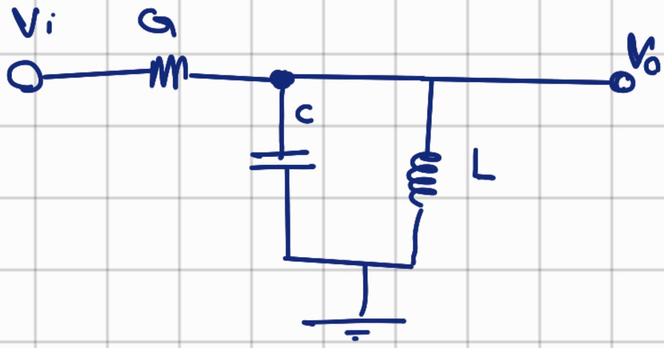
Diseño del filtro:

Aplico Metodo de voltage feed forward



$$T(\$) = \frac{V_2}{V_i} = \left[\frac{b\$^2 + \$\,\frac{G\,a}{C} + \frac{d}{CL}}{\$^2 + \$\,\frac{G}{C} + \frac{1}{LC}}\right]$$

$b = 0$
$d = 0$
$a = 1$



filtro 1:

$$T(\$) = \frac{\$\,0{,}0694}{\$^2 + \$0{,}0694 + 1{,}224} \; ; \; T(\$) = \frac{\$\,\frac{G}{C}}{\$^2 + \$\,\frac{G}{C} + \frac{1}{LC}}$$

$$\frac{1}{LC} = 1{,}224 \; ; \; \frac{1}{RC} = 0{,}0694$$

Supongo $R = 1$

$C = 14{,}409$ F
$L = 0{,}05669$ Hy

filtro 2:

$$T(\$) = \frac{\$\,0{,}124}{\$^2 + \$0{,}124 + 0{,}998} \; ; \; T(\$) = \frac{\$\,\frac{G}{C}}{\$^2 + \$\,\frac{G}{C} + \frac{1}{LC}}$$

$$\frac{1}{LC} = 0{,}998 \; ; \; \frac{1}{RC} = 0{,}124$$

Supongo $R = 1$

$C = 8{,}0645$ f
$L = 0{,}1242$ Hy

filtro 3°

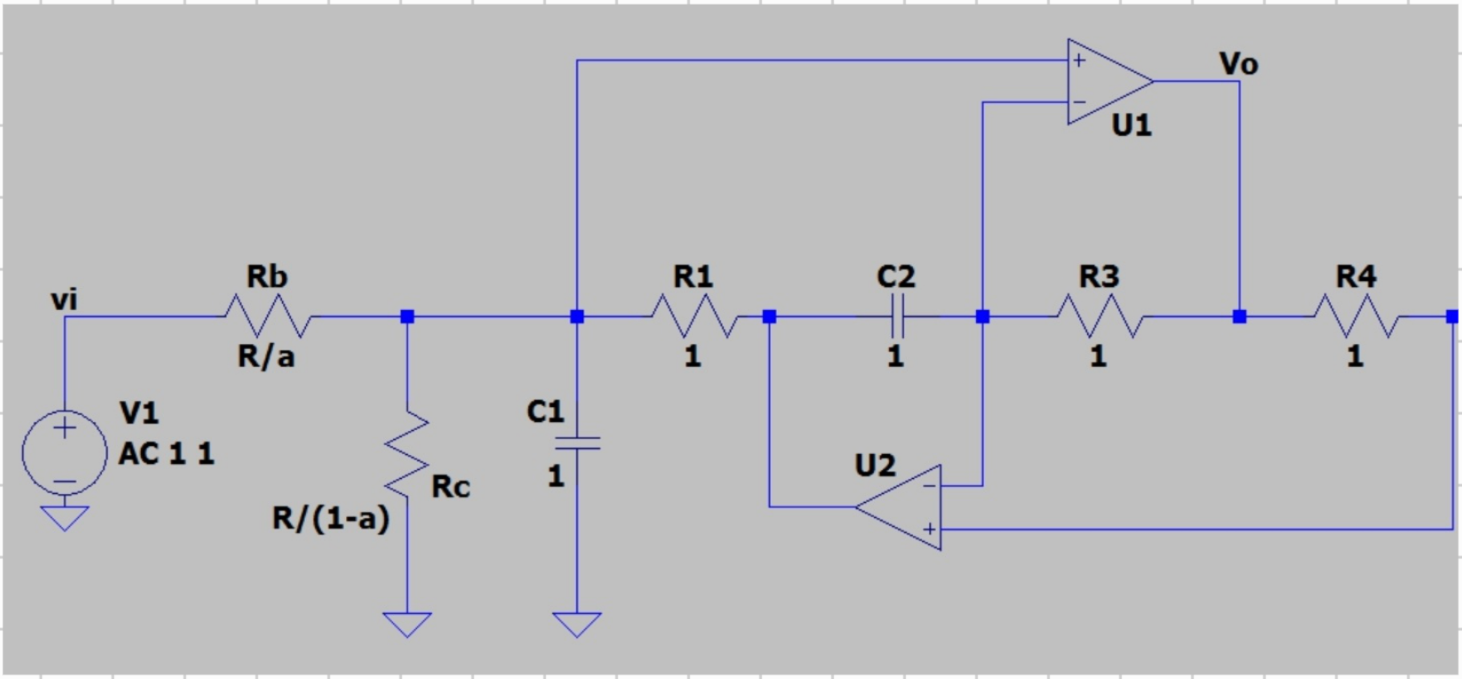
$$T(\$) = \frac{\$\,0{,}056}{\$^2 + \$\,0{,}056 + 0{,}816} \; ; \; T(\$) = \frac{\$\,\frac{G}{C}}{\$^2 + \$\,\frac{G}{C} + \frac{1}{LC}}$$

$$\frac{1}{LC} = 0{,}816 \; ; \; \frac{1}{RC} = 0{,}056$$

Supongo $R = 1$

$C = 17{,}85$ f

$L = 0{,}0686$ Hy


Vo
U1
vi
Rb
R/a
Rc
R/(1-a)
V1
AC 1 1
C1
1
R1
1
C2
1
R3
1
R4
1
U2