世界著名大学核心教材（电子电工类）

电路原理（影印版）

Principles of Electric Ciruits: Coventional Current Version

Seventh Edition

（美）Floyd 著

Pearson Education

科学出版社
www.sciencep.com

世界著名大学核心教材（电子电工类）

电 路 原 理

（影印版）

Principles of Electric Circuits

Seventh Edition

（美） Floyd 著

科 学 出 版 社

北 京

图字：01-2003-6985 号

内 容 简 介

本书主要讲述电子电路的基础知识，将引领学生迈进基本电子电路的殿堂。
本书实用价值高，章末附有问题及学习指导，可作为电子电工类教材或相关人员的参考用书。

图书在版编目(CIP)数据

电路原理=Principles of Electric Circuits: Conventional Current Version/（美）Floyd（弗洛伊德）著.—影印本. —北京：科学出版社，2004

ISBN 7-03-012471-5

Ⅰ.电… Ⅱ.弗… Ⅲ.电子电路—电路理论—高等学校—教材—英文 Ⅳ.TN7012

中国版本图书馆 CIP 数据核字（2003）第 099955 号

策划编辑：李佩乾/责任编辑：王日臣
责任印制：吕春珉/封面制作：东方人华平面设计室

科学出版社 出版
北京东黄城根北街16号
邮政编码：100717
http://www.sciencep.com
双青印刷厂 印刷

科学出版社发行 各地新华书店经销
*
2004 年 1 月第 一 版 开本：787×960 1/16
2004 年 1 月第一次印刷 印张：63
印数：1—3 000 字数：1 482 000

定价：100.00 元

（如有印装质量问题，我社负责调换〈环伟〉）

敬告读者：

本书光盘如有需求，请向我社索取，费用 20.00 元/张。

联系人：朱敏 电话：010-62622941 E-mail: zhumin@abook.cn

Preface

This seventh edition of *Principles of Electric Circuits: Conventional Current Version* provides a complete and straightforward coverage of the basics of electrical components and circuits, with emphasis on analysis, applications, and troubleshooting. Many improvements have been made over the previous edition, but the coverage and organization remain the same. A new text design and layout enhance the text's appearance and usability.

New Features and Improvements

Troubleshooter Quiz A multiple-choice quiz in the chapter end matter tests the student's grasp of what happens in a circuit as a result of certain changes or faults. The student must determine whether a specified quantity or parameter increases, decreases, or remains the same as a result of the introduction of a fault or a change in another circuit parameter. Answers are at the end of the chapter.

Engineering Notation Chapter 1 includes an expanded coverage of engineering notation and the use of the calculator in scientific and engineering notation.

Electrical Safety The topic of electrical safety is introduced in Chapter 2. It is supplemented by a feature called "Safety Note" located at appropriate points throughout the text and identified by a special logo.

Troubleshooting An improved coverage of troubleshooting begins in Section 3–6 with an introduction. A systematic method called APM (analysis, planning, and measurement) is introduced and used in many of the troubleshooting sections and examples. Troubleshooting features are identified by a new logo.

Circuit Simulations In addition to the EWB circuit simulations for Troubleshooting and Analysis problems that are available on the CD-ROM accompanying the textbook, Multisim circuits have been added. To avoid any backward compatibility issues, the EWB files have been retained for those who have not yet upgraded to Multisim.

Circuit Simulation Tutorials The EWB and PSpice tutorials continue to be available on the website. In addition, Multisim tutorials are now available online. All of the tutorials can be downloaded for student use from www.prenhall.com/floyd.

Key Terms Terms identified as most important in each chapter are listed in the chapter opener. Within the chapter, the key terms are in color boldface and indicated with a "key" icon. Each key term is defined at the end of the chapter and in the comprehensive glossary at the end of the book.

Answer Reminders Notes to remind students where to find the answers to the various exercises and problems appear throughout each chapter.

Additional Features

Full-color format

Two-page chapter openers with a chapter outline, introduction, chapter objectives, and key terms list

An introduction and objectives at the beginning of each section within a chapter

A TECHnology Theory into Practice (TECH TIP) feature at the end of most chapters

Abundance of high-quality illustrations

Short biographies of key figures in the history of electricity in several chapters.

Many worked examples

A Related Problem in each worked example with answers at the end of the chapter

Section Reviews with answers at the end of the chapter

Troubleshooting section in many chapters

Self-test at the end of each chapter with answers at the end of the chapter

Summary at the end of each chapter

Formula list at the end of each chapter

Sectionalized problem set for each chapter with the more difficult problems indicated by an asterisk. Answers to odd-numbered problems are at the end of the book.

A comprehensive glossary at the end of the book that defines all boldface and key terms in the textbook

The conventional direction of current is used. (An alternate version of this text uses electron-flow direction.)

Accompanying Student Resources

Experiments in Basic Circuits, Fifth Edition: lab manual by David Buchla (ISBN: 0-13-098669-0). Solutions are provided in the Instructor's Resource Manual.

Experiments in Electric Circuits, Seventh Edition: lab manual by Brian Stanley (ISBN: 0-13-098660-7). Solutions are provided in the Instructor's Resource Manual.

Electronics Workbench/Multisim CD-ROM. Packaged with each text, this CD-ROM contains a set of EWB simulation circuit files and a corresponding set of Multisim circuit files for problems in the text. Many of these circuits have hidden faults. Also included on this CD-ROM is the Enhanced Textbook Edition of Multisim for the purpose of reading only the circuit files provided. Electronics Workbench software is available for purchase by individuals who want it for other applications, and this can be obtained by contacting a local Prentice Hall sales representative or Electronics Workbench.

Companion Website (www.prenhall.com/floyd). For the student, this website offers the opportunity to test his or her own progress and practice answering sample test questions.

Instructor Resources

PowerPoint® CD-ROM. Contains slides featuring all figures from the text, as well as Lecture Presentations for each chapter. This CD-ROM also includes innovative PowerPoint slides for the lab manual by David Buchla.

Companion Website (www.prenhall.com/floyd). For the instructor, this website offers the ability to post a syllabus online with our Syllabus Builder. This is a great solution for classes that are taught online or self-paced, or in any computer-assisted manner.

Online Course Support. If your program is offered in a distance learning format, please contact your local Prentice Hall sales representative for a list of product solutions.

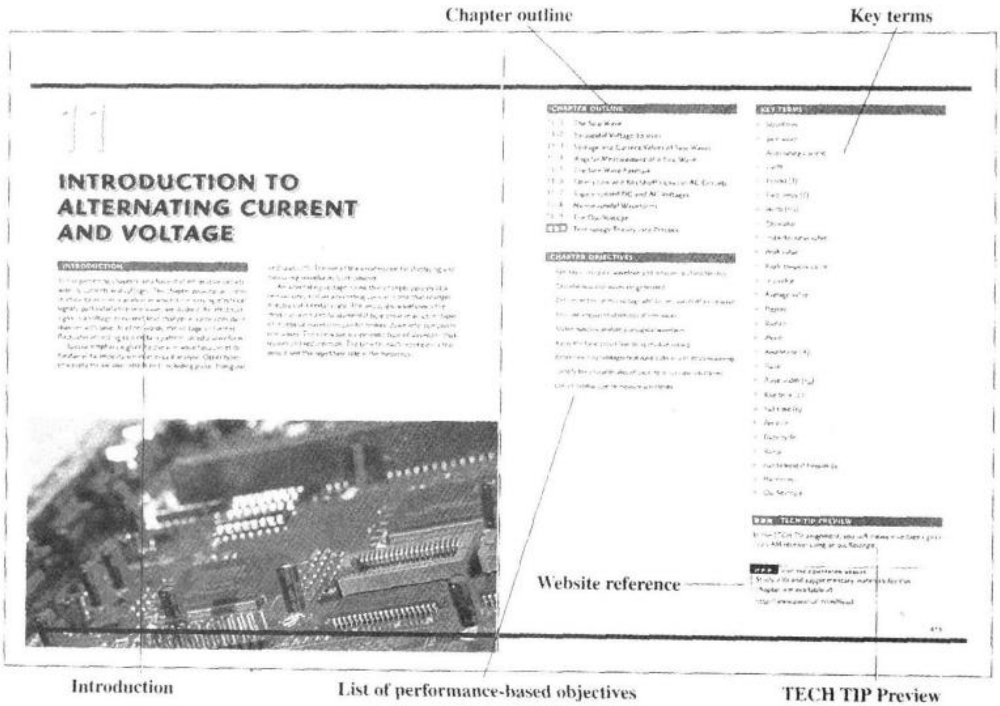


FIGURE P–1

A typical chapter opener.

Instructor's Resource Manual. Includes solutions to chapter problems, solutions to TECH TIPs, a summary of EWB/Multisim simulation results, a test item file, and solutions to both lab manuals.

Prentice Hall Test Manager This is a computerized test bank on CD-ROM.

Illustration of Chapter Features

Chapter Opener Each chapter begins with a two-page spread, as shown in Figure P–1. Each chapter opener includes the chapter number and title, a brief introduction, lists of text sections and chapter objectives, a key terms list, a TECH TIP preview, and a website reference for study aids and supplementary materials.

Section Opener Each section in a chapter begins with a brief introduction that includes a general overview and section objectives. An illustration is given in Figure P–2.

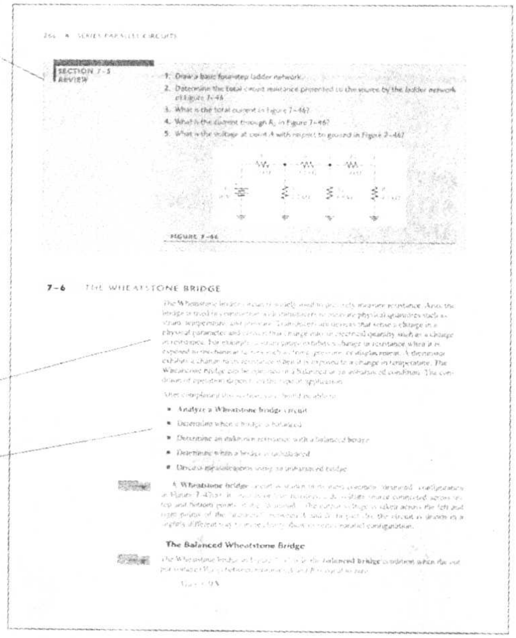
Section Review Each section in a chapter ends with a review consisting of questions or exercises that emphasize the main concepts covered in the section. An example is shown in Figure P–2. Answers to the Section Reviews are at the end of the chapter.

Worked Examples and Related Problems Numerous worked examples throughout each chapter help to illustrate and clarify basic concepts or specific procedures. Each example ends with a Related Problem that reinforces or expands on the example by requiring the student to work through a problem similar to the example. A typical worked example with a Related Problem is shown in Figure P–3.

FIGURE P–2

A typical section opener and section review.

Section review questions end each section.



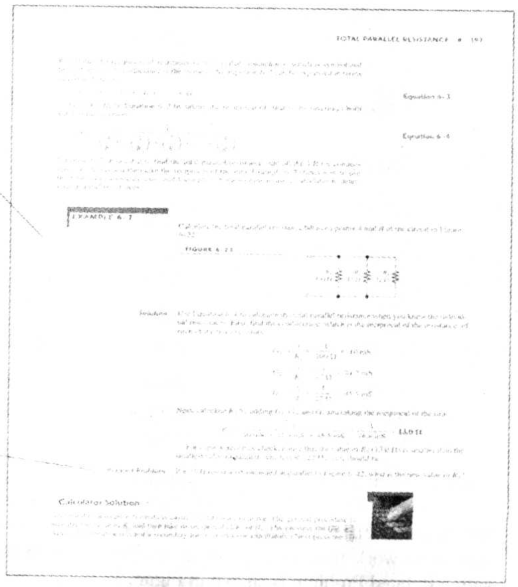
Introductory paragraph begins each section.

Performance-based section objectives

FIGURE P–3

A typical worked example and related problem.

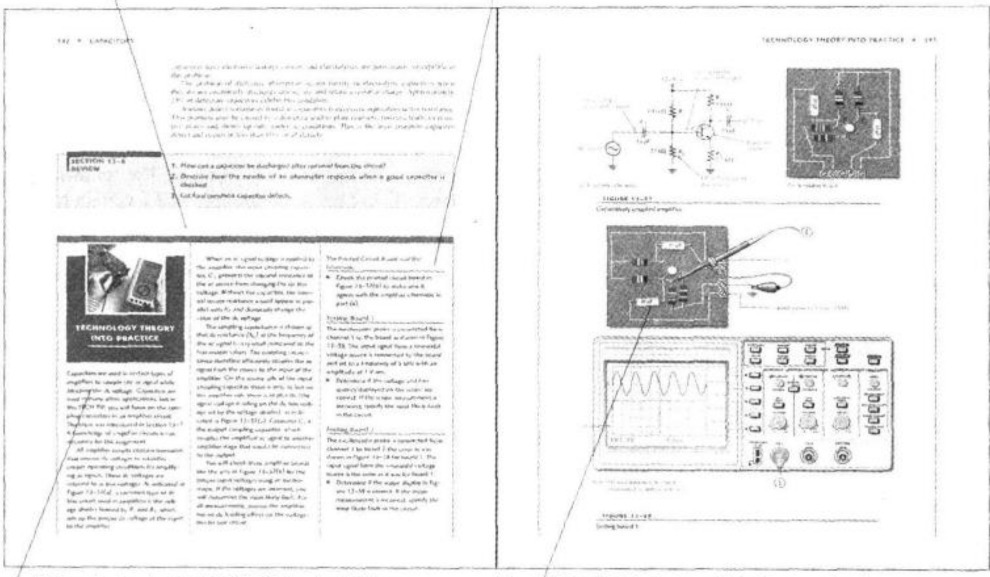
Examples are set off from text.



Each example contains a related problem relevant to the example.

TECH TIP is set off from text.

A series of activities relates theory to practice.



An overall introduction to the TECH TIP begins this feature.

Most TECH TIPs include realistic PC board and instrument graphics.

FIGURE P–4

A portion of a typical TECH TIP feature.

Troubleshooting Sections Many chapters include a troubleshooting section that relates to the topics covered in the chapter and emphasizes logical thinking as well as a structured approach called APM (analysis, planning, and measurement) where applicable. Particular troubleshooting methods such as half-splitting are applied when appropriate.

TECHnology Theory Into Practice (TECH TIP) This special feature at the end of each chapter (except Chapters 1 and 22) presents a practical application of certain topics covered in the chapter. Each of these TECH TIPs includes a series of activities, many of which involve comparing circuit board layouts with schematics, analyzing circuits, using measurements to determine circuit operation, and in some cases, developing simple test procedures. Results and answers are found in the Instructor's Resource Manual (IRM). A portion of a representative TECH TIP feature is illustrated in Figure P–4.

Chapter End Matter The following pedagogical features are found at the end of each chapter:

Summary

Key terms glossary

Formula list

Self-Test

Troubleshooter Quiz

Problems

Answers to section reviews, related problems for examples, self-test, and the troubleshooter quiz

Suggestions for Teaching with *Principles of Electric Circuits*

Selected Course Emphasis and Flexibility of the Text This textbook is designed primarily for use in a two-term course sequence in which dc topics (Chapters 1 through 10) are covered in the first term and ac topics (Chapters 11 through 22) are covered in the second term. A one-term course covering dc and ac topics is possible but would require very selective and abbreviated coverage of many topics.

If time limitations or course emphasis restricts the topics that can be covered, as is usually the case, there are several options for selective coverage. The following suggestions for light treatment or omission do not necessarily imply that a certain topic is less important than others but that, in the context of a specific program, the topic may not require the emphasis that the more fundamental topics do. Because course emphasis, level, and available time vary from one program to another, the omission or abbreviated treatment of selected topics must be made on an individual basis. Therefore, the following suggestions are intended only as a general guide.

1. Chapters that may be considered for omission or selective coverage:

   Chapter 8, Circuit Theorems and Conversions

   Chapter 9, Branch, Mesh, and Node Analysis

   Chapter 10, Magnetism and Electromagnetism

   Chapter 19, Basic Filters

   Chapter 20, Circuit Theorems in AC Analysis

   Chapter 21, Pulse Response of Reactive Circuits

   Chapter 22, Polyphase Systems in Power Applications

2. The TECH TIPs and troubleshooting sections can be omitted without affecting other material.

3. Other specific topics may be omitted or covered lightly on a section-by-section basis at the discretion of the instructor.

The order in which certain topics appear in the text can be altered at the instructor's discretion. For example, the topics of capacitors and inductors (Chapter 13 and 14) can be covered at the end of the dc course in the first term by delaying coverage of the ac topics in Sections 13–6, 13–7, 14–6, and 14–7 until the ac course in the second term. Another possibility is to cover Chapters 13 and 14 in the second term but cover Chapter 16 (*RC* Circuits) immediately after Chapter 13 (Capacitors) and cover Chapter 17 (*RL* Circuits) immediately after Chapter 14 (Inductors).

TECH TIPs These features are useful for motivation and for introducing applications of basic concepts and components. Suggestions for using these sections are:

> As an integral part of the chapter to illustrate how the concepts and components can be applied in a practical situation. The activities can be assigned for homework.
>
> As extra credit assignments.
>
> As in-class activities to promote discussion and interaction and to help students understand why they need to know the material.

Coverage of Reactive Circuits Chapters 16, 17, and 18 have been designed to facilitate two approaches to teaching these topics on reactive circuits.

The first option is to cover the topics on the basis of components. That is, first cover all of Chapter 16 (*RC* Circuits), then all of Chapter 17 (*RL* Circuits), and, finally, all of Chapter 18 (*RLC* Circuits and Resonance).

The second option is to cover the topics on the basis of circuit type. That is, first cover all topics related to series reactive circuits, then all topics related to parallel reactive circuits, and finally, all topics related to series-parallel reactive circuits. To facilitate this second approach, each of the chapters has been divided into the following parts: *Part 1: Series Reactive Circuits, Part 2: Parallel Reactive Circuits, Part 3: Series-Parallel Reactive Circuits, and Part 4: Special Topics*. So, for series reactive circuits, cover Part 1 of all three chapters in sequence. For parallel reactive circuits, cover Part 2 of all three chapters in sequence. For series-parallel reactive circuits, cover Part 3 of all three chapters in sequence. Finally, cover Part 4 of all three chapters.

To the Student

Any career training requires hard work, and electronics is no exception. The best way to learn new material is by reading, thinking, and doing. This text is designed to help you along the way by providing an overview and objectives for each section, numerous worked-out examples, practice exercises, and review questions with answers.

Don't expect every concept to be crystal clear after a single reading. Read each section of the text carefully and think about what you have read. Work through the example problems step by step before trying the related problem that goes with the example. Sometimes more than one reading of a section will be necessary. After each section, check your understanding by answering the section review questions.

Review the chapter summary and equation list. Take the multiple-choice self-test. Finally, work the problems at the end of the chapter. Check your answers to the troubleshooting quiz and self-test at the end of the chapter and your answers to the odd-numbered problems against those provided at the end of the book. Working problems is the most important way to check your comprehension and solidify concepts.

Careers in Electronics

The field of electronics is very diverse, and career opportunities are available in many areas. Because electronics is currently found in so many different applications and new technology is being developed at a fast rate, its future appears limitless. There is hardly an area of our lives that is not enhanced to some degree by electronics technology. Those who acquire a sound, basic knowledge of electrical and electronic principles and are willing to continue learning will always be in demand.

The importance of obtaining a thorough understanding of the basic principles contained in this text cannot be overemphasized. Most employers prefer to hire people who have both a thorough grounding in the basics and the ability and eagerness to grasp new concepts and techniques. If you have a good training in the basics, an employer will train you in the specifics of the job to which you are assigned.

There are many types of job classifications for which a person with training in electronics technology may qualify. A few of the most common job functions are discussed briefly in the following paragraphs.

Service Shop Technician Technical personnel in this category are involved in the repair or adjustment of both commercial and consumer electronic equipment that is returned to the dealer or manufacturer for service. Specific areas include TVs, VCRs, CD players, stereo equipment, CB radios, and computer hardware. This area also offers opportunities for self-employment.

Industrial Manufacturing Technician Manufacturing personnel are involved in the testing of electronic products at the assembly-line level or in the maintenance and troubleshooting of electronic and electromechanical systems used in the testing and manufacturing of products. Virtually every type of manufacturing plant, regardless of its product, uses automated equipment that is electronically controlled.

Laboratory Technician These technicians are involved in breadboarding, prototyping, and testing new or modified electronic systems in research and development laboratories. They generally work closely with engineers during the development phase of a product.

Field Service Technician Field service personnel service and repair electronic equipment—for example, computer systems, radar installations, automatic banking equipment, and security systems—at the user's location.

Engineering Assistant/Associate Engineer Personnel in this category work closely with engineers in the implementation of a concept and in the basic design and development of electronic systems. Engineering assistants are frequently involved in a project from its initial design through the early manufacturing stages.

Technical Writer Technical writers compile technical information and then use the information to write and produce manuals and audiovisual materials. A broad knowledge of a particular system and the ability to clearly explain its principles and operation are essential.

Technical Sales Technically trained people are in demand as sales representatives for high-technology products. The ability both to understand technical concepts and to communicate the technical aspects of a product to a potential customer is very valuable. In this area, as in technical writing, competency in expressing yourself orally and in writing is essential. Actually, being able to communicate well is very important in any technical job category because you must be able to record data clearly and explain procedures, conclusions, and actions taken so that others can readily understand what you are doing.

Milestones in Electronics

Before you begin your study of electric circuits, let's briefly look at some of the important developments that led to the electronics technology we have today. The names of many of the early pioneers in electricity and electromagnetics still live on in terms of familiar units and quantities. Names such as Ohm, Ampere, Volta, Farad, Henry, Coulomb, Oersted, and Hertz are some of the better known examples. More widely known names such as Franklin and Edison are also significant in the history of electricity and electronics because of their tremendous contributions. Short biographies of some of these pioneers, like shown here, are located throughout the text.

James Watt 1736–1819 Watt was a Scottish inventer and was well known for his improvements to the steam engine that made it practical for industrial use. Watt patented several inventions, including the rotary engine. The unit of power is named in his honor. (Photo credit: Library of Congress.)

The Beginning of Electronics Early experiments with electronics involved electric currents in vacuum tubes. Heinrich Geissler (1814–1879) removed most of the air from a glass tube and found that the tube glowed when there was current through it. Later, Sir William Crookes (1832–1919) found the current in vacuum tubes seemed to consist of particles. Thomas Edison (1847–1931) experimented with carbon filament bulbs with plates and discovered that there was a current from the hot filament to a positively charged plate. He patented the idea but never used it.

Other early experimenters measured the properties of the particles that flowed in vacuum tubes. Sir Joseph Thompson (1856–1940) measured properties of these particles, later called *electrons*.

Although wireless telegraphic communication dates back to 1844, electronics is basically a 20th century concept that began with the invention of the vacuum tube amplifier. An early vacuum tube that allowed current in only one direction was constructed by John A. Fleming in 1904. Called the Fleming valve, it was the forerunner of vacuum tube diodes. In 1907, Lee deForest added a grid to the vacuum tube. The new device, called the audiotron, could amplify a weak signal. By adding the control element, deForest ushered in the electronics revolution. It was with an improved version of his device that made transcontinental telephone service and radios possible. In 1912, a radio amateur in San Jose, California, was regularly broadcasting music!

In 1921, the secretary of commerce, Herbert Hoover, issued the first license to a broadcast radio station; within two years over 600 licenses were issued. By the end of the 1920s radios were in many homes. A new type of radio, the superheterodyne radio, invented by Edwin Armstrong, solved problems with high-frequency communication. In 1923, Vladimir Zworykin, an American researcher, invented the first television picture tube, and in 1927 Philo T. Farnsworth applied for a patent for a complete television system.

The 1930s saw many developments in radio, including metal tubes, automatic gain control, "midgit sets," directional antennas, and more. Also started in this decade was the development of the first electronic computers. Modern computers trace their origins to the work of John Atanasoff at Iowa State University. Beginning in 1937, he envisioned a binary machine that could do complex mathematical work. By 1939, he and graduate student Clifford Berry had constructed a binary machine called ABC, (for Atanasoff-Berry Computer) that used vacuum tubes for logic and condensers (capacitors) for memory. In 1939, the magnetron, a microwave oscillator, was invented in Britain by Henry Boot and John Randall. In the same year, the klystron microwave tube was invented in America by Russell and Sigurd Varian.

During World War II, electronics developed rapidly. Radar and very high-frequency communication were made possible by the magnetron and klystron. Cathode ray tubes were improved for use in radar. Computer work continued during the war. By 1946, John von Neumann had developed the first stored program computer, the Eniac, at the University of Pennsylvania. The decade ended with one of the most important inventions ever, the transistor.

Solid-State Electronics The crystal detectors used in early radios were the forerunners of modern solid-state devices. However, the era of solid-state electronics began with the invention of the transistor in 1947 at Bell Labs. The inventors were Walter Brattain, John Bardeen, and William Shockley. PC (printed circuit) boards were introduced in 1947, the year the transistor was invented. Commercial manufacturing of transistors began in Allentown, Pennsylvania, in 1951.

The most important invention of the 1950s was the integrated circuit. On September 12, 1958, Jack Kilby, at Texas Instruments, made the first integrated circuit. This invention literally created the modern computer age and brought about sweeping changes in medicine, communication, manufacturing, and the entertainment industry. Many billions of "chips"—as integrated circuits came to be called—have since been manufactured.

The 1960s saw the space race begin and spurred work on miniaturization and computers. The space race was the driving force behind the rapid changes in electronics that followed. The first successful "op-amp" was designed by Bob Widlar at Fairchild Semiconductor in 1965. Called the μA709, it was very successful but suffered from "latch-up" and other problems. Later, the most popular op-amp ever, the 741, was taking shape at Fairchild. This op-amp became the industry standard and influenced design of op-amps for years to come.

By 1971, a new company that had been formed by a group from Fairchild introduced the first microprocessor. The company was Intel and the product was the 4004 chip, which had the same processing power as the Eniac computer. Later in the same year, Intel announced the first 8-bit processor, the 8008. In 1975, the first personal computer was introduced by Altair, and Popular Science magazine featured it on the cover of the January, 1975, issue. The 1970s also saw the introduction of the pocket calculator and new developments in optical integrated circuits.

By the 1980s, half of all U.S. homes were using cable hookups instead of television antennas. The reliability, speed, and miniaturization of electronics continued throughout the 1980s, including automated testing and calibrating of PC boards. The computer became a part of instrumentation and the virtual instrument was created. Computers became a standard tool on the workbench.

The 1990s saw a widespread application of the Internet. In 1993, there were 130 websites, and now there are millions. Companies scrambled to establish a home page and many of the early developments of radio broadcasting had parallels with the Internet. In 1995, the FCC allocated spectrum space for a new service called Digital Audio Radio

Service. Digital television standards were adopted in 1996 by the FCC for the nation's next generation of broadcast television.

The 21st century dawned in January 2001. The major technology story was the continued explosive growth of the Internet. Traffic on the Internet doubles every 100 days with no end in sight. The future of technology looks brighter than ever.

Acknowledgments

Many capable people have been part of this revision of *Principles of Electric Circuits*. It has been thoroughly reviewed and checked for both content and accuracy. Those at Prentice Hall who have contributed greatly to this project throughout the many phases of development and production include Rex Davidson, Kate Linsner, and Dennis Williams. Lois Porter, whose attention to details is unbelievable, has once more done an outstanding job of editing the manuscript. Jane Lopez has again provided the excellent illustrations and beautiful graphics work used in the text. As with the previous edition, Gary Snyder created the circuit files for the Electronics Workbench and Multisim features in this edition.

I wish to express my appreciation to those already mentioned as well as those who provided many valuable suggestions and constructive criticism that have greatly influenced this textbook. I thank Herbert Hall, Lakeland Community College; Leslie E. Johnson, Delaware Tech and Community College; Steve Kuchler, Ivy Tech State College; Stuart Peterson, Ridgewater College; Charles R. Morgan, Denver Technical College; Jon Speer, Northwest State Community College, and Victor L. Stateler, Kirkwood Community College.

Tom Floyd

1

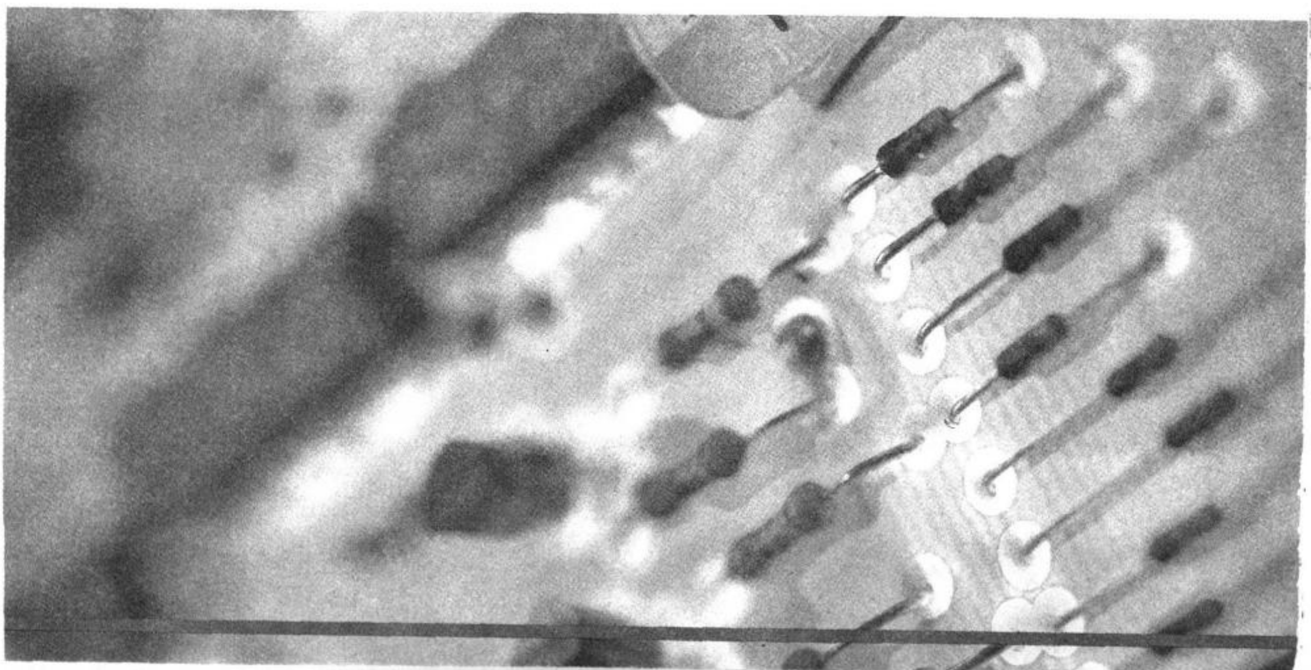
COMPONENTS, QUANTITIES, AND UNITS

INTRODUCTION

The topics in this chapter present a basic introduction to the field of electronics. An overview of electrical and electronic components and instruments gives you a preview of the types of things you will study throughout this book.

You must be familiar with the units used in electronics and know how to express electrical quantities in various ways using metric prefixes. Scientific notation and engineering notation are indispensable tools whether you use a computer, a calculator, or do computations the old-fashioned way.

CHAPTER OUTLINE



Contents