



Revised Print

PRINCIPLES
and
APPLICATIONS
of
ELECTRONIC
ENGINEERING

Rizzoni

PRINCIPLES AND APPLICATIONS OF ELECTRICAL ENGINEERING

Giorgio Rizzoni
The Ohio State University

IRWIN
Burr Ridge, Illinois
Boston, Massachusetts
Sydney, Australia

Cover image: Frank Wing / The Image Bank

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Designer: Heidi J. Baughman

Art manager: Kim Meriwether

Compositor: Technique Typesetting

Typeface: 10/12 Times Roman

Printer: R. R. Donnelley & Sons Company

Library of Congress Cataloging-in-Publication Data

Rizzoni, Giorgio.

Principles and applications of electrical engineering / Giorgio Rizzoni.

p. cm.

Includes index.

ISBN 0-256-17688-4 ISBN 0-256-12969-X (Int'l ed.)

1. Electrical engineering. I. Title.

TK146.R473 1993

621.3—dc20

Printed in the United States of America

1 2 3 4 5 6 7 8 9 0 DOC 9 8 7 6 5 4

About the Author

Giorgio Rizzoni is an assistant professor in the Department of Mechanical Engineering at The Ohio State University. He received his Ph.D. from the University of Michigan and then became a lecturer and research scientist in University of Michigan's EECS Department and assistant director of the Vehicular Electronics Laboratory. As a lecturer there, he taught the nonmajors course sequence and designed the related lab, for which he received Tau Beta Pi's College of Engineering Outstanding Teaching Award (1990).

In 1991, The National Science Foundation awarded Professor Rizzoni the Presidential Young Investigator Award, a research-based five-year grant. In 1992, Rizzoni received the Ralph R. Teetor Educational Award from the Society of Automotive Engineers (SAE) for his contribution to teaching, research, and student development. In addition to his teaching, Professor Rizzoni is active in ASME, IEEE, and SAE and has published a number of articles and papers.

Preface

The pervasive presence of electronic devices and instrumentation in all aspects of engineering design and analysis is one of the manifestations of the electronic revolution that has characterized the second half of the 20th century. Every aspect of engineering practice, and even of everyday life, has been affected in some way or another by electrical and electronic devices and instruments. Computers are perhaps the most obvious manifestations of this presence. However, many other areas of electrical engineering are also important to the practicing professional in a range of fields, from mechanical and industrial engineering to chemical, nuclear, and materials engineering, the aerospace and astronautical disciplines, and civil engineering. Engineers today must be able to communicate effectively within the interdisciplinary teams in which they work.

OBJECTIVES

The aim of *Principles and Applications of Electrical Engineering* is to provide the nonelectrical engineering student—typically in the third year of a

four-year curriculum—with a foundation for understanding the basic principles of electrical and electronic systems. This book should help build a solid foundation for further study, either in the classroom or on the job.

It would be overly ambitious to attempt to summarize all important aspects of electrical engineering in a single book, without its taking on an undesired encyclopedic nature. Thus, this book differs in two respects in content and style of presentation from many of the leading textbooks that are currently available in the market. First, no attempt is made to provide an exhaustive treatment of electrical and electronic circuits, and of electrical machinery. Rather, the intent is to help the student in building a fundamental understanding of the basic principles, without clouding the main concepts with excessive detail. The reader interested in a more in-depth treatment of a particular subject will be able to refer to more advanced books, while the instructor who wishes to cover some particular area in greater depth will find that each chapter includes a number of homework problems designed for more advanced study. Second, a number of topics that are commonly found in some of the popular books that take a more encyclopedic approach to presenting the subject will not be found here. For example, topics such as control or communication systems are not included, although some discussion of relevant ideas is given when appropriate. The author believes that such subjects are best dealt with in a specially designed course (for example, many undergraduate engineering degree programs require a senior level course in control systems). Further, in attempting to include too many subjects, many authors have been forced to reduce the coverage of those essential topics that form the basis of electrical engineering. An honest effort has been made to avoid this shortcoming in the present book; a multitude of examples and exercises are provided in the early circuit analysis chapters to ensure a solid and complete understanding of the material that forms the basis of the entire discipline. This approach is based on the author's belief that learning the foundations of circuits and electronics and gaining a mastery of the fundamentals of AC and DC circuit analysis greatly simplifies the task of understanding the more advanced material.

The emphasis in *Principles and Applications of Electrical Engineering* is on teaching relevant electrical engineering concepts to engineers who will be users, not designers, of electrical, electromechanical, and electronic systems. Thus, the book provides a user's perspective of electrical engineering, focusing on those principles and applications that are likely to be of use to engineers of tomorrow. Electrical and electronic subsystems are an integral part of any complex plant or engineering system—from the self-contained power systems aboard a ship or an aircraft, to the control of industrial processes and power plants or the management of propulsion systems for automobiles and spacecrafts. In all of these applications, the common threads are *instrumentation*, which is required to perform measurement for process and plant performance evaluation and control, and the *devices*, which are used to implement the controls and which make up the measuring instruments.

Thus, this book will focus on the application of devices to specific measurements and control tasks and on the basic components of instrumentation and measurement systems that are likely to be encountered in practice.

ORGANIZATION AND CONTENT

The wide range of requirements that characterize four-year engineering programs in the United States presents a challenge to writing a useful and versatile book for the nonmajor audience. The following paragraphs provide a rationale for the organization and content of this book and suggest various sequences that may be adopted to match the requirements of varied curricula.

The book is structured in three parts: circuit analysis, electronics and computers, and electromechanics. It is difficult to decouple completely one subject from the others. Aside from the fact that circuit analysis forms the foundation of the entire book, the operation of modern electric machines cannot be separated from the solid-state electronic control circuits that drive them. Further, where possible, examples are given of the application of a specific circuit or device to measurements and instrumentation. Chapters 1 through 6 (and part of 10) cover the fundamentals; Chapters 7 through 12 cover electronics and computers; and Chapters 5 and 14 through 16 cover power systems and electric machines. The material in the first six chapters provides a basic understanding of DC and AC circuit analysis and of transient analysis and frequency response. The instructor who wishes to emphasize the role of operational amplifiers early will find that the first two sections of Chapter 10 can be covered early in conjunction with Chapter 3. Another alternative (employed by the author for several semesters) introduces the op-amp immediately after Chapter 4, to use it as a vehicle for presenting the concept of frequency response early on.

The electronics material in Part II can be covered in a variety of ways, to suit the requirements of different audiences. For example, a very light treatment in a one-quarter course might involve all or only parts of Chapters 8 and 9, while an entire course in electronics might include Chapters 7 through 13. A number of options are available to the instructor between these extremes. If time permits treatment of discrete electronic devices, Chapters 7, 8, and 9 provide substantial amounts of material; if the preferred emphasis is on IC electronics, Chapters 10 and 11 are self-contained and do not require a background in discrete electronics. If the instructor prefers to devote time to digital logic circuits and systems, parts of Chapter 11, and Chapters 12 and 13 should suit his or her needs. Instructors who teach a survey-oriented course will find that the chapters go into progressively more depth in the later sections, so that it is possible to cover only part of each chapter and achieve substantial coverage of different topics. It is conceivable, for example, to touch on part or all of the first 12 chapters in a one-semester course if desired.

Part III, dealing with electric machines, is geared toward providing the student with an understanding of the fundamental principles of operation of the principal electric machines, with some focus on the performance and selection criteria for different applications. In addition to an introduction to the basic properties of DC, synchronous, and induction motors, emphasis is also given to special-purpose machines, such as servos, stepper motors, brushless DC motors, and other devices commonly used in motion control systems, in the hope that the interested student may use this material as a stepping stone to more advanced courses.

The following chart illustrates possible coverage options. Each instructor will be able to tailor the book to the specific needs of his or her course.

Suggested sequences	
1-quarter course	Part I, Circuits, plus one chapter on electronics (Chapter 7 on Semiconductors and Diodes or Chapter 10 on Op-Amps, or Chapter 12 on Digital Logic Circuits).
1-semester course	Part I, Circuits, plus two introductory chapters on Electronics (Chapters 7 and 8, or Chapters 10 and 11, or Chapters 10 and 12).
2-quarter sequence	Part I, Circuits, plus chapters on energy systems (Chapters 5, 14, 15, and 16). or Part I, Circuits, plus Electronics, selected parts of Chapters 7 through 13.
2-semester sequence	Part I, Circuits, plus complete coverage of chapters on Energy Systems (Chapters 5, 14, 15, and 16). or Part I, Circuits, plus complete coverage of Electronics, Chapters 7 through 13.

PEDAGOGY

Each chapter has an introduction with chapter objectives, an abundance of illustrations (over 1,500 total), many completely worked examples (over 260 overall), drill exercises to reinforce concepts just learned, a chapter summary, and key terms lists. Also, there is a variety of homework problems at the end of each chapter. The problems are intended to assist the student in understanding and applying the basic concepts presented. More challenging problems are indicated with an asterisk (*). There are approximately 750 homework problems—an average of 50 per chapter. Answers to selected problems can be found at the back of the book.

In addition to an appendix on linear algebra, complex numbers, and the Laplace transform, there is an Engineer-in-Training (EIT) review appendix, designed to help students prepare for the Fundamentals of Engineering (FE)

examination. Key topics found on the exam are identified and keyed to sections in the text that discuss these concepts. For each of the exam's nine subsections related to electrical engineering, there are two or more sample problems, representative of the type of problem the student will encounter on the FE exam. It is hoped that the nonmajor will be well prepared to succeed on the exam after studying from this book, with the appendix as a guide.

ACCURACY

Every example, drill exercise, and homework problem was double-checked for accuracy by two independent instructors (University of Arkansas and University of Michigan—Dearborn). In addition to being checked for errors, the manuscript was class tested at Ohio State University and University of Michigan—Ann Arbor. These schools used the manuscript in the classroom to test the readability, approach, and content; over 1,000 students used all or part of this book prior to publication. This rigorous process of checking the accuracy and approach of the book has greatly improved it.

SUPPLEMENTS

The Instructor's Manual, available to adopters from the publisher, contains complete solutions to the homework problems. Manufacturers' data sheets for important devices are included at the back of the Instructor's Manual; the instructor is permitted to reproduce these data sheets for classroom use. Transparency masters of important figures and example problems are also available.

ACKNOWLEDGMENTS

This book has been read critically by over 30 reviewers. Richard D. Irwin, Inc. and the author would like to thank the following reviewers for their contribution to *Principles and Applications of Electrical Engineering*:

Joe Baker, University of Southern California, Los Angeles
Kenneth Breeding, The Ohio State University
Fred Brockhurst, Rose Hulman Institute of Technology
Grigore Burdea, Rutgers University
Don Calahan, University of Michigan
Richard Cockrum, California State Polytechnic University
Norman Cox, University of Missouri-Rolla
Timothy Darling, University of California-Santa Barbara
John Dollar, Kansas State University
John Flemming, Texas A&M University

Edward Gardner, University of Colorado
Victor Gerez, Montana State University
James Holte, University of Minnesota
Mansell H. Hopkins, Virginia Polytechnic Institute and State University
John Hug, University of Arkansas
Charles Ih, University of Delaware
Sid James, Auburn University
Edward MacDonald, Drexel University
Dennis Malone, State University of New York-Buffalo
Dan McAuliff, Clemson University
Richard Miller, University of Central Florida
M. Paul Murray, Mississippi State University
Mesut Muslu, University of Wisconsin-Platteville
Robert Nethken, Louisiana State University
John O'Malley, University of Florida
Gerald Park, Michigan State University
William Potter, University of Washington
Ronald Scott, Northeastern University
W. David Stratton, Dartmouth College
Tony Valois, University of Minnesota
John Wait, University of Arizona

The author is indebted to these reviewers for their valuable insights and for the patient reviews that have greatly improved the accuracy and readability of this book. Special thanks also go to John Hug and Jim Daws for their hard work at uncovering errors and to Valdis Liepa and James G. Gottling for agreeing to use the manuscript in their classes.

The careful assistance provided by graduate students James C. Mejeur (University of Michigan) and Bahman Samimy and Jiande Wu (Ohio State University) in producing the solutions manual and by Ms Izena Goulding in typing the manuscript is gratefully acknowledged. The author would also like to recognize the continuing support of the project from three Department Chairs: Thomas B.A. Senior and Edward J. Davidson at the University of Michigan and Lawrence A. Kennedy at the Ohio State University.

Finally, the love, patience, and support provided by my wife, Kathryn, have made it possible to endure the long hours of work inevitably associated with such a challenging project.

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Index I.1

Introduction to Electrical Engineering

The aim of this chapter is to introduce electrical engineering. The chapter is organized to provide the newcomer with a view of the different specialties making up electrical engineering and to place the intent and organization of the book into perspective. Perhaps the first question that surfaces in the mind of the student approaching the subject is, Why electrical engineering? Since this book is directed at a readership having a mix of engineering backgrounds other than electrical engineering, the question is well justified and deserves some discussion. The chapter defines the various branches of electrical engineering, showing some of the interactions among them, and illustrating by means of a simple example how electrical engineering is intimately connected to many other engineering disciplines. A brief historical perspective is also provided, to outline the growth and development of this relatively young engineering specialty. Next, the fundamental physical quantities and the system of units are defined, to set the stage for the chapters that follow. Finally, the organization of the book is discussed, to give the student, as well as the teacher, a sense of continuity in the development of the different subjects covered in Chapters 2 through 16.