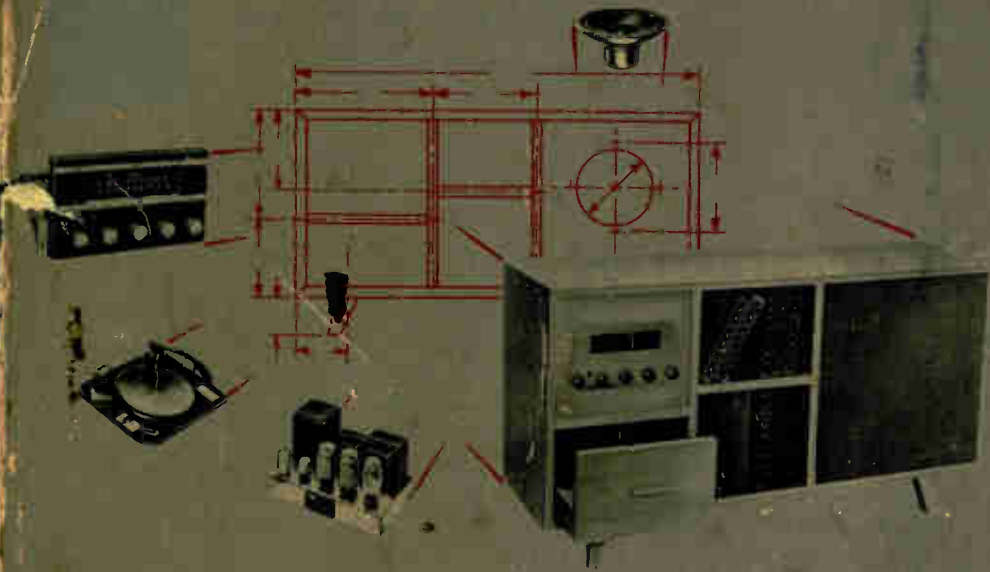
HI-FI HANDBOOK

by William J. Kendall



HOW TO

- PLAN your home music system
- CHOOSE the best components
- INSTALL your system easily
- MAINTAIN it by yourself

...and SAVE MONEY

(Continued from front flap)

Illustrated by more than fifty photos and drawings and written with technical explanations that all can understand, this informative book will be useful to everyone interested in hi-fi music systems, both builders and prospective owners.

Specifically, this book features:

- Understanding the physical requirements of hi-fi sound reproduction
- Evaluating manufacturers' specifications of: speakers and speaker systems, audio amplifiers, radio tuners, record turntables, phono pickups, automatic record changers, and tape recorders
- Acoustical treatment of rooms
- Plans for building speaker enclosures
- Instructions for interconnecting and installing hi-fi components
- How to test the sound reproduction quality of your system
- How to make your own repairs
- Discussion of binaural sound
- Where to buy hi-fi components
- Glossary of hi-fi terms

About the Author

The author is a professional writer well-equipped to write this book. Married to a musician, and an ardent music listener himself, Mr. Kendall served as a radar specialist for the Navy during the last war. A graduate of Yale University and formerly employed by Allen B. DuMont Laboratories, he is now a member of the General Publicity Department of Union Carbide and Carbon Corporation.

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HI-FI HANDBOOK

William J. Kendall

The first encounter with music reproduced by a high-fidelity system is startling – the richness and *live quality* of the music is almost unbelievable. Perhaps just as startling is the discovery that you can buy the separate components of one of these amazing radio-phonographs for as little as $150. Moreover, if you are willing to learn a few basic principles of sound reproduction and make some simple connections, you can install your own system for only a few dollars. When you are through, you will have a home music system that is commercially unobtainable except at a minimum cost of around $350.

Here is the complete and up-to-date book explaining this new kind of radio-phonograph which brings the concert hall into your living room. This book explains how high-fidelity systems operate, how to buy the separate components discriminately, and how to install them for the best in home sound reproduction. Mr. Kendall's frank appraisal of hi-fi components (speakers, amplifiers, phono pickups, etc.) will enable you to buy your system at a great saving. The well-illustrated sections on home acoustics, speaker enclosures, interconnections, and installation will make your job easy and rewarding.

(Continued on back flap)

Jacket by Ted Melnechuk. Photo Credits. Cabinet, David Bogen Company; record changer, Garrard Sales Corporation through British Industries Corporation; radio tuner and audio amplifier, The Radiocraftsmen Inc.; speaker, Permoflux Corporation.

Hi-Fi Handbook

A GUIDE TO

HOME INSTALLATION

BY

William J. Kendall

Revised Edition

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THE HIGH-FIDELITY INSTALLATION . . . QUALITY SOUND REPRODUCTION FOR MODERN LISTENING

HI-FI HANDBOOK

PREFACE

HIGH FIDELITY GOT its start about twenty years ago when a few pioneers first assembled their rigs from public-address systems. Although the fidelity of these early rigs was not high by present standards, their owners called them high-fidelity sound systems because the sound reproduced was as faithful to the originating sound as mechanical and electronic equipment could make it.

Today, because of research and engineering, the art of faithful sound reproduction is as near perfect as it can be. What is more, this near perfection is available to those who can discriminate between true high-fidelity equipment and that merely claiming the distinction.

To buy and install a hi-fi sound system, you do not have to master the engineering lore of electronics and acoustics, but you should understand the over-all physical and electronic requirements for high-fidelity sound reproduction. Armed with the basic facts, a music lover can buy his equipment discriminately and install it at a considerable saving. It is the purpose of this book to present these basic facts as simply and concisely as possible.

I wish to extend my sincere appreciation to the people and organizations who have helped me in the preparation of this book: to the manufacturers who have cooperated by supplying illustrations of their equipment, to Ted Melnechuk for his work on the drawings, to Steven Hahn for his technical assistance, and to the staff of Thomas Y. Crowell Company for its aid in planning and preparing this book. Special thanks are extended to my wife, Jean, for all things concerned with music and for her editing and typing of the manuscript.

W. J. K.

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HI-FI HANDBOOK

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HIGH FIDELITY

WHEN THE TERM "high fidelity" is mentioned in connection with music, most people have some idea of the subject. They know that it is new. It has something to do with making radio and phonograph music sound better. It is associated with FM radio and record players. These concepts, while somewhat vague and certainly not specific, are correct. However, there are also a number of mistaken beliefs about high fidelity, such as: it is a rich man's toy and too expensive for the average man; it is just a fad; it is a complicated hobby for skilled technicians and electrical engineers. These beliefs are definitely false.

High fidelity is not expensive. Today there are over fifty companies manufacturing the various hi-fi components. Competition has been keen, so keen that a good system can be purchased for as little as $150. Moreover, an inexpensive hi-fi system will easily outperform the conventional $250 radio and phonograph combination that comes wrapped up in a fancy piece of furniture.

High fidelity is not a fad. In fact it is nothing more than the final improvement on the standard electrical and mechanical means for reproducing sound. The emergence of the hi-fi concept has given to music listeners the opportunity to hear recorded or broadcast music that possesses almost the same audible quality that they hear in the studio or concert hall. It is hard to believe, so accustomed are we to hearing music in our homes, that the average home radio and record player reproduces only about one-third of the audible sound that is generated in the broadcast or recording studio.

High fidelity is not complicated. The components of the system come ready to be mounted and interconnected. The actual electrical hook-up is about as difficult as wiring a door buzzer to a couple of dry cells. All that is required is a nontechnical understanding of some of the basic principles of acoustics and sound reproduction. It is hoped that the remaining pages of this book will supply such an understanding.

What Is High Fidelity?

High fidelity might be simply defined as the attempt to reproduce musical sound without distortion, and for the full range of human hearing, by electro-mechanical means. To elaborate upon this definition, let us briefly consider what is involved in human hearing before we tackle the problem of electro-mechanical means of sound reproduction, or the hi-fi system.

The Range of Human Hearing

All of us are aware of varying pitch from a low or bass sound to a high or shrill sound. Most of us also know that sound is a vibratory disturbance which occurs in any medium such as air or water and that the higher the frequency (number of vibrations or cycles per second) the higher the pitch of the sound. Very few of us, however, are ever called upon to establish an exact relationship between frequency (number of vibrations per second) and pitch. Furthermore, very few of us concern ourselves with the range of human hearing, from the lowest pitch to the highest pitch, in terms of the number of vibrations or cycles per second (c.p.s.). Actually the human ear can hear sound frequencies from about 20 c.p.s. to 15,000 c.p.s.

The Range of Musical Sound

In a direct relationship to the range of human hearing is the range of musical sound. For example, the range of a piano is 27.5 c.p.s. for the lowest fundamental note to 4,186 c.p.s. for the highest. However, aside from the fundamental frequency of vibration which determines its pitch, every musical note contains an infinite number of overtones, or harmonics, whose frequencies of vibration are exact multiples of the fundamental frequencies. For example, A-440 (the note from which all instruments in an orchestra are tuned) possesses a second harmonic of 880 c.p.s., a third harmonic of 1320 c.p.s., and so forth. Thus in the case of the piano, the fourth harmonic ranges from 110 c.p.s. to 16,744 c.p.s., or to the upper limit of human hearing. It should be understood that, while the intensity of sound produced by the harmonic vibrations is insignificant to that produced by the fundamental vibration, these harmonics or overtones are the important factor in establishing an instrument's characteristic sound, or timbre. In other words, the intensity of the harmonics and the stressing of certain harmonics vary for each type of musical instrument. This arrangement of the harmonics, called overtone structure by musicians, is determined by the physical characteristics of the instrument. For example, while the same note played on an oboe and a clarinet has the same fundamental frequency of vibration (pitch), the sound from the two instruments is not the same since their overtone structures differ.

Range of Audible Reproduction

The importance of harmonics in music leads us to the obvious conclusion that, if we are going to reproduce music that is rich and contains all the subtleties of tone inherent in the different instruments, the harmonics must be faithfully reproduced. Furthermore, since the harmonic range for musical instruments ideally extends to the upper limit of human hearing, our ultimate aim should be to reproduce all frequencies of sound vibrations within this audible range. The logic of this aim seems so simple that you may well wonder what the fuss is about.

In short, the fuss is high fidelity, and the fuss has been brought about because the average commercial radio and phonograph does not reproduce sound vibrations above 6,000 cycles per second (c.p.s.). When you consider that the reproduction of at least the first four harmonics is required for differentiation between the various instruments, it is apparent that this limited range of 6,000 c.p.s. is insufficient. In other words, the average radio and phonograph has been stealing the richness and distinction from the music that is reproduced in our homes. A clear picture of this thievery is shown in the chart of Figure 1.

As shown in Figure 1, the audible range (varying slightly for individuals with normal hearing) extends from about 20 c.p.s. to 15,000 c.p.s. While the range of the three instruments shown on the chart extends only to the limit necessary for differentiation, it should be recognized that harmonics of the fifth, sixth, seventh, and even the eighth order are an important part in the overtone structure of most instruments. It is interesting to note that while the conventional radio

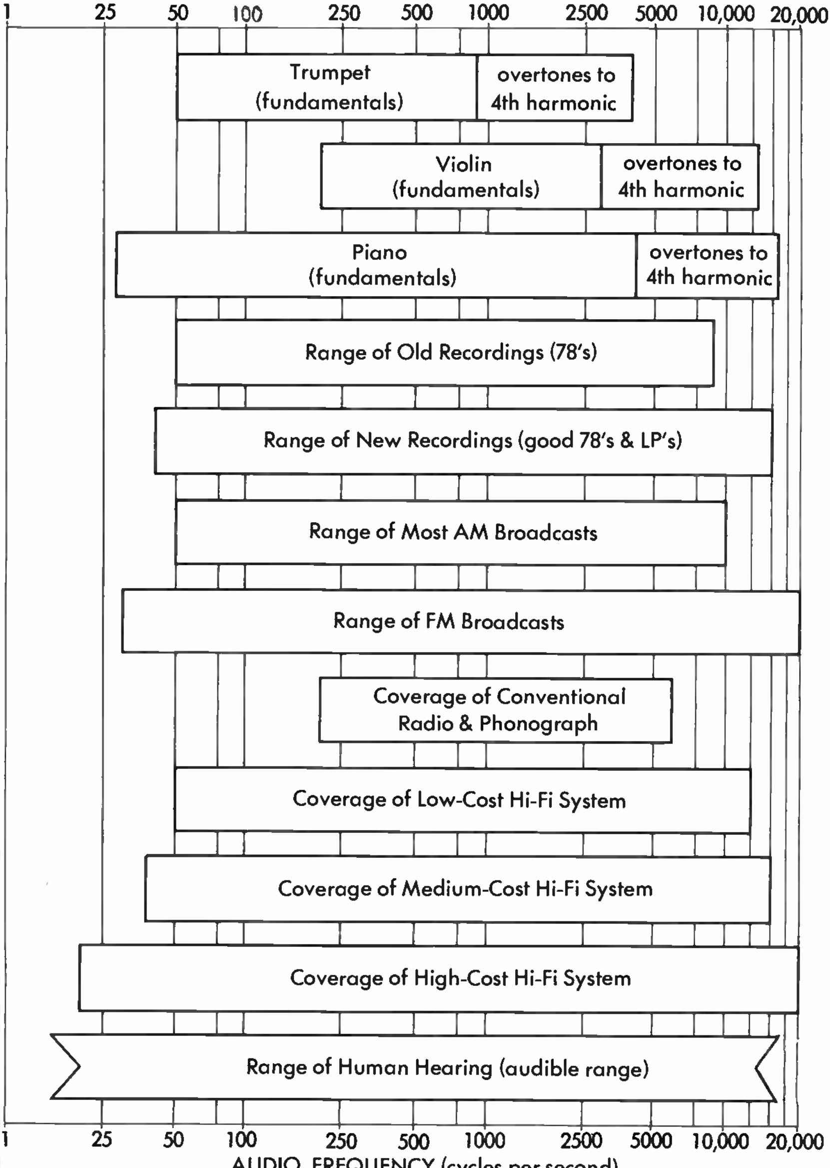


FIGURE 1. AUDIO COMPARISON CHART

and phonograph is woefully inadequate, the range of the old 78 recordings is not too bad, even by present-day standards. While all of the old 78's are probably not as good as indicated in Figure 1, it is generally recognized that they are much better than the phonographs for which they were made. Quite obviously, you should not throw these old records away when you get your hi-fi system installed, since it will enable you actually to "hear" them for the first time.

The Hi-Fi System

High-fidelity systems may be roughly classified into three groups: low-cost, medium-cost, and high-cost systems. The approximate capabilities of the three groups are shown in Figure 1. The range of the low-cost system, which does not quite extend to the full limits of the audible range, represents a compromise by the manufacturers between cost and performance. Although all hi-fi systems are basically similar, it just requires more expensive components and more elaborate electronic circuitry to reproduce the entire audible range. However, don't get the idea that a low-cost system is not a good buy. It is cheaper than most conventional radio and phonograph combinations and possesses the same facilities with twice the performance. The price of a low-cost installation is about $150.

The medium-cost hi-fi system just about covers the range of human hearing and runs between $200 and $500. The high-cost system, whose coverage extends just beyond the upper limit of human hearing, runs anywhere from $500 to $1,000. The great difference in price between the low-cost and high-cost installation exists because the high-cost installation strives toward ultimate perfection in sound reproduction. The most expensive parts are used and laboratory precision is exercised in circuit design and construction.

THE UNITS OF A HI-FI SYSTEM (Figure 2)

The components that make up a basic hi-fi system are: (1) the record turntable and pickup whose function is to translate the sound vibrations pressed upon the record into electrical voltage variations; (2) the radio-input tuner which "tunes in" and receives the signals from broadcasting stations; (3) the audio amplifier which amplifies (strengthens) the weak audio signal from either the radio tuner or the phono pickup; and (4) the speaker which transforms the amplified audio voltage variations into sound.

All hi-fi components are distinct units and are purchased separately. Actually, this is a blessing since it provides flexibility in choosing a system that will fit both your needs and your pocketbook. If you want FM and not AM radio, you can get an FM radio tuner. If you want both, you can get an AM-FM radio tuner. Purchasing the components separately also permits careful buying on your part. You do not have to buy an audio amplifier made by one manufacturer because you have chosen one of his radio tuners. As a matter of fact, it is not uncommon for a hi-fi buyer, not through any perversity but merely to satisfy his own requirements, to purchase a system in which all of the components have been made by different manufacturers.

It may be of general interest to mention the fact that the hi-fi system and the conventional radio and phonograph combination have the same basic components. What, then, is the reason for the poor performance of the conventional set? Actually, there are two main reasons. Although the record pickup and radio tuner sections compare somewhat with their hi-fi counterparts, the audio amplifier section of the conventional set does not employ the additional circuits and costlier parts required to amplify audio voltage variations

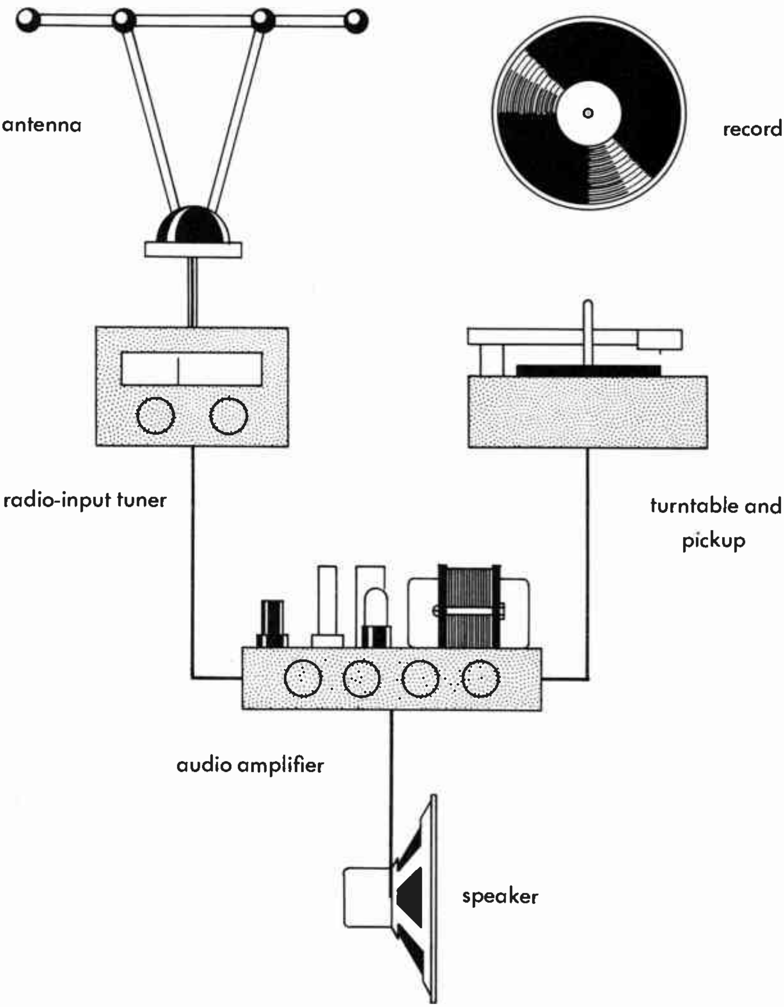


FIGURE 2. THE BASIC HI-FI SYSTEM

below 200 c.p.s. and above 6,000 c.p.s. Furthermore, the speakers used are normally inferior and incorrectly enclosed because of the requirement which places the set in a relatively compact cabinet designed to serve as a pleasant piece of furniture.

With the ever-increasing demand by music listeners for good sound reproduction, you may wonder if manufacturers will bring out a single-unit hi-fi system similar to the conventional radio and phonograph combination. No doubt some will (or claim so in their advertisements), but it is almost certain that the trend toward separate components will continue. Proper mounting and enclosure of the speaker requires space that is not available in conventional cabinets; this is especially true since large speakers are required for good reproduction of the low frequencies.[1] Also, as previously mentioned, separate components offer a great deal of flexibility. The hi-fi system can be tastefully and practically integrated into the present-day home. It can be placed in a bookcase, in a wall compartment, in an end table, or in almost any nook or cranny that satisfies your particular needs. Moreover, the hi-fi system is suited to the sound reproduction requirements of other equipment. It can be used for the sound of your TV set; a tape recorder can be added to the system; it can even be used to reproduce the sound track of a motion picture projector if you happen to own such equipment.

Yet, the important aspect of a high-fidelity system is that it opens new avenues of enjoyment for music listening. It permits you to hear all of the music. It brings the concert hall into your home.

[1] Not entirely true, since the very expensive small speakers are also capable of low-frequency reproduction. However, the cost of these small speakers would put them beyond the range of commercial sets.

· 2 ·

THE SPEAKER

IN LEARNING MORE about the specific components that make up a hi-fi system, let us begin with the speaker. Although this approach requires starting with the final element of the system, it permits us to consider the simplest but in many ways most important component first.

The speaker, as we all know, is an electro-mechanical device that produces audible sound from varying audio voltages. In evaluating the performance of speakers, we shall assume that the applied audio voltage represents undistorted sound containing a full range of values (i.e., complete coverage of the audible range from 20 to 16,000 c.p.s.). The job, then, of the hi-fi speaker is to reproduce accurately the sound represented by the full-valued audio-voltage variations.

HOW THE SPEAKER WORKS (Figure 3)

As shown in Figure 3, the speaker cone is fastened along the circumference of its base to the speaker frame, which mounts a permanent magnet. The speaker voice coil is wrapped around and fastened to the cylindrical neck of the cone that fits over the magnet pole. When audio-voltage variations are applied to the voice coil, a changing electromagnetic field is established, causing the voice coil either to be attracted or repulsed by the constant field of the magnet. Thus the voice coil, and hence the speaker cone, moves back and forth along its axis in accordance with the variations of the applied audio voltage. The motion of the speaker cone causes a corresponding movement of air to create the sound. If the voltage variations applied to the voice coil are increased in magnitude, the cone's displacement along its axis will also increase to produce sound of greater intensity. If the voltage variations increase in frequency, the cone will move back and forth at a correspondingly faster rate, resulting in higher pitched sound.

In addition to reproducing intensity and frequency vari-

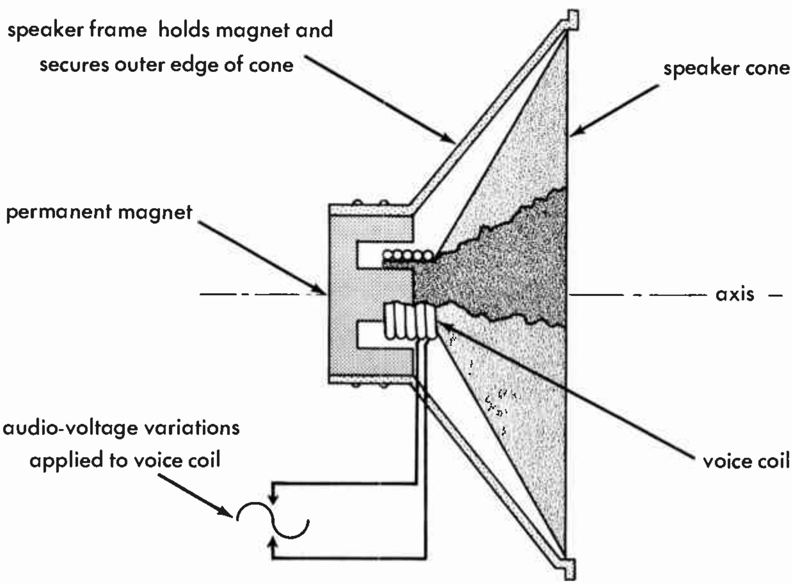


FIGURE 3. A SKETCH OF THE BASIC SPEAKER

ations accurately, the speaker faces an even more difficult task: the total volume of air displaced by the speaker must vary inversely as the frequency to produce a given intensity of sound. This means that larger volumes of air must be displaced to produce low frequencies with the same intensity as high frequencies. Thus, a good low-frequency speaker requires a large cone and a fair amount of back-and-forth movement to displace the required volumes of air. Such a speaker, however, is too sluggish for the rapid cone movements required by high frequencies. In spite of these difficulties, the manufacturers of high-fidelity speakers are making units capable of reproducing almost the full audible range (20 to 16,000 c.p.s.). These hi-fi speakers are expensive, but compared with the production-line models of commercial sets, they are pieces of precision equipment.

There are three distinct types of hi-fi speakers: (1) the single-cone unit, (2) the coaxial unit, and (3) the multiple-speaker unit.

The Single-Cone Speaker (Figure 4)

Of the three types of hi-fi speakers, the single-cone unit is the simplest and usually the cheapest. In appearance and operation it is similar to the basic speaker sketched in Figure 3. However, a great deal of effort has gone into designing units that will reproduce both the lows (large air displacement) and the highs (rapid cone movements). As a result, the average hi-fi single-cone speaker will reproduce audio frequencies from about 45 to 12,000 c.p.s. This represents a great improvement over the conventional speaker (also a single-cone unit) whose range is roughly 200 to 5,000 c.p.s.

Hi-fi single-cone speakers are usually 12 inches or larger in order to reproduce the low frequencies. The coverage of the high frequencies is obtained by specially designed cones and careful manufacturing with the best materials. There are

A hi-fi single-cone speaker. This type of extended-range speaker employs a single voice coil operating in the field of a permanent magnet. (Courtesy of Permoflux Corporation)

FIGURE 4. AN EXAMPLE OF A SINGLE-CONE SPEAKER

some smaller 8- and 10-inch speakers that also give good performance. An outstanding example of the well-designed small speaker is the 8-inch Wharfedale with a range of 50 to 15,000 c.p.s. This British-made speaker achieves its amazing performance by a special cloth suspension of the cone, a very heavy magnet, and craftsmanlike construction.

Unfortunately, single-cone units concentrate the high frequencies in a relatively narrow beam along the speaker axis. Although this fault can be partially remedied by proper placement of speaker and room furniture, the result is a restricted angle of hearing with full-frequency coverage existing only in a direct line with the speaker. Some single-cone units have tried to correct this fault by installing special diffusing devices at the center of the cone. Such devices help, but still do not provide complete scattering of the high frequencies.

In general, single-cone units give creditable performances, but the required use of large cones usually results in poor high-frequency reproduction above 11,000 c.p.s. However, single-cone speakers are a good buy. They are simple, dependable, and cheap in comparison with other types of hi-fi speakers. The cost of single-cone speakers ranges from about $15 to $75.

The Coaxial Speaker (Figure 5)

Coaxial speakers were developed to provide full coverage of the audio range. Since a large speaker displaces the air required for good low-frequency reproduction and since a small, fast-acting speaker easily reproduces the high frequencies, why not combine the two in a single unit? The hi-fi coaxial unit is such a combination. The small speaker, called the tweeter, is mounted along the axis and near the cone apex of the large speaker.

In coaxial speakers, the large, or low-frequency, element is similar to the single-cone speaker discussed above. The tweeter, or high-frequency element, although different in appearance, operates in a manner similar to the basic cone speaker sketched in Figure 3. The tweeter has a voice coil whose back-and-forth movements in a magnetic field are determined by the applied audio voltage. However, to achieve the sound-producing displacement of air, the tweeter, instead of a cone, may have a small flat diaphragm attached to the voice coil. This small disk has no trouble reproducing the rapid variations of high frequencies. The amount of air displaced is small, so small that a horn outlet is used to increase sound intensity. The horn employed on tweeter units is a smaller version of the horn employed by public-address speakers. The horn also helps to scatter the high-frequency sound generated by the tweeter. Complete dispersion of the beam does not result, but in this respect coaxials are better than single-cone speakers.

Associated with the two units of a coaxial speaker is a crossover network. The crossover network is a simple electrical circuit which divides the full range of the audio voltage variations into low- and high-frequency components.[1] From the crossover network the low frequencies are fed to the voice

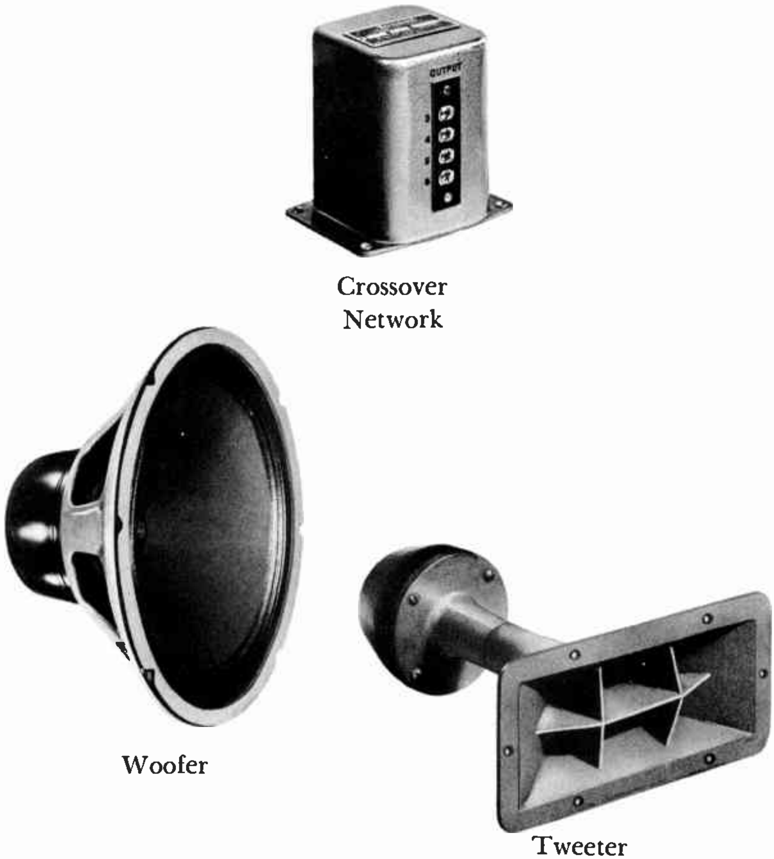
A coaxial speaker. Coaxial speakers use separate sound-producing elements for the low and high frequencies. Notice the flaring, high-frequency dispersing horn. (Courtesy of University Loudspeakers, Incorporated)

FIGURE 5. AN EXAMPLE OF A COAXIAL SPEAKER

coil of the large speaker while the high frequencies are fed to the tweeter's voice coil. The actual point in the audio range at which this division occurs depends upon the type of tweeter employed. Some coaxial speakers have the crossover point at 2,000 c.p.s.; others may have it at 6,000 c.p.s.

In general, coaxial speakers are costlier but provide greater coverage than single-cone units. The particular advantage of

[1] There are speakers labeled as coaxials that use a mechanical crossover consisting of a stiff high-frequency reproducer mechanically connected to a compliant low-frequency reproducer. Since these units have only one voice coil, they do not need electrical crossover networks. They generally do not perform as well as coaxials with two separate voice coils.



An effective division of labor is achieved by the components of this two-way speaker system. The tweeter reproduces the highs; the woofer reproduces the lows. The crossover network separates the highs from the lows. (Courtesy of Jensen Manufacturing Company)

FIGURE 6. COMPONENTS OF A MULTIPLE-SPEAKER SYSTEM

coaxials is that they reproduce high-frequency sound right up to the limit of human hearing (the frequency coverage of a good coaxial is about 40 to 15,000 c.p.s.). The coaxial also extends the low-frequency range since its large speaker must reproduce only the lows with no design concessions to reproducing the highs. Some coaxials go as low as 30 c.p.s. When considering coaxial speakers, it is important to remember that they are complicated devices containing two completely separate sound-producing elements which should generate the same relative sound intensity. The crossover network, while electrically simple, should be a quality item that introduces no phase distortion or loud spot at the crossover point. The mechanical construction of coaxials is especially important. Speakers are mechanical vibrating devices and the task of successfully mounting one inside the other is not simple. Quite frankly, I prefer the expensive single-cone unit to the low-priced coaxial (both around the same price). But don't get me wrong; a well-designed coaxial speaker with quality parts and workmanship is a beautiful instrument for reproducing full, undistorted sound. The cost of coaxial speakers ranges from about $25 to $200.

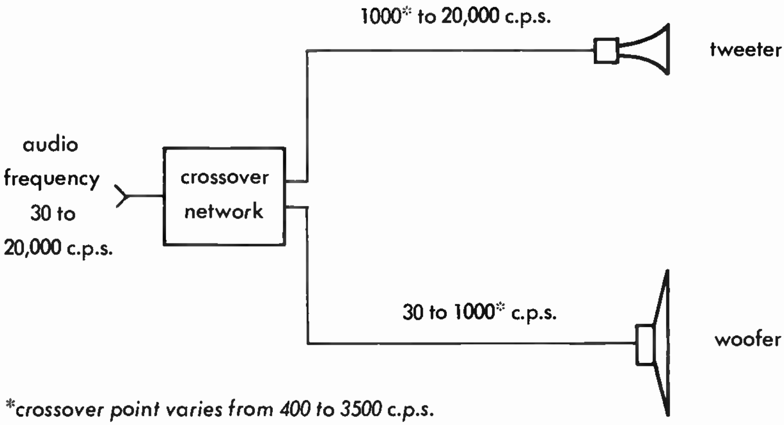
THE MULTIPLE-SPEAKER SYSTEM (Figure 6)

Whereas the coaxial speaker combines the low- and the high-frequency elements in a single unit, the multiple-speaker system reverses the procedure and separates the two elements. In the separation process, a new name is given the low-frequency element and it becomes known as the "woofer." An electrical crossover network, similar to that used for coaxials, feeds the lows to the woofer and the highs to the tweeter.

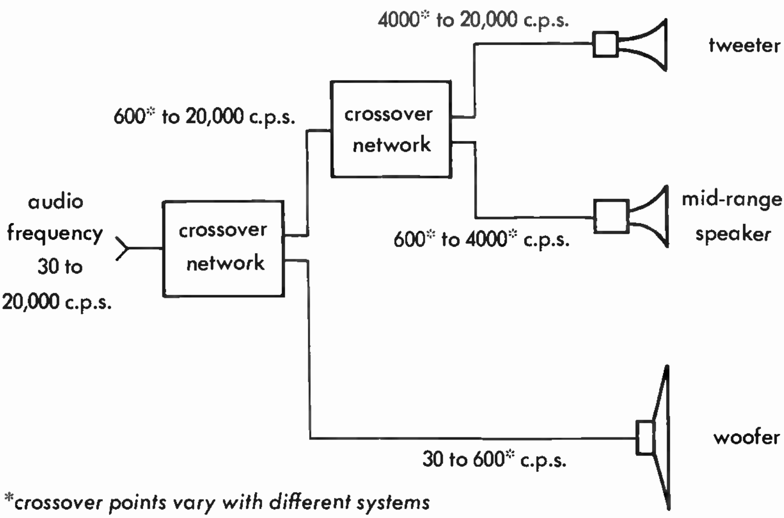
There are two basic types of multiple-speaker systems: the two-way system and the three-way system. The two-way system, as diagramed in Figure 7, uses a tweeter, a woofer, and a crossover network whose crossover point may vary from about 400 to 3,500 c.p.s., depending upon the type of tweeter used. From an engineering standpoint, the system with a low crossover point is generally better than one with a high crossover point. However, tweeters whose range begins at 400 c.p.s. are more expensive than those whose range starts higher. An important factor with woofers is the lowest frequency they will effectively reproduce. Additional woofers and tweeters may be added in parallel to the original units. Such elaborations of the basic two-way system usually employ an extra woofer to obtain a richer bass. Extra tweeters are also used to obtain optimum dispersion of the highs into the listening area. However, the task of adding extra woofers and tweeters is not simple. Special problems of impedance matching are encountered and undesirable acoustical effects may result. If you feel that you need that "little extra" provided by additional tweeters and woofers, it is advisable to buy a completely matched unit.

The three-way system, also diagramed in Figure 7, consists of a woofer, a mid-range speaker, a tweeter, and two crossover networks. Although the types of three-way systems vary slightly, an average one might have these operating ranges: woofer 30 to 600 c.p.s., mid-range speaker 600 to 4,000 c.p.s., and tweeter 4,000 to 20,000 c.p.s. The two networks employed must have crossover points at 600 and 4,000 c.p.s. Although expensive, a good three-way system is superior equipment. Since each of the three speakers is designed to reproduce a specific portion of the audio frequency range, it goes without saying that they can reproduce more effectively than a single-cone speaker or even a two-way system.

Multiple-speaker systems offer many advantages over coaxial and single-cone speakers. For example, the multiple-speaker system is capable of reproducing sounds above the upper limit of human hearing, as high as 20,000 c.p.s. Al-



The Two-Way Multiple-Speaker System



The Three-Way Multiple-Speaker System

FIGURE 7. THE BASIC TYPES OF MULTIPLE-SPEAKER SYSTEMS

though this can hardly be considered an outstanding advantage, it does guarantee reproduction of the uppermost audible frequencies. The flexibility of a multiple-speaker system also provides the opportunity of solving difficult acoustical problems. As will become apparent from the discussion of room acoustics in Chapter 7, the tasks of scattering the highs and preventing excessive reflections of the lows are individual, but serious, problems that can sometimes be solved by proper placement of the tweeter and woofer. However, the most important advantage of multiple-speaker systems is acquiring faithful and even reproduction of full-range sound by careful selection of the individual elements. Woofers, tweeters, and crossover networks have separate characteristics and should be considered as separate purchases. Even if you are buying a matched system (a three-way system or a two-way system with extra tweeters and woofers), a careful evaluation of elements comprising the system should be made. The minimum cost of a multiple-speaker system is about $60.

Speaker Specifications

In buying speakers, price is the measure of what you are getting. Nevertheless, within given price ranges, accurate appraisal should be based upon evaluation of the manufacturer's specifications. In publishing specifications, manufacturers are guaranteeing a minimum standard of performance. The table below is designed to help in evaluating the principle speaker specifications.

SPEAKER SPECIFICATIONS	EVALUATION
Frequency response	Frequency response is expressed in c.p.s. and supposedly designates the range of audio frequencies that a speaker can effectively reproduce. Unfortunately, no standards have been established as to what constitutes effective re-

SPEAKER SPECIFICATIONS	EVALUATION
	production. Ideally, frequency response should define that range of frequencies over which a constant intensity of sound is reproduced for a fixed level of applied audio voltage. Frequency-response ratings of speakers should be regarded as interesting information, but no basis for judging a speaker. Fortunately, evaluation of other speaker specifications, listed below, provides a good means of judging.
Power handling	Power handling is expressed in electrical watts and indicates the amount of electrical power that can be applied to the voice coil without damaging the speaker. The power handling capabilities of a speaker should not be less than the rated power output of the audio amplifier to which it is connected.
Impedance	Impedance is the electrical resistance of a speaker's voice coil. It is expressed in ohms. A voice coil's impedance is the major factor in electrically matching a speaker to its audio amplifier. For example, a speaker with an impedance of 8 ohms should be connected to an audio amplifier with an output impedance of 8 ohms. A further discussion of impedance matching is given in Chapter 6.
Crossover frequency	This specification applies only to coaxials and multiple-speaker systems. The crossover is that frequency above which all sound is generated by the driver or tweeter and below which all sound is generated by the large speaker or woofer. The crossover point is important for multiple-speaker systems. Woofers and tweeters used together should have the same specified crossover points; the crossover network used should provide the required crossover

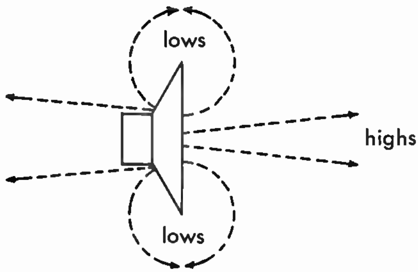
SPEAKER SPECIFICATIONS	EVALUATION
	point. A low crossover point is generally preferred. The matching and interconnecting of woofers, tweeters, and crossover networks is discussed in Chapter 6.
Magnet (field)	This specification is not always given but when it is, it tells the type of permanent magnet used (should be Alnico V or equivalent alloy) and the weight of the magnet in pounds. The heavier the magnet, the greater the operating range and efficiency of the speaker.
Flux density	This specification, which is not always given, also indicates magnet size and gives a relative indication of speaker efficiency. Flux density is expressed in gausses or the number of magnetic lines of force. Flux density for the average 12-inch speaker should be around 11,000 gausses or lines of force. The 12-inch Wharfedale, which employs a very heavy magnet, has a flux density of 17,000 lines.
Resonance	Resonance, or cone resonance, is an important, though not always given, specification for large cone speakers. Resonance is the frequency at which the speaker cone naturally tends to vibrate; this frequency is determined by the physical construction of the speaker. Resonance (usually around 50 c.p.s. or lower for 12-inch speakers) determines the low-frequency response of a speaker.

Baffles and Enclosures

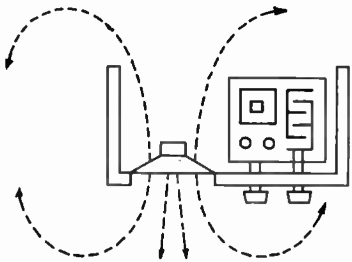
So far our discussion has been limited to considering speakers as separate functioning units, with no mention of how they are mounted. Correct mounting is important. Any speaker, regardless of its price, must be correctly mounted to furnish its best sound reproduction.

The primary factor for correct mounting is "baffling," or isolating the front of the speaker cone from the back. The need for baffling exists because a speaker is essentially a two-way machine producing sound both in front and in back. As a speaker cone is driven back and forth, the sound-producing displacement of air occurs on both sides of the cone. Furthermore, when air is being pushed in front, it is being pulled in back, and vice versa. Thus the sound waves generated on the back side of the cone are exactly opposite to those generated in the front. To prevent the front and back sound waves from canceling one another, the front of the cone must be isolated from the back; that is, the speaker must be properly baffled. The sketch of the unmounted speaker in Figure 8 illustrates the canceling effect of the front and back radiations. Notice that canceling takes place only for the low frequencies, with the highs being beamed out along the speaker axis. This is so because, as frequency increases, the length of the sound wave becomes shorter. When the length of the sound wave becomes small in respect to the diameter of the speaker cone, the cone itself serves as a baffle.

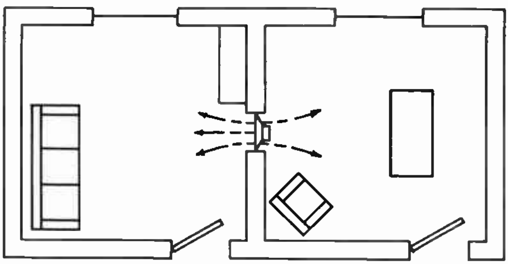
The principal types of speaker mountings and enclosures are sketched in Figure 8. You will observe that the conventional open-back cabinet does not provide sufficient isolation to prevent canceling of the lows. If the back of the conventional cabinet is sealed off, isolation is achieved; but another form of distortion now arises since the enclosed volume usually becomes too small. The volume enclosing the back of a speaker must be large to minimize the distorting effect of the air compressed during the back-and-forth movement of the speaker cone.



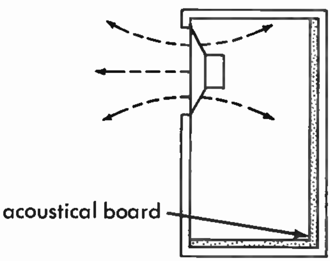
An unmounted speaker.



An open-back cabinet of a conventional radio.

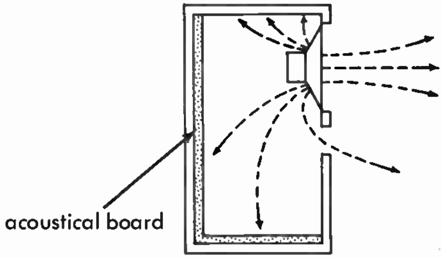


The wall between two rooms serving as an infinite baffle.

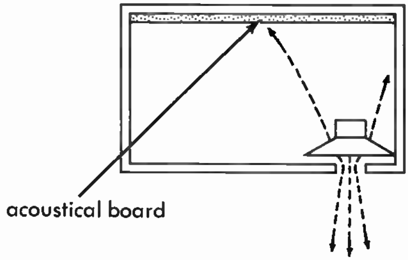


A total enclosure serving as an infinite baffle.

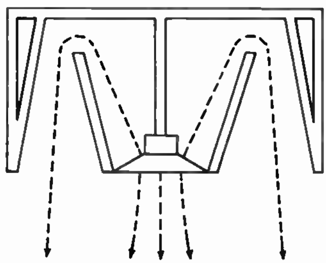
The bass-reflex enclosure; usable lows are emitted by the port.



The R-J enclosure; small opening emits highs and equalizes front and back cone pressure.



The folded horn enclosure boosts the lows.



The acoustical labyrinth enclosure boosts the lows.

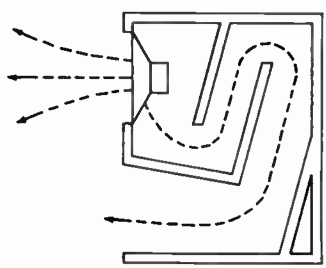


FIGURE 8. THE VARIOUS TYPES OF SPEAKER MOUNTINGS AND ENCLOSURES

The Infinite Baffle

One method of properly mounting a speaker is to employ an infinite baffle. An infinite baffle is so called because it achieves complete isolation between the front and back of a speaker. Figure 8 gives two examples of an infinite baffle: mounting the speaker in the wall between two rooms or using a completely enclosed cabinet. If the rooms can be completely isolated from one another, mounting the speaker in the adjoining wall is excellent. Complete isolation is obtained and the volume for absorbing the sound waves from the back of the speaker is wonderfully large. The use of a total enclosure is usually limited to the small 8-inch speakers since the larger the speaker, the larger the enclosure required. The volume for 8-inch speakers must be a minimum of 3 cubic feet. Total enclosures should also be lined with sound-absorbing acoustical material. Plans and specifications for these two types of infinite baffles are given in Chapter 7.

The Bass-Reflex Enclosure

The bass-reflex enclosure differs from the infinite baffle in that it makes use of a portion of the low-frequency energy that is generated at the back of the speaker cone. As diagramed in Figure 8, the bass reflex is an enclosure similar to the total enclosure except that it has a square port cut below the speaker. The port permits a portion of the low-frequency energy from the back of the speaker to be directed out into the listening area. Because of the size and position of the port and because the sound waves must be reflected from the back of the enclosure to pass through the port, the lows emitted reinforce rather than cancel those being produced at the front of the speaker. The highs and those lows not passed through the port are absorbed by strategically placed sound-absorbing material. The natural resonance of a bass-reflex enclosure should be the same as the cone resonance of the speaker. If this is so, the bass reflex reduces the undesirable sound intensification at cone resonance as well as slightly improving the low-frequency response of a speaker. Plans and specifications for bass-reflex enclosures, as well as examples of commercial kits and ready-made units, are given in Chapter 7.

Commercial Enclosures

In addition to the infinite baffle and the bass-reflex enclosures, there are a number of commercial enclosures that have been developed recently. It is advisable not to make these enclosures yourself since all aspects of their construction are based upon well-considered acoustical design. However, most types of commercial enclosures are available in kit as well as the completely assembled form.

Representative of commercial enclosures is the folded horn and the acoustical labyrinth enclosure (see Figure 8). These two enclosures are similar to the bass-reflex since they improve the low-frequency response of a speaker by utilizing part of the lows generated at the back of the speaker. For both the folded horn and the acoustical labyrinth, the path followed by the back sound causes the highs to be absorbed and the lows to be emitted in phase, augmenting the lows generated by the front of the speaker. As with the bass reflex, the resulting increase of low-frequency sound intensity improves the low-frequency response of speakers.

A unique commercial enclosure is the R-J, which permits mounting large speakers in relatively small enclosures. A simplified sketch of an R-J is shown in Figure 8. Briefly, the R-J is a small enclosure with the speaker mounted inside, looking out a small hole. This causes both the front and the back of the speaker cone to work against resistance. The enclosure is so designed that the resistance on the front and back of the cone are equal. This damping of the cone movement effectively lowers the frequency response of a speaker as well as reducing relative intensity variations over the operating range. Although effective, the R-J is tricky. The balancing of front and back cone resistance must be exact to avoid distortion. If you have a space problem, the R-J is excellent, but be sure to use a speaker that is known to work well in an R-J.

Examples of commercial enclosures, both in kit and assembled form, are given in Chapter 7 where the problems of integrating the speaker and its enclosure into your living quarters are discussed.

Selecting Your Speaker

The actual selection of a speaker or speaker system depends upon the requirements of your over-all installation and the ability of your pocketbook to meet these requirements. But when the time comes, remember that the speaker is the weakest link of your system. It is much easier for the audio amplifier, the radio tuner, and even the phono pickup to achieve near perfection of audio reproduction than the speaker. Speakers, like violins, have inherent qualities of their own. If you can listen to speakers mounted in the type of enclosure you have decided to use, so much the better. But a word of caution: do not be fooled by a brief ten minutes of listening in a hi-fi store. The first taste of hi-fi sound is overwhelming. A speaker set up in an audio salon to give an excessive amount of bass is soothing and delightful at first. But with continued listening, the unnatural intensification of the low frequencies palls when you become aware of the accompanying lack of definition between musical tones. In the final analysis, you want accurate reproduction that comes as close as possible to what you would hear *au naturel* at a live concert. The trouble is, of course, that very few of us hear much live music these days. We have become so accustomed to the poor reproduction of the conventional radio that we have no accurate basis for correct judgment.

In choosing a speaker, be guided by the manufacturer's specifications (magnet weight or flux density as an indication of operating efficiency, and cone resonance, which indicates the true limit of low-frequency response), the quality of workmanship, and the price. Like good violins, good speakers are not cheap. Price comes fairly close to being the best indication of quality.

• 3 •

THE AUDIO AMPLIFIER

In the basic hi-fi system there are two components[1] that generate the electrical voltage variations which the speaker, or multiple-speaker system, transforms into sound—the phono pickup and the radio tuner. However, since the outputs of these two components are not strong enough to operate the speaker, a third component must be used, the all-important audio amplifier. The audio amplifier increases the weak audio-voltage variations of the phono pickup and radio tuner to the strength required for operating the speaker. In performing its task of amplifying (i.e., strengthening), the audio amplifier must slavishly respond to every change and fluctuation of the applied audio voltage. A small voltage variation at 15,000 c.p.s. must receive the same relative amplification as a large voltage variation at 80 c.p.s. Like the speaker, it must respond to voltage and frequency change, not to reproduce sound but to reproduce amplified

[1] The major part of this book deals only with the basic hi-fi system. Chapter 11 discusses such supplementary sources of sound intelligence as the magnetic-tape recorder and the television set.

audio voltage. Fortunately, the audio amplifier accomplishes its task with relative ease. Unlike the speaker, which is partly mechanical, the audio amplifier is completely electrical. To understand the inner workings of its vacuum tubes and electrical circuitry requires an engineering background. But, happily, the music listener need concern himself only with basic principles and results. And the results are good. The audio amplifier is the strongest link in the hi-fi system.

Power Output

An important yet confusing factor is the classification of audio amplifiers by power output. Simply defined, the power-output rating of audio amplifiers is an indication of the electrical energy they can deliver. Power output is rated in watts (i.e., electrical energy). Hence a 20-watt amplifier can deliver twice as much electrical energy as a 10-watt amplifier. The power-output ratings of different audio amplifiers range anywhere from 10 watts to 50 watts. There are a few 5-watt amplifiers, but their performance is poor by hi-fi standards. This brings to mind two questions. Why do amplifiers have such a range of power outputs? And how much power is actually required to operate a speaker in the average-size room?

The energy required for a speaker to reproduce the sound of a symphony orchestra in an average room would be small if a speaker were 100 per cent efficient. The acoustic output of a symphony orchestra varies from about .005 watts for the weaker sounds to about 1.5 watts for the louder sounds. Unfortunately, the efficiency of the average cone speaker is about 5 per cent. In other words, to reproduce the full acoustic range of a symphony orchestra, an audio amplifier would have to deliver to our inefficient speaker about 0.1 watt for a soft sound and about 30 watts for a loud sound. However, the average person does not want the full blast of a symphony orchestra in his living room, even for short intervals. An audio amplifier capable of delivering 20 or even 10 watts satisfies the average listener. A speaker producing an average volume of sound in the normal room draws about 2 or 3 watts from the audio amplifier. When the music becomes very soft, the speaker requires less than a watt. As the music becomes louder, the speaker might draw 7 or 8 watts. Momentary bursts of intense loudness might require 15 or 20 watts from the amplifier. When we talk about high wattage outputs for short intervals, we must bring in the concept of reserve power.

Reserve Power

Reserve power, as its name implies, is extra output power that an amplifier is capable of delivering, but scarcely ever does. We have already seen how the reserve power is required for driving the speaker to reproduce short intervals of intense sound. Reserve power is important for another reason. The more reserve power an audio amplifier has, the less harmonic and intermodulation distortion it generates. To understand how reserve power keeps distortions at a minimum, we should understand that the more power (i.e., the more electrical energy) audio amplifiers are required to deliver, the greater will be the distortion. The reasons for this phenomenon are inherent in the operation of vacuum tubes. The harder they work, the less accurate is their work.

Some manufacturers define the power-output ratings of their audio amplifiers by specifying the percentage of distortion for a given power output. For example, an amplifier may be rated with 3 per cent distortion at 10 watts with a usable peak power of 15 watts. This is better than an unqualified power rating; but, unfortunately, we do not know what type of distortion is referred to. A 3 per cent rating is good for intermodulation distortion but only fair for har-

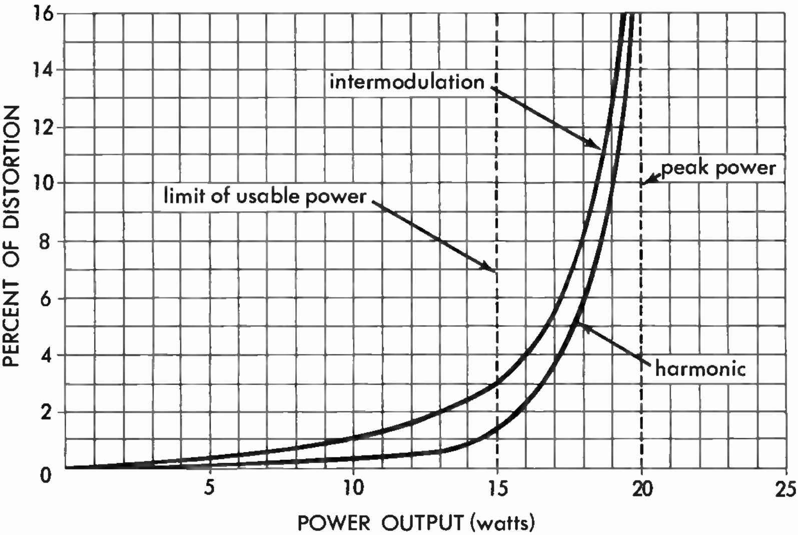


FIGURE 9. POWER OUTPUT VERSUS DISTORTION FOR A HYPOTHETICAL 15-WATT AMPLIFIER

monic distortion. Some manufacturers give more exact information in the form of graphs that plot percentage of distortion versus power output. Figure 9 shows hypothetical graphs of harmonic and intermodulation distortions. Notice how the percentage of distortions increases very rapidly near the peak power output of the amplifier.

DISTORTION

Up to this point, I have mentioned distortion without defining it. Distortion of any kind can be simply defined as that portion of the electrical sound intelligence (for speakers it would be the actual sound) which is not present at the input but appears at the output of a component. Distortion in any hi-fi component results in undesirable and extraneous sound at the speaker. Actually, the speaker generates more distortion than any other component. When we discussed speakers, not much was said about speaker distortion because, aside from using a good speaker properly mounted, not much can be done. When it comes to the completely electric audio amplifier, however, you can expect a minimum of distortion. The inexpensive hi-fi amplifiers generate very little distortion, the more expensive amplifiers next to none.

Intermodulation distortion, previously mentioned, produces extraneous and discordant tones. The unwanted tones are created by the interaction of musical tones in the vacuum tubes of an amplifier. Harmonic distortion, also generated in an amplifier's vacuum tubes, is the creation of additional harmonics. Although amplifiers generate other kinds of distortion, they are too insignificant to consider. Even harmonic and intermodulation distortions are negligible factors in most hi-fi amplifiers. As can be seen from the graphs in Figure 9, however, distortion ratings do define the usable power output of audio amplifiers.

One final word about distortion: you are sure to hear the terms "feedback" and "push-pull." These terms designate the two types of electronic circuits that reduce distortion. Do not be overawed by advertising claims about these circuits. They are used in all creditable hi-fi amplifiers.

Frequency Response

Like speakers, audio amplifiers have frequency-response ratings to indicate their operating range of frequencies, or that range of frequencies which receives the same relative amplification. To elaborate upon this point briefly, let us assume that an audio amplifier amplifies the low frequencies with greater stress than the high frequencies. When audio voltages representing low and high musical tones are applied to such an amplifier, the low-frequency tones are reproduced at the speaker with greater intensity than the high-frequency tones. While not actual distortion, this represents a deviation from the original sound. In other words, to do its job properly, an audio amplifier should respond evenly to the full audible range. When an amplifier responds evenly (with the same relative amplification) it is said to have a "flat" response.

Fortunately, as previously mentioned, the audio amplifier is completely electric. Good frequency-response ratings for hi-fi amplifiers are to be expected as a matter of course. Inexpensive amplifiers may have frequency responses from 30 to 15,000 c.p.s., flat within 1 db.[2] An expensive amplifier may have a frequency response of 20 to 20,000 c.p.s., flat within 0.1 db. It is interesting to note that the frequency response of an inexpensive audio amplifier is flatter (within 1 db) than even the best speaker system. (5 db is considered good for any speaker system.)

Amplifier Controls

Associated with power output and frequency response are the three main controls of an audio amplifier: the volume, bass, and treble controls. The function of the volume control is simple enough. It varies the power output of an amplifier

[2] The unit "db" (decibel) is confusing to the layman. By definition, the decibel unit expresses a ratio between two amplitudes or energies. The decibel unit between two amplitudes is computed as twenty times the common logarithm of the ratio. The decibel unit between two energies is computed as ten times the common logarithm of the ratio. A practical way of evaluating db ratings is to remember that the smallest change in sound intensity that the ear can distinguish is approximately 1 db. Hence, an amplifier with a frequency response flat within 1 db from 50 to 15,000 c.p.s. will introduce no discernible deviation of sound intensity over its operating range. A speaker that has a 5-db variation over its range will introduce a deviation in sound of five discernible increments of intensity. But even this is slight when you consider how small a change in sound intensity the human ear can hear. Furthermore, in the case of a speaker system with a response of 50 to 15,000 c.p.s., the 5-db variation of relative sound intensity is spread out from the low bass to the almost inaudible treble. As you can see, a 5-db variation for a speaker's frequency response is really excellent.

to permit adjustment of the intensity, or volume, of sound being produced by the associated speaker. In most audio amplifiers the volume control serves the additional function of an on-off switch. The action of the bass and treble controls is more elaborate.

The bass and treble controls of a hi-fi amplifier are calibrated with a center, or zero, position so that they can exercise either a positive or negative effect. For example, if we turn the bass control in a positive direction, the speaker attached to the amplifier emphasizes the low frequencies, or bass tones. If we turn the bass control in a negative direction, the bass tones are de-emphasized by the speaker. The same strengthening or weakening of the high-frequency, or treble, tones results when we move the treble control from its zero position. What the bass and treble controls are actually doing is varying the frequency-response characteristic of the amplifier. When both controls are in the zero position, the response of the amplifier is flat. Turning the bass control negatively or positively decreases or increases the amount of relative amplification for the low frequencies. The treble control does the same for the high frequencies. Figure 10 illustrates this effect upon the frequency response of an audio amplifier. In the graph of Figure 10 the solid line represents the flat response with both controls set at zero. The dotted lines indicate steps of increase or decrease for the two controls. Actually the negative or positive action of the bass and treble controls is usually continuous.

The question next arises, why go to the trouble of making an expensive amplifier with a flat frequency response (flat with bass and treble controls set at zero) for faithful reproduction and then incorporate the means for disturbing this perfection? There are two important reasons: (1) tone controls permit compensating for the acoustical peculiarities of individual rooms, and (2) tone controls allow us to correct for the deliberate weakening of the lows and stressing of the highs that exist in most phonograph records.

There are no precise methods for determining how to compensate for acoustical peculiarities of individual rooms. The discussion of room acoustics in Chapter 7 points the way to keeping these peculiarities at a minimum. However, try

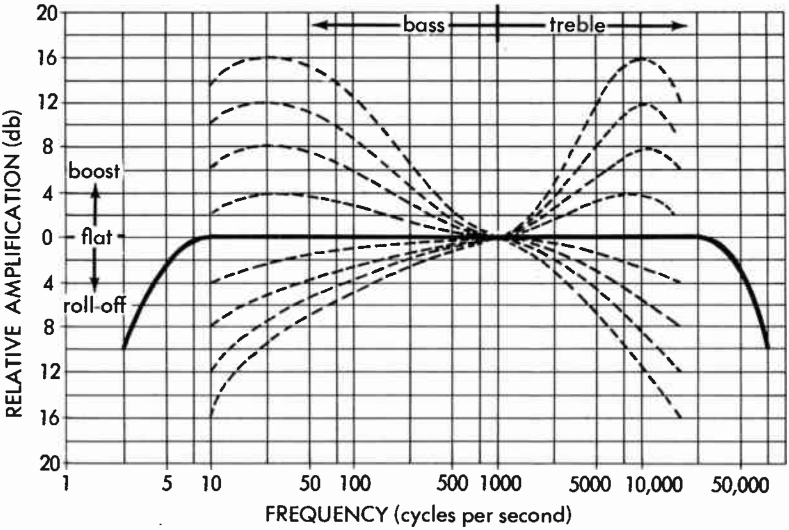


FIGURE 10. THE EFFECT OF BASS AND TREBLE CONTROLS ON THE FREQUENCY RESPONSE OF AN AMPLIFIER

as we may, we can never make the average living room acoustically perfect. The physical properties of a room may actually cause an intensification of the bass or treble tones. When your ear becomes aware of this unnatural condition, the tone controls offer a simple remedy. A noticeable intensification of high-pitched sound is quickly corrected by a small negative adjustment of the treble control. Similar adjustment of the bass control corrects too much bass.

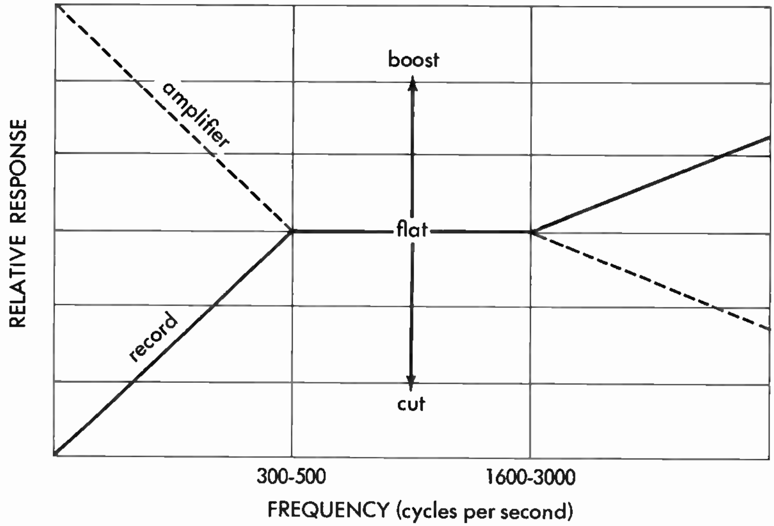


FIGURE 11. THE FREQUENCY RESPONSE (RECORDING CURVE) OF MODERN RECORDS

The need for using tone controls to correct, or effectively flatten out, the response of phonograph records is shown by the graphs of Figure 11. The solid-line graph of Figure 11 approximates the frequency-response characteristic of modern records. Notice the falling off of the bass and the boosting of the treble. Correction of this deficiency is accomplished by adjusting the bass and treble controls so that the frequency response of our amplifier assumes the frequency-response characteristic of the dotted line in Figure 11.

Record Compensation

The process of correcting for a record's frequency response is called record compensation (or equalization). Why are the responses of records not flat? Without going too deeply into the techniques of recording, the problem is concerned with the magnitude of "needle travel."

In all commercial recordings the configuration of the record groove causes the needle to vibrate back and forth within the groove.[3] Unfortunately, the back-and-forth movement of the needle in the record groove has imposed requirements similar to the movement of a speaker cone. For low frequencies, the lateral movement of the needle is large, for high frequencies, small. Faced with this dilemma and desirous of making narrow-groove records with an extended range, the manufacturers were forced to modify the recording curves (i.e., frequency responses) of their records by progressively reducing the large lateral movement of low frequencies (for narrow grooves) and progressively increasing the small lateral movements of the high frequencies (for extended range).

As can be seen from the recording curve of Figure 11, the transition points for high-frequency boost and low-frequency cut, commonly referred to as the turnover frequencies, are shown as a variable quantity. This is a point of confusion. Whereas all manufacturers must follow the general curve of Figure 11 to make narrow-groove wide-range records, the selection of turnover frequencies has not been standardized. At present, most records conform to two recording standards: the NAB (National Association of Broadcasters) and the AES (Audio Engineering Society). The NAB has a bass turnover at 500 c.p.s. with treble emphasis above 1,600 c.p.s.; the AES has a bass turnover at 400 c.p.s. with treble emphasis above 2,500 c.p.s. All RCA records, except the early 78's, use the AES standard, whereas other recent American records, long-play London FFRR, and old Columbia records use the NAB standard. However, most European records, Telefunken, old American disks, and Capitol are best equalized with a 500

[3] The needle vibrates in accordance with the audio intelligence placed on the record. The pickup device which mounts the needle transforms the mechanical vibrations of the needle into representative electrical voltage variations, or the weak audio voltages that are applied to the input of the audio amplifier.

c.p.s. bass turnover with no treble emphasis. As you can see, the problem of exact compensation for all types of records is difficult.

One method of record compensation has already been discussed, that of using the tone controls. This method is not exact. A person knows that most records require boosting the bass and reducing the treble. How much? The best answer to this question, considering that your room will probably cause some acoustical inequalities, is as much as is required to please your ear.

Aside from using the regular tone controls of an amplifier, another means of record compensation is available with a "record compensator." The record compensator, inserted between the phono pickup and the amplifier, can be a separate unit or an incorporation within the amplifier. From a functional standpoint, it consists of a single multiple-position switch with about five or six positions. The various positions might be labeled in the following manner: (1) LP, (2) RIAA, (3) AES, (4) Noisy Records. The idea is to set the compensator switch according to the type of record being played. This provides the listener with more or less accurate compensation. No compensator (or equalizer as they are sometimes called) will provide exact compensation because of acoustical variations of different rooms, speakers, and enclosures; furthermore, the responses of records themselves will vary from the intended norm because repeated stamping of a record-making master disk will effect the amount of treble boost. Theoretically, flat response is obtained with the compensator set to the correct position and the tone controls in the zero or flat position. In actual practice, most listeners will make some adjustments of the tone controls to allow for the acoustical peculiarities of their speakers and rooms, and to get the "right tone."

The decision to buy an amplifier with or without a record compensator is difficult for the average listener. They are an added complication since the compensator must be correctly positioned for the particular record being played; and unfortunately, even the major record manufacturers have not standardized on one recording curve. In general, crystal pickups, which inherently provide average compensation for all records, do not require record compensators. When a magnetic pickup is used, compensators are advisable for best results, although full-range base and treble will provide an adequate compensation.

Preamplifiers

To complete our picture of the audio amplifier, we should briefly consider the preamplifier. The need for a preamplifier (or additional amplification at the input of the audio amplifier) arises when a magnetic phono pickup is used. Magnetic pickups generate a much weaker audio voltage than crystal pickups. The audio voltage from a crystal pickup may be applied directly to the audio amplifier. The audio voltage from a magnetic pickup must be applied to a preamplifier, which in turn is connected to the audio amplifier. Many audio amplifiers now have incorporated preamplifiers to accommodate magnetic pickups. For those audio amplifiers without preamplifiers, separate preamps ($12 to $80) may be purchased when a magnetic pickup is used.

Purchasing Your Audio Amplifier (Figure 12)

When it comes to purchasing an audio amplifier (prices range from $45 to $250), exercise restraint. Why restraint? Well, simply because hi-fi audio amplifiers are good.

As previously mentioned, amplifiers are purely electrical. Their ability to provide for faithful sound reproduction sur-

An inexpensive 10-watt amplifier with a built-in preamplifier and separate bass and treble controls. The switch at the very left is a selector switch for centrally controlling hi-fi inputs. (Courtesy of David Bogen Company, Incorporated)

An expensive, 20-watt amplifier with a remote control unit. The preamplifier and record compensator are contained in the remote control unit. (Courtesy of Fisher Radio Corporation)

FIGURE 12. HIGH-FIDELITY AUDIO AMPLIFIERS

passes any other component of the hi-fi system. When you stop to consider, you can imagine how much easier it is to make a faithful amplifier than an electro-mechanical vibrating speaker, a constant-speed turntable, or even a completely electrical, yet delicate, radio tuner. If you have to skimp a little on the total amount you spend for your system, the place to effect a saving is in purchasing your audio amplifier. This does not mean that any old amplifier will be satisfactory. Your amplifier should have a minimum power output of 10 watts, an almost flat response from 40 to 15,000 c.p.s., and full-range continuous-adjustment bass and treble controls. If you plan to use a magnetic cartridge, you should purchase an amplifier with a built-in preamplifier.

Audio Amplifier Specifications

To aid you in selecting the proper audio amplifier, the table below lists and evaluates specifications.

AUDIO AMPLIFIER SPECIFICATION	EVALUATION
Frequency response	Frequency response is expressed in c.p.s. and indicates an amplifier's operating range of audio frequencies. The response of amplifiers should be essentially flat within at least 1 db. A hi-fi amplifier should have a minimum frequency response of 40 to 15,000 c.p.s.
Power output	Power output expresses the amount of electrical energy that an amplifier is capable of delivering (hence the amount of potential sound energy). To operate single-speaker units for the average room, amplifiers should have a minimum power output of 10 watts. Amplifiers for multiple-speaker units and coaxial speakers should have greater power outputs of 15 and 20 watts.
Distortion	Distortion ratings indicate the amount of ex-

AUDIO AMPLIFIER SPECIFICATION	EVALUATION
	traneous sound that an amplifier can introduce. Since distortion increases with the amount of power output an amplifier is required to deliver, distortion ratings define the usable power output. Some manufacturers specify over-all distortion; this should be no higher than 3 per cent at the rated power output. When specified as harmonic and intermodulation distortion, harmonic distortion should be less than 3 per cent and intermodulation distortion should be less than 5 per cent at the rated power output.
Hum and noise level	All amplifiers generate a constant hum or noise. With hi-fi amplifiers this background noise is scarcely audible at the speaker. The hum level should be at least 60 db below rated output. The higher the db rating, the less background noise or hum.
Sensitivity	This specification is not usually given since its meaning is not always clear to the layman. Essentially, a sensitivity rating shows the ability of an amplifier to respond to weak input signals. It is expressed as the amount of input voltage required to produce a given output voltage. For example, an amplifier may have a sensitivity such that .01 volt (of audio signal) at the input produces 1 volt (of audio signal) at the output. The more sensitive an amplifier is (the smaller the input voltage required to produce a given output voltage), the more capable it is of reproducing the small, low-intensity nuances of sound.
Tone controls	This specification is important in that it indicates an amplifier's range of tonal variation. Full-range tone controls are indispensable for proper record compensation. Tone controls

AUDIO AMPLIFIER SPECIFICATION	EVALUATION
	should be continuously adjustable with the following minimum ratings: treble, 12 db boost and cut (roll-off) above 10,000 c.p.s.; bass, 13 db boost and cut below 100 c.p.s.
Inputs	The number and type of amplifier inputs vary. Amplifiers without built-in preamplifiers should have a minimum of two inputs, phono and radio. Amplifiers with preamplifiers should have two magnetic pickup inputs (a high-level input for the strong magnetics and a low-level input for the weak magnetics), a radio input, and crystal-pickup input. See Chapter 6 for complete details on amplifier input connections.
Output impedance	Most amplifiers have three or four output impedances available (such as 4, 8, 12, or 16 ohms). The amplifier you select should have an output impedance that will equal your speaker's voice-coil impedance. With multiple-speaker units output impedance of amplifiers should match the input impedance of the crossover network. See Chapter 6 for detailed instructions on amplifier output connections.
Power consumption	Expressed in watts, this rating indicates the total line or house current that the amplifier consumes. Your wall outlet should be able to supply this current. A 10-watt amplifier usually draws around 75 watts, a 20-watt amplifier about twice this. The power-consumption rating is important in that it also expresses the amount of heat that an amplifier will generate. In other words, a 10-watt amplifier will generate the same heat as a 75-watt light bulb.
Output transformers	Output transformers couple an audio amplifier to its speaker. The excellence of output

AUDIO AMPLIFIER SPECIFICATION	EVALUATION
	transformers can be judged by their size. The larger and heavier, the better. Since an output transformer is one of the more expensive parts of an amplifier, its size is a good indication of amplifier quality. The better amplifiers have large output transformers visibly mounted. Inexpensive amplifiers have small output transformers mounted underneath the chassis.
Compensated volume	This is a feature available on expensive amplifiers. It functions by boosting the bass and treble when the volume control is set for a low level of sound intensity. This permits listeners to have a low level of sound intensity and still hear the weaker bass and treble notes. What you are doing is introducing a deviation from a flat frequency response. It is analogous to moving away from a source of live music; as the music becomes softer, the weaker bass and treble tones become inaudible. With a compensated volume control, this condition is automatically corrected as you reduce the volume. Sometimes you achieve the correction by setting the amount of simultaneous bass and treble boost you desire with an additional control (usually labeled "Loudness Control").
Record compensator (equalizer)	Advisable for use with magnetic pickups. At a minimum should provide compensation for RIAA, AES and LP recording curves.

• 4 •

TURNTABLES AND PHONO PICKUPS

A GOOD TURNTABLE and phono pickup are important for high-fidelity sound reproduction from modern records. Whereas you need not purchase the most expensive audio amplifier for creditable hi-fi performance, you should always try to buy a good turntable and phono pickup. Taking the turntable and pickup from your old phonograph is seemingly economical, but usually inadvisable. (Sometimes turntables are usable but old pickups should be replaced.) There are two important reasons for getting a good turntable and pickup. First of all, the extended frequency range over which a hi-fi audio amplifier and speaker operate makes the failings of a poor turntable and pickup annoyingly apparent. Distortions hidden by the conventional amplifier and speaker, such as background rumble, scratch, and uneven turntable revolution, can become audible with the extended hi-fi range. A second reason is to protect your records. Although it seems obvious, many people forget this point. Records wear out and their quality of sound reproduction decreases with every playing. A record collection represents a costly investment that should be preserved as long as possible. A good turntable and a balanced pickup arm with a proper stylus [1] will preserve the quality of your records an infinitely longer time than the conventional rig.

Phono Pickups (Figure 13)

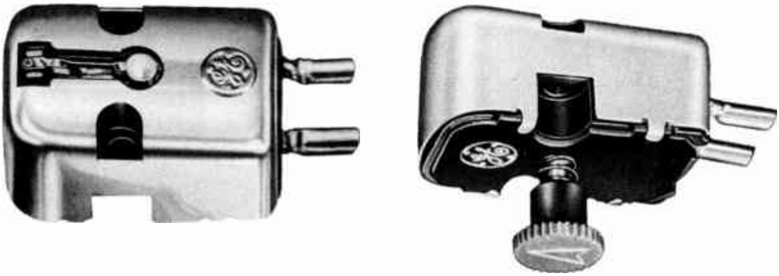
In the preceding chapter crystal and magnetic pickups were introduced in connection with the discussion of preamplifiers. Each of these pickups (the only types you should consider) is distinctly different. Although magnetics are becoming more popular, crystals are still worth considering for the inexpensive hi-fi system. As mentioned in the discussion on preamplifiers, the crystal pickup has a strong audio-voltage output and does not require a preamplifier. The magnetic pickup has a weak audio-voltage output and needs a preamplifier.

The Crystal Pickup

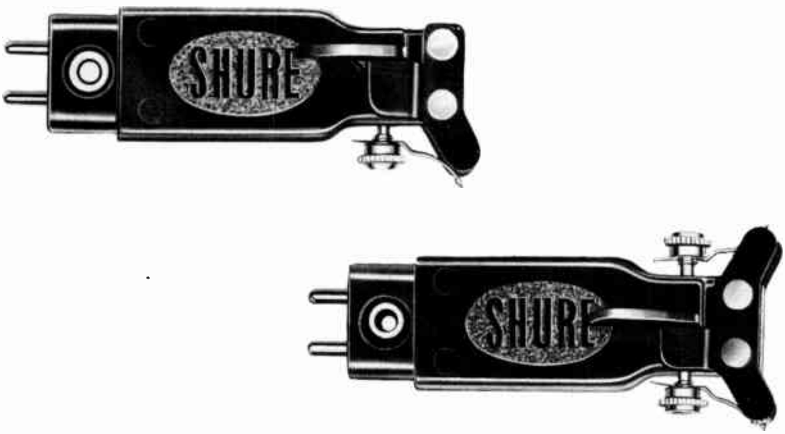
The crystal pickup ($1 to $8) functions because of what is technically known as the piezoelectric principle. The vibrations from the stylus cause a physical strain to be exerted upon the crystal. The property of the crystal is such that it generates an electrical voltage which varies in accordance with frequency and magnitude of the strain-producing vibrations. This electrical output of the crystal (varying in accordance with the sound intelligence carried in the record grooves) is the weak audio voltage that is applied to the input of an audio amplifier.

It is interesting to note that the audio-voltage output of crystal pickups is not directly proportional to the amplitude and frequency of the stylus vibration. In hi-fi language, crystal pickups do not have flat frequency response. Actually, this

[1] In hi-fi terms a needle is commonly referred to as a stylus.



A single and dual magnetic cartridge. On the right is the dual-purpose pickup using a single magnetic unit with a double stylus. (Courtesy of General Electric Company)



A single and dual crystal cartridge. Dual-purpose pickup, shown on the right, uses two styluses, top and bottom. Changing styluses is accomplished by mounting cartridge so that it may be turned over. (Courtesy of Shure Brothers, Incorporated)

FIGURE 13. PHONO PICKUPS FOR HIGH FIDELITY

is a blessing in disguise. Crystal pickups boost the low frequencies (bass) and attenuate the high frequencies (treble). If you refer to the discussion of record compensation in Chapter 3, you will see that the frequency response (i.e., recording curve) of phonograph records shown in Figure 11 does the opposite. With records, the bass is attenuated and the treble is boosted. Thus, the crystal pickup automatically furnishes record compensation. It is not complete compensation since the responses of both records and crystals vary. But crystal pickups do provide an average amount of record compensation.

Although crystals have the advantages of record compensation and a strong audio-voltage output requiring no preamplification, they also have faults. Crystals are affected by dampness and temperature. In warm, damp climates they function poorly. Furthermore, although the frequency response of crystals follows the general characteristic of boosting bass and cutting treble, it does so somewhat erratically. For the best pickup we must consider the magnetic.

The Magnetic Pickup

The magnetic pickup ($5 to $20), as its name might imply, is an electromagnetic device. It works in the same manner as an electric generator. As the record stylus vibrates, it cuts across magnetic lines of force to induce an electrical voltage in a coil of fine wire wrapped about a small permanent magnet. The voltage produced varies in accordance with the frequency and magnitude of the stylus vibrations. Unlike the crystal pickup, the magnetic pickup has a uniform and flat frequency response.

Unfortunately, this flat response does not provide any inherent record compensation. But, as previously mentioned, magnetic pickups require preamplifiers. As you may have guessed, preamplifiers boost the bass and attenuate the treble to compensate for the poor bass and strong treble response of phonograph records. Hence, a magnetic pickup and its preamplifier deliver an audio signal to the amplifier that is essentially flat. Some preamplifiers have elaborate compensators, such as those discussed in Chapter 3, with a position switch for the various kinds of records (LP's, 78's, European, etc.). Less elaborate preamplifiers give you an average compensation with the amplifier bass and treble controls providing the additional tonal adjustment demanded by your ear.

There are two types of magnetic pickups, those with a weak output (General Electric, Clarkstan, and Audak) and those with a strong output (Pickering). When using a separate preamplifier, make sure that it is designed for the magnetic pickup you have purchased. Those audio amplifiers with built-in preamplifiers should have two preamp inputs, one for weak magnetics and one for strong magnetics.

The Stylus

When it comes to selecting a stylus, you should limit yourself to two types, those with sapphire points and those with diamond points. There are other types but their wearing qualities are so poor that their use is not recommended. The difference between the sapphire and diamond point is one of price and durability. The sapphire is relatively inexpensive (around $2) whereas the much more durable diamond costs around $18.

A good stylus is important not only for quality sound reproduction, but for protecting your records. Under ideal conditions, the point of a stylus should have a minimum area of contact in the record groove. With constant use, the stylus point tends to assume the shape of the record groove, thereby increasing the area of contact and the amount of friction. An excessive amount of friction between the record groove and the stylus point eventually destroys the configurations of the groove, and hence the quality of the recording. For this reason, a point that keeps its original shape, like the hard and nonwearing diamond, helps to preserve records. Mounted on a good pickup arm, a diamond-pointed stylus may last for more than fifteen hundred hours of playing shellac records; when used on the less wearing polystyrene and vinylite records, the diamond has an almost indefinite life. The less expensive sapphire-pointed stylus needs replacement sooner. Under ideal conditions a sapphire may last for as many as two thousand plays on shellac records and considerably longer on polystyrene and vinylite records. The best way to judge stylus wear, aside from actual inspection under a microscope, is to listen for signs of distortion on the inner grooves of a record known to be good.

One inconvenience of the hi-fi stylus is that the same stylus cannot be used for long-playing (33⅓ and 45 r.p.m.) records and for 78 r.p.m. records. If your collection consists only of long-playing records, a single crystal or magnetic pickup cartridge with an LP stylus will suffice. If you wish to play 78's in addition to LP's, you need a dual magnetic or crystal pickup. Some dual pickups have two separate cartridges, one with an LP stylus and the other with a stylus for 78's. Other dual pickups have a single cartridge with a double stylus. In both cases the change of stylus is easily accomplished by a flick of a reversing lever or knob. When selecting styluses for dual pickups, two diamonds are obviously the best. However, since this is a costly investment (around $30), many hi-fi listeners use a diamond for their LP's and a sapphire for their infrequently played 78's (the usual case in this day of long-playing records).

Turntables in General

Before elaborating on record changers, cast aluminum turntables, and the like, there are a few basic facts worth mentioning about turntables.

To achieve a constant and accurate rotation, two types of drives are commonly used: the belt drive and the rim drive. Belt drives use a friction belt from the motor to either the center shaft or the rim of the turntable. Belt drives are good in that the turntable is isolated from motor vibrations. One objection to belt-drive systems is that they cannot be made very compact. The rim-drive turntable is more common and quite satisfactory when well made. In rim-drive systems rotation is obtained by a direct friction drive from the motor to the rim of the turntable. There is the disadvantage of motor vibrations being transferred to the turntable, but the soft friction drive and the numerous idler wheels used on the more expensive systems correct this fault. In spite of this and other disadvantages, the rim drive is widely used, especially in the inexpensive systems. It is compact, can use a low-torque motor (less costly than a high-torque), and gives acceptable performance inexpensively.

THE CHANGER (Figure 14)

Most listeners want an automatic record changer, although the avid hi-fi fan scorns them. Hi-fi fans have reasons for scorning them. Even the best changers don't treat records too kindly nor do they perform as well as the unadorned but well-made turntable (i.e., they don't rotate the record with an almost perfectly accurate speed). However, the avid listener notwithstanding, a changer is practically a necessity for playing an album of 78's. Furthermore, there is something to be said for stacking a changer with six LP's and having three hours of unattended playing.

The standard brands of changers (about $30 to $90 without pickup cartridges) use two types of record-dropping devices, the center hole and the rim drop. The center drop

This automatic record changer uses a rim drop and has three record speeds. With most changers, stylus pressure is fixed at the factory since the pickup arm is an integral part of the changing mechanism. (Courtesy of Webster-Chicago Corporation)

FIGURE 14. A RECORD CHANGER

works by a cleverly devised catch on the turntable spindle which allows the bottom record of the pile to drop on the one which has just finished playing. The rim drop works in a similar manner except that the bottom record of the pile is made to drop by a slight sideways push at the rim of the record. In both cases the pickup arm is automatically lifted and repositioned to play the record just dropped. Of the two types, the rim drop is preferable since it is less harmful to the records. With constant playing on a center drop mechanism, a record's center hole becomes enlarged and out of shape. This has two results: (1) the records will not work properly on a center drop mechanism, and (2) the records assume an off-center position on the turntable which causes "wow," or an unpleasant distortion in sound reproduction.

These faults are not completely objectionable, but the slightly more expensive rim drop is better.

More elaborate and expensive changers are also available. One such changer plays first one side and then the other of a stack of records. This is an expensive way of obtaining continuous playing of old sequence albums. As a general rule the elaborate and complex changers are not recommended since they add little to hi-fi sound reproduction except expense.

Turntables and Pickups (Figure 15)

To get the best sound reproduction from your records, you should choose a turntable simple and unadorned. Without a changer, you have to change a 12-inch LP every thirty minutes. Is it worth it? If you value your records and want the best listening, it is.

The plain turntable costs anywhere from $30 with a pickup arm to $250 without a pickup arm. Pickup arms by themselves cost from $15 to $45. This seems expensive when you consider the cheaper cost of the changer apparatus. But you must remember that you are now paying for quality. What are you getting for this extra cost? Good sound reproduction. The turntables are heavy and well-balanced with a flywheel action that eliminates wow. The motors are expensive and the drive mechanisms are constructed to deliver almost exact speeds (78.26, 33⅓, and 45 r.p.m.). You are also protecting your records against unnecessary wear. Pickup arms are designed free of resonant vibrations that cause a stylus to jump record grooves. Good pickup arms are also delicately suspended for a minimum of lateral pressure against the record grooves. The pressure of the stylus on the record can be accurately adjusted, 5 grams for LP's and 15 grams for 78's.[2]

[2] Stylus pressure gauges, calibrated in grams, are available for around $2.

Purchasing Your Record Player

When you buy your turntable and pickup, with either automatic or manual record changing, remember you are buying a mechanical device. The quality of workmanship is important. Well-made mechanical devices usually perform well. The table below will help you evaluate the specifications of turntables and phono pickups.

TURNTABLE AND PICKUP SPECIFICATIONS	EVALUATION
Motor	There are two types of motors used for turntables, synchronous and induction. A synchronous motor is the best since its speed depends upon the normally stable and accurate power-line frequency. Induction motors, whose speed depends upon line voltage (more apt to fluctuate than frequency), are generally used since they are less expensive. A heavy four-pole induction motor performs well. The inexpensive two-pole induction motor performs poorly and is not generally recommended.
Speeds	Your turntable should have all three record speeds (33⅓, 45, and 78 r.p.m.). This feature is so obvious as to be expected, but check to make sure.
Drives	Almost always rim drives. Published information as to the idler system used will give you some idea of the amount of isolation between the motor and the turntable. If a belt drive is used, check the over-all dimensions; they may be too large for the planned location.
Changing mechanism	The changing mechanism should work for 7-, 10-, and 12-inch records. It is also desirable

A balanced pickup arm with provision for adjusting stylus pressure. This type of arm gives the best in sound reproduction and a minimum of record wear. (Courtesy of General Electric Company)

A simple turntable. Precision-made with a cast turntable, this unit gives accurate and constant record speeds. (Courtesy of Rek-O-Kut Company)

FIGURE 15. A HI-FI TURNTABLE AND PICKUP ARM

TURNTABLE AND PICKUP SPECIFICATIONS	EVALUATION
	to have an automatic shutoff after the last record. The rim-push type of drop mechanism is considered less damaging to records.
Turntable	This is only mentioned in connection with non-changing turntables. A cast turntable is preferred (inexpensive turntables are stamped) since it usually indicates a heavier one. A turntable that has been balanced by machining is best since anything that aids in making the speed of rotation more constant is desirable.
Frequency response	This specification indicates the operating range of pickup cartridges. This means little since the defining circumstances are not standardized. Magnetics have better responses than crystals. Both types of pickups perform well when properly used.
Styluses	Diamonds last longer and cost more. Sapphires cost less, work just as well, but wear out much more rapidly. If you can afford it, the diamond is better. Points with radii of .0025 to .003 are for 78's; those with a radius of .001 are for LP's.
Pickup arms	Pickup arms with adjustable stylus pressure are better (5 grams for LP's, 15 grams for 78's). The pickup arm should be capable of mounting the pickup cartridge you have chosen.
Signal muting switch	This switch grounds the output from the pickup during the changing cycle to reduce noise of record changing.

• 5 •

THE RADIO TUNER

THE RADIO TUNER, like the record player, is a source of audio intelligence for the hi-fi system. Commercial radio broadcasts are excluded by some hi-fi listeners who contend that only classical recordings require high-fidelity amplification and speaker reproduction. This somewhat narrow viewpoint maintains that since radio transmits primarily speech and popular music, it doesn't require high-fidelity reproduction; popular music has an almost constant level of sound intensity, no crashing crescendos, only a steady beat and a hard tone that find sufficient expression in the conventional radio. I will grant that speech is adequately reproduced by the conventional radio, but I question the right to exclude popular music from the hi-fi picture. After all, music is music. The percussion, wind, or string instrument produces the same basic musical sounds whether in an eight-piece band or a symphony orchestra. And then, what about semiclassical music employing full orchestration? Certainly full-range sound reproduction can be beneficial to radio as well as to classical recordings.

The lover of classical music should also take note of the steadily increasing amount of classical music being played over the radio. In many urban areas there are stations, like WQXR in New York, which feature practically nothing but serious music. And, of course, there is always the Sunday afternoon symphony—a listening pleasure that has taken on new meaning since I installed my hi-fi system, complete with a radio tuner.

The Function of Tuners

Almost everybody is aware of one distinction between AM and FM radio—FM is static-free and sounds better than AM. Without getting too involved in electronic theory, a few more facts will help us to understand hi-fi tuners.

To begin with, there is the question of modulation, or the process of imparting the audible intelligence of a program to the radio-frequency signal. With AM (amplitude modulation) the amplitude of the radio-frequency signal is made to vary in accordance with audio-voltage variation representing a program's intelligence. To reproduce a program in your home, an AM radio receiver does the following jobs: (1) picks up the radio signal on its antenna, (2) tunes in the radio frequency of the desired station to the exclusion of other stations in the broadcast range of frequencies (500 to 1,650 kilocycles [1]), (3) extracts the audio voltage representing the program's sound intelligence, and (4) finally amplifies this audio voltage so it can operate the sound-producing speaker. This is the way a conventional AM radio works. A hi-fi AM tuner differs only in that it picks up, tunes, and extracts the program intelligence from the radio-frequency signal. The final job of amplifying the audio signal and reproducing the sound is done by the hi-fi audio amplifier and speaker.

[1] One kilocycle equals 1,000 c.p.s.

The hi-fi FM tuner does the same job as the AM tuner (picks up, tunes, and extracts the program intelligence from the radio-frequency signal) under somewhat different circumstances. First of all, FM stations broadcast at higher radio frequencies than AM stations (88 to 108 megacycles[2]). Also, as the term FM (frequency modulation) indicates, a different method of modulation is used. FM stations modulate by varying not the amplitude but the frequency of the radio signal itself—the rate of radio-frequency variation changing in accordance with the program's audible intelligence. This method of modulation is free from atmospheric interference, hence no static. The higher radio frequencies used by FM stations are also advantageous since they permit modulating with a full range of audible frequencies. AM stations, operating at lower radio frequencies, are not permitted the luxury of full-range audio modulation (10,000 c.p.s. at the most).

FM radio, then, is ideal for high fidelity. FM broadcasts carry the full audible range and are crystal clear with no static from atmosphere, furnace motors, electric razors, and the like. Unfortunately, although fairly widespread, FM reception is not available in all sections of the country. The higher radio frequencies of FM transmission limit a station's range to about seventy-five miles.

AM reception, on the other hand, is available everywhere. Although its quality of sound reproduction is limited by comparison with FM standards, an AM tuner with a hi-fi amplifier and speaker is an improvement over the conventional radio.

Hi-Fi Tuners

When it comes to selecting a hi-fi tuner, the versatility and economy of the hi-fi concept is ever apparent. There are three types of tuners to choose from: the AM-FM, the FM,

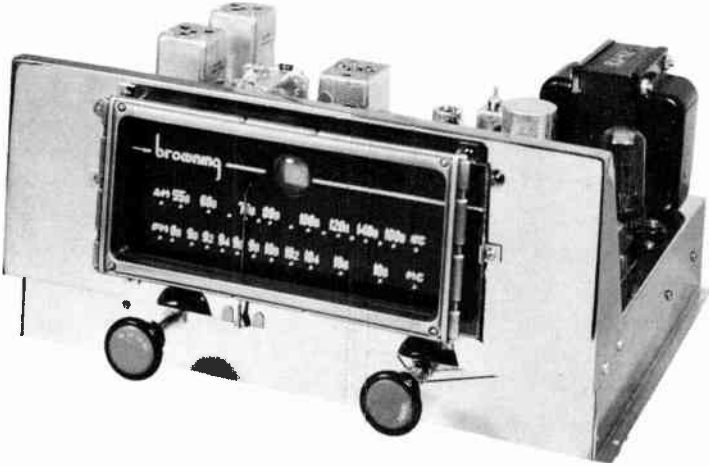
[2] One megacycle equals 1,000,000 c.p.s.

or the AM tuner. Of these three types, one will satisfy your needs.

THE AM-FM TUNER (Figure 16)

The AM-FM tuner (from about $60 to $280) is perhaps the most widely used unit. Since it offers both kinds of radio reception, it is ideal for areas that can receive only a few FM stations. Expensive AM-FM tuners furnish almost unbelievable radio reception. Aside from using better materials and more extensive radio circuitry than inexpensive units, they have added features to make exact FM tuning easier. This doesn't mean that the less expensive AM-FM tuners are poor performers. On the contrary, dollar for dollar they are wonderful bargains. Their reception is good and the materials used in their construction will insure dependable service. However, an inexpensive AM-FM tuner requires a little more attention from the operator for exact tuning. Station settings made immediately after the unit is turned on have to be readjusted when it has warmed up (about two minutes later).

There is one aspect of AM-FM tuners that merits close attention. Some units are designed to work with a matched audio amplifier made by the same manufacturer. When this is the case, the input section of the matched amplifier is usually placed on the tuner chassis. Thus the tuner, in addition to its regular radio controls, has the amplifier volume, bass, treble, and (if used) record compensator controls. Phono pickup and auxiliary sources of sound (tape recorder, etc.) are now fed to the audio amplifier through the radio tuner. A switch on the front of the tuner permits selection of the desired sound source (AM, FM, phono, or auxiliary). The accompanying audio amplifier has no controls. Although such a system is a restriction in that you have to buy a



The simple AM-FM tuner designed to work with any audio amplifier that features a full set of controls. This tuner has only two controls, an AM-FM selector and a tuning knob. An adjustable gain (radio volume) control is located at the rear of the chassis. Once this gain control has been set to an average level, the volume control of the audio amplifier is used to adjust sound intensity. (Courtesy of Browning Laboratories, Incorporated)

An AM-FM tuner and matched audio amplifier. The input section of the audio amplifier is on the tuner chassis. This permits all major controls of a hi-fi system (tone, volume, tuning, sound selection, and record compensation) to be located at the tuner. (Courtesy of Pilot Radio Corporation)

FIGURE 16. AM-FM TUNERS

matched amplifier and AM-FM tuner, it offers the advantage of having all controls on one unit.

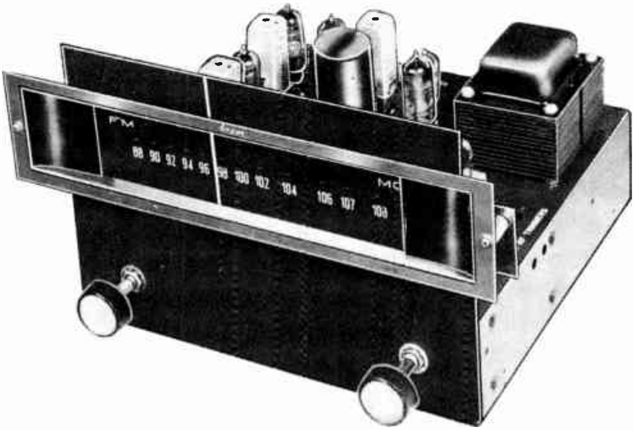
The simple AM-FM tuner has only three controls: a switch to select either AM or FM, a tuning knob, and a radio gain (volume) control. The simple AM-FM tuner needs an audio amplifier, complete with all its controls. This requires selecting the desired sound input (radio, phono, or auxiliary) at the audio amplifier. At the tuner you select either AM or FM and tune for the desired station. Leaving the radio gain control at a middle setting, you can adjust the sound intensity and tone with the volume, bass, and treble controls of the audio amplifier.

The FM Tuner (Figure 17)

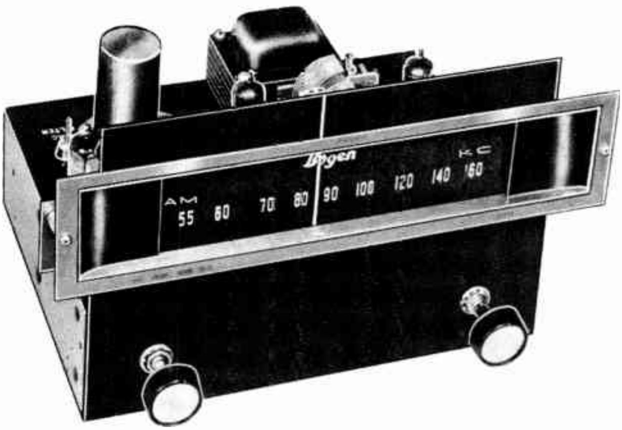
If you live in or near a large urban area where all major stations transmit FM as well as AM, you can save by purchasing an FM tuner ($40 to $100). Inexpensive FM tuners are excellent buys and give dependable performance. The more costly FM tuners are characterized by expensive construction and special features which facilitate tuning. Since FM tuners come equipped with two controls, a tuning knob and a radio gain (volume) control, they need an audio amplifier with a full set of controls (input selector, tone, and volume).

The AM Tuner (Figure 17)

If you live in an area where there is no FM, an AM tuner (around $50) will serve your needs. Since AM stations modulate with a limited range of audio frequencies, AM reception is, strictly speaking, not high fidelity. However, if it is all you have, you should make the best of it. In buying an AM tuner, there is an important distinction to make between the "tuned radio frequency" (TRF) and the "superheterodyne" (superhet) tuners. The TRF AM tuner operates on



The FM tuner. If you live in an area with complete FM reception, you can save money by using this type of tuner. (Courtesy of David Bogen Company, Incorporated)



The AM tuner. When FM reception is not available, a hi-fi tuner will give you the best AM reception. (Courtesy of David Bogen Company, Incorporated)

FIGURE 17. THE SEPARATE AM AND FM TUNERS

the same principle as the old radio of 1930. It has a relatively limited range, tunes very broadly (cannot separate stations that are close together), but reproduces the full range of a station's audio modulation. The superhet AM tuner operates like a modern radio. It has a good range, tunes selectively (has no trouble separating stations close together), but does not reproduce the full range of audio modulation. If you live fairly close to your AM stations (around seventy-five miles), then the TRF might be considered since it provides the best sound reproduction. However, with a TRF you should expect some interference from distant stations during nighttime listening, especially with stations above 1,000 kilocycles. For reception from more distant stations and for no interference between stations, you should use the superhet AM tuner.

Using Your Old Radio

I have often been asked about using an old AM, FM, or AM-FM radio in connection with a hi-fi audio amplifier and speaker. The answer is yes. However, such a procedure is recommended only as a temporary expedient. A proper hi-fi tuner is always preferable. Connecting into an old radio to bypass its audio amplifier tubes (sometimes only one tube) and speaker is a simple task that can be performed by a serviceman. Although an old radio can be improved with a hi-fi audio amplifier and speaker, the best reception still requires a hi-fi tuner which is designed for full-range sound reproduction.

Tuner Specifications

Once you have decided on the type of tuner you need (AM, FM, or AM-FM), a careful study of manufacturers' specifications will help you to buy wisely. The more important specifications are listed and evaluated below.

TUNER SPECIFICATION	EVALUATION
AM tuning range	540 to 1,650 kilocycles. This is the AM broadcast range of frequencies.
FM tuning range	88 to 108 megacycles. This is the FM broadcast range of frequencies.
FM frequency response	This rating indicates the ability of a tuner to reproduce the full range of audio frequencies. With FM tuners you should expect a minimum response of 50 to 15,000 c.p.s., flat within 2 db. Over-generous responses of 20 to 20,000 c.p.s., flat within ½ db, are common.
AM frequency response	An AM tuner's response is essentially limited by the audio modulation of AM broadcasting (no more than 10,000 c.p.s., usually less). AM-FM tuners should have AM responses of 20 to 5,500 c.p.s., flat within 2 db. Some AM tuners have responses extending to 7,500 c.p.s. To be effective, the AM receiver with this wide response requires "variable bandwidth i-f" which permits reduction of frequency response to approximately 5,000 c.p.s. when stations run together.
Automatic frequency control (a-f-c)	This feature facilitates FM tuning. It causes the FM tuner to assume proper tuning automatically once manual tuning has effected an approximate tuning of the desired station. Provision should be incorporated for disabling the a-f-c, since it can prevent the tuning in of weak stations.
Sensitivity	This specification rates the ability of tuners to receive weak signals. If you live in the fringe area of FM reception, an FM tuner with a rated sensitivity of 3 to 10 microvolts[3] should

[3] A microvolt is a millionth part of a volt.

TUNER SPECIFICATION	EVALUATION
	be used. If you live in the area of good FM reception, sensitivity is not an important factor. AM tuners should have a sensitivity of from 1 to 10 microvolts.
Power consumption	This specification, expressed in watts, indicates the amount of outlet power that a tuner consumes. When equated with a light bulb of equivalent wattage, power consumption indicates the amount of heat generated by a tuner.
AM-FM tuners with the input sections of matched audio amplifiers	The specifications for inputs, volume, tone, and record compensator controls of AM-FM tuners with matched amplifiers should meet the requirements outlined for audio amplifiers in Chapter 3.

· 6 ·

INTERCONNECTING HI-FI COMPONENTS

THE PRECEDING CHAPTERS have discussed the nature and function of the individual hi-fi components. This chapter is concerned with interconnecting hi-fi components to make a system. There are only a few principles underlying the interconnection of a hi-fi system; but a thorough understanding of these principles is important. Such knowledge will not only permit you to interconnect your components but will also help you to acquire fully compatible components.

CONNECTING THE SPEAKER AND AUDIO AMPLIFIER

An important factor when connecting a speaker or speaker system to the output of an audio amplifier is impedance matching, making sure that the output impedance of the amplifier is the same as the input impedance of the speaker. Matching a single-cone speaker is easy; the amplifier output impedance should equal the voice-coil impedance. With multiple-speaker systems a crossover network is introduced between the amplifier and speakers (refer to Figure 7 to refresh your memory of the function of crossover networks). Crossover networks should be chosen so that they will match both the amplifier output impedance and the voice-coil impedances of the speakers. Coaxial speakers have their crossover networks connected at the factory. Thus, coaxial speakers are treated like single-cone units, the amplifier output impedance matching the specified input impedance.

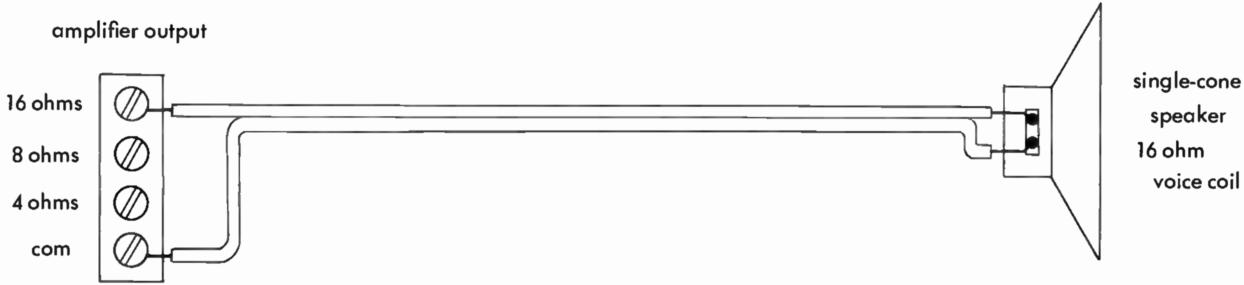
What are the results of mismatching an amplifier and speaker? No distortion is introduced, but a power loss is incurred. A mismatched speaker will not reproduce the maximum sound intensity that an amplifier is capable of delivering. However, the power loss is small for the low-impedance speakers (practically all hi-fi speakers have voice-coil impedances ranging from 4 to 16 ohms). For example, connecting a 4-ohm amplifier output to a 16-ohm voice coil results in about a 10 per cent power loss. Nevertheless, you should always try for as close a match as possible. Reserve power, discussed in Chapter 3, is important for keeping amplifier distortions to a minimum and should not be wasted by improper matching.

Figure 18 shows typical amplifier-to-speaker connections for a single-cone speaker, a two-way, and a three-way multiple-speaker system. Notice how simple the single-cone speaker is to connect. The wire employed from the amplifier to the usually distant speaker (or speaker system) is ordinary two-conductor lamp wire. The amplifier output terminals shown in Figure 18 have 4, 8, and 16 ohms of impedance available. These output impedances are common, but not standard. Some amplifiers may have a wider selection of impedances.

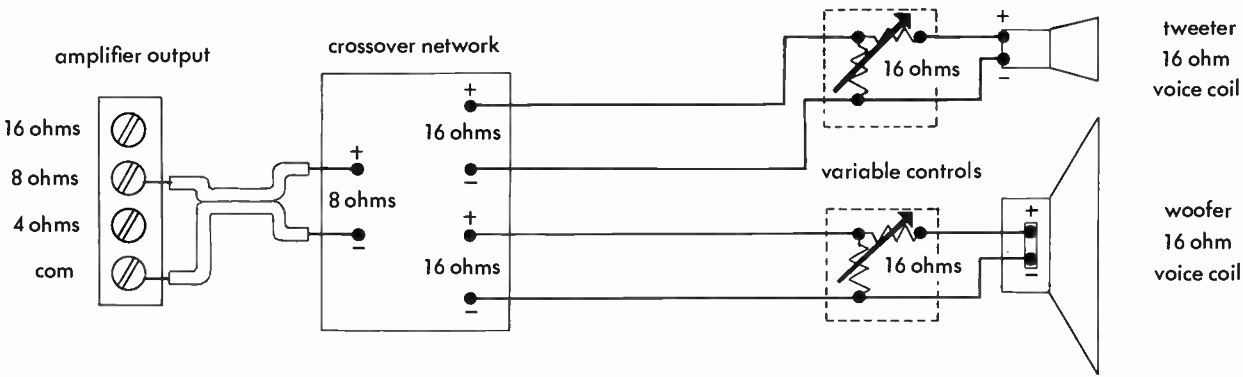
In Figure 18 the variable control shown for the tweeters is a simple variable resistor of about 40 ohms. The variable controls shown for the mid-range speaker and the woofers are known as variable resistance pads or balanced controls. As shown in this diagram, a resistance pad should be rated so that its impedance matches that of the associated speaker and crossover network. The use of these variable controls is optional. Theoretically, they permit balancing out any inequalities of relative sound intensity that may exist between the different speakers of a system. Once these controls have balanced the sound levels of the speakers they can be left alone. Although these individual speaker-intensity controls are theoretically justified, they are an added complication. Actually, if good speakers are used, differences in relative sound levels will be slight. In two-way systems individual speaker controls can be safely eliminated. In three-way systems, where there is more chance of distinguishable differences in speaker sound levels, individual controls are normally used.

You will notice that the multiple-speaker systems diagramed in Figure 18 show positive and negative designations at the speakers and crossover networks. When they exist, such polarity markings (or other suitable markings) are a great help in phasing speaker units. A two-way system is properly phased when the woofer cone and the tweeter diaphragm operate in correct accord, that is, both pushing when they should push, and both pulling when they should pull. When the polarities are marked, the job is simple: positive to positive, negative to negative, as shown in Figure 18. When the network, woofer, and tweeter are unmarked, proceed by making all connections permanent except for the two wires leading to the tweeter. Listen for signs of distortion with the two tweeter wires connected first one way and then the other.[1] Choose the connections that sound better. Phasing a three-way system, when the speakers and networks are not marked, is more difficult. In this case connect the woofer

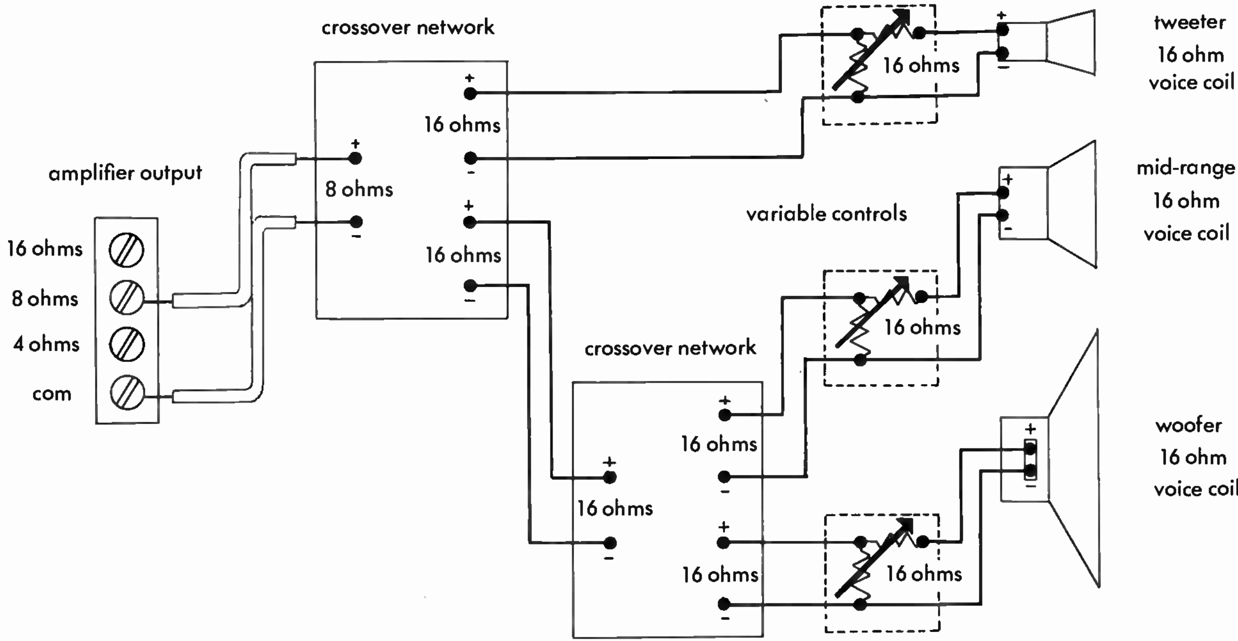
[1] The best way to describe the distortion caused by a woofer and tweeter being out of phase is to say that the sound is vaguely reminiscent of old acoustical recording. Articulation is slightly reduced. There is also a slight reduction in sound level, but this is usually indistinguishable. Get the opinion of a trained musician if possible. He can usually detect the distortion.



Using conventional two-conductor lamp cord, a single-cone or coaxial speaker is easily connected to its amplifier. Speaker connections are soldered.



Connection for a two-way multiple-speaker system. Variable intensity controls are optional. Polarity markings are an aid in phasing speakers.



Connections for a three-way multiple-speaker system. Variable intensity controls are usually recommended to balance the outputs of the three speakers.

FIGURE 18. AUDIO AMPLIFIER AND SPEAKER CONNECTIONS

permanently, and experiment by reversing the mid-range and tweeter wires until your ear indicates the best arrangement.

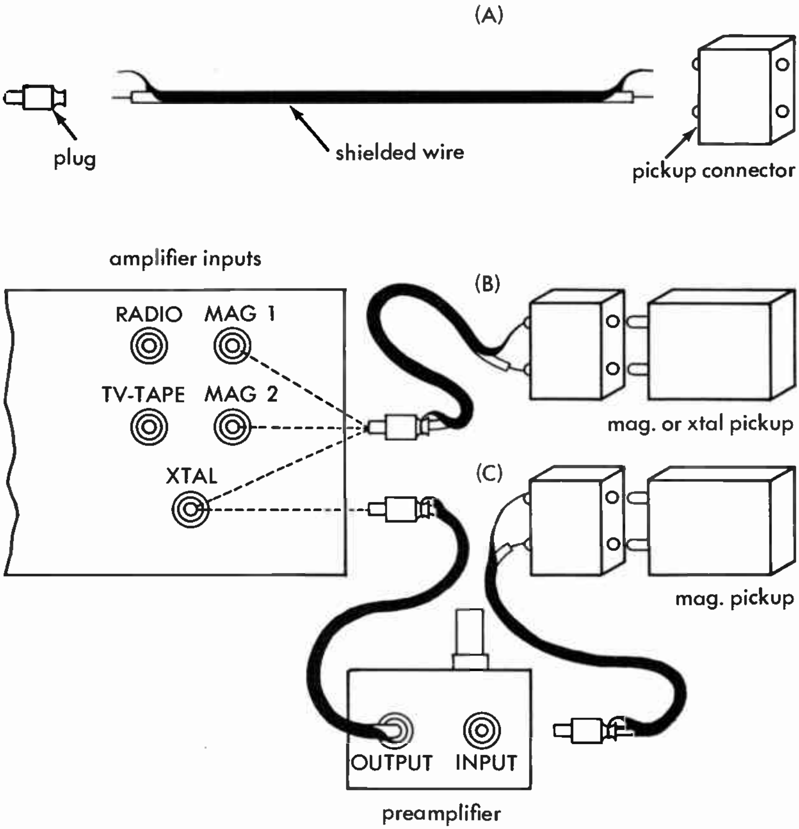
If the crossover network (or networks) is marked but the speakers are not, a uniform polarity for the voice-coil connections of the speakers can usually be established with a 1½-volt battery. Connect the battery directly to each speaker input and note the movement of the cone or diaphragm. Observe the polarity of the battery connections which cause the same direction of cone or diaphragm movement for the speakers to be phased.

The wire used to connect the audio amplifier to the speaker installation has already been specified as conventional two-conductor lamp cord. This same type of two-conductor wire can be used to interconnect the speakers and crossover networks of multiple-speaker systems. However, it should be of the flat rubberized variety so that individual wires can be traced.

Connecting the Phono Pickup and the Audio Amplifier

The phono pickup is connected to the input of the audio amplifier by a single-conductor shielded wire as shown in Figure 19. The use of a shielded wire [2] is important because the input of an audio amplifier is sensitive to electrostatic disturbances. If the input leads to the audio amplifier were unshielded, electrostatic disturbances (the most disturbing is a 60 c.p.s. hum caused by AC house current) would be picked up, amplified, and reproduced by the speaker. Of course, the inputs to audio amplifiers must be sensitive since the audio voltages from the phono pickup are weak. So weak, in fact, that phono-to-amplifier connections should be as short as possible. It is advisable to have the phono turntable located within six feet of the audio amplifier.

[2] Shielded single-conductor wire has an insulated center conductor covered with a braided copper mesh.



(A) Preparation of shielded wire before soldering.
(B) Phono-to-amplifier connection; amplifier input employed depends upon the type of pickup used.
(C) Connection for a separate preamplifier.

FIGURE 19. CONNECTING PHONO PICKUP TO AUDIO AMPLIFIER

You will notice in Figure 19 that the connection to the audio amplifier is made by a small plug. This connector is almost standard. The center wire of the shielded lead is inserted into the center prong. Hold the soldering iron against the outside shank of the prong, and melt solder down into the prong to make a secure connection. The shield is soldered to the body of the plug. Make a good connection by unraveling the copper mesh for about one inch and twisting this about the body of the plug before soldering.

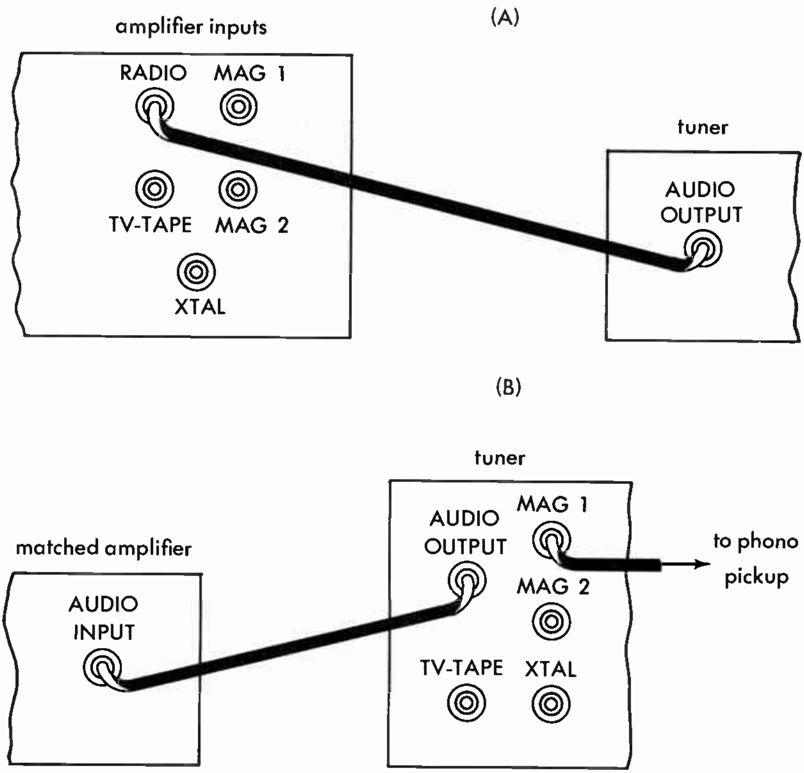
The amplifier indicated in Figure 19 has a built-in preamplifier with three phono inputs: XTAL (crystal), MAG 1, and MAG 2. Crystal pickups are connected to XTAL. MAG 1 is the usual designation for low-voltage magnetic pickups; MAG 2 is for high-voltage magnetic pickups. Check the instruction sheets packed with your amplifier to make sure.

If you are using a separate preamplifier for your magnetic pickup, the output from the pickup is connected to the input of the preamplifier. The output of the preamplifier is in turn connected to the XTAL jack of your amplifier. Single-conductor shielded wire is used for these connections.

A word of caution about making the actual connection to phono pickups. The particular type of connector required is usually supplied with the pickup. Use it, and under no circumstances attempt to solder connections directly to the pickup. Pickups are delicate (especially crystals) and the heat from a soldering iron can easily burn them out.

Connecting the Tuner and Audio Amplifier

The radio tuner is connected to the input of the audio amplifier in much the same manner as the phono pickup. As shown in Figure 20, single-conductor shielded wire is used to avoid electrostatic disturbances. Connection to the tuner and amplifier is made by a small plug. The audio-volt-



(A) Conventional shielded wire connection between tuner and audio amplifier.

(B) Audio connection for a matched tuner and amplifier; phono connection shown is for a low-voltage magnetic pickup.

FIGURE 20. CONNECTING RADIO TUNER TO AUDIO AMPLIFIER

age output from the tuner, like the phono pickup, is weak. Locate the tuner as close as possible to the audio amplifier (no more than six feet), and make the connecting lead as short as possible. There is one exception to this. If the tuner has a cathode-follower output (this will be stated in the manufacturer's specifications), it can be remotely located with respect to the amplifier. With a cathode-follower output, a tuner can be located in one room and the amplifier in another.

A tuner designed to work with a matched audio amplifier requires somewhat different connections. This type of tuner, as you will remember, incorporates the input sections (preamplifier, sound-selector switch, volume, tone, and compensator controls) of the associated audio amplifier. For this type of equipment, the phono connections shown in Figure 20 are made to the tuner chassis. A single-conductor shielded wire is connected between the tuner and the audio amplifier. The audio voltage applied to the associated amplifier depends upon the position (AM, FM, phono, or auxiliary) of the selector switch located on the front of the tuner.

Tuner Antennas

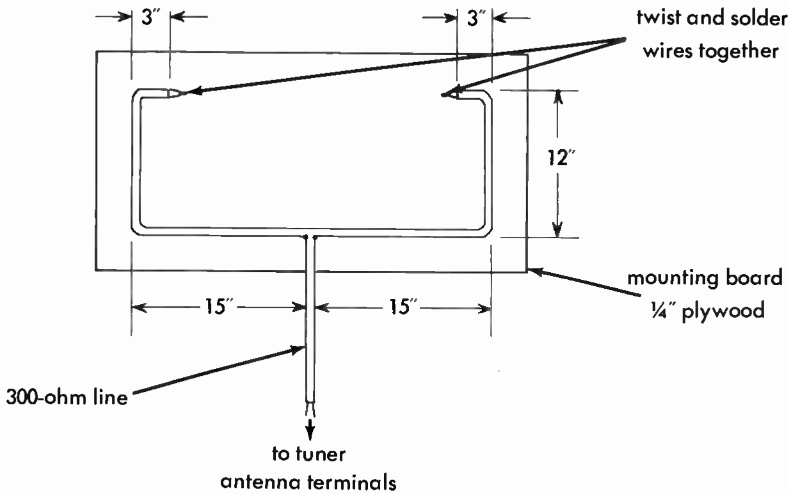
Practically all FM tuners have built-in antennas that work well if you are located near the desired broadcast stations. When your tuner does not have a built-in antenna or when you live over fifty miles from the desired FM stations, you will probably have to use an external antenna. However, if you already have a television antenna, it will usually serve both TV and FM, provided you do not wish both going at the same time. To utilize an existing TV antenna, proceed as follows. (1) Check the type of TV lead-in cable used; it will be either a 78-ohm line (round coaxial cable with a center conductor and surrounding braided shield) or a 300-ohm line (two conductors bonded in a flat ribbon of plastic). (2) When a 300-ohm line is used, connect a conveniently located changeover switch as shown in Figure 21. (3) If your TV set uses a 78-ohm line, your FM tuner must also have a 78-ohm antenna input or you cannot use your existing TV antenna. (300-ohm antenna inputs are standard for hi-fi tuners; although some FM tuners have provision for both 300-ohm and 78-ohm antenna inputs.) When your tuner has provisions for a 78-ohm antenna input, connect the antenna changeover switch as shown in Figure 21.

If you do not have an existing television antenna, you can purchase a commercial FM antenna or you can make your own as shown in Figure 21. In each case, the antenna should be mounted in the highest location, in the attic or on the roof. The antennas shown in Figure 21 should be oriented to face in the direction of the desired FM stations.

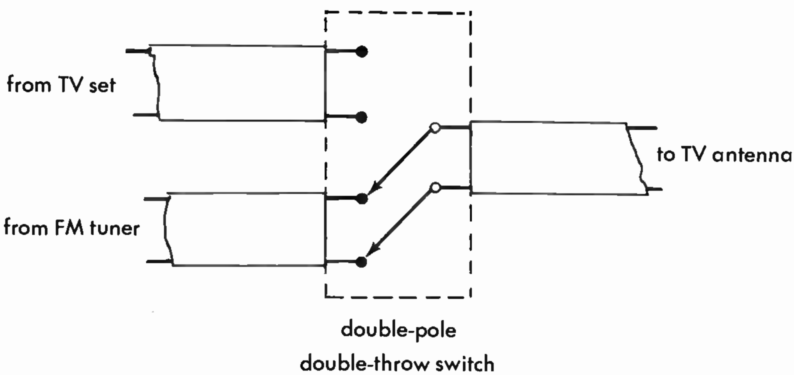
As a general rule, superhet AM tuners do not need external antennas. The built-in ones work well. However, if your AM tuner does not have a built-in antenna (very exceptional) a 20- or 30-foot length of insulated wire will do nicely. A good arrangement is to run the wire from the tuner along the baseboard of a wall and up the molding of a door frame.

AC Power

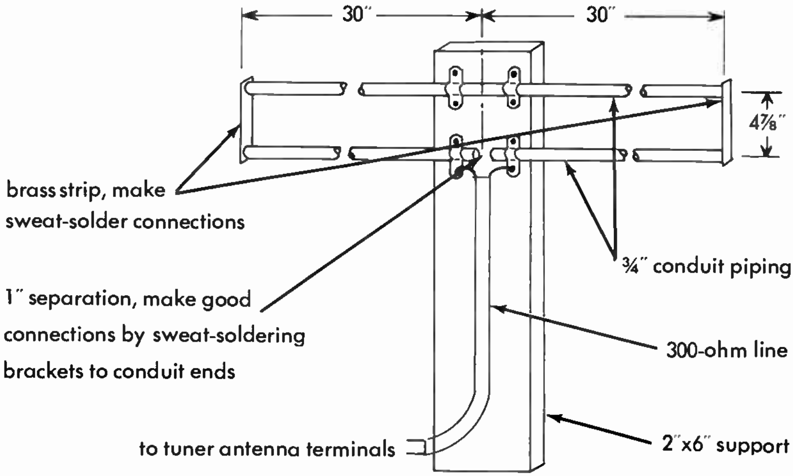
Up to this point, we have been interconnecting the basic hi-fi system with no mention of AC power connections. The audio amplifier, radio tuner, and phono turntable require a primary power source of 115 volts, 60-cycle AC. All three units are equipped with a standard power cord and an on-off switch. An extension cord with a three-way receptacle will serve to connect all three from the nearest wall outlet. There is also an alternative method when the audio amplifier has



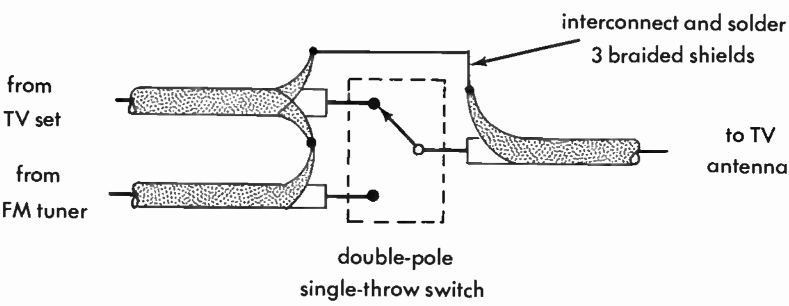
A simple FM antenna made from 300-ohm line; this antenna should be mounted indoors.



TV-FM antenna changeover switch for 300-ohm line.



An FM antenna that may be mounted outdoors; tuner antenna terminals are of the washer-screw variety that do not require soldered connections.



TV-FM antenna changeover switch for 78-ohm line.

FIGURE 21. TWO EASY-TO-MAKE FM ANTENNAS AND TV-FM ANTENNA SWITCHING

a convenience outlet at the rear of its chassis. Connect the audio amplifier directly to the nearest outlet. Connect the power cords of the phono turntable and the tuner to this convenience outlet. This latter method offers the advantage of being able to shut off the entire system by turning off the audio amplifier.

Instruction Sheets

With each piece of hi-fi equipment the manufacturer usually includes specific instructions for installation and interconnection of the equipment. Read these instructions carefully before making the actual interconnections.

· 7 ·

INSTALLATION

SINCE THE PRECEDING chapters have discussed the components that make up a home hi-fi system, the next step should logically be a discussion of how to install these components. It is important to understand the requirements of a good installation before purchasing a hi-fi system because, as will become apparent, particular types of system components are often required to meet the needs of individual homes. In the following pages the requirements of good home installations are considered from the standpoint of helping you decide upon an installation that will best suit your needs.

The first step in planning your installation is to decide upon the physical arrangement of the hi-fi components—an arrangement that will meet the acoustical and electrical requirements of good sound reproduction as well as the aesthetic demands of your living space. Of course, if you have no demands for interior décor, your problem is simplified since you will not have to integrate your hi-fi system into the existing motif of modern, provincial, colonial, or what have you. However, most of us must face the problem of placing our hi-fi sets in living quarters whose purpose is primarily social, with the production of faithful and undistorted sound coming second. It is difficult, but with some care and imagination we can arrive at that happy state where the hi-fi set is artistically integrated, as well as acoustically and electrically as perfect as room and financial status will permit.

Of all the basic components (radio tuner, phonograph turntable, audio amplifier, and speaker) the placement and mounting of the speaker is the most critical. An improperly placed speaker, and even more important, an improperly mounted speaker can greatly reduce the quality of sound reproduction. Though the placements of tuner, amplifier, and turntable are also important, here a person has more or less a free rein, being restricted only by such mechanical problems as vibration and heat dissipation. But in the placement and mounting of the speaker you encounter the problem of listening acoustics. Listening acoustics present two considerations: the selection of the best speaker location, which involves a basic understanding of room acoustics, and the proper mounting or enclosure of the speaker, which involves speaker acoustics.

Room Acoustics

When sound is produced by a speaker in a room, it proceeds from the speaker in spherical waves. After the sound waves strike the surfaces of the room they are reflected and absorbed in varying degrees, depending upon the physical nature of the surfaces. If the surfaces of a room are highly reflective and absorb only a small percentage of the energy, the sound will persist in the room at an audible level, bouncing from surface to surface. When this condition exists, a listener hears the sound first direct from the speaker and then as it is reflected from the room's surfaces. Thus, the listener hears the sound for a longer period than its actual duration.

Of course, the sound will eventually die out, being dissipated in the air and absorbed by the surfaces of the room. The continuation of the sound beyond its actual duration depends upon how much energy striking the surfaces of the room is absorbed and how much is reflected. This persistence of sound due to the reflections of surrounding surfaces is called reverberation.

Reverberation

Controlling the amount of reverberation is the most important factor in obtaining satisfactory room acoustics. An excessive amount of reverberation results in a lack of definition between both the musical notes and the instruments of an orchestra. Excessive reverberation also noticeably reduces vocal articulation. However, it is generally agreed that some reverberation is required to give music the natural, resonant quality that we expect and have become accustomed to hearing in concert halls.

The Amount of Reverberation for Hi-Fi

The next question that arises is how much reverberation is desirable in the room that contains a hi-fi speaker. Here the answer is not clear-cut; it is a matter of personal taste. Some people like to listen to music that has more resonance, or the "hollering down a rain barrel" effect. Some people prefer their music to have less resonance because they like greater definition of tones. In my estimation the important factor is how the professionals are handling the question of reverberation.

Before World War II, broadcasting and recording studios were designed to eliminate practically all reverberation. Although radio and recording artists were often bothered by unnaturalness, or the fact that nothing "came back," the practice of killing reverberation was continued in the belief that pure sound was being achieved. However, the professionals have come to realize that they must have reverberation to achieve the resonance that people have become accustomed to in theaters and concert halls. The control of reverberation has become such an art that today recording companies sometimes record the music and its reverberation separately. The reverberation is later added in carefully controlled amounts to achieve a natural effect. Radio stations have also increased the amount of reverberation in their studios for presenting live shows.

What all this leads to is the suggestion that you should try to keep reverberation at a minimum for home high fidelity. The reasoning is thus. The professionals of the recording and broadcasting studios are supplying what is judged to be the correct amount of resonance and life by accurate control of reverberation. Your hi-fi system should therefore reproduce accurately that which is placed on a record or broadcast from a radio station. If your rooms add an excessive amount of reverberation to that already contained in the sound being reproduced by your speaker, you will hear sound that is indistinct, inarticulate, and too resonant.

Back in the days when broadcasts and recordings lacked naturalness, the average living room probably did not provide enough reverberation to make the music natural. But today, where great pains are taken to supply broadcasts and recordings with just the proper amount of life, it is preferable to keep the reverberation in your home to a minimum. If you do this, you will then hear the actual sound that your speaker is producing, sound broadcast or recorded with the right amount of resonance or naturalness.

Controlling Reverberation

Placement of the speaker in the room is an important consideration in keeping reverberation at a minimum. However, before going into this problem, it is best to understand those physical characteristics of a room that reduce reverberation and provide for an even distribution of sound intensity. The table below lists room characteristics and their acoustical effects.

ROOM CHARACTERISTICS	ACOUSTICAL EFFECTS
Parallel walls	The parallel walls of rooms that exist in most homes are objectionable because they provide a constant angle of reflection for sound from a speaker. If the walls are at all reflective they may set up standing waves which are resonant at certain frequencies, causing undesirable loudness and persistence at these resonant frequencies. The effect is counteracted by rooms with fireplaces, structural protuberances, two or more doorways, built-in bookcases, bookcases or large pieces of furniture placed against the walls, or any other factors which in effect make the walls irregular.
Floors	Floors that are carpeted from wall to wall or are amply covered by rugs are best, since they reduce the amount of sound energy reflected from normally hard-surfaced floors. Thick soft rugs are better than hard-surfaced rugs.
Ceilings	Plastered ceilings are highly reflective and tend to increase reverberation. Peaked ceilings with visible structural beams present less of a problem. Acoustical tile, similar to that used in offices and public buildings, can be installed on the ceiling for relatively little cost and is well worth the expense, if desired. If not, highly reflective plastered ceilings have to be endured.
Concave surfaces	Concave surfaces, such as bay windows and concave walls, are objectionable because they

ROOM CHARACTERISTICS	ACOUSTICAL EFFECTS
	focus sound, causing distortions and locations of extreme loudness. Bay windows can be draped with heavy curtains. Concave walls should be broken up as much as possible by large pieces of furniture, wall hangings, etc.
Treatment of walls	In addition to the steps outlined for breaking up parallel walls, the surfaces of walls should be made as absorbent and irregular as possible. Paintings and pictures help. If you have tapestries or wall hangings, so much the better. Walls with rough surfaces or corrugations are excellent.
Room size	In general, the larger the room the better, unless the large room has too many undesirable acoustical aspects.

Placement of the Speaker

The placement of the speaker will in most cases involve integration with the existing arrangement of furniture and fixtures. There are two basic types of speaker placements: the corner placement and the wall placement. Select one of these basic types of speaker placement and adjust it to suit your particular needs.

The Corner Placement

Placing the speaker in a corner of the room is in most cases the simplest and cheapest method, and the results obtained are usually excellent. Figure 22 shows a floor plan of a room with the speaker placed in a corner. Three reasons for the generally satisfactory performance of a corner placement are as follows: (1) such a placement usually puts listeners in direct line with the speaker; (2) any chance of standing-

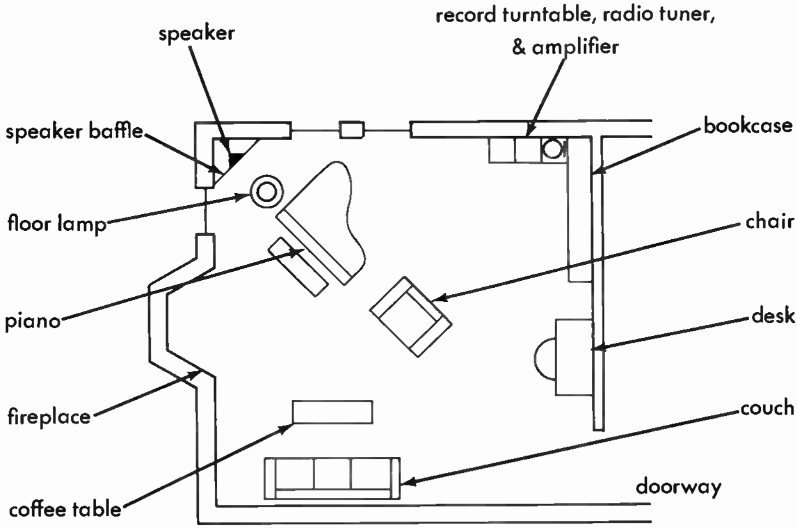


FIGURE 22. FLOOR PLAN SHOWING CORNER PLACEMENT OF SPEAKER

wave resonance due to parallel walls is practically eliminated; and (3) the effective speaker baffle becomes very large since (as can be seen in Figure 22) the baffle becomes an integral part of the two walls that meet at the corner. Important considerations of a corner placement and their effects are given in the table below.

CONSIDERATIONS	ACOUSTICAL EFFECTS
Selecting the corner	Try to select a corner from which the speaker will face toward the least reflective and most irregular surfaces of the room. Notice in Figure 22 that the speaker faces the walls with no windows and is opposite the entrance. The speaker is also placed facing probable listening positions.

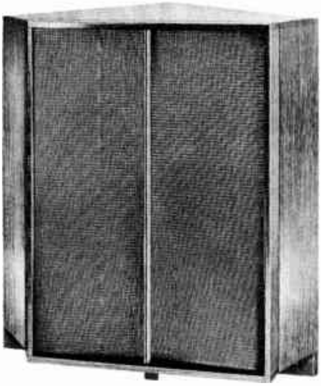
CONSIDERATIONS	ACOUSTICAL EFFECTS
Scattering the high frequencies	The concentrated beam of high frequencies that most speakers produce is best scattered by placing a hard-surfaced irregular object in front of the speaker. In Figure 22 this effect has been achieved by a piano and a floor lamp. A table and a group of wooden chairs would serve the same purpose.
Acoustical treatment	The bookcase and desk in Figure 22 show good treatment of one of the walls facing the speaker. A bookcase, wall hangings, or acoustical treatment of the wall behind the couch would be further improvements. Drapes for the windows, carpeting on the floor, and acoustical tile or a rough surface on the ceiling would make this room acoustically excellent.

Corner Mountings and Enclosures

The problem of corner-mounting your speaker can be solved either by making your own corner baffle or enclosure, or by buying a commercial enclosure. Examples of the commercial types available are shown in Figure 23. Prices on the commercial models run anywhere from $20 for a kit to $100 for a well-made labyrinth type of enclosure. When buying a corner enclosure, you should select one that will meet the requirements of your speaker (size and cone resonance).

If you decide to save money by making your own enclosure, you have two avenues of approach—a fixed installation integral with the walls or a movable enclosure similar to commercial types.

The fixed installation will prove the cheapest, since it consists of nothing more than a suitable speaker baffle secured to the two walls and the floor, then covered over on top. Ex-



ALTEC LANSING CORNER ENCLOSURE, MODEL 821A

For 2 woofers and 1 tweeter.
Employs a direct radiating horn type of baffle.
Dimensions: 47⅜ inches high, 42½ inches wide, 29 inches deep.
Finish: Mahogany.

CABINART KIT MODEL 61

For 12-inch speakers.
Folded-horn type of enclosure.
Dimensions: 32 inches high, 32 inches wide, 22½ inches deep.
Shipping weight: 26 lbs.

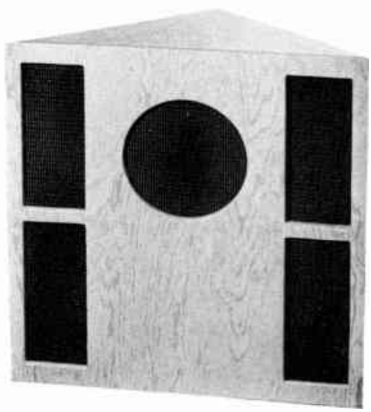


FIGURE 23. TWO CORNER ENCLOSURES, COMPLETELY ASSEMBLED, AND KIT

cellent results have been obtained with this inexpensive corner mounting, results where the full frequency range of the speaker was realized. The general requirements for this type of fixed corner installation are given in Figure 24.

If you prefer the advantages of a movable enclosure (providing the ability to rearrange your room or experiment to obtain the best corner for proper acoustics) you can make your own either from scratch or by buying a prefabricated kit. The kits cost about $20 and are a good buy in that they represent a proven design. To make your own, some carpentry skill is required, but a well-made job using top grade wood is well worth the effort. The plans for a simple 12- or 15-inch speaker enclosure are given in Figure 25.

SPECIFICATIONS FOR FIGURE 24

Baffle must be well secured to walls and floor. Removable cover is secured to rear post and wall supports by wood screws. Careful work is required to obtain sealing of enclosure.

Mount speaker with 4 or more machine screws and nuts; use ¼ inch screws for 12- and 15-inch speakers and number 8 screws for 8-inch speaker. Volume of the enclosure is dependent upon speaker size, see Appendix A.

Diameter of speaker openings: 15-inch speaker, 13 inches; 12-inch speaker, 10¼ inches; 8-inch speaker, 6⅞ inches.

Speaker port: centered 12 to 14 inches below edge of speaker hole; see Appendix A for port size dependent upon cone resonance.

Attach the sheets of acoustical material with linoleum cement.

Cover baffle with loose-weave cloth (such as burlap) and secure with a suitable molding.

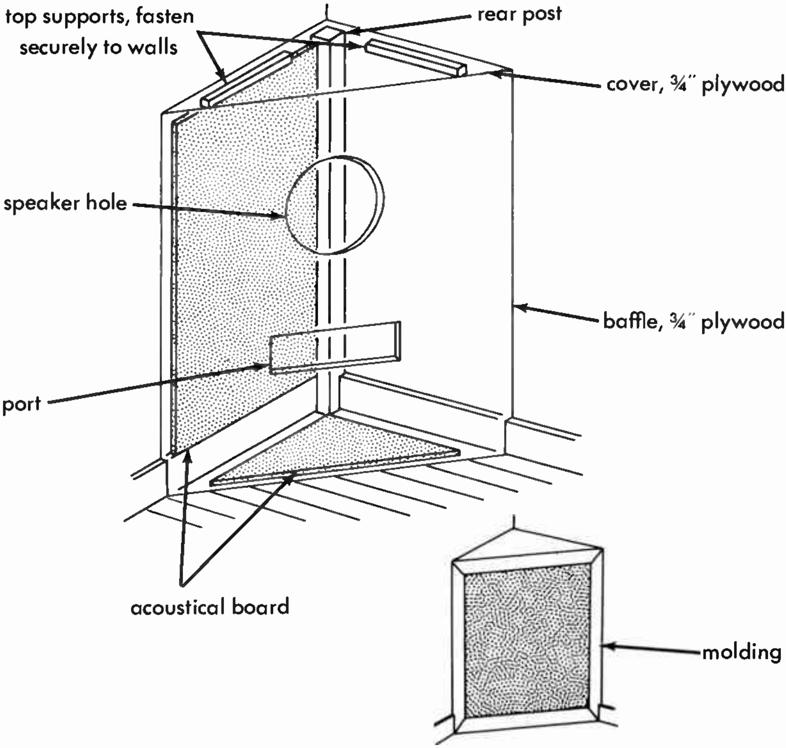


FIGURE 24. THE SIMPLEST OF CORNER ENCLOSURES—WALLS AND FLOOR FURNISH THREE SIDES OF ENCLOSURE (BASS REFLEX)

See specifications on facing page.

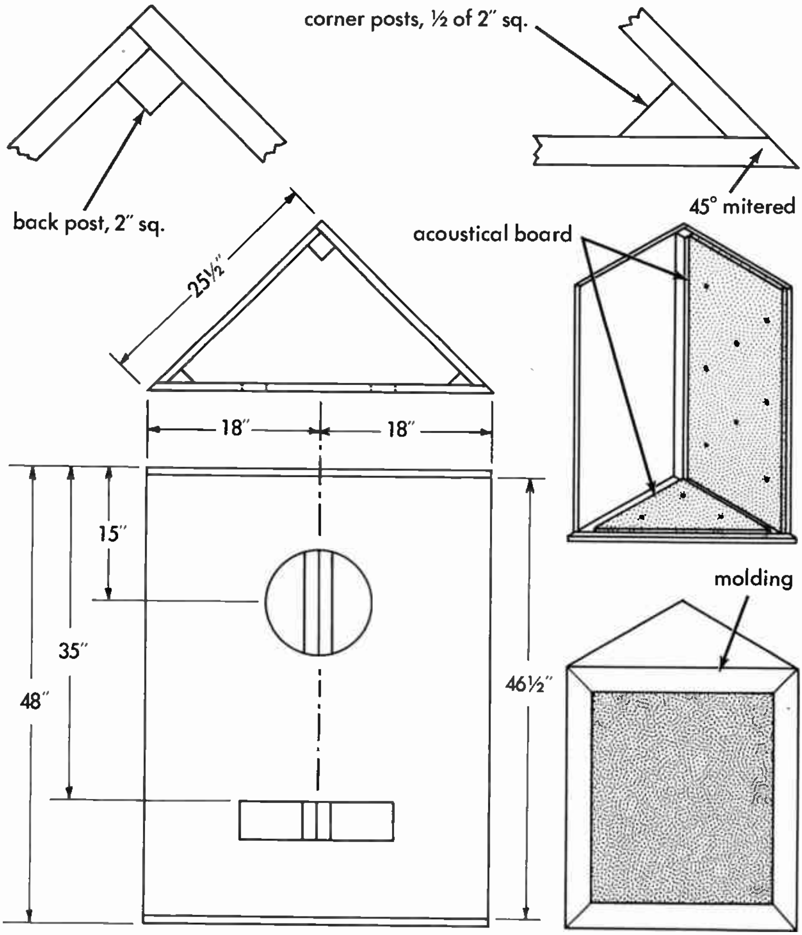


FIGURE 25. PLANS OF A MOVABLE CORNER ENCLOSURE FOR 12-INCH SPEAKERS (BASS REFLEX)

See specifications on facing page.

The Wall Placement

It is usually easier to integrate the speaker into the décor of your living space when it is installed in or along a wall. However, overcoming the resonance of parallel walls and dispersing the high frequencies is more difficult with wall placements than with corner placements. Figure 26 shows the floor plan of a room with a wall placement. Notice that the speaker is placed along the short wall of the rectangular room, and as far from the listening positions as possible, to permit maximum scattering of the high-frequency beam. Placing the speaker away from the center of the wall helps prevent standing-wave resonance due to parallel walls. Important considerations of a wall placement and their effects are given in the following table.

SPECIFICATIONS FOR FIGURE 25

Use ¾ inch plywood for all panels. All joints should be well glued and fastened with screws, except top cover which should be secured with wood screws so that it can be removed. Fasten speaker with 4 or more ¼ inch machine screws and nuts (diameter of speaker hole is 10¼ inches). Sheets of acoustical material (preferably Fiberglas) should be glued with linoleum cement and secured by wood screws and flat washers. Cover the baffle with a loose-weave material (such as burlap) and fasten molding strips in place. See Appendix A for size of speaker port dependent upon cone resonance.

CONSIDERATIONS	ACOUSTICAL EFFECTS
Selecting the wall	Select the short wall of a rectangular room to obtain as much length of travel for the sound as possible. Choose the wall that faces the most irregular and absorbent wall. In Figure 26 the speaker faces the fireplace and the bookcase and is placed as far away from the listening positions as possible.
Scattering the high frequencies	The concentrated beam of high frequencies from the speaker should be scattered by hard objects. In Figure 26 this is accomplished by a library table and a lamp.
Acoustical treatment	The bookcase, fireplace, and brick facing in Figure 26 are good treatment of the wall opposite the speaker. Heavy drapes for the windows are a must. Carpeting on the floor and acoustical treatment of the ceiling would make the room acoustically very good.

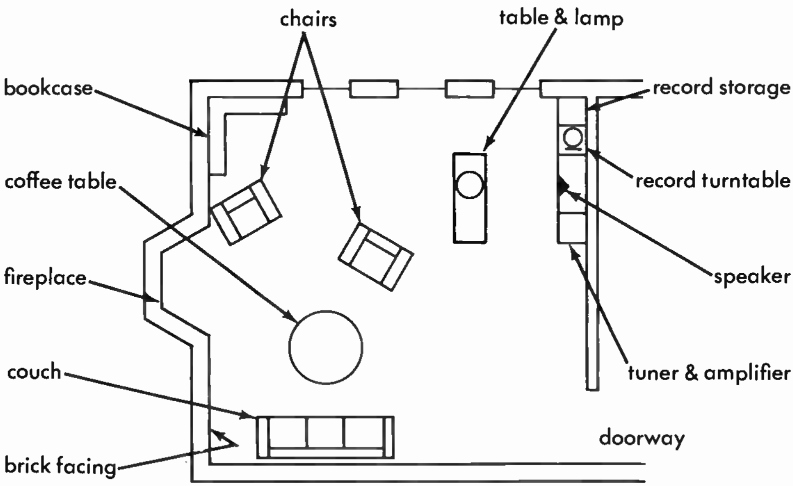


FIGURE 26. FLOOR PLAN SHOWING A WALL PLACEMENT OF SPEAKER

Wall Mountings and Enclosures

There are two ways of mounting and enclosing wall-placed speakers: mounting the speaker directly in the wall or mounting the speaker in an enclosure that is placed against the wall. When mounting the speaker in the wall itself, the wall chosen must be a partition so that the room behind it can absorb the back radiations of the speaker. For example, the speaker shown in Figure 26 could be mounted in the wall instead of in the fixed enclosure. The room that absorbs the back radiations of the speaker should be closed off from the listening room to avoid the severe distortions that would exist if both the front and back sound from the speaker were heard. Details and specifications for wall mountings are given in Figure 27.

There are many variations for speaker enclosures designed to be placed against walls. The usual arrangement is to have the speaker enclosure matched with the cabinetry containing the record changer, audio amplifier, radio tuner, and perhaps record storage and book shelves. Such arrangements are, of course, custom installations and left to individual tastes. Those planning to build their own homes should instruct their architects to have their installations built in. An example of a built-in installation is shown in Figure 32.

The problem of a speaker enclosure for a complete wall installation can be solved either by incorporating a commercial enclosure or by building your own enclosure into the over-all installation. Commercial enclosures for this purpose range in price from $20 for a prefabricated kit to $100 for an assembled enclosure. Examples of these commercial enclosures are shown in Figure 28. When you build your own speaker enclosure or have your architect include it in the plans for your new house, there are certain requirements that should be adhered to for optimum results. Specifications for a simple wall enclosure are given in Figure 29.

Multiple-Speaker Enclosures

The enclosures discussed up to this point have been for mounting single units such as the single-cone speaker or the coaxial speaker. However, as discussed in Chapter 2, multiple-speaker units can be used to achieve a richness and a coverage of the audio frequency range that is not possible with single-unit speakers.

Like single speakers, multiple-speaker units can be placed in a corner or along a wall. The acoustical considerations for wall and corner placements of single speakers also apply for multiple-speaker systems. A simple but effective multiple-

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SPECIFICATIONS FOR FIGURE 27

Notch wall joists to receive ¾ inch plywood baffle; secure baffle by gluing and fastening with 3 inch wood screws.

Fasten speaker with 4 or more machine screws; use ¼ inch screws for 12-inch and 15-inch speakers and number 8 screws for 8-inch speaker.

Diameter of speaker openings: 15-inch speaker, 13 inches; 12-inch speaker, 10¼ inches; 8-inch speaker, 6⅞ inches.

Back opening similar to front opening must also be constructed; ½ inch plywood may be used in place of the ¾ inch required for front.

Both front and back openings should be covered with a material of loose weave to protect speaker from dust. Walls should be re-plastered so that the baffle board is securely bonded to plastered surface of wall.

Pictures may be mounted on a slide to cover speaker openings when speaker is not in use.

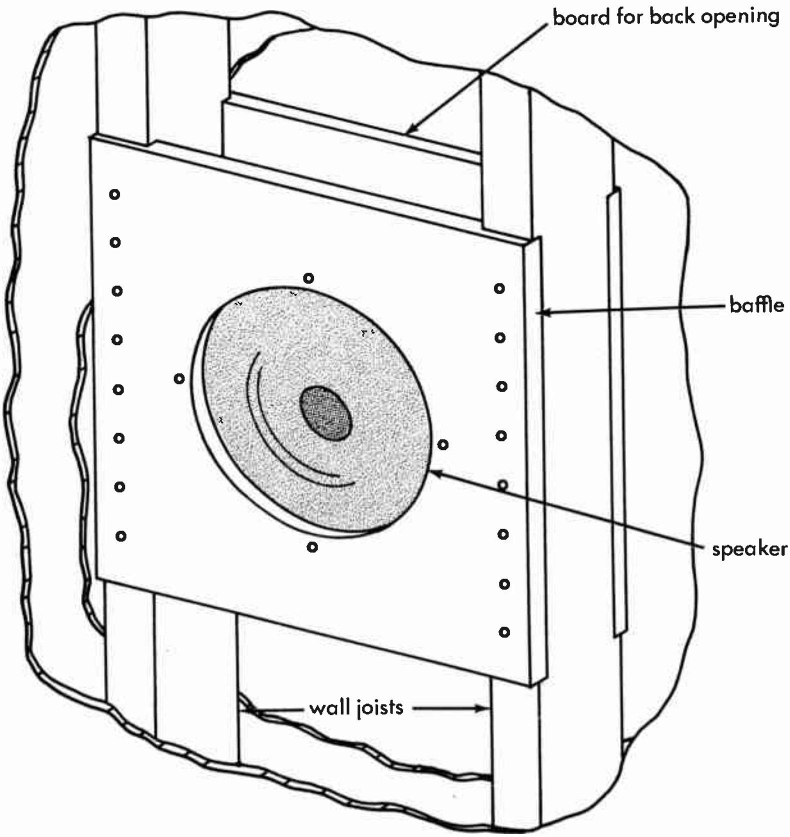
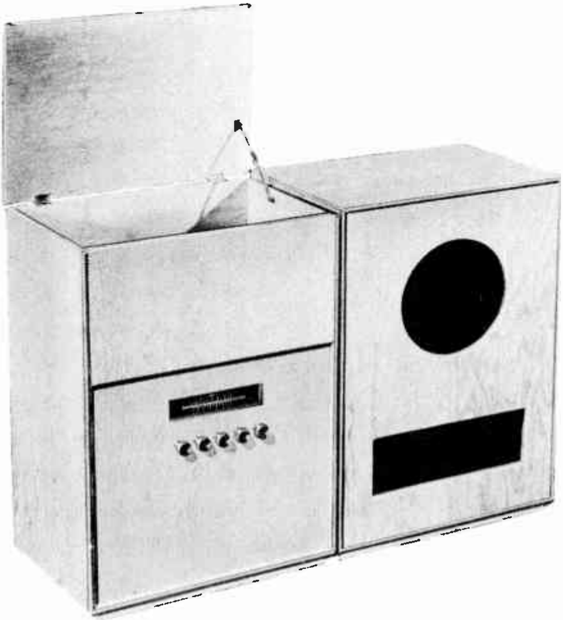


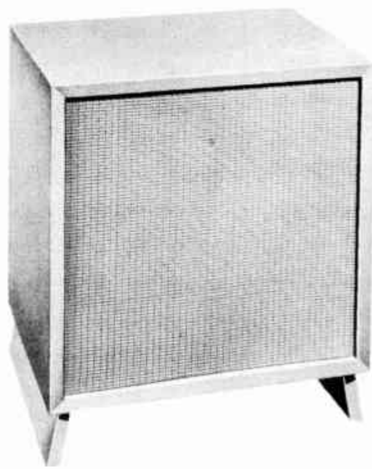
FIGURE 27. MOUNTING A SPEAKER IN THE WALL

See specifications on facing page.



CABINART KIT MODEL
8112 *(above)*

Bass-reflex type of enclosure (shown with matching equipment cabinet) for 12-inch speakers.
Dimensions: 33⅓ inches high, 21¾ inches wide, 15¼ inches deep.



R-J SPEAKER ENCLOSURE
(right)

For 12-inch and 15-inch speakers.
Dimensions: 20 inches high, 20 inches wide, 16 inches deep.
Finish: Mahogany or blond.
Legs are removable.

FIGURE 28. TWO COMMERCIAL ENCLOSURES FOR WALL INSTALLATIONS

speaker enclosure can be made by using the same bass-reflex enclosures specified in Figures 24, 25, and 29. When using these enclosures the woofer is mounted in the normal speaker hole. The tweeter is placed above the woofer. The crossover network should be securely mounted to the bottom of the enclosure and interconnected as discussed in Chapter 6.

A wall mounting may also be used for two-way multiple-speaker systems. Both the woofer and tweeter should be mounted by using a baffle board fastened to the wall joists as specified in Figure 27. Mount the crossover network in a convenient location. Some two-way multiple-speaker systems come in matched units with the woofer, tweeter, and cross-over network all mounted and interconnected on a single baffle board. Such matched units simplify the task of making a wall installation.

A simple bass-reflex enclosure can be made for a three-way multiple-speaker system (woofer, mid-range speaker, and tweeter). The plans and specifications for this enclosure are given in Figure 30.

You can buy a multiple-speaker system that has the speakers completely interconnected and mounted in a specially designed enclosure. These complete units, examples of which are shown in Figure 31, limit you to accepting the proffered cabinet styling. However, you are assured of a system whose enclosure is tailor-made to the speakers used. Furthermore, if you feel that you must have something more elaborate than the straight two-way or three-way system, you should get a complete unit. The problem of effectively enclosing and matching multiple-speaker systems with extra woofers and tweeters is complex and requires the skill of a trained engineer. The price of complete units ranges from about $160 for a simple woofer and tweeter combination to over $600 for four- and five-speaker combinations.

Installation of the Tuner, Amplifier, and Turntable

When it comes to installing the radio tuner, audio amplifier, and phonograph turntable, you face few problems other than exercising some ingenuity in obtaining an installation that is both convenient and aesthetically pleasing. Amplifiers and tuners may be mounted in any position. The units can be placed just about anywhere that suits your particular fancy—in a bookcase, in an end table, or even in an antique sideboard. Examples of complete installations are shown in Figures 32 and 33.

There are, however, some mechanical requirements that must be met to insure dependable operation. These are listed in the table below.

SPECIFICATIONS FOR FIGURE 29

Use ¾ inch plywood throughout; glue joints with casein glue and secure with wood screws (rear panel is fastened only with screws, so that it can be removed).

Mount speaker with 4 or more machine screws and nuts; use ¼ inch screws for 12-inch and 15-inch speakers, number 8 screws for 8-inch speakers.

Volume of enclosure is dependent upon speaker size; see Appendix A. Best results are obtained with a maximum baffle area and a minimum depth of enclosure (12 inches minimum for 12- and 15-inch speakers, 9 inches minimum for 8-inch speakers).

Diameter of speaker openings: 15-inch speaker, 13 inches; 12-inch speaker, 10¼ inches; 8-inch speaker, 6⅞ inches.

Port is centered at least 12 inches below edge of speaker. See Appendix A for port area dependent upon cone resonance.

Fasten acoustical board with linoleum cement and secure with large washers and wood screws.

Cover baffle with material of loose weave and fasten with suitable molding.

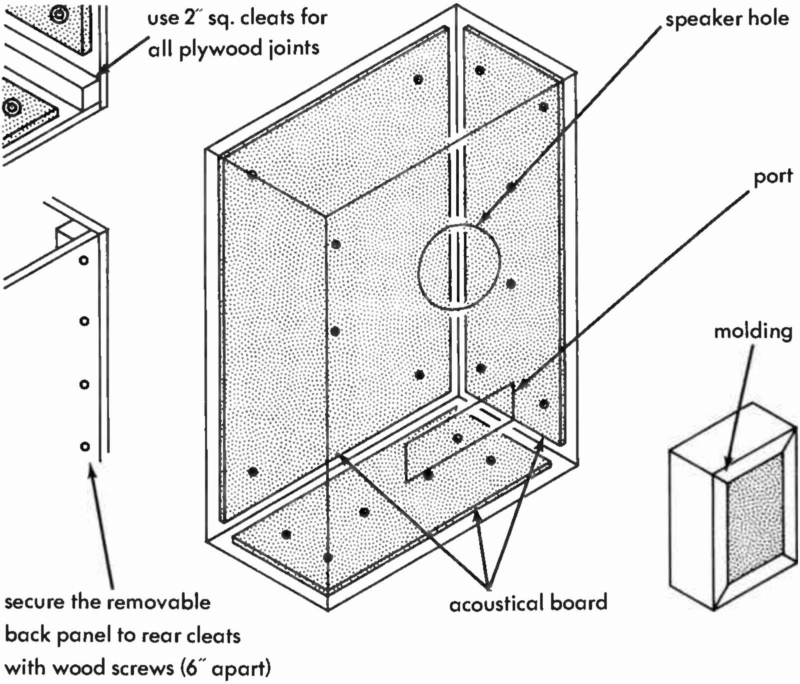


FIGURE 29. REQUIREMENTS FOR A SIMPLE WALL ENCLOSURE (BASS REFLEX)

See specifications on facing page.

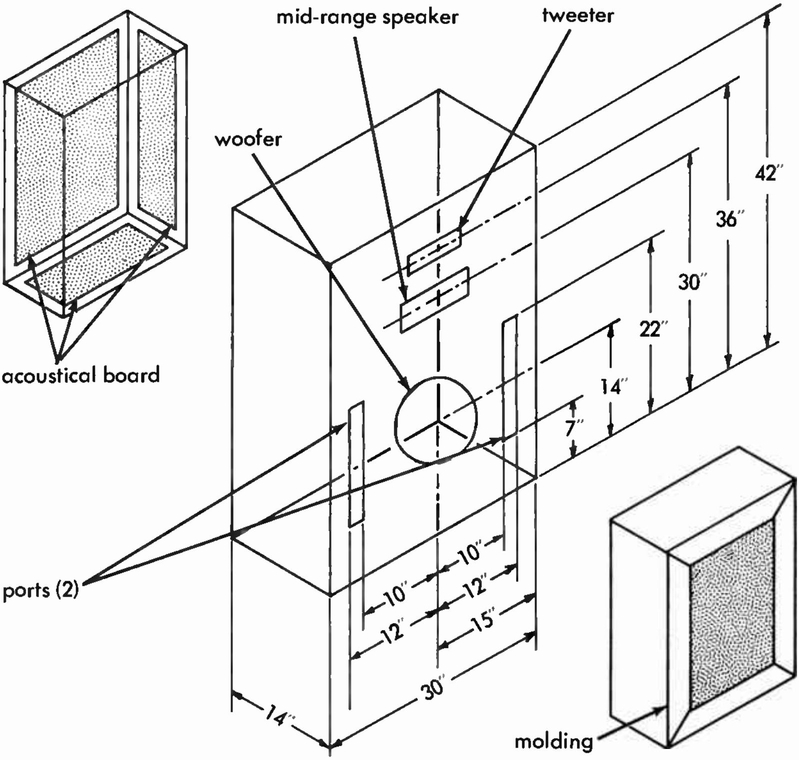


FIGURE 30. A BASS-REFLEX ENCLOSURE FOR A THREE-WAY SYSTEM (12- OR 15-INCH WOOFER)

See specifications on facing page.

COMPONENT	INSTALLATION REQUIREMENTS
Phono turntable	(a) Should be mounted level on simple rubber shock mounts, usually supplied by the manufacturer. (b) Sufficient ventilation should be provided for drive motor. Wooden housing for underside of the turntable should be open to the room. Although there is little danger of a turntable overheating, ventilation does no harm. (c) Your turntable should have as much protection from dust as possible. (d) The turntable mounting should not be

SPECIFICATIONS FOR FIGURE 30

Use ¾ inch plywood throughout; glue joints with casein glue and secure with wood screws; fasten rear panel with screws only, so that it can be removed (see Figure 29 for details of joints and rear panel fastening).

Cut woofer, mid-range speaker, and tweeter openings to fit.

Use machine screws and nuts for securing speaker units to baffle board; ¼ inch screws for woofer, number 8 screws for mid-range and tweeter.

Fasten acoustical board with linoleum cement and secure with large washers and wood screws.

Mount crossover networks inside enclosure on left side wall; secure with ½ inch wood screws. If speaker gain controls are used, mount where convenient—either side, top, or front of enclosure. Interconnect speaker units, crossover networks, and gain controls (if used) as discussed in Chapter 6.

Cover baffle with material of loose weave and fasten with suitable molding.

Port openings specified in drawing will tune enclosure for woofer with a cone resonance of approximately 45 c.p.s. For the combined port area needed to tune enclosure for other cone resonances, see Appendix A.

COMPONENT	INSTALLATION REQUIREMENTS
	a part of, or rigidly attached to, the speaker enclosure. This prevents speaker vibrations from affecting the phono pickup.
Radio tuner and audio amplifier	(a) Proper ventilation of the space containing the tuner and amplifier is important to insure stable operation and long life of the electronic components. The housing should be open to the room during operation. Using a thermometer, measure the temperature near the tuner and amplifier after half an hour of operation. It should be no more than 15° above room temperature. (b) Both tuner and amplifier should be securely mounted to protect them from jarring. (c) Controls should be free to turn without binding.

Wiring

The physical act of wiring the components together is relatively simple. The primary prerequisite is the ability to use a soldering iron. If you have had some experience, so much the better; but if you are completely inexperienced, do not become discouraged. The art can be quickly mastered.

The technique of good electrical soldering is based upon two principles: (1) using rosin-core solder, which automatically cleans away the oxide coating of the wire and insures a good connection, and (2) making sure that you heat the work enough to permit the bond between the solder and the wire to take place. Practice making a few soldered connections in the following manner:

1. Remove half an inch of insulation from the ends of the wire to be joined; if the wire is excessively corroded or has an enamel coating, scrape with a knife.

UNIVERSITY MULTI-SPEAKER SYSTEM ("THE DEAN")

Folded-horn enclosure for corner placement. Components: a tweeter, a mid-range speaker, a 15-inch woofer, and matching networks.
Dimensions: 36¼ inches high, 36 inches wide, 22 inches deep.
Finish: Cherry or blond mahogany.

UNIVERSITY MULTI-SPEAKER SYSTEM ("THE CLASSIC")

Folded-horn enclosure for wall placement Components: a tweeter, a mid-range speaker, a 15-inch woofer, and matching networks.
Dimensions: 34½ inches high, 40½ inches wide, 24¾ inches deep.
Finish: cherry or blond mahogany.

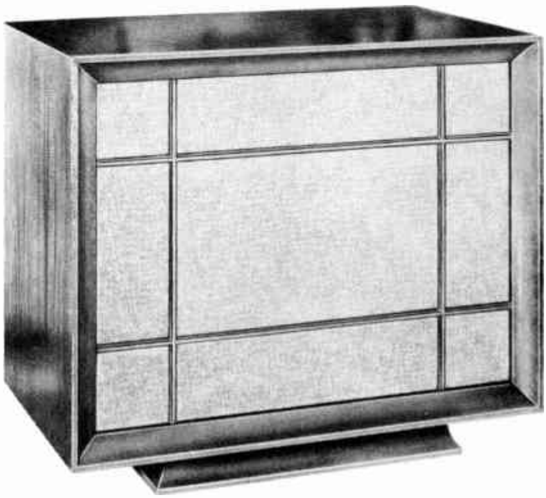


FIGURE 31. TWO COMPLETELY ASSEMBLED MULTIPLE-SPEAKER SYSTEMS

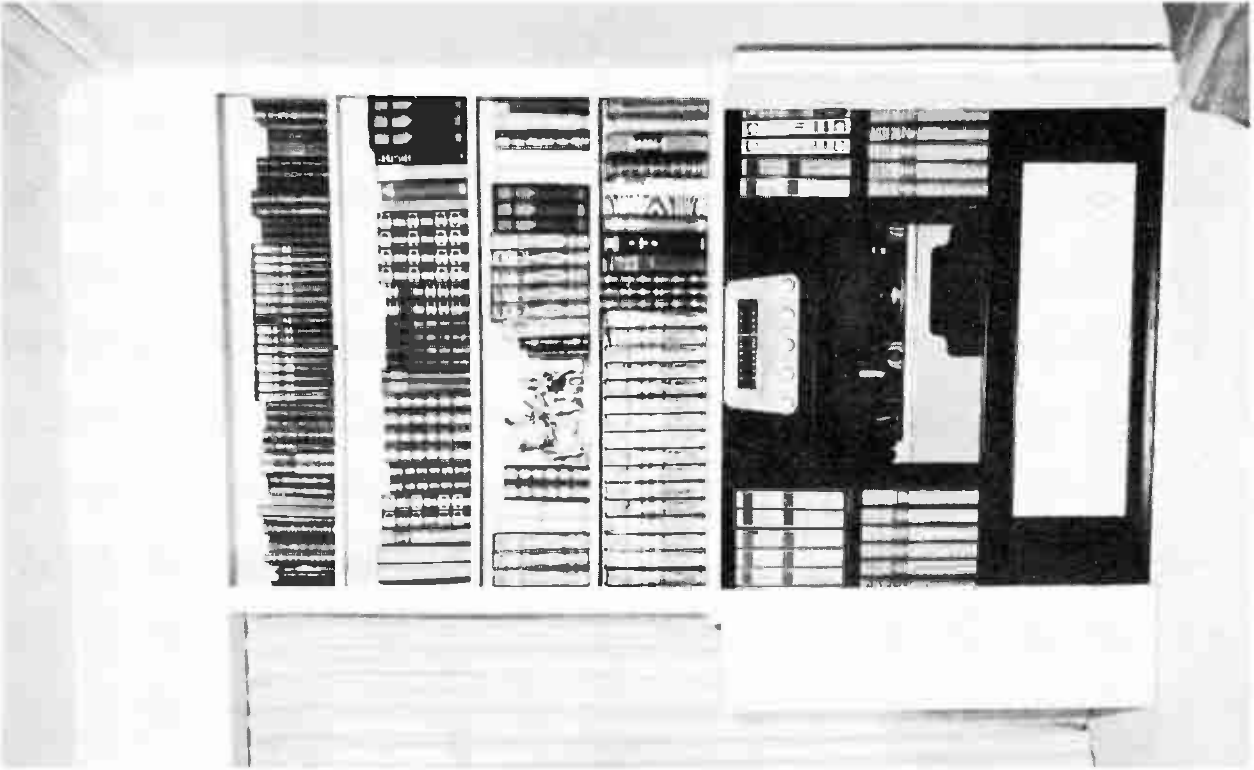


FIGURE 33. A WALL INSTALLATION

Here is a specially constructed wall installation. From right to left: television, audio amplifier, AM-FM tuner, record player, speaker enclosure (with bamboo grille). Notice the acoustical board mounted on underside of cover for record player cabinet. This helps reduce mechanical noise of record changer. (Courtesy of Douglas Fir Plywood Association)

FIGURE 32. A BOOKCASE INSTALLATION *(facing page)*

Here is a compact bookcase installation with all operating controls at the AM-FM tuner. The associated audio amplifier is mounted in the speaker enclosure below. This particular installation has both a record changer and a plain turntable mounted above speaker enclosure. When a record player is next to the speaker-enclosure special care is required to isolate speaker vibrations from record player. (Courtesy of David Bogen Company, Incorporated)

2. Twist the ends of the wire together, firmly but not with such force as to fracture the wire.
3. Make sure that the tip of your soldering iron is clean and properly tinned (coated with a shiny surface of solder). Tinning is accomplished by filing the tip of a heated iron until clean copper is exposed and then quickly applying rosin-core solder to the exposed copper before it has a chance to oxidize. Wipe away excess solder with a cloth; the faces of the tip should have a shiny silver coating.
4. Melt a small drop of solder on one face of the iron's tip and place this against the connection to heat the twisted wire. After a moment apply the rosin-core solder to the twisted wire; when the wire is hot enough, the solder will melt over the joint. Please note that it is important to apply the solder to the work and not to the hot tip. This insures a good connection since the flux contained in the core of the solder, and the solder itself, will not melt until the work is hot enough for a good bond.
5. Melt off excess solder from the joint so that the twists of the wire are visible. An excessive amount of solder does not necessarily indicate a good connection. Test by pulling the wire. If the connection does not hold, it is probably a "cold-solder" bond. If so, resolder the connection, making sure that the twisted wires are well heated before applying the solder.

When laying out the wiring of your installation, be neat. The interconnecting wires should be as short as possible to reduce the chance of stray pickup and line losses. Never leave excess wire coiled up; cut the wire to its proper length, leaving only the slack required for easy removal of the components from their cabinets. Most important of all, of course, is using the proper type of wire for the various interconnections as specified in Chapter 6.

The Purchase

When you have reached the point of mentally plugging in your soldering iron, you are ready to dig out your checkbook and take the plunge. Decide upon the cost of your system and head for the dealer. If there are no hi-fi dealers near by, you can obtain your system by mail order. Select two or three of the dealers listed in Appendix E of this book and write for their catalogues. You will find that the catalogues of the larger dealers offer a wide selection of components with specifications well spelled out.

As a further aid in helping you purchase your hi-fi system, low-cost, medium-cost, and high-cost systems are discussed in the following chapters. The components mentioned in these chapters are typical of many that you can purchase. Within a given price range, similar components of different manufacturers are basically the same. If you prefer the amplifier of one manufacturer because of some special feature, then by all means purchase it. In the final analysis, any purchase you make should be based upon an analysis of the specific component as set forth in the preceding chapters.

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LOW-COST SYSTEMS ($150 AND LESS)

Complete Low-Cost Systems

You can actually buy a complete hi-fi system (radio tuner, audio amplifier, record player, and speaker) for approximately $150, although this is as low as you can go and still get true hi-fi performance unless you purchase used components.

When you buy a low-cost system you are getting hi-fi plain and simple—no refinements but a quality of sound reproduction which, while not the best by hi-fi standards, far exceeds the conventional radio-phonograph combination. The audio amplifier should have approximately 10 watts of rated power output and separate bass, treble, and volume controls. Your speaker will be a single-cone unit mounted in the most economical way (i.e., in the wall or in an enclosure that is completely homemade or assembled from a kit).

When selecting the pickup cartridge for a low-cost installation, do not overlook crystal pickups (the so-called ceramic cartridge is also a crystal). Since crystal pickups are not as sensitive as magnetic pickups, they do not "expose" the imperfections (wow, rumble, vibrations) of inexpensive turntables and record changers. Also, crystal pickups work well with amplifiers that do not have record compensators because, as discussed in Chapter 4, they provide an average amount of compensation for all records. The good crystal or ceramic pickup is priced just below the inexpensive magnetic pickup.

Listed below are two complete low-cost systems typical of many you can purchase for under $150. Approximate prices at the time of this printing are given.

A. Audio amplifier: Grommes model LJ-4, 10 watts of output power with built-in preamplifier	$ 39.00
Speaker: General Electric model 1201, 12-inch	20.00
Radio tuner: Granco model T-160	35.00
Record changer: V-M 1200, 3-speed with dual ceramic pickup cartridge (sapphire styluses)	31.00
Total cost (material for enclosure extra)	$125.00
B. Audio amplifier: Challenger HF8-A, 8 watts of output power with built-in preamplifier and phono compensator	$ 40.00
Speaker: G.E. 1203, 12-inch	14.00
Radio tuner: Harman-Kardon model A-200, AM-FM	70.00
Turntable: General Industries model DSS, 3-speed	15.00
Pickup arm: G.E. model UPX-006, with dual magnetic pickup cartridge (sapphire styluses)	11.50
Total cost (material for enclosure extra)	$150.50

Modified Low-Cost System

If you are willing to exclude the hi-fi tuner from your low-cost system, you can get a better speaker and record player for your $150. This is especially advisable if your taste runs to recorded music. The importance of your turntable and pickup in obtaining good sound reproduction and preserving your record collection cannot be overemphasized.

By excluding a hi-fi tuner from your original purchases, you do not have to exclude radio broadcasts as a source of sound intelligence for your hi-fi system. As previously mentioned, the front-end or radio-frequency tuning and detection sections of your existing AM or FM radio can be used with your audio amplifier and speaker. For a few dollars a radio repairman will make the necessary connections. Specify the type of coaxial connection required by the radio input of your audio amplifier as well as the length of coaxial cable needed between radio and amplifier. I think you will find that using your existing radio is a good compromise until your finances permit buying a regular hi-fi tuner.

Given below are two examples of modified systems that you can purchase for about $150. System A features a record changer with a magnetic cartridge that has a diamond stylus for LP's and a sapphire stylus for 78's. System B has a manual record player with the same magnetic cartridge as System A. Approximate prices at the time of this printing are given.

A. Audio amplifier: Bell model 2122, 10 watts of output power with built-in preamplifier and phono compensator	$52.00
Speaker: Stephens model 112FR, 12-inch	32.00
Record changer: Garrard model 121, 3-speed (minus pickup cartridge)	43.00
Pickup: G.E. model RPX-052, dual magnetic (diamond stylus for LP's and sapphire stylus for 78's)	23.00
Total cost (material for enclosure extra)	$150.00

B. Audio amplifier: Harman-Kardon model PC-200, 10 watts of output power with built-in preamplifier and phono compensator	$ 55.00
Speaker: Wharfedale model W/10/CSB, 10-inch	40.00
Record player: Garrard model T, 3-speed manual with pickup arm (minus pickup cartridge)	32.00
Pickup: G.E. model RPX-052, dual magnetic cartridge with diamond stylus for LP's, sapphire for 78's	23.00
Total cost (material for enclosure extra)	$150.00

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MEDIUM-COST SYSTEMS ($200 TO $500)

WHEN YOU SPEND between $200 and $500 you are getting a medium-cost system (this range is considered medium-cost because you can spend over $1,000 for a system). Actually, a medium-cost system gives you high fidelity with really good sound reproduction at fairly moderate cost. The sound reproduction is almost the best. It is not the best (the high-cost systems discussed in Chapter 10 achieve this), but *almost* the best. The distinction is a subtle one based on the law of diminishing return. The more you spend on a hi-fi system, the smaller the increase in the quality of sound reproduction.

When you set out to assemble a medium-cost system, you will find a multitude of components from which to choose. Before you begin your price-versus-performance evaluation of specific components, you should think about the over-all nature of the system that will best satisfy your particular requirements. What is the total amount you are willing to spend? Do you want a system that stresses recorded music or broadcast programs? Do you want a radio tuner that mounts all the operating controls of your system? Are you willing to build your own speaker enclosure?

There is nothing difficult or complex about the procedure of selecting a medium-cost system, but familiarity with some of the different systems should simplify the task. The rest of this chapter discusses different medium-cost systems. Typical hi-fi equipments and their costs are given.

A. Audio amplifier: Pilot AA-903, 10 watts of output power with built-in preamplifier and phono compensator	$ 70.00
Speaker: University 6201 coaxial, 12-inch, supplied with variable balance control	44.00
Radio tuner: Harman-Kardon model A-200 AM-FM	70.00
Record changer: Webcor model 1631-27, 3-speed (minus pickup cartridge)	41.00
or Turntable: Garrard model T, 3-speed manual with pickup arm (minus pickup cartridge)	32.00
Pickup: G.E. RPX-052 dual magnetic with diamond stylus for LP's and sapphire for 78's	23.00
or Pickup: G.E. RPX-050 dual magnetic with sapphire styluses for both LP's and 78's	8.50
Total cost: record changer with G.E. RPX-052	$248.00
G.E. RPX-050	233.50
Total cost: manual player with G.E. RPX-052	241.00
G.E. RPX-050	224.50

(Material for enclosure extra)

System A is an example of what might comprise a moderate-cost, general-purpose installation. Good radio listening with complete coverage of FM and AM stations is provided. The record changer and the manual player specified, while not the best, are adequate. The magnetic cartridge, on the other hand, is a very sensitive type of pickup. The choice between sapphire and diamond styluses is arbitrary. If you have mostly LP's and can afford the extra cost, I would suggest the diamond and sapphire combination. Since a diamond stylus will outlast at least four or five sapphire styluses, it will cost you no more in the long run, and you will gain the assurance of minimum record wear. However, since the styluses of G.E. cartridges can be replaced singly, you can start with a sapphire for LP's and switch to a diamond later without having to discard the sapphire used for 78's.

The University 6201 coaxial speaker can be inexpensively mounted in the wall as shown in Figure 27 or in an enclosure such as those specified in Figures 24, 25, and 29. If you don't feel up to making your own enclosure, you can buy any number of ready-made enclosures in various contemporary or traditional styles. However, purchasing a ready-made enclosure will cost you another $30 to $100.

B. Audio amplifier: Scott model 99-B, 22 watts of output power with built-in preamplifier and phono compensator	$100.00
Radio tuner: Scott model 330 AM-FM	170.00
Speaker: Wharfedale Super 12/CS/AL 12-inch	75.00
Speaker enclosure: R-J enclosure for 12-inch speakers (unfinished)	30.00
Record changer: Garrard model RC-98, 3-speed (minus pickup cartridge)	65.00
Pickup cartridge: G.E. RPX-052, dual magnetic with diamond stylus for LP's, sapphire for 78's	23.00
Pickup cartridge: G.E. RPX-053, dual magnetic with diamond styluses for both LP's and 78's	34.00
Total cost (G.E. RPX-052)	$463.00
(G.E. RPX-053)	474.00

System B illustrates what can go into a general-purpose installation when you are willing to spend close to $500. The AM-FM tuner chosen, one of the best you can buy, has a particularly good AM section in addition to a fine FM section. A good AM section for an AM-FM tuner is particularly important in areas that do not have complete FM coverage. The Wharfedale 12-inch speaker, although a single-cone unit, is a really fine performer and well suited for use in the compact R-J enclosure. The 3-speed record changer is one of the best available. If you have mostly LP's, you should use the G.E. RPX-052 magnetic pickup with the combination sapphire and diamond styluses. If you have a great many 78's in addition to LP's, it is not a bad idea to use the G.E. RPX-053 with two diamond styluses.

C. Radio tuner: Pilot model AF-825 AM-FM, with built-in phono preamplifier and phono compensator; mounts all system controls on its front panel	$130.00
Audio amplifier: Pilot model AA-410 power amplifier (no controls), 15 watts of output power	50.00
Speaker: Stephens model 122AX, 12-inch coaxial	54.00
Turntable: Rek-O-Kut model LP-743, 3-speed, pickup arm not included	60.00
Pickup arm: Audax 12-inch	19.00
Pickup cartridge: Audax model DL-6 dual magnetic with diamond stylus for LP's and sapphire for 78's (turnover type cartridge with two separate styluses)	41.00
Total cost (material for enclosure extra)	$354.00

System C is an example of one that locates all operating controls at the front panel of the tuner. The Rek-O-Kut turntable and the Audax pickup arm provide the record enthusiast with a fine manual record player at reasonable cost. No enclosure has been specified for the coaxial speaker. There is the obvious choice of installing the speaker in the wall (for about $5), making your own enclosure (for about

$15), buying a kit (for about $25), or buying a ready-made enclosure (for $50 and up).

D. Audio amplifier: Bogen model DB90 with 20 watts of output power, built-in preamplifier and phono compensator	$ 99.00
Speaker: Electro-Voice model 116 Two-Way System, 15-inch woofer, tweeter, and crossover network all connected and mounted on a baffle board	118.00
Radio tuner: Browning model L-300 FM	88.00
Turntable: Rek-O-Kut model CVS-12, 3-speed (continuously variable)	85.00
Pickup arm: Pickering model 190	32.00
Pickup cartridge: Pickering model 260 magnetic, with diamond styluses for both LP's and 78's (turnover type of cartridge with two separate styluses)	60.00
Total cost (material for enclosure extra)	$482.00

This example emphasizes quality sound reproduction for recorded music. The Rek-O-Kut turntable and the Pickering pickup arm and cartridge will provide accurate rotation and minimum record wear. The Electro-Voice two-way speaker system and the Bogen 20-watt amplifier furnish full-range reproduction with plenty of reserve power and a minimum of distortion. The two-way speaker system, equipped with its own baffle board, is ideal for a wall mounting. However, it may also be mounted in an enclosure that is suitable for 15-inch speakers.

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HIGH-COST SYSTEMS (OVER $500)

IF YOU ARE willing to spend over $500 for a hi-fi system you can buy equipment that, in addition to providing excellent sound reproduction, is carefully manufactured with the finest materials. The quality and workmanship of expensive hi-fi components are undeniable. Do high-cost systems furnish better sound reproduction than the medium-cost systems? Generally speaking, yes; but with some reservations. First of all, it is questionable whether the costliest audio amplifiers are better than the medium-cost amplifiers. It is no reflection on the expensive amplifier, but, quite frankly, a medium-cost amplifier with 15 watts of output power, a flat response from 20 to 20,000 c.p.s., a hum level 70 db below rated output, and distortion ratings below the audible level, is more than adequate. What you get when you buy an expensive amplifier is assurance of continuing high-quality performance that only the best electrical parts can give.

The ability of high-cost radio tuners to perform better than medium-cost tuners is also somewhat questionable. However, in this connection it is important to remember that radio tuners (FM tuners in particular) are delicate devices that lose alignment and become poorer and more erratic performers the more they are used. Employment of the best electrical parts in the more expensive tuners retards this deterioration process. If you can afford an expensive tuner, it is perhaps the best bet for the long run.

Any increase in performance of high-cost systems over medium-cost systems can usually be attributed to the use of the more expensive speakers and record players. These units are the weak sisters of a hi-fi system. With low- and medium-cost systems, the amount spent on speakers and record players is limited by the necessity of acquiring a satisfactory amplifier and tuner. In discussing high-cost systems, however, I have opened wide our mythical pocketbook. If you want to, you can actually spend as much as $250 for a turntable and pickup, and as much as $700 for a de luxe speaker system. How much would this increase the quality of sound reproduction? It is impossible to say exactly. It is more or less true, however, that the more you spend for hi-fi equipment, the smaller is the increase in the quality of sound reproduction. At what point you snap shut the pocketbook is something you have to decide for yourself.

Listed below, with comments, are two examples of high-cost systems. Approximate prices at the time of this printing are given.

A. Audio amplifier: McIntosh models MC-30 (amplifier) and C-8 (preamplifier), rated at 30 watts, with remote-control preamplifier and phono compensator	$232.00
Woofer: Jensen model P15-LL 15-inch	57.00
Crossover network: Jensen model A-61, 600-cycle (input from amplifier divides to woofer and network for mid-range and tweeter)	17.50

Crossover network: Jensen model A-402 (input from 600-cycle network divides for mid-range and tweeter)	8.50
Mid-range speaker: Jensen model RP-201	43.00
Tweeter: Jensen model RP-302 high-frequency	34.00
Balance control: Jensen ST-901 high-frequency (permits adjustment of tweeter volume)	4.00
Radio tuner: Altec model 304A AM-FM	186.00
Turntable: Rek-O-Kut model B-12H, 3-speed minus pickup arm	120.00
Pickup arm: Pickering model 190	32.00
Pickup cartridge: Pickering model 260 magnetic, with diamond styluses for both LP's and 78's (turnover type with two separate styluses)	60.00
Total cost (material for enclosure extra)	$794.00

This is by no means the most expensive hi-fi system you can purchase. The three-way speaker system listed offers the advantage of being easy to install since it is a matched system produced by a single manufacturer. It could be effectively mounted in the partition wall between two closed-off rooms or in an enclosure like that shown in Figure 30. The audio amplifier and radio tuner of this installation are examples of high-cost units that have been manufactured with quality materials for continued peak performance. The turntable, pickup arm, and cartridge will furnish the best in recorded sound reproduction with a minimum of record wear.

B. Audio amplifier: Fisher model 50-AZ, with 40 watts of output power (a basic amplifier with no controls)	$160.00
Control: Fisher model 80-C Master Audio Control, a separate audio input amplifier designed to work with the 50-AZ basic amplifier;	

contains preamplifier, phono compensator, audio selector switch and full-range bass and treble controls	100.00
Radio tuner: Fisher model 80-R AM-FM	170.00
Speaker system: Altec Lansing model 820C, 2-way system with one tweeter and two woofers; mounted and interconnected in a mahogany corner enclosure	525.00
Record changer: Garrard model RC-98, 3-speed (minus pickup cartridge)	65.00
Pickup cartridge: G.E. RPX-053 dual magnetic with diamond styluses for LP's and 78's	34.00
Total cost	$1,054.00

By far the most expensive item here is the speaker system, complete and ready to connect to the amplifier. Since the cost of the speaker system itself is a little over $300, it is apparent how much you are paying for the enclosure and the installation of the system. The audio amplifier, the audio control unit, and the tuner are matched units specially designed to work together. In this particular case, one of the best record changers has been listed.

• 11 •

ADDITIONAL SOUND SOURCES FOR HI-FI

Up to now we have considered only two sound sources for a hi-fi system, radio broadcasts and disk recordings. However, the versatility of an audio amplifier permits the use of other sound sources. Television, tape recording, electric guitar, microphone, sound movies—whatever the source of electrical sound intelligence may be, your hi-fi amplifier and speaker offer the best means for quality sound reproduction.

Magnetic Recorders

In many ways the magnetic recorder can be a worth-while addition to your hi-fi system. With it you will be able to record just about every conceivable sound—family gatherings of sentimental importance, sound tracks for home movies, music recitals by your family and friends, radio programs, or musical works from your friends' disk recordings.[1]

Although the magnetic recorder existed before World War

[1] The legality of recording broadcast material or copying disk records is not quite clear. However, such recording is apparently acceptable so long as it is done for personal use and not for profitable resale.

I, it did not reach its present state of perfection until the introduction of magnetic tape just after World War II. The earlier types of recorders, many of which are still in use, employed wire as the recording medium. The wire recorder, although it offers the advantage of continuous recording for long periods, records too small a range of audio frequencies for good music reproduction, develops wire snarls, has a slow rewind, and is generally inferior to tape. In the following paragraphs, only tape recording will be discussed, since it has become universally recognized as preferable for all but those few applications where compact equipment and excessively long recording time are valued above performance.

Tape Recording

Magnetic tape consists of a thin strip of plastic or paper that is coated on one side with a thin layer of minute particles of iron oxide. Sound intelligence is recorded on a moving strip of this tape by magnetizing the iron-oxide coating to a degree that varies in accordance with the frequency and amplitude of the sound intelligence. To accomplish this, the tape is drawn at a constant speed across the poles of an electromagnet through whose coiled wire are passed electrical variations representative of the sound to be recorded. To reproduce the sound thus recorded, the tape is drawn across the poles of a reproducing electromagnet at the same constant speed. This action causes the magnetized tape to induce electrical variations representative of the recorded sound intelligence in the coiled wire of the reproducing electromagnet. Needless to say, these electrical variations are amplified and applied to a speaker to reproduce the actual sound.

Once a tape has been recorded, it may be played over and over again without changing the quality of sound reproduction. How long will tape hold its recorded intelligence? Since tape is such a new recording medium, this question cannot be definitely answered. At the present time, properly stored tape has been kept in good condition for more than ten years. However, it must be emphasized that if you wish to keep tape in good condition for more than a year, it must be properly stored. The reel of recorded tape should be kept in a metal can to protect it from contamination by magnetic fields. Also, for best results, it should be stored in temperatures between 58° and 72° F. with a relative humidity of approximately 50 per cent. Proper temperature and relative humidity are important factors in minimizing "magnetic printing," or the transfer of sound intelligence between adjoining layers of tape wound on a reel.

The recorded intelligence on magnetic tape can be erased and the tape re-recorded practically indefinitely (i.e., as long as the tape remains physically whole). The theory of erasing is simple—the tape is first magnetized to the point of saturation and then demagnetized to a zero level. In practice, however, care must be exercised to insure a complete removal of the previous recording. The most effective means of erasing is "AC erasing." In AC erasing the tape is passed through an alternating magnetic field [2] of decreasing intensity. The magnetic field is at first very strong to saturate the tape and then becomes progressively weaker to demagnetize the tape. To cut cost, some of the less expensive recorders use a form of "DC erasing" in which the tape is first magnetized to saturation in one polarity and then slightly magnetized in the opposite polarity. Theoretically, this returns the tape to zero magnetization. However, this form of erasing results in a higher noise level upon recording.

When tapes have been recorded at a particularly high level of sound, they are harder to erase. Erasure of such tapes can sometimes be achieved by running the tape over the erasing

[2] At a fixed point in an alternating magnetic field, the polarity would be first north, then south, then north, then south, and so on.

head of the recorder for a second time. Failing this, a greatly overloaded tape can be effectively erased by a bulk erase. A bulk erase is a large electromagnet using 120-volt, 60-cycle power. When placed directly over the reel of tape and energized, it erases the entire reel.

TAPE RECORDERS (Figure 34)

There are two classes of tape recorders, the low-cost home recorder and the high-cost professional or semiprofessional recorder. Whereas you can buy a home recorder for about $75, the cheapest professional model you can buy costs around $300. The main distinction, aside from the price, is the range of audio frequencies that the instruments can effectively record and reproduce. The operating range of home recorders averages about 70 to 6,000 c.p.s. Professional machines are capable of operating over a range of 40 to 15,000 c.p.s.

Home machines are obviously not capable of reproducing high-fidelity sound. They are fine for recording voice and they do a fair job of recording music. However, you cannot expect them to record a symphonic work from your FM tuner and then reproduce the broadcast with its original quality. Home recorders generally use 7-inch reels and tape speeds of 3¾ or 7½ inches per second. A tape speed of 3¾ inches per second offers a longer recording, though poorer in quality, than the faster speed. Home recorders usually have a common recording and reproducing head (i.e., electromagnet). This is a cost-saving compromise: the best performance is obtained with separate recording and reproducing heads. When you buy what is commonly classified as a home tape recorder, you are getting an inexpensive recorder that is easy to operate, but offers limited performance.

If you want high-fidelity sound reproduction from recorded tape, you must have what is referred to as a professional tape recorder. Generally speaking, professional recorders are not as simple to operate as home recorders. Some study and practice are required to master the techniques of making quality recordings. Professional machines use separate recording and reproducing heads and require you to adjust the recording bias (i.e., the voltage level across the recording head) in addition to establishing the strength of the signal being recorded. An accurately adjusted bias (the home recorder has a nonadjustable bias) is important in recording with a minimum of distortion.

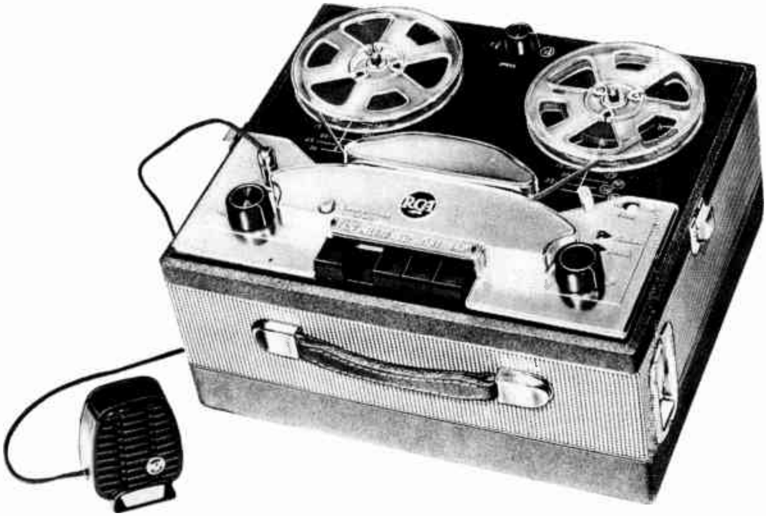
Professional machines are equipped with the fast tape speed of 15 inches per second required for recording audio frequencies from 40 to 15,000 c.p.s. Such a speed naturally reduces the continuous recording time for a reel of tape. However, professional machines can generally handle the large 10½-inch reels as well as the standard 7-inch reels. In addition to the fast speed, professional machines usually have the slower speeds of 7½ and 3¾ inches per second for longer continuous recordings with reduced performance.

Recorder Specifications

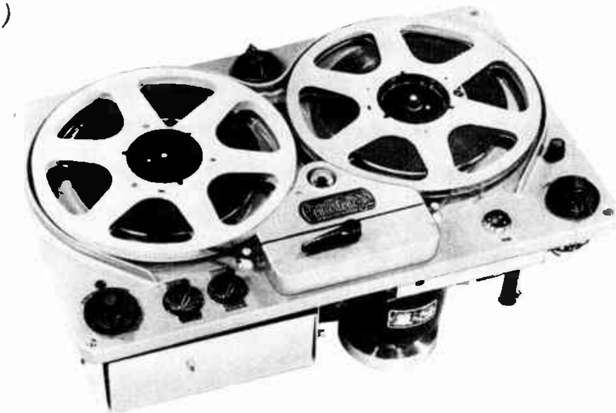
Listed and evaluated below are specifications and features of tape and tape recorders. This list is compiled not only to help prospective buyers but to supplement the preceding brief discussion on tape recorders.

TAPE AND TAPE RECORDERS—SPECIFICATIONS AND FEATURES	EVALUATION
Paper tape	A paper-based tape is not as strong and does not give as uniform recordings as plastic-based tape. However, it is cheaper and should be used when quality of recording is not vital.

TAPE AND TAPE RECORDERS—SPECIFICATIONS AND FEATURES	EVALUATION
Plastic tape	Plastic-based tape is preferred for most recordings. It has a very even and smooth surface required for uniform recordings.
Red oxide coating	Red oxide is the standard magnetic coating. It furnishes good recordings and is easy to erase.
Black oxide coating	Black oxide is a less commonly used magnetic coating. It has a slightly better response to high frequencies than red oxide, but is much harder to erase.
Physical properties of tape	To produce uniform recordings with a maximum of high-frequency response, tape should be thin (approximately .0015 inches thick), lie flat with no tendency to curl, and have uniform width with evenly dressed edges.
Weight of tape recorders	The over-all weight of a tape recorder is an important factor if you want your recorder to be portable.
Inputs	Tape recorders should have a minimum of two inputs: one for microphone and one high-impedance input for radio tuner or phono pickup.
Outputs	A tape recorder should have its own amplifier and speaker for use away from home. It should also have a high-impedance output (tapped off before its own audio amplifier and speaker) for connection to the input of your hi-fi audio amplifier.
Recording and reproducing heads	Unless otherwise specified, a common head is used for both recording and reproducing. Separate heads for recording and reproducing



An example of the home recorder that is portable and easy to operate. Home recorders are low in cost, but offer limited performance in that they do not record or reproduce the full audio range. (Courtesy of Radio Corporation of America)



An example of the more costly professional tape recorder. Professional recorders provide full-range recording and reproducing at the fastest tape speed. (Courtesy of Berlant Associates)

FIGURE 34. MAGNETIC TAPE RECORDERS

TAPE AND TAPE RECORDERS—SPECIFICATIONS AND FEATURES	EVALUATION
	give better performance. Some tape recorders have dual recording heads which permit the recording of two separate sound tracks on a single tape. This represents an obvious economy since any given reel of tape is now good for twice as much recording. However, recording a dual sound track practically prevents editing since one track cannot be edited without affecting the other.
Tape speed	The frequency response of a tape recorder is directly related to the tape speed. Professional machines have a fast tape speed of 15 inches per second that provides a frequency response of approximately 40 to 15,000 c.p.s. Home recorders, as well as most professional models, have slower tape speeds of $7\frac{1}{2}$ and $3\frac{3}{4}$ inches per second. At these speeds a professional machine can be expected to have the following responses: 40 to 12,000 c.p.s. at $7\frac{1}{2}$ inches per second and 40 to 7,000 c.p.s. at $3\frac{3}{4}$ inches per second. A home recorder can be expected to have the following responses: 70 to 8,000 c.p.s. at $7\frac{1}{2}$ inches per second and 70 to 4,000 c.p.s. at $3\frac{3}{4}$ inches per second. Some machines also have a very slow tape speed of $1\frac{7}{8}$ inches per second with a correspondingly reduced frequency response. Some professional machines also have available a tape speed of 30 inches per second. This very fast speed does not provide much more increase in frequency response than 15 inches per second, but does effect a reduction of background noise.
Reel size	Home recorders will usually handle reels of tape no bigger than 7 inches in diameter. Pro-

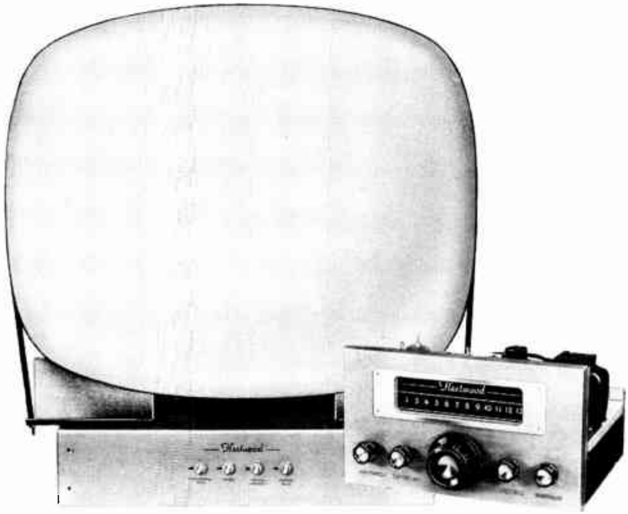
TAPE AND TAPE RECORDERS—SPECIFICATIONS AND FEATURES	EVALUATION
	fessional machines should handle reels up to 10½ inches in diameter. A 7-inch reel will record single track approximately 2 hours at 1⅞ inches per second, 1 hour at 3¾ inches, ½ hour at 7½ inches, and ¼ hour at 15 inches. A 10½-inch reel will record single track approximately 4½ hours at 1⅞ inches per second, 2¼ hours at 3¾ inches, 1 hour and 5 minutes at 7½ inches, and ½ hour at 15 inches.
Fast forward and rewind	Tape recorders should have a fast forward speed for selecting specific sections of a recording. All recorders have motors for rewinding a recorded tape. Fast rewinds are obviously convenient.
Motors	This specification is not always given. Other than giving dependable operation, expensive rewind motors are not required. Recording motors should furnish accurate and constant rotation. A hysteresis synchronous motor is the best since its speed is independent of line voltage.
Flutter	Flutter is similar to wow of record turntables. When specified, flutter should be less than 0.5 per cent. A greater percentage can be detected by ear. A test for flutter can be made by recording a constant tone and then playing it back. The tone should remain audibly in the same pitch.
Signal-to-noise ratio	This specification (not always given) expresses the amount of noise generated during recording. Professional recorders should be capable

TAPE AND TAPE RECORDERS—SPECIFICATIONS AND FEATURES	EVALUATION
	of recording with a signal-to-noise ratio as high as 50 to 60 db with 1 or 2 per cent harmonic distortion. It should be understood, however, that the amount of noise on a tape recording is dependent upon such factors as recording technique, tape, and quality of erasing.
Microphones	Some home recorders include a microphone; professional machines usually do not. The frequency response of your microphone should be comparable to that of your recorder. Like phono pickups, microphones are either crystal or dynamic. Dynamic microphones (similar in operation to magnetic pickups) usually have better responses than crystal microphones. Microphones cost anywhere from $7 to $90.

Television

Practically all television sets have poor sound systems—low-wattage audio amplifiers and small speakers inadequately mounted. If you have a television set or are contemplating getting one, you should use your hi-fi audio amplifier and speaker to reproduce the TV sound unless such use conflicts with radio or record listening.

If you presently have a television set, it can be modified for use with your hi-fi system by a TV repairman. He can make the necessary connection ahead of the TV audio amplifier and speaker. Specify the length of coaxial cable needed for making the connection to the back of your audio amplifier. One word of warning: if your television set is to be located remote from your audio amplifier (more than ten feet away) you may need a cathode-follower output for your



A custom television set for installation with a hi-fi system is supplied without audio amplifier and speaker. The set shown above is particularly adaptable since the TV tuner chassis and video amplifier picture tube chassis are separate. A cathode-follower output for TV sound permits mounting the TV tuner chassis remote from the hi-fi audio amplifier. (Courtesy of Conrac, Incorporated)

FIGURE 35. A CUSTOM TELEVISION SET FOR HI-FI INSTALLATION

television set. A competent repairman can make this type of installation but it will cost you more.

If you are about to buy a television set, you should seriously consider a custom set which is specifically designed for hi-fi installation. Actually, a custom set like that shown in Figure 35 represents a saving since you do not pay for cabinet, audio amplifier, and speaker. Custom TV chassis usually have cathode-follower outputs for TV sound. This allows the TV chassis to be located at any desired distance from your audio amplifier.

Connections for Supplementary Sound Sources

In Chapter 6 we discussed connecting the two sound sources (radio tuner and phono pickup) of a basic hi-fi system to the audio amplifier. The connections were easy to make with coaxial cables running from the output of the radio tuner and phono pickup to their respective input jacks at the audio amplifier. The selector switch of the audio amplifier permitted selecting either phono or radio sound. When you expand the basic hi-fi system by making additional sound sources available to the audio amplifier, the connections can become a little more complicated.

TV Sound Connection

Of all the supplementary sound sources, TV sound is usually the simplest to connect since most audio amplifiers have a TV input jack internally connected to the sound selector switch. When this is the case, make the same sort of coaxial cable connection from the TV set to the audio amplifier as you would make for the radio and phono sound. When you have done this, the selector switch on the front of the audio amplifier will select TV as well as radio and phono sound. The same applies when you use a straight power amplifier with a radio tuner that has all the operating controls of your system. This type of tuner nearly always has a TV input jack internally connected to the sound selector switch.

If your audio amplifier has no provision for TV, use the same input jack for TV sound as you use for your radio tuner by installing a switch. Mount the switch in a convenient location, and connect as shown in Figure 36.

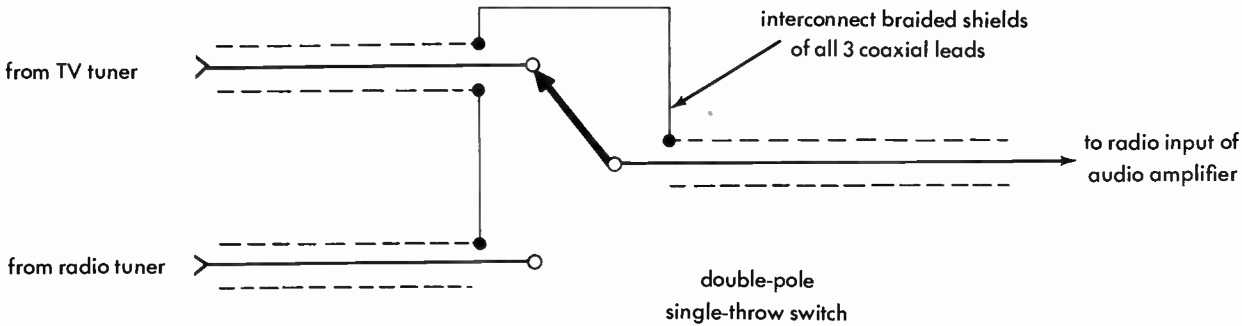
Tape Recorder Sound Connections

When you expand your system by the addition of a tape recorder, you have two connection jobs to do. First of all, you must make the sound reproduced by the tape recorder (the output from the reproducing head) available to the audio amplifier. Secondly, you must make the radio and phono sound available to the recorder (i.e., the input to the recording head).[3]

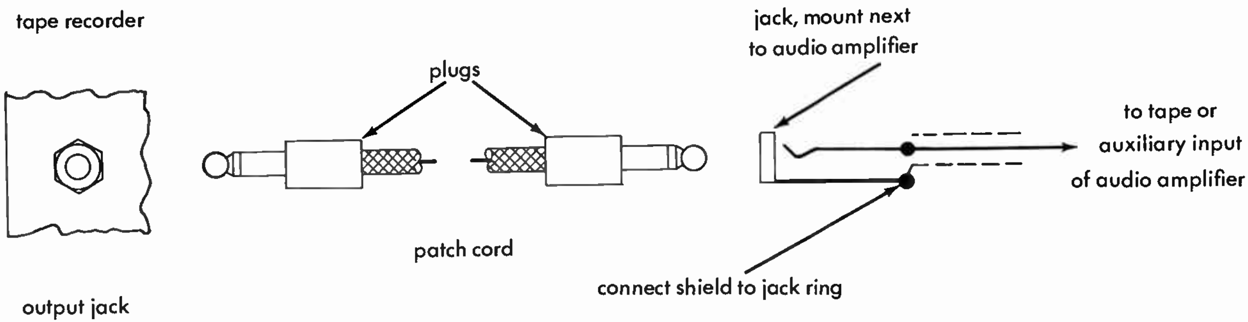
Since tape recorders are portable, a direct connection is not used from recorder to audio amplifier. As shown in Figure 36, the recorded sound is available from a telephone jack at the tape recorder. A patch cord, made of conventional coaxial cable and terminated at both ends by a telephone plug, is used to connect a second telephone jack mounted near your audio amplifier. This second telephone jack is wired to your audio amplifier by coaxial cable. If your audio amplifier has an input marked "Tape" or "Auxiliary," the mounted jack is connected directly to this input and selection of tape recorded sound is made by the sound selector switch of the audio amplifier. If your amplifier does not have input provisions for "Auxiliary" or "Tape," then use the radio input and a secondary selector switch as shown in Figure 36.

The job of making radio and phono sound available to the input of your recorder is accomplished by means of telephone jacks as shown in Figure 36. The jack for radio sound is connected between the tuner and the audio amplifier. If you use a crystal pickup, the jack for phono sound can be connected between the pickup and the audio amplifier. When you use a magnetic pickup, you will have to connect the jack after the preamplifier unless your tape recorder is sensitive enough to record directly from a magnetic pickup (check the specifications of your recorder). Connecting the jack after the preamplifier is simple enough if your preamplifier is a separate unit. When the preamplifier is incorporated with the audio

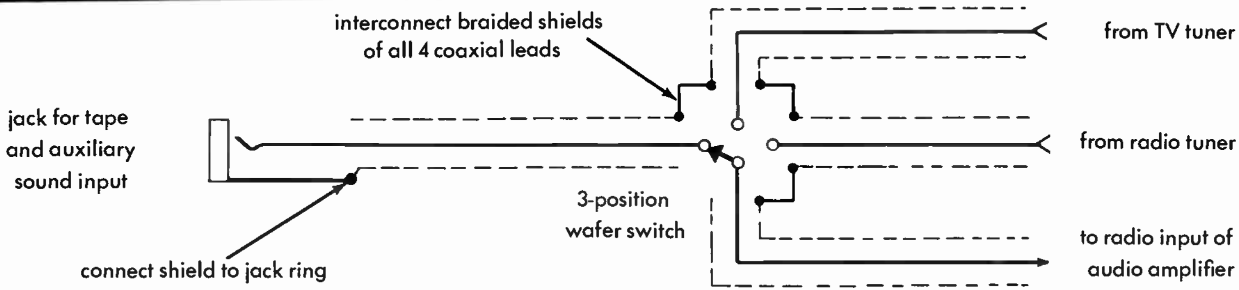
[3] Required only if you want to record radio programs or disk recordings.



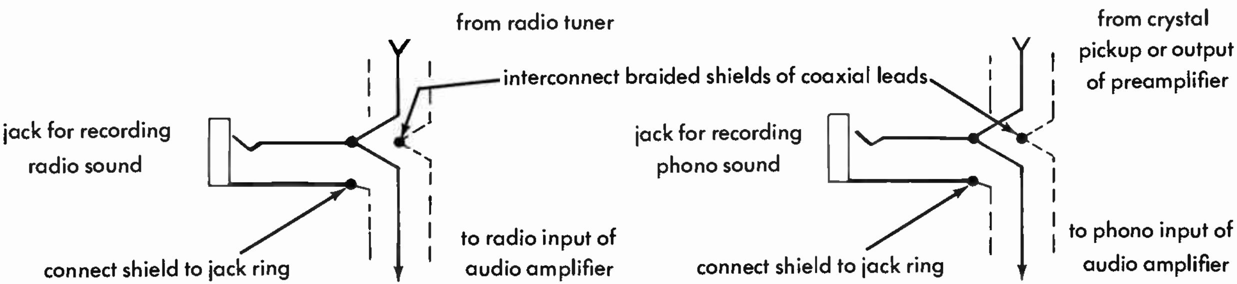
Switching TV and radio sound for an audio amplifier with no TV sound input.



Arrangement for connecting tape and other auxiliary sound sources to an audio amplifier with a "Tape" (sometimes designated "Auxiliary") input jack.



Switching TV, radio, and tape (or auxiliary) sound by a secondary selector switch for an audio amplifier with only radio and phono inputs.



Wiring telephone jacks to permit tape recording of radio and phono sound.

FIGURE 36. INTERCONNECTIONS FOR SUPPLEMENTARY SOUND SOURCES

amplifier, get your radio serviceman to make the internal connection (usually made at the selector switch). The same patch cord used for connecting recorded sound to the audio amplifier can be used for connecting radio and phono sound to the tape recorder. This patch cord should be as short as possible to minimize signal loss.

Additional Sound Sources

If you own such equipment as a sound motion-picture projector or an electric guitar, its sound can also be reproduced by your system. The arrangement just described for making the recorded sound of a tape recorder available to the input of the audio amplifier can be used for these auxiliary sound sources. The coaxial sound lead from your motion picture projector or guitar pickup should be terminated by a telephone plug.

APPENDIX A

CALCULATING SIZE OF BASS-REFLEX PORTS

THE BASS REFLEX is an effective speaker enclosure, well suited for home construction. When properly made, it extends the low-frequency response of a speaker and provides excellent dampening of a speaker's back radiations. The bass-reflex enclosures shown in Figures 24, 25, 29, and 30 illustrate the simplicity of construction.

Like organ tubes, bass-reflex enclosures can be tuned to resonate at different frequencies, dependent upon their volume and port size. For ideal operation, a bass-reflex enclosure should resonate at the frequency of its speaker's cone resonance. This dampens the excessive vibrations (to minimize the unnatural sound intensification, or booming) that normally occur when a speaker reproduces at its cone resonance. The dampening effect at cone resonance also extends a speaker's frequency response a few cycles lower.

Depending upon the size of speaker used, a bass-reflex enclosure should have enough volume for effective dampening of back radiations. For 8-inch speakers the volume of the enclosure should be between 3 and 4 cubic feet, for 10-inch speakers between 4½ and 6 cubic feet, for 12-inch speakers between 7½ and 9 cubic feet, and for 15-inch speakers between 10 and 12 cubic feet. Although bass-reflex enclosures can be made with slightly smaller volumes and still be properly tuned with the right size port, best results are obtained within the limits specified above. The port should be at least 12 inches from the edge of the speaker and rectangular in shape with a length-to-width ratio of roughly 3:1.

To determine the port size that will tune a bass-reflex enclosure of a given volume to the specified cone resonance of a speaker,[1] make the simple calculations required by the formula given below.[2]

$$\sqrt{P} = (E\,f^2)\ .0004$$

Where: P equals the area of the port in square inches
E equals the volume of the enclosure in cubic feet
f equals the resonant frequency of the speaker cone in cycles per second (and hence the desired resonant frequency of the enclosure)

Example: Let E equal 7 cubic feet and f equal 50 c.p.s. Find the port area P that will resonate the enclosure at 50 c.p.s.

$$\sqrt{P} = (E\,f^2)\ .0004$$
$$\sqrt{P} = 7 \times (50)^2 \times .0004$$
$$\sqrt{P} = 7 \times 2500 \times .0004$$
$$\sqrt{P} = 7$$
$$P = 49 \text{ square inches}$$

[1] If cone resonance is not given in your speaker's specifications, it may be determined by applying the output of a variable audio generator to your unmounted speaker. Starting at 100 c.p.s., reduce the frequency until the speaker vibrates excessively. The frequency at which this occurs is the frequency of cone resonance. A radio repairman can perform this task.

[2] Adapted from the Helmholtz formula.

APPENDIX B

TEST RECORDS

ONCE YOU HAVE installed your system, you can use a test record to evaluate the sound-reproducing ability of your record player, audio amplifier, and speaker. There are a number of test records available, ranging in price from $2 to $10. Although varying in form and purpose, all test records are the same in that the evaluation is made by ear. Instructions for a step-by-step procedure are included with each record. The tests are simple to make and the results give valid indications of performance.

The Dubbings Company D100 is one example of a test record. This 12-inch 33⅓ r.p.m. disk has been recorded with thirteen intervals of even-intensity sound signals ranging in frequency from 30 to 12,000 c.p.s. These thirteen sound signals, arranged in ascending order, permit you to determine the approximate frequency response of your system's phono pickup, audio amplifier and speaker. The Dubbings record also has other tests for determining the tracking ability of your pickup arm, and for detecting wow and rumble in your turntable.

There are also some test records designed for a single purpose. The most notable of these is the N-A Beam test put out by Cook Laboratories. This record indicates any intermodulation distortion generated in your pickup, amplifier, and speaker that exceeds 2 per cent.

APPENDIX C

MAKING YOUR OWN REPAIRS

YOUR SYSTEM MAY function without trouble for more than five years or it may break down after only one or two years. Sooner or later it will fail. If your first instinct is to bundle your system off to a radio repairman, restrain yourself. Nine out of ten times you can take care of the trouble yourself. Hi-fi components are well constructed with good parts (even the less expensive components) and over 90 per cent of all troubles will be the result of a vacuum tube failure or a loose connection between components.

Your first job is tracing the trouble to a specific component. Most of the time it will be a simple check to determine which sound source is dead. If all sound sources are dead, the chances are your audio amplifier is dead. Once you have found the defective component, the trouble is usually remedied by replacing a defective tube. The table below lists faults that are likely to occur and their probable remedy. If you fail to correct the fault after referring to this table, take the defective component to your local repairman.

TROUBLE	PROBABLE REMEDY
All sound sources are dead.	Is the system receiving power? Check wall outlet connections, house fuse, and extension cord connection to system. Listen at speaker for faint hum or hiss to

TROUBLE	PROBABLE REMEDY
	determine if speaker is functioning. If not, inspect amplifier-to-speaker connections. If necessary, remove speaker connections at the amplifier and place a 1½-volt dry cell across speaker leads. Do you hear click or can you detect movement of speaker cone? If not, inspect all connections of speaker or speaker system thoroughly. If necessary, make dry-cell test directly at speaker or speakers. Speakers almost never fail. However, if all indications point to a defective speaker, take it to a repairman for a resistance check. Defective speakers should be sent back to the manufacturer for repair. If speaker is functioning, fault is with audio amplifier. Observe whether vacuum tubes light up (touch metal tubes to find out if they are warm). Replace any tubes that do not light up or become warm. If all of amplifier's tubes are out (or cold), check amplifier's fuse. Replace fuse if blown (check manufacturer's instructions to see that fuse of correct amperage is used). If fuse blows when replaced, rectifier tube is probably defective. See manufacturer's instructions for location and identification of rectifier tube (usually located next to large power transformer). Have rectifier tube tested; if defective, replace. If rectifier tube checks good, fault lies with amplifier circuitry. Have amplifier fixed by repairman.
Radio is dead, all other sound sources normal.	Check radio-input jack of amplifier by turning selector switch to "Radio" and plugging another sound source into radio jack. If sound is heard (sound from magnetic pickup will be weak and thin) radio tuner or coaxial lead is at fault.

TROUBLE	PROBABLE REMEDY
	Check the coaxial connection between amplifier and tuner; center conductor may be shorted to braided shield at plug terminations. Positive check can be made by substituting a coaxial lead known to be good. Inspect all vacuum tubes of radio tuner. Tubes that do not light or become warm should be replaced. If all of the tuner's tubes are out, check fuse. If blown, replace. If fuse of correct amperage blows when replaced, have rectifier tube tested. If bad, replace. If good, tuner circuitry is defective and should be fixed by repairman.
Phono is dead, all other sound sources normal.	Check phono-input jack of amplifier by turning selector switch to "Phono" and plugging in another sound source. If sound is heard, fault lies with pickup or coaxial connection between pickup and amplifier. Inspect coaxial lead for possible shorting between shield and center conductor. Check to see if center conductor has become disconnected at plug or phono pickup. If coaxial connection between pickup and amplifier appears to be good, pickup is defective. Magnetic pickups can usually be sent back to factory for either repairs or replacement. Crystal pickups have to be replaced.
TV sound is dead, all other sound sources normal.	Check TV-input jack of audio amplifier by substituting radio sound. If radio sound is heard, the TV set or the TV-to-audio amplifier coaxial lead is at fault. Inspect coaxial lead for shield and center conductor shorting. Check to see if center conductor has become disconnected at plugs. You can also replace any vacuum tubes that fail to light or become warm. But be careful.

TROUBLE	PROBABLE REMEDY
	Unlike a radio tuner or audio amplifier, your TV set has high-voltage leads above its chassis. Turn TV set off before reaching in to replace a defective tube. If all tubes fail to light, check fuse and replace if defective. If fuse blows when replaced, call in a repairman.
Recorder fails to record or reproduce, yet rest of system functions normally.	Check the input jack to the audio amplifier by substituting radio sound. If radio sound is heard, fault lies with either the tape recorder, the coaxial patch cord, the telephone jack for auxiliary sound, the telephone jacks for recording radio and phono sound, or, if used, the secondary selector switch. Inspect all coaxial leads and connections. Check to see that all telephone jacks make connection with shank and tip of telephone plugs. If necessary, check secondary selector switch by bypassing with a short piece of wire. Replace any vacuum tubes in the recorder that fail to light. If all tubes fail to light, check fuse and replace if defective. If fuse blows when replaced, have repairman fix recorder.
60-cycle hum.	A steady 60-cycle hum picked up from AC house current can be an annoying trouble to track down. It is usually caused by improper shielding of sound inputs to the audio amplifier. First, determine the sound source or sources where hum is present. If hum is present for all sound sources the audio amplifier is probably at fault. Reverse the amplifier power plug. If hum persists, ground amplifier to radiator or water pipe; use single-conductor insulated wire connected

TROUBLE	PROBABLE REMEDY
	to chassis screw and bare metal of the pipe or radiator. If this fails, disconnect all sound sources. If hum is still present, it is probably being generated in power supply of amplifier. Take amplifier to repairman, or if still within the guarantee, return to dealer. If hum occurs only with phono, check to see if shield of pickup-to-amplifier lead is securely soldered to collar of input plug. This is important since shield must be grounded to amplifier chassis. Also try reversing power plug to phono motor; notice effect on hum, if any. If hum increases as you touch the pickup arm, reverse the connections to the pickup. If hum occurs with other sound sources such as radio, TV, or recorder, inspect input connections of affected source. Make sure that braided shields are well soldered to collars of input plugs. Also find out whether reversing power plugs has any effect. If hum still persists, the component itself is probably at fault. Take component to repairman or return to dealer if still within the guarantee.
Poor radio reception from stations that previously gave good reception.	For AM radio this usually indicates weak radio tubes. Have all radio tubes tested by repairman. Replace weak tubes. The same is true for FM radio, although increasingly poor reception can also indicate that realignment is required. It is sometimes necessary to have a repairman realign your FM tuner after a tube has been replaced. Antenna connections are important for good FM reception. Make sure that each connection achieves good electrical contact. This is especially important if you have an outside antenna.

TROUBLE	PROBABLE REMEDY
Sound slowly fades out, then returns strongly only to fade again.	This indicates a loose or shorted connection inside a vacuum tube. If fading occurs for all sound sources, have repairman test audio amplifier's tubes. If fading occurs for a particular sound source, have the component's tubes tested.
All sound is uniformly weak.	Usually indicates that audio amplifier has a weak or defective tube. Have repairman test all audio-amplifier tubes.
A variation of pitch (wow).	Wow is caused by the uneven revolution of record. Listed below are common causes of wow; check the obvious first. Center hole of record is off-center. Enlarge hole so that record can be manually centered for each playing. Record is warped or manufactured with defective grooves. Warped records can sometimes be flattened with continuous pressure (place on the bottom of record stack). Record is slipping on turntable. Adhere tape to record label with sticky side out. The rubber drive wheel of rim-drive machine is out of round. Should be replaced since any attempt to reshape would reduce diameter and lower turntable speed. Oil on inside rim (rim drive) or on belts and pulleys (belt drive) causes slipping. Wipe clean; if necessary, use soap and water; do not use gasoline or any agent which affects natural rubber. Check tension of drive mechanism, motor and wheel lubrication, and mounting (should be level). Turntable is warped or center shaft is bent. If really bad, you may have to replace turntable or entire drive unit. However, when this is the case, you have nothing to lose by trying to restraighten.

TROUBLE	PROBABLE REMEDY
Inaccurate turntable speeds.	Slight inaccuracies in turntable speed are hard to detect by ear. However, an accurate check can be made by the use of a stroboscopic card, available at most hi-fi outlets. Card is placed on the revolving turntable under a 60-cycle light source. When turntable is rotating at correct speed, corresponding speed pattern on the card remains stationary. From time to time, it is a good idea to check your turntable speeds with a stroboscopic card. Slight speed variations are tolerable to most listeners. When turntable speeds are much slower than they should be, it generally indicates that motor needs replacing, although lubrication of motor and turntable bearings sometimes helps. When turntable speeds are much faster than they should be, check the drive idle wheel (rim-drive units). It may be worn and need replacement.
Excessive stylus wear.	As discussed in Chapter 4, diamond styluses with proper operating pressure will last a long time, sapphire styluses not so long. In any event, it is worth while to check styluses from time to time. This can be done by some stores. Actually, if you have access to a magnifier of 4 power or more, you can make the inspection yourself. The correct shape of a stylus is conical and nearly pointed.

APPENDIX D

BINAURAL SOUND

BINAURAL SOUND IS a new development that strives to make music in the home more like that heard in the concert hall by imparting to reproduced sound a stereophonic, or three dimensional, effect. When we hear live music, we hear it with two ears which, being the width of our head apart, are perceptive to depth and dimension. When we listen to conventional recorded or broadcast music, the stereophonic effect is lost because we are listening to music that originates from a point source (a single microphone) and is reproduced at a point source (our speaker or speaker system). Listening to conventional, or monaural, sound reproduction is the same as listening to live music with only one ear; the sense of depth and dimension is lost.

Binaural reproduction achieves a stereophonic effect by having the sound to be reproduced picked up by two microphones placed apart from one another. The signal from each microphone is then amplified by its own amplifier and reproduced by its own speaker. Placing the speakers in the same relative position as the microphones reproduces the original sound with a certain amount of dimension and depth. Binaural reproduction does not achieve complete reality, but the effect is startling. In a good binaural reproduction, for example, the listener is aware of the relative positions of various sections of the orchestra.

At the time of this printing, there are around seventy-five binaural disk recordings commercially available. With a binaural recording, the sound from one microphone is placed on the first half of the record while the sound from the second microphone is placed on the second half of the record. Binaural reproduction is achieved by using an arm with two pickup cartridges mounted side by side. The lateral distance between the two pickup styluses is identical with that between the two styluses used in cutting the master disk. The outputs from the two pickup styluses are amplified and reproduced by two amplifiers and speakers. It is apparent that reproducing from binaural disks is an expensive proposition since you need two of everything except turntables—two pickups, two audio amplifiers, and two speakers. At the present time you can buy a binaural system (without radio tuner) for around $675. If you have a plain turntable, you can convert an existing monaural system by purchasing a binaural arm, an additional pickup cartridge, audio amplifier, and speaker.

Binaural broadcasting is also possible, but to date only WQXR in New York has produced even a limited number of programs. In binaural broadcasting, the sound picked up by one microphone is broadcast on AM while the sound picked up by the second microphone is simultaneously broadcast on FM. These broadcasts may be enjoyed by people with both AM and FM radios in the house.

Binaural reproduction can also be obtained by recording simultaneouly the two sound signals on tape. Dual recording and reproducing heads with separate amplifiers and speakers are required.

The ability of binaural to achieve more natural sound reproduction is unquestioned, but its future is still in doubt. Binaural radio with FM stations transmitting two sound signals on a single FM channel is possible. But it is doubtful whether radio stations will ever install the new transmitting equipment required. The probable future for binaural sound reproduction lies with disk and tape recording. However, the duplication of equipment is expensive. Whether enough people consider the benefits worth the added expense is also questionable. Moreover, the repertory of binaural recording will obviously be limited until there is sufficient demand.

If you can afford it, binaural sound will provide pleasurable listening. Fine equipment is available, manufactured by such companies as Cook Laboratories and Livingston Electronic Corporation. Of course, binaural equipment can also reproduce conventional, monaural recordings.

APPENDIX E

THE ELECTROSTATIC LOUDSPEAKER

THE PRINCIPLE OF the electrostatic speaker has been known for some time. While some were made in the past, they were never successful enough to challenge the electromagnetic or moving-coil speaker. Electrostatic speakers are appearing on the market today in limited numbers. These units are all high-frequency reproducers and must be used with a conventional low-frequency reproducer.

As its name implies, an electrostatic speaker functions because of an electrostatic force that exists between two charged plates. When two plates with like charges (either both negative or both positive) are placed next to one another, the electrostatic force tends to move the plates apart. If the plates have unlike charges (one negative and the other positive), the electrostatic force tends to draw the plates together. Working on this principle, an electrostatic speaker is essentially a flexible plate placed next to, but insulated from, a rigid plate. When a steady or DC electrical charge is placed on the rigid plate and the electrical voltage variations from the output of an audio amplifier are placed on the flexible plate, the flexible plate will be attracted to and repulsed from the rigid plate in accordance with the audio voltage variations from the amplifier. As the flexible plate moves in and out it displaces air and reproduces the sound intelligence represented by the audio voltage variations. The advantage of this over the cone-type, moving-coil speaker is that force causing the flexible plate to move is applied at every point instead of at one point in the center of the cone. This uniform application of force is better suited for faithful reproduction since it is difficult for minute secondary vibrations to be set up along the surface of the flexible plate such as can occur along the surface of a cone. Also, the flexible plate, actually a very thin membrane, can be made very light for the amount of sound-reproducing force as compared with the relatively heavy cone. In any speaker the lighter the element displacing the air, the more faithful the reproduction of the resultant sound. Electrostatic speakers are also very effective in obtaining an even distribution of sound. This is done by curving the plates to disperse the reproduced sound over a wide area. The big drawback to electrostatic speakers is that the two plates must be placed very close to one another for the electrostatic force to be effective. The electrostatic force exerted diminishes as the square of the distances between the two plates. This means that the amount of air that an electrostatic speaker can displace limits practical use to reproducing high frequencies. Of course, it is possible for an electrostatic speaker to reproduce low frequencies, but to do so, the area of plates as well as the voltages used would have to be very large.

Some of the electrostatic tweeters on the market today work very well but, unfortunately, over-all results are inconsistent. I have heard both good and bad reports on their performance. From a theoretical standpoint, the electrostatic has many undeniable advantages over the electromagnetic speaker. However, its technical development has really just begun and it is still too early for a fair evaluation. In deciding on whether or not to buy one, the best thing is to listen to electrostatic speakers hooked up to an amplifier that is equivalent to yours. Unlike conventional speakers, they cannot be purchased on the basis of complete published specifications. Before buying one, be sure to inquire as to how it should be connected to your amplifier. Electrostatic speakers do not require output transformers; however, some special circuitry is required to connect them to the output of the final amplifier stage.

APPENDIX F

REMOTE SPEAKER INSTALLATION

ONCE A HI-FI SYSTEM is installed, the question of installing one or more remote speakers usually arises. Why not get the benefit of high-quality sound reproduction in other parts of the house? All that is required is the purchase of speaker, switch, and two-conductor line.

Fortunately, the strong, low-level output of an audio amplifier imposes no actual limit on the length of two-conductor line connecting the audio amplifier to its speaker as far as installation in the home is concerned. There are some other problems, however. First of all, unless the rooms where the speakers are located are completely isolated from one another, it is inadvisable, because of the sound disturbance, to have speakers all operating at once. Thus, a switching arrangement is needed to apply the output of the amplifier to one speaker at a time. Also, the problem of impedance matching is simpler if the speakers used all have the same voice-coil impedances. Thus, when buying a remote speaker, make sure it has the same impedance as your system's main unit. You may also wish to have a remote volume control mounted at the remote speaker. This added convenience may be had by installing an L-pad attenuator (approximately $3) at the remote speaker. The impedance of the L-pad should be the same as that of the speaker. Thus, a 16-ohm speaker requires a 16-ohm L-pad, an 8-ohm speaker an 8-ohm L-pad, etc.

Figure 37 gives some of the different ways by which remote speakers may be connected. In (A), two speakers of the same impedance (in this case 16 ohms) are connected by two-conductor line to the audio amplifier's common and 16-ohm connections. A single-pole, single-throw switch is located at each speaker to turn the speakers on or off. This is a simple switching arrangement, but may require a little shuttling back and forth since the main speaker (1) must be turned off before the remote speaker (2) is turned on, and vice versa. An L-pad attenuator, connected as in drawing (B), could also be installed with the remote speaker (2).

In Figure 37 (B) a central switching arrangement for two remote speakers is shown. In this case two-conductor line is run from each speaker with one conductor of each line being connected to the common terminal of the audio amplifier. The other conductor from each speaker line is then connected to a three-position selector switch. Here the pole contact of the switch is shown connected to the 8-ohm tap of the amplifier, indicating that the three speakers are 8-ohm units. For 16-ohm speakers, connection would obviously be made to the 16-ohm tap. The L-pad attenuators shown with the two remote speakers are optional. For only one remote speaker, a single-pole, double-throw switch would be used.

Figure 37 (C) shows how a main speaker (1) of 16 ohms and a remote speaker (2) of 8 ohms are connected for a central switching arrangement. Notice that the single-pole, double-throw switch is placed in the common connection lead to each speaker. The other leads from the 16-ohm and 8-ohm speakers go to the 16- and 8-ohm taps respectively.

Figure 37 (D) shows how two speakers of the same impedance may be switched on separately or together. This arrangement may be used when the remote speaker is sufficiently isolated from the main speaker so that they may both operate simultaneously without any disturbing effects. A

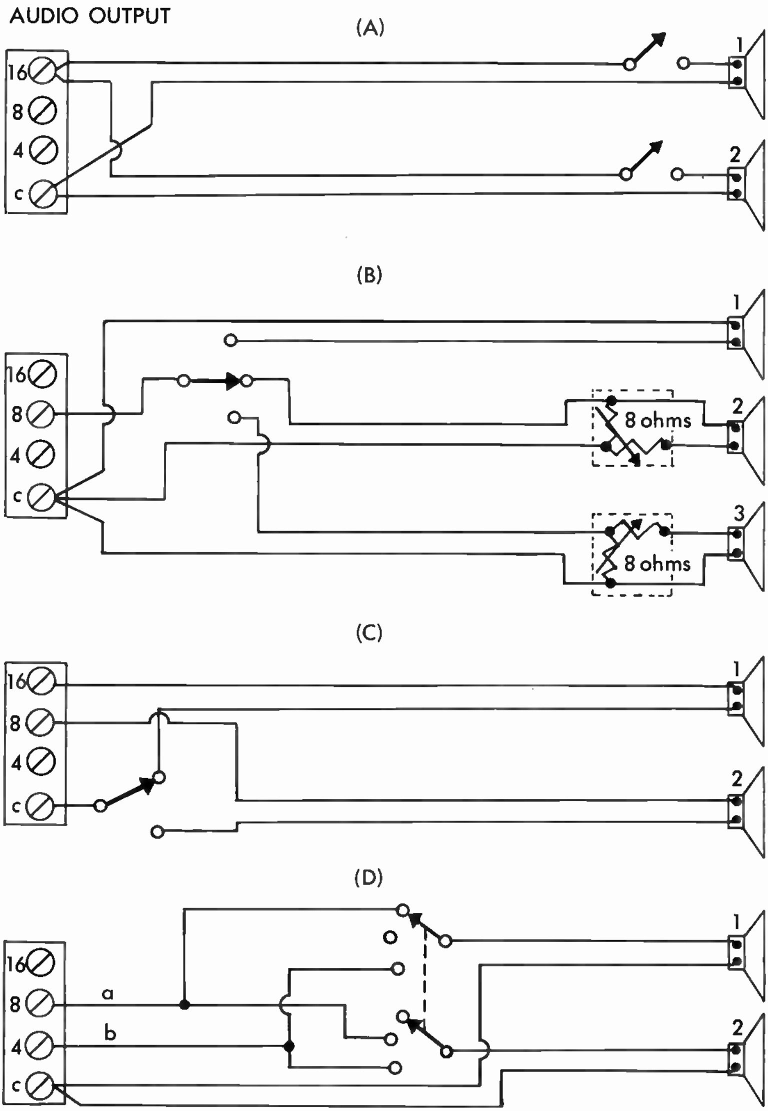


FIGURE 37. REMOTE SPEAKER CONNECTIONS

two-pole, three-position switch is employed. The connection shown is for two 8-ohm speakers. If two 16-ohm speakers are used line "a" is moved to the 16-ohm tap of the audio amplifier and line "b" is moved to the 8-ohm tap. In the switch position shown, the main speaker (1) is operating. In the next position, the remote speaker (2) will operate. In the third position, both speakers will operate simultaneously. If desired, an L-pad attenuator could be used to control the volume of the remote speaker (2).

APPENDIX G

BUILDING FROM KITS

IF THE PROSPECTIVE buyer wants to save on costs and is willing to spend a few constructive hours, he should investigate hi-fi components that come in kit form. For example, an 8-watt amplifier with preamplifier costs between $40 and $50 fully assembled while an equivalent unit can be had for around $20 in kit form. The more expensive amplifier, consisting of a separate preamplifier (with record compensation and provision for about five sound inputs) and basic 20-watt amplifier can be obtained in a kit for as low as $60 while an equivalent fully assembled unit would cost anywhere from $150 to $200. Separate AM and FM tuners are also available in kit form for as low as $25 each. Aside from the financial saving in building hi-fi components from kits, there is the personal satisfaction of "making your own."

What is involved in building from kits? Does the builder have to be a technician or mechanically and electrically expert? Anybody who has ever looked under a radio chassis is confronted with a maze of parts and interconnected wiring. Without doubt, electronic devices are complex. But, fortunately, most of the kits sold today come with complete step-by-step instructions and pictorial diagrams so that assembly is a matter of following printed instruction closely. What is required is the mechanical ability to mount parts with nuts and bolts, and to make good soldered connections. If the

A preamplifier and basic 20-watt power amplifier. Preamplifier has record compensation and provisions for 5 sound inputs and tape recorder. (Courtesy of Heath Company)

A 7-watt amplifier with incorporated preamplifier and FM tuner. (Courtesy of Heath Company)

FIGURE 38. HI-FI COMPONENTS ASSEMBLED FROM KITS

builder has mastered the techniques of soldering as given in Chapter 7, and possesses some mechanical ability with pliers and screwdriver, he will have no trouble as long as he follows the directions exactly.

The author has assembled the Heathkit 20-watt basic amplifier, preamplifier, and FM tuner with excellent results. The Heathkit point-by-point instructions and large pictorial diagrams are very clear, even to the point of special soldering instructions for such items as phono jacks, shielded cables, etc. The Heathkit preamplifier and FM tuner, because of their compactness, were more difficult than the basic 20-watt amplifier, which is a relatively simple unit to assemble.

In deciding upon what kit to buy, the best procedure is to write to a manufacturer and ask for the instruction book on the particular unit you intend to make. The thoroughness of the building instructions will give you some idea of the quality of the kit. Because of the established reputation of the Heath Company, as well as my own experience in building some of their Heathkits, I rate them particularly high. However, there are kits of other manufacturers on the market, giving the builder plenty of choice.

To build a kit very little is required in the way of outside equipment. A table top, a roll of rosin-core electrical solder, long-nosed pliers, a few screwdrivers, soldering iron, knife, and diagonal cutting pliers are all you need. Even if you have to buy all these tools, it should cost you no more than $5.

Lay out your tools, open up your kit, and you are ready to proceed.

APPENDIX H

WHERE TO BUY HI-FI EQUIPMENT

For those who live in or near cities and large towns, there is no problem in purchasing hi-fi equipment. Stores that sell conventional radios are beginning to stock hi-fi equipment. In the larger cities many radio supply companies have special audio salons equipped to demonstrate various combinations of speakers, amplifiers, tuners, and the like. There are also a few stores that sell hi-fi equipment exclusively. If you live in an area where there is no store handling equipment, you can order by mail.

Listed below are a few suppliers who sell hi-fi equipment by mail. Write to two or three suppliers and request their hi-fi catalogues. Such a procedure will give you a listing of the specifications and prices for practically all hi-fi equipments made. The list below is not complete and is not meant as a recommendation.

Arrow Electronics, Inc.
65 Cortlandt Street
New York, New York

Allied Radio Corporation
833 West Jackson Boulevard
Chicago, Illinois

The Audio Exchange, Inc.
159-19 Hillside Avenue
Jamaica, New York
(used equipment)

Concord Radio Corporation
901 West Jackson Boulevard
Chicago, Illinois

Harvey Radio Company
103 West 43rd Street
New York, New York

Hudson Radio & Television Corporation
48 West 48th Street
New York, New York

Kierulff & Company
820 West Olympic Boulevard
Los Angeles, California

Lafayette Radio, Inc.
100 Sixth Avenue
New York, New York

Radio Products Sales Company
1237 West 16th Street
Denver, Colorado

Radio Shack Corporation
167 Washington Street
Boston, Massachusetts

Sun Radio & Electronics, Inc.
650 Sixth Avenue
New York, New York

H. Steele y Cia, S.A.
Avenida Juarez y Balderas
Mexico D. F., Mexico

Terminal Radio Corporation
85 Cortlandt Street
New York, New York

Zach's Radio Supply
1426 Market Street
San Francisco, California

Atlas Wholesale Radio Company
7179 Waverly Street
Montreal, Quebec
Canada

Dicks & Company, Ltd.
St. Johns, Newfoundland

Electronic Sonic Supply Company
534 Yonge Street
Toronto, Ontario
Canada

APPENDIX I

GLOSSARY OF HI-FI TERMS

AMPLIFICATION—The amount of strengthening achieved by an amplifier. Also referred to as GAIN.

AMPLIFIER—A unit with one or more vacuum tubes that strengthens electrical current or voltage. Radio-frequency (r-f) and intermediate-frequency (i-f) amplifiers are used in radio tuners to strengthen broadcast signals before detection (i.e., removal of audible intelligence). Audio-frequency amplifiers strengthen audio-voltage variations to the strength required for operating loudspeakers.

AMPLITUDE MODULATION (AM)—The imparting of audible intelligence to a radio signal by varying its voltage amplitude in accordance with the audible intelligence.

ATTENUATION—The reduction in strength of an electrical energy such as a radio signal or an audio voltage.

ATTENUATOR—A device for causing attenuation of electrical energy. An attenuator usually consists of some form of electrical resistance. The volume control of an audio amplifier is one form of attenuator since it can reduce the amplification or gain of an audio amplifier.

AUDIO VOLTAGE—An electrical voltage with amplitudes varying at an audible frequency (approximately 20 to 16,000 c.p.s.).

AUTOMATIC VOLUME CONTROL—A radio circuit which maintains the established sound volume at the loudspeaker in spite of varying strength of the received radio signal.

BAFFLE—A partition or barrier which separates the sound generated at the front of the speaker from the sound generated at the back of the speaker.

BASS—Low-frequency audio tones.

BASS REFLEX—A speaker enclosure designed with a small opening in the baffle to improve the low-frequency sound reproduction.

BINAURAL SOUND—Sound reproduction that achieves a stereophonic, or natural, effect through the use of two sound reproduction channels.

CAPACITOR—An electrical part capable of storing an electrical charge. Capacitors, which pass alternating but not direct current, have many uses in electronic circuits. One such use is to couple amplifier stages. Capacitors are also called condensors.

CATHODE FOLLOWER—A special type of electronic circuit employing a vacuum tube. This type of circuit is particularly effective in coupling the output of a radio tuner to an audio amplifier.

COUPLING—The transfer of electrical energy from one integral unit to another.

COMPENSATOR—An electrical circuit which alters the frequency response of an audio amplifier to correct for the uneven response of phono recordings. Also referred to as an EQUALIZER.

CROSSOVER NETWORK—A simple electrical circuit which separates the high audio frequencies (for the TWEETER) from the low audio frequencies (for the WOOFER). Also referred to as a DIVIDING NETWORK.

CROSSOVER POINT—the frequency at which a crossover network divides the high from low frequencies.

CRYSTAL PICKUP—A crystalline substance which converts the mechanical vibrations of a record stylus into representative electrical audio voltage variations. Also referred to as a CRYSTAL CARTRIDGE.

CYCLES PER SECOND (c.p.s.)—A term defining the frequency of radio-wave transmission, sound propagation, or alternating electrical current as the number of cycles (or vibrations) in one second.

DECIBEL (db)—A term expressing a ratio between two amplitudes or energies. Consider a decibel as the smallest change in sound intensity detectable by the human ear.

DETECTION—The electronic process of separating sound intelligence from a radio-frequency signal of a broadcast station.

DISTORTION—A modification of the original sound intelligence by the introduction of unwanted and extraneous noise or tones.

DIVIDING NETWORK—See CROSSOVER NETWORK.

EQUALIZER—See COMPENSATOR.

FIDELITY—The faithfulness of reproduced sound to the original broadcast or recorded sound.

FLUTTER—A term designating the distortion (varying and untrue pitch) caused by variation in tape speed of a tape recorder.

FREQUENCY RESPONSE—The ability to reproduce a range of frequencies evenly so that all frequencies in the specified range are amplified or reproduced with the same relative intensity.

FREQUENCY MODULATION (FM)—The imparting of audible intelligence to a radio signal by changing the rate of frequency variations in accordance with the audible intelligence.

FUNDAMENTAL FREQUENCY—The lowest or basic frequency of an audible tone.

GAIN—See AMPLIFICATION.

HARMONIC FREQUENCY—A frequency that is a unit multiple of a fundamental frequency. For example, the sound component of a fundamental frequency that is twice the fundamental frequency is called the second harmonic.

HUM—A low-pitched buzzing sound usually caused by the unwanted interjection of the power line frequency or its second harmonic into the hi-fi system.

IMPEDANCE—The opposition or resistance to the passage of varying electrical energy such as audio voltage.

KILOCYCLE (kc)—1,000 cycles per second.

MAGNETIC PICKUP—An electro-mechanical device which transfers the mechanical vibrations of a record stylus into representative audio-voltage variations. Also referred to as a MAGNETIC CARTRIDGE.

MATCHING—The process of interconnecting hi-fi units so that the transfer of energy is as efficient as possible.

MEGACYCLE (mc)—1,000,000 cycles per second.

MICROVOLT—One millionth of a volt.

MILLIVOLT—One thousandth of a volt.

MODULATION—The process of imparting audio intelligence to a broadcast radio signal.

NOISE SUPPRESSION—The reduction of high-frequency surface noise or hiss during phono reproduction. This is accomplished at the audio amplifier by means of an electrical circuit.

OHM—The unit of electrical resistance and impedance.

POWER OUTPUT—The electrical energy (expressed in watts) that an audio amplifier is capable of delivering to a speaker.

PM—Abbreviation for permanent magnet.

RADIO FREQUENCY (r-f)—The frequency at which electrical magnetic energy is transmitted for radio broadcasting. The radio-frequency range begins at 100 kilocycles and extends to 100,000 megacycles.

RECORDING HEAD—The electromagnetic device which translates audio voltage into representative magnetic variation on the recording tape.

RESISTANCE—Opposition to the flow of electrical current.

RESISTOR—An electrical part which opposes the flow of electrical current.

RESONANCE—The frequency at which a vibrating unit vibrates in unison with its own physical period.

REVERBERATION—The persistence of sound due to reflection from surrounding surfaces.

ROLL-OFF—A term used to describe the progressive reduction of relative intensity to cause a controlled alteration of frequency response.

RUMBLE—A low growling noise produced by improper shock-mounting of a turntable or turntable motor.

SELECTIVITY—The ability of a radio tuner to select a desired broadcast signal and exclude the signals of adjacent stations.

SENSITIVITY—The ability of a tuner or amplifier to tune in or amplify weak signals.

SIGNAL—A radio-frequency signal is the electromagnetic energy radiated by a broadcast station. An audio-frequency signal is the voltage variations representative of sound intelligence.

SIGNAL-MUTING SWITCH—A switch which grounds the output of the phono pickup during record changing to reduce the noise of the changer action.

STYLUS—Hi-fi language for phonograph needle.

TRACKING—A term used to describe the action of a phono pickup when riding in the record groove.

TRANSDUCER—A device which transforms one type of energy into another. A phono pickup is a transducer.

TRANSFORMER—An electrical device, basically two separate coils of wire wrapped about a common iron core. If a varying voltage is applied across one coil, a representative varying voltage of either increased or reduced magnitude will be induced in the other coil. Hence a transformer can be used to couple the electrical energy from one source to another without a direct electrical connection.

TREBLE—High-frequency audio tones.

TURNOVER POINT—The frequency at which the relative intensity of a phonograph record's frequency response is progressively reduced for bass and progressively increased for treble.

TWEETER—A speaker designed to reproduce treble tones.

VARIABLE BAND WIDTH I-F—A feature of some AM radio tuners that permits either a sensitive or a broad selection of stations.

VARIABLE-RELUCTANCE CARTRIDGE—The same as MAGNETIC PICKUP.

WOOFER—A speaker designed to reproduce bass tones.

WOW—A hi-fi term designating the distortion (varying and untrue pitch) caused by variations in the speed of a record turntable.

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