# TS6

2-

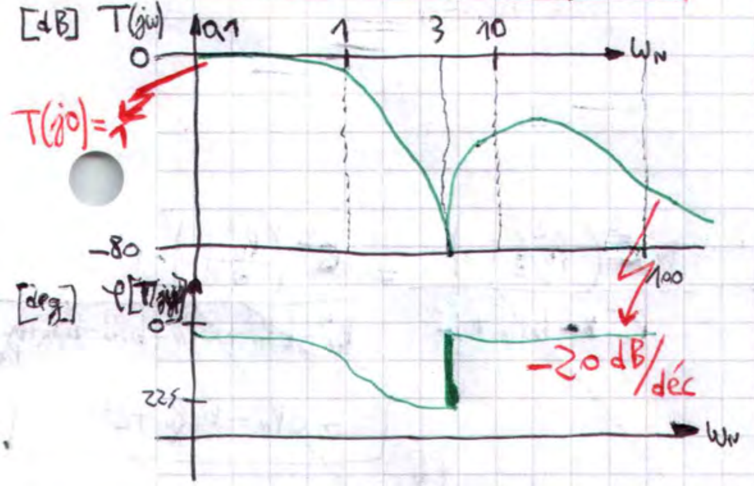
**FILTRO PASA ALTOS (OBJETIVO)**

✓ MÁXIMA PLANICIDAD EN BANDA DE PASO

↳ $F_P = 300\ Hz$

✓ CERO TRANSMICIÓN → $F_z = 100\ Hz$

**FILTRO PASABAJOS (PROTOTIPO) NORMAL.**




- **NORMALIZO PLANTILLA OBJETIVO**

$\Omega_w = 2\pi F_P = 2\pi\, 300\ Hz$

$\Rightarrow \omega_{P_N} = \dfrac{\omega_P}{\Omega_w} = \boxed{1}$

$\omega_{z_N} = \dfrac{\omega_z}{\Omega_w} = \dfrac{\cancel{2\pi} F_z}{\cancel{2\pi} F_P} = \boxed{\dfrac{1}{3}}$

- **TRANSFORMO FRECUENCIAS A PROTOTIPO**

$K(\Omega) = \omega = \dfrac{1}{\Omega}$

$\Rightarrow \Omega_{P_N} = \dfrac{1}{\omega_{P_N}} = \boxed{1}$

$\Omega_{z_N} = \dfrac{1}{\omega_{z_N}} = \boxed{3}$

Siendo: $s = \sigma + j\omega$ (OBJETIVO)
$p = \Sigma + j\Omega$ (PROTOTIPO)

- **DISEÑO PASABAJOS PROTOTIPO**

(1) $T(j0) = 1 = 0\,dB$
(2) $T(j\Omega \to \infty) = -20\,\dfrac{dB}{déc}$
(3) $T(j3) = 0$
SE IMPONE ARBITRARIAMENTE EN BP (4) $T(j1) = -1{,}5\,dB$

(2) Teniendo 1 cero de transmisión no infinito

$\Rightarrow T(j\Omega_N) = \dfrac{N(\Omega_N)}{D(\Omega_N)} \begin{array}{l} \to \text{ORDEN} = \boxed{m = 2} \\ \to \text{ORDEN} = n - m \end{array}$

Si en $T(j\Omega_N \to \infty) \to -20\,dB/déc \Rightarrow n - m = 1$

$n = 1 + 2 = \boxed{3} \to$ ORDEN 3 (MÁX. PLAN.)

(3)

$$|T(j\Omega_N)|^2 = \frac{\left(\frac{\Omega_N^2}{9} - 1\right)^2}{\left(\frac{\Omega_N^2}{9} - 1\right)^2 + \varepsilon^2 \cdot \Omega_N^6}$$

y aplicando (4)

$$|T(j1)|^2 = \frac{1}{1 + \frac{\varepsilon^2 \cdot 1^6}{\left(\frac{1^2}{9} - 1\right)^2}} = \frac{1}{1 + \frac{\varepsilon^2}{\frac{64}{81}}} = \frac{1}{\sqrt{2}} \Rightarrow$$

RESUELVO →

$$\sqrt{2} = 1 + \frac{81}{64}\varepsilon^2$$

$$\frac{64}{81}\left(\sqrt{2}-1\right) = \varepsilon^2 \quad \Rightarrow \quad \boxed{\varepsilon^2 = 0{,}32728} \qquad \boxed{\varepsilon = 0{,}57208}$$

$$\Rightarrow \left|T(j\Omega_N)\right|^2 = \frac{\left(\frac{-\Omega_N^2}{9}-1\right)^2}{\left(\frac{-\Omega_N^2}{9}-1\right)^2 + 0{,}32728\cdot\Omega_N^6} \quad \underset{\frac{p_N}{j}=\Omega_N}{\Rightarrow} \quad \left|T(p_N)\right|^2 = \frac{\left(-\frac{p_N^2}{9}-1\right)^2}{\left(\frac{-p_N^2}{9}-1\right)^2 - 0{,}32728\cdot p_N^6}$$

$$\boxed{\left|T(p_N)\right|^2 = \frac{\left(\frac{p_N^2}{9}+1\right)^2}{-\varepsilon^2 p_N^6 + \frac{p_N^4}{81} + \frac{2}{9}p_N^2 + 1}} \quad (A)$$

TOMANDO UNA $T(p_N)$ GENÉRICA $\longrightarrow \left|T(p_N)\right|^2 = T(p_N)\cdot T(-p_N) = \dfrac{K\left(\frac{p_N^2}{e}+1\right)}{p_N^3+bp_N^2+cp_N+d}\cdot\dfrac{K\left(\frac{p_N^2}{e}+1\right)}{-p_N^3+bp_N^2-cp_N+d}$

$$= \frac{K^2\left(\frac{p_N^2}{e}+1\right)^2}{-p_N^6 + \cancel{bp_N^5} - cp_N^4 + \cancel{dp_N^3} \cancel{-bp_N^5} + b^2p_N^4 \cancel{-bcp_N^3} + dbp_N^2 - cp_N^4 \cancel{+bcp_N^3} - c^2p_N^2 \cancel{+cdp_N} \cancel{-dp_N^3} + bdp_N^2 \cancel{-dp_N} + d^2}$$

$$= \frac{K^2\left(\frac{p_N^2}{e}+1\right)^2}{-p_N^6 + (b^2-2c)p_N^4 + (2dB-c^2)p_N^2 + d^2} \overset{(A)}{=} \frac{\frac{1}{\varepsilon^2}\cdot\left(\frac{p_N^2}{9}+1\right)^2}{-p_N^6 + \frac{p_N^4}{\varepsilon^2\cdot 81} + \frac{2}{9\cdot\varepsilon^2}p_N^2 + \frac{1}{\varepsilon^2}}$$

$\Rightarrow \boxed{e=9}$

$K^2 = \dfrac{1}{\varepsilon^2}$ $\qquad \boxed{K = \dfrac{1}{\varepsilon}}$

$-2c + b^2 = \dfrac{1}{\varepsilon^2 81}$ $\qquad 2bd - c^2 = \dfrac{1}{\varepsilon^2 9}$ $\qquad d^2 = \dfrac{1}{\varepsilon^2}$ $\qquad \boxed{d = \dfrac{1}{\varepsilon}}$

SOLUCIÓN NUMÉRICA

$\boxed{c = 2,74637}$ $\qquad \boxed{b = 2,35169}$

$$T_{LP_N}(p_N) = \frac{\frac{1}{\varepsilon}\left(\frac{p_N^2}{9}+1\right)}{p_N^3 + 2,35169\,p_N^2 + 2,74637\,p_N + \frac{1}{\varepsilon}} = \frac{0,19422\,(p_N^2+9)}{p_N^3 + 2,35169\,p_N^2 + 2,74637\,p_N + 1,74801}$$

a) $T(j0) = 1$ ✓ VERIFICA

- TRANSFORMO A PASAALTOS (OBJETIVO) CON $\longrightarrow$ $K(s_N) = p_N = \dfrac{1}{s_N}$

$$T_{LP_N}(p_N)\Big|_{p_N=\frac{1}{s_N}} = T_{HP_N}(s_N) = \frac{0,19422\left(\frac{1}{s_N^2}+9\right)}{\frac{1}{s_N^3} + 2,35169\cdot\frac{1}{s_N^2} + 2,74637\,\frac{1}{s_N} + 1,74801}$$

$$T_{HP_N}(s_N) = \frac{0,19422\,(s_N + 9\,s_N^3)}{1 + 2,35169\,s_N + 2,74637\,s_N^2 + 1,74801\,s_N^3}$$

$$T_{HP_N}(s_N) = \frac{s_N^3 + \frac{1}{9}s_N}{s_N^3 + 1,57114\,s_N^2 + 1,34535\,s_N + 0,57208}$$

b- DIAGRAMA DE POLOS Y CEROS PASAALTOS NORMALIZADO

$$\frac{\omega_{o2_N}}{Q} = \frac{0,85337}{1,08648}$$

$$T_{HP_N}(s_N) = \underbrace{\frac{s_N}{s_N + \underbrace{0,78558}_{\omega_{o1_N}}}}_{\text{ORDEN 1}} \cdot \underbrace{\frac{s_N^2 + \frac{1}{9}}{s_N^2 + 0,78556\cdot s_N + \underbrace{0,72823}_{\omega_{o2_N}^2}}}_{\text{ORDEN 2}}$$

ORDEN 1 (PASAALTOS)

$\downarrow$

$z_1 = (0;0)$

$P_1 = (-0,78558;0)$

ORDEN 2 (PASAALTOS CON CERO DE TRANSM.)

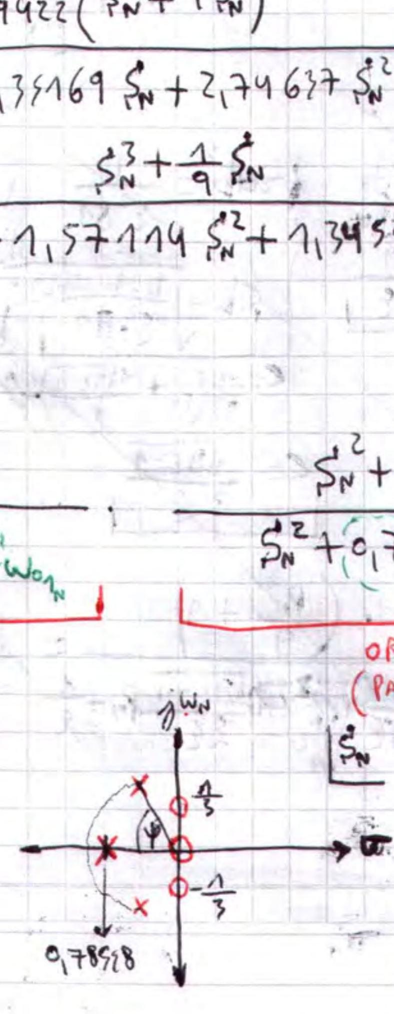
$\downarrow$

$z_{2-3} = \left(0;\pm\frac{1}{3}\right)$

$P_{2-3} = -0,39278 \pm j0,7776 = \underbrace{0,85337}_{\omega_{o2_N}}\cdot e^{\pm j62,6°}$

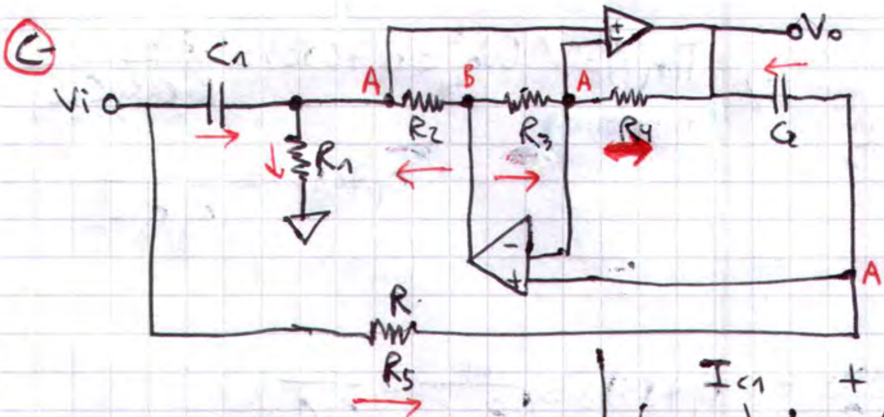
$Q = \dfrac{1}{2\cos(62,6°)}$

$Q = 1,08648$



FECHA

C




$I_{R5} = I_{C2}$

$$\frac{(V_i - V_A)}{R_5} = (V_A - V_o)(sC_2)$$

$$\frac{V_i}{R_5} + (sC_2)V_o = V_A\left(sC_2 + \frac{1}{R_5}\right)$$

$$\frac{V_i}{R_5} + sC_2 V_o = \left(V_i sC_1 - \frac{R_3}{R_2R_4}V_o\right)\underbrace{\left(\frac{sC_2+\frac{1}{R_5}}{sC_1+\frac{1}{R_1}+\frac{1}{R_2}-\frac{R_3+R_4}{R_2R_4}}\right)}_{K}$$

$$\left(sC_2 + \frac{R_3}{R_2R_4}K\right)V_o = \left(K sC_1 - \frac{1}{R_5}\right)V_i$$

$I_{C1} + I_{R2} = I_{R1}$

$$(V_i - V_A)sC_1 + \frac{(V_B - V_A)}{R_2} = \frac{V_A}{R_1}$$

$$\frac{V_A}{R_1} + \frac{V_A}{R_2} + V_A sC_1 = V_i sC_1 + \frac{V_B}{R_2}$$

$$V_A\left(\frac{1}{R_1}+\frac{1}{R_2}+sC_1\right) = V_i sC_1 + V_A\left(\frac{R_3+R_4}{R_2R_4}\right) - \frac{R_3V_o}{R_2R_4}$$

$$V_A\left(-\frac{R_3+R_4}{R_2R_4}+\frac{1}{R_1}+\frac{1}{R_2}+sC_1\right) = V_i sC_1 - \frac{R_3}{R_2R_4}V_o$$

$$V_A = \left(V_i sC_1 - \frac{R_3}{R_2R_4}V_o\right)\left(\frac{R_1R_2R_4}{R_1(R_3+R_4)+R_2R_4+R_1R_4+sC_1R_1R_2R_4}\right)$$

$I_{R3} = I_{R4}$

$$\frac{(V_B - V_A)}{R_3} = \frac{(V_A - V_o)}{R_4}$$

$$\frac{V_B}{R_3} = \left(\frac{1}{R_3}+\frac{1}{R_4}\right)V_A - \frac{V_o}{R_4}$$

$$V_B = \left(1+\frac{R_3}{R_4}\right)V_A - \frac{R_3V_o}{R_4}$$

(A)

$$T(s) = \frac{V_o}{V_i} = \frac{K sC_1 - \frac{1}{R_5}}{sC_2 + \frac{R_3}{R_2R_4}K} = \frac{\dfrac{s^2C_1C_2 + \frac{sC_1}{R_5}}{sC_1+\frac{1}{R_1}+\frac{1}{R_2}-\frac{R_3+R_4}{R_2R_4}} - \dfrac{1}{R_5}}{sC_2 + \dfrac{R_3}{R_2R_4}\left(\dfrac{sC_2+\frac{1}{R_5}}{sC_1+\frac{1}{R_1}+\frac{1}{R_2}-\frac{R_3+R_4}{R_2R_4}}\right)} = \frac{\dfrac{R_5s^2C_1C_2 + s\cancel{C_1} - \cancel{sC_1} - \frac{1}{R_1} - \frac{1}{R_2} + \frac{R_3+R_4}{R_2R_4}}{R_5\cancel{\left(sC_1+\frac{1}{R_1}+\frac{1}{R_2}-\frac{R_3+R_4}{R_2R_4}\right)}}}{\dfrac{R_3\left(sC_2+\frac{1}{R_5}\right)+R_2R_4sC_2\left(sC_1+\frac{1}{R_1}+\dots\right)}{R_2R_4\cancel{\left(sC_1+\frac{1}{R_1}+\frac{1}{R_2}-\frac{R_3+R_4}{R_2R_4}\right)}}}$$

$$T(s) = \frac{\dfrac{s^2C_1C_2R_5 - \frac{1}{R_1} - \frac{1}{R_2} + \frac{R_3+R_4}{R_2R_4}}{R_5}}{s^2C_1C_2 + \frac{C_2}{R_1}s + \frac{C_2}{R_2}s - \frac{(\cancel{R_3}+R_4)C_2}{R_2R_4}s + \cancel{\frac{R_3C_2}{R_2R_4}}s + \frac{R_3}{R_2R_4R_5}}$$

$$T(s) = \frac{\frac{\cancel{C_1}C_2}{\cancel{C_1}C_2}s^2 - \frac{1}{R_1R_5C_1C_2} - \frac{1}{R_2R_5C_1C_2} + \frac{R_3+R_4}{R_2R_4R_5C_1C_2}}{s^2 + \left(\frac{1}{R_1C_1} + \cancel{\frac{1}{R_2C_1}} - \cancel{\frac{1}{R_2C_1}}\right)s + \frac{R_3}{R_2R_4R_5C_1C_2}}$$

$$T(s) = \frac{s^2 + \frac{R_1R_3 + \cancel{R_1R_4} - R_2R_4 - \cancel{R_1R_4}}{R_1R_2R_4R_5C_1C_2}}{s^2 + \frac{1}{R_1C_1}s + \frac{R_3}{R_2R_4R_5C_1C_2}} = \boxed{T(s) = \frac{s^2 + \frac{R_1R_3 - R_2R_4}{R_1R_2R_4R_5C_1C_2}}{s^2 + \frac{1}{R_1C_1}s + \frac{R_3}{R_2R_4R_5C_1C_2}}}$$

• ECUACIONES DE DISEÑO

ORDEN 2

Siendo $C_{1_N} = C_{2_N} = C_N$

$R_{4_N} = R_{3_N} = R_{5_N} = R_N$ $\Rightarrow$ $\omega_{o_{2N}}^2 = 0,72823 = \frac{\cancel{R_{3N}}}{R_{2_N}\cancel{R_{4_N}}R_{5_N}C_{1_N}C_{2_N}}$

$$0,72823 = \frac{1}{R_{2_N} R_N C_N^2}$$

$$\frac{\omega_{o_{2N}}}{q} = 0,78556 = \frac{1}{R_{1_N}C_{1_N}} = \frac{1}{R_{1_N}C_N}$$

$$\frac{1}{q} = \frac{R_1R_{3_N} - R_2R_{4_N}}{R_{1_N}R_{2_N}R_{4_N}R_{5_N}C_{1_N}C_{2_N}} = \frac{R_1\cancel{R_N} - R_2\cancel{R_N}}{R_{1_N}R_{2_N}R_N^2C_N^2} = \frac{R_{1_N} - R_{2_N}}{R_{1_N}R_{2_N}R_NC_N^2} = \frac{R_{1_N} - R_{2_N}}{R_{1_N}} \cdot \overbrace{\frac{1}{R_{2_N}R_NC_N^2}}^{\omega_{o_{2N}}^2}$$

Adopto $\boxed{C_N = 1}$ $\Rightarrow$

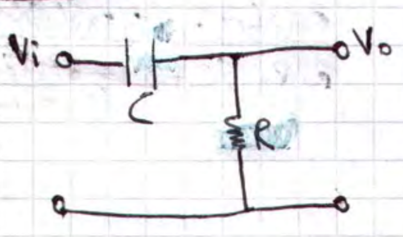
$$0,72823 = \frac{1}{R_{2_N}R_N} \Rightarrow \boxed{R_N = 1,27294}$$

$$0,78556 = \frac{1}{R_{1N}} \Rightarrow \boxed{R_{1_N} = 1,27298}$$

$$\frac{1}{q} = \left(1 - \frac{R_{2N}}{R_{1N}}\right) \cdot 0,72823 \Rightarrow \frac{R_{2N}}{R_{1N}} = 0,84742$$

$$\boxed{R_{2N} = 1,07875}$$

ORDEN 1




$$\frac{V_o}{V_i} = T(s) = \frac{R}{R + \frac{1}{sC}} = \frac{sCR}{sCR + 1}$$

$$\boxed{T(s) = \frac{s}{s + \frac{1}{RC}}}$$

$\Rightarrow$ $0,78558 = \omega_{o_{1N}} = \frac{1}{R_N C_N}$

Adopto $\boxed{C_N = 1}$ $\Rightarrow$ $0,78558 = \frac{1}{R_N}$

$$\boxed{R_N = 1,27294}$$

• PARA DESNORMALIZAR CIRCUITO (COMPONENTES)

$C = \frac{C_N}{\Omega_w \Omega_z}$ asigno $\boxed{C = 100\ nF}$

$100\ nF = \frac{1}{2\pi 300Hz \cdot \Omega_z} \Rightarrow \Omega_z = 5,30516 k\Omega$

$R = R_N \cdot \Omega_z = 1,27294 \cdot 5,30516\ k\Omega$

$\boxed{R = 6,75\ k\Omega}$

$R_2 = R_{2N} \cdot \Omega_z \Rightarrow \boxed{R_2 = 5,72\ k\Omega}$

HOJA

FECHA

D- El circuito propuesto por SCHAUMMAN es un BIQUAD basado en GIC (general Impedance converter) GENERAL. El circuito utilizado en el ítem C- es un CASO PARTICULAR de este cuando $\boxed{a=1}$. donde el capacitor en derivación se abre ($C=0$), es decir desaparece.

Por otra parte, agrega un resistor en la entrada, otro parámetro de ajuste para los diferentes modos

En el GIC, en vez de hacer que $Z_4 = \frac{1}{sC}$, lo hace en $Z_2$ (permuta R y C) cosa que no trae ninguna diferencia a nivel físico.

El general BIQUAD puede utilizarse para diferentes tipos de filtros (PASABANDA, PASAALTOS, PASABAJOS, PASATODO, NOTCH, PASAALTOS CON NOTCH Y PASABAJOS CON NOTCH).