Preface

PHILOSOPHY AND GOALS

Microelectronics: Circuit Analysis and Design is intended as a core text in electronics for undergraduate electrical and computer engineering students. The purpose of the fourth edition of the book is to continue to provide a foundation for analyzing and designing both analog and digital electronic circuits. A goal is to make this book very readable and student-friendly.

Most electronic circuit design today involves integrated circuits (ICs), in which the entire circuit is fabricated on a single piece of semiconductor material. The IC can contain millions of semiconductor devices and other elements and can perform complex functions. The microprocessor is a classic example of such a circuit. The ultimate goal of this text is to clearly present the operation, characteristics, and limitations of the basic circuits that form these complex integrated circuits. Although most engineers will use existing ICs in specialized design applications, they must be aware of the fundamental circuit's characteristics in order to understand the operation and limitations of the IC.

Initially, discrete transistor circuits are analyzed and designed. The complexity of circuits being studied increases throughout the text so that, eventually, the reader should be able to analyze and design the basic elements of integrated circuits, such as linear amplifiers and digital logic gates.

This text is an introduction to the complex subject of electronic circuits. Therefore, more advanced material is not included. Specific technologies, such as gallium arsenide, which is used in special applications, are also not included, although reference may be made to a few specialized applications. Finally, the layout and fabrication of ICs are not covered, since these topics alone can warrant entire texts.

DESIGN EMPHASIS

Design is the heart of engineering. Good design evolves out of considerable experience with analysis. In this text, we point out various characteristics and properties of circuits as we go through the analysis. The objective is to develop an intuition that can be applied to the design process.

Many design examples, design exercise problems, and end-of-chapter design problems are included in this text. The end-of-chapter design problems are designated with a "D". Many of these examples and problems have a set of specifications that lead to a unique solution. Although engineering design in its truest sense does not lead to a unique solution, these initial design examples and problems are a first step, the author believes, in learning the design process. A separate section, Design Problems, found in the end-of-chapter problems, contains open-ended design problems.

COMPUTER-AIDED ANALYSIS AND DESIGN

Computer analysis and computer-aided-design (CAD) are significant factors in electronics. One of the most prevalent electronic circuit simulation programs is Simulation Program with Integrated Circuit Emphasis (SPICE), developed at the University of California. A version of SPICE tailored for personal computers is PSpice, which is used in this text.

The text emphasizes hand analysis and design in order to concentrate on basic circuit concepts. However, in several places in the text, PSpice results are included and are correlated with the hand analysis results. Obviously, at the instructor's discretion, computer simulation may be incorporated at any point in the text. A separate section, Computer Simulation Problems, is found in the end-of-chapter problems.

In some chapters, particularly the chapters on frequency response and feedback, computer analysis is used more heavily. Even in these situations, however, computer analysis is considered only after the fundamental properties of the circuit have been covered. The computer is a tool that can aid in the analysis and design of electronic circuits, but is not a substitute for a thorough understanding of the basic concepts of circuit analysis.

PREREQUISITES

This book is intended for junior undergraduates in electrical and computer engineering. The prerequisites for understanding the material include dc analysis and steady-state sinusoidal analysis of electric circuits and the transient analysis of RC circuits. Various network concepts, such as Thevenin's and Norton's theorems, are used extensively. Some background in Laplace transform techniques may also be useful. Prior knowledge of semiconductor device physics is not required.

ORGANIZATION

The book is divided into three parts. Part 1, consisting of the first eight chapters, covers semiconductor materials, the basic diode operation and diode circuits, and basic transistor operations and transistor circuits. Part 2 addresses more advanced analog electronics, such as operational amplifier circuits, biasing techniques used in integrated circuits, and other analog circuits applications. Part 3 covers digital electronics including CMOS integrated circuits. Five appendices are included at the end of the text.

Content

Part 1. Chapter 1 introduces the semiconductor material and pn junction, which leads to diode circuits and applications given in Chapter 2. Chapter 3 covers the field-effect transistor, with strong emphasis on the metal-oxide-semiconductor FET (MOSFET), and Chapter 4 presents basic FET linear amplifiers. Chapter 5 discusses the bipolar junction transistor, with basic bipolar linear amplifier applications given in Chapter 6.

The frequency response of transistors and transistor circuits is covered in a separate Chapter 7. The emphasis in Chapters 3 through 6 was on the analysis and

design techniques, so mixing the two transistor types within a given chapter would introduce unnecessary confusion. However, starting with Chapter 7, both MOSFET circuits and bipolar circuits are discussed within the same chapter. Finally, Chapter 8, covering output stages and power amplifiers, completes Part 1 of the text.

Part 2. Chapters 9 through 15 are included in Part 2, which addresses more advanced analog electronics. In this portion of the text, the emphasis is placed on the operational amplifier and on circuits that form the basic building blocks of integrated circuits (ICs). The ideal operational amplifier and ideal op-amp circuits are covered in Chapter 9. Chapter 10 presents constant-current source biasing circuits and introduces the active load, both of which are used extensively in ICs. The differential amplifier, the heart of the op-amp, is discussed in Chapter 11, and feedback is considered in Chapter 12. Chapter 13 presents the analysis and design of various circuits that form operational amplifiers. Nonideal effects in analog ICs are addressed in Chapter 14, and applications, such as active filters and oscillators, are covered in Chapter 15.

Part 3. Chapters 16 and 17 form Part 3 of the text, and cover the basics of digital electronics. The analysis and design of MOS digital electronics is discussed in Chapter 16. The emphasis in this chapter is on CMOS circuits, which form the basis of most present-day digital circuits. Basic digital logic gate circuits are initially covered, then shift registers, flip-flops, and then basic A/D and D/A converters are presented. Chapter 17 introduces bipolar digital electronics, including emitter-coupled logic and classical transistor-transistor logic circuits.

Appendices. Five appendices are included at the end of the text. Appendix A contains physical constants and conversion factors. Manufacturers' data sheets for several devices and circuits are included in Appendix B. Standard resistor and capacitor values are given in Appendix C, and references and other reading sources are listed in Appendix D. Finally, answers to selected end-of chapter problems are given in Appendix E.

Order of Presentation

The book is written with a certain degree of flexibility so that instructors can design their own order of presentation of topics.

1. *Op-Amp Circuits:* For those instructors who wish to present ideal op-amp circuits as a first topic in electronics, Chapter 9 is written such that sections 9.1 through 9.5.5 can be studied as a first chapter in electronics.

> Chapter Presentation
> Ideal Op-Amp Circuits:
> 1. Chapter 9, Sections 9.1–9.5.5.
> 2. Chapters 1, 2, etc.

2. *MOSFETs versus Bipolars:* The chapters covering MOSFETs (3 and 4) and the chapters covering bipolars (5 and 6) are written independently of each other. Instructors, therefore, have the option of discussing MOSFETs before bipolars, as

given in the text, or discussing bipolars before MOSFETs in the more traditional manner.

Chapter Presentation

	Text			Traditional	
Chapter	**Topic**		**Chapter**	**Topic**	
1	pn Junctions		1	pn Junctions	
2	Diode Circuits		2	Diode Circuits	
3	MOS Transistors		5	Bipolar Transistors	
4	MOSFET Circuits		6	Bipolar Circuits	
5	Bipolar Transistors		3	MOS Transistors	
6	Bipolar Circuits		4	MOSFET Circuits	
etc.			etc.		

3. *Digital versus Analog:* For those instructors who wish to present digital electronics before analog electronics, Part 3 is written to be independent of Part 2. Therefore, instructors may cover Chapters 1, 2, 3, and then jump to Chapter 16.

Chapter Presentation:

Chapter	**Topic**
1	pn Junctions
2	Diode Circuits
3	MOS Transistors
16	MOSFET Digital Circuits
5	Bipolar Transistors
17	Bipolar Digital Circuits
etc.	Analog Circuits

NEW TO THE FOURTH EDITION

- Addition of over 250 new Exercise and Test Your Understanding Problems.
- Addition of over 580 new end-of-chapter problems.
- Addition of over 50 new open-ended Design Problems in the end-of-chapter problems sections.
- Addition of over 65 new Computer Simulation Problems in the end-of-chapter problems sections.
- Voltage levels in circuits were updated to more closely match modern day electronics.
- MOSFET device parameters were updated to more closely match modern day electronics.
- Chapter 9 was rewritten such that ideal op-amp circuits can be studied as a first topic in electronics.
- Maintained the mathematical rigor necessary to more clearly understand basic circuit operation and characteristics.

RETAINED FEATURES OF THE TEXT

- A short introduction at the beginning of each chapter links the new chapter to the material presented in previous chapters. The objectives of the Chapter, i.e., what the reader should gain from the chapter, are presented in the Preview section and are listed in bullet form for easy reference.
- Each major section of a chapter begins with a restatement of the objective for this portion of the chapter.
- An extensive number of worked examples are used throughout the text to reinforce the theoretical concepts being developed. These examples contain all the details of the analysis or design, so the reader does not have to fill in missing steps.
- An Exercise Problem follows each example. The exercise problem is very similar to the worked example so that readers can immediately test their understanding of the material just covered. Answers are given for each exercise problem so readers do not have to search for an answer at the end of the book. These exercise problems will reinforce readers' grasp of the material before they move on to the next section.
- Test Your Understanding exercise problems are included at the end of most major sections of the chapter. These exercise problems are, in general, more comprehensive that those presented at the end of an example. These problems will also reinforce readers' grasp of the material before they move on to the next section. Answers to these exercise problems are also given.
- Problem Solving Techniques are given throughout each chapter to assist the reader in analyzing circuits. Although there can be more than one method of solving a problem, these Problem Solving Techniques are intended to help the reader get started in the analysis of a circuit.
- A Design Application is included as the last section of each chapter. A specific electronic design related to that chapter is presented. Over the course of the book, students will learn to build circuits for an electronic thermometer. Though not every Design Application deals with the thermometer, each application illustrates how students will use design in the real world.
- A Summary section follows the text of each chapter. This section summarizes the overall results derived in the chapter and reviews the basic concepts developed. The summary section is written in bullet form for easy reference.
- A Checkpoint section follows the Summary section. This section states the goals that should have been met and states the abilities the reader should have gained. The Checkpoints will help assess progress before moving to the next chapter.
- A list of review questions is included at the end of each chapter. These questions serve as a self-test to help the reader determine how well the concepts developed in the chapter have been mastered.
- A large number of problems are given at the end of each chapter, organized according to the subject of each section. Many new problems have been incorporated into the fourth edition. Design oriented problems are included as well as problems with varying degrees of difficulty. A "D" indicates design-type problems, and an asterisk (*) indicates more difficult problems. Separate computer simulation problems and open-ended design problems are also included.
- Answers to selected problems are given in Appendix E. Knowing the answer to a problem can aid and reinforce the problem solving ability.
- Manufacturers' data sheets for selected devices and circuits are given in Appendix B. These data sheets should allow the reader to relate the basic concepts and circuit characteristics studied to real circuit characteristics and limitations.

SUPPLEMENTS

The website for Microeletronics features tools for students and teachers. Professors can benefit from McGraw-Hill's COSMOS electronic solutions manual. COSMOS enables instructors to generate a limitless supply of problem material for assignment, as well as transfer and integrate their own problems into the software. For students, there are profiles of electrical engineers that give students insight into the real world of electrical engineering by presenting interviews with engineers working at a number of businesses, from Fairchild Semiconductor to Apple. In addition, the website boasts PowerPoint slides, an image library, the complete Instructor's Solution Manual (password protected), data sheets, laboratory manual, and links to other important websites. You can find the site at **www.mhhe.com/neamen.**

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