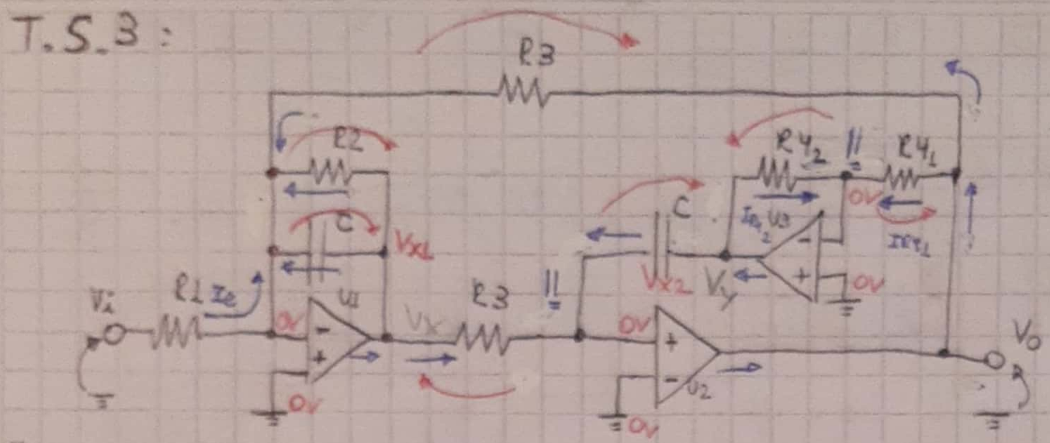
T.5.3 :



Método sistemático de Nodos:
- No usar nodos con salida de op.

$① \; 0V.(G1+G2+\$C+G3) - Vi.G1 - Vo.G3 - Vx.\$C - Vx.G2 = 0$

$Vi.G1 = -Vo.G3 - V_x.\$C - V_x.G2 \Rightarrow V_x = Vo.(\ldots) \; ; \; V_x = V_{R3} = R3.I_{R3} \; ; \; I_{R3} = I_{C_2}$

$Vx = V_{C1} = I_{C1}.Z_{C1} \; ; \; Vx = V_{R2} = I_{R2}.R2 \Rightarrow I_{C1}.Z_{C1} = I_{R2}.R2 \; ;$

$\{ i_C = C.\dot{x} \; ; \; V_C = x \; ; \}$ Estados operacionales, método modelo de estados: $x1 = V_{C1}$; $x2 = V_{C2}$;

$i_{C1} = C.\dot{x}_1 \; ; \; i_{C2} = C.\dot{x}_2 \; ; \quad Vi.G1 = -Vo.G3 - \underbrace{X1.\$C}_{\text{cambiar nomenclatura}} - X1.G2$ $: X1.\$C = i_{C1} = C.\dot{x}_1$

$\dot{x}_1.C = -Vo.G3 - X1.G2 - Vi.G1 \; ; \Rightarrow [\dot{x}] = [A].[x] + [B].Vi \Rightarrow$ tengo que sacar Vo ;

$Vo = V_{R4_1} = i_{R4_1}.R4_1 \; ; \; i_{R4_1} = i_{R4_2} \Rightarrow V_{C2} = X2 = +V_{R4_2} \; ; \; V_{R4_2} = I_{R4_2}.R4_2 = -I_{R4_1}.R4_2 = -I_{R4_1}.R4_1$

$\Rightarrow [X2 = -I_{R4_1}.R4_1 = -V_{R4_1} = -Vo]$

$: \dot{x}_1 C = X2.G3 - X1.G2 - Vi.G1 \Rightarrow \boxed{\dot{x}_1(t) = \left(-\frac{G2}{C}\right).x1(t) + \left(\frac{G3}{C}\right).x2(t) + \left(-\frac{G1}{C}\right).Vi(t)}$

$i_{C2} = C.\dot{x}_2 \Rightarrow V_{C2} = I_{C2}.Z_{C_2} \; ; \; X2.\$C = i_{C2} = C\dot{x}_2 \; ; \; X2 = I_{C2}.\frac{1}{\$C} \Rightarrow X2.\$C = I_{C2} \; ;$

$i_{C2} = -\frac{V_x}{R3} = -\frac{X1}{R3} \Rightarrow C.\dot{x}_2 = -\frac{X1}{R3} \Rightarrow \boxed{\dot{x}_2(t) = \left(-\frac{G3}{C}\right).X1(t)}$

$Vo = -X2 \Rightarrow Vo.G3 = -X1.G2 - Vi.G1 - \{\dot{x}_1 C\} \Rightarrow I_{C_1}$

↳ No hace falta nada más : $\boxed{Vo(t) = (-1).X2(t)}$

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \underbrace{\begin{bmatrix}-\frac{G2}{C} & \frac{G3}{C}\\ -\frac{G3}{C} & 0\end{bmatrix}}_{A} . \begin{bmatrix}x1\\ x2\end{bmatrix} + \underbrace{\begin{bmatrix}-\frac{G1}{C}\\ 0\end{bmatrix}}_{B} .Vi \; ; \; [Vo] = \underbrace{\begin{bmatrix}0 & -1\end{bmatrix}}_{C} . \begin{bmatrix}x1\\ x2\end{bmatrix} + \underbrace{0}_{D}.Vi$$

$$H(\$) = \frac{Vo(\$)}{Vi(\$)} = C.(\$.I - A)^{-1}.B + D \; ; \; (\$I - A) = \begin{bmatrix}\$ & 0\\ 0 & \$\end{bmatrix} - \begin{bmatrix}-\frac{G2}{C} & \frac{G3}{C}\\ -\frac{G3}{C} & 0\end{bmatrix} = \begin{bmatrix}\$+\frac{G2}{C} \; ; & -\frac{G3}{C}\\ \frac{G3}{C} \; ; & \$\end{bmatrix}$$

$$(\$I - A)^{-1} = \frac{M.Adj[\$I-A]}{det(\$I-A)} = \frac{\begin{pmatrix}\$ & \frac{G3}{C}\\ -\frac{G3}{C} & \$+\frac{G2}{C}\end{pmatrix}}{(\$+\frac{G2}{C}).\$ - (-\frac{G3}{C}).\frac{G3}{C}} \; ; \; H(\$) = \frac{[0 \; ; -1]^{1\times2}.\begin{bmatrix}\$ & G3/C\\ -\frac{G3}{C} & \$+\frac{G2}{C}\end{bmatrix}^{2\times2}.\begin{bmatrix}-\frac{G1}{C}\\ 0\end{bmatrix}^{2\times1}}{\$(\$+\frac{G2}{C}) + \frac{G3^2}{C^2}} = \frac{\begin{bmatrix}\frac{G3}{C} \; , & -\$-\frac{G2}{C}\end{bmatrix}.\begin{bmatrix}-\frac{G1}{C}\\ 0\end{bmatrix}}{\$^2 + \$\frac{G2}{C} + \frac{G3^2}{C^2}}$$

$$H(s) = \frac{\frac{G3}{C}\cdot\frac{-G1}{C}}{s^2 + s\cdot\frac{G2}{C} + \frac{G3^2}{C^2}} = \frac{-\frac{G3\,G1}{C^2}}{s^2+s\cdot\frac{G2}{C}+\frac{G3^2}{C^2}} = -\frac{G3\cdot G1}{C^2}\cdot\frac{1}{s^2+s\cdot\frac{G2}{C}+\frac{G3^2}{C^2}}$$

$$H(s) = \frac{-1}{C^2 R1 R3}\cdot\frac{1}{s^2+s\cdot\frac{1}{CR2}+\frac{1}{C^2R3^2}} ; \left[\left(\frac{1}{CR3}\right)^2 = w_p^2\right] \Rightarrow \left[\frac{1}{CR3} = w_p\right] ; \frac{1}{CR2} = \frac{w_p}{Q} \Rightarrow Q = w_p \cdot C \cdot R2$$

$$\left[Q = \frac{C\,R2}{C\,R3} = \frac{R2}{R3}\right] ; \left[\frac{K}{w_0^2} = \frac{+1}{C^2 R1 R3}\right] ; \Rightarrow \boxed{H(s) = K\cdot\frac{w_0^2}{s^2+s\frac{w_p}{Q}+w_p^2}}$$

$$[K = -1]$$

$$\Rightarrow [\text{si } R1 = R3 : w_0 = w_p]$$

Obs:

$$s_{1,2} = \frac{-\frac{w_p}{Q} \pm \sqrt{\left(\frac{w_p}{Q}\right)^2 - 4\,w_p^2}}{2} \Rightarrow s_{1,2} = \frac{w_p}{2}\cdot\left[\frac{-1}{Q} \pm \sqrt{\frac{1}{Q^2}-4}\right]$$

$$s_{1,2} = \frac{1}{2\cdot C\,R3}\cdot\left[-\frac{R3}{R2} \pm \sqrt{\frac{1}{\left(\frac{R2^2}{R3^2}\right)}-4}\right]$$

$$\text{sia}: \frac{1}{\left(\frac{R2}{R3}\right)^2} = 4 : s_{1,2} = \frac{-1}{2\cdot C R2} = \frac{-1}{2}\frac{w_p}{Q} ;$$

$$\to K = -1 = |K|\,e^{180^\circ}$$

$$H(jw) = \frac{K\cdot w_0^2}{-w^2 + jw\frac{w_p}{Q} + w_p^2} = \frac{|K\cdot w_0^2|\cdot e^{180^\circ}}{\left|(w_p^2-w^2)+jw\frac{w_p}{Q}\right|\cdot e^{tg^{-1}\left(\frac{w\cdot\frac{w_p}{Q}}{w_p^2-w^2}\right)}} = \underbrace{\frac{|K|\,w_0^2}{\sqrt{(w_p^2-w^2)^2+\left(w\cdot\frac{w_p}{Q}\right)^2}}}_{K\cdot|H(jw)|}\cdot \underbrace{e^{180^\circ - tg^{-1}\left(\frac{w\frac{w_p}{Q}}{w_p^2-w^2}\right)}}_{e^{\theta(jw)}}$$

·Análisis módulo:

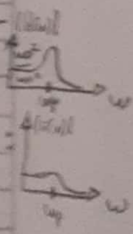
$$w = 0 \Rightarrow |H(0)| = \frac{w_0^2}{w_p^2} \Rightarrow \text{si } R1 = R3 \Rightarrow |H(0)| = 1 ;$$

$$w = w_p \Rightarrow |H(w_p)| = \frac{w_0^2}{\frac{w_p^2}{Q}} = Q\cdot\frac{w_0^2}{w_p^2} \Rightarrow \text{si } R1 = R3 \Rightarrow |H(w_p)| = Q ; \quad R1=R3 \Rightarrow \frac{Q}{10}\cdot\frac{1}{\sqrt{100Q^2+1}} \simeq \frac{1}{100}$$

$$w = 10w_p \Rightarrow |H(10w_p)| = \frac{w_0^2}{\sqrt{\left[w_p^2(1-100)\right]^2 + \left(\frac{10\,w_p^2}{Q}\right)^2}} = \frac{w_0^2}{\sqrt{w_p^4\left(99^2+\frac{100}{Q^2}\right)}} = \frac{w_0^2}{w_p^2}\cdot\frac{1}{\sqrt{\frac{99^2Q^2+100}{Q^2}}}$$

$$w = \infty \Rightarrow |H(\infty)| = \frac{w_0^2}{\sqrt{\infty^4+\infty^2}} \simeq \frac{w_0^2}{\infty^2} = 0$$

$$w = w_0 \Rightarrow |\,| = \frac{w_0^2}{\sqrt{(w_p^2-w_0^2)^2+\left(\frac{w_0\cdot w_p}{Q}\right)^2}}$$

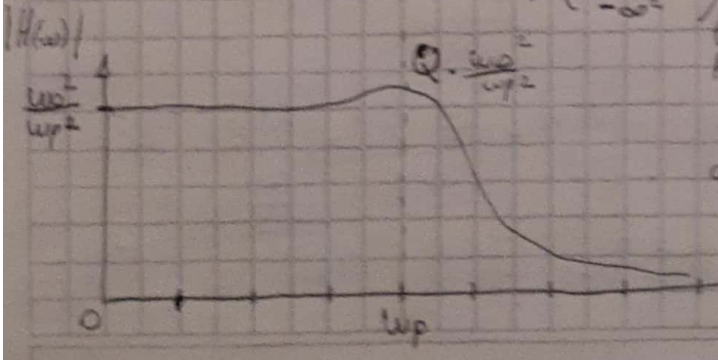


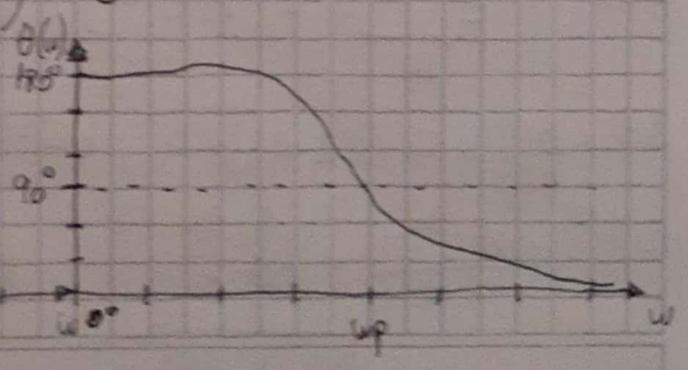
·Análisis fase:

$$w = 0 \Rightarrow \theta(0) = 180^\circ - tg^{-1}\left(\frac{0}{w_p^2}\right) = 180^\circ$$

$$w = w_p \Rightarrow \theta(w_p) = 180^\circ - tg^{-1}\left(\frac{w_p^2}{Q}\cdot\frac{1}{0}\right) = 90^\circ$$

$$w = \infty \Rightarrow \theta(\infty) = 180^\circ - tg^{-1}\left(\frac{\infty\cdot()}{-\infty^2}\right) = 0^\circ$$





FECHA

• Normalización : Norma $\Omega_w = w_p$: $T(s^*)\Big|_{s=s^*.\Omega_w} = \dfrac{K.\ w_o^2}{s^{*2}\Omega_w^2 + s^*.\Omega_w.\frac{w_p}{Q} + w_p^2} = \dfrac{K.\ w_o^2}{w_p^2\left(s^{*2}+s^*\frac{1}{Q}+1\right)}$

Norma $\Omega_z = R3 \rightarrow$ me conviene :

$K=-1$; $R3'=1$; $Q=\dfrac{R2}{R3} = R2'$; $w_o^2 = \dfrac{1}{C^2R1R3} = \dfrac{1}{C'^2R1'}$; $w_p^2 = \dfrac{1}{C^2R3^2} = \dfrac{1}{C'^2}$; $\dfrac{w_p}{Q} = \dfrac{1}{CR2} = \dfrac{1}{C'R2'}$

$\Rightarrow w_o^2 = \dfrac{1}{R1'} . w_p^2 \Rightarrow$ puedo meter $\dfrac{1}{R1'}$ dentro de la ganancia para simplificar :

$$\left[T(s^*) = \frac{-1}{R1'} \cdot \frac{1}{s^{*2}+s^*\frac{1}{Q}+1} \Rightarrow K' = \frac{-1}{R1'}\ ;\right]$$

$w_p = \dfrac{1}{C'} \Rightarrow C' = 1$; $C = C'.\dfrac{1}{R3.\Omega_w}$;

$R3' = R4' = 1 \rightarrow R4$ no influye ;

$R2' = \dfrac{R2}{R3} = \dfrac{R2}{\Omega_z}$; $R1' = \dfrac{R1}{R3} = \dfrac{R1}{\Omega_z}$;

• Tipo de Filtro : Pasabajos :

- Los polos dependerán de Q, a mayor Q el paso será más abrupto pero tendrá un mayor pico en wp
- La ganancia dependerá de la relación entre R3 y R1 o entre Wo y Wp.
- La fase presenta una inversión de la señal por la banda de trabajo.

• Estudio Sensibilidad : Considero : $w_o^2 = \dfrac{1}{C^2R1R3} \cdot \dfrac{R3}{R3} = \dfrac{R3}{R1} . w_p^2 \Rightarrow \boxed{K = \dfrac{-R3}{R1}}$

$w_p = \dfrac{1}{CR3}$; $S_C^{w_p} = \dfrac{C}{w_p} \cdot \dfrac{\delta w_p}{\delta C} = \dfrac{C}{w_p} \cdot \dfrac{d}{\delta C}\left[\dfrac{1}{CR3}\right] = \dfrac{C}{w_p} \cdot \dfrac{-1}{R3} \cdot \dfrac{1}{C^2} = \dfrac{-1}{w_p R3 C}$;

$\hookrightarrow = \dfrac{-1}{w_p R3 C} = \dfrac{-1}{\frac{1}{CR3} . R3 C} = \boxed{-1}$;

$S_{R3}^{w_p} = \dfrac{R3}{w_p} \cdot \dfrac{\delta w_p}{\delta R3} = \dfrac{R3}{\frac{1}{CR3}} \cdot \dfrac{\delta}{\delta R3}\left[\dfrac{1}{CR3}\right] = \dfrac{\cancel{R3}}{\frac{1}{\cancel{CR3}}} \cdot \dfrac{-1}{\cancel{C}} \cdot \dfrac{1}{R3^{\cancel{2}}} = \boxed{-1}$

$$\left[\frac{\Delta w_p}{w_p} = -1 \cdot \frac{\Delta C}{C} + -1 \cdot \frac{\Delta R3}{R3}\right]$$

$K = \dfrac{-R3}{R1}$; $S_{R3}^{K} = \dfrac{R3}{K} \cdot \dfrac{\delta K}{\delta R3} = \dfrac{R3}{K} \cdot \dfrac{\delta}{\delta R3}\left[\dfrac{-R3}{R1}\right] = \dfrac{\cancel{R3}}{\frac{-\cancel{R3}}{\cancel{R1}}} \cdot \dfrac{-1}{\cancel{R1}} = \boxed{1}$

$S_{R1}^{K} = \dfrac{R1}{K} \cdot \dfrac{\delta}{\delta R1}\left[\dfrac{-R3}{R1}\right] = \dfrac{\cancel{R1}}{\frac{-\cancel{R3}}{\cancel{R1}}} \cdot \dfrac{\cancel{R3}}{R1^{\cancel{2}}} = \boxed{-1} \Rightarrow \left[\dfrac{\Delta K}{K} = 1 \cdot \dfrac{\Delta R3}{R3} + -1 \cdot \dfrac{\Delta R1}{R1}\right]$

$Q = \dfrac{R2}{R3}$; $S_{R2}^{Q} = \dfrac{R2}{Q} \cdot \dfrac{\delta}{\delta R2}\left[\dfrac{R2}{R3}\right] = \dfrac{\cancel{R2}}{\frac{\cancel{R2}}{\cancel{R3}}} \cdot \dfrac{1}{\cancel{R3}} = \boxed{1}$; $S_{R3}^{Q} = \dfrac{R3}{Q} \cdot \dfrac{\delta}{\delta R3}\left[\dfrac{R2}{R3}\right] = \dfrac{R3}{Q} \cdot \dfrac{-R2}{R3^2}$

$\hookrightarrow = \boxed{-1}$

$$\left[\frac{\Delta Q}{Q} = 1 \cdot \frac{\Delta R2}{R2} + -1 \cdot \frac{\Delta R3}{R3}\right]$$