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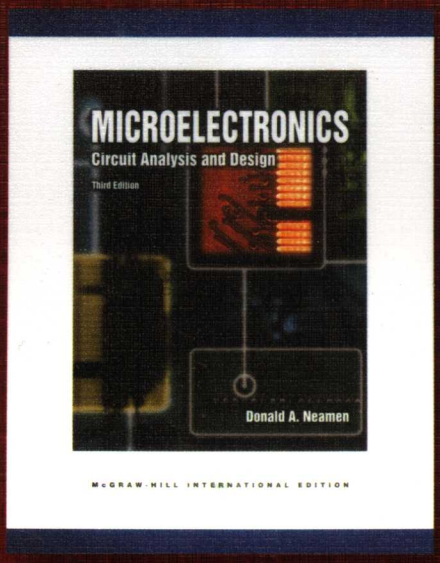

电子电路分析与设计（第3版）
——半导体器件及其基本应用

Microelectronics
Circuit Analysis and Design
(Third Edition)

Donald A. Neamen

清华大学出版社

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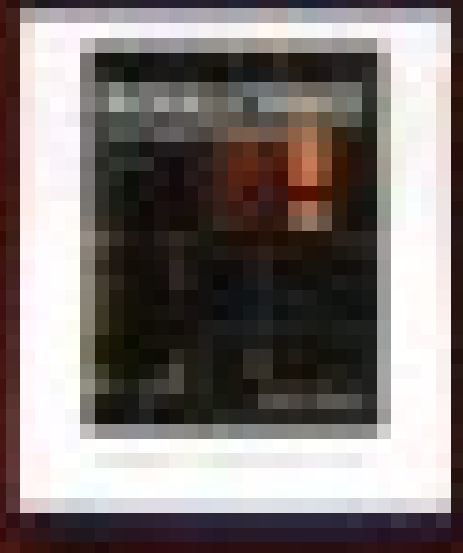

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——产学合作专业规划教材

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Microelectronics Circuit Analysis and Design, Third Edition
影印版序

清华大学出版社曾经于2000年引进Donald A. Neamen教授的《电子电路分析与设计》(Electronic Circuit Analysis and Design)(第2版),受到了国内广大高校师生的欢迎。最近,本书推出了第3版,应清华大学出版社之邀,本人再次推荐本书。

Microelectronics Circuit Analysis and Design(第3版)与第2版在总体结构、章节安排、体例、内容编排和叙述方法上基本相同。

全书包括半导体器件及其基本应用、模拟电子学和数字电子学三个部分,共17章。第一部分包括第1~8章,主要阐述半导体材料和二极管、二极管电路、场效应管及其放大电路、晶体三极管及其放大电路、频率响应、输出级和功率放大电路等。第二部分包括第9~15章,主要阐述理想运放及其基本应用、集成电路的偏置电路和有源负载、差分及多级放大电路、反馈及稳定性、运算放大电路、运算放大电路中非理性因素的影响、集成电路的应用和设计等。第三部分包括第16和17章,主要阐述NMOS、CMOS、BiCMOS、ECL逻辑电路的组成,不同类型门电路的工作原理和电气特性,触发器、时序逻辑电路、存储器的构成和逻辑功能,并介绍模数转换器和数模转换器的基本组成和工作原理。

一、本书第3版与第2版的主要区别

1. 上述三个部分的前面增加了"序言",以概述有关的基本知识、基本概念和基本方法。"序言1"是电子学序言,介绍电子技术发展简史、有源元件和无源元件、电子电路方框图、分立和集成电路、模拟信号和数字信号等基本知识。"序言2"是电子设计序言,介绍设计流程、系统设计和电子设计的方法和步骤。"序言3"是数字电子学序言,介绍逻辑代数与逻辑门、逻辑电平、噪声容限、传输时间和开关时间等数字电路的有关概念和方法。

2. 各章均增加了"设计应用"一节,设计题目均为结合本章基本内容的实际问题。例如,利用二极管、MOSFET管和BJT管设计电子温度计,利用二极管和稳压管设计直流电源,利用FET和BJT设计实用放大器,利用集成运放设计有源滤波器,利用CMOS和ECL电路的基本结构设计门电路,等等。

3. 在第一部分中,虽然章节内容基本没变,但将场效应管及其放大电路置于晶体三极管及其放大电路之前,适应了集成电路的发展和当前芯片应用的现状。此外,在全书中有关场效应管的例题习题也略有增加。

4. 在第三部分中,增加了模数转换器和数模转换器部分,讲述了有关基本概念、常见电路和转换原理,使数字电子学部分更加全面。

二、本书的基本特点

1. 内容丰富,视野开阔,知识面较宽,涵盖了我国高等院校模拟电子技术和数字电

子技术课程大部分教学基本要求，因而可作为电子技术基础及同类课程的参考书或教材。

2. 本书虽然篇幅较多（1300 多页），但各章结构合理、层次清楚、思路清晰、叙述详细、文字流畅，因而易于阅读。一般在叙述一个重要问题之后，均有例题及其评述或讨论，有些还给出设计举例、自测题等。因此便于自学，使读者像面对一个循循善诱的老师一样，在启发引导下，由浅入深，循序渐进。

3. 全书每一章的最后一节均为“Summary”，并有“Checkpoint”和“Review Questions”，以说明学完本章后应达到的目的和本章所讨论的基本问题。各章后面的习题均分为三部分，第一部分“Problems”按节出题，习题所涉及的知识主要针对本节基本内容，以满足教学基本要求；第二部分“Computer Analysis Problems”是计算机仿真习题，以训练对 EDA 软件的应用能力；第三部分“Design Problems”是提高题，以训练对所学知识的综合应用能力。三种习题的教学目的层次分明。

4. 设计举例单独设节，强调理论联系实际，且叙述具有示范性，和各章的“Design Problems”相互呼应，以提高电子电路的设计能力。

综上所述，与国内出版的同类教材相比，本书具有明显的特色。它正好弥补国内同类教材因篇幅所限叙述不够详尽、内容较为浓缩、例题和习题较少、设计举例不多的缺憾。因此，无论对于教师还是对于学生，本书均具有很好的参考价值。

另外，为了更好地适应国内教学的需要，并根据国内电子技术类课程教学的特点，将本书分成三册出版。这样可以更加方便读者选用。第一册为《半导体器件及其基本应用》，包括原版书的第 1～8 章；第 2 册为《模拟电子技术》，包括原版书的第 9～15 章；第 3 册为《数字电子技术》，包括原版书的第 16 和 17 章。

华成英

2007 年 3 月于清华园

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Preface

PHILOSOPHY AND GOALS

Electronic Circuit Analysis and Design is intended as a core text in electronics for undergraduate electrical and computer engineering students. The purpose of the third edition of the book is to provide a foundation for analyzing and designing both analog and digital electronic circuits.

The majority of electronic circuit design today involves using integrated circuits (ICs). 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 an example of such a circuit. The ultimate goal of this text is to understand the operation, characteristics, and limitations of the basic circuits that form these integrated circuits.

Initially, discrete transistor circuits are analyzed and designed. The complexity of the circuits studied is then increased. Eventually the reader should be able to analyze and design the basic elements of integrated circuits, such as 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.

COMPUTER-AIDED ANALYSIS AND DESIGN (PSPICE)

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. A comprehensive appendix on the PSpice circuit modeling program is included in this text. Example programs are also given in Appendix B. Instructors may introduce PSpice at any point in the course.

The text emphasizes hand analysis and design. However, in several places in the text, PSpice results are included and are correlated with the hand analysis results. The PSpice capture schematic diagrams are included, as well as the computer simulation results. Specific computer simulation problems are included at the end of most chapters. However, at the instructor's discretion, PSpice can be used for any exercise or problem, to verify the hand analysis.

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.

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 design examples and problems have a set of specifications that lead to a unique solution. Engineering design in its truest sense does not lead to a unique solution. Although the type of design problem given in the text may not be design in its strictest form, the author believes that this is a first step in learning the design process. A separate section, Design Application, found in the end-of-chapter problems, contains open-ended design problems.

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. Six appendices are included at the end of the text.

Part 1. Chapter 1 introduces the semiconductor material and pn junction, which leads to the 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 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

Possible Order of Initial 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

of discussing MOSFETs before bipolars as given in the text, or discussing bipolars before MOSFETs in the more traditional manner as shown in the following table.

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.

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. This jump may be somewhat disconcerting to students, but it is possible.

Appendices. Six appendices are included at the end of the text. Appendix A contains physical constants and conversion factors. Appendix B is a discussion of PSpice, including examples of various types of analyses. Several examples are presented in which the PSpice circuit schematic diagram is given as well as the output response. This will allow the reader to get started with PSpice.

Manufacturers' data sheets for several devices and circuits are included in Appendix C. Standard resistor and capacitor values are given in Appendix D, and references and other reading sources are listed in Appendix E. Finally, answers to selected end-of-chapter problems are given in Appendix F.

FEATURES OF THE THIRD EDITION

- 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 third 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 F. 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 C. These data sheets should allow the reader to relate the basic concepts and circuit characteristics studied to real circuit characteristics and limitations.

SUPPLEMENTS

The book is supported by a wide variety of supplements both online and in addition to the text. The book's website contains resources for both instructors and students. The student portion of the site contains two new features: algorithmic problems and Profiles. The algorithmic problems allow students to practice step-by-step problem-solving using a recursive computational procedure to create an infinite number of problems. The Profiles give students insight into the real world of electrical engineering by presenting interviews with engineers working at a number of different businesses, from Fairchild Semiconductor to Apple. A number of useful links also appear on the site.

The secure and convenient instructor portion of the site contains PowerPoints with all figures from the text, the full solutions, and a laboratory manual. In addition, instructors can access a demo for COSMOS, McGraw-Hill's new tool for professors.

ACKNOWLEDGMENTS

I am indebted to the many students I have taught over the years who have helped in the evolution of this text. Their enthusiasm and constructive criticism have been invaluable, and their delight when they think they have found an error their professor may have made is priceless. I also want to acknowledge Professor Hawkins, Professor Fleddermann, Dr. Vadiee, and Dr. Ed Graham of the University of New Mexico who have taught from the second edition and who have made excellent suggestions for improvement.

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Donald A. Neamen

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