Analog Circuit Theory and Filter Design in the Digital World

George S. Moschytz

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With an Introduction to the Morphological Method for Creative Solutions and Design

Springer

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To my wife, Brenda,
who reinvigorated my life.

Preface

In the 1960s and 1970s, students in electrical engineering were studying mainly analog circuit theory and design, and only a small elite group had ventured into the digital circuit and system world. Today, the opposite is true; only a small number of electrical engineers are knowledgeable in analog circuit design. The digital revolution and with it the corresponding theory and design basics in an EE curriculum have taken over, leaving only a relatively small group of electrical engineers capable of analog circuit and system design.

Since the "front end," i.e., the interface between man and machine of most electronic systems, has remained largely analog – and presumably always will – this trend, i.e., the neglect of analog circuit theory and design in the EE curriculum, has resulted in a shortage of analog circuit and filter designers. On the one hand, to obtain the necessary but missing number of analog circuit specialists, a basic body of analog circuit theory and design courses should be included in the EE curriculum. On the other hand, because of the predominance of digital circuits and systems and the requirement of maintaining a 4-year time span for the first degree, the academic EE curriculum has of necessity dropped the traditional basic courses in circuit and system design that all earlier EE students were required to take.

As a result of this development, there is a decided "shortfall" in current textbooks for courses on analog circuit and filter design. Whereas there is no need any more for the intense circuit and filter theory courses of yesteryear, there is a general realization that the neglect of analog know-how has been detrimental to the required, and expected, general knowledge of the average EE engineer. This book attempts to bring together a "general knowledge" of one aspect of analog engineering, e.g., that of network theory, filter design, system theory, and sampled-data signal processing. A single book cannot be comprehensive in this respect, but the intention is for it to be adequate for a start, to be followed, as required, by the specific needs of the practicing electrical engineer.

It is hoped that this book will help to fill the existing gap in analog-circuit know-how by extracting many of the most important and useful features of analog circuit theory and design which the author found most important during his own activity in industrial and academic research and development (a decade at AT&T Bell Labs in the USA and three decades at the Swiss Federal Institute – ETH – in Zurich). The book is intended as a basis for one or more graduate courses – and for self-study – in analog and sampled-data circuit theory and design for ongoing or active electrical engineers wishing, or needing, to become proficient in analog circuit design on a system, rather than on a device, level. The material can be considered as a basic educational staple in the EE curriculum which has been neglected in recent decades and is now found to be missing in the general know-how of an academically educated electrical engineer.

Another goal of this book is to emphasize methodology and creative analysis and design techniques that can be applied to areas beyond those specifically addressed in the book. This is reflected

in the subtitle which refers to the "morphological method for creative solutions and design." This is a generic method of creative design which was developed by a prolific Swiss/American scientist and inventor, Professor Fritz Zwicky. Zwicky claimed to have used this method for research and development topics ranging from astrophysics (discovery of super novae) to the design of airplane jet engines for takeoff on extremely short runways (the so-called jato system for aircraft carriers). The author has adapted and used this morphological method for the creative and successful design of analog circuits, devices, and systems. It is shown that much of the design of known as well as new circuit devices, e.g., gyrators, impedance converters, can be surprisingly easily accomplished using the morphological method of design. Numerous examples from different fields are presented, e.g., circuit devices, switched capacitor circuits and filters. However, there is a strong emphasis also on other analysis and design methodology throughout the book, besides that of the morphological method.

The course material has been carefully prepared for audiences including both professional electrical engineers and graduate EE students. As such it was presented by PowerPoint slides with accompanying commentary and explanations. The book has a similar format. It consists of slides with accompanying commentary and explanations in the form of text. A CD with the slides of the book material is available.

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Acknowledgments

I am deeply grateful to Dr. Drazen Jurisic, Professor in the EE Department of the University of Zagreb, who is a former Ph.D. student of mine. Prof. Jurisic transferred onto PowerPoint most of the slides used in this book from my hand-written notes and illustrative material. He was also of immeasurable help throughout the writing of the book, patiently helping me with the quirks and intricacies of the Word and other computer programs used.

It is also a pleasure to acknowledge with gratitude the direct and indirect contributions, as well as the inspiring enthusiasm of well over 50 Ph.D. students, and a far larger number of undergraduate and graduate students, during over more than three decades of joint study and acquisition of insight into the material covered in this book. I also thank my colleagues at the ETH for valuable interaction through those three decades, and especially to the late Professor James L. Massey and to Professor Qiuting Huang, together with whom I taught some of the materials in the book. Prof. Massey's contributions to the mathematical formulation of sampling theory and discrete-time signal processing and Prof. Huang's contributions to the presentation of noise in analog and discrete-time circuits were immensely helpful. Finally, I wish to acknowledge the fundamental contribution made by the late Carl C. Kurth, while working together at AT&T Bell Labs, on the four-port analysis of switched capacitor circuits.

Finally, my wholehearted gratitude goes to my wife Brenda. Without her encouragement, patience, and devotion, I could not have written this book.

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