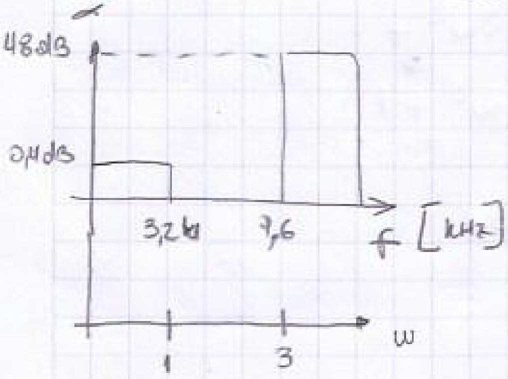
a) **Ejercicio 4** (CHEBY) $\Omega_\omega = 2\pi \cdot 3{,}2 \text{ kHz}$

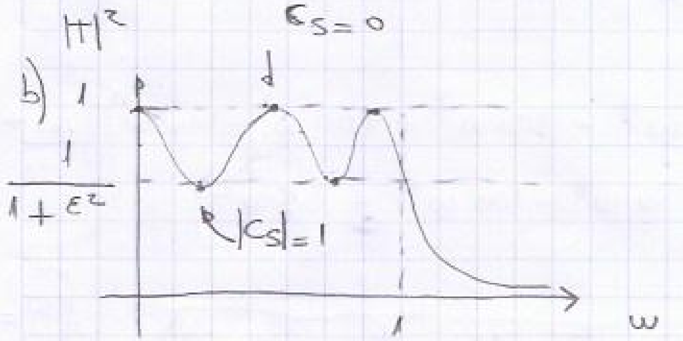


$$\varepsilon^2 = 10^{\frac{\alpha_{min}}{10}} - 1 \rightarrow \boxed{\varepsilon^2 = 0{,}096}$$

$$\rightarrow \boxed{\varepsilon = 0{,}311}$$

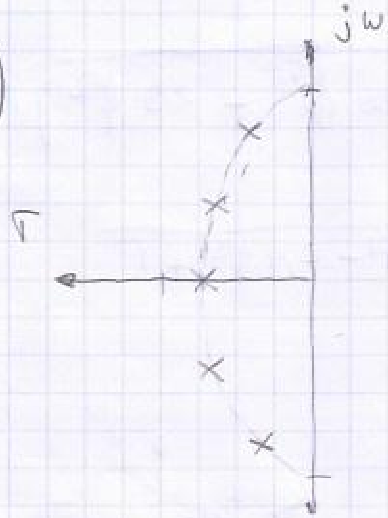
n	α_{MIN}	Iteración
⋮		
4	45dB	
5	60dB	← n = 5

b)



n = 5 IMPAR, 5 TOPES

c)



Se utiliza:

$$a = \frac{1}{n} \operatorname{senh}\left(\frac{1}{\varepsilon}\right)$$

$$\sigma_k = -\operatorname{senh}(a)\ \operatorname{sen}\left(\frac{2k-1}{2n}\pi\right)$$

$$\omega_k = \cosh(a)\ \cos\left(\frac{2k-1}{2\pi}\pi\right)$$

$$|T|^2 = \frac{1}{1+\varepsilon^2 C_m^2} \rightarrow C_5 = 16\omega^5 - 20\omega^3 + 5\omega$$

$$C_4 = 2\omega C_3 - C_2 = 2\omega(4\omega^3 - 3\omega) - 2\omega^2 + 1$$
$$= (8\omega^4 - 6\omega^2 - 2\omega^2 + 1)$$

$$C_5 = 16\omega^5 - 16\omega^3 + 2\omega - 4\omega^3 + 3\omega$$

$$\left[C_5 = 16\omega^5 - 20\omega^3 + 5\omega\right]$$

$$= \frac{1}{1+\varepsilon^2 (16\omega^5 - 20\omega^3 + 5\omega)^2} \qquad (16\omega^5 - 20\omega^3 + 5\omega)$$

$$= 1 + \varepsilon^2 (256\omega^{10} - 320\omega^8 + 80\omega^4 - 320\omega^8 + 400\omega^6 - 100\omega^4 \ldots +$$
$$\ldots + 80\omega^6 - 100\omega^4 + 25\omega^2)$$

$$= \frac{1}{1+\varepsilon^2(256\omega^{10} - 640\omega^8 + 480\omega^6 - 120\omega^4 + 25\omega^2)} \qquad \omega = \frac{s}{j}$$

$$= \frac{1}{1+\varepsilon^2(-256 s^{10} - 640 s^8 - 480 s^6 - 120 s^4 - 25 s^2)}$$

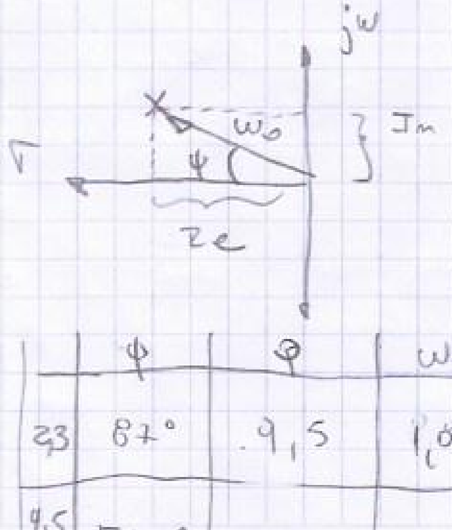
$$= \frac{1}{-24{,}576\, s^{10} - 61{,}44\, s^8 - 46{,}08\, s^6 - 11{,}52\, s^4 - 2{,}4\, s^2 + 1}$$

- OBTENGO LAS RAÍCES CON ROOTS

$P_1 = -0{,}409$

$P_{2,3} = -0{,}057 \pm j\,1{,}083$

$P_{4,5} = -0{,}357 \pm j\,0{,}538$



$$\varphi = Tg^{-1}\left(\frac{Im}{Re}\right) \qquad Q = \frac{1}{2\cos\varphi}$$

$$\omega_0 = \frac{Im}{SEN(\varphi)}$$

	φ	Q	ω0
2,3	87°	9,5	1,08
4,5	56,4°	0,9	0,65

NOTA

HOJA N°

FECHA

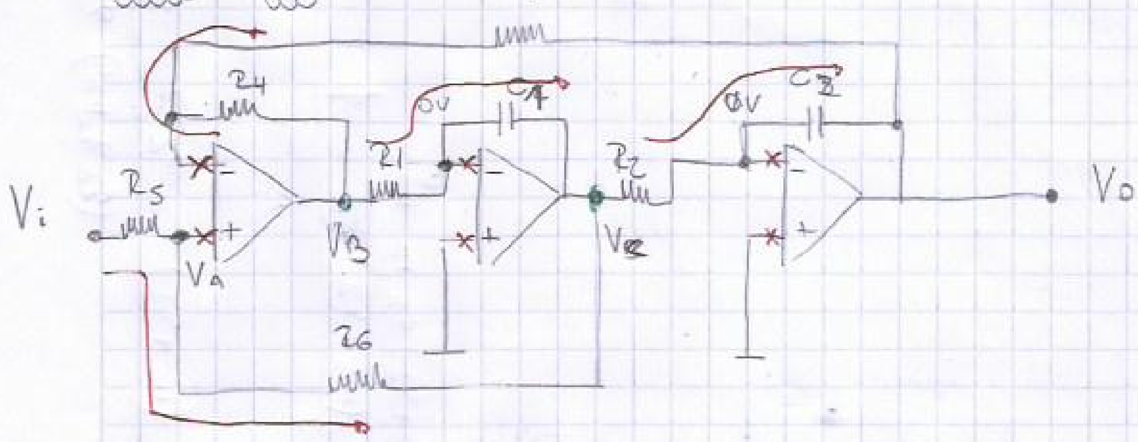
- TRANSFERENCIA → $T_2 = \dfrac{\omega_0^2}{s^2 + \frac{\omega_0}{Q} s + \omega_0^2}$

$$T(s) = \frac{0{,}409}{s + 0{,}409} \cdot \frac{1{,}16}{s^2 + 0{,}93\, s + 1{,}16} \cdot \frac{0{,}42}{s^2 + 0{,}72\, s + 0{,}42}$$

$K = 0{,}409 \cdot 1{,}16 \cdot 0{,}42 = 0{,}2$ 0dB

$K_1 = 1{,}3$; $K_2 = 3$, $K_3 = 1{,}3$ X

- FILTRO KHN



$$\bullet \quad (V_i - V_A)\frac{1}{R_5} = (V_A - V_C)\frac{1}{R_6} \rightarrow \left[\frac{V_i}{R_5} - V_A\left(\frac{R_5+R_6}{R_5 R_6}\right) + V_C\frac{1}{R_6} = \phi\right]$$

$$\bullet \quad \left(\frac{V_B - V_A}{R_4}\right) = -\frac{V_o}{R_3} \rightarrow \frac{V_B}{R_4} - \frac{V_A}{R_4} = \frac{V_A}{R_3} - \frac{V_o}{R_3}$$

$$\left[V_B\frac{1}{R_4} - V_A\left(\frac{R_3+R_4}{R_3 R_4}\right) = -\frac{V_o}{R_3}\right] \quad \text{III}$$

$$\bullet \quad \frac{V_B}{R_1} = -V_C\, \$C_1 \rightarrow \left[V_B = -V_C\, \$C_1 R_1\right] \quad \text{II}$$

$$\bullet \quad \frac{V_C}{R_2} = -V_o\, \$C_2 \rightarrow \left[V_C = -V_o\, \$C_2 R_2\right] \quad \text{I}$$

$$\left[V_B = V_o\, \$^2 C_1 C_2 R_1 R_2\right]$$

<u>EN III</u>

$$V_o\, \frac{\$^2 C_1 C_2 R_1 R_2}{R_4} - V_A\left(\frac{R_3+R_4}{R_3 R_4}\right) = -\frac{V_o}{R_3}$$

$$V_o\left[\frac{\$^2 C_1 C_2 R_1 R_2}{R_4} + \frac{1}{R_3}\right]\frac{R_3 \cdot R_4}{R_3+R_4} = V_A$$

$$V_o \left[\frac{\$^2 C_1 C_2 R_1 R_2 R_3 + R_4}{R_3 + R_4}\right] = V_A$$

$$\frac{V_i}{R_5} - V_o\left(\frac{s^2 C_1C_2R_1R_2R_3 + R_4}{R_3+R_4}\right)\left(\frac{R_5+R_6}{R_5R_6}\right) - V_o\,\frac{sC_2R_2}{R_6} = 0$$

$$\frac{V_i}{\cancel{R_5}} = V_o\left[\frac{(s^2 C_1C_2R_1R_2R_3 + R_4)}{R_3+R_4}\cdot\frac{(\overbrace{R_5+R_6}^{A})}{\cancel{R_5}R_6} + \frac{sC_2R_2R_5}{R_6}\right]$$

$$V_i = V_o\left[\frac{s^2 C_1C_2R_1R_2R_3A + R_4A}{\underbrace{(R_3+R_4)}_{B}R_6} + \frac{sC_2R_2R_5B}{R_6}\right]$$

$$V_i = V_o\left[\frac{s^2 C_1C_2R_1R_2R_3A + R_4A + sC_2R_2R_5\cdot B}{R_6\cdot B}\right]$$

$$T(s) = \frac{V_o}{V_i} = \frac{R_6\cdot B}{s^2 C_1C_2R_1R_2R_3A + sC_2R_2R_5B + R_4A}$$

$$T(s) = \frac{R_6B}{C_1C_2R_1R_2R_3A}\cdot\frac{1}{s^2 + s\frac{R_5B}{C_1R_1R_3A} + \frac{R_4}{C_1C_2R_1R_2R_3}}$$

$$\boxed{T(s) = \frac{B}{A}\cdot\frac{\frac{R_6}{C_1C_2R_1R_2R_3}}{s^2 + s\frac{R_5B}{C_1R_1R_3A} + \frac{R_4}{C_1C_2R_1R_2R_3}}}$$

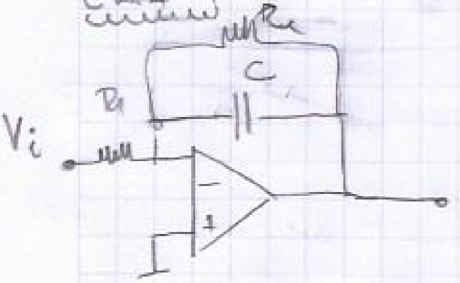
$A = R_5+R_6 \qquad B = R_3+R_4$

$A = B \rightarrow R_5+R_6 = R_3+R_4$

$$\boxed{T(s) = \frac{R_6}{C_1C_2R_1R_2R_3}\cdot\frac{1}{s^2 + s\frac{R_5}{C_1R_1R_3} + \frac{R_4}{C_1C_2R_1R_2R_3}}}$$

d) Para $n=5$ utilizo 2 estructuras KHN + 1 de 1er orden.

Etapa 1



$$\frac{V_o}{V_i} = \frac{G_1}{\$ + \frac{G_2}{C}} = \frac{1}{R_1} \cdot \frac{1}{\$ + \frac{1}{R_2 C}}$$

$$\frac{1}{R_2 C} = 0{,}409 \rightarrow \boxed{R_2 = 2{,}44}$$

$\boxed{C = 1}$

$$\frac{1}{R_1} = 0{,}409 \cdot 1{,}3 \Rightarrow \boxed{R_1 = 1{,}88}$$

Etapa 2 y 3 — Para KHN → $A = B$ → $R_3 = R_4 = R_5 = R_6 = 1$

$C_1 = C_2 = 1$

$$\left[T(\$) = \frac{1}{R_1 R_2} \cdot \frac{1}{\$^2 + \$ \frac{1}{R_1} + \frac{1}{R_1 R_2}} \right]$$

(2) $\frac{1}{R_1 . R_2} = 1{,}16$ $\qquad \frac{1}{R_1} = 0{,}93 \rightarrow \boxed{R_1 = 1{,}08}$

$R_2 = 0{,}8$

(3) $[R_1 = 1{,}4]$ $\qquad [R_2 = 1{,}7]$

HOJA Nº

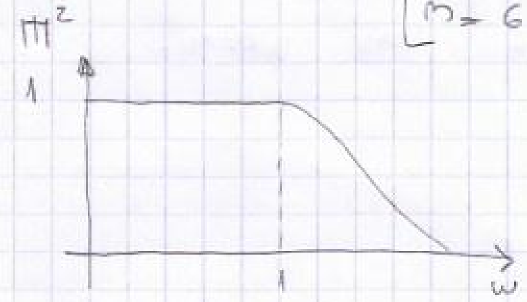
FECHA

E.a) Butter → $\varepsilon = 1$

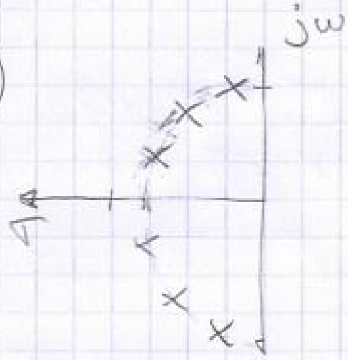
Iteración de n → $n = 5$ → $\alpha_{min} = 47,7$ dB

[$n = 6$ → $\alpha_{min} = 57,255$ dB]

E.b)



E.c)



n par   Polos $\frac{\pi}{2n} = \frac{\pi}{12}$

Separación de $\frac{\pi}{n} = \frac{\pi}{6}$

E.d)

Polos	$Q = \frac{1}{2\cos\varphi}$
$\pi/12$	0,52
$\pi/12 + \pi/6$	0,71
$\pi/12 + \frac{2\pi}{6}$	1,93

SOS → $T(s) = \dfrac{1}{s^2 + \frac{1}{Q}s + 1}$

$$T_B(s) = \frac{1}{s^2 + 1,92\,s + 1} \cdot \frac{1}{s^2 + 1,41\,s + 1} \cdot \frac{1}{s^2 + 0,52\,s + 1}$$

3 etapas KHN

① $R_1 = 0,52$; $R_2 = 1,92$

② $R_1 = 0,71$ $R_2 = 1,41$

③ $R_1 = 1,92$ $R_2 = 0,51$

NOTA

CHEBY	BUTTER
• ATENUA MEJOR A ALTAS FCIAS	• MAXIMA PLANICIDAD EN BP.
• Q MAS GRANDE	• Q MÁS CHICO
• ORDEN MENOR	• ORDEN MAYOR
• MEJOR TRANSICIÓN	• FASE MAS LINEAL.