$\alpha_{max} = 0{,}4\ dB$ $\quad$ $\alpha_{min} = \cancel{48dB}\ 24dB$

$F_p = 3{,}2\ kHz$ $\quad$ $F_s = 9{,}6\ kHz$ $\quad$ $\Omega\omega = 2\pi F_s$

$\omega_p = 1 \ ; \ \omega_s = 3$

$\varepsilon^2 = 10^{0{,}4/10} - 1 = 0{,}096 \ ; \quad \varepsilon = 0{,}31$

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

$n=2 \Rightarrow 14\ dB$

$\boxed{n=3 \Rightarrow 29{,}7\ dB}$

$n=4 \Rightarrow 45{,}06\ dB$

$[n=5 \Rightarrow 60{,}38\ dB] \rightarrow$ con butter sería orden 7

$$T(s)\cdot T(-s) = |T(\omega)|^2 = \frac{1}{1+\varepsilon^2 C_3^2(\omega)}$$

$$C_n(\omega) = 2\omega\, C_{n-1}(\omega) - C_{n-2}(\omega)$$

$$C_3(\omega) = 2\omega\, C_2(\omega) - C_1(\omega)$$

$C_1(\omega) = \omega \ ; \ C_0(\omega) = 1$

$\Rightarrow C_2(\omega) = 2\omega\cdot\omega - 1 = 2\omega^2 - 1 \longrightarrow C_3(\omega) = 4\omega^3 - 2\omega - \omega = (4\omega^3 - 3\omega)$

$$|T(\omega)|^2 = \frac{1}{1+\varepsilon^2(4\omega^3-3\omega)^2} = \frac{1}{1+\varepsilon^2(16\omega^6 - 24\omega^4 + 9\omega^2)}$$

$$|T(\omega)|^2 = \frac{1}{16\varepsilon^2\omega^6 - 24\varepsilon^2\omega^4 + 9\varepsilon^2\omega^2 + 1} = \frac{1}{a\omega^6 - b\omega^4 + c\omega^2 + 1}$$

$a = 16\varepsilon^2$
$b = 24\varepsilon^2$
$c = 9\varepsilon^2$

$$T(s)\cdot T(-s) = \frac{1}{-a s^6 - b s^4 - c s^2 + 1}$$

$$\frac{1}{As^3 + Bs^2 + Cs + 1} \cdot \frac{1}{-As^3 + Bs^2 - Cs + 1}$$

$A^2 = a \quad ; \quad -2AC + B^2 = -b \qquad -C^2 + 2B = -c$

$$A = \sqrt{a} = 4\varepsilon \qquad C(-8\varepsilon) + B^2 = -24\varepsilon^2$$

$$B = \frac{-c + C^2}{2}$$

$$B = \frac{C^2 - 9\varepsilon^2}{2}$$

$$\left[\frac{C^2 - 9\varepsilon^2}{2}\right]^2 = 8\varepsilon C - 24\varepsilon^2$$

$$\frac{C^4 - 18\varepsilon^2 C^2 + 81\varepsilon^4}{4} = 8\varepsilon C - 24\varepsilon^2$$

$$C^4 - 18\varepsilon^2 C^2 + 81\varepsilon^4 = 32\varepsilon C - 96\varepsilon^2$$

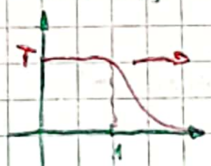
$$C^4 - 18\varepsilon^2 C^2 - 32\varepsilon C + (81\varepsilon^4 + 96\varepsilon^2) = 0$$

$C = 2{,}05 \Rightarrow B = 1{,}66$ ✓

$C = 0{,}93 \Rightarrow B = -1{,}7 \rightarrow$ Negativo $\rightarrow$ polo a la derecha

$$T_c(s) = \frac{1}{1{,}24\,s^3 + 1{,}66\,s^2 + 2{,}05\,s + 1} = \frac{0{,}8}{s^3 + 1{,}34\,s^2 + 1{,}65\,s + 0{,}8}$$

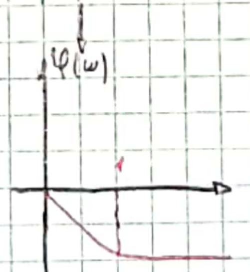
Aproximación de Bessel (group delay)



$\rightarrow$ mantener el retardo cte en la banda de paso

$$\frac{|y|}{|x|} = M(\omega)\, e^{j\varphi(\omega)}$$

$$= 1\, e^{j(-T\omega)}$$



$$H(\omega) = e^{-j\,\underbrace{\omega T}_{\Omega\omega}}$$

$$H(\omega)\big|_{j\omega = s} = e^{-sT} \Rightarrow e^{x} = \sinh(x) + \cosh(x)$$

$$\Rightarrow H(s) = \frac{P(s)}{Q(s)} = \frac{1}{\sinh(sT) + \cosh(sT)}$$

$$\sinh(s) = s + \frac{s^3}{3!} + \frac{s^5}{5!} + \dots$$

$$\operatorname{cotgh}(s) = \frac{\cosh(s)}{\sinh(s)} = \frac{1}{s} + \frac{1}{\frac{3}{s} + \frac{1}{\frac{5}{s} + \dots}}$$

$$\cosh(s) = 1 + \frac{s^2}{2!} + \frac{s^4}{4!} + \dots$$

S. n = 1:

$$\coth(s) = \frac{1}{s} \longrightarrow H(s) = \frac{1}{s+1} = H_B(s) = H_{BW}(s) = H_{CH}(s)$$

Si n=2

$$\coth(s) = \frac{1}{s} + \frac{1}{\frac{3}{s}} = \frac{s^2+3}{3s}$$

$$H_B(s) = \frac{k}{s^2+3s+3} = \frac{3}{s^2+3s+3}$$ para que de 0dB en $w=0$

Si n=3

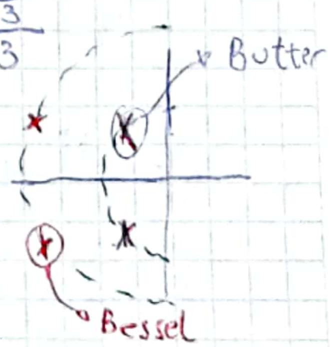
$$\coth(s) = \frac{1}{s} + \frac{1}{\frac{3}{s} + \frac{1}{5/s}} = \frac{1}{s} + \frac{1}{\frac{15 \cancel{s} + s^2}{5s}} = \frac{s^2+5s^2+15}{s^3+15s} = \frac{6s^2+15}{s^3+15s}$$

$$H_B'(s) = \frac{ks}{s^3+6s^2+15s+15}$$

Bessel asegura group delay cte

para n=2.

$$H_B(s) = \frac{3}{s^2+3s+3} \Rightarrow W_0^2 = 3 \qquad \frac{W_0}{Q} = 3 \Rightarrow Q = \frac{\sqrt{3}}{3}$$



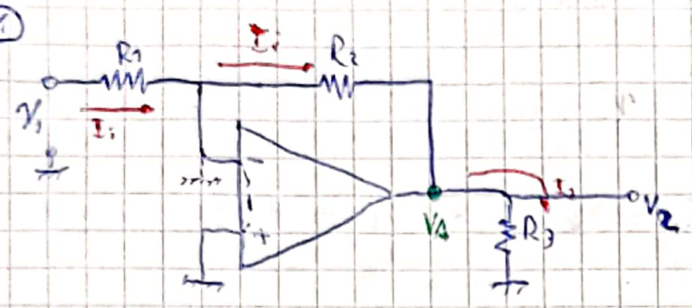
Los filtros de Bessel se resuelven por tablas con frecuencia normalizada, que describen
- ripple en banda de paso
- Error en la demora
- Atenuación en stop

HOJA N°

FECHA

Guía opamps y OTA

1



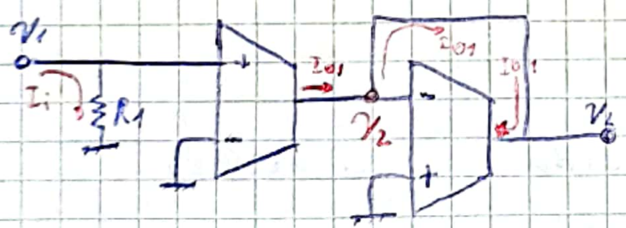
$I_i = \frac{V_1}{R_1} \Rightarrow Z_i = \frac{V_i}{I_i} = R_1 = 47k\Omega$ $\qquad \Omega_Z = R_1$

$\frac{0_V - V_2}{R_2} = I_i \Rightarrow \frac{-V_2}{R_2} = \frac{V_1}{R_1} \Rightarrow T(s) = \frac{V_2}{V_1} = -\frac{R_2}{R_1} = -70\,dB \Rightarrow$

$-70dB = 20dB\,\log(x)$

$x = 316{,}22 \cdot 10^{-6}$

$-\frac{R_2}{R_1} = 316{,}22 \cdot 10^{-6} \Rightarrow R_2 = 316{,}22 \cdot 10^{-6} R_1$



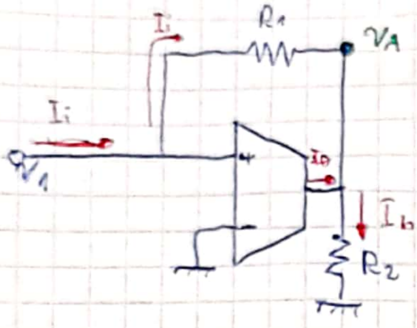
$\frac{V_1}{R_1} = I_i \Rightarrow Z_i = R_1$ $\qquad \frac{I_{01}}{V_1 - 0} = g_{m1}$

$I_{01} = g_{m1} \cdot V_1$

$I_{02} = -I_{01} = -g_{m2} \cdot V_2 \Rightarrow -g_{m1} V_1 = -g_{m2} \cdot V_2$

$\frac{V_2}{V_1} = \frac{g_{m1}}{g_{m2}}$

Ejercicio #3



$$I_o = g_m v_1$$

$$I_i = \frac{v_1 - v_A}{R_1}$$

$$\frac{v_A}{R_2} = I_o + I_i \Rightarrow \frac{v_A}{R_2} = g_m v_1 + \frac{v_1 - v_A}{R_1}$$

$$\frac{v_A}{R_2} + \frac{v_A}{R_1} = v_1\left(g_m + \frac{1}{R_1}\right)$$

$$I_i = v_1 \cdot \left[\frac{1}{R_1} - \frac{R_2}{R_1+R_2}\left(g_m + \frac{1}{R_1}\right)\right]$$

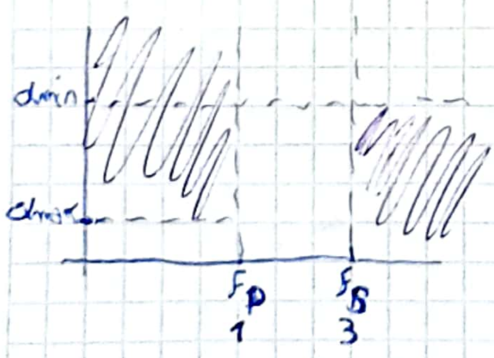
$$v_A = v_1 \cdot \frac{R_1 R_2}{R_1+R_2}\left(g_m + \frac{1}{R_1}\right)$$

$$\frac{I_i}{v_1} = \frac{R_1 + R_2 - R_1R_2(g_m + 1/R_1)}{R_1^2 + R_1R_2}$$

$$Z_i = \frac{v_1}{I_i} = \frac{R_1^2 + R_1R_2}{R_1 + R_2 - R_1R_2(g_m + 1/R_1)} \longrightarrow \text{Resistivo}$$

Guia #2 ej #3

Cheby



$F_p = 3{,}2\ kHz$ $\qquad \Omega_w = 2\pi F_p$

$F_s = 9{,}6\ kHz$

$\alpha_{min} = 0{,}4\ dB$

$\alpha_{max} = 48\ dB$

$$\varepsilon^2 = 10^{0{,}04} - 1$$

$$\varepsilon^2 = 0{,}096$$

$$\alpha_{min} = 20\log\left(1 + \varepsilon^2 \cosh^2(n \cosh^{-1}(\omega_s))\right) \Rightarrow n = 4$$

Se soluciona por simulación