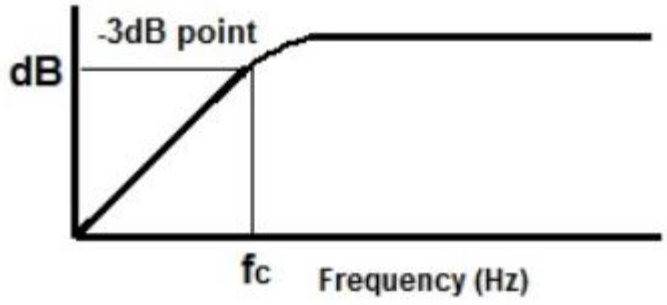
FILTRO BUTTERWORTH PASA-ALTAS



1. Pasa-Altas orden 7 (Método de normalización por capacitores iguales)

$Ap = 3\ dB \qquad fp = 100\ Hz \qquad As = 75\ dB \qquad fs = 25\ Hz$

Cálculos:

$$n = \frac{\log\left(\frac{\epsilon_2}{\epsilon_1}\right)}{\log\left(\frac{fp}{fs}\right)} = \frac{\log\left(\frac{5623.41}{0.99}\right)}{\log\left(\frac{100\ Hz}{25\ Hz}\right)} = 6.23 \approx 7$$

$$\epsilon_1 = \sqrt{10^{0.1*A_p} - 1} = \sqrt{10^{0.1*(3dB)} - 1} = 0.99$$

$$\epsilon_2 = \sqrt{10^{0.1*A_s} - 1} = \sqrt{10^{0.1*(75dB)} - 1} = 5623.41$$

Se propone el valor de los capacitores iguales, C = 15 nF

$$R_n = \frac{1}{2\pi C f_p} = \frac{1}{2\pi(15\ nF)(100\ Hz)}$$

$$R_n = 106\ k\Omega$$

Tabla 13.2 Valores para pasa-bajas activo Butterworth.*

Orden n	$C_1=C$ o $R=R_1$	$C_2=C$ o $R=R_2$	$C_3=C$ o $R=R_3$
2	1.414	0.7071	
3	3.546	1.392	0.2024
4	1.082	0.9241	
	2.613	0.3825	
5	1.753	1.354	0.4214
	3.235	0.3090	
6	1.035	0.9660	
	1.414	0.7071	
	3.863	0.2588	
7	1.531	1.336	0.4885
	1.604	0.6235	
	4.493	0.2225	
8	1.020	0.9809	
	1.202	0.8313	
	1.800	0.5557	
	5.125	0.1950	
9	1.455	1.327	0.5170
	1.305	0.7661	
	2.000	0.5000	
	5.758	0.1736	
10	1.012	0.9874	
	1.122	0.8908	
	1.414	0.7071	
	2.202	0.4540	
	6.390	0.1563	

Tabla 1 *"Valores Butterworth"*

$$R_1 = \frac{R_n}{1.531} = 69.23\ k\Omega$$

$$R_2 = \frac{R_n}{1.336} = 79.34\ k\Omega$$

$$R_3 = \frac{R_n}{0.4885} = 216.99\ k\Omega$$

$$R_4 = \frac{R_n}{1.604} = 66.08\ k\Omega$$

$$R_5 = \frac{R_n}{0.6235} = 170\ k\Omega$$

$$R_6 = \frac{R_n}{4.493} = 23.59\ k\Omega$$

$$R_7 = \frac{R_n}{0.2225} = 476.4\ k\Omega$$

Simulación:

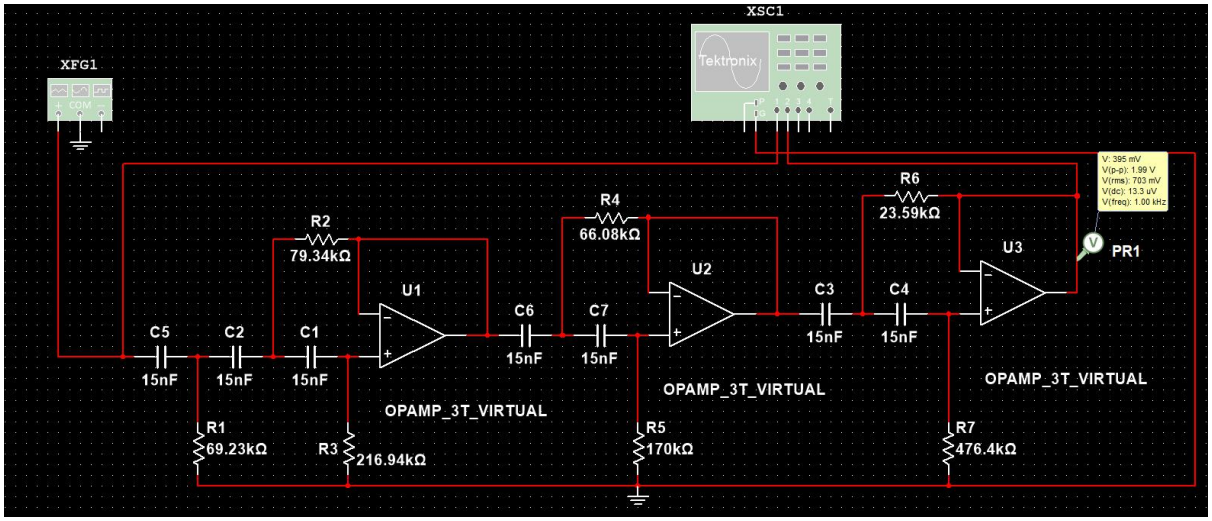


Fig. 1 "Circuito filtro Pasa-Altas orden 7"

Analisis de Voltaje en función de la frecuencia:

Canal 1 (Amarillo): Señal de entrada, Canal 2 (Azul): Señal de salida

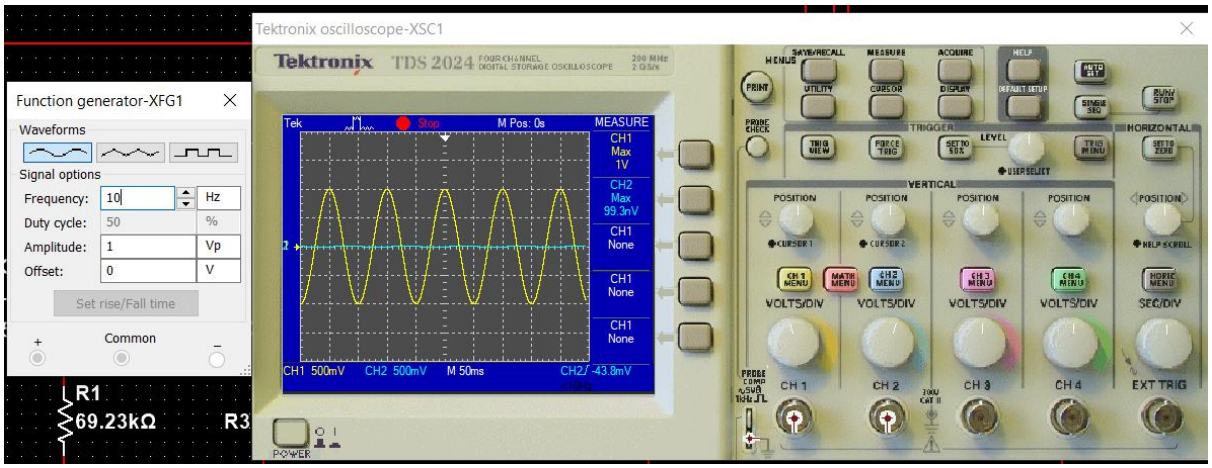


Fig. 2 "Señal Entrada/Salida a 10 Hz (Antes de fc)"

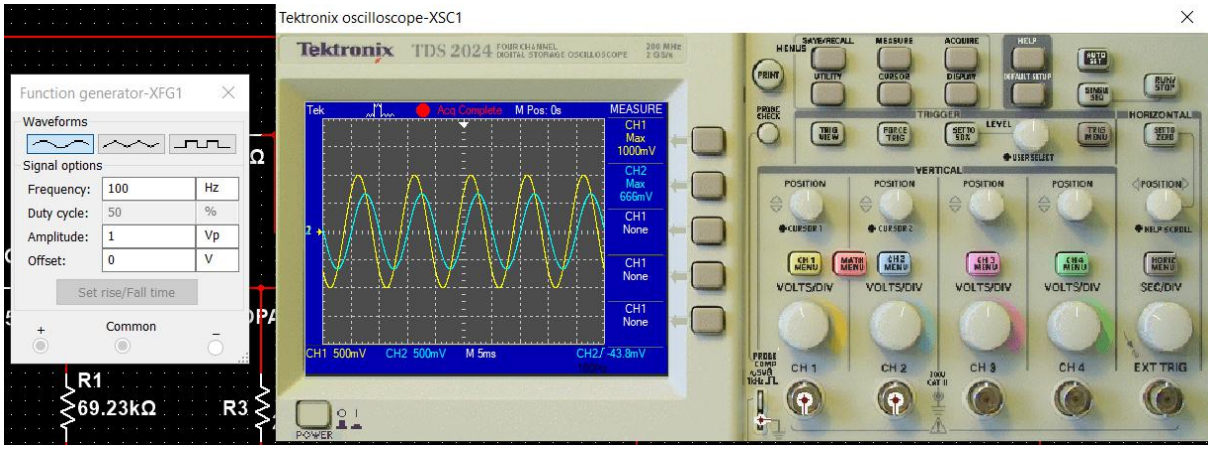


Fig. 3 "Señal Entrada/Salida a 100 Hz (fc)"

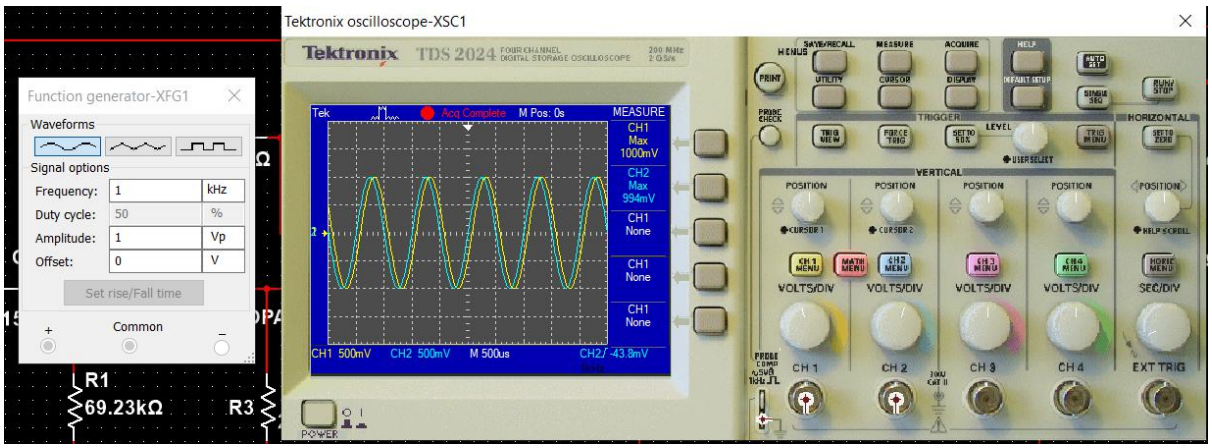


Fig. 4 "Señal Entrada/Salida a 1 kHz (Después de fc)"

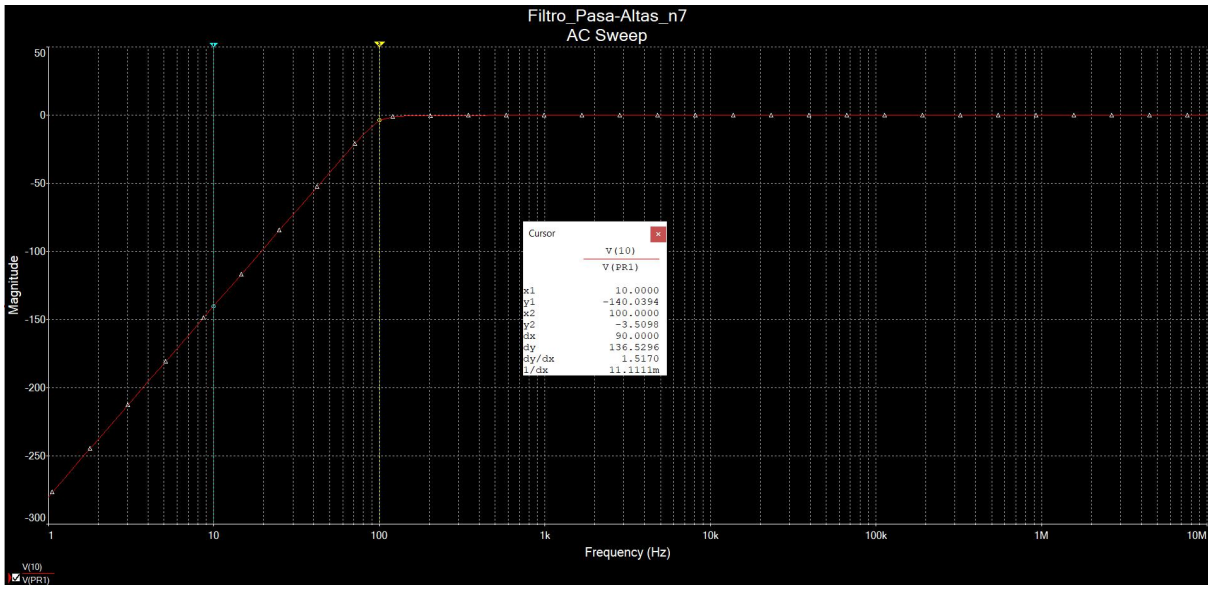


Fig. 5 "Diagrama de Bode"

2. *Pasa-Altas orden 2 (Componentes diferentes)*

$C = 4.7\ nF$ $R_2 = 12\ k\Omega$ $R_1 = 24\ k\Omega$ $A_v = 1$

Cálculos:

$$Q = 0.5\sqrt{\frac{R_1}{R_2}} = 0.5\sqrt{\frac{24\ k\Omega}{12\ k\Omega}} = 0.707 \quad \text{(Filtro Butterworth)}$$

$$f_p = \frac{1}{2\pi C\sqrt{R_1 R_2}} = \frac{1}{2\pi\sqrt{(24\ k\Omega)(12\ k\Omega)}} = 1.99\ kHz$$

$$f_p = f_c$$

Q	K_0	K_c	K_3	A_p(dB)
0,577	—	0,786	1	—
0,707	—	1	1	—
0,75	0,333	0,471	1,057	0,054
0,8	0,467	0,661	1,115	0,213
0,9	0,620	0,874	1,206	0,688
1	0,708	1,000	1,272	1,25
2	0,935	1,322	1,485	6,3
3	0,972	1,374	1,523	9,66
4	0,984	1,391	1,537	12,1
5	0,990	1,400	1,543	14
6	0,992	1,402	1,546	15,6
7	0,994	1,404	1,548	16,9
8	0,995	1,406	1,549	18
9	0,997	1,408	1,550	19
10	0,998	1,410	1,551	20
100	1,000	1,414	1,554	40

Tabla 2 "Valores de Q"

Simulación:

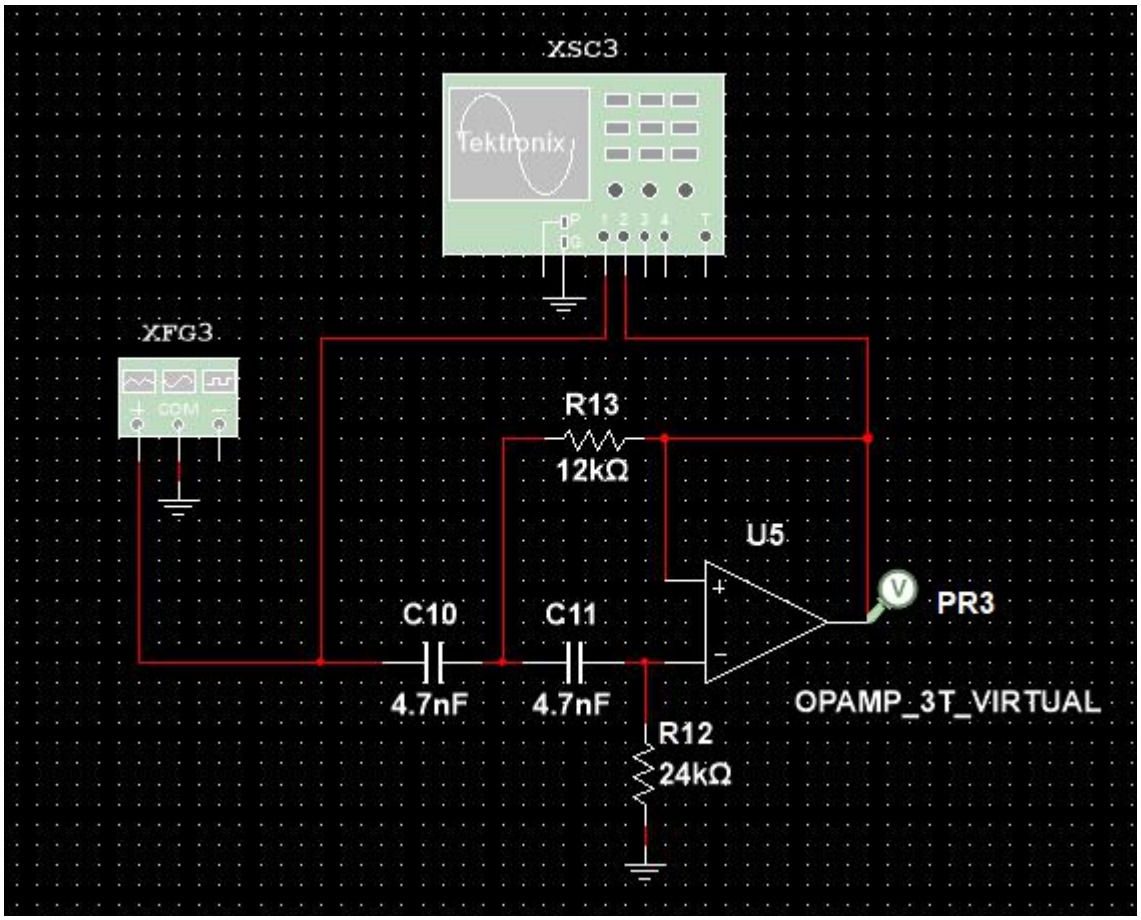


Fig. 6 "Circuito filtro Pasa-Altas orden 2 (Componentes iguales)"

Analisis de Voltaje en función de la frecuencia:

Canal 1 (Amarillo): Señal de entrada, Canal 2 (Azul): Señal de salida

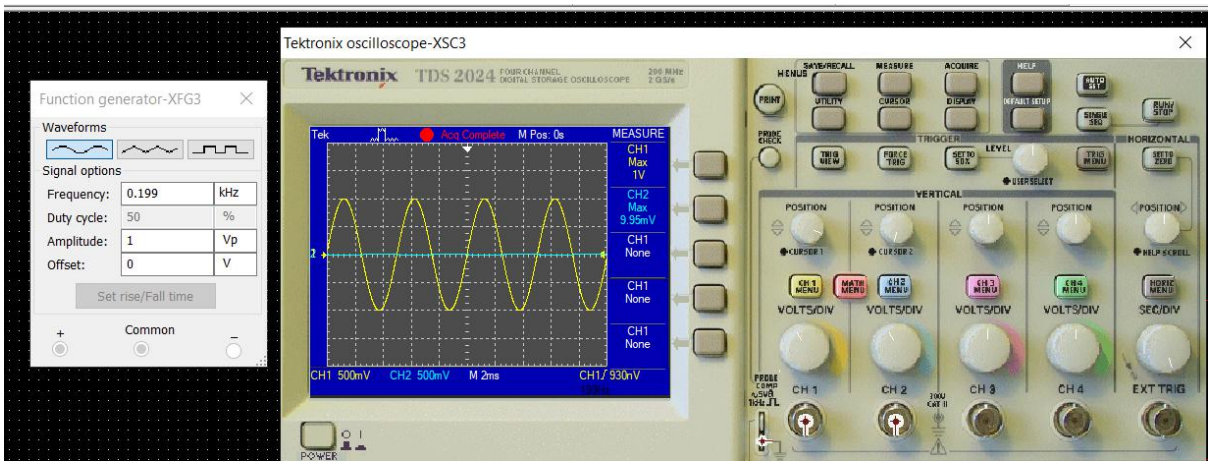


Fig. 6 "Señal Entrada/Salida a 199 Hz (Antes de fc)"

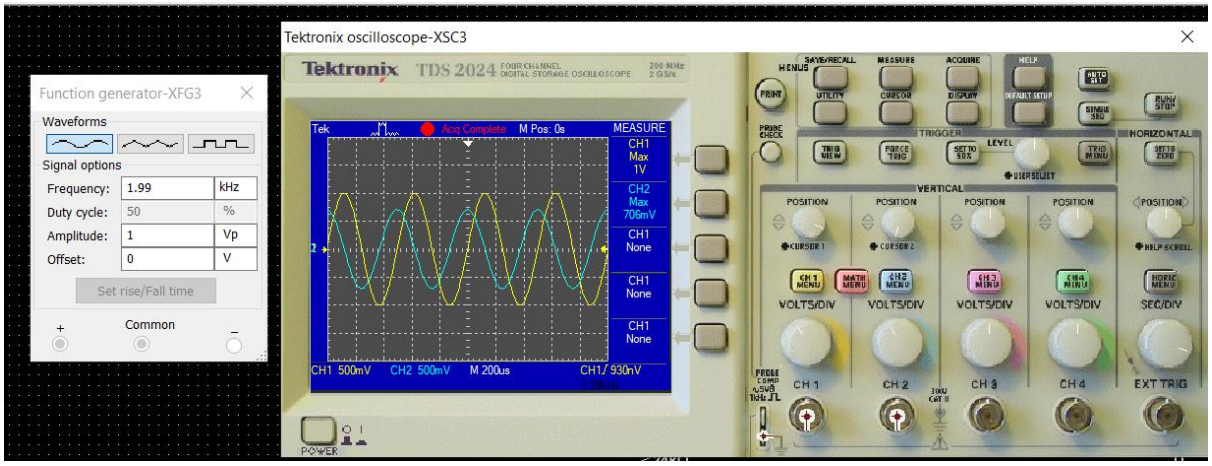


Fig. 7 "Señal Entrada/Salida a 1.99 kHz (fc)"

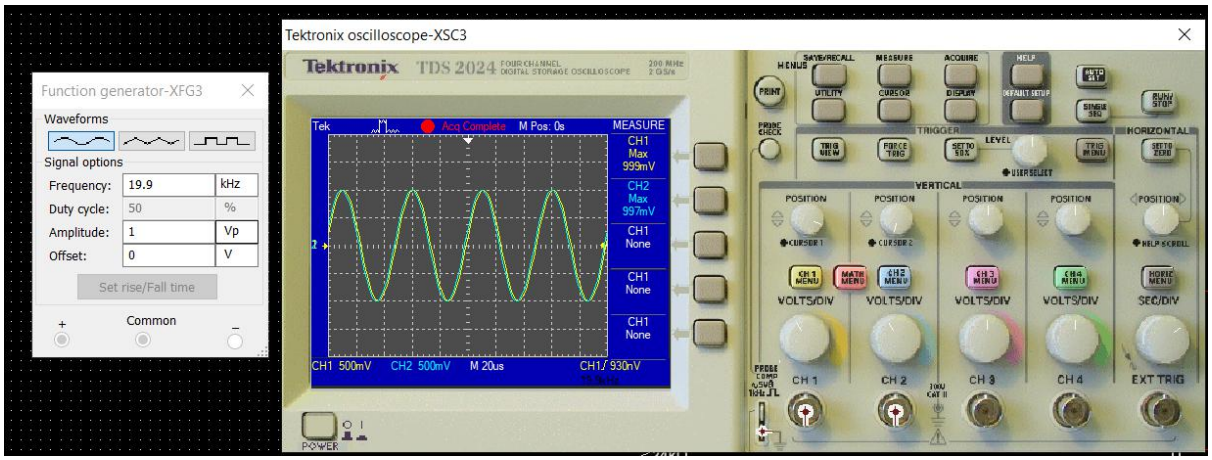


Fig. 8 "Señal Entrada/Salida a 19.9 kHz (Después de fc)"

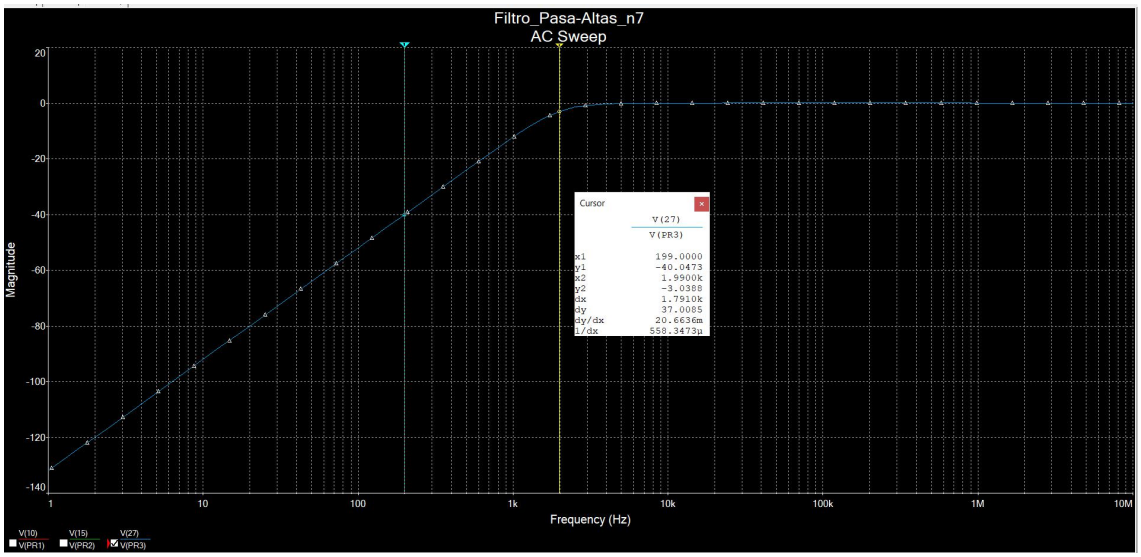


Fig. 9 "Diagrama de Bode"

3. *Pasa-Altas (Componentes iguales)*

Filtro Butterworth $Q = 0.707$ $f_p = 1.5\ k\Omega$

Cálculos:

$$Q = \frac{1}{3 - A_v} \quad \Rightarrow \quad A_v = 3 - \frac{1}{Q} \quad = \quad 3 - \frac{1}{0.707} \quad = \quad 1.58$$

Se propone $R_1 = 10\ k\Omega$

$$A_v = \frac{R_2}{R_1} + 1 \quad \Rightarrow \quad R_2 = (A_v - 1)R_1 \quad = \quad (1.58 - 1)(10\ k\Omega) \quad = \quad 5.8\ k\Omega$$

Se propone $R = 270\ k\Omega$

$$f_p = \frac{1}{2\pi RC} \quad \Rightarrow \quad C = \frac{1}{2\pi R f_p} \quad = \quad \frac{1}{2\pi(270\ k\Omega)(1.5\ kHz)} \quad = \quad 0.39\ nF$$

Se vuelve a calcular f_p *con la R propuesta y la C calculada*

$$f_p = \frac{1}{2\pi RC} \quad = \quad \frac{1}{2\pi(270\ k\Omega)(0.39\ nF)} \quad = \quad 1511.44\ Hz$$

Q	K_0	K_c	K_3	A_p(dB)
0,577	—	0,786	1	—
0,707	—	1	1	—
0,75	0,333	0,471	1,057	0,054
0,8	0,467	0,661	1,115	0,213
0,9	0,620	0,874	1,206	0,688
1	0,708	1,000	1,272	1,25
2	0,935	1,322	1,485	6,3
3	0,972	1,374	1,523	9,66
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5	0,990	1,400	1,543	14
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7	0,994	1,404	1,548	16,9
8	0,995	1,406	1,549	18
9	0,997	1,408	1,550	19
10	0,998	1,410	1,551	20
100	1,000	1,414	1,554	40

Tabla 3 "Valores de Q"

Simulación:

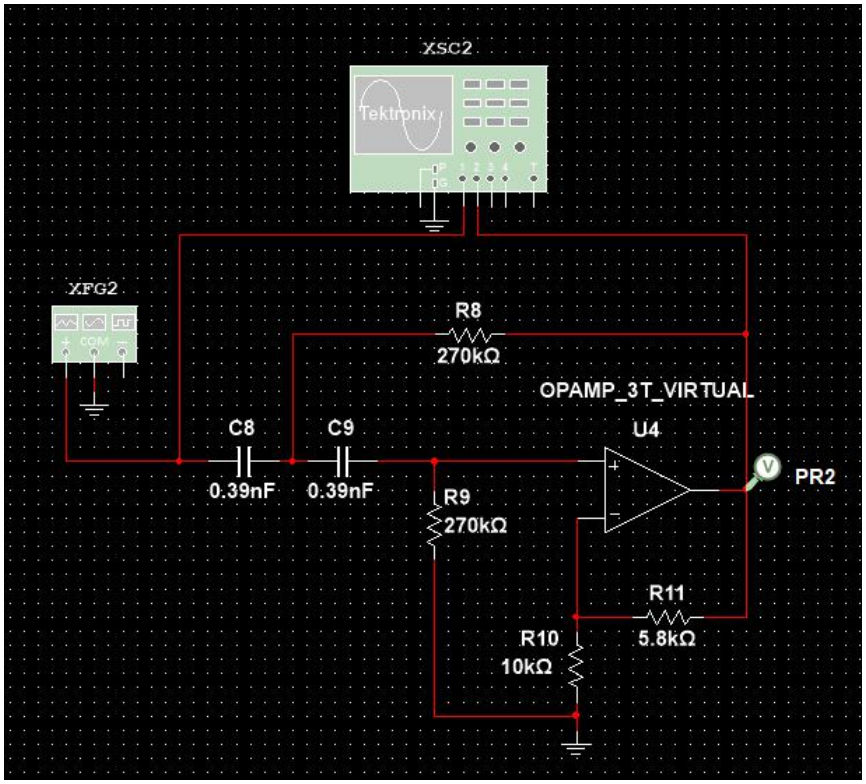

Fig. 10 "Circuito filtro Pasa-Altas orden 2 (Componentes diferentes)"

Analisis de Voltaje en función de la frecuencia:

Canal 1 (Amarillo): Señal de entrada, Canal 2 (Azul): Señal de salida

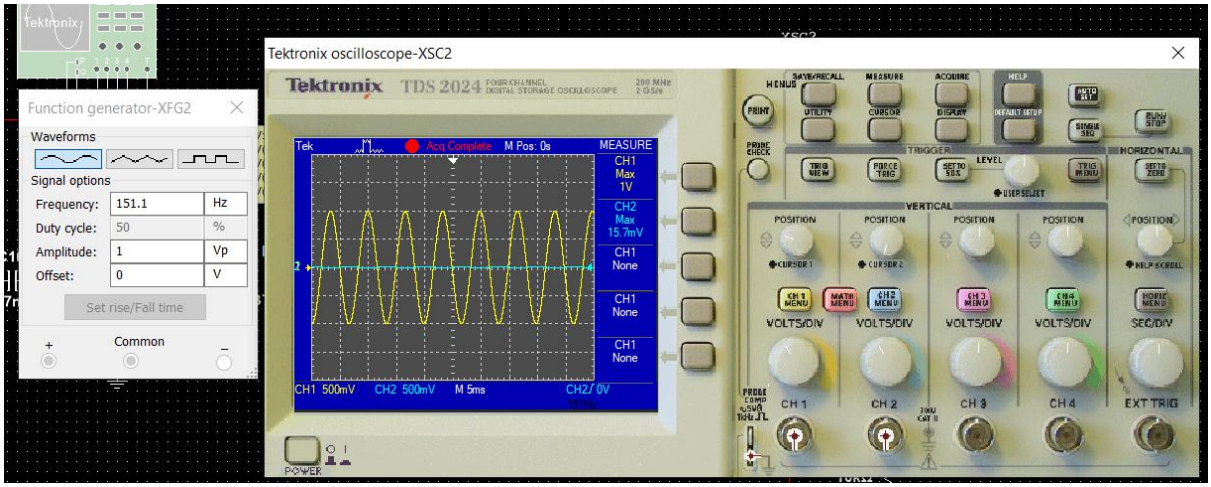

Fig. 11 "Señal Entrada/Salida a 151.1 Hz (Antes de fc)"

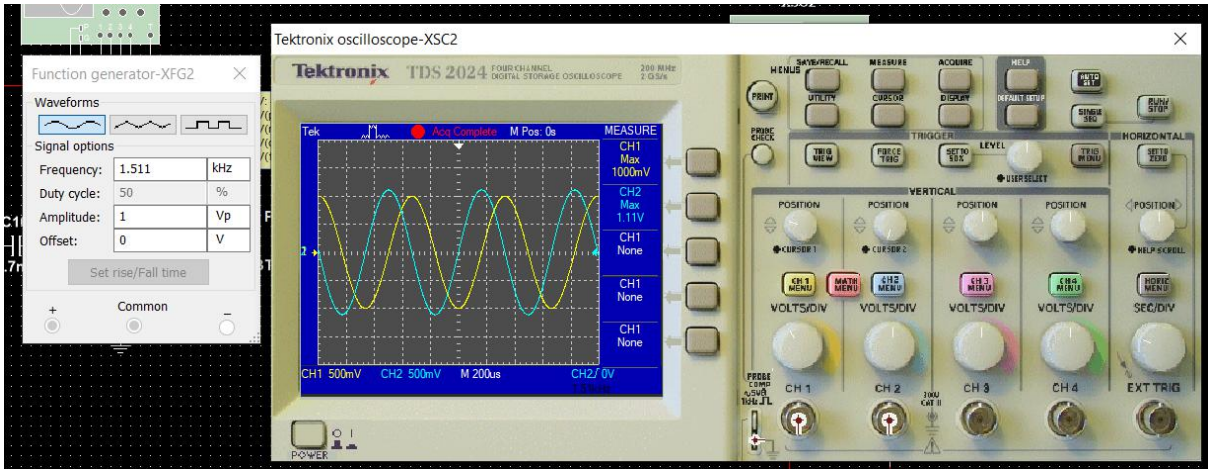

Fig. 12 "Señal Entrada/Salida a 1.51 kHz (fc)"

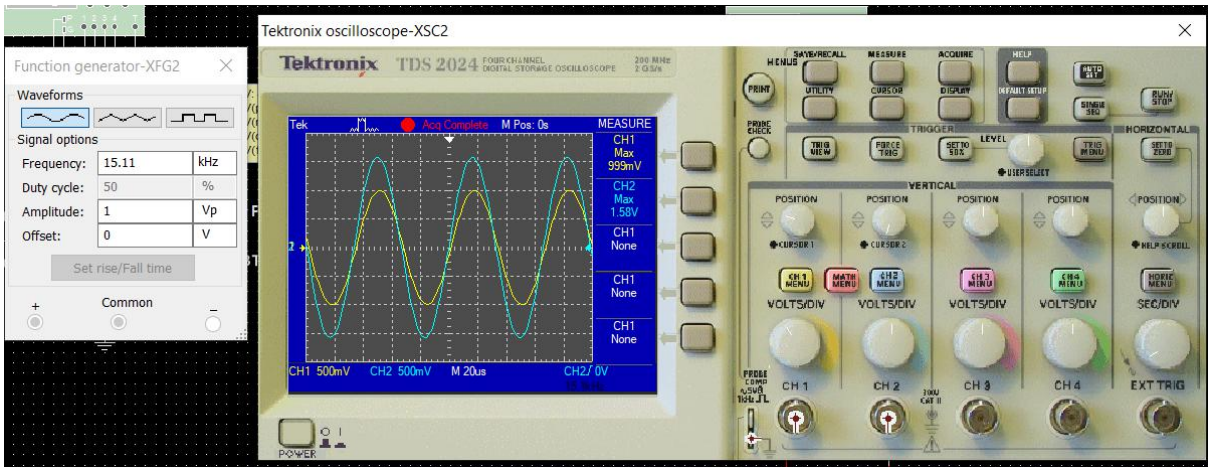

Fig. 13 "Señal Entrada/Salida a 15.1 kHz (Después de fc)"

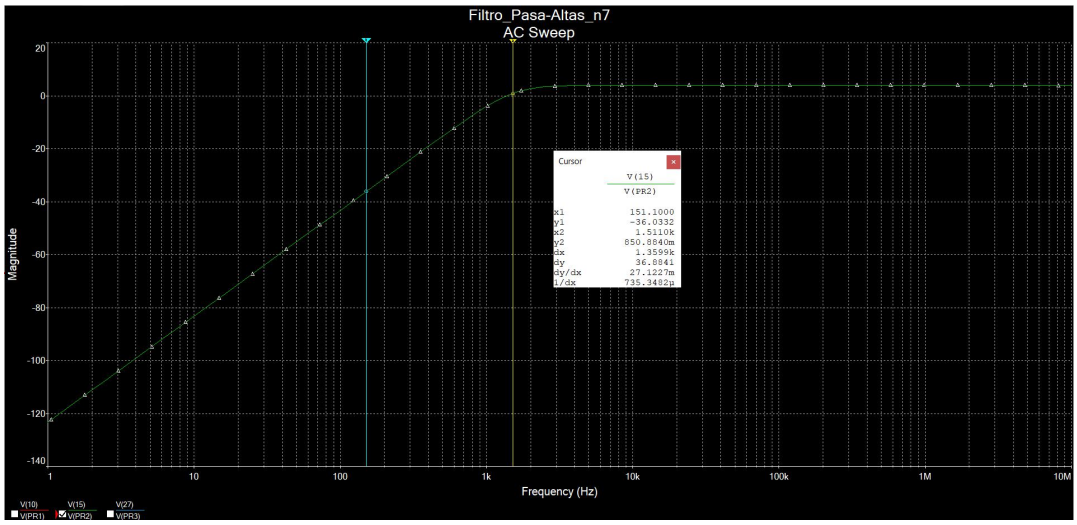

Fig. 14 "Diagrama de Bode"