AUDIO TECHNOLOGY SYSTEMS:

Principles, Applications, and Troubleshooting

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Preface

Audio technology is one of the most rapidly growing areas of electronics. The high-fidelity field, in particular, has evolved greatly within recent years. To provide optimum perspective in a coverage of the prevailing state of the art, this text employs a descriptive/design/troubleshooting format. This unique approach facilitates the learning process and establishes a broad base for comprehension. In turn, this is an essential text-handbook for the classroom and home-study student, audiophile, junior engineer, experimenter, and audio troubleshooter. Mathematics has been held to a minimum in the text, and quantitative relations are presented in graphical form. However, the reader is assumed to be familiar with basic algebra, plane trigonometry, and electrical circuit calculations.

The first chapter provides an introduction to audio technology; it discusses high-fidelity component systems, audio amplifier design basics, distortion analysis, and basic audio troubleshooting principles. Decibel measurements are also explained, and common pitfalls are noted. In the second chapter, audio preamplifiers are considered. Basic amplifier parameters are noted. Component and device tolerance effects are explained. Various types of negative feedback are analyzed. Worst-case design factors are tabulated. Additional troubleshooting techniques are detailed, including quick checks and in-circuit test methods. The third chapter covers audio power amplifiers. Class A, AB, B, D, and G modes of operation are explained. Design principles of complementary-symmetry amplifiers are developed. Pulse-width-modulation amplifiers are outlined. Various methods of troubleshooting audio power amplifiers are explained.

In the fourth chapter, FM tuners and stereo decoders are discussed. Fundamentals of RF circuit operation are outlined, with essential design parameters. Troubleshooting techniques for FM tuners and stereo decoders are included, with notes on audio channel cross-checks. Electrophonic music systems are described in the fifth chapter. The basic function generator is explained, with basic programming methods. Unconventional scales such as the open and the pentatonic scales are noted. Subharmonic generation is analyzed. The sixth chapter covers quadraphonic sound systems. Both discrete and synthesized four-channel sound sources are discussed. Audioscope monitor operation is included. Biphonic sound fundamentals are outlined.

Electronic organs are discussed in the seventh chapter. Basic organization and functions are stressed. Voicing arrangements and formant filters are detailed. Each function is illustrated with circuit diagrams. In the eighth chapter, problems of audio system interference are considered. Audio rectification is analyzed, and basic interference filter arrangements are shown. Trap action of a properly designed shielded cable is explained. The text concludes with a comprehensive glossary and eight appendices. Profuse illustration is employed throughout the text to clarify the technical points that are discussed. Numerous charts have been included for summarization of relations and data.

The format and the treatment are the outcome of many years of teaching experience, both on the part of the author and of his associates. In a significant sense, this book represents a team effort, and the author gratefully acknowledges the constructive criticisms and suggestions of his co-workers. In addition, the author is indebted to numerous electronic manufacturers, as noted throughout the text, for illustrative material and various technical data.

It is appropriate that this text be dedicated as a teaching tool to the instructors and students of our junior colleges, technical institutes, and vocational schools.

DEREK CAMERON

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Introduction to Audio Technology

1-1 GENERAL CONSIDERATIONS

Audio technology is primarily concerned with electrical and electronic processing of vocal and musical information in the frequency range from 20 Hz to 20 kHz. In its broader aspect, audio technology is also concerned with the generation of waveforms corresponding to sounds, tonal patterns, and timbres with novel characteristics. Audio technology extends further into fields of scientific exploration, such as psychophysics, wherein the relations between physical and mental events are investigated. In turn, audio technology includes diverse disciplines; it is primarily a science, secondarily an art form that transcends the useful arts, and ultimately a psychological tool with philosophical facets.

Devices, circuits, systems, and audio instruments enter into consideration in the theory and practice of audio technology. A block diagram of a typical high-fidelity system is shown in Fig. 1-1. This system employs various kinds of devices, such as diodes, transistors, integrated circuits, crystals, and thermistors. It utilizes components such as resistors, capacitors, and inductors. It also uses various forms of hardware, including heat sinks, switches, needles, magnets, transformer cores, and so on. Circuits include amplifiers, oscillators, mixers, detectors, equalizers, filters, control networks, and power supplies. Both active and passive types of filter circuitry are utilized.

Most industry authorities agree that high-fidelity reproduction involves a frequency response that is uniform within ±1 dB from 20 Hz to at least 20 kHz, with a harmonic distortion less than 1 percent at any frequency within this range. Component systems, such as that illustrated in Fig. 1-2, are very popular, and are often preferred by critical audio enthusiasts. For example, a chosen set of speakers may be utilized with a preferred type of amplifier, plus a selected type of record player (turntable), a chosen design of AM-FM tuner, a selected reel-to-reel tape deck and/or an eight-track deck, or a preferred type of cassette deck. There is a marked trend to the inclusion of stereo fre-

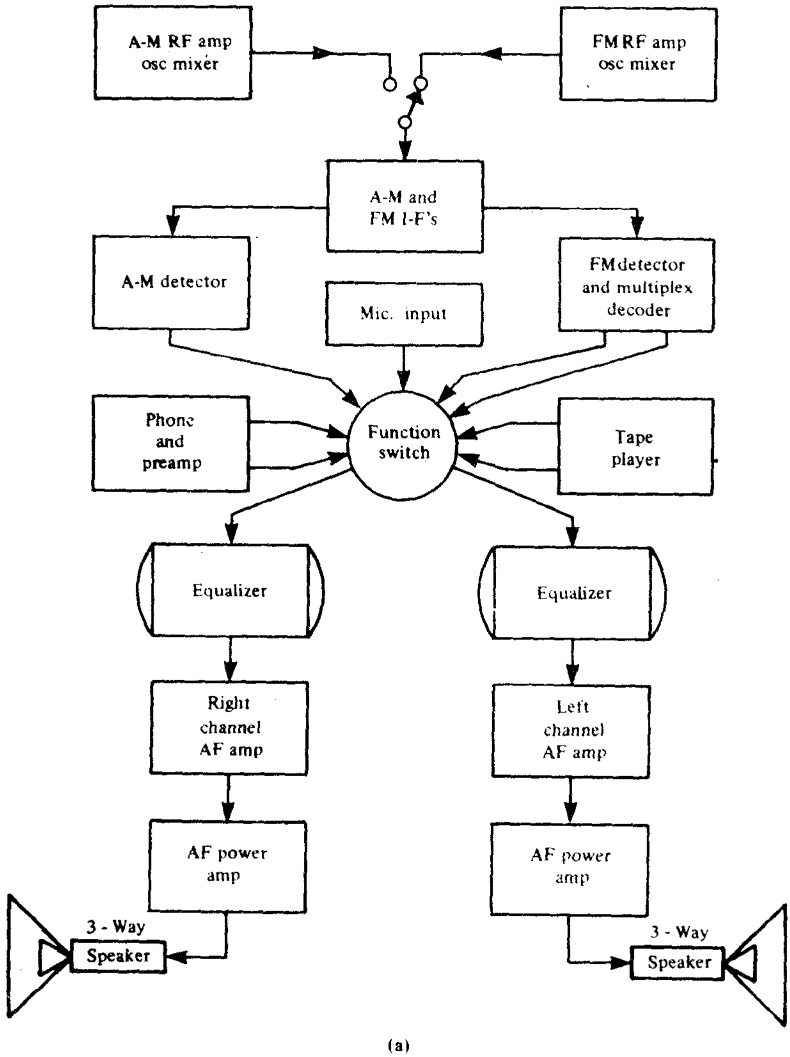
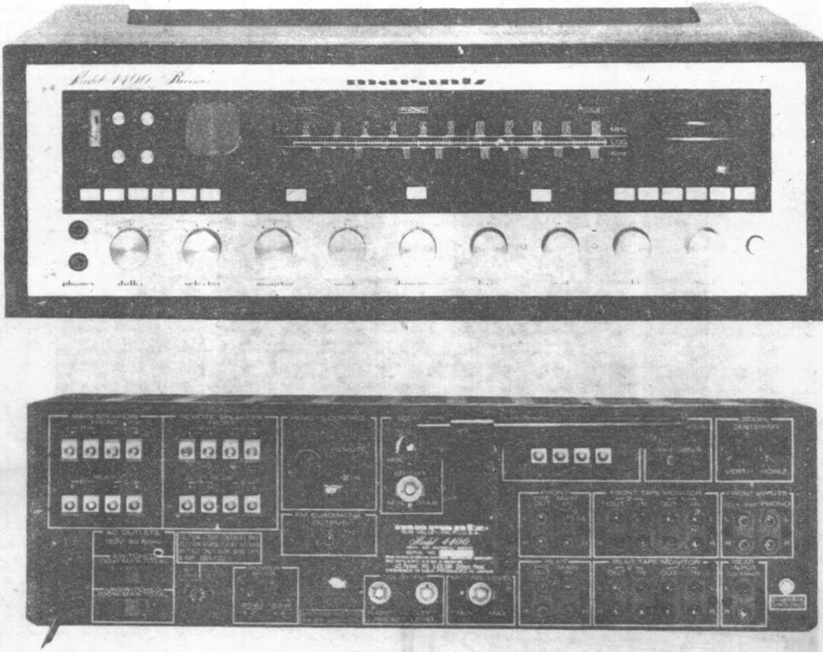


Figure 1-1 Block diagram of FM/AM Stereo multiplex high-fidelity system: (a) arrangement;



(b)

Figure 1-1 *Continued* **(b)** appearance of a hi-fi system. (*Courtesy of Marantz.*)

quency equalizers (Fig. 1-3) in component systems. Frequency equalizers are more elaborate than conventional tone controls, in that they permit the operator to increase or decrease the frequency response through five sectors of the audio-frequency range.

High-fidelity stereo-quadraphonic systems are also designed in unitized form and housed in elegant furniture cabinets. A unitized system is called a *console,* and it contains at least two speakers. Another type of stereo-quad design, called the *compact,* has separate speakers with a record turntable and a stereo amplifier on the same base. The chief unit in a compact may include an FM or FM/AM tuner with a multiplex decoder, plus a turntable. Another design of compact features a record changer mounted on top of the main unit, protected by a clear plastic cover. Hi-fi enthusiasts also refer to a compact as a *modular system.* Note that a hi-fi speaker enclosure is usually designed with several speaker units of various sizes, as shown in Fig. 1-2(b). The largest speaker in a group is termed a *woofer,* and it operates to reproduce low bass tones. Most of the audio power is contained in the bass tones.

Figure 1-2 Appearance of a component system: (a) individual components. *(Courtesy of Radio Shack, a Tandy Corp. Company)*

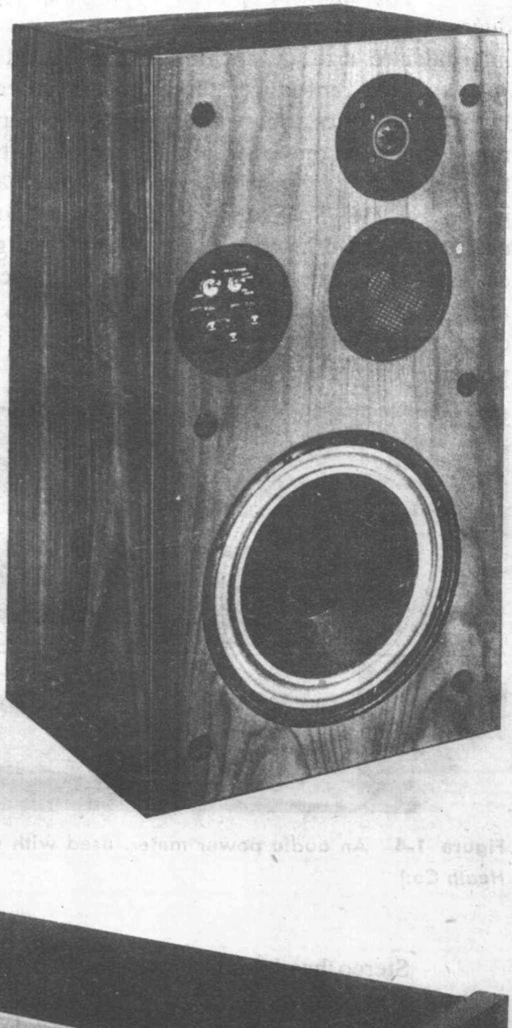


Figure 1-2 *Continued* (b) interior view of typical speaker enclosure. (*Courtesy of Heath Co.*)

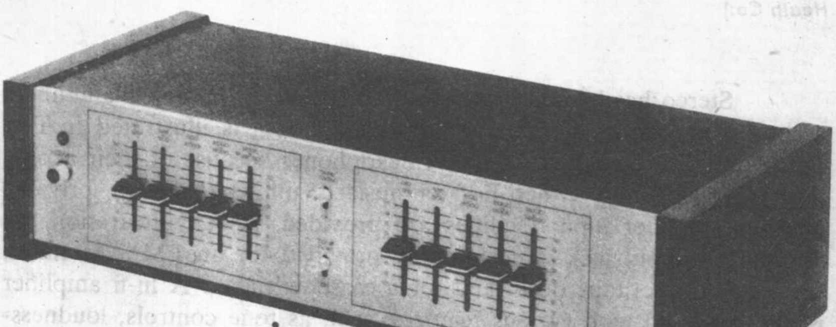


Figure 1-3 Appearance of a stereo frequency equalizer. (*Courtesy of Heath Co.*)

The smallest speaker in a group is called a *tweeter;* it reproduces the high treble tones. Also, a speaker enclosure includes an intermediate size of speaker, often called a *squawker* or *midrange speaker,* that reproduces the middle tonal range between low bass and high treble tones. Some designs of enclosures contain a pair of midrange speakers, one of which is larger than the other. As a general rule, the size of a speaker is proportional to the amount of audio power that it can radiate. Speakers in an enclosure operate in association with crossover networks that direct suitable ranges of audio frequencies to each speaker. The speakers with their associated electrical networks in an enclosure are called a *speaker system.* A component system may include an audio power meter, as illustrated in Fig. 1-4, to monitor the power levels for each enclosure.

Figure 1-4 An audio power meter, used with a speaker system. (*Courtesy of Heath* Co.)

Stereo headphone jacks are often provided in stereo amplifiers and compact units. A pair of stereo headphones is illustrated in Fig. 1-5. Some hi-fi connoisseurs prefer headphones because of their acoustical characteristics. Other hi-fi enthusiasts utilize them for privacy. Various amplifier input facilities are provided. As an illustration, an appropriate input jack is customarily provided for an FM/AM tuner, for a reel-to-reel tape deck, and for a cassette player. A hi-fi amplifier is also designed with various features, such as tone controls, loudness-type volume control, terminals for additional speakers, stereo balance control, and various input facilities (see Fig. 1-6). Hi-fi connoisseurs who make their own tape recordings require an amplifier that provides an appropriate stereo signal for a particular tape recorder.

Figure 1-5 A pair of stereo headphones. (*Courtesy of Radio Shack, a Tandy Corp. Company.*)

A receiver for a hi-fi system is basically a tuner; it must be supplemented by an amplifier to operate a speaker system. Some component systems are designed with a separate tuner and a separate stereo amplifier. All stereo tuners include a multiplex decoder section to reconstitute the two stereo signals from the incoming encoded FM signal. Note that a tape recorder provides both recording and playback facilities, whereas a tape player lacks recording facilities. A tape deck lacks a built-in amplifier, and is operated with an external amplifier and speaker system. Tape decks may or may not include recording facilities. Tape recorders are designed as monophonic, stereophonic, or quadraphonic units. Audiophiles tend to prefer reel-to-reel machines over cartridge or cassette-type machines. Eight-track cartridge tape players, however, are popular because of their compactness and simplicity of operation. Most eight-track cartridge tape machines are designed as player decks. In other words, a player deck lacks recording facilities. All eight-track tape players provide stereo reproduction, and many qualify as high-fidelity units.

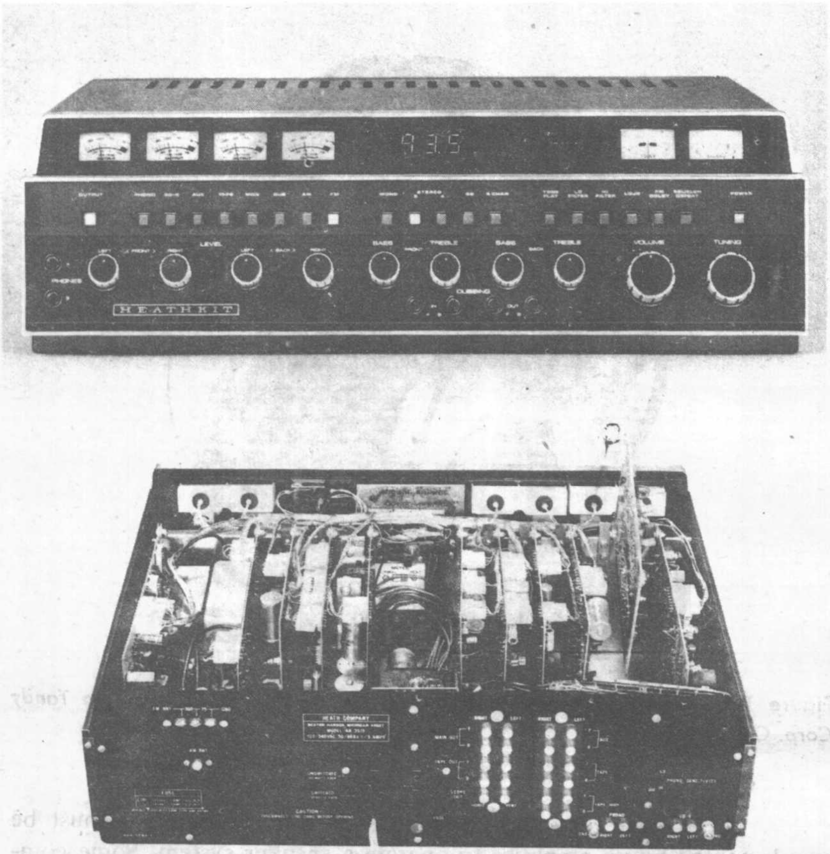


Figure 1-6 Controls and input/output facilities for a hi-fi system. (*Courtesy of Heath Co.*)

1-2 AUDIO AMPLIFIER DESIGN BASICS

An audio amplifier is designed as a part of a system, as exemplified in Fig. 1-7. An audio-amplifier channel in a high-fidelity system may have a maximum usable gain (MUG) of 5000 times, or more. System distortion is customarily less than 1 percent total harmonic distortion (THD). Amplitude and phase characteristics for a typical hi-fi amplifier system are shown in Fig. 1-8(a). Percentage of distortion is generally stated for maximum rated power output at 1 kHz. In addition, power bandwidth is defined as the frequency range between an upper limit and a lower limit, at a power level 3 dB below maximum rated power output,

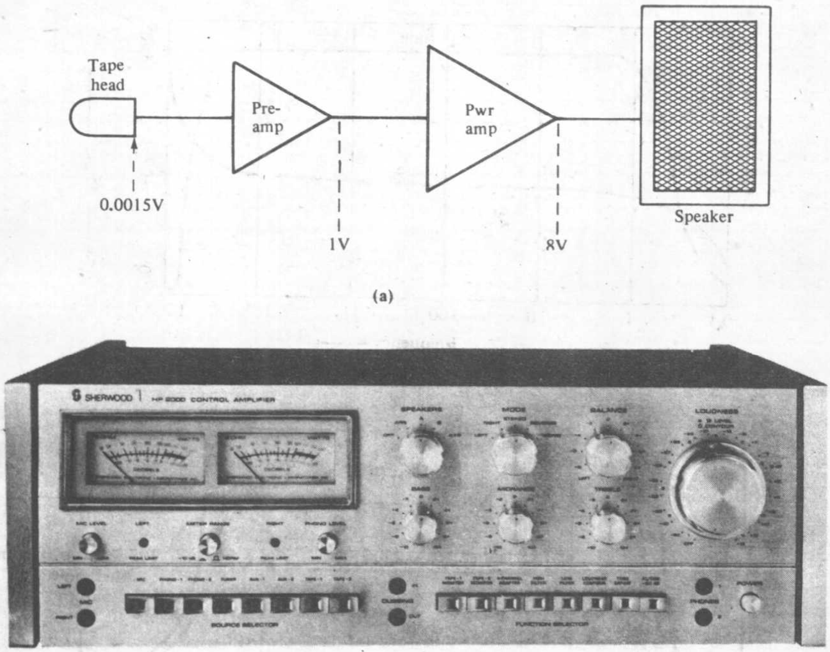


Figure 1-7 Audio voltage levels in an amplifier system: **(a)** block diagram; **(b)** appearance of a control amplifier. (*Courtesy of Sherwood.*)

where the harmonic distortion starts to exceed the value that occurs at the midband frequency with maximum rated power output. The definition of power bandwidth is illustrated in Fig. 1-8(b).

Also, the music-power rating of an amplifier is defined as the peak power that can be delivered to the speakers for a very short period of time, with no more harmonic distortion than at the maximum rated sine-wave output. This period of time is generally considered to be 1 millisecond, (ms), at a repetition rate of 100 pulses per second. In other words, a music-power rating for an amplifier denotes its ability to process sudden peak musical waveforms without objectionable distortion. Music-power output is limited chiefly by the capability of the power-supply filter capacitors to sustain the peak current demand of the amplifier. Note that the peak-power value of a 10-watt sine wave is 20 watts. On the other hand, a musical tone that has 20 watts of peak power may have less than 5 watts of average (rms) power. For this reason, hi-fi amplifiers are often rated for both rms power and music power output.