

Lowpass-like Bandpass Filters

By George Szentirmai

This brief note presents some extensions to the design of bandpass filters that look like lowpass ones.

Introduction

Dr. Ralph Levy in a paper [1] described a method to design bandpass filters that look like lowpass ones, and have equal terminations. His method works for odd degree filters and he provided a short table for various degrees, bandwidths and passband loss ripple values. His method provides a closed form solution but relies on computing some esoteric functions leading to a fairly complicated design procedure.

Here, I present a different method, based on iterative optimization, that is easy to implement, works for both even and odd degree functions and can also be extended in other directions. The procedure is now part of the S/Filsyn [2] design program. This note will provide a brief description of the method and illustrate it with a pair of examples beyond the capability of Levy's technique.

Theory

The overall transfer function $H(s)$ of the complex frequency variable 's' can be written as:

$$H(s)H(-s) = 1.0/(1.0 + K(s)K(-s))$$

where the characteristic function $K(s)$ in this case is of the form:

$$K(s) = K_0 s^m \prod_i (s_2 + x_i^2)$$

For our purposes, m can take on the values of one or two and all the x_i values must be in the filter's passband. Normalizing the frequency to the upper passband edge and denoting the ratio of the lower passband edge to the upper:

$$\alpha = f_a/f_b < 1.0$$

the values x_i must be in the range:

$$\alpha < x_i < 1.0$$

If we start with a more or less even distribution of the x_i values in this range, it is easy to find the maximum points of the polynomial $K(s)$ magnitude in the passband between the zeros. Then we just need to devise an algorithm that adjusts the locations of these zeros until the values of all extrema become equal.

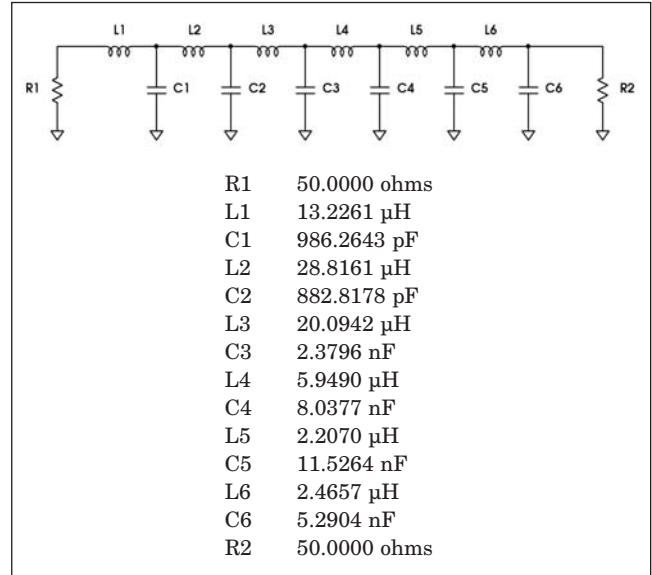


Figure 1 · Lowpass-like bandpass filter with equal-ripple passband.

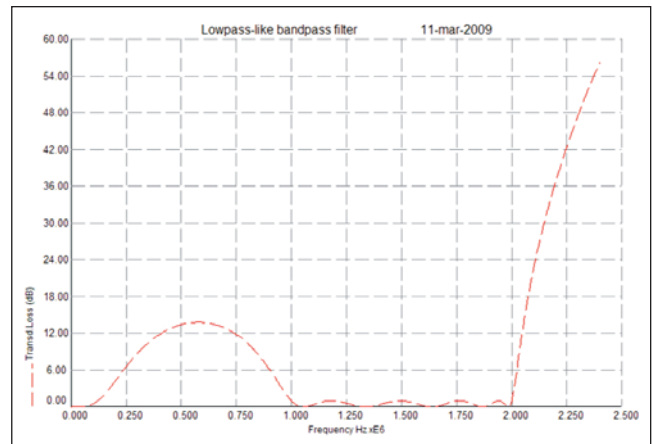


Figure 2 · Computed loss characteristics of equal-ripple passband filter.

Standard routines are readily available for such an operation and in fact, S/Filsyn already contains one for the generation of lowpass filters with equal ripple delay.

Examples

Having developed such a routine, we wish to demonstrate the results. To start, we design a bandpass filter of degree 12 with a passband from 1 MHz to 2 MHz with a 1 dB equal ripple passband behavior. The resulting circuit with element values is shown in Figure 1.

Frequency domain analysis then confirms that this

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filter is indeed the one we requested (Figure 2).

In order to extend the capabilities presented here even further, we included the option of having a maximally flat type of passband as well. This is very simple, since it means that all the x_i values will be the same and this value can be easily computed from the requirement that the loss should be the same at the two passband edge frequencies, yielding a closed form solution:

$$x_0^2 = (1 + \alpha^{(2+m/n)}) / (1 + \alpha^{m/n})$$

where the overall degree is:

$$\text{degree} = 2n + m$$

Consider therefore the same set of requirements, except that the degree is required to be 11 and the passband is maximally flat. The resulting circuit is shown in Figure 3.

The subsequent analysis again confirms the correctness of this design (Figure 4).

The program can handle filter degrees from 5 (the minimum) to about 20 and can also handle an output termination of zero in order to facilitate the usage of such filters in multiplexers.

While the lower stopband of these filters is out of our control, the upper stopband loss is steeper than that of a pure lowpass of the same degree would be.

As a final comment please note that, as Dr. Levy has explained, there is a lower limit for the value of α beyond which the process does not work and this is true for both types of passband behavior. In S/Filsyn, if we request a value below the limit, the program prints an advisory message.

References

1. R. Levy, "Characteristics and Element Values of Equally Terminated Achieser-Zolotarev Quasi-Low-Pass Filters," *IEEE Trans. on Circuit Theory*, Vol. CT-18, No. 5, Sept. 1971, pp. 538-544.
2. G. Szentirmai, "FILSYN—A General Purpose Filter Synthesis Program," *Proc. IEEE*, Vol. 65 Oct. 1977 pp. 1443-1458.

About the Author

George Szentirmai has an MS ('51) degree from the Technical University of Budapest, a Candidate of the Technical Sciences ('55) degree from the Hungarian Academy of Sciences and a Ph.D. ('63) from the Polytechnic Institute of Brooklyn, all in Electrical Engineering. Dr. Szentirmai has been very active in the IEEE Circuits and Systems Society's work over the

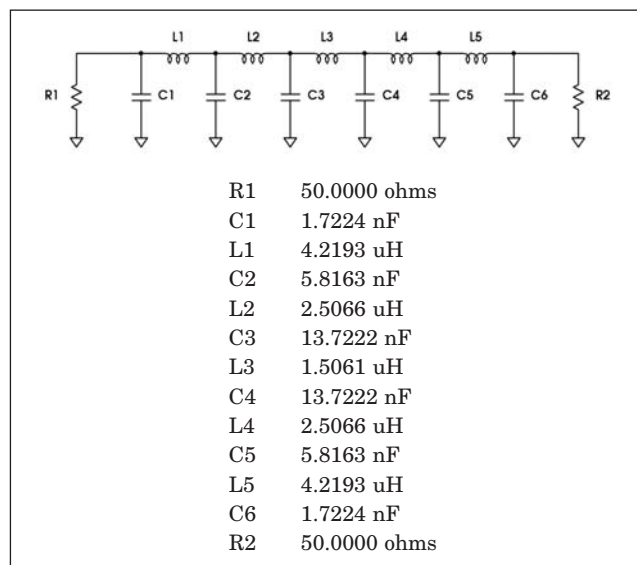


Figure 3 · Lowpass-like bandpass filter with maximally flat passband.

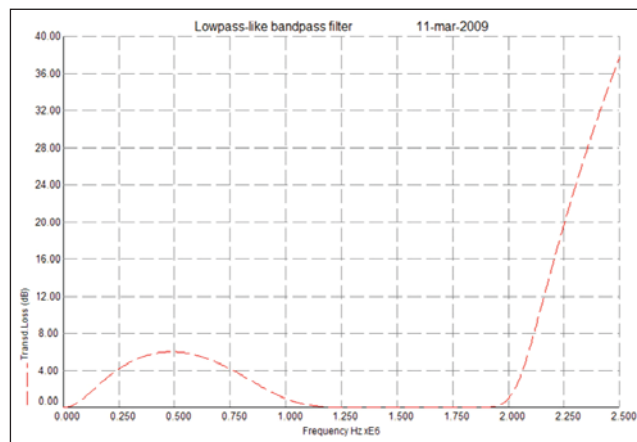


Figure 4 · Computed loss characteristics of maximally-flat passband filter.

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