ANALOG CMOS FILTERS FOR VERY HIGH FREQUENCIES

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by

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To Ellen

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PREFACE

This book deals with the design of fully integrated analog CMOS filters for very high frequencies. It describes various synthesis methods and electronic circuit designs suitable for filters with cut-off frequencies ranging from the low megahertz range to several hundreds of megahertz. The book is intended for engineers in research or development and advanced level students.

Today IC technology is widely used for fully integration of electronic systems. These systems are in general for a large part realized using digital techniques implemented in CMOS technology. The low power dissipation, high packing density, high noise immunity, ease of design and the relative ease of scaling are the driving forces of CMOS technology for digital applications. Parts of these systems cannot be implemented in the digital domain and will remain analog. In order to achieve complete system integration these analog functions are preferably integrated in the same CMOS technology. An important class of analog circuits that need to be integrated in CMOS are analog filters.

This book deals with very high frequency (VHF) filters, which are filters with cut-off frequencies ranging from the low megahertz range to several hundreds of megahertz. Up till recently the maximal cut-off frequencies of CMOS filters were limited to the low megahertz range. By applying the techniques presented in this book the limit could be pushed into the true VHF domain, and integrated VHF filters became feasible. Application of these VHF filters can be found in the field of communication, instrumentation and control systems. For example pre and post filtering for high-speed AD and DA converters, signal reconstruction, signal decoding, etc.

The general design philosophy used in this book is, to allow only the absolute minimum of signal carrying nodes throughout the whole filter. This strategy starts at the filter synthesis level and is extended to the level of electronic circuitry. The result is a filter realization in which all capacitors (including parasitics) have a desired function. The advantage of this technique is that high-frequency parasitic effects (parasitic poles/zeros) are minimally present.

The first part of the book (chapters 1-3) is on general design for VHF filters, including synthesis methods and analysis of the effects of various non-idealities. The second part (chapters 4-6) describes more specific electronic circuitry suitable for implementing these VHF filters in CMOS technology. This part also includes the experimental results of several demonstration filters. An outline of each chapter is

given below.
Chapter 1 gives an introduction to continuous-time integrated filters, including an historical overview. In chapter 2 various synthesis methods for VHF, such as cascaded biquad, signal flow graph, state-space, gyrator and couple resonator synthesis, are described. All methods use transconductors and capacitors as building blocks and result in filter topologies with on every node a desired capacitance. The methods are compared with respect to sensitivity and scaling properties. In chapter 3 the effects of non-idealities in the transconductor realizations on filter performance is discussed. These effects are illustrated with calculations carried out on a second order bandpass filter. Effects considered are: finite integrator quality factor, noise, distortion, dynamic range, dissipation and chip area. Several compact analytical expressions are derived giving insight in these effects. Chapter 4 deals with transconductor design. A transconductor is presented that has high linearity, and a very large bandwidth (10GHz in 3μm CMOS) thanks to the absence of internal nodes. The parasitic output resistance of the transconductor is compensated and thus a useful building block for VHF filters is obtained. A detailed analysis of the transconductor is given, including non-quasi-static transistor operation. A link is made with parameters derived in chapter 3. Chapter 5 deals with automatic frequency and quality factor tuning. A special quality factor tuning circuit without signal carrying nodes is presented and analyzed. Furthermore a method is presented for making a wide-band, low-ohmic supply voltage regulation. This regulation is required to tune the cut-off frequency and quality factors of the filters built with the transconductors of chapter 4. In chapter 6 experimental results of 5 demonstration filters designed in 3μm CMOS are given. These filters are: four third-order elliptic filters with cut-off frequencies ranging from 0.5MHz to 100MHz, and one 22-nd order TV-IF filter with 36MHz center frequency. In chapter 7 finally a summary and conclusions are given.
This book was originally a Ph.D. thesis. It describes the results of a research project carried out at the University of Twente, The Netherlands. The project dated from 1987 to 1991 and was sponsored by the Dutch Innovative Research Program (IOP-IC Technology). The author would like to acknowledge the helpful discussions with many colleagues and students at the University of Twente, University of Delft and Philips. Special thanks are given to Prof. Hans Wallinga and Prof. J. Davidse (Delft University of Technology) for fruitful discussions and for their useful and detailed comment on the manuscript.

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