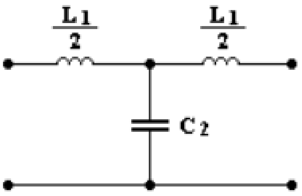
FILTRO K-CONSTANTE

pasa bajos



$$L_1 = \frac{2 * R_O}{\omega_C}$$

$$C_2 = \frac{2}{R_O * \omega_C}$$

$$\omega_C = \frac{2}{\sqrt{L_1 * C_2}}$$

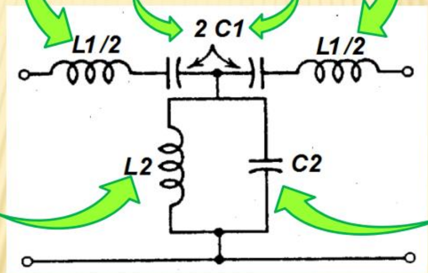
PASA BANDA

RESUMEN :

$$L_1 = \frac{2R_O}{BW}$$

$$C_1 = \frac{BW}{2R_O\omega_O^2}$$

$$L_2 = \frac{R_O \bullet BW}{2\omega_O^2}$$



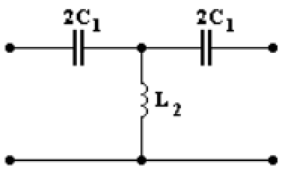
$$C_2 = \frac{2}{BW \bullet R_O}$$

$$BW = \frac{2}{\sqrt{L_2 \times C_1}} = \frac{2Ro}{L_2}$$

$$Ro = \sqrt{\frac{L_1}{C_2}} = \sqrt{\frac{L_2}{C_1}}$$

$$\omega_O = \frac{1}{\sqrt{L_1 \times C_1}} = \frac{1}{\sqrt{L_2 \times C_2}}$$

pasa altos



$$C_1 = \frac{1}{2 * R_O * \omega_C}$$

$$L_2 = \frac{R_O}{2 * \omega_C}$$

$$\omega_C = \frac{1}{2 * \sqrt{L_2 * C_1}}$$

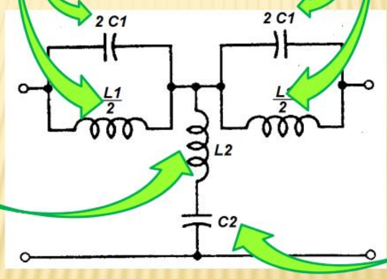
ELIMINA BANDA

RESUMEN :

$$L_1 = \frac{2R_O \bullet BW}{\omega_O^2}$$

$$C_1 = \frac{1}{2R_O \bullet BW}$$

$$L_2 = \frac{R_O}{2 \bullet BW}$$



$$C_2 = \frac{2 \bullet BW}{R_O \bullet \omega_O^2}$$

$$BW = \frac{1}{2 \bullet \sqrt{L_2 \times C_1}} = \frac{1}{2RoC_1}$$

$$Ro = \sqrt{\frac{L_1}{C_2}} = \sqrt{\frac{L_2}{C_1}}$$

$$\omega_O = \frac{1}{\sqrt{L_1 \times C_1}} = \frac{1}{\sqrt{L_2 \times C_2}}$$

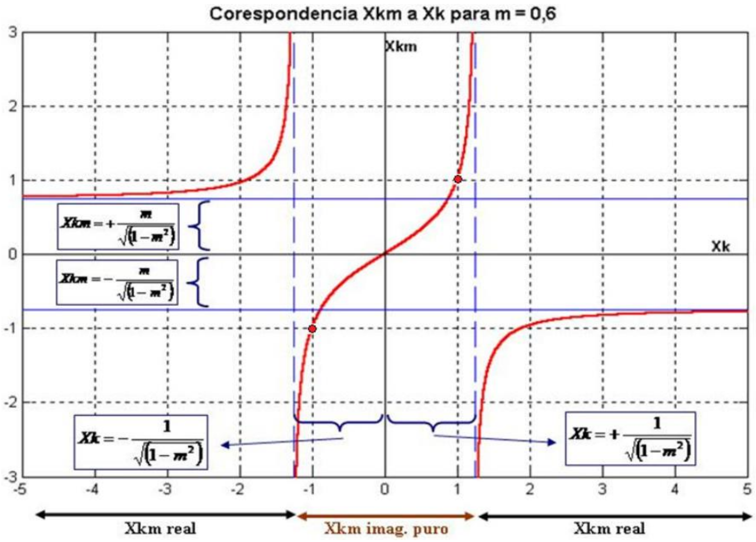
R_o = Impedancia de carga; ω_C = Pulsación de corte (pb y pa); ω_1 = Pulsación de corte inferior; ω_2 = Pulsación de corte superior; W = Ancho de banda = ω_2-ω_1 y ω_o = Pulsación de Resonancia.

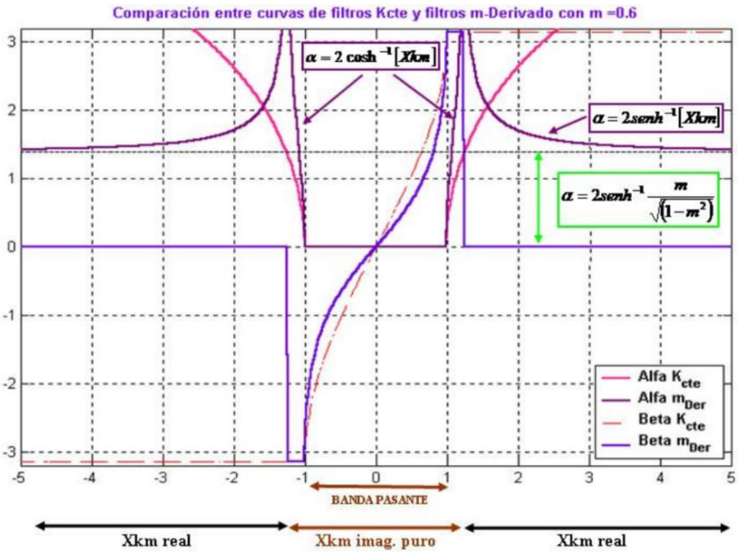
$$AB = W = \omega_{c2} - \omega_{c1}$$

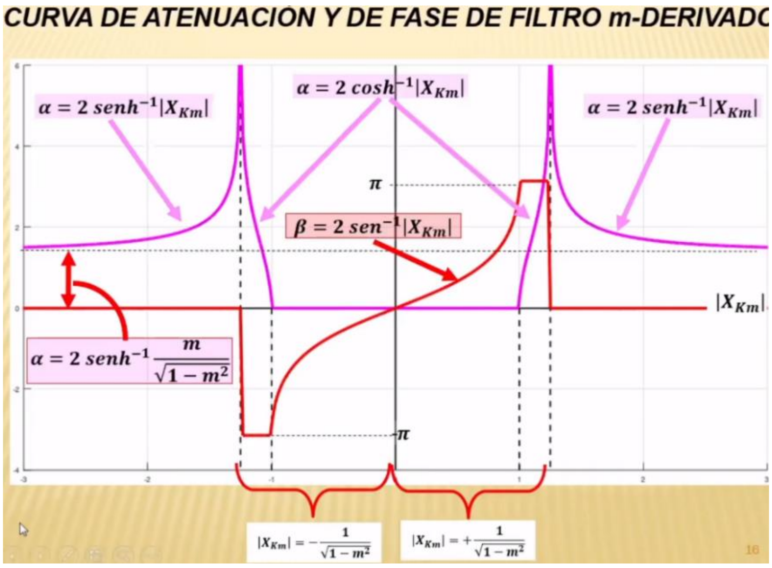
$$\omega_0 = \sqrt{\omega_{c2} . \omega_{c1}}$$

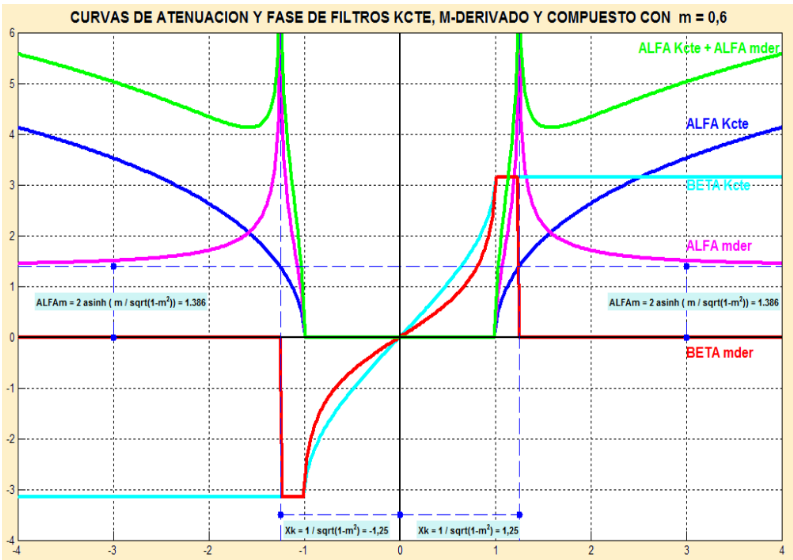
FILTRO M-DERVIADO GRÁFICOS

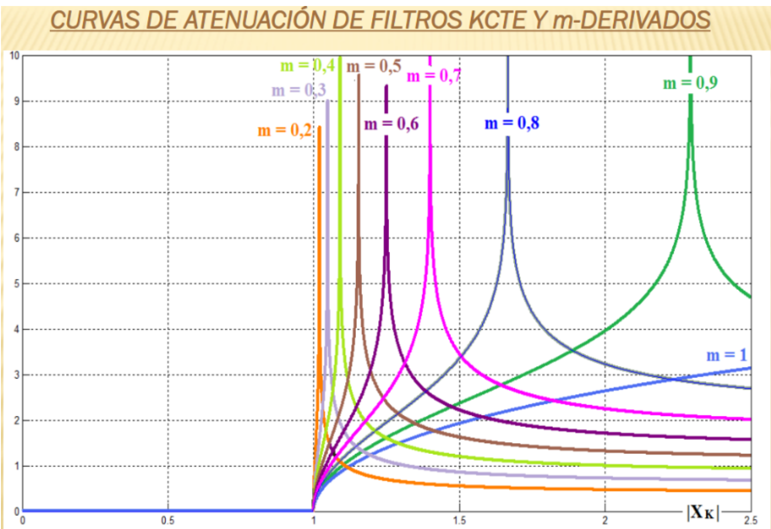
$$Z_{1Km} = m \bullet Z_{1K} \qquad Z_{2Km} = \frac{Z_{2K}}{m} + Z_{1K}\left(\frac{1-m^2}{4m}\right)$$





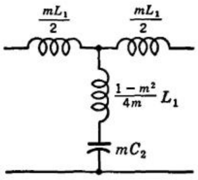






ANÁLISIS DE M-DERIVADO

pasa bajos



$$\omega_0 = \frac{2}{\sqrt{1-m^2}} \cdot \frac{1}{\sqrt{L_1 C_2}}$$

$$\omega_\infty = \frac{1}{\sqrt{L_{2m} C_{2m}}}$$

$$\omega_c = \omega_\infty \cdot \sqrt{1-m^2}$$

$$m = \sqrt{1-\left(\frac{\omega_c}{\omega_\infty}\right)^2}$$

$$m = \sqrt{\frac{L_{1m}}{L_{1m}+4L_{2m}}}$$

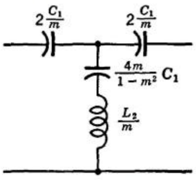
$$\frac{L_{1m}}{2} = \frac{L_1}{2} \cdot m \Rightarrow L_1 = \frac{2}{m}\left(\frac{L_{1m}}{2}\right)$$

$$C_{2m} = m C_2 \Rightarrow C_2 = \frac{C_{2m}}{m}$$

$$L_{2m} = L_1\left(\frac{1-m^2}{4m}\right) \Rightarrow L_1 = L_{2m} \cdot \frac{4m}{1-m^2}$$

$$R_0 = \sqrt{\frac{L_{1m}}{C_{2m}}}$$

pasa altos



$$\omega_\infty = \frac{\sqrt{1-m^2}}{2} \cdot \frac{1}{\sqrt{C_1 L_2}}$$

$$\omega_\infty = \frac{1}{\sqrt{C_{2m} \cdot L_{2m}}}$$

$$\omega_c = \frac{\omega_\infty}{\sqrt{1-m^2}}$$

$$m = \sqrt{\frac{C_{2m}}{C_{2m}+4C_{1m}}}$$

$$m = \sqrt{1-\left(\frac{\omega_\infty}{\omega_c}\right)^2}$$

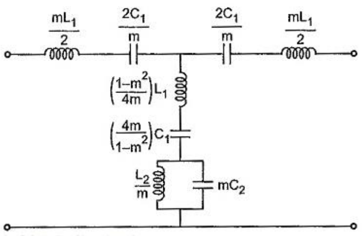
$$2C_{1m} = \frac{2C_1}{m} \Rightarrow C_1 = C_{1m} \cdot m$$

$$L_{2m} = \frac{L_2}{m} \Rightarrow L_2 = L_{2m} \cdot m$$

$$C_{2m} = C_1 \frac{4m}{1-m^2} \Rightarrow C_1 = C_{2m} \frac{1-m^2}{4m}$$

$$R_0 = \sqrt{\frac{L_{2m}}{C_{1m}}}$$

PASA BANDA



$$m = \sqrt{1-\left(\frac{BW_K}{BW_\infty}\right)^2}$$

$$L_{1m} \cdot C_{1m} = L_{3m} C_{3m}$$

$$m = \sqrt{\frac{L_{1m}}{L_{1m}+4L_{3m}}} \quad ó \quad m = \sqrt{\frac{C_{3m}}{C_{3m}+4C_{1m}}}$$

$$BW_\infty = \frac{BW_K}{\sqrt{1-m^2}} = \frac{1}{2\sqrt{L_2 C_1}} \cdot \frac{1}{\sqrt{1-m^2}}$$

$$\frac{2}{m}\sqrt{\frac{1}{L_{2m} C_{1m}}} = BW_\infty \quad (?)$$

$$\omega_\infty^2 - \frac{BW}{\sqrt{1-m^2}}\,\omega_\infty - \omega_0^2 = 0 \quad (?)$$

$$\frac{L_{1m}}{2} = m\frac{L_1}{2} \Rightarrow L_1 = \frac{L_{1m}}{m}$$

$$2C_{1m} = \frac{2C_1}{m} \Rightarrow C_1 = C_{1m}.m$$

$$L_{2m} = \frac{L_2}{m} \Rightarrow L_2 = m \cdot L_{2m}$$

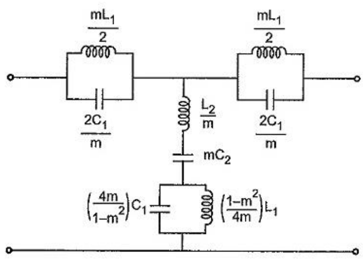
$$C_{2m} = m C_2 \Rightarrow C_2 = \frac{C_{2m}}{m}$$

$$L_{3m} = L_1 \frac{1-m^2}{4m} \Rightarrow L_1 = L_{3m} \cdot \frac{4m}{1-m^2}$$

$$C_{3m} = C_1 \frac{4m}{1-m^2} \Rightarrow C_1 = C_{3m} \cdot \frac{1-m^2}{4m}$$

$$R_0 = \sqrt{\frac{L_{1m}}{C_{2m}}} = \sqrt{\frac{L_{2m}}{C_{1m}}}$$

ELIMINA BANDA



$$m = \sqrt{1-\left(\frac{BW_\infty}{BW_K}\right)^2}$$

$$m = \sqrt{\frac{L_{1m}}{L_{1m}+4L_{3m}}} = \sqrt{\frac{C_{3m}}{C_{3m}+4C_{1m}}}$$

$$BW_\infty = BW_K\sqrt{1-m^2}$$

$$BW_\infty = \frac{1}{2\sqrt{L_2 \cdot C_1}} \cdot \sqrt{1-m^2}$$

$$L_{1m} C_{1m} = L_{3m} C_{3m}$$

$$\omega_\infty^2 - \frac{BW}{\sqrt{1-m^2}}\,\omega_\infty - \omega_0 = 0$$

$$BW_\infty = \frac{1}{2m} \cdot \frac{1}{\sqrt{L_{2m} \cdot C_{1m}}}$$

$$2C_{1m} = \frac{2C_1}{m} \Rightarrow C_1 = C_{1m}.m$$

$$\frac{L_{1m}}{2} = \frac{L_1}{2}.m \Rightarrow L_1 = \frac{L_{1m}}{m}$$

$$L_{2m} = \frac{L_2}{m} \Rightarrow L_2 = L_{2m}.m$$

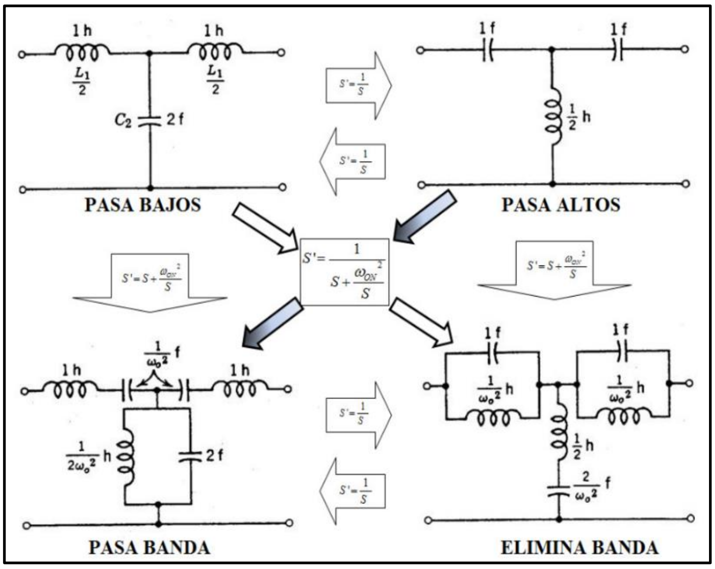
$$C_{2m} = C_2.m \Rightarrow C_2 = \frac{C_{2m}}{m}$$

$$C_{3m} = C_1.\frac{4m}{1-m^2} \Rightarrow C_1 = C_{3m}.\frac{1-m^2}{4m}$$

$$L_{3m} = L_1.\frac{1-m^2}{4m} \Rightarrow L_1 = L_{3m}.\frac{4m}{1-m^2}$$

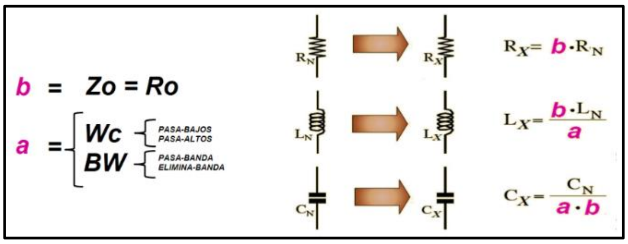
$$R_0 = \sqrt{\frac{L_{1m}}{C_{2m}}} = \sqrt{\frac{L_{2m}}{C_{1m}}}$$

DISEÑO DE FILTRO COMPUESTO



1. Cálculo del filtro k-cte prototipo partiendo de uno normalizado

2. Desnormalización del filtro k-cte prototipo



3. Cálculo de "m" (para atenuación alfa = infinito)

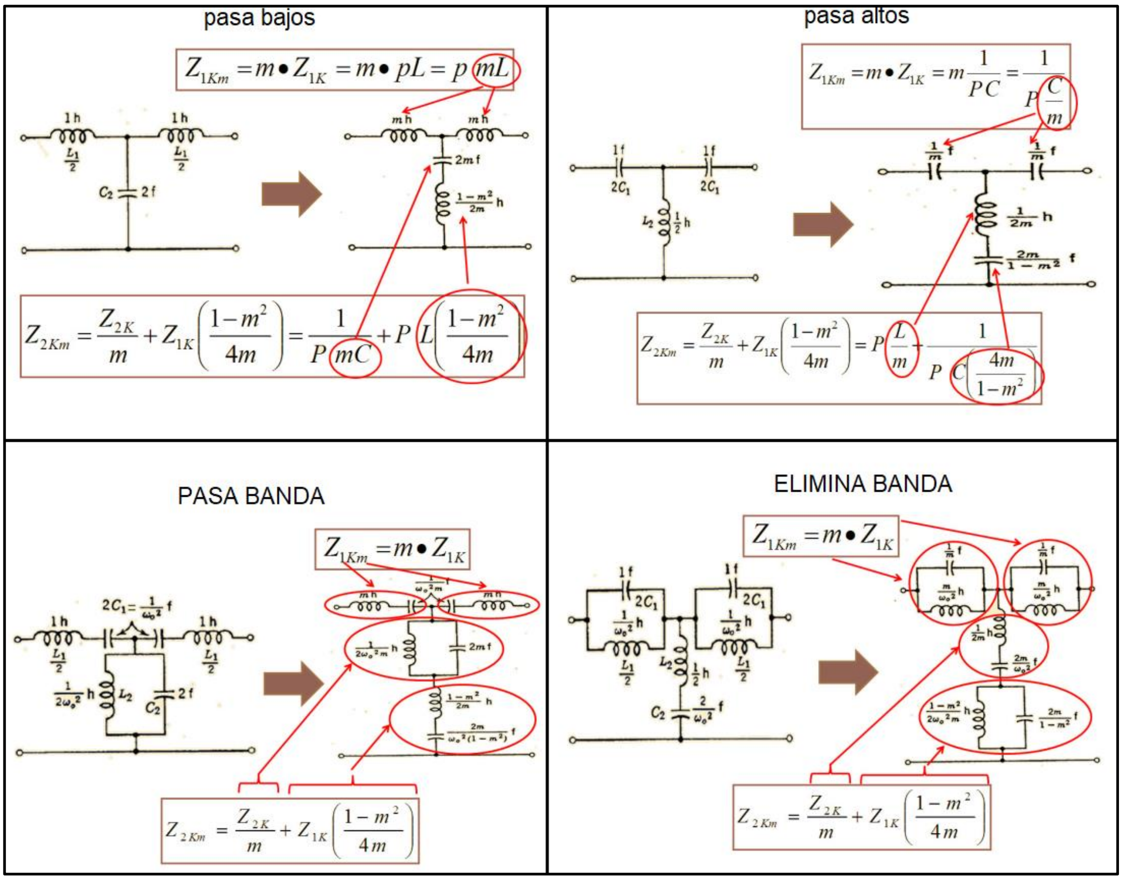
$$m=\sqrt{1-\left(\frac{f_\infty}{f_c}\right)^2}\rightarrow En\ Filtros\ pasa-bajos$$

$$m=\sqrt{1-\left(\frac{f_c}{f_\infty}\right)^2}\rightarrow En\ Filtros\ pasa-altos$$

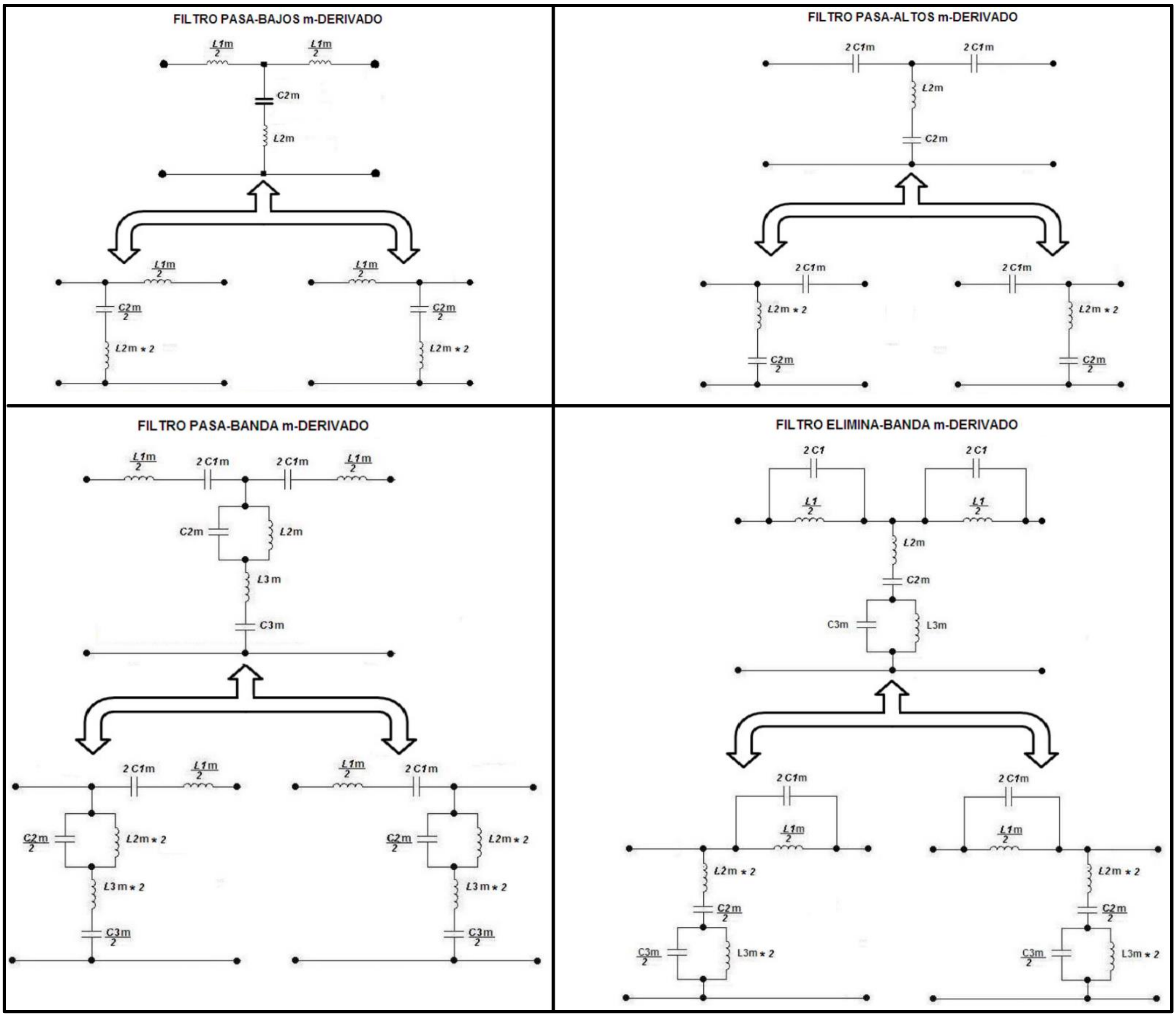
$$m=\sqrt{1-\left(\frac{BW}{BW_\infty}\right)^2}=\sqrt{1-\left(\frac{\omega_{C2}-\omega_{C1}}{\omega_{C2}*\frac{\omega_{\infty2}}{\omega_{C2}}-\frac{\omega_{C1}}{\frac{\omega_{\infty2}}{\omega_{C2}}}}\right)^2}\rightarrow En\ Filtros\ Pasa-Banda$$

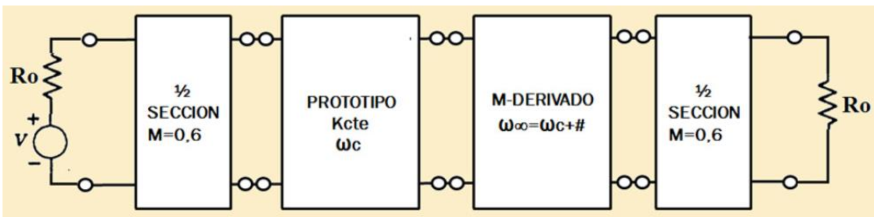
$$m=\sqrt{1-\left(\frac{BW_\infty}{BW}\right)^2}=\sqrt{1-\left(\frac{\omega_{C2}*\frac{\omega_{\infty2}}{\omega_{C2}}-\frac{\omega_{C1}}{\frac{\omega_{\infty2}}{\omega_{C2}}}}{\omega_{C2}-\omega_{C1}}\right)^2}\rightarrow En\ Filtros\ Elimina-Banda$$

4. Cálculo del filtro m-derivado



5. Cálculo de las semisecciones adaptadoras m-derivadas





BUTTERWORTH

Desnormalización:

$$\varepsilon = \sqrt{10^{(0,1 * Amax_{dB})} - 1}$$

$$R_X = R_{OUT} \qquad L_X = R_{OUT} * \varepsilon^{1/n} * \frac{1}{\omega_P} * L_N \qquad C_X = \frac{1}{R_{OUT}} * \varepsilon^{1/n} * \frac{1}{\omega_P} * C_N$$

Se calcula ε para cualquier Amax y se multiplican todos los valores de esta tabla por ε^(1/n)

VALORES DE COMPONENTES PARA Amax = 3 dB

n	Epsilon^(1/n)	L1	C1	L2	C2	L3
1	1					1
2	1				0,70710678	1,41421356
3	1			0,5	1,33333333	1,5
4	1		0,382683	1,08239	1,57716	1,53073
5	1	0,309017	0,894427	1,38197	1,69443	1,54508

COMPONENTES ORIGINALES	COMPONENTES DE CIRCUITO RESONANTE
$R_X = R_O$	$L_X\# = L_N \dfrac{Ro}{\omega_{on}^2 * BW}$
$L_X = L_N \dfrac{Ro * \varepsilon^{1/n}}{\omega_P}$	$C_X\# = C_N \dfrac{1}{\omega_{on}^2 * BW * Ro}$
$C_X = C_N \dfrac{\varepsilon^{1/n}}{\omega_P * Ro}$	$\omega_{ON}^2 = \dfrac{\omega_O^2}{BW^2} = \dfrac{(\omega_{C2} \times \omega_{C1})}{(\omega_{C2} - \omega_{C1})^2}$

Se debe eliminar de la función de transferencia los componentes que no correspondan al grado del filtro:

$$G_5(S) = \frac{V_{OUT}}{V_{IN}} = \frac{1}{S^5.L_1.L_2.L_3.C_1.C_2 + S^4.L_2.L_3.C_1.C_2 + S^3[L_1.(L_2.C_1 + L_3.C_1 + L_3.C_2) + L_2.L_3.C_2] + S^2.[C_1.(L_2 + L_3) + L_3.C_2] + S.(L_1 + L_2 + L_3) + 1}$$

Otros cálculos de utilidad:

$$|H(j\omega)|_{dB} = A(\omega)|_{dB} = 10.\log_{10}\left[1 + \varepsilon^2 \left(\frac{\omega}{\omega_p}\right)^{2n}\right][dB]$$

$$n = \frac{\log_{10}\left(\dfrac{10^{0,1.A_{min}} - 1}{\varepsilon^2}\right)}{\log_{10}\left(\dfrac{\omega_s}{\omega_p}\right)^2}$$

$$\Omega = \varepsilon^{1/n}\left(\frac{\omega}{\omega_p}\right) \Rightarrow A(\Omega) = 10.\log_{10}(1 + \Omega^{2n})$$

n	*Polinomios de Butterworth Normalizados - H(S)*
1	S + 1
2	S^2 + 1.414 S + 1
3	(S^2 + S + 1).(S + 1)
4	(S^2 + 0.765 S + 1).(S^2 + 1.848 S + 1)
5	(S + 1).(S^2 + 0.618 S + 1).(S^2 + 1.618 S + 1)
6	(S^2 + 0.517 S + 1).(S^2 + 1.414 S + 1).(S^2 + 1.932 S + 1)
7	(S + 1).(S^2 + 0.445 S + 1).(S^2 + 1.247 S + 1).(S^2 + 1.802 S + 1)
8	(S^2 + 0.39 S + 1).(S^2 + 1.111 S + 1).(S^2 + 1.663 S + 1).(S^2 + 1.962 S + 1)

n	Butterworth Polynomials
1	$s+1$
2	$s^2 + 1.414s + 1$
3	$s^3 + 2s^2 + 2s + 1$
4	$s^4 + 2.613s^3 + 3.414s^2 + 2.613s + 1$
5	$s^5 + 3.236s^4 + 5.236s^3 + 5.236s^2 + 3.236s + 1$

CHEBYSHEV

Coeficientes de los polinomios de Chebychev ($\alpha_p = 1dB$)
($\varepsilon = 0.5089$)

n	a_0	a_1	a_2	a_3	a_4
1	1.9652267				
2	1.1025103	1.0977343			
3	0.4913067	1.2384092	0.9883412		
4	0.2756276	0.7426194	1.4539248	0.9527114	
5	0.1228267	0.5805342	0.9743961	1.6888160	0.9368201

n	Chebyshev Polynomials
1	$s+1.965$
2	$s^2+1.097s+1.102$
3	$s^3+0.7378s^2+1.0222s+0.3269$
4	$s^4+0.952s^3+1.453s^2+0.742s+0.275$
5	$s^5+0.7064s^4+1.4995s^3+0.6935s^2+0.4594s+0.0817$

BESSEL

Polinomios de Bessel y ecuación de recurrencia

$B_0(p)=1$

$B_1(p)=p+1$ ➡ **Amax = 3 [dB]**

$B_2(p)=p^2+3p+3$ ➡ **Amax = 1,597 [dB]**

$B_3(p)=p^3+6p^2+15p+15$ ➡ **Amax = 0,903 [dB]**

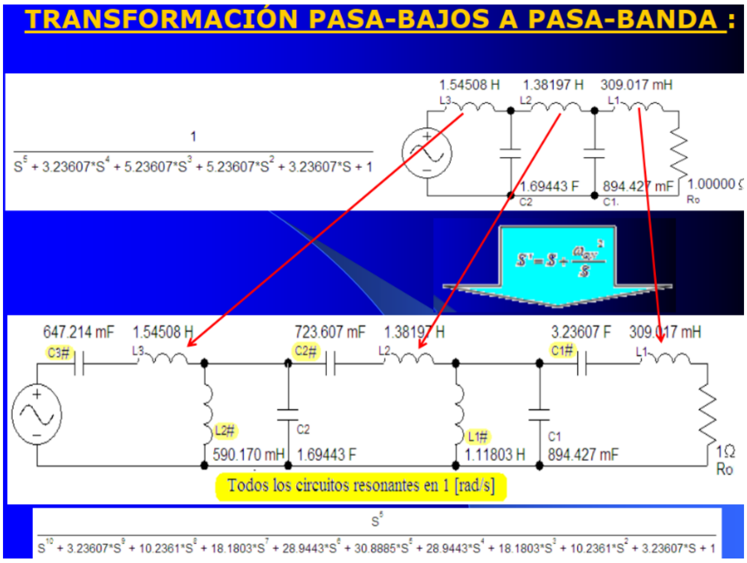
$B_4(p)=p^4+10p^3+45p^2+105p+105$ ➡ **Amax = 0,63 [dB]**

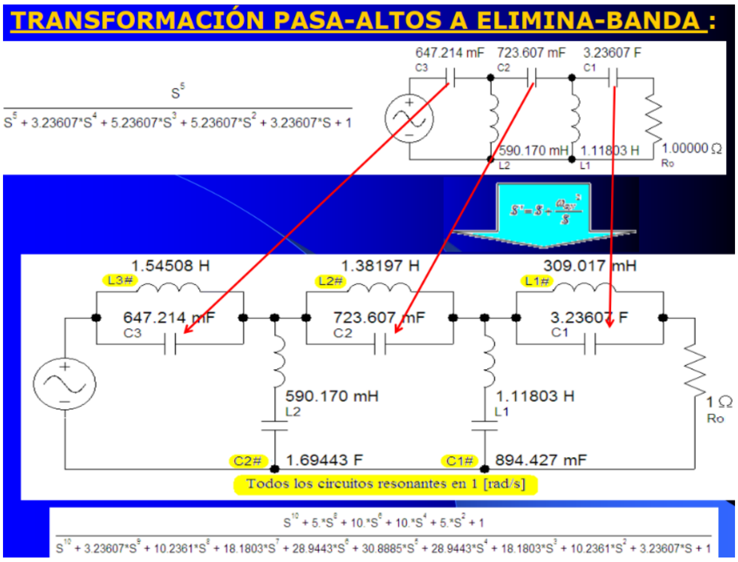
$B_5(p)=p^5+15p^4+105p^3+420p^2+945p+945$ ➡ **Amax=0,4865 [dB]**

$B_6(p)=p^6+210p^4+1260p^3+4725p^2+10395p+10395$

$\vdots$

$B_{N+1}(p)=(2N+1)B_N(p)+p^2B_{N-1}(p)$





FILTROS ACTIVOS: SALLEN-KEY

ai y bi definen el tipo de filtro (Butterworth, chebyshev, etc)

$$A(s)\Big|_{pasa-bajos} = \frac{A_O}{\left(1 + a_i S + b_i S^2\right)}$$

$$A(s)\Big|_{pasa-altos} = \frac{A_O S^2}{\left(1 + a_i S + b_i S^2\right)}$$

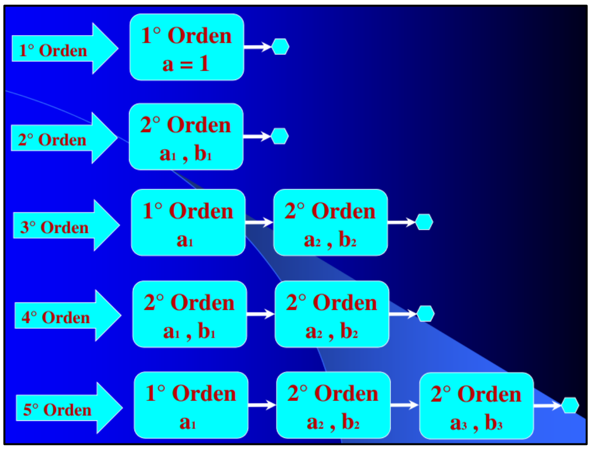
$$A(s)\Big|_{Pasa-Banda} = \frac{A_O S}{\left(1 + a_i S + b_i S^2\right)}$$

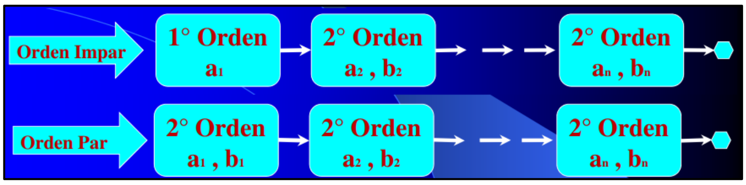
$$A(s)\Big|_{Elimina-Banda} = \frac{A_O\left(1 + c_i S + d_i S^2\right)}{\left(1 + a_i S + b_i S^2\right)}$$

$$A_O \Rightarrow \text{ganancia}$$

$$b_i \Rightarrow \omega_O^{\,2}$$

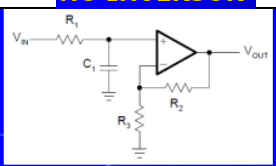
$$a_i \Rightarrow \frac{\omega_O}{Q_O} \quad \text{ó} \quad Q_O = \frac{\sqrt{b_i}}{a_i}$$





PASA BAJOS 1º ORDEN

NO INVERSOR



$$A(s) = \frac{1 + \frac{R_2}{R_3}}{1 + \omega_c R_1 C_1 s}$$

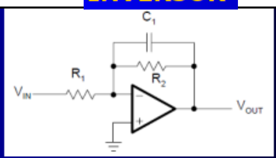
$$A_0 = 1 + \frac{R_2}{R_3}$$

$$a_1 = \omega_c R_1 C_1$$

$$R_1 = \frac{a_1}{2\pi f_c C_1}$$

$$R_2 = R_3(A_0 - 1)$$

INVERSOR



$$A(s) = \frac{-\frac{R_2}{R_1}}{1 + \omega_c R_2 C_1 s}$$

$$A_0 = -\frac{R_2}{R_1}$$

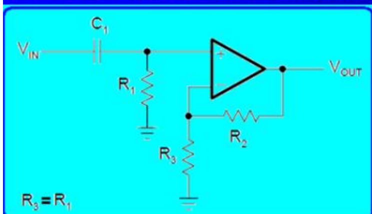
$$a_1 = \omega_c R_2 C_1$$

$$R_2 = \frac{a_1}{2\pi f_c C_1}$$

$$R_1 = -\frac{R_2}{A_0}$$

PASA ALTOS 1º ORDEN

PASA-ALTO NO INVERSOR

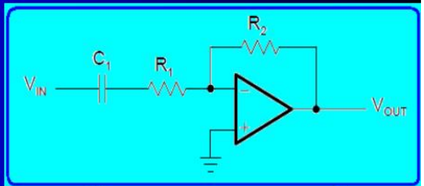


$$A(s) = \frac{1 + \frac{R_2}{R_3}}{1 + \frac{1}{\omega_c R_1 C_1}\cdot\frac{1}{s}}$$

$$A_\infty = 1 + \frac{R_2}{R_3}$$

$$R_2 = R_3(A_\infty - 1)$$

PASA-ALTO INVERSOR



$$A(s) = -\frac{\frac{R_2}{R_1}}{1 + \frac{1}{\omega_c R_1 C_1}\cdot\frac{1}{s}}$$

$$A_\infty = -\frac{R_2}{R_1}$$

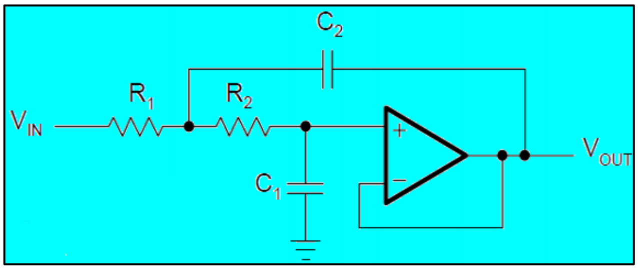
$$R_2 = -R_1 A_\infty$$

PARA AMBOS CIRCUITOS → $a_1 = \frac{1}{\omega_c R_1 C_1}$ → $R_1 = \frac{1}{2\pi f_c a_1 C_1}$

38

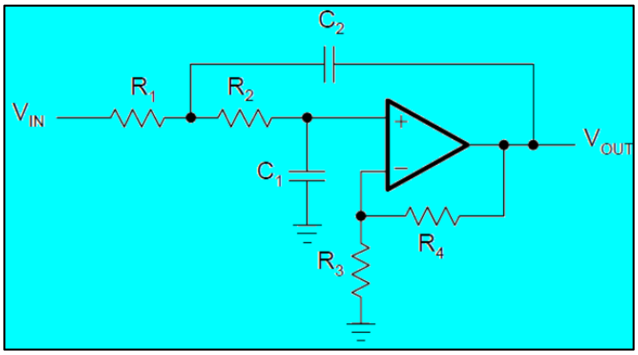
Para cualquier configuración, si la ganancia es unitaria, desaparecen R2 y R3.

SALLEN-KEY 2º ORDEN PASA BAJOS:



Ao=1

$$A(s) = \frac{1}{1 + \omega_c C_1 (R_1 + R_2)\, s + \omega_c^2 R_1 R_2 C_1 C_2 s^2}$$



Ao≠1

$$A(s) = \frac{A_0}{1 + \omega_c \left[C_1 (R_1 + R_2) + (1 - A_0) R_1 C_2\right] s + \omega_c^2 R_1 R_2 C_1 C_2 s^2}$$

<u>Método 1:</u> Se fija C1<100pF. Se calcula C2 y se toma su valor normalizado más próximo. Se calcula R1 y R2.

$$A_0 = 1$$

$$a_1 = \omega_c C_1 (R_1 + R_2)$$

$$b_1 = \omega_c^2 R_1 R_2 C_1 C_2$$

$$R_{1,2} = \frac{a_1 C_2 \mp \sqrt{a_1^2 C_2^2 - 4 b_1 C_1 C_2}}{4\pi f_c C_1 C_2}$$

$$C_2 \geq C_1 \frac{4 b_1}{a_1^2}$$

<u>Método 2:</u> Se toma [R1 = R2 = R] y [C1 = C2 = C < 100pF]

$$A(s) = \frac{A_0}{1 + \omega_c RC (3 - A_0) s + (\omega_c RC)^2 s^2}$$

$$A_0 = 1 + \frac{R_4}{R_3}$$

$$a_1 = \omega_c RC (3 - A_0)$$

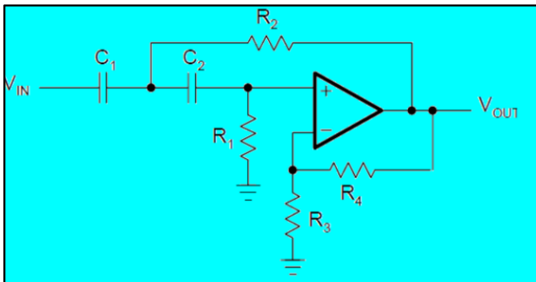
$$b_1 = (\omega_c RC)^2$$

$$R = \frac{\sqrt{b_1}}{2\pi f_c C}$$

$$Q = \frac{1}{3 - A_0} \qquad A_0 = 3 - \frac{a_1}{\sqrt{b_1}}$$

SALLEN-KEY 2º ORDEN PASA ALTOS:

Ganancia ≠ 1



$$A(s) = \frac{\alpha}{1 + \frac{R_2(C_1+C_2)+R_1C_2(1-\alpha)}{\omega_c R_1R_2C_1C_2}\cdot\frac{1}{s} + \frac{1}{\omega_c{}^2 R_1R_2C_1C_2}\cdot\frac{1}{s^2}}$$

$$\alpha = 1 + \frac{R_4}{R_3}$$

Ganancia = 1

$$A(s) = \frac{1}{1 + \frac{2}{\omega_c R_1 C}\cdot\frac{1}{s} + \frac{1}{\omega_c{}^2 R_1R_2C^2}\cdot\frac{1}{s^2}}$$

$$A_\infty = 1$$

$$a_1 = \frac{2}{\omega_c R_1 C} \qquad R_1 = \frac{1}{\pi f_c C a_1}$$

$$b_1 = \frac{1}{\omega_c{}^2 R_1 R_2 C^2} \qquad R_2 = \frac{a_1}{4\pi f_c C b_1}$$

SALLEN-KEY: cálculos de utilidad

Orden del filtro:

$$\varepsilon = \sqrt{10^{0,1.A_{\max}} - 1}$$

$$n \geq= \frac{\log_{10}\left(\frac{\delta}{\varepsilon}\right)}{\log_{10}\Omega} \geq= \frac{\log_{10}\left[\sqrt{\frac{10^{(0,1*A\min)}-1}{10^{(0,1*A\max)}-1}}\right]}{\log_{10}\frac{\omega_S}{\omega_P}} = \frac{\log_{10}\left(\frac{10^{0,1.A_{\min}}-1}{\varepsilon^2}\right)}{\log_{10}\left(\frac{\omega_s}{\omega_p}\right)^2}$$

Desnormalización de función de transferencia:

$$S = s.\left(\frac{\varepsilon^{1/n}}{\omega_p}\right)$$

Valores normalizados de componentes:

E-12 Resistor / Capacitor Values

1.0, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8, and 8.2; multiplied by the decade value.

Normalización de componentes de un filtro S-K: (ωp=1 rad/s | Rn=1 Ω | Qp=√1/2)

$$K = 1 \qquad R1 = R2 = 1\,\Omega$$

$$C_1 = \frac{2\ \ Q_P}{\omega_P} \qquad C_2 = \frac{1}{2\ \ Q_P\ \ \omega_P}$$

Desnormalización de componentes de un filtro S-K ya diseñado (datos: ωc=ωp y R=Rx)

$$Rx = Rn * R_{TABLA}$$

$$Cx = \frac{Cn}{\omega_P * Rx} = \frac{Cn}{2*\pi*f_P*Rx}$$

TABLAS DE COEFICIENTES

Butterworth

n	i	a_i	b_i	$k_i = f_{Ci} / f_C$	Q_i
1	1	1.0000	0.0000	1.000	—
2	1	1.4142	1.0000	1.000	0.71
3	1	1.0000	0.0000	1.000	—
	2	1.0000	1.0000	1.272	1.00
4	1	1.8478	1.0000	0.719	0.54
	2	0.7654	1.0000	1.390	1.31
5	1	1.0000	0.0000	1.000	—
	2	1.6180	1.0000	0.859	0.62
	3	0.6180	1.0000	1.448	1.62

Tschebyscheff 1-dB

n	i	a_i	b_i	$k_i = f_{Ci} / f_C$	Q_i
1	1	1.0000	0.0000	1.000	—
2	1	1.3022	1.5515	1.000	0.96
3	1	2.2156	0.0000	0.451	—
	2	0.5442	1.2057	1.353	2.02
4	1	2.5904	4.1301	0.540	0.78
	2	0.3039	1.1697	1.417	3.56
5	1	3.5711	0.0000	0.280	—
	2	1.1280	2.4896	0.894	1.40
	3	0.1872	1.0814	1.486	5.56

Tschebyscheff 2-dB

n	i	a_i	b_i	$k_i = f_{Ci} / f_C$	Q_i
1	1	1.0000	0.0000	1.000	—
2	1	1.1813	1.7775	1.000	1.13
3	1	2.7994	0.0000	0.357	—
	2	0.4300	1.2036	1.378	2.55
4	1	2.4025	4.9862	0.550	0.93
	2	0.2374	1.1896	1.413	4.59
5	1	4.6345	0.0000	0.216	—
	2	0.9090	2.6036	0.908	1.78
	3	0.1434	1.0750	1.493	7.23

Tschebyscheff 3-dB

n	i	a_i	b_i	$k_i = f_{Ci} / f_C$	Q_i
1	1	1.0000	0.0000	1.000	—
2	1	1.0650	1.9305	1.000	1.30
3	1	3.3496	0.0000	0.299	—
	2	0.3559	1.1923	1.396	3.07
4	1	2.1853	5.5339	0.557	1.08
	2	0.1964	1.2009	1.410	5.58
5	1	5.6334	0.0000	0.178	—
	2	0.7620	2.6530	0.917	2.14
	3	0.1172	1.0686	1.500	8.82

Tschebyscheff 0.5-dB

n	i	a_i	b_i	$k_i = f_{Ci} / f_C$	Q_i
1	1	1.0000	0.0000	1.000	—
2	1	1.3614	1.3827	1.000	0.86
3	1	1.8636	0.0000	0.537	—
	2	0.0640	1.1931	1.335	1.71
4	1	2.6282	3.4341	0.538	0.71
	2	0.3648	1.1509	1.419	2.94
5	1	2.9235	0.0000	0.342	—
	2	1.3025	2.3534	0.881	1.18
	3	0.2290	1.0833	1.480	4.54

Bessel

n	i	a_i	b_i	$k_i = f_{Ci} / f_C$	Q_i
1	1	1.0000	0.0000	1.000	—
2	1	1.3617	0.6180	1.000	0.58
3	1	0.7560	0.0000	1.323	—
	2	0.9996	0.4772	1.414	0.69
4	1	1.3397	0.4889	0.978	0.52
	2	0.7743	0.3890	1.797	0.81
5	1	0.6656	0.0000	1.502	—
	2	1.1402	0.4128	1.184	0.56
	3	0.6216	0.3245	2.138	0.92