

# An Analog Filter Design Software Package Using Mathematica

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## ABSTRACT

In this paper a software package used to design analog filters is described. This filter design tool uses Mathematica from Wolfram Research as the numerical engine. This is called MathFilters. With this package, students or practicing engineers should be able to do an analog filter design in a few seconds, giving more attention to what it can be done with a filter instead of getting lost in endless cumbersome numerical calculations. Several examples showing how MathFilters works are included. This package runs on an IBM-compatible PC under Windows 95 with Mathematica 3.0.

## INTRODUCTION

Electric filters have a relevant importance in electronic systems because they are present in almost any system [1]. For example, communicating systems make intensive use of filtering to separate unwanted noise from the desired signal. Power supplies use filters to reject ripple and improve the dc signal quality. Audio equalizers use filters to amplify or attenuate bands in the audio range to improve audio quality depending upon room acoustical characteristics. Digital

video needs digital filters to reduce noise due to coding and transmission through a noisy channel.

Filter design is an intensive computational task requiring a significant amount of numerical calculations to obtain either the parameters of a filter transfer function or the element values for a filter circuit realization.

On the other hand, computer usage has reached every corner in everyday life. Thus, computer software development has become an important part of technological development. An area that has been most influenced by this development is education. Nowadays, there exists a large number of software packages especially dedicated to filter design, but they have several drawbacks. One of the most important is that those packages have a very high price.

This article describes a software package whose purpose is to provide a tool to be used as a teaching aid in analog filter design courses. The feature of this package is that it uses Mathematica [2] for the numerical computations.

There are several advantages in having a tool similar to the one described in this article. First, it takes care of all the cumbersome calculations which do not

provide insight into the solution of the problem. Second, it allows students to design a complete filter from specifications by only giving the input data required and selecting the desired output data.

## MATHFILTERS

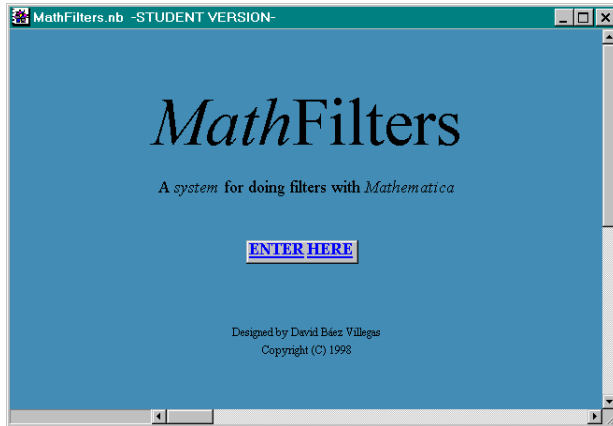


Fig. 1 MathFilters main window

MathFilters is capable of handling the two fundamental problems of filter design: approximation and synthesis. The available magnitude approximation include Butterworth, Chebyshev, Inverse Chebyshev, Elliptic and Thomson. For synthesis of the network, MathFilters has the capability of obtaining either the passive ladder circuit or a cascade of second order stages (for an odd order there is a first-order stage) where the user has freedom to choose from a number of different configurations such as Sallen-Key, multiple feedback, state variable KHN, Tow-Thomas and the GIC based biquad. Figure 1 is the presentation window.

## THEORETICAL BACKGROUND

## Mathematica 3.0

Mathematica is a relatively new software designed for technical computations. Produced by Wolfram Research, it first appeared in 1988. Since then, it has become an important tool for engineers, scientists, etc. [2,3].

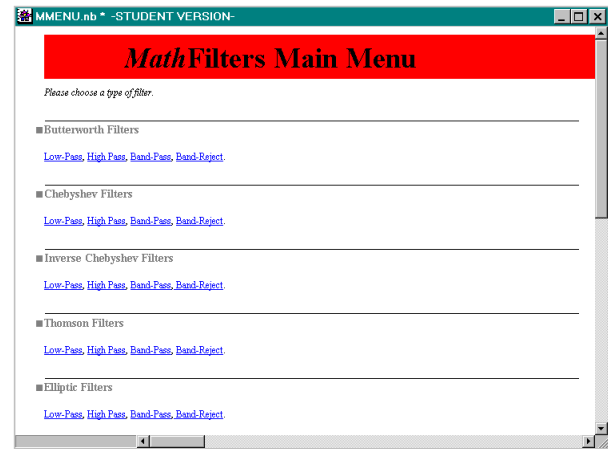


Fig. 2 MathFilters main menu

## Approximation Techniques

The approximation techniques used in MathFilters are the ones available almost in any filter design course, that is, Butterworth, Chebyshev, Inverse Chebyshev, Elliptic and Thomson. These approximation characteristics were chosen because they are some of the most commonly used in textbooks dedicated to analog filter design and also in applications in industry. Figure 2 shows the main window for MathFilters. Figure 3 shows the input window to enter data for a lowpass Butterworth filter.

## Spectral Transformations

Calculations are first done for lowpass filters. Spectral transformations are used to obtain the desired parameters for highpass, bandpass, and bandreject filters.

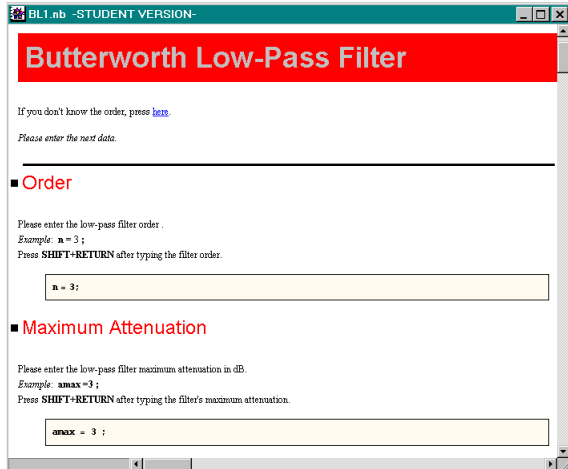


Fig. 3 Input window for a lowpass butterworth filter

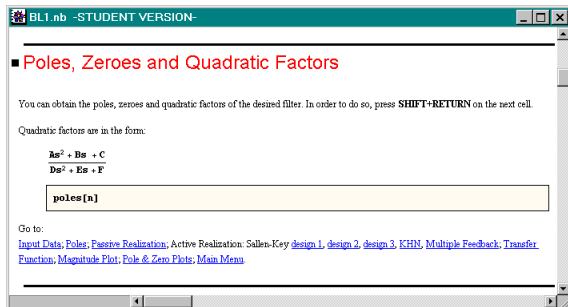


Fig. 4 Here the poles, zeroes and quadratic factors can be obtained.

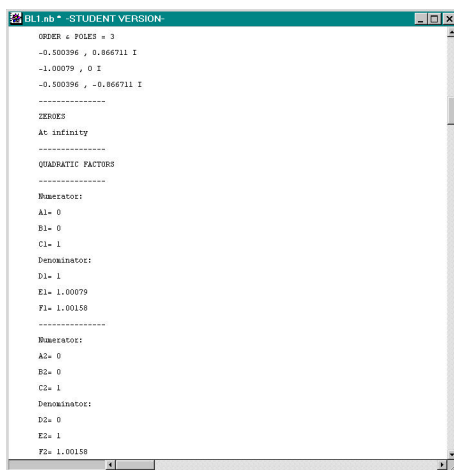


Fig. 5 Output windows for the poles of a lowpass butterworth filter.

## Passive Filters

Passive Filter design is available for Butterworth, Chebyshev, Elliptic and

Thomson filters. The topology obtained is the ladder one.

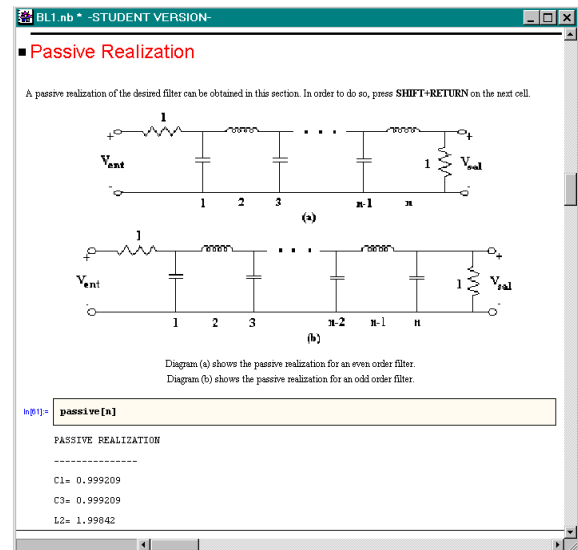


Fig. 6 Passive realization window.

## Active Filters

The cascade approach is used for active filter design. There are several available topologies for the biquad stages: Sallen-Key, multiple feedback and state variable KHN and Tow-Thomas stages as well as the GIC-based biquad.

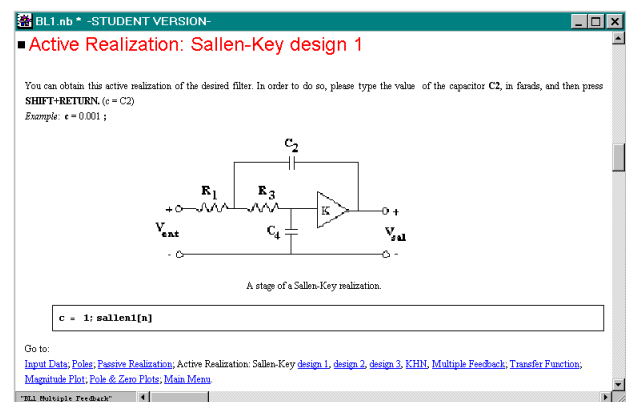


Fig. 7 Input window for an active design Sallen-Key design 1.

## Transfer Function Data

It is possible to obtain poles, zeroes and quadratic factors, and the numerator and denominator polynomials for the transfer function. Magnitude, phase, and group delay plots, as well as a pole and zero plots can be obtained. Figs. 8, 9, and 10 show typical windows. Figs. 11 and 12 show an example for a 10<sup>th</sup> order Chebyshev bandreject filter.

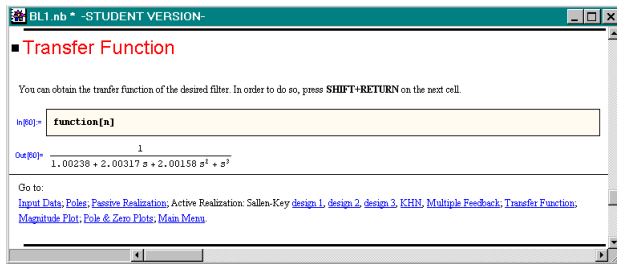


Fig. 8 Transfer function window.

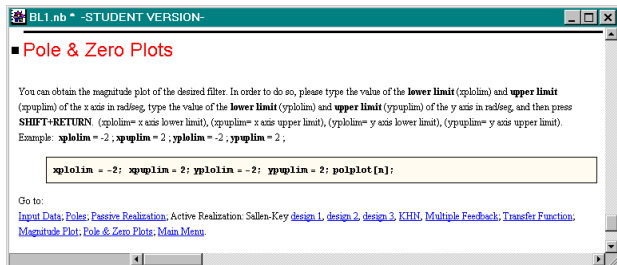


Fig. 9 Pole & Zero Plot window.

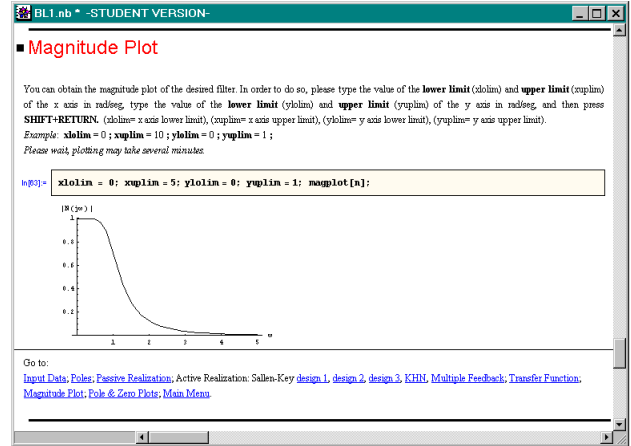


Fig. 10 Magnitude plot window.

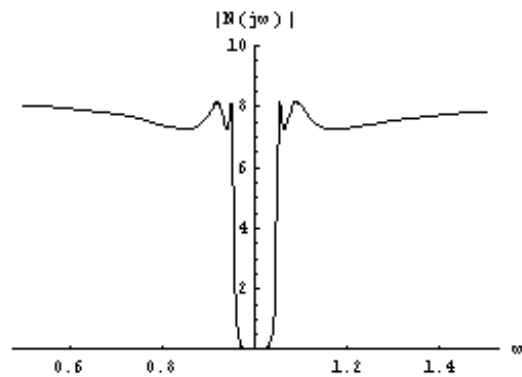
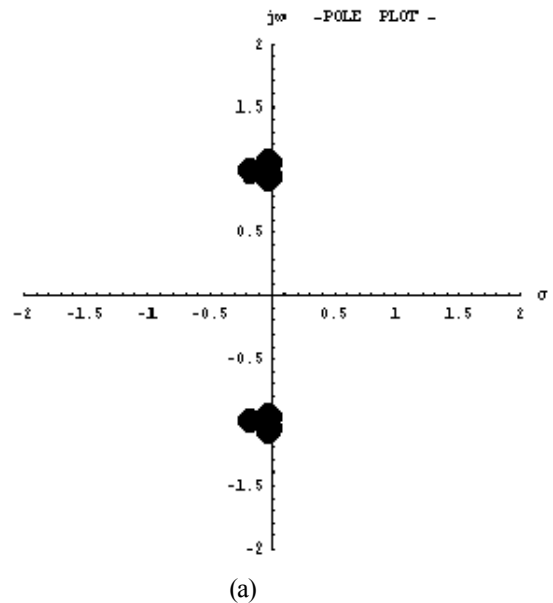
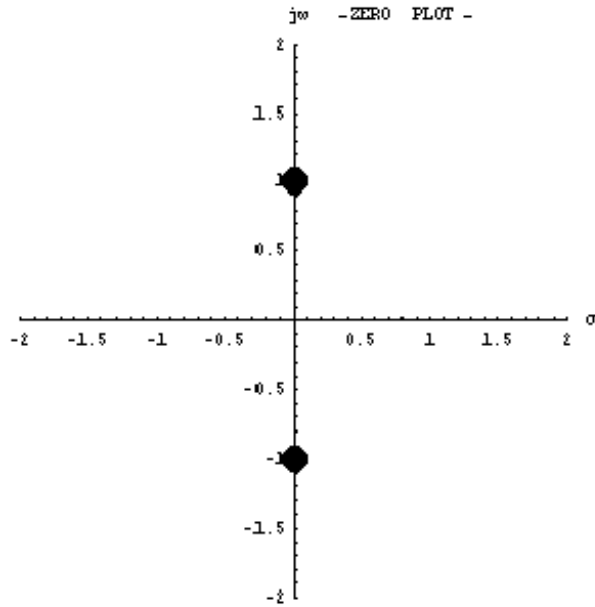


Fig. 11. Example showing the magnitude for a 10<sup>th</sup> order bandreject Chebyshev filter.



(a)



(b)

Fig. 12. Pole and zero plots for the bandreject Chebyshev filter.

## CONCLUSIONS

In this article we presented a description of a software package that can be used to design analog filters that is named MathFilters. This package can be used in the classroom or by practicing engineers. It is user friendly and can be used with any IBM-compatible computer with Windows 95 and Mathematica 3.0. Examples showed the main characteristics of MathFilters.

## REFERENCES

- [1] L. P. Huelsman; *Active and Passive Analog Filter Design*; Mc Graw Hill; 1993.
- [2] S. Wolfram, *The Mathematica Book*; Cambridge Press; 1996.
- [3] J. Gray, *Mastering Mathematica*; AP Professional; 1994.