Faith and reason are like two wings
on which the human spirit rises
to the contemplation of truth; . . .

John Paul II, Fides et Ratio

Advances in VLSI technology have allowed designers to integrate digital and analog circuits on a single chip. This possibility is very useful in signal processing; signals are taken from the analog world and processed with digital systems. These signals require the use of analog pre- and postprocessing blocks such as converters, filters, sensors, drivers, buffers, and actuators. There exist many digital-oriented design systems, so-called silicon compilers whose common features are presented in the book. However, the lack of universal computer tools for the synthesis, simulation, and layout of the analog part on the chip is a design bottleneck of modern VLSI circuits. This book is devoted to design methods of both digital and analog integrated circuits. Some design methods and computer tools that are described in the book are not yet applied in any compiler. Hence, this work can be a source of information not only for graduate students and integrated circuit designers, but also for developers of silicon compilers.

There are many computer systems such as Cadence, Saber, Compass, Mentor Graphics, and Synopsis that can be helpful in the design of integrated circuits. There are books and manuals describing each system. This book is more general in character. It does not describe any particular system. Part II of the book presents the basic methods, procedures, and tools used in silicon compilers. The Part II is preceded by Part I, in which basics that are necessary for a user of a particular compil-
er are described. Part I presents basic information about CMOS technology. The techniques most frequently used and fully implemented in this technology are also included in Part I.

Each author faces the dilemma of which subjects can be omitted and which must be included in his book. Such choice was especially difficult in this book, which is on the border of three main areas: signal processing, systems on a chip, and computer tools. If too many problems and approaches were considered, the book would be unclear and difficult to absorb for the reader. Hence, the reader will not find separated, detailed descriptions of CMOS technology, CMOS circuits techniques, and computer tools for synthesis and design of these circuits in this book. The book is focused on the problems in these areas, which are strictly connected each other.

The book is composed of eight chapters and divided into two parts. The chapters that describe analog and discrete signals, basics of CMOS technology, and basic cells that can be obtained in digital, OTA-C, switched-capacitor, and switched-current techniques are included into Part I. Part II is devoted to methods and tools that can be used to implement mixed-signal systems on a chip.

In the first chapter, we review topics concerning analog and digital signals, which are continuous- and discrete-time functions. Notation and description of mixed-signals is briefly presented. The topics are: Fourier, Z, and Laplace transforms, the sampling theorem, and the aliasing problem. Exponential, Euler, and bilinear mappings from $s$ to $z$ domains are also presented. Transfer functions describing two-dimensional systems in both domains are considered. The discrete cosine transform, which is very important in image compression and is used in the second part of the book, is also described in this chapter.

The second chapter describes the properties of MOS transistors used to realize all basic cells of integrated circuits. Operation, performance, and design of these cells are also presented in this chapter.

The third chapter contains brief description of the basic CMOS processes: wafer preparation, oxidation, deposition, litography and etching, epitaxy, diffusion, and ion implantation. The designer of integrated circuits ought to be familiar with these processes in order to understand the project steps and the design rules and to be able to modify the operations that violate these rules.

The fourth chapter describes digital techniques that are very frequently used in mixed-signal integrated circuit design. In particular, we describe static and dynamic logic gates, finite-state machines, and memories.

The fifth chapter presents the basic elements of passive and active circuits. We describe various implementations of integrators, i.e., switched-current, switched-capacitor and OTA-C implementations. These integrators are basic cells of mixed-signal processing systems. We also consider low-voltage and low-power operation of these elements.

The sixth chapter describes the low-sensitivity strategy in the design of one-dimensional filters implemented in switched-current, switched-capacitor, and OTA-C techniques. The gyrator introduced in the previous chapter plays a special role in this strategy. The chapter shows how to realize low-sensitivity strategy in digital filter design. Analog-to-digital converters based on delta-sigma modulation, which
can be implemented in switched-current and switched-capacitor techniques, are also presented in this chapter.

In the next chapter we describe the architecture of a system on a chip, applicable for image processing. We assume that image sensing arrays are built on the chip in the standard CMOS process. Switched-current circuits are used for image preprocessing in the analog part of the chip.

Software systems that can automatically generate integrated circuits are called silicon compilers. The most popular systems are oriented on digital integrated circuit designs that are advantageous in the design, based on the hierarchy of the cells and the libraries of standard cells. Very effective computer systems for design of digital circuits exist, and tools that can be used in mixed-signal integrated circuit design are being intensively developed. The last chapter briefly presents the basic ideas that are necessary for the use and development of such systems.

Each chapter describes topics that are the background to further issues. A reader who is familiar with some of these topics can omit them. In order to help navigate the book, the most important connections between the chapters can be summarized out as:

- Euler and bilinear mappings in Chapter 1 are basic to the integrators described in Chapter 5 and the SI, SC, and digital filters described in Chapter 6.
- 2-D SI filters described in Chapter 7 are based on the novel 2-D multiport network description given in Chapter 1.
- Chapter 2 describes basic CMOS cells, which are used in Chapters 4 and 5.
- Chapter 3 is useful for understanding the design steps described in Chapters 7 and 8.
- Each digital part of the system on a chip presented in Chapter 7 is based on digital cells described in Chapter 4. The clock that is also described in this chapter is often used to control SC and SI circuits presented in Chapters 5, 6, and 7.
- The SC and SI cells described in Chapter 5 are used for the signal processing described in Chapters 6 and 7.
- Chapters 6 and 7 are focused on filters and other macrocells of mixed-signal processing systems.
- Chapter 8 explains the role of computer tools that are helpful in the design of systems presented in Chapters 6 and 7.

Most chapters contain novel problems that the reader could not find in existing books or overview articles. The novel topics include description of transfer functions of 2-D multiport networks (Chapter 1), novel SI memory and SI integrator cells (Chapter 5), implementation of the Darlington model of synthesis based on gyrator–capacitor multiport networks (Chapter 6), synthesis method of 2-D SI and SC filters (Chapter 7), and computer tools based on topological methods (Chapter 8).

The chapters contain problems that can be used as exercises for graduate stu-
The book presents an approach to one- and two-dimensional filter design based on the gyrator–capacitor prototype network. This approach is illustrated by image processing systems for implementation on a single chip and shows the reader the way from synthesis methods to silicon assembly.

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I sincerely hope that this book will be helpful to readers. I will be very grateful for comments and opinions.

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