Intuitive Analog Circuit Design

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A Problem-Solving Approach using Design Case Studies

By

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In memoriam

To my mother, Minnie Ann Thompson,
who bought me my first transistors when I was a child.

Dedication

To Lisa and Sophie M., for your love and patience.
The book is finally done. Mazel tov!

Contents

Preface

What? Another textbook on analog circuit design? Well, this is not a textbook *per se*; rather, it is designed to be more of a design handbook for practicing engineers and students interested in learning more real-world techniques for designing and analyzing analog circuits using transistors, diodes, and operational amplifiers. The hope is that the reader will find a good mixture of theoretical techniques and also real-world design examples and test results.

This author is a practicing electrical engineer in the analog and power electronics realm who also has had the opportunity to teach at Worcester Polytechnic Institute.

The careful reader, upon review of the chapter references, will note that I have a fondness for using older references. This is due in part to the fact that the authors of these older texts and papers did not have computers available to them for circuit simulations and mathematical number-crunching. These references, in many cases, give very useful approximations, intuitive insights, and different ways of looking at difficult circuit analysis problems.

Intended Audience

This text is loosely based on a set of course notes designed for my graduate-level analog circuit design seminar offered at Worcester Polytechnic Institute. Students who take my course have already taken undergraduate-level courses covering transistors, signal processing, Bode plots and the like. Furthermore, it is the author's hope that the techniques shown in the book will be useful for practicing analog (and perhaps even *digital*!) design engineers.

Text Outline

Chapters 1 and 2 offer introductory material. Chapter 1 serves as an introduction and motivation to analog circuit design in general, with selected history thrown into the mix. Chapter 2 covers important signal-processing concepts that are used in later chapters, so that the reader will be on the "same page" as the author.

Chapters 3 to 8 cover the bipolar device physics, the bipolar junction transistor (BJT), transistor amplifiers, and approximation techniques for bandwidth estimation and switching speed analysis.

Chapter 9 covers the basics of CMOS and CMOS amplifiers. The bandwidth estimation techniques developed in earlier chapters for amplifier design work well for CMOS devices as well.

Chapter 10 covers transistor switching. How do you get a transistor to turn ON and OFF quickly, and how do you estimate that speed?

Chapter 11 is a review of feedback systems and of the Bode plot/phase margin method of designing stable feedback systems.

Chapters 12–13 cover the design, use and limitations of real-world operational amplifiers, including voltage-feedback and current-feedback op-amps.

Chapter 14 covers the basics of analog low-pass filter design, including ladder and active implementations of Butterworth, Chebyshev, elliptic and Bessel filters.

Chapter 15 covers real-world design issues such as PC board layout rules-of-thumb and the use and limitations of passive components.

Chapter 16 is a potpourri of useful design techniques and tricks that don't fit into the other chapters.

Throughout the text, some illustrative analysis problems and MATLAB® and PSPICE design examples are haphazardly sprinkled.

Acknowledgments

The author would like to acknowledge the learned professors and teaching assistants at the Massachusetts Institute of Technology who taught him many of the techniques shown in this book. They include Prof. Jim Roberge, Prof. Bill Siebert, Prof. Bill Peake, Prof. Marty Schlecht, Leo Casey, Tom Lee, Prof. Harry Lee, Prof. Campbell Searle, Prof. Amar Bose, and Prof. Dick Thornton.

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Plots were created using MATLAB and the Microsim Student Version of PSPICE, version 8.0.

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