

DFE, DFES, and DFE+AP Crossovers

Charlie Laub – May 2024

Nomenclature: Due to the large palette of DFE crossovers a nomenclature has been created to help identify the salient features within the filter name itself, using the following form:

[ORDER][TYPE]_[STOPBAND_FREQUENCY]_A[STOPBAND_DEPTH]_P[PHASE_ANGLE_AT_Fc]

ORDER is the order of the highpass and lowpass filters used to construct the crossover.

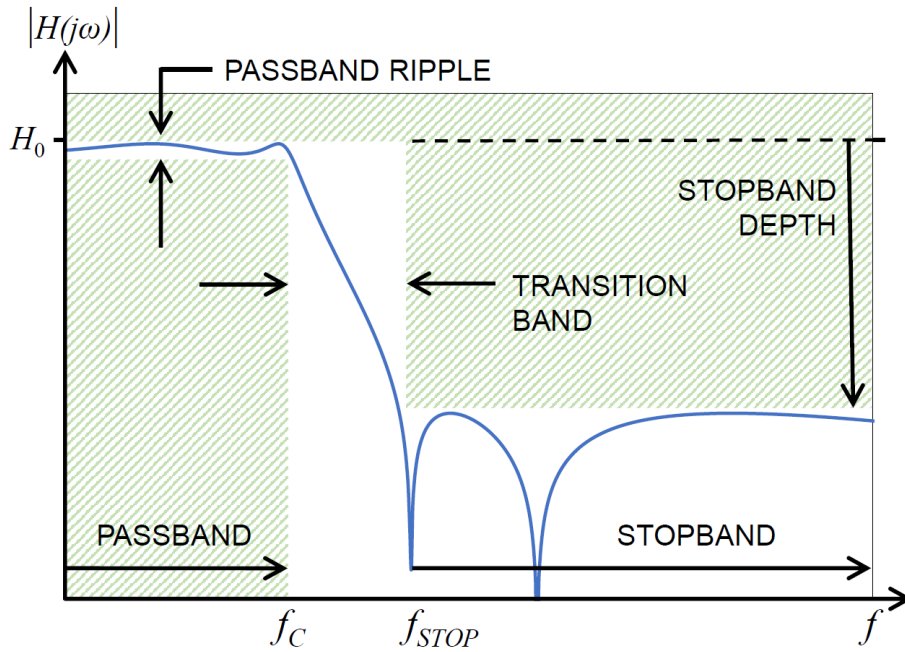
TYPE can consist of Derived from Elliptic (DFE), DFE Squared (DFES), and All-Pole plus DFE (AP-DFE).

STOPBAND_FREQUENCY is the frequency at which the stopband region begins, f_{stop} , normalized by F_c , for the lowpass filter

STOPBAND_DEPTH is the attenuation below which the response remains in the stopband

PHASE_ANGLE_AT_Fc is the relative phase angle between lowpass and highpass crossover filters at the crossover frequency.

The stopband depth and stopband frequency are illustrated in the figure below for a lowpass filter.



DFE filters make extensive use of second order highpass and lowpass notch filters. The continuous-time notch filter transfer function takes the following form:

$$H(s) = H_0 \cdot \frac{s^2 + \omega_z^2}{s^2 + \frac{\omega_p}{Q} s + \omega_p^2}$$

The symbol ω refers to the frequency in radians, where $\omega = 2\pi F$ and F is the frequency in Hertz. Note that the pole and zero frequencies, ω_p and ω_z , may take on different values. When $\omega_p < \omega_z$ the response shape is termed a lowpass notch (LPN). When $\omega_p > \omega_z$, the response shape is termed a highpass notch (HPN). H_0 sets the gain at high frequencies.

Each crossover found in this document can be implemented using the filters listed in its filter table. An example of a filter table is shown below:

Filters:	LP	LPN	LPN		HP(+)	HPN	HPN	
gain [dB]:	0.000	-5.710	-14.931		0.000	0.000	0.000	
Fp/Fc:	0.7709	1.1340	0.9986		1.2973	0.8819	1.0014	
Qp:		1.262	1.501			1.262	1.501	
Fz/Fc:		1.5752	2.3586			0.6348	0.4240	

The Nth order crossovers described herein are formed from Nth order lowpass and Nth order highpass responses, each expressed as a set of first and second order filters, and there is one filter per column in the table. The column header describes the type of filter, where:

LPN indicates a second order lowpass notch filter

LP indicates a first order lowpass filter

LP2 indicates a second order lowpass filter.

HPN indicates a second order highpass notch filter

HP indicates a first order highpass filter

HP2 indicates a second order highpass filter.

The example table above is for a 5th order crossover with the lowpass or highpass sections consisting of a first order LP or HP filter plus two second order notch filters LPN or HPN.

The filter tables show the pole and zero frequencies Fp and Fz normalized by the crossover frequency F_c. Multiply the values shown by the desired crossover frequency F_c in Hertz to obtain the corresponding Fp and Fz frequencies.

The overall polarity of the set of highpass filters is indicated by adding (+) for normal polarity or (–) for reversed polarity next to the first filter in the set. This polarity must be obeyed in order to ensure that highpass and lowpass responses sum to the proper level, e.g. 0dB. The set of lowpass filters always uses normal polarity overall.

Filter gain for each lowpass notch filter is shown in the table and corresponds to the factor H₀ of the continuous-time (analog domain) transfer function. These gains are needed to make the passband gain of the lowpass notch filter equal to 0dB. The gain for highpass notch filters is always 0dB. Note that when implementing the notch as an IIR digital filter, the LPN gain correction must be calculated using pre-warped frequencies and will be different from that shown in the tables, depending on the values of F_p, F_z, and F_s. The IIR gain correction is:

$$40 \log_{10} \left(\tan(\pi F_p/F_s) / \tan(\pi F_z/F_s) \right)$$

where F_s is the sampling rate. The author is indebted to Dr. Ulrich Brüggemann for his advice regarding this formula.

NOTES:

Units and Labels: The x-axis in all plots is the frequency in Hertz. The y-axis of the crossover sum and lowpass response plots is in Decibels. The y-axis for the phase plot is Degrees. The y-axis for group delay plots is in seconds. 1 millisecond = 0.001 seconds.

The corner or crossover frequency in all plots is 1k Hz.

The group delay for a variety of Butterworth and Linkwitz-Riley crossovers is provided at the end of the document. These may be used as a basis for comparison against the group delay of DFE crossovers.

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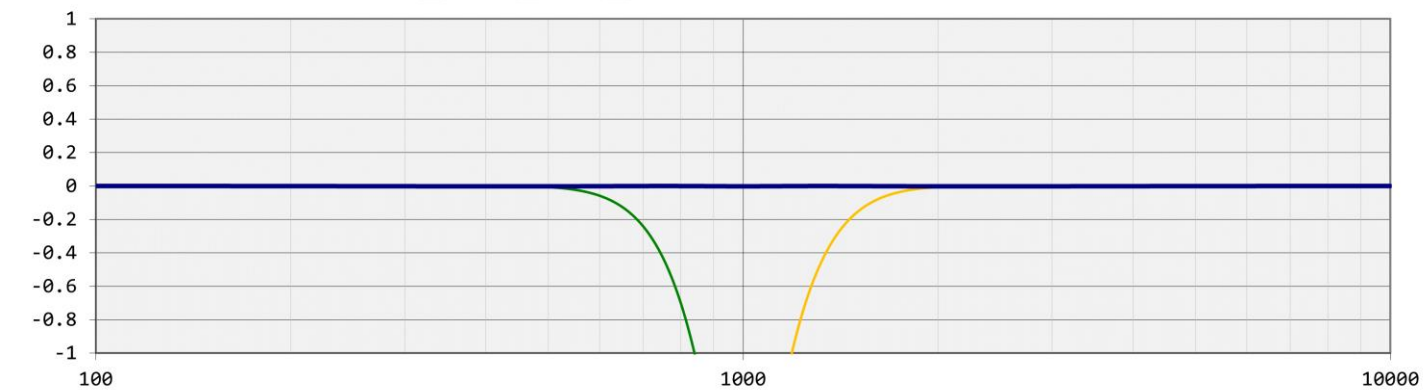
Crossover 3DFE_2.02_A30_P90:

Filters used to construct the 3DFE_2.02_A30_P90 Crossover:

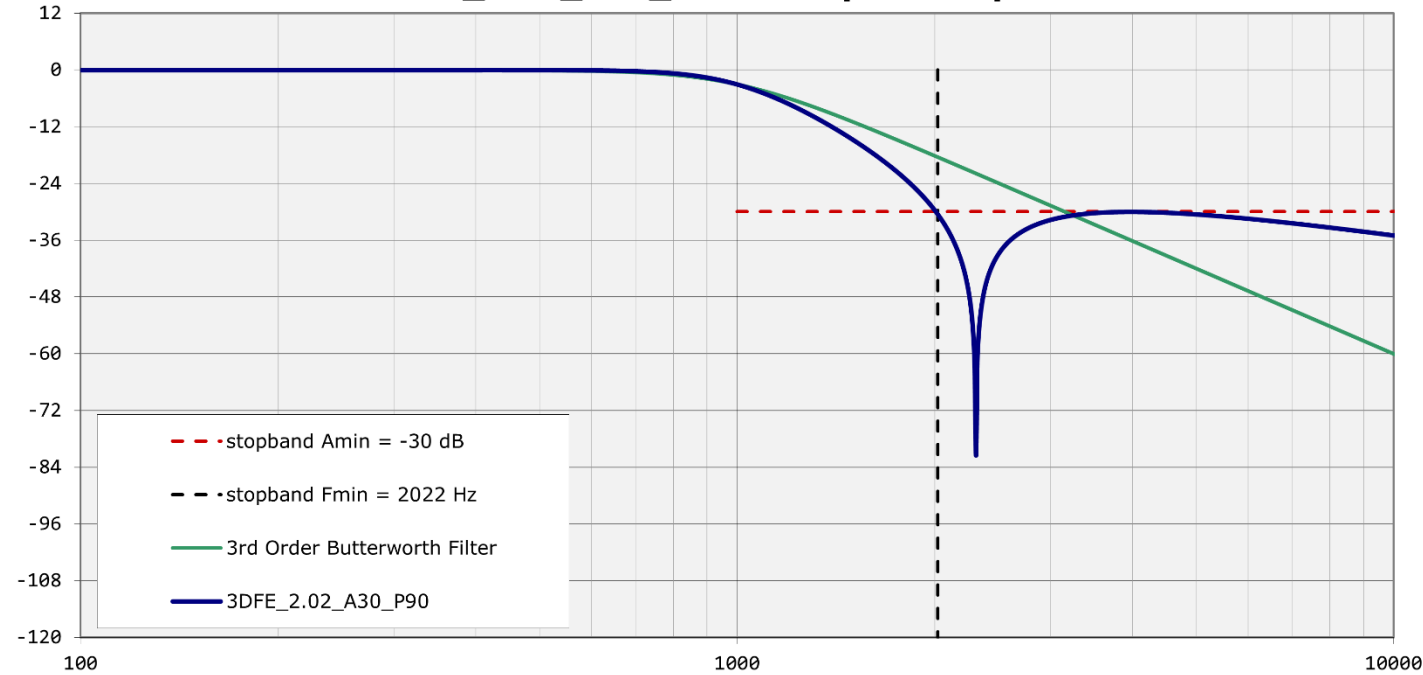
Filters:	LP	LPN			HP(-)	HPN		
gain [dB]:	0.000	-14.551			0.000	0.000		
Fp/Fc:	1.0040	1.0000			0.9960	1.0000		
Qp:		1.226				1.226		
Fz/Fc:		2.3109				0.4327		

Response Plots for the Crossover may be found below.

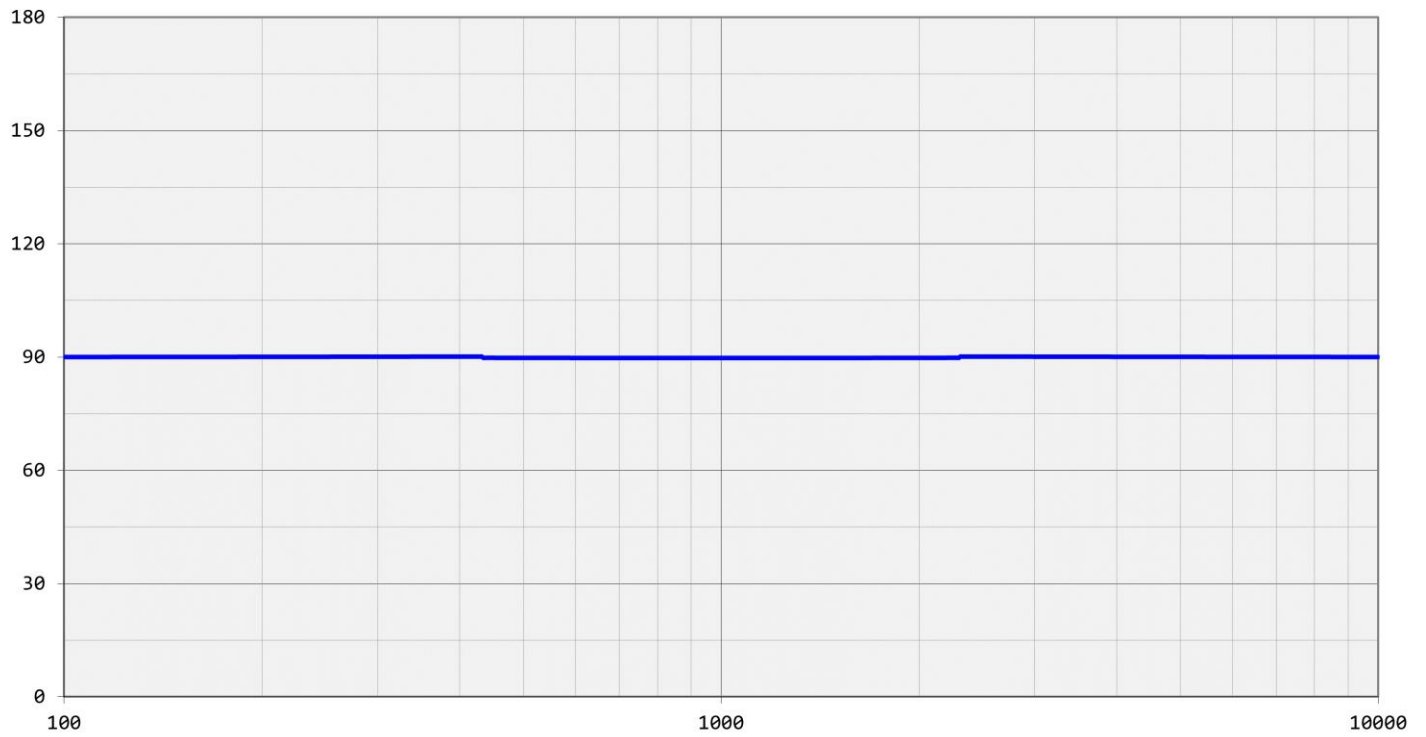
3DFE_2.02_A30_P90 : Sum of HP and LP filters



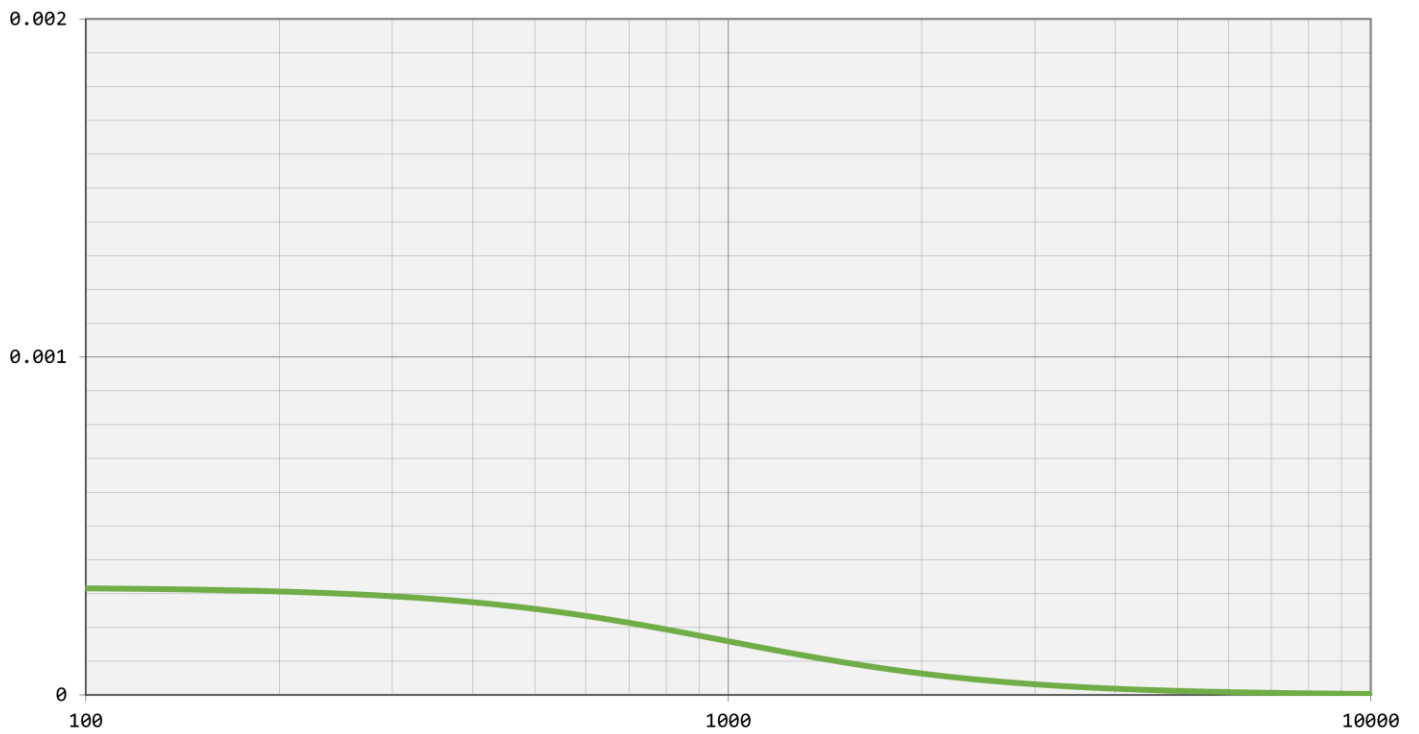
3DFE_2.02_A30_P90 : Lowpass Response



3DFE_2.02_A30_P90 : Relative Phase Angle in Degrees



3DFE_2.02_A30_P90 : Group Delay for Fc = 1k Hz



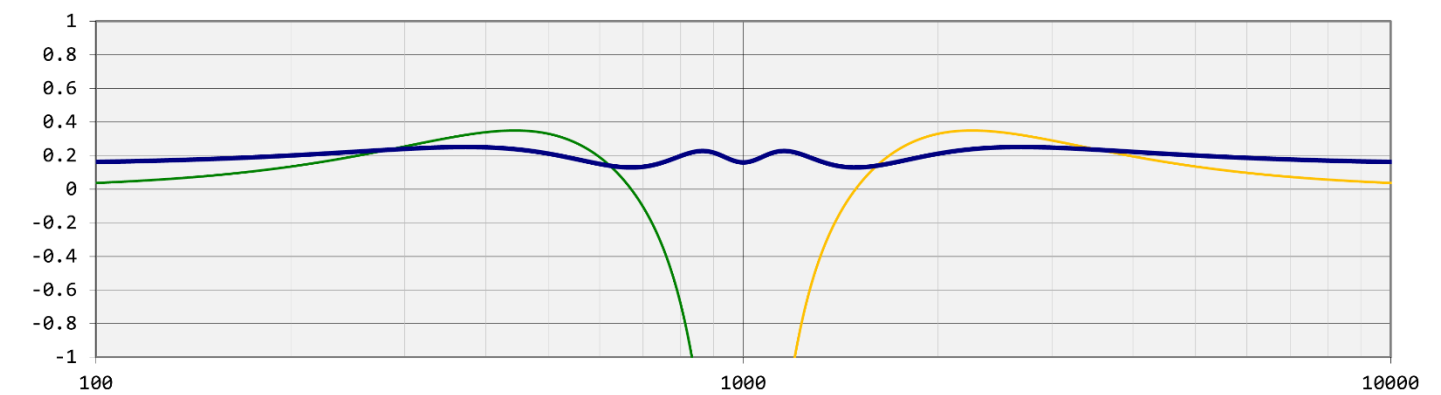
Crossover 4DFE_1.51_A36_P53:

Filters used to construct the 4DFE_1.51_A36_P53 Crossover:

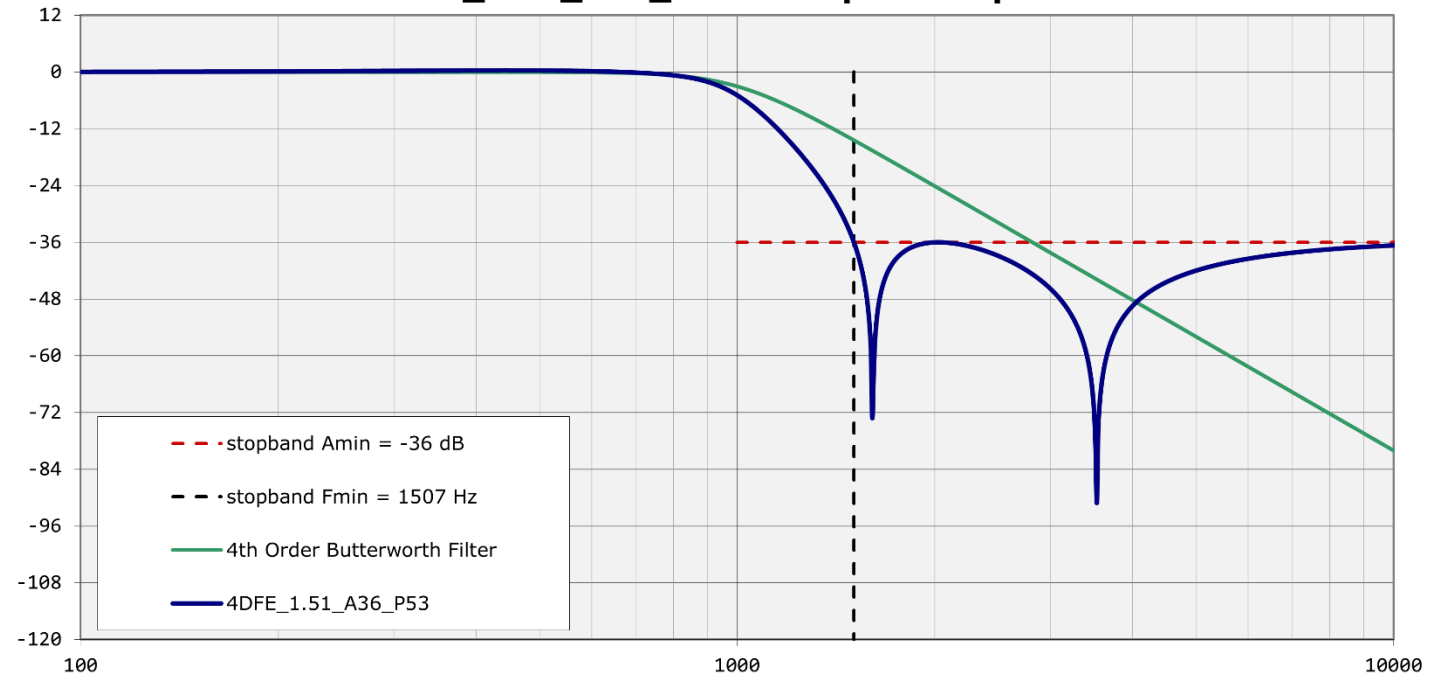
Filters:	LPN				HPN(+)			
gain [dB]:	-8.631	-26.714			0.000	0.000		
Fp/Fc:	0.9789	0.7581			1.0216	1.3191		
Qp:	2.087	0.703			2.087	0.703		
Fz/Fc:	1.6089	3.5284			0.6216	0.2834		

Response Plots for the Crossover may be found below.

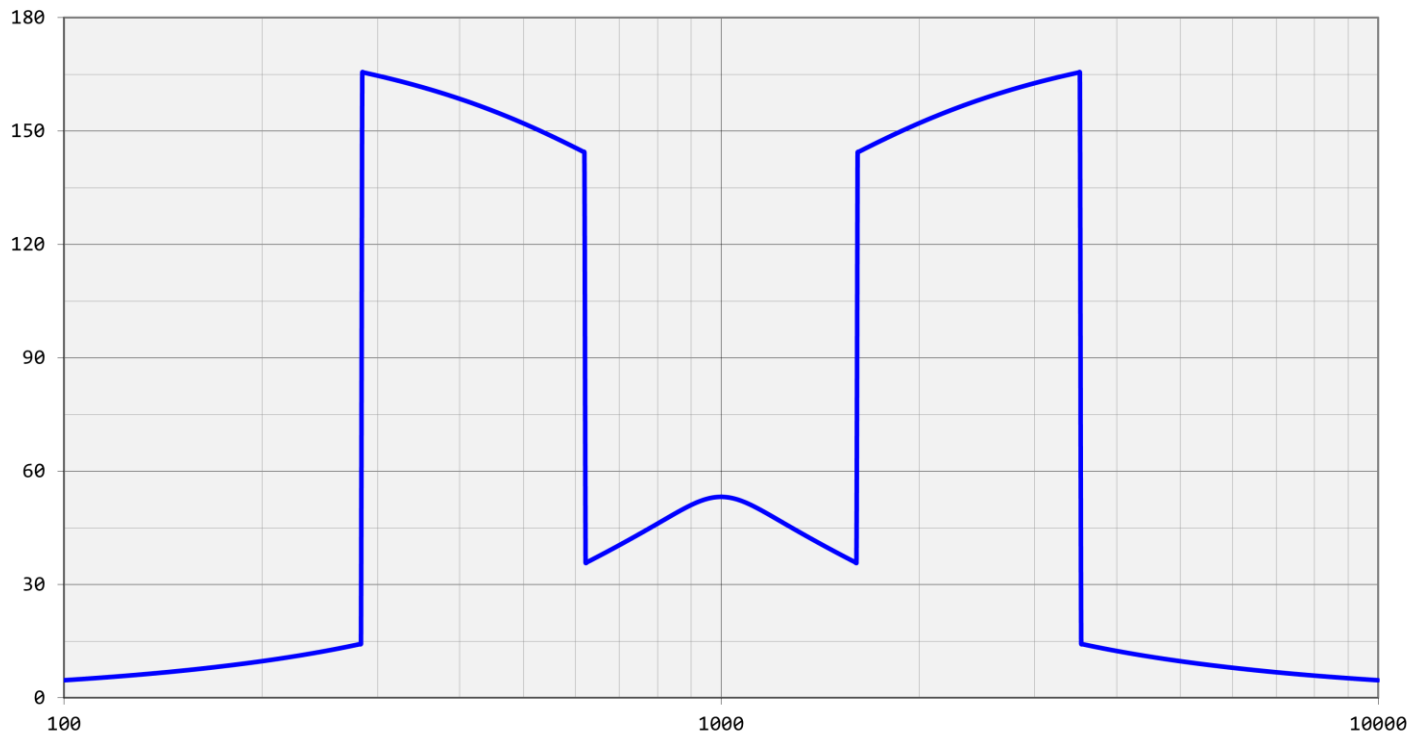
4DFE_1.51_A36_P53 : Sum of HP and LP filters



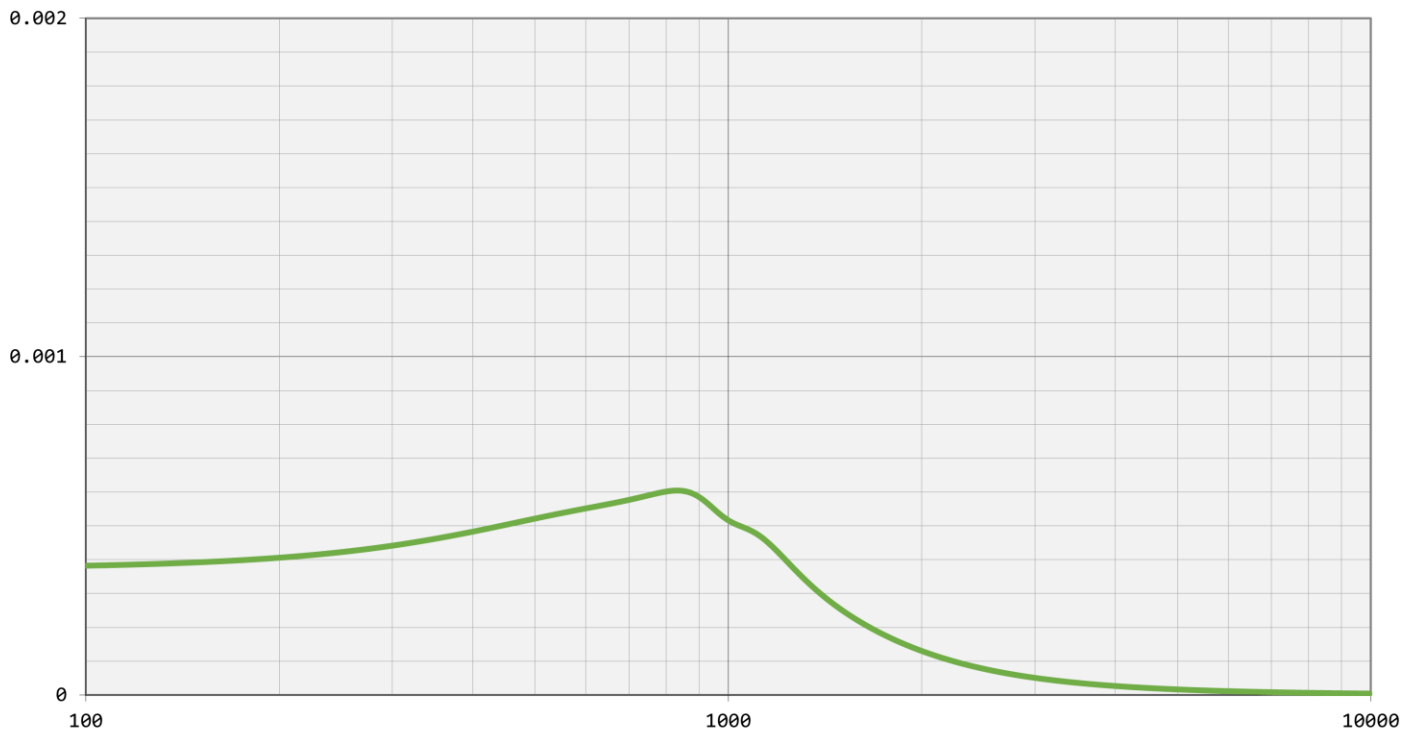
4DFE_1.51_A36_P53 : Lowpass Response



4DFE_1.51_A36_P53 : Relative Phase Angle in Degrees



4DFE_1.51_A36_P53 : Group Delay for Fc = 1k Hz



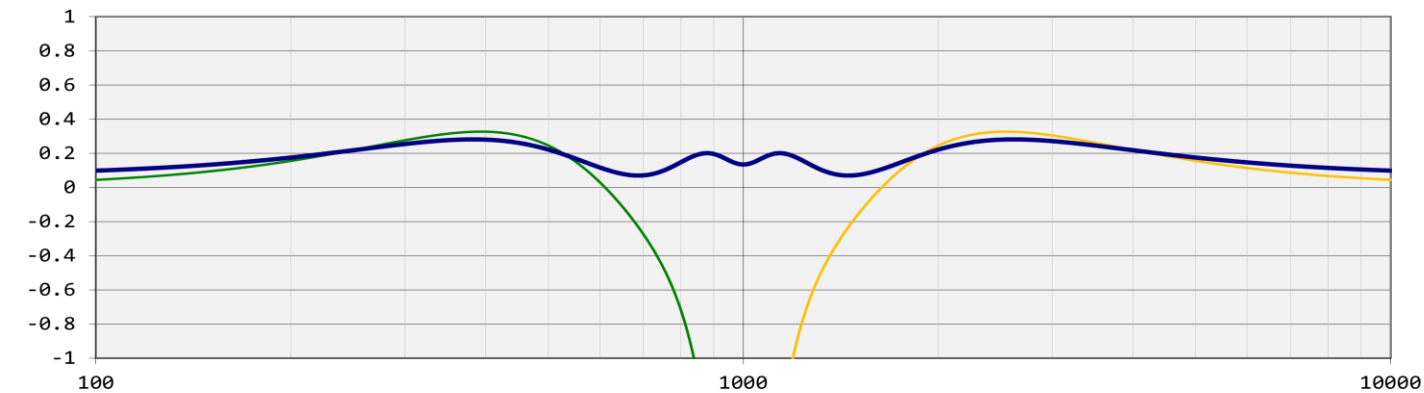
Crossover 4DFE_1.75_A44_P67:

Filters used to construct the 4DFE_1.75_A44_P67 Crossover:

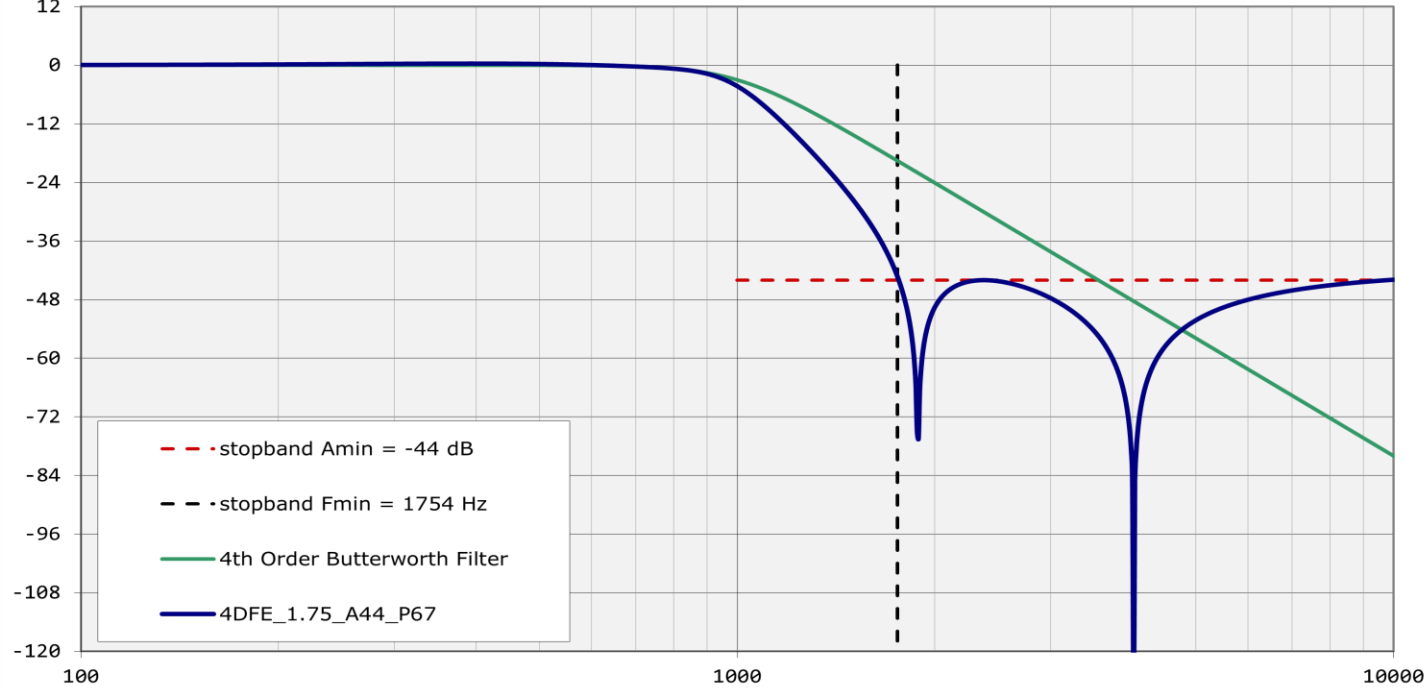
Filters:	LPN	LPN			HPN(+)	HPN		
gain [dB]:	-11.356	-30.773			0.000	0.000		
Fp/Fc:	0.9799	0.6834			1.0205	1.4632		
Qp:	2.218	0.696			2.218	0.696		
Fz/Fc:	1.8840	4.0181			0.5308	0.2489		

Response Plots for the Crossover may be found below.

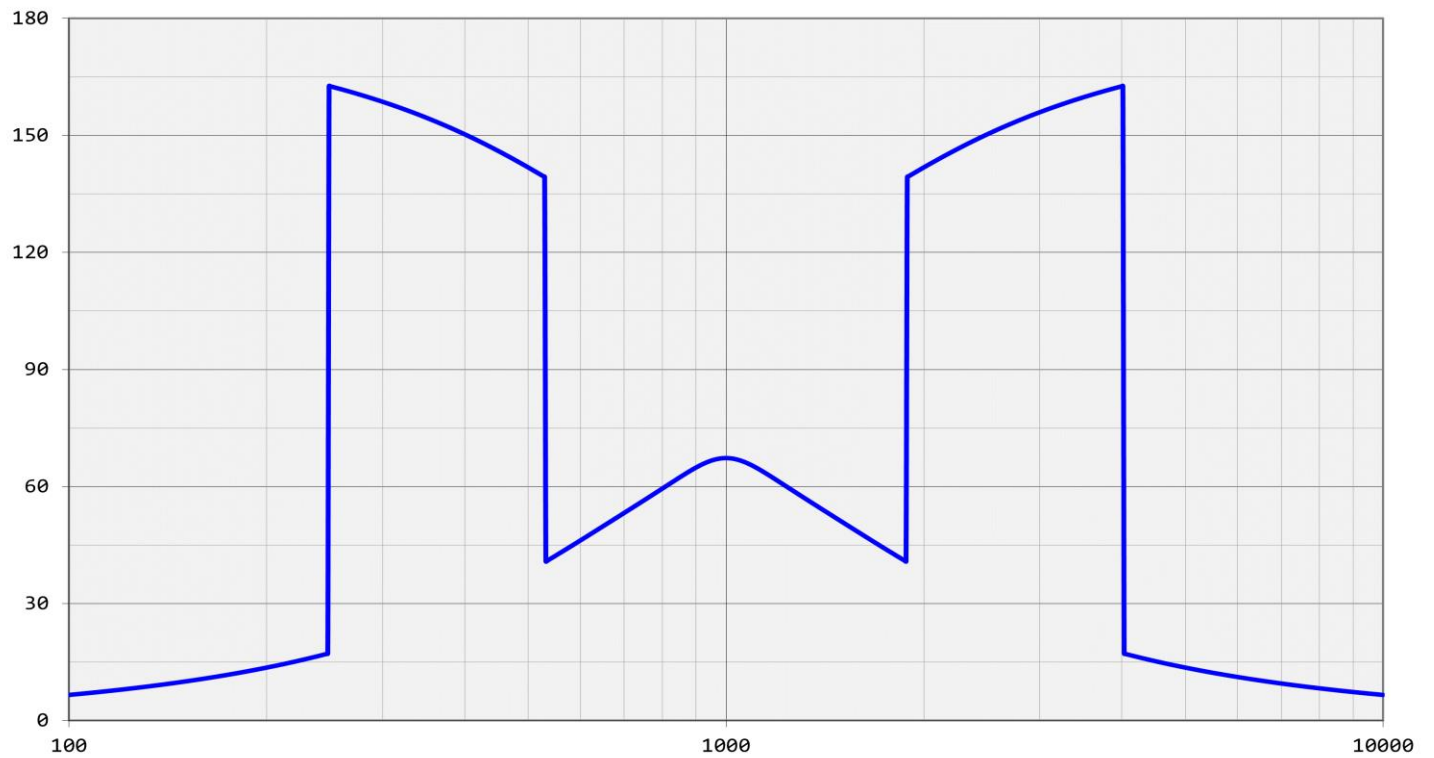
4DFE_1.75_A44_P67 : Sum of HP and LP filters



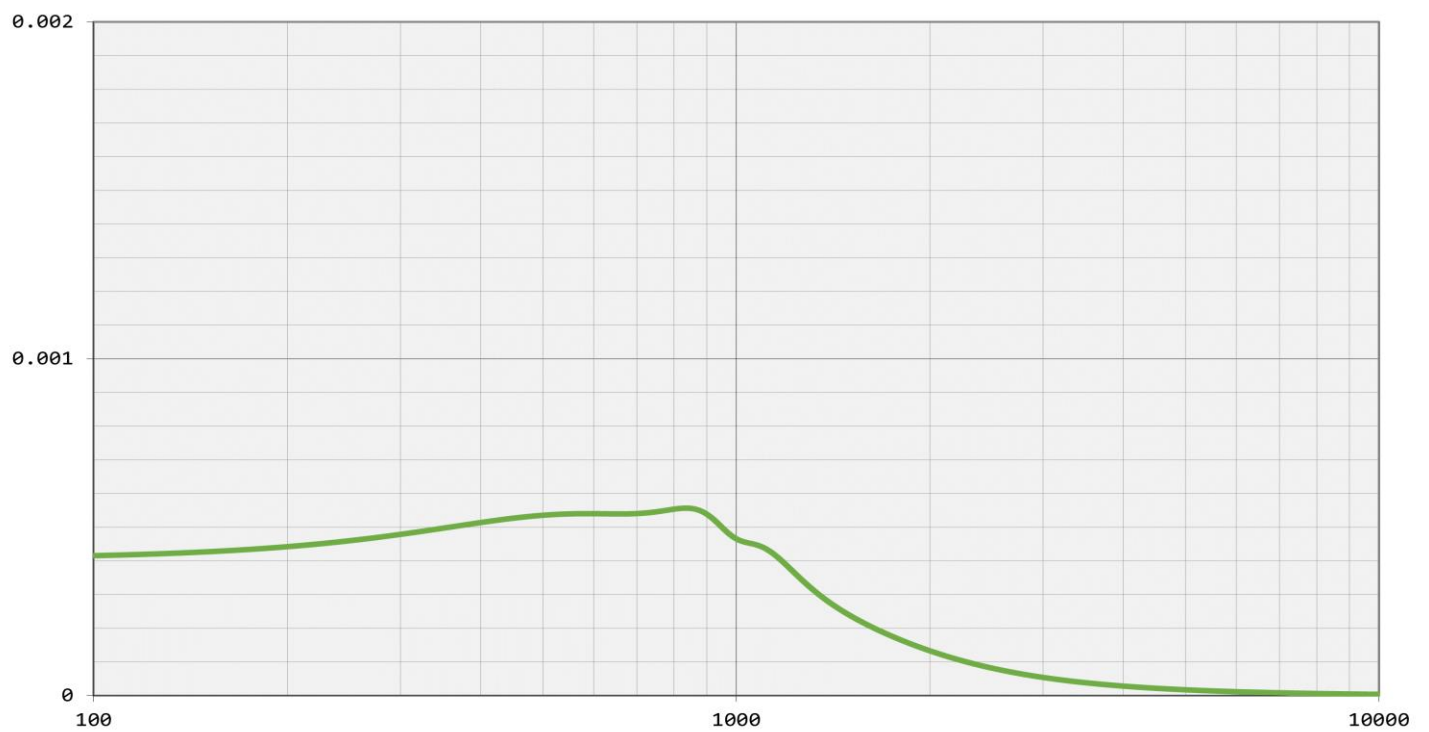
4DFE_1.75_A44_P67 : Lowpass Response



4DFE_1.75_A44_P67 : Relative Phase Angle in Degrees



4DFE_1.75_A44_P67 : Group Delay for Fc = 1k Hz



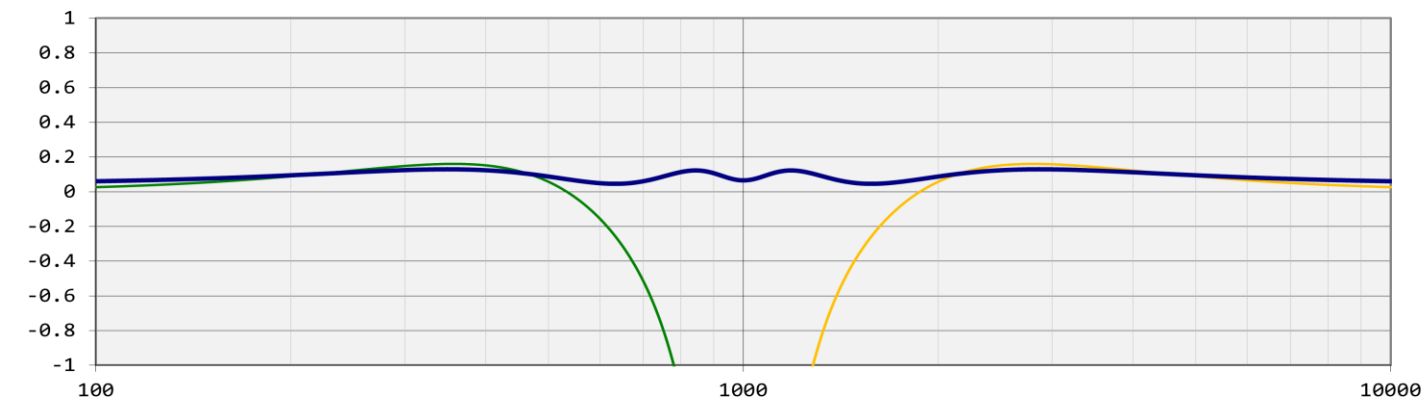
Crossover 4DFE_2.00_A48_P55:

Filters used to construct the 4DFE_2.00_A48_P55 Crossover:

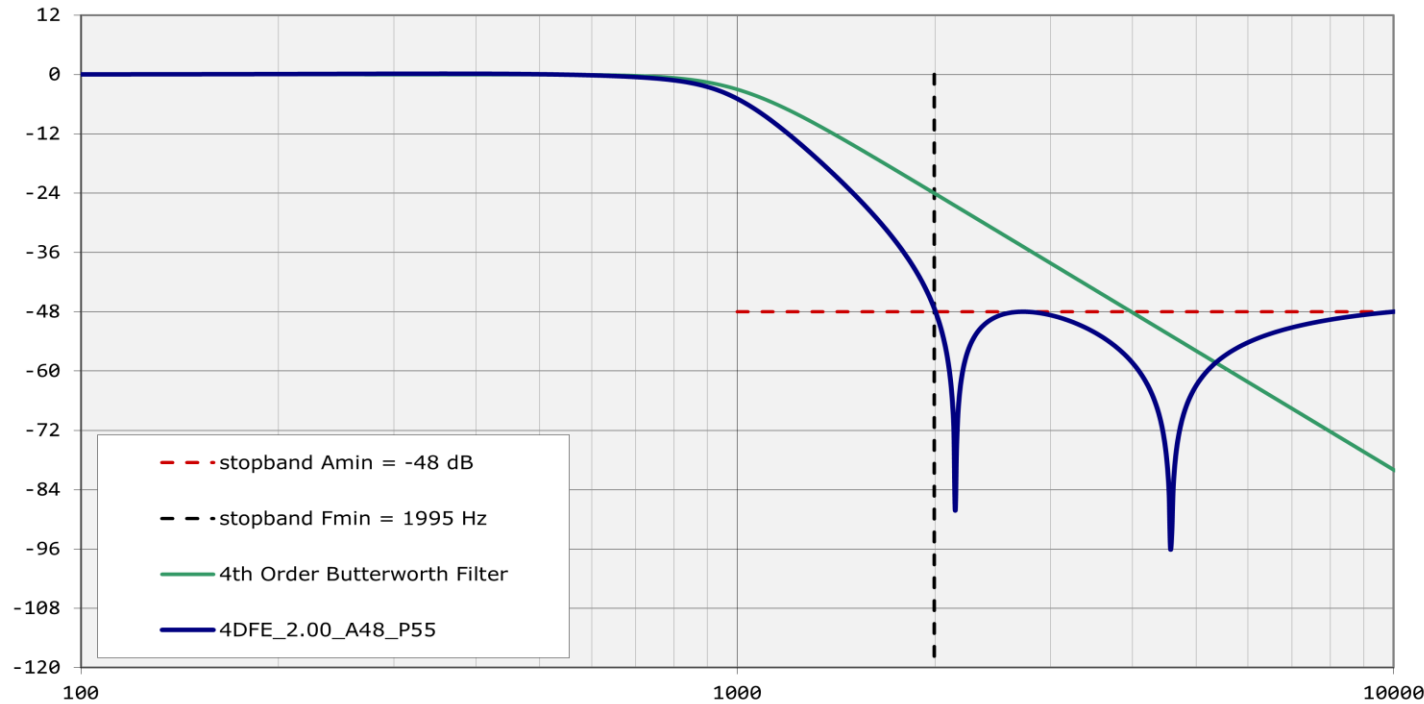
Filters:	LPN		HPN(+)		HPN	
gain [dB]:	-13.707	-31.900	0.000	0.000		
Fp/Fc:	0.9766	0.7300	1.0240	1.3698		
Qp:	1.773	0.656	1.773	0.656		
Fz/Fc:	2.1498	4.5795	0.4652	0.2184		

Response Plots for the Crossover may be found below.

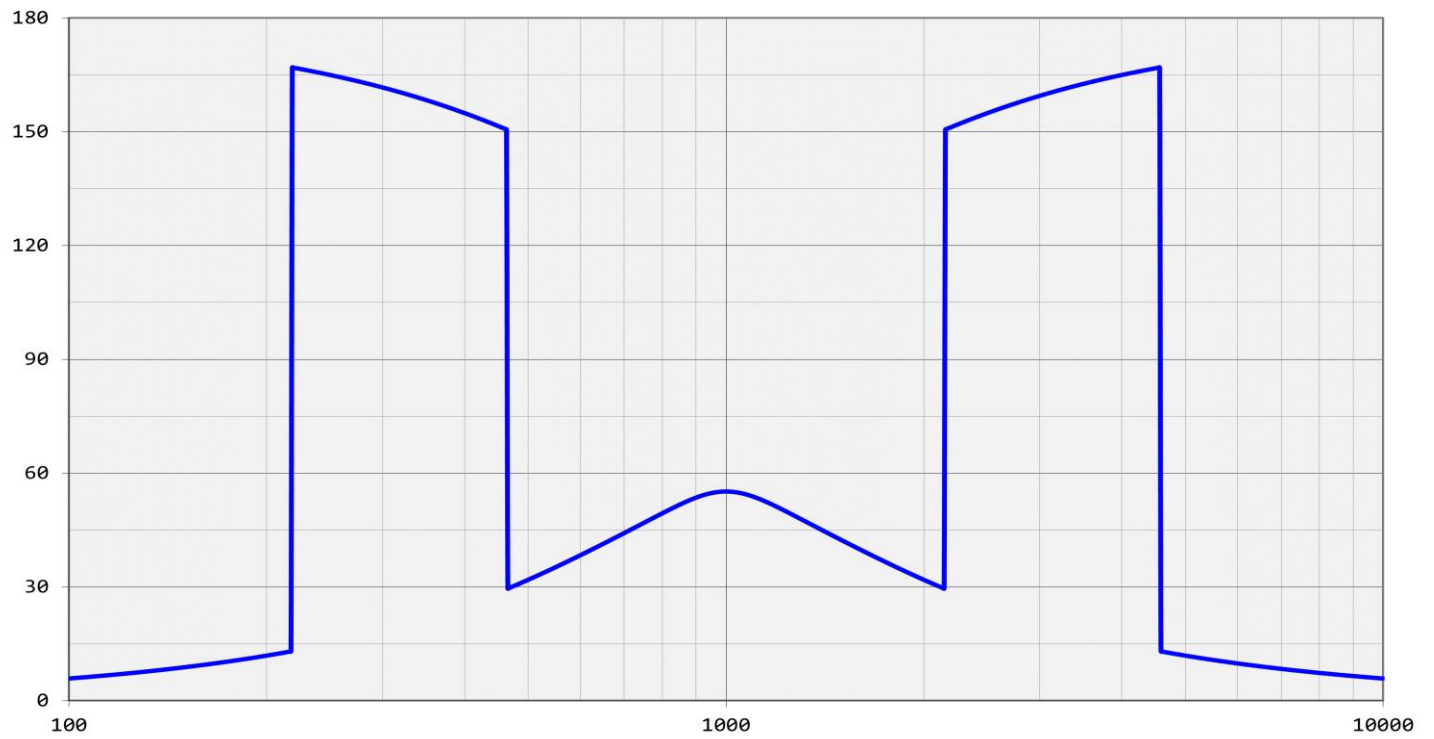
4DFE_2.00_A48_P55 : Sum of HP and LP filters



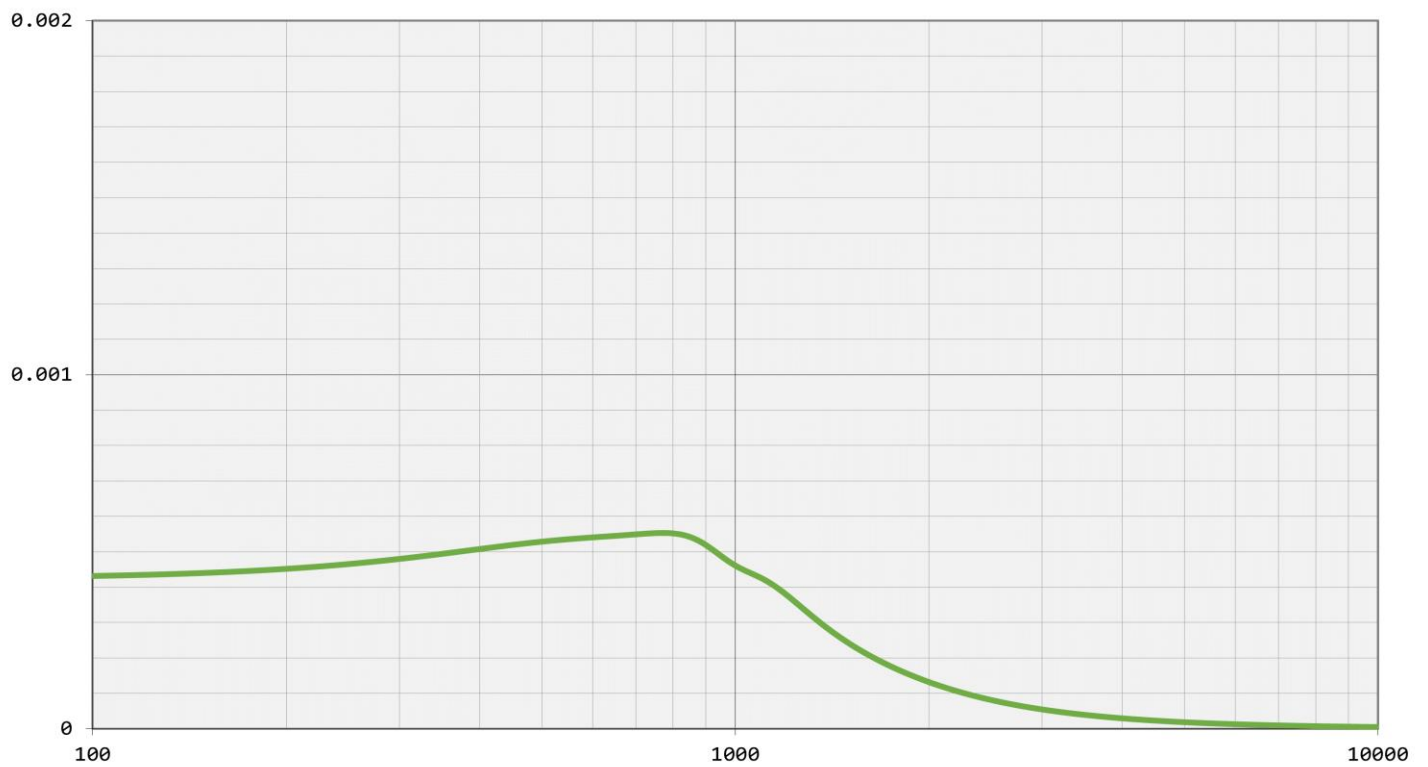
4DFE_2.00_A48_P55 : Lowpass Response



4DFE_2.00_A48_P55 : Relative Phase Angle in Degrees



4DFE_2.00_A48_P55 : Group Delay for Fc = 1k Hz



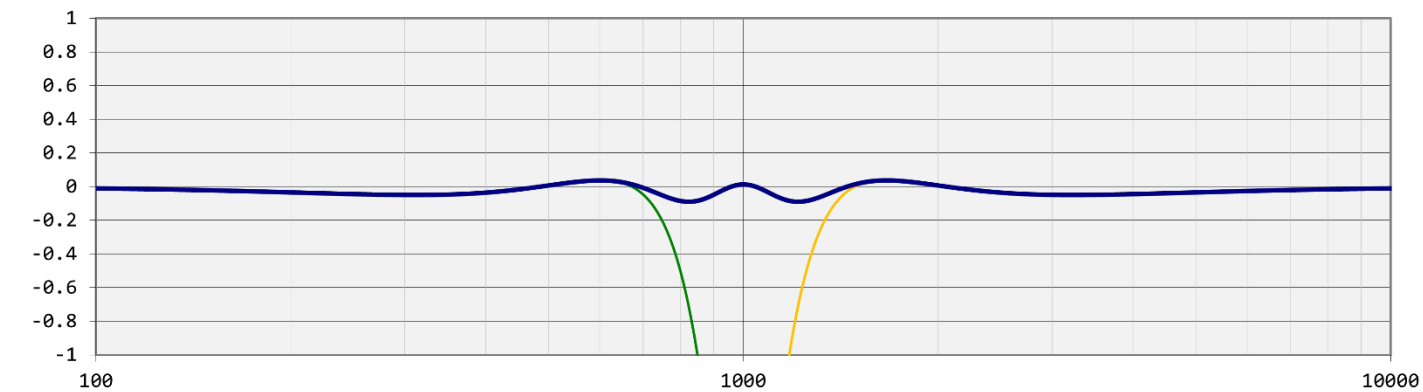
Crossover 5DFE_1.52_A39_P70:

Filters used to construct the 5DFE_1.52_A39_P70 Crossover:

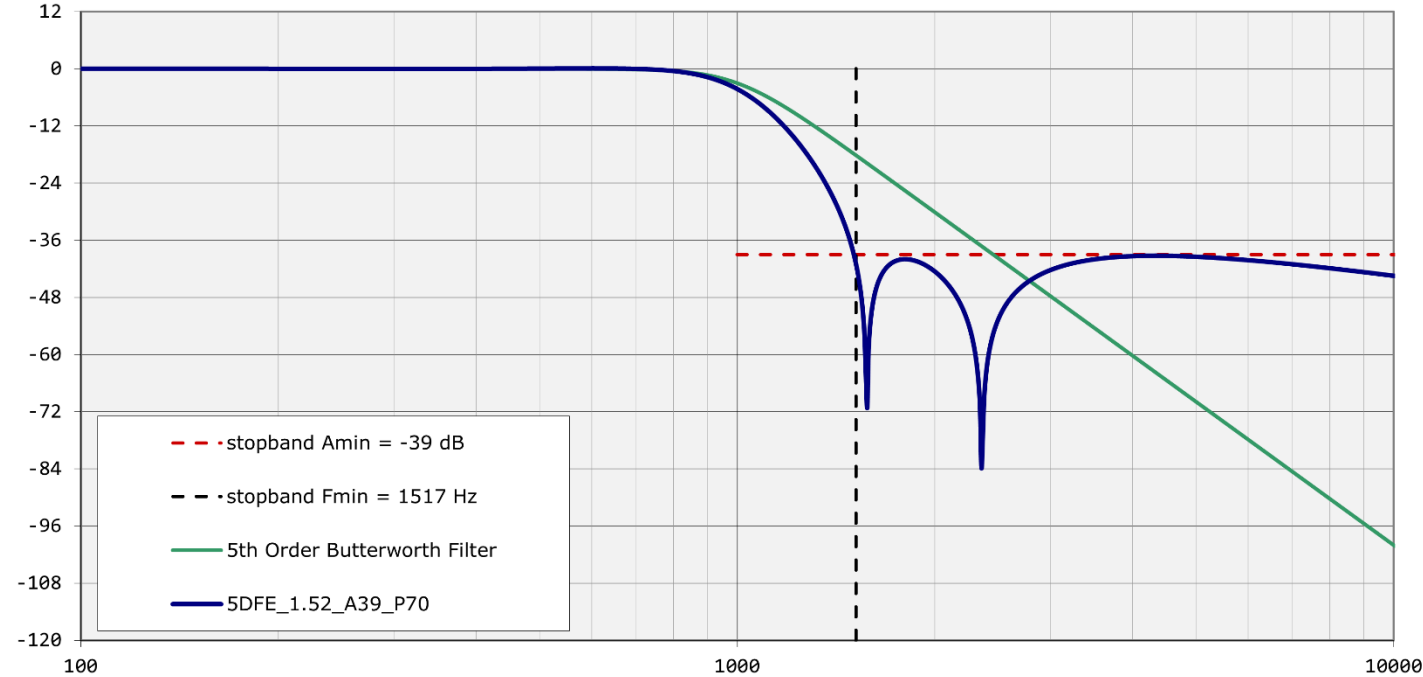
Filters:	LP	LPN	LPN		HP(+)	HPN	HPN	
gain [dB]:	0.000	-5.710	-14.931		0.000	0.000	0.000	
Fp/Fc:	0.7709	1.1340	0.9986		1.2973	0.8819	1.0014	
Qp:		1.262	1.501			1.262	1.501	
Fz/Fc:		1.5752	2.3586			0.6348	0.4240	

Response Plots for the Crossover may be found below.

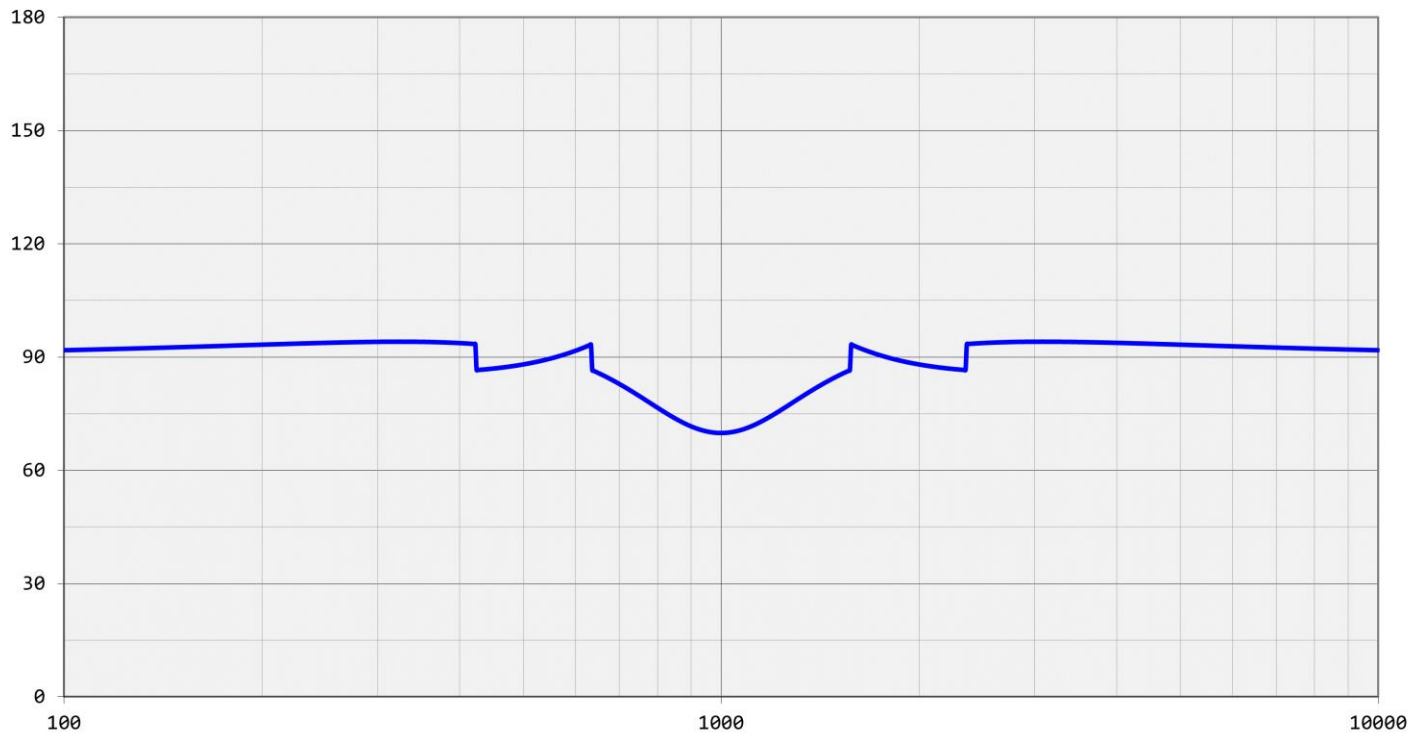
5DFE_1.52_A39_P70 : Sum of HP and LP filters



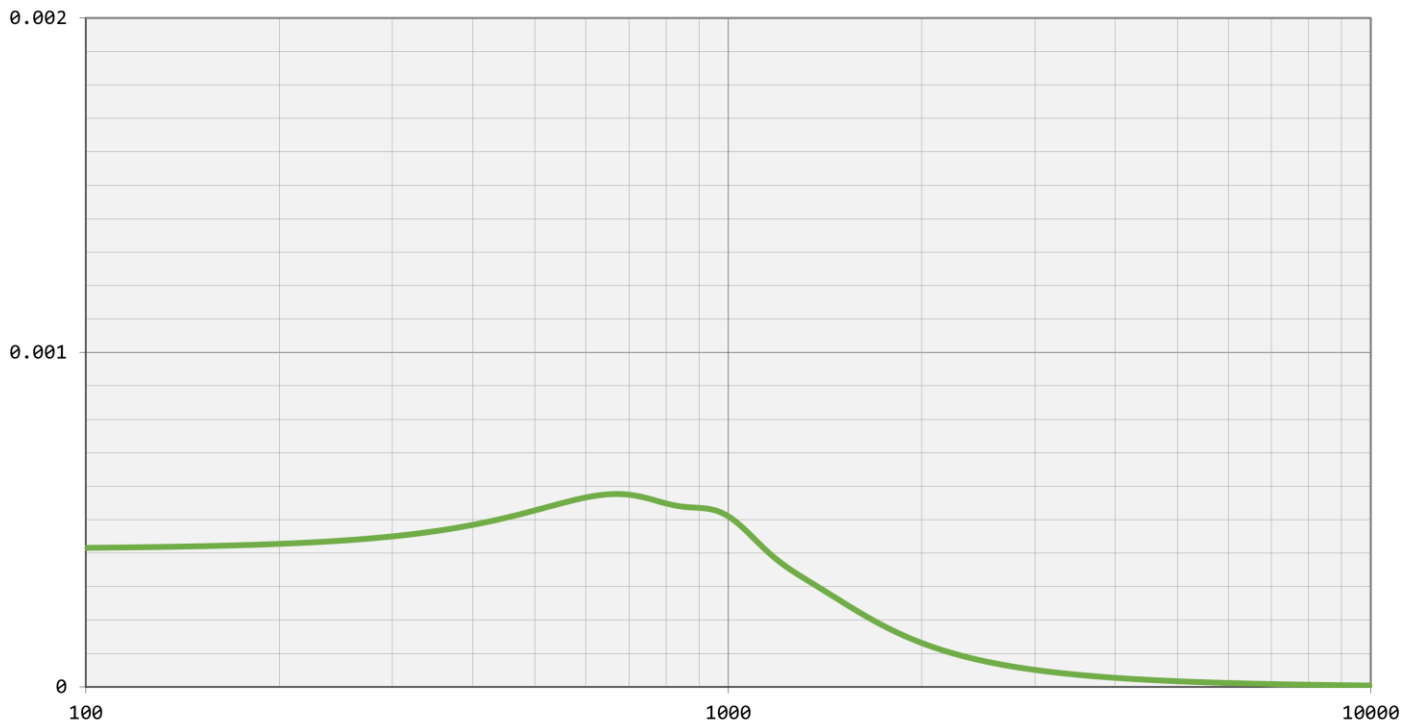
5DFE_1.52_A39_P70 : Lowpass Response



5DFE_1.52_A39_P70 : Relative Phase Angle in Degrees



5DFE_1.52_A39_P70 : Group Delay for Fc = 1k Hz



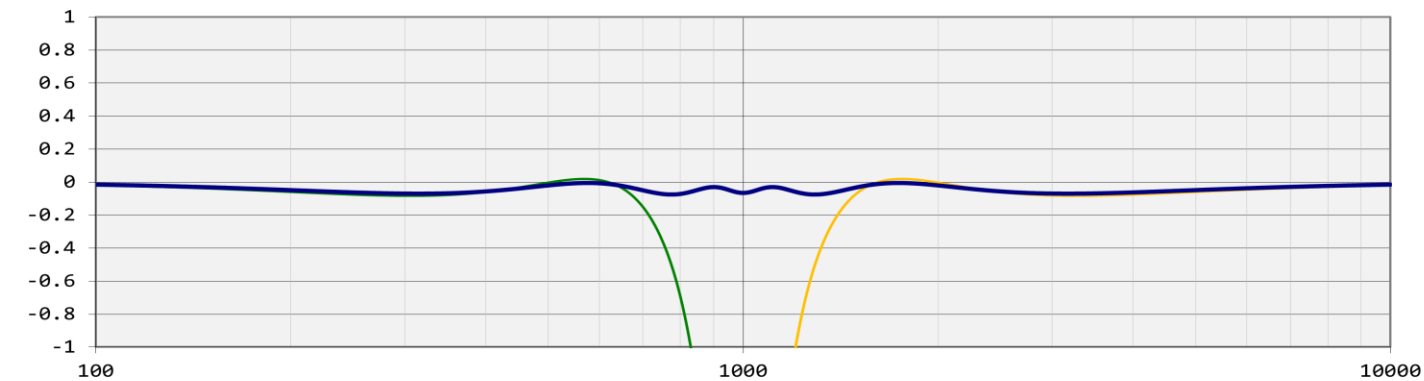
Crossover 5DFE_1.50_A48_P0:

Filters used to construct the 5DFE_1.50_A48_P0 Crossover:

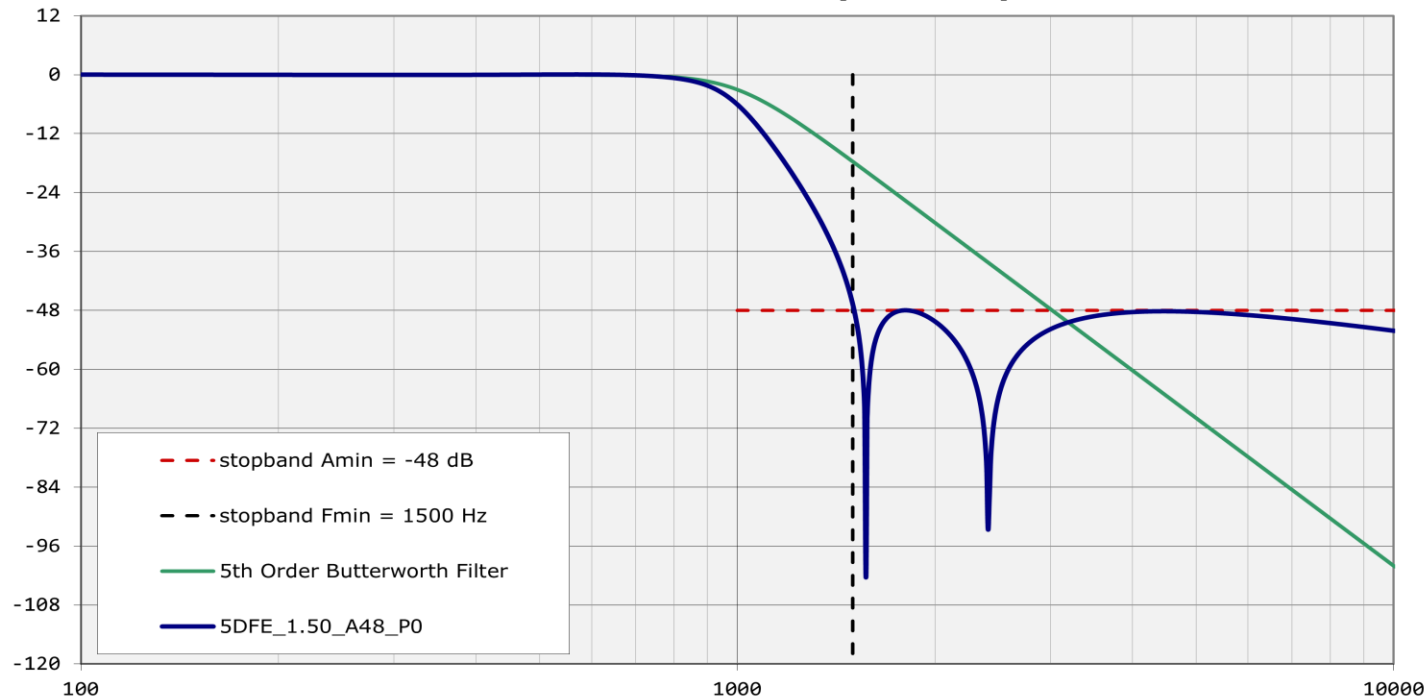
Filters:	LP	LPN	LPN		HP(-)	HPN	HPN	
gain [dB]:	0.000	-8.363	-18.642		0.000	0.000	0.000	
Fp/Fc:	0.5949	0.9705	0.8253		1.6810	1.0304	1.2116	
Qp:		2.613	1.025			2.613	1.025	
Fz/Fc:		1.5705	2.4136			0.6367	0.4143	

Response Plots for the Crossover may be found below.

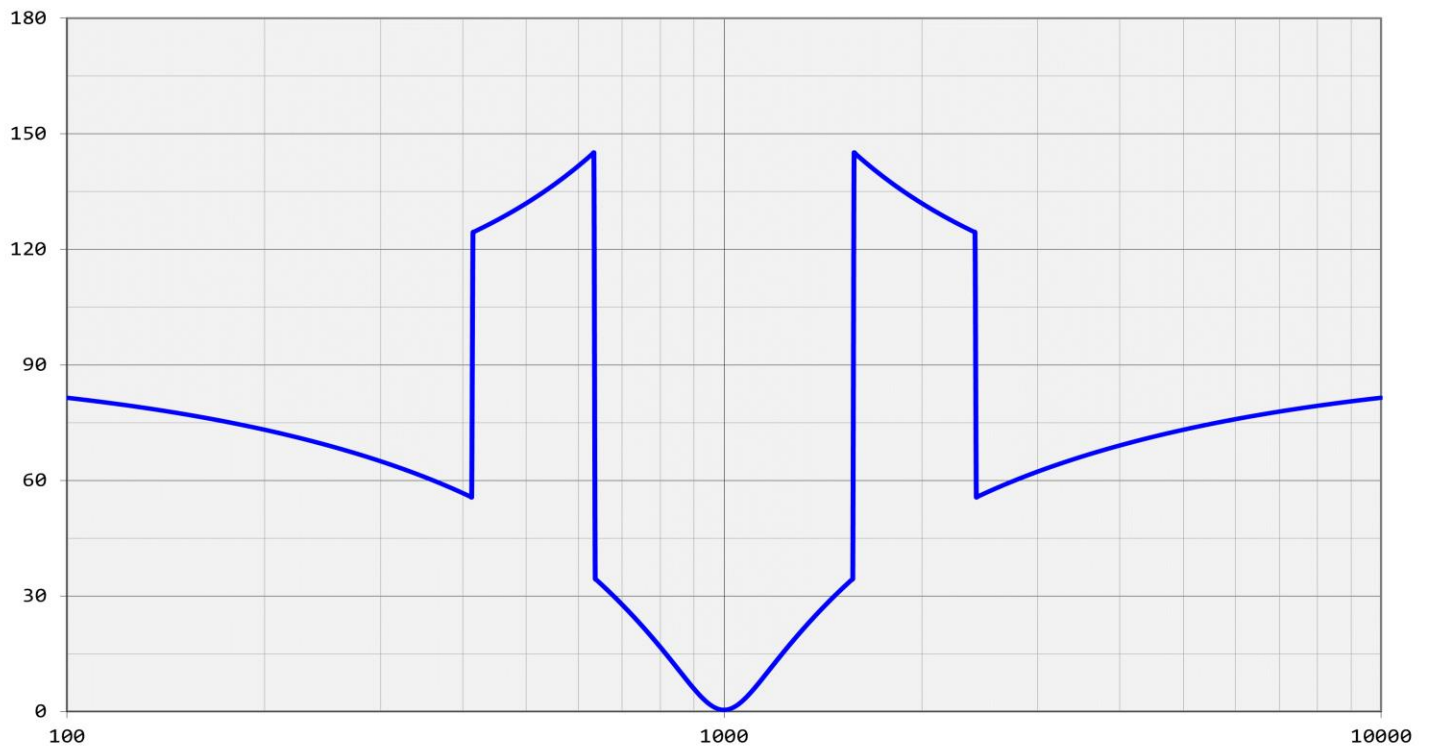
5DFE_1.50_A48_P0 : Sum of HP and LP filters



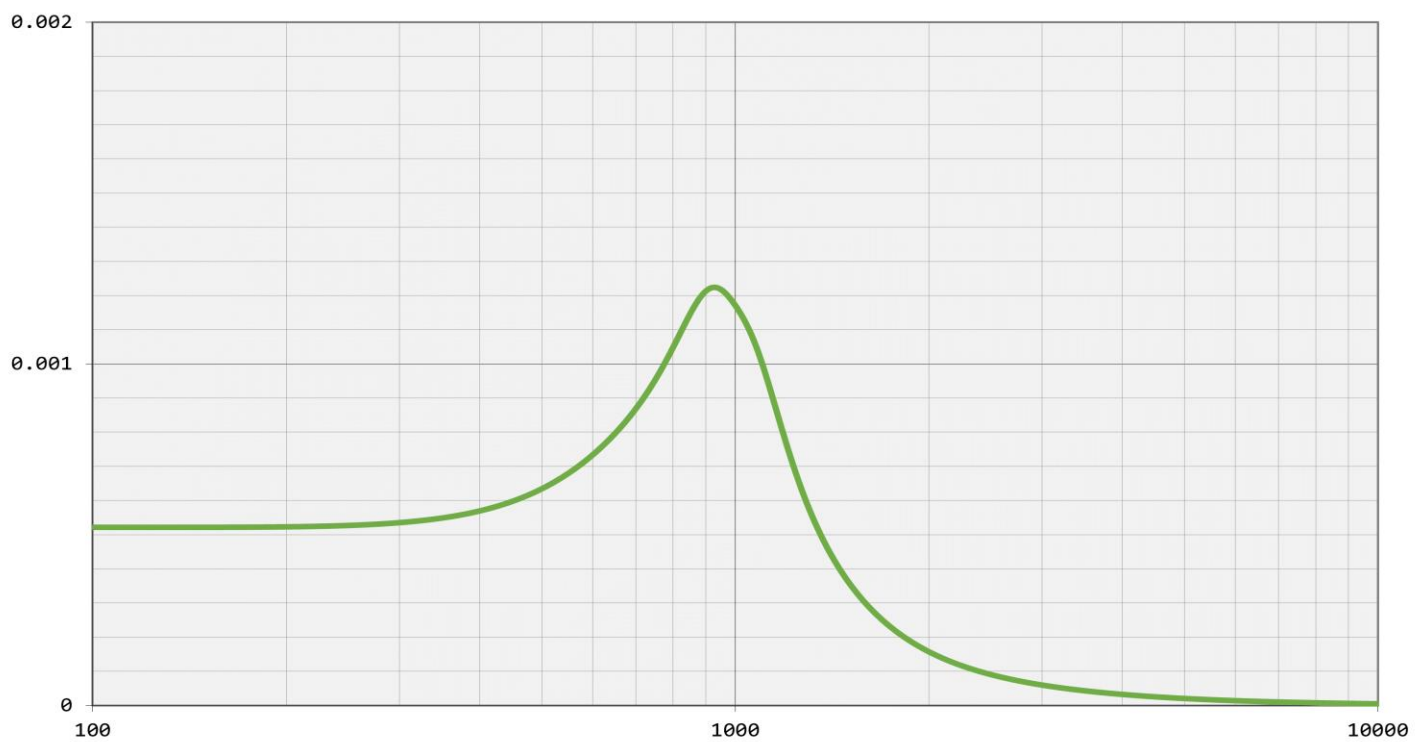
5DFE_1.50_A48_P0 : Lowpass Response



5DFE_1.50_A48_P0 : Relative Phase Angle in Degrees



5DFE_1.50_A48_P0 : Group Delay for $F_c = 1\text{ k Hz}$



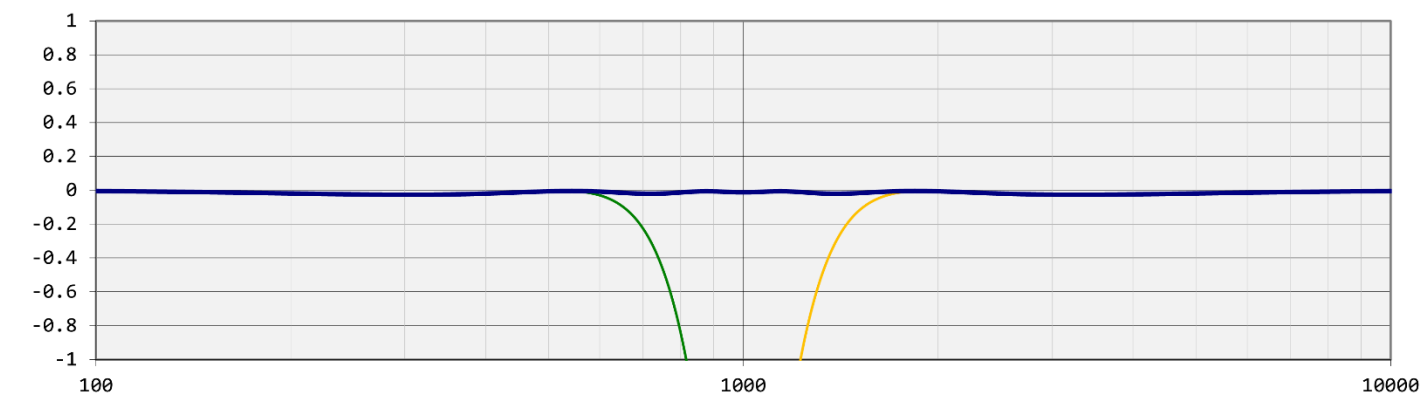
Crossover 5DFE_1.75_A45_P66:

Filters used to construct the 5DFE_1.75_A45_P66 Crossover:

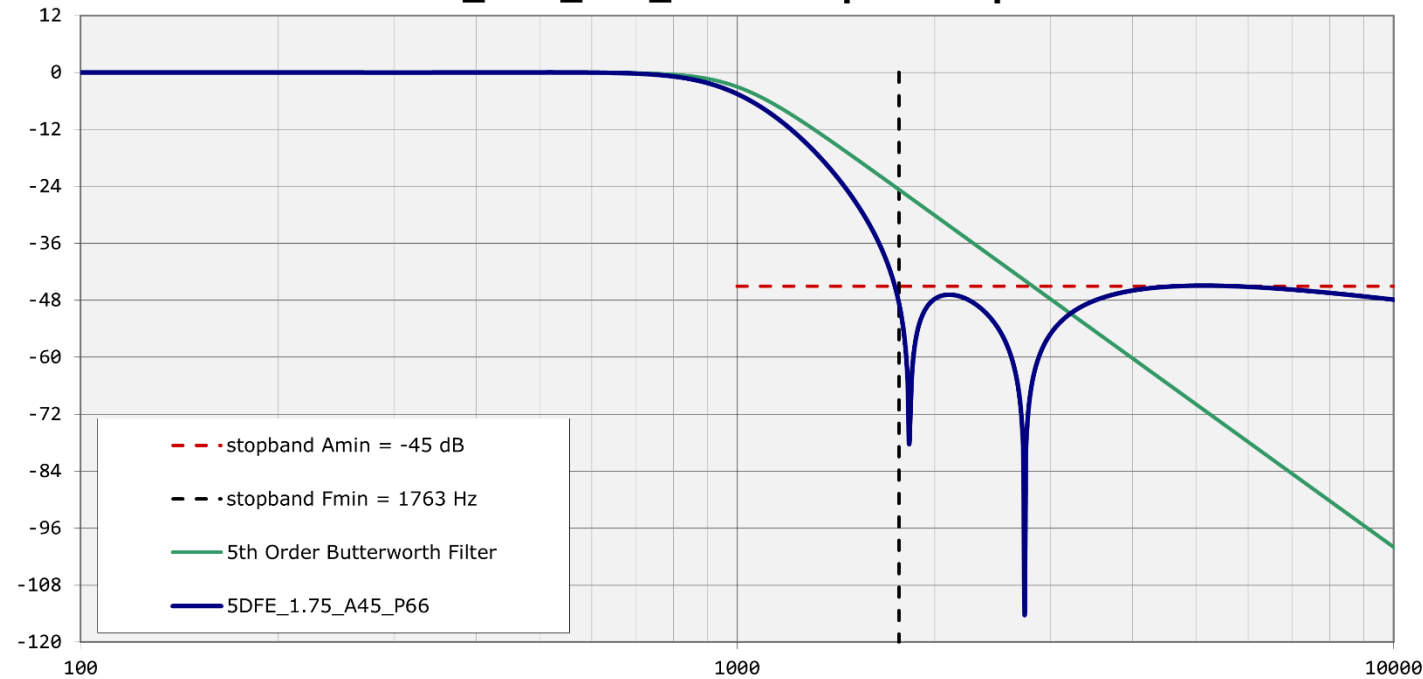
Filters:	LP	LPN	LPN		HP(+)	HPN	HPN	
gain [dB]:	0.000	-6.920	-18.083		0.000	0.000	0.000	
Fp/Fc:	0.7953	1.2293	0.9680		1.2573	0.8135	1.0330	
Qp:		1.055	1.371			1.055	1.371	
Fz/Fc:		1.8309	2.7413			0.5462	0.3648	

Response Plots for the Crossover may be found below.

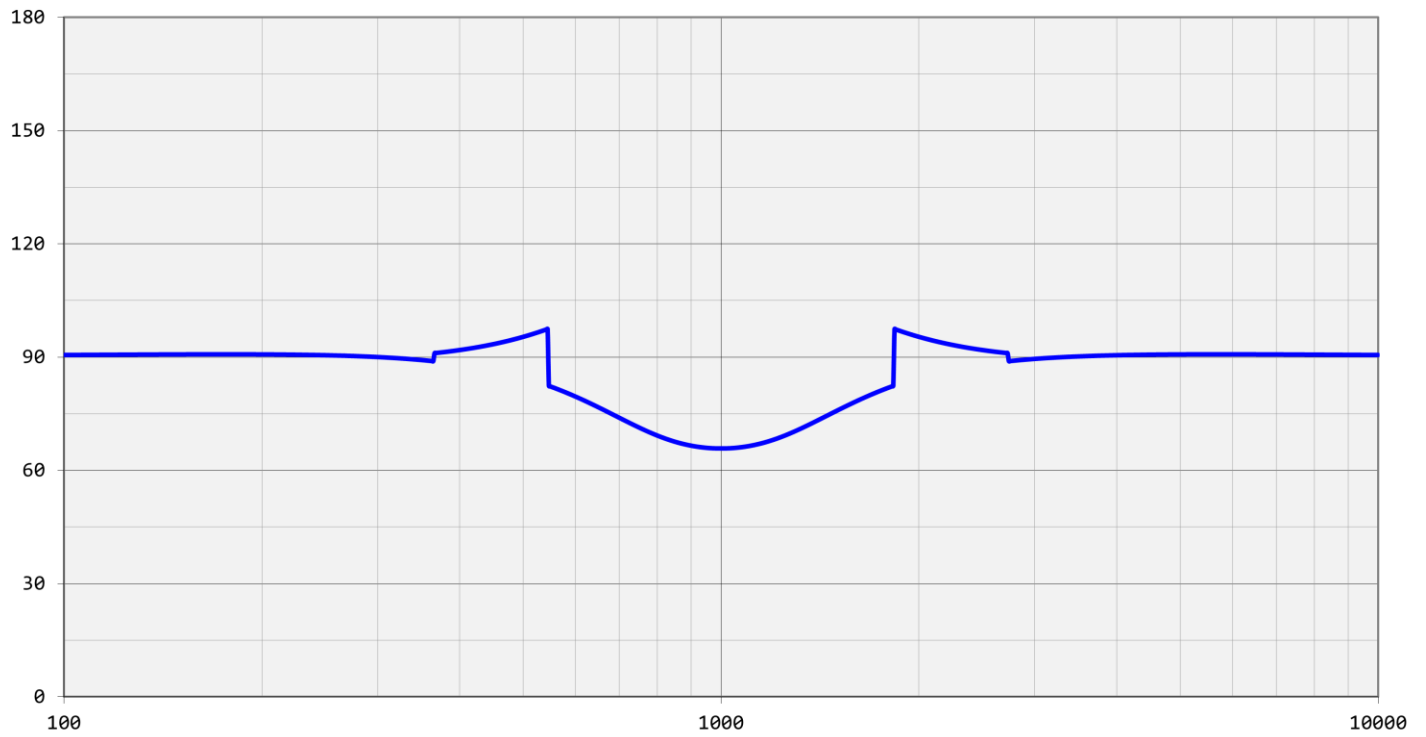
5DFE_1.75_A45_P66 : Sum of HP and LP filters



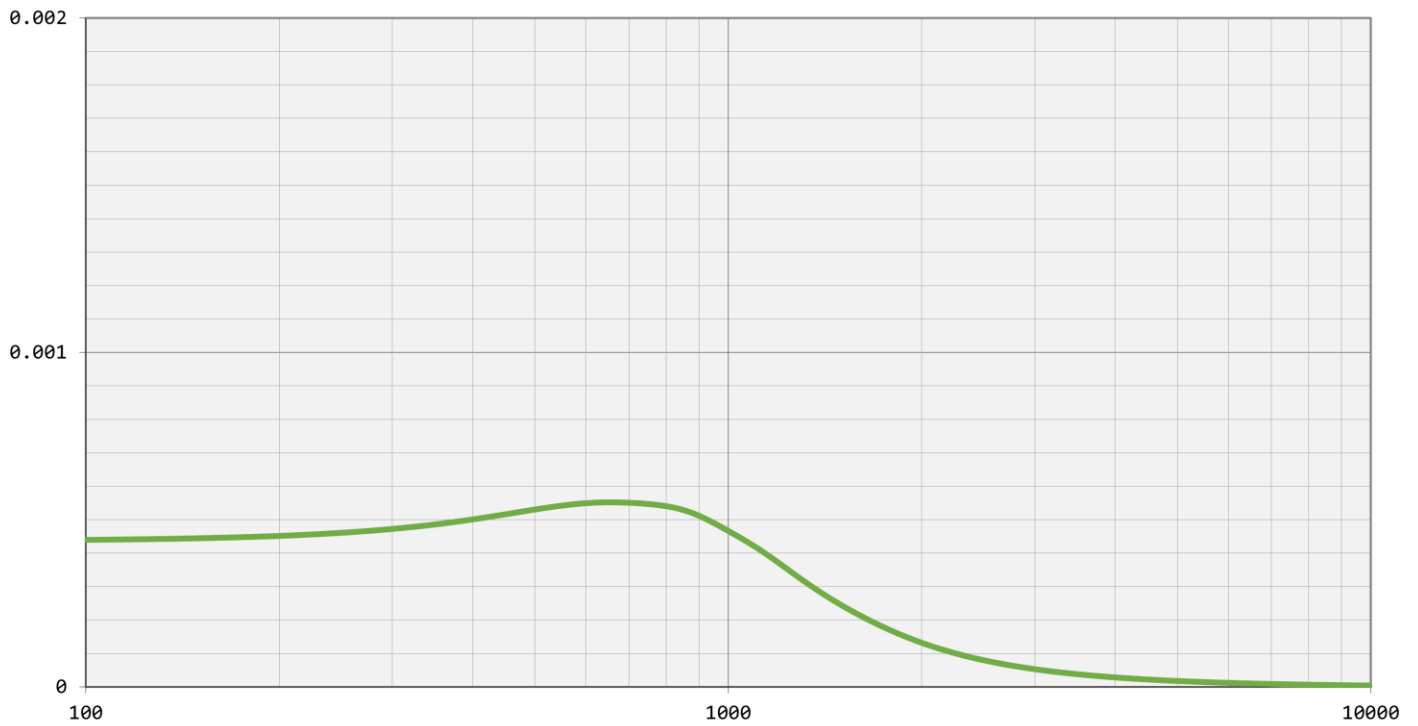
5DFE_1.75_A45_P66 : Lowpass Response



5DFE_1.75_A45_P66 : Relative Phase Angle in Degrees



5DFE_1.75_A45_P66 : Group Delay for Fc = 1k Hz



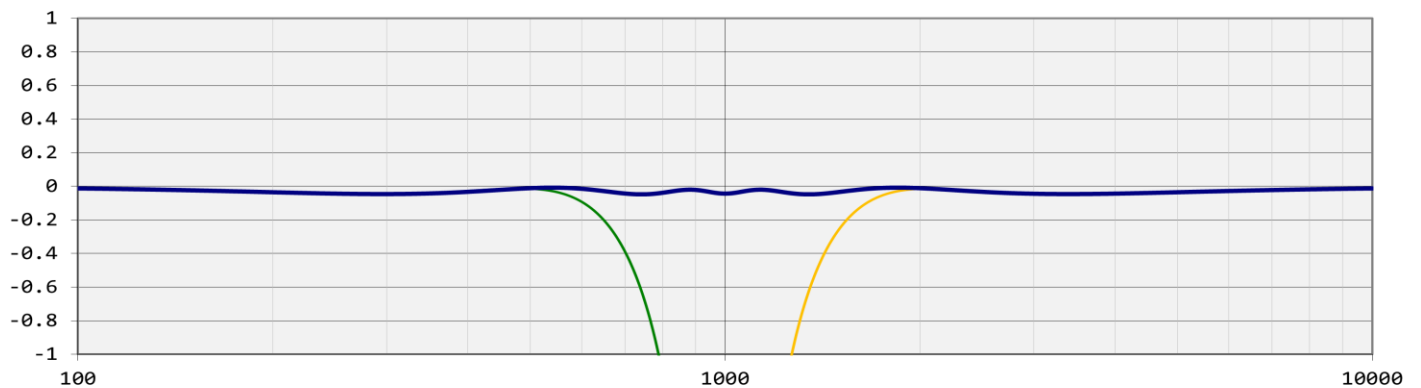
Crossover 5DFE_2.00_A62_P2:

Filters used to construct the 5DFE_2.00_A62_P2 Crossover:

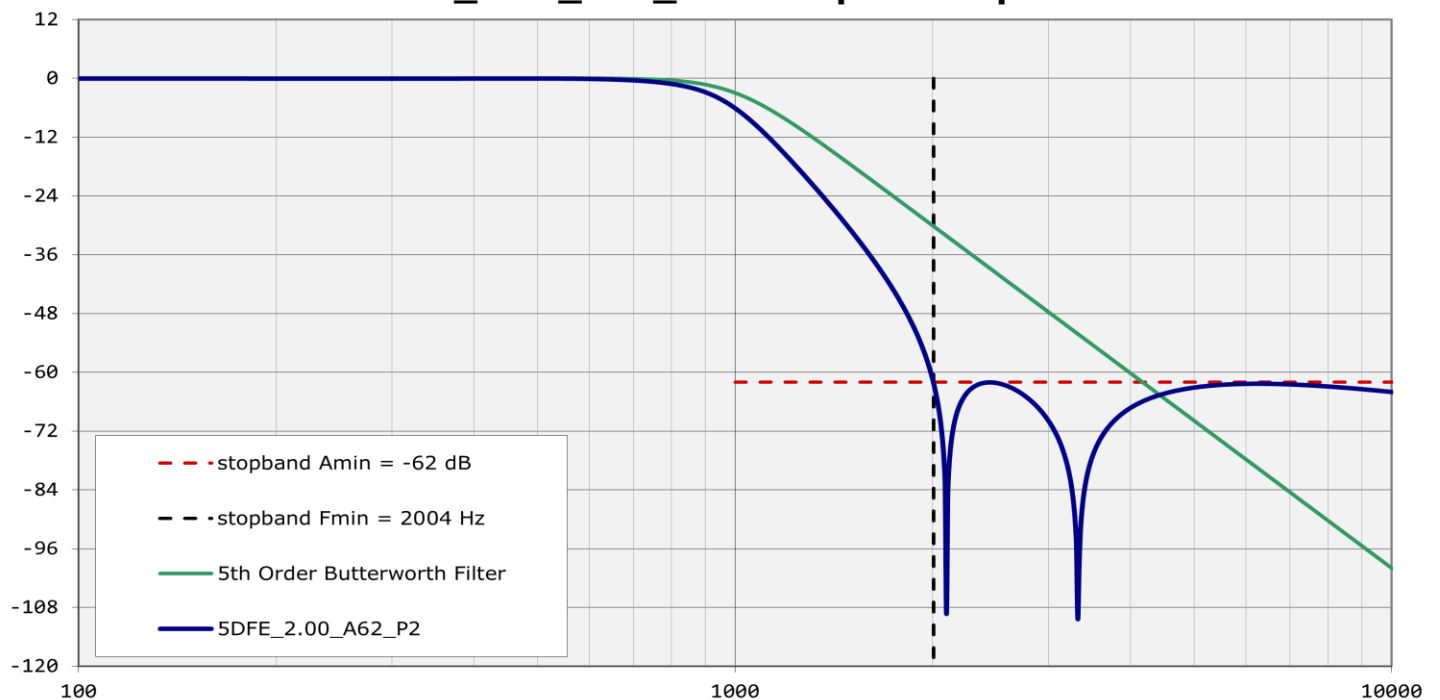
Filters:	LP	LPN	LPN		HP(-)	HPN	HPN	
gain [dB]:	0.000	-13.459	-24.669		0.000	0.000	0.000	
Fp/Fc:	0.5934	0.9675	0.8049		1.6851	1.0336	1.2424	
Qp:		2.111	0.917			2.111	0.917	
Fz/Fc:		2.0995	3.3301			0.4763	0.3003	

Response Plots for the Crossover may be found below.

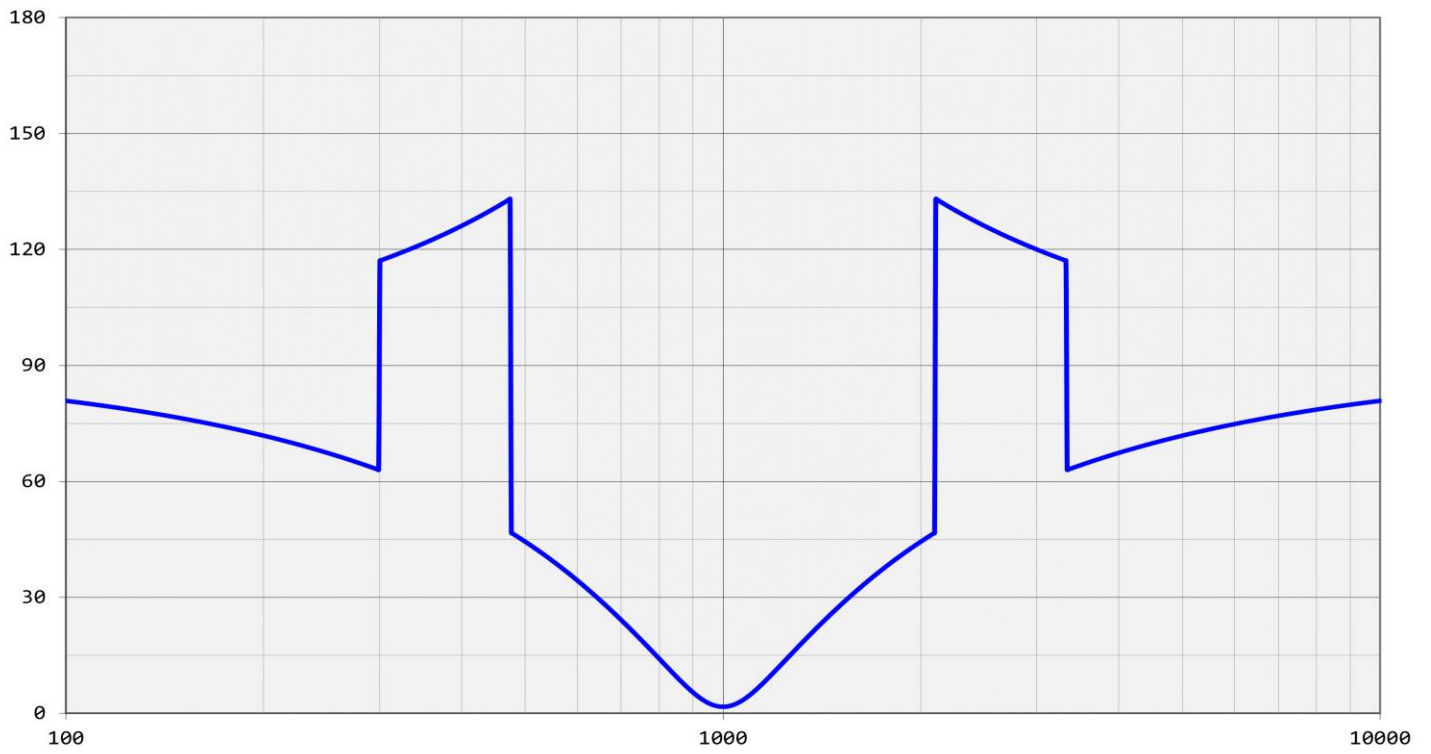
5DFE_2.00_A62_P2 : Sum of HP and LP filters



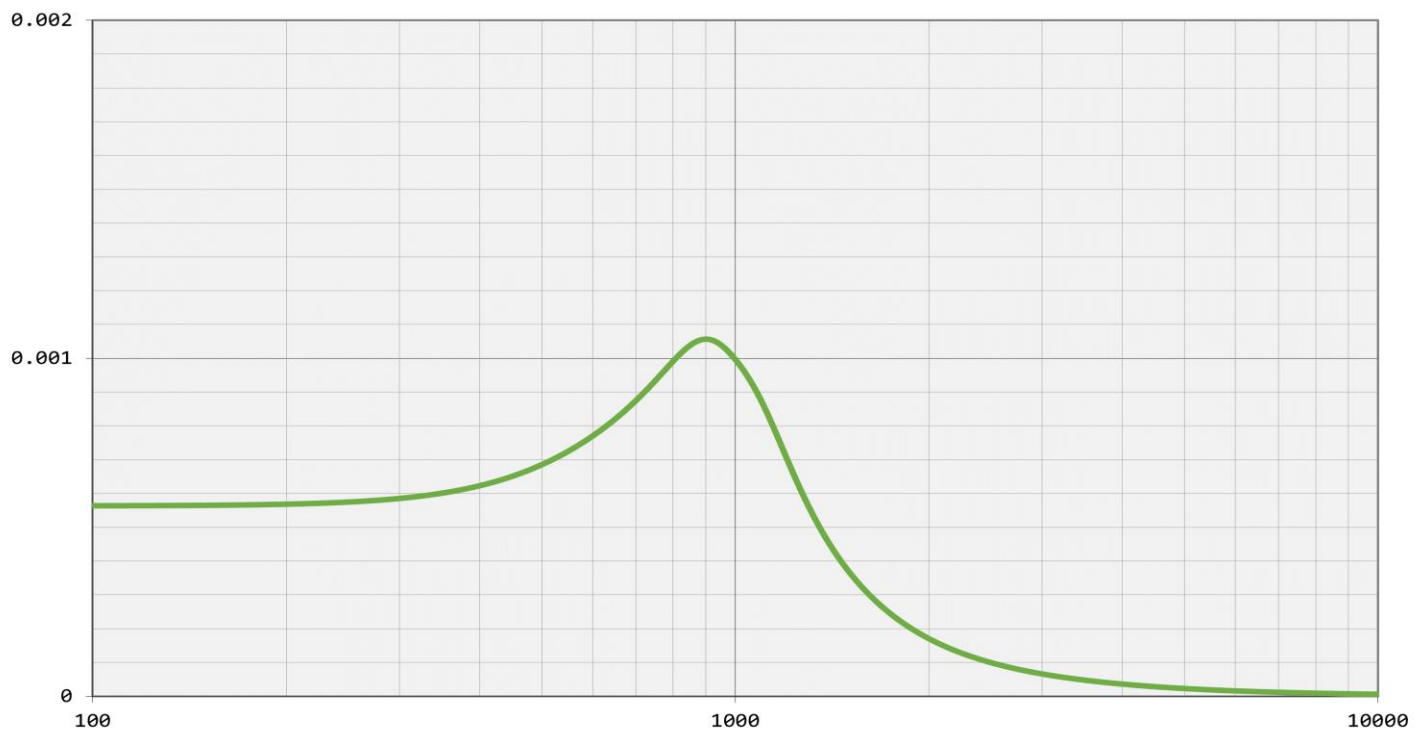
5DFE_2.00_A62_P2 : Lowpass Response



5DFE_2.00_A62_P2 : Relative Phase Angle in Degrees



5DFE_2.00_A62_P2 : Group Delay for Fc = 1k Hz



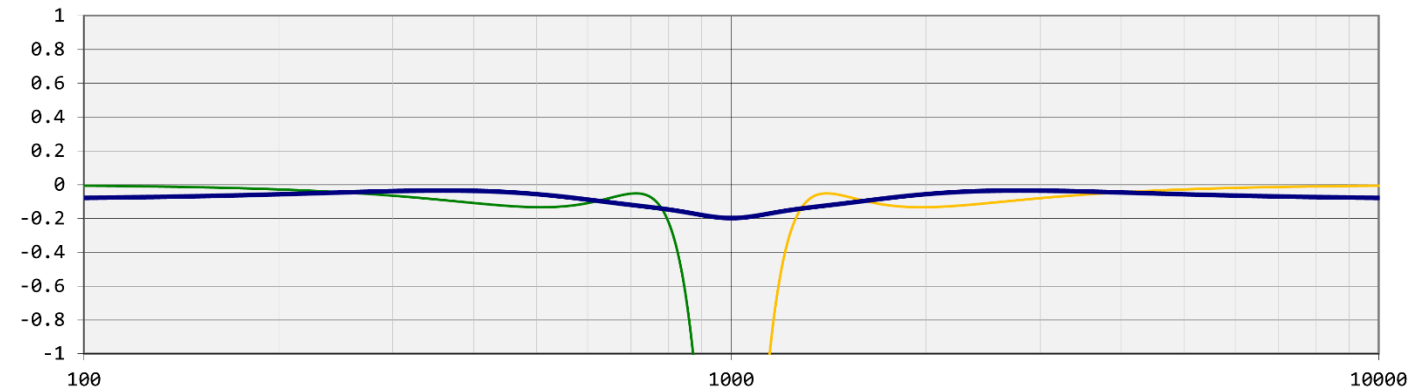
Crossover 6DFE_1.25_A40_P22:

Filters used to construct the 6DFE_1.25_A40_P22 Crossover:

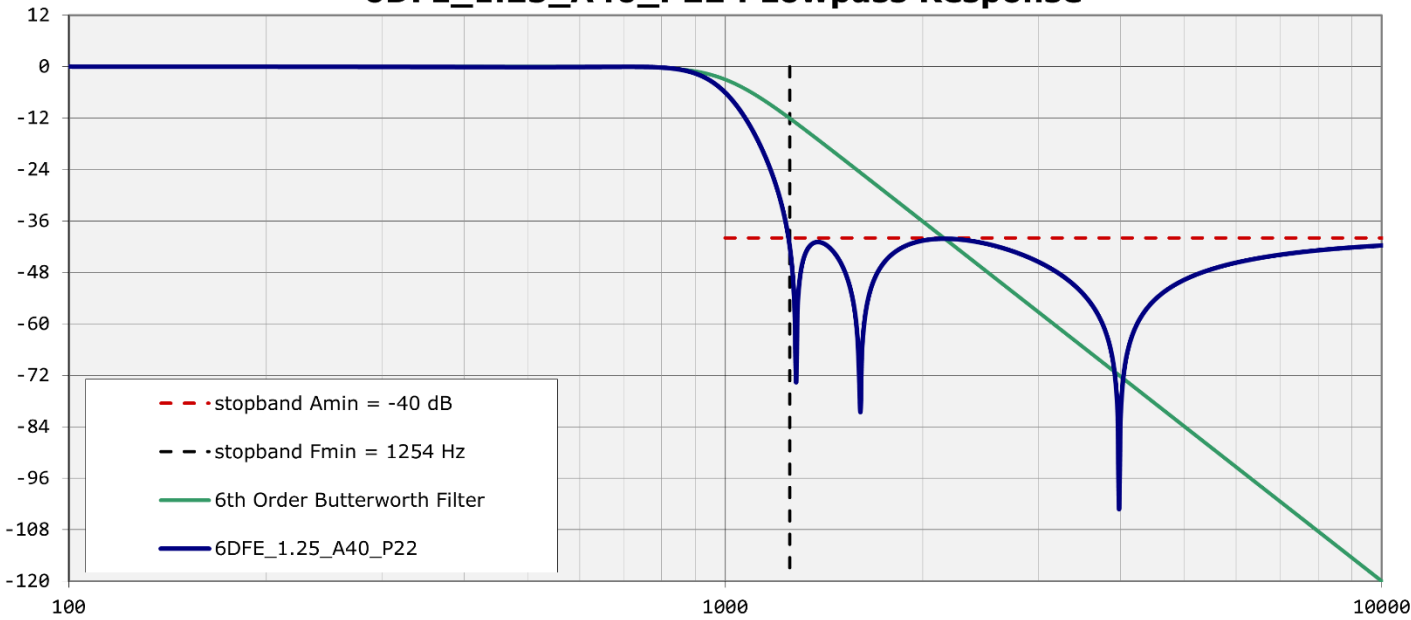
Filters:	LP	LPN	LPN		HP(-)	HPN	HPN	
gain [dB]:	0.000	-12.444	-25.296		0.000	0.000	0.000	
Fp/Fc:	0.4901	1.0256	0.7634		2.0406	0.9750	1.3099	
Qp:		2.151	1.155			2.151	1.155	
Fz/Fc:		2.0993	3.2747			0.4763	0.3054	

Response Plots for the Crossover may be found below.

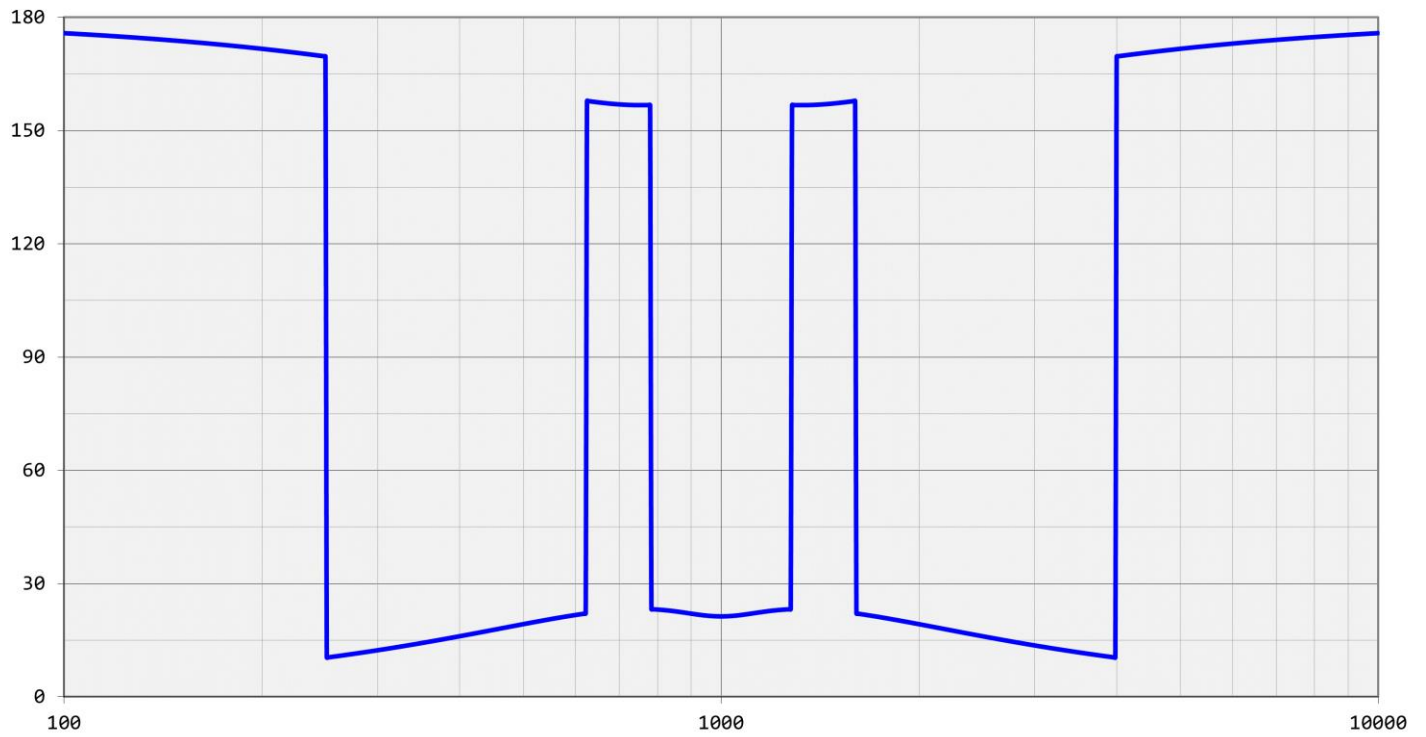
6DFE_1.25_A40_P22 : Sum of HP and LP filters



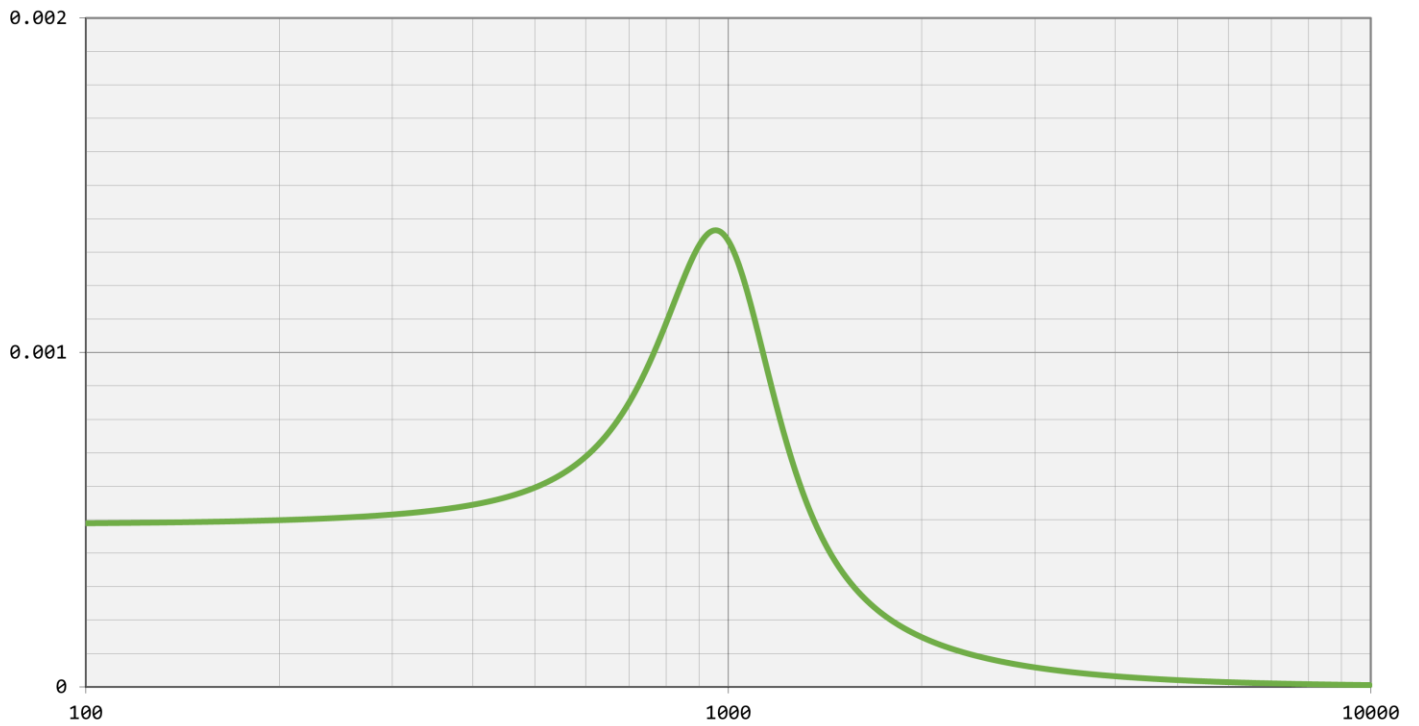
6DFE_1.25_A40_P22 : Lowpass Response



6DFE_1.25_A40_P22 : Relative Phase Angle in Degrees



6DFE_1.25_A40_P22 : Group Delay for Fc = 1k Hz



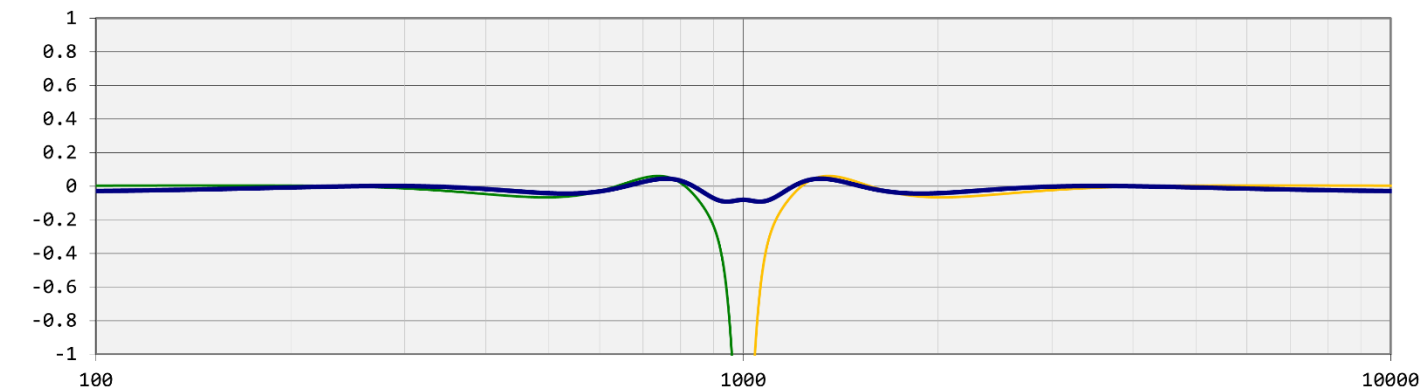
Crossover 6DFE_1.25_A44_P90:

Filters used to construct the 6DFE_1.25_A44_P90 Crossover:

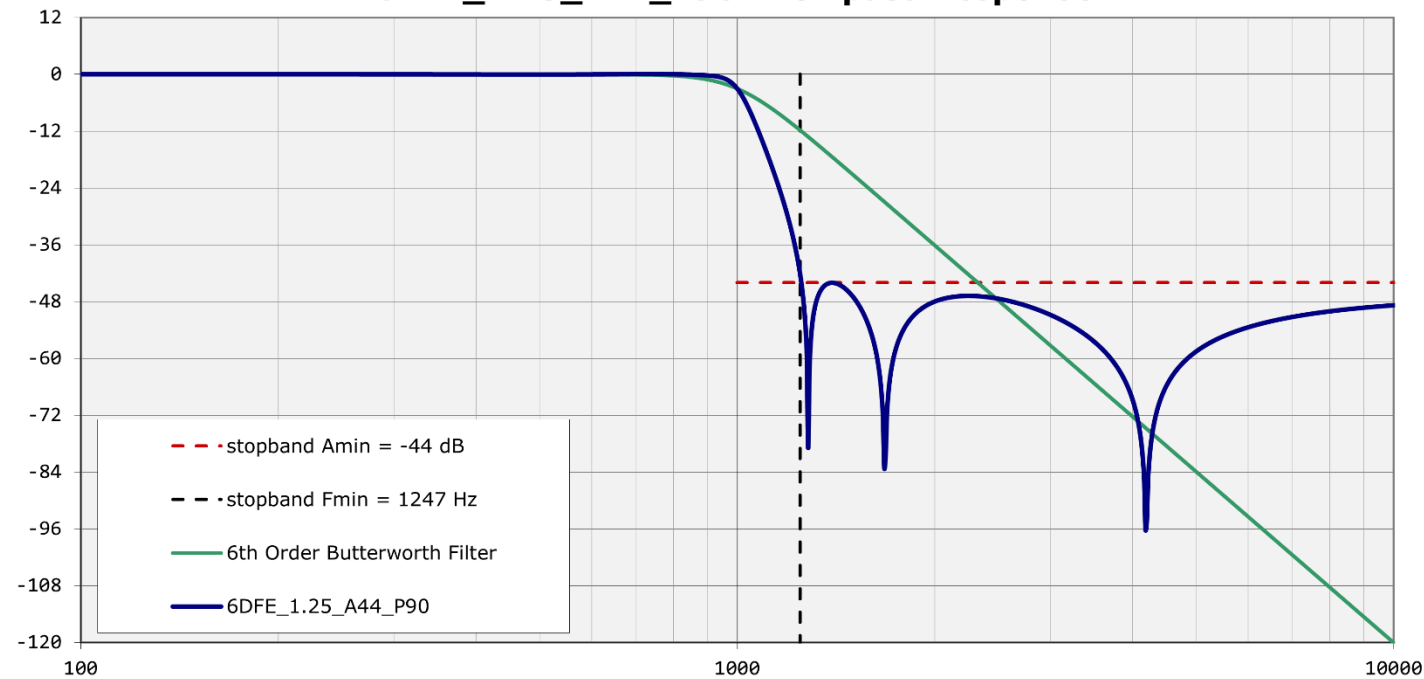
Filters:	LPN	LPN	LPN		HPN(-)	HPN	HPN	
gain [dB]:	-4.333	-10.998	-31.499		0.000	0.000	0.000	
Fp/Fc:	0.9998	0.8911	0.6846		1.0002	1.1223	1.4608	
Qp:	5.931	1.626	0.588		5.931	1.626	0.588	
Fz/Fc:	1.2831	1.6782	4.1966		0.7794	0.5959	0.2383	

Response Plots for the Crossover may be found below.

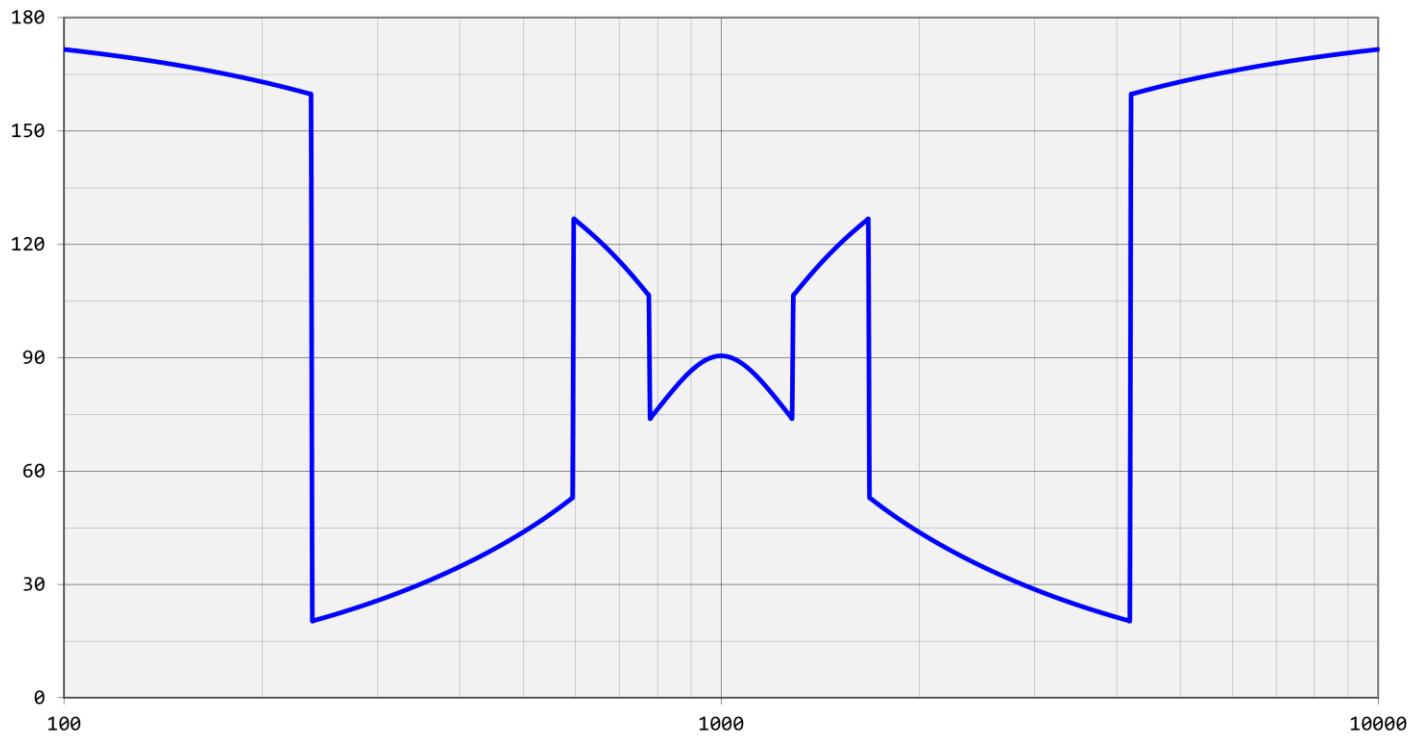
6DFE_1.25_A44_P90 : Sum of HP and LP filters



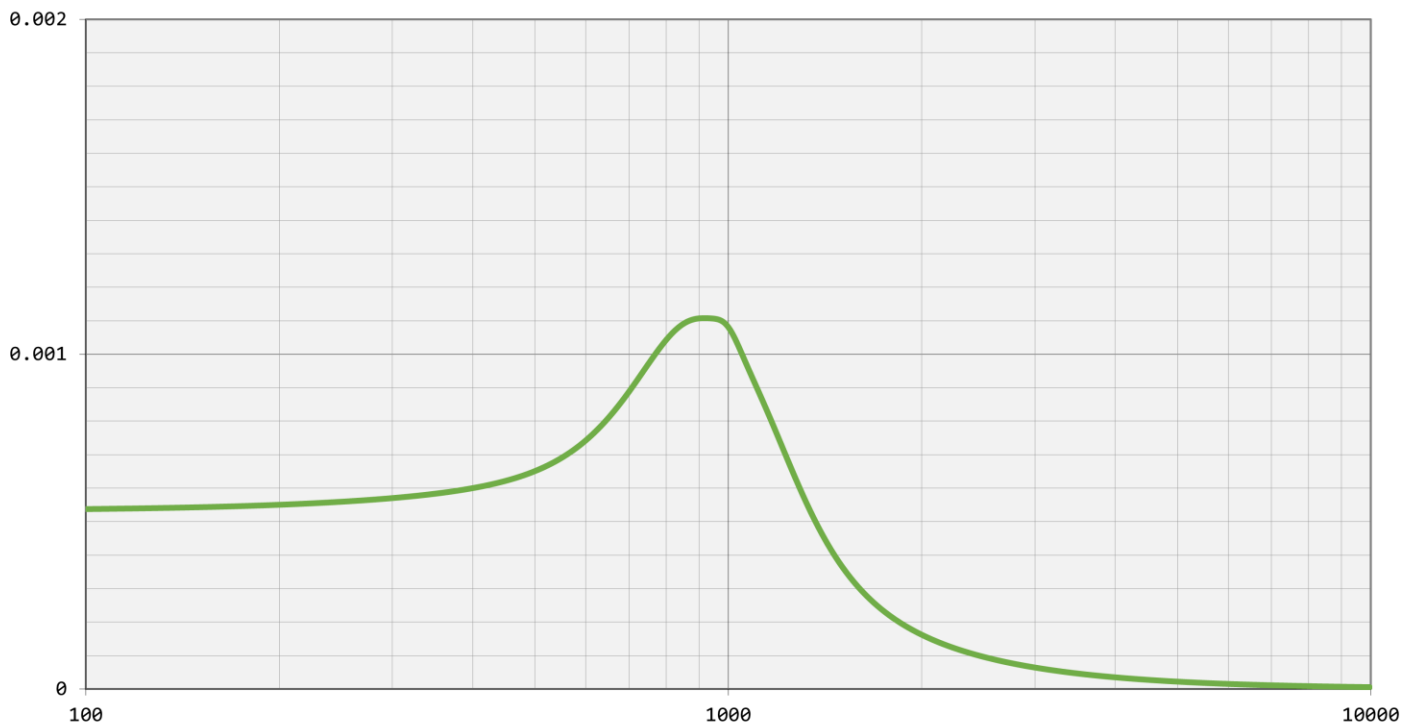
6DFE_1.25_A44_P90 : Lowpass Response



6DFE_1.25_A44_P90 : Relative Phase Angle in Degrees



6DFE_1.25_A44_P90 : Group Delay for Fc = 1k Hz



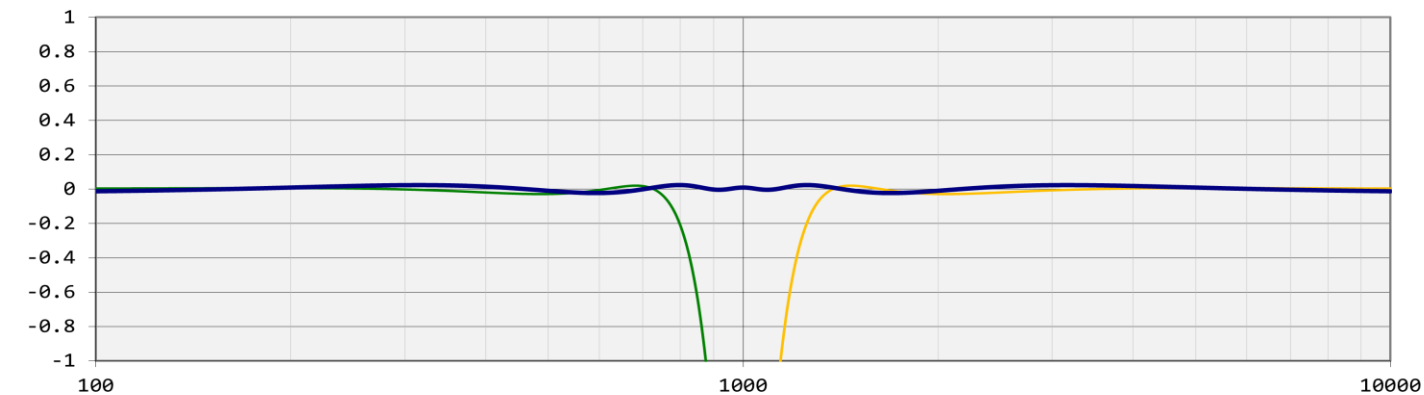
Crossover 6DFE_1.35_A47_P45:

Filters used to construct the 6DFE_1.35_A47_P45 Crossover:

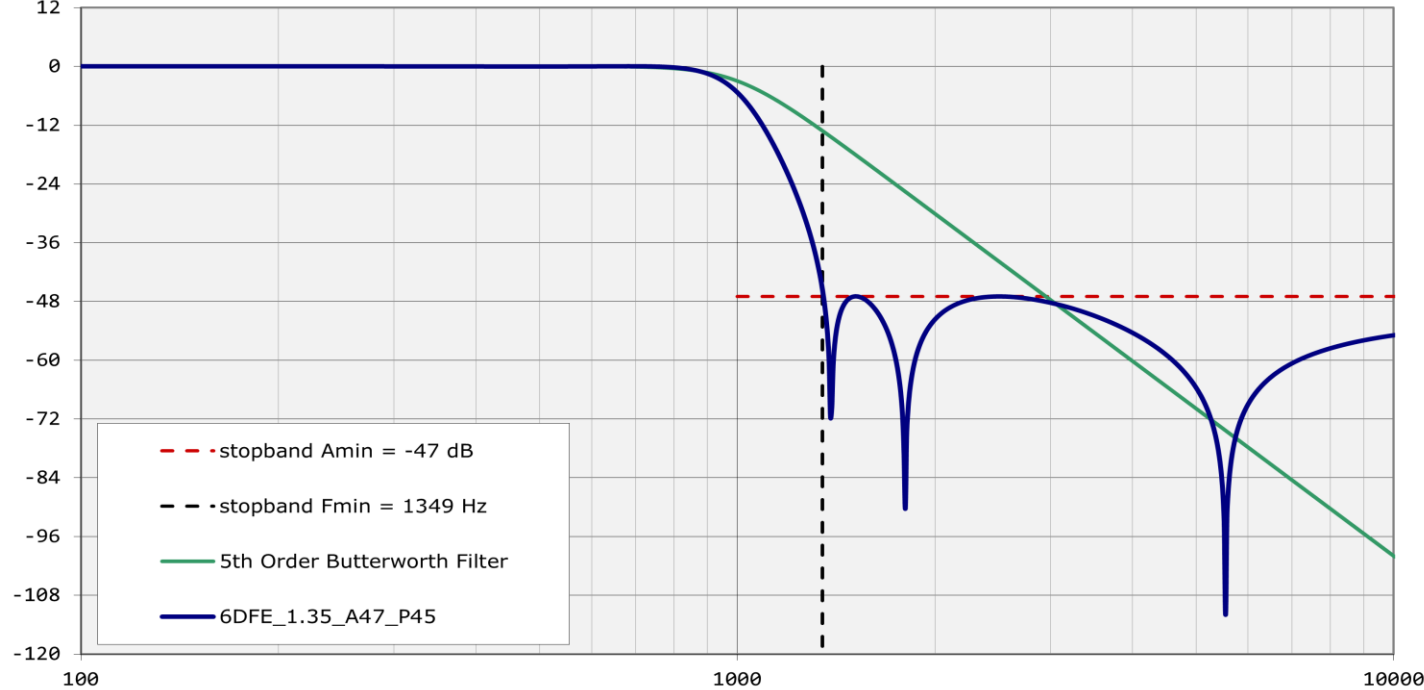
Filters:	LPN	LPN	LPN		HPN(-)	HPN	HPN	
gain [dB]:	-5.484	-10.823	-35.105		0.000	0.000	0.000	
Fp/Fc:	1.0133	0.9660	0.7348		0.9868	1.0352	1.3610	
Qp:	2.622	1.644	0.582		2.622	1.644	0.582	
Fz/Fc:	1.3895	1.8012	5.5433		0.7197	0.5552	0.1804	

Response Plots for the Crossover may be found below.

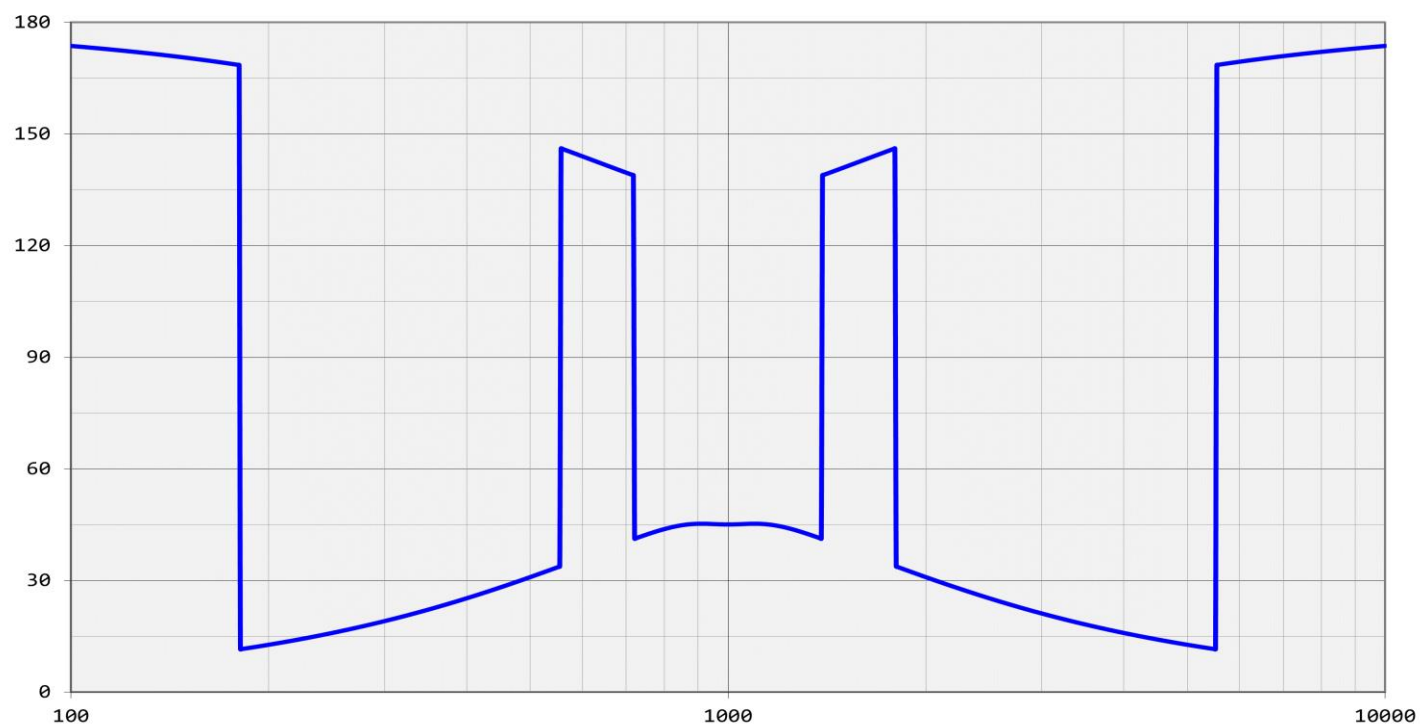
6DFE_1.35_A47_P45 : Sum of HP and LP filters



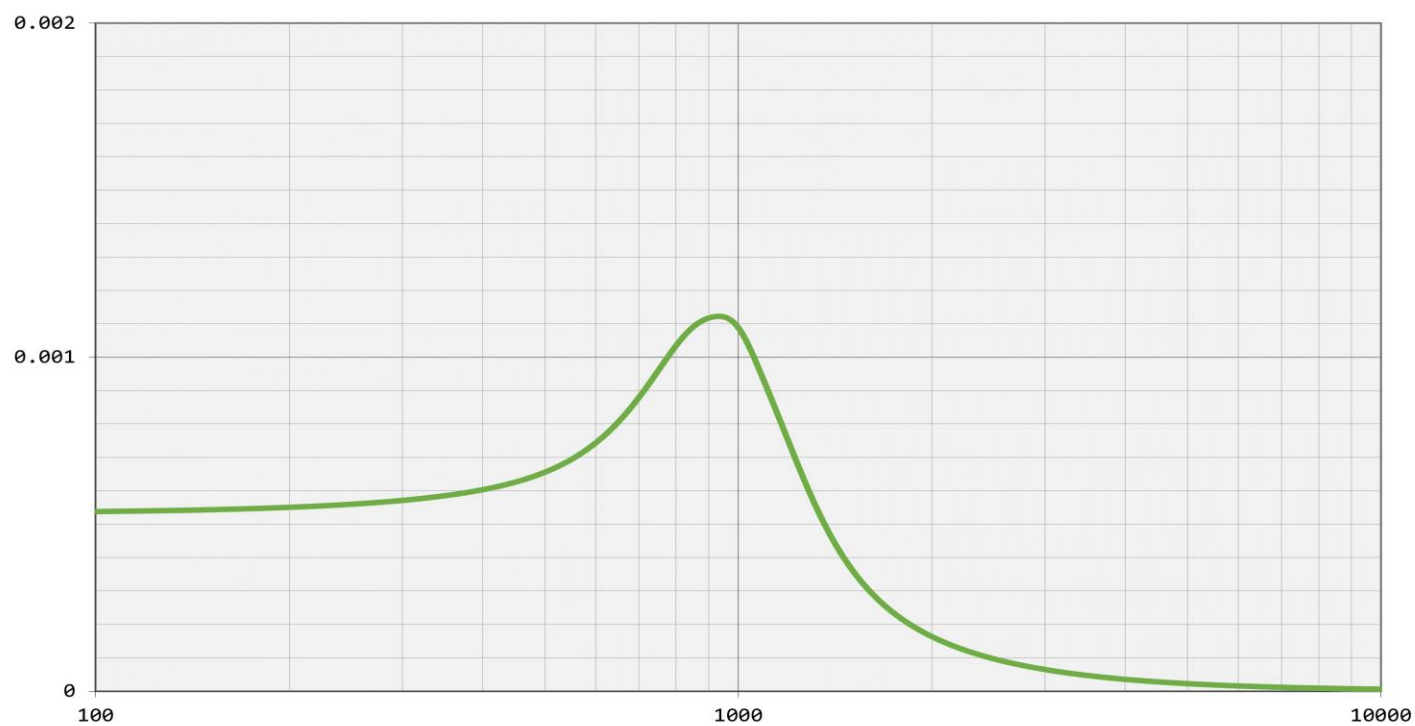
6DFE_1.35_A47_P45 : Lowpass Response



6DFE_1.35_A47_P45 : Relative Phase Angle in Degrees



6DFE_1.35_A47_P45 : Group Delay for Fc = 1k Hz



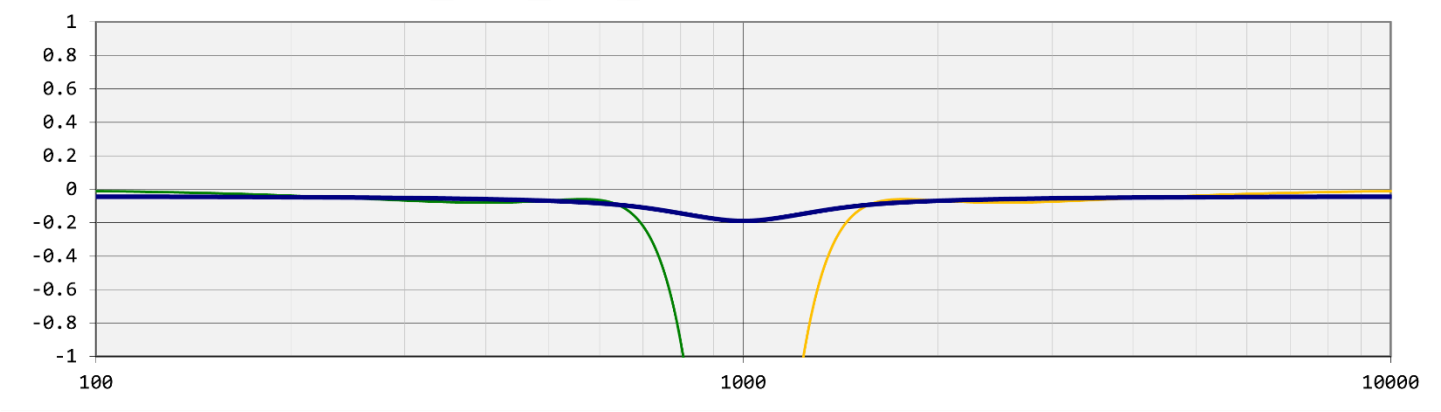
Crossover 6DFE_1.50_A52_P0:

Filters used to construct the 6DFE_1.50_A52_P0 Crossover:

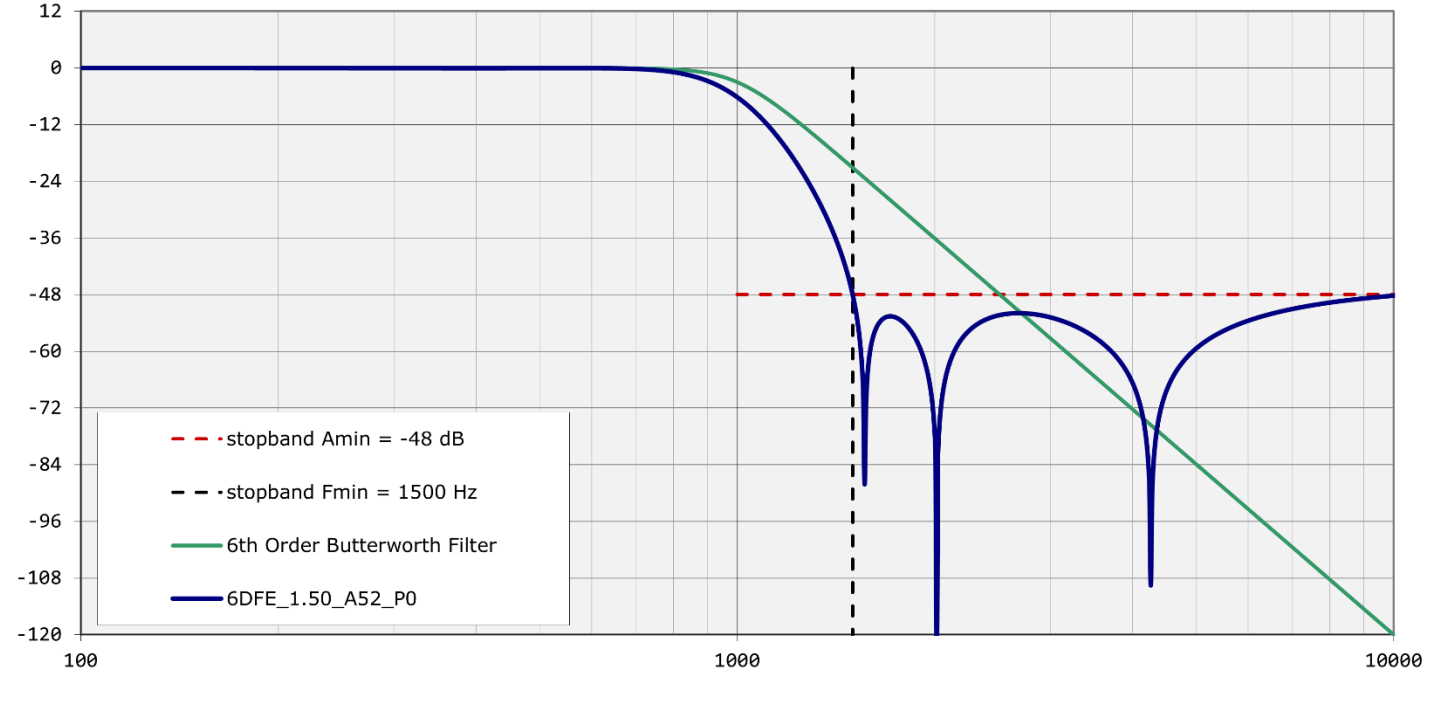
Filters:	LPN	LPN	LPN		HPN(-)	HPN	HPN	
gain [dB]:	-6.207	-13.360	-26.432		0.000	0.000	0.000	
Fp/Fc:	1.0942	0.9333	0.9320		0.9140	1.0715	1.0730	
Qp:	1.624	1.556	0.516		1.624	1.556	0.516	
Fz/Fc:	1.5641	2.0137	4.2678		0.6393	0.4966	0.2343	

Response Plots for the Crossover may be found below.

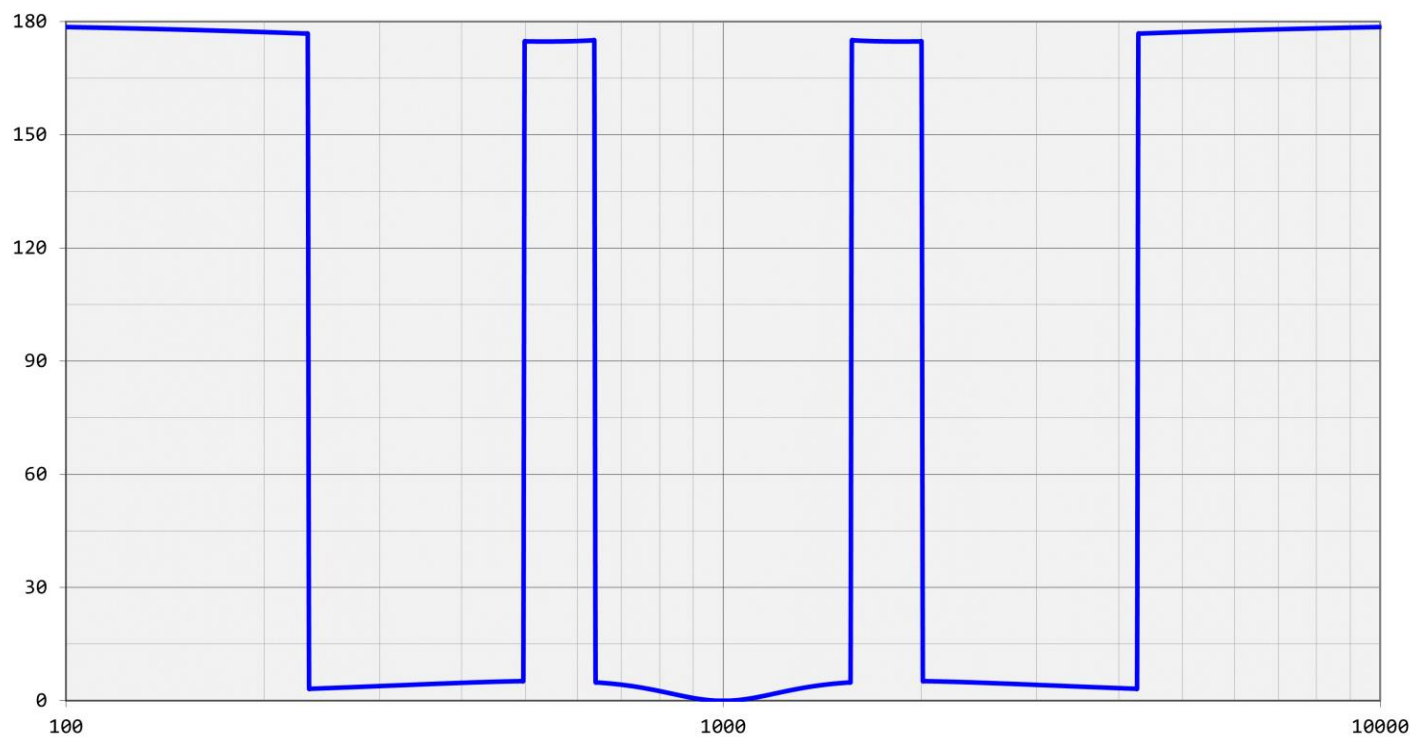
6DFE_1.50_A52_P0 : Sum of HP and LP filters



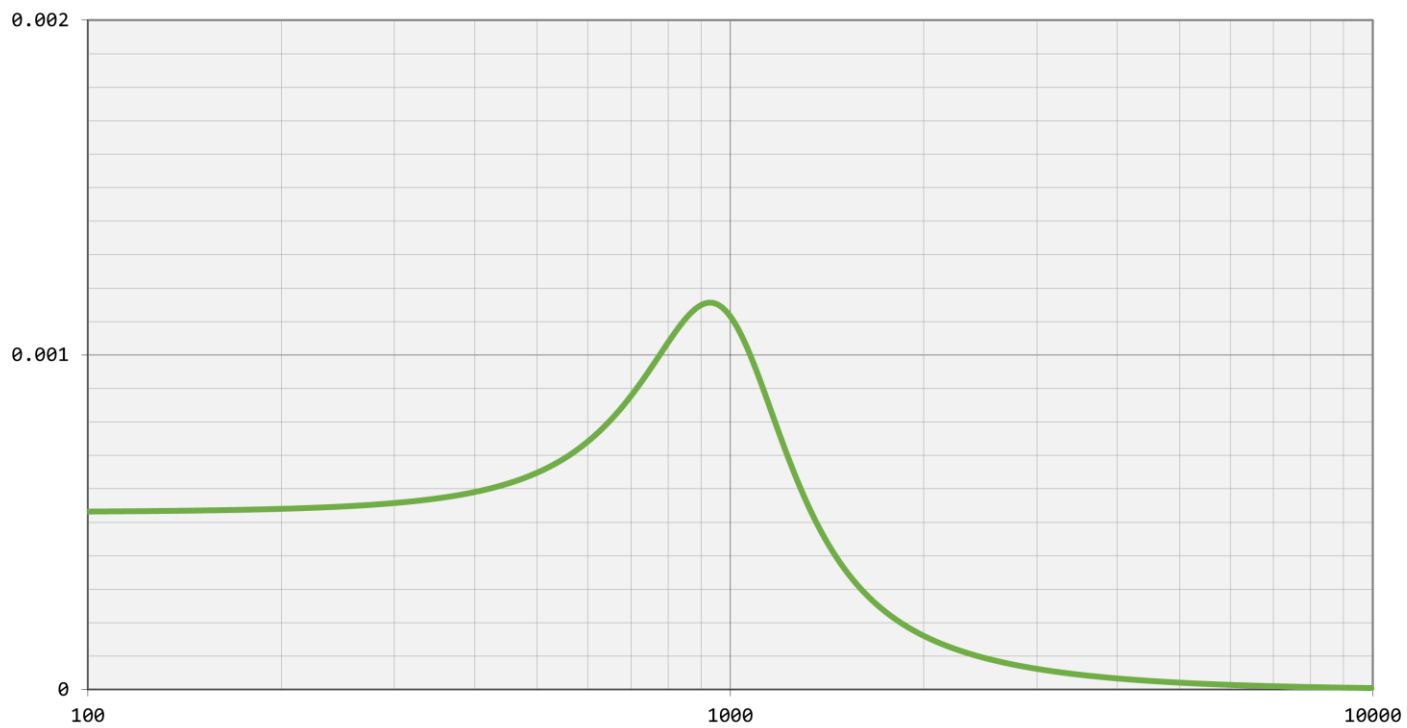
6DFE_1.50_A52_P0 : Lowpass Response



6DFE_1.50_A52_P0 : Relative Phase Angle in Degrees



6DFE_1.50_A52_P0 : Group Delay for Fc = 1k Hz



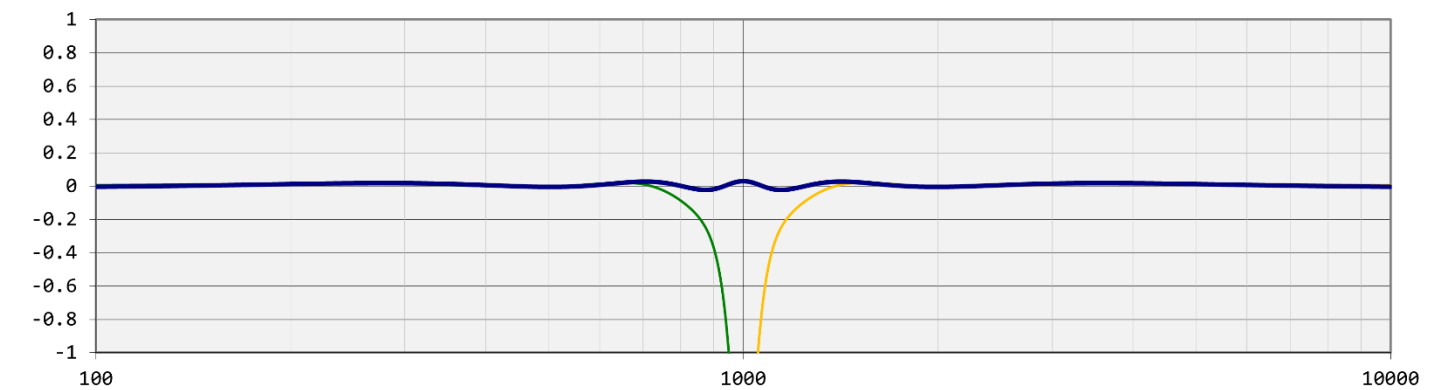
Crossover 6DFE_1.50_A58_P90:

Filters used to construct the 6DFE_1.50_A58_P90 Crossover:

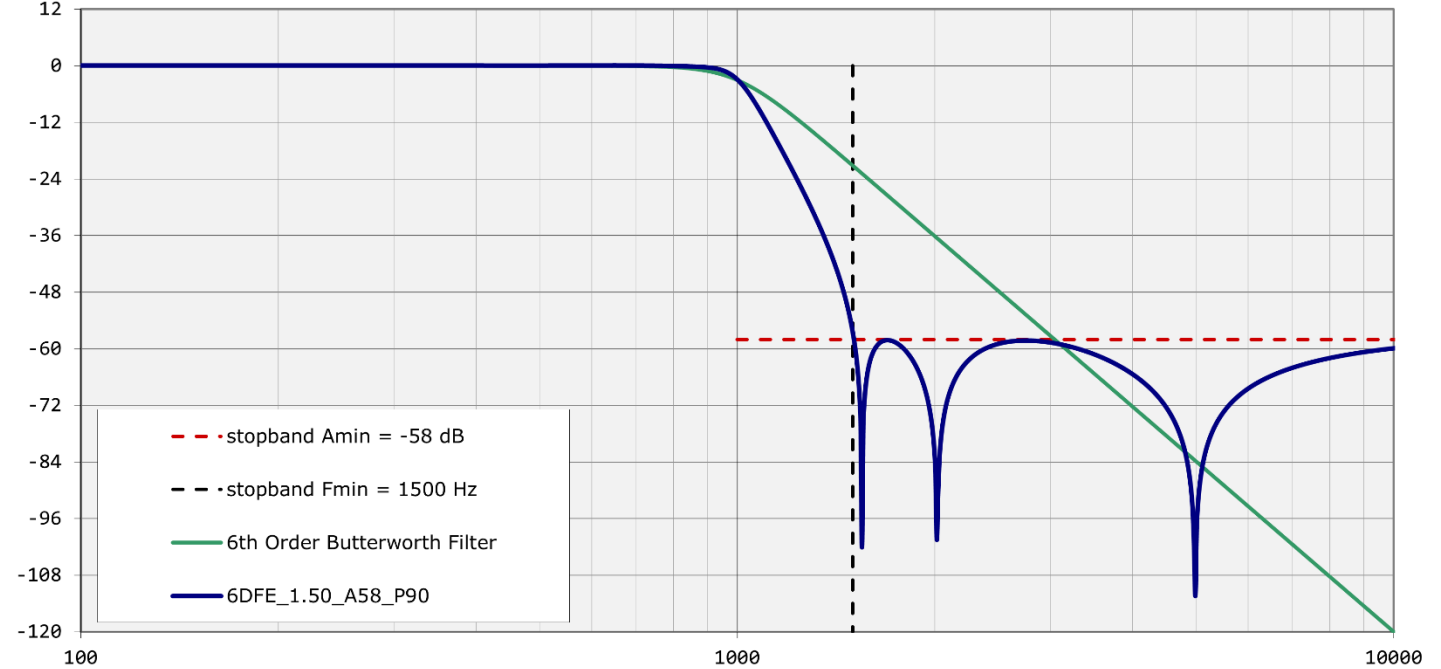
Filters:	LPN	LPN	LPN		HPN(-)	HPN	HPN	
gain [dB]:	-7.607	-14.520	-34.872		0.000	0.000	0.000	
Fp/Fc:	0.9994	0.8740	0.6695		1.0006	1.1442	1.4937	
Qp:	4.486	1.315	0.575		4.486	1.315	0.575	
Fz/Fc:	1.5485	2.0160	4.9835		0.6458	0.4960	0.2007	

Response Plots for the Crossover may be found below.

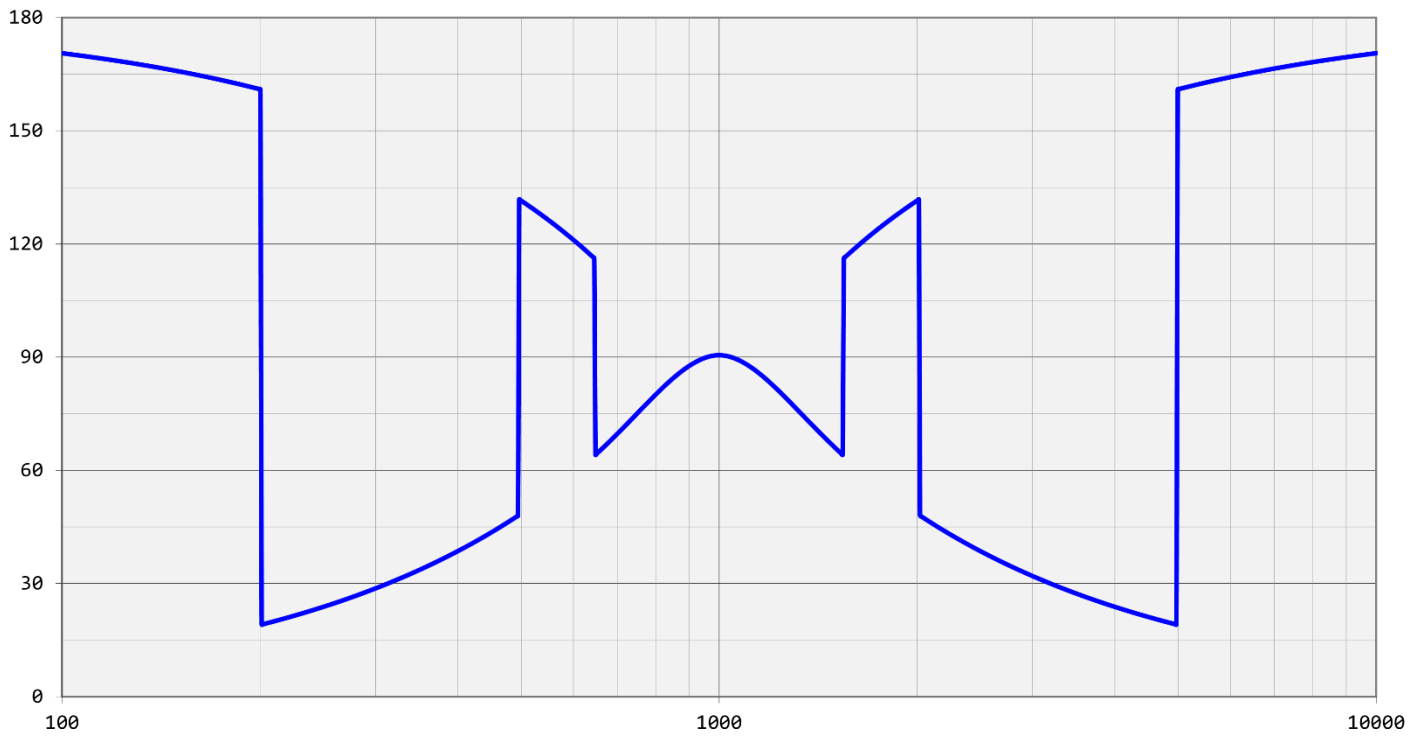
6DFE_1.50_A58_P90 : Sum of HP and LP filters



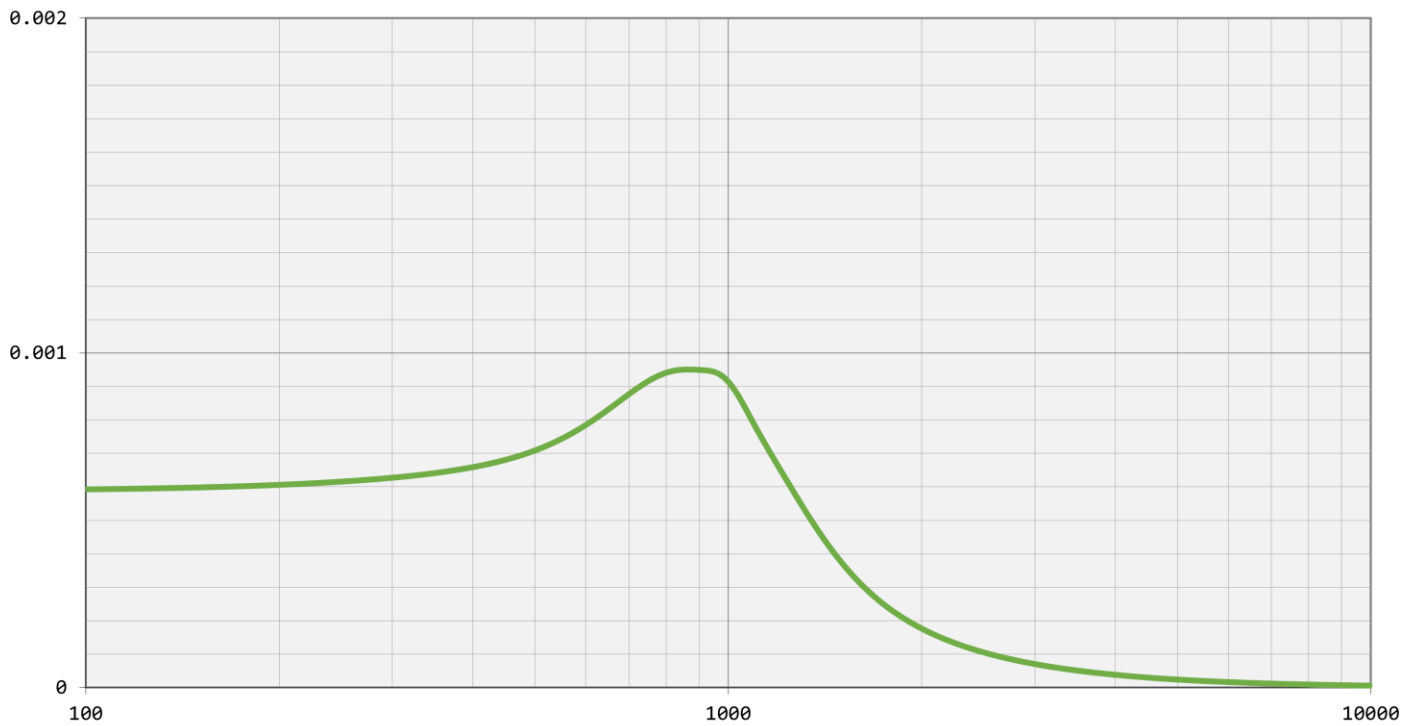
6DFE_1.50_A58_P90 : Lowpass Response



6DFE_1.50_A58_P90 : Relative Phase Angle in Degrees



6DFE_1.50_A58_P90 : Group Delay for $F_c = 1\text{ k Hz}$



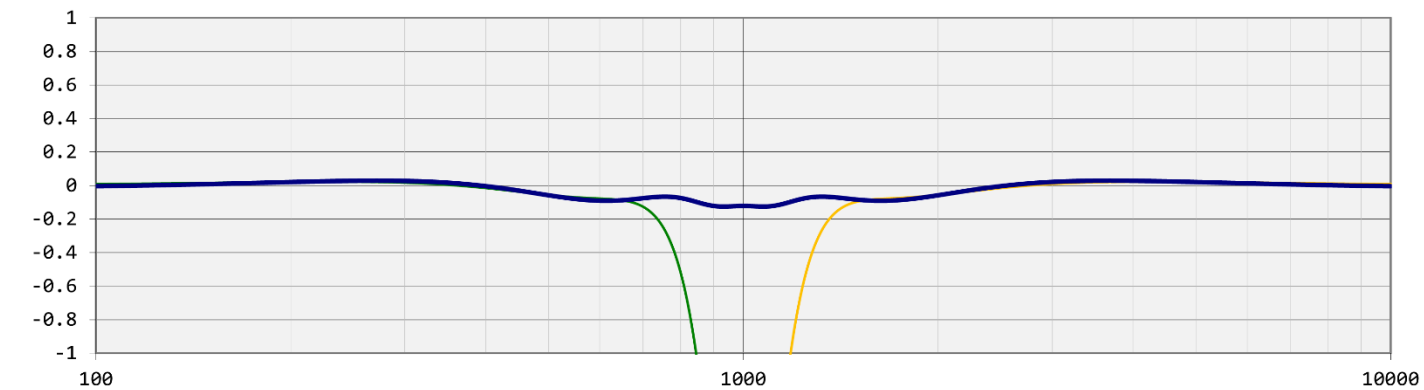
Crossover 6DFE_1.51_A55_P44:

Filters used to construct the 6DFE_1.51_A55_P44 Crossover:

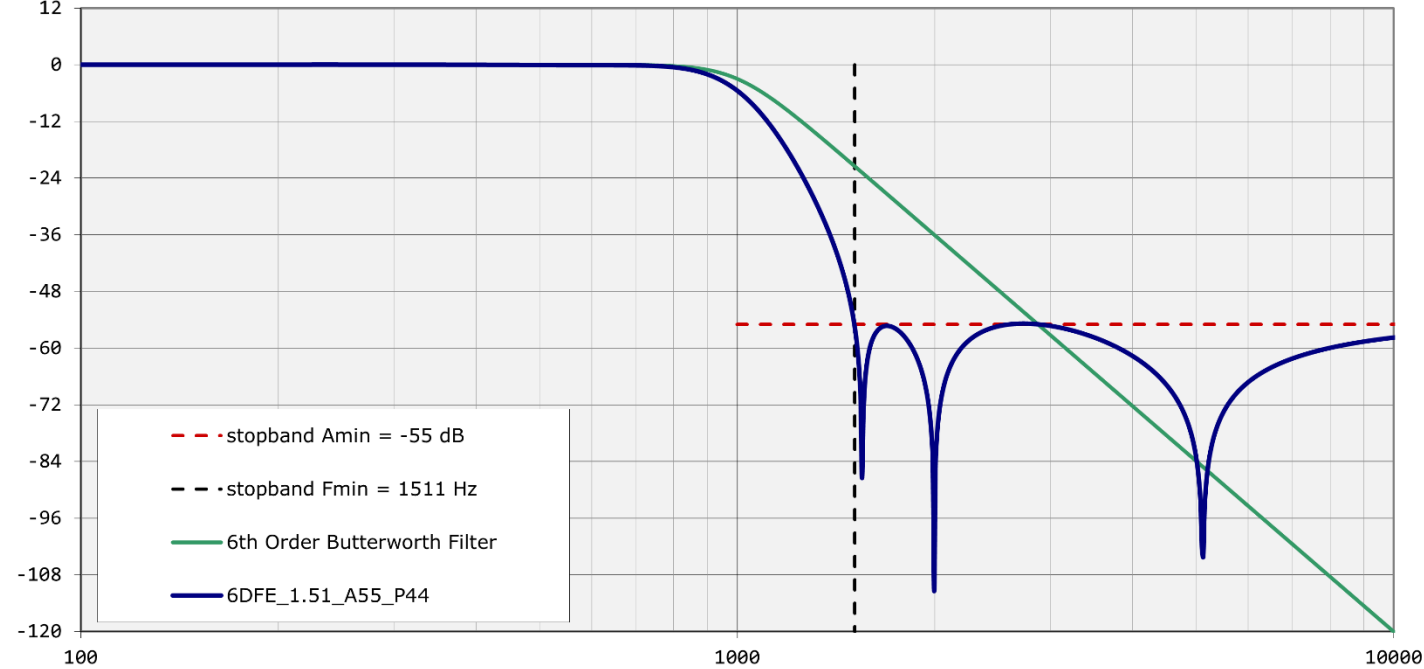
Filters:	LPN	LPN	LPN		HPN(-)	HPN	HPN	
gain [dB]:	-6.344	-13.175	-35.168		0.000	0.000	0.000	
Fp/Fc:	1.0759	0.9348	0.6759		0.9295	1.0697	1.4794	
Qp:	2.091	1.788	0.593		2.091	1.788	0.593	
Fz/Fc:	1.5501	1.9957	5.1180		0.6451	0.5011	0.1954	

Response Plots for the Crossover may be found below.

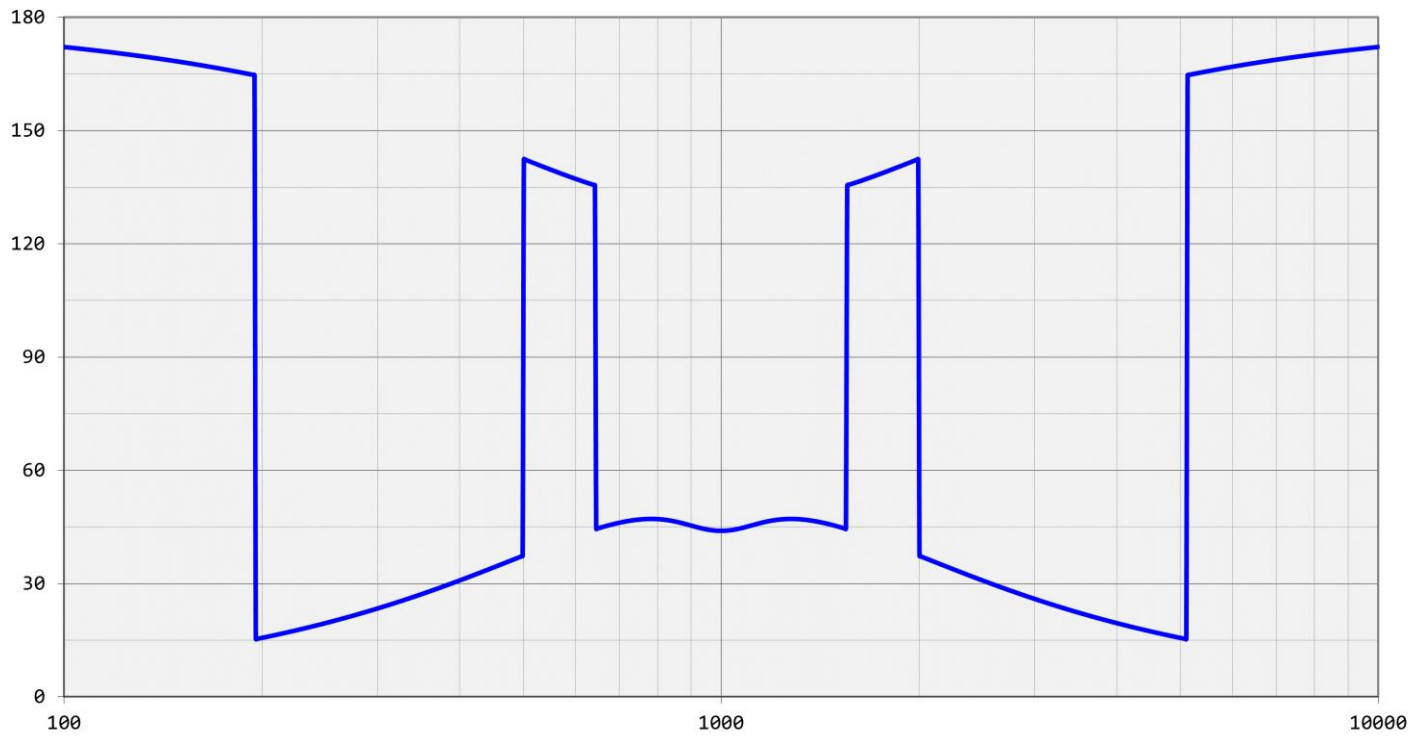
6DFE_1.51_A55_P44 : Sum of HP and LP filters



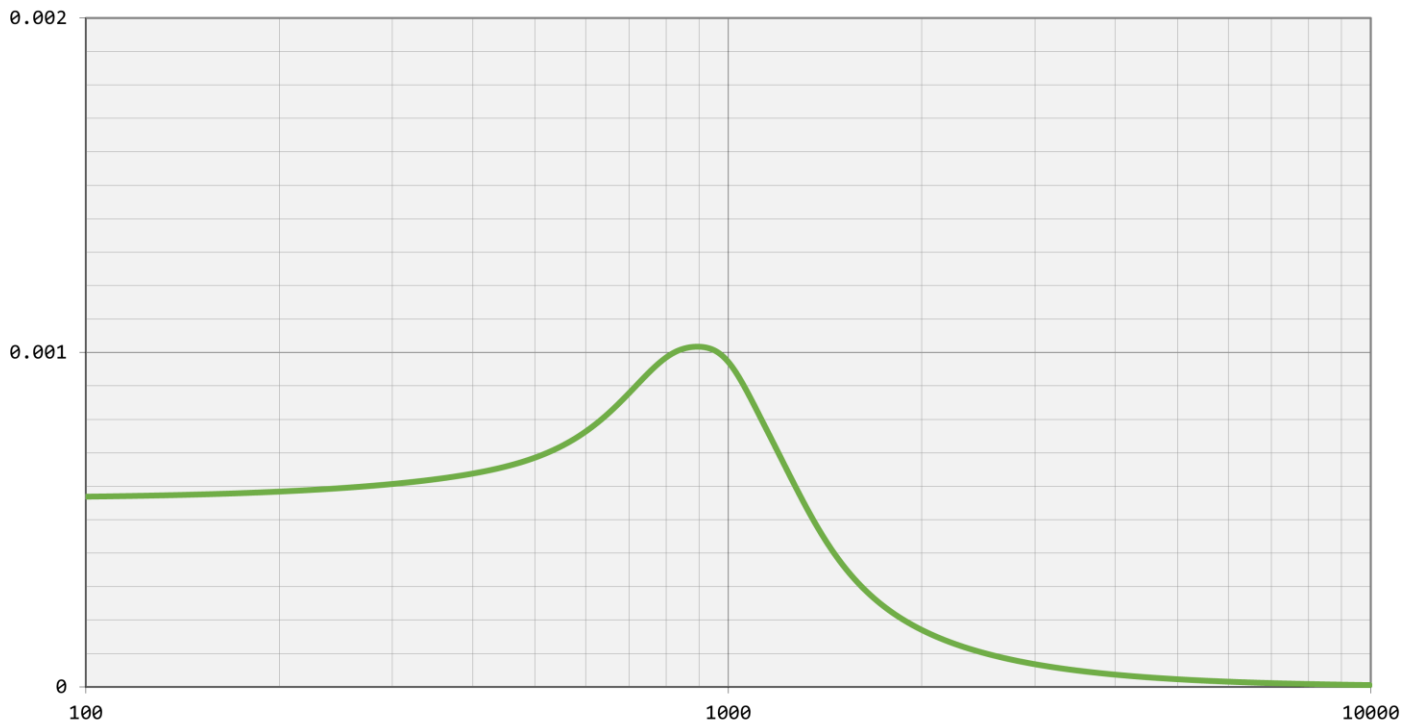
6DFE_1.51_A55_P44 : Lowpass Response



6DFE_1.51_A55_P44 : Relative Phase Angle in Degrees



6DFE_1.51_A55_P44 : Group Delay for Fc = 1k Hz



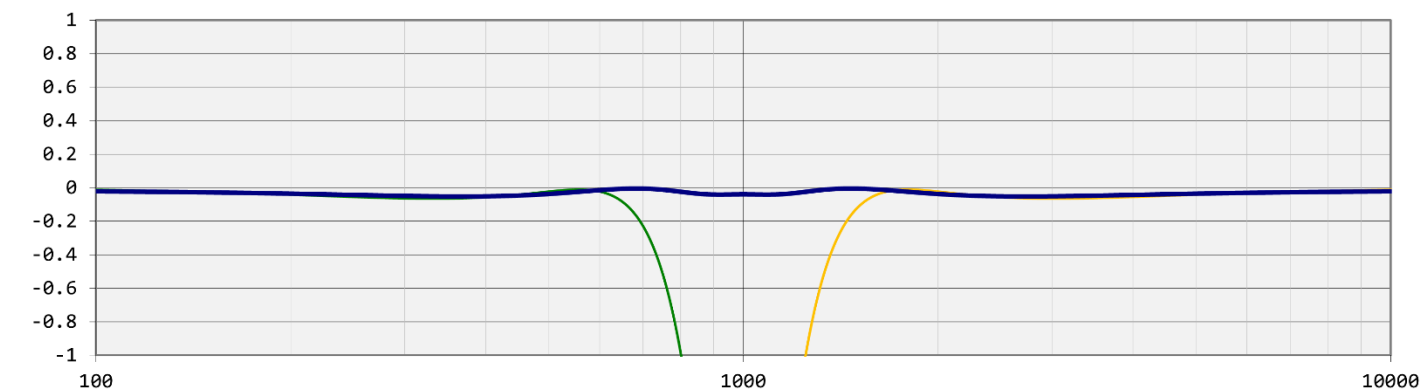
Crossover 6DFE_1.64_A55_P1:

Filters used to construct the 6DFE_1.64_A55_P1 Crossover:

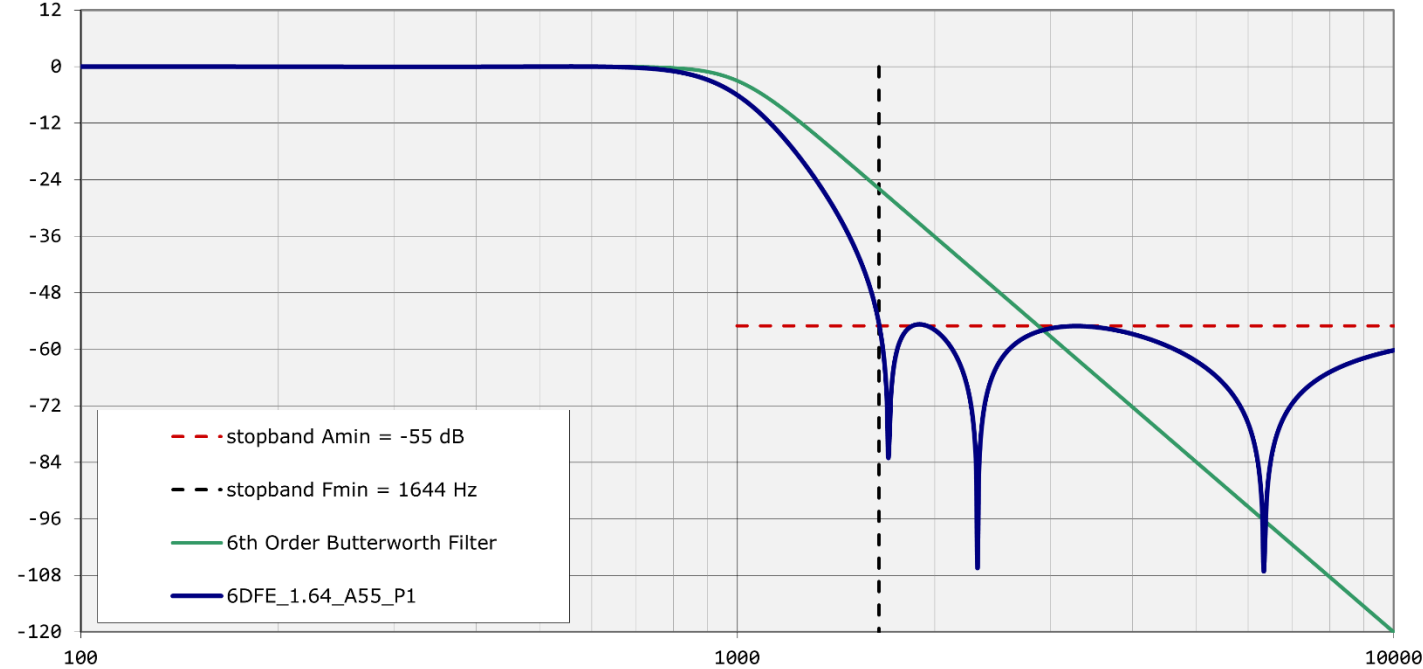
Filters:	LPN	LPN	LPN		HPN(-)	HPN	HPN	
gain [dB]:	-10.308	-14.400	-30.293		0.000	0.000	0.000	
Fp/Fc:	0.9398	1.0144	1.1101		1.0641	0.9858	0.9008	
Qp:	1.204	1.675	0.456		1.204	1.675	0.456	
Fz/Fc:	1.7011	2.3238	6.3487		0.5878	0.4303	0.1575	

Response Plots for the Crossover may be found below.

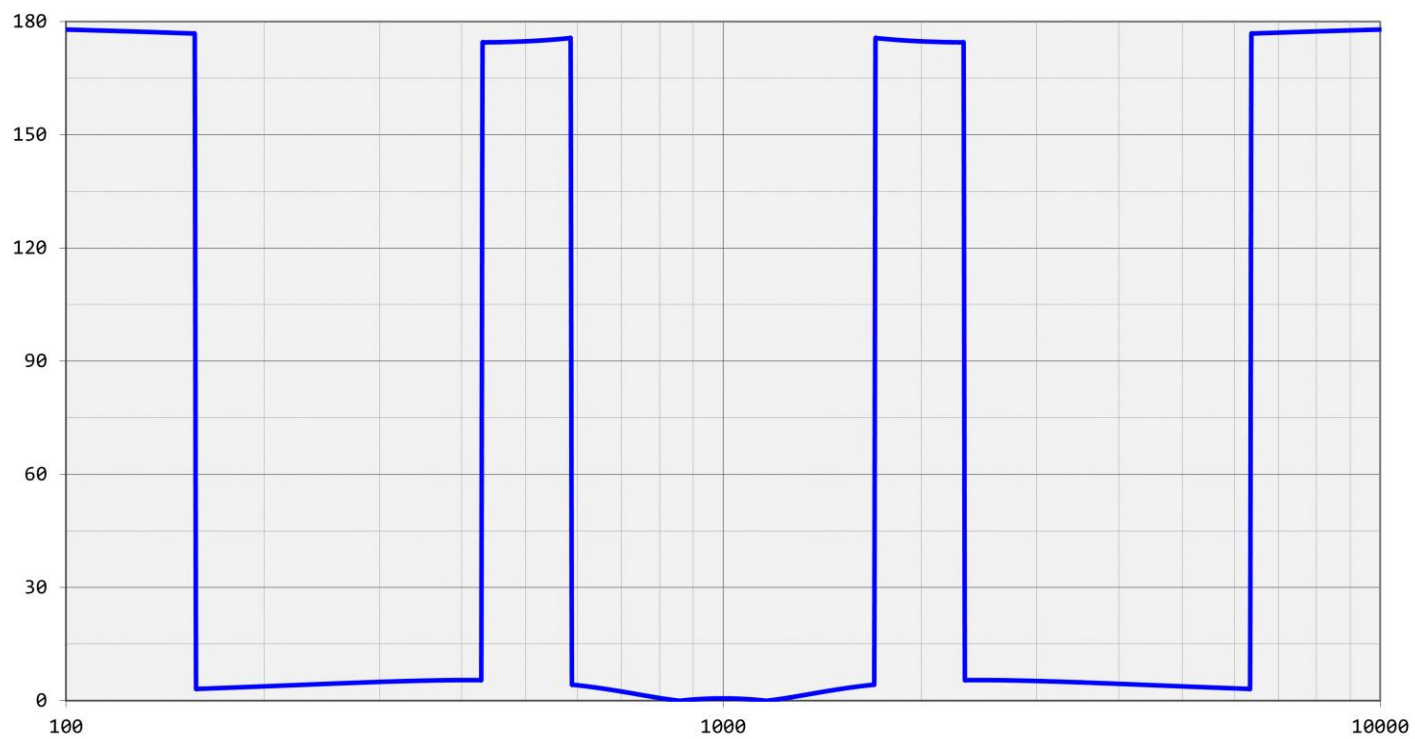
6DFE_1.64_A55_P1 : Sum of HP and LP filters



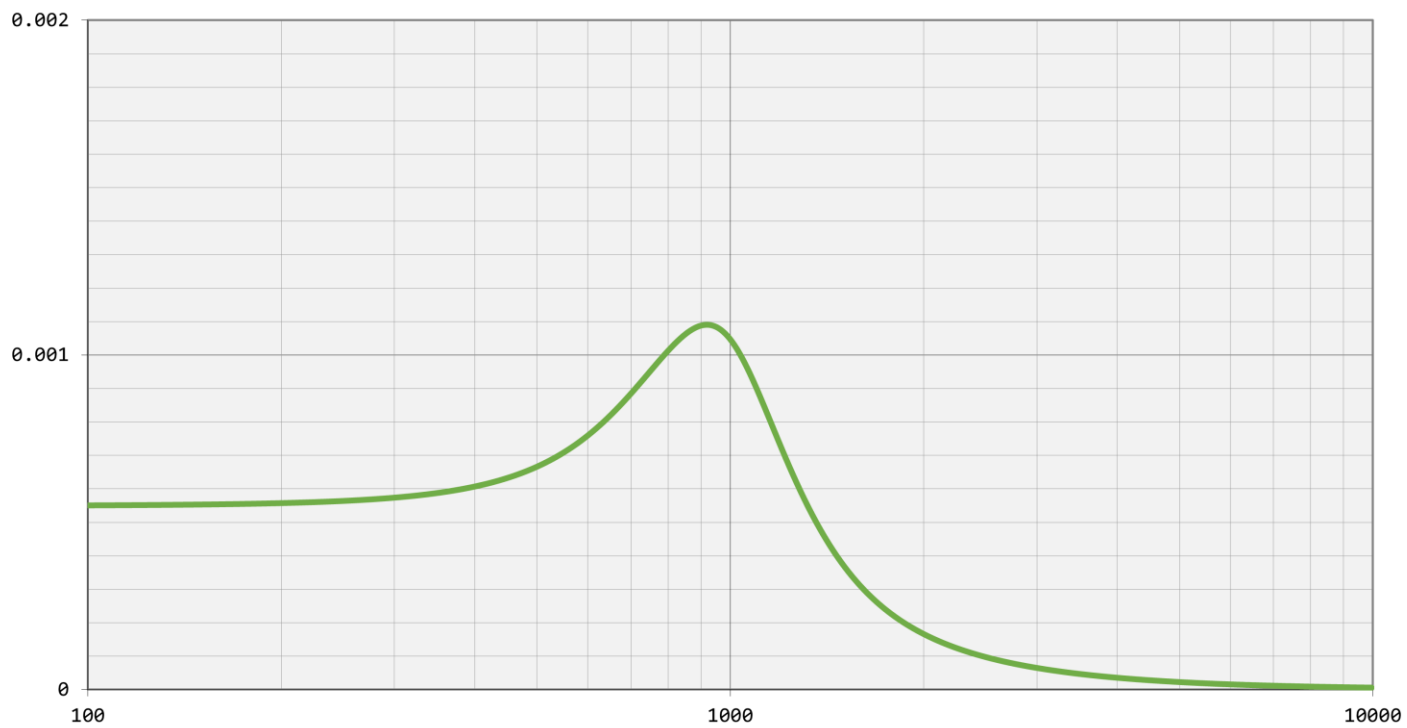
6DFE_1.64_A55_P1 : Lowpass Response



6DFE_1.64_A55_P1 : Relative Phase Angle in Degrees



6DFE_1.64_A55_P1 : Group Delay for $F_c = 1\text{ k Hz}$



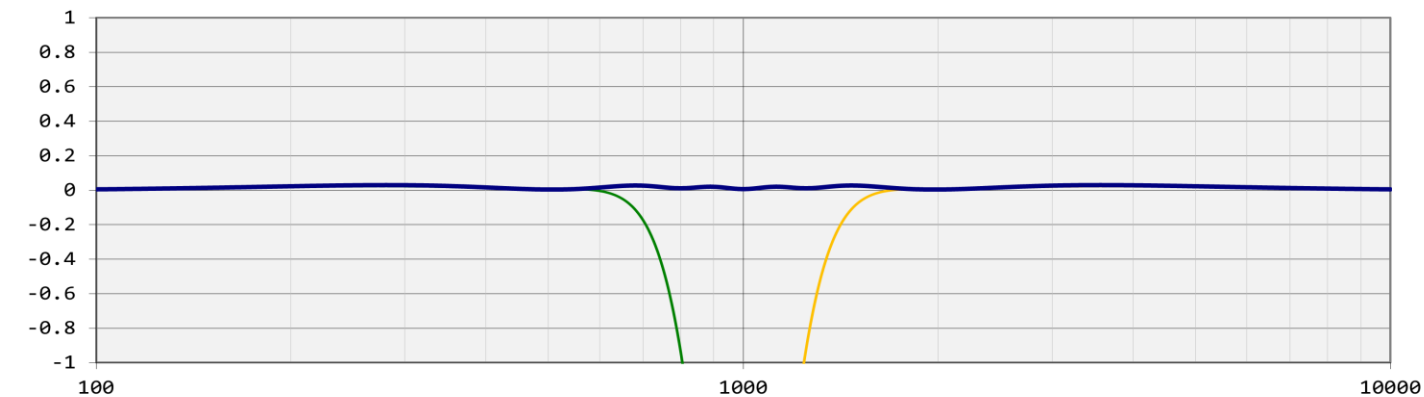
Crossover 6DFE_1.75_A63_P28:

Filters used to construct the 6DFE_1.75_A63_P28 Crossover:

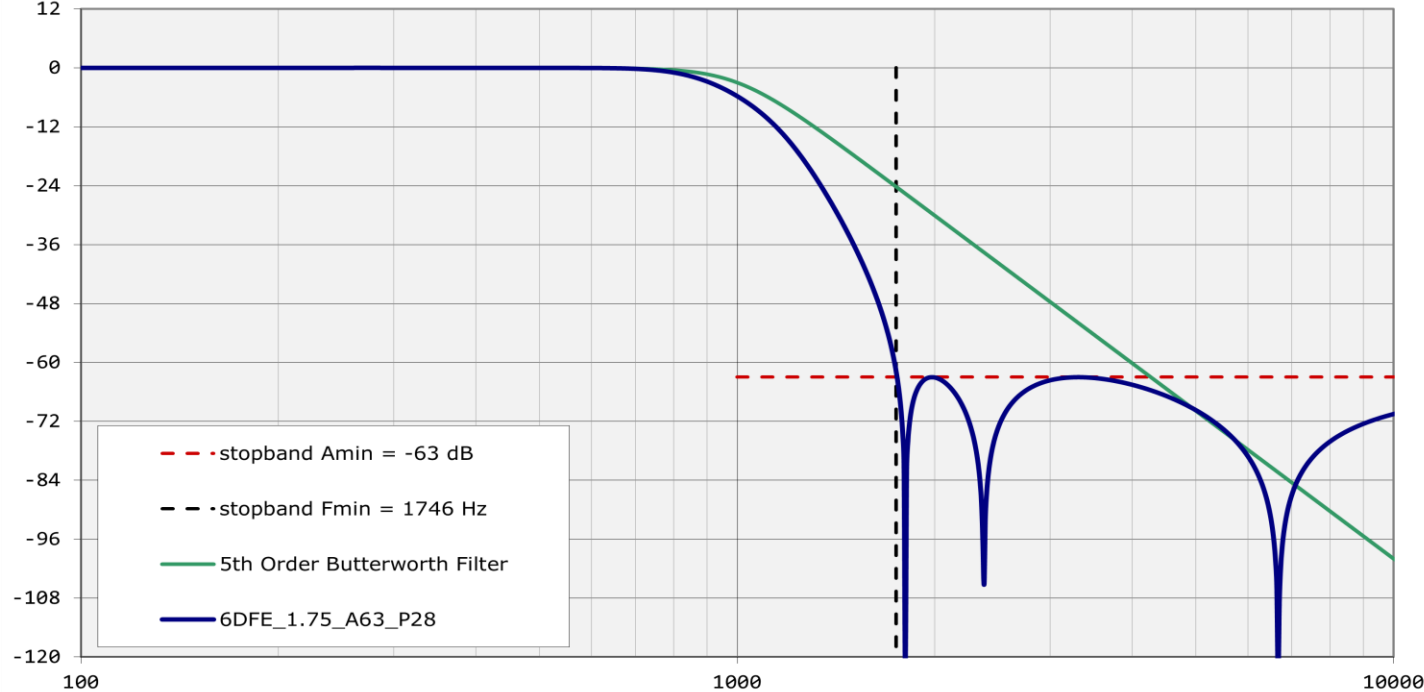
Filters:	LPN	LPN	LPN		HPN(-)	HPN	HPN	
gain [dB]:	-7.367	-17.356	-40.025		0.000	0.000	0.000	
Fp/Fc:	1.1799	0.8741	0.6663		0.8475	1.1440	1.5008	
Qp:	2.136	1.618	0.580		2.136	1.618	0.580	
Fz/Fc:	1.8031	2.3740	6.6726		0.5546	0.4212	0.1499	

Response Plots for the Crossover may be found below.

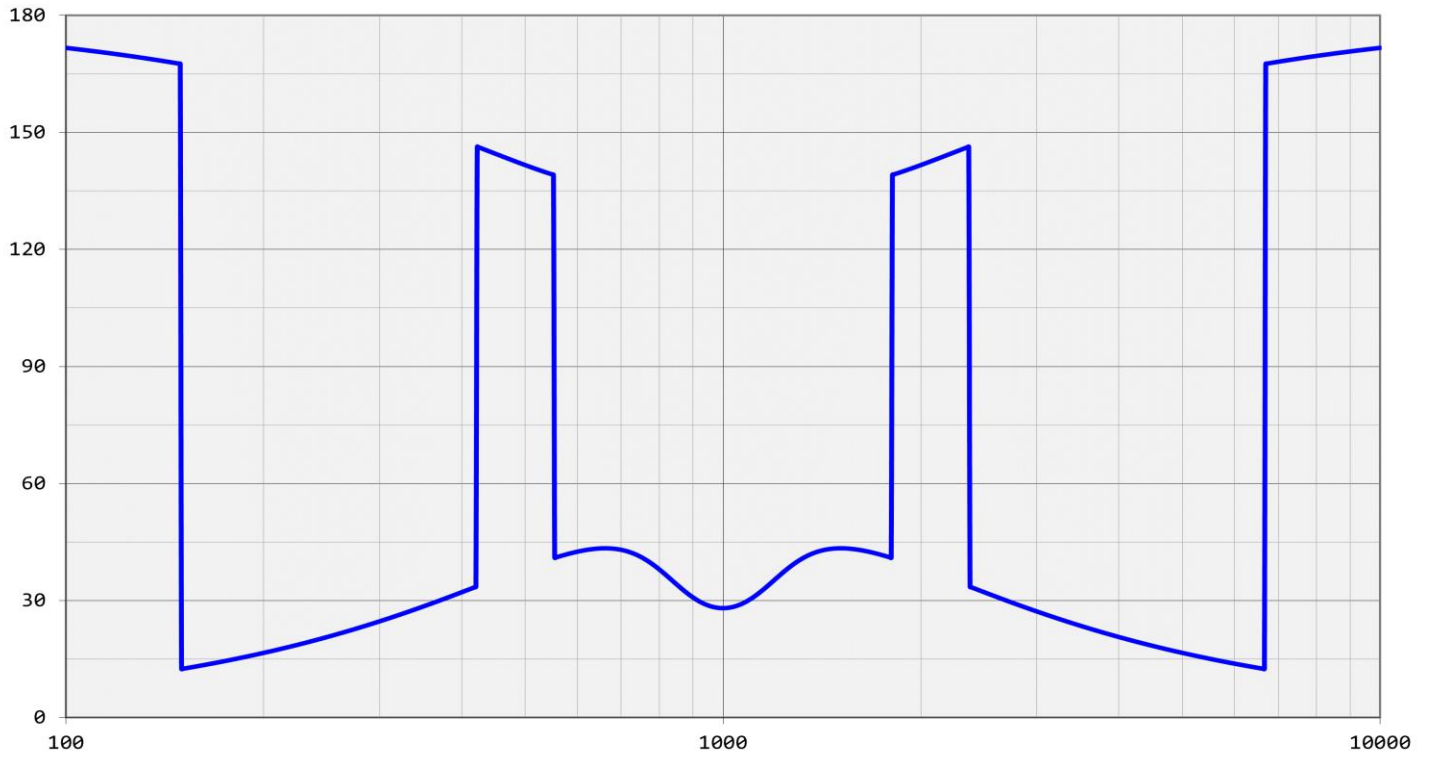
6DFE_1.75_A63_P28 : Sum of HP and LP filters



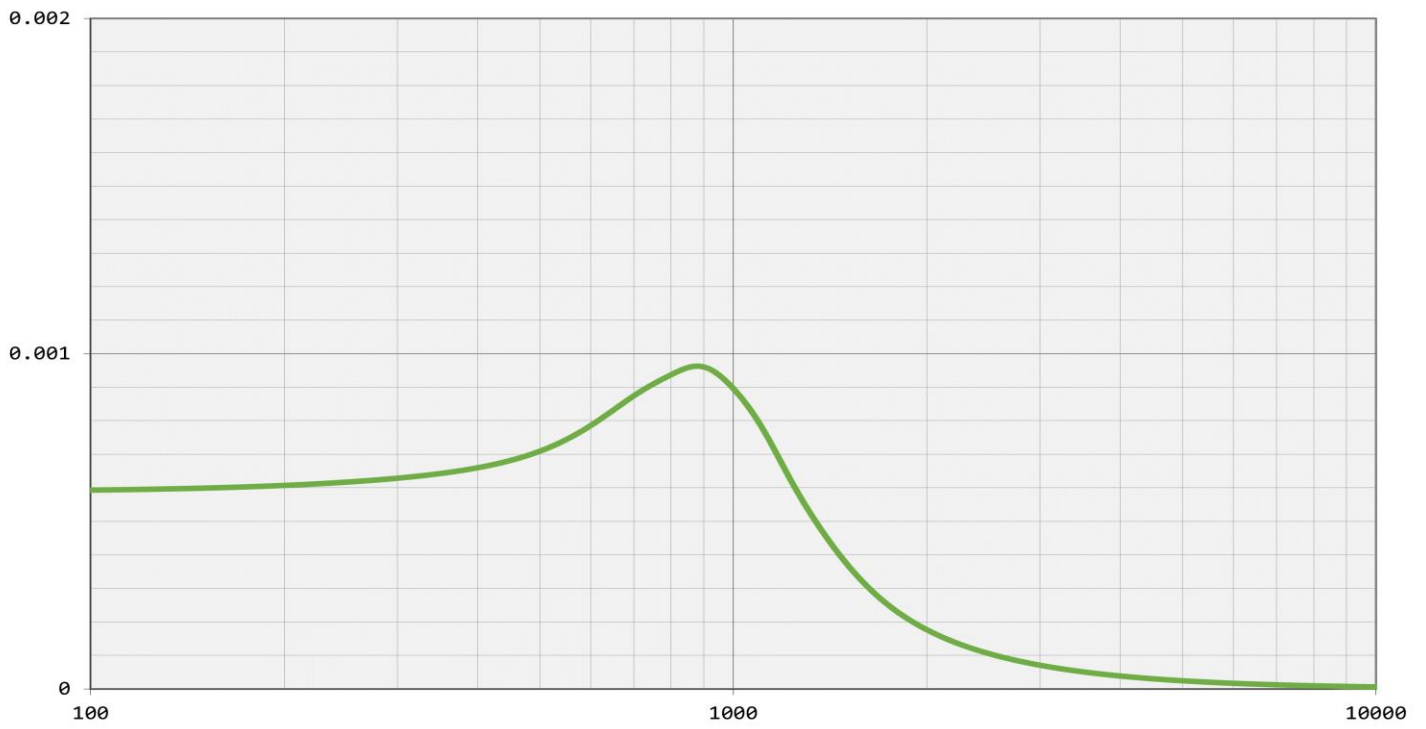
6DFE_1.75_A63_P28 : Lowpass Response



6DFE_1.75_A63_P28 : Relative Phase Angle in Degrees



6DFE_1.75_A63_P28 : Group Delay for Fc = 1k Hz



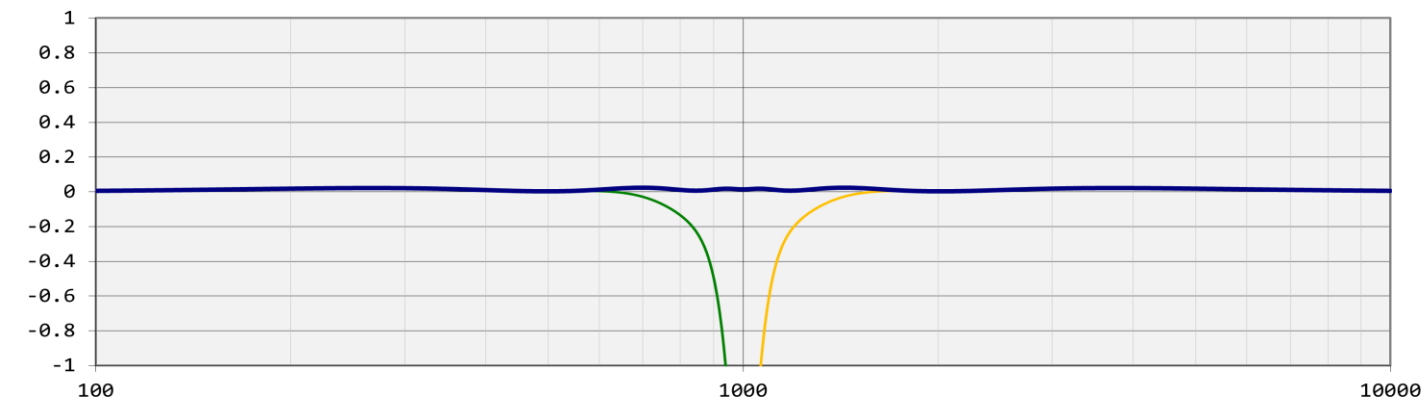
Crossover 6DFE_1.75_A66_P90:

Filters used to construct the 6DFE_1.75_A66_P90 Crossover:

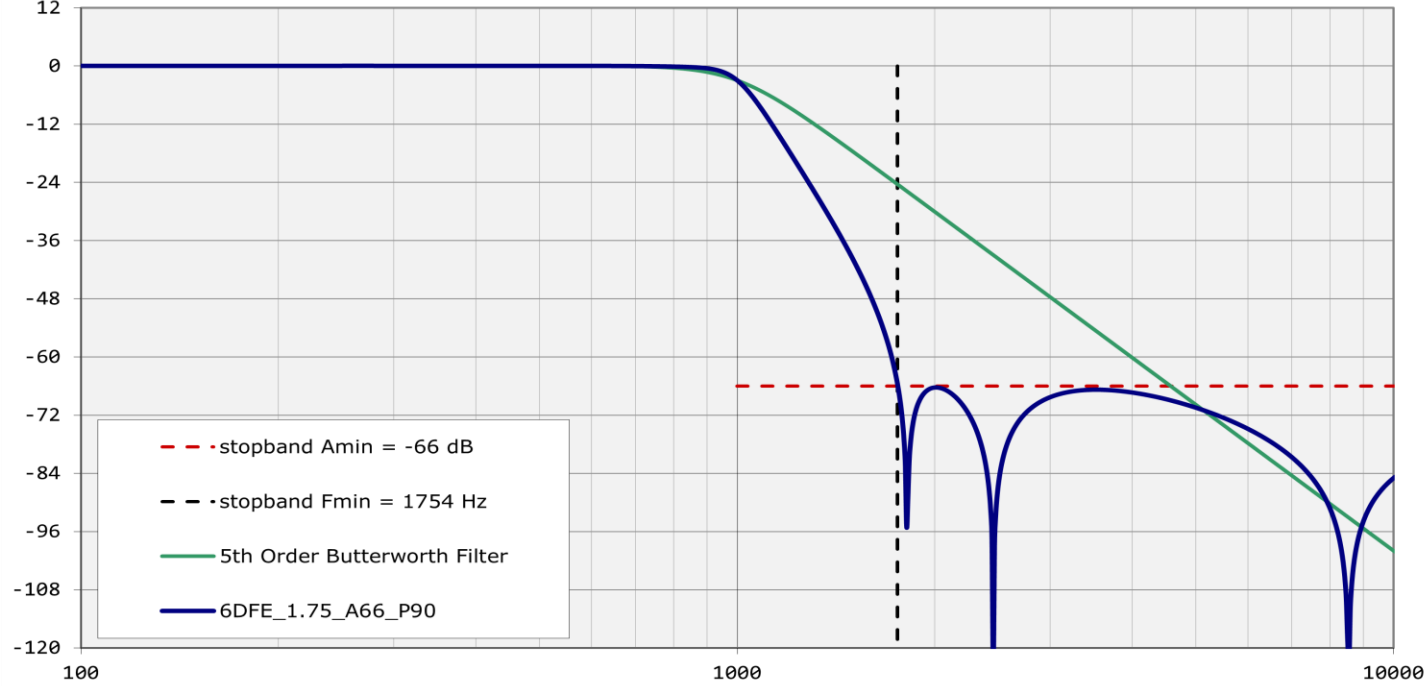
Filters:	LPN	LPN	LPN	HPN(-)	HPN	HPN	
gain [dB]:	-10.370	-18.073	-44.466	0.000	0.000	0.000	
Fp/Fc:	0.9986	0.8675	0.6601	1.0014	1.1527	1.5149	
Qp:	3.800	1.176	0.568	3.800	1.176	0.568	
Fz/Fc:	1.8140	2.4553	8.5360	0.5513	0.4073	0.1172	

Response Plots for the Crossover may be found below.

6DFE_1.75_A66_P90 : Sum of HP and LP filters



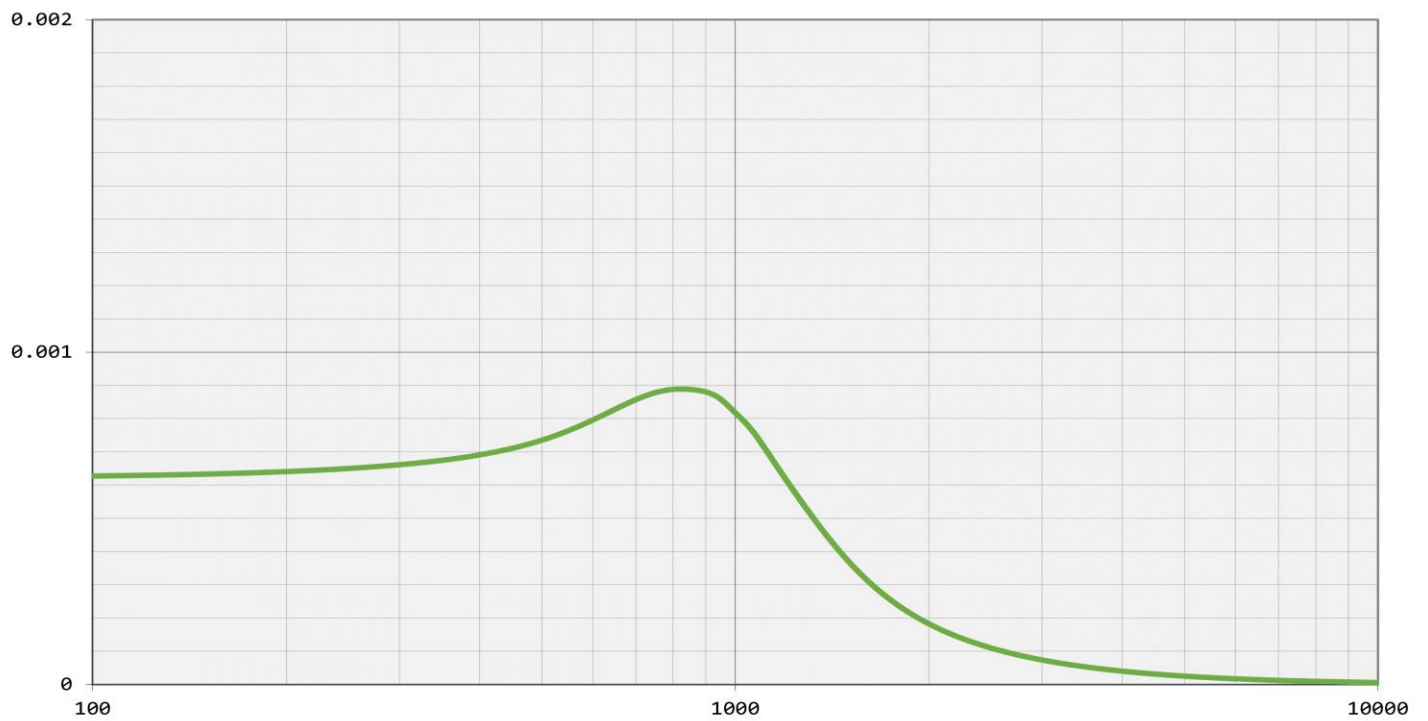
6DFE_1.75_A66_P90 : Lowpass Response



6DFE_1.75_A66_P90 : Relative Phase Angle in Degrees



6DFE_1.75_A66_P90 : Group Delay for $F_c = 1\text{ k Hz}$



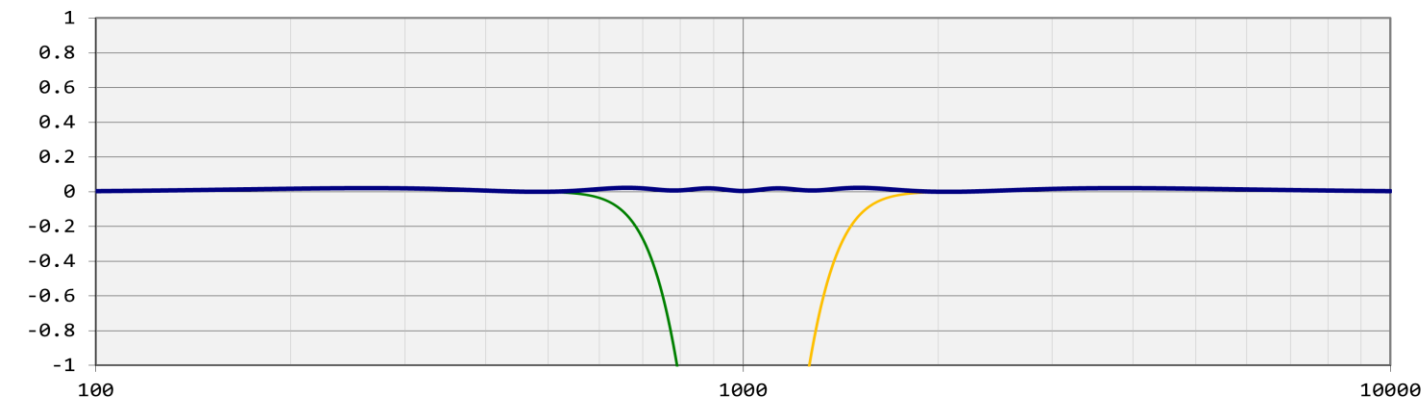
Crossover 6DFE_2.00_A72_P29:

Filters used to construct the 6DFE_2.00_A72_P29 Crossover:

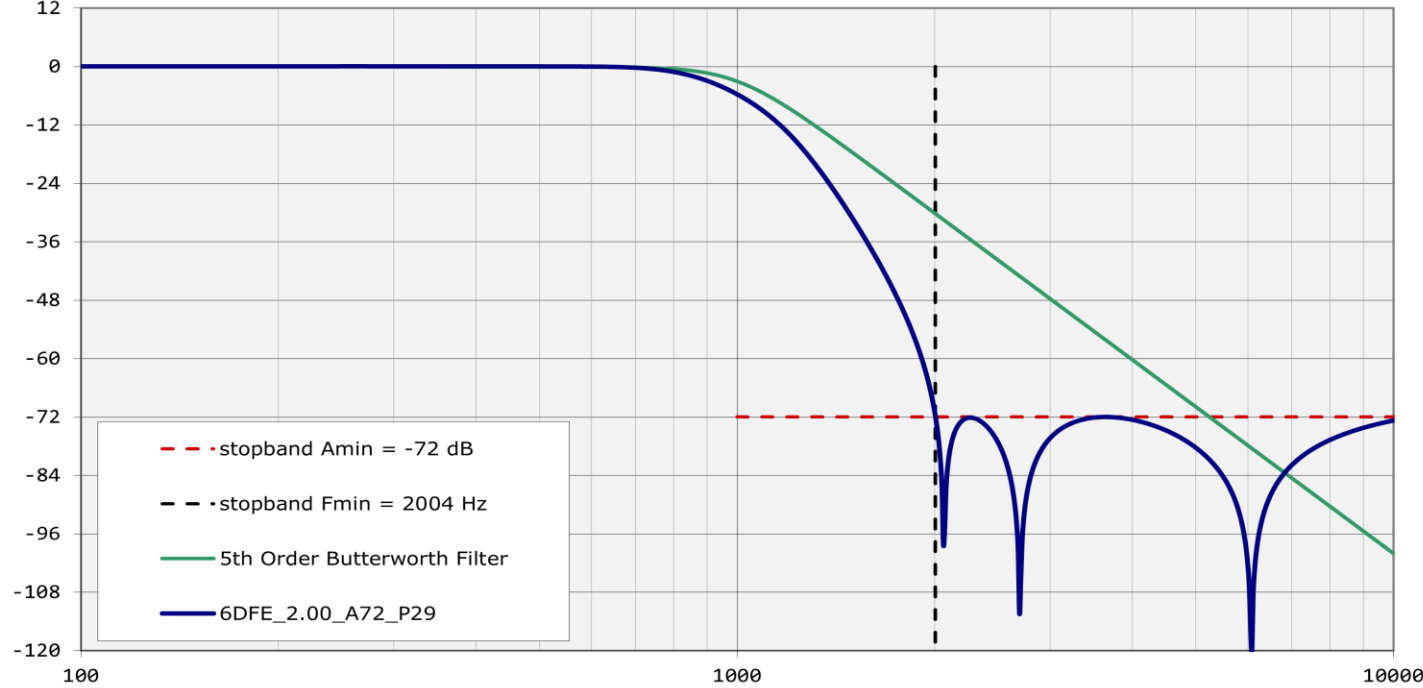
Filters:	LPN	LPN	LPN		HPN(-)	HPN	HPN	
gain [dB]:	-9.525	-19.755	-38.550		0.000	0.000	0.000	
Fp/Fc:	1.1931	0.8644	0.6600		0.8382	1.1568	1.5152	
Qp:	2.031	1.524	0.574		2.031	1.524	0.574	
Fz/Fc:	2.0644	2.6953	6.0714		0.4844	0.3710	0.1647	

Response Plots for the Crossover may be found below.

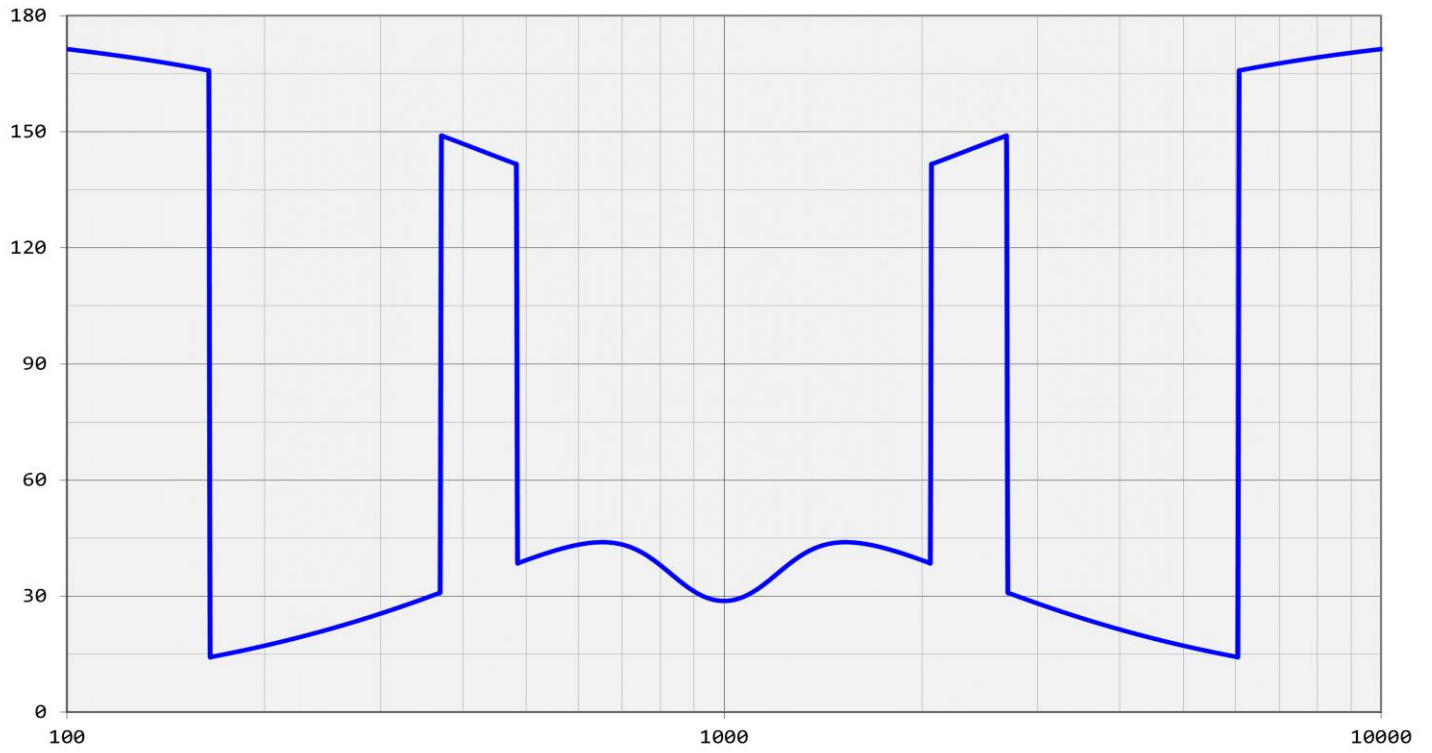
6DFE_2.00_A72_P29 : Sum of HP and LP filters



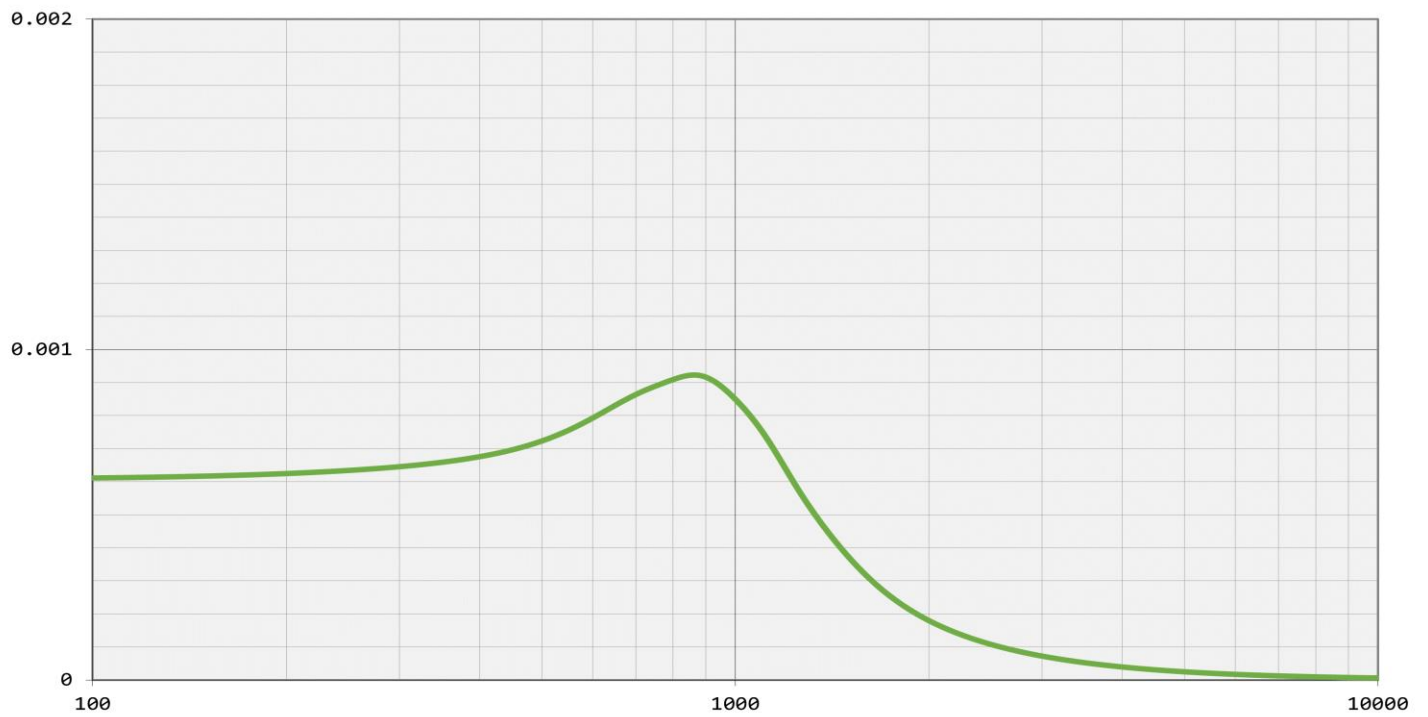
6DFE_2.00_A72_P29 : Lowpass Response



6DFE_2.00_A72_P29 : Relative Phase Angle in Degrees



6DFE_2.00_A72_P29 : Group Delay for Fc = 1k Hz



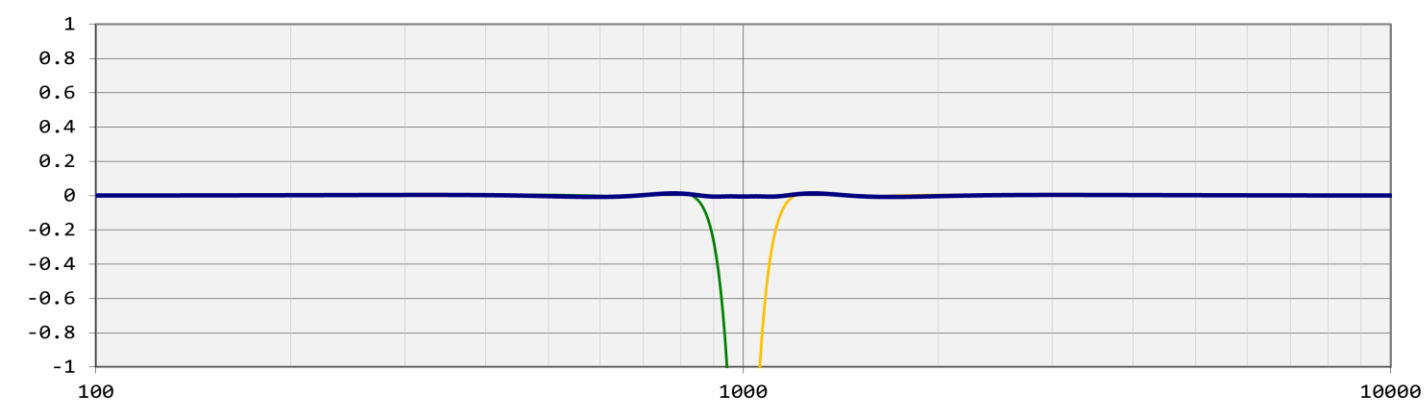
Crossover 7DFE_1.24_A45_P81:

Filters used to construct the 7DFE_1.24_A45_P81 Crossover:

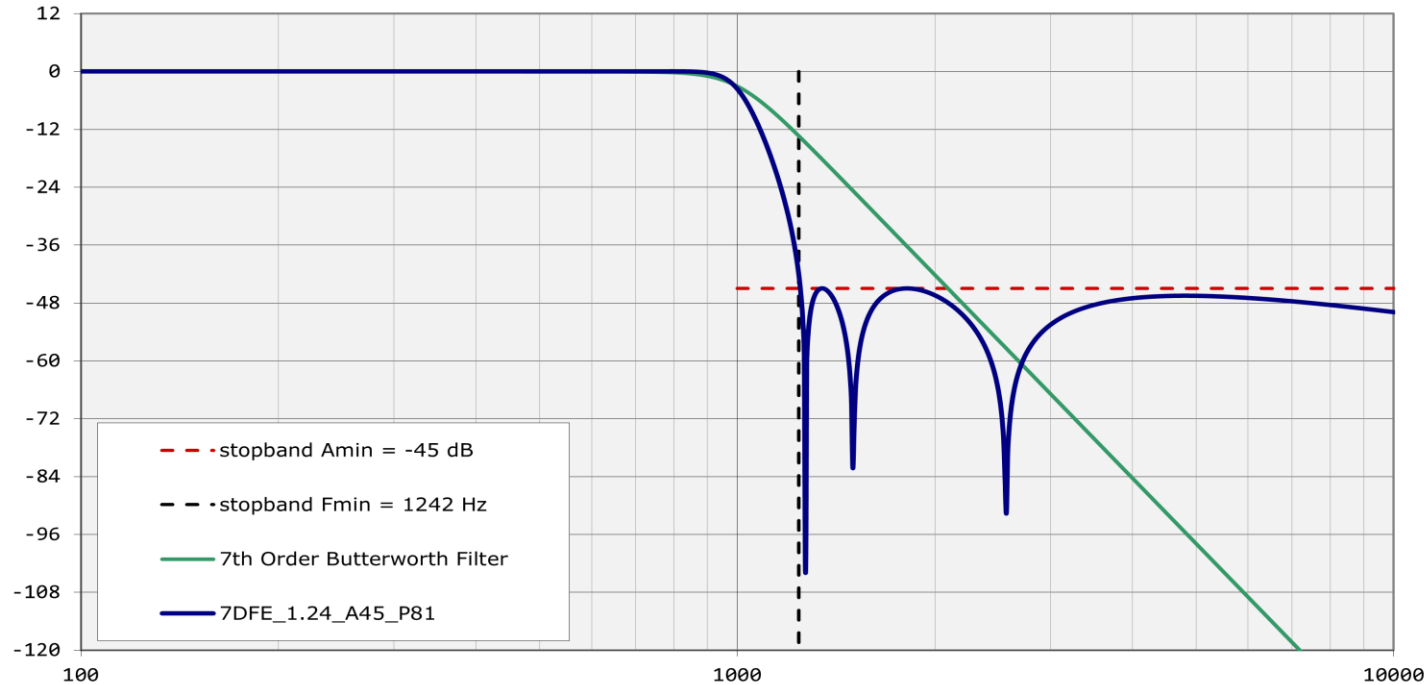
Filters:	LP	LPN	LPN	LPN	HP(-)	HPN	HPN	HPN
gain [dB]:	0.000	-2.623	-7.083	-17.874	0.000	0.000	0.000	0.000
Fp/Fc:	0.8360	1.0925	0.9988	0.9173	1.1962	0.9153	1.0012	1.0902
Qp:		1.826	4.197	0.789		1.826	4.197	0.789
Fz/Fc:		1.2705	1.5015	2.5666		0.7871	0.6660	0.3896

Response Plots for the Crossover may be found below.

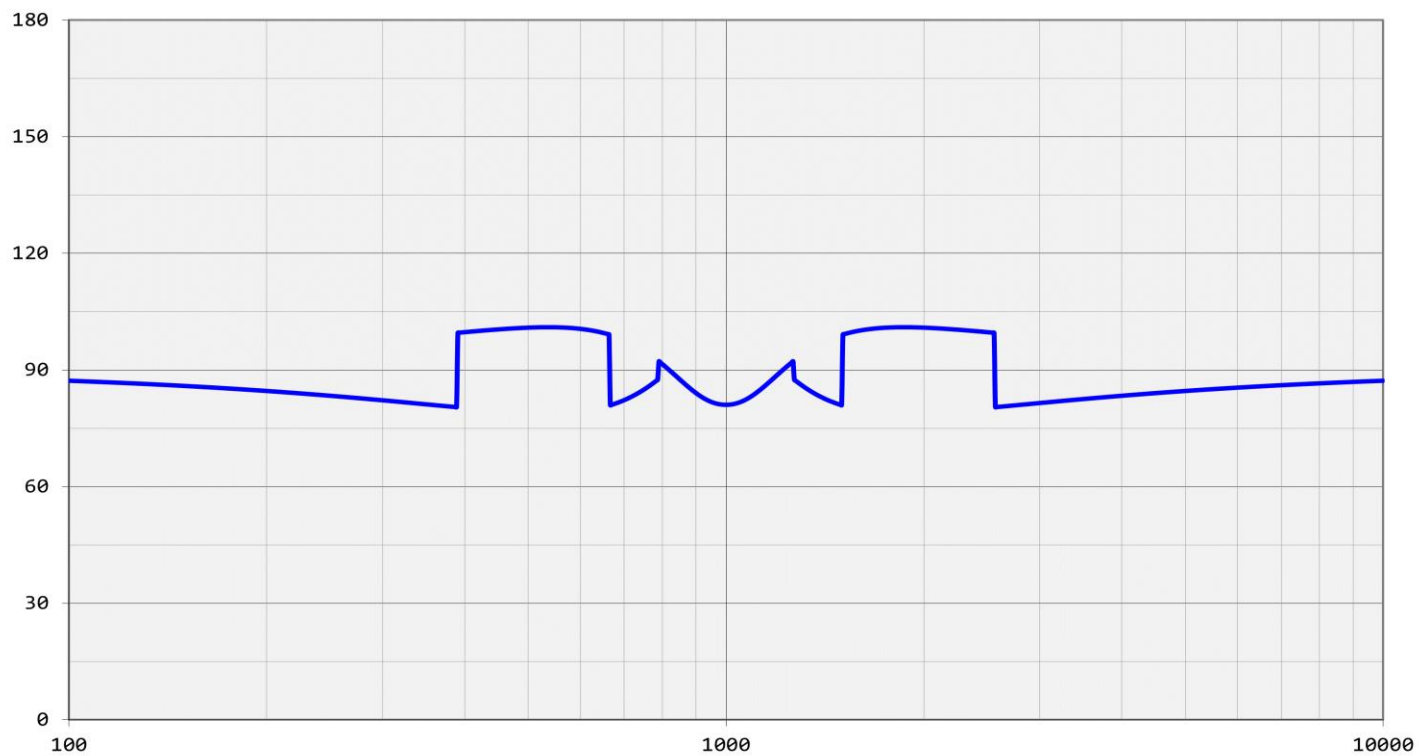
7DFE_1.24_A45_P81 : Sum of HP and LP filters



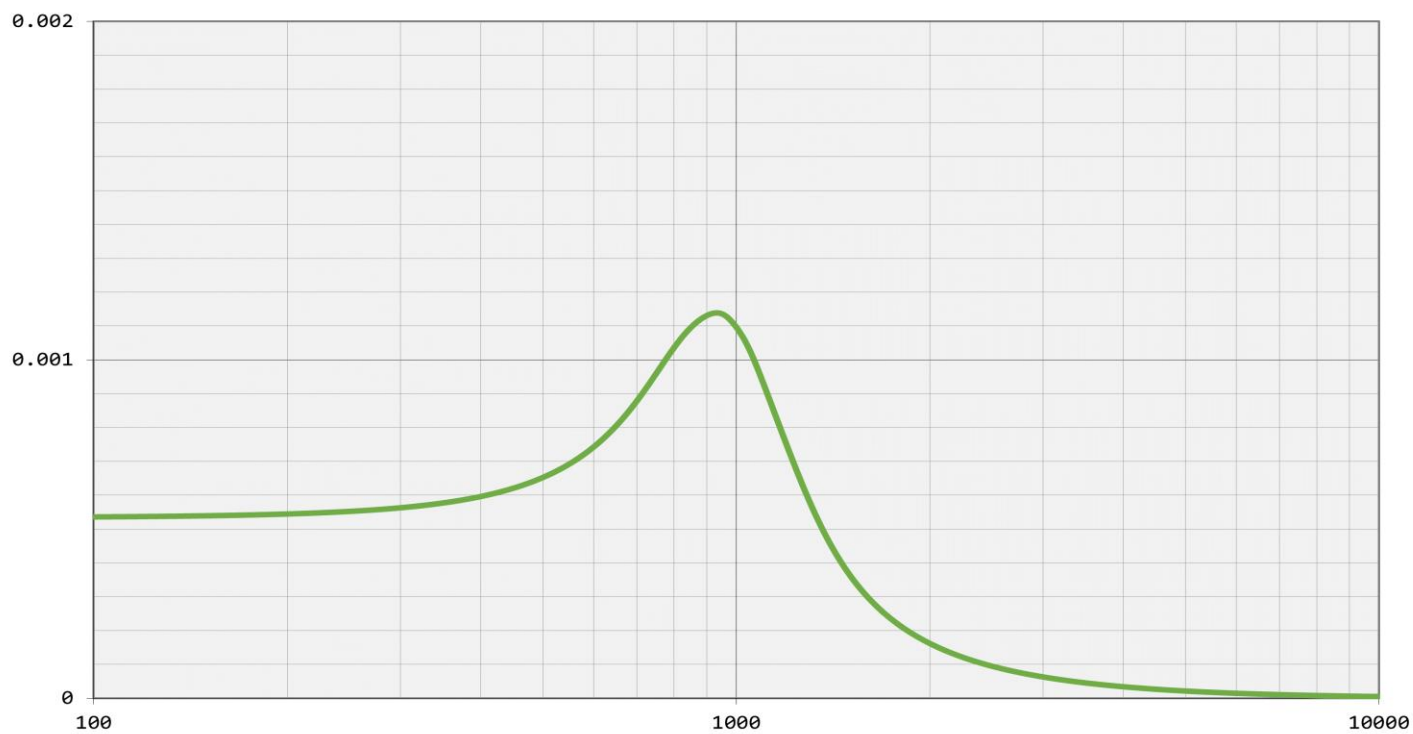
7DFE_1.24_A45_P81 : Lowpass Response



7DFE_1.24_A45_P81 : Relative Phase Angle in Degrees



7DFE_1.24_A45_P81 : Group Delay for Fc = 1k Hz



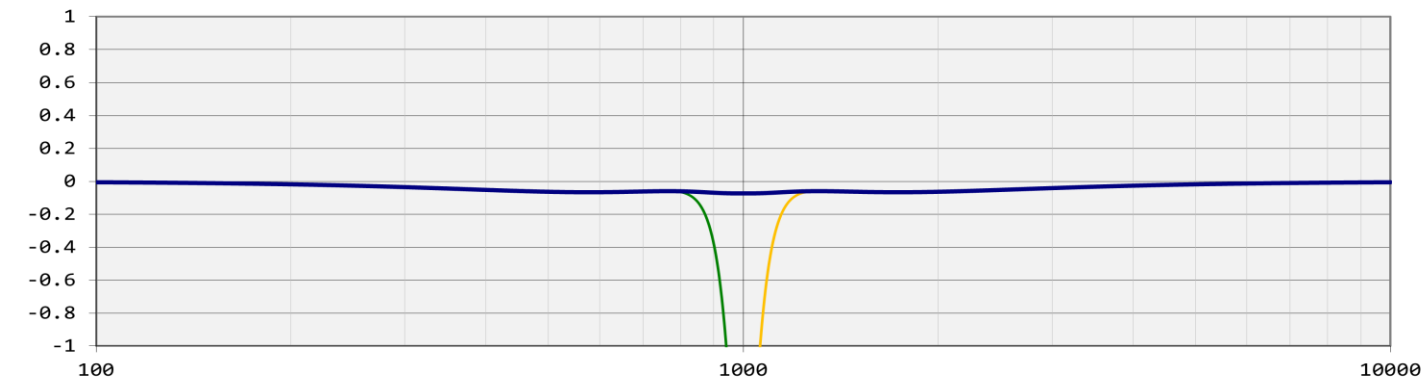
Crossover 7DFE_1.35_A52_P86:

Filters used to construct the 7DFE_1.35_A52_P86 Crossover:

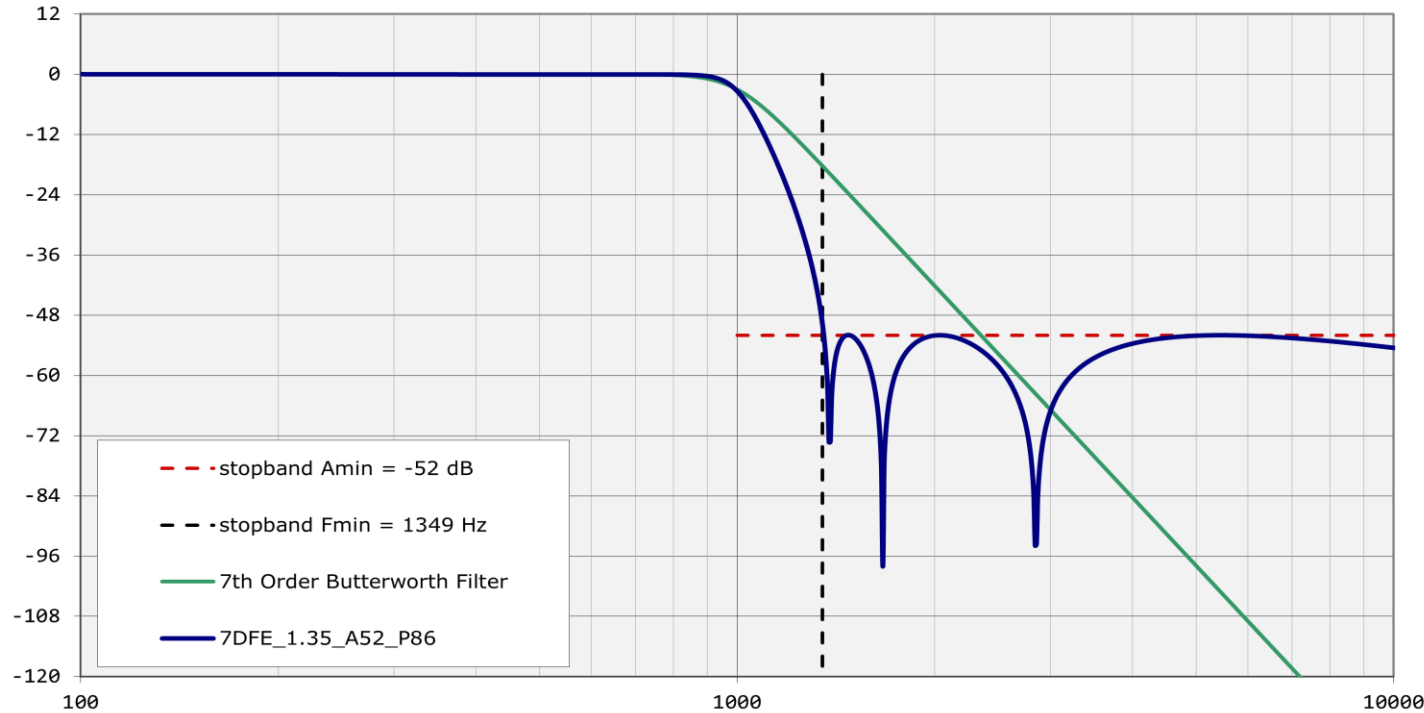
Filters:	LP	LPN	LPN	LPN	HP(-)	HPN	HPN	HPN
gain [dB]:	0.000	-4.806	-8.871	-18.330	0.000	0.000	0.000	0.000
Fp/Fc:	0.8443	1.0491	1.0000	0.9925	1.1844	0.9532	1.0000	1.0076
Qp:		1.322	4.018	0.717		1.322	4.018	0.717
Fz/Fc:		1.3835	1.6664	2.8509		0.7228	0.6001	0.3508

Response Plots for the Crossover may be found below.

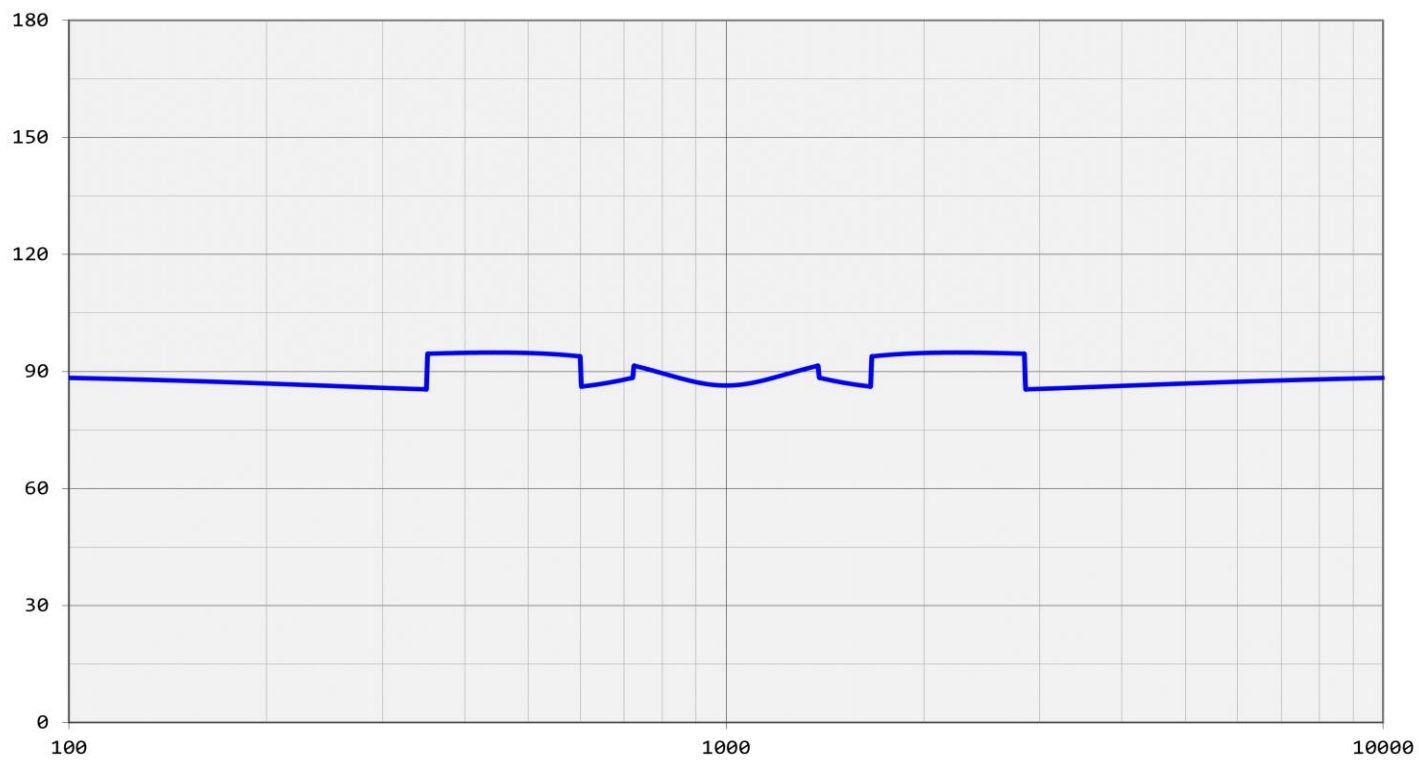
7DFE_1.35_A52_P86 : Sum of HP and LP filters



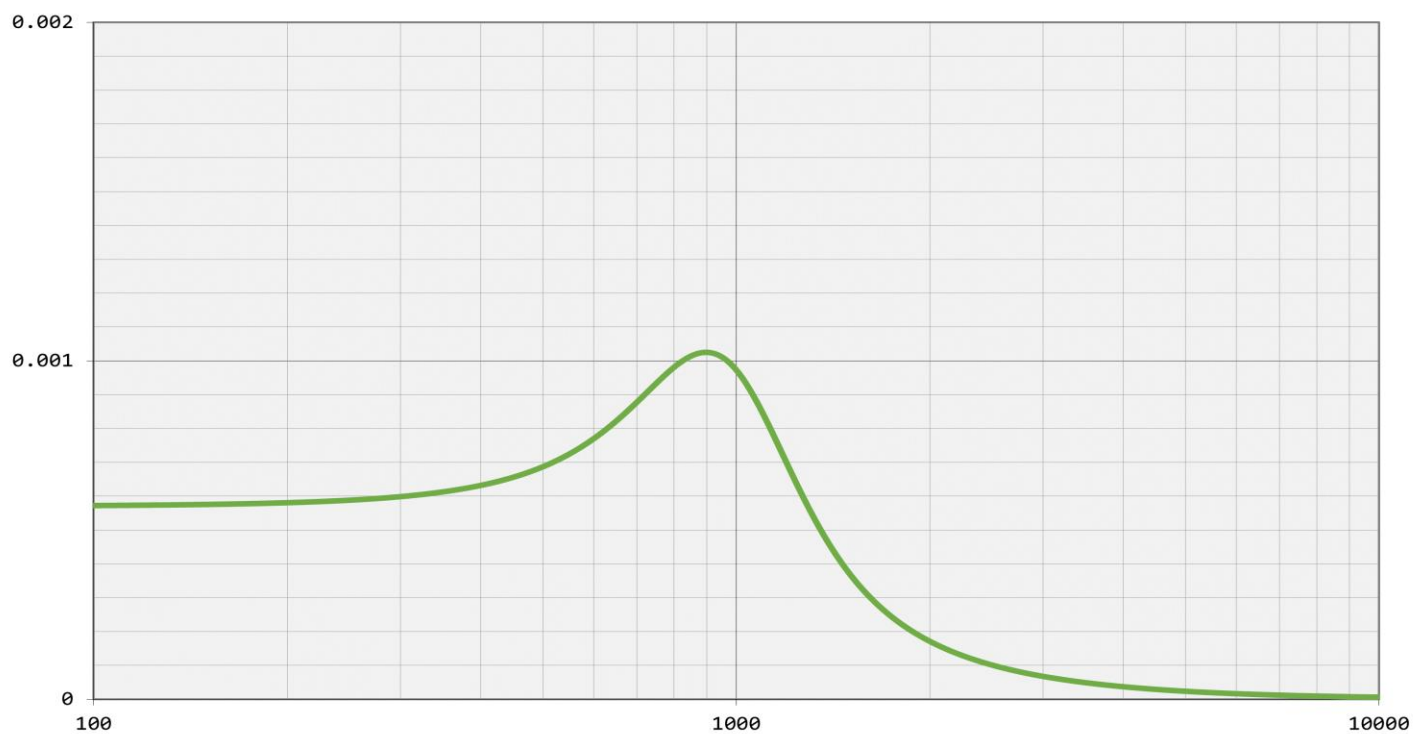
7DFE_1.35_A52_P86 : Lowpass Response



7DFE_1.35_A52_P86 : Relative Phase Angle in Degrees



7DFE_1.35_A52_P86 : Group Delay for $F_c = 1\text{ k Hz}$



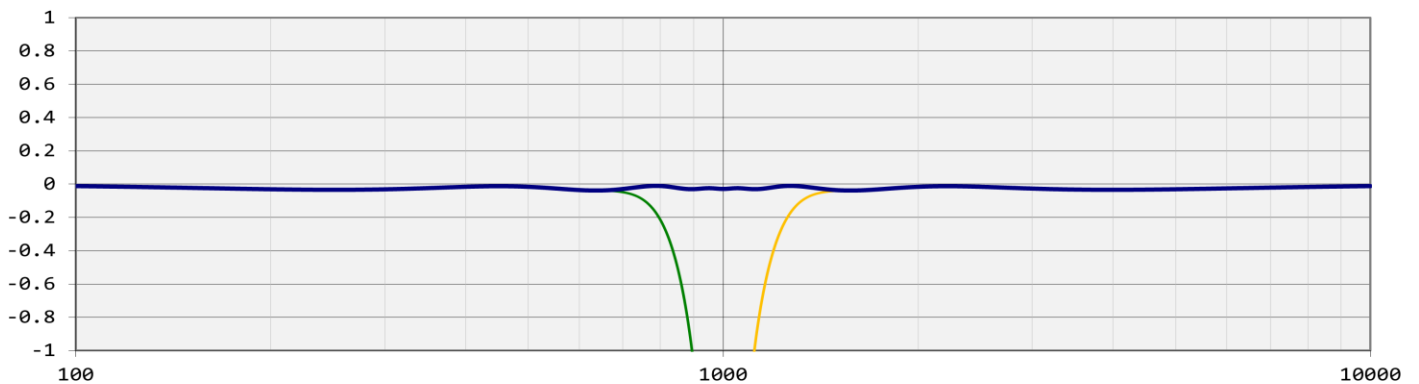
Crossover 7DFE_1.50_A68_P55:

Filters used to construct the 7DFE_1.50_A68_P55 Crossover:

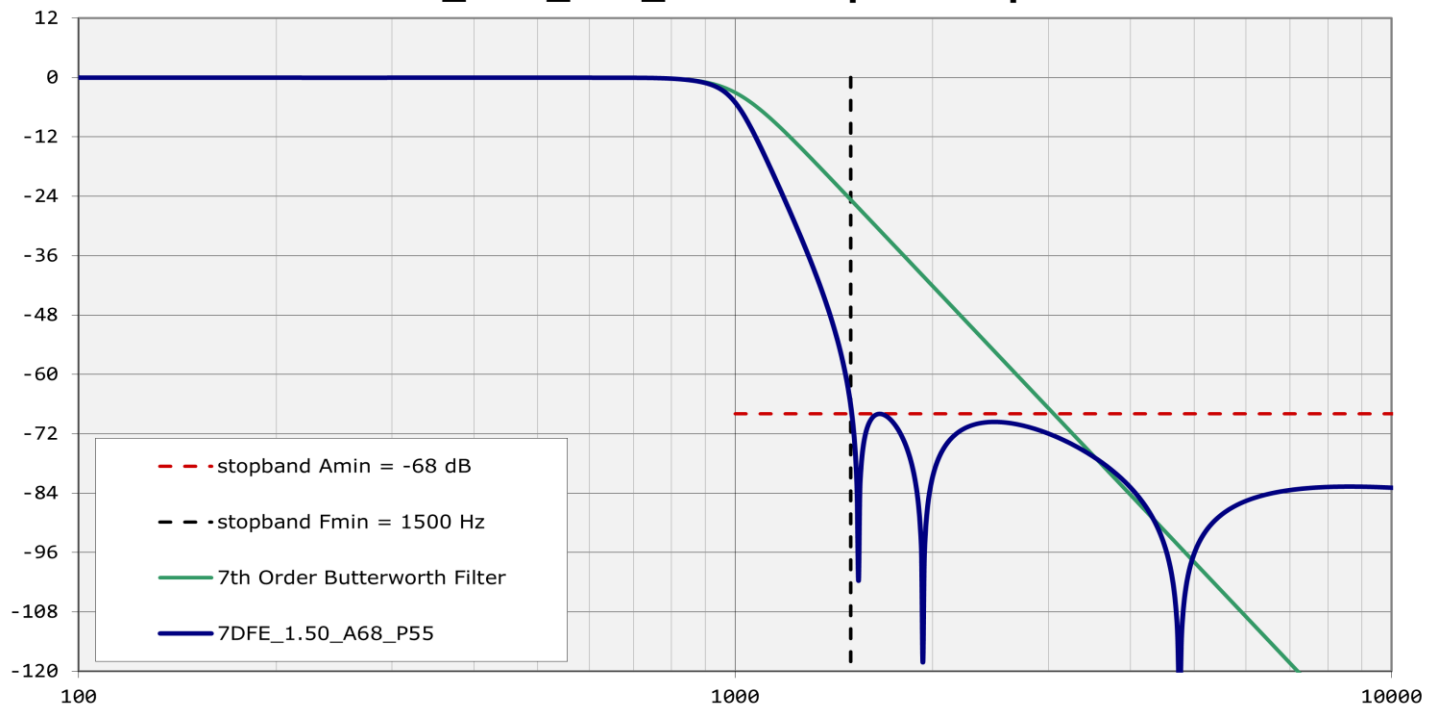
Filters:	LP	LPN	LPN	LPN	HP(+)	HPN	HPN	HPN
gain [dB]:	0.000	-7.567	-13.373	-33.701	0.000	0.000	0.000	0.000
Fp/Fc:	0.5213	0.9967	0.8951	0.6832	1.9183	1.0033	1.1172	1.4638
Qp:		4.391	1.812	0.781		4.391	1.812	0.781
Fz/Fc:		1.5407	1.9328	4.7540		0.6490	0.5174	0.2103

Response Plots for the Crossover may be found below.

7DFE_1.50_A68_P55 : Sum of HP and LP filters



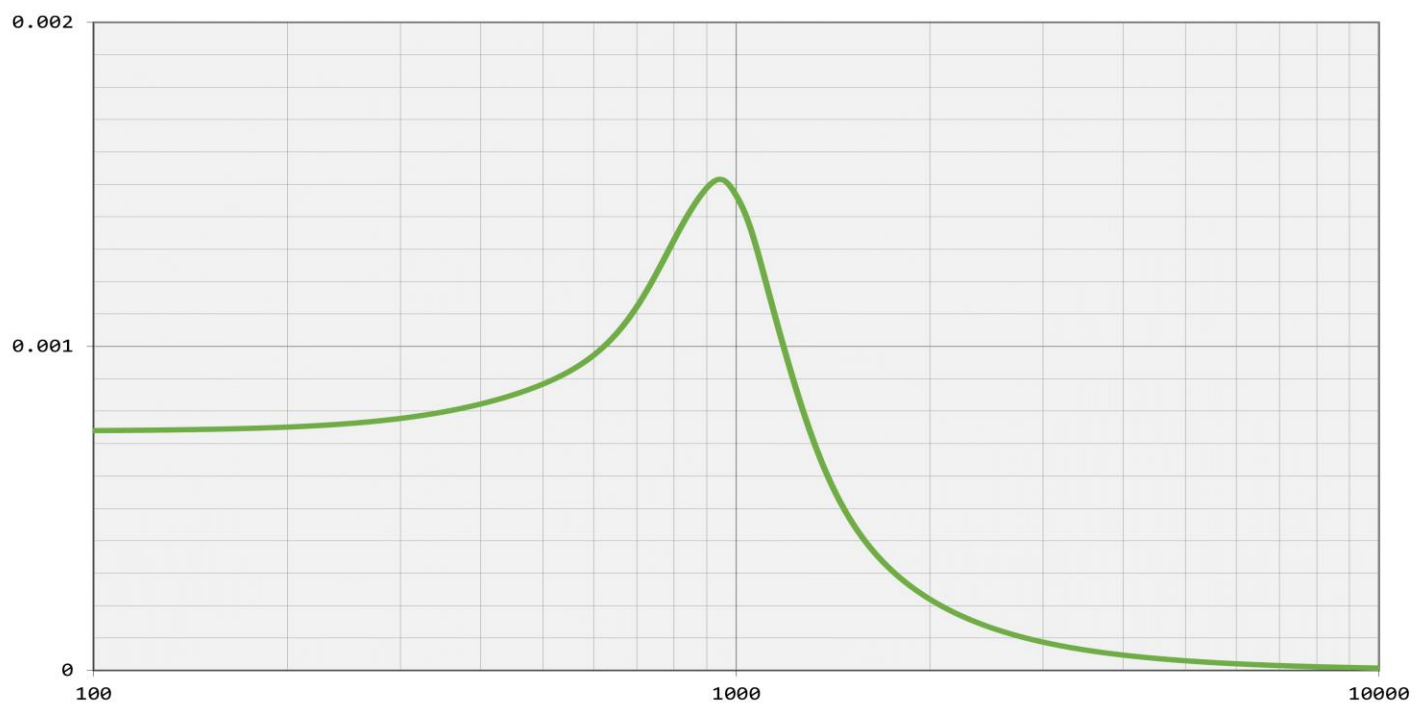
7DFE_1.50_A68_P55 : Lowpass Response



7DFE_1.50_A68_P55 : Relative Phase Angle in Degrees



7DFE_1.50_A68_P55 : Group Delay for $F_c = 1\text{ k Hz}$



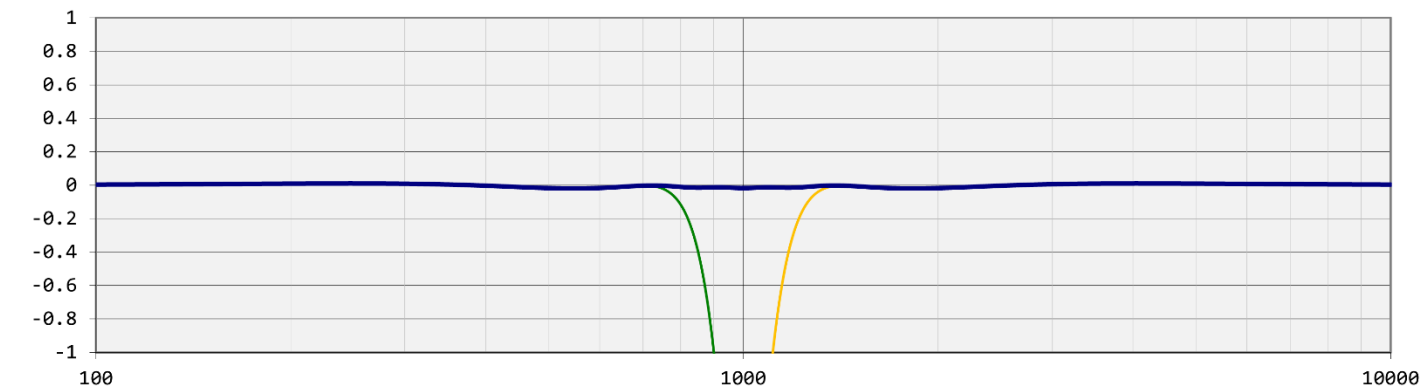
Crossover 7DFE_1.58_A63_P77:

Filters used to construct the 7DFE_1.58_A63_P77 Crossover:

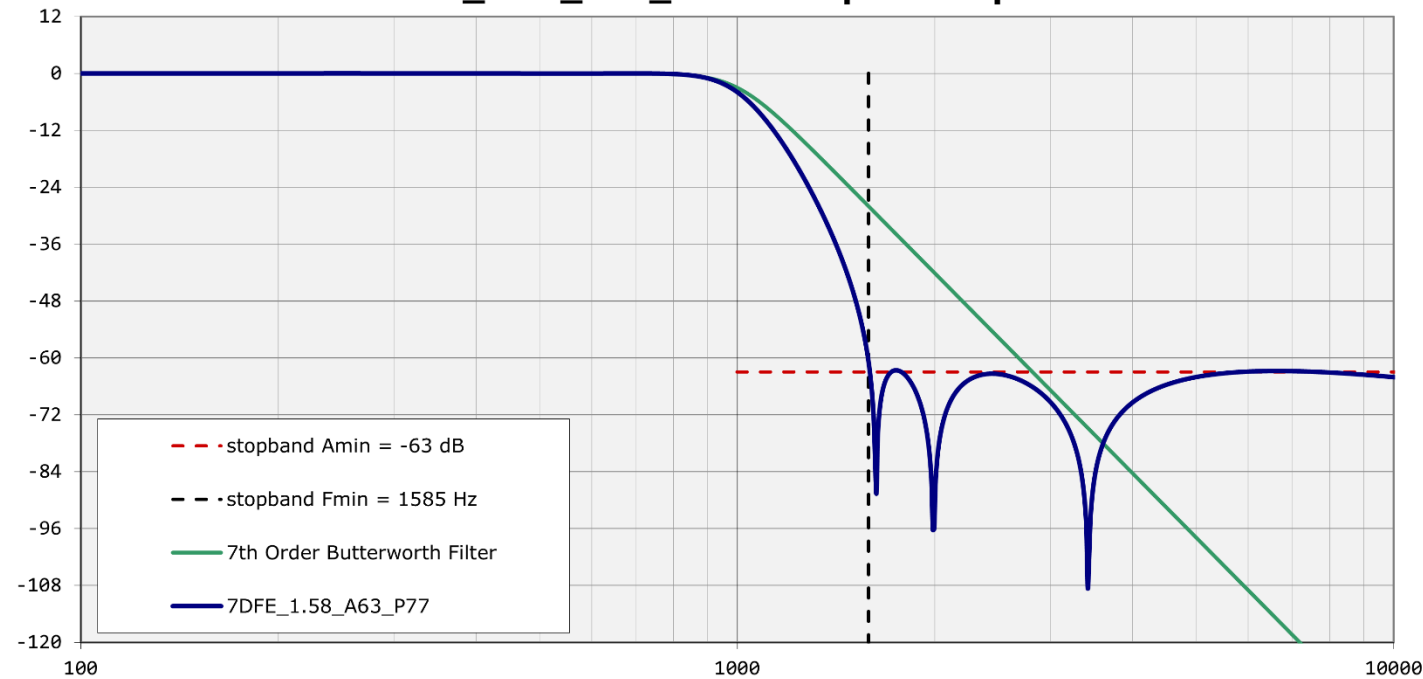
Filters:	LP	LPN	LPN	LPN	HP(-)	HPN	HPN	HPN
gain [dB]:	0.000	-6.534	-12.162	-24.574	0.000	0.000	0.000	0.000
Fp/Fc:	1.0927	1.1169	0.9884	0.8323	0.9151	0.8954	1.0118	1.2015
Qp:		1.662	2.332	0.623		1.662	2.332	0.623
Fz/Fc:		1.6269	1.9906	3.4249		0.6147	0.5024	0.2920

Response Plots for the Crossover may be found below.

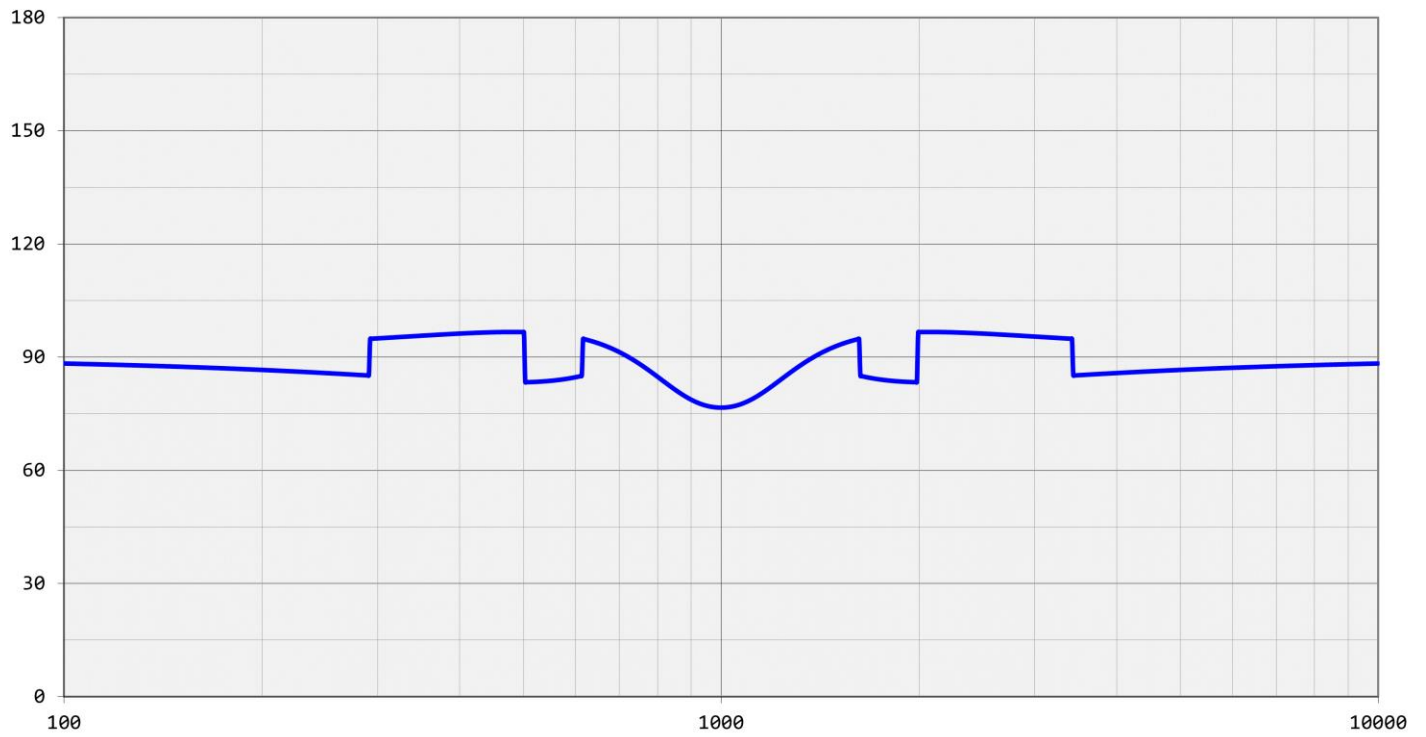
7DFE_1.58_A63_P77 : Sum of HP and LP filters



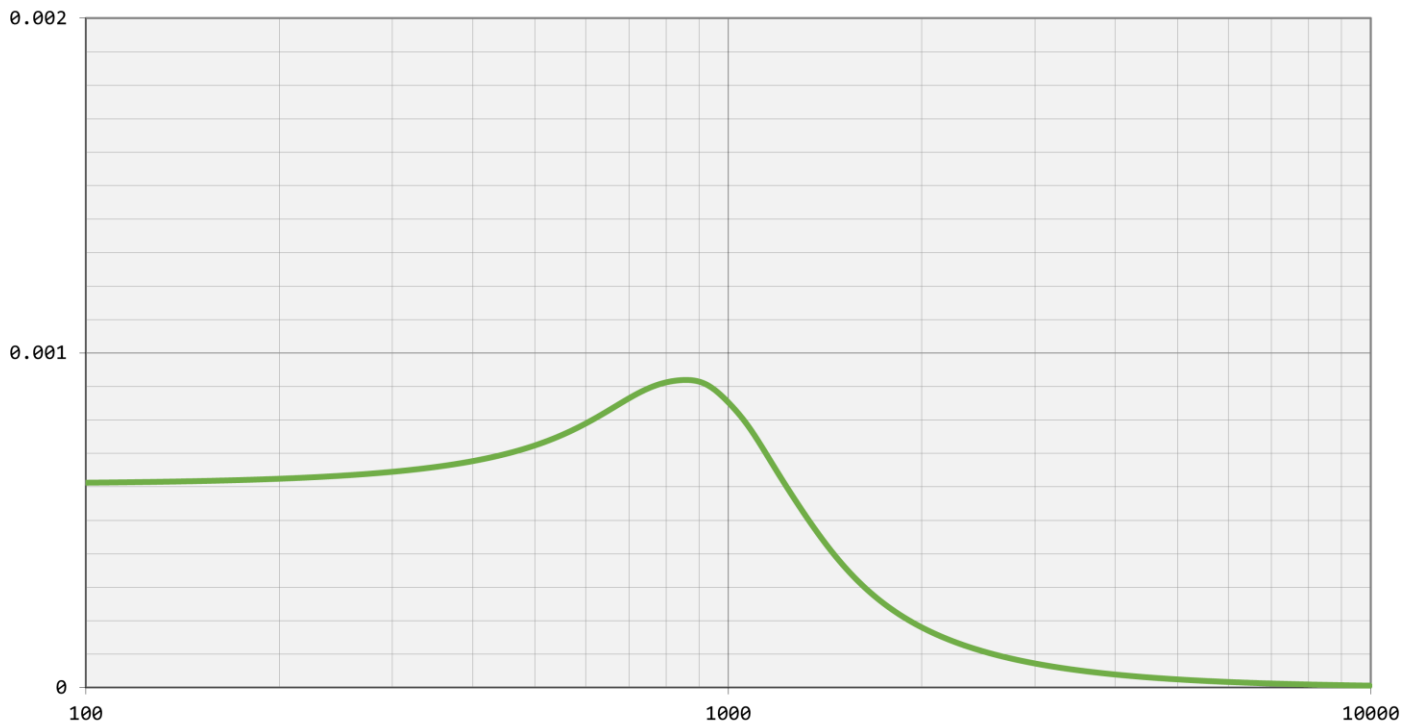
7DFE_1.58_A63_P77 : Lowpass Response



7DFE_1.58_A63_P77 : Relative Phase Angle in Degrees



7DFE_1.58_A63_P77 : Group Delay for Fc = 1k Hz



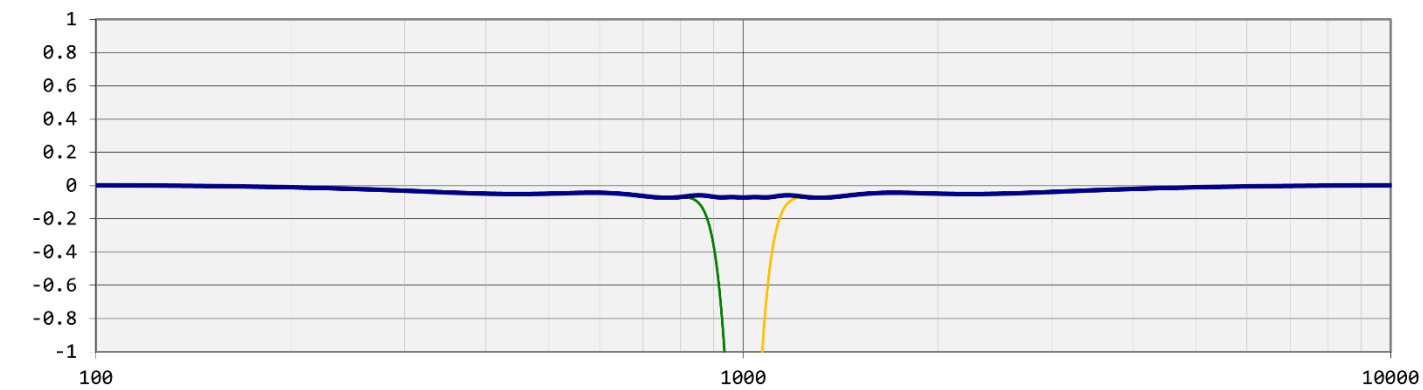
Crossover 8DFE_1.22_A50_P70:

Filters used to construct the 8DFE_1.22_A50_P70 Crossover:

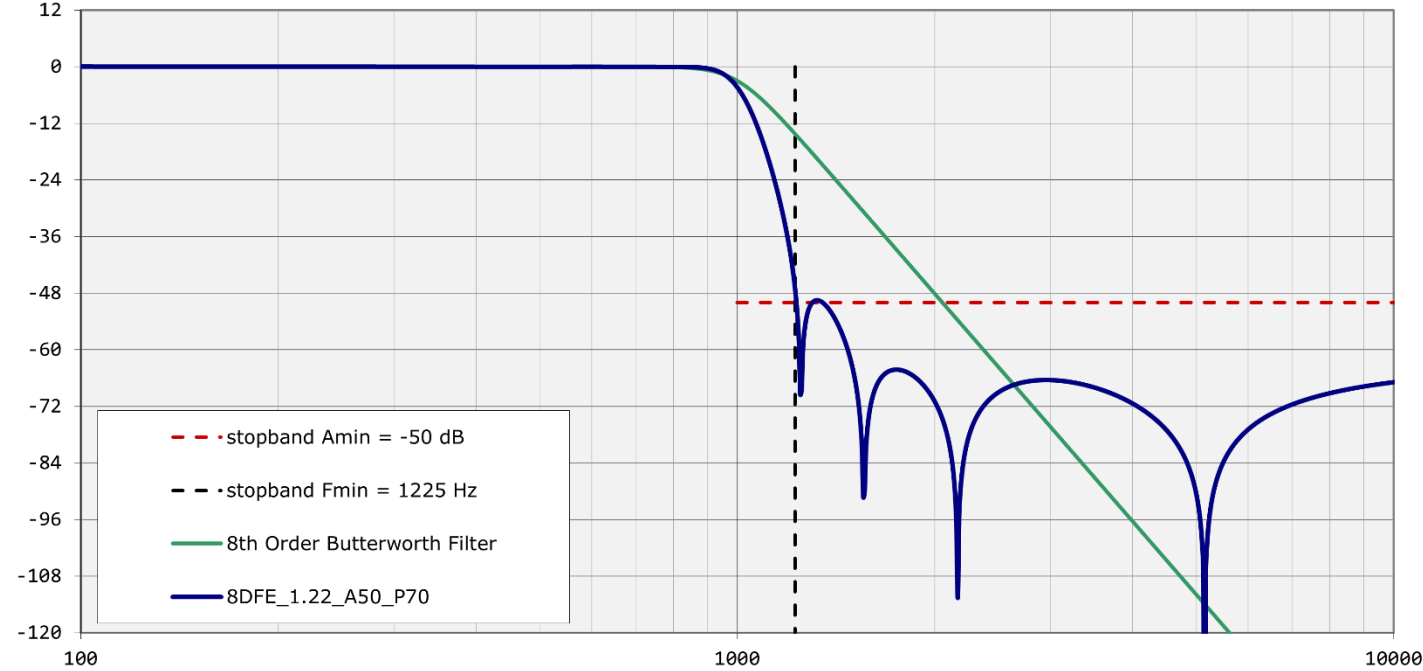
Filters:	LPN	LPN	LPN	LPN	HPN(+)	HPN	HPN	HPN
gain [dB]:	-2.855	-8.053	-16.726	-36.027	0.000	0.000	0.000	0.000
Fp/Fc:	1.0606	0.9808	0.8271	0.6476	0.9429	1.0195	1.2091	1.5442
Qp:	3.713	3.894	1.126	0.557	3.713	3.894	1.126	0.557
Fz/Fc:	1.2500	1.5593	2.1662	5.1522	0.8000	0.6413	0.4616	0.1941

Response Plots for the Crossover may be found below.

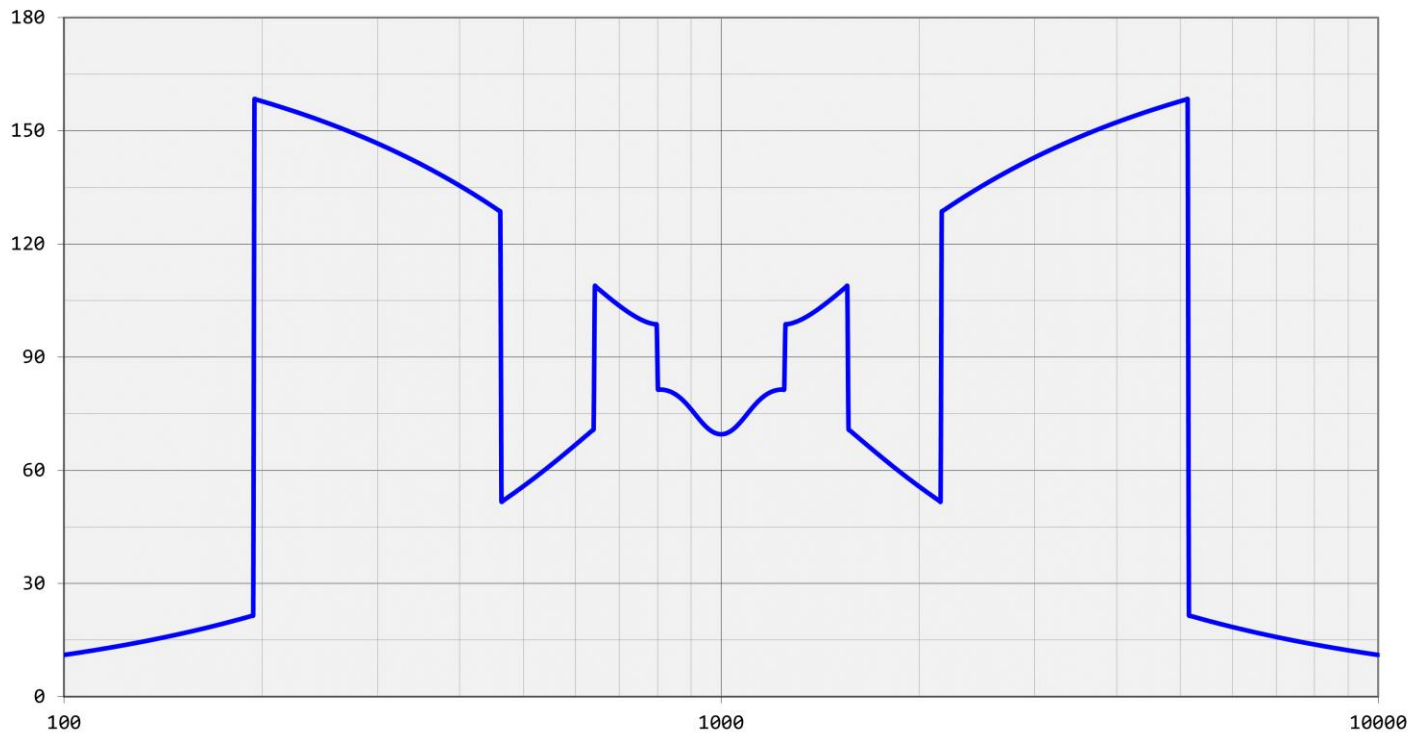
8DFE_1.22_A50_P70 : Sum of HP and LP filters



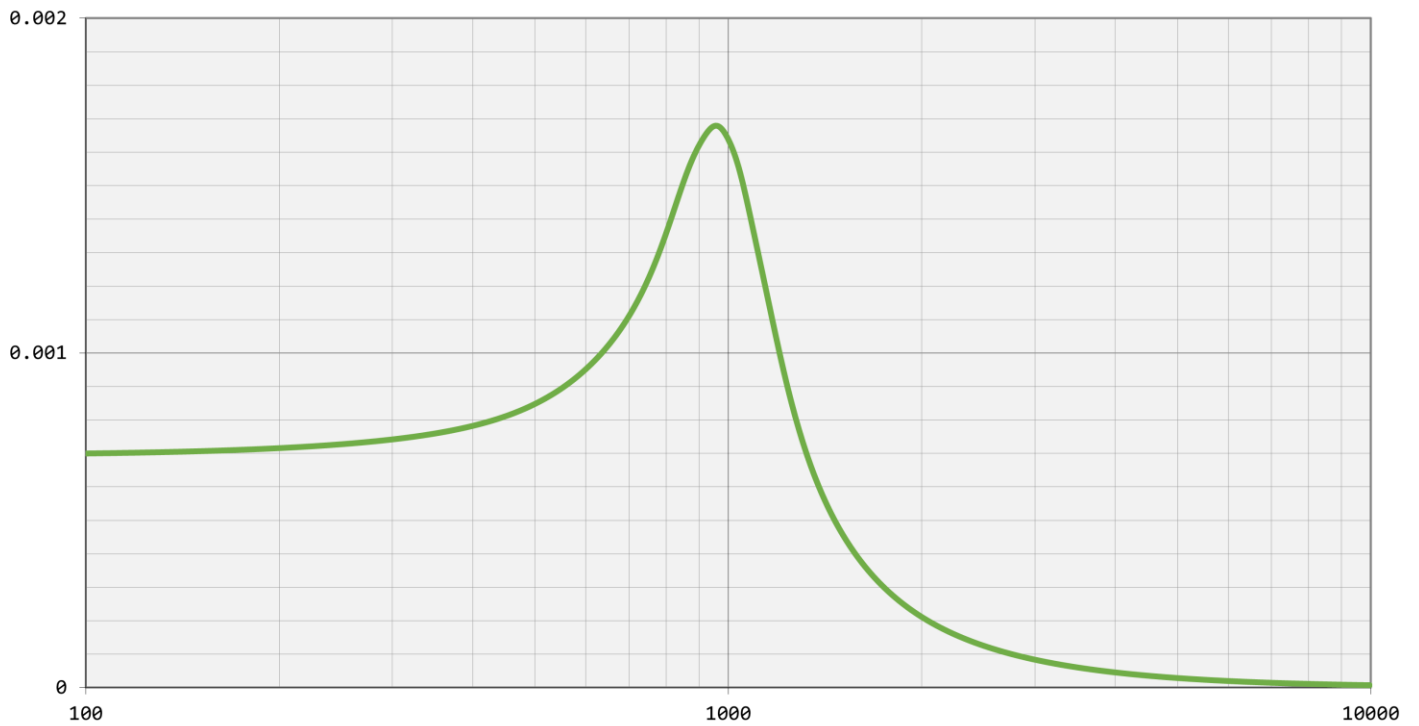
8DFE_1.22_A50_P70 : Lowpass Response



8DFE_1.22_A50_P70 : Relative Phase Angle in Degrees



8DFE_1.22_A50_P70 : Group Delay for $F_c = 1\text{ k Hz}$



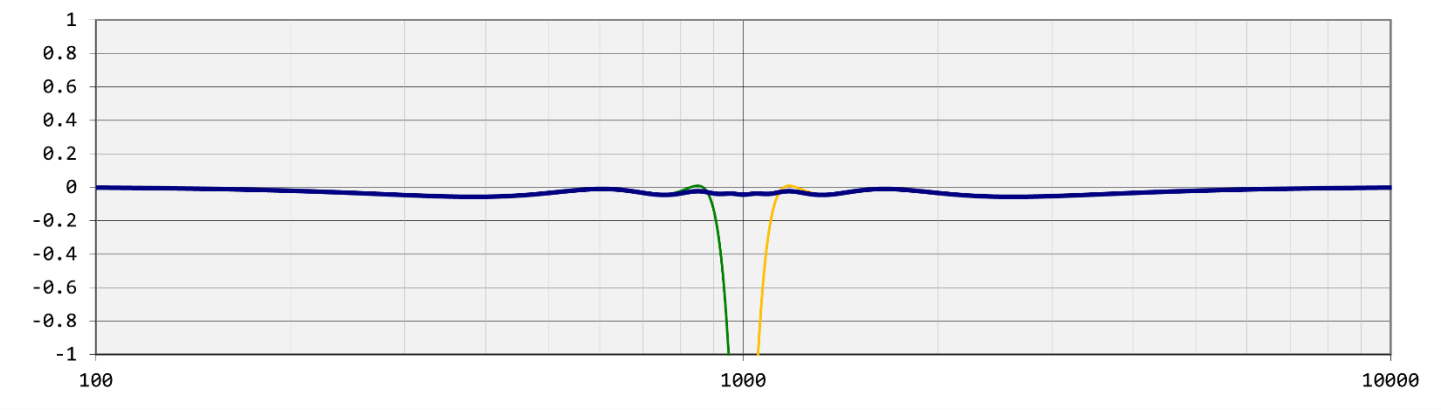
Crossover 8DFE_1.38_A71_P84:

Filters used to construct the 8DFE_1.38_A71_P84 Crossover:

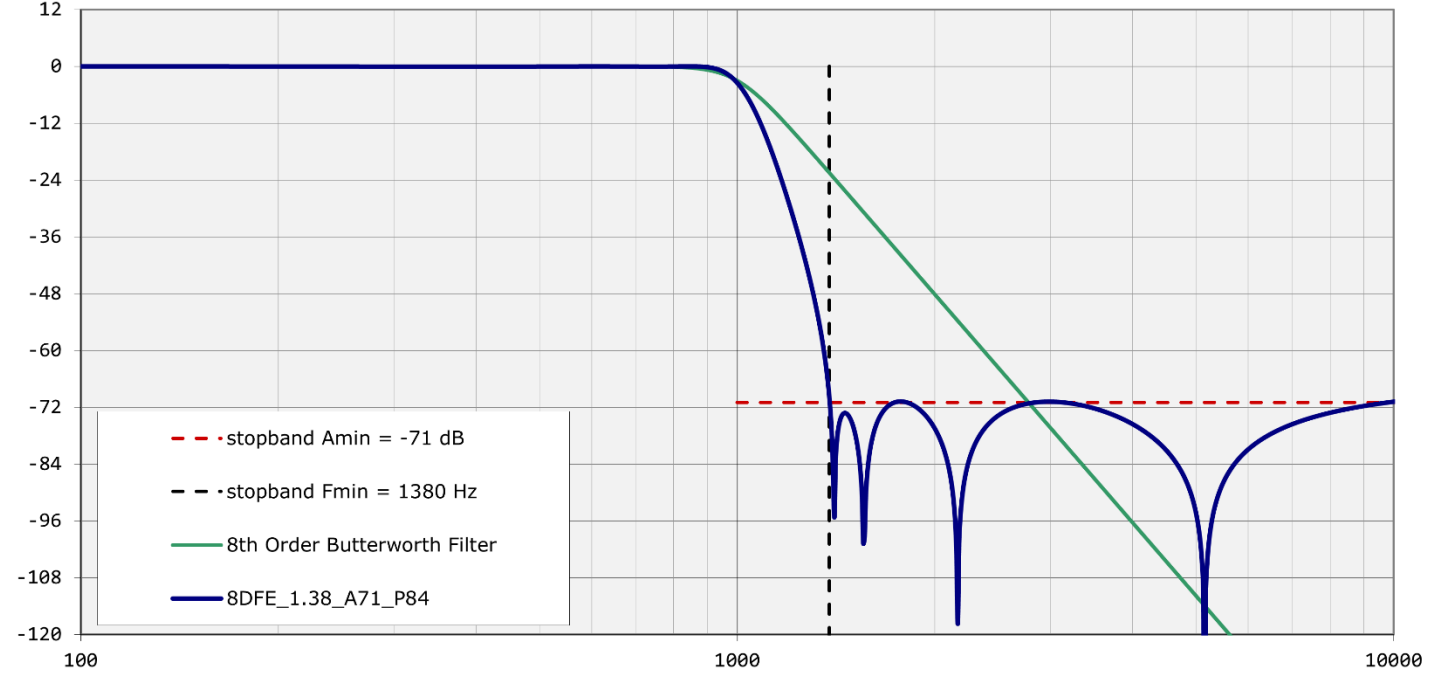
Filters:	LPN	LPN	LPN	LPN	HPN(+)	HPN	HPN	HPN
gain [dB]:	-4.761	-8.106	-17.560	-37.083	0.000	0.000	0.000	0.000
Fp/Fc:	1.0676	0.9779	0.7883	0.6094	0.9366	1.0226	1.2685	1.6409
Qp:	3.741	3.823	1.140	0.552	3.741	3.823	1.140	0.552
Fz/Fc:	1.4042	1.5593	2.1662	5.1522	0.7121	0.6413	0.4616	0.1941

Response Plots for the Crossover may be found below.

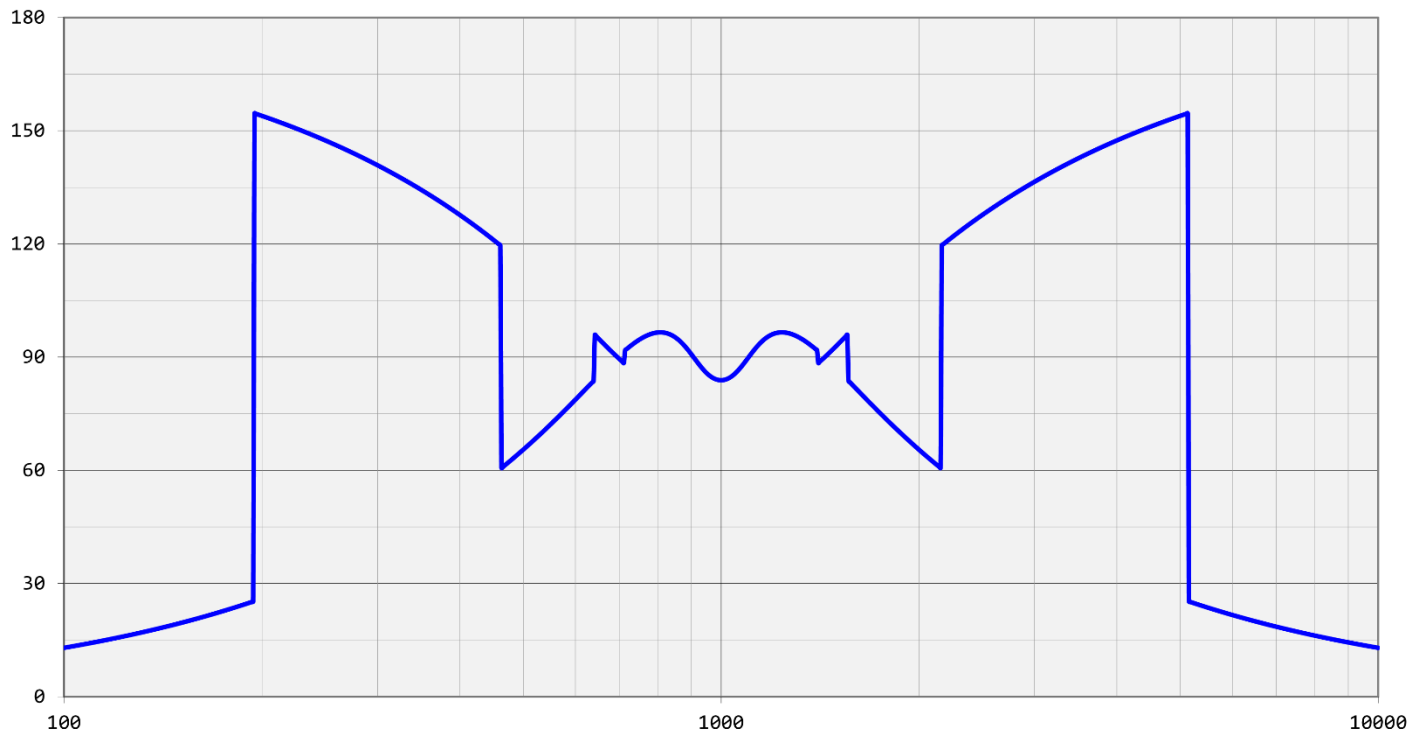
8DFE_1.38_A71_P84 : Sum of HP and LP filters



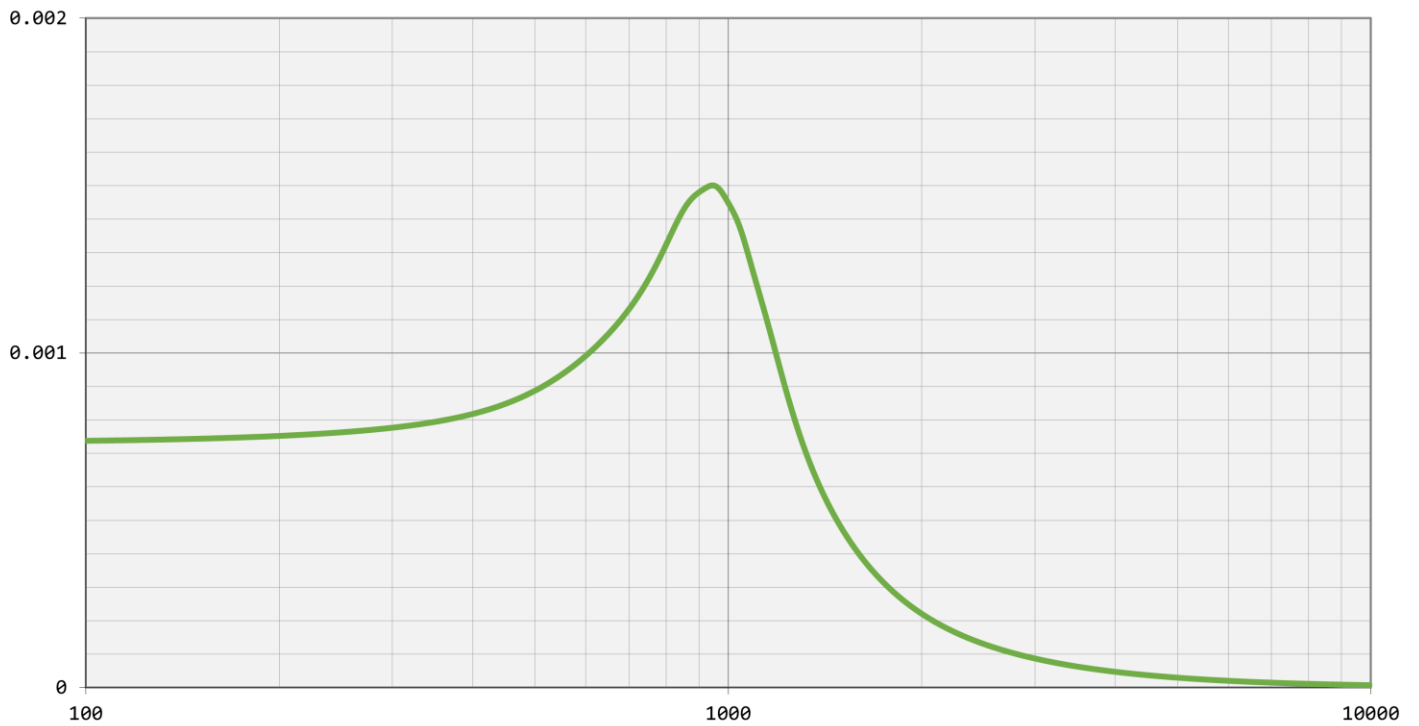
8DFE_1.38_A71_P84 : Lowpass Response



8DFE_1.38_A71_P84 : Relative Phase Angle in Degrees



8DFE_1.38_A71_P84 : Group Delay for $F_c = 1\text{ k Hz}$



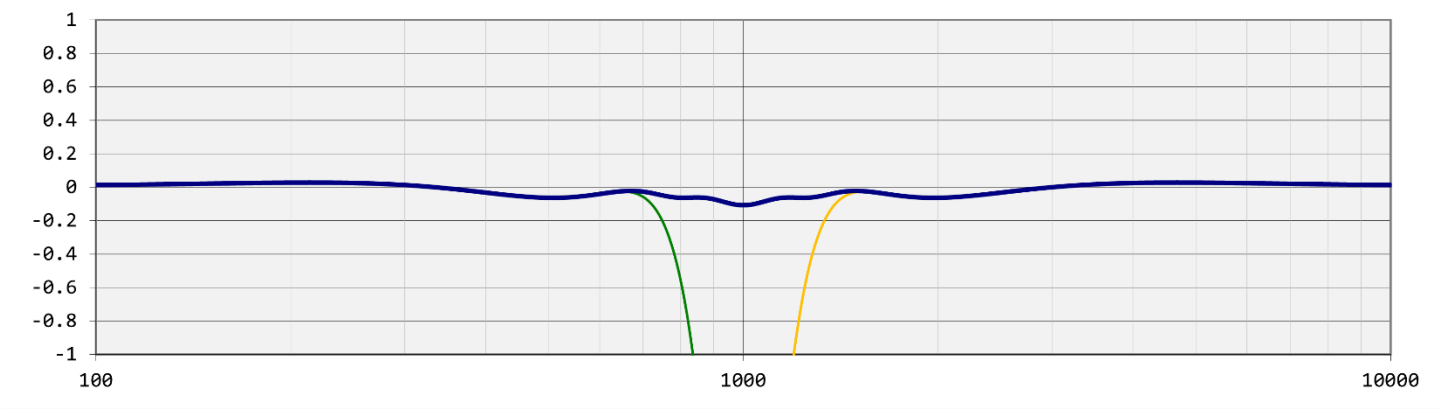
Crossover 8DFE_1.55_A75_P1:

Filters used to construct the 8DFE_1.55_A75_P1 Crossover:

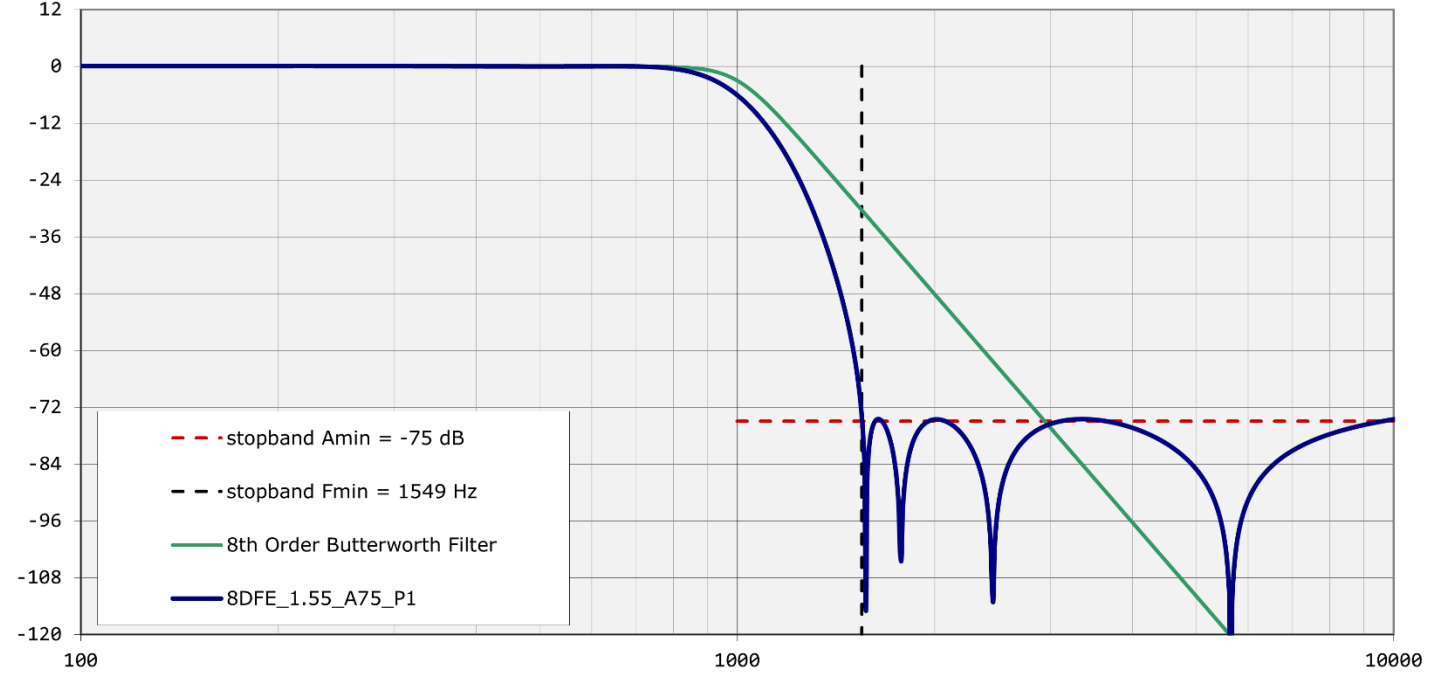
Filters:	LPN	LPN	LPN	LPN	HPN(+)	HPN	HPN	HPN
gain [dB]:	-3.938	-9.767	-17.267	-39.468	0.000	0.000	0.000	0.000
Fp/Fc:	1.2521	1.0114	0.9068	0.5825	0.7987	0.9887	1.1028	1.7167
Qp:	2.433	1.887	1.564	0.588	2.433	1.887	1.564	0.588
Fz/Fc:	1.5706	1.7746	2.4501	5.6495	0.6367	0.5635	0.4081	0.1770

Response Plots for the Crossover may be found below.

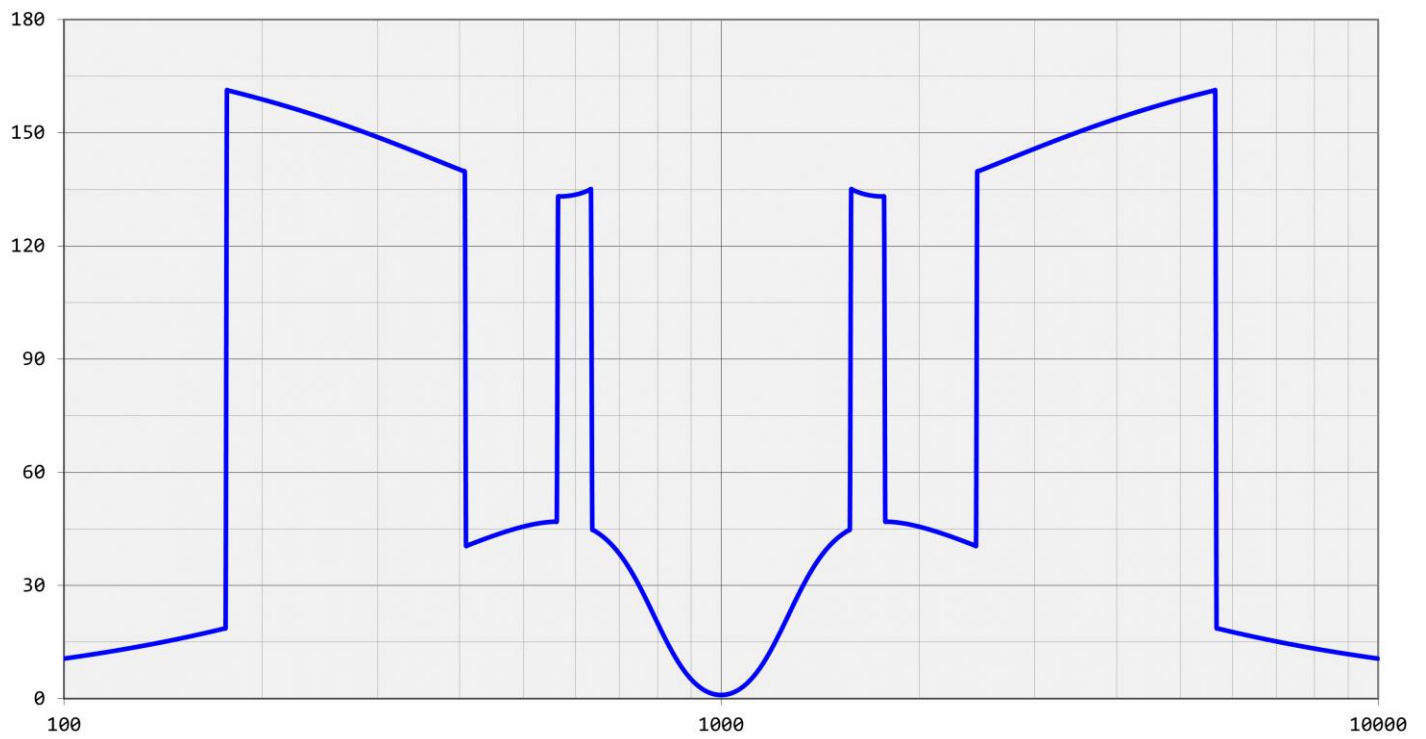
8DFE_1.55_A75_P1 : Sum of HP and LP filters



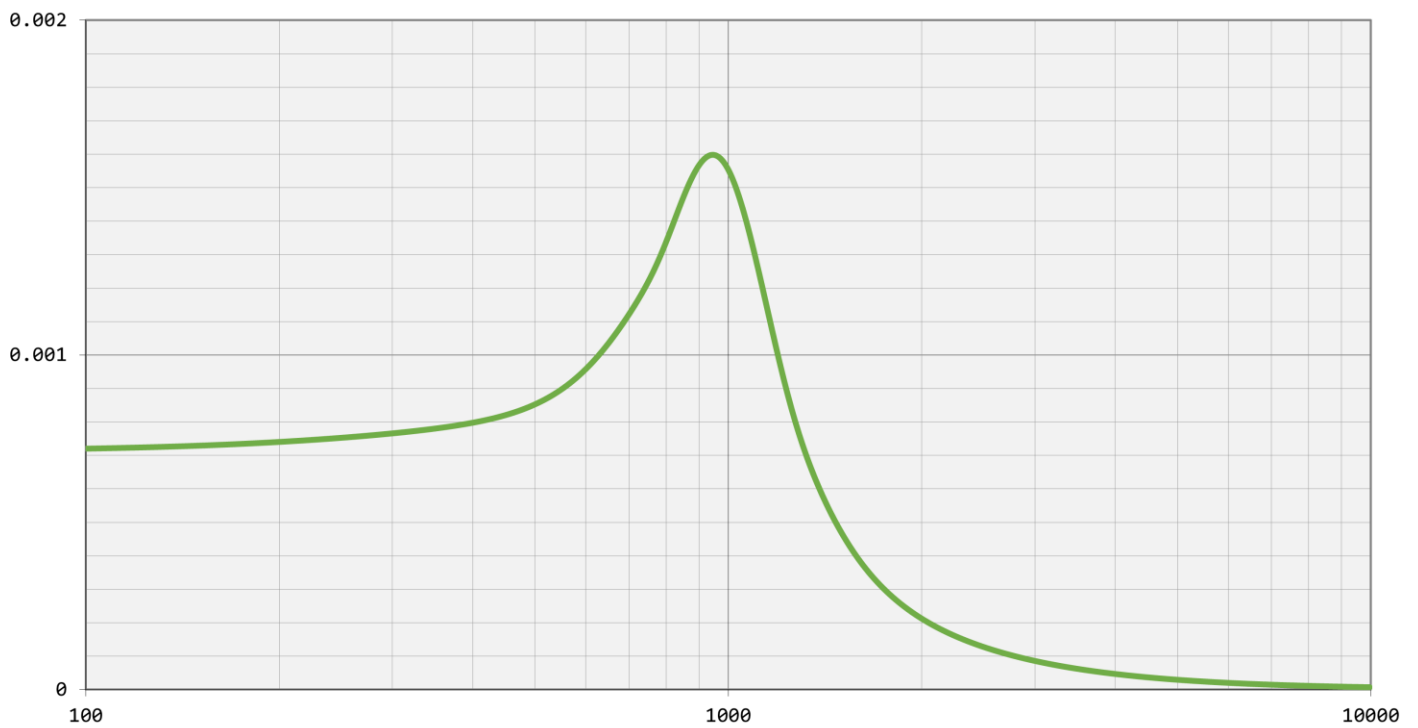
8DFE_1.55_A75_P1 : Lowpass Response



8DFE_1.55_A75_P1 : Relative Phase Angle in Degrees



8DFE_1.55_A75_P1 : Group Delay for $F_c = 1\text{ k Hz}$



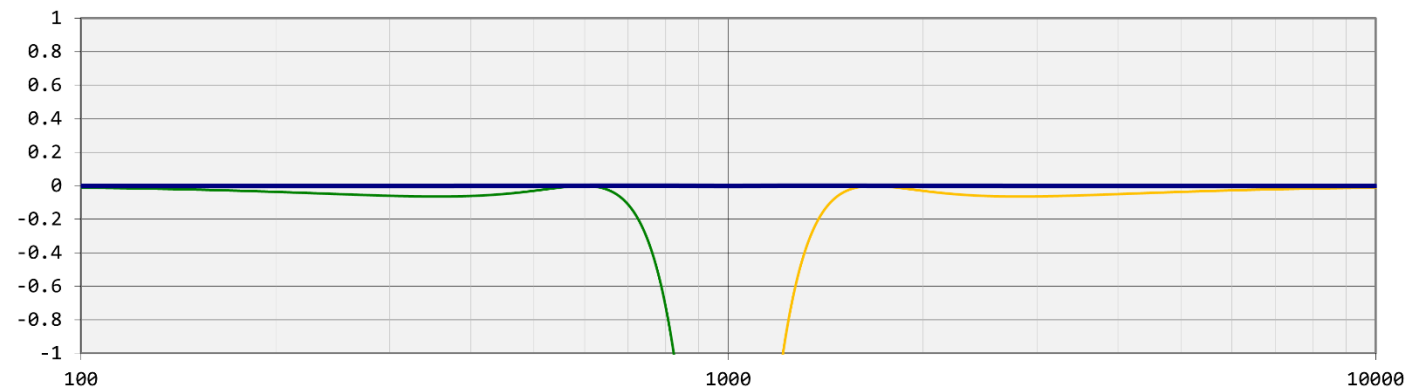
Crossover 6DFES_1.47_A43_P0:

Filters used to construct the 6DFES_1.47_A43_P0 Crossover:

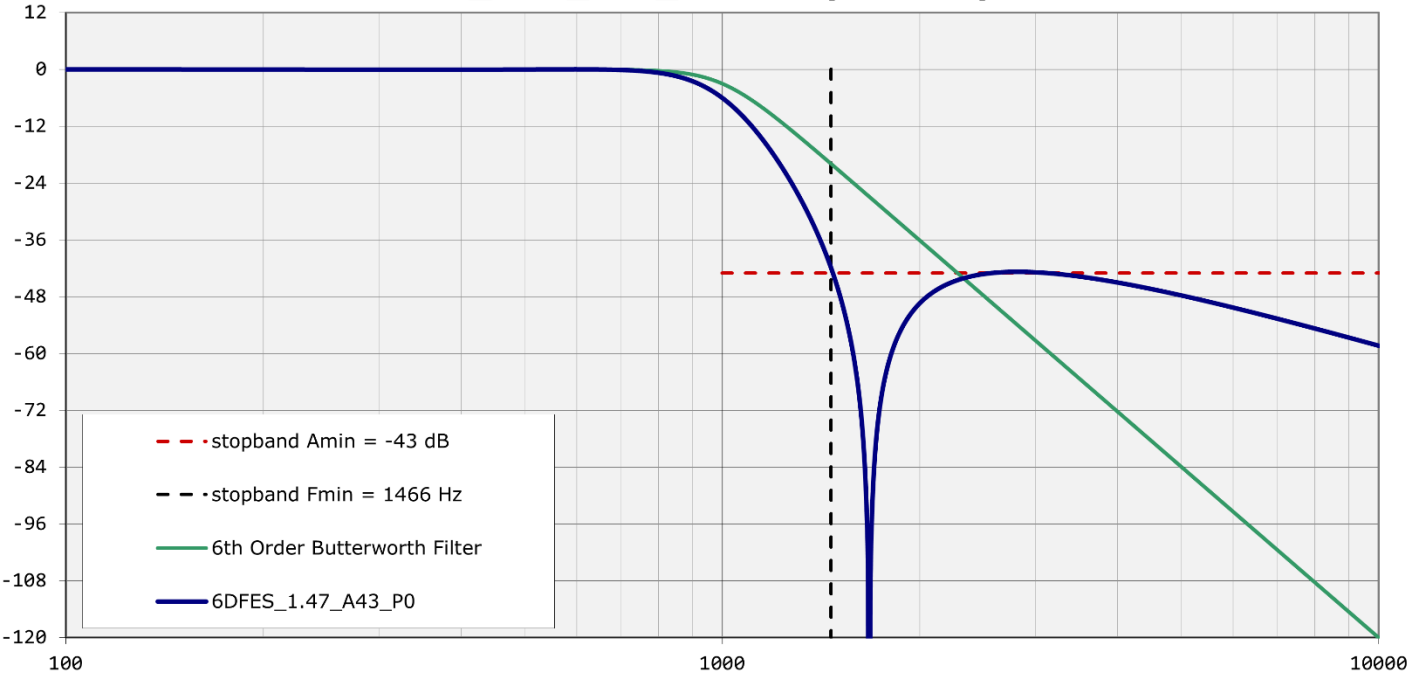
Filters:	LP	LPN	LP	LPN	HP(-)	HPN	HP	HPN
gain [dB]:	0.000	-8.962	0.000	-8.962	0.000	0.000	0.000	0.000
Fp/Fc:	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Qp:		1.554		1.554		1.554		1.554
Fz/Fc:		1.6751		1.6751		0.5970		0.5970

Response Plots for the Crossover may be found below.

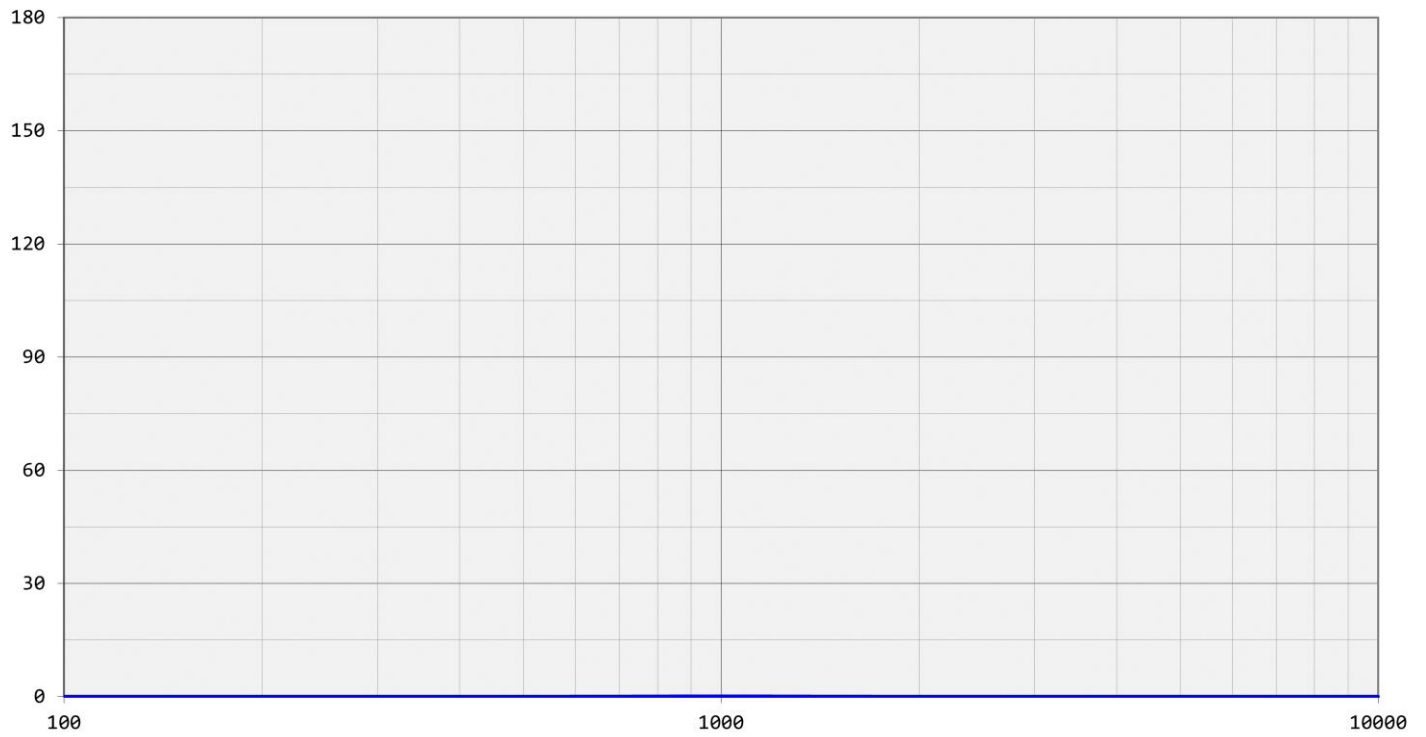
6DFES_1.47_A43_P0 : Sum of HP and LP filters



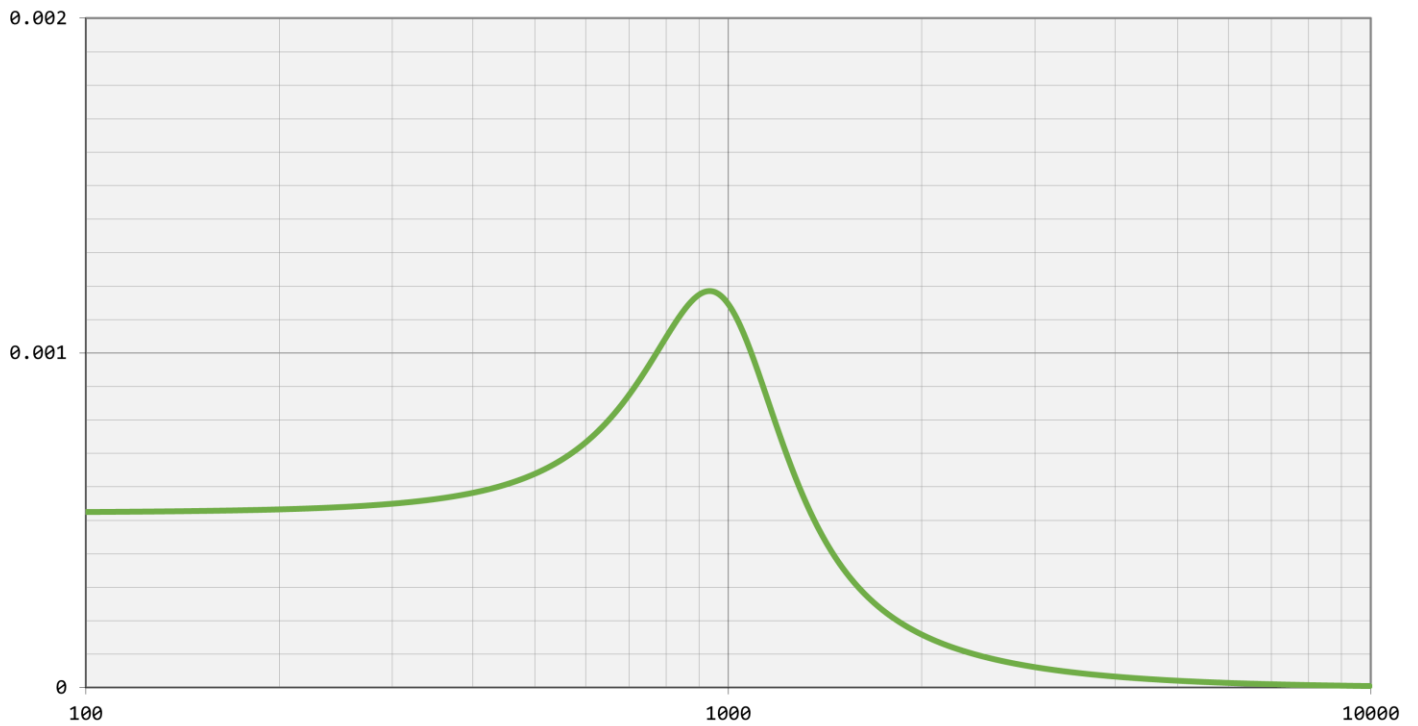
6DFES_1.47_A43_P0 : Lowpass Response



6DFES_1.47_A43_P0 : Relative Phase Angle in Degrees



6DFES_1.47_A43_P0 : Group Delay for Fc = 1k Hz



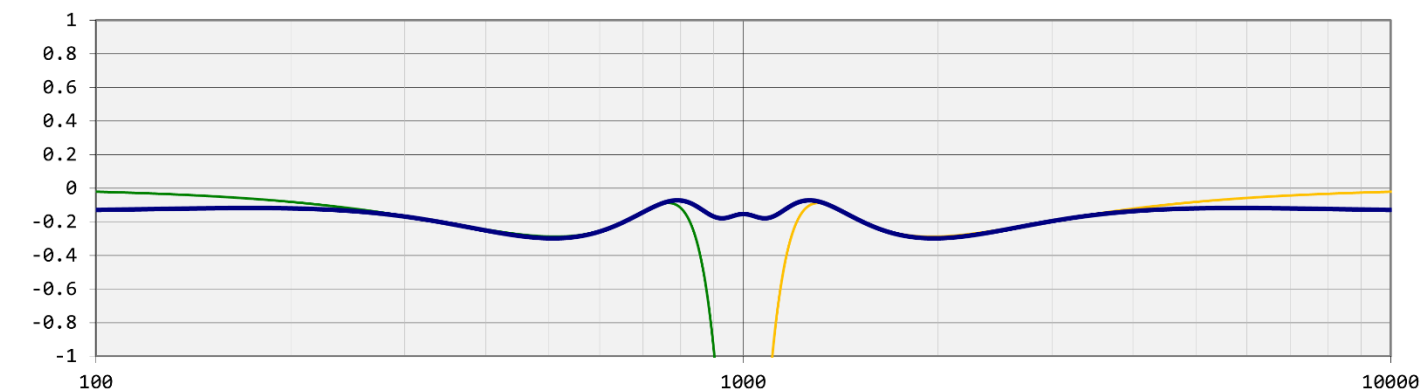
Crossover 8DFES_1.33_A46_P66:

Filters used to construct the 8DFES_1.33_A46_P66 Crossover:

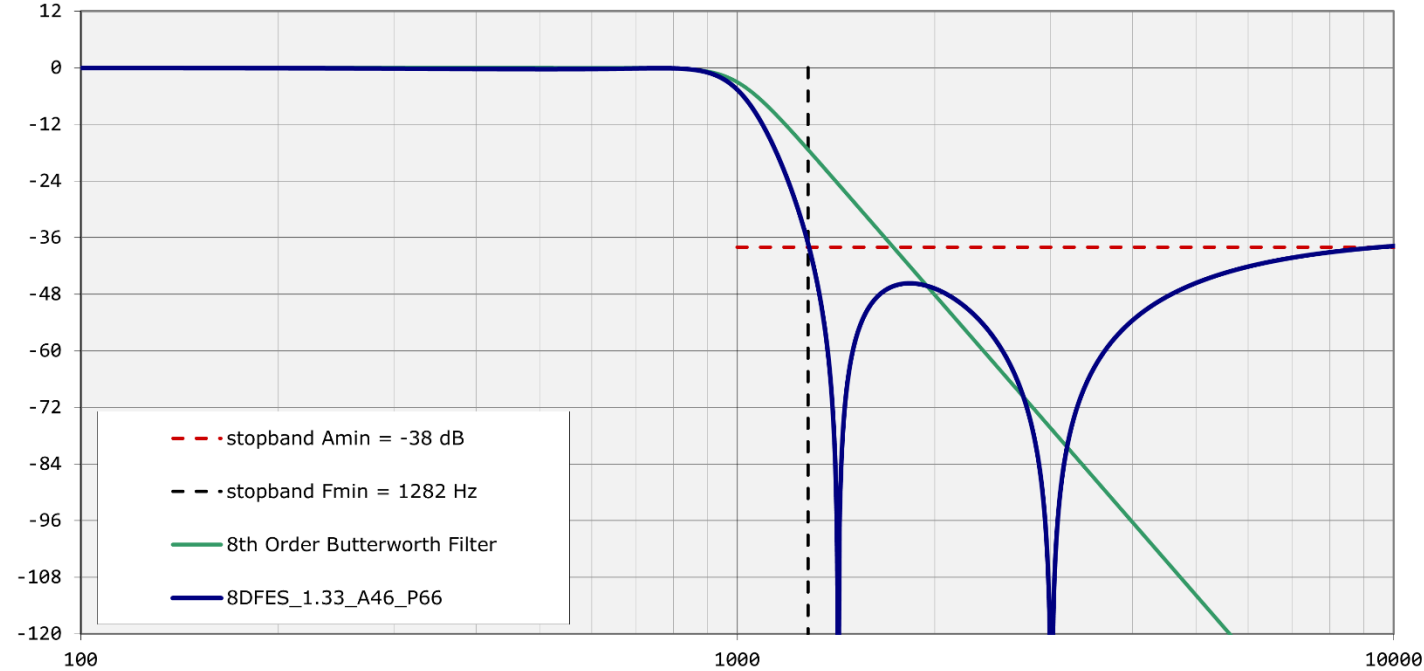
Filters:	LPN	LPN	LPN	LPN	HPN(-)	HPN	HPN	HPN
gain [dB]:	1.018	-18.817	1.018	-18.817	0.000	0.000	0.000	0.000
Fp/Fc:	1.5107	1.0188	1.5107	1.0188	0.6620	0.9815	0.6620	0.9815
Qp:	0.511	2.362	0.511	2.362	0.511	2.362	0.511	2.362
Fz/Fc:	1.4247	3.0097	1.4247	3.0097	0.7019	0.3323	0.7019	0.3323

Response Plots for the Crossover may be found below.

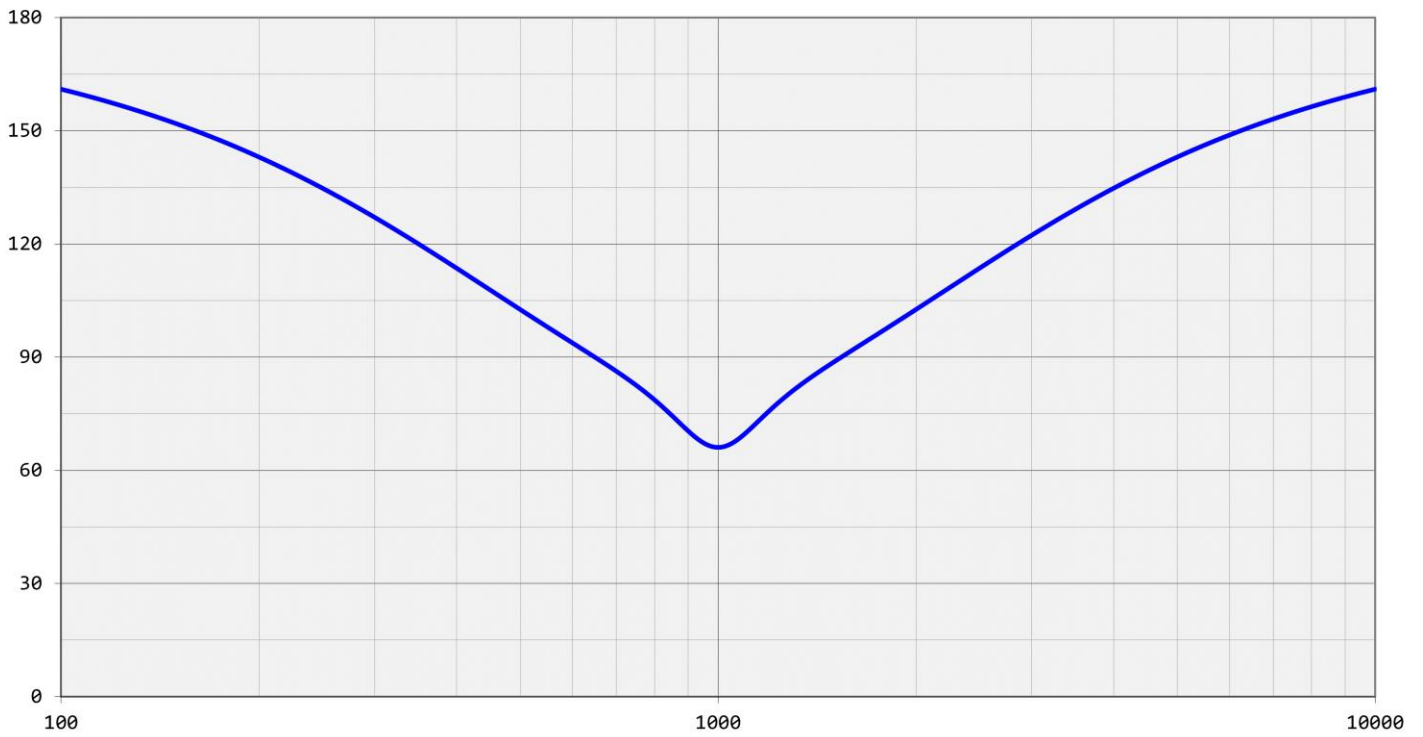
8DFES_1.33_A46_P66 : Sum of HP and LP filters



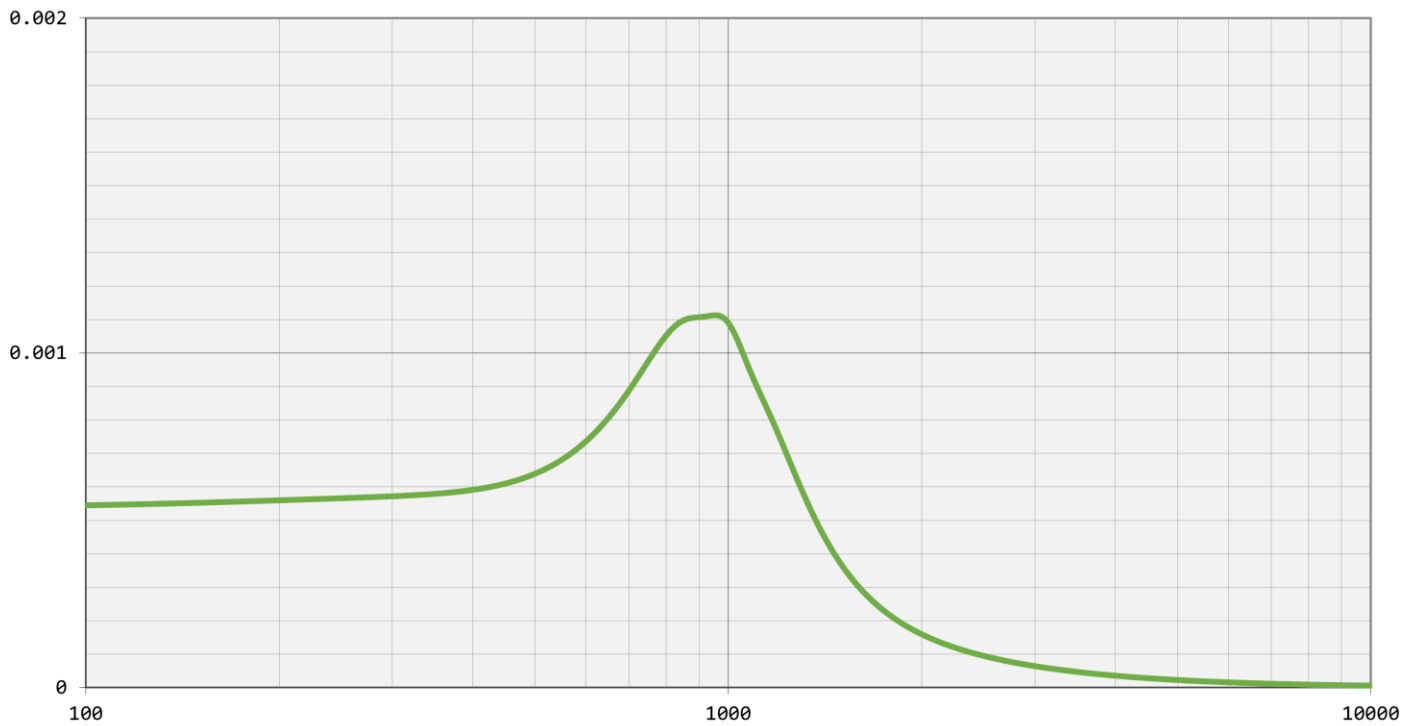
8DFES_1.33_A46_P66 : Lowpass Response



8DFES_1.33_A46_P66 : Relative Phase Angle in Degrees



8DFES_1.33_A46_P66 : Group Delay for $F_c = 1\text{ k Hz}$



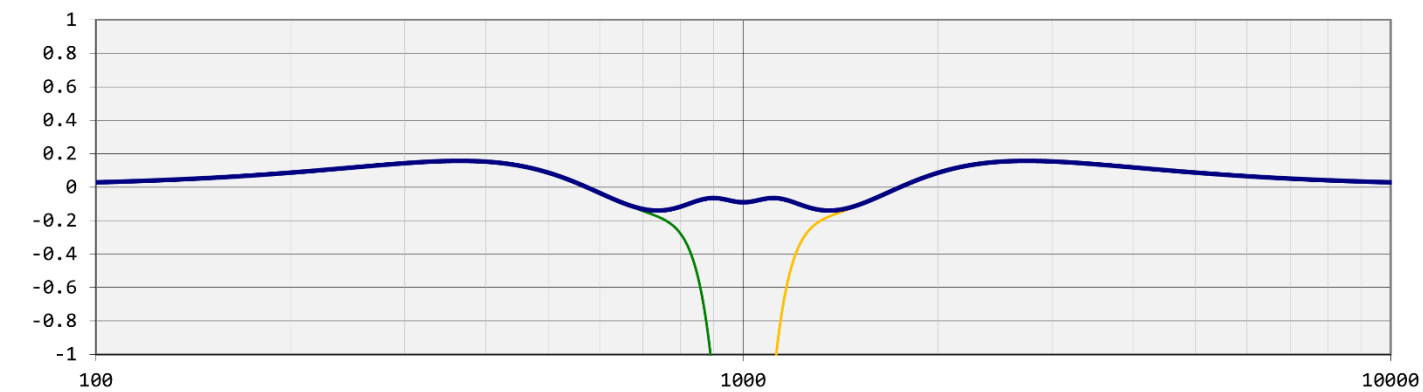
Crossover 8DFES_1.49_A68_P52:

Filters used to construct the 8DFES_1.49_A68_P52 Crossover:

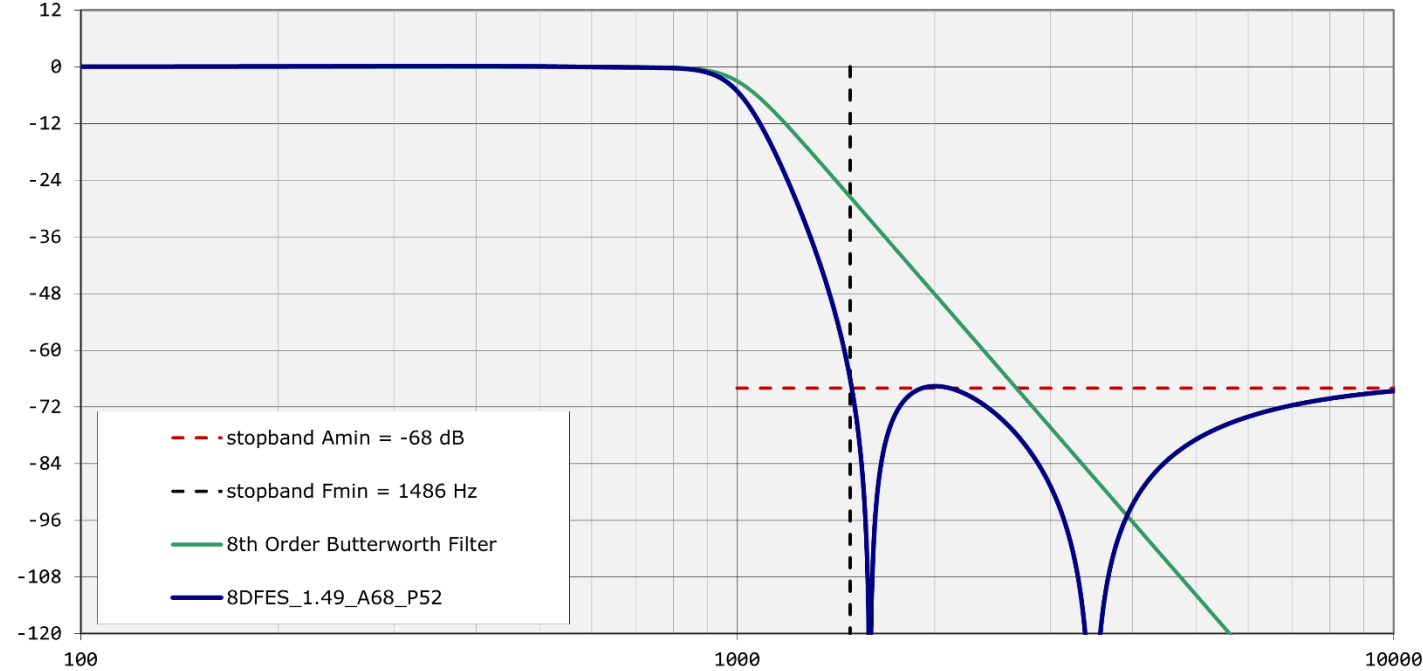
Filters:	LPN	LPN	LPN	LPN	HPN(+)	HPN	HPN	HPN
gain [dB]:	-11.463	-21.584	-11.463	-21.584	0.000	0.000	0.000	0.000
Fp/Fc:	0.8231	1.0041	0.8231	1.0041	1.2149	0.9959	1.2149	0.9959
Qp:	0.647	2.578	0.647	2.578	0.647	2.578	0.647	2.578
Fz/Fc:	1.5923	3.4784	1.5923	3.4784	0.6280	0.2875	0.6280	0.2875

Response Plots for the Crossover may be found below.

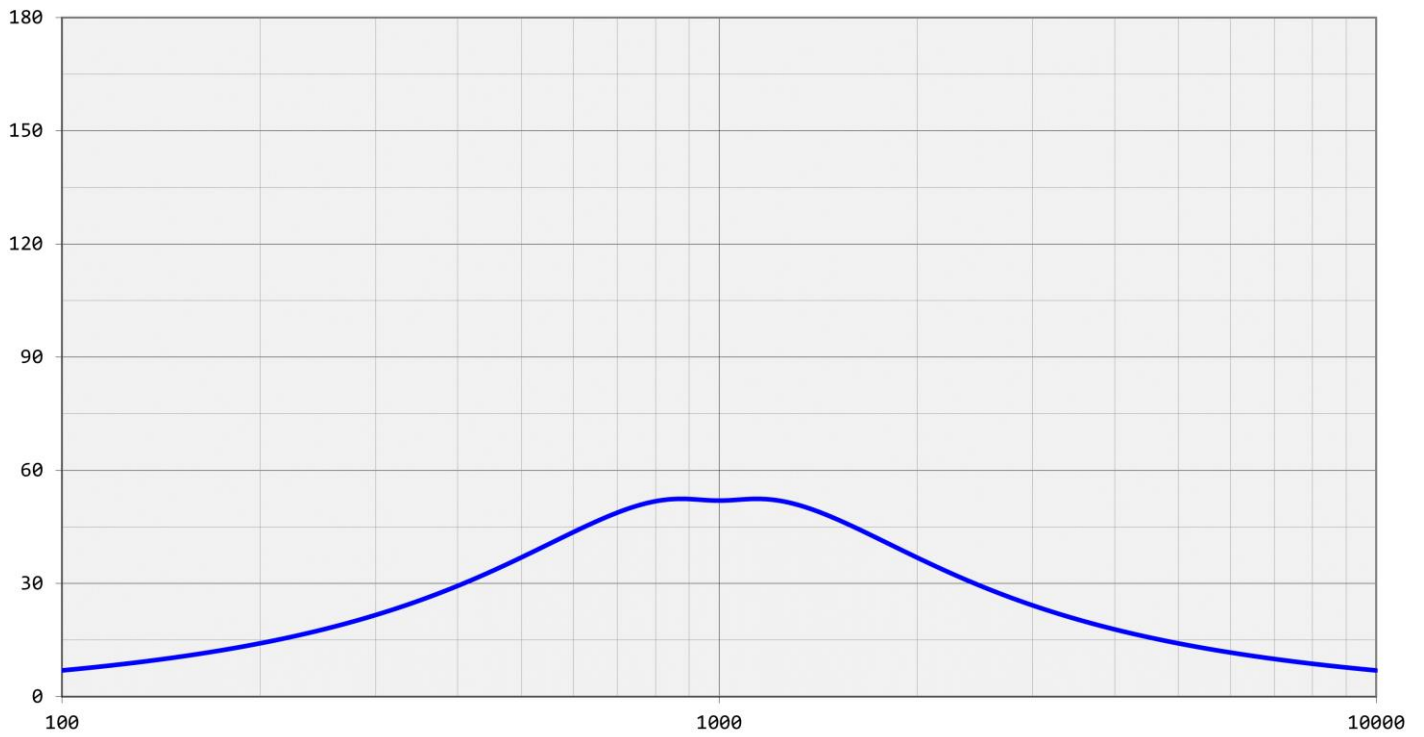
8DFES_1.49_A68_P52 : Sum of HP and LP filters



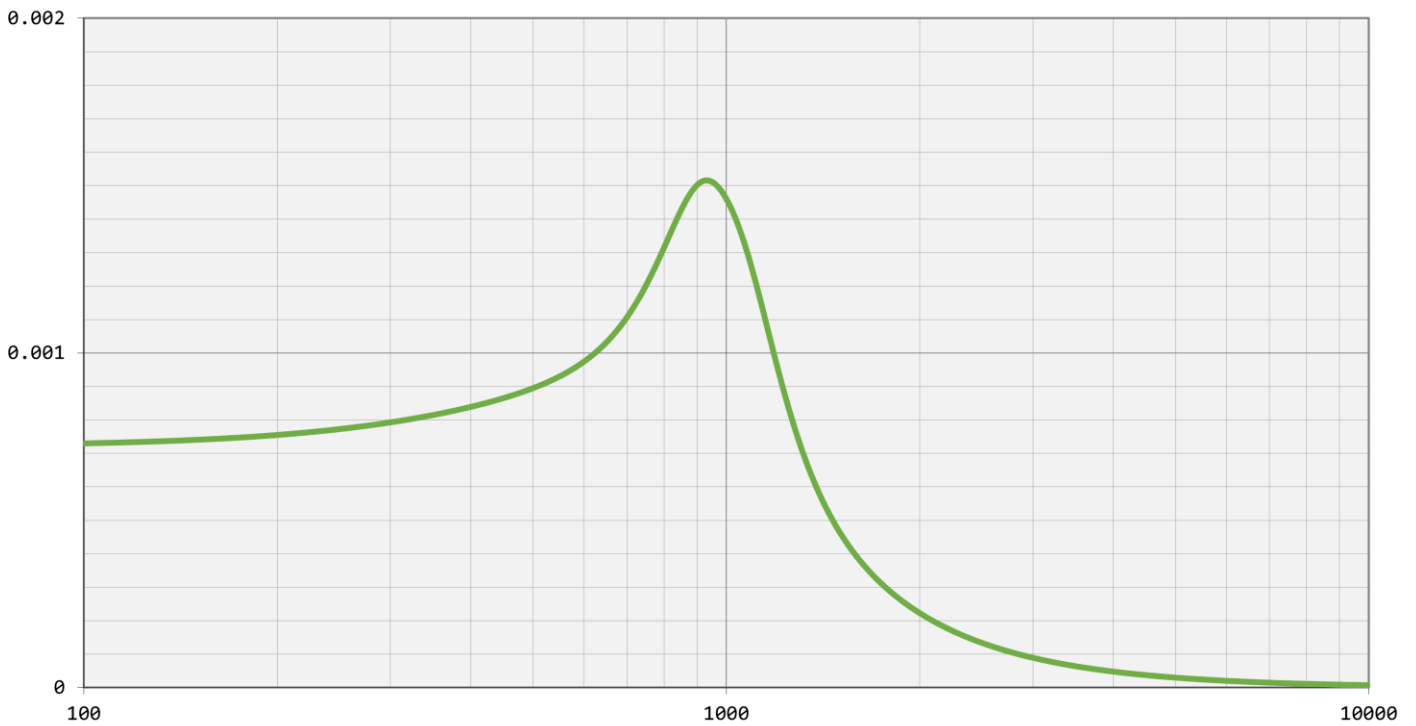
8DFES_1.49_A68_P52 : Lowpass Response



8DFES_1.49_A68_P52 : Relative Phase Angle in Degrees



8DFES_1.49_A68_P52 : Group Delay for Fc = 1k Hz



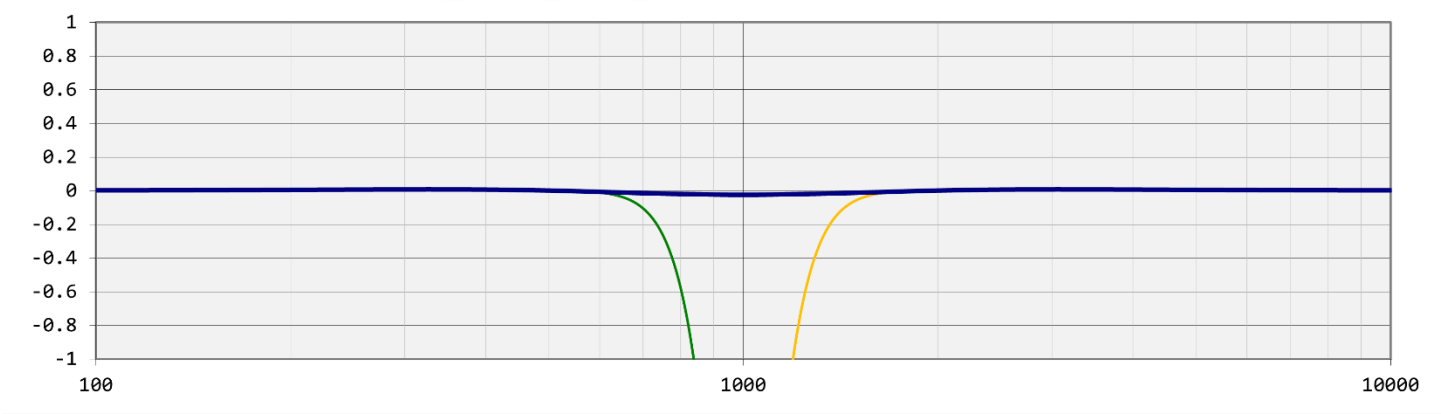
Crossover 8DFES_1.73_A75_P6:

Filters used to construct the 8DFES_1.73_A75_P6 Crossover:

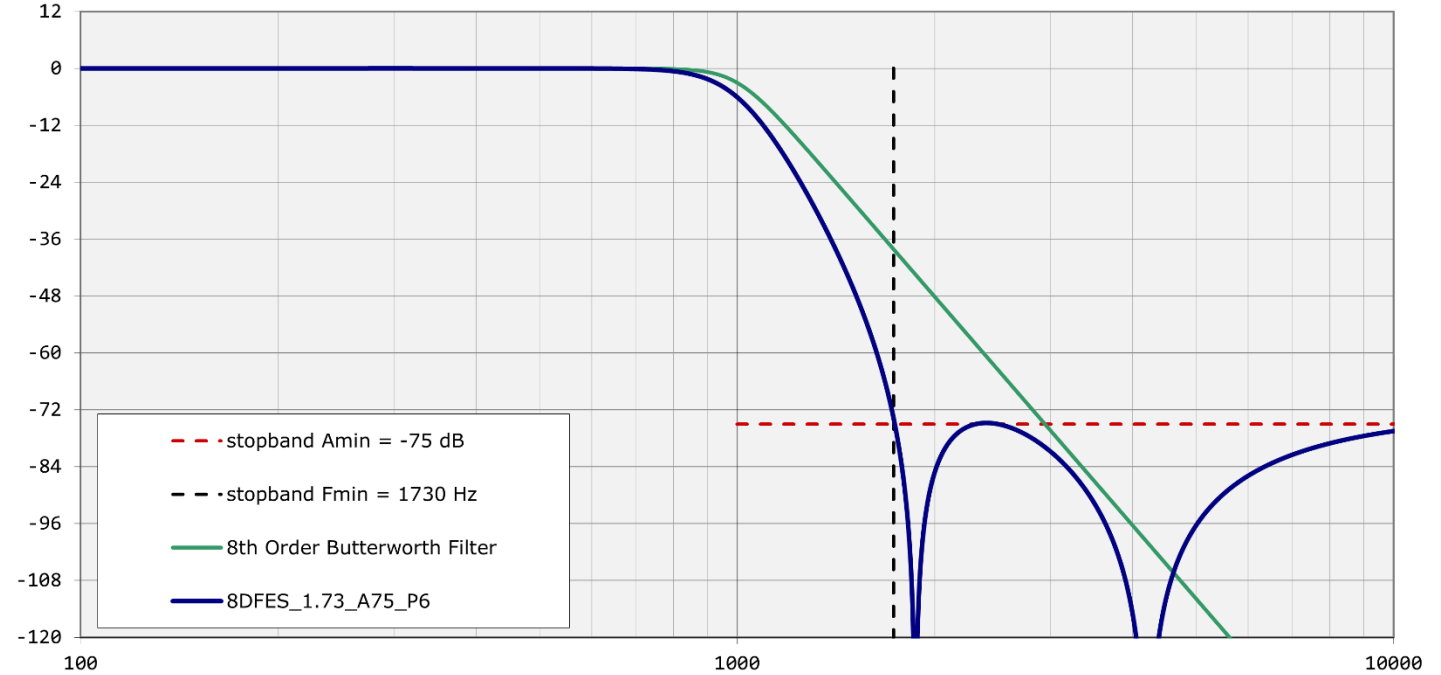
Filters:	LPN	LPN	LPN	LPN	HPN(+)	HPN	HPN	HPN
gain [dB]:	-10.862	-25.402	-10.862	-25.402	0.000	0.000	0.000	0.000
Fp/Fc:	1.0000	0.9766	1.0000	0.9766	1.0000	1.0240	1.0000	1.0240
Qp:	1.846	0.582	1.846	0.582	1.846	0.582	1.846	0.582
Fz/Fc:	1.8687	4.2144	1.8687	4.2144	0.5351	0.2373	0.5351	0.2373

Response Plots for the Crossover may be found below.

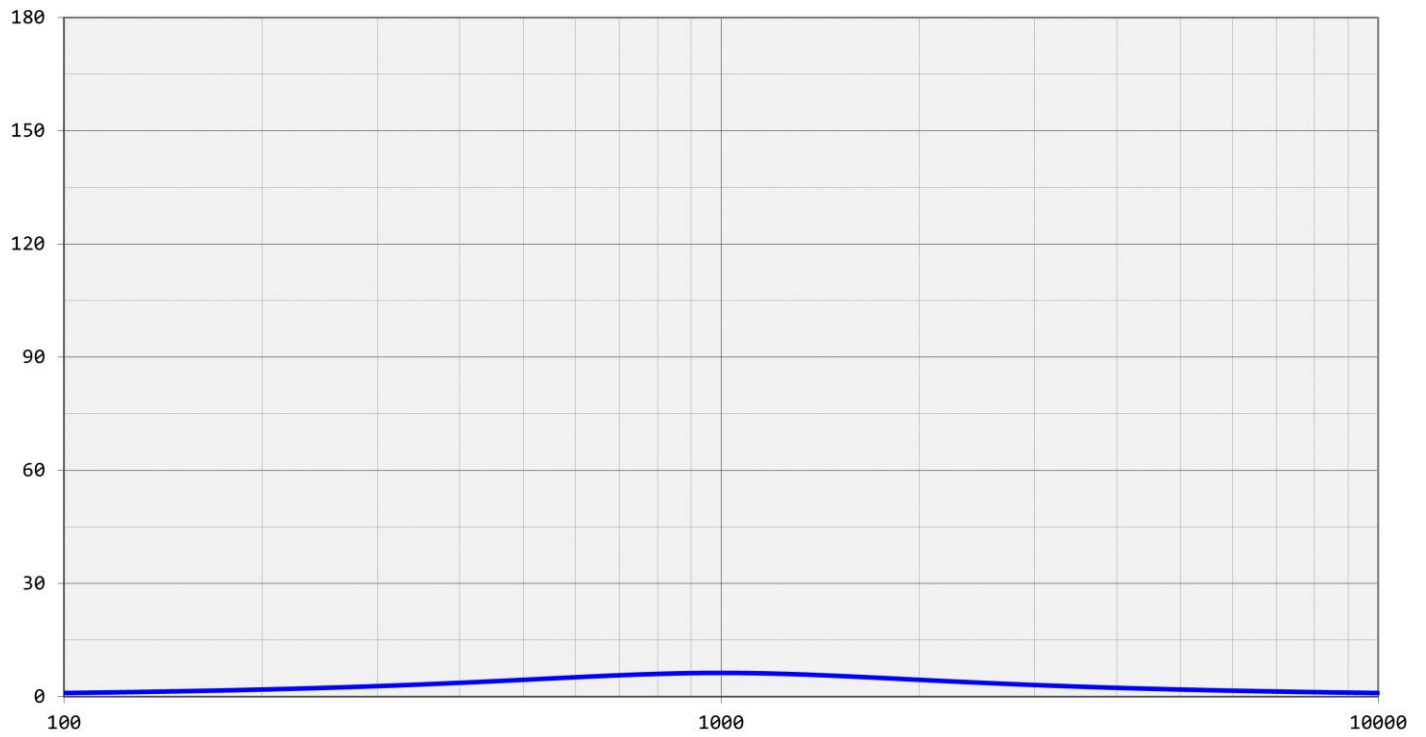
8DFES_1.73_A75_P6 : Sum of HP and LP filters



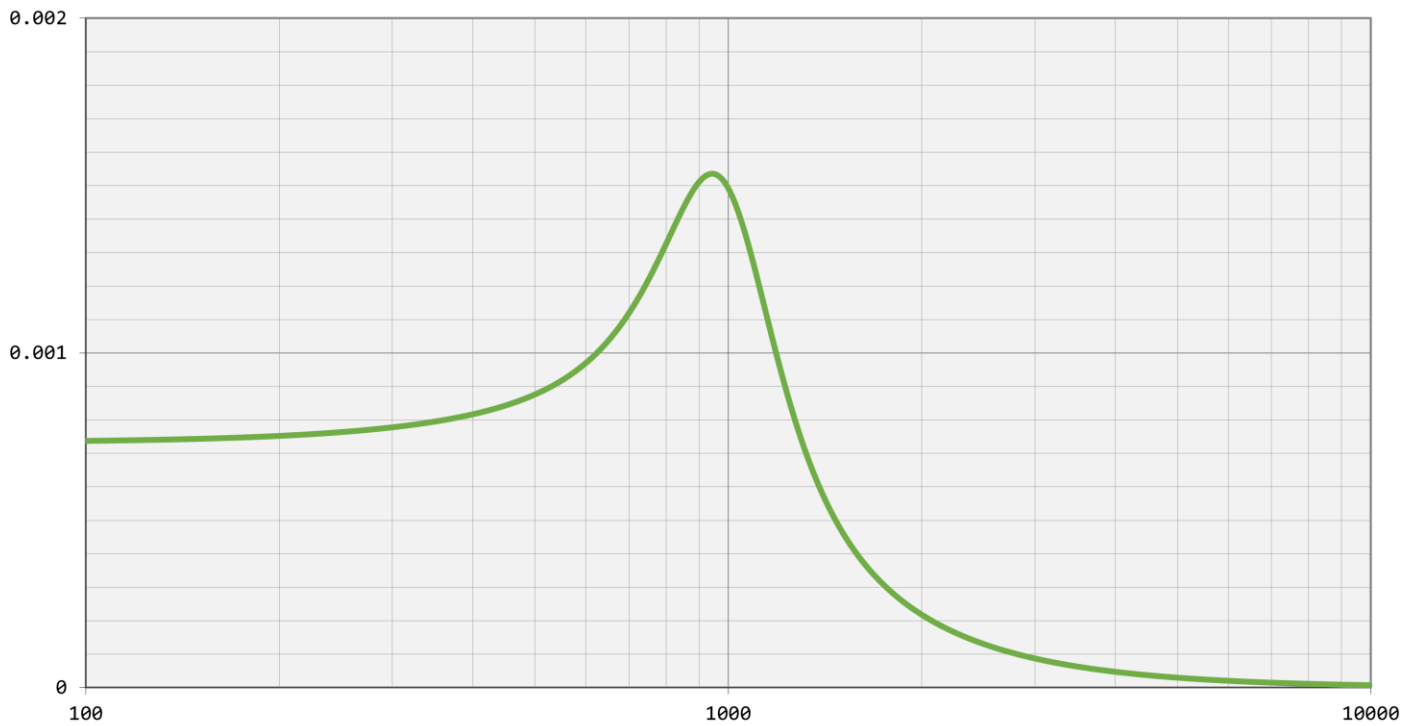
8DFES_1.73_A75_P6 : Lowpass Response



8DFES_1.73_A75_P6 : Relative Phase Angle in Degrees



8DFES_1.73_A75_P6 : Group Delay for Fc = 1k Hz



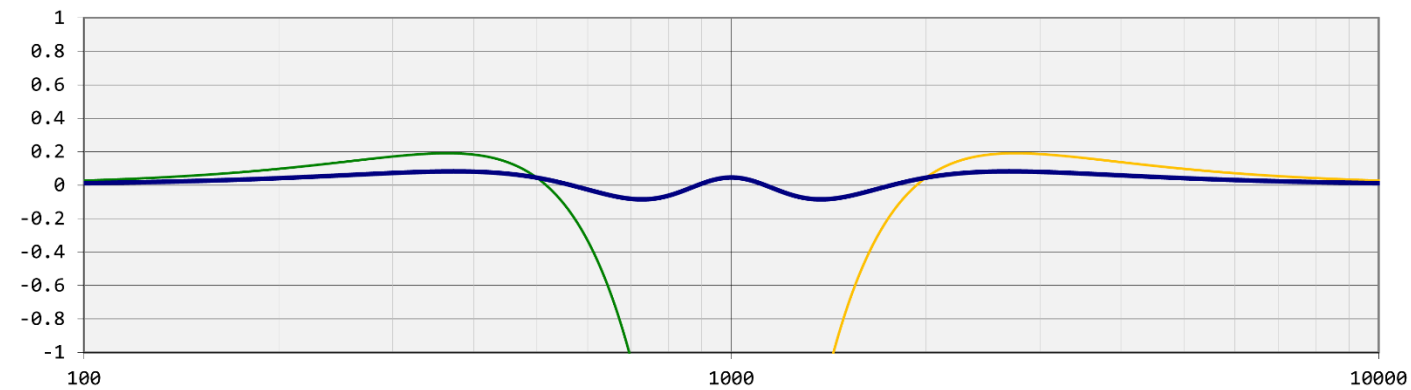
Crossover AP2_2DFE_1.82_A38_P15:

Filters used to construct the AP2_2DFE_1.82_A38_P15 Crossover:

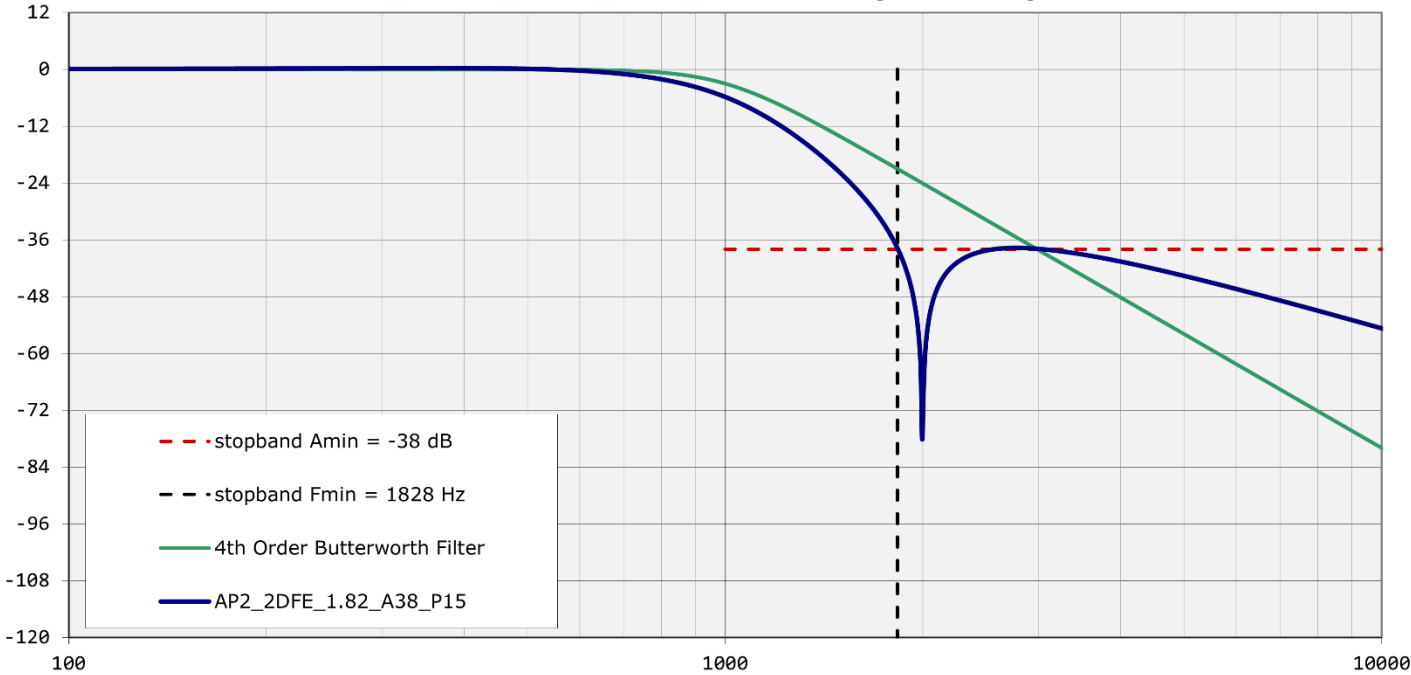
Filters:	LPN	LP2			HPN(+)	HP2		
gain [dB]:	-10.954	0.000			0.000	0.000		
Fp/Fc:	1.0633	0.8200			0.9405	1.2195		
Qp:	1.139	0.717			1.139	0.717		
Fz/Fc:	1.9975				0.5006			

Response Plots for the Crossover may be found below.

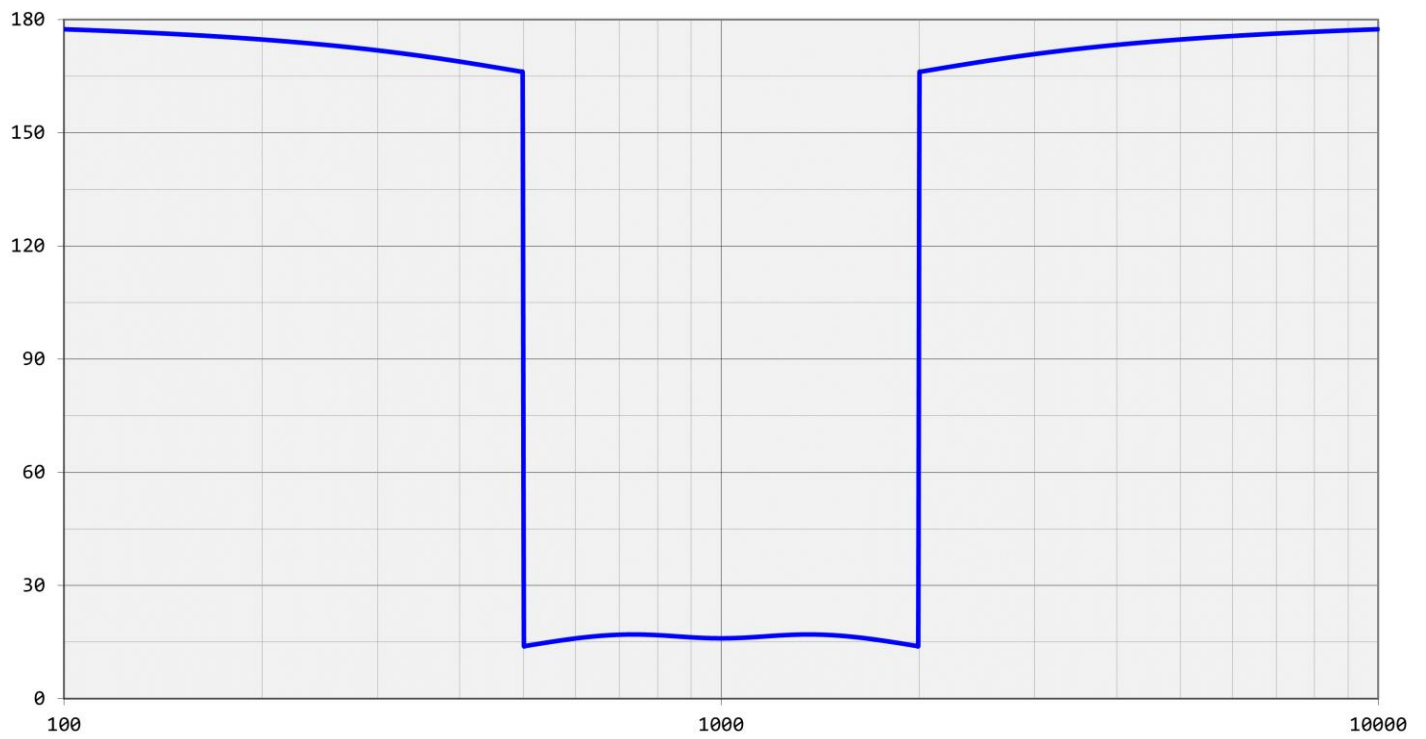
AP2_2DFE_1.82_A38_P15 : Sum of HP and LP filters



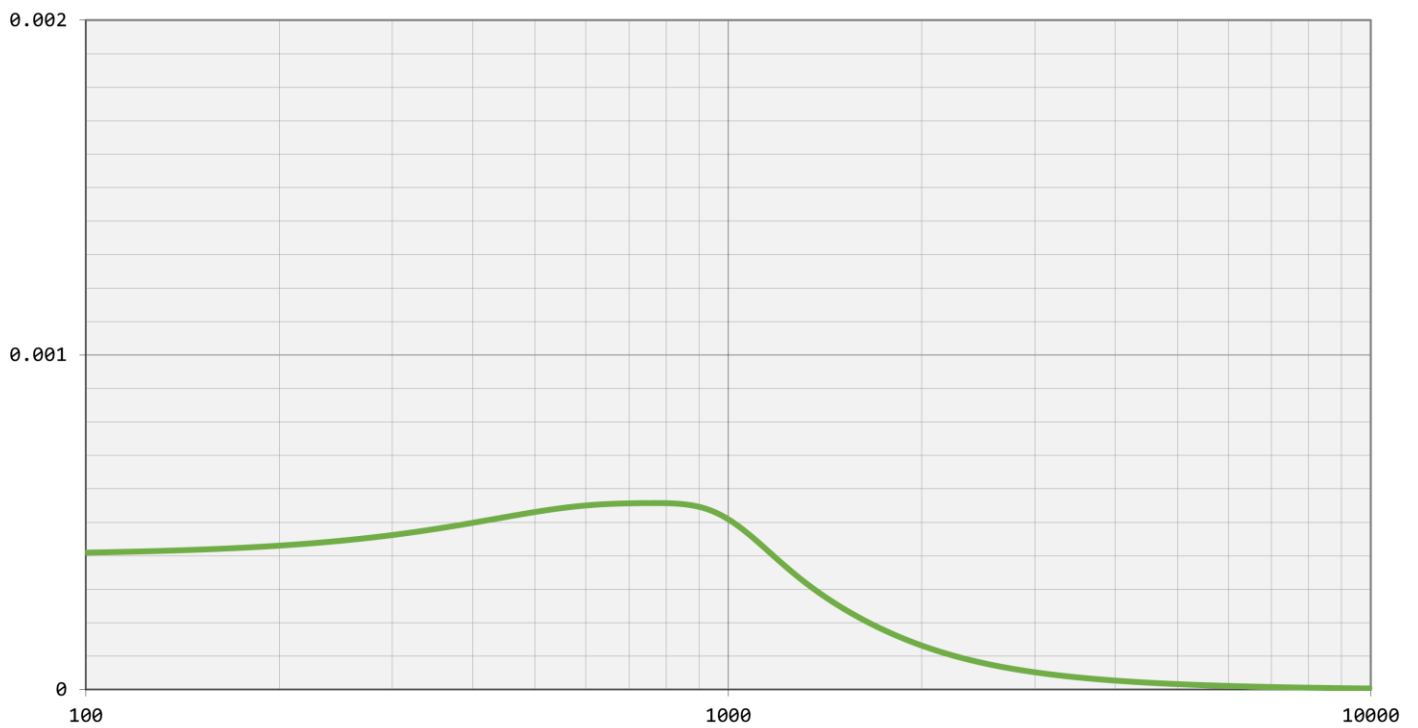
AP2_2DFE_1.82_A38_P15 : Lowpass Response



AP2_2DFE_1.82_A38_P15 : Relative Phase Angle in Degrees



AP2_2DFE_1.82_A38_P15 : Group Delay for Fc = 1k Hz



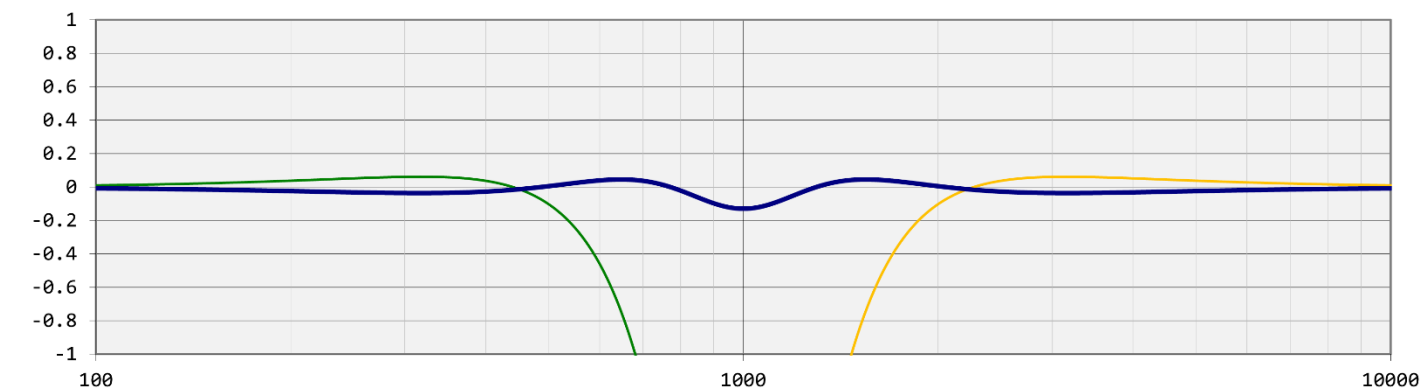
Crossover AP2_2DFE_2.00_A39_P0:

Filters used to construct the AP2_2DFE_2.00_A39_P0 Crossover:

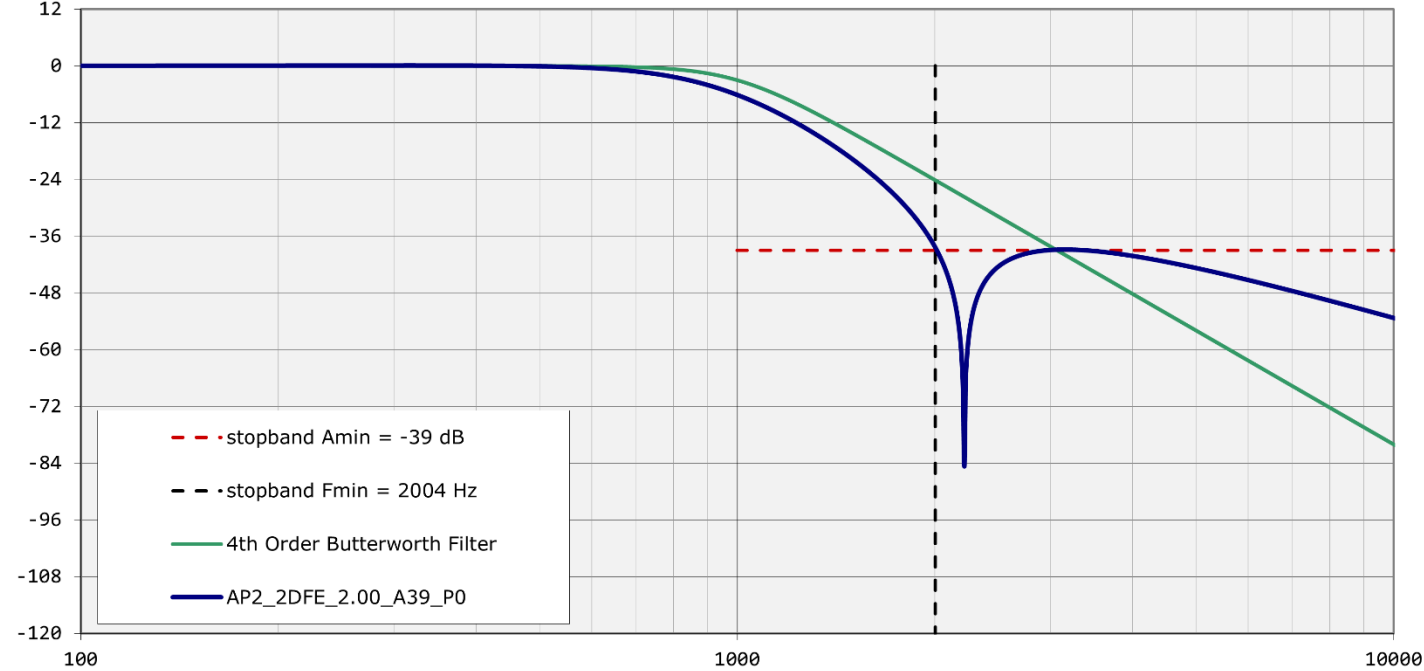
Filters:	LPN	LP2			HPN(+)	HP2		
gain [dB]:	-11.237	0.000			0.000	0.000		
Fp/Fc:	1.1609	0.9100			0.8614	1.0989		
Qp:	0.612	0.989			0.612	0.989		
Fz/Fc:	2.2167				0.4511			

Response Plots for the Crossover may be found below.

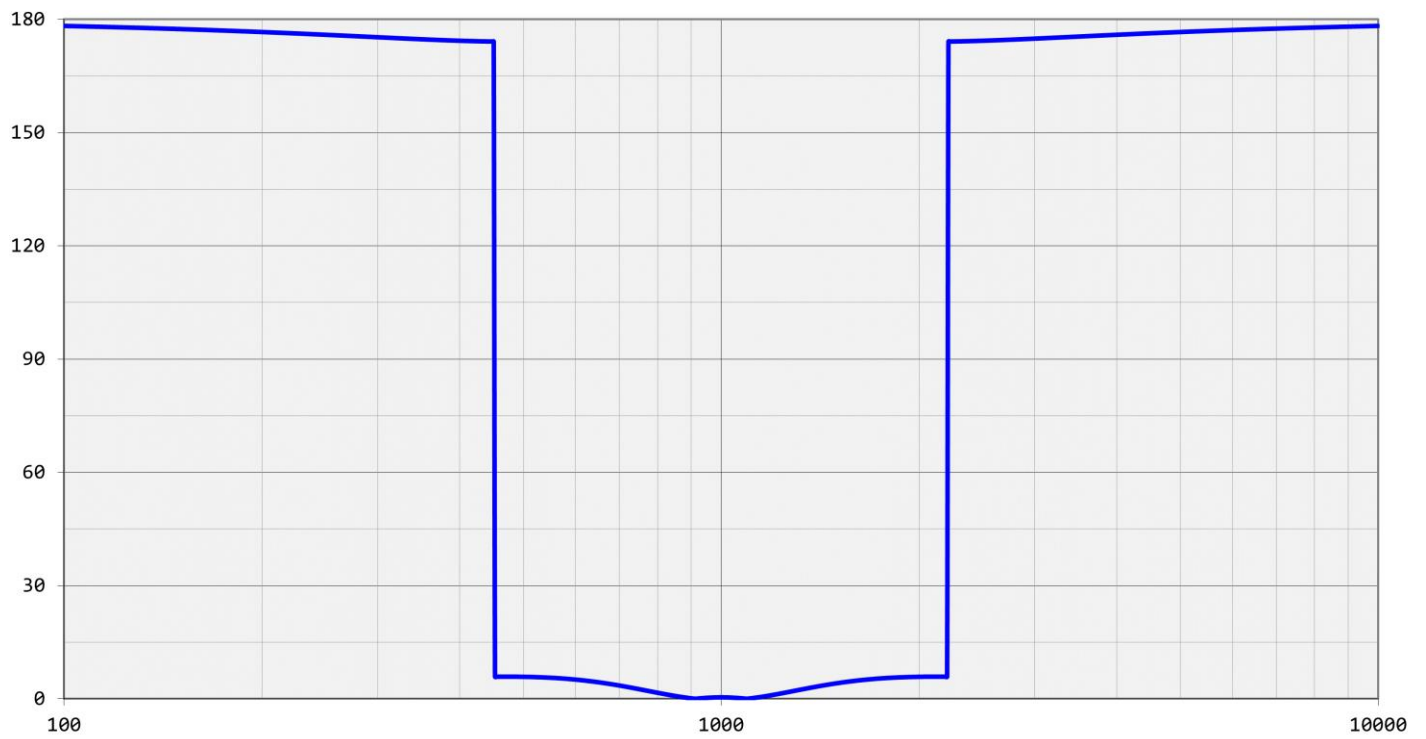
AP2_2DFE_2.00_A39_P0 : Sum of HP and LP filters



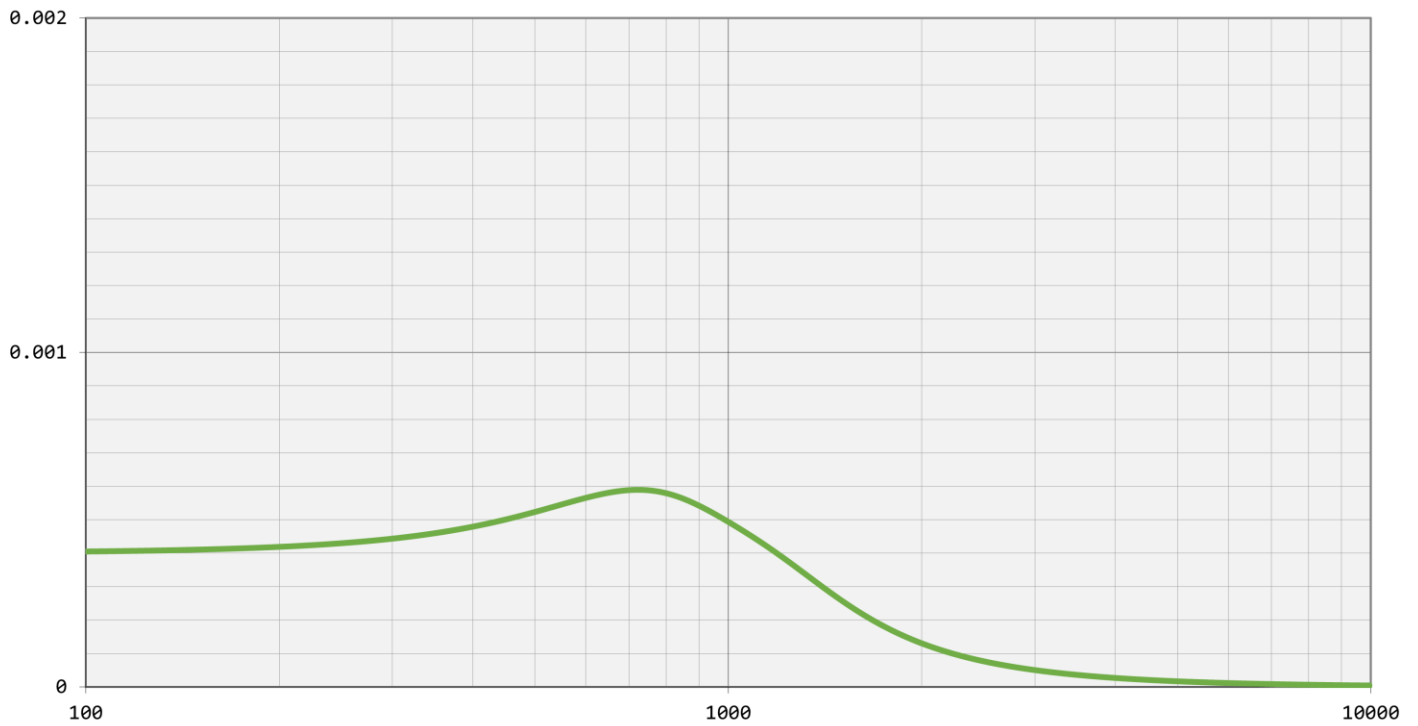
AP2_2DFE_2.00_A39_P0 : Lowpass Response



AP2_2DFE_2.00_A39_P0 : Relative Phase Angle in Degrees



AP2_2DFE_2.00_A39_P0 : Group Delay for Fc = 1k Hz



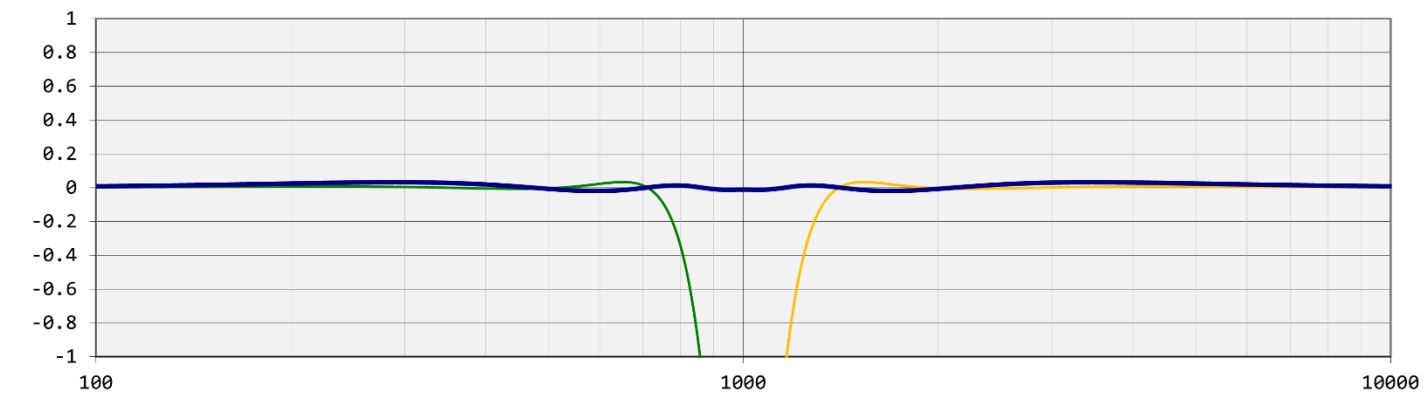
Crossover AP2_4DFE_1.36_A43_P36:

Filters used to construct the AP2_4DFE_1.36_A43_P36 Crossover:

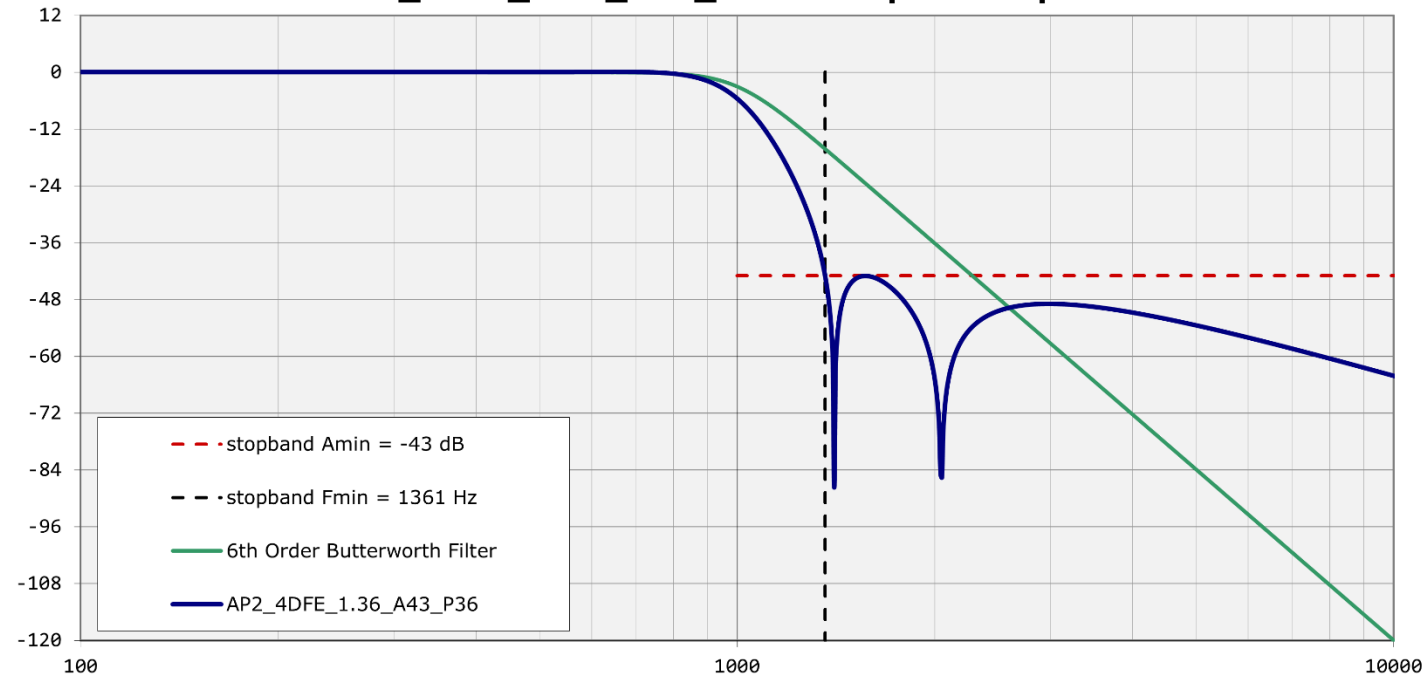
Filters:	LPN	LPN	LP2		HPN(-)	HPN	HP2	
gain [dB]:	-11.348	-11.621	0.000		0.000	0.000	0.000	
Fp/Fc:	0.7318	1.0484	0.9572		1.3665	0.9539	1.0447	
Qp:	0.577	2.025	1.785		0.577	2.025	1.785	
Fz/Fc:	1.4064	2.0466			0.7110	0.4886		

Response Plots for the Crossover may be found below.

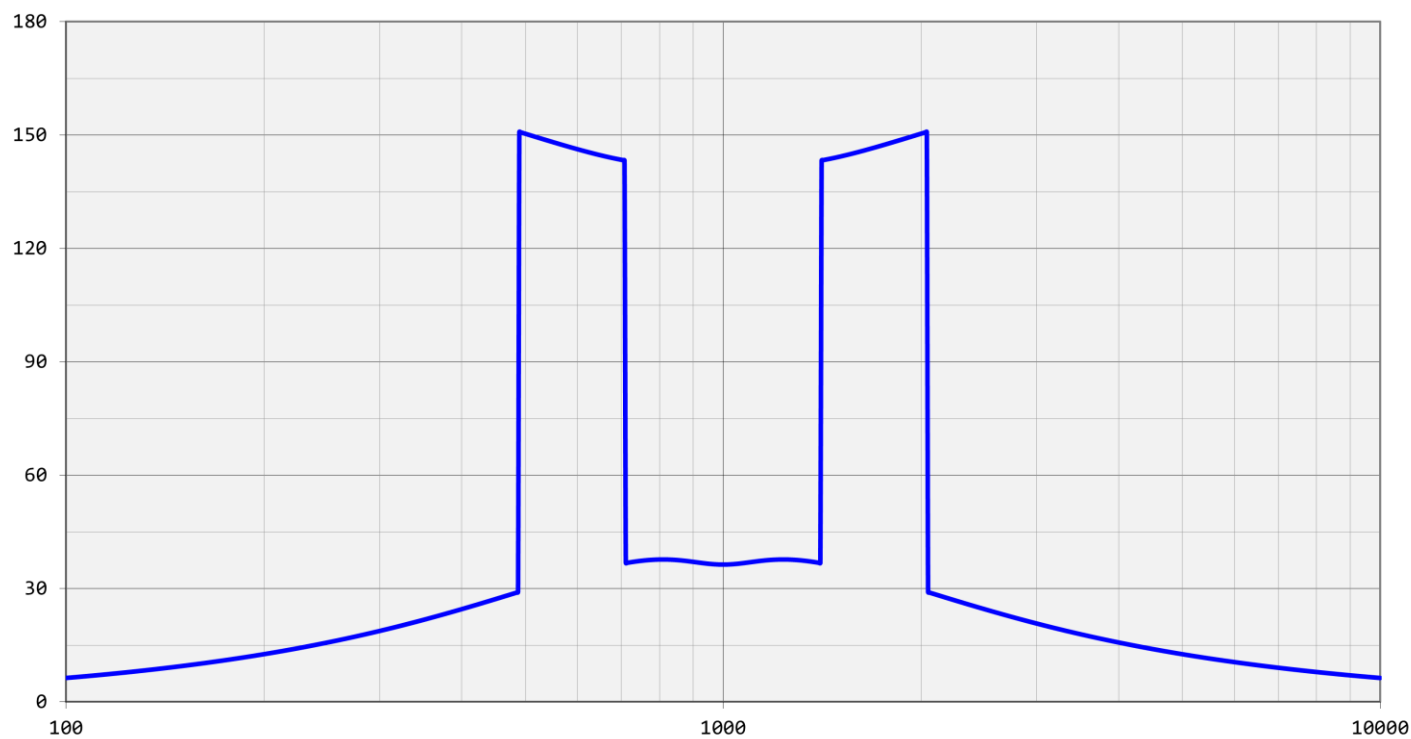
AP2_4DFE_1.36_A43_P36 : Sum of HP and LP filters



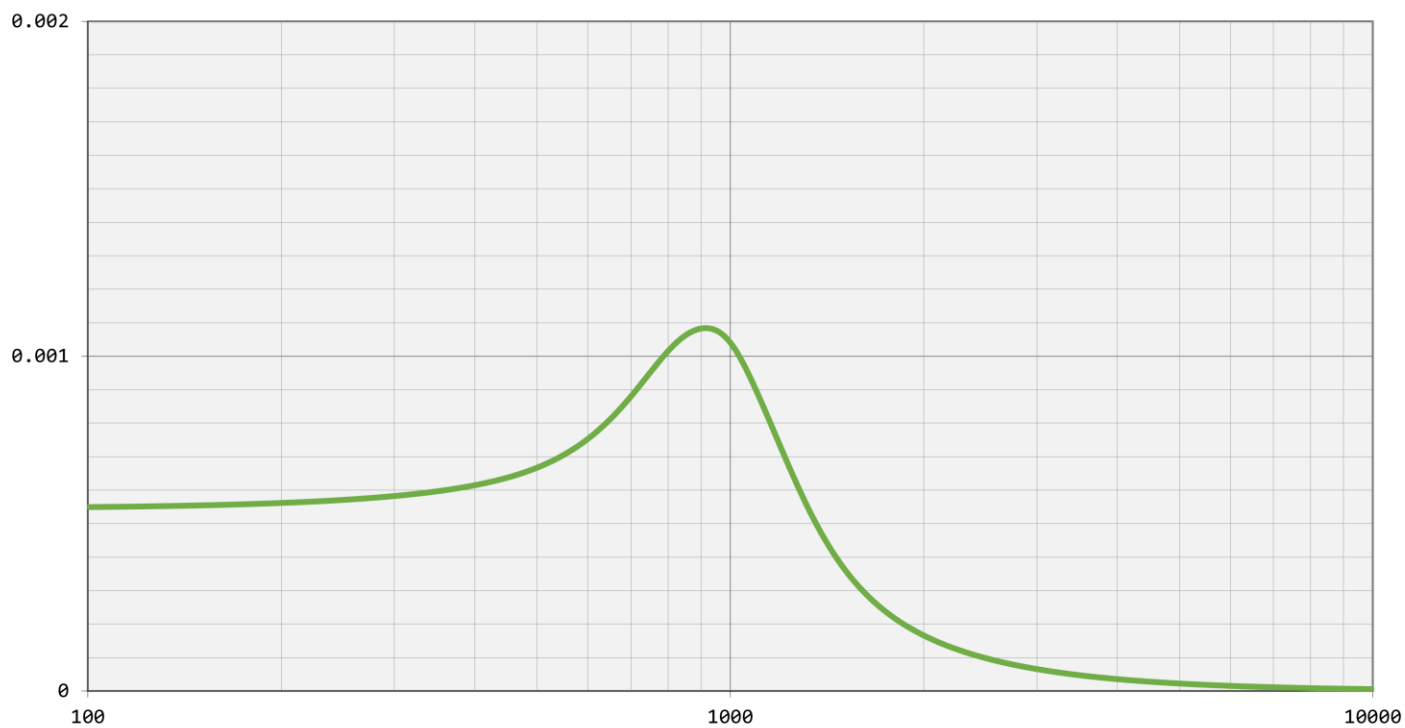
AP2_4DFE_1.36_A43_P36 : Lowpass Response



AP2_4DFE_1.36_A43_P36 : Relative Phase Angle in Degrees



AP2_4DFE_1.36_A43_P36 : Group Delay for Fc = 1k Hz



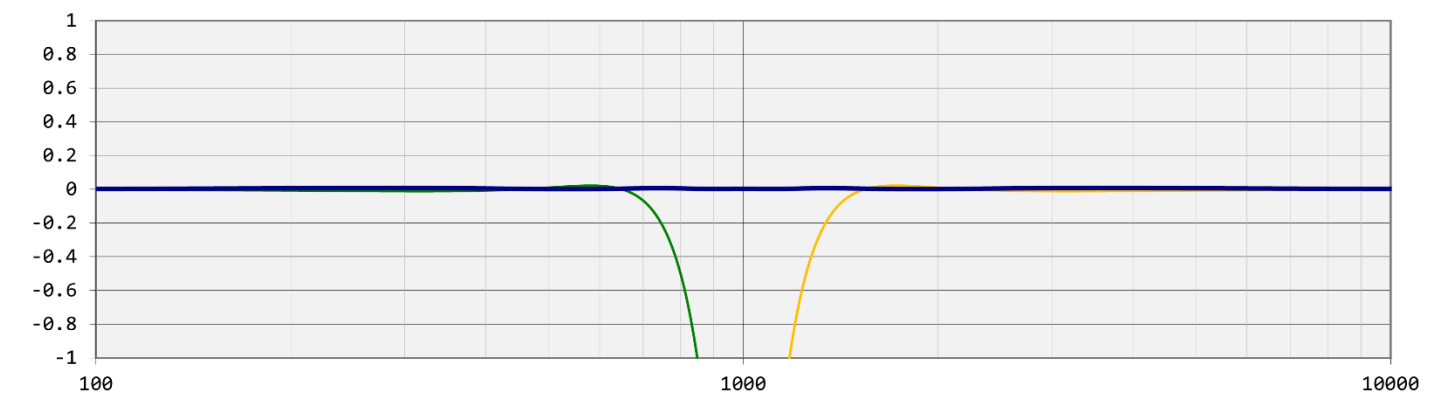
Crossover AP2_4DFE_1.50_A51_P44:

Filters used to construct the AP2_4DFE_1.50_A51_P44 Crossover:

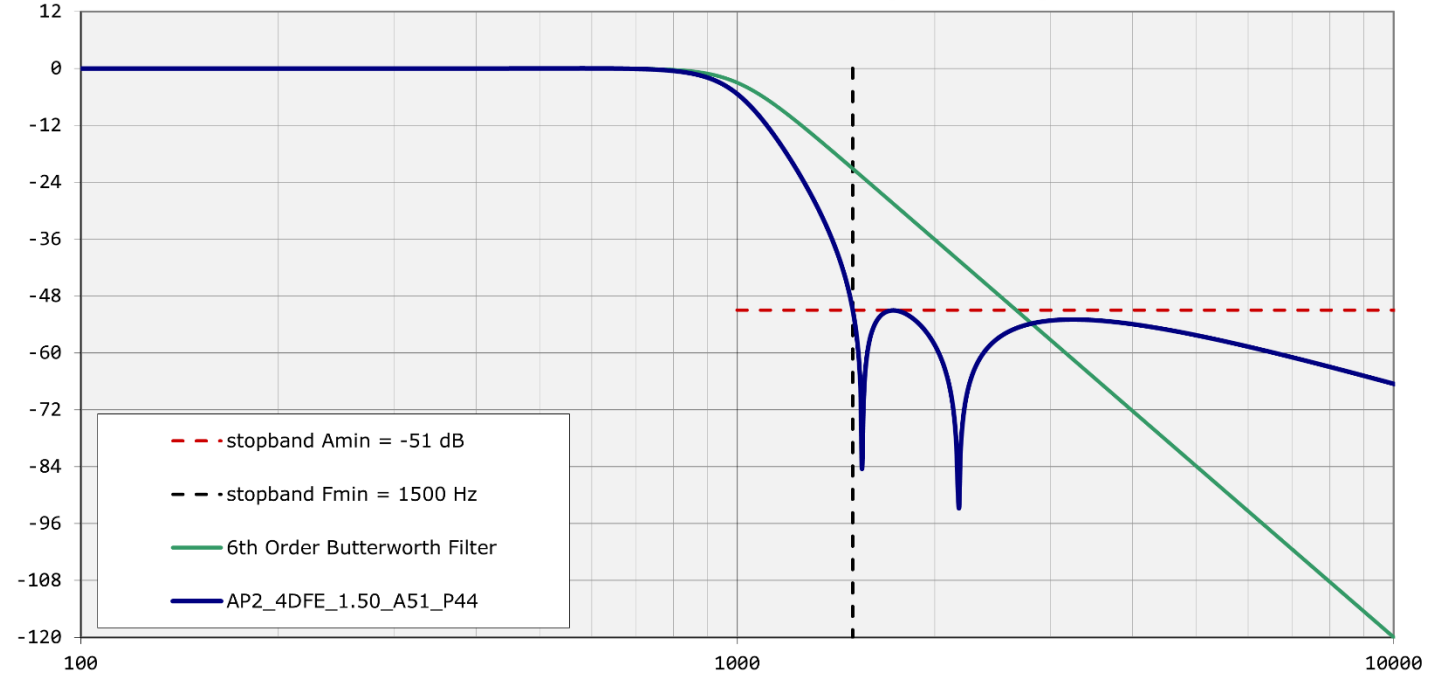
Filters:	LPN	LPN	LP2		HPN(-)	HPN	HP2	
gain [dB]:	-11.479	-14.518	0.000		0.000	0.000	0.000	
Fp/Fc:	0.8006	0.9425	1.0000		1.2491	1.0610	1.0000	
Qp:	0.547	1.210	2.441		0.547	1.210	2.441	
Fz/Fc:	1.5502	2.1738			0.6451	0.4600		

Response Plots for the Crossover may be found below.

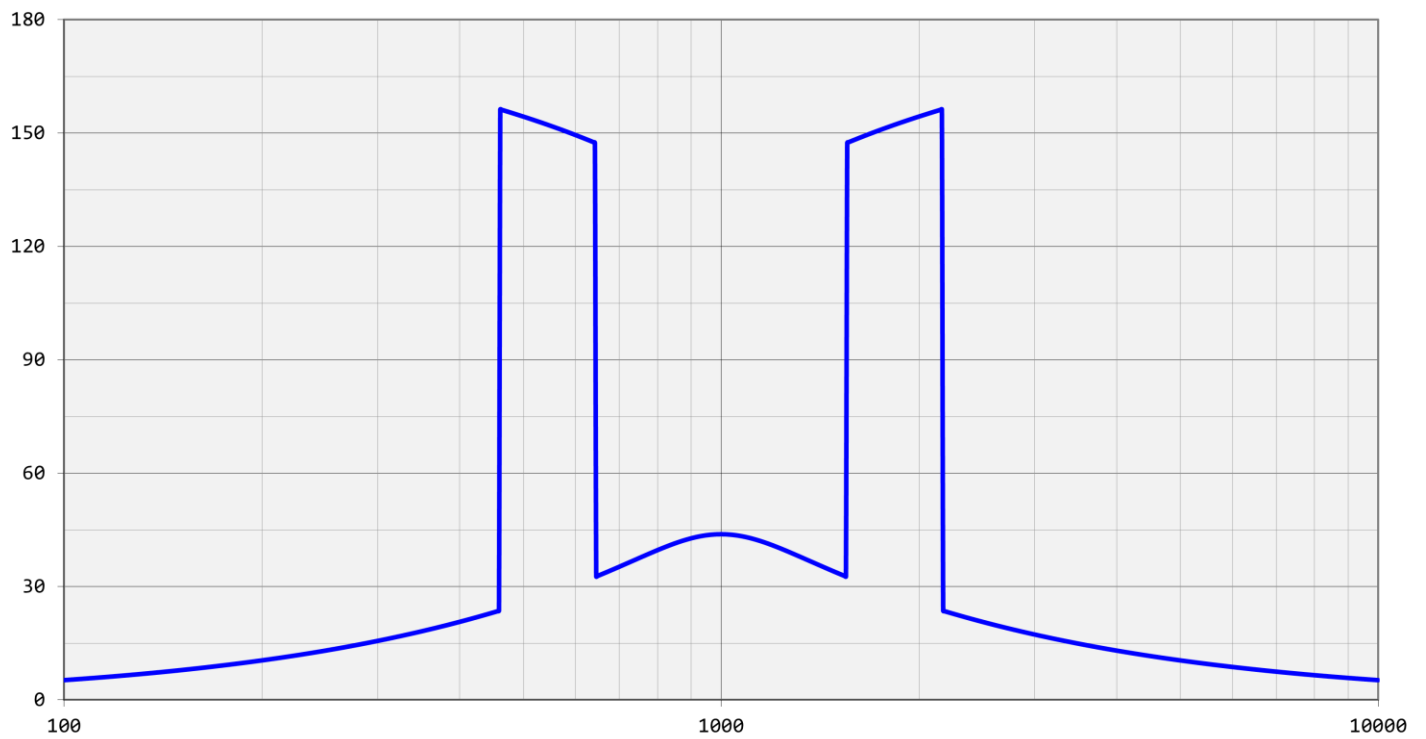
AP2_4DFE_1.50_A51_P44 : Sum of HP and LP filters



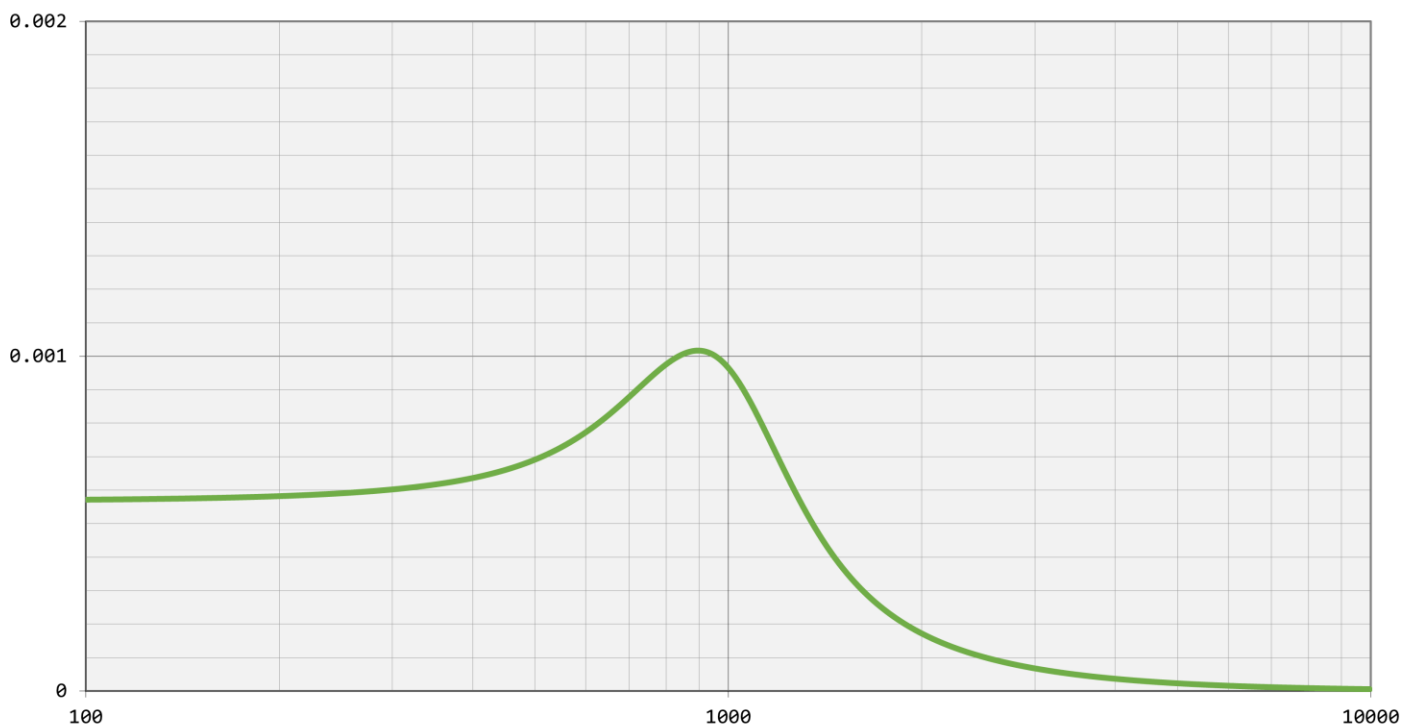
AP2_4DFE_1.50_A51_P44 : Lowpass Response



AP2_4DFE_1.50_A51_P44 : Relative Phase Angle in Degrees



AP2_4DFE_1.50_A51_P44 : Group Delay for $F_c = 1\text{ k Hz}$



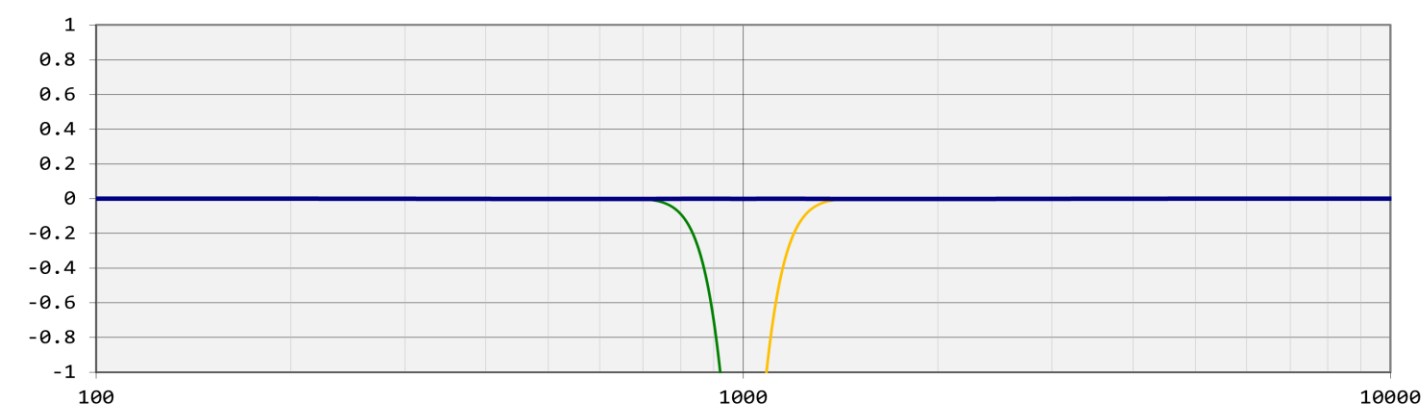
Crossover AP3_2DFE_1.41_A32_P90:

Filters used to construct the AP3_2DFE_1.41_A32_P90 Crossover:

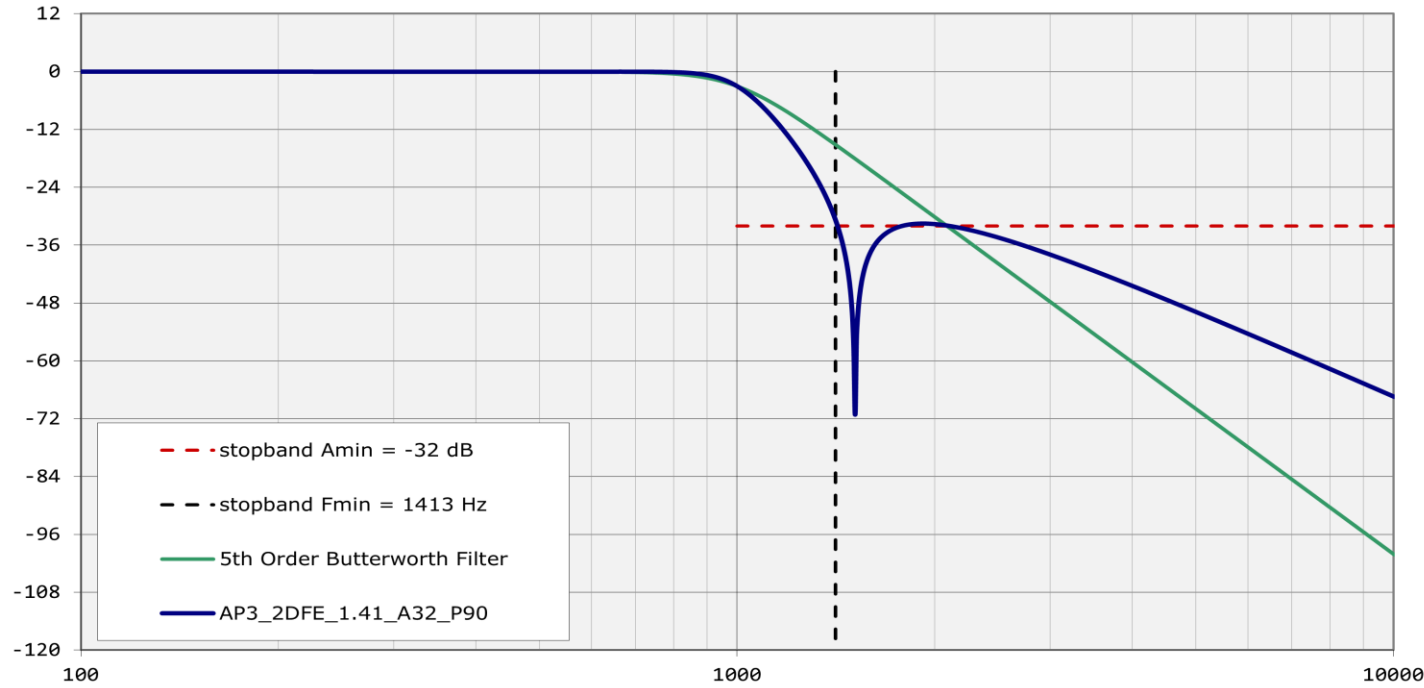
Filters:	LPN	LP	LP2		HPN(+)	HP	HP2	
gain [dB]:	-7.194	0.000	0.000		0.000	0.000	0.000	
Fp/Fc:	0.9995	0.9999	1.0000		1.0005	1.0001	1.0000	
Qp:	0.713		2.495		0.713		2.495	
Fz/Fc:	1.5122				0.6613			

Response Plots for the Crossover may be found below.

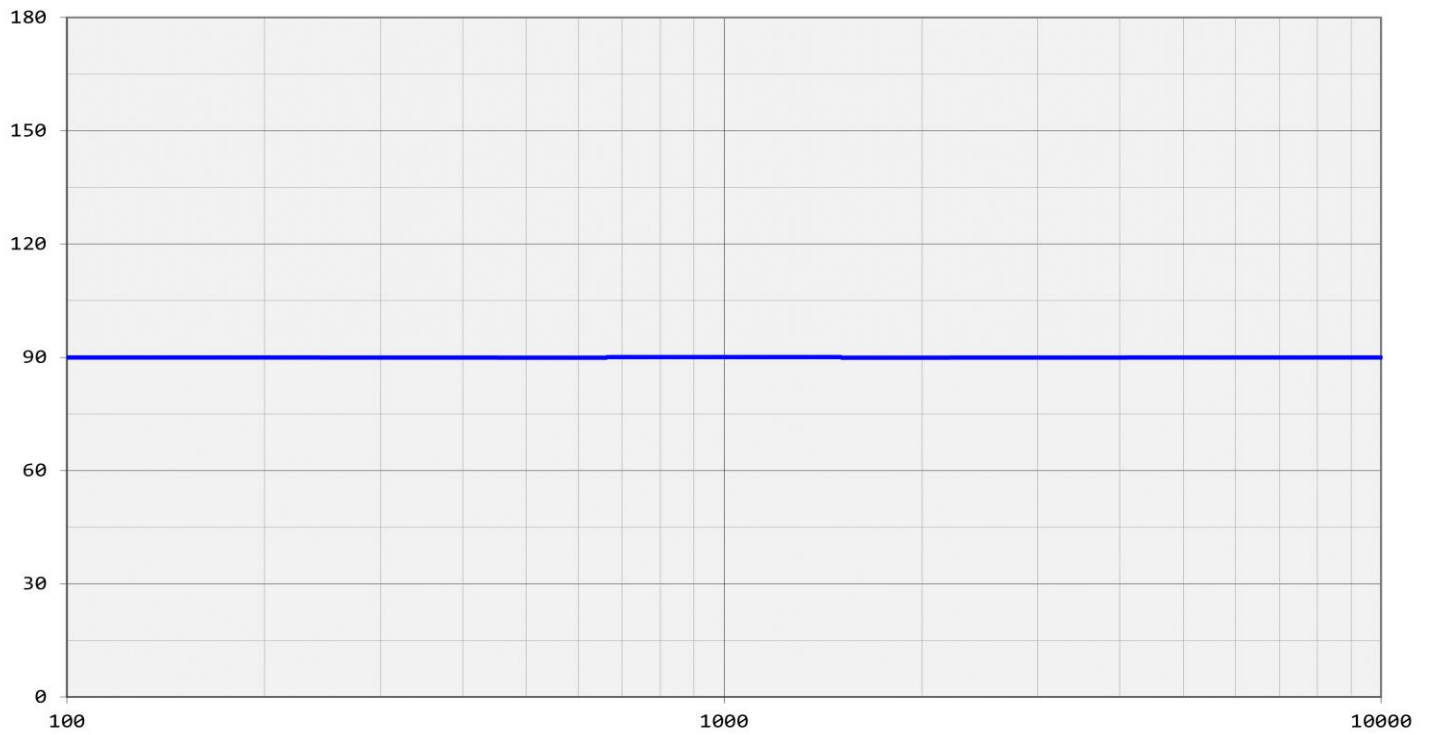
AP3_2DFE_1.41_A32_P90 : Sum of HP and LP filters



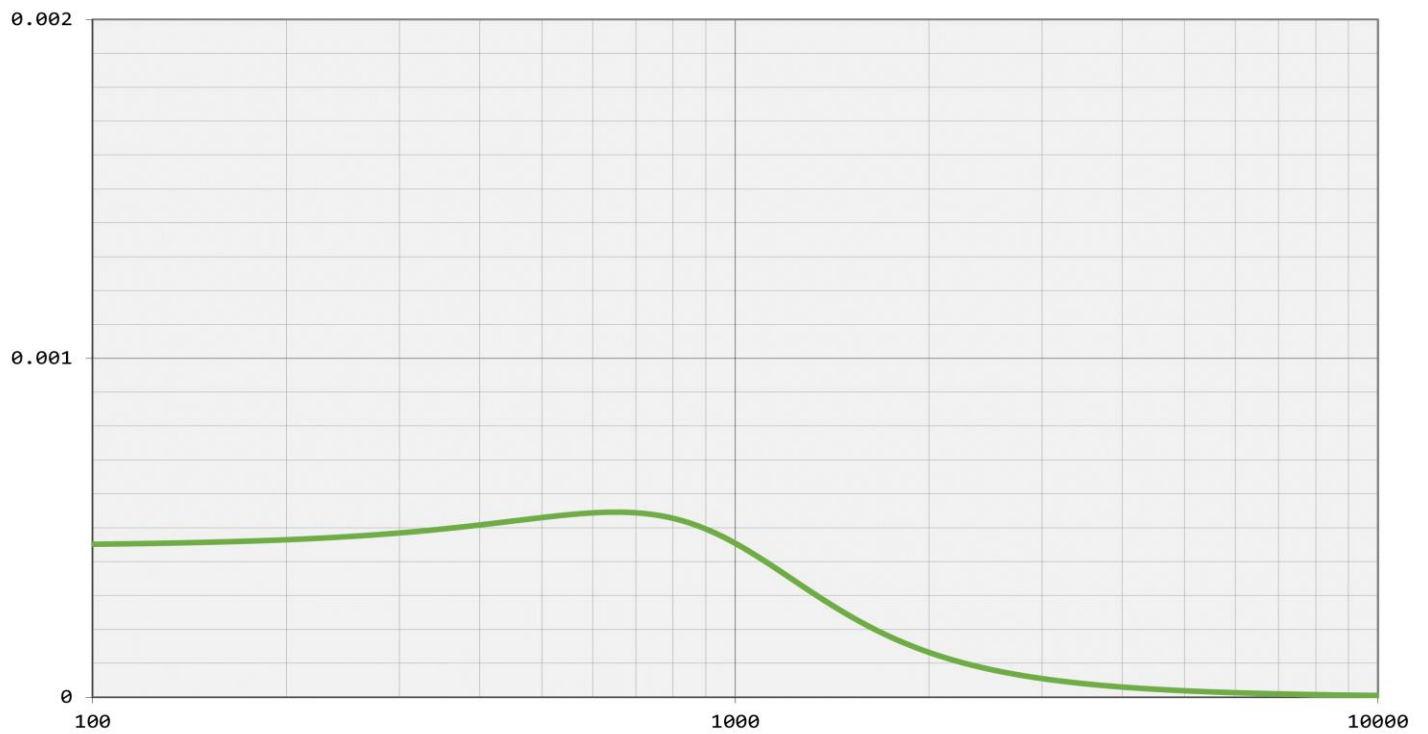
AP3_2DFE_1.41_A32_P90 : Lowpass Response



AP3_2DFE_1.41_A32_P90 : Relative Phase Angle in Degrees



AP3_2DFE_1.41_A32_P90 : Group Delay for Fc = 1k Hz



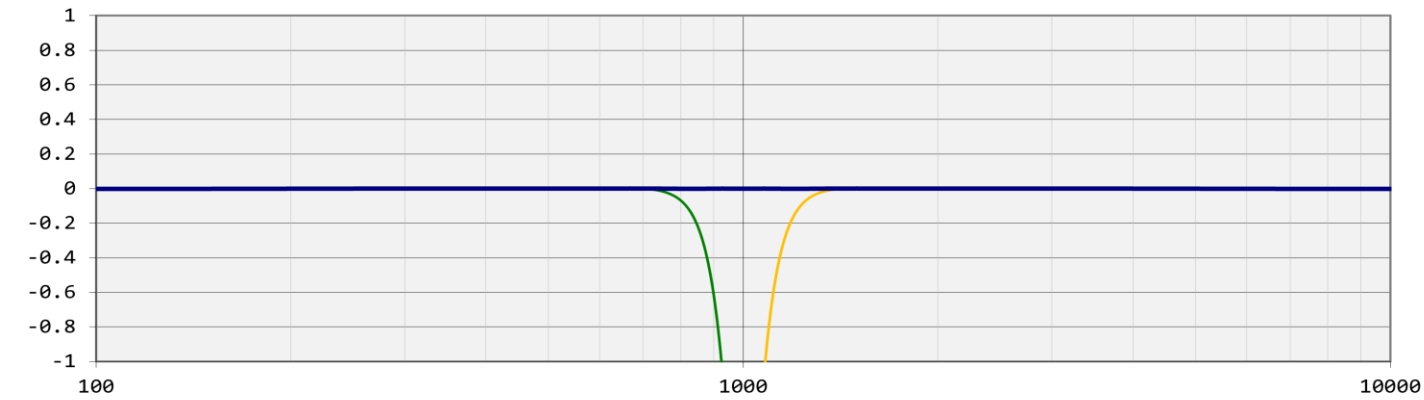
Crossover AP3_4DFE_1.41_A46_P83:

Filters used to construct the AP3_4DFE_1.41_A46_P83 Crossover:

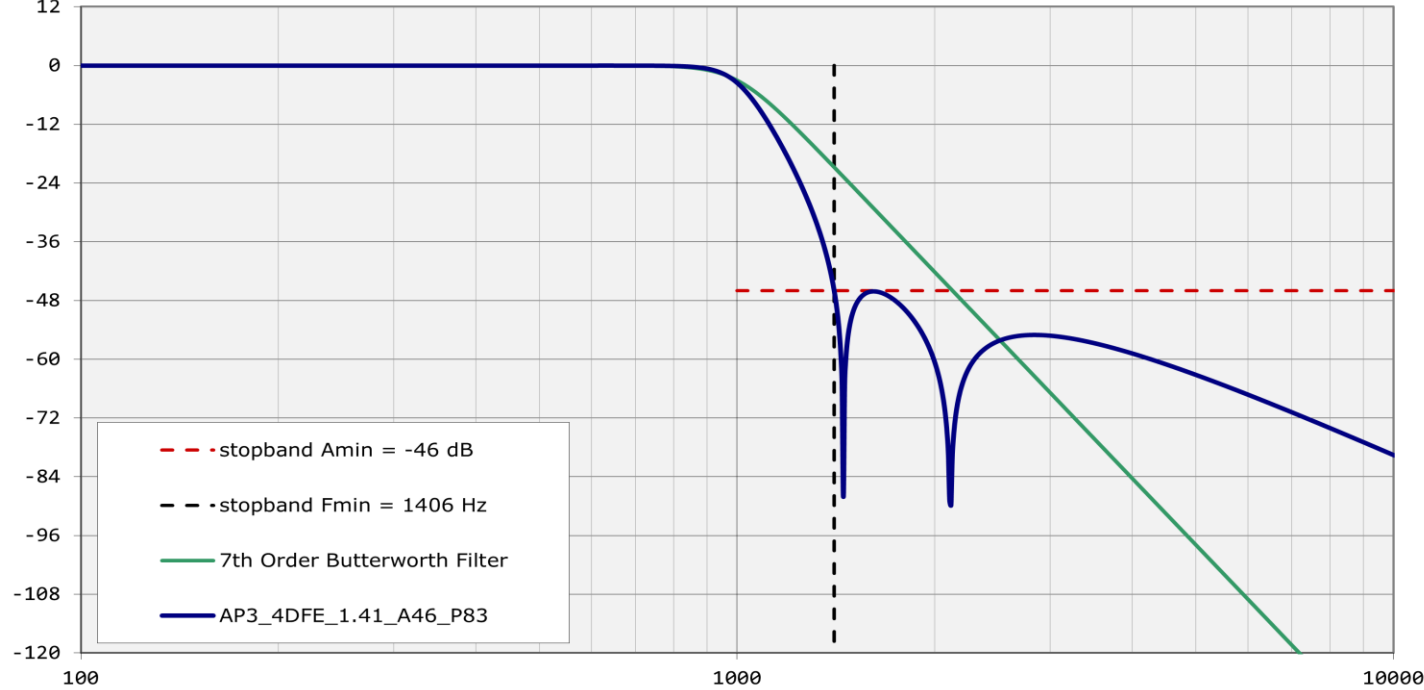
Filters:	LPN	LPN	LP	LP2	HPN(-)	HPN	HP	HP2
gain [dB]:	-6.476	-13.198	0.000	0.000	0.000	0.000	0.000	0.000
Fp/Fc:	0.9999	0.9888	1.0158	1.0302	1.0001	1.0113	0.9844	0.9707
Qp:	3.280	0.613		1.125	3.280	0.613		1.125
Fz/Fc:	1.4516	2.1137			0.6889	0.4731		

Response Plots for the Crossover may be found below.

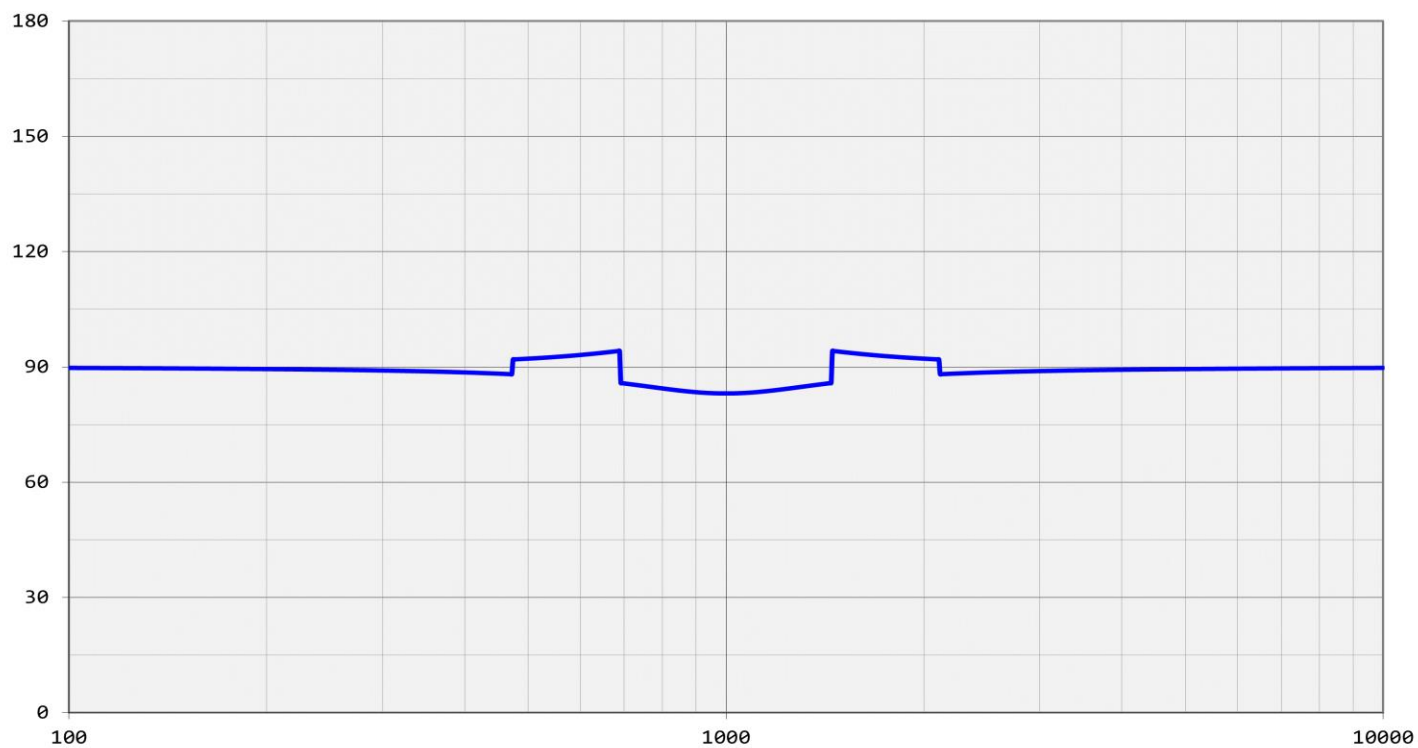
AP3_4DFE_1.41_A46_P83 : Sum of HP and LP filters



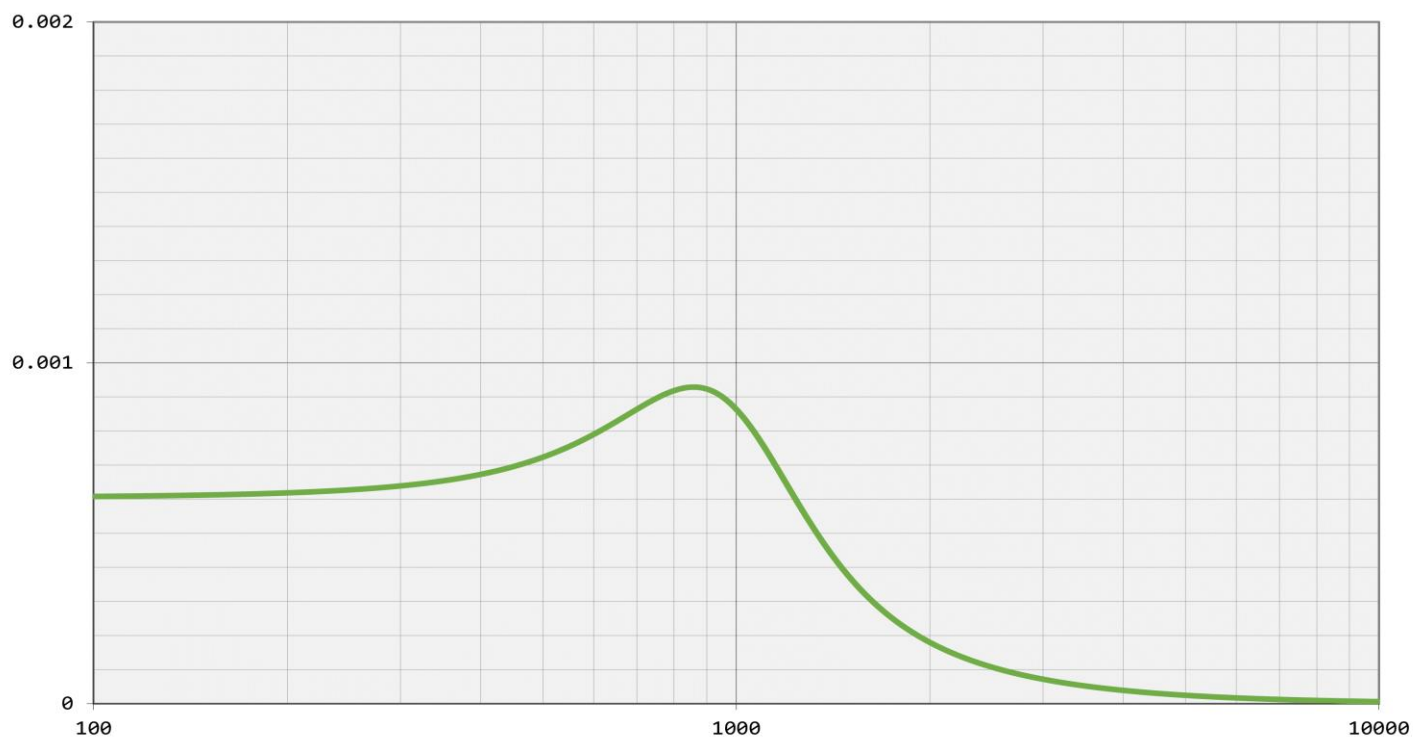
AP3_4DFE_1.41_A46_P83 : Lowpass Response



AP3_4DFE_1.41_A46_P83 : Relative Phase Angle in Degrees



AP3_4DFE_1.41_A46_P83 : Group Delay for Fc = 1k Hz



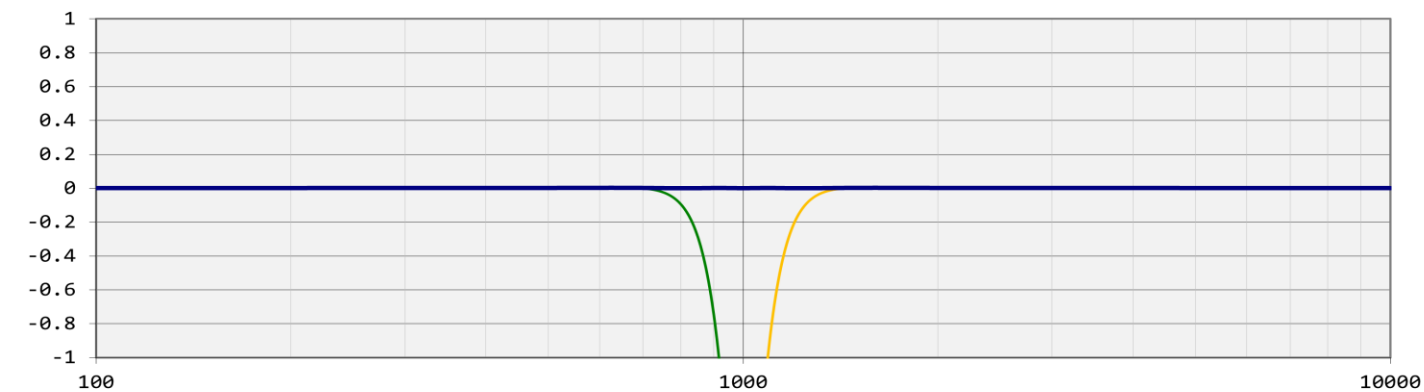
Crossover AP3_4DFE_1.61_A58_P84:

Filters used to construct the AP3_4DFE_1.61_A58_P84 Crossover:

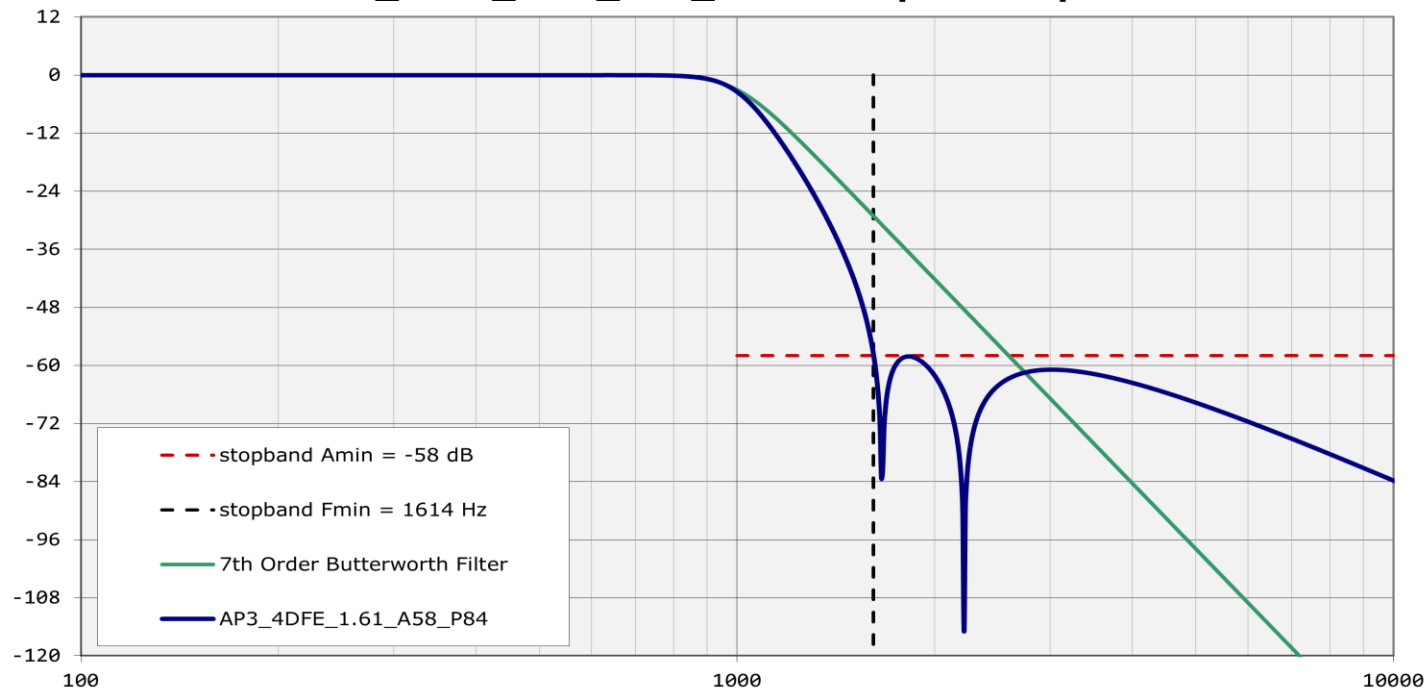
Filters:	LPN	LPN	LP	LP2	HPN(-)	HPN	HP	HP2
gain [dB]:	-8.847	-14.831	0.000	0.000	0.000	0.000	0.000	0.000
Fp/Fc:	0.9993	0.9443	0.8969	1.0885	1.0007	1.0590	1.1149	0.9187
Qp:	2.808	0.642		1.091	2.808	0.642		1.091
Fz/Fc:	1.6630	2.2176			0.6013	0.4509		

Response Plots for the Crossover may be found below.

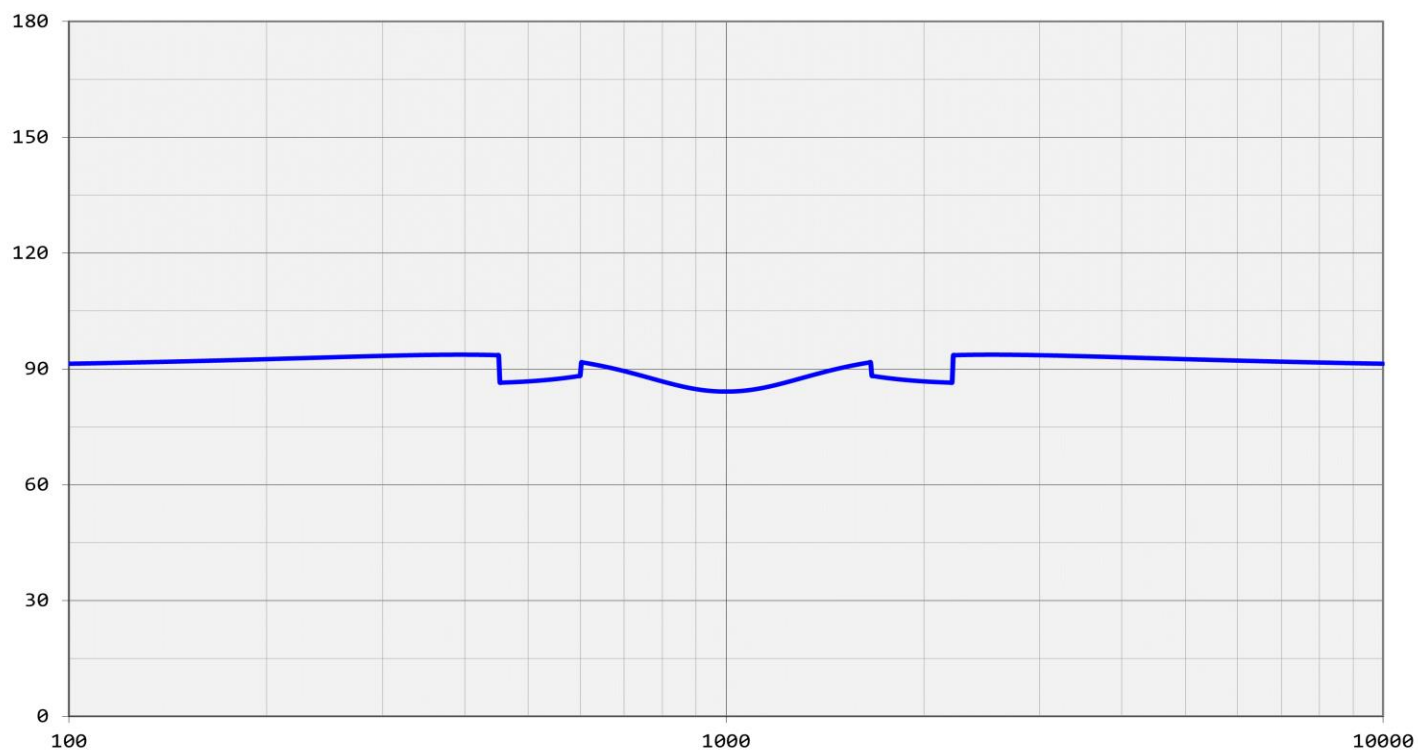
AP3_4DFE_1.61_A58_P84 : Sum of HP and LP filters



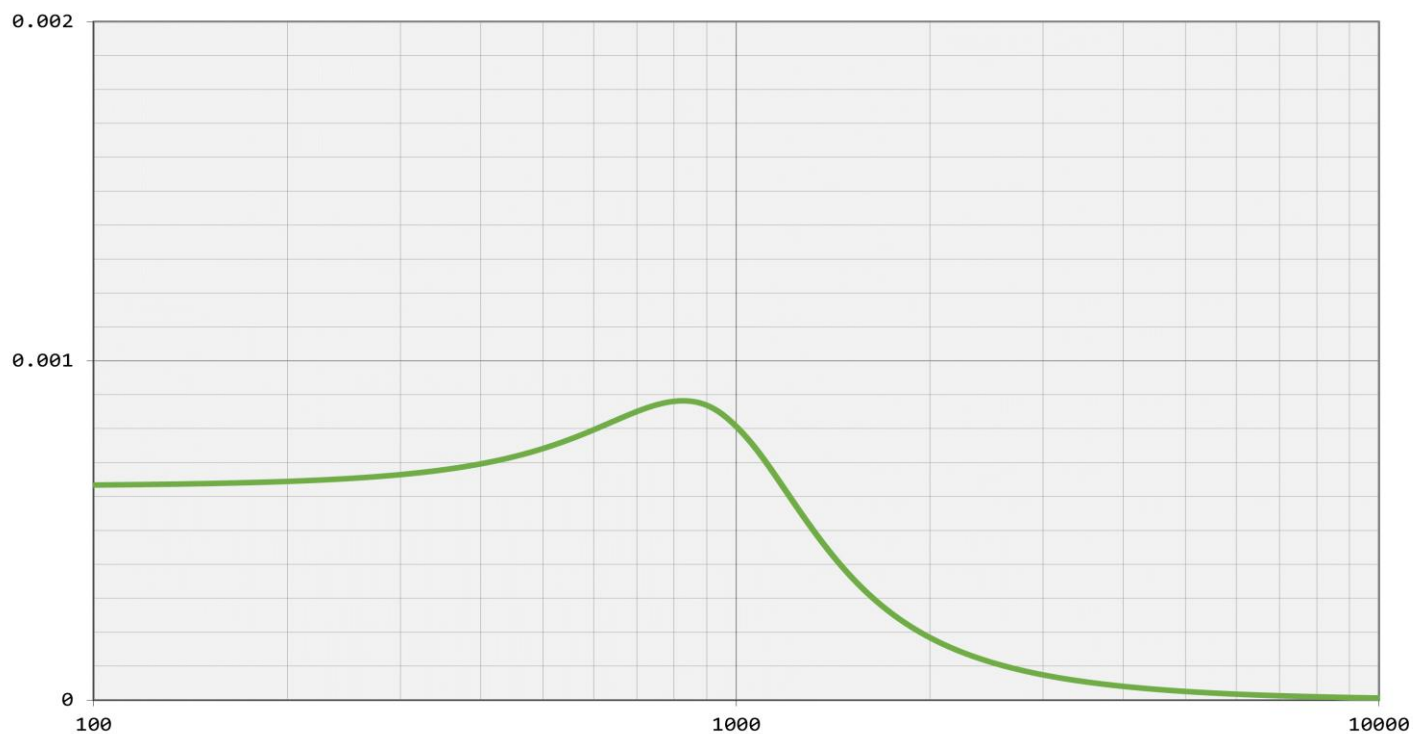
AP3_4DFE_1.61_A58_P84 : Lowpass Response



AP3_4DFE_1.61_A58_P84 : Relative Phase Angle in Degrees



AP3_4DFE_1.61_A58_P84 : Group Delay for $F_c = 1\text{ k Hz}$



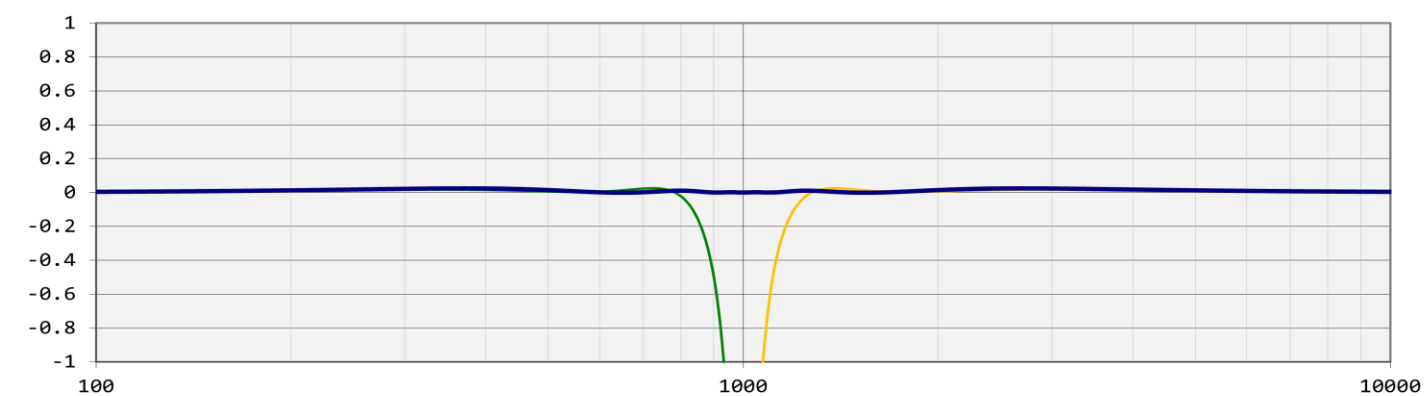
Crossover AP4_4DFE_1.26_A48_P72:

Filters used to construct the AP4_4DFE_1.26_A48_P72 Crossover:

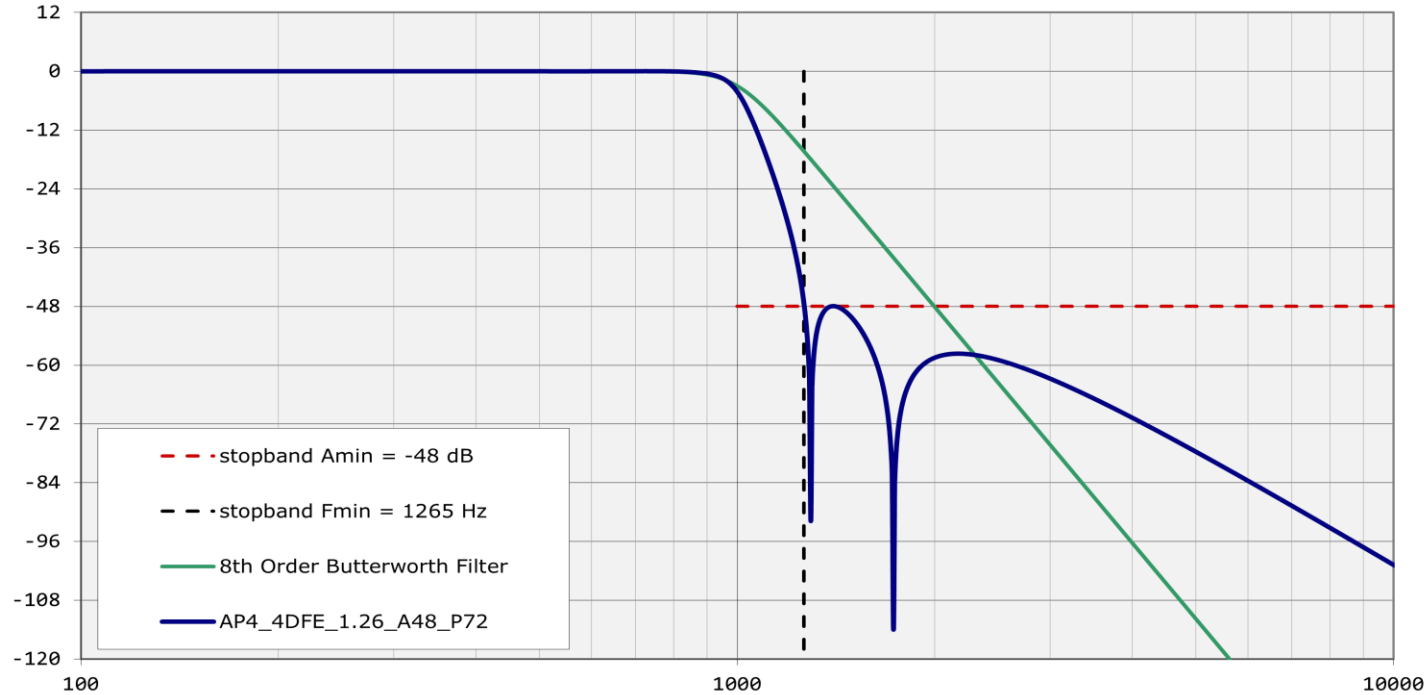
Filters:	LPN	LPN	LP2	LP2	HPN(+)	HPN	HP2	HP2
gain [dB]:	-4.489	-12.456	0.000	0.000	0.000	0.000	0.000	0.000
Fp/Fc:	0.9993	0.8446	0.9357	0.8732	1.0007	1.1840	1.0687	1.1452
Qp:	5.167	0.722	1.810	0.528	5.167	0.722	1.810	0.528
Fz/Fc:	1.2939	1.7301			0.7728	0.5780		

Response Plots for the Crossover may be found below.

AP4_4DFE_1.26_A48_P72 : Sum of HP and LP filters



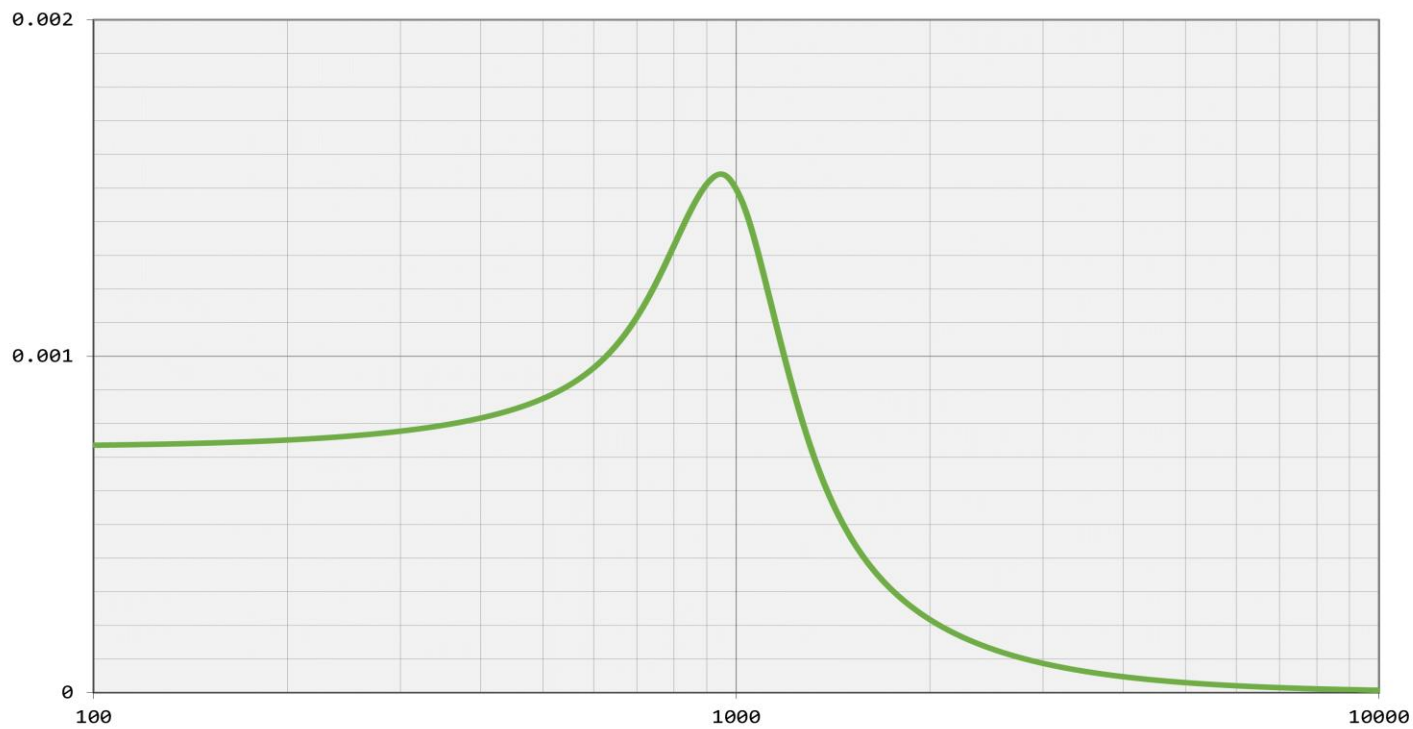
AP4_4DFE_1.26_A48_P72 : Lowpass Response



AP4_4DFE_1.26_A48_P72 : Relative Phase Angle in Degrees



AP4_4DFE_1.26_A48_P72 : Group Delay for $F_c = 1\text{ k Hz}$



Crossover AP4_4DFE_1.31_A55_P63:

Filters used to construct the AP4_4DFE_1.31_A55_P63 Crossover:

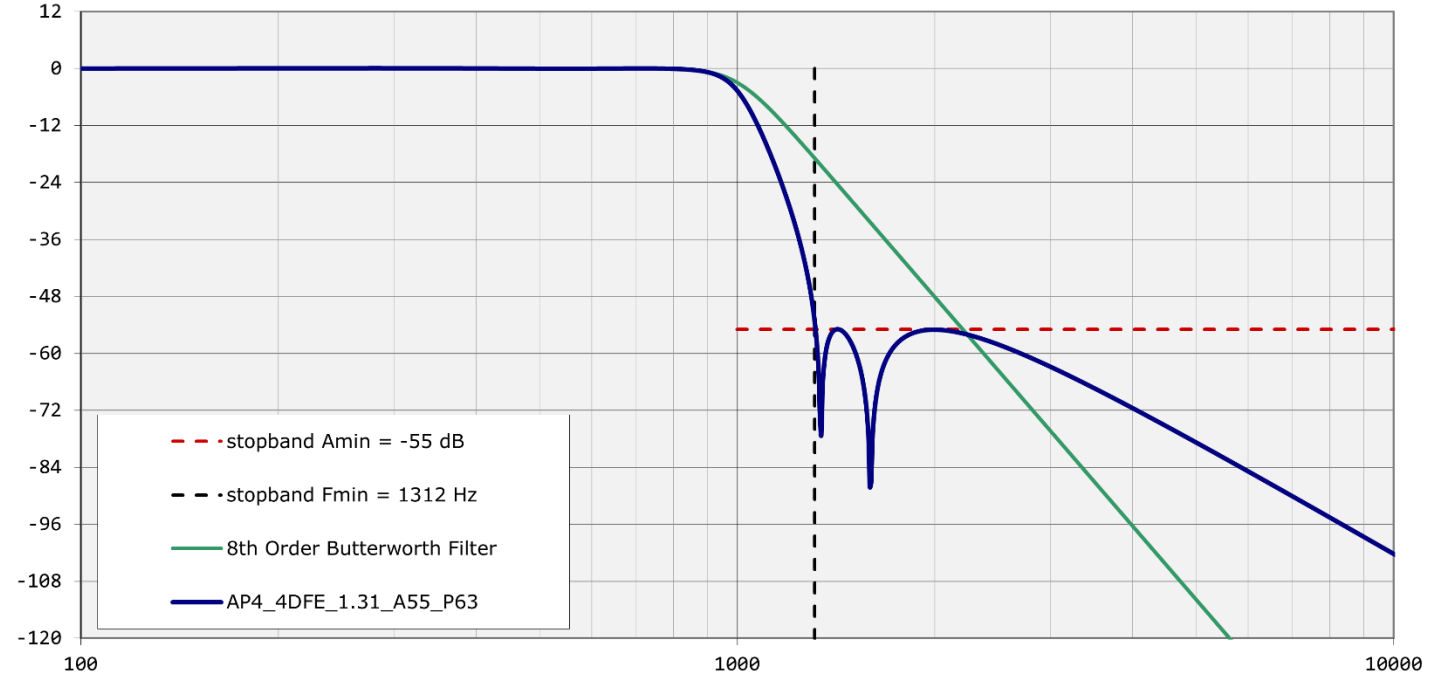
Filters:	LPN	LPN	LP2	LP2	HPN(+)	HPN	HP2	HP2
gain [dB]:	-5.108	-17.051	0.000	0.000	0.000	0.000	0.000	0.000
Fp/Fc:	0.9988	0.5979	0.9879	1.0208	1.0012	1.6724	1.0123	0.9796
Qp:	4.130	0.591	1.315	1.337	4.130	0.591	1.315	1.337
Fz/Fc:	1.3402	1.5956			0.7461	0.6267		

Response Plots for the Crossover may be found below.

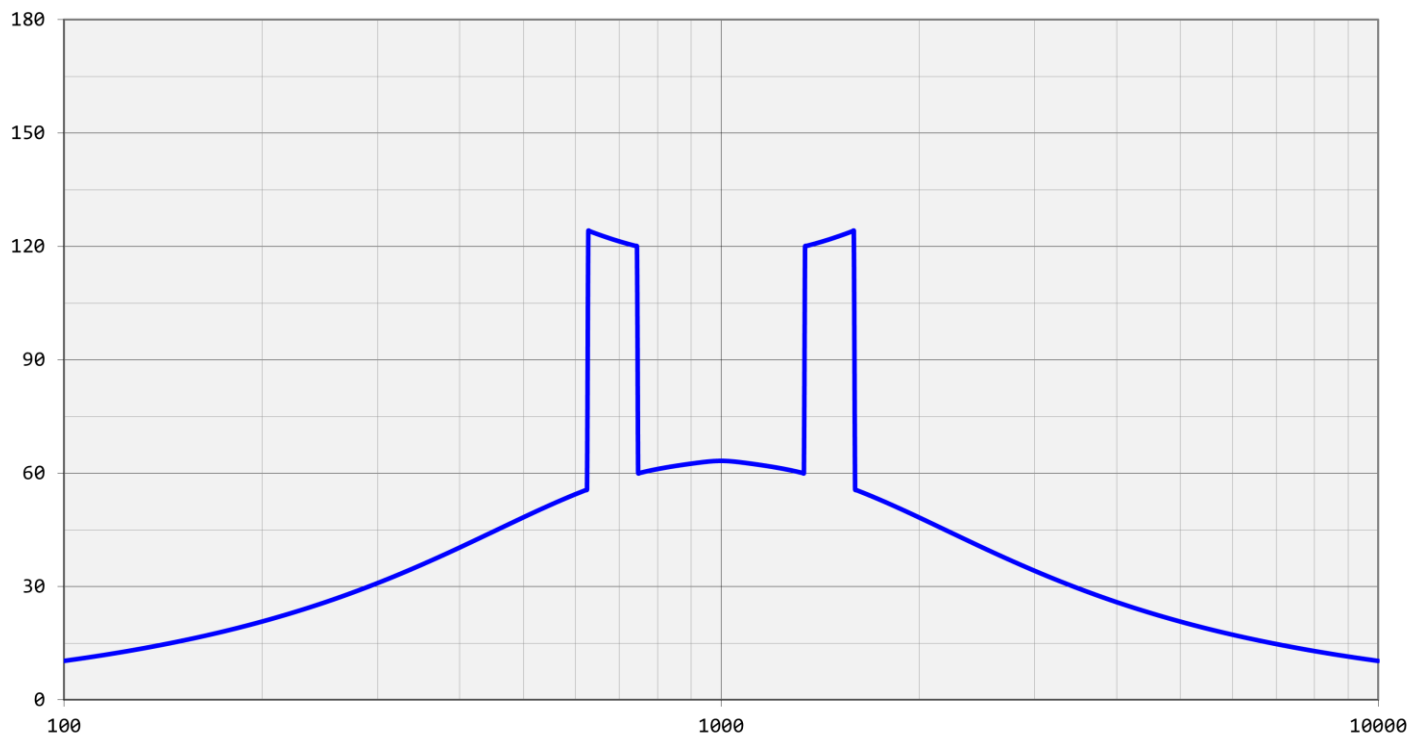
AP4_4DFE_1.31_A55_P63 : Sum of HP and LP filters



AP4_4DFE_1.31_A55_P63 : Lowpass Response



AP4_4DFE_1.31_A55_P63 : Relative Phase Angle in Degrees



AP4_4DFE_1.31_A55_P63 : Group Delay for Fc = 1k Hz



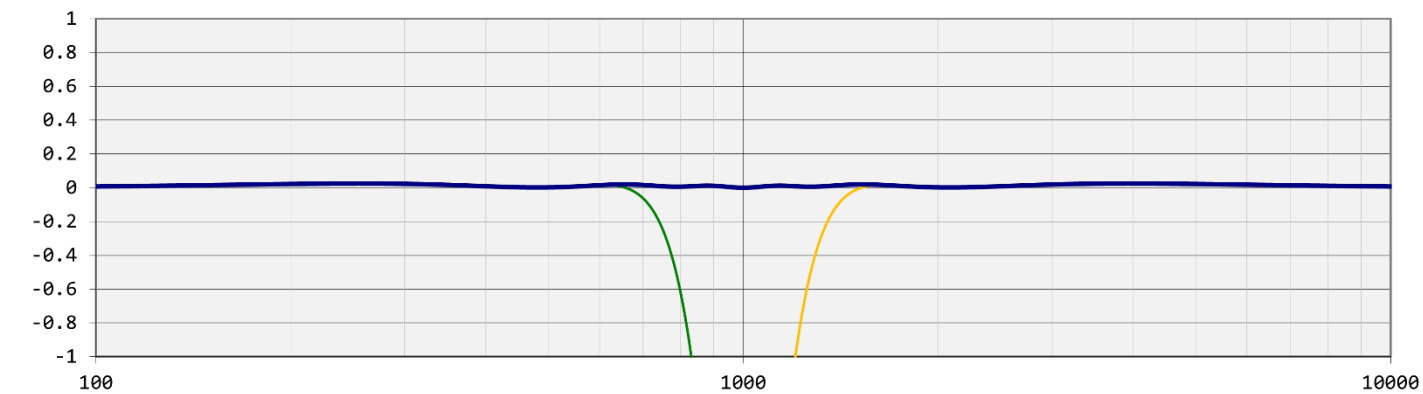
Crossover AP4_4DFE_1.59_A66_P9:

Filters used to construct the AP4_4DFE_1.59_A66_P9 Crossover:

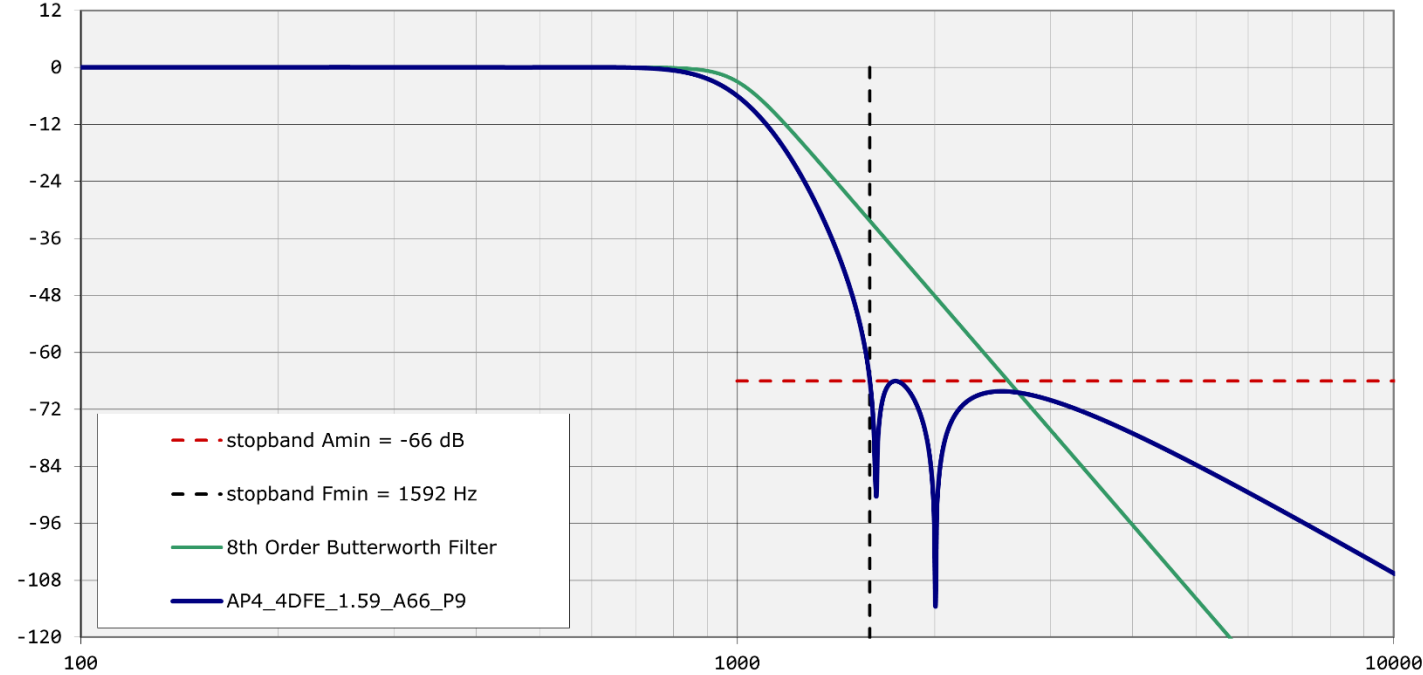
Filters:	LPN	LPN	LP2	LP2	HPN(+)	HPN	HP2	HP2
gain [dB]:	-5.280	-20.479	0.000	0.000	0.000	0.000	0.000	0.000
Fp/Fc:	1.2002	0.6163	0.9543	1.0236	0.8332	1.6226	1.0479	0.9770
Qp:	1.657	0.572	1.700	1.264	1.657	0.572	1.700	1.264
Fz/Fc:	1.6265	2.0034			0.6148	0.4992		

Response Plots for the Crossover may be found below.

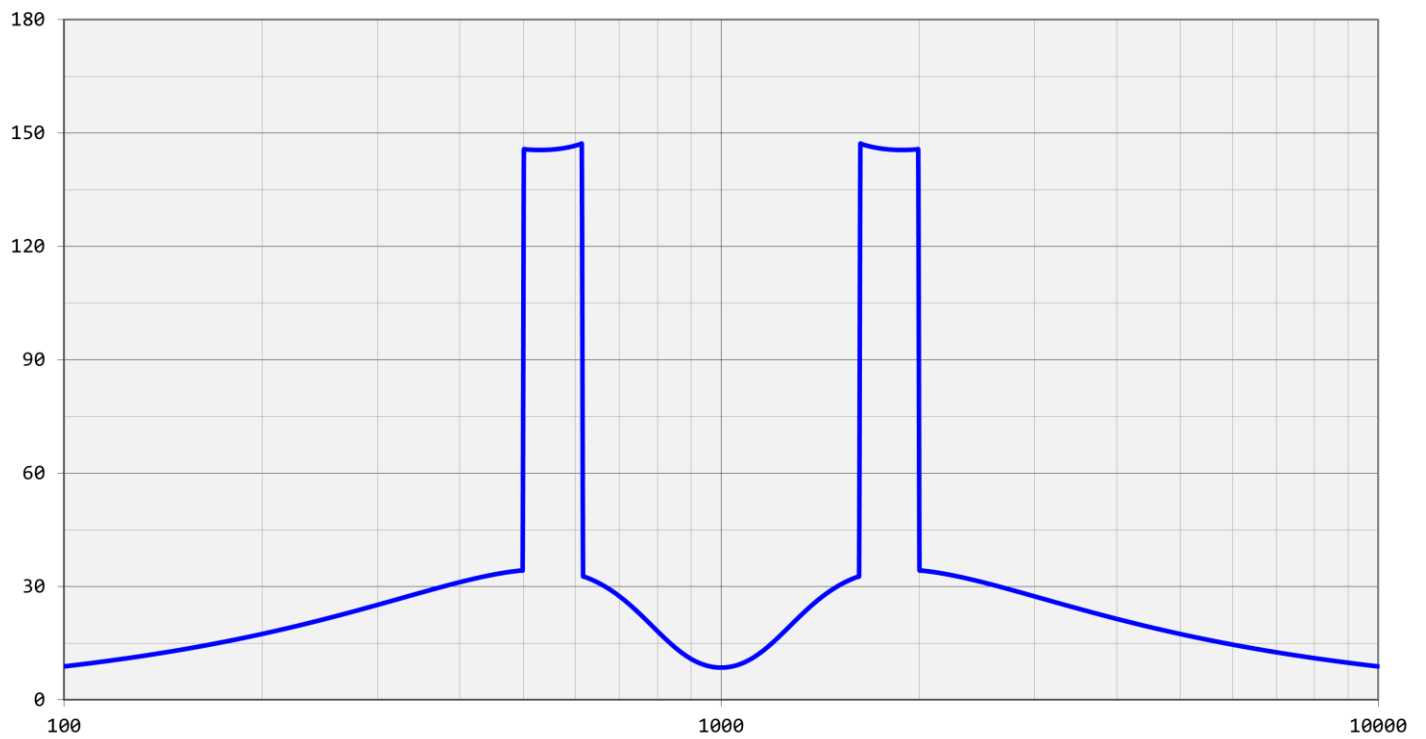
AP4_4DFE_1.59_A66_P9 : Sum of HP and LP filters



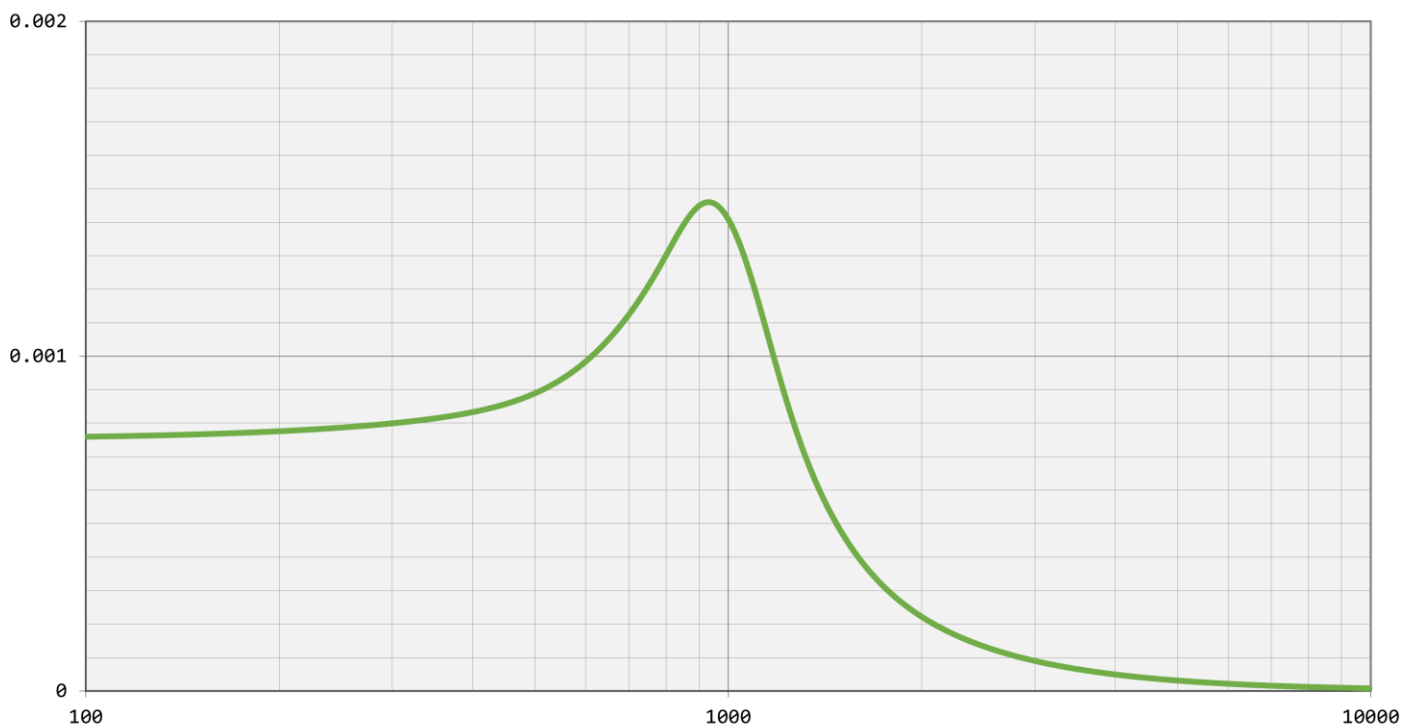
AP4_4DFE_1.59_A66_P9 : Lowpass Response



AP4_4DFE_1.59_A66_P9 : Relative Phase Angle in Degrees



AP4_4DFE_1.59_A66_P9 : Group Delay for $F_c = 1\text{ k Hz}$



Group Delay Response for Fc = 1kHz:

