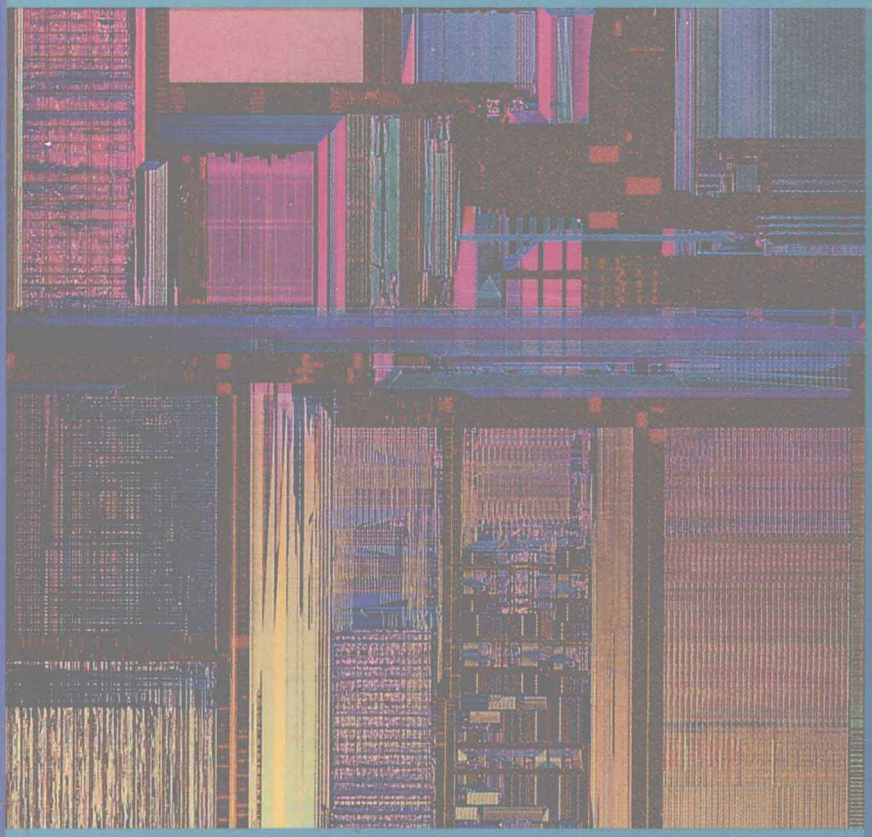
Introduction to ELECTRICAL ENGINEERING



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Introduction to Electrical Engineering

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Introduction to Electrical Engineering

DEDICATION

To Edie and Sherra

and our far-flung, still growing families

ACKNOWLEDGMENTS

The authors wish to express their thanks to a number of their collegues and other individuals who have contributed to the preparation of this text. We are especially indebted to Professor Charles A. Gross of Auburn University for making substantial contributions to the material on machines and preparing the sections of the text that deal with ac residential power circuits and transformer applications. Professor C. H. "John" Wu of Auburn University made major contributions to the chapter on microprocessors, complimented by suggestions from Professor Lloyd W. Massengill of Vanderbilt. Professor Lloyd A. "Pete" Morley of the University of Alabama and Professor S. Mark Halpin of the Mississippi State University made a number of contributions to the problem sets; the critique of the chapters on electronics by Professor Robert Fox of the University of Florida is greatly appreciated. We also recognize the help of Ashwin Matta, Randall Milanowski, and Manish Pagey all of Vanderbilt University for their assistance with homework problems and solutions.

Preface

P.1 Purpose

This book is intended to serve as a text for an introductory course or course sequence in electrical engineering. It is a broad and comprehensive introduction to the field designed to provide the student with an understanding of the fundamental concepts and a practical working knowledge of the application of these basic principles to real-world, up-to-date problems.

The fundamental strength of the text is the clear, solid and concise presentation of the essential components of the analysis of electric circuits, electronic circuits and systems, and electromechanical systems and safety. Furthermore, the book contains a number of other related topics outlined below, that greatly enhance the flexibility of presentation. The material is organized and presented in a manner that permits the instructor great latitude in the selection of topics and their order of presentation.

When used with a survey course comprising one or two semesters, typically only selected chapters or portions of chapters can be covered. In general, because of the breadth of the electrical engineering field, there simply is insufficient time to cover all the important elements of the discipline. However, this text is designed to assist the skillful instructor to empower students with the confidence and understanding that they are capable of solving electrical engineering problems outside of those specifically addressed in class. By becoming familiar with the entire organization of this book and treating it not only as a text, but as a reference as well, the student can learn one of the most crucial points about any survey course—how to access the information they need when they need it in the future. In this way the experience of a survey course provides a life-long benefit.

All the major disciplines within electrical engineering are represented in this text. Therefore, if students retain this book as part of their permanent library, they will be able to address throughout their careers the many electrical and electronic issues that literally permeate the engineering problems that are encountered in our modern technological world. In addition, the book is designed to be a very useful reference for students who wish to take the Fundamentals of Engineering exam (see Appendix C) that is a prerequisite for becoming licensed as a Professional Engineer.

This text is also suitable for the reader who wishes to use a self-study approach to learn the fundamentals of electrical engineering. The many worked examples, drill problems, and careful explanations within each chapter test the student's understanding, clarify key points, and provide necessary feedback.

For students who may later study many of these subjects in more detail, this text provides a clear presentation of fundamentals including the relationships among the various disciplines within electrical engineering and a comprehensive foundation for further advanced study in any selected area.

P.2 Features

This book contains a number of unique features that enhance its use as a survey text and valuable reference.

- The first chapter sets the stage for the study of electrical engineering topics by outlining the many disciplines within the field, their interrelationships, and the work of an electrical engineer including the value of operating as a member of a team consisting of many professionals with diverse backgrounds.
- The book is organized around six major parts, each of which represents a principle area of study within the field. The outline of topics within each part provides a logical grouping of the subject material as well as the relationship of these subjects to the field as a whole.
- After a brief study of the first few chapters, the book is organized in such a way that the topics may be selected for presentation in almost any order. Chapters are designed, to the extent possible, to be independent; therefore, the instructor has great flexibility in the selection of chapters, or sections within a chapter, to meet the special objectives of any particular course.
- A large number of examples, strategically placed, reinforce learning. In addition to these examples, which follow essentially every topic after it's introduced, there are a number of drill problems designed to quickly test the readers' understanding of the material. The combination of these features enhances both learning and retention by providing immediate demonstrations of the concept under discussion.
- The frequent use of analogies is a valuable aid to the newcomer in developing intuition for the fundamental principles. The use of fluid flow and mechanical analogies have been shown to be particularly helpful in quickly providing new students or those from other engineering disciplines an intuitive grasp of the principles that govern electrical engineering subjects.

- The subject of digital electronics and systems is presented prior to analog circuits, reflecting the growing importance of digital systems in today's world. Simple "switch" models for the transistor provide an easily understood, and very practical introduction to electronic circuits.

In addition to these general features, a number of specific features, not generally found in other texts, have been included to enhance the learning experience for the student and provide significant latitude to the instructor.

- A compact introduction to the topics of both digital and analog electronics is covered in a single chapter (Chapter 7) for use in courses where time does not permit the luxury of a more detailed analysis.
- Although the diode is covered in some detail in Chapter 8, this chapter is organized such that the device physics (sections 8.1 to 8.5) can be easily skipped and the diode circuit models used directly to analyze practical circuits containing these elements.
- The microprocessor is covered in a relevant and practical manner in Chapter 12. This chapter emphasizes the Personal Computer, its specification, selection, and operation.
- An introduction to microelectronics design and manufacturing (Chapter 13) is presented in such a way that it can be easily understood by someone unfamiliar with the area. This material is a very useful reference for any engineer associated with the design of an electronic system in which integrated circuits must be procured. The importance of this unique presentation is the fact that the economic competitiveness of today's world in electronic systems of all types requires that some familiarity with chip technology options be included in an engineering education.
- Electrical safety, a critically important topic which unfortunately is often neglected, is a consideration throughout the text and is presented in a very practical manner in Chapter 21. The fundamentals of electrical safety are discussed in the context of numerous illustrations of potentially hazardous conditions together with suggestions for avoiding injury.
- The topic of communications, an area of growing importance in our world where machines and human beings are interconnected throughout the globe, is presented in a way that fosters the student's understanding and appreciation of the subject. Many of the modern topics, which they encounter in their everyday lives, are explained in a simple and straightforward manner in Chapter 23.

P.3 Using This Text

No particular background in electric circuits, electronics, or electrical systems is assumed. This text is intended to be a first course in this field. There is, however, sufficient advanced material and depth to support the needs of students who wish to study some aspect in more detail.

This text is divided into six major parts. The first part includes a quantitative and intuitive definition of the terms and parameters used in the text. The fundamentals of circuit analysis are also presented, and while portions of the second and fourth chapters are

prerequisite for much of the material that follows, the remaining topics can be skipped or included as desired without adversely affecting a carefully planned study of the remaining subjects.

Part II of the text is organized such that coverage of Chapter 7 and a selection of other material to fit particular course needs, can provide a basis for an introduction to the area of electronics. For example, this chapter together with selected topics on diodes and transistors would permit a quick introduction to the field.

The presentation of Digital Systems, Part III, provides great flexibility in its use. Topics may be selected from any of the chapters in this section consistent with the instructor's priorities without losing continuity with subsequent chapters.

One of the most important topics in Part IV is the operational amplifier presented in Chapter 14. This chapter is virtually independent and may be presented at any point in a course. The coverage of this topic, together with a selection of topics in small-signal and large-signal analysis, would provide an excellent introduction to analog transistor circuits.

Part V of the text presents the traditional topics in electromechanical systems. A brief presentation of these topics, which includes some very practical examples readily identified by the students, can provide them with a basic understanding of electric machines. The topics in the chapter on safety can be of enormous value to them throughout their lives.

The topics in control contained in Part VI are traditional and cover important fundamentals while introducing the importance of this subject. The material on communications provides historical perspective and an up-to-date discussion of many elements of today's modern communication technologies. These subjects are presented in an easily understood format and emphasize the importance and usefulness of this critically important area.

It is important to note that whatever route through this text is chosen for a particular course, the instructor may well provide the student the greatest long-term benefit by communicating the breadth of the field of electrical engineering, the interrelationship of its topics, and the confidence to address related problems as needed in their future careers.

Finally, for teachers employing this text in their courses, a manual that contains solutions to all drill problems and end-of-chapter problems, is available as a Laboratory Manual.

P.4 System of Units

The system of units used in this text is the international system of units, the Systéme International des Unités, which is normally referred to as the SI standard system. This system, which is composed of the basic units meter (m), kilogram (kg), second (s), ampere (A), degree Kelvin (K), and candela (cd), is defined in all modern physics texts and therefore will not be defined here; we will, however, discuss the units in some detail as we encounter them in our subsequent analyses.

The abbreviations and symbols used to represent the various quantities studied in this text follow standard practice. Table P.1 may be a useful reference if you encounter unfamiliar symbols.

Table P.1 Standard Abbreviations and Symbols

ac	Alternating Current
A	Ampere
C	Coulomb
db	Decibel
dc	Direct current
F	Farad
H	Henry
Hz	Hertz
J	Joule
m	Meter
N	Newton
N-m	Newton-meter
Ω	Ohm
PF	Power factor
rad	Radian
RLC	Resistance-inductance-capacitance
rms	Root-mean-square
s	Second
S	Siemens
V	Volt
VA	Voltampere
W	Watt

The standard prefixes that are employed in SI are shown in Fig. P.1. Note the decimal relationship between these prefixes. These standard prefixes are employed throughout our study of electrical engineering.

Only a few decades ago, a millisecond, 10^{-3} s, was considered to be a short time in the analysis of electric circuits and devices. Advances in technology, however, have led to a state in which we now think of doing such things as performing calculations in nanoseconds or even picoseconds. The remarkable increases in speed and functional performance have been accompanied by phenomenal decreases in the physical size of electronic systems. Miniaturized integrated circuits are commonplace in calculators, computers, and other electronic equipment. A single such chip (typically about 1 cm on each side) can contain millions of devices, while the size of each device or circuit element on the chip is measured in fractions of a micron (1 micron = 10^{-6} m). As an example, consider the advanced integrated circuit chip shown in Fig. P.2.

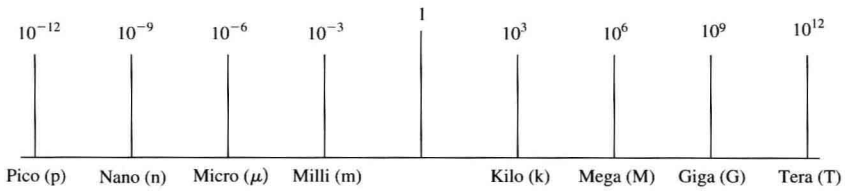

Figure P.1 Standard SI multiplier prefixes.

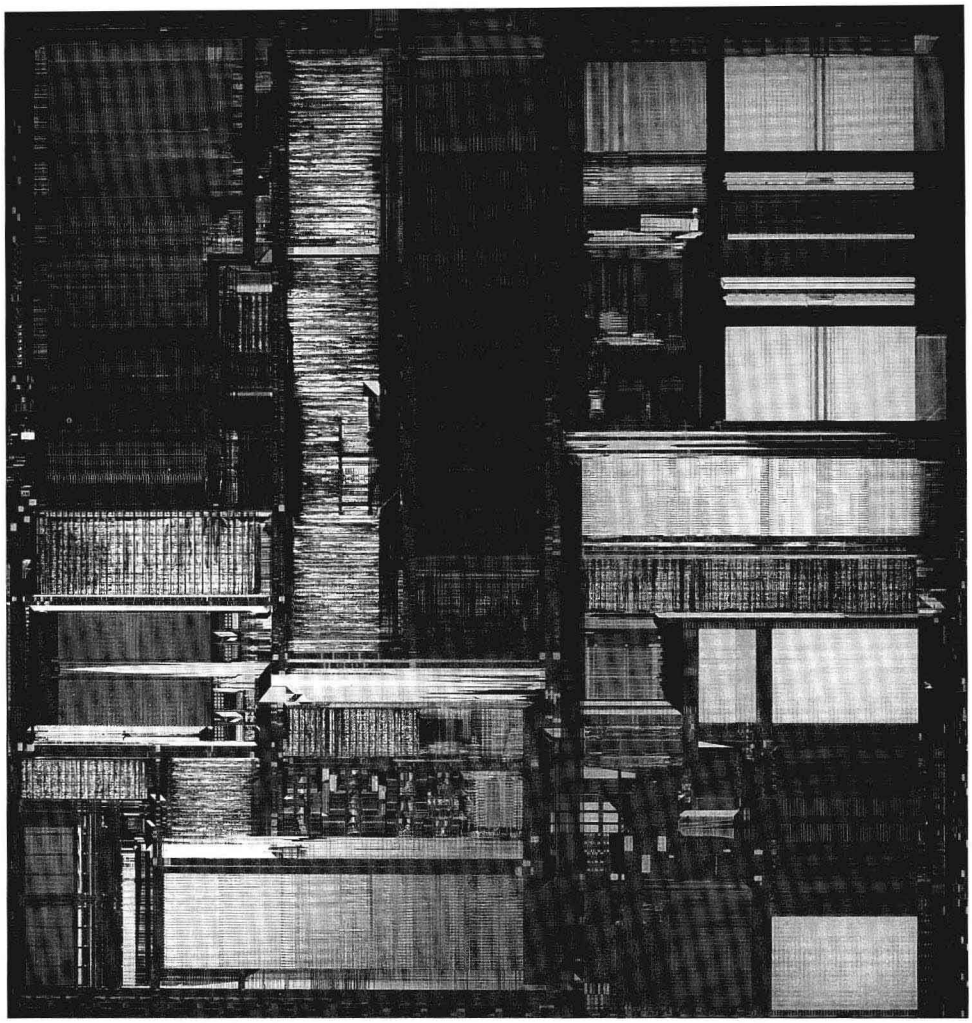

Figure P.2 An example of an advanced integrated circuit, the Intel Pentium™ Processor, contains 3.1 million transistors. (Courtesy of Intel; Pentium is a trademark of Intel Corporation)

P.5 Notation

Two of the most commonly used symbols in the study of electrical engineering are those for voltage (V) and current (I). The use of lowercase or uppercase letters and the particular subscript used with the letter provide information about the voltage or current as illustrated in the following example:

V, V_1, or V_A = a dc (direct current) value. The use of a capital V or I with number or capital subscript following indicates a constant, dc value.
$v(t)$, $v_1(t)$, $v_a(t)$, or v_A = the instantaneous value. The use of lowercase v or i with "(t)," or with a capital subscript, indicates the total instantaneous value "as a function of time."

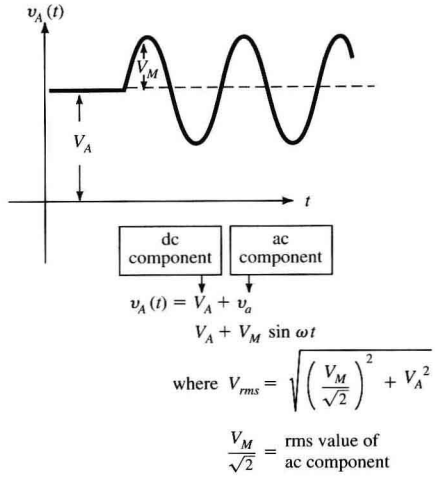

Figure P.3 Notation for Voltage and Current

V_M, V_m, I_M, or I_m = the amplitude or maximum value of a sinusoidally varying voltage or current.

V_{rms} or I_{rms} = the RMS or root-mean-square value of a sinusoidally varying voltage or current.

v_a or v_1 = the instantaneous value of the time-varying component (zero average).

The use of these quantities is illustrated graphically in Fig. P.3.

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