Designing Audio Power Amplifiers Preface

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This the Second Edition of *Designing Audio Power Amplifiers* expands and updates the First Edition, with five new chapters and significant expansion of many of the original chapters. There have been many developments in audio power amplifier design since the release of the First Edition and 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. It is targeted to professionals in the audio field as well as students learning electronics and enthusiasts. 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. Practical amplifier circuits of numerous different topologies and circuit features are described in depth and many are accompanied by performance measurements.

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. Nor is it focused on numerous variations of just one simple topology or design philosophy.

The design of modern high-performance audio power amplifiers touches on most aspects of electronic design, including solid state devices, feedback theory, low noise design, thermal analysis, switching power supplies, laboratory measurement and circuit simulation, to name a few. As such, skills acquired in power amplifier design can provide a sound educational basis for the study of more specialized areas in electronics.

I have divided the book into six parts. Part One 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. A new chapter covers the design

and construction of a complete amplifier based on the evolved designs. The section concludes with a chapter on negative feedback principles and a new chapter on low-noise amplifier design.

Part Two 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. A new second chapter covering the all-important output stage is included, where additional circuits like the DoubleCross™ output stage are discussed. This section also includes a detailed treatment of lateral and vertical MOSFET power amplifiers, error correction techniques, advanced feedback compensation, ultra-low distortion drive circuits and DC servos.

Part Three 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. A new chapter is dedicated to in-depth coverage of switch-mode power supplies (SMPS), including power factor correction. Electromagnetic interference ingress and egress via the input, output and mains ports of the amplifier are also treated here. In like manner, conductive and radiated emissions suppression and regulatory limits are discussed. Amplifier thermal design, thermal stability and temperature compensation are covered, including simple thermal models and simulations.

SPICE simulation can be very important to power amplifier design, and its use is described in detail in Part Four. Even those with no SPICE experience will learn how to use this valuable tool, helped along by a tutorial chapter on the free LTspice simulator, with ready-to-run amplifier simulations and transistor models available at www.cordellaudio.com. Feedback loop gain simulations employing the Middlebrook and Tian probes are explained. A full chapter describes how you can create your own accurate SPICE models for BJT, JFET and MOSFET transistors, many of which are poorly modeled by manufacturers. Numerous approaches to distortion measurement are also explained in Part Four. 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 Five, 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 as well. Integrated circuit power amplifiers and drivers are also discussed. A new chapter devoted to modern professional power amplifiers is included. This chapter covers all of the special design considerations and features necessary in professional audio amplifiers, including microcomputer control, DSP, integrated functionality, networked control and AoIP.

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 Six cover this exciting technology. PWM and Sigma Delta modulators, negative feedback, noise shaping, class D shortcomings and special measurement techniques for class D amplifiers are discussed.

In summary, 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
- Low-noise amplifier design
- unconventional feedback compensation techniques
- Lateral and Vertical MOSFET power amplifiers
- Output stage error correction circuits
- Switch-mode power supplies (SMPS)
- Thermal 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
- Measurement techniques for class D amplifiers

No single text can cover all aspects of audio power amplifier design. It is my hope that an experienced designer, a student or an enthusiast who seeks to learn more about audio amplifier design and circuit design in general 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.