

Laboratory Work 3 Active filter circuits design and simulation

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Summary

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- 1. Filter approximation theory review
- 2. Laboratory work 3: ideal and real amplifier comparison

Step 3: Step response (time domain simulation)

- 3. Active filter circuits design
- 4. Second Order Filters
- 6. Step 1: check of scheme gain

Frequency Transformation

- 7. Step 2: time domain simulation
- •
- 9. Step 4: frequency domain simulation)
- 10. Results and conclusions
- 10. Results and conclusio

Uploading report

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parameters that fully describe the filter transfer function

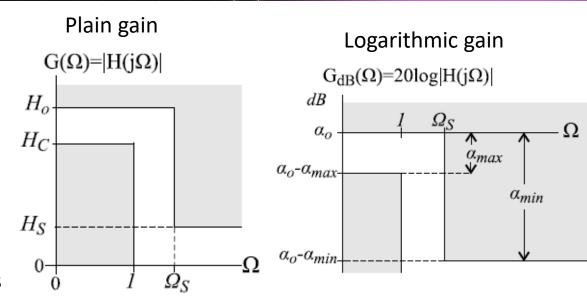
$$\{H_o, H_C, H_S, \Omega_S\}$$
 $(\Omega_C = 1)$

In terms of logarithmic gain

$$\{\alpha_o, \alpha_{\text{max}}, \alpha_{\text{min}}, \Omega_S\}$$
 $(\Omega_C = 1)$

If $H_0 = 1$, the filter requirements can be determined by three parameters

$$\Omega_S$$
 and $\{H_C, H_S\}$ or $\{a_{\max}, \alpha_{\min}\}$



Butterworth proposed the monotonic function

$$G(\Omega) = \frac{H_o}{\sqrt{1 + \beta^2 \Omega^{2N}}}$$

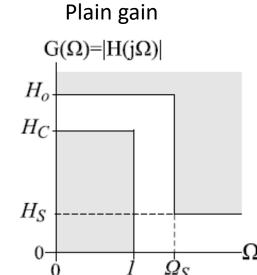
with N, the order of the approximation, a positive integer, and β a design parameter related to the passband tolerance.

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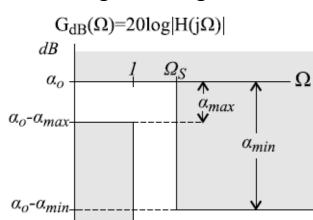
$$G(\Omega) = \frac{H_o}{\sqrt{1 + \beta^2 \Omega^{2N}}}$$

 $G(0) = H_o$

For $\Omega = 0$



Logarithmic gain



$$G(1) = \frac{H_o}{\sqrt{1+\beta^2}} \ge H_C \quad \Leftrightarrow \quad \beta^2 \le (H_o/H_C)^2 - 1$$

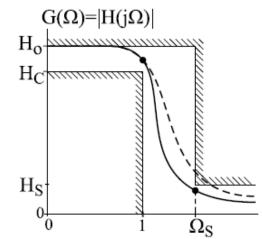
$$\beta \le \beta_{\text{max}} = \sqrt{\left(\frac{H_o}{H_C}\right)^2 - 1} = \sqrt{10^{\frac{a_{\text{max}}}{10}} - 1}$$

For $\beta = \beta_{max}$ the gain $G(1) = H_C$

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$$G(\Omega) = \frac{H_o}{\sqrt{1 + \beta^2 \Omega^{2N}}}$$

$$G(\Omega_S) = \frac{H_o}{\sqrt{1 + \beta^2 \Omega_S^{2N}}} \le H_S$$

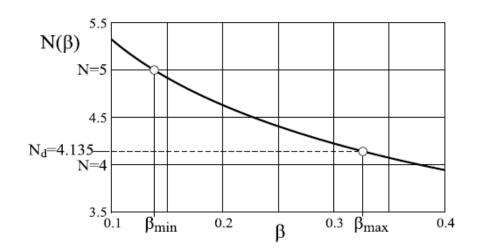


$$N \ge \frac{\log(\frac{(H_o/H_S)^2 - 1}{\beta^2})}{2\log\Omega_S}$$

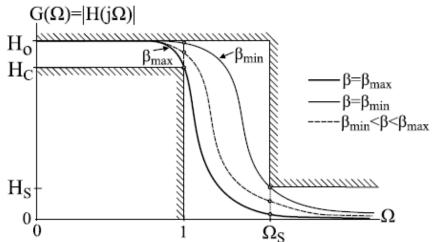
$$N \ge \frac{\log(\frac{(H_o/H_S)^2 - 1}{\beta^2})}{2\log\Omega_S} \qquad N \ge N_d = \frac{\log(\frac{(H_o/H_S)^2 - 1}{\beta^2})}{2\log\Omega_S}$$

$$n_{f \min} = \frac{\log(\frac{\frac{H_o^2}{H_S^2} - 1}{\frac{H_o^2}{H_C^2} - 1})}{2\log\Omega_S} = \frac{\log(\frac{10^{\frac{a_{\min}}{10}} - 1}{10^{\frac{a_{\max}}{10}} - 1})}{2\log\Omega_S}$$

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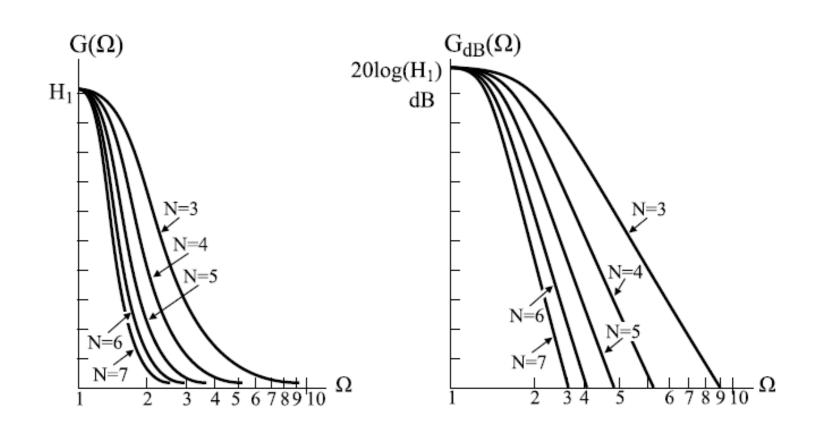


filter designed with normalized specifications $H_o = 1$, $H_C = 0.95$, $H_S = 0.05$ and $\Omega_S = 2.7$



$$\beta_{\min} = \frac{\sqrt{\frac{H_o^2}{H_S^2} - 1}}{\Omega_S^N} \le \beta \le \sqrt{\frac{H_o^2}{H_C^2} - 1} = \beta_{\max}$$

$$\beta_{\min} = \frac{\sqrt{10^{\frac{\alpha_{\min}}{10}} - 1}}{\Omega_S^N} \le \beta \le \sqrt{10^{\frac{\alpha_{\max}}{10}} - 1} = \beta_{\max}$$



The All-Pole Chebyshev Approximation



parameters that fully describe the filter transfer function

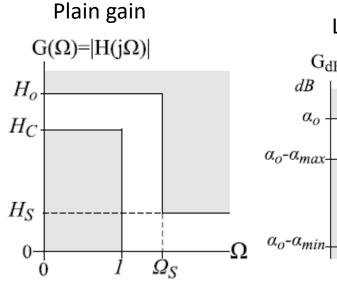
$$\{H_o, H_C, H_S, \Omega_S\}$$
 $(\Omega_C = 1)$

In terms of logarithmic gain

$$\{\alpha_o, \alpha_{\text{max}}, \alpha_{\text{min}}, \Omega_S\}$$
 $(\Omega_C = 1)$

If $H_0 = 1$, the filter requirements can be determined by three parameters

$$\Omega_S$$
 and $\{H_C, H_S\}$ or $\{a_{\max}, \alpha_{\min}\}$



Logarithmic gain

$$G_{dB}(\Omega)=20\log|H(j\Omega)|$$

$$a_{o}$$

$$a_{o}$$

$$a_{o}$$

$$a_{min}$$

$$A_{min}$$

Chebyshev approximation

$$G_{CH}(\Omega) = \frac{H_o}{\sqrt{1 + \varepsilon^2 C_N^2(\Omega)}}$$

The ripple factor ϵ and order N are so chosen to keep the response GCH(Ω) within the specifications.

The All-Pole Chebyshev Approximation

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$$G_{CH}(\Omega) = \frac{H_o}{\sqrt{1 + \varepsilon^2 C_N^2(\Omega)}}$$

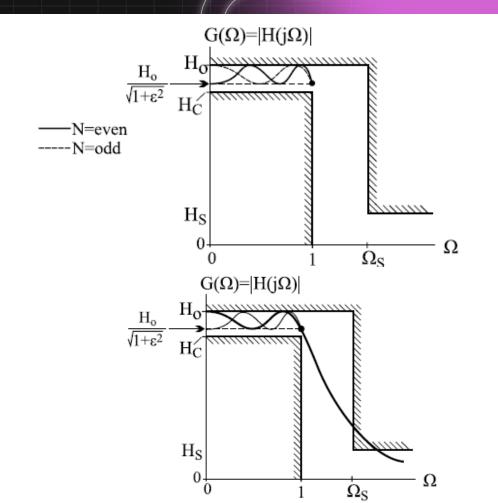
$$\varepsilon \le \sqrt{\frac{H_o^2}{H_c^2} - 1} = \sqrt{10^{\frac{\alpha_{\text{max}}}{10}} - 1} = \varepsilon_{\text{max}}$$

For
$$\varepsilon \leq \varepsilon_{max}$$

$$H_0 \ge G_{CH}(\Omega) \ge \frac{H_0}{\sqrt{1+\varepsilon^2}} \ge H_C$$

For
$$\Omega = 1$$

$$G_{CH}(1) = \frac{H_0}{\sqrt{1+\epsilon^2}} \ge H_C$$



The All-Pole Chebyshev Approximation

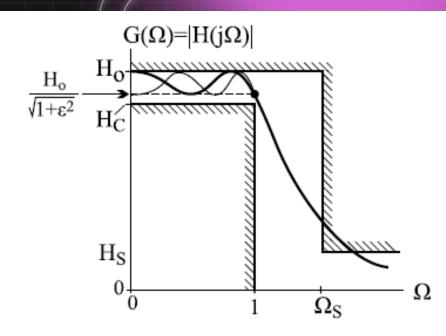
$$G_{CH}(\Omega_s) = \frac{H_o}{\sqrt{1 + \varepsilon^2 C_N^2(\Omega_s)}} \le H_s$$

$$\Leftrightarrow C_N^2(\Omega_S) \ge \frac{(H_o/H_S)^2 - 1}{\varepsilon^2}$$

$$\Leftrightarrow N \cosh^{-1}(\Omega_S) \ge \cosh^{-1} \sqrt{\frac{(H_o/H_S)^2 - 1}{\varepsilon^2}}$$

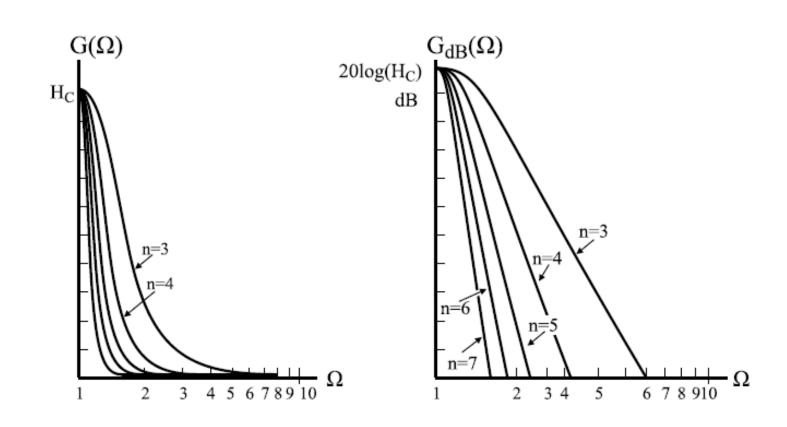
for N:
$$N \ge N_d = \frac{\cosh^{-1}(\sqrt{\frac{(H_o/H_S)^2 - 1}{\varepsilon^2}})}{\cosh^{-1}(\Omega_S)}$$

$$N \ge N_d = \frac{\cosh^{-1}(\sqrt{\frac{(H_o/H_S)^2 - 1}{\varepsilon_{\max}^2}})}{\cosh^{-1}(\Omega_S)} = \frac{\cosh^{-1}(\sqrt{\frac{(H_o/H_S)^2 - 1}{(H_o/H_C)^2 - 1}})}{\cosh^{-1}(\Omega_S)}$$

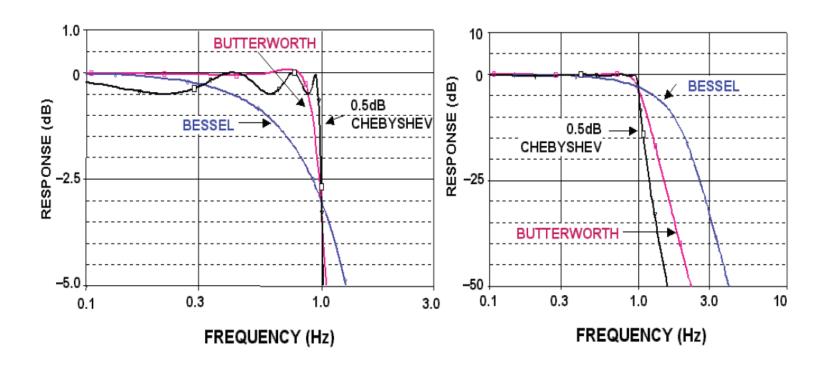


logarithmic gain specifications
$$N \ge N_d = \frac{\cosh^{-1}(\sqrt{\frac{10^{\frac{\alpha_{\min}}{10}} - 1}{10^{\frac{\alpha_{\max}}{10}} - 1}})}{\cosh^{-1}(\Omega_S)}$$

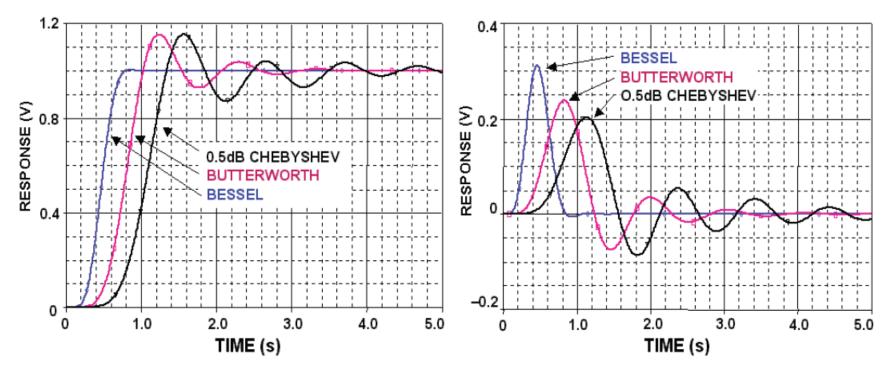




Comparison of Amplitude Response



Comparison of Step and Impulse Responses



Butterworth VS Chebyshev

	Butterworth Filter	Chebyshev Filter
Order of Filter	The order of the Butterworth filter is higher than the Chebyshev filter for the same desired specifications.	The order of the Chebyshev filter is less compared to the Butterworth filter for the same desired specifications.
Hardware	It requires more hardware.	It requires less hardware.
Ripple	There is no ripple in passband and stopband of frequency response.	There is either ripple in passband or stopband.
Poles	All poles lie on a circle having a radius of the cutoff frequency.	All poles lie on ellipse having major axis R, ξ , minor axis r.
Transition band	The Butterworth filter has a wider transition band compared to the Chebyshev filter.	The Chebyshev filter has a narrow transition band compared to the Butterworth filter.
Types	It doesn't have any types.	It has two types; type-1 and type-2.
Cutoff Frequency	The cutoff frequency of this filter is not equal to the passband frequency.	The cutoff frequency of this filter is equal to the passband frequency.

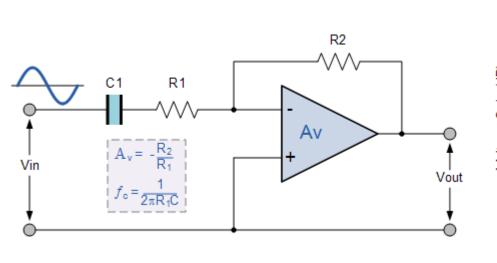


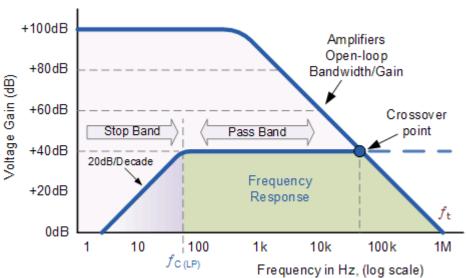
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First-order Filter

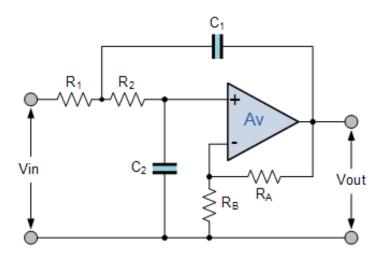


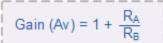




Second Order Filters

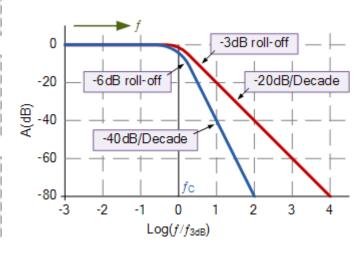
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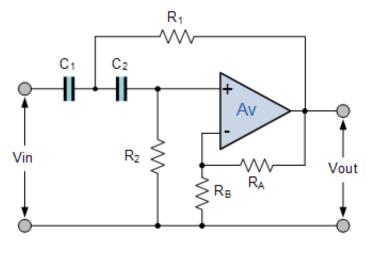
If Resistor and Capacitor values are different: $f_{C} = \frac{1}{2\pi \sqrt{R_1 R_2 C_1 C_2}}$

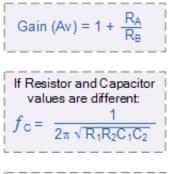
If Resistor and Capacitor values are the same: $f_{\rm C} = \frac{1}{2\pi \; {\rm RC}}$



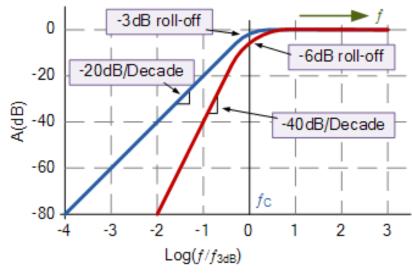
Second Order High Pass Filter

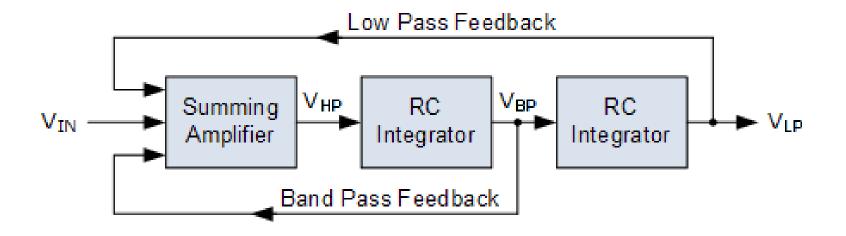






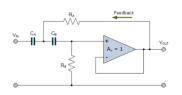
If Resistor and Capacitor values are the same:
$$f_{\rm C} = \frac{1}{2\pi \; {\rm RC}}$$

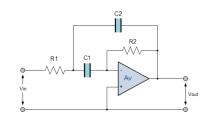




Sallen-Key Filter VS Multiple Feedback Filter







Sallen-Key	Multiple Feedback
Non-inverting	Inverting
Very precise DC-gain of 1	Any gain is dependent on the resistor precision
Less components for gain = 1	Less components for gain > 1 or < 1
Op-amp input capacitance must possibly be taken into account	Op-amp input capacitance has almost no effect
Resistive load for sources even in high-pass filters	Capacitive loads can become very high for sources in high-pass filters



Frequency Transformation

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Typical values of low-pass filter parameters



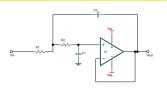
$$H_{LP}(f) := \frac{K}{b_1 \cdot \left[\left(\frac{2 \cdot \mathbf{m} \cdot f \cdot \mathbf{i}}{\omega_p} \right)^2 \right] + a_1 \cdot \frac{\left(2 \cdot \mathbf{m} \cdot f \cdot \mathbf{i} \right)}{\omega_p} + 1}$$

n	i	a_i	b_i	$f_{\mathrm{gi}}/f_{\mathrm{g}}$	Q_i	n	i	a_i	b_{i}	$f_{\mathrm{gi}}/f_{\mathrm{g}}$	Q_i	1	n	i	a_i	b_i	$f_{\rm gi}/f_{\rm g}$	Q_i
Butte	rworth					Cheb	yshev					E	Bessel					
1	1	1,0000	0,0000	1,000	-	1	1	1,0000	0,0000	1,000	-		1	1	1,0000	0,0000	1,000	-
2	1	1,4142	1,0000	1,000	0,71	2	1	1,0650	1,9305	1,000	1,30	:	2	1	1,3617	0,6180	1,000	0,58
3	1	1,0000	0,0000	1,000	121	3	1	3,3496	0,0000	0,299	-	;	3	1	0,7560	0,0000	1,323	-
	2	1,0000	1,0000	1,272	1,00		2	0,3559	1,1923	1,396	3,07			2	0,9996	0,4772	1,414	0,69
4	1	1,8478	1,0000	0,719	0,54	4	1	2,1853	5,5339	0,557	1,08	4	4	1	1,3397	0,4889	0,978	0,52
	2	0,7654	1,0000	1,390	1,31		2	0,1964	1,2009	1,410	5,58			2	0,7743	0,3890	1,797	0,81
5	1	1,0000	0,0000	1,000	-	5	1	5,6334	0,0000	0,178	-		5	1	0,6656	0,0000	1,502	-
	2	1,6180	1,0000	0,859	0,62		2	0,7620	2,6530	0,917	2,14			2	1,1402	0,4128	1,184	0,56
	3	0,6180	1,0000	1,448	1,62		3	0,1172	1,0686	1,500	8,82			3	0,6216	0,3245	2,138	0,92
6	1	1,9319	1,0000	0,676	0,52	6	1	3,2721	11,6773	0,379	1,04	(6	1	1,2217	0,3887	1,063	0,51
	2	1,4142	1,0000	1,000	0,71		2	0,4077	1,9873	1,086	3,46			2	0,9686	0,3505	1,431	0,61
	3	0,5176	1,0000	1,479	1,93		3	0,0815	1,0861	1,489	12,78			3	0,5131	0,2756	2,447	1,02
7	1	1,0000	0,0000	1,000	-	7	1	7,9064	0,0000	0,126	-		7	1	0,5937	0,0000	1,684	_
	2	1,8019	1,0000	0,745	0,55		2	1,1159	4,8963	0,670	1,98			2	1,0944	0,3395	1,207	0,53
	3	1,2470	1,0000	1,117	0,80		3	0,2515	1,5944	1,222	5,02			3	0,8304	0,3011	1,695	0,66
	4	0,4450	1,0000	1,499	2,25		4	0,0582	1,0348	1,527	17,46			4	0,4332	0,2381	2,731	1,13
8	1	1,9616	1,0000	0,661	0,51	8	1	4,3583	20,2948	0,286	1,03		8	1	1,1112	0.3162	1,164	0,51
	2	1,6629	1,0000	0,829	0,60		2	0,5791	3,1808	0,855	3,08			2	0,9754	0,2979	1,381	0,56
	3	1,1111	1,0000	1,206	0,90		3	0,1765	1,4507	1,285	6,83			3	0,7202	0,2621	1,963	0,71
	4	0,3902	1,0000	1,512	2,56		4	0,0448	1,0478	1,517	22,87			4	0,3728	0,2087	2,992	1,23
9	1	1,0000	0,0000	1,000	-	9	1	10,1759	0,0000	0,098	-	9	9	1	0,5386	0.0000	1,857	_
	2	1,8794	1,0000	0,703	0,53		2	1,4585	7,8971	0,526	1,93			2	1,0244	0,2834	1,277	0,52
	3	1,5321	1,0000	0,917	0,65		3	0,3561	2,3651	1,001	4,32			3	0.8710	0,2636	1,574	0,59
	4	1,0000	1,0000	1,272	1,00		4	0,1294	1,3165	1,351	8,87			4	0,6320	0,2311	2,226	0,76
	5	0,3473	1,0000	1,521	2,88		5	0,0348	1,0210	1,537	29,00			5	0,3257	0,1854	3,237	1,32
10	1	1,9754	1,0000	0,655	0,51	10	1	5,4449	31,3788	0,230	1,03		10	1	1.0215	0,2650	1,264	0,50
	2	1,7820	1,0000	0,756	0,56		2	0,7414	4,7363	0,699	2,94			2	0,9393	0,2549	1,412	0,54
	3	1,4142	1,0000	1,000	0,71		3	0,2479	1,9952	1,094	5,70			3	0,7815	0,2351	1,780	0,62
	4	0,9080	1,0000	1,322	1,10		4	0,1008	1,2638	1,380	11,15			4	0,5604	0,2059	2,479	0,81
	5	0,3129	1,0000	1,527	3,20		5	0,0283	1,0304	1,530	35,85			5	0,2883	0,1665	3,466	1,42

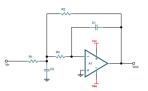
Typical values of low-pass filter parameters



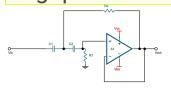
Lowpass Filter



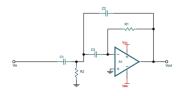
Sallen-Key
$$H_{LP_SK}(f) := \frac{K}{(2 \cdot \mathbf{\pi} \cdot f \cdot \mathbf{i})^2 \cdot R_{1LP} \cdot R_{2LP} \cdot C_{1LP} \cdot C_{2LP} + C_{2LP} \cdot (R_{1LP} + R_{2LP}) \cdot (2 \cdot \mathbf{\pi} \cdot f \cdot \mathbf{i}) + 1}$$



Highpass Filter



Sallen-Key
$$\frac{H_{HP_SK}(f) := \frac{K}{1}}{\frac{1}{(2 \cdot \mathbf{n} \cdot f \cdot \mathbf{i})^{2} \cdot R_{1HP} \cdot R_{2HP} \cdot C_{1HP} \cdot C_{2HP}} + \frac{R_{2HP} \cdot \left(C_{1HP} + C_{2HP}\right) + \left(1 - K\right) \cdot R_{1HP} \cdot C_{2HP}}{R_{1HP} \cdot R_{2HP} \cdot C_{1HP} \cdot C_{2HP} \cdot 2 \cdot \mathbf{n} \cdot f \cdot \mathbf{i}} + 1}$$



$$H_{HP_MF}(f) := \frac{\left(2 \cdot \mathbf{\pi} \cdot f \cdot \mathbf{i}\right)^2 \cdot R_{1HP} \cdot R_{2HP} \cdot C_{1HP} \cdot C_{3HP}}{\left(2 \cdot \mathbf{\pi} \cdot f \cdot \mathbf{i}\right)^2 \cdot R_{1HP} \cdot R_{2HP} \cdot C_{2HP} \cdot C_{3HP} + R_{2HP} \cdot \left(C_{1HP} + C_{2HP} + C_{3HP}\right) \cdot \left(2 \cdot \mathbf{\pi} \cdot f \cdot \mathbf{i}\right) + C_{2HP} \cdot C$$

Frequency Transformation

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Type of Transformation	Frequency transform
The Lowpass to Highpass (LP-HP) Frequency Transformation	$s \Leftrightarrow \frac{1}{s}$ $H_{HP}(s) = H_{LP}\left(\frac{1}{s}\right)$
The Lowpass to Bandpass (LP-BP) Frequency Transformation	$s \Leftrightarrow \frac{s^2 + \omega_0^2}{sBW}$ $H_{BP}(s) = H_{LP}\left(\frac{s^2 + \omega_0^2}{sBW}\right)$
The Lowpass to Band-Reject (LP-BR) Frequency Transformation	$s \Leftrightarrow \frac{sBW}{s^2 + \omega_0^2}$ $H_{BR}(s) = H_{LP}\left(\frac{sBW}{s^2 + \omega_0^2}\right)$

Typical values of High-pass filter parameters



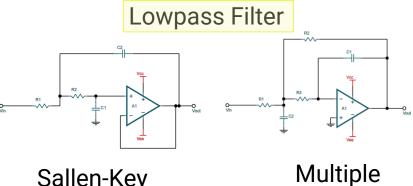
$$H_{HP}(f) := \frac{K}{\left[\left(\frac{2 \cdot \mathbf{m} \cdot f \cdot \mathbf{i}}{\omega_{p}}\right)^{2}\right] + \frac{a_{1}}{\left(2 \cdot \mathbf{m} \cdot f \cdot \mathbf{i}\right)} + 1}$$

n	i	a_i	b_i	$f_{ m gi}/f_{ m g}$	Q_i	n	i	a_i	b_i	f_{gi}/f_{g}	Q_i	n	i	a_i	b_i	$f_{\rm gi}/f_{\rm g}$	Q_i
Butter	worth					Cheb	vshev					Besse					
1	1	1,0000	0,0000	1,000	1-1	1	1	1,0000	0,0000	1,000	-	1	1	1,0000	0,0000	1,000	-
2	ï	1,4142	1,0000	1,000	0,71	2	1	1,0650	1,9305	1,000	1,30	2	1	1,3617	0,6180	1,000	0,58
3	1	1,0000	0,0000	1,000	120	3	1	3,3496	0,0000	0,299	-	3	1	0,7560	0,0000	1,323	_
	2	1,0000	1,0000	1,272	1,00		2	0,3559	1,1923	1,396	3,07		2	0,9996	0,4772	1,414	0,69
4	1	1,8478	1,0000	0,719	0,54	4	1 2	2,1853 0,1964	5,5339 1,2009	0,557 1,410	1,08 5,58	4	1	1,3397	0,4889	0,978	0,52
	2	0,7654	1,0000	1,390	1,31		2				5,58		2	0,7743	0,3890	1,797	0,81
5	1	1,0000	0,0000	1,000	-	5	1 2	5,6334 0,7620	0,0000 2,6530	0,178 0,917	- 2,14	5	1	0,6656	0,0000	1,502	-
	2	1,6180	1,0000	0,859	0,62		3	0,7620	1,0686	1,500	2,14 8,82		2 3	1,1402 0,6216	0,4128 0,3245	1,184 2,138	0,56 0,92
	3	0,6180	1,0000	1,448	1,62								3				
6	1	1,9319	1,0000	0,676	0,52	6	1 2	3,2721 0,4077	11,6773 1,9873	0,379 1,086	1,04 3,46	6	1	1,2217	0,3887	1,063	0,51
	2	1,4142 0,5176	1,0000	1,000 1,479	0,71 1,93		3	0,0815	1,0861	1,489	12,78		2 3	0,9686 0,5131	0,3505 0,2756	1,431 2,447	0,61 1,02
	3				1,93	7	4	7,9064	0,0000	0,126							1,02
7	1	1,0000	0,0000	1,000	-	,	2	1,1159	4,8963	0,126	1,98	7	1	0,5937	0,0000	1,684	
	2	1,8019 1,2470	1,0000 1,0000	0,745 1,117	0,55 0,80		3	0,2515	1,5944	1,222	5,02		2	1,0944 0,8304	0,3395 0,3011	1,207 1,695	0,53 0,66
	4	0,4450	1,0000	1,499	2,25		4	0,0582	1,0348	1,527	17,46		4	0,4332	0,2381	2,731	1,13
8	1	1,9616	1,0000	0,661	0,51	8	1	4,3583	20,2948	0,286	1,03	8	1	1,1112	0.3162	1,164	0,51
0	2	1,6629	1,0000	0,829	0,60		2	0,5791	3,1808	0,855	3,08	0	2	0.9754	0,2979	1,381	0,56
	3	1,1111	1,0000	1,206	0,90		3	0,1765	1,4507	1,285	6,83		3	0,7202	0,2621	1,963	0,71
	4	0,3902	1,0000	1,512	2,56		4	0,0448	1,0478	1,517	22,87		4	0,3728	0,2087	2,992	1,23
9	1	1,0000	0,0000	1,000	-	9	1	10,1759	0,0000	0,098	-	9	1	0,5386	0,0000	1,857	_
	2	1,8794	1,0000	0,703	0,53		2	1,4585	7,8971	0,526 1,001	1,93		2	1,0244	0,2834	1,277	0,52
	3	1,5321	1,0000	0,917	0,65		3	0,3561 0,1294	2,3651 1,3165	1,351	4,32 8,87		3	0,8710	0,2636	1,574	0,59
	4	1,0000 0,3473	1,0000	1,272 1,521	1,00 2.88		5	0,0348	1,0210	1,537	29,00		4	0,6320	0,2311	2,226	0,76
	э		1,0000			10	4			0,230			5	0,3257	0,1854	3,237	1,32
10	1	1,9754	1,0000	0,655	0,51	10	2	5,4449 0,7414	31,3788 4,7363	0,230	1,03 2,94	10	1	1,0215	0,2650	1,264	0,50
	2	1,7820 1,4142	1,0000	0,756 1,000	0,56 0,71		3	0,2479	1,9952	1,094	5,70		2	0,9393	0,2549	1,412	0,54
	3 A	0,9080	1,0000	1,322	1,10		4	0,1008	1,2638	1,380	11,15		3	0,7815	0,2351	1,780	0,62
	5	0,3129	1,0000	1,527	3,20		5	0,0283	1,0304	1,530	35,85		4 5	0,5604 0,2883	0,2059 0,1665	2,479 3,466	0,81 1,42
	*	5,5120	1,0000	1,021	0,00								3	0,2883	0,1005	5,400	1,42

Typical values of low-pass filter parameters

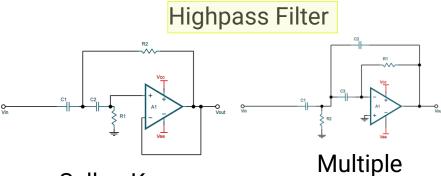


			,		1	Source		1	1	1							
1	'	1	,	Required absolute	Source	voltage	Source	1	1	1			1				'
1	1	Voltage sou		gain of amplifier	1.	frequency	voltage	Source voltage	Load	1			1				'
	1	supp		(sign of the gain is		, '	frequency,		resistance,	F?	ilter resistance	.e,	1		Filter	capacitance,	. '
Filter scheme	Filter type		[V]	not considered)	[Hz]	[Hz]	[Hz]	[V]	[Ω]	1	[Ω]		'				
Sallen-Key Multiple Feedback	Lowpass Highpass	Vcc	Vee	$ K_{NI} $	$f_{\mathit{test_l}}$	$f_{\it test_2}$	$f_{\it test_3}$	V testAC= V test	R _{Load}	R_{I}	R 2	R 3	Resistor tolerance	C_{i}	C 2	C 3	Capacitor tolerance
Sallen-Key	Lowpass	6	-6	1,000	50	1000	100000	2,000	1000000	8200	15000	-	5%	6 1e-9	2,20E-09	-	20%
Multiple Feedback	Highpass	6	-6	1,000	60	1200	120000	2,000	1000000	3300	820	-	5%	6 1,50E-08	1,50E-08	2,20E-08	20%
				+		+			-	$\overline{}$	$\overline{}$	-	-		-	$\overline{}$	



Sallen-Key

Feedback



Sallen-Key

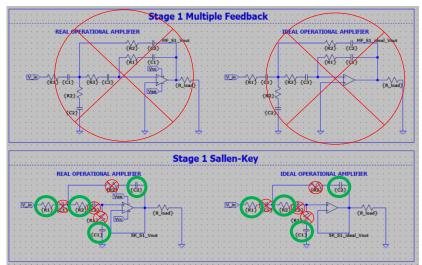
Feedback

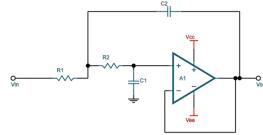
Collect the scheme

ітмо

					·	Source											
				Required absolute	Source	voltage	Source										
		Voltage sou		gain of amplifier	1.	frequency	voltage	Source voltage	Load								
		_				,	frequency,	amplitude,	resistance,	Fi	lter resistance	e,			Filter	capacitance,	
Filter scheme	Filter type	[N	V]	not considered)	[Hz]	[Hz]	[Hz]	[V]	[Ω]		[Ω]					[Ω]	
Sallen-Key Multiple Feedback	Lowpass Highpass	Vcc	Vee	$ K_{NI} $	$f_{\mathit{test_l}}$	$f_{\it test_2}$	$f_{\mathit{test_3}}$	$V_{test,AC} = V_{test}$	R _{Load}	R_{j}	R_2	R_3	Resistor tolerance	C_1	C ₂	C 3	Capacitor tolerance
Sallen-Key	Lowpass	6	-6	1,000	50	1000	100000	2,000	1000000	8200	15000	-	5%	1e-9	2,20E-09	-	20%
Multiple Feedback	Highpass	6	-6	1,000	60	1200	120000	2,000	1000000	3300	820	-	5%	1,50E-08	1,50E-08	2,20E-08	20%
			+	$\overline{}$	-											$\overline{}$	

Lowpass Filter



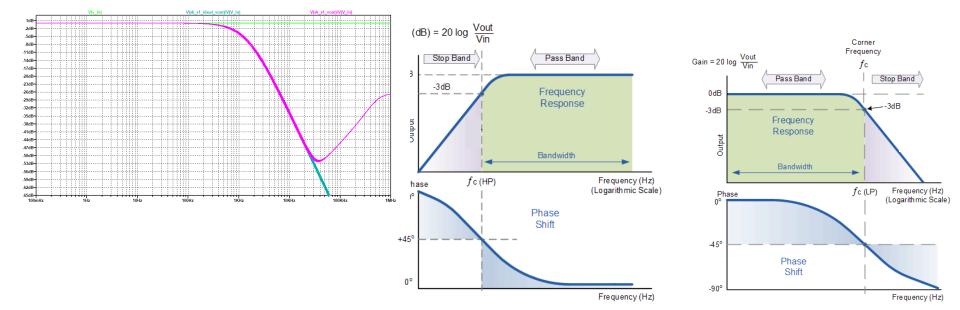


Specify your personal Jib file according to your variant	
Right-click to edit:	Jib.OPAMP_V10.lib
Simulation parameters:	
Transient analysis parameters:	.tran 0 {3*1/f_test_1} {2*1/f_test_2} {1/f_test_2/200} uid
Time step parameters:	
Signal source voltage amplitude [V]:	.param V_test=1
Step source voltage amplitude [V]:	.param V_step=0 · · · · · · · · · · · · · · · · · · ·
Signal test frequency 1 [Hz]:	.param f_test_1=50
Signal test frequency 2 [Hz]:	.param f_test_2=10k
Signal test frequency 3 [Hz]:	.param f_test_3=100k
AC sweep analysis parameters:	*.ac dec 100 0.1 1000000
Signal source voltage amplitude AC [V]:	.param V_test_AC={V_test}.
Flament parameters for a	imulation
R1 [0]:	.baram R1=8200
R2 [Ω]:	.param R2=15000
R3 [Ω]:	.param R3=1n
C1 [F]:	.param C1=1n
C2 [F]:	.param C2=2.2n
G (F):	.param C3=2.20n
	44444444
Load resistance R load (D):	.param R_load =1000k
· · · · · · · · · · · · · · · · · · ·	· · · · · · · · · · · · · · · · · · ·
Power supply source voltage Vcc[V]:	.param Vcc=12
Power supply source voltage Veq[V]:	.param Vee=-12
Step for R1 Tolerance	*.step param R1 list 9500 10000 10500
Step for R2'Tolerance	*.step param R2 list 9500 10000 10500
Step for R3 Tolerance	*.step param R3 list 9500 10000 10500
Step for C1,Tolerance	.step param C1 list 9500p 10000p 10500p
Step for C2 Tolerance	step param C2 list 9500p 10000p 10500p
Step for C3 Tolerance	step param C3 list 9500p 10000p 10500p
Step for R_load	*.step param R_load list 0:01k 0.1k 10k 50k 100k
. This line is required to simulate ideal OpAMPs	Jib.opamp.sub

Define the filter passband

ITMO

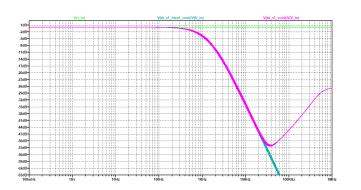
Filter scheme	Filter type	Voltage so sup	urce power	Required absolute gain of amplifier (sign of the gain is not considered)	voltage	Source voltage frequency , [Hz]	Source voltage frequency, [Hz]	Source voltage amplitude, [V]	Load resistance, [Ω]	Fi	lter resistanc	2 ,			Filter	capacitance, [Ω]	
Sallen-Key Multiple Feedback	Lowpass Highpass	Vcc	Vee	$ K_{NI} $	$f_{\mathit{test_l}}$	$f_{\it test_2}$	$f_{\it test_3}$	$V_{test,AC} = V_{test}$	R_{Load}	R_{l}	R_2	R_3	Resistor tolerance	c_i	C ₂	C 3	Capacitor tolerance
Sallen-Key	Lowpass	6	-6	1,000	50	1000	100000	2,000	1000000	8200	15000	-	5%	1e-9	2,20E-09	-	20%
Multiple Feedback	Highpass	6	-6	1,000	60	1200	120000	2,000	1000000	3300	820	-	5%	1,50E-08	1,50E-08	2,20E-08	20%

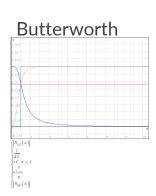




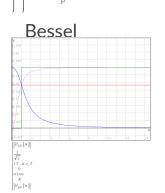
						Source											
				Required absolute	Source	voltage	Source										
		Voltage sou		gain of amplifier	voltage	frequency	voltage	Source voltage	Load								
		sup		(sign of the gain is	frequency,	,	frequency,	amplitude,	resistance,	Fi	lter resistance	,			Filter	capacitance,	
Filter scheme	Filter type	[\	/]	not considered)	[Hz]	[Hz]	[Hz]	[V]	[Ω]		[Ω]					[Ω]	
Sallen-Key Multiple Feedback	Lowpass Highpass	Vcc	Vee	$ K_{NI} $	$f_{\mathit{test_l}}$	$f_{\it test_2}$	$f_{\it test_3}$	$V_{testAC} = V_{test}$	R_{Load}	R_I	R_2	R_3	Resistor tolerance	c_{i}	C ₂	C 3	Capacitor tolerance
Sallen-Key	Lowpass	6	-6	1,000	50	1000	100000	2,000	1000000	8200	15000	-	5%	1e-9	2,20E-09	-	20%
Multiple Feedback	Highpass	6	-6	1,000	60	1200	120000	2,000	1000000	3300	820	-	5%	1,50E-08	1,50E-08	2,20E-08	20%
	•			'			<u> </u>			_			1			'	
n i	a_i b_i	$f_{\rm gi}/f_{\rm g}$	Q_i	n	i	a_{i}	b_{i}	$f_{\rm gi}/f_{\rm g}$	Q_i		n	i		a_i	b_i	$f_{gi}/$	f_g Q_i
Butterworth				Cheby	/shev						Be	ssel					
1 1	1,0000 0,0000	1,000	-	1	1	1,0000	0,0000	1,000	-		1	1	I	1,0000	0,0000	1,00) –
2 1	1,4142 1,0000	1,000	0,71	2	1	1,0650	1,9305	1,000	1,30		2	1		1,3617	0,6180	1,00	0,58

$$H_{LP}\left(f\right) \coloneqq \frac{K}{b_{1} \cdot \left[\left(\frac{2 \cdot \mathbf{m} \cdot f \cdot \mathbf{i}}{\omega_{p}}\right)^{2}\right] + a_{1} \cdot \frac{\left(2 \cdot \mathbf{m} \cdot f \cdot \mathbf{i}\right)}{\omega_{p}} + 1}$$



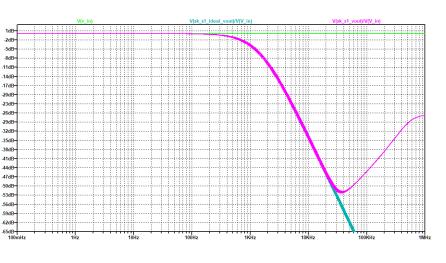


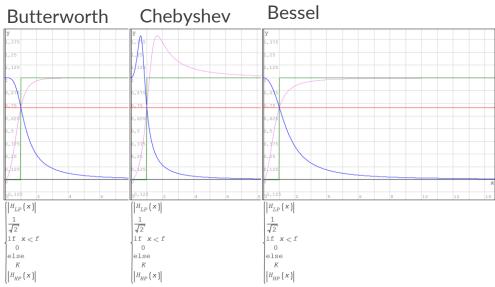






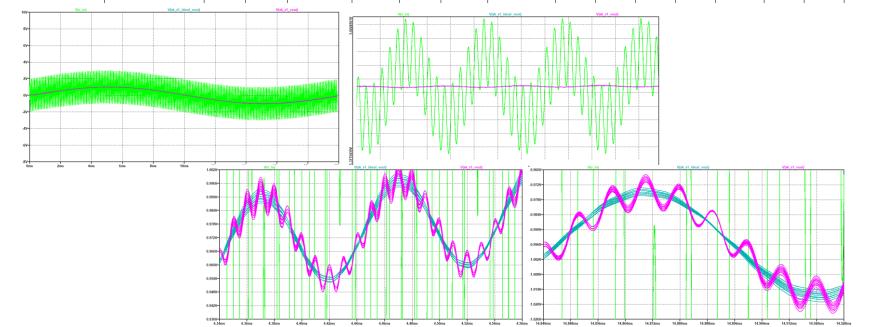
Filter scheme	Filter type	Voltage sou sup [\	urce power ply	Required absolute gain of amplifier (sign of the gain is not considered)	voltage	Source voltage frequency , [Hz]	Source voltage frequency, [Hz]	Source voltage amplitude, [V]	Load resistance, [Ω]	Fi	lter resistance [Ω]	· 9			Filter	capacitance, [Ω]	
Sallen-Key Multiple Feedback	Lowpass Highpass	Vcc	Vee	$ K_{NI} $	$f_{\mathit{test_l}}$	$f_{\it test_2}$	$f_{\it test_3}$	$V_{testAC} = V_{test}$	R_{Load}	R_{I}	R_2	R_3	Resistor tolerance	C_i	C ₂	C 3	Capacitor tolerance
Sallen-Key	Lowpass	6	-6	1,000	50	1000	100000	2,000	1000000	8200	15000	-	5%	1e-9	2,20E-09	-	20%
Multiple Feedback	Highpass	6	-6	1,000	60	1200	120000	2,000	1000000	3300	820	-	5%	1,50E-08	1,50E-08	2,20E-08	20%





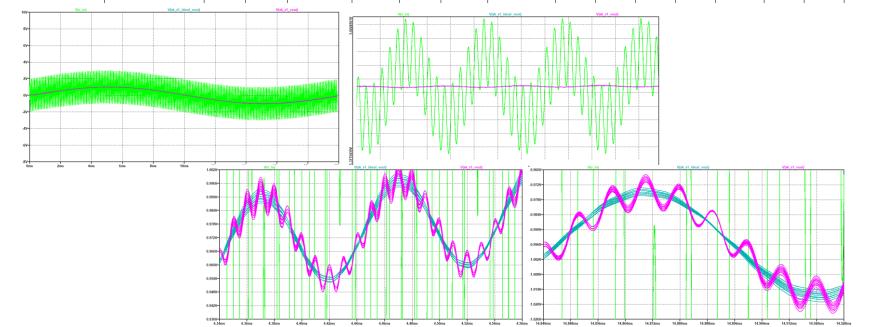


Filter scheme	Filter type	Voltage sou sup	urce power	Required absolute gain of amplifier (sign of the gain is not considered)	•	Source voltage frequency , [Hz]	Source voltage frequency, [Hz]	Source voltage amplitude, [V]	Load resistance, [Ω]	Fil	ter resistance [Ω]	,			Filter	capacitance,	
Sallen-Key Multiple Feedback	Lowpass Highpass	Vcc	Vee	$ K_{NI} $	$f_{\mathit{test_l}}$	f_{test_2}	$f_{\it test_3}$	$V_{testAC} = V_{test}$	R _{Load}	R_I	R_2	R_3	Resistor tolerance	$c_{\scriptscriptstyle l}$	C ₂	C 3	Capacitor tolerance
Sallen-Key	Lowpass	6	-6	1,000	50	1000	100000	2,000	1000000	8200	15000	-	5%	1e-9	2,20E-09	-	20%
Multiple Feedback	Highpass	6	-6	1,000	60	1200	120000	2,000	1000000	3300	820	-	5%	1,50E-08	1,50E-08	2,20E-08	20%





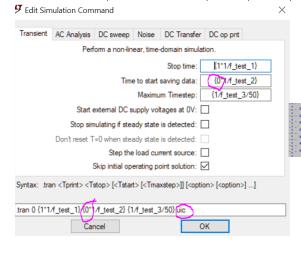
Filter scheme	Filter type	Voltage source power		Required absolute gain of amplifier (sign of the gain is not considered)	voltage	Source voltage frequency , [Hz]	Source voltage frequency, [Hz]	Source voltage amplitude, [V]	Load resistance, [Ω]	Fil	Filter resistance, $[\Omega]$			Filter capacitance, $[\Omega]$			
Sallen-Key Multiple Feedback	Lowpass Highpass	Vcc	Vee	$ K_{NI} $	$f_{\mathit{test_l}}$	$f_{\it test_2}$	$f_{\it test_3}$	$V_{testAC} = V_{test}$	R_{Load}	R_I	R_2	R_3	Resistor tolerance	$c_{\scriptscriptstyle l}$	C ₂	C 3	Capacitor tolerance
Sallen-Key	Lowpass	6	-6	1,000	50	1000	100000	2,000	1000000	8200	15000	-	5%	1e-9	2,20E-09	-	20%
Multiple Feedback	Highpass	6	-6	1,000	60	1200	120000	2,000	1000000	3300	820	-	5%	1,50E-08	1,50E-08	2,20E-08	20%

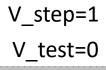


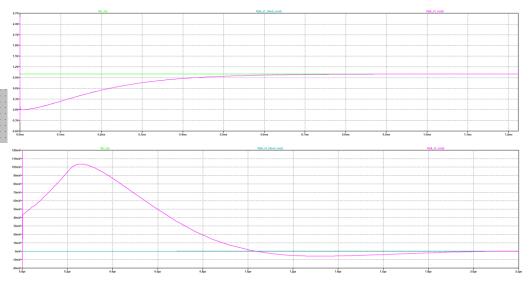
Define the step response



Filter scheme	Filter type	1	urce power	Required absolute gain of amplifier (sign of the gain is not considered)	voltage	Source voltage frequency , [Hz]	Source voltage frequency, [Hz]	Source voltage amplitude, [V]	Load resistance, [Ω]	Filter resistance, [Ω]		à.			Filter capacitance, [Ω]		
Sallen-Key Multiple Feedback	Lowpass Highpass	Vcc	Vee	$ K_{NI} $	$f_{\mathit{test_l}}$	$f_{\it test_2}$	$f_{\it test_3}$	$V_{testAC} = V_{test}$	R _{Load}	R_{I}	R_2	R_3	Resistor tolerance		C ₂	C 3	Capacitor tolerance
Sallen-Key	Lowpass	6	-6	1,000	50	1000	100000	2,000	1000000	8200	15000	-	5%	1e-9	2,20E-09	-	20%
Multiple Feedback	Highpass	6	-6	1,000	60	1200	120000	2,000	1000000	3300	820	-	5%	1,50E-08	1,50E-08	2,20E-08	20%







Conclusions



Filter scheme	Filter type	Voltage source power		Required absolute gain of amplifier (sign of the gain is not considered)	voltage	Source voltage frequency , [Hz]	Source voltage frequency, [Hz]	Source voltage amplitude, [V]	Load resistance,	Filter resistance, [Ω]			Filter capacitance,				
Sallen-Key Multiple Feedback	Lowpass Highpass	Vcc	Vee	$ K_{NI} $	$f_{\mathit{test_l}}$	f_{test_2}	f_{test_3}	V testAC= V test	R _{Load}	R_{I}	R_2	R_3	Resistor tolerance	C_{I}	C ₂	C 3	Capacitor tolerance
Sallen-Key	Lowpass	6	-6	1,000	50	1000	100000	2,000	1000000	8200	15000	-	5%	1e-9	2,20E-09	-	20%
Multiple Feedback	Highpass	6	-6	1,000	60	1200	120000	2,000	1000000	3300	820	-	5%	1,50E-08	1,50E-08	2,20E-08	20%

Conclusions should contain:

- Which filter type were used?
- What was the bandwidth?
- What was the maximum/minimum gain relation in the passband?

https://forms.yandex.com/cloud/637a65df5d2 a068973e26fba/

https://clck.ru/32jqcy

1st deadline: 02.12.2022 23:59 (GMT +8)



