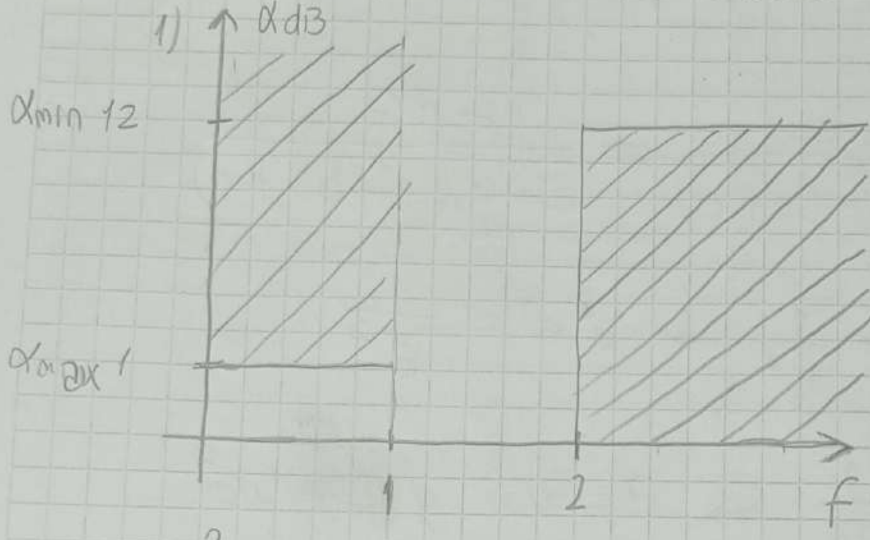
TS3 — Hoja #1

$\alpha_{max} = 1$ $\qquad$ $\alpha_{min} = 12$

$f_p = 1500$ $\qquad$ $f_s = 3000$

1)



$$\xi^2 = 10^{0,1\alpha_{max}} - 1 \Rightarrow \xi = 0,5088$$

$$\alpha_{min} = 10\log\left(1+\xi^2\,\omega_s^{2n}\right) \rightarrow n = 2,92 \rightarrow \boxed{n=3}$$

$\omega_s = 2$

↑

Normalizada

$\Omega_\omega = \omega_p = 2\pi f_p$

$\omega'_s = 2\pi \cdot f_s$

$$Q(s) = (s+a)(s^2+bs+c)$$

$$Q(-s) = (-s+a)(s^2-bs+c)$$

Hoja #2

$$T(s) = \frac{1}{Q(s)} = \frac{a \cdot c}{(s+a)(s^2+bs+c)}$$

$$|T(s)|^2 = \frac{1}{Q(s)\,Q^*(s)} = \frac{1}{1-\xi^2 s^6} = \frac{-1/\xi^2}{s^6 - \frac{1}{\xi^2}}$$

$$T(-s) = \frac{a \cdot c}{(-s+a)(s^2-bs+c)} = \frac{-a \cdot c}{(s-a)(s^2-bs+c)}$$

$$-a^2c^2 = -\frac{1}{\xi^2} \rightarrow a^2c^2 = \frac{1}{\xi^2}$$

$$a \cdot c = \frac{1}{\xi} \rightarrow a = \omega_0 \ \text{y}\ c = \omega_0^2$$

$$c = a^2$$

$$a^3 = \frac{1}{\xi} \rightarrow \boxed{a = \frac{1}{\sqrt[3]{\xi}}}$$

$$\boxed{c = \frac{1}{\xi^{2/3}}}$$

$$T(s)\,T(-s) = \frac{-a^2 \cdot c^2}{(s-a)(s+a)(s^2-bs+c)(s^2+bs+c)}$$

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

Hoja # 3

$$T(s)T(-s) = \frac{-a^2c^2}{(s^4 - bs^3 + cs^2 - a^2s^2 + a^2bs - a^2c)(s^2+bs+c)}$$

$$T(s)T(-s) = \frac{-a^2c^2}{(s^4 - bs^3 + (c-a^2)s^2 + a^2bs - a^2c)(s^2+bs+c)}$$

$$T(s)T(-s) = \frac{-a^2c^2}{\begin{gathered}(s^6 - bs^5 + (c-a^2)s^4 + a^2bs^3 - a^2cs^2 + bs^5 - b^2s^4 + (c-a^2)bs^3 \\ + a^2b^2s^2 - a^2cbs + cs^4 + b\cdot cs^3 + (c-a^2)cs^2 + a^2bcs \\ - a^2c^2)\end{gathered}}$$

$$0\cdot \cancel{s^4} = (c-a^2)\cancel{s^4} - b^2\cancel{s^4} + c\cancel{s^4}$$

$$0 = 2c - a^2 - b^2 \rightarrow b = \sqrt{\underset{\omega_0^2}{2c} - \underset{\omega_0}{(a)}^2}$$

$$b = \omega_0 = \frac{1}{\sqrt[3]{\xi}}$$

$a = 1,2526$

$b = 1,2526$

$c = 1,569$

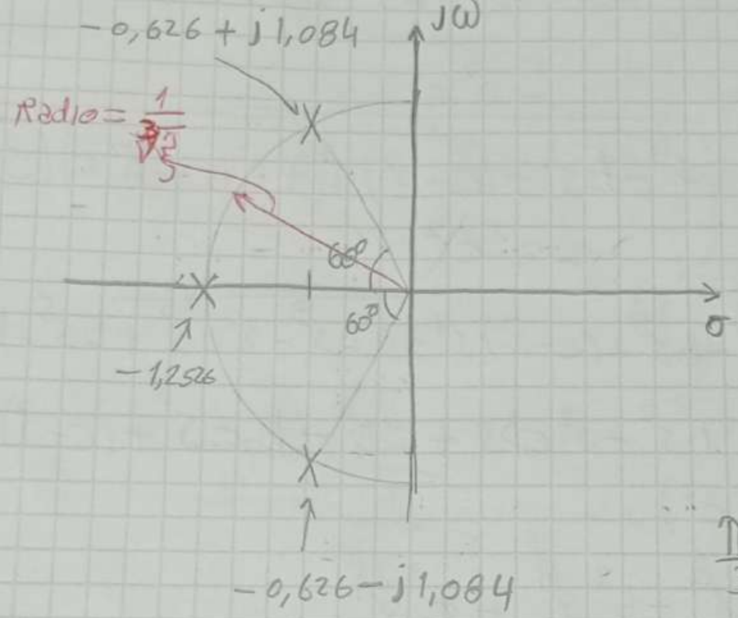
Verificación

$$Q = \frac{1}{2\cos\left(\frac{\pi}{3}\right)} = 1$$

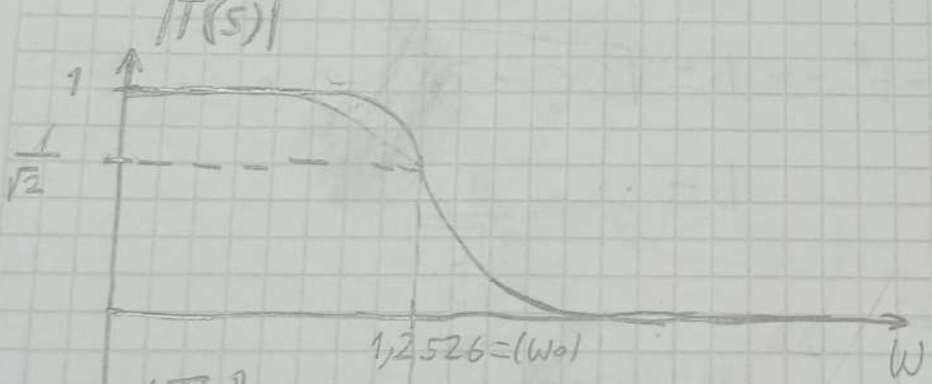
$$b = \frac{\omega_0}{\underset{1}{Q}} \Rightarrow b = \omega_0 \checkmark$$

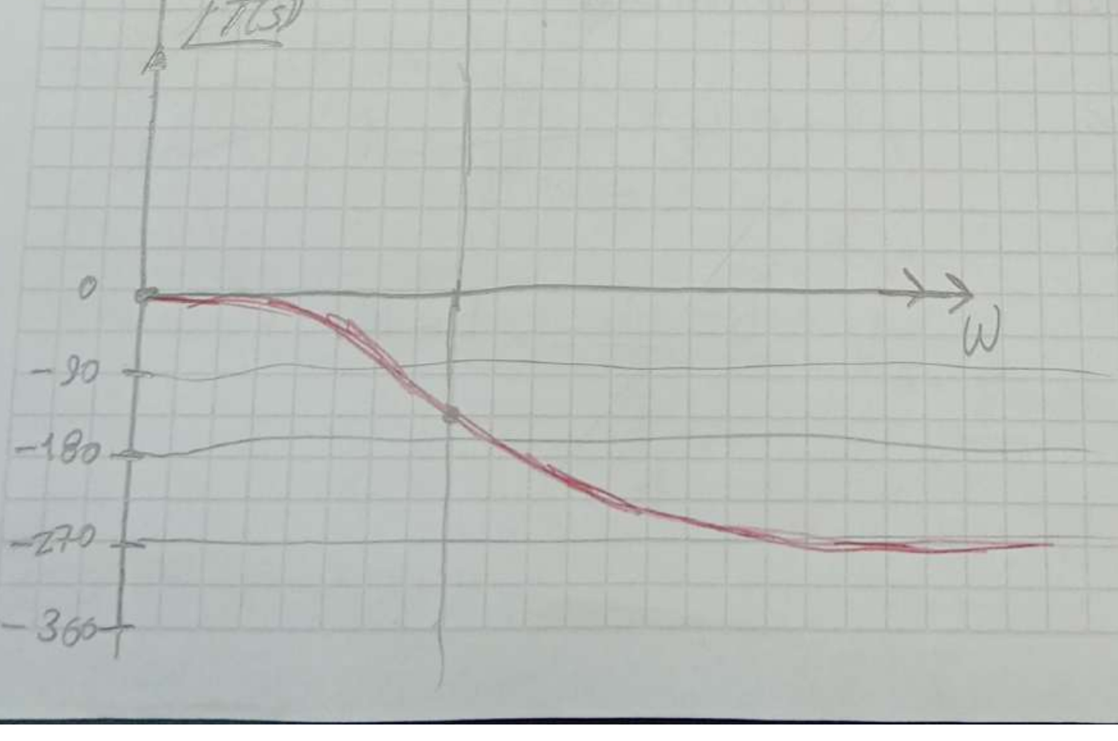
2) $$T(s) = \frac{a \cdot c}{(s+a)(s^2+bs+c)} = \frac{(1,2526)\,(1,569)}{(s+1,2526)(s^2+1,2526\,s+1,569)}$$

3)



$\frac{\pi}{3} \Rightarrow 60°$

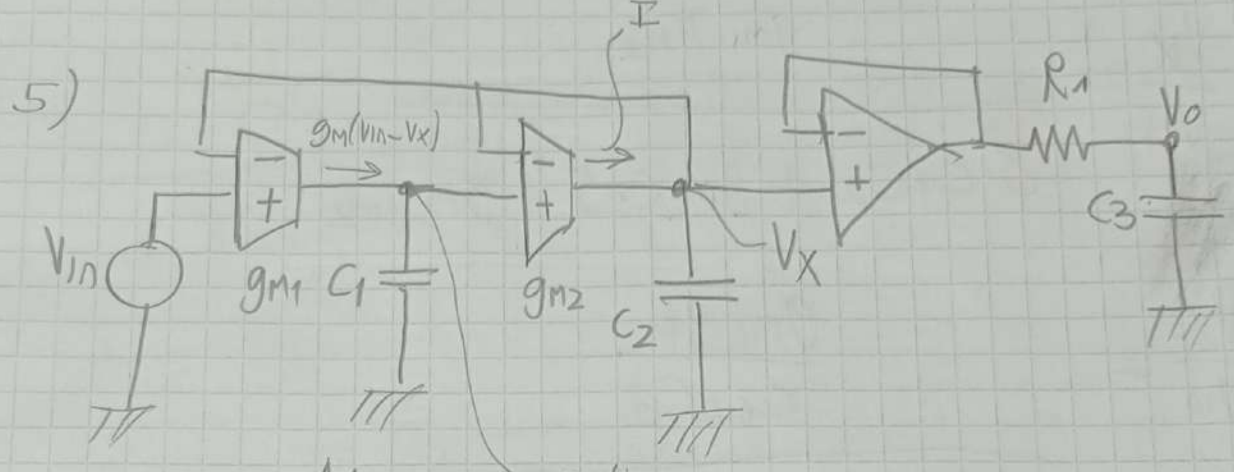




Hoja #5

4) No es un filtro Butterworth porque $\xi \neq 1$, pero se puede trabajar como Butterworth si se renormaliza la red en frecuencia

5)



$$\frac{g_{m_1}(V_{in}-V_x)}{sC_1}$$

$$\frac{V_o}{V_x} = \frac{1/R_1C_3}{s + \frac{1}{R_1C_3}}$$

$$I = g_{m_2}\left(\frac{g_{m_1}(V_{in}-V_x)}{sC_1} - V_x\right)$$

$$V_x = g_{m_2}\left(\frac{g_{m_1}(V_{in}-V_x)}{sC_1} - V_x\right)\cdot\frac{1}{sC_2}$$

$$V_x = \frac{g_{m1}g_{m2}V_{in}}{s^2C_1C_2} - \frac{g_{m1}g_{m2}V_x}{s^2C_1C_2} - \frac{g_{m2}V_x}{sC_2}$$

$$V_x\left(1 + \frac{g_{m1}g_{m2}}{s^2C_1C_2} + \frac{g_{m2}}{sC_2}\right) = V_{in}\cdot\frac{g_{m1}g_{m2}}{s^2C_1C_2}$$

Hoja #6

$$V_x\left(\frac{s^2C_1C_2 + g_{m_2}C_1 s + g_{m_1}g_{m_2}}{\cancel{s^2C_1C_2}}\right) = V_{in}\,\frac{g_{m_1}g_{m_2}}{\cancel{s^2C_1C_2}}$$

$$\frac{V_x}{V_{in}} = \frac{g_{m_1}g_{m_2}}{s^2C_1C_2 + g_{m_2}C_1 s + g_{m_1}g_{m_2}}$$

$$\frac{V_x}{V_{in}} = \frac{\dfrac{g_{m_1}g_{m_2}}{C_1\cdot C_2}}{s^2 + \dfrac{g_{m_2}}{C_2}s + \dfrac{g_{m_1}g_{m_2}}{C_1C_2}}$$

$G(s)$ $H(s)$

$$T(s) = \frac{V_x}{V_{in}}\cdot\frac{V_o}{V_x} = \frac{\dfrac{g_{m_1}g_{m_2}}{C_1C_2}}{s^2 + \underbrace{\dfrac{g_{m_2}}{C_2}}_{\frac{\omega_o}{Q}} s + \underbrace{\dfrac{g_{m_1}g_{m_2}}{C_1C_2}}_{\omega_o^2}}\cdot\frac{1/RC_3}{s + \underbrace{\dfrac{1}{RC_3}}_{\omega_o}}$$

Hoja #7

$$G(s) = \frac{\frac{g_{m1} g_{m2}}{C_1 C_2}}{s^2 + \frac{g_{m2}}{C_2} s + \underbrace{\frac{g_{m1} g_{m2}}{C_1 C_2}}_{\omega_0^2}} = \frac{1{,}569}{s^2 + \underbrace{1{,}2526}_{=\frac{\omega_0}{Q}} s + \underbrace{1{,}569}_{\omega_0^2}}$$

$$\Omega z = \frac{1}{g_{m2}}$$

$$G(s) = \frac{\frac{g_{m1}'}{C_1' C_2'}}{s^2 + \frac{1}{C_2'} s + \frac{g_{m1}'}{C_1' C_2'}} = \frac{1{,}569}{s^2 + 1{,}2526 s + 1{,}569}$$

$$C_2' = \frac{Q}{\omega_0} \rightarrow C_2 = g_{m2} \cdot \frac{Q}{\omega_0} = \frac{g_{m2} \cdot Q}{\omega_0 \cdot \omega_p}$$

$$\frac{g_{m1}'}{C_1' C_2'} = \omega_0^2 \longrightarrow C_1' = \frac{g_{m1}'}{\omega_0^2 \cdot C_2'}$$

$$C_1 = \frac{g_{m1} \cdot g_{m2}}{\omega_0^2 \cdot C_2} = \frac{g_{m1} \cdot g_{m2}}{\omega_0^2 \cdot \omega_p^2 \cdot C_2}$$

Hoja #8

$\Omega_W = W_S$

$\Omega_Z = R_1$

$$H(s) = \frac{\frac{1}{R_1 C_3}}{s + \frac{1}{R C_3}}$$

$$H(s) = \frac{\frac{1}{C'_3}}{s + \frac{1}{C'_3}} = \frac{1,2526}{s + \underbrace{1,2526}_{W_0}}$$

$$\frac{1}{C'_3} = W_0 \rightarrow \frac{1}{W_0} = C'_3$$

$$\boxed{C_3 = \frac{1}{W_0 . R_1}} \quad ó \quad R_1 = \frac{1}{W_0 C_3}$$

Despues hay que desnormalizar por W_p

$$C_3 = \frac{1}{W_0 W_p . R_1}$$

Bonus #3 Hoja #9

$C_3 = 10nF \rightarrow R_1 = \frac{1}{\omega_0 \omega_p C_3} = 8471\,\Omega$

$C_1 = C_2 = 100nF$

$C_2 = g_{m_2} \cdot \frac{Q}{\omega_0 \omega_p} \rightarrow g_{m_2} = \frac{\omega_0 \omega_p}{Q} \cdot C_2$

$\updownarrow$

$g_{m_2} = \frac{I_2}{2 \cdot 25{,}6mV}$

$\downarrow$

$I_2 = 60{,}44uA$

$C_1 = \frac{g_{m_1} \cdot g_{m_2}}{\omega_0^2 \cdot \omega_p^2 \cdot C_2}$

$C_1 \cdot \cancel{C_2} \cdot \omega_0^{\cancel{2}} \cdot \omega_p^{\cancel{2}} = g_{m_1} \cdot \frac{\cancel{\omega_0 \omega_p}}{Q} \cdot \cancel{C_2}$

1 (Lo calculamos antes)

$g_{m_1} = C_1 \cdot \omega_0 \omega_p = g_{m2} \rightarrow I_1 = I_2 = 60{,}44uA$