QuickFil 5.1

Features

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Introduction

In this article you will find the features of QuickFil 5.1 in short form, so you can get an overview of it.

QuickFil is a CAE program for designing electronic filters. Electronic filters are used in communication engineering to remove signals and noise, that cause disturbance.

Electronic filters can be realized by different components:

- passive components: resistors, capacitors and inductors
- mechanical components: for example quartz crystals
- active elements: operational amplifiers + resistors + capacitors
- digital circuits: ADC + digital logic + DAC

QuickFil is a program specialized for passive filters consisting of capacitors and inductors.

The development of filters can be divided into the following steps:

- Specifying the characteristics of the passive filter.
- Designing an initial circuit using a filter design program.
- Modifying this initial circuit (circuit transformations).
- Analyzing the characteristic of the filter
- Realizing the filter.

QuickFil will help you at the specification step, designing the initial circuit and modifying and analyzing the circuit.

Some basic tasks to do in order to perform this:

- Approximation of the transfer function
- Calculating the element values for the transfer function
- Manipulating the circuit using transformations and so on
- Analyzing the circuit

The most complicated task is the approximation of the transfer function for the demands of the communication engineer.

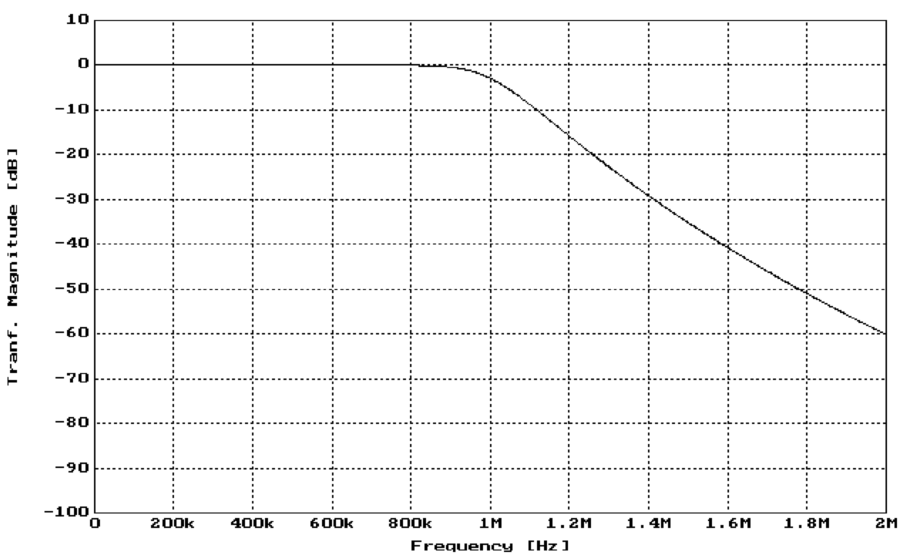
Now the most interesting features are described.

Standard Approximations

Standard approximations are commonly used by almost every filter design program. The following approximations are available for QuickFil:

Butterworth:

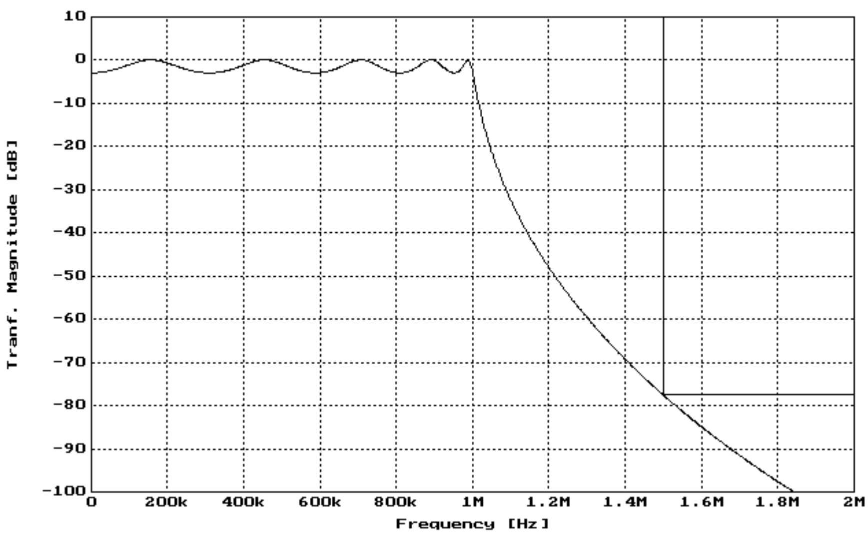
	SPECIFICATIONS to : Butterworth - lowpass filter		
(O)			
(A)	Passband edge frequency	:	1.000 000 MHz
(C)	Stopband edge frequency	:	2.000 000 MHz
(E)	Passband bandedge loss	:	3.000 000 dB
(F)	Passband bandedge return loss	:	3.02 dB
(R)	Passband reflection factor	:	70.63 %
(G)	Stopband loss	:	60.19 dB ◄
(H)	Filter degree	:	10
(J)	Variable value (A,C,E,F,G,H,R)	:	G
	3dB edge frequency	:	1.000 237 MHz
	Filter quality	:	3.20



Characteristics: maximally flat in the passband and monotonic in the stopband

Chebychev

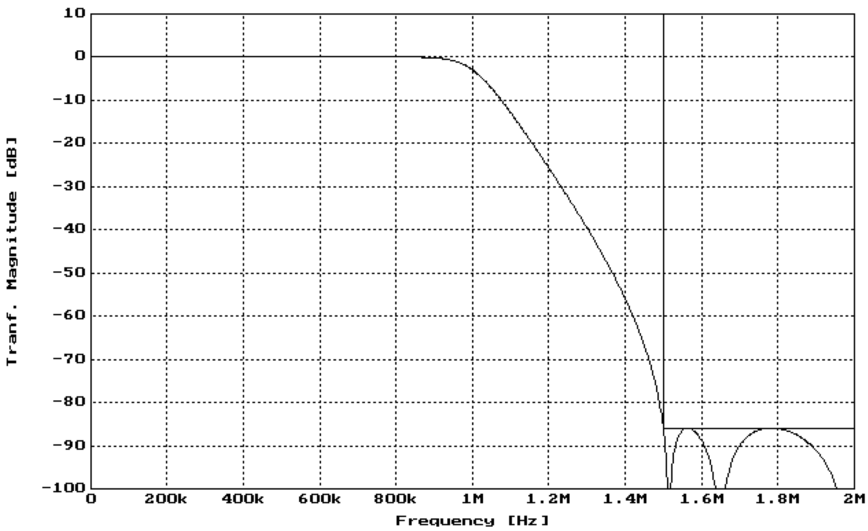
	SPECIFICATIONS to : Chebychev - lowpass filter		
(O)			
(A)	Passband edge frequency	:	1.000 000 MHz
(C)	Stopband edge frequency	:	1.500 000 MHz
(E)	Passband bandedge loss	:	3.000 000 dB
(F)	Passband bandedge return loss	:	3.02 dB
(R)	Passband reflection factor	:	70.63 %
(G)	Stopband loss	:	77.55 dB ◄
(H)	Filter degree	:	10
(I)	Case (b, c)	:	b
(J)	Variable value (A,C,E,F,G,H,R)	:	G
	3dB edge frequency	:	1.000 024 MHz
	Filter quality	:	35.85



Characteristics: equal ripple in the passband and monotonic in the stopband

Inverse Chebychev

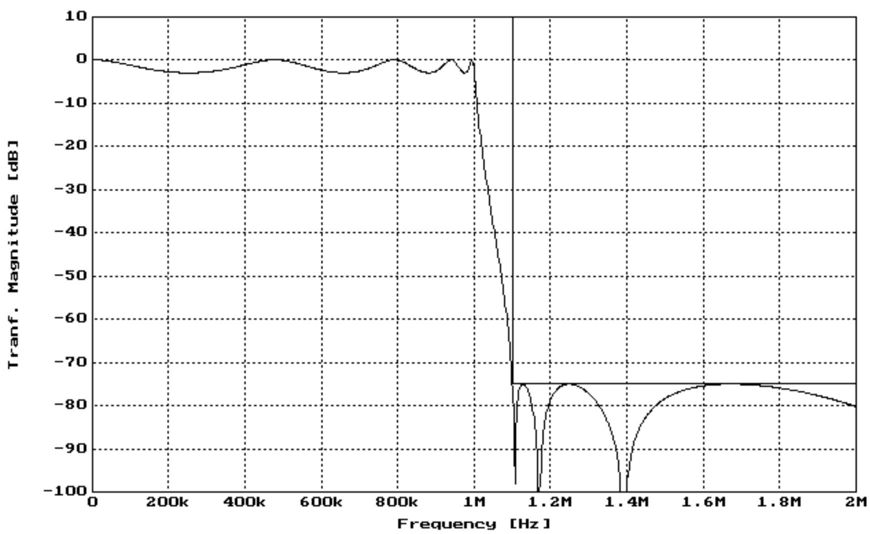
SPECIFICATIONS to : Inverse Chebychev - lowpass filter (O)			
(A)	Passband edge frequency	:	1.000 000 MHz
(C)	Stopband edge frequency	:	1.500 000 MHz
(E)	Passband bandedge loss	:	3.000 000 dB
(F)	Passband bandedge return loss	:	3.02 dB
(R)	Passband reflection factor	:	70.63 %
(G)	Stopband loss	:	77.55 dB ◄
(H)	Filter degree	:	10
(I)	Case (b, c)	:	b
(J)	Variable value (A,C,E,F,G,H,R)	:	G
	3dB edge frequency	:	1.000 024 MHz
	Filter quality	:	35.85



Characteristics: maximally flat in the passband and equal minima in the stopband

Elliptic (Cauer)

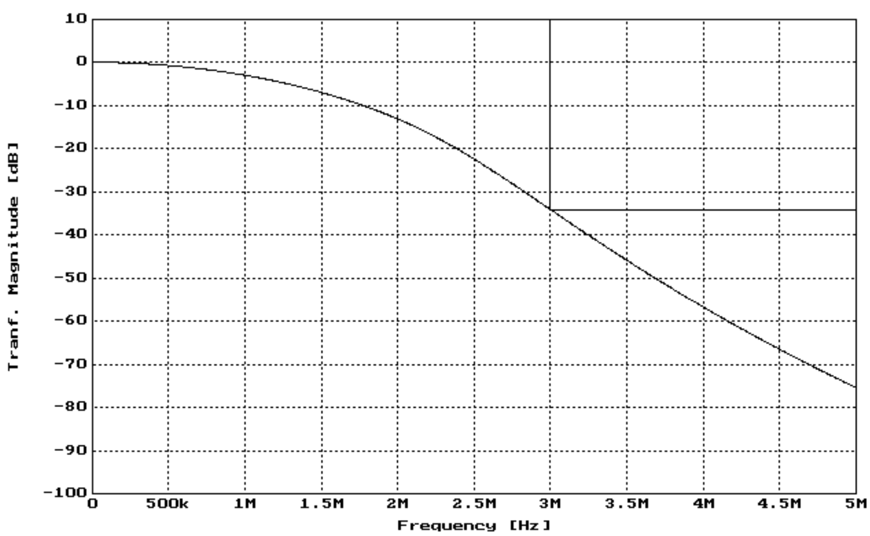
(O)	SPECIFICATIONS to : Elliptic (Cauer) - lowpass filter		
(A)	Passband edge frequency	:	1.000 000 MHz
(C)	Stopband edge frequency	:	1.100 000 MHz
(E)	Passband bandedge loss	:	3.000 000 dB
(F)	Passband bandedge return loss	:	3.02 dB
(R)	Passband reflection factor	:	70.63 %
(G)	Stopband loss	:	75.01 dB ◄
(H)	Filter degree	:	9
(I)	Case (a, b, c)	:	c
(J)	Variable value (A,C,E,F,G,H,R)	:	G
	3dB edge frequency	:	1.000 011 MHz
	Filter quality	:	74.92



Characteristics: equal ripple in the passband and equal minima in the stopband

Bessel

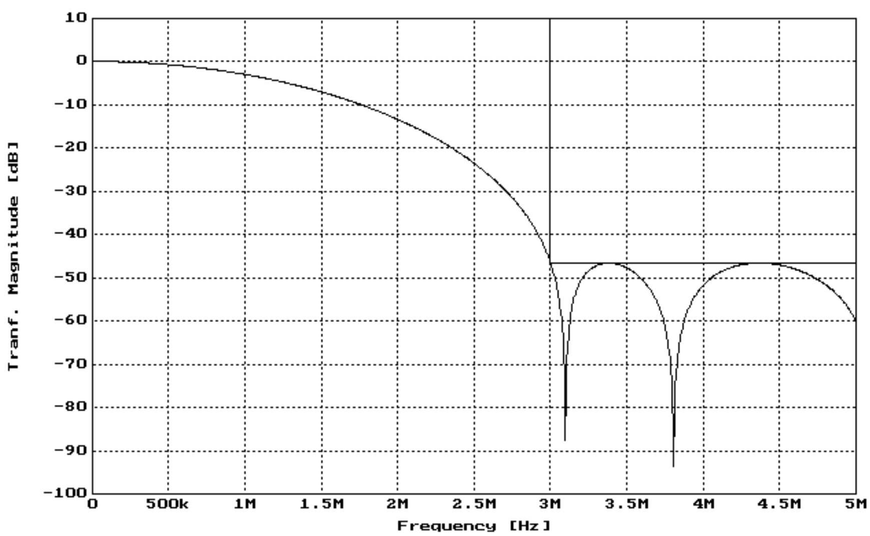
SPECIFICATIONS to: Bessel - Lowpass - Filter				
(O)				
(A)	3dB edge frequency	:	1.000 000 MHz	
(B)	Group delay at zero	:	571.522 302 ns	
(C)	Stopband edge frequency	:	3.000 000 MHz	
(D)	Stopband loss	:	34.15 dB	◄
(E)	Filter degree	:	10	
(G)	Variable value (A, C, D)	:	D	
	Filter quality	:	1.42	
	Frequency at 90% group delay	:	2.371 886 MHz	



Characteristics: maximally flat group delay and monotonic stopband

Modified Bessel

SPECIFICATIONS to: Modified Bessel - Lowpass - Filter				
(O)				
(A)	3dB edge frequency	:	1.000 000 MHz	
(B)	Group delay at zero	:	326.991 676 ns	
(C)	Stopband edge frequency	:	3.000 000 MHz	
(D)	Stopband loss	:	46.62 dB	◄
(E)	Filter degree	:	10	
(F)	Case (a, b)	:	b	
(G)	Variable value (A, C, D)	:	D	
	Filter quality	:	1.42	
	Frequency at 90% group delay	:	4.145 628 MHz	



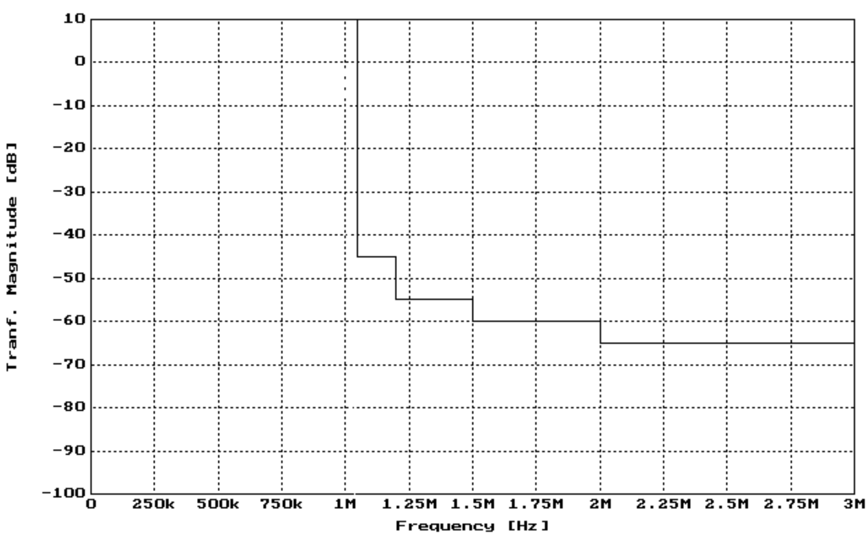
Characteristics: maximally flat group delay and equal minima stopband

General Amplitude Approximations

For the more sophisticated filter designer, there are two more general amplitude approximations available: the maximally flat and the equal ripple approximation for the passband. The stopband can be specified by the transmission zeros of the transfer function. Furthermore, there is an optimization algorithm included for placing the transmission zeros to optimal values. The user can define a step profile for the stopband loss and the optimization algorithm of QuickFil will place the finite transmission zeros in an optimal manner.

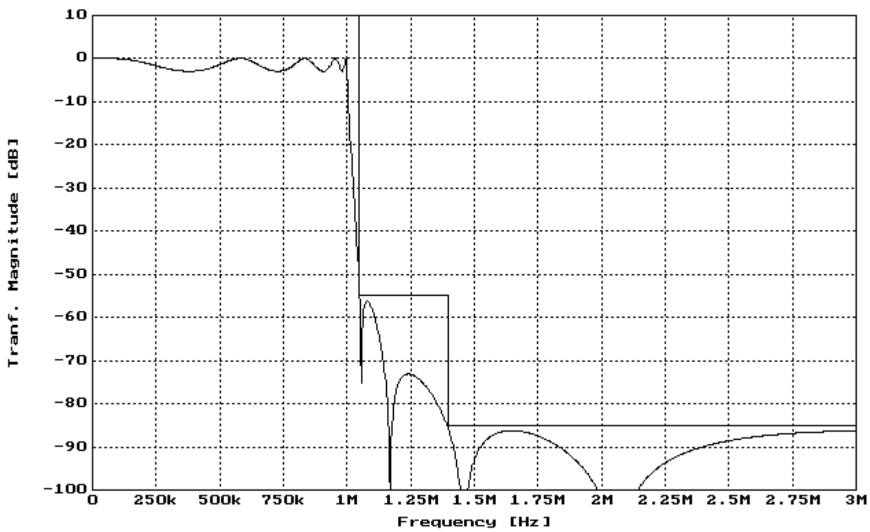
Stopband specifications

No.	Frequency range			Loss
1	1.050 000 MHz	to	1.200 000 MHz	45.00 dB
2	1.200 000 MHz	to	1.500 000 MHz	55.00 dB
3	1.500 000 MHz	to	2.000 000 MHz	60.00 dB
4	2.000 000 MHz	to	infinity	65.00 dB



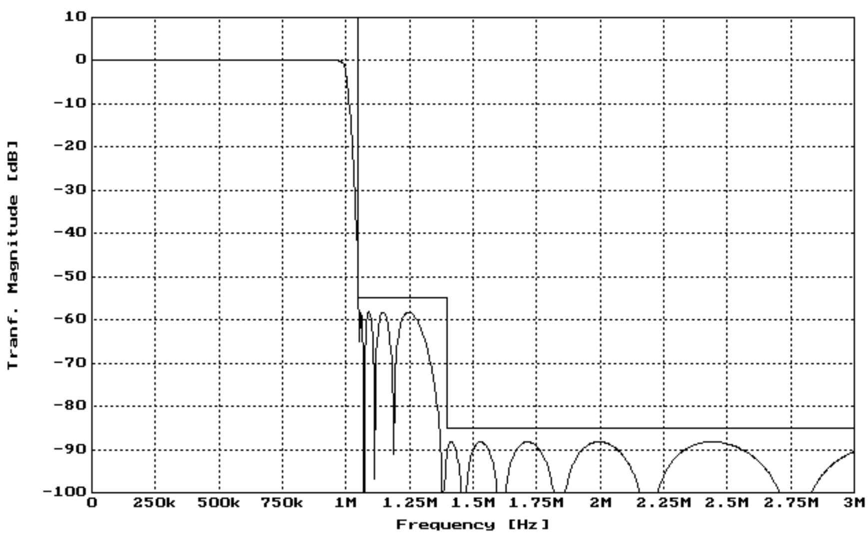
Equal Ripple Lowpass

(O)	SPECIFICATIONS to : Equal ripple - lowpass filter				
(A)	Passband edge frequency	:	1.000 000 MHz		
(E)	Passband bandedge loss	:	3.000 000 dB		
(F)	Passband bandedge return loss	:	3.02 dB		
(R)	Passband reflection factor	:	70.63 %		
	Transm. zeros at zero	: 0	Fixed transm. zero pairs:	0	
(H)	Transm. zeros at infinity	: 2	Var. transm. zero pairs:	4 opt.	
(V)	Loss at zero	:	0.000 000 dB		
(W)	Resistance ratio	:	1.000 000		
	Filter degree	:	10		
	3dB edge frequency	:	1.000 008 MHz		
	Filter quality	:	99.96		



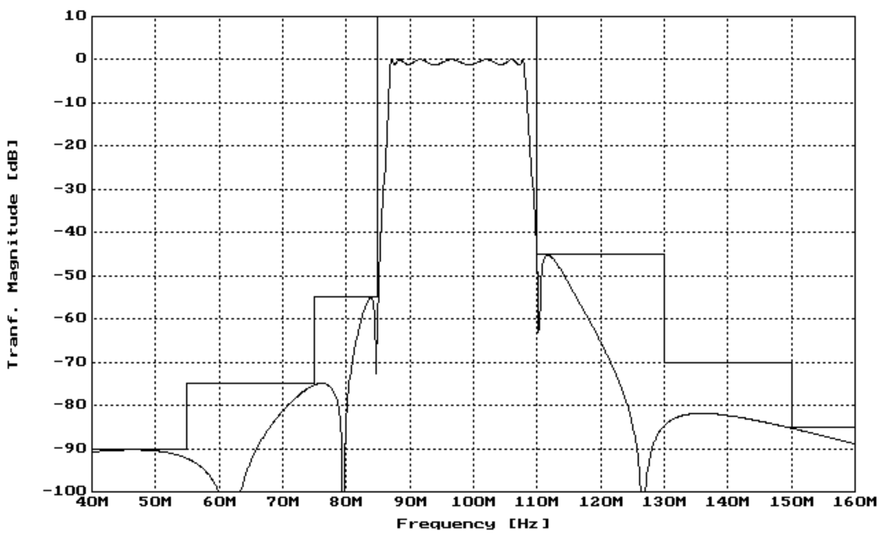
Maximally Flat Lowpass

	SPECIFICATIONS to :	Maximally flat - lowpass filter	
(O)			
(A)	Passband edge frequency	:	1.000 000 MHz
(E)	Passband bandedge loss	:	3.000 000 dB
(F)	Passband bandedge return loss	:	3.02 dB
(R)	Passband reflection factor	:	70.63 %
	Transm. zeros at zero : 0	Fixed transm. zero pairs: 0	
(H)	Transm. zeros at infinity : 2	Var. transm. zero pairs: 12 opt.	
	Filter degree	:	26
	3dB edge frequency	:	1.000 030 MHz
	Filter quality	:	24.84



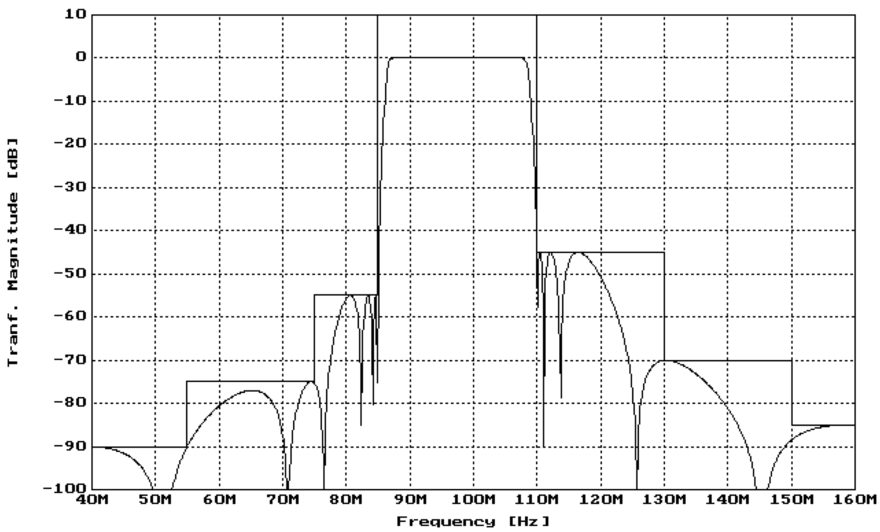
Equal Ripple Bandpass

(O)	SPECIFICATIONS to : Equal ripple - bandpass filter	
	Kind of bandpass :	conventional
(A)	Lower passband edge frequency :	87.000 000 MHz
(B)	Upper passband edge frequency :	108.000 000 MHz
(E)	Passband bandedge loss :	1.200 000 dB
(F)	Passband bandedge return loss :	6.17 dB
(R)	Passband reflection factor :	49.13 %
(G)	Transm. zeros at zero : 1	Fixed transm. zero pairs: 0
(H)	Transm. zeros at infinity : 1	Var. transm. zero pairs : 6 opt.
	Filter degree :	14
	Lower 3dB edge frequency :	86.920 469 MHz
	Upper 3dB edge frequency :	108.105 591 MHz
	Filter quality :	176.58



Maximally Flat Bandpass

(O)	SPECIFICATIONS to : Maximally flat - bandpass filter		
	Kind of bandpass	: conventional	
(A)	Lower passband edge frequency	: 87.000 000 MHz	
(B)	Upper passband edge frequency	: 108.000 000 MHz	
(E)	Passband bandedge loss	: 0.300 000 dB	
(F)	Passband bandedge return loss	: 11.76 dB	
(R)	Passband reflection factor	: 25.84 %	
(G)	Transm. zeros at zero	: 2	Fixed transm. zero pairs: 0
(H)	Transm. zeros at infinity	: 2	Var. transm. zero pairs : 12 opt.
	Filter degree	: 28	
	Lower 3dB edge frequency	: 86.487 081 MHz	
	Upper 3dB edge frequency	: 108.594 360 MHz	
	Filter quality	: 80.15	

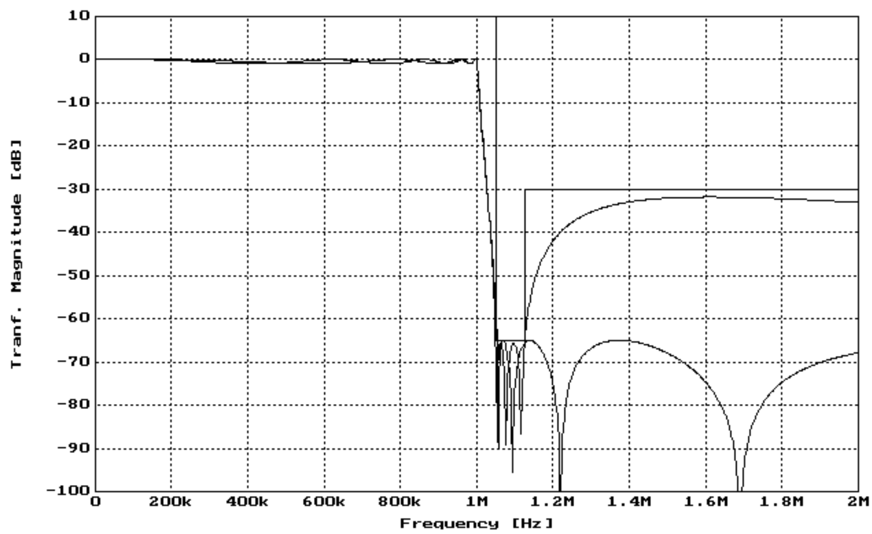


Reduction of the Number of Components

Standard approximations are optimal for the same minimum loss for the whole stopband. Sometimes a specific loss is demanded only for a short part of the stopband; for the rest of the stopband the filter is oversized.

Using the general amplitude approximations, the number of components can be reduced.

Example:



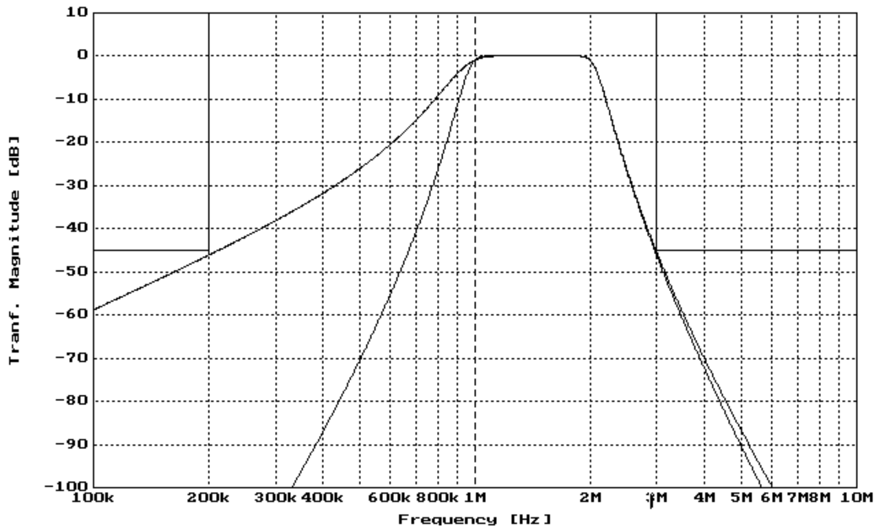
Elliptical lowpass: 10th degree

Equal ripple lowpass: 8th degree

Asymmetric Bandpass Filters

Different to the standard approximations, the number of transmission zeros at zero and at infinity can be different for the equal ripple approximation.

For some demands of the selectivity you can reduce the number of components using the general amplitude approximation instead of the standard approximations.



Effort:

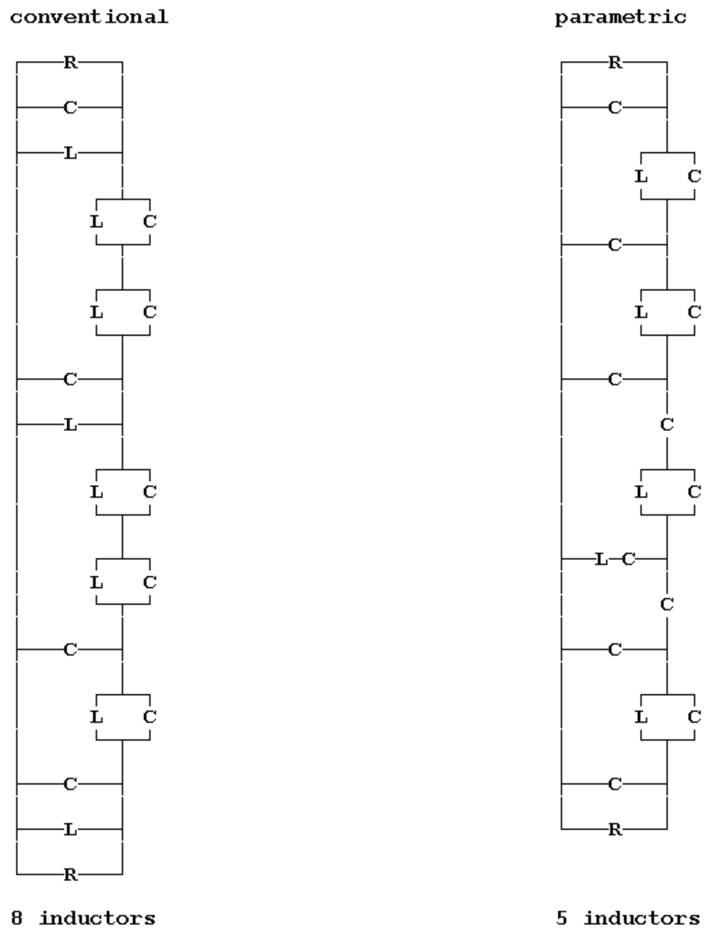
Butterworth bandpass filter, 14th degree

Maximally flat filter, 10th degree

Bandpass Filters with Minimum Number of Inductors

Using parametric bandpass filters, you can design filters with a minimum number of inductors. There is a free parameter, which has little influence on the transfer characteristic, but you can change some component values.

Parametric bandpass filters are part of the general amplitude approximations.



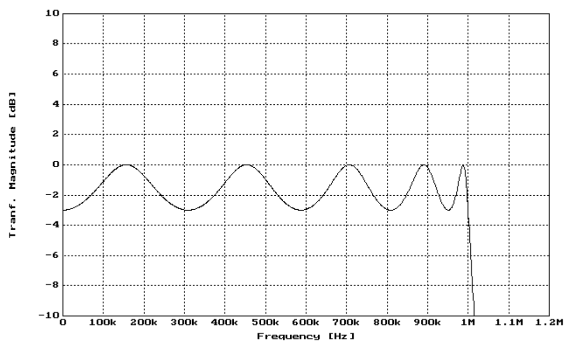
Terminating Resistance

For lowpass, highpass and bandstop filters, the ration of the termination resistance of the double terminated filter depends of the approximation. The ratio of the termination resistance is directly coupled with the loss at zero for the lowpass and the loss at infinity for the highpass.

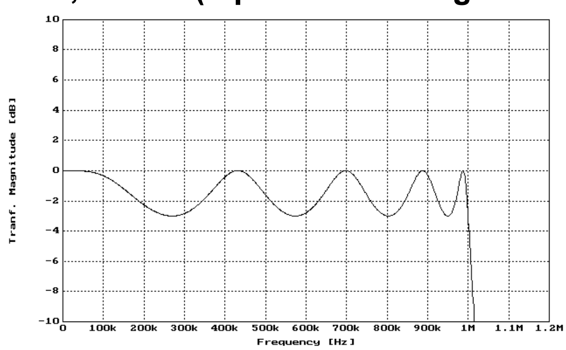
Terminating Resistance for Standard Approximations

The loss at zero for standard lowpass filters is zero for every odd degree filter, but for even degree filters there are differences for the Chebychev and the Elliptical filters. Using a special frequency transformation, the loss at zero can be changed, which is characterized by cases.

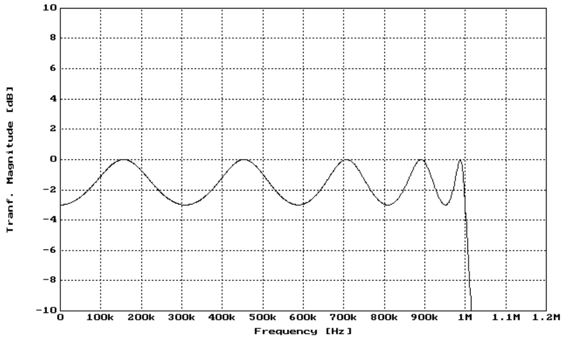
Chebychev filter, case b (optimal approximation)



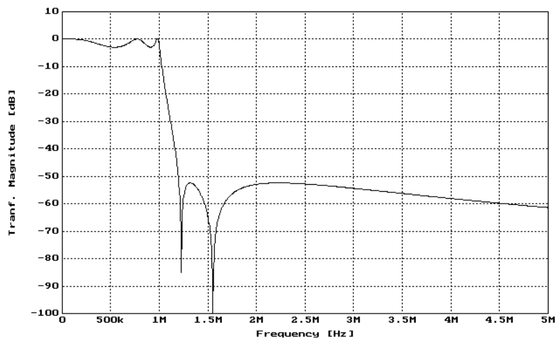
Chebychev filter, case c (equal terminating resistance)



Ellitic filter, case b



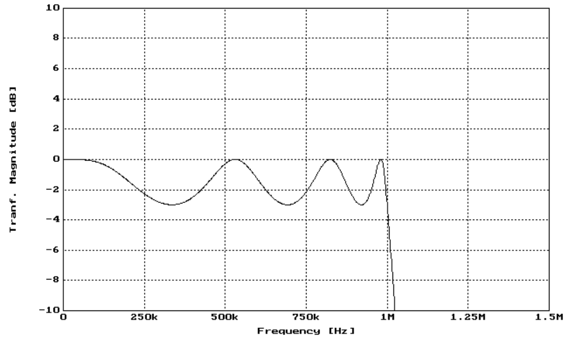
Elliptic filter, case c (equal terminating resistance)



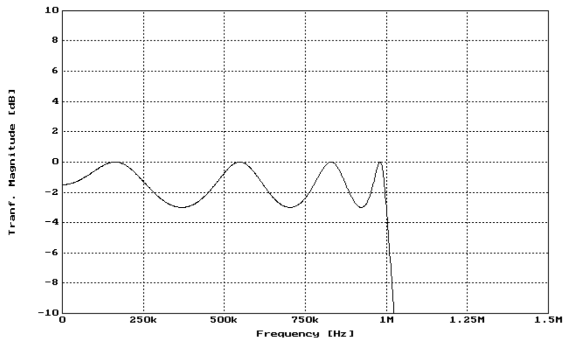
Terminating Resistance for General Amplitude Approximation

For maximally flat lowpass filters and for equal ripple lowpass filters of odd degree, the loss at the frequency zero is zero and therefore, the resistance ratio is one. But for equal ripple lowpass filters of even degree, the loss at the frequency zero is not zero and there is a special transformation available. The loss at the frequency zero or the resistance ratio can be chosen.

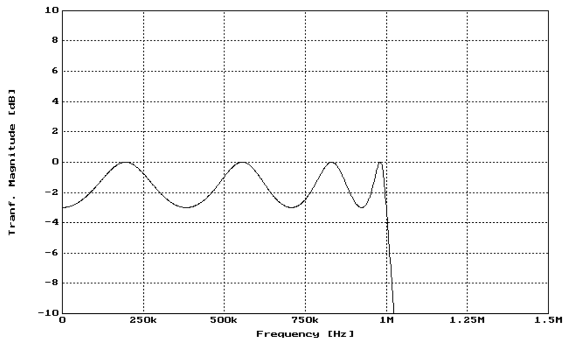
Equal ripple lowpass
loss at zero = 0



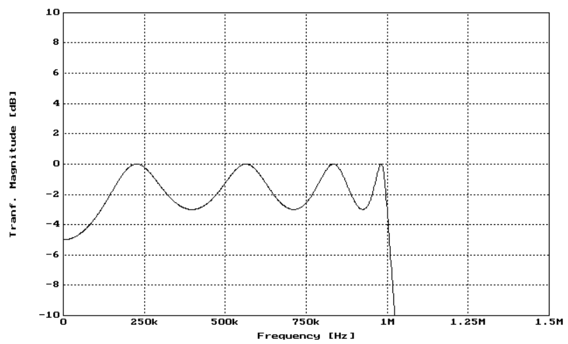
Equal ripple lowpass
loss at zero = 1.5dB



equal ripple lowpass
loss at zero = 3dB (optimal filter)



equal ripple lowpass
loss at zero = 5dB (for impedance transformations)



Group Delay Approximations

For many transmission systems the group delay of the transfer function is important. The requirements for the group delay is that it is flat. Normally the value of the group delay is not important.

Typically, the group delay demands are realized by an allpass filter, which is added to a filter or is a stand alone allpass filter. If the allpass is added to a filter, the requirements for the group delay corresponds to the combination of the filter and the allpass filter.

For the approximation of the group delay QuickFil uses least-p optimization. An error norm for the error function is defined:

$$\|f(x)\|_p = \left[\frac{1}{x_B - x_A}\int_{x_A}^{x_B} |f(x)|^p \, dx\right]^{\frac{1}{p}}$$

The norm is defined in the interval [x_A, x_B] and has a further parameter, the exponent p. If the parameter p tends to infinity the norm will converge to the max norm.

$$\|f(x)\|_\infty = max_{x_A \le x \le x_B} |f(x)|$$

The user can define a specific curve for the group delay and can specify the number of transmission zeros. Afterwards the transmission zeros are initialized and the user can optimize the position of the transmission zeros.

Furthermore the user can choose the main delay time as a further parameter of the optimization, since the value of the group delay is not important, only the flatness of the group delay is considered.

After determining the transfer function of the allpass filter, QuickFil will calculate an allpass circuit consisting of partial allpass circuits cascaded.

Example:

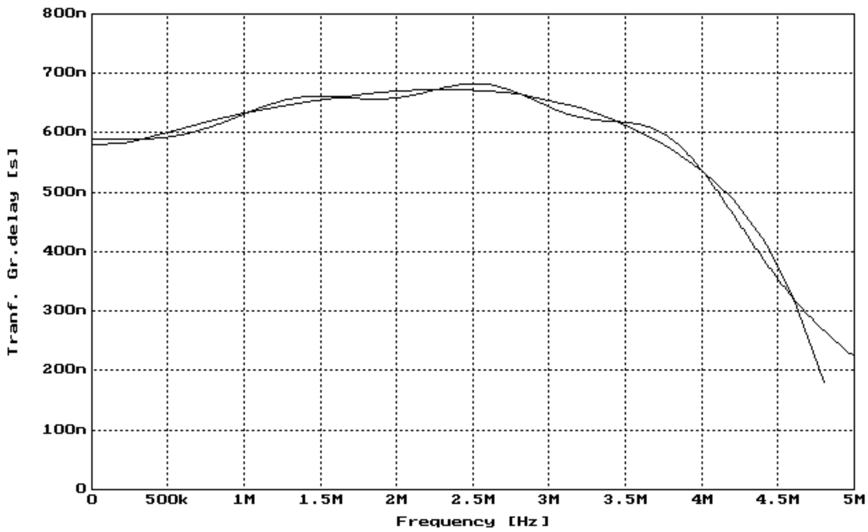
```
                              Allpass

(A)  Lower frequency bound (proposal:      not defined):    0.000 000  Hz
(B)  Upper frequency bound (proposal:      not defined):    4.800 000 MHz

(C)  Filter degree         (proposal:               7):                7
(D)  Exponent p                                        :                2
(E)  Number of points                                  :               50

(F)  Main delay time (Tg0)                             :   580.208 788 ns

     Original group delay difference                   :   494.202 041 ns
     Group delay difference with correction            :   122.079 976 ns
     Error norm                                        :    18.009 583 ns
                                                                optimized
     With optimization of main delay time              :              Yes
     With group delay specifications                   :              Yes
```



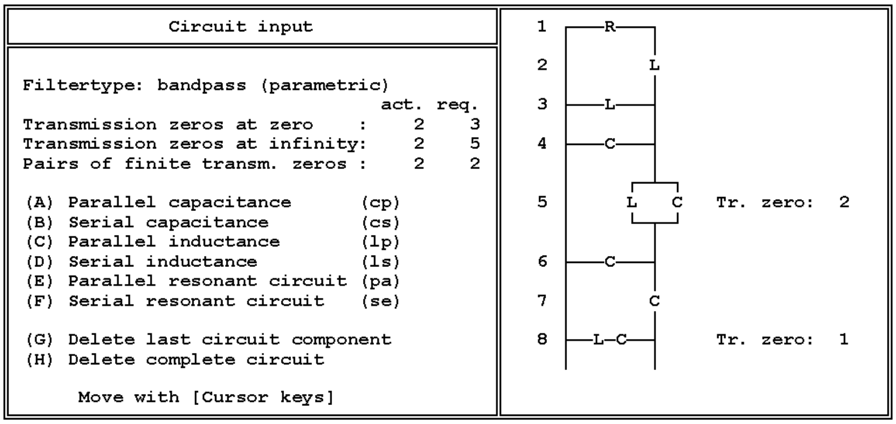
Specifying a Ladder Circuit

There are two possibilities to specify the passive circuit:

Defining a Circuit for a Transfer Function

The synthesis of the passive circuit for a specified transfer function is not unique, there is some freedom to choose a circuit out of all possible circuits for that transfer function. For the best support of the customer, QuickFil offers all possible circuits and the user can choose his circuit.

To specify a circuit, you can choose subcircuits step by step and all these subcircuits are cascaded to build the whole ladder circuit:

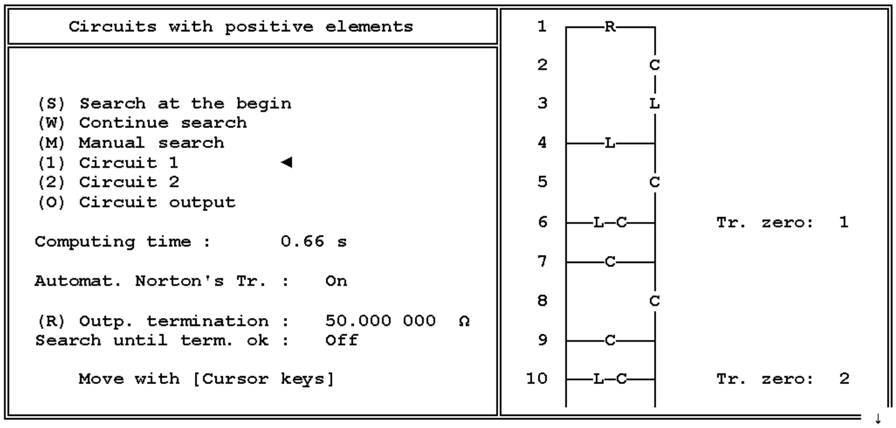


QuickFil will control the possible subcircuits, and the user can only choose some of the available subcircuits in each step. Furthermore the number of realized transmission zero of the circuit and the number of transmission zeros of the transfer function are indicated.

Searching a Circuit with Positive Elements

Since there is no guarantee for passive ladder filters, that there is any realizable circuit for any transfer function, a search algorithm is implemented to find a circuit, which has positive element values only and is realizable in reality.

This search algorithm will search systematically for circuits, which have positive elements only.



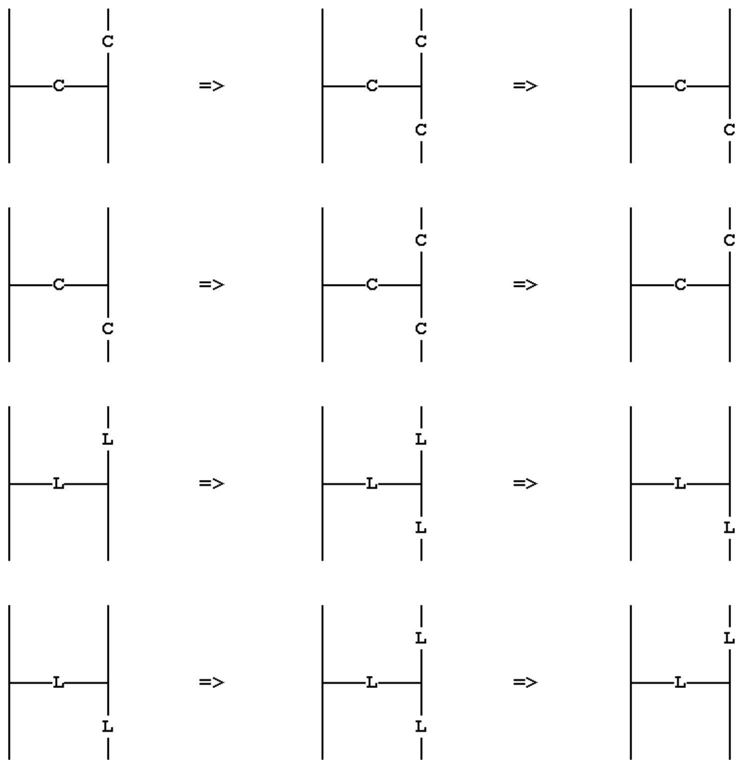
Using this feature you will get one or more possible circuits and you can choose the best one for the realization of the hardware.

Norton’s Transformation

For bandpass filters there is a very effective circuit transformation available, called Norton’s transformation. Using Norton’s transformation, you can change the element values to a specific value, without any change of the transfer function.

Here are examples of simple Norton’s transformations:

before transformation after normal transformation after max, min transformation



Using Norton’s transformation you can get circuits, which will have equal inductors, and the realization will be cheaper, because you need produce only one type of coil.

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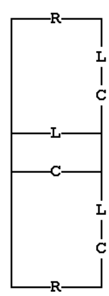
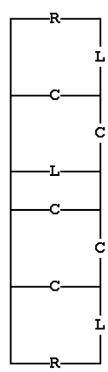
```
              SPECIFICATIONS to :  Chebychev - bandpass filter
 (O)

 (A)  Lower passband edge frequency      :            8.000 000 MHz
 (B)  Upper passband edge frequency      :           10.000 000 MHz
 (C)  Lower stopband edge frequency      :            7.000 000 MHz
 (D)  Upper stopband edge frequency      :           11.428 571 MHz

 (E)  Passband bandedge loss             :             0.457 575 dB
 (F)  Passband bandedge return loss      :                10.00 dB
 (R)  Passband reflection factor         :                31.62 %
 (G)  Stopband loss                      :                21.80 dB   ◄

 (H)  Filter degree                      :                    6
 (I)  Case                       (b, c)  :                    b
 (J)  Variable value (A,B,C,D,E,F,G,H,R) :                    G

      Lower 3dB edge frequency           :            7.843 816 MHz
      Upper 3dB edge frequency           :           10.199 117 MHz
      Filter quality                     :                13.98
```

You will get following circuit:



1	R	50.000 000 Ω
2	L	6.178 808 µH
3	C	51.244 301 pF
4	L	179.908 027 nH
5	C	1.759 948 nF
6	L	6.178 808 µH
7	C	51.244 301 pF
8	R	50.000 000 Ω

Using Norton's transformation for equal inductors you will get:



1	R	50.000 000 Ω
2	L	6.178 808 µH
3	C	42.500 133 pF
4	C	8.744 168 pF
5	L	6.178 808 µH
6	C	36.740 120 pF
7	C	8.744 168 pF
8	C	42.500 133 pF
9	L	6.178 808 µH
10	R	50.000 000 Ω

Numerical Accuracy

The evaluation of the component values of a passive ladder filter is numerically very ill-conditioned and the element values will be like random numbers if the degree of the filter is very high.

For QuickFil, there are no numerical problems for the calculation of high order filters, since QuickFil uses multiple precision arithmetic for the circuit extraction process. The user can specify the number of digits in the range of 24 decimal digits up to 120 decimal digits.

Example of a 18th degree Bessel lowpass

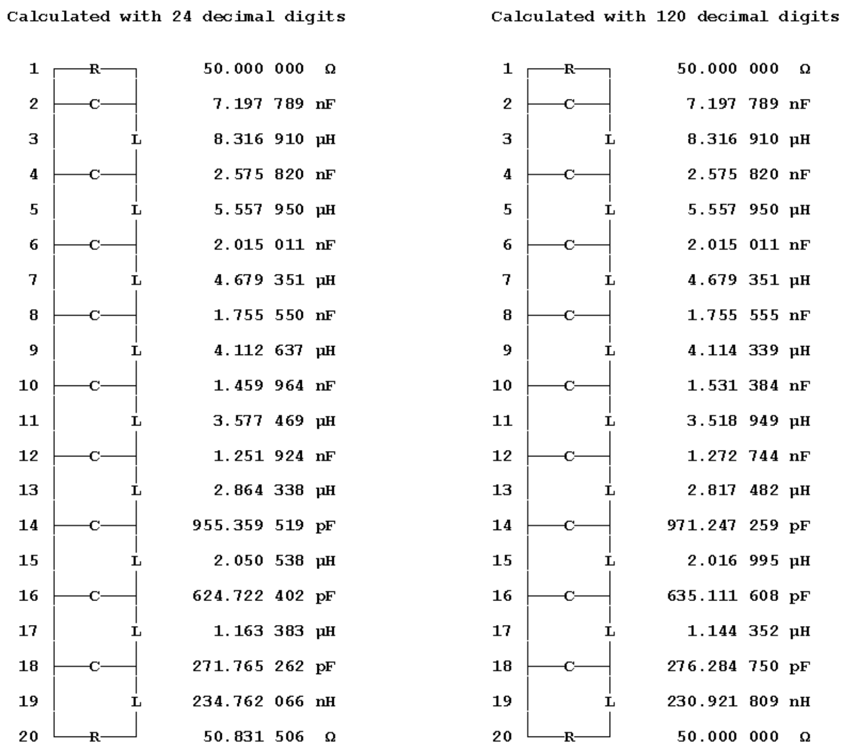
SPECIFICATIONS to: Bessel - Lowpass - Filter			
(O)			
(A)	3dB edge frequency	:	1.000 000 MHz
(B)	Group delay at zero	:	779.746 159 ns
(C)	Stopband edge frequency	:	3.000 000 MHz
(D)	Stopband loss	:	30.60 dB ◄
(E)	Filter degree	:	18
(G)	Variable value (A, C, D)	:	D
	Filter quality	:	2.09
	Frequency at 90% group delay	:	3.335 687 MHz

For that filter specifications a passive ladder circuit is designed:

- for minimum accuracy of 24 decimal digits
- for maximal accuracy of 120 decimal digits

The first example is very inaccurate and there is a message at the begin of the circuit:

```
***   The circuit calculation is inaccurate!   ***
```



The circuit is calculated using the input and the output reactance and the two circuits are compared. If there is a big difference there will be an indication that the calculation accuracy is bad.

Normally the IEEE numbers will have:

- 7 decimal digits (single precision)
- 14 decimal digits (double precision)
- 19 decimal digits (extended precision)

For QuickFil, the minimum accuracy is 24 decimal digits. Therefore the circuits will be much more accurate for high order filters.