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projects you can build

HIGH-POWER AUDIO AMPLIFIER CONSTRUCTION MANUAL

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**50 TO 500 Watts for
the Audio Perfectionist**

G. Randy Slone

McGraw-Hill

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PREFACE

This book is designed for audiophiles and electronics hobbyists who want to build their own high-quality audio power amplifiers. The amplifier designs contained here are not just mediocre power amplifiers; they are audiophile-quality designs, with the majority capable of significantly superior performance in comparison to commercially available amplifiers. My philosophy is simple: If you're going to invest the time and expense to build audio power amplifiers, why not build a project of exemplary performance?

I believe this book is unique in its approach. Most books devoted to audio amplifier construction have traditionally focused on one type or design topology. In contrast, I have attempted to present an honest and factual analysis of all the major power amplifier architectures, naturally progressing to the optimum design in each case. In addition, a variety of modifications are stressed for application compatibility, such as professional audio, musical instrument amplifiers, domestic hi-fi, and budget applications.

I have assumed that the reader is experienced in the fundamentals of electronics and electronic construction; however, I assume the reader to be a complete novice in the specifics of audio power amplifiers. Consequently, the principles and theory of operation begin at the most fundamental level and progress to the current state of the art. I have never assumed that the reader understands the function and purpose of any component within an amplifier design, so the specific details of every component in every amplifier schematic are fully explained. The conscientious reader will not end up with myriad confusing loopholes relating to any amplifier design in this textbook.

Design engineers and serious audiophiles will benefit from several areas of new research contained here. A portion of this amplifier design information has seldom been documented, with some of it

appearing to be totally obscure and unpublished. These subject areas include push-pull VA stage design and certain anomalies involving the physics of crossover distortion.

This book is for hobbyists and audiophiles who have been discouraged by the apparent schism between audio professionals and extravagant esoterics. It is designed to help anyone experience the ultimate in sonic quality at a reasonable expense. The concepts and principles presented are not subjective, mythical, or traditional; they are scientific and extensively supported with provable analyses. Many readers will be pleasantly surprised at the low cost involved with even the best audio power amplifiers.

Above all, I have directed this book toward people who want to experience the fun, satisfaction, and fulfillment of superb and practical electronic projects (not to mention the significant cost savings). I have personally constructed and tested the amplifier projects in this textbook, using the exact PC board artwork contained in Appendix C, so the careful and conscientious builder can be virtually assured of excellent results. Everything in this book is as accurate as theory, experimentation, simulation, testing, analysis, and late-night worrying can make it—I sincerely hope that many will enjoy it and benefit from it.

ACKNOWLEDGMENTS

As a sincere and dedicated Christian, I always try my best to remember to acknowledge my Lord and Savior, Jesus Christ, whom I believe assists me in the accomplishment of all honorable and wholesome goals.

A heartfelt thanks goes out to the outstanding group at Interactive Image Technologies, distributors of the Electronics Workbench program. While I operated at an efficiency level of two good ideas for every eight crazy ideas, I must honestly state that the people at Interactive Image Technologies were consistently patient with me, while providing invaluable technical assistance in the production of this textbook. I especially want to thank Joe Koenig and Luis Alves for helping out in many problematic areas.

The heart of this book has been beating in audiophiles for the past four decades, so the majority of the credit really belongs to many pioneers of both past and present. Progress in the audio fields is effectively a group effort, with many excellent audio engineers deserving the majority of credit. I hope my meager contributions can be another stepping stone for future progress.

I would also like to acknowledge the professional group at McGraw-Hill. I believe an author can only achieve the success allowed by the professionalism of his or her publisher. In this respect, I am certainly indebted to the dedicated personnel at McGraw-Hill.

G. Randy Slone

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Fundamentals of High-Power Audio Amplifiers

What Is Audio Amplification?

All types of audio information recorded for playback began as very low level electrical signals. For example, the signal levels at the outputs of microphones, musical instrument pickups, or audio tape heads will typically average out to only a few millivolts. Such *signal-level voltages* must be increased in amplitude (amplified) to become usable. Voltage amplifiers designed to accomplish this task are referred to as *preamplifiers*. For normal audio applications, signal-level voltages will be preamplified to about 1 or 2 volts RMS. This level is commonly referred to as the *line level*, and it is the common output level produced by almost all consumer audio equipment (i.e., tape decks, CD players, FM receivers, etc.). On some musical instrument amplifiers, the line-level output is referred to as the *preamp output*.

In addition to amplifying signal-level voltages, preamplifiers normally contain all signal conditioning circuits. *Signal conditioning circuits* modify, or customize, the original audio signal to accommodate

the listener's preference, room acoustics, or system idiosyncrasies. Examples of signal conditioning circuits are tone controls, equalizers, bass boost controls, reverb units, and various types of filter and phase circuits. Preamplifiers used for professional recording applications and commercial public address (PA) systems may also incorporate pan controls, delay lines, and harmonic modification capabilities. Input devices (i.e., tape deck, CD player, FM receiver, microphone, etc.) may be switched within the preamplifier circuitry.

All preamplifiers are voltage amplifiers. Their function is to condition and amplify a signal voltage to a line-level audio signal, in preparation for sending it to an audio power amplifier. In contrast, an audio power amplifier is designed to amplify a line-level voltage to a corresponding high-level voltage and current, capable of driving a low-impedance speaker (typically 4 or 8 ohms).

A high-quality audio power amplifier is said to be “transparent.” This means the output voltage is an (almost) exact replication of the input voltage, without any modifications having been made to phase relationships, harmonic integrity, transient response, or frequency response. If a “perfect” audio power amplifier could be constructed, the only difference between the line-level input signal and the output signal would be the increased amplitude at the output (both current and voltage). Any other difference between the input signal and output signal of an audio power amplifier is considered *distortion*.

This book provides the reader with the tools necessary to construct high-power, high-quality (almost distortionless) audio power amplifiers. Throughout this book, amplifier quality is equated directly with the lowest-distortion specifications, and I make no apologies for this fact. Throughout the last few decades, there has been an unfortunate trend among a minority group of audio esoterics to advocate the introduction of certain types of harmonic distortion mechanisms within audio power amplifiers. I am quite certain that I have the unanimous support of every legitimate sound engineer (at least the ones who can pay their bills) when I unconditionally state that all signal conditioning should occur at the line level (i.e., within the preamp stage or external signal processors). All audio power amplifiers should be as distortion free as possible because sonic accuracy is desirable for a host of practical and performance factors. (This subject will be discussed in more detail in Chapter 2.)

The Social and Economic Importance of Audio Amplification

It is very difficult to imagine what our world would be like without electronic audio amplification. Every radio, television, telephone, and stereo system contains one or more audio amplifiers. Imagine, if you can, the condition of our society without these devices!

Without audio amplifiers, Elvis Presley and the Beatles would have been limited to audiences within the confines of their audible vocal range. Rock 'n roll could not exist. All musical instruments would have to be acoustic, and there would be no point to recording them (you would have to have an audio amplifier to play back the recording!). Preachers could not be heard in large church buildings, dance bands would have to revert to Glen Miller's type of orchestration, and the city of Nashville would have to come up with an entirely new tourist attraction. In essence, our culture, as we know it today, would die.

The economic considerations are equally massive. Out of all possible consumer electronic building blocks, the humble audio amplifier is most common. As we have become more sonically sophisticated in this electronic age, the listening perception of the average person has increased logarithmically. When the first gramophones became the newest consumer gadgets, they were publicly acclaimed to provide the finest audio reproduction possible. Try getting someone to compliment the sound of a gramophone today! The point here is simple: The general public of today is more educated in the subtleties of good sound, and they are more than willing to pay for it.

At present, high-quality, high-power audio amplifiers capture a very substantial portion of the consumer electronics market, with the latest manufacturing targets being in the home theater and multimedia arenas. Dedicated audiophiles have increased in number since the 1960s, and the exorbitant price tags on audiophile-quality equipment prove this market to be in good health. Although not as dramatic as the consumer electronics field, the entertainment and professional requirements for high-quality amplifiers continue to prosper. Indeed, there are few homes today that do not contain at least one high-power audio amplifier system.