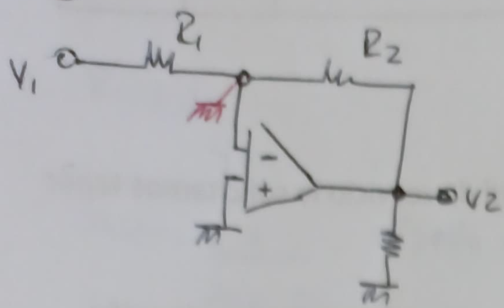
Guía N°1: OPAMP y OTA

(1)



Es un inversor a simple vista

$$H(s) = -\frac{R_2}{R_1}$$ pero lo demuestro

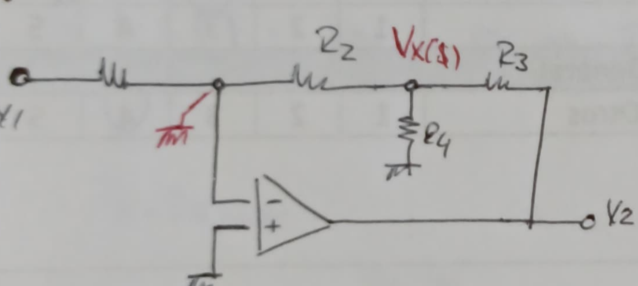
$$-V_1(s).G_1 - V_O(s).G_2 = \phi$$

$$\boxed{\frac{V_O}{V_I} = H(s) = -\frac{G_1}{G_2} = \frac{-R_2}{R_1}}$$

$$Z_1(s) = \frac{V_1(s)}{I_{R_1}(s)} = \frac{I_{R_1}(s).R_1}{I_{R_1}(s)} = \boxed{R_1 = \frac{1}{G_1} = Z_1(s)}$$

Si lo quisiera diseñar para $H(s) = 3000 \wedge Z_1 = 10k$

$\Rightarrow R_2 = 30M\Omega \Rightarrow$ IMPOSIBLE



$$\cdot Z_1(s) = \frac{V_1(s)}{I_{R_1}(s)} \Rightarrow \boxed{Z_1(s) = R_1 = \frac{1}{G_1}}$$

Nodos

$$-V_1(s)(G_1) - V_X(s)(G_2) = \phi$$

$$V_X(s)(G_2+G_3+G_4) - V_O(s).G_3 = \phi \Rightarrow \frac{V_X}{V_O} = \frac{G_3}{G_2+G_3+G_4}$$

$$-V_1(s).G_1 = \frac{V_X(s)}{V_O(s)}.V_O(s).G_2 \Rightarrow -V_1(s).G_1 = V_O(s).\frac{G_2.G_3}{G_2+G_3+G_4}$$

$$H(s) = -\frac{G_1}{G_2 G_3}.\frac{G_2+G_3+G_4}{} = -\frac{\cancel{R_2 R_3}}{R_1}\frac{R_3R_4+R_2R_4+R_2R_3}{\cancel{R_2R_3}R_4}$$

Pág. 1 de 1

$$\boxed{(s) = -\frac{1}{R_1R_4} \quad R_3R_4+R_2R_4+R_2R_3}$$ → Veo que ya no necesito un valor ↑ de Rfeedback

$R_1 = 10k$

$$3000 = \frac{-1}{10k \cdot R_4} \quad R_3 \cdot R_4 + R_2 \cdot R_4 + R_2 \cdot R_3 = -\frac{1}{10k \cdot R_4} \quad R_4(R_3+R_2) + R_2 \cdot R_3$$

Si $R_2 = R_3 = R_4 \Rightarrow$ Numerador $\frac{3 \cdot R^{\cancel{2}}}{10k \cdot \cancel{R}} \Rightarrow$ Entonces es $\frac{3R}{10k} = 3000$

$R = 10M$ no!!

Supongo $R_4 = 1k \Rightarrow -\frac{1}{10k \cdot 1k} \quad R_3 \cdot 1k + R_2 \cdot 1k + R_2 \cdot R_3 = 3000$

Adopto $R_3 = 1k \Rightarrow -\frac{1}{10k \cdot \cancel{1k}} \quad 1k \cdot \cancel{1k} + R_2 \cdot \cancel{1k} + R_2 \cdot \cancel{1k} = 3000$

$1k + 2R_2 = \frac{3000}{1} \cdot 10k \Rightarrow R_2 =$

$R_4 = R_3 = 10k \Rightarrow \frac{1}{10k \cdot \cancel{10k}} \quad 10k \cdot \cancel{10k} + R_2 \cdot \cancel{10k} + R_2 \cdot \cancel{10k} = 3000$

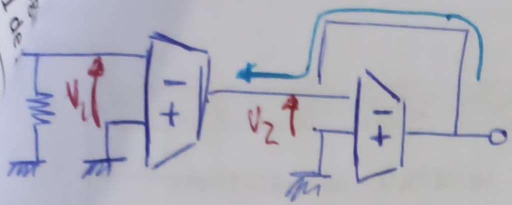
$10K + 2R_2 = 3000 \cdot 10k$

$\left.\begin{matrix} R_4 = 1k \\ R_3 = 100k \end{matrix}\right\} \Rightarrow \frac{1}{10k \cdot 1k} \quad 100k \cdot 1k + R_2 \cdot 1k + R_2 \cdot 100k = 3000$

$R_2 = 296k \Rightarrow R_2 = 300k$

$$\boxed{\begin{matrix} R_1 = 10k \\ R_2 = 300k \\ R_3 = 100k \\ R_4 = 1k \end{matrix}}$$

Pág. 1 de



44.695,60

2362

MONICA VAZQUEZ

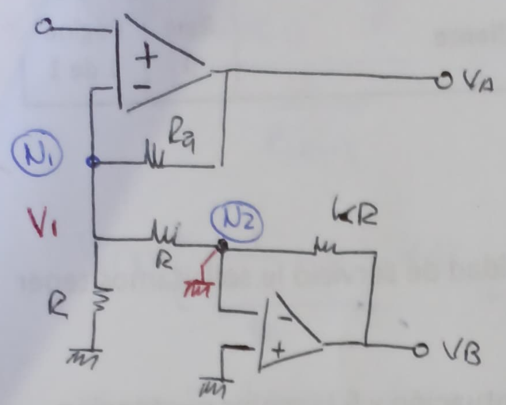
TRASPASO OBRA SOCIAL

FORMULARIO

$I_{o1} = I_{o2}$ porque ningum entrada tem corriente

$I_{o1} = g_{m1} \cdot V$; $I_{o2} = g_{m2} \cdot V_2$

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



$$R_a = \frac{R(k-1)}{2}$$

N_1 $V_1(\$)\left(G_a + G + G\right) - V_A(\$)\, G_a = \emptyset \Rightarrow V_A(\$) = V_1(\$)\,\frac{(G_a+2G)}{G_a}$

N_2 $-V_1(\$)\,.\,G - V_B(\$)\,.\,G_k = \emptyset \Rightarrow -V_1(\$)\,G = V_B(\$)\,G_k \; ; \; G_k = \frac{1}{kR}$

$$V_{AB} = V_A(\$) - V_B(\$) = V_1(\$)\left[\frac{G_a+2G}{G_a} + \frac{G}{G_k}\right]$$

$$V_{AB}(\$) = V_1(\$)\left[\frac{G_k(G_a+2G)+G.G_a}{G_a\,G_k}\right]$$

$$= V_1(\$)\left[\frac{\frac{1}{kR}\left(\frac{2}{R(k-1)}+\frac{2}{R}\right)+\frac{1}{R}\,\frac{2}{R(k-1)}}{\frac{2}{R(k-1)}\cdot\frac{1}{kR}}\right]$$

$$= V_1(\$)\left[\frac{\frac{2}{kR^2}\left(\frac{1}{k-1}+1\right)+\frac{2}{R^2}\,\frac{1}{k-1}}{\frac{2}{kR^2(k-1)}}\right]$$

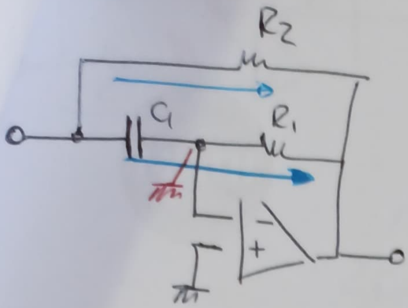
$$V_1(\$)\left[\frac{\frac{2}{R^2}\left(\frac{1}{k}\left(\frac{1}{k-1}+1\right)+\frac{1}{k-1}\right)}{\frac{2}{kR^2(k-1)}}\right] = V_1 .\, k(k-1)\left[\frac{1}{k}\right.$$

$$V_i(\$)\left[\frac{\frac{2}{\cancel{R}(k-1)}+\frac{2}{\cancel{R}}}{\frac{2}{\cancel{R}(k-1)}}+\frac{\frac{1}{\cancel{R}}}{\frac{1}{k\cancel{R}}}\right]$$

$$V_i(\$)\left[\left(\frac{1}{k-1}+\frac{1}{1}\right)(k-1)+k\right]$$

$$V_i(\$)\left[\frac{1+(k-1)}{\cancel{k-1}}\cancel{(k-1)}+k\right]=V_i(\$)\left(1+k\cancel{-1}+k\right)$$

$$\boxed{V_{AB}(\$)=V_i(\$)\,.\,2k}$$



$\cancel{[V_1(\$)](\$C)} - \cancel{V_2(\$)} \cdot G_1 = \emptyset$

$$Z_1(\$) = \frac{V_1(\$)}{I_1(\$)}$$

$$I_1(\$) = [V_1(\$) - V_2(\$)] \cdot G_2 + V_1(\$)(\$C)$$

$$-V_1(\$)(\$C) - V_2(\$)(G_1) = \emptyset$$

$$\frac{V_2(\$)}{V_1(\$)} = -\frac{\$C}{G_1}$$

$$\Rightarrow \quad I_1(\$) = \left[V_1(\$) - \frac{V_2(\$)}{V_1(\$)} \cdot V_1(\$)\right] G_2 + V_1(\$) \cdot \$C$$

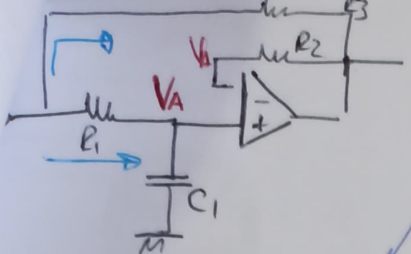
$$I_1(\$) = V_1(\$)\left[\left(1 + \frac{\$C}{G_1}\right) G_2 + \$C\right]$$

$$I_1(\$) = V_1(\$)\left[\left(\frac{1}{1} + \$CR_1\right)\frac{1}{R_2} + \$C\right]$$

$$I_1(\$) = V_1(\$)\left[\frac{\$CR_1 + 1}{R_2} + \$C\right] = \frac{\$C(R_1+R_2)+1}{R_2}$$

$$\frac{V_1(\$)}{I_1(\$)} = \frac{R_2}{\$C(R_1+R_2)+1} = \frac{R_2}{C(R_1+R_2)} \boxed{\frac{1}{\$ + 1/C(R_1+R_2)} = Z_1(\$)}$$

$$Y = \$C + \frac{1}{R} = \frac{\$CR+1}{R} \Rightarrow Z = \frac{R}{\$CR+1}$$



$$V_A(s) = V_1(s)\,\frac{1/sC}{1/sC + R_1} = \frac{1}{sCR_1+1}$$

2 formas de verlo

$$V_1(s)\,\frac{G_1}{G_1+G_2} = V_1(s)\,\frac{1/R_1}{1/R_1 + sC} = V_1\,\frac{1}{sCR_1+1}$$

$$\cancel{I_1(s) = I_{R1}(s) + I_{R3}(s) = \left[V_1(s) - V_A(s)\right]G_1 + V_1(s)\left(R_1 + \frac{1}{sC}\right) + \frac{V_1(s) - V_2(s)}{R_3}}$$

ojo $\Rightarrow$ $V_A = V_0$ porque por R_2 no circula corriente

$$\Rightarrow V_2 = V_A \Rightarrow I_1(s) = \frac{V_1(s)}{R_1 + 1/sC} + \left[V_1(s) - \frac{V_2(s)}{V_1(s)}V_1(s)\right]\frac{1}{R_3}$$

$$\frac{V_2(s)}{V_1(s)} \rightarrow \frac{1}{sCR_1+1}$$

$$I_1(s) = V_1(s)\left[\frac{sC}{sCR_1+1} + \frac{1}{R_3} - \frac{1}{R_3}\,\frac{1}{sCR_1+1}\right]$$

$$\cancel{I_1(s) = V_1(s)\left[\frac{sCR_3R_1(sCR_1}{sCR_3(sCR_1+1)}\right.}$$

$$I_1 = V_1\left[\frac{sCR_3 + sCR_1 + \cancel{1} - \cancel{1}}{R_3(sCR_1+1)}\right] = V_1\,\frac{sC(R_1+R_3)}{R_3(sCR_1+1)}$$

$$\frac{V_1(s)}{I_1(s)} = R_3\,\frac{sCR_1+1}{sC(R_1+R_3)} = \frac{R_3R_1C}{C(R_1+R_3)}\,\frac{s + 1/CR_1}{s} = \cancel{R_3}$$

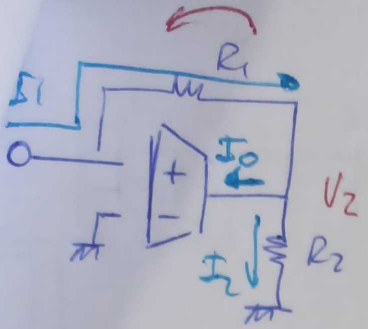
$$\boxed{Z_i(s) = \frac{R_1R_3}{R_1+R_3}\,\frac{s + 1/CR_1}{s}}$$

$$\frac{s\,\square + \square}{\triangle}$$

$$R + \frac{1}{sC} = \frac{sCR+1}{sC}$$

$\Rightarrow$ Se comporta como un RC serie

#7



$$Z_1 = \frac{V_1}{I_1}$$

$$I_1 = \frac{V_1 - V_2}{R_1} \qquad V_2 = V_1 + I_1 . R_1$$

$$\Rightarrow V_2 = V_1 - \frac{(V_1 - V_2)}{R_1} . R_1$$

$$I_0 = g_m . V_1$$

$$I_1 = \frac{V_1 - V_2}{R_1} \quad ; \quad I_1 = I_2 + I_0 = g_m . V_1 + \frac{V_2}{R_2}$$

$$\Rightarrow \frac{V_1 - V_2}{R_1} = \frac{V_2}{R_2} + g_m . V_1$$

$$V_1 \left(\frac{1}{R_1} - g_m \right) = V_2 \left(\frac{1}{R_2} + \frac{1}{R_1} \right)$$

$$V_1 \frac{1 - g_m R_1}{\cancel{R_1}} = V_2 \frac{R_1 + R_2}{R_2 . \cancel{R_1}}$$

$$\frac{V_2}{V_1} = \frac{R_2 (1 - g_m R_1)}{R_1 + R_2}$$

$$Z_1 = \frac{V_1}{I_1} = \frac{V_1}{\frac{V_2}{V_1} V_1 \frac{1}{R_2} + g_m . V_1} = \frac{\cancel{V_1}}{\cancel{V_1}} \frac{1}{\frac{\cancel{R_2}}{R_2} \frac{(1 - g_m R_1)}{R_1 + R_2} + g_m}$$

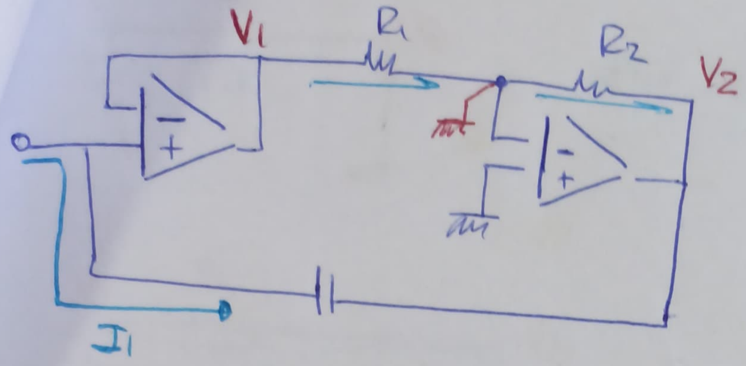
$$Z_1 = \frac{1}{\frac{1 - g_m R_1}{R_1 + R_2} + g_m} = \frac{1}{\frac{1 - g_m R_1 + g_m R_1 + g_m R_2}{R_1 + R_2}}$$

$$\boxed{Z_1 = \frac{R_1 + R_2}{1 + g_m R_2}}$$

Resta implementar en su repartido

(48)

Zin



$$\frac{V_1(s)}{R_1} = -\frac{V_2(s)}{R_2}$$

$$I_1 = (V_1(s) - V_2(s))\, sC \;;$$

$$V_2(s) = -V_1(s) \cdot \frac{R_2}{R_1} \Rightarrow \frac{V_2(s)}{V_1(s)} = -\frac{R_2}{R_1}$$

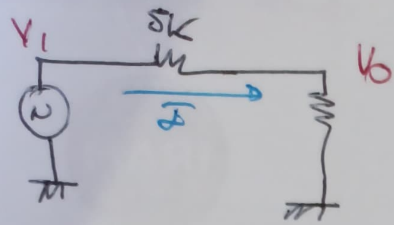
Ya sé que es inversor

$$\Rightarrow Z_1(s) = \frac{V_1(s)}{I_1(s)} = \frac{\cancel{V_1(s)}}{sC \cdot \cancel{V_1(s)}\left(1 - \frac{V_2(s)}{V_1(s)}\right)}$$

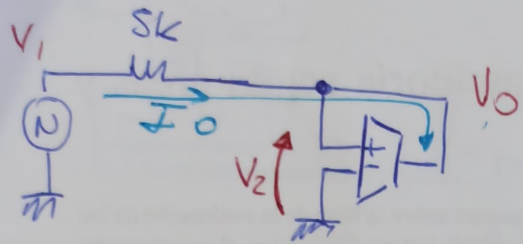
$$Z_1(s) = \frac{1}{sC}\,\frac{1}{\frac{1}{1} + \frac{R_2}{R_1}} = \frac{1}{sC}\,\frac{R_1}{R_1+R_2}$$

$$Z_1(s) = \frac{R_1}{C(R_1+R_2)}\,\frac{1}{s} \longrightarrow \boxed{\frac{1}{s\,\frac{C(R_1+R_2)}{R_1}}}$$

$\Rightarrow$ se comporta como un capacitor de mayor impedancia que el original



$Z_1 = 5K + 5K = R_1 + R_2 = Z_1$



$Z_1 = \frac{V_1}{I_0}$; $I_0 = \frac{V_1 - V_2}{R_1}$

$I_0 = g_m . V_2$

$\Rightarrow \frac{V_1}{R_1} = V_2\left(g_m + \frac{1}{R_1}\right)$

$\frac{V_2}{V_1} = \frac{1}{R_1} \frac{1}{g_m + \frac{1}{R_1}} = \frac{1}{R_1} \frac{1}{\frac{g_m R_1 + 1}{R_1}}$

$\frac{V_2}{V_1} = \frac{1}{g_m R_1 + 1}$

$\Rightarrow I_0 = \frac{V_1}{R_1}\left(1 - \frac{V_2}{V_1}\right)$

$I_0 = \frac{V_1}{R_1}\left(1 - \frac{1}{g_m R_1 + 1}\right)$

$I_0 = \frac{V_1}{R_1} \frac{g_m R_1 \cancel{+1} \cancel{-1}}{g_m R_1 + 1}$

$\Rightarrow Z_1 = \frac{V_1}{I_0} = \frac{\cancel{V_1}}{\frac{\cancel{V_1}}{\cancel{R_1}} \frac{g_m . \cancel{R_1}}{g_m R_1 + 1}}$

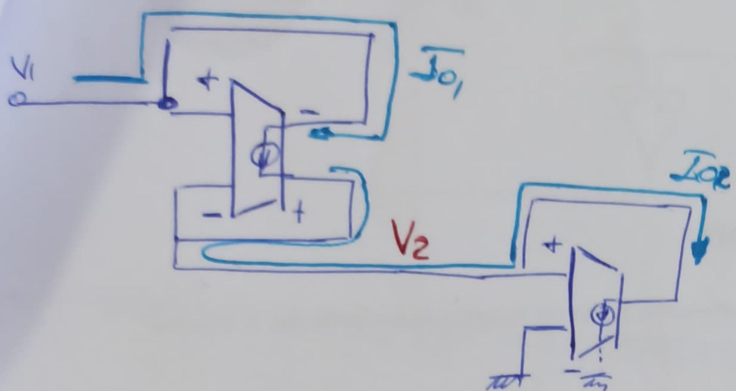
$Z_1 = \frac{g_m R_1 + 1}{g_m}$

$\boxed{Z_1 = R_1 + 1/g_m} = R_1 + R_2$

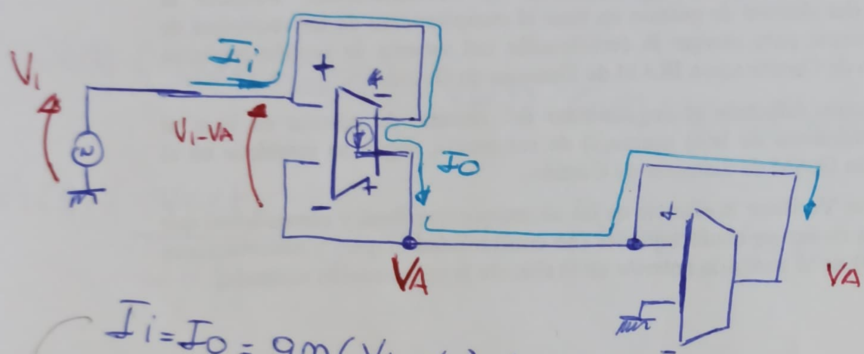
Si Consigo armar un OTA de $\underbrace{g_m = 200 \mu S}$

Depende del diferencial armado con CMOS

Quiero una R flotando



$$\left.\begin{array}{l} I_{o1} = I_{o2} \\ I_{o1} = g_{m1} \cdot V_1 \\ I_{o2} = g_{m2} \cdot V_2 \end{array}\right\} \rightarrow \text{Algo está mal !!!}$$



$$\left.\begin{array}{l} I_i = I_o = g_{m1}(V_1 - V_A) \\ I_o = g_{m2} \cdot V_A \end{array}\right\} \quad g_{m1}(V_1 - V_A) = g_{m2} \cdot V_A$$

$$V_1 \cdot g_{m1} = V_A (g_{m1} + g_{m2})$$

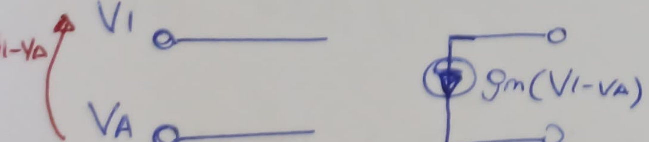
$$\frac{V_A}{V_1} = \frac{g_{m1}}{g_{m1} + g_{m2}} \Rightarrow \frac{1/R_1}{1/R_1 + 1/R_2} = \frac{\frac{1}{R_1}}{\frac{R_2 + R_1}{R_1 R_2}} = \frac{R_2}{R_2 + R_1}$$

$$Z_1 = \frac{\cancel{V_1}}{\cancel{V_1}\, g_{m1}\left(1 - \frac{g_{m1}}{g_{m1} + g_{m2}}\right)} = \frac{1}{g_{m1}} \frac{1}{\frac{g_{m1} + g_{m2} - g_{m1}}{g_{m1} + g_{m2}}} = \frac{g_{m1} + g_{m2}}{g_{m1} \cdot g_{m2}} = \frac{\frac{1}{R_1} + \frac{1}{R_2}}{\frac{1}{R_1} \cdot \frac{1}{R_2}} = \frac{\frac{R_2 + R_1}{R_1 R_2}}{\frac{1}{R_1 R_2}}$$

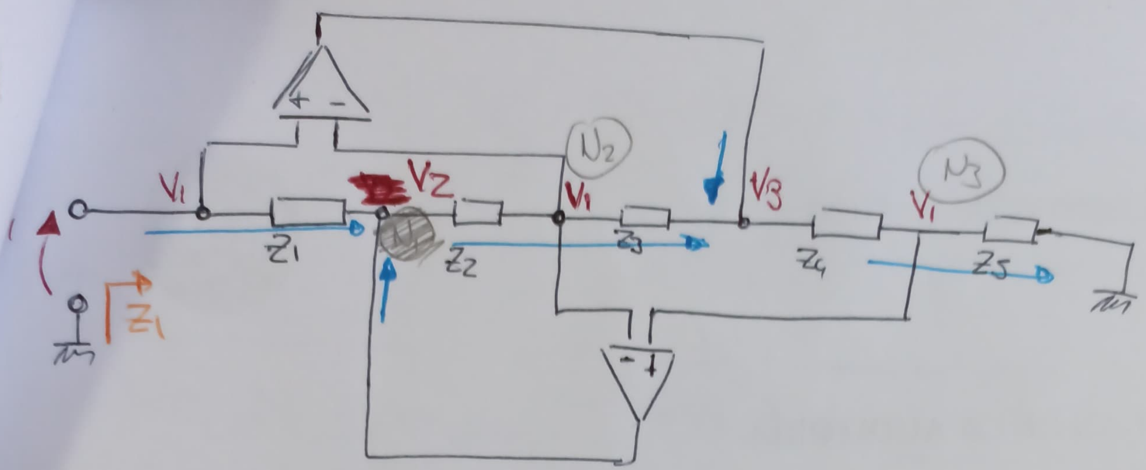
$$\boxed{Z_1 = R_2 + R_1}$$

se comporta igual que un circuito R serie

Porque $I_o = g_m(V_1 - V_A)$?



$\Rightarrow$ Ahora sí cierra todo



$\cancel{N_1 \quad V_2(s)\left(G_1(s)+G_2(s)\right) - V_1(s)\left(G_1(s)+G_2(s)\right) = \emptyset}$

$N_2 \quad V_1(s)\left(G_2(s)+G_3(s)\right) - V_2(s)\cdot G_2(s) - V_3(s)\cdot G_3(s) = \emptyset \Rightarrow$

$N_3 \quad V_1(s)\left(G_4(s)+G_5(s)\right) - V_3(s)\cdot G_4(s) = \emptyset \Rightarrow V_1(s)\left(G_4(s)+G_5(s)\right) = V_3(s)\, G_4(s)$

$$Z_1(s) = \frac{V_1(s)}{I_1(s)} \; ; \quad I_1(s) = \left[V_1(s) - V_2(s)\right] G_1(s)$$

$$\cancel{\frac{V_2(s)}{V_1(s)} = G_1(s)+G_2(s)}$$

N_2 $$V_1(s)\left[G_2(s)+G_3(s) - \frac{V_3(s)}{V_1(s)} G_3(s)\right] = V_2(s)\cdot G_2(s)$$

$$V_1(s)\left[G_2(s)+G_3(s) - \frac{G_4(s)+G_5(s)}{G_4(s)}\cdot G_3(s)\right] = V_2(s)\cdot G_2(s)$$

$$\frac{V_2(s)}{V_1(s)} = \frac{1}{G_2(s)}\left(G_2(s)+G_3(s) - \frac{G_3(s)}{G_4(s)}\left(G_4(s)+G_5(s)\right)\right)$$

$$= \frac{1}{G_2(s)}\left(\frac{G_4(s)\left(G_2(s)+\cancel{G_3(s)}\right) - \cancel{G_3(s)G_4(s)} - G_3(s)G_5(s)}{G_4(s)}\right)$$

$$\frac{Z}{I} = \frac{1}{G_2(s)} \cdot \frac{\frac{G_4(s) \cdot G_2(s) - G_3(s) \cdot G_5(s)}{G_4(s)}}{} = \frac{G_4(s) G_2(s) - G_3(s) G_5(s)}{G_2(s)\, G_4(s)}$$

$$Z_1(s) = \frac{V_1(s)}{\cancel{V_1(s)}\left[1 - \frac{V_2(s)}{V_1(s)}\right] G_1(s)} = \frac{1}{G_1(s)} \cdot \frac{1}{1 - \frac{G_4(s) \cdot G_2(s) - G_3(s)\, G_5(s)}{G_2(s) \cdot G_4(s)}}$$

$$= \frac{1}{G_1(s)} \cdot \frac{1}{\frac{\cancel{G_2(s)\, G_4(s)} - \cancel{G_4(s)\, G_2(s)} + G_3(s)\, G_5(s)}{G_2(s)\, G_4(s)}}$$

$$\boxed{Z_1(s) = \frac{G_2(s)\, G_4(s)}{G_1(s)\, G_3(s)\, G_5(s)} = \boxed{\frac{Z_1(s)\, Z_3(s)\, Z_5(s)}{Z_2(s)\, Z_4(s)}}}$$

función de excitación genérica

Aplicado al 1° circuito

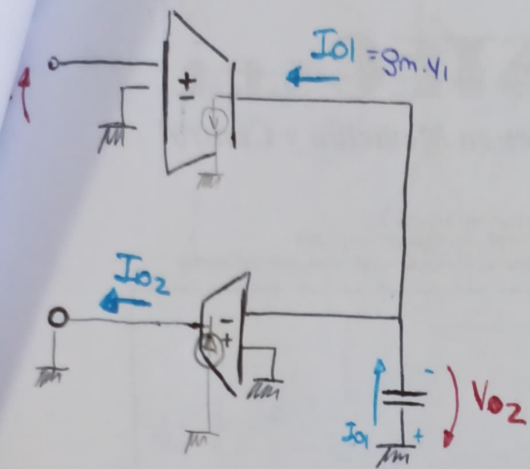
$$Z_1(s) = -\frac{s\, C_1 R_1 R_2 R_4}{R_3}$$ ≡ Negativo de Impedancia

~~lo puedo normalizar?~~ → $Z_1(s) = -s\, \omega_0$

$$\cancel{\Omega_\omega = \frac{C_1 R_1 R_2 R_4}{R_3}}$$

Aplicado al 2° circuito

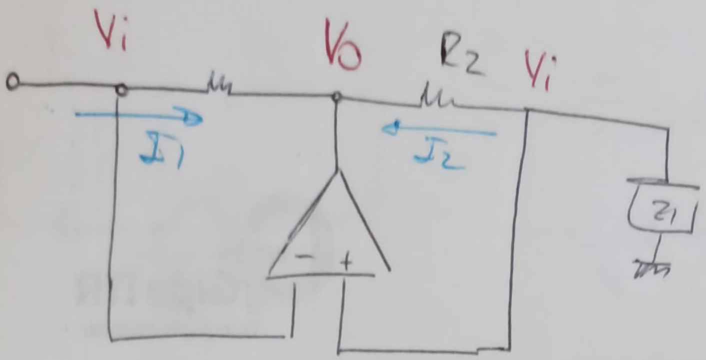
$$Z_1(s) = \frac{R_4}{s^2 C_1 C_2 R_1 R_3}$$



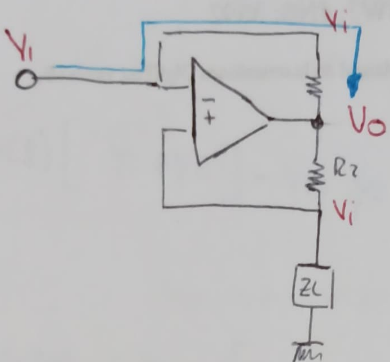
$$V_{o2} = \frac{g_{m1} \cdot V_1}{sC}$$

$$Z_i = \frac{V_1}{I_{o2}} = \frac{V_1}{\frac{g_{m2} \cdot g_{m1} \cdot V_1}{sC}}$$

$$Z_i = \frac{sC}{g_{m2} \cdot g_{m1}}$$



$$\cancel{V_O(G_1+G_2)} \; Z V_1 (G_1 + R_2) = \phi$$



$$Z_1 = \frac{V_1}{I_1} = \frac{V_I}{\frac{V_1 - V_O}{R_1}} = \frac{V_1}{\frac{V_1}{R_1}\left(1 - \frac{V_O}{V_1}\right)}$$

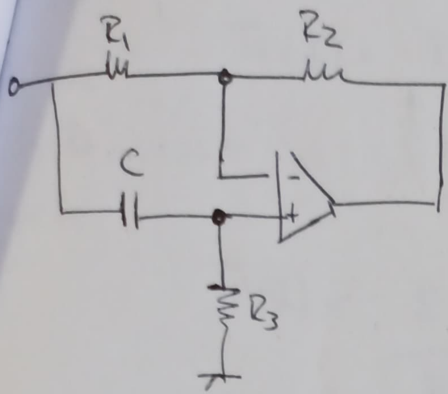
$$\frac{V_O - V_I}{R_2} = \frac{V_1}{Z_L}$$

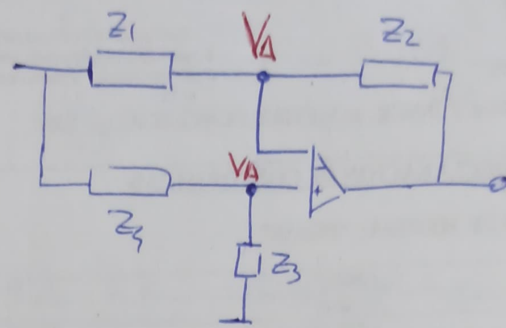
$$\frac{V_O}{R_2} = V_1\left(\frac{1}{Z_L} + \frac{1}{R_2}\right)$$

$$\frac{V_O}{V_1} = \frac{R_2(R_2 + Z_L)}{Z_L . R_2}$$

$$\Rightarrow Z_1 = \frac{R_1}{\frac{1}{1} - \frac{R_2(R_2+Z_L)}{Z_L . R_2}} = \frac{R_1}{\frac{\cancel{Z_L . R_2} - R_2^2 - \cancel{Z_L R_2}}{Z_L . R_2}} = -\frac{Z_L . R_1 . \cancel{R_2}}{R_2^{\cancel{2}}}$$

$$\boxed{Z_1 = -\, Z_L \frac{R_1}{R_2}}$$





$$V_A(s) = V_i(s) \cdot \frac{Z_3}{Z_3 + Z_4} = V_i(s) \cdot \frac{Y_4}{Y_3 + Y_4} = \frac{1/Z_4}{\frac{1}{Z_3} + \frac{1}{Z_4}} = \frac{1/Z_4}{\frac{Z_4 + Z_3}{Z_3 \cdot \cancel{Z_4}}}$$

$$V_A(s)\left[Y_1 + Y_2 \right] - V_o \cdot Y_2 - V_i \, Y_1 = \varnothing$$

$$\Rightarrow \quad V_i(s) \cdot \frac{Y_4}{Y_3 + Y_4} \left[Y_1 + Y_2 \right] - V_i(s) \cdot Y_1 = V_o \cdot Y_2$$

$$\frac{V_o(s)}{V_i(s)} = \frac{1}{Y_2} \left(\frac{Y_4}{Y_3 + Y_4} \left(Y_1 + Y_2 \right) - Y_1 \right) =$$

$$= \frac{1}{Y_2} \left[\frac{\cancel{Y_4 \cdot Y_1} + Y_4 \cdot Y_2 - Y_1 \cdot Y_3 - \cancel{Y_1 \cdot Y_4}}{Y_3 + Y_4} \right]$$

$$\Rightarrow \boxed{T(s) = \frac{1}{Y_2} \, \frac{Y_4 \cdot Y_2 - Y_1 \cdot Y_3}{Y_3 + Y_4}}$$

$Y_1 = 1/R_1$

$Y_2 = 1/R_2$

$Y_3 = 1/R_3$

$Y_4 = \$C$

$$T_1(\$) = R_2 \frac{\frac{\$C}{R_2} - \frac{1}{R_1 \cdot R_3}}{\frac{1}{R_3} + \$C} = \cancel{R_2} \frac{\frac{\$ C \cdot R_1 \cdot R_3 - R_2}{R_1 \cdot \cancel{R_2} \cdot \cancel{R_3}}}{\frac{1 + \$ \cdot C \cdot R_3}{\cancel{R_3}}}$$

$$T_1(\$) = \frac{\$ \cdot C \cdot R_1 \cdot R_3 - R_2}{R_1(1 + \$ C \cdot R_3)} = \frac{C \cdot \cancel{R_1} \cdot R_3}{C \cdot \cancel{R_1} \cdot R_3} \cdot \frac{\$ - R_2 / C \cdot R_1 \cdot R_3}{\$ + 1 / C \cdot R_3}$$

reemplazando valores

$$T_1(\$) = \frac{\$ - 1000}{\$ + 1000} \quad ; \text{ normalizo } \Omega_\omega = 1000$$

$$\boxed{T_1(\$) = \frac{\$ - 1}{\$ + 1}} \longrightarrow \text{PASA TODO}$$

$Y_1 = 1/R_A$

$Y_2 = 1/R_B$

$$Y_3 = \frac{1}{R} + \$C = \frac{\$CR + 1}{R} \Rightarrow Z_3 = \frac{R}{\$CR + 1}$$

$$Y_4 = 1/Z_4 ; \; Z_4 = R + 1/\$C = \frac{\$CR + 1}{\$C}$$

$$T_2(\$) = R_B \cdot \frac{\frac{\$C}{\$CR + 1} \frac{1}{R_B} - \frac{\$CR + 1}{R} \frac{1}{R_A}}{\frac{\$CR + 1}{R} + \frac{\$C}{\$CR + 1}}$$

$$R_B \cdot \frac{\dfrac{sC}{(sCR+1)R_B} - \dfrac{(sCR+1)}{R \cdot R_A}}{\dfrac{(sCR+1)^2 + sCR}{R(sCR+1)}}$$

$$\cancel{R_B} \cdot \frac{s \cdot C \cdot R \cdot R_A - (sCR+1)^2 \cdot R_B}{\cancel{(sCR+1)} \cdot \cancel{R_B} \cdot \cancel{R} \cdot R_A} \cdot \frac{\cancel{R(sCR+1)}}{(sCR+1)^2 + sCR}$$

$$T_Z(s) = \frac{1}{R_A} \cdot \frac{-s^2C^2R^2R_B - 2sCR \cdot R_B - R_B + sCR \cdot R_A}{s^2C^2R^2 + 2sCR + 1 + sCR}$$

$$T_Z(s) = \frac{1}{R_A} \cdot \frac{-s^2C^2R^2R_B + s \cdot C \cdot R(R_A - 2R_B) - R_B}{s^2C^2R^2 + 3sCR + 1} ;$$

$$-1/5$$

$$= \frac{1}{R_A} \cdot \frac{-\cancel{C^2} \cdot \cancel{R^2} R_B}{\cancel{C^2} \cdot \cancel{R^2}} \cdot \frac{s^2 + s\,(2R_B - R_A)/C \cdot R \cdot R_B + \cancel{R_B}/C^2 \cdot R^2 \cdot \cancel{R_B}}{s^2 + s\;3/CR + 1/C^2R^2}$$

$$\frac{-1}{5} \cdot \frac{s^2 + s\,\dfrac{(2R_B - 5R_B)}{C \cdot R \cdot R_B} + \dfrac{1}{C^2R^2}}{s^2 + s\;3/CR + 1/C^2R^2}$$

$$\frac{1}{s} \quad \boxed{\frac{\$^2 - \$ \; 3/CR + 1/C^2 \cdot R^2}{\$^2 + \$ \; 3/CR + 1/C^2 \cdot R^2} = T2(\$)}$$

También es un PASATODO

Normalizo

$$-\frac{1}{s} \quad \frac{\$^2 - \$ \cdot 3 \cdot \frac{1}{CR} + \left(\frac{1}{CR}\right)^2}{\$^2 + \$ \cdot 3 \cdot \frac{1}{CR} + \left(\frac{1}{CR}\right)^2}$$

ω_0

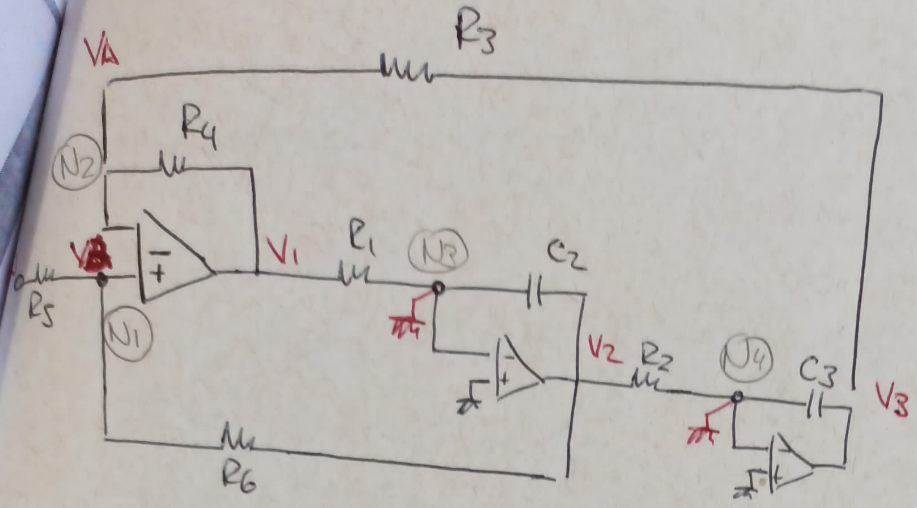
$\Rightarrow \omega_0^2$

$\Rightarrow$ Si TOMO

$\Omega\omega = \omega_0$

Me saco de encima varias cosas

$$-\frac{1}{s} \quad \frac{\$^2 - 3\$ + 1}{\$^2 + 3\$ + 1}$$



(N1) $V_A(G_5+G_6) - V_{IN}\,G_5 - V_2\,G_6 = \emptyset$

(N2) $V_A(G_4+G_3) - V_3 . G_3 - V_1 . G_4 = \emptyset$

(N3) $-V_1\,G_1 - V_2\,sC = \emptyset \Rightarrow -V_1\,G_1 = V_2\,sC_2$

(N4) $-V_2 . G_2 = V_3 . sC_3$

$$\left.\begin{array}{l} -V_1\,G_1 = V_2\,sC_2 \\ -V_2 . G_2 = V_3 . sC_3 \end{array}\right\} -V_1\,G_1 = -\frac{V_3 . sC_3}{G_2} . sC_2$$

de (N1) y (N2)

$$V_{IN}\frac{G_5}{G_5+G_6} + V_2\frac{G_6}{G_5+G_6} = V_3\frac{G_3}{G_4+G_3} + V_1\frac{G_4}{G_4+G_3}$$

$$\Rightarrow \left| \begin{array}{l} V_1\dfrac{G_4}{G_4+G_3} - V_2\dfrac{G_6}{G_5+G_6} + V_3\dfrac{G_3}{G_4+G_3} = V_{IN}\dfrac{G_5}{G_5+G_5} \\ \\ -V_1\,G_1 = V_2\,sC_2 \\ -V_2\,G_2 = V_3\,sC_3 \\ -V_1\,G_1 = -\dfrac{V_3\,sC_3\,sC_2}{G_2} \end{array}\right.$$

$RC \cdot \Omega \cdot \frac{S}{\Omega}$ $\frac{1}{2\pi f C}$ $\frac{1}{\frac{1}{S}\frac{S}{\Omega}}$

$$\left[\frac{G4}{G4+G3} + \frac{G1}{\$C2}\frac{G6}{G5+G6} + \frac{G1\,G2}{\$C3\,\$C2}\frac{G3}{G4+G3}\right] = V_{IN}\frac{G5}{G5+G6}$$

$$V_1 \; \frac{G4(G5+G6)\$C2\,\$C3 + G1G6\,\$C3(G4+G3) + G1G2G3(G5+G6)}{(G4+G3)(G5+\cancel{G6})\,\$C2\,\$C3} = V_{IN}\frac{G5}{G5+\cancel{G6}}$$

$$\frac{V_1}{V_{IN}} = \frac{\$^2\,C2\,C3\,(G4+G3)\,G5}{\$^2 C2C3\,G4(G5+G6) + \$\,C3\,G1G6(G4+G3) + G1G2G3(G5+G6)}$$

$S^{-2} \cdot S^2/\Omega^2$

$$\frac{\frac{1}{S^2}\left(\frac{S}{\Omega}\right)^2\frac{1}{\Omega}\frac{1}{\Omega} = \frac{1}{\Omega^4}}{\frac{1}{S^2}\frac{S^2}{\Omega^2}\frac{1}{\Omega^2} + \frac{1}{S}\frac{S}{\Omega}\frac{1}{\Omega}\frac{1}{\Omega}\frac{1}{\Omega} + \frac{1}{\Omega^4}}$$

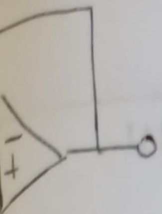
[ ] Adimensional

$$H_1(\$) = \frac{\cancel{C2}\,\cancel{C3}\,(G4+G3)\,G5}{\cancel{C2}\,\cancel{C3}\,G4\,(G5+G6)}\;\frac{\$^2}{\$^2 + \$\,\frac{G1\,G6(G4+G3)}{C2\,(G5+G6)} + \frac{G1G2G3}{C2C3\,G4}}$$

$$\boxed{H_1(\$) = \frac{(G4+G3)}{(G5+G5)}\frac{G5}{G4}\;\frac{\$^2}{\$^2 + \$\,\frac{G1\,G6(G4+G3)}{C2(G5+G6)} + \frac{G1G2G3}{C2C3G4}}}$$

F.H.P

ES una cuestión algebraica sacar las otras transferencias



$$V_x(s)\left(\frac{1}{R_1}+\frac{1}{R_4}+sC_2+\frac{1}{R_3}\right)-\frac{V_o(s)}{R_4}-\frac{V_i(s)}{R_1}=0$$

$$\frac{-V_x(s)}{R_3}-V_o(s)\cdot sC_5=0 \Rightarrow V_x(s)=-V_o(s)\cdot sC_5R_3$$

$$\left[sC_5R_3\left(\frac{1}{R_1}+\frac{1}{R_3}+\frac{1}{R_4}+sC_2\right)+\frac{1}{R_4}\right]=\frac{V_i(s)}{R_1}$$

$$)\left[s\cdot C_5\cdot \cancel{R_3}\ \frac{R_3R_4+R_1R_4+R_1R_3+s\cdot C_2\cdot R_1R_3R_4}{R_1\cancel{R_3}R_4}+\frac{1}{R_4}\right]=\frac{V_i(s)}{R_1}$$

$$s)\left[\frac{sC_5(R_3\cdot R_4+R_1\cdot R_4+R_1\cdot R_3+s\cdot C_2\cdot R_1\cdot R_3\cdot R_4)+R_1}{\cancel{R_1}\cdot R_4}\right]=\frac{V_i(s)}{\cancel{R_1}}$$

$$\frac{V_o(s)}{V_i(s)}=-R_4\frac{1}{s^2C_2\cdot C_5\cdot R_1\cdot R_3\cdot R_4+s\cdot C_5(R_3\cdot R_4+R_1\cdot R_4+R_1\cdot R_3)+R_1}$$

$$\frac{V_o(s)}{V_i(s)}=-R_4\cdot\frac{1}{C_2C_5R_1R_3R_4}\ \frac{1}{s^2+s\frac{\cancel{C_5}(R_3R_4+R_1R_4+R_1R_3)}{C_2\cdot\cancel{C_5}\cdot R_1R_3R_4}+\frac{R_1}{C_2C_5R_1R_3R_4}}$$

$$=\frac{-R_4}{R_1}\ \frac{1/C_2\cdot C_5\cdot R_3\cdot R_4}{s^2+s\frac{R_3R_4+R_1R_4+R_1R_3}{C_2\cdot R_1\cdot R_3\cdot R_4}+\frac{1}{C_2\cdot C_5\cdot R_3\cdot R_4}}$$

$$=-\frac{R_4}{R_1}\ \frac{1/C_2\cdot C_5\cdot R_3\cdot R_4}{s^2+s\underbrace{\frac{1}{C_2}\left(\frac{1}{R_1}+\frac{1}{R_3}+\frac{1}{R_4}\right)}_{\frac{w_0}{q}}+\frac{1}{C_2\cdot C_5\cdot R_3\cdot R_4}}$$

$$w_0^2=\frac{1}{C_2C_5R_3R_4}$$

$$q=\frac{\sqrt{C_2C_5R_3R_4}}{R_3R_4+R_1R_4+R_1R_3}$$

$w_0\ 2$

$$\Omega w=w_0=\frac{\sqrt{1}}{\sqrt{\ldots}}=10\ r/s$$

como estoy ω_0

$$\frac{V_o(\$)}{V_i(\$)} = \frac{-R_4}{R_1} \cdot \frac{1}{\$^2 + \frac{\$}{Q} + 1} \quad ; \quad Q = \frac{\sqrt{C_2 C_5 R_3 R_4}}{R_3 R_4 + R_1 R_4 + R_1 R_3}$$

$$\frac{V_o(\$)}{V_i(\$)} = -\frac{R_4}{R_1} \cdot \frac{\overbrace{1/C_2 \cdot C_5 \cdot R_3 \cdot R_4}^{\omega_0^2}}{\$^2 + \$\underbrace{\frac{C_5(R_3R_4 + R_1R_4 + R_1R_3)}{C_2 \cdot C_5 \cdot R_1 R_3 R_4}}_{\omega_0 / Q} + \underbrace{\frac{1}{C_2 C_5 R_3 R_4}}_{\omega_0^2}}$$

$$\omega_0 = \frac{1}{\sqrt{C_2 C_5 R_3 R_4}} = \Omega\omega = 10$$

me Asegura que la relación entre

$$\frac{\omega_0}{Q} = \frac{C_5(R_3R_4 + R_1R_4 + R_1R_3)}{C_2 \cdot C_5 R_1 R_3 R_4} = \frac{1}{\sqrt{C_2 C_5 R_3 R_4}}$$

$$Q = \frac{1}{\sqrt{C_2 C_5 R_3 R_4}} \cdot \frac{C_2 \cancel{C_5} R_1 R_3 R_4}{\cancel{C_5}(R_3R_4 + R_1R_4 + R_1R_3)}$$

$$Q = \frac{\sqrt{C_2 R_3 R_4}}{\sqrt{C_5}} \cdot \frac{R_1}{R_3R_4 + R_1R_4 + R_1R_3}$$

$$\frac{V_o(\$)}{V_i(\$)} = -\frac{R_4}{R_1} \cdot \frac{1}{\$^2 + \$ \cdot 1/Q + 1}$$

NORMALIZACIÓN Combinada

$$R_N = \frac{R}{\Omega_Z}$$

$$L_N = L \cdot \frac{1}{\Omega_Z} \cdot \Omega_W$$

$$C_N = C \; \Omega_Z \cdot \Omega_W$$

=> Tengo mi func normalizada en $C_Z = 1F$, $C_S = 0{,}01\,F$, $\omega_0 = 10$, $R = 1$

Pero sólo dispongo de $C = 47\,pF$, $C = 4700\,pF$

$1F = 47pF \cdot \Omega_Z \cdot \Omega_W$ ⇝ Pasó de 10 a 1000

$1F = 47\,pF \cdot \Omega_Z \cdot \frac{1000}{10} \Rightarrow \Omega_Z = 212{,}76\,M$ → muy grande

⇓

Invierto el C.

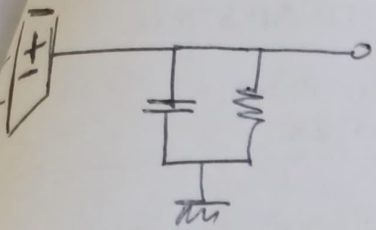
$1F = 4700\,pF \cdot \Omega_Z \cdot \frac{1000}{10} \Rightarrow \Omega_Z = 2{,}12\,M$ Ok

Chequeo con el otro C

$0{,}01\,F = 47\,pF \cdot 2{,}12\,M \cdot 100$ Ok

[$C_Z = 4700pF$, $C_S = 47\,pF$ — $R_1 = R_3 = R_4 = 2{,}12M$, $\omega_0 = 1000\,s^{-1}$ => Rediseñé mi circuito en 2 pasadas]

$$I = \frac{V}{Z} = V \cdot Y$$



$$I_o = g_m \cdot V_1$$

$$V_{oz} = I_o \cdot (Z_p) \longrightarrow \frac{\frac{1}{sC} \cdot R}{\frac{1}{sC} + R} = \frac{R}{sCR+1}$$

$$V_{oz} = g_m \cdot V_1 \frac{R}{sCR+1} \Rightarrow \frac{V_{oz}}{V_1} = \frac{g_m \cdot R}{sCR+1} \frac{[\ ]}{\frac{1}{s}\cancel{\frac{s}{s}} + [\ ]} \quad [\ ]$$

$$\left[\frac{V_{oz}}{V_1} = \frac{g_m \cdot R}{sCR+1} \right] = \boxed{\frac{g_m}{C} \quad \frac{1}{s + 1/CR}}$$