BOOK REVIEW:
FILTER DESIGN FOR SIGNAL PROCESSING
Using **MATLAB** *and Mathematica*

Miroslav D. Lutovac, Dejan V. Tošić, and Brian L. Evans

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IN GENERAL ABOUT THE BOOK

This book is addressed to the mathematician, scientist or engineer interested in filter theory and design. The book is also addressed to educators who wish to integrate their curriculum with computer -based learning tools. In an exceptional way, the authors incorporate the modern powerful software packages such as **MATLAB** and *Mathematica* into fundamental filter theory. Those interested in sophisticated filter theory will find profound interpretation of filter approximation methods with latest developments in the accurate replacements of Jacobi elliptic functions with functions comprising polynomials, square roots, and algorithms. Filter designers and researchers will discover a new and comprehensive design approach. Instead to present only one solution for a given set of specifications, this book develops alternative techniques and software to produce a set of designs that meet the specifications. The appropriate design may be chosen according to the additional criteria such as minimal passband ripple, maximal stopband attenuation, transition bandwidth, minimal Q factors of the transfer function poles, minimal coefficient sensitivity. Thus, the designer can search for the optimum solution regarding the target technology.

The book presents theory and problem-solving skills for contemporary analog and digital IIR filter design, and overcomes the gap between filter theory and practice. The book includes ready-to-use filter design algorithms and implementations in both **MATLAB** and *Mathematica*. In order to make the material accessible to both practitioner and researcher, authors divide the book into two parts. Part I reviews conventional filter design technique, presents several new ready-to-use algorithms, and discusses many case studies. The case studies present filters that cannot be designed with conventional techniques but can be designed with advanced methods. Part II discusses the theory underlying the new advanced design methods. The book also contains appendices to show examples of using advanced filter design software in **MATLAB** and *Mathematica* and it includes filter design problems for the reader to solve.

The primary benefit of this book is convenient access to the latest advances in algorithms and software for analog and digital IIR filter design. These advanced techniques can design many types of filters that conventional techniques cannot design. A secondary benefit is a large collection of case studies for filter designs that require advanced techniques. Another benefit is a unique treatment of elliptic function filter.

CHAPTER CONTENT

The book is divided in 13 chapters.

Chapter 1 presents an overview of basic classes of continuous-time and discrete-time signals. The mathematical representation of signals is discussed. Two computer environments, **MATLAB** and *Mathematica*, are introduced and used to analyze and process signals.

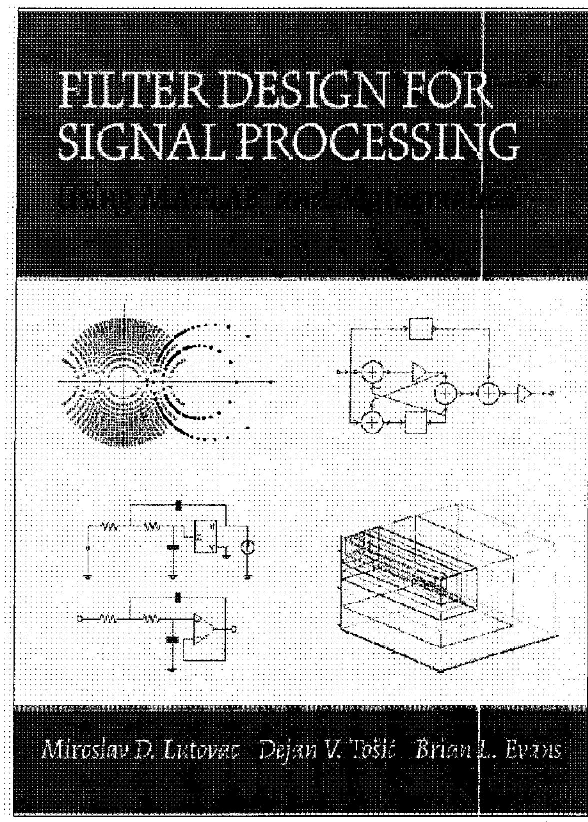

Fig. 1. - Cover page of the book

In **Chapter 2**, the fundamentals of linear system theory are introduced, and basic system properties are defined.

Chapter 3 is intended to review the most important transforms required by the filter design studied in this book. The focus is on the phasor transformation, Fourier series and harmonic analysis, Fourier transformation, Laplace transformation, discrete Fourier transformation, and *z* transformation.

In **Chapter 4**, the basics of analog filter design are reviewed. Classification, salient properties and sensitivity of transfer functions are given. The most important analog filter realizations are presented. A detailed case study is given for realization of various transfer functions.

Chapter 5 reviews basic definitions of analog filter design. It introduces straightforward procedures to map the filter specification into design space. The authors search this design space for the optimum solution according to given criteria. The chapter is concluded by an application example.

The case studies of optimal analog filters that cannot be designed with classical techniques are presented in **Chapter 6**.

Chapter 7 presents an extensible framework for designing analog filters that exhibit several desired behavioral properties after being realized in circuits.

Chapter 8 is intended to review the basics of classical digital IIR filter design. Classifications, salient properties and sensitivity of transfer functions in the z-domain are given. The most important digital filter realizations are presented. This chapter provides complete design equations and procedures that make the design easily applicable to a board variety of digital filter design problems.

Chapter 9 reviews basic definitions of digital IIR filter design. It introduces straightforward procedures to map the filter specification into a design space. Authors search this design space for the optimum solution according to given criteria. The chapter is concluded with several important application examples illustrating low- sensitivity multiplierless IIR filters, power-of-two IIR filters, half-band IIR filters, 1/3-band filters, narrow-band IIR filters, Hilbert transformers, and zero-phase IIR filters. Each example design is followed by a comprehensive step-by-step procedure for computing the filter coefficients.

Chapter 10 presents case studies of optimal digital filters that cannot be designed with classical techniques, and the formal mathematical framework that underlines the solutions.

Chapter 11 presents an extensible framework for the simultaneous constrained optimization of multiple properties of digital IIR filters.

Chapter 12 introduces the basic Jacobi elliptic functions and reviews the most important relations between them. Several related theorems not found in standard textbooks are presented. Various useful approximation formulas are offered to facilitate the derivation of elliptic functions is derived. A

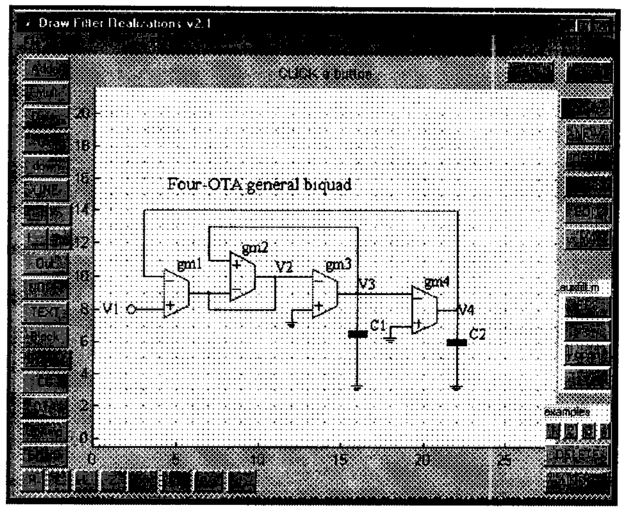

Fig. 2. - DRAWFILT toolbox main screen with schematic

nesting property of the Jacobi elliptic functions is derived. In this chapter, authors present a novel approach to the design of elliptic filters in which they use exact closed-form expressions based on the nesting property.

In **Chapter 13**, the authors introduce the elliptic rational function as a natural generalization of the Chebyshev polynomial and they bypass mathematical theory of special functions required in the previous chapter. The goal is to build the knowledge of the elliptic rational function using simple algebraic manipulations, even without mentioning the Jacobi elliptic functions.

APPLICATION

As the title indicates, the emphasis of this book is upon automating filter design in software (**MATLAB** and *Mathematica*). The book is supported by free downloadable **MATLAB** scripts and *Mathematica* notebooks.

How this book can be useful to the reader, and how he or she can use, and benefit from this frees software?

First, the authors start with **MATLAB** that is an industry standard and a widespread and inexpensive tool in academia and among students. DrawFilt **MATLAB** toolbox is used to draw circuits, i.e., resistors, capacitors, inductors, OpAmp, OTA, CC, etc. DrawFilt saves a schematic as a stand alone **MATLAB** function or as a *Mathematica* script, see Figure 2.

The user has to run *Mathematica* to import the schematic, next to use simple rules to perform Reduced Modified Nodal Analysis (RMNA), and then to specify mathematically the circuit (by equations) according to the schematic.

Authors use the basic *Mathematica* command Solve[] to symbolically (i.e. closed- form, analytically) analyze the circuit, as shown in Figure 4, and derive closed-form expressions for various responses such as

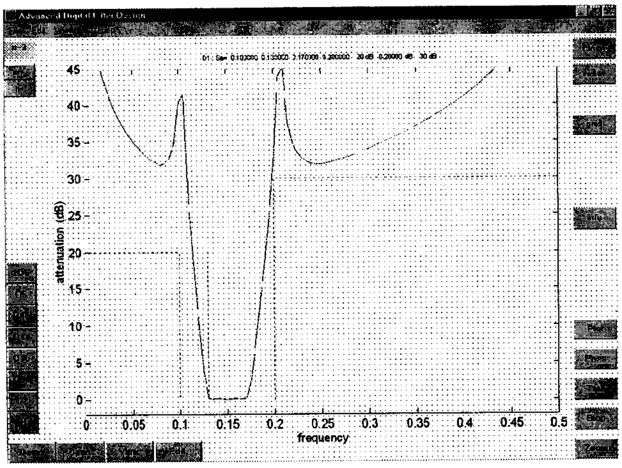

Fig. 3. - AFDESIGN toolbox main screen with frequency response

- ❑ a branch/port voltage or current in terms of other parameters kept as symbols,
- ❑ input impedance,
- ❑ *z*-parameters of a twoport network,
- ❑ DC voltages and currents of an electronic circuit,
- ❑ transfer functions, or
- ❑ time-domain response.

Mathematica documents can be viewed with MathReader (free software). MathReader is a viewer for notebook documents created with *Mathematica*. MathReader lets you display and print *Mathematica* notebooks, animate graphics, play sounds, and copy information from notebooks to other documents. It means that user can easily exchange the coded knowledge via *Mathematica* notebooks. An example is given in Figure 4.

A mouse-driven toolbox in **MATLAB** (called AFDESIGN), for advanced elliptic continuous-time filter design, consists of several parts: computation of transfer functions, computation of poles and zeros, and plotting the frequency response. The AFDESIGN toolbox is a collection of **MATLAB** script files. The filter design is visualized by plots of attenuation against frequency, as shown in Figure 3.

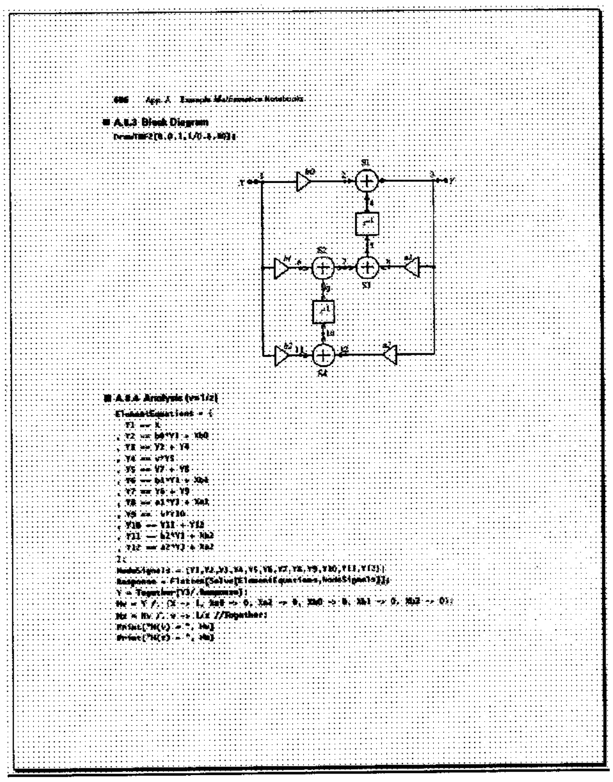

Fig. 4. - Digital filter schematic and symbolic analysis equations generated in Mathematica

CONCLUSION

This book presents a new approach to filter theory and design. The authors incorporate modern powerful software packages such as **MATLAB** and *Mathematica* into fundamental filter theory, and thus open new vistas in the field. This exceptional book builds a bridge between filter theory and design and brings to the practitioner a wealth of sophisticated filter theory. The book is of great use for the professionals, and also can be very useful for the beginners who are making the first steps in understanding and using filters for signal processing.