PREFACE

Through study of this text, the reader will develop a comprehensive understanding of the basic techniques of modern electronic circuit design, analog and digital, discrete and integrated. Even though most readers may not ulti-mately be engaged in the design of integrated circuits (ICs) themselves, a thorough understanding of the internal circuit structure of ICs is prerequisite to avoiding many pitfalls that prevent the effective and reliable application of integrated circuits in system design.

Few chapters related to digital electronics, which has evolved to be an extremely important area of circuit design, is available on the supplementing web site. We present a focussed coverage of analog circuits. The writing integrates the authors' extensive industrial backgrounds in precision analog and digital design with their many years of experience in the classroom. A broad spectrum of topics is included, and material can easily be selected to satisfy a two-semester course in electronics.

WHAT'S NEW

This major revision has focused on making the material more readable and accessible to the students. A comprehensive **Structured Problem Solving Approach** is an important feature of the second edition, and this method is used throughout the examples. Another new feature, called **Electronics in Action,** highlights the use of electronics in a wide variety of exciting applications. New **Chapter Openers** have been written to enhance the reader's understanding of historical developments in electronics. **Design Notes** have been added to highlight important things for the circuit designer to remember.

A significant portion of our effort has focused on improving the presentation and flow of the material. Chapters have been reorganized, merged, and split, and some limited new material has been added. Improved section transitions have been developed, extraneous mathematical detail has been reduced, and the details of several derivations have been moved to the web.

Major new features of the book are outlined below.

- The Structured Problem-Solving Approach is used throughout the examples
- Electronics in Action features in each chapter
- Chapter openers highlighting developments in the field of electronics
- Design Notes and enhanced emphasis on practical circuit design
- Greatly increased use of SPICE throughout the text and examples
- Integrated treatment of device modeling in SPICE
- Numerous new Exercises, Examples, and Design Examples
- Approximately 500 new problems
- Integrated web materials

New topics and material

- Discussion of semiconductor device models in SPICE
- Enhanced focus on the differences in the dc, ac, transient, and transfer function analysis modes in SPICE
- Overview of IC Fabrication
- PTAT circuits and bandgap references
- IC voltage regulators
- MOS transistor layout and scaling
- MOS transistor cutoff frequency limitations and subthreshold conduction

Improved treatment of noise margins

Bipolar transistor layout

BiCMOS logic and amplifiers

Blackman's Theorem

Gilbert Multipliers and Mixers

ΣΔ A/D converters

Increased emphasis on low-voltage and low-power design

The Problem-Solving Approach

Solving problems is a centerpiece of an engineer's activity. As engineers, we use our creativity to find new solutions to problems that are presented to us. Here we present a well-structured approach to solving problems that will assist students in solving problems and becoming design engineers. The examples in this text highlight the problem-solving approach that can be used in all facets of one's career, both as a student and as an engineer in industry. The method is outlined in the nine steps below.

1. State the **Problem** as clearly as possible.
2. List the **Known Information and Given Data**.
3. Define the **Unknowns** that must be found to solve the problem.
4. List your **Assumptions**. All problems have hidden assumptions, and additional assumptions may be discovered as the analysis progresses.
5. Develop an **Approach** from a group of possible alternatives
6. Perform an **Analysis** to find a solution to the problem. As part of the analysis, be sure to *draw the circuit and label the variables.*
7. **Check the Results**. Has the problem been solved? Is the math correct? Have all the unknowns been found? Have the assumptions been satisfied? Do the results satisfy simple consistency checks?
8. **Evaluate the Solution**. Is the solution realistic? Can it be built? If not, repeat steps 4–7 until a satisfactory solution is obtained.
9. **Computer-Aided Analysis**. SPICE and other computer tools are highly useful to check the results and see if the solution satisfies the problem requirements.

Electronics in Action

This feature, and the new chapter openers, attempt to capture some of the excitement associated with the application of integrated circuit technology to today's problems, as well as explore a number of circuits that the electronics engineer will encounter in everyday design. A list of the EIA features can be found inside the front cover of this text.

GENERAL OVERVIEW

Chapters 1 and 2 emphasize the economically important devices—the diode, MOSFET, and BJT. Moving from the diode to the MOSFET provides a smoother and less confusing transition for students than attempting to work with the less intuitive internal behavior of the bipolar device. The MOSFET presentation begins with a qualitative discussion of the MOS capacitor, followed by a derivation of the linear region *i-v* characteristics. Although enough discussion is provided to understand the basic fundamentals of device operation, the major focus remains on device behavior from the terminals. A more heuristic approach is used to develop the Transport (simplified Gummel-Poon) model for the BJT.

The analog section begins in Chapter 3 with a discussion of concepts related to amplifiers and amplification. Chapters 4 and 5 present a comprehensive discussion of the operational amplifier and its many limitations. Chapter 6 presents a comprehensive development of the small-signal models for diode, BJT, and MOSFET. The hybrid-pi model and pi-models for the BJT and FET are used throughout.

Design concepts and device and circuit comparisons are emphasized wherever possible. A significantly stronger emphasis is given to MOS analog circuits than in many texts, and the treatment of bipolar and FET

analog circuits is merged from Chapter 7 onward, permitting a continual comparison of design options and reasons for choosing one device over another in a particular circuit.

Chapters 6–9 provide an in-depth discussion of single-stage and multi-stage amplifier design using transistors. Chapter 9 presents a detailed discussion of frequency response. In the final chapter, the classical two-port approach is taken in the presentation of feedback. However, a section is included that stresses the errors that can occur when the approach is incorrectly applied. A new section discussing Blackman's Theorem has been added and shows how the problems associated with the two-port formulations can be avoided. Feedback amplifier stability and oscillators are discussed, as is the method of determining loop-gain using successive voltage and current injection.

DESIGN

Design remains a difficult issue in educating engineers. The use of the well-defined problem-solving methodology presented in this text can significantly enhance an engineer's ability to understand the issues related to design. New design examples have also been added to the text to assist in building an understanding of the design process.

The effects of device and passive-element tolerances are discussed throughout the text. In today's world, low-power, low-voltage design, often supplied from batteries, is playing an increasingly important role. Discussion of low-voltage design issues are included throughout this text, and many problems are included in this important area. The use of the computer, including MATLAB, spreadsheets, or standard high-level languages to explore design options is a thread that continues throughout the text.

Methods for making design estimates and decisions are stressed throughout the analog portion of the text. Expressions for amplifier behavior are simplified beyond the standard hybrid-pi model expressions whenever appropriate. For example, the expression for the voltage gain of an amplifier in most texts is simply written as $|A_v| = g_m R_L$, which tends to hide the power supply voltage as the fundamental design variable. Rewriting this expression in approximate form as $g_m R_L \cong 10V_{CC}$ for the BJT, or $g_m R_L \cong V_{DD}$ for the FET, explicitly displays the dependence of amplifierdesign on the choice of power supply voltage and provides a simple first-order design estimate for the voltage gain of the common-emitter and common-source amplifiers. Similar results are developed for the differential and common-mode behavior of differential amplifiers and simple operational amplifiers. These approximation techniques and methods for performance estimation are included as often as possible.

Worst-case and Monte-Carlo analysis techniques are introduced at the end of the first chapter. These are not topics traditionally included in undergraduate courses. However, the ability to design circuits in the face of wide component tolerances and variations is a key component of electronic circuit design, and the design of circuits using standard components and tolerance assignment are discussed in examples and included in many problems. Comparisons and design tradeoffs between the properties of BJTs and FETs are also included.

PROBLEMS AND INSTRUCTOR SUPPORT

Specific design problems, computer problems, and SPICE problems are included at the end of each chapter. Design problems are indicated by  , computer problems are in-dicated by  , and SPICE problems are indicated by  . The problems are keyed to the topics in the text and are also graded into three levels of difficulty with the more difficult or time-consuming problems indicated by * and **. An Instructor's Manual containing solutions to all the problems is available from the authors. In addition, copies of the original versions of all of the graphs and figures are available as PowerPoint files and can be retrieved from the world wide web. Instructor notes are available as Power-Point slides.

COMPUTER USAGE AND SPICE

The computer is used as a tool throughout the text. The authors firmly believe that this means more than just the use of the SPICE circuit analysis program. In today's computing environment, it is often appropriate to use the computer to explore a complex design space rather than to try to reduce a complicated set of equations to some manageable analytic form. Examples of the process of setting up equations for iterative evaluation by computer through the use of spreadsheets, MATLAB and/or standard high-level language programs are illustrated in several places in the text. MATLAB is also used for Nyquist and Bode plot generation and is very useful for Monte Carlo analysis.

On the other hand, SPICE is used throughout the text. Results from SPICE simulation are included throughout and numerous SPICE problems are to be found in the problem sets. Wherever useful, a SPICE analysis is used with most examples. This edition also emphasizes the differences and utility of the dc, ac, transient, and transfer function analysis modes in SPICE.

WEB SUPPORT

There are four chapters related to Digital electronics, one chapter on Analog Integrated Circuits and two Appendices on the Web site for the users of the book. Apart from this, the instructor Manual has PowerPoint slides and solutions to all the problems in the book. The Students' Manual contains Study Outlines, Students' Solution Manual and Glossary.

ACKNOWLEDGMENTS

We want to thank the large number of people who have had an impact on the material in this text and on its preparation. Our students have helped immensely in polishing the manuscript and have managed to survive the many revisions of the manuscript. J. D. Irwin, head of Electrical Engineering at Auburn, has always been extremely supportive of faculty efforts to develop improved texts.

We want to thank all the reviewers including David P. Shattuck, University of Houston; Stuart K. Tewsbury, Stevens Institute of Technology; Harry W. Li, University of Idaho; and David Braun, California Polytechnic State University-San Luis Obispo as well as important suggestions from John R. Houser at NC State. We also thank Mike Fuller for his work on circuit simulations and William Dillard for his efforts on preparing material for the solution manual. Finally, we want to be sure to thank the team at McGraw-Hill including Carlise Paulson, Emily Lupash, and Kay Brimeyer for a myriad of important suggestions and changes that helped polish the final version of the manuscript.

In developing this text, we have attempted to integrate our industrial backgrounds in precision analog and digital design with many years of experience in the classroom. We hope we have at least succeeded to some extent. Constructive suggestions and comments will be appreciated.

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