

Designing Audio Power Amplifiers

Bob Cordell



New York Chicago San Francisco
Lisbon London Madrid Mexico City
Milan New Delhi San Juan
Seoul Singapore Sydney Toronto

Preface

There are several very good books on audio power amplifier design already out there, so you might ask why we need yet another book on power amplifier design. Hopefully this preface will answer that question. However, the short answer can be found in two observations. First, there have been many developments in audio power amplifier design since the release of most of the prior books. Second, there are some important topics that deserve more depth of coverage.

Designing Audio Power Amplifiers is written to address many advanced topics and important design subtleties. At the same time, however, it has enough introductory and tutorial coverage to allow designers relatively new to the field to absorb the material of the book without being overwhelmed. To this end, the book starts off at a relaxing pace that helps the reader develop an intuitive feel and understanding for amplifier design. Although this book covers advanced subjects, highly involved mathematics is kept to a minimum—much of that is left to the academics. Design choices and decisions are explained and analyzed.

This is not just a cookbook; it is intended to teach the reader how to think about power amplifier design and understand the many concepts and nuances, then analyze and synthesize the many possible variations of amplifier design.

I have divided the book into six parts. Part 1 introduces audio power amplifier design and includes the basics. This part is designed to be readable and friendly to those with less technical background while still providing a very sound footing for the more detailed design discussions that follow. In this part I show how a simple power amplifier design evolves in several steps to a modern architecture, describing how performance deficiencies are mitigated with circuit improvements at each step in the evolution. Even experienced designers may gain valuable insights here.

Part 2 delves into the design of advanced power amplifiers with state-of-the-art performance. Crossover distortion, one of the most problematic distortions in power amplifiers, is covered in depth. Special attention is paid to dynamic crossover distortion, which is less well understood. This part also includes a detailed treatment of MOSFET power amplifiers, error correction techniques, advanced feedback compensation, ultralow distortion drive circuits, and DC servos.

Part 3 covers those real-world design considerations that influence sound quality and reliability, including power supplies and grounding, short circuit and safe area protection, and amplifier behavior when driving difficult loads. Thermal design and thermal stability are given special attention. Electromagnetic interference ingress and egress via the input, output, and mains ports of the amplifier are also treated here.

SPICE simulation can be very important to power amplifier design, and its use is described in detail in Part 4. Even those with no SPICE experience will learn how to use this valuable tool, helped along by a tutorial chapter and ready-to-run amplifier simulations and transistor models available at www.cordellaudio.com. A full chapter describes how you can create your own accurate SPICE models for BJT and MOSFET transistors, many of which are poorly modeled by manufacturers. Numerous approaches to distortion measurement are also explained in Part 4. I've also described

some techniques for achieving the high sensitivity required to measure the low-distortion designs discussed in the book. Less well-known distortion measurements, such as TIM, PIM, and IIM, are also covered here. In the quest for meaningful correspondence between listening and measurement results, other non-traditional amplifier tests are also described.

Part 5, Topics in Amplifier Design, covers all of those other important matters that do not fit neatly into the other parts. Advanced designers as well as audiophiles will find many interesting topics in this part. Some of the controversies in audio, such as the use of negative feedback, are addressed here. For balance, the design of amplifiers without negative feedback is covered. Integrated circuit power amplifiers and drivers are also discussed.

Class D amplifiers are playing a more important role in audio amplification as every day passes. They have enjoyed vast improvements in performance over the last several years and can be expected to improve much further in the future. Four chapters in Part 6 cover this exciting technology.

Many of the following topics covered in *Designing Audio Power Amplifiers* should prove especially interesting to readers familiar with earlier texts:

- Ultra-low distortion input and voltage amplifier topologies
- Non-conventional feedback compensation techniques
- Lateral and vertical MOSFET power amplifiers
- Output stage error correction circuits
- Thermal stability analysis of BJT and MOSFET output stages
- Output transistors with temperature tracking diodes
- Integrated circuit amplifiers and drivers
- SPICE simulation and modeling for amplifier design
- Amplifier measurement instrumentation and techniques
- PC-based instrumentation for amplifier evaluation
- How amplifiers misbehave and why they sound different
- Sources of distortion in class D amplifiers
- PWM, sigma-delta, and direct digital class D amplifiers

No single text can cover all aspects of audio power amplifier design. It is my hope that an experienced designer or a hobbyist who seeks to learn more about audio amplifier design will find this book most helpful. I also hope that this text will provide a sound basis for those wishing to learn analog circuit design.

Bob Cordell