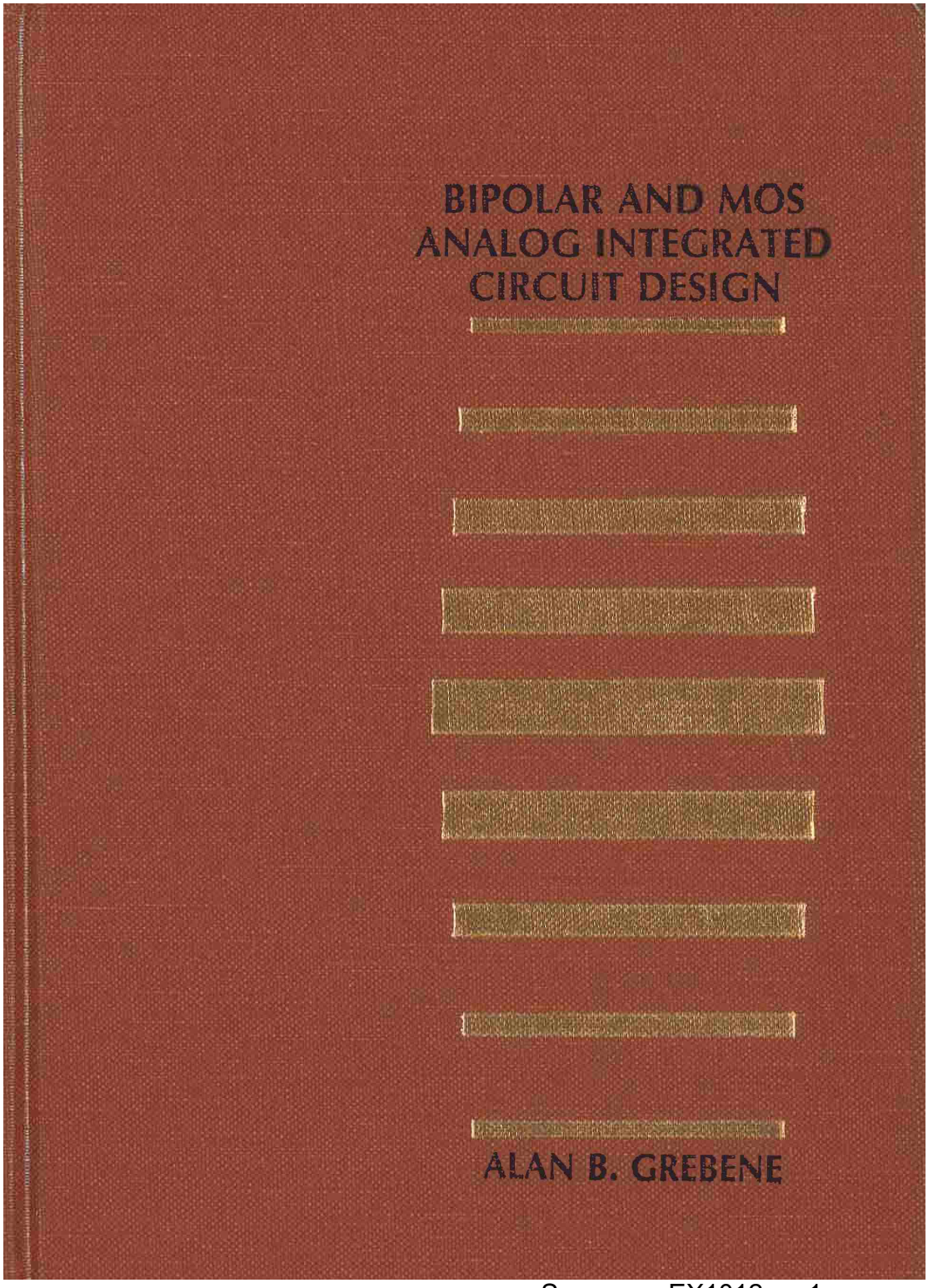

BIPOLAR AND MOS ANALOG INTEGRATED CIRCUIT DESIGN

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PREFACE

The contents and organization of this book are primarily aimed at the practicing engineer in the field of solid-state electronics. It is intended as a valuable reference for the IC designer and user alike. For the analog IC designer, it provides rigorous design guidelines and examples, while for the user, it offers a detailed analysis of various classes of analog circuits, points out their design philosophy, capabilities, and limitations, and presents application examples and guidelines.

It is intended to be an easy and smooth reading book on a rapidly evolving, high-technology subject. To this end, the lengthy and detailed mathematical treatment of the subject matter is minimized. Long derivations of device or circuit equations are avoided whenever possible; instead, the emphasis is placed on the end result, and the basic design philosophy leading up to it, with a clear understanding of the underlying assumptions and trade-offs. Whenever possible, each new design idea or concept is also demonstrated with a practical example.

The advent of integrated circuit technology has altered many of the established circuit design techniques and principles. This is particularly evident in the field of analog integrated circuits where the designer is faced with a new set of design constraints and ground rules. In writing this book, it is my intention to educate the practicing electronics engineer in the fundamental design principles, capabilities, and applications of monolithic analog circuits. However, the subject matter is treated rigorously and from a fundamental viewpoint, to make this book suitable as a text for graduate study in semiconductor circuits.

This book is an updated sequel to an earlier book by the author, *Analog Integrated Circuit Design* (published by Van Nostrand Reinhold, 1972) which covered the analog IC design technology of the 1960's. Since then, many significant changes have occurred in the world of microelectronics. Perhaps the most important of these has been the "microprocessor revolution," which has resulted in a truly revolutionary growth of digital signal-processing techniques. In turn, this has led to a rapid evolution and advancement of analog circuit methods, particularly in the areas that interface with digital techniques and technologies. As a result, complete LSI systems have evolved which combine complex analog and digital functions on the same chip.

A great deal of this development has been possible by extending the capabilities of MOS devices and process technology to cover analog functions. Consequently, analog IC design using MOS technology has rapidly evolved into a major area of growth. These developments of recent years are profoundly reflected in the contents and the organization of this book.

In the preparation of the text, it is assumed that the reader is familiar with the basic theory and principles of solid-state devices. Therefore, the solid-state device theory, which is already well covered elsewhere in the literature, is reviewed only briefly, and almost all of the space is devoted to circuit approaches unique to monolithic integrated circuits. Hybrid integrated circuits, which represent an area of overlap between discrete and monolithic circuits, are not covered explicitly.

The text of the book is comprised of fifteen chapters which follow a logical sequence in the form of three "sections." The first section of the book, comprised of Chapters 1–3, reviews the basic "tools" of analog IC design and fabrication, namely, process technology, IC components, and techniques for placing these components on the chip, that is, the chip layout. These chapters are intended to familiarize the designer with the physical structures, advantages, and limitations of monolithic components. This knowledge is imperative to an analog IC design engineer since a successful design is one that efficiently utilizes the advantages of monolithic devices while avoiding their shortcomings.

The second section of the text, made up of Chapters 4–6, covers the basic "building blocks," or subcircuits, of analog IC design. One important chapter in this section, Chapter 6, deals with the use of MOS technology in analog or combined analog/digital LSI design. All the subcircuits covered in this section serve as essential building blocks of the complex IC designs that are covered in the remainder of the book.

The third and main section of the book, comprised of Chapters 7–15, covers the entire field of analog integrated circuits by dividing them into functional categories and then examining each category separately. Thus, for example, circuit classes such as operational amplifiers, multipliers, oscillators, phase-locked loops, filters, and data conversion circuits are examined separately. In this section, particular emphasis is given to the recent developments in the field of analog circuits, particularly in the areas of switched-capacitor filters, switching regulators, voltage-controlled oscillators, high-resolution data conversion circuits, and the precision reference circuitry associated with them.

Part of the material in this book is patterned after a sequence of graduate level courses in integrated electronics which I taught at Santa Clara University. Therefore, when preceded by courses on solid-state circuits and semiconductor electronics, this book will be well suited for a senior or graduate level course.

I am grateful to many people who have contributed directly or indirectly to the preparation of this book. In particular, I would like to thank my wife, Karen, who has been a constant source of encouragement for me during the long years of effort that have gone into this book. I would also like to extend my appreciation to many colleagues and associates in the IC industry for their assistance and guidance in the

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