Preface

In recent years, the focus on analog integrated circuits has become more pronounced due to their ubiquitous use in electronic products. This has placed more attention on analog process technologies. Whereas analog technology was once the exclusive domain of a small circle of integrated device manufacturers, it has proliferated to foundries worldwide and hence is available to all design houses. At the root of analog technologies are components—transistors, resistors, capacitors, inductors, and varactors—that embody the performance requirements of the analog products.

This book was written for undergraduate electrical engineering students and for practicing engineers in the field of analog, power, and RF silicon integrated technologies. Its primary purpose is to provide a unified treatment of design, integration, and applications of analog components fabricated on silicon. There are several books available on semiconductor physics, but few if any that have focused on the components and characteristics aimed at analog applications. The authors hope that this book constitutes a foundation, using device physics to help the reader get a deeper understanding of how the component functions and highlighting those salient attributes important for analog applications, with examples along the way to reinforce key concepts and best practices. Overviews of selected product applications are presented, showing how these analog components are used, while avoiding complex circuit analysis. At the end of each chapter, problems are provided to test and stretch the reader's understanding, and several references are listed, allowing the reader to delve deeper into the topics discussed.

The level at which this book is written assumes that the reader has had introductory physics, calculus, statistics, and an undergraduate college-level course on semiconductor devices.

This book is based on years of experience by the authors in analog technology at both integrated device manufacturers and foundries, and on industrial and academic teaching. This includes direct experience in defining analog component specifications based on circuit performance and scaling requirements, integrating those components into an analog process technology, validating the reliability, and then qualifying that technology for eventual production.

This book is organized into eleven chapters and six appendices. Silicon is emphasized since this is the main material used in most analog, power, and RF technologies.

Chapter 1 is an introduction to the "world of analog." It provides an overview, framing the importance of analog products in everyday life.

Chapters 2–4 give a review of silicon properties, pn junctions, and rectifying and ohmic contacts, establishing the proper device physics background for the reader to move into the more analog-oriented components. While several excellent books on these topics have already been published, these chapters are intended to present engineers and scientists, in a concise form, those parts of semiconductor and device physics that are most important to the discussion of analog components.

Chapter 5 covers fundamentals of bipolar junction transistors and junction field-effect transistors, which are constructed in a base CMOS technology with no or little added complexity. This chapter also provides an understanding of important bipolar effects in CMOS, such as subthreshold current, snapback, and latch-up.

Chapter 6 deals with analog and RF CMOS components. This chapter includes a concise discussion of the surface effects and the metal–oxide–silicon (MOS) structure that is a key part of the MOSFET and a powerful device and process characterization tool. Both digital and analog/RF CMOS device topics are then discussed. The modes of transistor operation and different transistor types are covered. Transistor current–voltage characteristics are then detailed with an emphasis on analog applications.

High-voltage and power devices are presented in Chap. 7, focusing on DECMOS and LDMOS transistors. Concepts such as the drift region are covered, and key figures of merit such as specific on-resistance and gate charge are introduced, many of these areas leveraging concepts introduced in Chap. 6. High-voltage effects, such as quasi-saturation, impact ionization, self-heating, and safe operating area, are detailed.

Chapter 8 describes passive components, which are fundamental components in analog, mixed-signal, RF CMOS, and power applications. Device design and properties of integrated precision resistors, capacitors, varactors, and inductors are covered in detail, with examples of their use in circuit applications.

Chapter 9 discusses process integration of active and passive analog components. This includes analog CMOS, mixed-signal CMOS, RF CMOS, and BCD technologies. The description is illustrated with many cross sections, highlighting key technology features, trade-offs, and best practices.

Component matching and noise are parameters that can have critical importance in analog applications. They are covered in detail in Chap. 10 for both active and passive devices.

Chapter 11 covers component reliability. Basic concepts, models, and distributions are introduced, highlighting their use for specific failure mechanisms and emphasizing analog reliability considerations. Practical examples are provided for illustration.

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