

Active filter design software

The manual of **AktivFilter 3.3**

How to design active filters with AktivFilter 3.3 software

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1 Introduction

AktivFilter 3.3 is a program for the design of active bandpass filters, notch filters, highpass filters and lowpass filters with operational amplifiers. The special feature of this software is, that it is able to co-ordinate the component values of the filter on the opamp type and on the standard series of components. Thus, a later adjustment of the built circuit is not necessary. For many applications, it is possible, to use cheap opamp types instead of expensive special opamps.

According to our information, **AktivFilter 3.3** is the only available tool, which is able to co-ordinate a filter design on opamp types.

While specifying a highpass, lowpass or bandpass filter in **AktivFilter 3.3**, you can select the characteristic from Bessel, Butterworth and Chebychev. When choosing Chebychev, you can set the ripple to a value at your own choice up to 20 dB. For highpass filters and lowpass filters, you can alternatively specify a user defined characteristic, by setting the normalized pole frequency and the pole quality of each stage. This could be a useful feature, e.g. when designing an active cross-over network for loudspeakers.

Did you design filters using a filter catalog? Now, there is no need for a filter catalog anymore, as it is implemented in **AktivFilter 3.3** (but you will never see this internal filter catalog - **AktivFilter 3.3** selects automatically the required parameters from its internal filter catalog and normalizes them).

Another useful feature of **AktivFilter 3.3** is, that every filter can be designed to reach its specified response while using components from a standard series. Because of its internal matching technique you can reach an optimized design with components from a standard series. When specifying a filter, you can select the standard series for the resistors from E12, E24, E48, E96, and E192 (for notch filters: E24, E48, E96, and E192). The program selects capacitors from the E12 standard series, but you can change every capacitor value manually and let the resistors be optimized by the software.

AktivFilter 3.3 runs under Windows 2000, Windows XP, Windows Vista, Windows 7, Windows 8, Windows 8.1, and Windows 10.

Three different editions of the software are available:

- **AktivFilter 3.3 Personal Edition** is a full version for one user with one computer and has the complete set of features. This edition can be purchased at Circuit Experts.
- **AktivFilter 3.3 Professional Edition** is a full version for one user with one computer, has the complete set of features, and allows to extend the list of supported opamps by user defined opamp types. This edition can be purchased at Circuit Experts.
- **AktivFilter 3.3 Campus Edition** is a full version for one user with one computer, has the complete set of features, and allows to extend the list of supported opamps by user defined opamp types. The software may be installed on as many computers as needed in a school or at an office. This edition can be purchased at Circuit Experts.
- **AktivFilter 3.3 Demo Edition** is freeware and is limited to support highpass and lowpass filters up to 2nd order and the opamp types uA741 and LF411. **AktivFilter 3.3 Demo Edition** can be downloaded from the website www.aktivfilter.de/en.

This manual is suitable for all editions; however, some features presented here can only be used with a full version.

2 Features of a full version

| | |
|---|--|
| Filter types and filter circuits : | <ul style="list-style-type: none"> - Highpass and lowpass with Sallen-Key circuit - Highpass and lowpass with multiple feedback - 3rd order Sallen-Key highpass with one opamp - 3rd order Sallen-Key lowpass with one opamp - Bandpass filter with multiple feedback - Active twin-T bandreject |
| Filter order : | Bandpass 2 nd to 30 th order; highpass and lowpass 1 st to 30 th order; bandreject 2 nd order |
| Filter characteristic for high- and lowpassfilters : | Bessel; Butterworth; Chebychev with given ripples up to 20 dB; user defined characteristic |
| Filter characteristic for bandpassfilters : | Bessel; Butterworth; Chebychev with given ripples up to 20 dB |
| Graphical output : | Amplitude response in dB and group delay after each calculation |
| Store the design : | As HTML file with circuit diagram as PNG file |
| Store / Load the specification : | As an AktivFilter specification file, *.afs. It is a text file, which can be read with every text editor, e.g. Notepad. When doubleclicking the file, AktivFilter runs and calculates the specified filter. |
| Spice interface : | Call interface for AC analysis with output of the amplitude response in dB, the phase response of the group delay; transient analysis for step response |
| Supported opamp types : | Every opamp in the following list (more than 300 opamp types) and the ideal opamp |

3 Supported opamp types

A full version of **AktivFilter 3.3**, version 3.3 or higher, supports at least these opamp types:

| | | | | | | | | | |
|----------|-----------|-----------|----------|---------|---------|----------|---------|----------|----------|
| AD648 | AD711 | AD712 | AD713 | AD741 | AD743 | AD797 | AD8031 | AD8032 | AD8045 |
| AD8047 | AD8057 | AD8058 | AD8099 | AD817 | AD822 | AD823 | AD825 | AD826 | AD845 |
| AD847 | ADA4528-1 | ADA4528-2 | CA3140 | CA3160 | EL2245 | EL2445 | FAN4174 | FAN4274 | HA-2600 |
| HA-2602 | HA-2620 | HA-2622 | HA-2841 | HA-2842 | HA-5020 | HA-5101 | HA-5102 | HA-5104 | HA-5112 |
| HA-5114 | HA-5127 | HA-5137 | HA-5147 | HA-5190 | HA-5221 | HA-5222 | HA17082 | HA17083 | HA17084 |
| HA17558 | HA17741 | LF351 | LF353 | LF356 | LF357 | LF411 | LF412 | LF441 | LF442 |
| LF444 | LF451 | LM107 | LM118 | LM124 | LM139 | LM148 | LM158 | LM193 | LM218 |
| LM224 | LM239 | LM258 | LM2902 | LM2904 | LM293 | LM307 | LM318 | LM324 | LM3302 |
| LM339 | LM358 | LM393 | LM4562 | LM6118 | LM6142 | LM6144 | LM6152 | LM6154 | LM6161 |
| LM6162 | LM6164 | LM6165 | LM6171 | LM6172 | LM833 | LMC6062 | LMC662 | LME49710 | LME49720 |
| LME49740 | LME49860 | LME49870 | LME49990 | LMH6624 | LMH6626 | LMH6642 | LMH6643 | LMH6644 | LMH6657 |
| LMH6658 | LMP7701 | LMP7702 | LMP7704 | LMV771 | LMV772 | LMV774 | LMV821 | LMV822 | LMV824 |
| LT1013 | LT1013D | LT1014 | LT1028 | LT1055 | LT1056 | LT1115 | LT1151 | LT1211 | LT1212 |
| LT1213 | LT1214 | LT1352 | LT1353 | LT1355 | LT1356 | LT1357 | LT1358 | LT1359 | LT1361 |
| LT1362 | LT1363 | LT1364 | LT1365 | LT1413 | LT1462 | LT1463 | LT1464 | LT1465 | LT1492 |
| LT1493 | LT1494 | LT1495 | LT1496 | LT1498 | LT1499 | LT1635 | LT1638 | LT1639 | LT1677 |
| LT1792 | LT1793 | LT1801 | LT1802 | LT1815 | LT1816 | LT1817 | LT1884 | LT1885 | LT2078 |
| LT2079 | LT2178 | LT2179 | LT6236 | LT6237 | LT6238 | MAX410 | MC1458 | MC1558 | MC33078 |
| MC33079 | MC33272 | MC33274 | MCP6001 | MCP6002 | MCP6004 | NCV33274 | NE5532 | NE5533 | NE5534 |
| OP07 | OP113 | OP1177 | OP15 | OP16 | OP160 | OP20 | OP21 | OP213 | OP2177 |
| OP27 | OP270 | OP275 | OP37 | OP413 | OP4177 | OP467 | OP470 | OPA130 | OPA132 |
| OPA134 | OPA141 | OPA1611 | OPA1612 | OPA1652 | OPA1654 | OPA2107 | OPA2132 | OPA2134 | OPA2141 |
| OPA2227 | OPA2228 | OPA227 | OPA228 | OPA2334 | OPA2335 | OPA2340 | OPA2354 | OPA2355 | OPA2356 |
| OPA2369 | OPA2604 | OPA2652 | OPA2725 | OPA2726 | OPA334 | OPA335 | OPA3355 | OPA340 | OPA354 |
| OPA355 | OPA356 | OPA369 | OPA4132 | OPA4134 | OPA4141 | OPA4227 | OPA4228 | OPA4340 | OPA4354 |
| OPA4820 | OPA604 | OPA606 | OPA627 | OPA637 | OPA650 | OPA655 | OPA725 | OPA726 | OPA820 |

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| | | | | | | | | | |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| OPA842 | OPA843 | THS4001 | THS4304 | TL022 | TL031 | TL032 | TL034 | TL051 | TL052 |
| TL054 | TL061 | TL062 | TL064 | TL071 | TL072 | TL074 | TL081 | TL082 | TL084 |
| TL3472 | TL3474 | TL971 | TL972 | TL974 | TLC2201 | TLC2202 | TLC2272 | TLC2274 | TLE2071 |
| TLE2072 | TLE2074 | TLE2081 | TLE2082 | TLE2084 | TLV2460 | TLV2461 | TLV2462 | TLV2463 | TLV2464 |
| TLV2465 | TS902 | TS904 | TS912 | TS914 | TS924 | TS951 | TS952 | TS954 | uA741 |

3.1 A hint concerning minimum gain

Because of stability reasons, some opamps require a minimum closed loop gain in the filter circuit. This means, you have to assure the opamp is used with a gain which is at least the minimum gain. In **AktivFilter 3.3** you can design all filter circuits with a gain greater 0 dB. If you are not sure, that your filter circuit will be stable with the chosen opamp type, you can do a Spice simulation with the designed filter (amplitude response in dB or linear). Alternatively, you could look up in a data sheet which minimum gain is required for the opamp.

3.2 Fundamental hints concerning the design of circuits with opamps

It is obvious, that the output amplitude of an opamp must not be so high that it will be clipped. Therefore, it is necessary, that the opamps supply voltage is considerable higher than the maximum output amplitude. E.g. opamps in audio circuits typically operate with signal levels of about 1 Volt and have a supply voltage of +/-12 Volt or more.

Resistors in opamp circuits should normally have values in the range 1 k Ω .. 100 k Ω . 10 k Ω is a good value for most opamp circuits. Values smaller than 1 k Ω mean a high load for the opamps output, which leads to a voltage drop at its internal output resistor. Values higher than 100 k Ω can be the reason for a bad signal-to-noise ratio. But there are always exceptions, where it could be necessary to leave the recommended area:

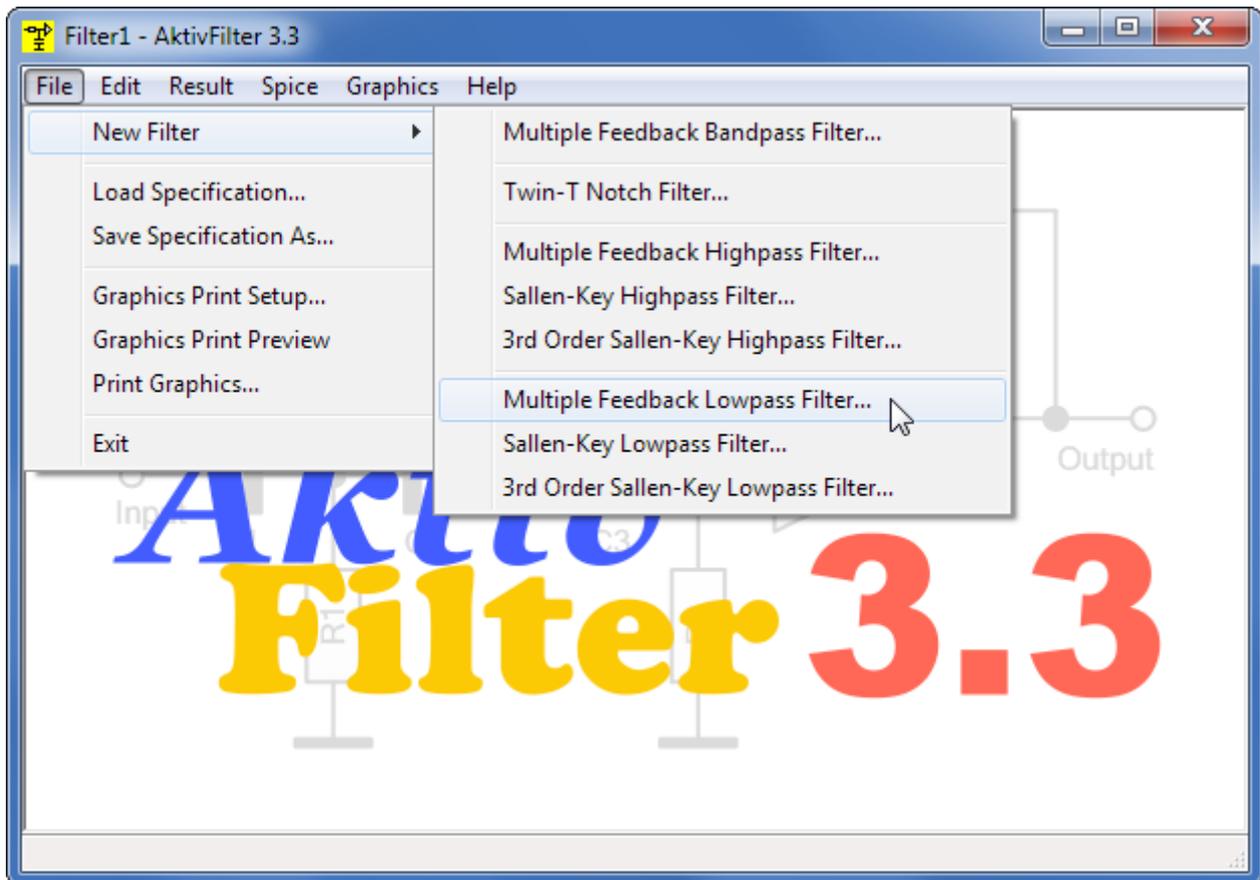
- If you build a circuit, which has to operate with frequencies above 1 MHz, resistors with less than 1 k Ω can be necessary.
- When you build a filter, which has to filter very low frequencies, e.g. frequencies with a cycle duration in the range of minutes or hours, you will need to use resistors with values above 100 k Ω

AktivFilter 3.3 allows you to design all these circuits, even the exceptional cases.

In most cases, you will probably need a filter which operates with audio frequencies or at least in the range 1 Hz .. 1 MHz. In these cases, the value of 10 k Ω is a good choice. This is also the value which AktivFilter 3.3 suggests for the impedance level when you start to design a new filter.

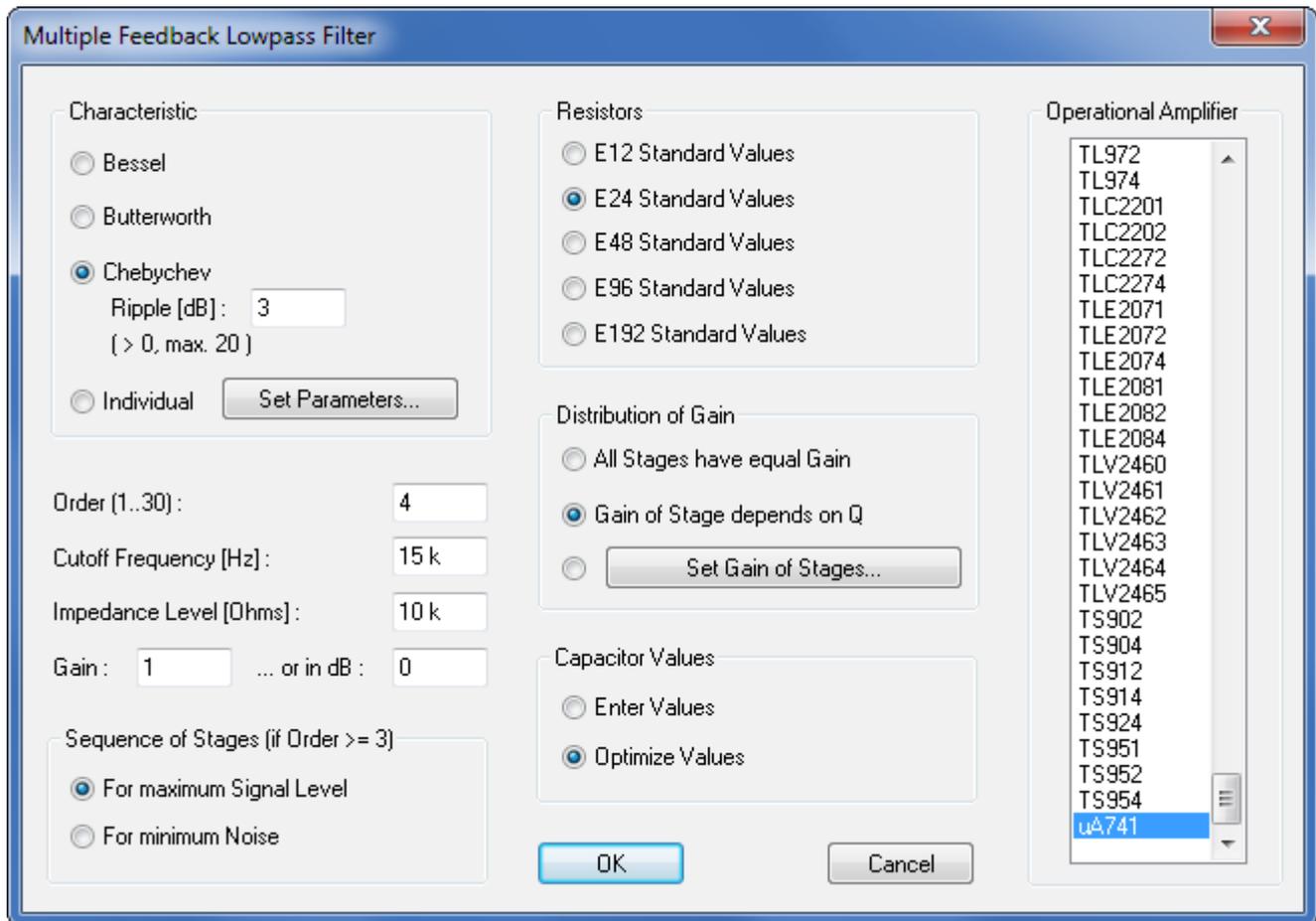
4 How to use the program

You always start a new filter design by clicking the menu item **FILE, NEW FILTER**. In the pull down menu, you choose the filter type and circuit. In the following example a lowpass with multiple feedback shall be designed:



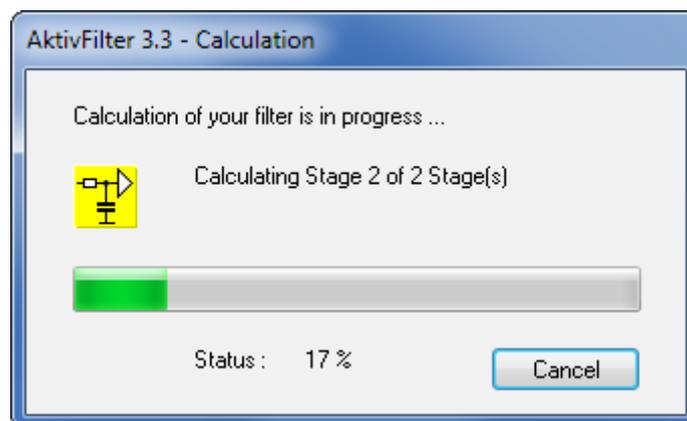
In the next dialog you specify all parameters of your filter:

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When you click **OK**, the calculation starts.

During the calculation, for every stage the progress of calculation is shown in %. So you can see, how long the calculation will take:

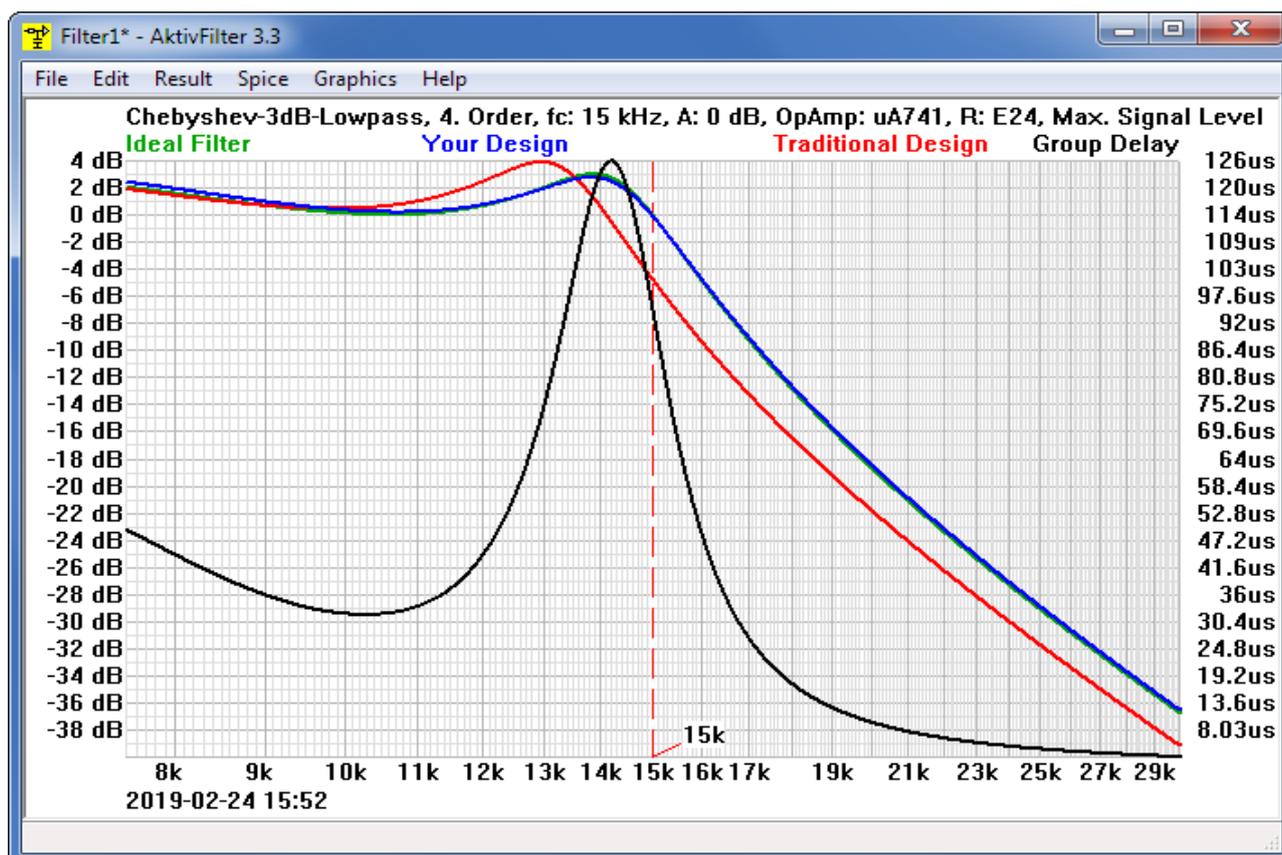


While calculating a stage of your filter, the program checks if a further optimization of the component values could improve the result. If this is the case, the progress dialog contains the text "Additional adjustment of this stage". This additional adjustment can be done up to four times for every stage.

5 The result

5.1 Output graphics

When the calculation is finished, **AktivFilter 3.3** shows you immediately a chart with the frequency response of the filter:



5.1.1 Amplitude response

Hint: For every amplitude response (the red, green and blue curve), the scale at the left margin applies.

In this chart, the **green curve** (which is almost covered by the blue curve) is the desired amplitude response. It is the curve you will get with an ideal opamp and components with continuous values.

The **blue curve** shows the amplitude response of your designed filter. The design has been matched on the opamp type and uses only components (resistors and capacitors) from the standard series you have chosen. As you can see, the green curve is nearly completely covered by the blue curve. This means, **AktivFilter 3.3** has perfectly matched your design.

The **red curve** shows the amplitude response which your filter would have, if you had designed it the traditional way. The traditional way means, your opamp has ideal parameters (in this way the programs of our competitors will do...). As you can see, the result of this traditional method is useless here. Please remember: The filter is a Chebychev lowpass of 4th order with a cutoff frequency of 15 kHz with the opamp uA741. These are obviously no unusual requirements.

Although you can see here the need for a special active filter matching software like **AktivFilter 3.3**.

Furthermore, the deviation between the red curve and the green curve gives you an impression about the dependency of this filter from the opamps parameters. Bear in mind, that a design which extremely compensates the frequency dependent opamp parameters, the more depends from manufacturing dependend tolerances of these parameters. So, if these deviations are too high, it is recommended to choose another opamp type.

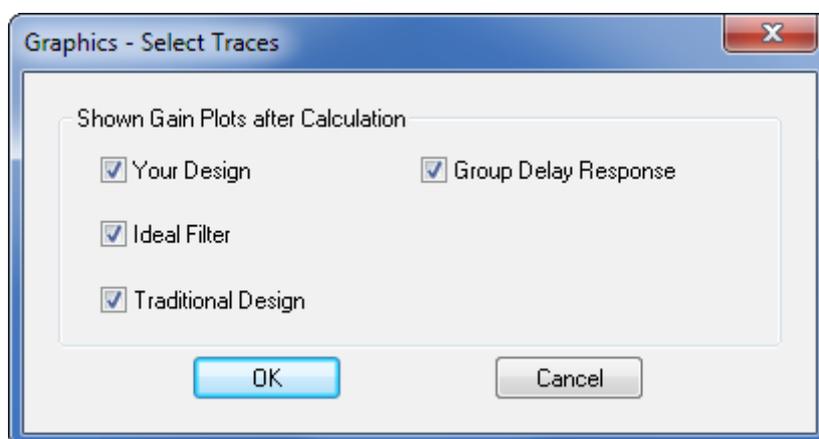
A hint concerning filters with Chebychev characteristic: The cut-off frequency of such filters is in **AktivFilter 3.3** always the point, were the amplitude response leaves the area of given ripple into the cut-off region. This is according the technical literatur about filter design (e.g. Lutz v.Wangenheim: Aktive Filter und Oszillatoren, 2. Auflage, Springer 2007). However, for filters with Bessel or Butterworth characteristic the cut-off frequency is the frequency, where the amplitude response has fallen to -3 dB.

5.1.2 Group delay response

The **black curve** shows the group delay response of your filter. For the group delay response the scale at the right margin applies.

5.1.3 Choosing which curves to show

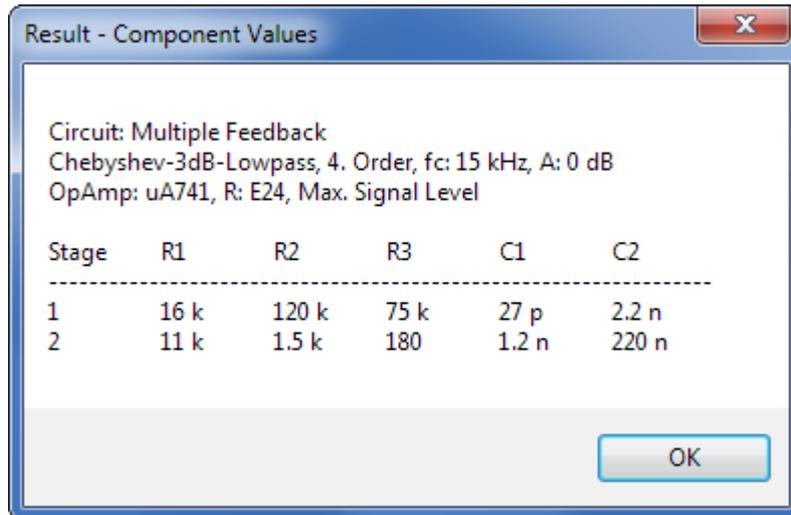
You can choose the curves, which are shown after a calculation, in a dialog after clicking on the menu item **GRAPHICS, SELECT TRACES**:



5.2 Component values

In order to display the component values please click on the menu item **RESULT, COMPONENT VALUES**:

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Result - Component Values

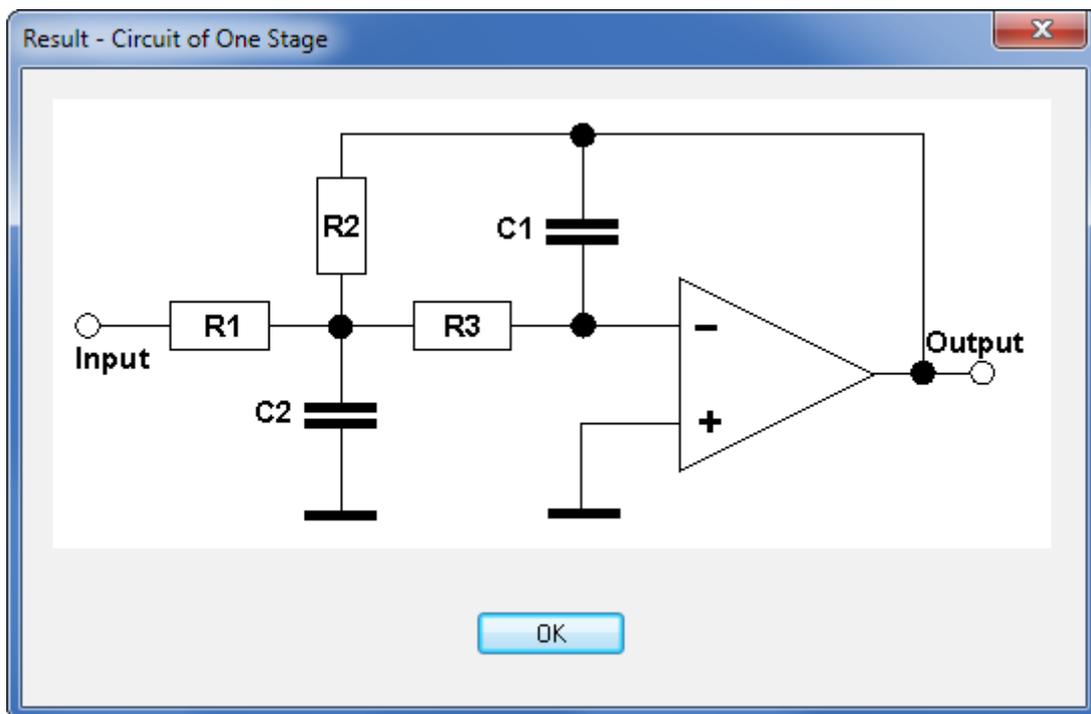
Circuit: Multiple Feedback
Chebyshev-3dB-Lowpass, 4. Order, fc: 15 kHz, A: 0 dB
OpAmp: uA741, R: E24, Max. Signal Level

| Stage | R1 | R2 | R3 | C1 | C2 |
|-------|------|-------|------|-------|-------|
| 1 | 16 k | 120 k | 75 k | 27 p | 2.2 n |
| 2 | 11 k | 1.5 k | 180 | 1.2 n | 220 n |

OK

5.3 Circuit

You should also dedicate a view to the circuit diagram. Click on the menu item **RESULT, CIRCUIT** to see the circuit diagram of one filter stage:



The software always shows the circuit diagram of one filter stage. If your filter consists of more than one stage, this circuit diagram applies for every stage. You must connect the stages in series, i.e. the output of stage 1 must be connected with the input of stage 2, the output of stage 2 must be connected with the input of stage 3, etc. The input of stage 1 is the input of your filter, and the output of the last stage is the output of your filter.

5.4 How to save the result

When you want to save your design, choose the menu item **RESULT, SAVE RESULT** and enter a filename for your filter design.

AktivFilter 3.3 will save your filter design as a HTML file with a picture file reference of the circuit. The picture file will be stored in a subfolder and has the filetype PNG. Please bear in mind, that you will need both files when you want to forward your result, e.g. when you want to copy it to another disk drive or upload it to the internet.

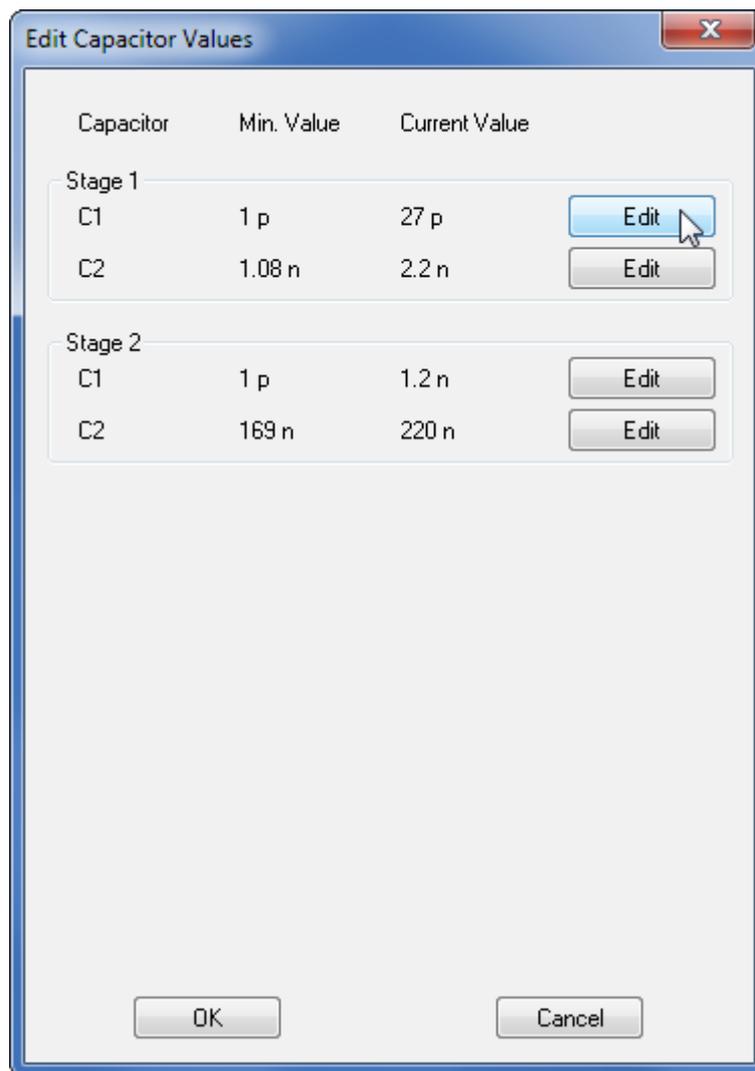
5.5 How to print the result

When you want to print your design, choose the menu item **RESULT, PRINT**.

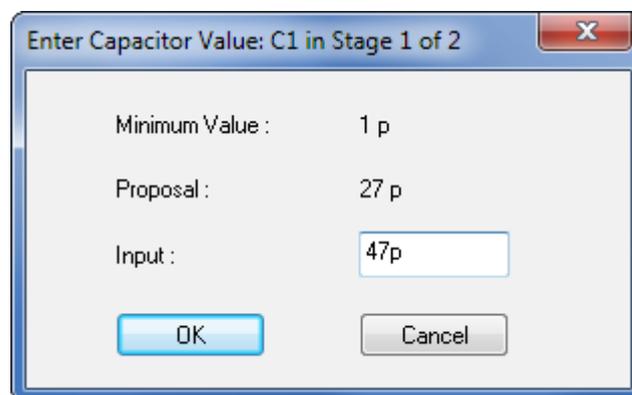
5.6 Edit capacitor values

Let's have a look at the component values of our latest design, especially the capacitor values (see 5.2). Perhaps, C1 of stage 1, which currently is 27 pF, should be increased to 47 pF. You can reach this target very easily with AktivFilter 3.3:

Choose menu item **EDIT, EDIT CAPACITOR VALUES** and have a look at the dialog:



This dialog shows all capacitor values of your designed filter and the allowed minimum values. You can edit every capacitor value separately. Click on the button **EDIT** for C1 in stage 1:

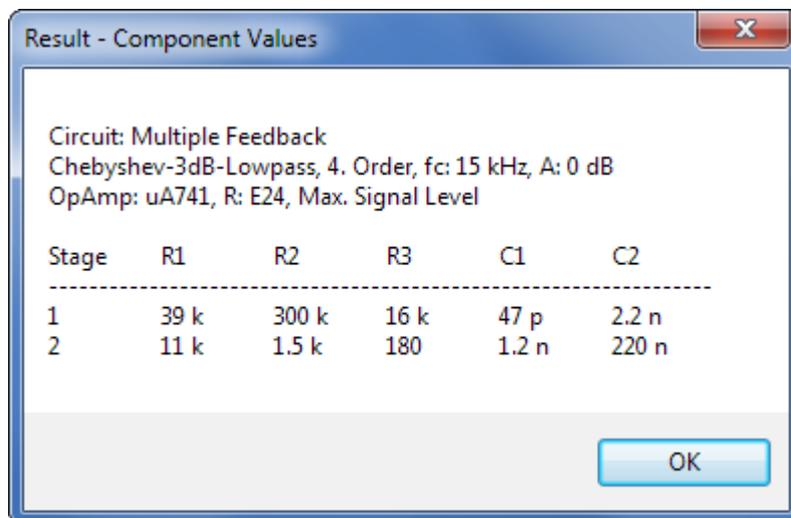


Here you can enter the new value of C1 in stage 1. Please enter **47p** and click on **OK**. Then the previous dialog “Edit Capacitor Values“ will appear again, so you could change another capacitor

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value. Because you do not want to change another capacitor value now, you click on **OK**.

AktivFilter 3.3 immediately starts calculating. After the calculation has finished, choose menu item **RESULT, COMPONENT VALUES** and have a look at the component values:



Result - Component Values

Circuit: Multiple Feedback
Chebyshev-3dB-Lowpass, 4. Order, fc: 15 kHz, A: 0 dB
OpAmp: uA741, R: E24, Max. Signal Level

| Stage | R1 | R2 | R3 | C1 | C2 |
|-------|------|-------|------|-------|-------|
| 1 | 39 k | 300 k | 16 k | 47 p | 2.2 n |
| 2 | 11 k | 1.5 k | 180 | 1.2 n | 220 n |

OK

6 Spice call interface

Maybe, you do not believe, that **AktivFilter 3.3**'s designed filters really match the wished frequency response as good as shown in the graphics. So it is a good idea to check the design with an independent tool, e.g. PSpice or LTSpice. **AktivFilter 3.3** has a built-in Spice call interface, which you can use to simulate your filter with a circuit simulation software like PSpice or LTSpice.

6.1 Spice tools

As an example, we will describe the usage of the Spice call interface with the simulation software PSpice. You can also use the free and powerful program LTSpice by Linear Technologies for that, which can be download from the website www.linear.com/designtools/software.

When you use PSpice it is first of all unimportant, if you have installed a free demo version or a commercial full version of PSpice. If you do not have the Pspice software, you could download a free PSpice version (the PSpice student edition or the OrCAD Lite Edition) from the Cadence website (www.cadence.com/products/orcad/pages/downloads.aspx). Alternatively you could use e.g. the PSpice book by Robert Heinemann (see www.spicelab.de), which contains these free versions of PSpice.

Compared to a PSpice full version, the free PSpice versions have some limitations, which you should know when using the Spice call interface of **AktivFilter 3.3**: You can only simulate circuits with not more than 2 opamps and the included libraries contain only the opamp types uA 741 und LF 411. If you want to use the Spice call interface for a filter which has another opamp type, you will need a library (.LIB file), which contains the Spice model of your opamp type. For almost every opamp supported by **AktivFilter 3.3**, such libraries can be downloaded for free from the websites of the opamp manufacturers; you must take care for the hints concerning the opamp model in the next chapter.

6.2 Hints concerning the opamp model

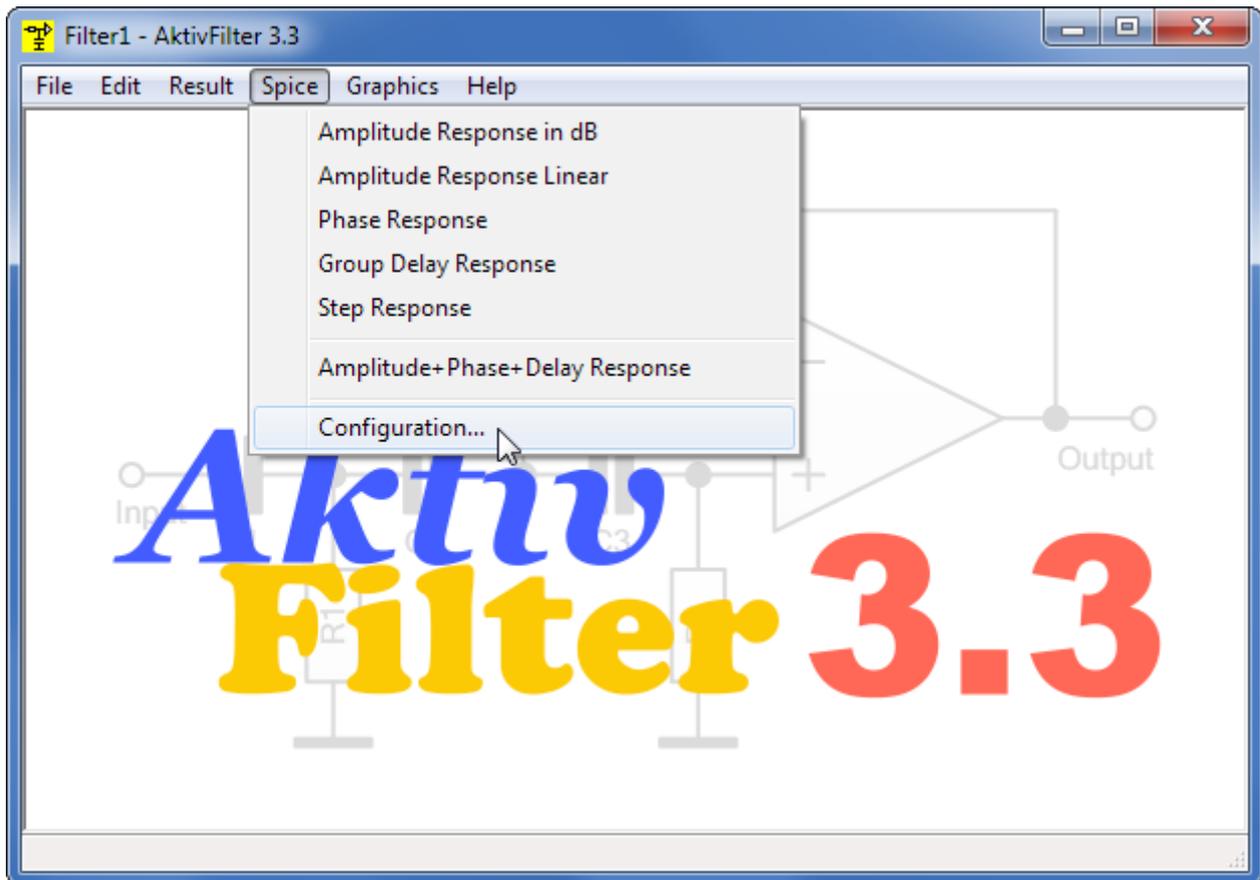
The files, which will be saved by **AktivFilter 3.3** for the Spice call interface have a fixed pin assignment of the opamp: The pins (+)-input, (-)-input, output, (+)-supply voltage and (-)-supply voltage have the same assignment as for the opamp types uA741 and LF411. If the opamp type you have chosen has further pins which need to be connected, you must add the connections in your LIB file, i.e. you must modify the model. A modified opamp model is also required, if the pins of your chosen opamp are interchanged compared to the pin assignment of the uA741. For the changed models we recommend to create a special LIB file, which contains only opamp models and which only should be used for **AktivFilter 3.3**.

Fortunately, most opamp types have the same pin assignment as the uA741 and require no additional connections. So, in most cases you need not to modify the Spice models.

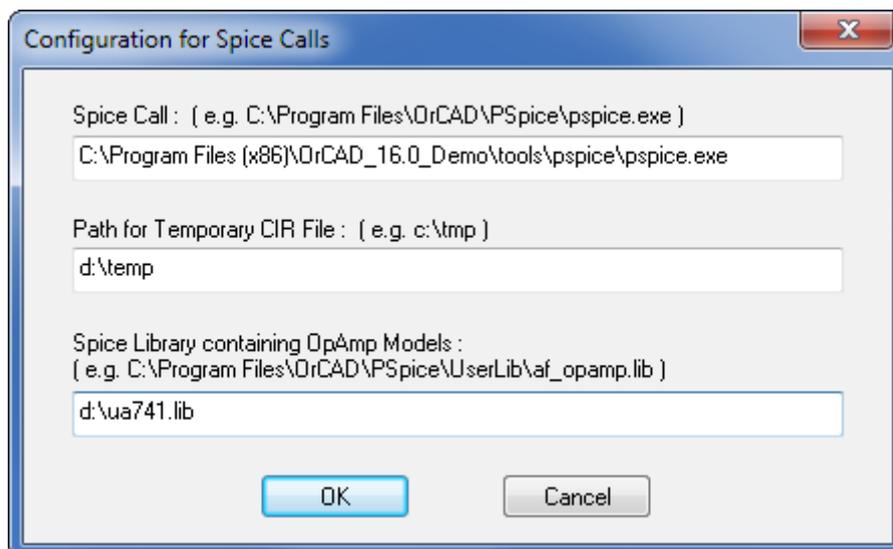
6.3 Configuration

Before you use the Spice call interface the first time, you must configure it: Choose menu item **SPICE, CONFIGURATION...**

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Then, the next dialog appears:



In the upper field **SPICE CALL** you must enter the complete path and file name of the spice program, which is installed on your PC.

In middle field **PATH FOR TEMPORARY CIR-FILE** you must enter a directory name, where AktivFilter 3.3 can store its temporary files which will be needed for the Spice call (these will be two files: a netlist-file (*.CIR) and an inputfile for PROBE (*.PRB)). **Important:** The directory must exist and you must have the right to write files there.

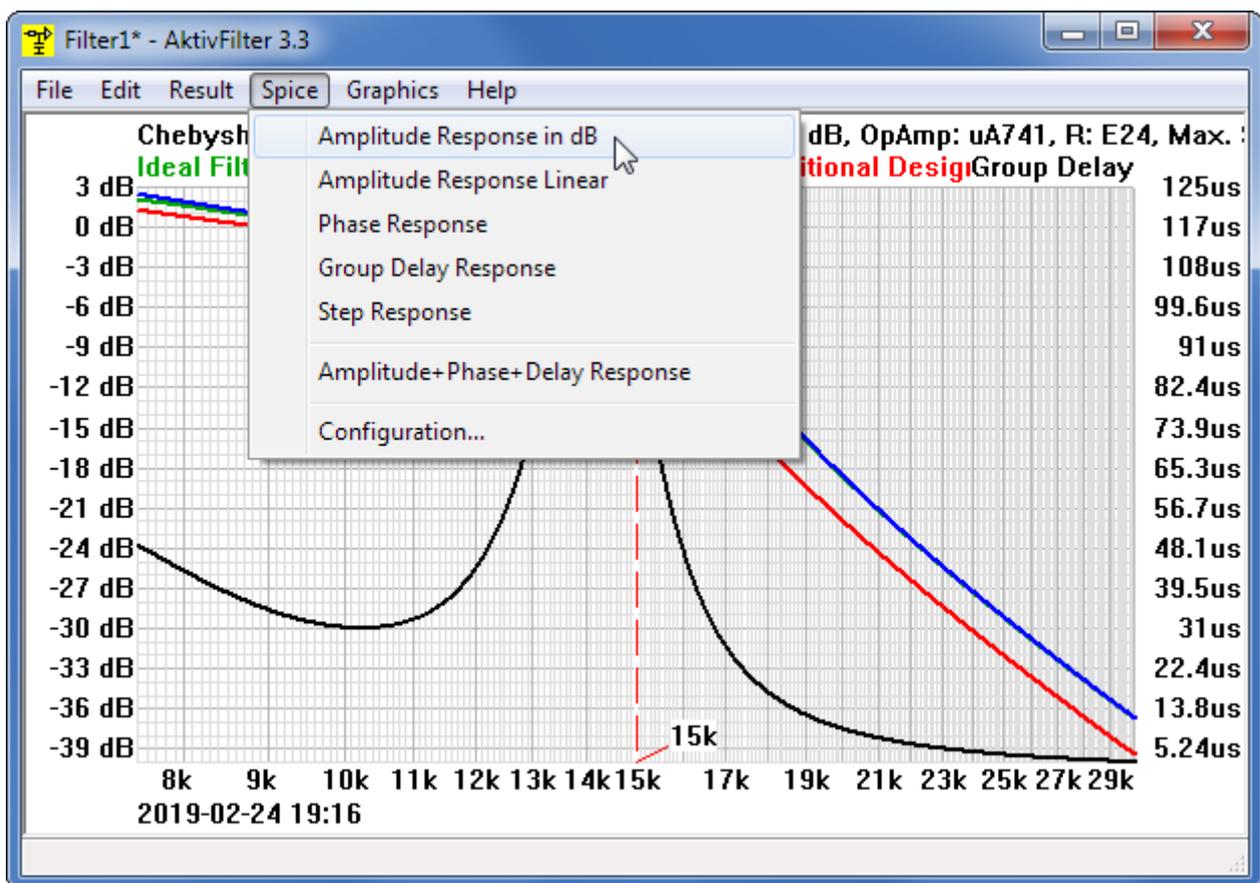
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In the lower field **SPICE LIBRARY CONTAINING OPAMP MODELS** you must enter the name of the library file, which contains your opamp models. If you use the Student Edition of Pspice, you can use the included library eval.lib to simulate filters with the opamps uA741 and LF411. If you have created your own file with opamp models, which you have e.g. downloaded from manufacturers websites, you can enter the name of this file here and store the file in the folder, where other Spice libraries are stored. In this example, we use a file "ua741.lib" which contains a Spice model of the uA741.

The settings you have made in this dialog stay permanent, even when you exit the program: The settings are stored in the Registry of Windows under HKEY_CURRENT_USER\Software\SoftwareDidaktik\AktivFilter and will be load automatically when starting **AktivFilter 3.3**.

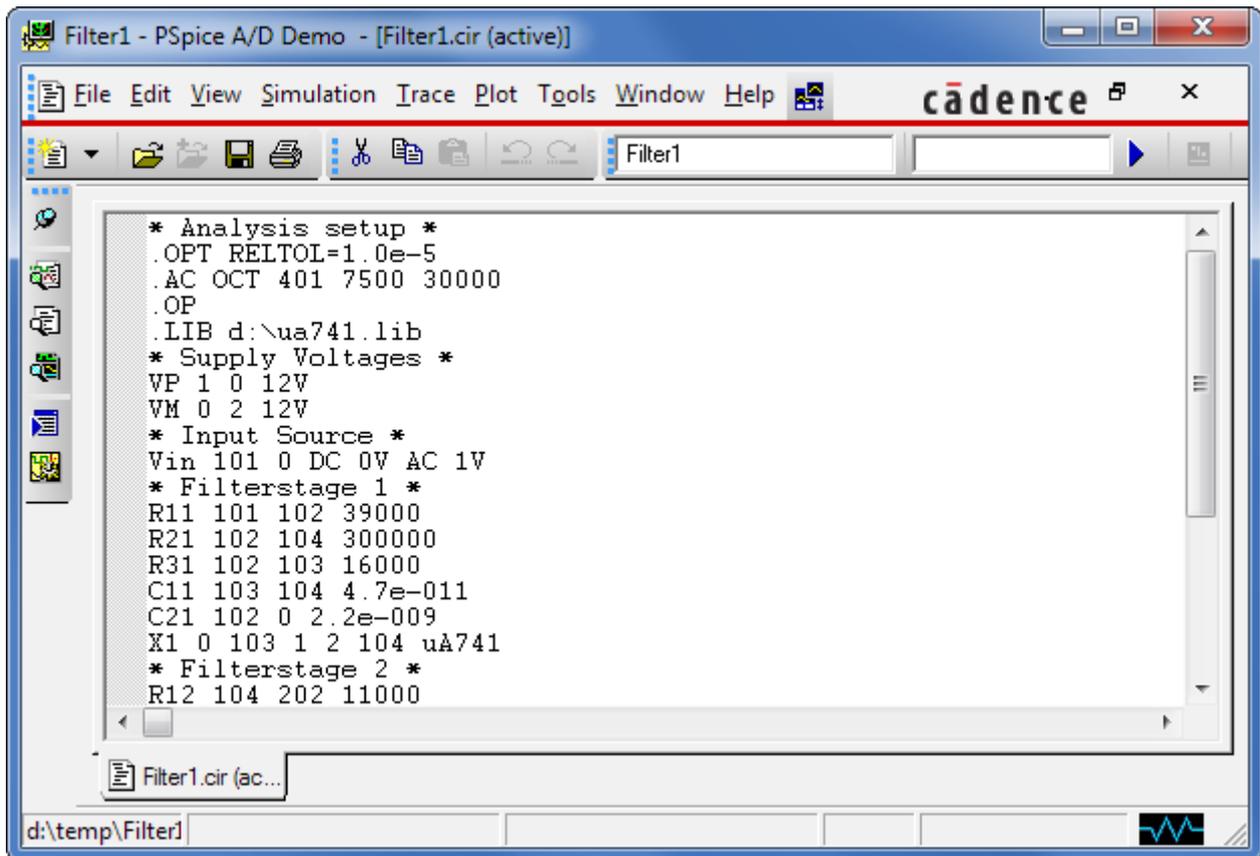
6.4 Simulating the amplitude response with Spice

Now you can use the Spice call interface. Choose menu item **SPICE, AMPLITUDE RESPONSE IN dB**:



If you have configured the Spice call interface correctly (see 6.3), you can see PSpice now:

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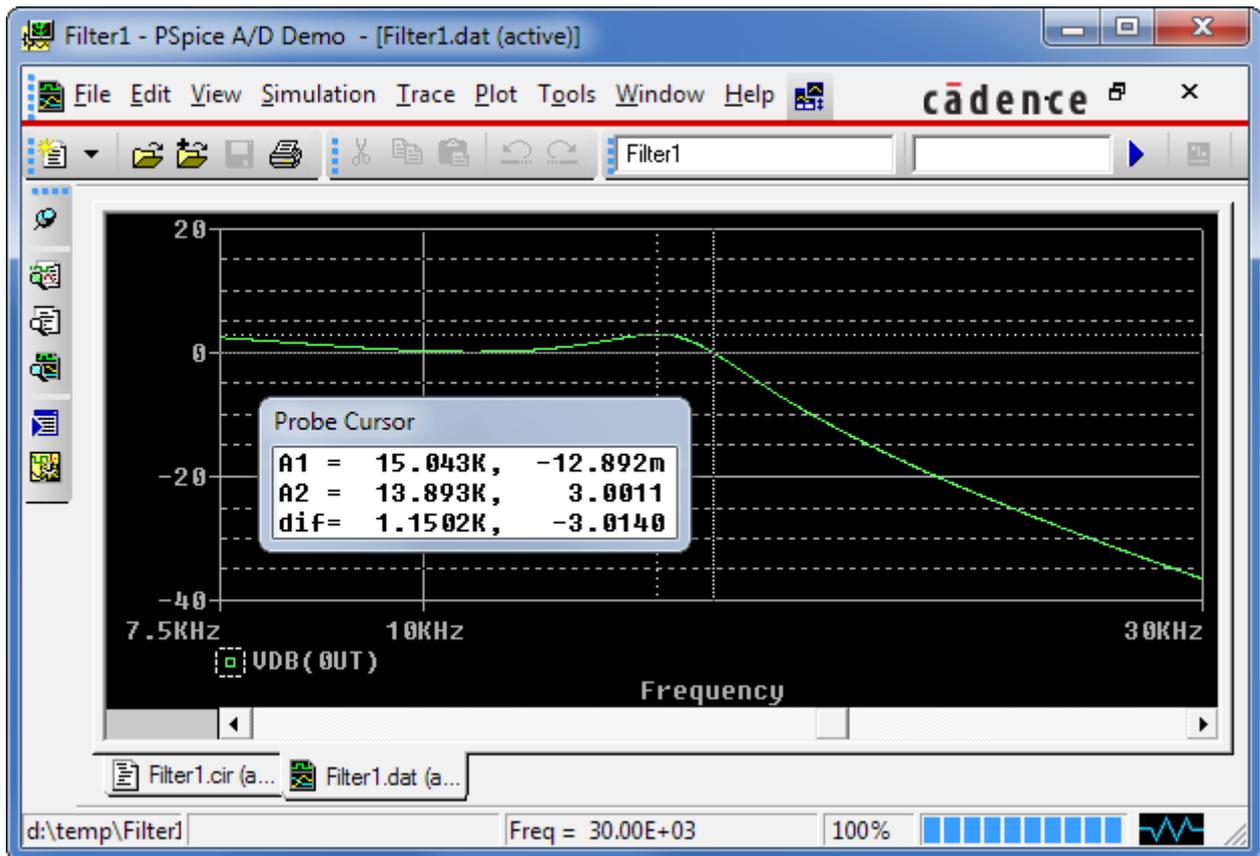


The netlist, which you can see in the text window of PSpice has been generated by **AktivFilter 3.3**. You could edit that netlist, but you should not do it; and of course it is not necessary to edit it.



Now, click on the blue arrow which is located at the upper margin of the window next to the filename. Then the simulation will start. Hint: Instead of clicking the arrow, you can alternatively choose **SIMULATION, RUN** in the menu of PSpice.

The simulation will have finished very soon. Then, a window opens and shows PSpice's simulation result (see next image). In that window you can switch on the cursor and have a detailed look at the result:



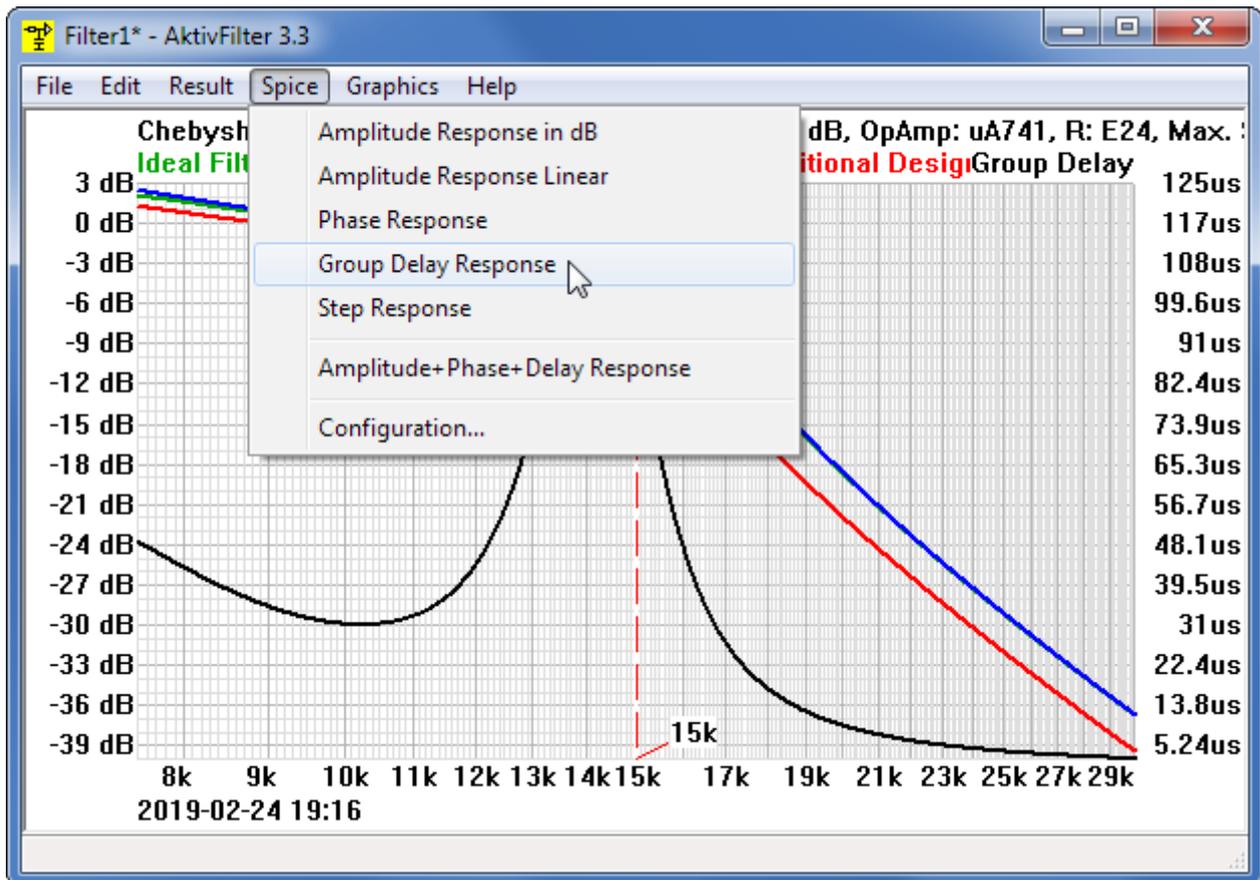
In our example, you can see, that the corner frequency is 15.043 kHz (see cursor A1 in the image above) and the maximum ripple is 3.0011 dB (see cursor A2). So, this filter is very close to the specification ($f_c = 15$ kHz, Ripple = 3 dB).

As you have seen, the outstanding result of **AktivFilter 3.3**'s work is confirmed by PSpice and now you can switch on your soldering iron to build a prototype.

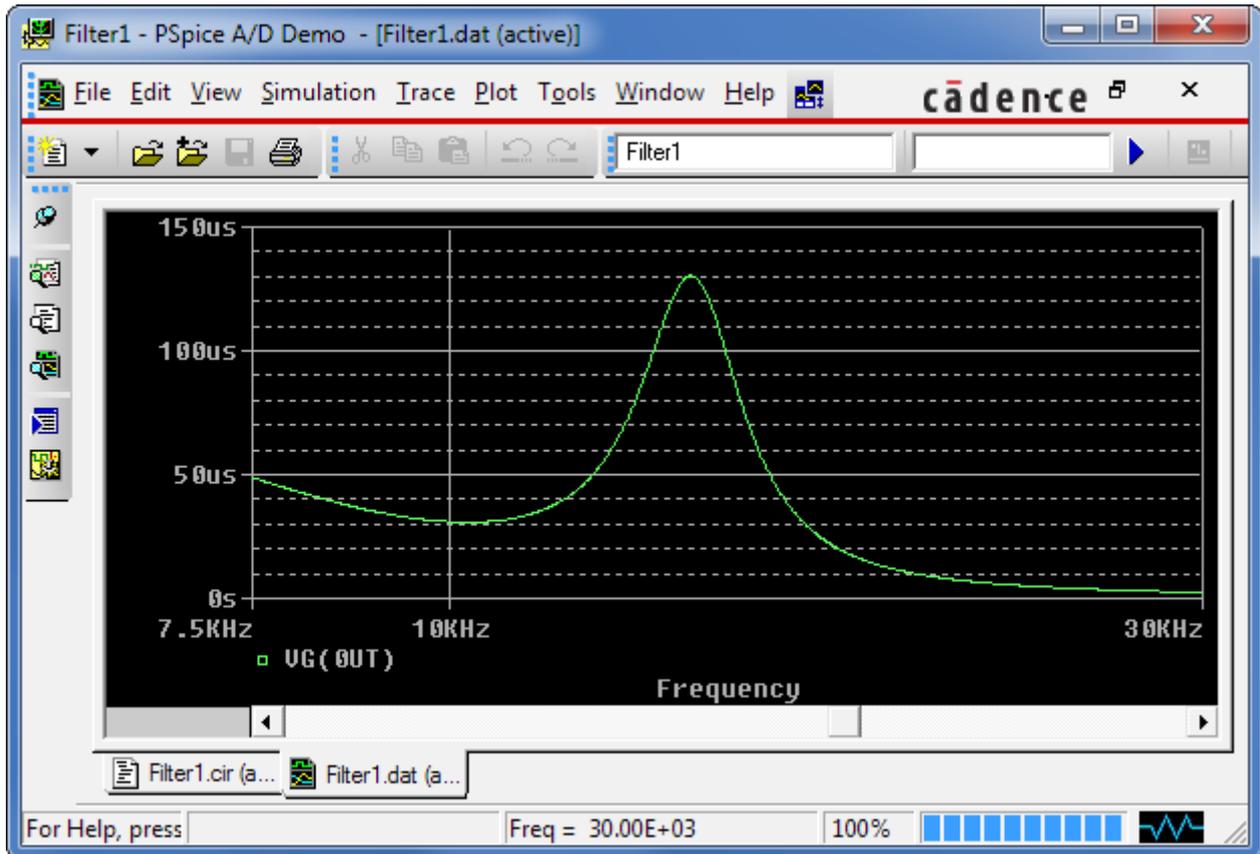
6.5 Simulating the group delay response with Spice

Now, quit PSpice. In **AktivFilter 3.3**, which is still open, choose menu item **SPICE, GROUP DELAY RESPONSE**:

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Again, you will see the netlist in Pspice. Click on the blue arrow to start the simulation. The image on the next page shows PSpice's simulation result:

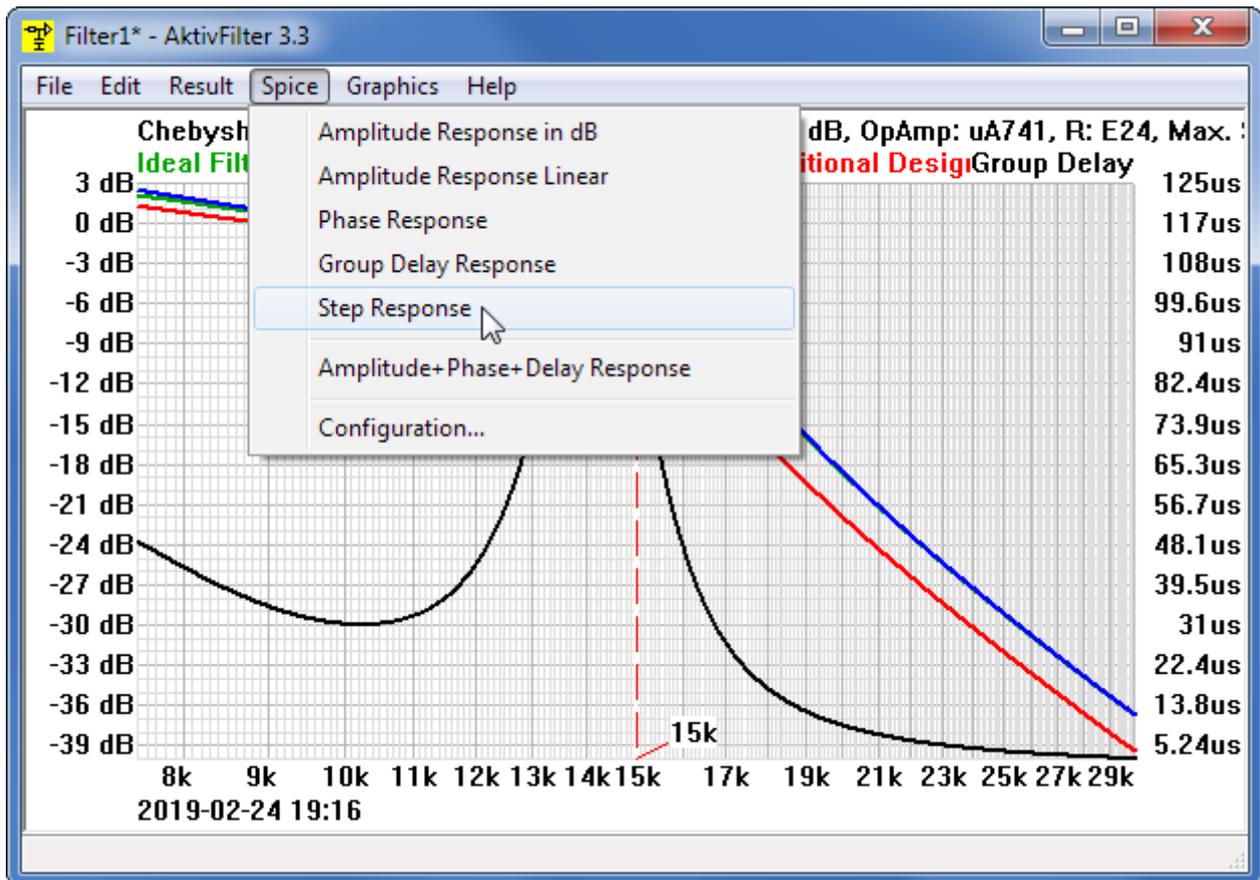


As you can see here, the output of PSpice is according the graphical preview in **AktivFilter 3.3**. By the way, you can see here a typical property of a Chebyshev lowpass filter: The great fluctuation of the group delay.

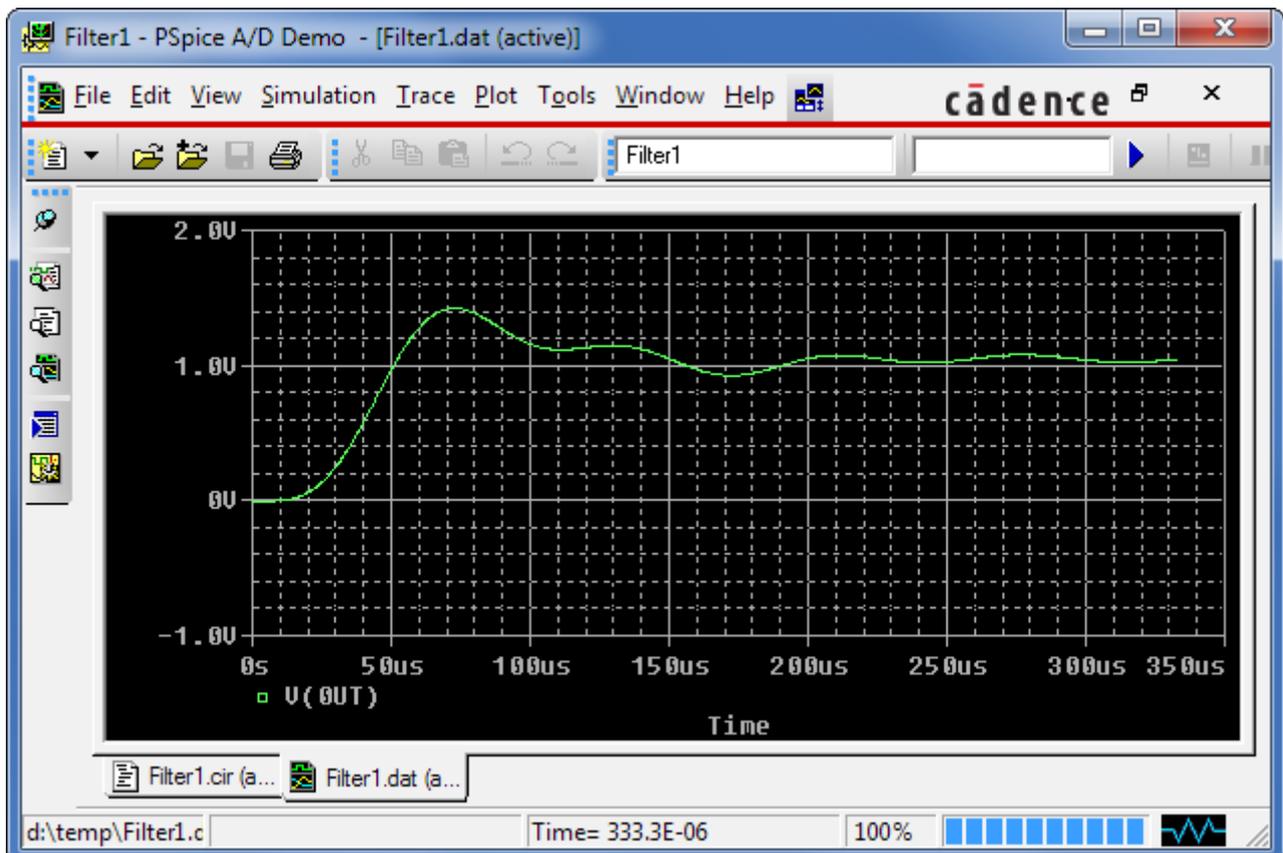
6.6 Simulating the step response with Spice

Now, again quit PSpice. In **AktivFilter 3.3**, which is still open, choose menu item **SPICE, STEP RESPONSE**. This will simulate the step response of the designed filter with Pspice:

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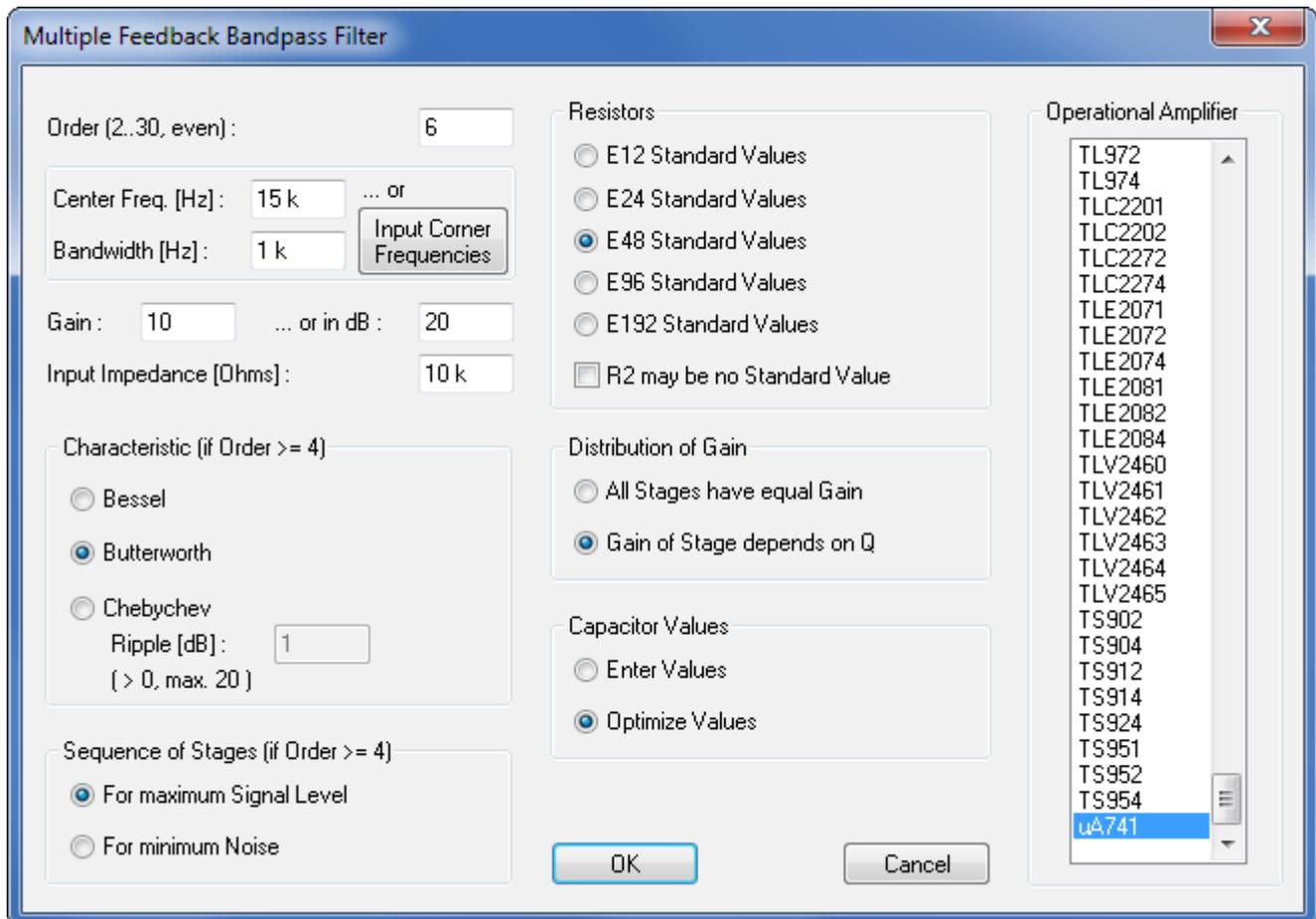


Again, you will see the netlist in the window of PSpice. Click on the blue arrow to start the simulation. The next image shows PSpice's simulation result:

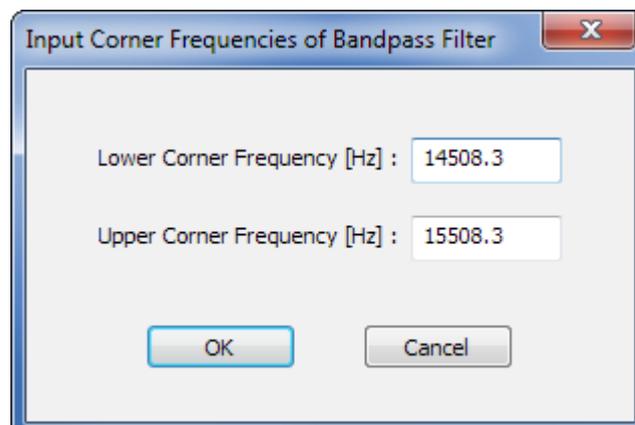


7 Input dialog for a bandpass filter

With the help of **AktivFilter 3.3** you can design bandpass filters with multiple feedback. The next image shows the input dialog for specifying a bandpass filter; please note, that **AktivFilter 3.3** is able to design bandpass filters of order 2 .. 30:

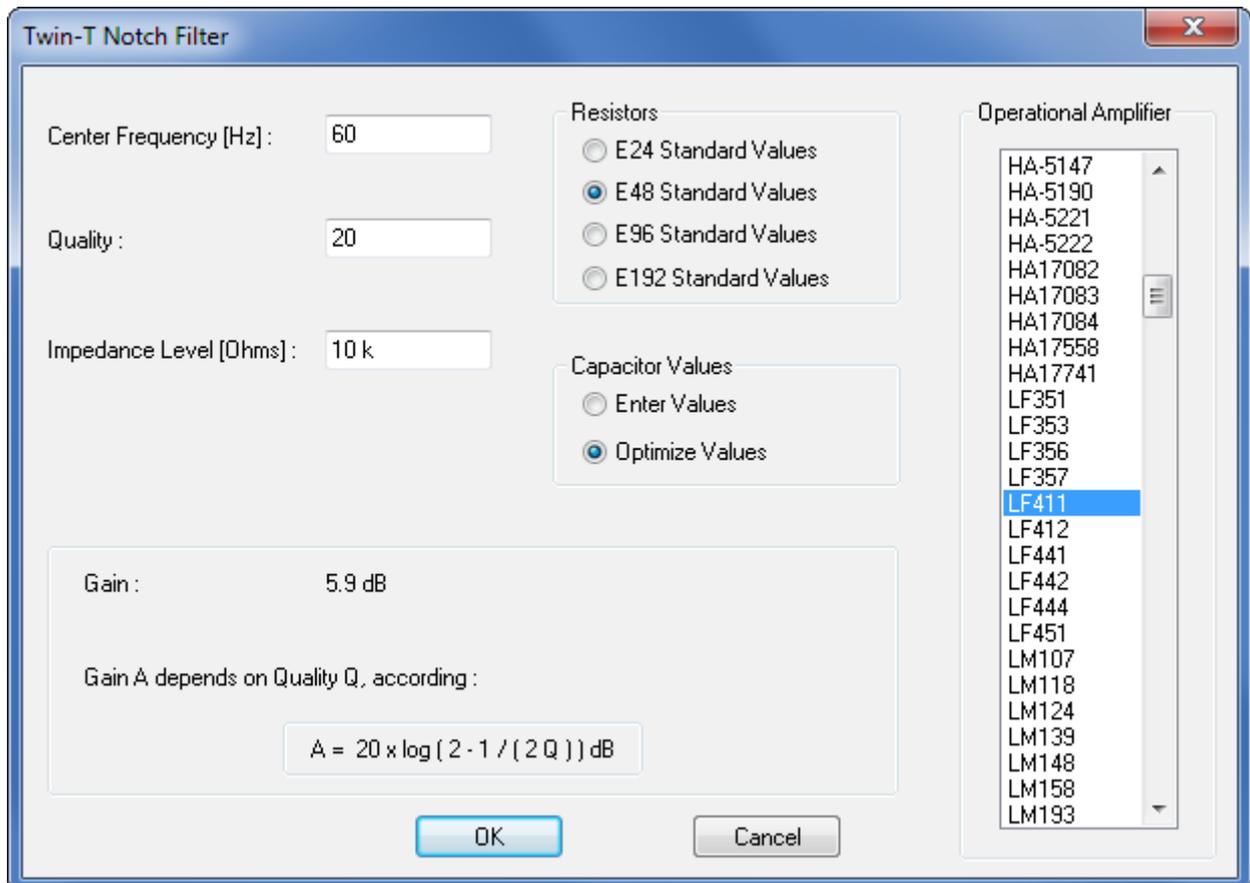


Alternatively to giving center frequency and bandwidth you can enter the corner frequencies of your filter. For that, click the button “Input Corner Frequencies” and enter the required values:



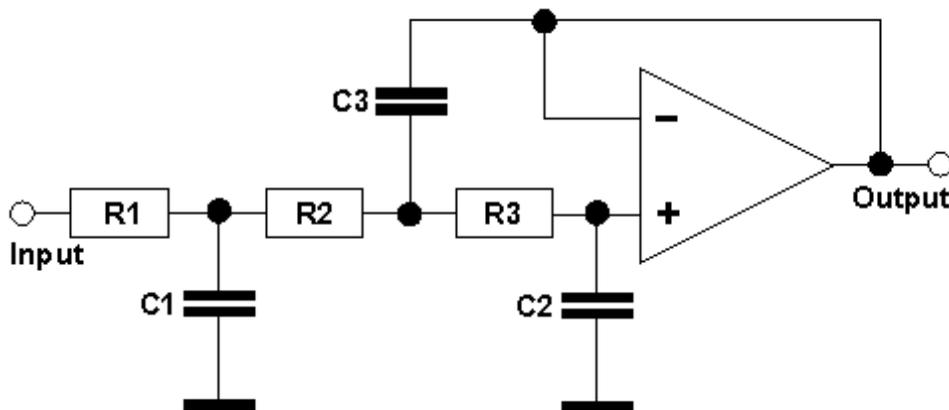
8 Input dialog for a notch filter

AktivFilter 3.3 enables you to design an active twin-T notch filter. The next image shows the input dialog for specifying such a bandgap filter:

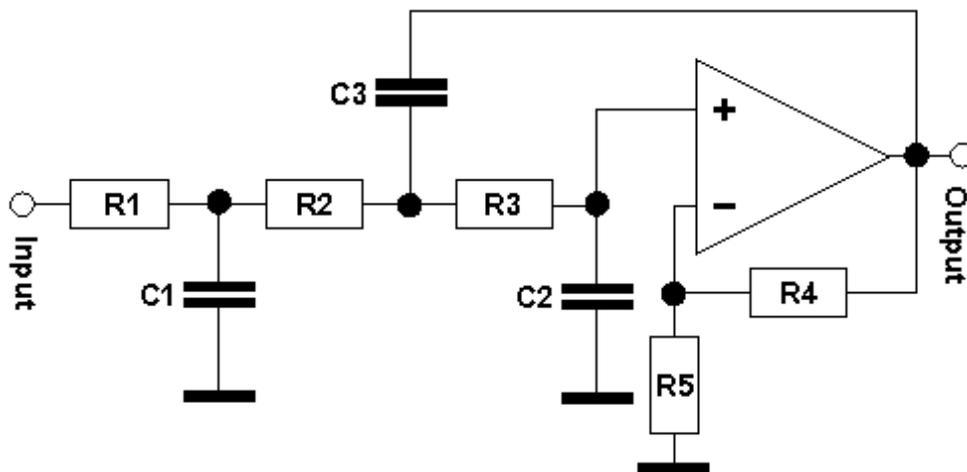


9 Input dialog for a 3rd order Sallen-Key lowpass with 1 opamp

AktivFilter 3.3 enables you to design a 3rd order Sallen-Key lowpass with one operational amplifier. Here are the circuits. The first circuit is for gain = 0 dB:

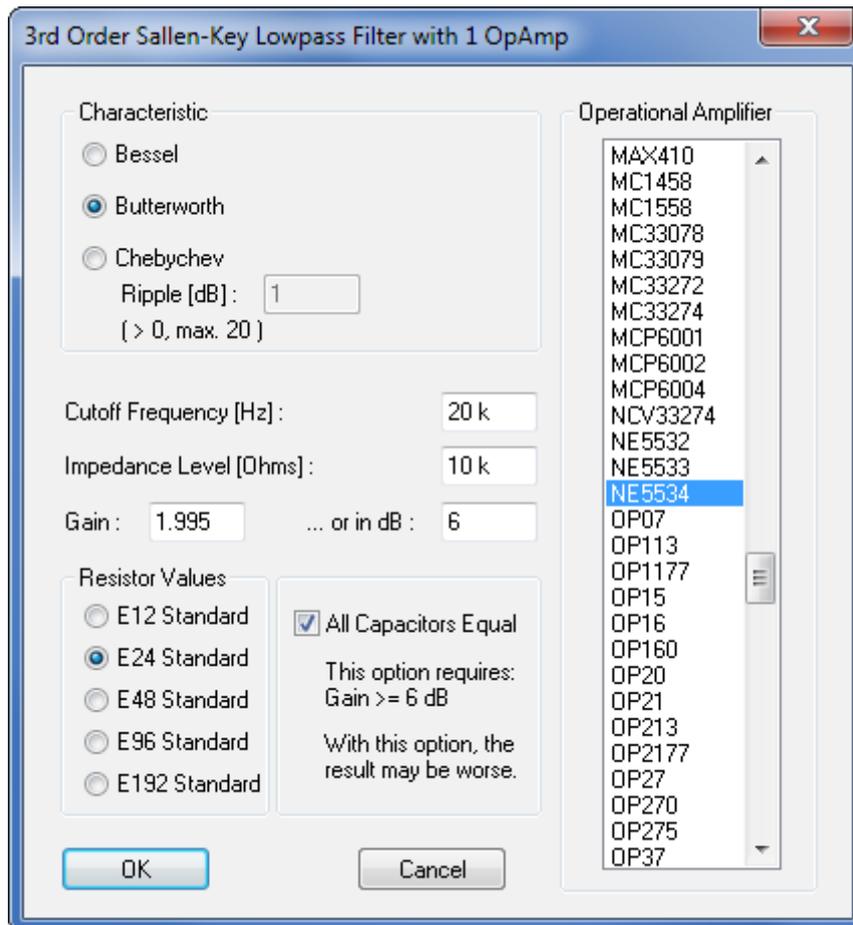


The second circuit is for gain > 0 dB:



AktivFilter 3.3 will automatically select one of the two circuits shown above.

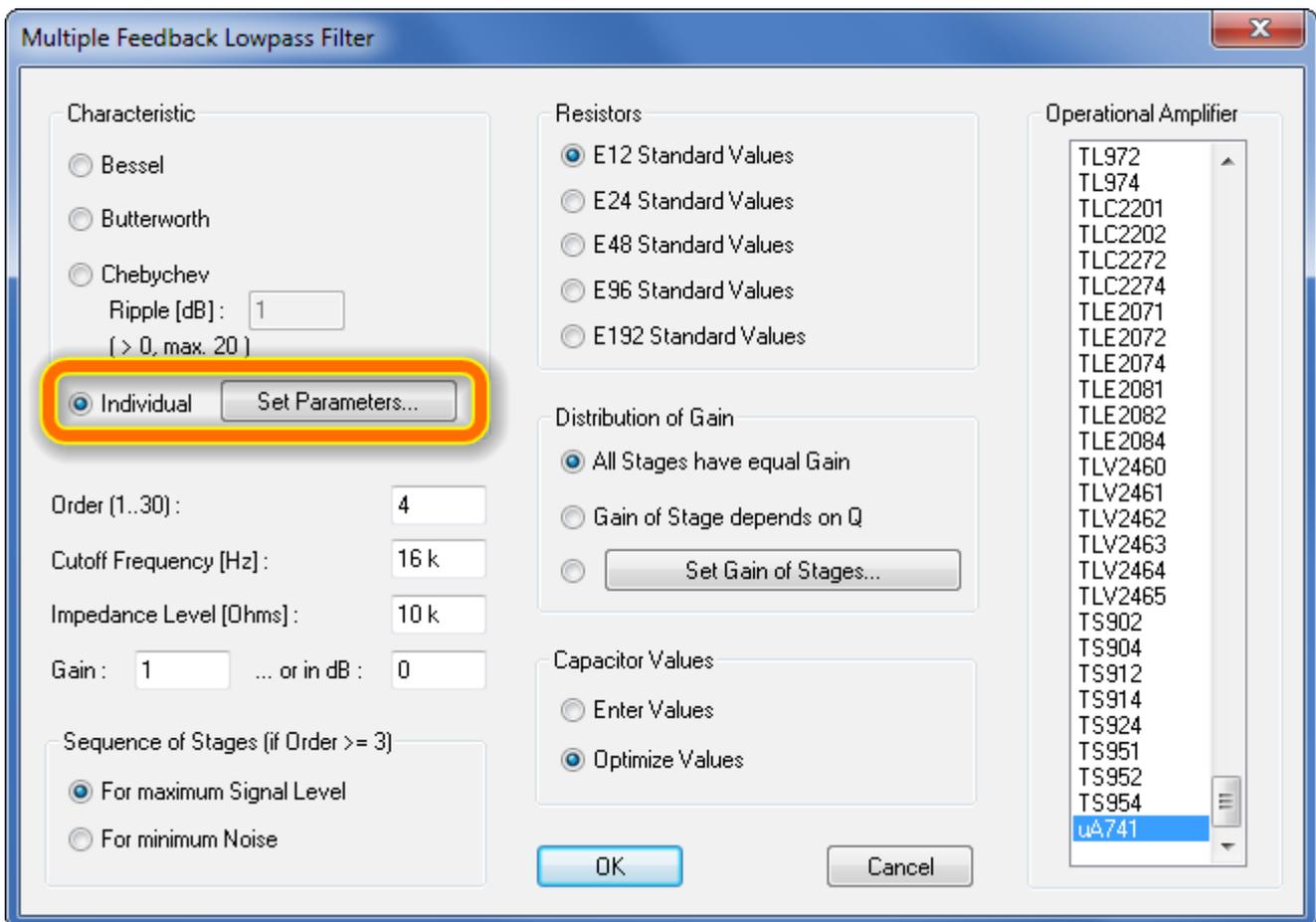
The next image shows the input dialog for specifying such a filter:



Activating the option "All Capacitors Equal" will create a filter with equal capacitor values. The disadvantage of activating that option is, that it is limited to filters with a gain of at least 6 dB, and the result may be worse than without that option – but in many cases it is sufficient.

10 Designing filters with a user defined characteristic

AktivFilter 3.3 enables you to design a highpass or lowpass filter, which has a filter characteristic of Bessel, Butterworth or Chebyshev or a user defined characteristic. You can specify the user defined characteristic by entering the normalized pole frequency and the pole quality Q for every stage of the filter. The dialog, which you need to enter this data will appear, when you click the button **SET PARAMETERS** in the dialog where you specify your filter (here: **FILE, NEW FILTER, MULTIPLE FEEDBACK LOWPASS FILTER**):



One hint: When you enter the parameters, you must know, that for a filter consisting of n stages, only the entries for the stages 1 up to n are relevant. For every stage, the normalized pole frequency and the pole quality Q must be greater than 0.

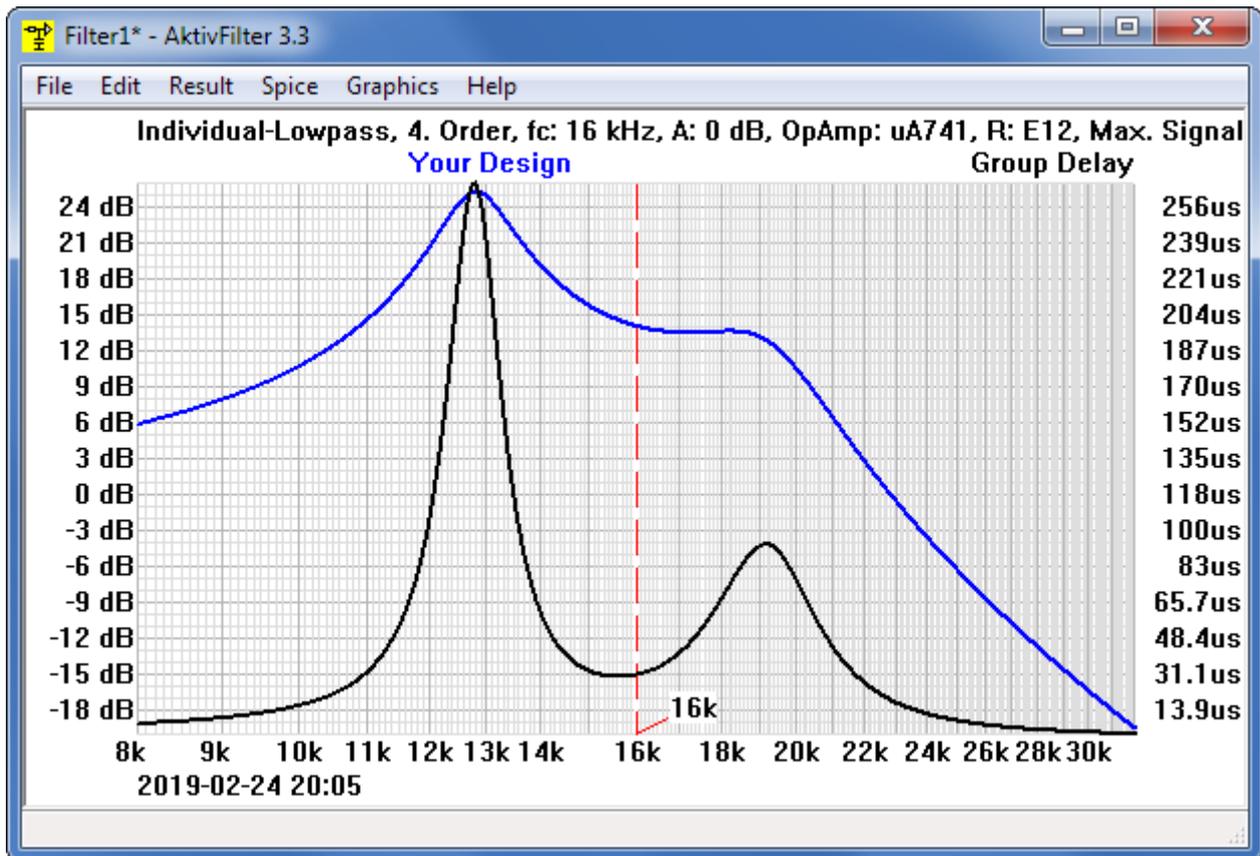
One example of a lowpass filter of order 4: The two stages shall have the normalized pole frequencies 0.8 f_g and 1.2 f_g . The pole qualities shall be 10 and 5.5:

| | Normalized Pole Frequency : (Pole Frequency of Stage divided by Cutoff Frequency of the Filter) | Pole Quality Q : |
|------------|---|------------------|
| Stage 1 : | 0.8 | 10 |
| Stage 2 : | 1.2 | 5.5 |
| Stage 3 : | 1.00000000 | 1.00000000 |
| Stage 4 : | 1.00000000 | 1.00000000 |
| Stage 5 : | 1.00000000 | 1.00000000 |
| Stage 6 : | 1.00000000 | 1.00000000 |
| Stage 7 : | 1.00000000 | 1.00000000 |
| Stage 8 : | 1.00000000 | 1.00000000 |
| Stage 9 : | 1.00000000 | 1.00000000 |
| Stage 10 : | 1.00000000 | 1.00000000 |
| Stage 11 : | 1.00000000 | 1.00000000 |
| Stage 12 : | 1.00000000 | 1.00000000 |
| Stage 13 : | 1.00000000 | 1.00000000 |
| Stage 14 : | 1.00000000 | 1.00000000 |
| Stage 15 : | 1.00000000 | 1.00000000 |

OK Cancel

In the dialog **FILE, NEW FILTER, MULTIPLE FEEDBACK LOWPASS FILTER** the corner frequency was chosen as 16 kHz. The opamp uA741 was chosen and the resistors were chosen as E12 standard values. The frequency response of this filter can be seen on the next image:

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Of course, you can simulate this filter circuit quick and easily with Spice, as described in the chapter Spice call interface, to check the result.