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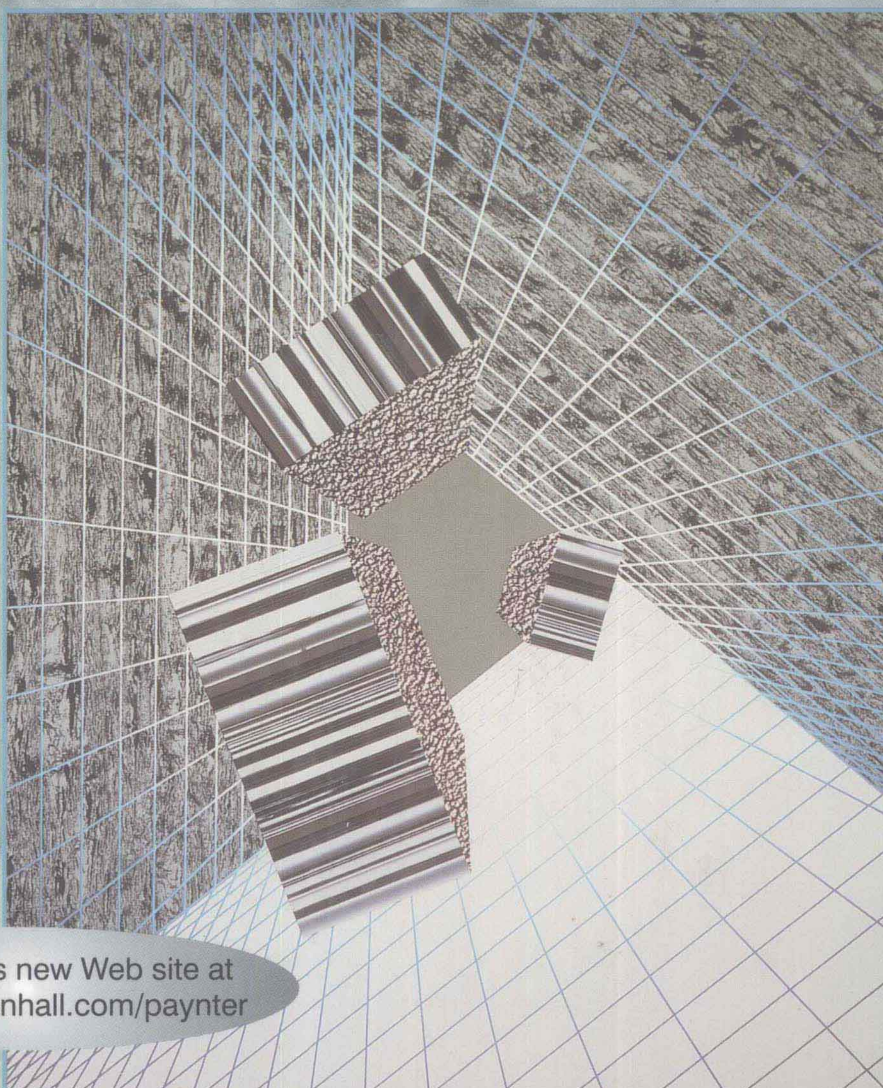
Electron Flow Version



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ROBERT T. PAYNTER

INTRODUCTORY ELECTRIC CIRCUITS

Electron Flow Version

Robert T. Paynter

With Technical Contributions by Toby Boydell

Prentice Hall
Upper Saddle River, New Jersey ■ Columbus, Ohio

Library of Congress Cataloging-in-Publication Data
Paynter, Robert T.
Introductory electric circuits: electron flow version/Robert T. Paynter.
p. cm.
Includes index.
ISBN 0-02-392500-0 (alk. paper)
1. Electric circuits. I. Title.
TK454.P29 1999 98-7299
621.319′2—dc21 CIP

Cover Photo: Copyright Orion/FPG International
Editor: Linda Ludewig
Developmental Editor: Carol Robison
Production Editor: Rex Davidson
Design Coordinator: Karrie M. Converse
Text Designer: Anne D. Flanagan
Cover Designer: Ceri Fitzgerald
Production Manager: Patricia A. Tonneman
Illustrations: The Clarinda Company
Marketing Manager: Ben Leonard

This book was set in Times Roman and Helvetica by The Clarinda Company and was printed and bound by R. R. Donnelley & Sons Company. The cover was printed by Phoenix Color Corp.

Photo credits: Anne Murphy

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN: 0-02-392500-0

Prentice-Hall International (UK) Limited, *London*
Prentice-Hall of Australia Pty. Limited, *Sydney*
Prentice-Hall of Canada, Inc., *Toronto*
Prentice-Hall Hisanoamericana, S. A., *Mexico*
Prentice-Hall of India Private Limited, *New Delhi*
Prentice-Hall of Japan, Inc., *Tokyo*
Simon & Schuster Asia Pte. Ltd., *Singapore*
Editora Prentice-Hall do Brasil, Ltda., *Rio de Janeiro*

Preface: To the Instructor

When I wrote the second edition of *Introductory Electronic Devices and Circuits* (1990), I incorporated a series of tools for learning that no one had used, to my knowledge, prior to that time. These tools for learning included **objective identifiers** that tie the text material to the chapter objectives, **summary illustrations,** and **marginal notes** designed to supplement the body of the text. In the fourth edition of the devices text (1997), the list of learning aids was expanded to include **highlighted lab references** that tie the text material to specific lab exercises. The response to that text has been overwhelming. As a result, it has served as a design model for *Introductory Electric Circuits.*

As always, my goal has been to produce an introductory textbook that students can really use in their studies. For this reason, the most useful learning aids from the *Devices* textbook have been incorporated into *Introductory Electric Circuits* (see pages vi and vii):

Note: The learning aids listed are identified (by number) on the following pages.

① **Performance-based objectives** provide a handy overview of the chapter organization and a road map to student learning.

② **Objective identifiers** in the margins cross-reference the objectives with the chapter material. These identifiers help the students to locate quickly the material that enables them to fulfill an objective.

③ **Marginal notes** include a running glossary of new terms, notes that highlight the differences between theory and practice, and brief reminders of principles covered in earlier sections and chapters.

④ **In-chapter practice problems** are included in the examples to provide your students with an immediate opportunity to apply the principles and procedures demonstrated in the examples.

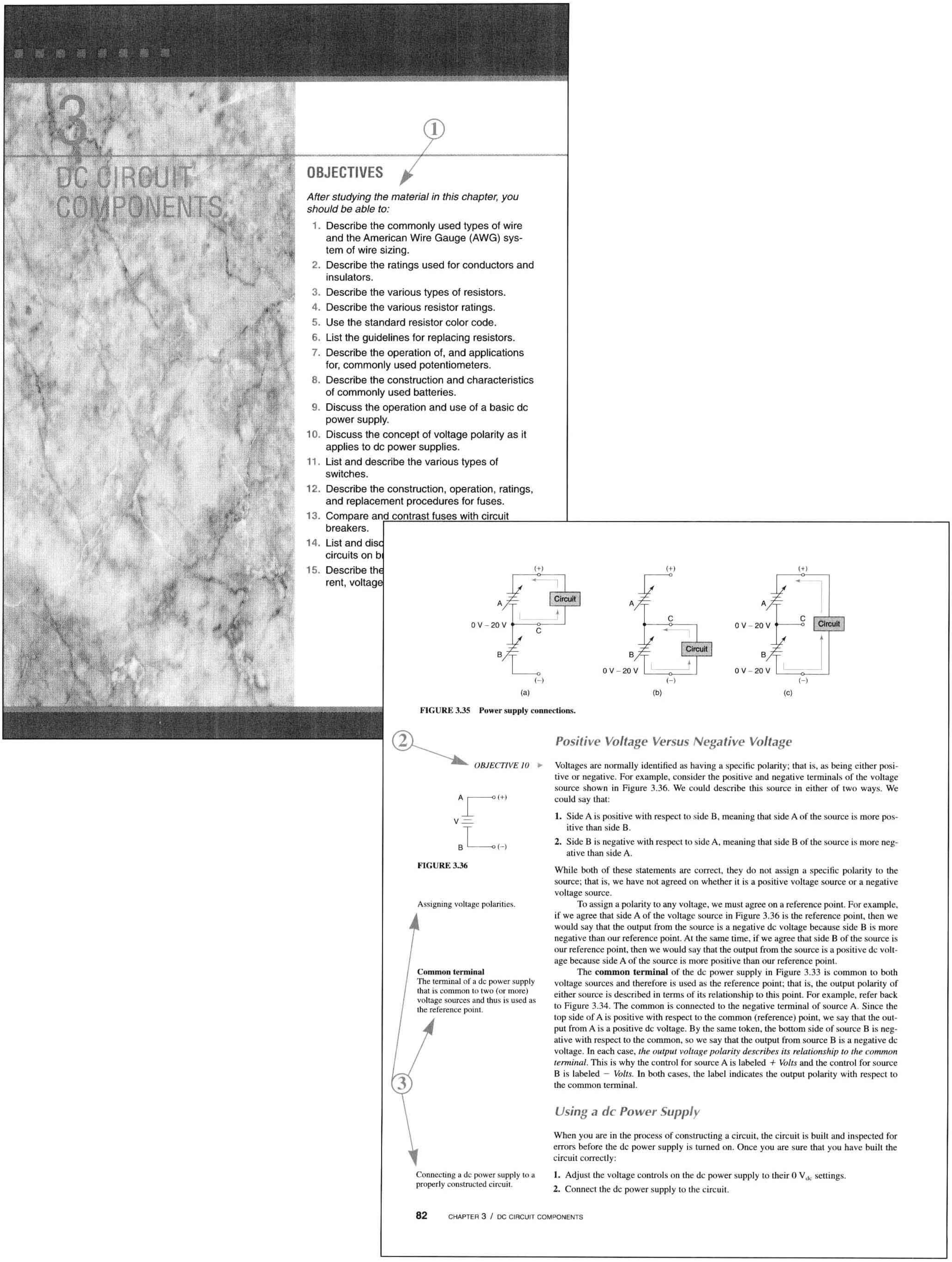
⑤ **Summary illustrations** provide a convenient summary of circuit operating principles and applications. Many provide comparisons between related circuits.

The following items have also been incorporated into *Introductory Electric Circuits* to help reinforce student learning:

- **Section review questions:** Each section of the text ends with a series of questions that students can use to check their learning.
- **Chapter summaries:** Each chapter ends with a detailed summary of the major points covered in the chapter, including an **equation summary** and a **key terms list.**
- **Practice problems:** An extensive set of practice problems appears at the end of each chapter. In addition to standard practice problems, most of the problem sets include **troubleshooting practice problems** and **the Brain Drain** (challengers).

FEATURES

In addition to the learning aids listed above, *Introductory Electric Circuits* contains several features designed to help your students learn the principles covered in the textbook (and more). Some of those features are described on the following pages.



3

DC CIRCUIT COMPONENTS

①

OBJECTIVES

After studying the material in this chapter, you should be able to:

1. Describe the commonly used types of wire and the American Wire Gauge (AWG) system of wire sizing.
2. Describe the ratings used for conductors and insulators.
3. Describe the various types of resistors.
4. Describe the various resistor ratings.
5. Use the standard resistor color code.
6. List the guidelines for replacing resistors.
7. Describe the operation of, and applications for, commonly used potentiometers.
8. Describe the construction and characteristics of commonly used batteries.
9. Discuss the operation and use of a basic dc power supply.
10. Discuss the concept of voltage polarity as it applies to dc power supplies.
11. List and describe the various types of switches.
12. Describe the construction, operation, ratings, and replacement procedures for fuses.
13. Compare and contrast fuses with circuit breakers.
14. List and disc... circuits on b...
15. Describe the... rent, voltage...

FIGURE 3.35 Power supply connections.

②

Positive Voltage Versus Negative Voltage

OBJECTIVE 10 ►

Voltages are normally identified as having a specific polarity; that is, as being either positive or negative. For example, consider the positive and negative terminals of the voltage source shown in Figure 3.36. We could describe this source in either of two ways. We could say that:

1. Side A is positive with respect to side B, meaning that side A of the source is more positive than side B.
2. Side B is negative with respect to side A, meaning that side B of the source is more negative than side A.

FIGURE 3.36

While both of these statements are correct, they do not assign a specific polarity to the source; that is, we have not agreed on whether it is a positive voltage source or a negative voltage source.

Assigning voltage polarities.

To assign a polarity to any voltage, we must agree on a reference point. For example, if we agree that side A of the voltage source in Figure 3.36 is the reference point, then we would say that the output from the source is a negative dc voltage because side B is more negative than our reference point. At the same time, if we agree that side B of the source is our reference point, then we would say that the output from the source is a positive dc voltage because side A of the source is more positive than our reference point.

Common terminal The terminal of a dc power supply that is common to two (or more) voltage sources and thus is used as the reference point.

The **common terminal** of the dc power supply in Figure 3.33 is common to both voltage sources and therefore is used as the reference point; that is, the output polarity of either source is described in terms of its relationship to this point. For example, refer back to Figure 3.34. The common is connected to the negative terminal of source A. Since the top side of A is positive with respect to the common (reference) point, we say that the output from A is a positive dc voltage. By the same token, the bottom side of source B is negative with respect to the common, so we say that the output from source B is a negative dc voltage. In each case, *the output voltage polarity describes its relationship to the common terminal*. This is why the control for source A is labeled *+ Volts* and the control for source B is labeled *− Volts*. In both cases, the label indicates the output polarity with respect to the common terminal.

③

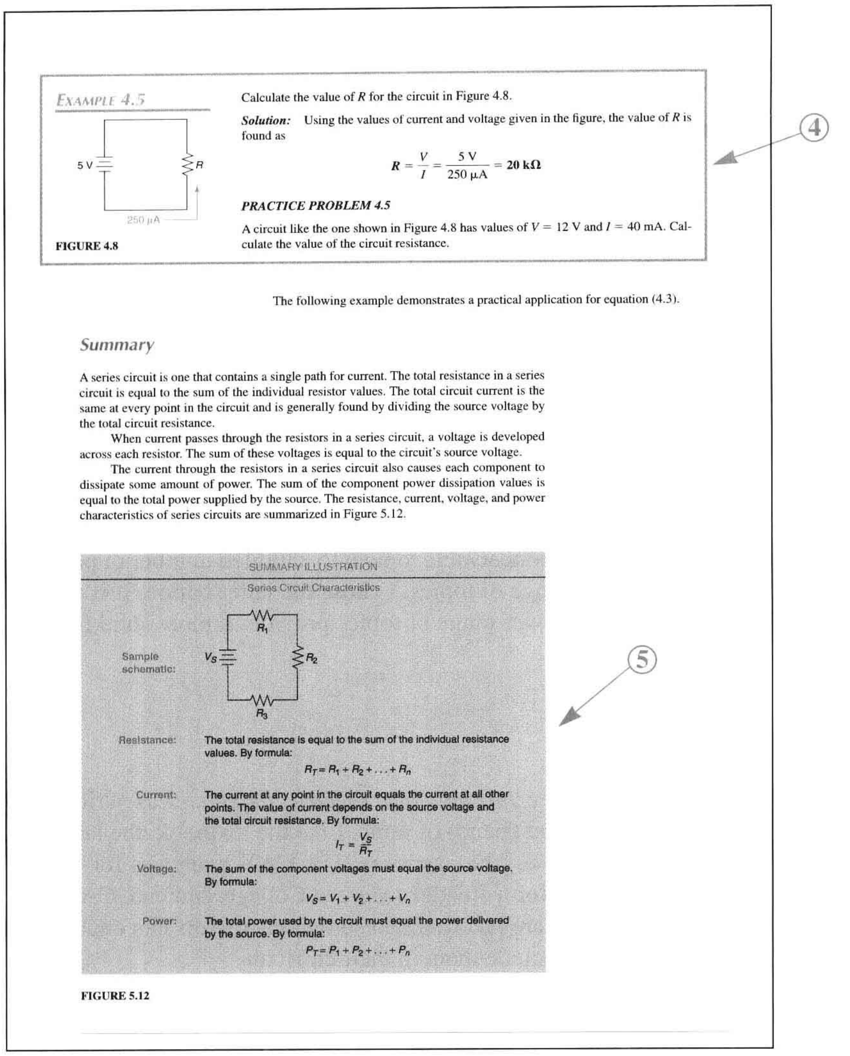
Using a dc Power Supply

When you are in the process of constructing a circuit, the circuit is built and inspected for errors before the dc power supply is turned on. Once you are sure that you have built the circuit correctly:

Connecting a dc power supply to a properly constructed circuit.

1. Adjust the voltage controls on the dc power supply to their 0 V_{dc} settings.
2. Connect the dc power supply to the circuit.

82 CHAPTER 3 / DC CIRCUIT COMPONENTS



EXAMPLE 4.5

Calculate the value of R for the circuit in Figure 4.8.

Solution: Using the values of current and voltage given in the figure, the value of R is found as

$$R = \frac{V}{I} = \frac{5\text{ V}}{250\ \mu\text{A}} = \mathbf{20\ k\Omega}$$

PRACTICE PROBLEM 4.5

A circuit like the one shown in Figure 4.8 has values of $V = 12$ V and $I = 40$ mA. Calculate the value of the circuit resistance.

FIGURE 4.8

The following example demonstrates a practical application for equation (4.3).

Summary

A series circuit is one that contains a single path for current. The total resistance in a series circuit is equal to the sum of the individual resistor values. The total circuit current is the same at every point in the circuit and is generally found by dividing the source voltage by the total circuit resistance.

When current passes through the resistors in a series circuit, a voltage is developed across each resistor. The sum of these voltages is equal to the circuit's source voltage.

The current through the resistors in a series circuit also causes each component to dissipate some amount of power. The sum of the component power dissipation values is equal to the total power supplied by the source. The resistance, current, voltage, and power characteristics of series circuits are summarized in Figure 5.12.

SUMMARY ILLUSTRATION

Series Circuit Characteristics

Sample schematic:

Resistance: The total resistance is equal to the sum of the individual resistance values. By formula:

$$R_T = R_1 + R_2 + \ldots + R_n$$

Current: The current at any point in the circuit equals the current at all other points. The value of current depends on the source voltage and the total circuit resistance. By formula:

$$I_T = \frac{V_S}{R_T}$$

Voltage: The sum of the component voltages must equal the source voltage. By formula:

$$V_S = V_1 + V_2 + \ldots + V_n$$

Power: The total power used by the circuit must equal the power delivered by the source. By formula:

$$P_T = P_1 + P_2 + \ldots + P_n$$

FIGURE 5.12

Electronics Workbench® (EWB) Applications Problems

In response to reviewer input, **Electronics Workbench® (EWB)** software has been fully integrated into this text. This simulation software has been incorporated so that instructors can choose (on an individual basis) whether or not to include it in their curricula. The EWB CD-ROM packaged with the text contains exercises that were developed and written by **George Shaiffer** (Pike's Peak Community College, Colorado Springs, CO). These exercises relate directly to various figures throughout the text. An EWB logo is used to identify those figures with an EWB file. A list of **EWB Applications Problems** at the end of each chapter provides the file numbers for the appropriate figures. (The directions for accessing the individual files are included with the CD.) In addition, the CD-ROM contains a tutorial that instructs students how to operate EWB and how to simulate circuits. The CD-ROM also includes a locked version of Electronics Workbench® Student Version 5.0 that can be unlocked by calling Interactive Image Technologies. Instructions for unlocking the software are included on the CD-ROM.

A personal thought: The use of simulation software in the classroom is still a matter of great debate. Many instructors see it as an invaluable learning tool, while others believe that its use should be limited to solving minor design problems encountered by more advanced students. (I count myself among the latter.) I believe that the method used to incorporate EWB into the textbook and lab manual will make it valuable for those who wish to use it while keeping it unobtrusive for those who don't.

Functional Use of Color

In my *Devices* textbook, I opted for a *functional* use of color. The same approach to a full-color format has been used in this text. Color is used to help your students distinguish between the parts and values that make up the various circuits and graphs. It is also used to draw their attention to certain figures and marginal notes.

The use of color in a textbook can be very helpful or simply distracting. I believe that the goal of limiting the use of color to enhance your students' learning experience has been accomplished in this textbook.

Text Content

It became clear early that a choice would have to be made regarding the content of this book. I could do my best to cram every conceivable topic into a limited number of pages or to explain thoroughly a more limited range of topics. I chose the latter option. It is my belief that an in-depth approach to a narrower range of topics provides a more solid foundation for growth.

Lab Manual

The *Laboratory Manual to Accompany Introductory Electric Circuits* was written by **William Muckler,** a colleague (and good friend) of mine. Like the textbook, the lab manual uses EWB to supplement (not replace) the exercises. The EWB exercises for the lab manual were developed and written by **John Reeder** (Merced College, Merced, CA). Like the text, the lab manual EWB exercises are incorporated so that instructors can choose (on an individual basis) whether or not to include them in their curricula.

Ancillaries

- Laboratory Manual
- Solutions Manual to the Lab Manual
- Instructor's Resource Manual
- Windows PH Custom Test
- PowerPoint Transparencies
- Web Site: www.prenhall.com/paynter

ACKNOWLEDGMENTS

A project of this size could not have been completed without help from many capable and concerned individuals. First and foremost, I would like to acknowledge the efforts of **Toby Boydell,** Seva Electronics, Ontario, Canada. Toby has played a major role in all my work of recent years, and this text was certainly no exception. He provided quality content, editorial, and technical assistance during every phase of the project. He also provided the solutions for the *Instructor's Resource Manual* for this text, the test item file, and the answers in Appendix G. I would also like to acknowledge the efforts of **Scott Bisland** (Sematech, Inc.) and **Richard Parrett** (ITT Technical Institute, St. Louis) for the quality input they provided from start to finish.

A special thanks goes out to the following professionals for their reviews of selected chapters:

Byron Paul (Bismark State College)
Phillip D. Anderson (Muskegon Community College)
Jeff Bigelow (Oklahoma Christian University)
Keith Bunting (Randolph Community College)
Thomas Elliott (The Victoria College)
David Longobardi (Antelope Valley College)
J. W. Roberts (West Georgia Tech)
Neal Willison (Oklahoma State University, Oklahoma City)
Larry J. Wheeler (Senior Engineer, Lockheed Martin Aerospace)
L'Houcine Zerrouki (ITT Technical Institute, Seattle)
Ted Rodriguez (Skagit Valley College)
Mauro Caputi (Hofstra University)
Frank Chandler (Randolph Community College)
John Reeder (Merced College)
David Juhola (Applications Engineer, Canon, USA)
Peter Kerckhoff (DeVry, Kansas City)
John Dyckman (Pennsylvania Institute of Technology)
Fred Evangelisti (American River College)
Dan Landiss (St. Louis Community College)
James A. Lookadoo (Pittsburgh State University)
Saeed Shaikh (Miami Dade Community College)
Michael Howard (Ivy Tech State College, Evansville)

The photographs that appear in the textbook and lab manual were produced by **Anne Murphy** (Anne Murphy Studio, Webster Groves, MO). The materials used in the photos were supplied by St. Louis Community College at Forest Park and **Tom Gowan** (Yorkshire TV and VCR Repair, Webster Groves, MO).

I would like to thank the staff at Prentice-Hall and others for their "behind-the-scenes" efforts on this textbook. The following people deserve special recognition:

Carol Robison, my developmental editor, for overseeing the review process and the initial stages of production. Although she has since moved on, Carol played a major role in the development of this text. (Good luck, Carol!)

Marianne L'Abbate, my copy editor, who has provided (once again) the highest quality copy editing possible.

Rex Davidson, my production editor, for helping me throughout the production process and helping to keep things on track.

Linda Ludewig, editor, for having enough faith in the project to go out on many limbs, providing for the use of a four-color format in a first edition text.

and

Dave Garza, editor-in-chief, for believing in the project and providing the support needed to make it a reality.

Finally, a special thanks goes out to my family and friends (especially Wayne Newcomb, Dick Arnoldy, and Rich Reeves) for their constant support and patience.

Bob Paynter

Preface: To the Student

"WHY AM I LEARNING THIS?"

Have you ever found yourself asking this question? If you have, then take a moment to read this preface.

I have always believed that any subject is easier to learn if you understand *why* it is being taught and how it relates to your long-term goals. For this reason, we're going to take a moment to discuss:

1. How the material in this book relates to a career in electronics technology
2. How you can get the most out of this course

Few developments have affected our lives over the past thirty years as profoundly as those made in electronics technology. Most of the electronic "gizmos" we take for granted, such as cellular phones, laptop computers, home theaters, pagers, and personal audio systems, have been developed during that time. These items, and many others, have been made possible by advances in production technology. As a result of these advances, many electronic systems that once filled an entire room can now be held in the palm of your hand. Even so, these systems are extremely complex devices that contain a wide variety of components. And, each of these components operates according to one or more fundamental principles. These components and their operating principles are the subject of this book.

Learning how to work on various electronic systems begins with learning the components and principles that are common to all of them. While these principles may not always have a direct bearing on *how* to repair a specific electronic system, they must be learned if you are to understand *why* things work the way they do. Learning why things work the way they do allows you to grow beyond the scope of any textbook (or course).

The material in this book forms the foundation for the courses that are to follow. This means that learning the material is critical if your knowledge is to advance beyond the point where it is now. The next question is:

"HOW CAN I GET THE MOST OUT OF THIS COURSE?"

There are several steps you can take to ensure that you will successfully complete this course and advance to the next. The first is to accept the fact that *learning electronics requires active participation on your part.* If you are going to learn the material in this book, you must take an active role in your education. It's like learning to play a musical instrument. If you want to learn how to play a musical instrument, you have to practice on a regular basis. You can't learn how to play a musical instrument simply by "reading the book." The same can be said about learning electronics. You must be actively involved in the learning process.

How do you get involved in the learning process? Here are some habits that will take you a long way toward successfully completing your course of study:

1. *Attend class on a regular basis.*
2. *Take part in classroom problem-solving sessions.* This means getting out your calculator and solving the problems along with the rest of the class.
3. *Do all the assigned homework.* Circuit analysis is a skill. As with any skill, you gain competency only through practice.
4. *Take part in classroom discussions.* More often than not, classroom discussions can serve to clarify points that may be confusing otherwise.
5. *Read the material before it is discussed in class.* When you know what is going to be discussed in class, read the related material *before* the discussion. That way, you'll know which parts (if any) are causing you problems before the class begins.
6. *Become an active reader.*

Being an *active reader* means that you must do more than simply "read the book." When you are studying new material, there are several things that you should do:

1. *Learn the terminology.* You are taught new terms because you need to know what they mean and how and when to use them. When you come across a new term in the book, take time to commit that term to memory. How do you know when a new term is being introduced? Throughout this text, new terms are identified in the margins. When you see a new term and its definition in the margin, stop and learn the term before going on to the next section.
2. *Use your calculator to work through the examples.* When you come across an example, get your calculator out and try the example for yourself. When you do this, you develop the skill necessary to solve the problems on your own.
3. *Solve the example practice problems.* Most of the examples in this book end with a practice problem that is identical in nature to the example. When you see these problems, solve them. Then you can check your answer(s) by looking them up at the end of the chapter.
4. *Use the chapter objectives to measure your learning.* Each chapter begins with an extensive list of performance-based objectives. *These objectives tell you what you should be able to do as a result of learning the material.*

Throughout this text, *objective identifiers* are included in the margins. For example, if you look on page 8, you'll see "Objective 4" printed in the margin. This identifier tells you that this is the point where you are taught the skill mentioned in Objective 4 on the opening page of the chapter. These identifiers can be used to help you with your studies. If you don't know how to perform the action called for in a specific objective, just flip through the chapter until you see the appropriate identifier. At that point in the chapter, you'll find the information you need to successfully meet the objective.

ONE FINAL NOTE

A lot of work is involved in being an active learner. However, the extra effort will pay off in the end. Your understanding of electronics will be better as a result of your efforts. I wish you the best of success.

Bob Paynter

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FREQUENCY RESPONSE AND PASSIVE FILTERS 789