

# Electronic Devices

## Electron Flow Version

*Fourth Edition*

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FOURTH EDITION

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# ELECTRONIC DEVICES

Electron Flow Version

Thomas L. Floyd

Prentice  
Hall

Upper Saddle River, New Jersey  
Columbus, Ohio

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**To Sheila and Taylor,  
with love.**

# Preface

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*Electronic Devices: Electron Flow Version*, Fourth Edition, has been carefully revised. Many suggestions and comments from reviewers and current users have been included to make this edition even more effective. A comprehensive coverage of electronic devices and circuits, including troubleshooting and practical applications, is provided. Chapters 1 through 11 are essentially devoted to discrete devices and circuits, whereas Chapters 12 through 18 primarily cover linear integrated circuits. The majority of chapters include a troubleshooting section, and most chapters have a System Application feature. The use of data sheets provides an important link between theory and the real world. Extensive exercises and problems using Electronics Workbench/Multisim circuit simulations help the student to verify circuit theory and develop troubleshooting and measurement skills. Referenced circuit files in both EWB Version 5 and Multisim are on the CD-ROM packaged with this book.

## New to This Edition

**New Chapter on Communications Circuits** Chapter 17 includes coverage of basic receivers, multipliers, amplitude and frequency modulation, demodulation, mixers, IF and audio amplifiers, and phase-locked loops.

**Two Chapters Combined** Chapter 12 and Chapter 13 have been combined by eliminating certain topics that have become nonessential or less important in the context of modern linear ICs.

**Chapters Reordered** Chapters 6 through 9, which cover amplifiers, have been reordered so that the chapter on power amplifiers is now the last in that sequence and includes both BJTs and FETs.

**Key Terms** A key terms list is now part of the chapter opener. These key terms are highlighted in color and indicated by a margin icon where they appear in the text. Definitions are given at the end of the chapter as well as at the end of the book in a comprehensive glossary.

**System Applications Feature** The System Applications, which were formerly numbered sections, are now presented as a special feature rather than a section. This approach is more appropriate to the optional nature of these topics.

**EWB and Multisim Troubleshooting Problems** A set of problems that reference EWB and Multisim files on the CD-ROM have been added to most chapters. Each reference circuit file contains a simulated circuit with an inserted fault. The student must troubleshoot each circuit to determine the faulty component.

**General Improvements** Numerous topics throughout the book have been revised either by being completely rewritten, expanded, or condensed to improve and clarify the presentation. Devices that have become obsolete have been replaced by newer, similar devices.

## Features

- New attractive text design and layout provides visual interest and ease of use.
- Full-color format
- Two-page chapter openers with a chapter outline, chapter objectives, introduction, list of key terms, and system application preview

- An introduction and list of objectives at the beginning of each section within a chapter
- Numerous worked examples, each with a related problem that provides a student exercise similar to that illustrated in the example. Answers to related problems are at the end of the chapter.
- An EWB/Multisim simulation on the CD-ROM for selected examples
- Section Reviews with answers at the end of the chapter
- A Troubleshooting section in the majority of chapters
- A System Application at the end of most chapters
- Chapter Summary, Key Term glossary, Key Formulas, and Self-Test at the end of each chapter. Answers to the self-test are also at the end of the chapter.
- Problem set at the end of each chapter divided by chapter sections and organized into basic and advanced categories. Selected problem circuits are available in EWB and Multisim on the CD-ROM. Additional problem categories of troubleshooting, data sheet, and EWB/Multisim Troubleshooting are found in many chapters.
- Table of standard resistor values, derivation of selected equations, data sheets, answers to odd-numbered problems, a comprehensive glossary, and the index are at the end of the book.

### Student Resources

**Companion Website ([www.prenhall.com/floyd](http://www.prenhall.com/floyd))** This website offers students a free online study guide that they can check for conceptual understanding of key topics.

**Electronics Workbench®/Multisim® CD-ROM** Packaged with each textbook, this software includes simulation circuits for selected examples, troubleshooting sections, and selected problems with and without inserted faults. Each simulated circuit is found in both EWB Version 5 and Multisim. Electronics Workbench and Multisim application software can be obtained through your local bookstore, or by contacting Electronics Workbench at 800-263-5552 or through their website at [www.electronicsworkbench.com](http://www.electronicsworkbench.com).

**Laboratory Exercises for Electronic Devices**, by Dave Buchla. ISBN: 0-13-092275-7

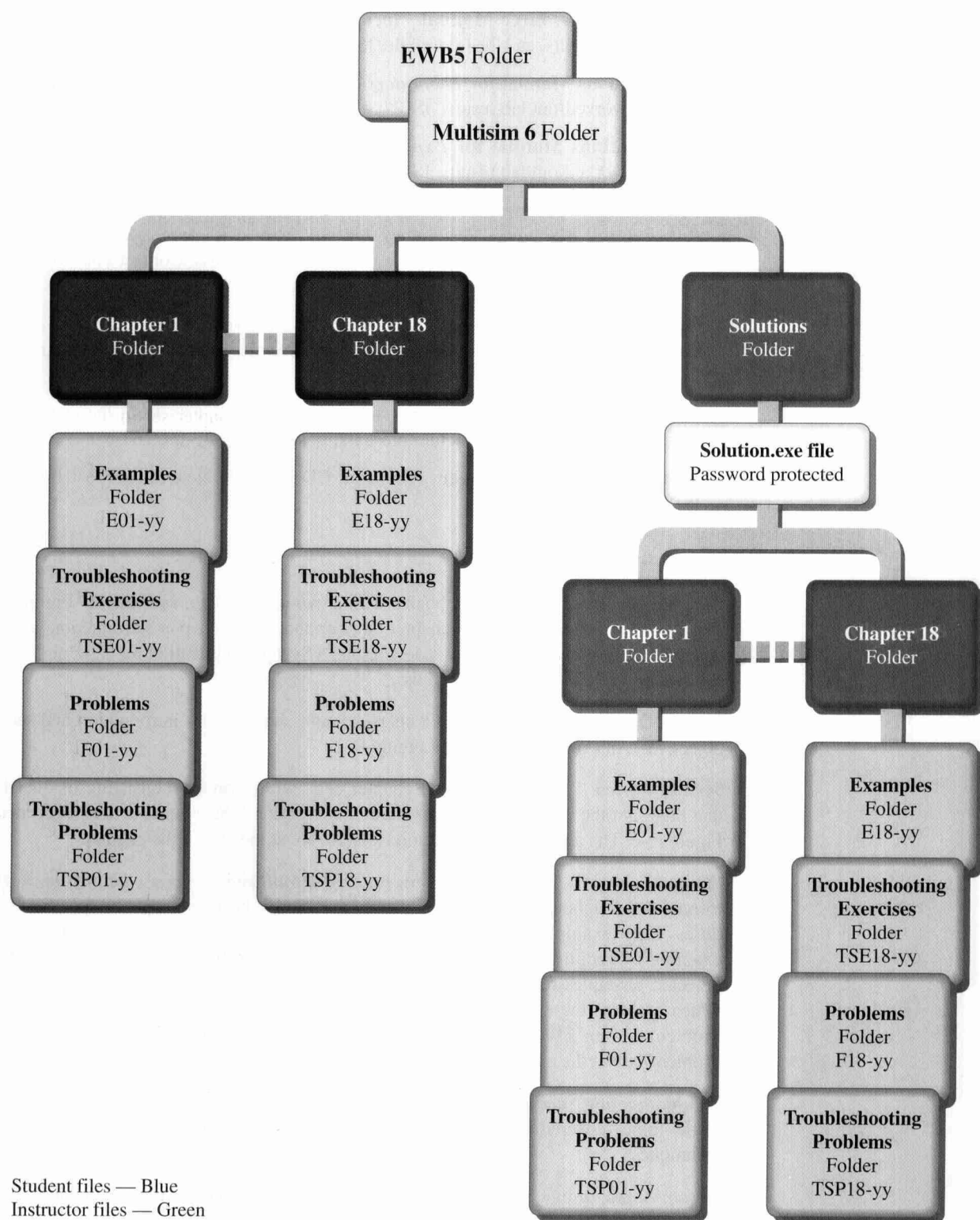
**Experiments in Electronic Devices**, by Howard Berlin et al. ISBN: 0-13-092256-0

**Electronics Supersite ([www.prenhall.com/electronics](http://www.prenhall.com/electronics))** Students will find additional troubleshooting exercises, links to industry sites, an interview with an electronics professional, and more.

### Instructor Resources

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

**Electronics Workbench/Multisim CD-ROM** Although the CD-ROM accompanying the textbook is primarily for the benefit of the student, solution and fault information is provided on the disk for the instructor's use. Refer to the CD-ROM organization diagram, which shows the folder hierarchy and file naming convention. Circuits containing faults are password-protected so that only the instructor can identify the faults. Solution files are available for each student circuit and are also password-protected and accessible only by the instructor.



CD-ROM Organizational Diagram



**Instructor's Resource Manual** Includes solutions to chapter problems, System Application results, and Test Item File. ISBN: 0-13-092257-9

**Lab Solutions Manual for *Laboratory Exercises for Electronic Devices* by Buchla** Includes worked-out lab results. ISBN: 0-13-092274-9

**Lab Solutions Manual for *Experiments in Electronic Devices* by Berlin et al.** Includes worked-out lab results. ISBN: 0-13-092254-4

**Electronics Supersite ([www.prenhall.com/electronics](http://www.prenhall.com/electronics))** Instructors will find the *Prentice Hall Electronics Technology Journal*, extra classroom resources, and all of the supplements for this text available online for easy access. Contact your local Prentice Hall sales representative for your "User Name" and "Passcode."

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

**PowerPoint® CD-ROM** Contains slides featuring all figures from the text, as well as text highlights for use in lecture presentations. ISBN: 0-13-092263-3

**Prentice Hall Test Manager** This is a CD-ROM version of the Test Item File. ISBN: 0-13-092259-5

## Chapter Features

**Chapter Opener** Each chapter begins with a two-page spread, as shown in Figure P-1. The chapter opener includes the chapter number and title, a chapter introduction, a list of chapter sections, chapter objectives, key terms, a System Application preview, and a website reference for associated study aids.

**Section Opener** Each section in a chapter begins with a brief introduction and section objectives. An example is shown in Figure P-2.

**Section Review** Each section in a chapter ends with a review consisting of questions that highlight the main concepts presented in the section. This feature is also illustrated in Figure P-2. The answers to the Section Reviews are at the end of the chapter.

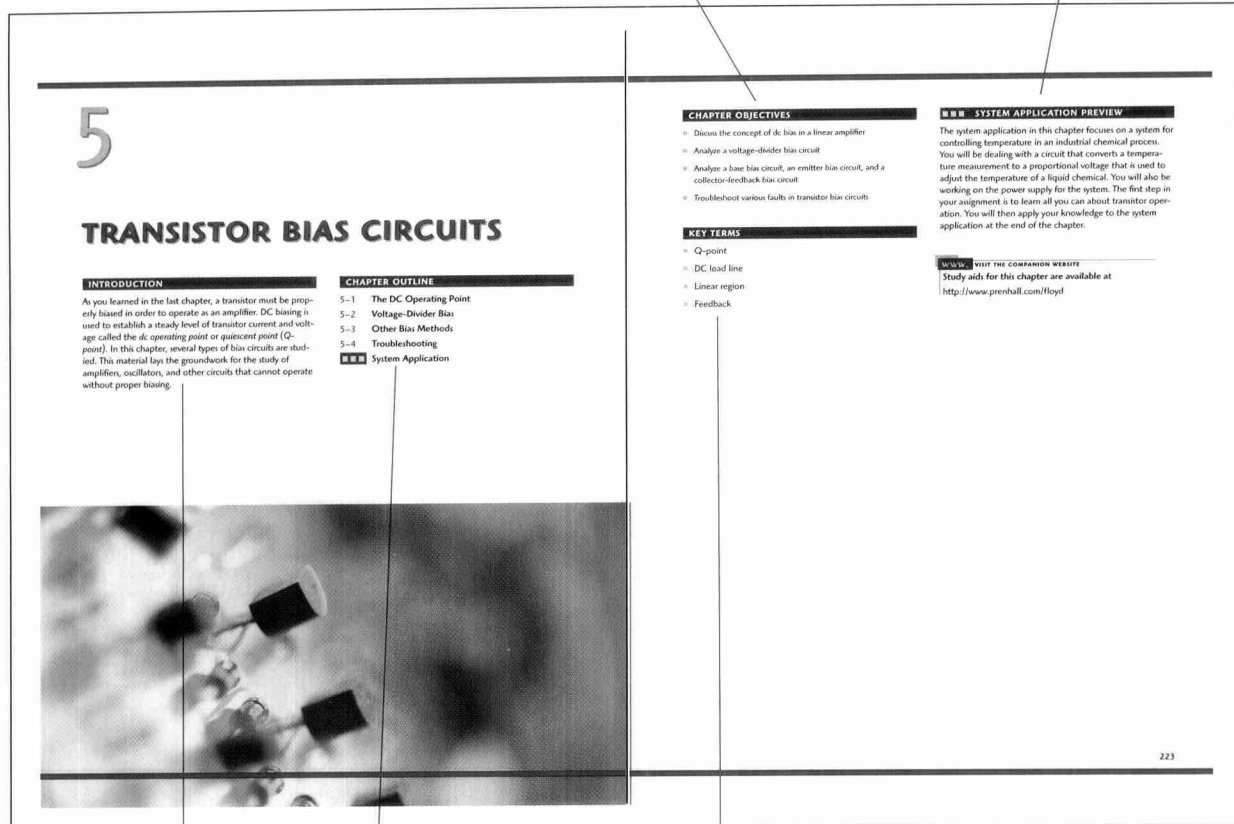
**Worked Examples, Related Problems, and EWB/Multisim Exercise** Numerous worked examples throughout each chapter illustrate and clarify basic concepts or specific procedures. Each example ends with a Related Problem that reinforces or expands on the example by requiring the student to work through a problem similar to the example. Selected examples feature an EWB/Multisim exercise keyed to a file on the CD-ROM which contains the circuit illustrated in the example. A typical example with a Related Problem and an EWB/Multisim exercise is shown in Figure P-3. Answers to Related Problems are at the end of the chapter.

**Troubleshooting Sections** Many chapters include a troubleshooting section that relates to the topics covered in the chapter and that illustrates troubleshooting procedures and techniques.

**System Application** System Applications follow the last section in each chapter (except Chapter 1) and are identified by a special photographic logo and colored background design. A practical application of devices or circuits covered in the chapter is presented. The student learns how the specific device or circuit is used and is asked to compare a schematic to a printed circuit board, develop a test procedure, and troubleshoot specific faults. A typical System Application is shown in Figure P-4. The System Applications are optional and skipping any of them does not affect any other coverage.

Although they are not intended or designed for use as a laboratory project, most System Applications use realistic graphics for printed circuit boards and instruments. Results for the System Applications are provided in the Instructor's Resource Manual.





Introduction

Chapter outline

Key terms

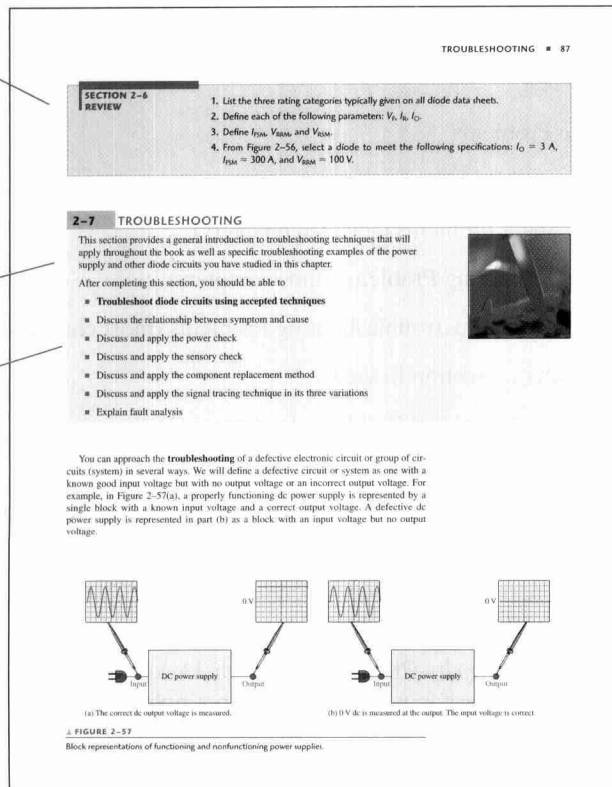
▲ FIGURE P-1

A typical chapter opener.

Section review questions end each section.

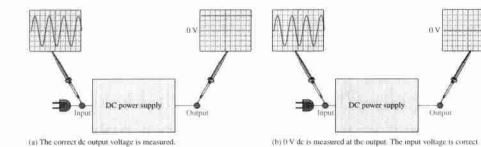
Introductory paragraph begins each section.

Performance-based section objectives.



◀ FIGURE P-2

A typical section opener and section review.



▲ FIGURE 2-57  
Block representations of functioning and nonfunctioning power supplies.

## ► FIGURE P-3

A typical example with a related exercise and EWB exercise.

Examples are set off from text

Each example contains a related exercise relevant to the example.

Selected examples include an EWB/Multisim exercise coordinated to the textbook CD-ROM.

COMMON-SOURCE AMPLIFIERS ■ 395

**EXAMPLE 8-4**

What is the total output voltage of the unloaded amplifier in Figure 8-10? For this particular JFET,  $I_{DSS}$  is 12 mA and  $V_{GS(off)}$  is  $-3$  V.

FIGURE 8-10

**Solution** First, find the dc output current using a calculator. When Equation 8-5 is solved with the parameter values given,  $I_D \approx 1.96$  mA. Using this value, calculate  $V_{DQ}$ .

$$V_{DQ} = V_{DD} - I_D R_D = 12 \text{ V} - (1.96 \text{ mA})(3.3 \text{ k}\Omega) = 5.53 \text{ V}$$

Next, calculate  $g_m$  as follows:

$$V_{GS} = -I_D R_S = -(1.96 \text{ mA})(910 \Omega) = -1.78 \text{ V}$$

$$g_{m0} = \frac{2I_{DSS}}{|V_{GS(off)}|} = \frac{2(12 \text{ mA})}{3 \text{ V}} = 8 \text{ mS}$$

$$g_m = g_{m0} \left( 1 - \frac{V_{GS}}{V_{GS(off)}} \right) = (8 \text{ mS}) \left( 1 - \frac{-1.78 \text{ V}}{-3 \text{ V}} \right) = 3.25 \text{ mS}$$

Finally, find the ac output voltage:

$$V_{out} = A_v V_{in} = g_m R_D V_{in} = (3.25 \text{ mS})(3.3 \text{ k}\Omega)(100 \text{ mV}) = 1.07 \text{ V rms}$$

The total output voltage is an ac signal with a peak-to-peak value of  $1.07 \text{ V} \times 2.828 = 3.03 \text{ V}$ , riding on a dc level of 5.53 V.

**Related Problem** What will happen in the amplifier of Figure 8-10 if a transistor with  $V_{GS(off)} = -2$  V is used? Assume the other parameters are the same.

Open file E08-04 in the Examples folder on your CD-ROM. Using the specified input voltage, measure the output voltage and compare with the calculated value.

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

- Summary
- Key Term glossary
- Key Formulas
- Self-Test
- Basic Problems
- Advanced Problems
- Data Sheet Problems (selected chapters)
- Troubleshooting Problems (most chapters)
- EWB/Multisim Troubleshooting Problems (most chapters)
- Answers to Section Reviews
- Answers to Related Problems for Examples
- Answers to Self-Test

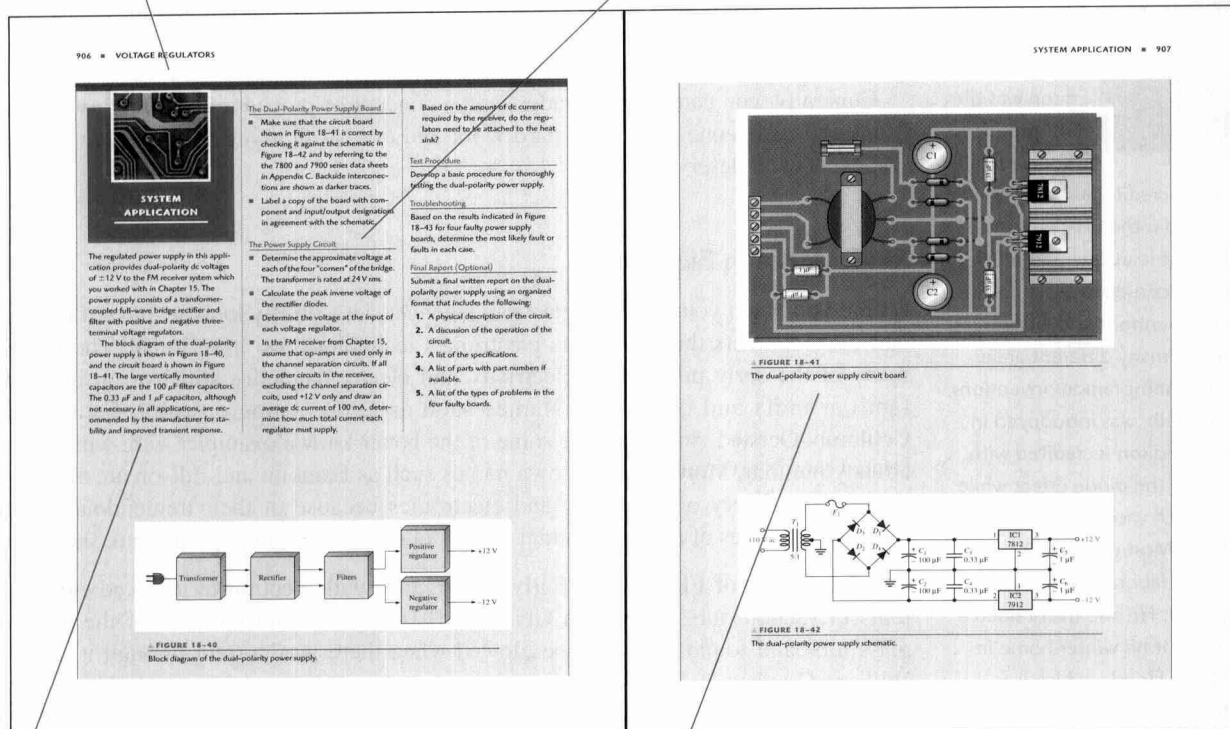
### Suggestions for Using This Textbook

As mentioned, this book covers discrete devices in Chapters 1 through 11 and integrated circuits in Chapters 12 through 18.

**Option 1 (two terms)** Chapters 1 through 11 can be covered in the first term. Depending on individual preferences and program emphasis, selective coverage may be necessary. For example, you may choose to omit Chapter 11 if the topic of thyristors is covered

System Applications are set off from text.

A series of activities is provided, which simulate “on-the-job” experiences.



An overall introduction to the system application is provided.

Most system applications include realistic PC board graphics.

▲ FIGURE P-4

Portion of a typical system application section.

in a later industrial electronics course. Chapters 12 through 18 can be covered in the second term. Again, selective coverage may be necessary.

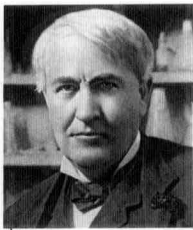
**Option 2 (one term)** By omitting certain topics and by maintaining a rigorous schedule, this book can be used in one-term courses. For example, a course covering only discrete devices and circuits would cover Chapters 1 through 11 with, perhaps, some selectivity.

Similarly, a course requiring only linear integrated circuit coverage would cover Chapters 12 through 18. Another approach is a very selective coverage of discrete devices and circuits topics followed by a limited coverage of integrated circuits (only op-amps for example).

## To the Student

There is an old saying that is very applicable to the study of this textbook as well as many other endeavors in life. It goes like this—*Do one thing at a time, do it very well, and then move on.*

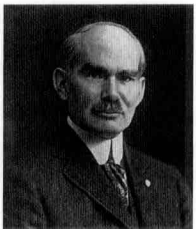
When studying a particular chapter, study one section until you understand it and only then move on to the next one. Read each section and study the related illustrations carefully, think about the material, work through each example step-by-step, work its Related Problem and check the answer, and then answer each question in the section review, checking your answers at the end of the chapter. Don't expect each concept to be crystal clear after a single reading; you may have to read the material two or even three times. Once you believe that you understand the material, review the chapter summary, key formula list, and



**Thomas Alva Edison**  
**1847–1931**

Born in Milan, Ohio, Thomas Edison was the most prolific inventor of all

time. He is credited with 1093 patents and is the only person to ever have at least one patent every year for 65 consecutive years. Mr. Edison's inventions and enterprises encompass many different areas. One of his most famous inventions, the light bulb, was introduced in 1879. Mr. Edison is credited with discovering the diode effect while working with vacuum tubes for the light bulb. Most of his work was done in his laboratory in West Orange, NJ. He also maintained a laboratory at his winter home in Fort Myers, Florida, which was devoted principally to the development of a synthetic rubber using the goldenrod plant. (Photo credit: Library of Congress)



**Lee DeForest**  
**1873–1961**

Born in Iowa, Lee DeForest became an inventor while in college to help defray

expenses. He graduated from Yale in 1899 with a PhD. His doctoral thesis, "Reflection of Hertzian Waves from the Ends of Parallel Wires," began his long career in radio. His invention of the vacuum tube triode for use in amplification (audion amplifier) was the most important of his more than 300 inventions. (Photo credit: The National Cyclopedic of American Biography, courtesy AIP Emilio Segrè Visual Archives, T. J. J. See Collection)

key term definitions at the end of the chapter. Take the multiple-choice self-test. Finally, work the assigned problems at the end of the chapter. Working through these problems is perhaps the most important way to check and reinforce your comprehension of the chapter. By working problems, you acquire an additional level of insight and understanding that reading or classroom lectures alone do not provide.

Generally, you cannot fully understand a concept or procedure by simply watching or listening to someone else. Only hard work and critical thinking will produce the results you expect and deserve.

## Milestones in Electronics

Before you begin your study of electronic devices, 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 with which you are already familiar. More widely known names such as Franklin and Edison are also significant in the history of electricity and electronics because of their tremendous contributions. Biographies of a few important figures in the history of electronics are shown.

**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, "midget 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 (Figure P-5), for which he was awarded a Nobel prize in the fall of 2000. 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  $\mu A709$ , 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. Precursors to the Internet began in the 1960s with remote networked



**John Bardeen**  
1908–1991

An electrical engineer and physicist born in Madison, Wisconsin, Dr.

Bardeen was on the faculty of the University of Minnesota from 1938 to 1941 and a physicist at the Naval Ordnance Lab from 1941 to 1945. He then joined Bell Labs and remained there until 1951. Some of his fields of interest were conduction in semiconductors and metals, surface properties of semiconductors, and superconductivity. While at Bell Labs he jointly invented the transistor with colleagues Walter Brattain and William Shockley. After leaving Bell Labs in 1951, Dr. Bardeen joined the faculty at the University of Illinois. (Photo credit: AIP Emilio Segrè Visual Archives, W. F. Meggers Collection)



**William Shockley**  
1910–1989

An American born in London, England, Dr. Shockley

obtained his PhD in 1936 from M.I.T. He joined Bell Labs upon graduation and remained there until 1955. His research emphasis included areas of energy bands in solids, theory of vacuum tubes, photoelectrons, ferromagnetic domains, and transistor physics. While at Bell Labs, Dr. Shockley joined John Bardeen and Walter Brattain in the invention of the transistor in 1947. After leaving Bell Labs, Dr. Shockley spent time at Beckman Instruments and at Stanford University. (Photo credit: AIP Emilio Segrè Visual Archives, Physics Today Collection)



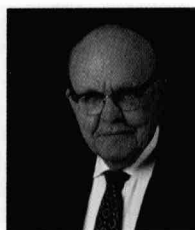
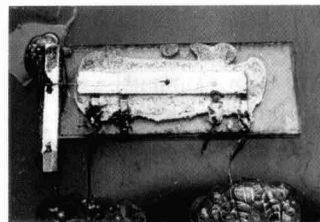
**Walter H. Brattain**  
1902–1987

An American born in China, Dr. Brattain joined Bell Telephone

Laboratories in 1929. One of his main areas of research was the surface properties of semiconductive materials. His chief contributions were the discovery of the photo effect at the surface of a semiconductor and the invention of the point-contact transistor in 1947, which he jointly invented with John Bardeen and William Shockley. (Photo credit: AIP Emilio Segrè Visual Archives, W. F. Meggers Collection)

► **FIGURE P-5**

The first integrated circuit. (Courtesy of Texas Instruments)



**Jack S. Kilby  
1923–**

Jack Kilby was born in Missouri and earned degrees in electrical engineering

from the University of Illinois and the University of Wisconsin. From 1947 to 1958, he worked at the Centralab Division of Globe Union, Inc. in Milwaukee. In 1958, he joined Texas Instruments in Dallas where he was responsible for integrated circuit development and applications. Within a year after joining TI he invented the monolithic integrated circuit and the rest is history. Mr. Kilby left TI in 1970. (Photo credit: Courtesy of Texas Instruments)

computers. Systems were in place within Lawrence Livermore National Laboratory that connected over 100 terminals to a computer system (colorfully called the “Octopus system”). In an experiment in 1969 with very remote computers, an exchange took place between researchers at UCLA and Stanford. The UCLA group hoped to connect to a Stanford computer and began by typing the word “login” on its terminal. A separate telephone connection was set up and the following conversation occurred.

The UCLA group asked over the phone, “Do you see the letter L?”

“Yes, we see the L.”

The UCLA group typed an O. “Do you see the letter O?”

“Yes, we see the O.”

The UCLA group typed a G. At this point the system crashed. Such was technology, but a revolution was in the making.

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 that 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; by the start of the new century (in 2001) there were over 24 million. In the 1990s, companies scrambled to establish a home page and many of the early developments of radio broadcasting had parallels with the Internet. The bean counters still want to know how it’s going to make money! The exchange of information and e-commerce fueled the tremendous economic growth of the 1990s. The Internet became especially important to scientists and engineers, becoming one of the most important scientific communication tools ever.

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. As the 20th century drew toward a close, historians could only breathe a sign of relief. As one wag put it, “I’m all for new technologies, but I wish they’d let the old ones wear out first.”

The 21st century dawned in January 2001 (although most people celebrated the new century the previous year, known as “Y2K”). 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 for the fourth edition of *Electronic Devices: Electron Flow Version*. 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 Scott Sambucci. Lois Porter, whose attention to details is unbelievable, has once more done an outstanding job editing the manuscript. Jane Lopez and Steve Botts have once again provided the excellent illustrations and beautiful graphics work used in the text. As with the previous edition, Gary Snyder has created the circuit files for the Electronics Workbench and Multisim features in this edition. A line-by-line review was done by Dave Hodder.

I wish to express my appreciation to those already mentioned as well as the reviewers who provided many valuable suggestions and constructive criticism that greatly influenced this edition. These reviewers are Roger Harlow, Mesa Community College; James L. Havens, Hallmark Institute of Technology; David Hodder, Yuba Community College; Ron Ingle, Midlands Technical College; Steven D. Johnson, DeVry Institute of Technology; Byron Paul, Bismarck State College; James F. Pechloff, Waukesha County Technical College; and Robert A. Powell, Oakland Community College.

Tom Floyd



# Brief Contents

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