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ELECTRONIC CIRCUIT ANALYSIS BASIC PRINCIPLES

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basic principles

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John Wiley & Sons

New York Chichester Brisbane Toronto Singapore

Cover photo by Geoffry Gove

Library of Congress Cataloging in Publication Data:

Colclaser, Roy A.
Electronic circuit analysis.

Includes index.
1. Electronic circuits. 2. Electronic apparatus and appliances. I. Neamen, Donald A. II. Hawkins, Charles F. III. Title.

TK7867.C57 1984 621.3815'3 83-21743
ISBN 0-471-86626-1

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

preface

Electronics is one of the fastest growing and most rapidly changing disciplines of engineering. To keep pace with these developments, it is important to reassess on a regular basis the manner in which students are introduced to the subject. Historically, analog electronics dominated the applications of electronic devices. The introduction of the electronic computer in the 1940s was the forerunner of a major change in the emphasis of electronics. The widespread acceptance of the bipolar transistor in the 1950s and the integrated circuit in the 1960s also changed the electronics curriculum. The emergence of very large-scale integrated circuits in the 1970s and 1980s has been responsible for new pressures to change the approach for the teaching of electronics.

A typical electrical engineering curriculum includes two semesters or three quarters of electronic circuits, usually during the junior year. These courses are required of all students and serve as prerequisite material for advanced elective courses in the subject area. Laboratory courses are frequently used to supplement the circuits courses. In many instances, the material is introduced in an order that parallels the history of electronics—analog applications followed by digital applications. Recently, several textbooks have appeared that reverse the order of presentation. In addition to the pedagogical arguments for these changes, there is a new need which must be met at a number of universities. This need is the requirement for a single-semester course in electronics for majors in computer engineering. The interests of these students demand that a major part of the first course be devoted to digital circuits. However, it is necessary to provide a background in semiconductors, diodes, and bipolar and field effect transistors before digital circuits can be introduced. In this introductory material, both digital and analog concepts are presented.

This book was intended for a two-semester course sequence in which both computer and electrical engineering students would take the first course. Predominantly electrical engineering students would take the second course that is devoted to analog electronics. This approach allows more class time for the more difficult concepts of analog electronics such as feedback, frequency response, and differential amplifiers. Our approach has been to select a limited number of circuits and analyze them in detail, rather than trying to cover all possible circuit configurations. It is our opinion that advanced topics shouldbe in elective courses with specialized textbooks.

The book is divided into three parts: Introduction to Device Concepts, Digital Circuits, and Analog Circuits. It is intended that the first two parts be covered in the first semester, followed by the third part in the second semester. Because of the independence of the subject matter, it is possible to cover the material in a different order, presenting Parts I and III before Part II. In this case, it is not wise to try and finish Part III in the first course.

For a three-quarter sequence: Part I (without Chapter 5) plus Chapter 6 could be presented in the first quarter. Chapters 7, 5, and 8–11, would be a reasonable division for the second quarter. The remainder of the book would be left for the third quarter.

It is assumed that the students will have had an introduction to dc and ac steady-state circuit analysis and transient analysis through second-order systems. The mathematical background should include calculus and differential equations, while the physics background should include electrical theory and some elementary concepts of modern physics.

Electronics is a branch of engineering that has been expanding at an ever increasing rate. In the past, analog circuits dominated, and were constructed from discrete components. The terminal characteristics of the individual electronic devices were investigated, and models were developed to represent these devices. The models were used in conjunction with circuit theory to simulate the operation of the circuits. To analyze a complex electronic system like a television receiver, the usual practice was to break down the system into functional blocks that were more readily understood. When digital electronics became important, topics concerned with certain aspects of analog electronics gradually were replaced. The emergence of integrated circuits made it difficult to decide what topics should be covered in an introductory electronics text.

There are three tasks that may face electronics engineers in the 1980s. Some individuals will have the opportunity to design integrated circuits. A much larger number will be designing electronic systems in which integrated circuits are an important part. In some cases, engineers will be involved in the design of electronic circuits based on discrete components.

To prepare the reader for all three of these possibilities, it is necessary to investigate the operation of the individual devices, as well as that of standard integrated circuits. Part I introduces the reader to a variety of devices, junction diodes, bipolar junction transistors, junction field effect transistors, and metal–oxide–semiconductor field effect transistors. There is an emphasis on developing the appropriate models for each device for both digital and analog applications. In Part II, certain standard small-scale integrated logic circuits are examined. Each of these circuits represents a different electronic principle. The last chapter in this part provides some insight into specific circuits that are more complicated than those described in the preceding chapters. Part III is devoted to the principles of analog electronic circuits. Integrated circuit techniques are emphasized and compared with those used in discrete component circuitry.

We thank the many students who suffered through the early drafts of this

text for their many constructive suggestions. We particularly acknowledge theassistance of Eliot Smyrl, Mark McLaughlin, Ross Dettmer, William Curtis, Mike Lang, and Adam Bryant for their help with the figures, and Hunter Snevily for his general assistance. We also thank Merrill Floyd for his guidance and patience during the evolution of this project.

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part I

INTRODUCTION TO DEVICE CONCEPTS

chapter 1

INTRODUCTION

Electronics is the field of science and engineering that deals with devices in which conduction is principally by electrons moving through a vacuum, gas, or semiconductor and with the utilization of these devices. It is an exciting part of electrical engineering because it permits us to construct and analyze circuitry containing components capable of performing marvelous operations on electrical signals. The most interesting of these operations is called amplification. In this process, the output of the electronic circuit is an enlarged version of the input. As far as the signal is concerned, the circuit appears to be active, in that the power delivered to the output terminals is greater than the input signal power to the circuit. It is important to recognize that electronic amplifiers do not violate that fundamental law of nature, "you cannot get something for nothing." An increase in the power carried by a signal is accompanied by an increase in the total power delivered to the circuit, usually from a dc power source. A familiar example of an electronic amplifier is the high fidelity music system found in many homes. In this system, the weak signal source may be the mechanical vibration of a stylus in contact with a record, a magnetic pattern on a plastic tape, or a radio wave arriving at the system through the air. In each case, the signal, if applied directly to a speaker, would not be able to provide enough power to reproduce the intended sound. An intermediate electronic system is placed between the weak input signal source and the speaker to convert the signal into an enhanced version containing the same information, but containing enough power to drive the speaker and provide enjoyment for the listener. The reader is also familiar with the controls on the front of the amplifier that enable the user to change the loudness and frequency characteristics of the system. The bass and treble controls allow the listener to alter