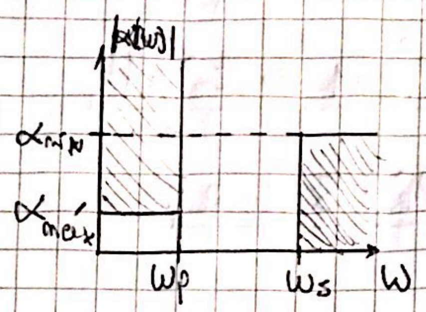
# Ejercicio 3 del TP2

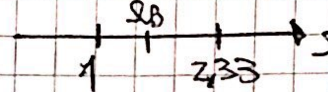
**3.1**




$f_p = 1KHz \longrightarrow \alpha_{máx} = 0{,}5\ dB$

$f_s = 2330\ Hz \longrightarrow \alpha_{mín} = 30\ dB$

↳ Tomamos $\Omega_\omega = \underbrace{1KHz}_{f_p} \cdot 2\pi$




a)

① $\varepsilon^2 = 10^{\frac{\alpha_{máx}}{10}} - 1 \Rightarrow \boxed{\varepsilon^2 = 0{,}122} \Rightarrow \boxed{\varepsilon = 0{,}349}$

② $\alpha_{mín} = 10\log(1+\varepsilon^2 \cdot \Omega_s^{2N}) \Rightarrow \boxed{N = 6} \rightarrow \alpha_{mín} = 34{,}9\ dB$

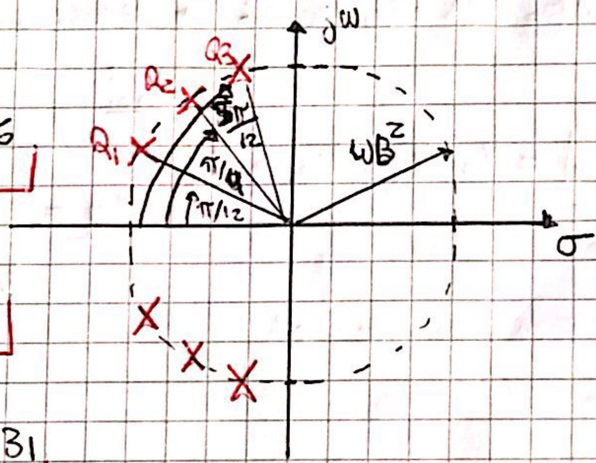
~~[illegible]~~ Max. Planicidad

$$\boxed{|T(s)|^2 = \frac{1}{1+\varepsilon^2\,\omega^{2N}}}$$

$\omega_B = \omega_p \cdot \varepsilon^{-1/N}$

b) Los polos se ubican cada $\pi/6$.

$\boxed{\omega_B = 7488{,}1\ rad/s}$




$$\boxed{Q_1 = \frac{1}{2\cos\pi/12} = 0{,}5176}$$

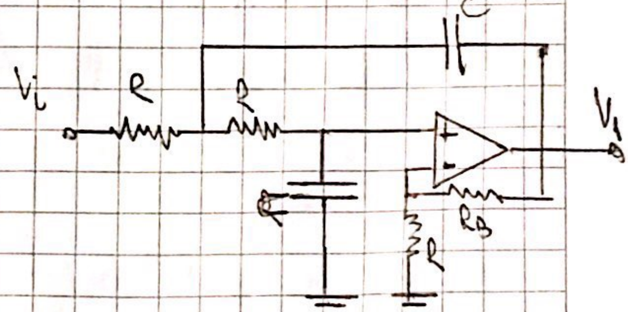
$$\boxed{Q_2 = \frac{1}{2\cos(\frac{3\pi}{12})} = 0{,}707}$$

$$\boxed{Q_3 = \frac{1}{2\cos(\frac{5\pi}{12})} = 1{,}931}$$

c)

Vamos a suponer que está normalizado con $\boxed{\omega_B = 7488{,}1\ rad/s}$

Primer etapa ~~[illegible]~~




$\boxed{R_1^\circ = 1\Omega} \Rightarrow \boxed{C_1^\circ = 1F}$

$Q_1 = \frac{1}{3-K} \Rightarrow$ ~~[illegible]~~ $3-K = 1/Q$

$\Downarrow$

$$\boxed{K = 3 - 1/Q_1 = 1{,}068}$$

$1{,}068 = 1 + \frac{R_{B_1}}{R}$

$\Downarrow$

$$\boxed{R_{B_1}^\circ = 68\ m\Omega}$$

**Segunda etapa**

$$Q_2 = 0{,}707 \Rightarrow \boxed{K_2 = 3 - 1/Q_2 = 1{,}585} \Rightarrow \boxed{R_2^{\circ} = 1\Omega} \Rightarrow \boxed{C_2^{\circ} = 1F}$$

$$\boxed{R_{B_2}^{\circ} = 585\, m\Omega}$$

**Tercer etapa**

$$Q_3 = 1{,}931 \rightarrow \boxed{K_3 = 2{,}481} \Rightarrow \boxed{R_3^{\circ} = 1\Omega} \Rightarrow \boxed{C_3^{\circ} = 1F}$$

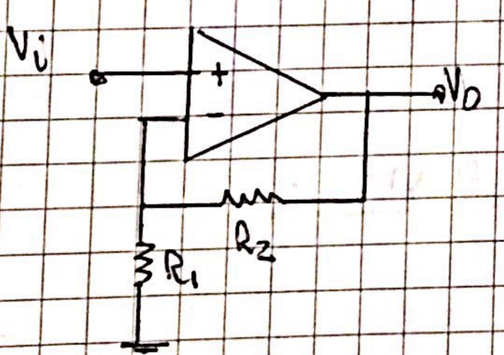
$$\boxed{R_{B_3}^{\circ} = 1{,}48\,\Omega}$$

Nos piden $|H(0)| = 20dB = 10$ veces! $\rightarrow$ Necesitamos amplificar la salida

$$|H(0)| = K_1 \cdot K_2 \cdot K_3 \cdot \underbrace{K_4}_{\text{Amp!}}$$

$$\boxed{K_4} = \frac{10}{1{,}068 \cdot 1{,}585 \cdot 2{,}481} = \frac{10}{4{,}2} = \boxed{2{,}38}$$

Proponemos etapa No inversora:




$$\nearrow H(0) = 1 + \frac{R_2}{R_1} \Rightarrow \text{si } K_4 = 2{,}38 \Rightarrow \boxed{R_5^{\circ} = 1{,}38} \quad \boxed{R_4^{\circ} = 1}$$

Desnormalizando:

$\Omega_W = 7488{,}1\ \mathrm{rad/s}$

$\Omega_Z = 1K\Omega$

$R_1^{\circ} = R_2^{\circ} = R_3^{\circ} = R_4^{\circ} = 1\Omega \Longrightarrow R_1 = R_2 = R_3 = R_4 = 1K\Omega$

$C_1^{\circ} = C_2^{\circ} = C_3^{\circ} = 1F \Longrightarrow C = \dfrac{C^{\circ}}{\Omega_Z \cdot \Omega_W} \Longrightarrow C_1 = C_2 = C_3 = 133{,}5\,nF$

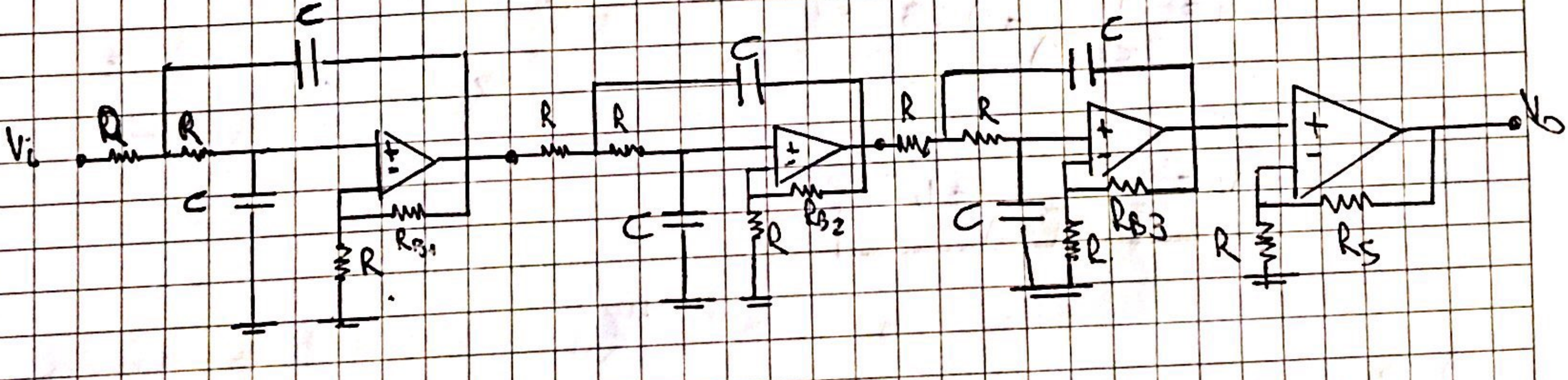
$R_{B1}^{\circ} = 68\,m\Omega \longrightarrow R_{B1} = 68\Omega$

$R_{B2}^{\circ} = 585\,m\Omega \longrightarrow R_{B2} = 585\,\Omega$

$R_{B3}^{\circ} = 1{,}48\,\Omega \longrightarrow R_{B3} = 1{,}48K\Omega$

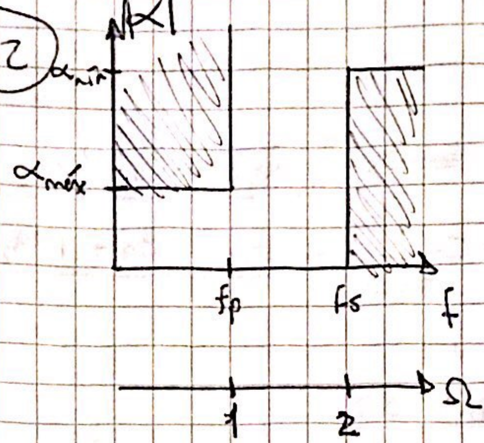
$R_S^{\circ} = 1{,}38\,\Omega \longrightarrow R_S = 1{,}38K\Omega$

Circuito Final:




d) El Circuito Fue simulado con Resultados positivos !

3.2




$f_p = 1KHz \rightarrow \alpha_{máx} = 0{,}5dB$

$f_{mín} = 2K \rightarrow \alpha_{mín} = 20dB$

a) ① $\varepsilon^2 = 10^{\frac{0{,}5dB}{10}} - 1 \Rightarrow \boxed{\varepsilon^2 = 0{,}122}$

$\boxed{\varepsilon = 0{,}349}$

② $\alpha_{mín} = 10 \log(1 + \varepsilon^2 \cdot \Omega_s^{2N})$

$\Rightarrow N \geq 4{,}83 \Rightarrow \boxed{N = 5}$

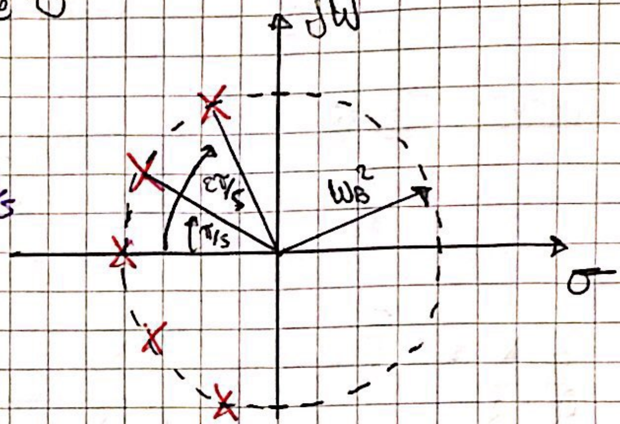
b) Por N impar, un polo va a estar en el eje $\sigma$

$\boxed{\omega_B = \omega_p \cdot \varepsilon^{-1/N} = 9{,}56 \, Krad/s}$ → ERROR de cálculo!

$\omega_B = 7{,}75 \, Krad/s$

⇓

$\boxed{\Omega_B = 1{,}52}$

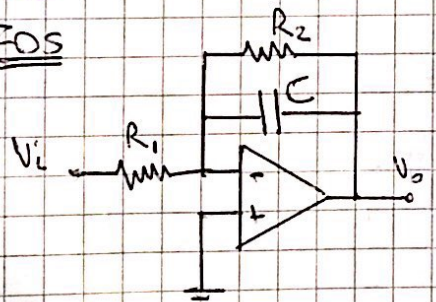



$\boxed{Q_1 = \frac{1}{2 \cdot \cos(\pi/5)} = 0{,}618}$

$\boxed{Q_2 = \frac{1}{2 \cdot \cos(2\pi/5)} = 1{,}618}$

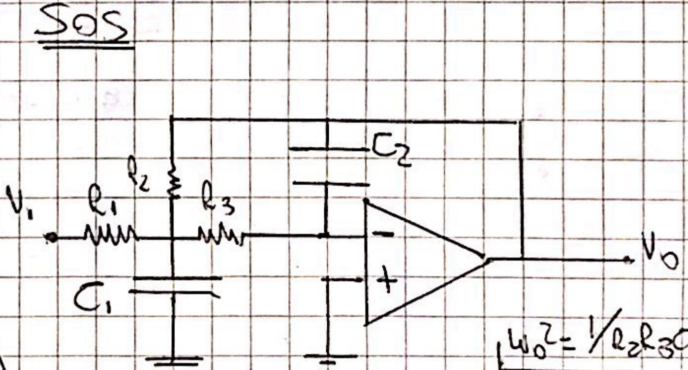
c) Para hacer esto vamos a necesitar dos SOS y un FOS.

FOS




$\boxed{H(s) = -\frac{R_2}{R_1} \cdot \frac{1/R_2C}{s + 1/R_2C}}$

SOS




$\boxed{\omega_0^2 = 1/R_2R_3C_1C_2}$

$\boxed{K = -R_2/R_1}$

$H(s) = \frac{K\omega_0^2}{s^2 + s\frac{\omega_0}{Q} + \omega_0^2}$

$\boxed{\frac{\omega_0}{Q} = \frac{1}{C_1}(G_1 + G_2 + G_3)}$

Vamos a empezar diseñando los SOS para ajustar la ganancia con el FAS.

Para el SOS1, necesitamos: $\Omega_0 = 1$ y $Q_1 = 0{,}618$.

Las ecuaciones de Diseño son: $\Omega_0^2 = \dfrac{1}{C_1^\circ C_2^\circ R_2^\circ R_3^\circ}$ y $\dfrac{\Omega_0}{Q_1} = \dfrac{1}{Q_1} = \dfrac{1}{C_1^\circ}\left(G_1^\circ + G_2^\circ + G_3^\circ\right)$

Proponemos:

$C_1^\circ = 1F$
$R_2^\circ = 10\Omega$
$R_3^\circ = 10\Omega$ $\Rightarrow$ $C_2^\circ = 10mF$ y $\dfrac{1}{Q_1} - 0{,}2 = G_1^\circ \Rightarrow R_1^\circ = \dfrac{1}{1/Q_1 - 0{,}2}$

$R_1^\circ = 705 m\Omega$

La Ganancia de esta etapa nos queda:

$|K_1| = \dfrac{R_2}{R_1} = 14{,}18$ $\longrightarrow$ si $\Omega_w = \omega_B = 9{,}56 \, Krad/s$ (7,75 Krad/s) y $\Omega_Z = 1K$

Desnormalizando:

| | | |
|---|---|---|
| $C_{11} = 1F$ | ~~$C_{11} \simeq 100nF$~~ | $C_{11} = 129nF$ |
| $C_{21} = 10mF$ | ~~$C_{21} \simeq 1nF$~~ | $C_{21} = 1{,}3nF$ |
| $R_{11} = 10\Omega$ | ~~$R_{31} = 10K\Omega$~~ | $R_{11} = 705\Omega$ |
| $R_{21} = 10\Omega$ | ~~$R_{21} = 10K\Omega$~~ | $R_{21} = 10K\Omega$ |
| $R_{31} = 705m\Omega$ | ~~$R_{31} = 705\Omega$~~ | $R_{31} = 10K\Omega$ |

---

Para el SOS2, necesitamos: $\Omega_0 = 1$ y $Q_2 = 1{,}618$

Proponemos mismos valores:

$C_1^\circ = 1F$
$R_2^\circ = 10\Omega$
$R_3^\circ = 10\Omega$ $\Rightarrow$ $C_2^\circ = 10mF$ y $1/Q_2 - 0{,}2 = G_1^\circ \Rightarrow R_1^\circ = \dfrac{1}{1/Q_2 - 0{,}2}$

$R_1^\circ = 2{,}39$

La ganancia de la etapa nos queda:

$|K_2| = \dfrac{R_2}{R_1} = \dfrac{10\Omega}{2{,}39} = 4{,}18$ Tomo mismo $\Omega_w$ y $\Omega_Z$

Desnormalizando:

$C_{12} \simeq 100nF \to 129nF$
$C_{22} \simeq 1nF \to 1{,}3nF$
$R_{12} = 2{,}39K\Omega$
$R_{22} = 10K\Omega$
$R_{32} = 10K\Omega$

Ahora Diseñamos la Fos: necesitamos $\boxed{\Omega_0 = 1}$ y $K_1 \cdot K_2 \cdot K_3 = 10$

$\Downarrow$

$\boxed{K_3 = 0,16}$

Proponemos $\boxed{R_2 = 1\Omega} \Rightarrow \boxed{C = 1F}$

$$|K_3| = \frac{R_2}{R_1} \Rightarrow R_1 = \frac{R_2}{|K_3|} = 6,25\Omega$$

<u>Desnormalizando:</u>

$C_{13} = 100nF \rightarrow 129nF$

$R_{13} = 6,25K\Omega$

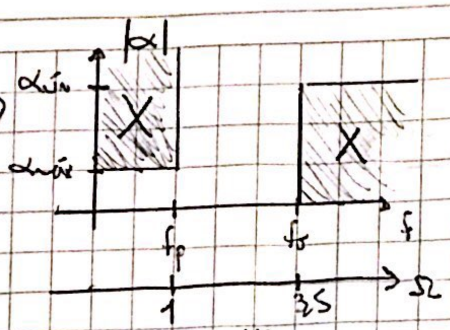
$R_{23} = 1K\Omega$

Cumple la simulación! → La ganancia en Banda quedo 19,5 dB.

↓

se puede Ajustar si $R_{13} \downarrow$

3.3




$f_p = 1\,kHz \rightarrow \alpha_{máx} = 1\,dB$

$f_s = 3{,}5\,kHz \rightarrow \alpha_{mín} = 35\,dB$

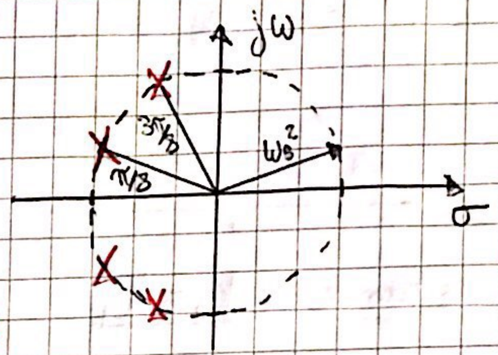
a) ① $\underline{\varepsilon^2} = 10^{\frac{1dB}{10}} - 1 = \underline{0{,}258} \longrightarrow \boxed{\varepsilon = 0{,}508}$

② $35\,dB = 10\log\left(1 + \varepsilon^2 \cdot (3{,}5)^{2N}\right) \longrightarrow N \geq 3{,}75 \Longrightarrow \boxed{N = 4}$

b)

$W_B = W_p\,\varepsilon^{-1/N}$

$\boxed{W_B = 7{,}44\,\frac{Krad}{s}}$




$\boxed{Q_1 = \frac{1}{2\cos(\pi/8)} = 0{,}54}$

$\boxed{Q_2 = \frac{1}{2\cos(3\pi/8)} = 1{,}3}$

c) Para la implementación vamos a cascadear dos SOS en Sallen-Key. Si necesitamos ajustar la ganancia, ponemos una etapa no inversora.

<u>Primer</u> <u>SOS 1</u>: Necesitamos $\underline{\Omega_0 = 1}$ y $\underline{Q_1 = 0{,}54}$

Las ecuaciones de diseño del Sallen-Key son:

$$\begin{cases} W_0 = 1/RC \\ K = 1 + R_B/R \\ Q = \frac{1}{3-K} \end{cases}$$

$3 - K = 1/Q_1 \Longrightarrow \underline{K = 3 - 1/Q_1 = 1{,}14}$

Por tanto,

$K = 1 + \frac{R_B}{R} \Longrightarrow \underline{R_B = 0{,}14 \cdot R}$

Propongo $\underline{R^\circ = 1\,\Omega} \Longrightarrow \underline{C^\circ = 1\,F}$ y $\underline{R_B = 140\,m\Omega}$

Si $\underline{\Omega_W = 7{,}44\,Krad/s}$ y $\underline{\Omega_Z = 1\,K\Omega}$

<u>Desnormalizo</u>:

$C_1 = 134\,nF$

$R_1 = 1\,K\Omega$

$\boxed{R_{B1} = 140\,\Omega}$

$2^{da}$ SOS 2: Necesitamos $\Omega_0 = 1$ y $Q_2 = 1,3$

$K_2 = 3 - 1/Q_2 = 2,23$

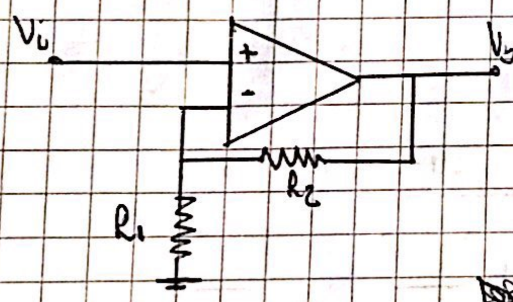
$K = 1 + \frac{R_B}{R} \Rightarrow R_B^{\circ} = 1,23 \cdot R^{\circ}$

Propongo: $R^{\circ} = 1 \Rightarrow C^{\circ} = 1$ y $R_B^{\circ} = 1,23$

Desnormalizo: $C_2' = 134\,nF$, $R_2 = 1K\Omega$, $R_{B2} = 1,23K\Omega$

Como $K_1 \cdot K_2 = 2,54 < 10 \Rightarrow$ necesitamos un $K_3 = 4$

Proponemos una etapa No Inversora

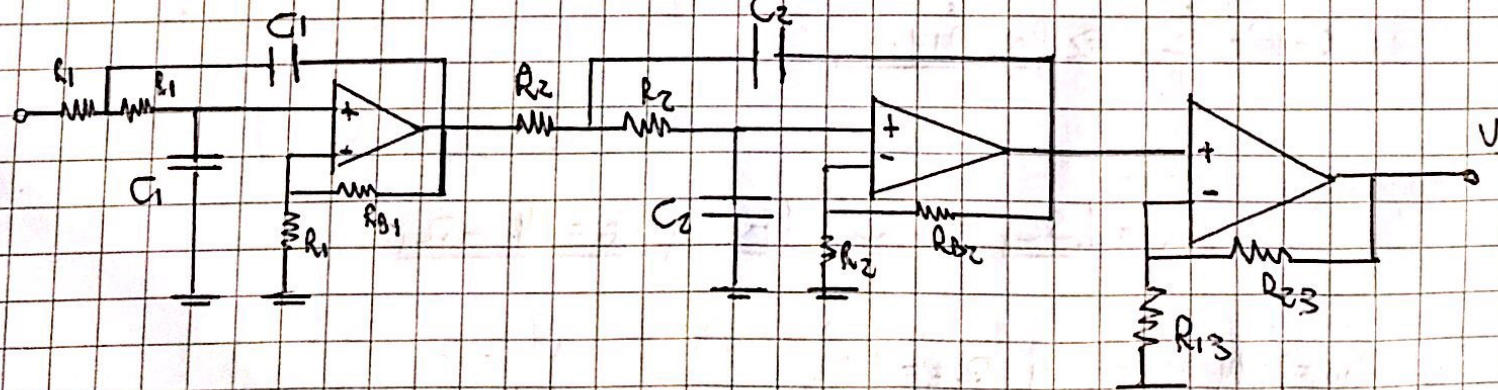



$\rightarrow H(s) = 1 + \frac{R_2}{R_1} \Rightarrow (K_3 - 1) R_1 = R_2.$

$\Downarrow$

$R_{13}^{\circ} = 1K \rightarrow R_{23}^{\circ} = 3K\Omega$

D) La simulación dió Bien



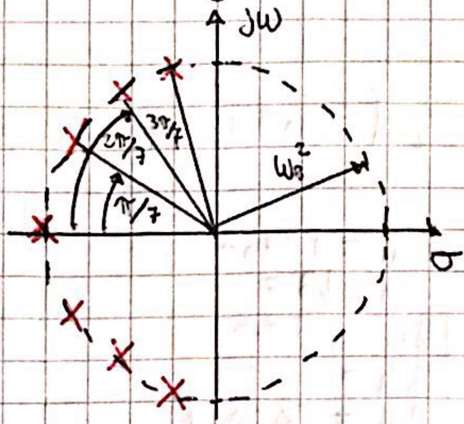
3.4 $f_p = 1KHz \longrightarrow \alpha_{máx} = 0{,}5dB$

$f_s = 1725Hz \longrightarrow \alpha_{mín} = 20dB$.

a) ① $\varepsilon^2 = 10^{\frac{0{,}5dB}{10}} - 1 \longrightarrow \boxed{\varepsilon^2 = 0{,}122} \rightarrow \boxed{\varepsilon = 0{,}349}$

② $20dB = 10\log\left(1 + \varepsilon^2 \cdot (1{,}725)^{2N}\right) \longrightarrow N \geq 6{,}14 \Longrightarrow \boxed{N=7}$

b)




$\boxed{W_B = W_p \cdot \varepsilon^{-1/N} = 7{,}3\, Krad/s}$

$\boxed{Q_1 = \frac{1}{2\cdot\cos(\pi/7)} = 0{,}55}$

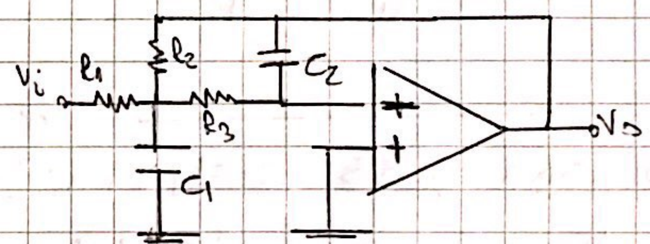
$\boxed{Q_2 = \frac{1}{2\cdot\cos(2\pi/7)} = 0{,}8}$

$\boxed{Q_3 = \frac{1}{2\cos(3\pi/7)} = 2{,}24}$

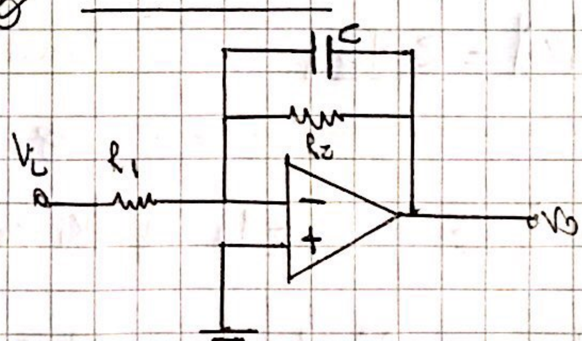
c) Lo vamos a hacer en 4 etapas: SOS1, SOS2, SOS3 y FOS.

Recordemos que para el MFB las expresiones de cálculo son:

$$\begin{cases} K = -\frac{R_2}{R_1} \\ w_0^2 = \frac{1}{R_2 R_3 C_1 C_2} \\ \frac{w_0}{Q} = \frac{1}{C_1}\left(G_1 + G_2 + G_3\right) \end{cases} \longrightarrow$$




Para la FOS usamos




$$\boxed{H(s) = -\frac{R_2}{R_1}\,\frac{1/R_2C}{s + 1/R_2C}}$$

Diseño SOS 1 $\Omega_0 = 1$ y $Q_1 = 0{,}55$

Propongo $C_1^\circ = 1F$, $R_2^\circ = 10\Omega$, $R_3^\circ = 10\Omega$ $\Rightarrow$ $C_2 = 10mF$ y $G_1^\circ = 1/Q_1 - 0{,}2$

$$R_1^\circ = \frac{1}{1/0{,}55 - 0{,}2} = 618m\Omega$$

Compruebo ganancia:

$$|K_1| = \frac{R_2}{R_1} = 16{,}1$$

Desnormalizo: ($\Omega_\omega = 7{,}3K\,rad/s$ ; $\Omega_Z = 1K$)

$C_{11} = 137nF$
$C_{21} \simeq 1{,}37nF$
$R_{11} = 618\Omega$
$R_{21} = 10K\Omega$
$R_{31} = 10K\Omega$

---

Diseño SOS 2 $\Omega_0 = 1$ y $Q_2 = 0{,}8$

Mantengo Valores de $C_1^\circ, C_2^\circ, R_2^\circ, R_3^\circ$ $\Rightarrow$ $R_1^\circ = \dfrac{1}{1/0{,}8 - 0{,}2} = 952m\Omega$

$$|K_2| = \frac{R_2}{R_1} = 10{,}5$$

Desnormalizo (mismos $\Omega_\omega$ y $\Omega_Z$):

$R_{12} = 952\Omega$

---

Diseñamos SOS3 $\Omega_0 = 1$ y $Q_3 = 2{,}24$

Vuelvo a mantener $C_1, C_2, R_2^\circ, R_3^\circ$ $\Rightarrow$ $R_1^\circ = \dfrac{1}{1/2{,}24 - 0{,}2} = 4{,}05\Omega$

$|K_3| = 2{,}46$

Desnormalizo: $R_{13} = 4{,}05K$

---

Diseño FOS $\Omega_0 = 1$ y $|K_1 \cdot K_2 \cdot K_3 \cdot K_4| = 10$ $\Rightarrow$ $|K_4| = \dfrac{10}{|K_1 \cdot K_2 \cdot K_3|} = 24 \cdot 10^{-3}$

Propongo $R_2^\circ = 1\Omega$, $C^\circ = 1F$ $\Rightarrow$ $R_1^\circ = \dfrac{R_2}{|K_4|} \simeq 41\Omega$ $\rightarrow$

Desnormalizo:

$C_{14} = 137nF$
$R_{14} = 1K\Omega$
$R_{24} = 41K\Omega$