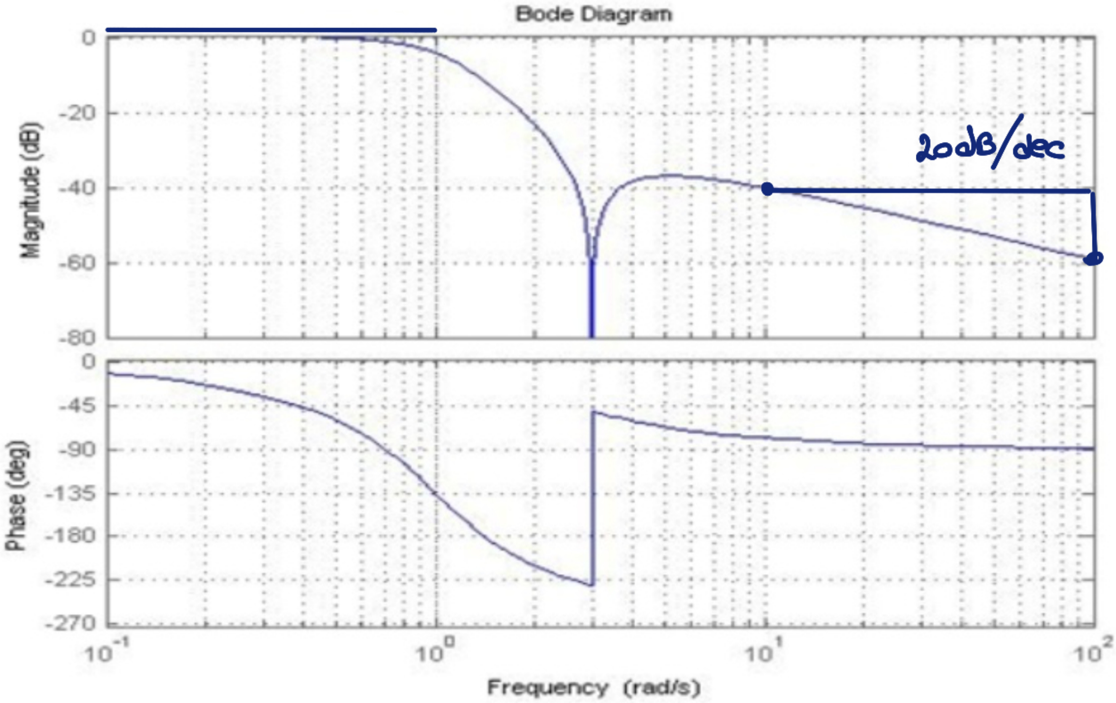
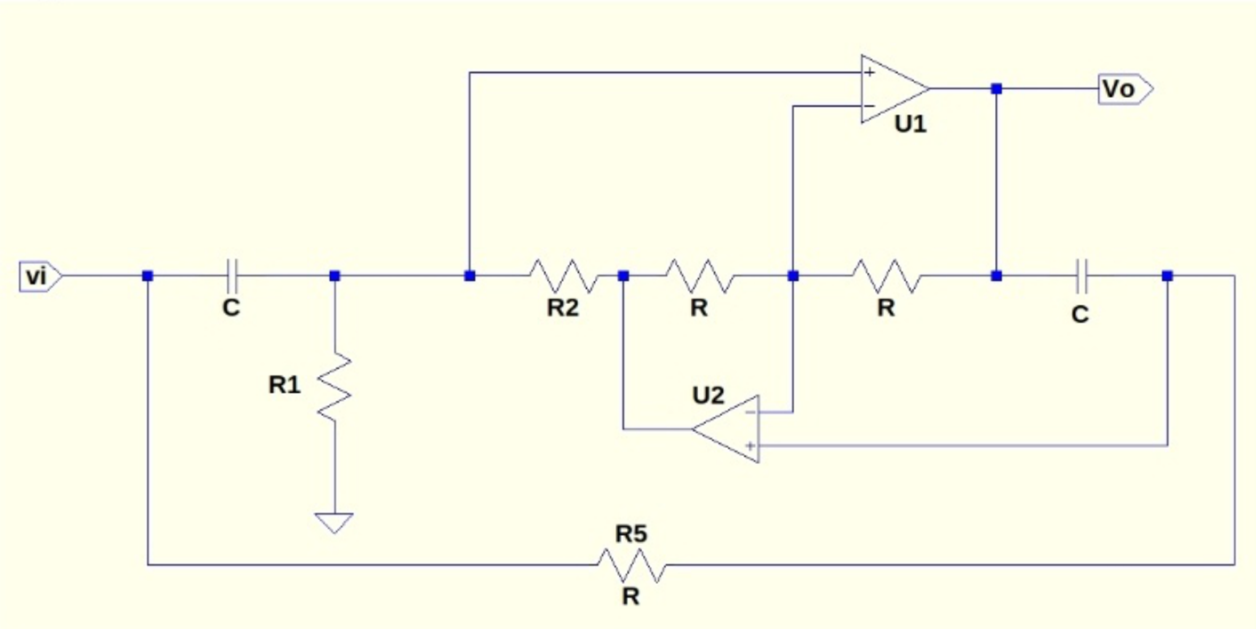
1) Se debe diseñar un filtro **pasa-altos**, que presente máxima planicidad en la banda de paso (frecuencia de corte = 300 Hz) y un cero de transmisión en 100 Hz. El **prototipo pasabajos normalizado** presenta la siguiente respuesta:



a) Determine la expresión de H(s) del filtro pasa-altos normalizado
b) Realizar el diagrama de polos y ceros de H(s)
c) Sintetice el circuito del filtro pedido. Se utilizará para la estructura de segundo orden el siguiente circuito:



d) Compare la estructura sugerida y discuta las similitudes y diferencias con la red propuesta por Schaumann:

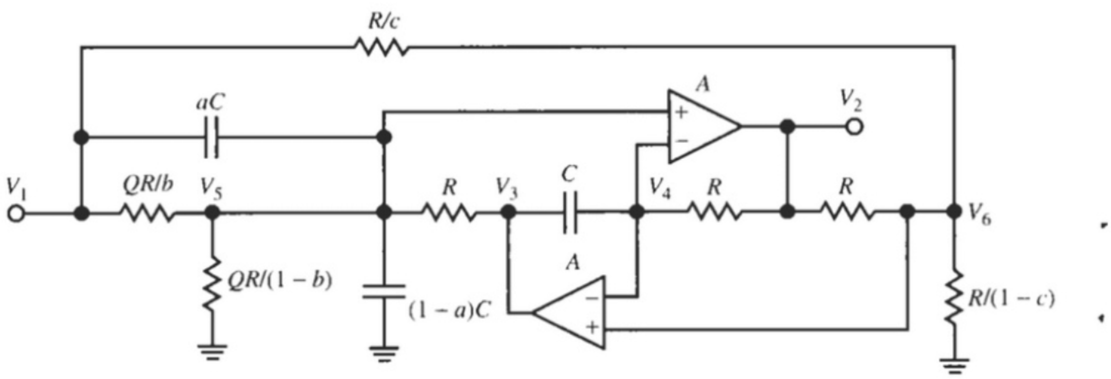


Figure 5.16 A general biquad based on the GIC circuit.

TABLE 5.4 Parameter Choice to Define the Filter Type for Eq. (5.36)[a]

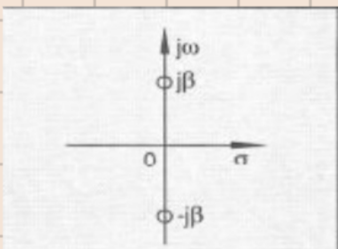
Filter type	a	b	c	Comments
Highpass	a	0	0	$2a$ sets the high-frequency gain
Lowpass	$c/2$	$c/2$	c	c sets the low-frequency gain
Bandpass	0	b	0	$2b$ sets the bandpass gain
Allpass	1	0	1	
Notch	1	1/2	1	
Highpass notch	$a > c$	$c/2$	c	c sets the low-frequency gain $(2a - c)$ sets the high-frequency gain
Lowpass notch	$a < c$	$c/2$	c	c sets the low-frequency gain $(2a - c)$ sets the high-frequency gain

[a]In all cases $R = 1/(\omega_0 C)$.

① plantilla pasa bajos normalizada:

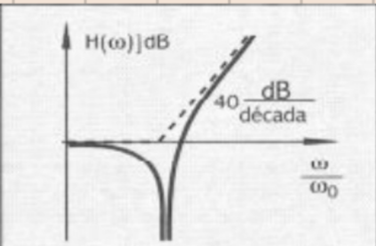
$\omega_p = 1 \longrightarrow \alpha_{max} = 3dB$ (lo supongo ya que la grafica no proporciona datos precisos)

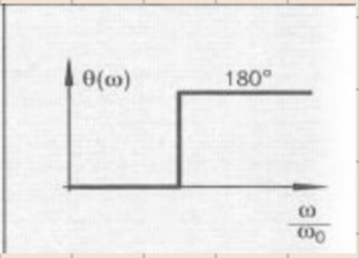
para determinar el N me fijo en la respuesta en frecuencia. En primer instancia vemos que hay un punto para el cual el modulo cae a $-\infty$ (elimina la banda) Esto es debido a un cero complejo conjugado



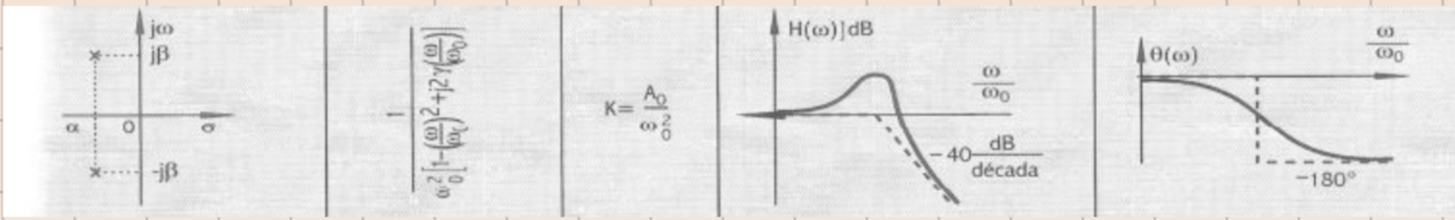
$$(j\omega + j\beta)(j\omega - j\beta) = \beta^2\left[1-\left(\frac{\omega}{\beta}\right)^2\right] = \omega_0^2\left[1-\left(\frac{\omega}{\omega_0}\right)^2\right]$$

$K = A_0\beta^2$

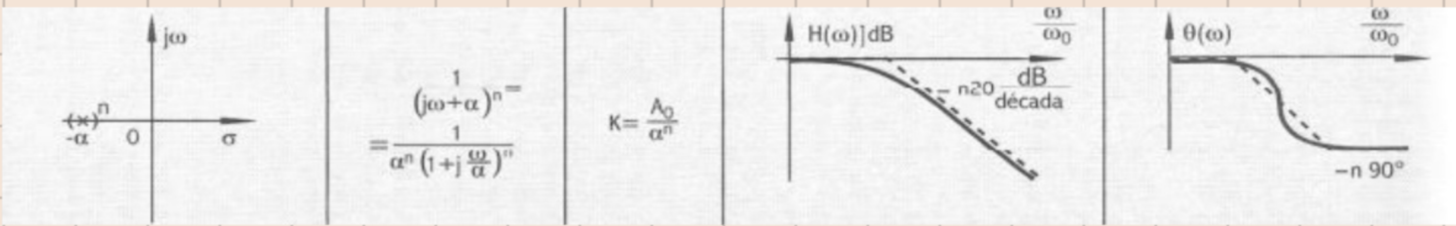




Luego, se observa que pasado este punto la transferencia la misma cae 20dB por decadas. Si elegimos un filtro de N=2 (2 polos complejos) tendriamos la siguiente transferencia.

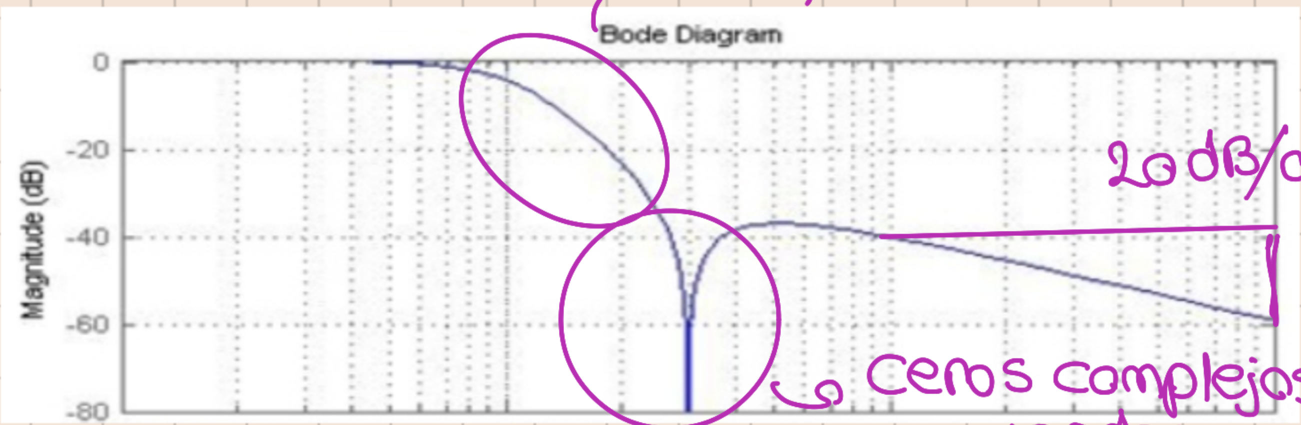


Sumando ambas (ceros y polos) nos quedaria que no sigue cayendo la transferencia. Es por ello que agregando un polo simple mas obtenemos el resultado deseado.



Entonces N=3.

60dB/dec



20dB/dec

ceros complejos conjugados

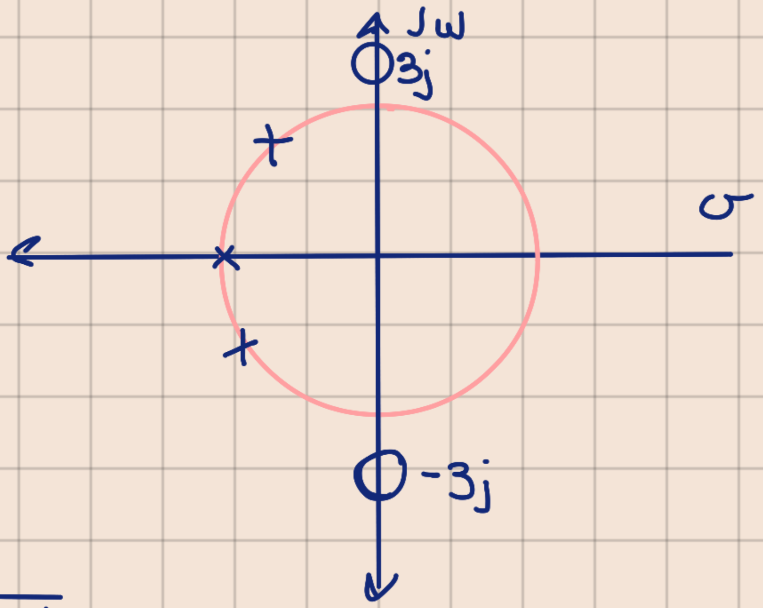
Butterworth

$W_{PHP} = 300Hz \rightarrow$ norma de freq $\equiv \Omega_n$

Nucleo: $K(\$) = \frac{1}{\$} \rightarrow \Omega = \frac{-1}{W}$ $\quad K(w)$

$Cero_{HP} = 100Hz \xrightarrow{\frac{cero}{\Omega_n}} C_{norm\,HP} = \frac{1}{3} \longrightarrow C_{norm\,LP} = 3$

Polos y ceros



$$|T(\omega)|^2 = \frac{1}{1+\omega^4}$$

$$T(s) = \frac{1}{s^2 + s\,2\cos(60^\circ) + 1} \cdot \frac{1}{(s+1)}$$

Como hay un par de ceros conjugados:

$$T(s) = \frac{(s^2+9)}{s^2 + s\,2\cdot\cos(60^\circ) + 1} \; \frac{1}{(s+1)}$$

ganancia

$$T(s) = \frac{(s^2+9)}{s^3 + 2s^2 + 2s + 1} \longrightarrow \text{para } s \to j\omega \Big|_{\omega=0} = 9$$

Como vemos que hay una ganancia y en la modelo no, divido la transferencia por dicha ganancia.

$$\boxed{T(s) = \frac{(s^2+9)}{s^3 + 2s^2 + 2s + 1} \cdot \frac{1}{9}}$$

Aplicando nucleo de transformación:

$$s \longrightarrow \frac{1}{s'}$$

$$T(s') = \frac{\left(\frac{1}{s'^2} + 9\right)}{\frac{1}{s'^3} + 2\frac{1}{s'^2} + 2\frac{1}{s'} + 1} \quad \frac{1}{9}$$

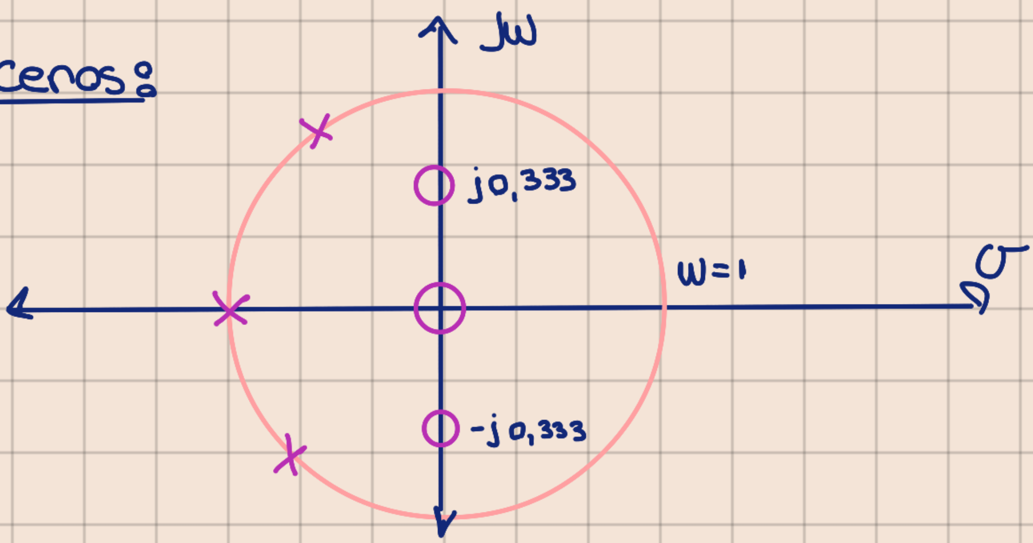
$$T(s') = \frac{\left(\frac{1}{9} + s'^2\right)\frac{1}{\cancel{s'^2}}}{\frac{s'^3 + 2s'^2 + 2s' + 1}{s'^{\cancel{3}}}}$$

$$T(s') = \frac{s'\left(s'^2 + 1/9\right)}{s'^3 + 2s'^2 + 2s' + 1}$$

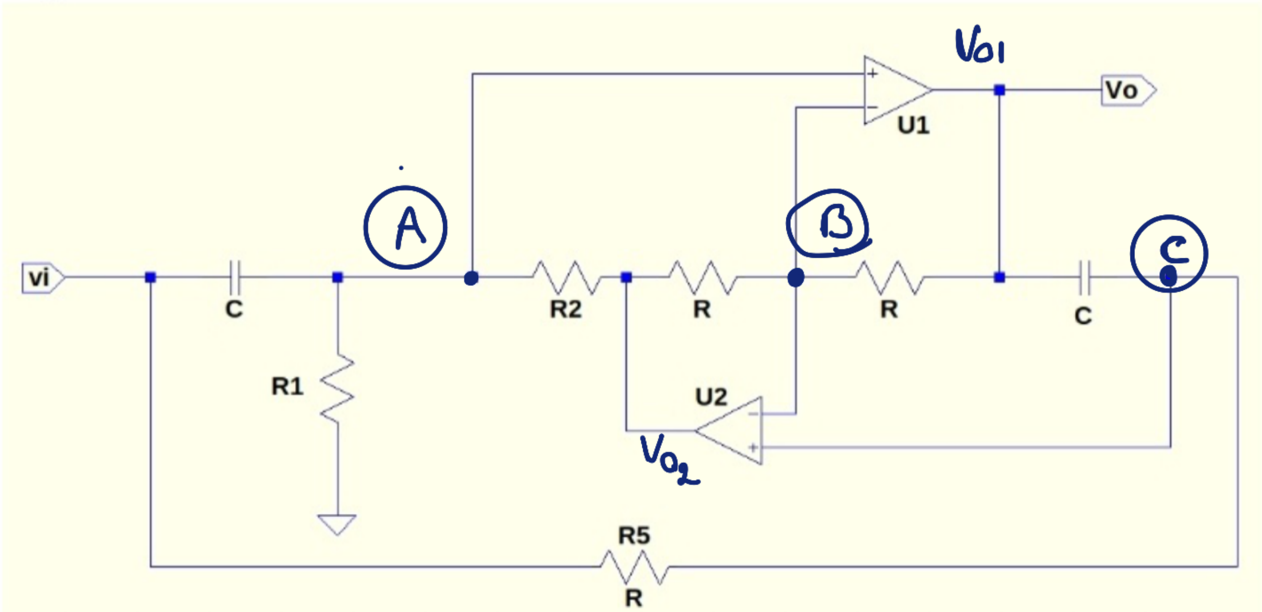
$$\boxed{T(s') = \frac{s'}{s'+1} \cdot \frac{\left(s'^2 + 1/9\right)}{s'^2 + s' + 1}}$$

transferencia filtro pasa altos normalizado.

Polos y ceros:



c) Sintetice el circuito del filtro pedido. Se utilizará para la estructura de segundo orden el siguiente circuito:



Calculo transferencia

(A)

$$V_A\left[sC + G_1 + G_2 \right] = V_{O2} \cdot G_2 + V_i \cdot sC$$

(B)

$$V_B\left[G + G \right] = V_{O2} \cdot G + V_{O1} \cdot G$$

(C)

$$V_C\left[sC + G_5 \right] = V_{O1} \cdot sC + V_i \cdot G_5$$

$$V_A = V_B = V_C = V$$

$$V_{O1} = V_O$$

$$(A) \rightarrow V_{O2} \cdot G_2 = V \cdot \left[sC + G_1 + G_2 \right] - V_i \, sC$$

$$V_{O2} = \frac{V \cdot \left[sC + G_1 + G_2 \right] - V_i \, sC}{G_2}$$

Ⓒ $\rightarrow V = \dfrac{V_o \cdot \$C + V_i G_5}{\$C + G_5}$

Ⓐ y Ⓑ

$$V\,[2G] = \frac{V\cdot[\$C + G_1 + G_2] - V_i \$C}{G_2} \cdot G + V_o G$$

$$V\left[2G - \frac{(\$C + G_1 + G_2)G}{G_2}\right] = \frac{-V_i \$C G}{G_2} + V_o \cdot G$$

$$\left[\frac{V_o \$C}{\$C + G_5} + \frac{V_i G_5}{\$C + G_5}\right]\left[\frac{2G.G_2 - \$CG - G(G_1 + G_2)}{\cancel{G_2}}\right] = V_o.G^{G_2} - \frac{V_i \$C G}{\cancel{G_2}}$$

$\hookrightarrow (\cancel{2}G_2 - \$C - G_1 - \cancel{G_2})G$

$(G_2 - \$C - G_1)G$

$$\left[\frac{V_o \$C}{\$C + G_5} + \frac{V_i G_5}{\$C + G_5}\right][G_2 - \$C - G_1]\cancel{G} = (V_o G_2 - V_i \$C)\cancel{G}$$

$$V_o\left[\frac{\$C}{\$C + G_5}(G_2 - \$C - G_1) - G_2\right] = -\left[V_i \$C + \frac{V_i G_5}{\$C + G_5}(G_2 - \$C - G_1\right.$$

$$V_o\left[\frac{\cancel{-}(\$C)^2 \cancel{-} \$CG_1 \cancel{-} G_5G_2}{\cancel{\$C + G_5}}\right] = \cancel{-} V_i\left[\frac{(\$C)^2 + G_2G_5 - G_1G_5}{\cancel{\$C + G_5}}\right]$$

$$\frac{V_o}{V_i} = \frac{\$^2C^2 + G_5(G_2 - G_1)}{\$^2C^2 + \$C G_1 + G_2G_5}$$

$$\boxed{\frac{V_o}{V_i} = \frac{\$^2 + \frac{G_5}{C^2}(G_2 - G_1)}{\$^2 + \$\frac{G_1}{C} + \frac{G_2 G_5}{C^2}}} = \frac{\frac{1}{seg^2} + \frac{1}{seg^2}}{\frac{1}{seg^2} + \frac{1}{seg^2} + \frac{1}{seg^2}} \checkmark$$

Implemento el filtro de segundo orden

$$\boxed{T(\$') = \frac{\$'}{\$'+1} \cdot \frac{(\$'^2 + 1/9)}{\$'^2 + \$' + 1}}$$

$$\frac{1}{R_1 C} = 1 \longrightarrow \boxed{R_1 = 1 \wedge C = 1}$$

$$\left(\frac{1}{R_2} - \frac{1}{R_1}\right)\frac{1}{R_5 C^2} = \frac{1}{9} \longrightarrow \frac{R_1 - R_2}{R_1 R_2 R_5 C^2} = \frac{1}{9}$$

$$\frac{1 - R_2}{R_2 R_5} = \frac{1}{9}$$

$$9(1 - R_2) = R_2 R_5$$

$$\frac{R_5}{9} = \frac{1 - R_2}{R_2}$$

$$\frac{R_5}{9} = \frac{1}{R_2} - 1 \rightarrow \frac{1}{R_2} = \frac{9 + R_5}{9} \rightarrow \boxed{R_2 = \frac{9}{9 + R_5}} \quad (A)$$

$$\frac{1}{R_2R_5C^2} = 1$$

$$\frac{1}{R_2R_5} = 1 \longrightarrow \frac{1}{R_5\,\frac{9}{9+R_5}} = 1$$

$$1 = \frac{9+R_5}{9R_5}$$

$$1 = \frac{1}{R_5} + \frac{1}{9} \longrightarrow \boxed{R_5 = \frac{9}{8}}$$ remplazando en (A)

$$\boxed{R_2 = \frac{8}{9}}$$

$R_1 = 1$

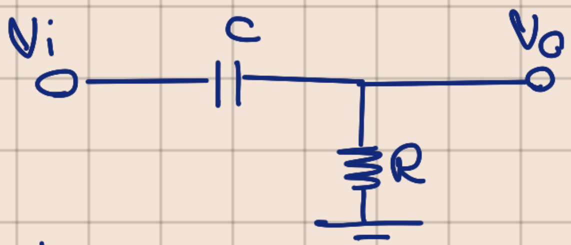
$C = 1$

$R_2 = \frac{8}{9}$

$R_5 = \frac{9}{8}$

Para el filtro de primer orden:

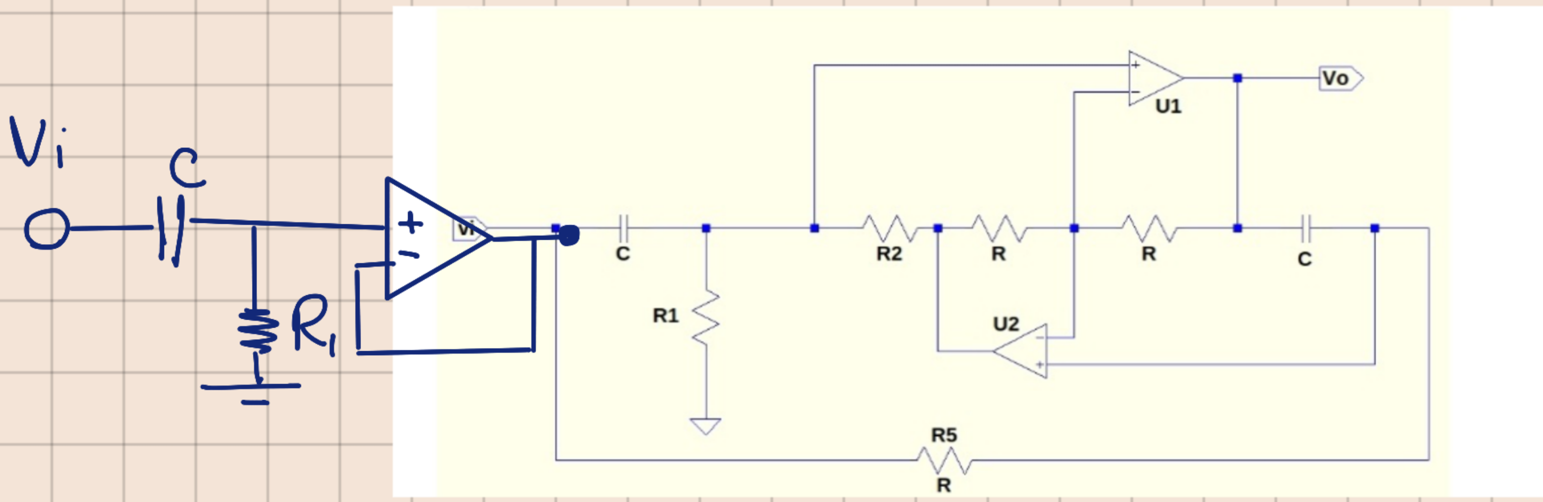
$$T(s) = \frac{s}{s+1} \longrightarrow$$



$$\frac{V_o}{V_i} = \frac{R}{\frac{1}{sC}+R} = \frac{s}{\frac{1}{CR}+s}$$

$$\frac{1}{CR} = 1 \longrightarrow \boxed{C = 1\ ;\ R = 1}$$

finalmente el circuito queda como:



$R_1 = 1$
$R_2 = 8/9$
$R = 9/8$
$C = 1$

componentes normalizados

Comparacion con el circuito del Schaumann:

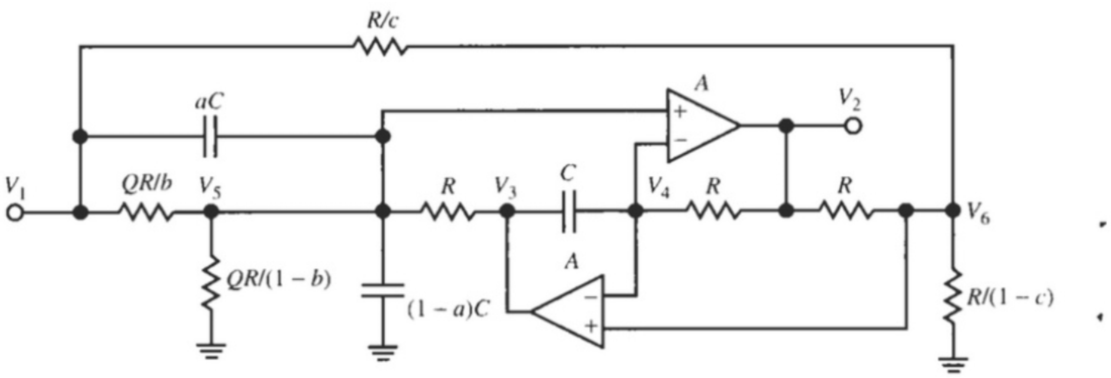


Figure 5.16 A general biquad based on the GIC circuit.

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[a]In all cases $R = 1/(\omega_0 C)$.

$$T(s)=\frac{V_2}{V_1}=\frac{s^2(2a-c)+s(\omega_0/Q)(2b-c)+c\omega_0^2}{s^2+s\omega_0/Q+\omega_0^2}$$

Para obtener un filtro pasa altos debemos adoptar las siguientes condiciones:

$$\frac{(s'^2+1/9)}{s'^2+s'+1}$$

expresion q' debo conseguir

- $b=\frac{c}{2}$

$$T(s)=\frac{s^2(2A-C)+C\omega_0^2}{s^2+s\frac{\omega_0}{Q}+\omega_0^2}$$

Por lo que:

wo normalizado

$$s^2(2A-C)+C\omega_0^2=s'^2+\frac{1}{9}\,1$$

- $2A-C=1$
- $C=\frac{1}{9}$

$$\left.\begin{matrix}2A-C=1\\ C=\frac{1}{9}\end{matrix}\right\} A=\frac{1+\frac{1}{9}}{2}=\frac{9+1}{18}=\frac{10}{18}=\frac{5}{9}$$

<u>finalmente:</u>

$$\boxed{A=\frac{5}{9};\ B=\frac{1}{18};\ C=\frac{1}{9}}$$

$$\left.\begin{matrix}\omega_0=\frac{1}{RC}=1\\ \\ \frac{Q}{\omega_0}=\frac{1}{R_QC}=1\end{matrix}\right\}\begin{matrix}R=1\\ C=1\\ R_Q=1\end{matrix}$$