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Fundamentals of Electronics

Book 1: Electronic Devices and Circuit Applications

Thomas F. Schubert, Jr.
Ernest M. Kim

SYNTHESIS LECTURES ON DIGITAL CIRCUITS AND SYSTEMS

Mitchell A. Thornton, *Series Editor*

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Book 1
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University of San Diego

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Fundamentals of Electronics

Book 1

Electronic Devices and Circuit Applications

Synthesis Lectures on Digital Circuits and Systems

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The *Synthesis Lectures on Digital Circuits and Systems* series is comprised of 50- to 100-page books targeted for audience members with a wide-ranging background. The Lectures include topics that are of interest to students, professionals, and researchers in the area of design and analysis of digital circuits and systems. Each Lecture is self-contained and focuses on the background information required to understand the subject matter and practical case studies that illustrate applications. The format of a Lecture is structured such that each will be devoted to a specific topic in digital circuits and systems rather than a larger overview of several topics such as that found in a comprehensive handbook. The Lectures cover both well-established areas as well as newly developed or emerging material in digital circuits and systems design and analysis.

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ABSTRACT

This book, *Electronic Devices and Circuit Application*, is the first of four books of a larger work, *Fundamentals of Electronics*. It is comprised of four chapters describing the basic operation of each of the four fundamental building blocks of modern electronics: operational amplifiers, semiconductor diodes, bipolar junction transistors, and field effect transistors. Attention is focused on the reader obtaining a clear understanding of each of the devices when it is operated in equilibrium. Ideas fundamental to the study of electronic circuits are also developed in the book at a basic level to lessen the possibility of misunderstandings at a higher level. The difference between linear and non-linear operation is explored through the use of a variety of circuit examples including amplifiers constructed with operational amplifiers as the fundamental component and elementary digital logic gates constructed with various transistor types.

Fundamentals of Electronics has been designed primarily for use in an upper division course in electronics for electrical engineering students. Typically such a course spans a full academic years consisting of two semesters or three quarters. As such, *Electronic Devices and Circuit Applications*, and the following two books, *Amplifiers: Analysis and Design* and *Active Filters and Amplifier Frequency Response*, form an appropriate body of material for such a course. Secondary applications include the use in a one-semester electronics course for engineers or as a reference for practicing engineers.

KEYWORDS

operational amplifiers, amplifiers, modeling, gain, semiconductor diodes, load lines, zener diodes, rectifiers, logic gates, transistors, bipolar junction transistors, TTL, ECL, transistor biasing, bias stability, field effect transistors, BJT, FET, MOSFET, SPICE modeling

Preface

It is expected that the reader of this text is familiar with the common passive elements of linear circuit analysis (resistors, inductors, capacitors, and transformers) as well as the idealized linear active elements (independent and dependent voltage and current sources). Unfortunately, the field of electronics makes great use of active elements that do not necessarily fall into either of the above categories. These active elements may behave in either a linear or non-linear fashion depending on their circuit application.

The study of electronic circuit behavior traditionally begins with three active semiconductor electronic elements:

- The Semiconductor Diode
- The Bipolar Junction Transistor (BJT)
- The Field Effect Transistor (FET)

To this trio of fundamental devices has been added an additional electronic circuit building block, the Operational Amplifier (OpAmp). While the OpAmp is composed of tens of transistors (usually either BJTs or FETs, but sometimes a mixture of both types) and often a few diodes, its easily understood terminal properties, high use in industry, and commercial availability make it a good companion for study with the other devices.

Quasistatic analysis explores the potentially non-linear action of each of these four elements (or any other similar element) in a variety of applications. The fundamental assumption in this exploration is that voltage and current transitions take place slowly and that the circuit is always in equilibrium: hence the term quasistatic.

The authors have chosen to begin the study of electronics with a chapter on the operational amplifier for several reasons, among which are:

- in most simple applications, the OpAmp behaves in a near-ideal fashion.
- typical analysis of OpAmp circuitry provides a good review of basic circuit analysis techniques.
- discussion of the OpAmp provides a good framework for understanding of electronic circuitry.

While many readers will find much in this chapter on OpAmps a review, the chapter presents several concepts fundamental to the study of electronic circuitry. Most significant among these concepts are:

- undistorted amplification
- gain
- device modeling
- conditions under which device models, particularly linear models, fail

Of particular importance is the concept that a device with extremely complex interior working mechanisms can be modeled simply by its terminal characteristics.

The remaining three chapters in this book present the semiconductor diode, the BJT and the FET. Each chapter follows the same basic framework and has the same goals:

- To present each device through real experimental data and through theoretical functional relationships.
- To use the above presented relationships to observe the action of the device in relatively simple circuits.
- To devise a progression of realistic piecewise-linear models for the devices. The theoretical basis for each model is presented and the appropriate use of these models is explored. Only when a model fails to properly predict device behavior will new, more complex, models be introduced. This simple-to-complex route provides for progressively more detailed analysis using the newly introduced models.
- To use realistic applications to demonstrate the usefulness of the device models.
- To provide a solid foundation for the linear and non-linear modeling and applications found in later books of this series.

Upon completing Book 1, the reader will have a good foundation in the operation of these four basic active, non-linear devices. The fundamental regions of operation for each device will have been explored: both linear and non-linear device models will be available for further investigations.

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