Ejercicio #7

Se debe diseñar un filtro pasabanda con las siguientes especificaciones:

- Frecuencia de corte inferior f_{ci}: 1600 KHz y frecuencia de corte superior f_{cs}: 2500 KHz

- Ripple máximo en la banda de paso ε: 3dB
- Máxima planicidad en la banda de paso.
- Ganancia máxima en la banda de paso: 10 dB
- Atenuación mínima $\alpha_{mín}$ de 20 dB a las frecuencias de 1250 KHz y 3200 KHz.

Se pide:

a) Obtener la función transferencia normalizada del filtro
b) Graficar el diagrama de polos y ceros
c) Graficar la transferencia (módulo y fase) del filtro pedido
d) Sintetizar el filtro utilizando estructuras Ackerberg-Mossberg (AM)(Ver apéndice)
e) Simular el filtro obtenido, verificando las especificaciones de diseño

Plantilla filtro pasa bandas

$\alpha_{max} = 3dB$

$\alpha_{min} = 20dB$

$k = 10dB$

(f_{p1}) (f_{p2})

1600 kHz a 2500 kHz

$f < 1250 kHz$; $f \geq 3200 kHz$

(f_{s1}) (f_{s2})

Normalizo

$$\Omega_w = \sqrt{w_{p1} \cdot w_{p2}} = 2\pi \cdot \sqrt{f_{p1} f_{p2}}$$

$w_{p1n} = 0,8$

$w_{s1n} = 0,625$

$w_{p2n} = 1,25$

$w_{s2n} = 1,6$

$w_{o\_n} = 1$

paso a plantilla paso bajos.

$$k(\$) = Q \cdot \frac{\$^2 + \omega_0^2}{\$\omega_0} \quad \text{Con } Q = \frac{\omega_0}{Bw} \; ; \; \omega_0 = 1$$

$$Q = \frac{1}{1,25 - 0,80} = 2,22 \; ; \; k(\$) = Q \cdot \frac{\$^2 + 1}{\$}$$

no entiendo por que es "-"

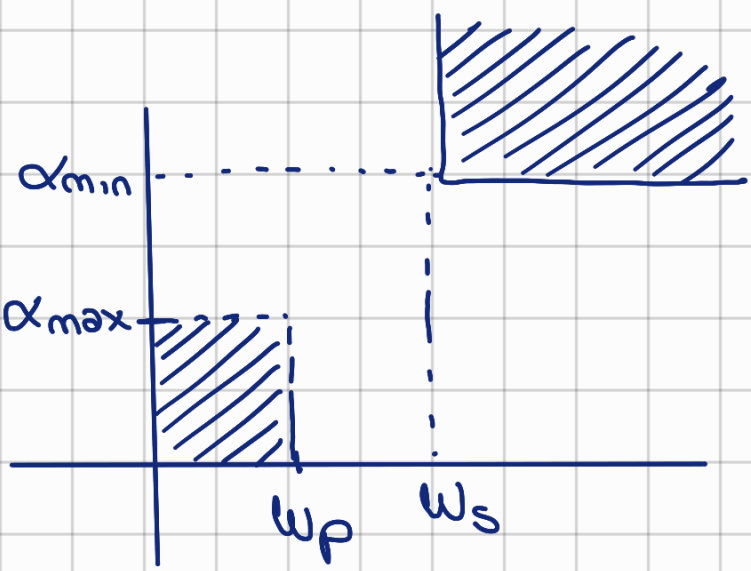
$$\Omega p_2 = Q \cdot \frac{(\omega p_{2n}{}^2 - \omega_{0-n}{}^2)}{\omega p_{2n}} = Q \frac{(\omega_{p_{2n}}{}^2 - 1)}{\omega p_{2n}}$$

$$\Omega p_2 = 1$$

$$\Omega s_2 = Q \frac{(\omega s_{2n}{}^2 - 1)}{\omega s_{2n}} = 2,16$$

plantilla:

$\Omega_s = 2,16$
$\Omega_p = 1$
$\alpha_{max} = 3\ dB$
$\alpha_{min} = 20 dB$



$\alpha_{max} = 3dB \longrightarrow$ Butterworth

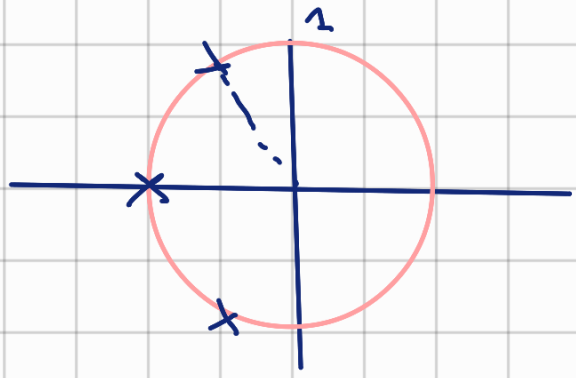
$\varepsilon = 1$

$$\alpha_{min} = 10 \, Log(1 + \varepsilon^2 \omega_s{}^{2n})$$

$$20dB = 10\,Log(1 + \Omega_s^{2n})$$

$n = 3$.

$$|T(j\omega)|^2 = \frac{1}{1 + \omega^{2n}}$$



$$T(\$) = \frac{1}{\$^2 + \$ \cdot \underbrace{2\cos(60°)}_{1} + 1} \qquad \frac{1}{\$ + 1}$$

Aplico el nucleo de transformación

$$\$ \longrightarrow \frac{\$'^2 + 1}{\$'}\,Q$$

$$T(\$') = \frac{1}{Q^2\left(\frac{\$'^2+1}{\$'}\right)^2 + \left(\frac{\$'^2+1}{\$'}\right)Q + 1} \qquad \frac{1}{Q\,\frac{\$'^2+1}{\$'} + 1}$$

$$T(\$') = \frac{\$'^2}{Q^2(\$'^4 + 2\$'^2 + 1) + (\$'^2 + 1)\$'Q + \$'^2} \qquad \frac{\$'}{Q(\$'^2 + 1) + \$'}$$

$$T(\$') = \frac{\$'^2 \frac{1}{Q^2}}{\$'^4 + \$'^3\frac{1}{Q} + \$'^2\left(2 + \frac{1}{Q^2}\right) + \$'\frac{1}{Q} + 1} \qquad \frac{\$'\frac{1}{Q}}{\$'^2 + \frac{\$'}{Q} + 1}$$

$$T(\$') = \frac{\$'}{(\$' - (-0{,}134 + 1{,}207j))(\$' - (-0{,}134 - 1{,}207j))} \qquad \frac{1}{Q}$$

$$\frac{\$'}{(\$'-(-0{,}0908+0{,}817\,j))(\$'-(-0{,}0908-0{,}817j))}\frac{1}{Q}$$

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

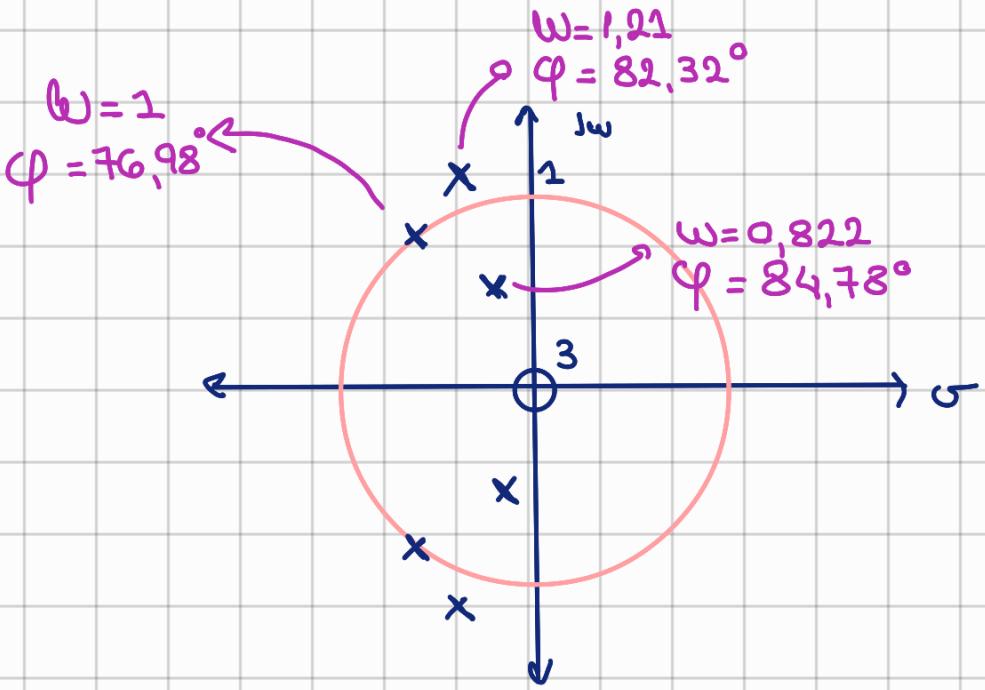
$$T(\$)=\frac{\$'\frac{1}{Q}}{\$'^2+\$'0{,}268+1{,}474}\;\frac{\$'\frac{1}{Q}}{\$'^2+\$'0{,}1816+0{,}675}\;\frac{\$'\frac{1}{Q}}{\$'^2+\frac{\$'}{Q}+1}$$

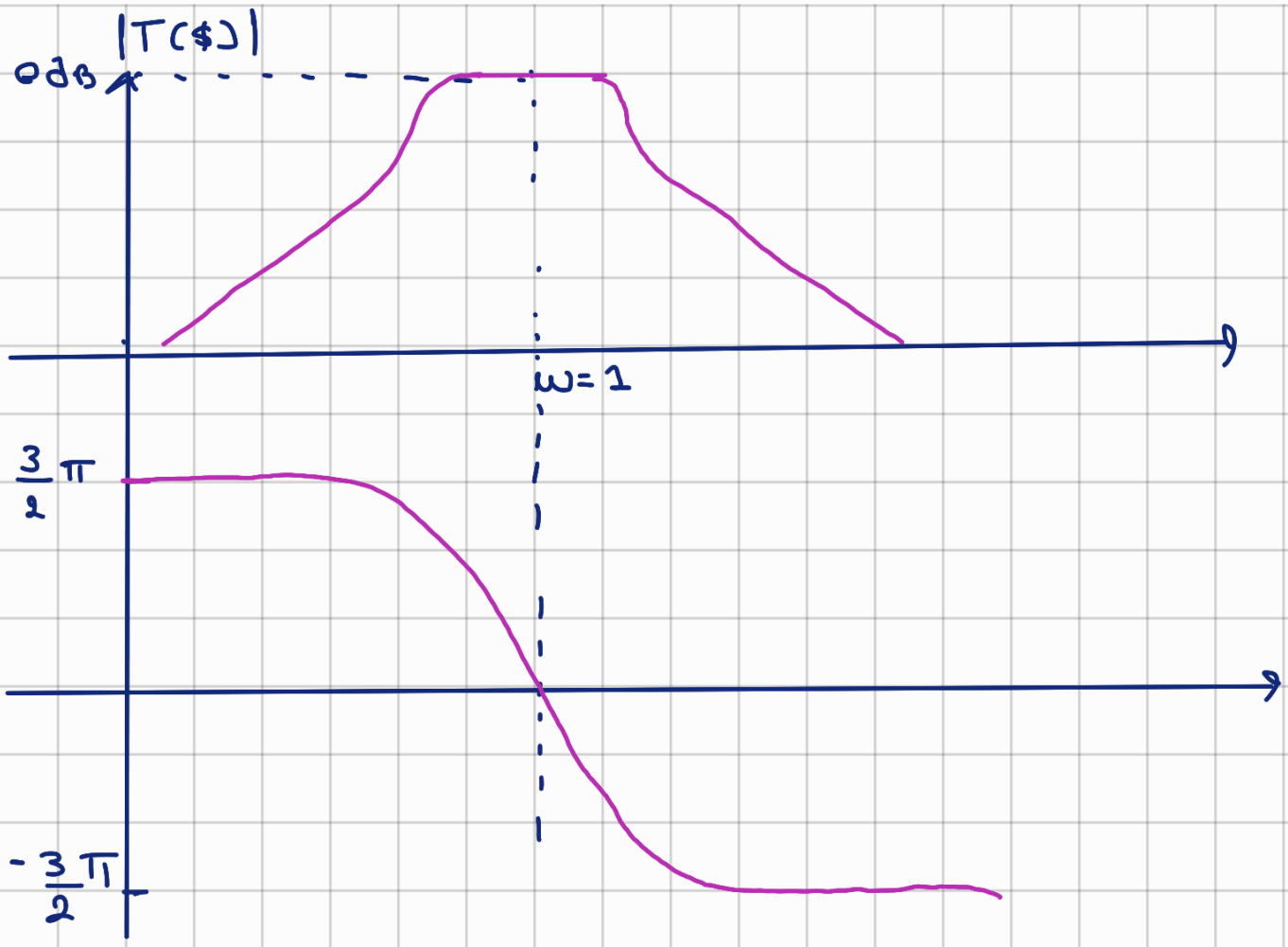
$$T(\$)=\frac{\$'.0{,}45}{\$'^2+\$'0{,}268+1{,}474}\cdot\frac{\$'0{,}45}{\$'^2+\$'0{,}1816+0{,}675}\cdot\frac{\$'0{,}45}{\$'^2+\$'0{,}45+1}$$

Polos y ceros

$$2\cos(\varphi)=\frac{\omega_c}{Q}$$

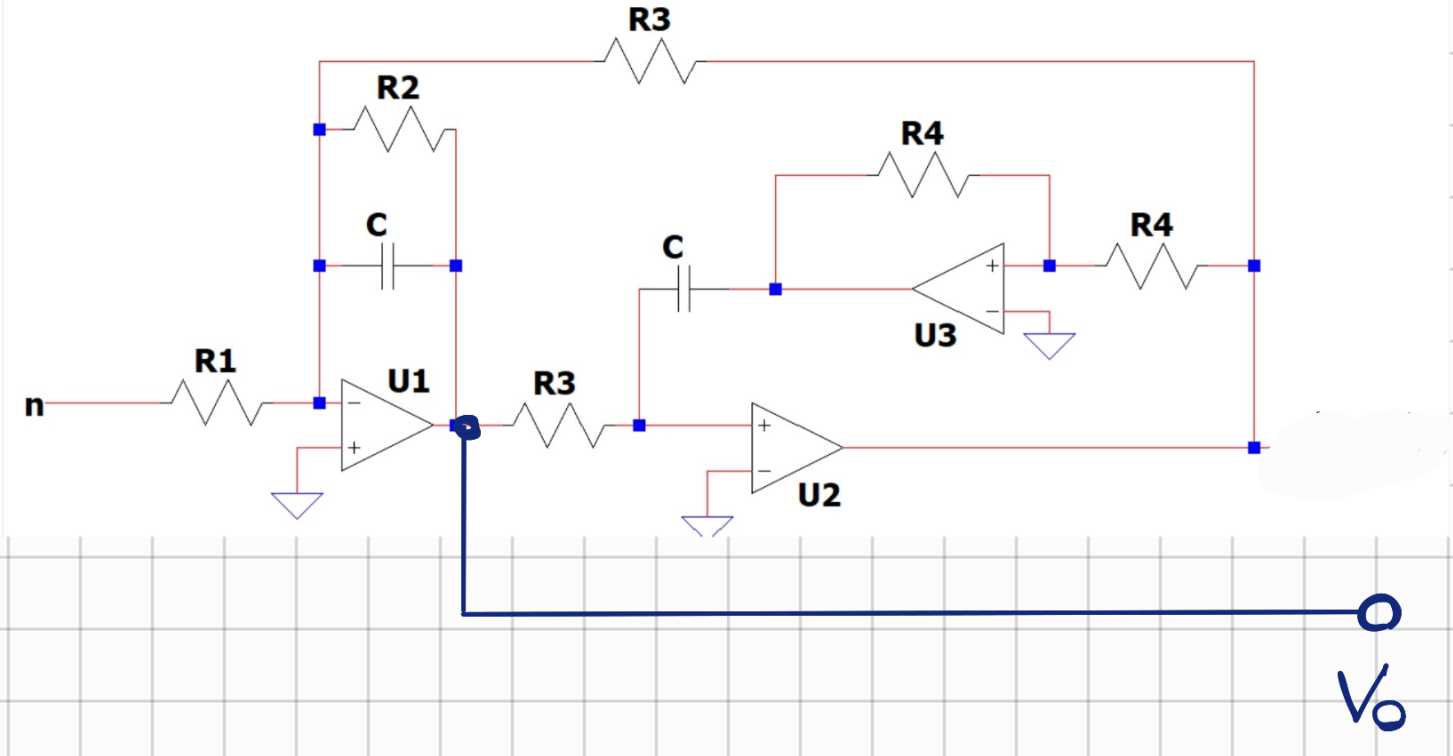
$$\varphi=\arccos\frac{\omega_c}{2Q}$$





Implementación Circuital

Se utiliza para cada transferencia de segundo orden un filtro Ackenberg Massberg.



ecuaciones de diseño

$$T(\$) = \frac{\$ \cdot \frac{1}{R_2 C}}{\$^2 + \$ \frac{1}{R_2 C} + \frac{1}{R_3^2 C^2}} \cdot \left(-\frac{R_2}{R_1}\right)$$

$$k = -\frac{R_2}{R_1}$$

$$\omega_o^2 = \frac{1}{R_3^2 C^2} \longrightarrow \omega_o = \frac{1}{R_3 C}$$

$$Q = \frac{R_2}{R_3}$$

$$T(\$) = k \cdot \frac{\$ \, \omega_o/Q}{\$^2 + \$ \, \omega_o/Q + \omega_o^2}$$

filtro 1 | filtro 2 | filtro 3

$$T(\$) = \frac{\$' \cdot 0{,}45}{\$'^2 + \$' 0{,}268 + 1{,}474} \cdot \frac{\$' \, 0{,}45}{\$'^2 + \$' 0{,}1816 + 0{,}675} \cdot \frac{\$' \, 0{,}45}{\$'^2 + \$' 0{,}45 + 1}$$

filtro 1

$$T(\$) = \frac{\$ \cdot 0{,}45}{\$^2 + \$ 0{,}268 + 1{,}474}$$

$$\omega_o^2 = 1{,}474 \longrightarrow \omega_o = 1{,}214$$

$$\frac{\omega_o}{Q} = 0{,}268 \longrightarrow Q = 4{,}53$$

$$k \cdot \frac{\omega_o}{Q} = 0{,}45 \longrightarrow |k| = 1{,}68$$

$$W_o = \frac{1}{R_3 \cdot C} \Rightarrow R_3 = 1 \; ; C = 0{,}8237$$

$$Q = \frac{R_2}{R_3} \Rightarrow R_3 = 1 \; ; R_2 = 4{,}53$$

$$|K| = \frac{R_2}{R_1} \Rightarrow R_2 = 4{,}53 \; ; R_1 = 2{,}696$$

filtro 2

$$T(\$) = \frac{\$ \cdot 0{,}45}{\$^2 + \$0{,}1816 + 0{,}675}$$

$$W_o^2 = 0{,}675 \longrightarrow W_o = 0{,}8215$$

$$\frac{W_o}{Q} = 0{,}1816 \longrightarrow Q = 4{,}524$$

$$K \cdot \frac{W_o}{Q} = 0{,}45 \longrightarrow |K| = 2{,}4779$$

$$W_o = \frac{1}{R_3 \cdot C} \Rightarrow R_3 = 1 \; ; C = 1{,}2172$$

$$Q = \frac{R_2}{R_3} \Rightarrow R_3 = 1 \; ; R_2 = 4{,}524$$

$$|K| = \frac{R_2}{R_1} \Rightarrow R_2 = 4{,}524 \; ; R_1 = 1{,}8257$$

Filtro 3

$$T(\$) = \frac{\$ \cdot 0{,}45}{\$^2 + \$\,0{,}45 + 1}$$

$$W_o^2 = 1 \longrightarrow W_o = 1$$

$$\frac{W_o}{Q} = 0{,}45 \longrightarrow Q = 2{,}22$$

$$K \cdot \frac{W_o}{Q} = 0{,}45 \longrightarrow |K| = 1$$

$$W_o = \frac{1}{R_3 \cdot C} \Rightarrow R_3 = 1 \; ; \; C = 1$$

$$Q = \frac{R_2}{R_3} \Rightarrow R_3 = 1 \; ; \; R_2 = 2{,}22$$

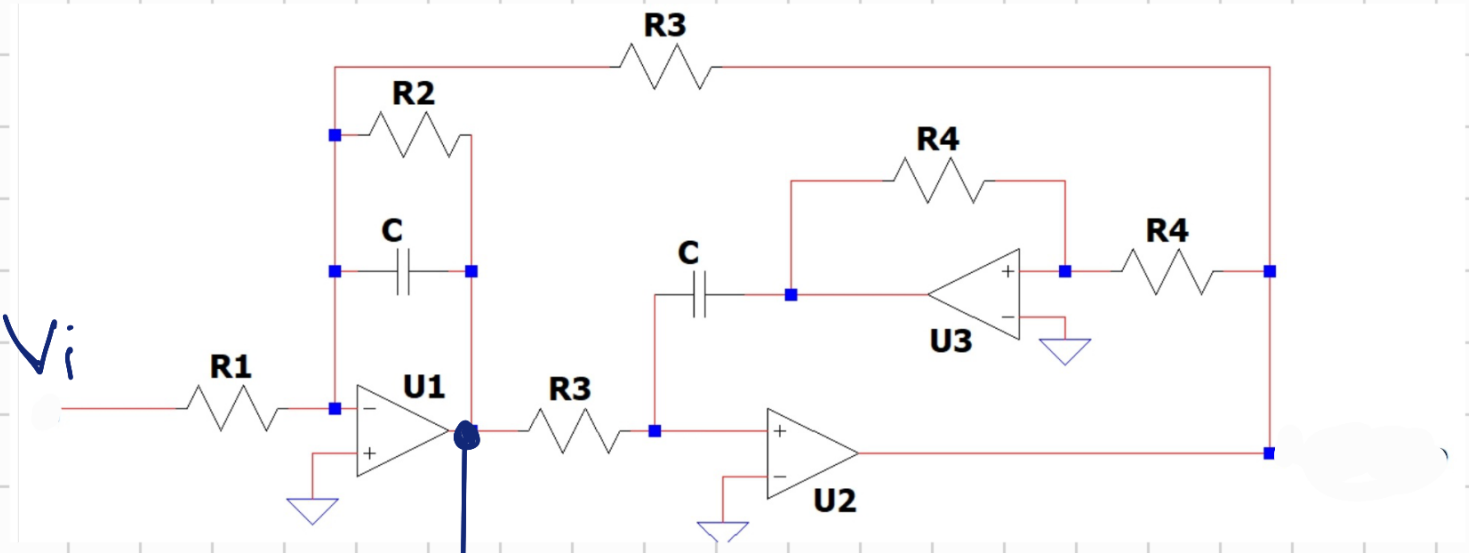
$$|K| = \frac{R_2}{R_1} \Rightarrow R_2 = 2{,}22 \; ; \; R_1 = 2{,}22$$

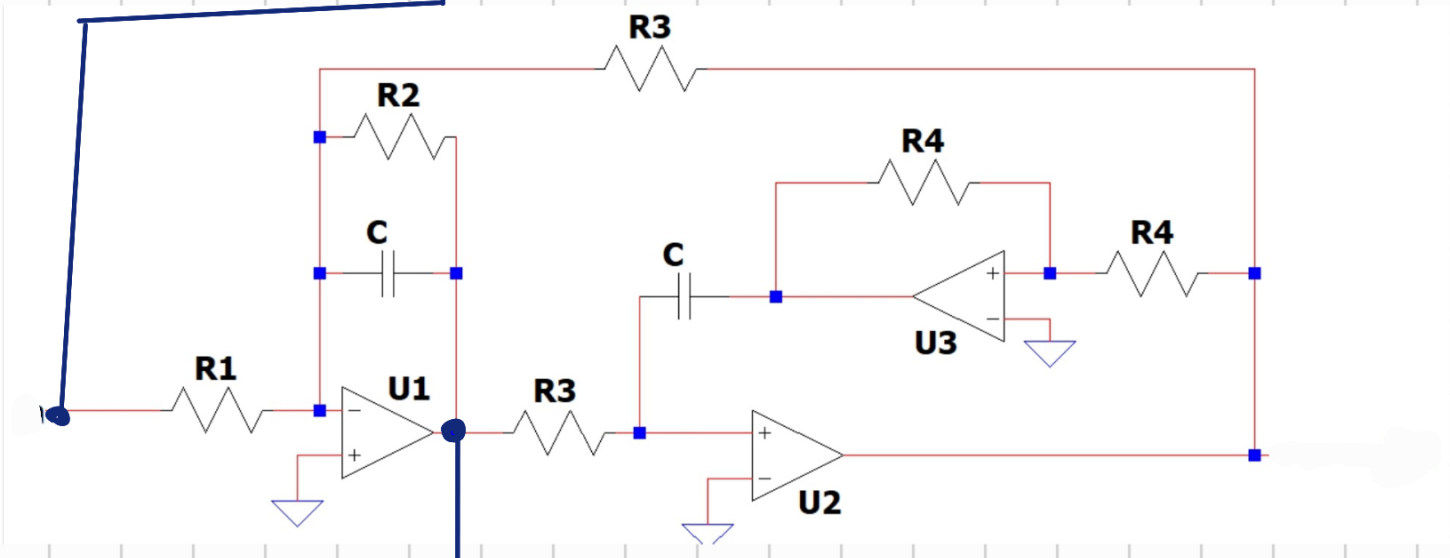
Valores componentes:

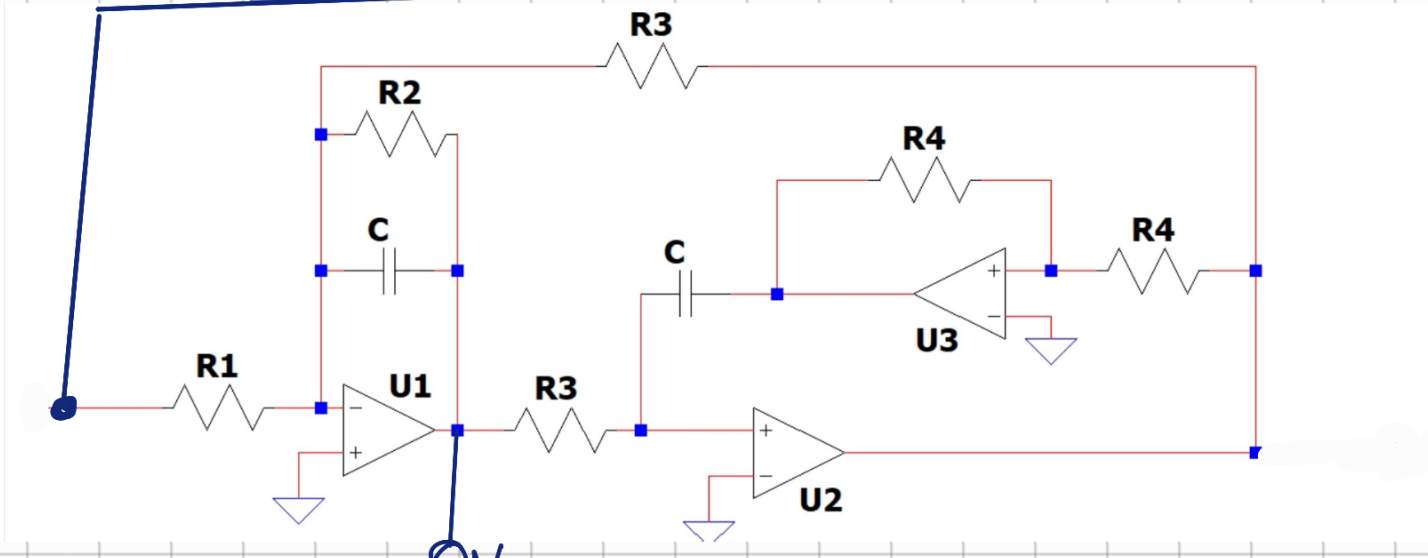
Circuito 1:
$R_1 = 2{,}696$
$R_2 = 4{,}53$
$R_3 = 1$
$C = 0{,}8237$

Circuito 2:
$R_1 = 1{,}8257$
$R_2 = 4{,}524$
$R_3 = 1$
$C = 1{,}2172$

Circuito 3:
$R_1 = 2{,}22$
$R_2 = 2{,}22$
$R_3 = 1$
$C = 1$


R3
R2
R4
C
C
R4
Vi
R1
U1
R3
U3
U2


R3
R2
R4
C
C
R4
R1
U1
R3
U3
U2


R3
R2
R4
C
C
R4
R1
U1
R3
U3
U2
Vo