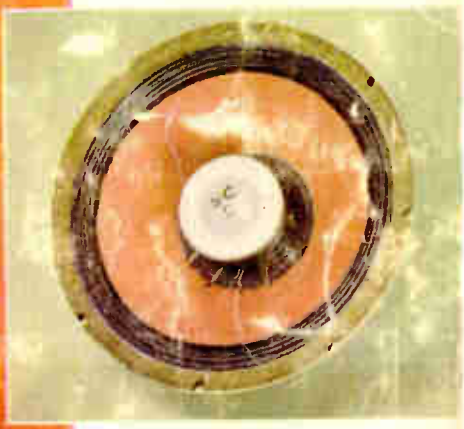
A FAWCETT
75
HOW-TO BOOK
389

HI-FI GUIDE

Special Stereo Section

...Amplifiers



...Speakers

...Tapes Recorders

...Turntables and Changers

...Cartridges

By Donald Carl Hoefler

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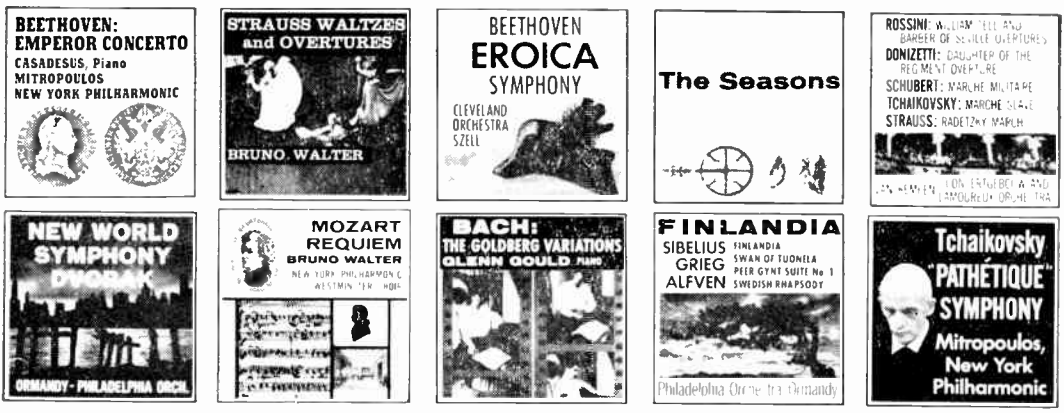

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20. Ports of Call
21. Debussy: La Mer; Ravel: La Valse, etc.
22. Bach: Brandenburg Conc. 1, 2, 3
23. Paganini and Saint-Saens Concertos
24. Strings of Philadelphia Orchestra M-22

Hi-Fi Guide

By Donald Carl Hoefler

Cover photographs by Mike Banvino, Fawcett Studios. Equipment shown:

H. H. Scott Type 299 40-watt stereo amplifier

Stromberg-Carlson RF-484 15-inch coaxial speaker

Norelco EL 3516 stereo tape recorder

Rek-O-Kut Rondine B-12GH turntable with stereo arm

Electro-Voice 26MDST 3-speed ceramic stereo cartridge

A FAWCETT BOOK • NUMBER 389

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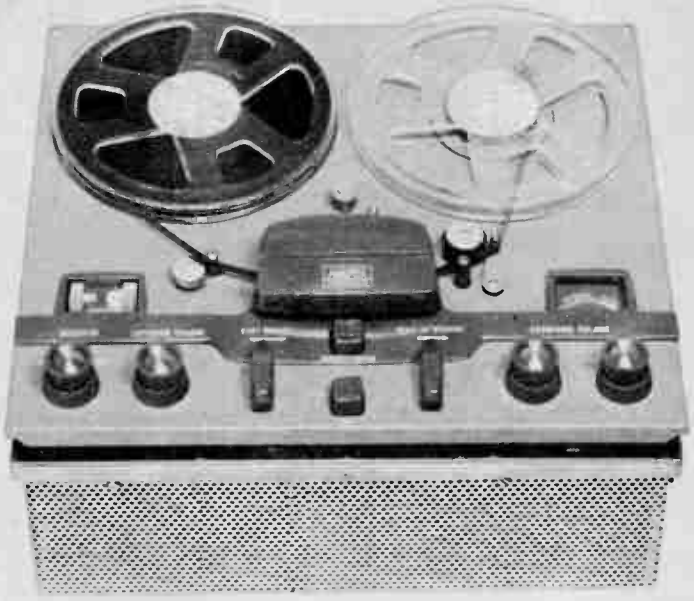
STEREO begins with the E-V totally compatible STEREO Cartridge—already the accepted standard.

About the Author

DONALD CARL HOEFLER, author and audio engineer, has been active in the hi-fi field since the early nineteen-thirties when high fidelity created its first flurry in the United States. He was for several years associated with Major Edwin H. Armstrong, the inventor of FM. He later designed and built frequency modulation broadcasting stations and served as chief engineer of the Continental FM Network. As a sound engineer for RCA-Victor he was responsible for several innovations in magnetic recording tape techniques. Mr. Hoefler has authored many volumes in Fawcett's high fidelity series, books that have been consistent best sellers in the field.

Contents

new AMPEX RECORDS STEREO



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Hi-Fi Guide

INTRODUCTION

FOR THE FIFTH consecutive year—ever since hi-fi became America's favorite pastime—FAWCETT is publishing a brand new book on high fidelity. And for the fifth year in a row, Don Hoefler is our author. The short biography of Don on page 4 will give the reader an idea of Mr. Hoefler's standing in the audio field; his is a voice that speaks with authority in simple, plain language, something that most other so-called experts usually neglect to do. You don't require an electronic engineering degree to understand him, and it's not even necessary for you to know the difference between a cathode loading resistor and a phase inverter. You, the average hi-fi fan, are interested only in the "sound" as it reaches your ears, how it is recorded and reproduced; the equipment needed to fully enjoy it; and how to get the most out of this equipment. Many writers on this subject seem to forget that when you invest $400 to $900 in hi-fi components you don't also sign up for a four-year course in physics. The average audiophile buys his equipment, records and tapes, and hopes that he will enjoy them. And this is what Don Hoefler helps you to do, explaining in language one can understand the function of all components, their capabilities and limitations, and how to get the most out of them—always with the one end result in mind: Listening Pleasure.

The search for truer and higher "fi" will continue as long as people are born with two ears. And as long as they are born with two hands also, they will not be able to resist twisting and turning all those fascinating knobs and dials. In a field as cloudy with technical terms as high fidelity is, it is refreshing to find a clear, understandable voice, one that speaks with technical knowledge and authority, yet speaks in terms that can be comprehended by all. The outstanding success of our past hi-fi best sellers is the indisputable evidence that music and "sound" lovers want and need these types of books, and we assure you that this latest HI-FI GUIDE will fill that need, whether you are a tyro or a dyed-in-the-wool audiomaniac with 12 amplifiers and 32 speakers.

Fred Hoefler

EDITOR

Your High Fidelity Equipment—

Stereophonic or Monaural —

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Your friends who own or sell fine high fidelity equipment will advise you to assemble your entire high fidelity system with B.I.C. quality endorsed components...each the finest, fully guaranteed, uniformly better, yet competitively priced with ordinary components. Your continuing satisfaction is assured by really complete parts and service facilities throughout the U. S.

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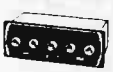

Leak Preamplifiers. Designed and built specifically for Leak amplifiers. All inputs and controls
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Stereophonic and Monaural

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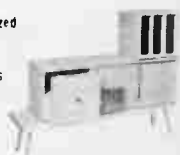

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Courtesy Edison Laboratory National Monument

Photo above shows Thomas A. Edison with his 1906 cylinder phonograph.

The Sound Idea

It has been a fascinating road from Edison's, "Mary had a little lamb," to today's 200-piece orchestras on stereophonic tapes

HIGH fidelity can and should be a source of great pleasure, even fun; but it can also become an addiction, a fetish, an infernal machine. And which of these things you make it is entirely up to you.

If you are a newcomer to hi-fi, perhaps we can show you how to enjoy your hobby without becoming a candidate for the funny farm. If you have already gone off the deep end into the hi-fi maelstrom, maybe we can help you regain your balance. And if you are one to whom hi-fi is neither more nor less than a good old friend, then come along with us. The world needs more of your kind.

For this book is only concerned with the *pleasures* of hi-fi, and how to make the most of them. We will have little care for electronic circuitry or engineering gobbledygook, although this writer has made his contributions to both in his time. We hope you'll find this book to be as comfortable as the well-known old shoe—but perhaps just a bit more interesting.

Before you get too settled, however, we'll stir things up a bit by attempting to set a definition for this occult something with the assonant nickname *hi-fi*. Such a quest is guaranteed to enliven dull parties, make friends, lose friends, and generally spread confusion and consternation among the populace.

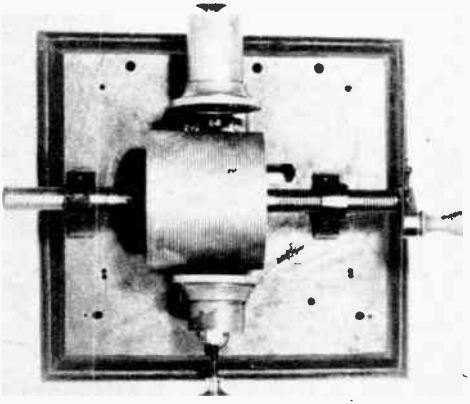
Throughout this world of ours you are assured of findings precisely as many definitions for high fidelity as there are definers. Not wishing to be counted outside this select group, we herewith offer ours in exactly ten words:

High fidelity is the nearest possible approach to perfect fidelity.

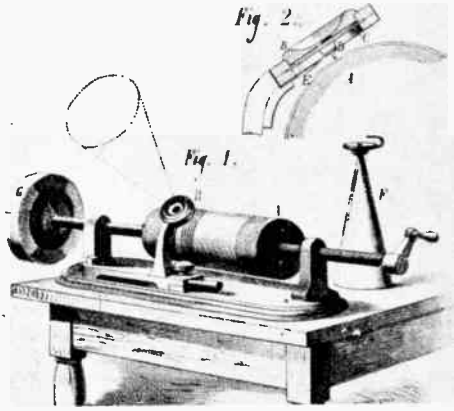
There it is, nice and pat, with all the loose ends tied up. Or are they? What's this business about *perfect fidelity?* True, it does seem that we've just answered the question with another question.

Let's look at it this way: when I listen to hi-fi today, even the best of it, I have the feeling that the sound has been wrapped into a nice neat package and delivered to me in my home. When the time comes that I am transported right to the scene of the performance, when I can say, "I was there and I heard it with my own two ears," that, friend, will be perfect fidelity.

If you infer from this that hi-fi doesn't have all of the realism imputed to it by some over-zealous promotion people, you're right. But hi-fi is many times better than anything we've had

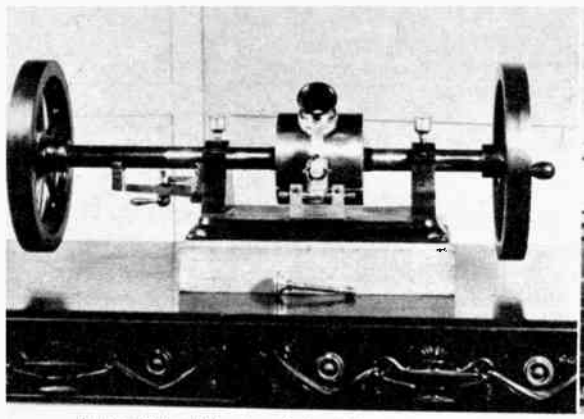


Courtesy Edison Laboratory National Monument



Courtesy Bell Telephone Laboratories

Above, left, is top view of Edison's original phonograph on which patent was obtained. Note crank drive. Above, right, drawing of the 1877 model showing diaphragm function and stylus action on the cylinder.



Courtesy Edison Laboratory National Monument

The first demonstration model of Edison's tinfoil cylinder phonograph. Note the speaking tube.

Courtesy Thomas Alva Edison Foundation, Inc.

Portrait of Edison at the National Academy of Science was taken by Mathew Brady, in April 1878.

before, and stereo hi-fi is that much better again. Still, it *isn't* perfect.

Another sure-fire argument starter is just what constitutes suitable hi-fi material. The professional music lovers seem to have staked out this area as their own private domain, and there is no denying that music is the largest and most important source of hi-fi programs.

Just about any form of music can now be heard in hi-fi, from ancient plain-song to ultramodern jazz. We can hear all varieties of vocal music from popular ballad to grand opera, instrumental music from lute solo to a 160-piece symphony orchestra. But there are other sounds which to some are equally pleasing and equally important.

Poets have for centuries been writing of the beauties born of murmuring sound, of wind and limb, of hammer and saw, of horns and motors, of revelry by night. We also read of that which is far sweeter than the sound of an instrument: the sound of thunder heard remote, of sounds and sweet airs, and of troublous sights and sounds. Is there any good reason why sounds such as these should not also be heard through the medium of hi-fi?

And what about the words which are better spoken than read? A great speech, comedy or drama; the reading of fine poetry. Surely the audiophile who welcomes these contributions to his sound library—or even prefers them—should not be drummed out of the corps.

Perhaps the overwhelming predominance of music as *the* sound of hi-fi has come about through the belief that music imposes the most stringent demands upon the hi-fi system. But even this premise is false, as we shall see. It would seem then that *sound* is the thing, from whatever the source. And the true audiophile finds that his ears are one of his most highly developed senses, and he really *listens* to all of the sounds around him, be they music, speech or noise.

Until now we have been speaking of hi-fi in completely subjective terms, but from an objective viewpoint high fidelity is the collection, transmission, storage and reproduction of sound by electrical and mechanical means. Since the mechanical sciences go back to antiquity, while the electrical arts are still relatively in infancy, it is obvious that the first steps taken toward hi-fi were mechanical ones.

It could well be that the very inception of this art took place just about a century ago, with the invention in France of the *phonautograph,* by Leon Scott in 1857. When this machine was actuated by sound waves, it traced an impression of them in the form of a lateral wavy line in the lampblack coating on a rotating cylinder.

Scott thereby proved the feasibility of recording waves of sound, but how frustrated he must have felt, for he was never able to devise a method for reconverting these recordings to sound. A direct outgrowth of his *phonautograph,* however, is the *phonodeik,* a device still used in school physics laboratories.

In this case a diaphragm actuates a mirror, which reflects a beam of light on a moving strip of film. An electronic modification of this device is the basis of many movie sound tracks, but that gets us ahead of our story. The first known experiment for the reproduction of sound from a record came twenty years after Scott's phonautograph.

Thomas Edison repeated the Scott experiments in 1877, first using waxed paper as the recording medium. A few weeks

A NORELCO MODEL 9762M 12-inch loudspeaker, finest unit in the NORELCO line. Peak power-handling capacity is 30 watts. Dual-cone construction, common to all NORELCO speakers, extends frequency response from 35 to 18,000 cps. Efficiency is 14% at 400 cps, due to extra-long air gap and unusually powerful Ticonal magnet.

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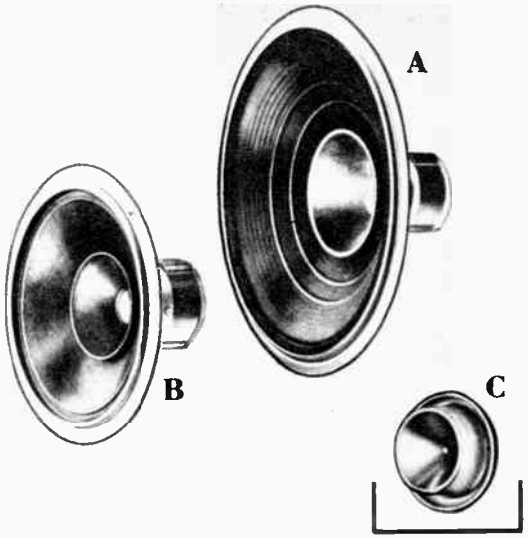


Conversion to Stereo Made Easy by Versatile NORELCO Hi-Fi Speakers

STEREO is here to stay. Pre-recorded stereophonic tapes are breaking all sales records. Sooner or later, most hi-fi enthusiasts will own a stereo tape recorder, if not one of the coming new stereo disc phonographs. Newcomers to high fidelity are showing a strong tendency to start with stereo tape right from the beginning.

Selecting a suitable loudspeaker system becomes doubly a problem with stereo, since a minimum of two speakers is required, and both must fit into the owner's space and budget allotment without undue stretching. That is where the NORELCO high-fidelity speaker line comes in.

Designed by world-renowned Philips of the Netherlands, largest electronics concern outside of the United States, these moderately priced, high-quality loudspeakers come in all sizes from 5 to 12 inches and are virtually tailor-made to the space and cost requirements of the typical hi-fi stereo installation. Not only do they take up remarkably little room in their handsome, acoustically matched NORELCO enclosures, but their sound is definitely in the "big speaker" class, with the suave, uncolored, undistorted quality which is so important in the revealing medium of stereo.

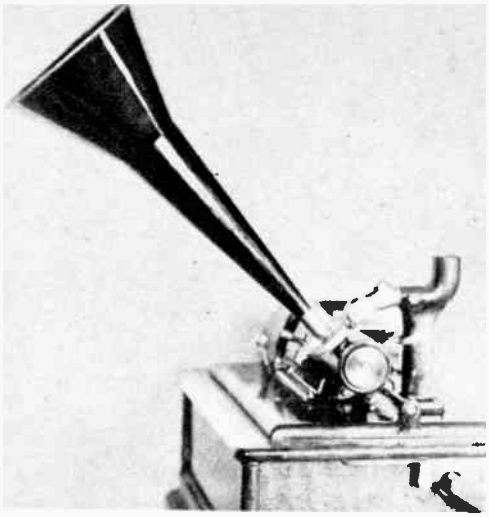
The special design features illustrated here are altogether exclusive to NORELCO loudspeakers in their price class and, together with exceptionally careful workmanship and quality control, are the main factors in the achievement of superior sound without extravagant spending.

Further information may be obtained by writing to North American Philips Co., Inc., High Fidelity Products Division, Dept. 4U0, 230 Duffy Avenue, Hicksville, L. I., N. Y.

D NORELCO SPEAKER ENCLOSURES are acoustically engineered to match the exact characteristics of NORELCO loudspeakers. Ingenious base arrangement permits choice of either horizontal or vertical cabinet placement. The enclosures are available in three sizes, with mahogany, walnut or blonde custom finishes.

E NEW STEREO VERSION of the famous NORELCO 'Continental' 3-speed portable tape recorder, soon to be available, will permit NORELCO sound quality from the very beginning of the stereo reproduction.

D



Courtesy Edison Laboratory National Monument

The Edison "Opera Phonograph" of 1912, equipped with recorder and horn for home recording.

later he instructed an assistant, John Kreusi, to construct a recorder which used tinfoil instead. When the machine was finished and the historic moment arrived for the first test, Edison for once forgot his flair for the dramatic and instead simply spoke, "Mary had a little lamb."

The stylus was then replaced in the first foil groove, the crank was turned, and the diaphragm began to vibrate, unmistakably miming Mr. Edison's reading of the first line of the nursery rhyme just a few moments before. The excitement of the occasion was too much for Kreusi, who exploded with the solid Germanic oath, *"Mein Gott im Himmel!"*

Maybe Edison's recorder was responsible for the use of the word "tinny" in reference to sound reproduction. At any rate, in 1881 Chichester Bell (a nephew of Alexander Graham Bell) and Charles Tainter conceived the idea of wax as a better recording medium. It isn't known whether they were influenced by Edison's waxed paper experiment, but it is a fact that wax was used thereafter for record masters right up until the second World War, when Montan wax, an essential ingredient, was controlled by the Axis powers. Now some experimenters are once again using wax for records, and it is quite possible that there will be a reversion to that medium.

The next big step on the road to hi-fi came in 1888, when Emile Berliner introduced the first flat disc record. The groove in this record had a lateral side-to-side movement, as against the vertical "hill-and-dale" system which had been employed by Edison and Bell up to this time.

Berliner also first used lampblack as the recording medium. But unlike Scott, who 31 years earlier had recorded sound in lampblack and then didn't know what to do with it, Berliner combined this method with an etching process which permitted the delicate original engraving to be transferred permanently to copper or nickel. This gave Berliner a master recording of some permanence, and it marked the first time that mass duplication of records was possible.

Some of these procedures were faulty, but Berliner knew he was on the right track, and by 1895 he had developed a system which consolidated the best ideas of his own and of his contemporaries. Combining Scott's lateral groove with his own flat disc coated with Bell's and Tainter's wax, he had the system which became the industry standard for half a century.

Equally important, he improved upon his original etching idea by switching to an electroplating process which was applied directly to the original recorded disc. Thus was born the negative metal master, which is still the basis of mass production of records.

Shortly thereafter, Berliner became associated with a machinist from Camden, New Jersey, named Eldridge Johnson. Many mechanical improvements resulted from this joint effort, including the spring-wound motor for reproducer turntables. Furthermore, Johnson had the creative imagination and promotional drive to realize the commercial potential of the phonograph. Visitors to the huge RCA complex at Camden can even today see that many of the buildings still bear the name of the Victor Talking Machine Company, monuments to the man and to the company which ceased to exist almost thirty years ago.

But in those hectic early days, Edison thought that Johnson was completely off base. His philosophy, in his own words, was: "I don't want the phonograph sold for amusement purposes. It is not a toy . . . no one would comprehend its value or appreciate its utility as an aid to businessmen and others for dictation purposes when seeing it only in that form."

Edison later capitulated, of course, but he was still swimming against the tide. While the majority of the industry was standardizing on a disc record with a lateral groove, the first Edison records were cylinders with a vertical groove, and infinitely more difficult to reproduce in quantity. But Edison's fatal mistake lay in his attempt to impose his own musical tastes on the record buying public; as an

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Courtesy Edison Laboratory National Monument

Some of the horn-type cylinder phonograph models available in the early days of the Edison machine.

artist-and-repertoire man he was a great inventor.

But whether cylinder or disc, vertical or lateral, all of the recording systems of the time were purely mechanical. Electrical recording was still some years away, and records of this earlier era are now referred to as *acoustical*. In this form of recording the actual sound produced by the performing artist was the sole source of energy for actuating the system.

The sound was collected in one or more large horns, which had a sensitive diaphragm at their apex connected to a cutting stylus. A wax disc was thus engraved with a groove by this vibrating stylus. The system was exceedingly simple, with the performers at one end of the horn and the recording lathe at the other. Often the entire system was right in the same room with the performer, although in some cases the throat of the horn passed through a hole in the wall.

Today we often "pipe" the sound from a recording studio control room through audio transmission lines to recording machines in another room, on a different floor, or even in a separate building. This is possible through the magic of electronics, which fifty years ago meant nothing to recording but was already beginning to make itself heard in other circles.

When the telephone of Alexander Graham Bell was added to the wireless of Guglielmo Marconi, there was born radio broadcasting, a major breakthrough in the

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Get this P·S·E booklet at your high fidelity dealer. It lists all the more popular systems you can build the P·S·E way, plus complete specifications on all University speakers, networks, enclosures and enclosure kits. **Or write Desk W-22, University Loudspeakers, Inc., 80 South Kensico Ave., White Plains, N. Y.**

HOW P·S·E WORKS...*a typical example*

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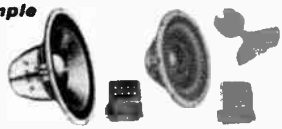
STEP 2 Improve the high frequency reproduction to beyond audibility by adding the Model HF-206 Hypersonic Tweeter and N-2B L/C crossover network.



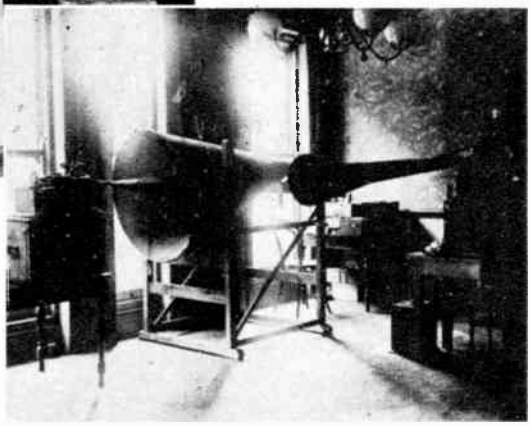
STEP 3 Reinforce bass response with the Model C-12W Adjustable Response 12" woofer and N-2A L/C network. The Diffusicone-8 now functions as a mid-range speaker. The result . . . the deluxe multi-speaker system you want tomorrow but started today . . . the P·S·E way!

LISTEN

University sounds better

The Bettmann Archive

French musicians during a recording session. The master disc can be seen on machine in front.



At right is the Music Room at Edison House in London, May 1889. Note large recording horns.

Courtesy Edison Laboratory National Monument

Courtesy Edison Laboratory National Monument

The 1911 Metal Amberola Cylinder Phonograph for schools had storage space for spare cylinders.

continuing upward climb toward high fidelity. In the Marconi system, the method of transmitting intelligence was simply to interrupt the radio wave into the dots and dashes of Morse code. The contribution of Dr. Lee De Forest was the *audion* tube, which allowed the radio wave to be emitted constantly and act as a "carrier" for the audio which was superimposed upon it.

The first broadcast performer in history was Mme. Eugenia Farrar, a young Swedish concert singer whom Dr. De Forest put on the air early in 1907, with a touching rendition of "I Love You Truly." Across the river in the Brooklyn Navy Yard, a few hard-bitten wireless operators jumped to attention when they heard these impossible sounds. For after all, everyone knew that the only thing you could send through the air was the beeping of Morse code.

When they became convinced that it was no hallucination, however, the chief electrician correctly guessed who was responsible. De Forest recalls that he answered the phone in his studio a few minutes later, to hear a voice at the other end say, "Doc, am I drunk or crazy, or are you sending out some talk and music over that wireless of yours?"

It is not recorded whether the electrician

This early magazine ad shows some of the recordings available for the "New Edison Concert Phonograph."

Culver Service

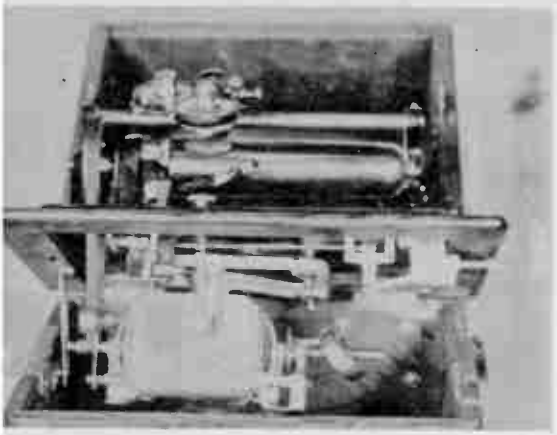
was drunk or crazy, or both, at the time, but De Forest most certainly was sending music and speech over the air. And his audion tube opened up new vistas in every other sphere of entertainment as well. The idea of using the front end of De Forest's radiotelephone to drive a recording system was first proposed in 1919.

Two Bell Telephone Laboratories engineers, H. C. Harrison and J. P. Maxfield, were working on the problem in this country, while two British experimenters, Lionel Guest and H. O. Merriman, were simultaneously at the same task in England, each group oblivious of the work being done by the other. Five years passed, though, before the two American giants, Victor and Columbia, began to take the thing seriously and it wasn't until 1926 that electrical recording was being done on a large scale.

The sluggishness of Victor and Columbia in embracing electrical recording was possibly not unwarranted, as the comments of one writer of the day were something less than laudatory: "The exaggeration of sibilants by the new method is abominable, and there is often a harshness which recalls some of the worst excesses of the past." This opinion appeared in *The Gramophone* in London, the November 1925 issue, but it could very well have been reproduced a quarter-century later as one of the familiar diatribes against hi-fi.

Western Electric, whose job it was to commercialize the research developments from Bell Labs, had simultaneously been trying to market the electrical recording in quite a different area, also with very little success. Like the recording companies, the movie producers had also remained aloof, but they too finally capitulated and the first full-length sound motion picture was presented at the Warner Theater in New York on August 6, 1926.

This first showing was in reality just a movie with phonograph accompaniment. There was no problem of dialogue synchronism on the records, because there was no spoken dialogue. The sound track consisted entirely of a musical score performed by the New York Philharmonic. The records were similar in many respects to those then appearing in the stores under the Victor and Columbia labels, except that they were larger and rotated more slowly. The diameter of these discs was 16 inches and their speed was 33⅓ rpm, a combination giving a playing time approaching 15 minutes. The first movie record was thus the granddaddy of today's LP. Even more closely related is the elec-



Courtesy Edison Laboratory National Monument

Above is the Edison Business Phonograph with a gyro governor. Motor was also made by Edison.

Courtesy Edison Laboratory National Monument

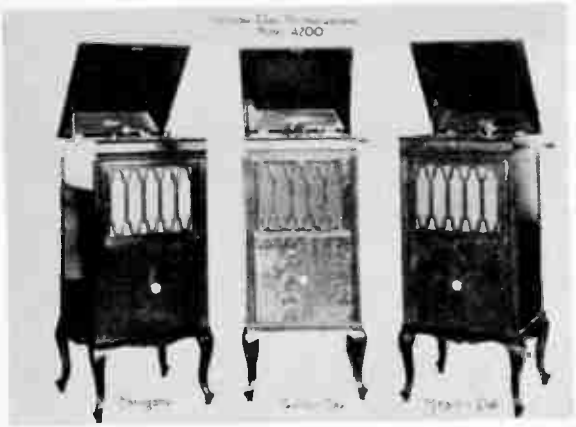
Edison's Excelsior Phonograph was probably the first juke box. Note coin insert next to horn.

Courtesy Edison Laboratory National Monument

Above, this ornate Statue Cylinder Phonograph with marble base was made by Edison about 1911.

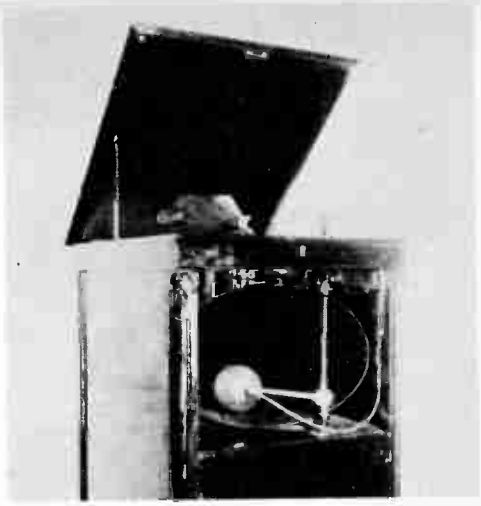
Courtesy Edison Laboratory National Monument

Here is one of the first disc phonograph consoles with a loud-speaking attachment; 1915.



Courtesy Edison Laboratory National Monument

The Model A200 Disc Phonograph was a handsome piece of furniture, came in several wood finishes.

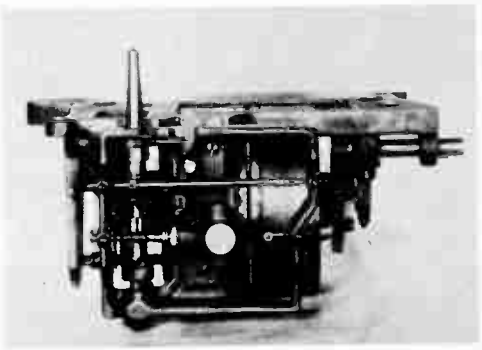


Courtesy Edison Laboratory National Monument

Inside view of disc phonograph shows the speaker with a muting attachment for volume control.

Courtesy Edison Laboratory National Monument

One of most popular phonographs was the 1911 disc player with crank drive, shown in photo, left.



Courtesy Edison Laboratory National Monument

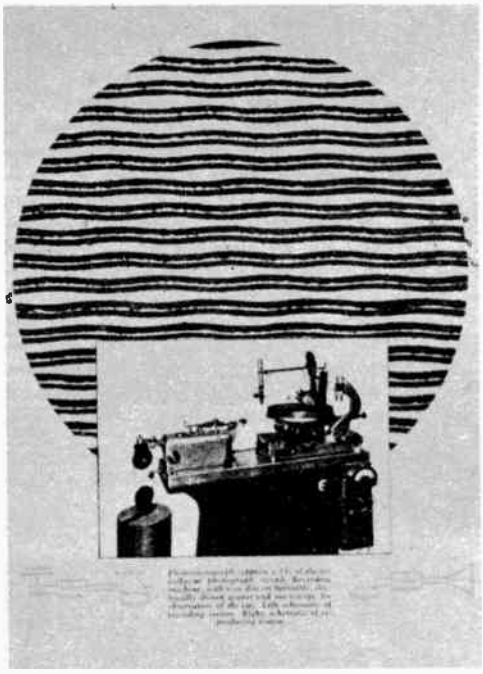
Above is the manual drive mechanism for the 1911 Edison disc player. Note the neat arrangement.

trical transcription used in radio and television stations, which is physically just about the same as the old motion picture recording.

The disc record had many disadvantages for film work, however: it was bulky to ship, subject to breakage, and required a new set of skills from the projectionist. Furthermore, there was always a loss of synchronization when a film broke and a few frames were lost. Obviously what was needed was a system for putting the sound right on the same film with the picture.

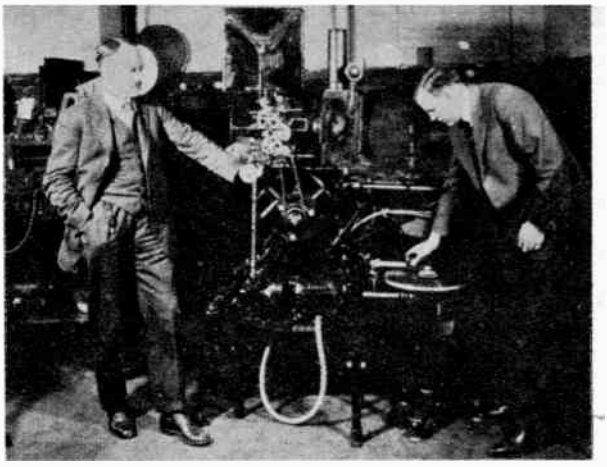
Dr. De Forest had had such an idea since around 1919, and on April 12. 1923, showed a soundfilm picture to the public at the Rivoli Theater in New York. Thus motion picture sound-on-film actually predated commercial sound-on-disc, although both Edison and D. W. Griffith had experimented with discs earlier, and soundfilm was ready to go when William Fox decided to meet the Warner Brothers challenge with his own sound pictures, with the sound track right on the film.

The first film to use the Fox Movietone system was presented at the Roxy in New York on October 28, 1927, and in a very short while sound-on-disc for movies was relegated to the history books. Optical



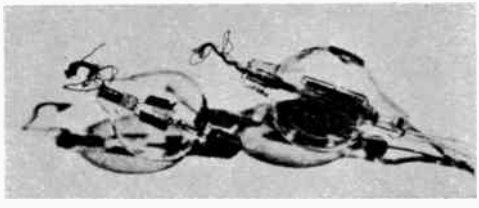
Courtesy Bell Telephone Laboratories

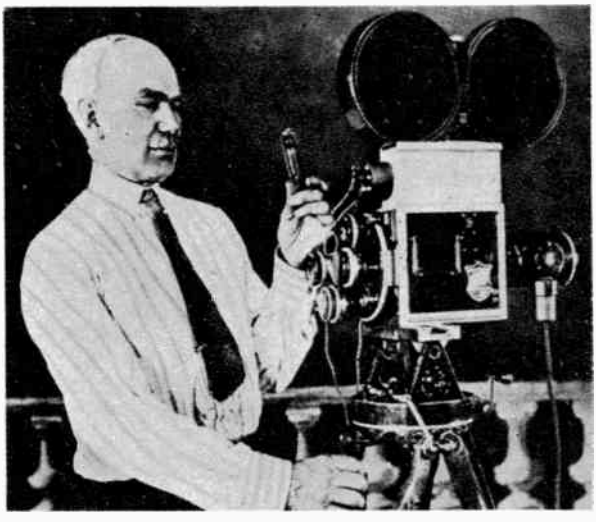
Method and machine for electrical recording of sound on wax was developed at Bell Laboratories.



Courtesy Bell Telephone Laboratories

H. M. Stoller (left) and W. Pfannenstiehl with first commercial model of the disc record attachment for the motion picture projection machine.





Courtesy Bell Telephone Laboratories

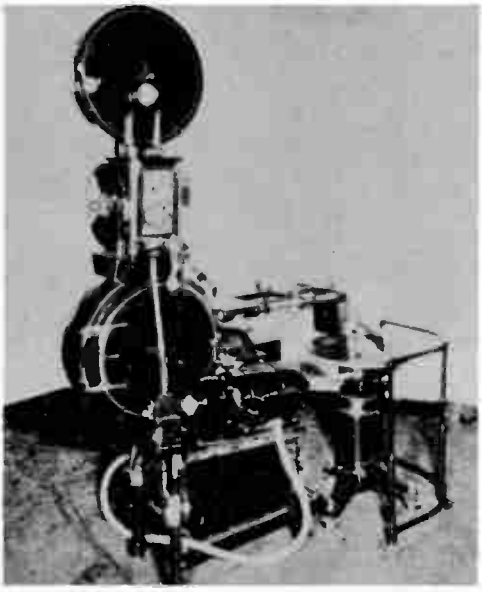
Above, left, is Lee De Forest's audion, the father of the vacuum tube. At right, Dr. De Forest with his invention which unlocked the door to a new scientific age. Projector shown is equipped for sound recording.

recording of sound on film became so good, in fact, that it was the most hi-fi method of sound recording until the perfection of magnetic recording about two decades later.

The one event which stands out as the dawn of the modern hi-fi was the opening of the first FM radio station by Major E. H. Armstrong in 1937. The technical standards adopted for this service still represent the bench mark for all types of hi-fi today, standards which even now are not always met by records and recorded tape.

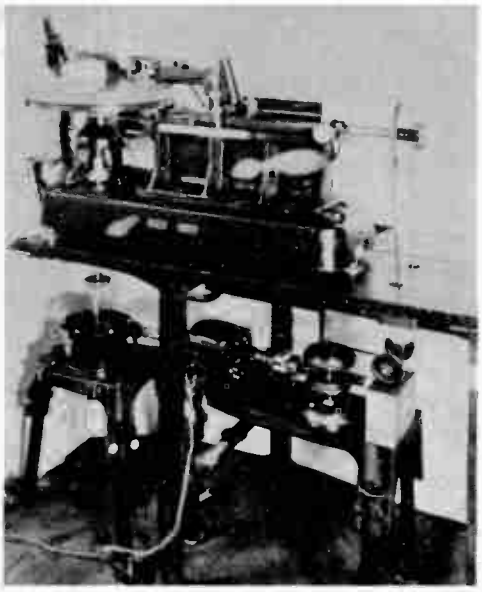
At the end of World War II we were brought up to date on the German developments in magnetic recording, a tremendous step forward in hi-fi. Shortly thereafter we had the introduction of the LP record, which signaled the first widespread public interest in hi-fi. As soon as home hi-fi was firmly established, stereo sound began to create a few ripples of excitement. This became a full-fledged boom with the advent of the stereo disc in late 1957. Just what stereo is and what it means to you is detailed in a special section of this book.

And there you have the essentials of what hi-fi is and where it came from. As for what you can do about it, begin by turning the page. •



Courtesy Bell Telephone Laboratories

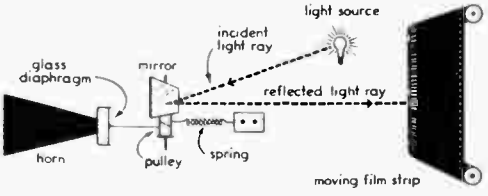
Motiograph de luxe motion picture projector with Universal Reproducing machine attached to it.



Courtesy Bell Telephone Laboratories

Above is an early machine for recording sound on phonograph discs. Note microscope above disc.

Right. The Phonodeik was one of the earliest devices for detection of sound waves (see text).



First public performance of first sound motion picture took place on Broadway, August 6, 1926.

Courtesy Bell Telephone Laboratories

It's Your Choice

The choice of weapons in the hi-fi war is up to you: Kits, components, packages.

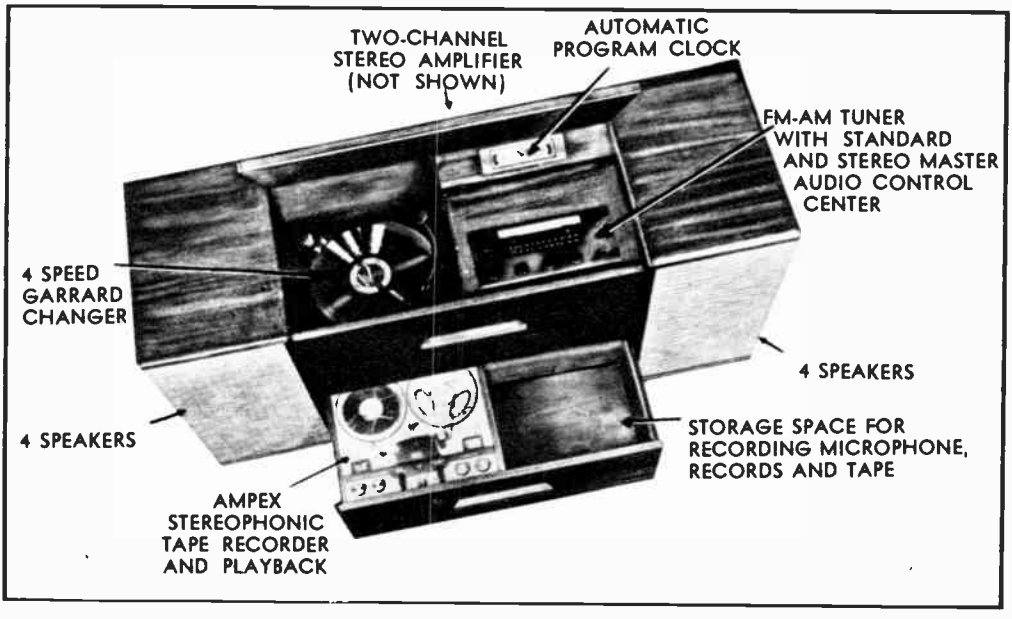
THE time is not long past when, to enter the exalted precincts of the hi-fi fraternity, one had to have college degrees in music and engineering—or the ability to fake both. It was enough to frighten away all but the most brash beginner. Happily, hi-fi has come back down to earth, and anyone who wants to adopt it as his hobby needs no longer fear his ignorance of the secret handshake or password.

There are three basic ways of assembling a hi-fi system, one of which is sure to meet your requirements. If you are short of cash, or if you just like to tinker in the home workshop, then a few construction kits will turn your little bungalow or apartment into a hi-fi haven as good as the best of them.

If you have more money or less time to spend, then you will probably assemble your system from a group of components. This is the most popular method, the real cornerstone of home hi-fi activity since the very beginning. If you really want to splurge, or if the lady of the house is very particular about the furniture which goes into it, then the complete hi-fi package is for you, especially if it's the only way to keep peace in the family.

The hi-fi kit maker is essentially a designer of audio systems and a purchaser or manufacturer of parts. (Some say he is nothing more than a shrewd copier of successful component designs, but don't expect me to get dragged into that argument.) When you buy a kit you get a box full of parts, a metal chassis on which to mount them, usually with all of the necessary holes prepunched, plus an instruction book which tells how to combine this batch of prosaic objects into a vital link in your hi-fi system.

The first steps in construction involve mounting on the chassis the larger parts and connecting points, such as transformers, choke coils, tube sockets, terminal strips and controls. This is done with machine screws and bolts or, in some cases, sheet-metal screws



The Fisher "Executive" is a luxury package which contains AM-FM tuner, Ampex tape recorder, 4-speed Garrard changer, stereo amplifier and program timer. Handsome cabinet houses eight speakers; $1,595.

Photo, left, shows the wide variety of General Electric components available to hi-fi fans. Included are 23 different styli, nine cartridges, tone arms, preamps, filters, speakers, cabinets, network.

and requires you only to be able to handle a screwdriver and pliers or small wrench.

Next, the smaller components and wire interconnections are added, most of this operation taking place on the underside of the chassis. Insulated wire is connected between a number of various points, as well as the wire leads on the parts. This phase requires the use of a soldering iron, and with the trend toward miniaturization this can be tricky. (See page 132.)

In such close quarters it is all too easy to solder two points together which should be separated by an air space. If you're not an old had at soldering, by all means go slow until you master the knack of it. Remember that impatience can easily lead to failure of the equipment to operate, and then a frustrating period of trouble-shooting after that.

The wire length on components is nearly always greater than necessary, and these must be trimmed to fit. Hookup wire must usually be cut to length and the insulation trimmed off each end for a quarter-inch or so. In some kits all of the hookup wires are already cut and stripped. In others, hookup wire isn't even furnished as part of the kit. In this case you buy your own roll of wire and cut and strip it as needed.

Practices also vary on the inclusion of such items as solder, glue, sandpaper, paint, varnish and special tools. It's a good idea to know before you buy just what you're getting. Hardly anything is more annoying than to sit down to a nice relaxing evening of kit building, only to find that you can't begin without some materials from the hardware store, which probably closed only a few minutes before.

The instruction books of most major companies, such as Heath, Eico and Knight, are well written and illustrated. If you can read English and handle a few simple tools, you'll have no trouble in assembling a complete system by the kit route. There are other construction manuals, however, which require an expert in engineering or semantics, or both, to decipher them.

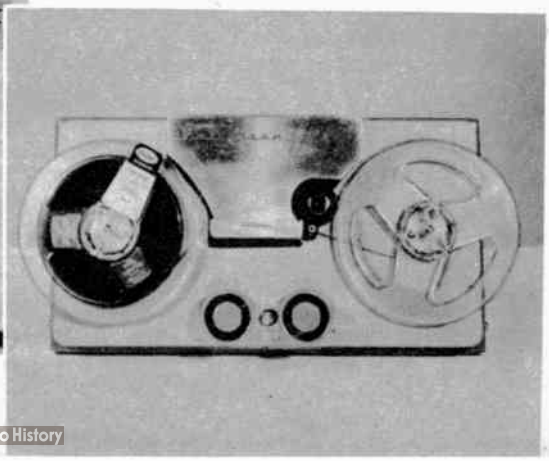
You should certainly bear in mind—even though some kit manufacturers do not—that the instruction book is every bit as important a part of the kit as the design on which it is based or the components which make it up. Most companies are willing to send you samples of their instruction material, either at nominal cost or free of charge. Some points may be obscure without the parts right in front of you, of course, but if the writing seems semi-illiterate, the drawings sloppy, or the printing barely legible, you'd be wise to take your patronage elsewhere.

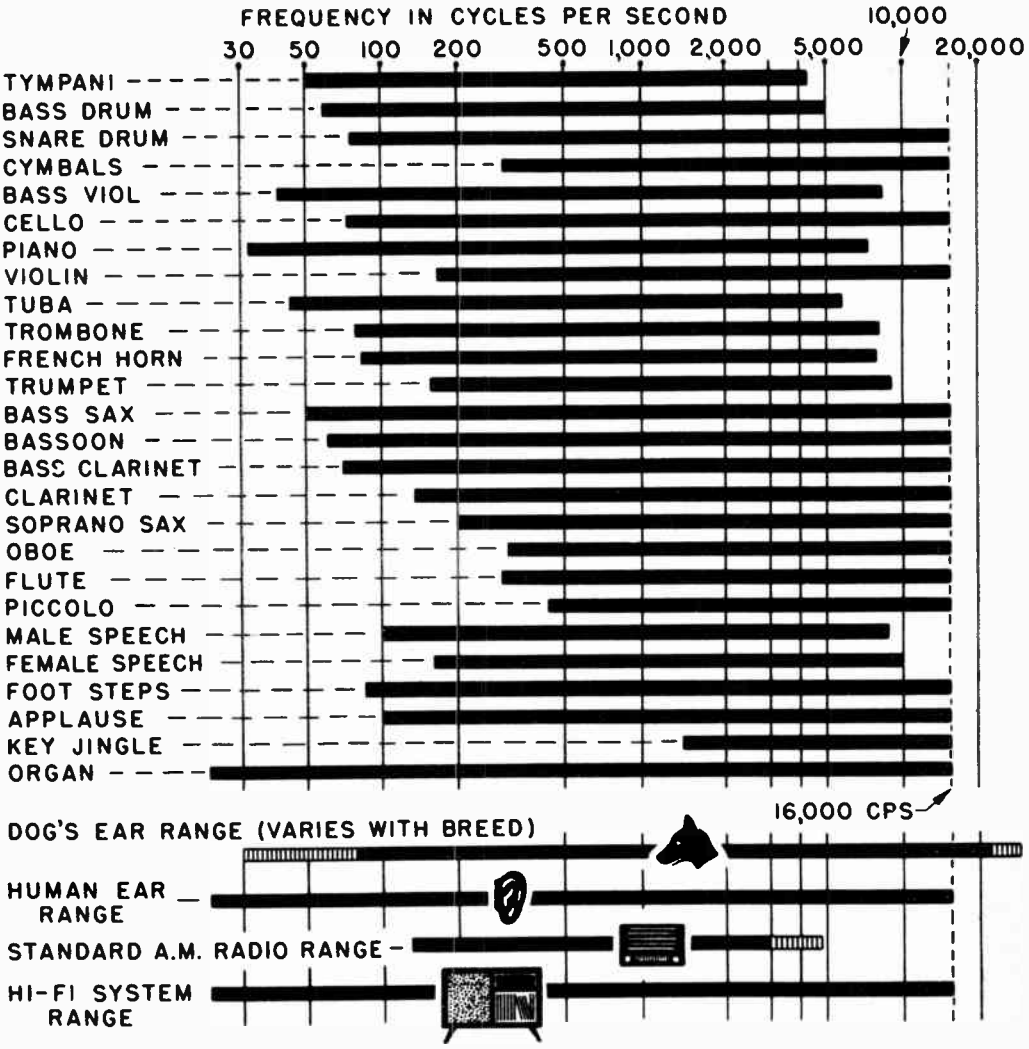
The greatest advantage of the kit method of hi-fi assembly is economy. This is the one way to get the very most for your money. Perhaps the next most important feature, as any experienced constructor can tell you, is the very real sense of personal gratification you'll feel when you look at your own finished handiwork and actually hear it working. This thrill is completely unknown to non-kit members of the hi-fi fraternity.

Another important advantage is the fact that kit buyers usually deal directly with the manufacturer, since most of the kit suppliers are in the mail-order business

Speaker system package and enclosure kit by General Electric has 6-in. woofer, tweeter, network; ½ cu. ft. cabinet; $49.95-$57.

Tape recorder in kit form is the "Starfire" by Patterson Research. It has 26 major parts, two motors, five tape speeds, three heads.

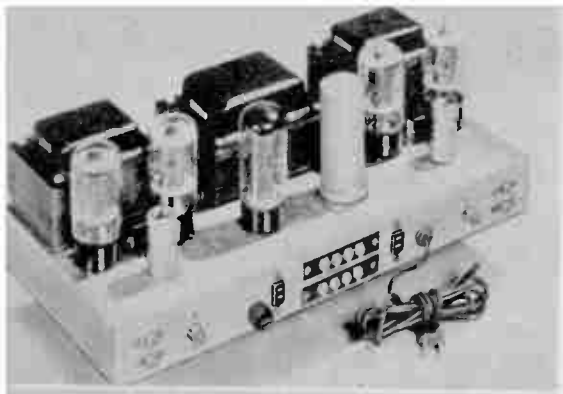


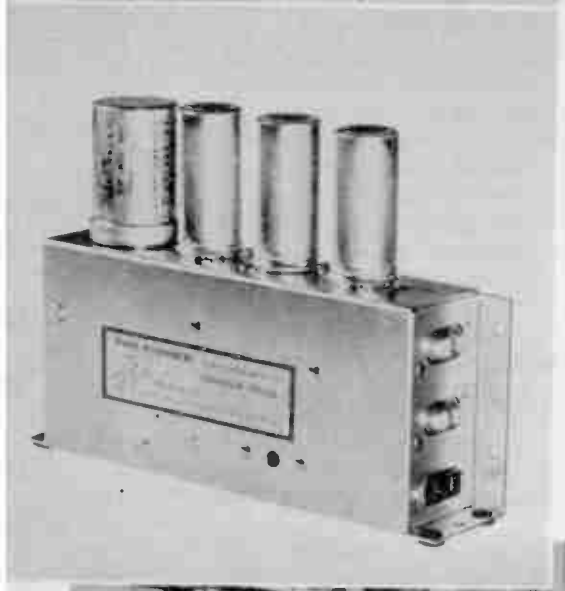


Balanced reproduction of sound by hi-fi system is necessary to cover the complete audible spectrum. Chart shows cps range of various instruments; although many go higher, human ears usually hear up to 16,000.

Concertone stereo tape recorder and two speaker-amplifier cabinets are handsome package deal.

Three-part Altec package: 306A AM-FM tuner, 440C preamp, Laguna speaker, amplifier (not shown).





only. This is quite important if your assembled kit fails to operate, or if you need service or wish to consult with the factory engineers. At a time like that you don't want to bother going through the distribution channel in reverse, from salesman to dealer to distributor to manufacturer, before you can get to the man who can help you with your problem.

The biggest disadvantage of kit construction, as compared with other methods, is simply that it is a lot of work. Much more of *you* has to go into a kit-assembled system. Furthermore, it is difficult or even impossible to see and hear a completed system assembled from the kits you'd like to buy. Some of the kit companies work through regular distribution channels, however, and in such cases this criticism doesn't apply.

When dealing with the mail-order com-

Arkay 55-watt amplifier in kit form is a component for use in concealed installations. It has two channels, about 30 watts each, for stereo system.

Fisher stereo preamp-equalizer, left, has no controls, is used for low-level magnetic stereo cartridges or tape playback heads; 20-20,000 cps.

Custom installation fits between two bookcases, includes Lansing speaker system, Garrard changer, Fisher tuner preamp, McIntosh amp, 21-in. TV.

panies, about the only way you can hear a demonstration of their products is to find someone who has already built them, or else find the finished kits displayed at one of the trade shows. The latter course is more difficult now, too, for the hi-fi trade association has fixed on a policy of components only at their shows, thus barring both kits and packages.

You needn't be too concerned if you have to buy blindly, however, as the mail-order operators in the kit business are of high integrity. Some of their top executives have moved up from old-line organizations such as Montgomery Ward and Sears Roebuck, where the customer is always right—even when he's wrong.

When a group of kits makes up a hi-fi system, the assembled components are essentially the same as a set of factory-built units, and the installation is identical. The component method of assembly is the "traditional" one, having been employed by experimenters and musicians for many years to obtain quality sound reproduction in their homes. With the inadequacies of the usual radio-phono home instrument painfully apparent, those who hadn't the knowledge or inclination to build their own turned to professional components, manufactured for broadcast, motion-picture or public-address work. The component assembly method of hi-fi today is a direct outgrowth of this original adaptation of professional equipment to home use.

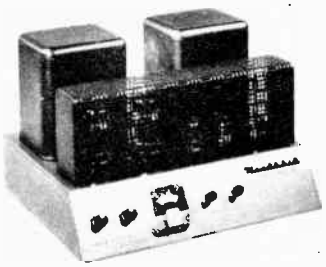
Each individual component in the chain is factory assembled, including such items as the turntable, amplifier, tuner and loudspeaker, but the group of components then must be combined by electrical interconnection to make up the complete system. Your choice of components will depend in part upon the amount of money you want to spend, as well as the compatibility of any given group. This means not only electrical compatibility, but logical combination as well. It wouldn't make much sense, for example, to expect to use a 6-inch speaker with a 50-watt amplifier.

You can get a comprehensive picture of the entire field by writing to the manufacturers advertised in this book, requesting their catalogs and literature. From these you can learn the performance specifications, operating features, physical dimensions and prices. With a tentative system worked out, you can go to a hi-fi distributor who will actually hook up the component combination you have in mind. You can then see it, hear it, and decide from the demonstration whether you'll be able to live with it.

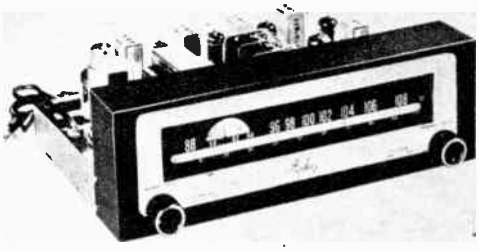
Interconnection of the components at home is quite simple: most of the connections are made through shielded phono cable with suitable plug connectors at each end. The phono pin plug is most commonly used, although you may also encounter phono plugs and mike plugs of various types. In a few cases, usually in the loudspeaker and antenna connections, bare ends of wires are held in place by the screws on a terminal strip.

Many components are rather spartan in appearance, and are best concealed by cabinetry or built into some part of the house, such as a wall, bookcase, closet door or balustrade. Whether to build in or build out will depend upon your particular requirements, but it's a safe bet that the components will be concealed in some fashion soon after the lady of the house lays eyes on them. Hi-fi cabinetry is available in a wide variety of styles, both completely assembled and knocked-down, prefinished and unfinished.

One of the greatest advantages of the component approach to hi-fi is the fact that the desired combination of units can be heard in a dealer demonstration. Also,



Heathkit 70-watt amplifier kit for concealed installation costs $109.95. Harmonic distortion at 70 watts is below 2%. IM distortion is below 1%.



Arkay kit of FM tuner has tuning meter, less than 1% distortion. Response is ½ db, 20-20,000 cps. Hum level: —70 db; tuning range: 88 to 108 MC.

Popular RJ enclosures take up little room, come in several sizes and shapes for 8-, 12- and 15-inch speakers, in floor or bookshelf model designs.

Jensen 4-speaker kit for custom installation in own cabinet includes 15-inch woofer, tweeters and mid-range speakers, crossover network, controls.

the amount of construction work necessary to put the system into operation initially is very slight. And for any kind of custom installation the only sensible approach is through components, either from kits or factory-made.

The British colloquial understanding of the term *package* as meaning a doxy, fits perfectly into the hi-fi lexicon, according to many audiophiles. This is probably because some home instrument makers, hoping to lay hands on some hi-fi loot, often refer to their shabby products as "packages." This is unfortunate because there are true hi-fi packages and they have a legitimate place in audio.

The term has two meanings today (in addition to the one just noted), and sometimes refers simply to a group of components. Many distributors offer such groups at reduced prices in a package deal. The only package we want to talk about here, however, is the concept of the hi-fi component which is already enclosed in its own attractive furniture to form an integral assemblage.

The installation of a hi-fi package involves hardly more than removing it from the carton, plugging into the nearest wall outlet and playing. The hi-fi package is, therefore, superficially similar to the low-fi home instrument, but there are several important differences.

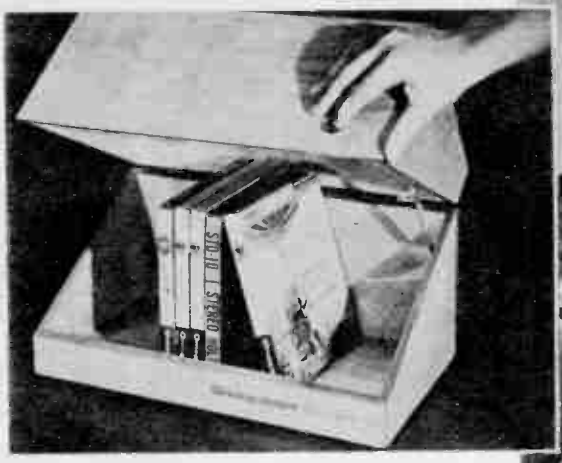
In the first place, the components which go to make up the package are truly high fidelity, with adequate power and frequency response, quite unlike the flimsy restricted-range radio-phono-TV combinations. For another thing, the speaker and its enclosure *must* be isolated from the electronic elements to avoid feedback, rumble and distortion. This identifying feature is *always* characteristic of the true hi-fi package, *never* of the low-fi home instrument.

The package method has much to offer the audiophile who wants a truly high grade system without the fuss and bother of stringing together a bunch of components and making them match. Since the package often resembles in external appearance the ordinary home instrument, and since the home instrument makers are very loose in their use of the term hi-fi, there are a few general rules you can follow to help separate the true hi-fi packages from the many impostors.

These rules set down the bare minimums which any package must have to qualify as a high fidelity instrument:

1. ***Completely separate speaker enclosure***
2. ***At least three record compensator positions***
3. ***Separate bass and treble tone controls***
4. ***True two-way (at least) speaker system***
5. ***Speaker enclosure of at least two cubic feet***

Although most of the record industry has now agreed to follow the RIAA recording characteristic, and the requirements for flexibility in record compensation are not as important as they once were,



Omegatape stereo chest is designed to hold about 25 stereo tapes. Cover closes to keep out dust and the handsome wood finish makes it quite unobtrusive.

Line between component and package becomes indistinct in the above set-up of Bell AM-FM tuner and 15-watt preamp/amplifier in one compact unit.

there are still many records around which were made with the old Columbia LP characteristic, and the European characteristic is something different again.

The reason for separate tone controls is obvious. No single control can make adjustments at both ends of the spectrum just the way you want them. And by the same reasoning, no single loudspeaker can reproduce the entire audible spectrum.

The size of the enclosure is one of the most important factors in determining the low frequency response of the system. In general, the larger the enclosure the better the bass response. The criterion of two cubic feet is based upon the fact that the lowest frequencies which will be emitted by *any* speaker in a box that size will be in the vicinity of 60 to 70 cps.

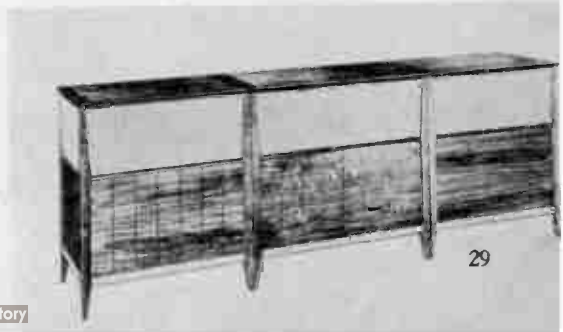
Since the lower limit of audibility is a couple of octaves below this figure, it is stretching things a bit to call such a system hi-fi. On the other hand, since about 90% of the time all of the music will be above this range, not too much will be lost by such a limitation.

These then are your three alternatives: kits are least expensive, a lot of fun, and also a lot of work; packages are the simplest, best looking and most expensive; between these two extremes lie the components, which are the compromise preferred by most audiophiles.

Now that you have your system, the next thing is what you will put through it. Your main choices here are records, tape radio and TV. More about these in the next chapter. •

Scott 310-B FM tuner comes in attractive wood-metal case, can be displayed anywhere in home; it also allows for custom installation. Sensitivity is 1 uv for 20 db quieting with 72-ohm antenna.

Jensen makes this custom equipment cabinet, seen here between two SS-200 speaker systems. This type unit makes for quality and handsome decor.



Sound Sources

Music may come from many sources: records, tapes, AM, FM, home recordings, sound tracks.

THE hi-fi art has progressed so rapidly in the last decade that we often forget how few sources of hi-fi listening we had in the beginning, compared to the many we have now. The dawn of modern hi-fi really dates back to 1937, when regular FM broadcasting was begun.

The small band of pioneer audiophiles of that era had FM—and that was absolutely all. Standard AM radio was better than it was given credit for, but where could one find a receiver which would detect these signals with fidelity? Records were noisy and limited in range. Movie soundtracks were sometimes very good and often very bad. Television was still in the early experimental stages, and tape recording was unknown here.

Today, however, every one of these media has come of age, and their sounds are those of high fidelity. Since they are the stuff of which our hi-fi listening pleasure is made, they deserve a closer examination.

The transmission of sound by means of radio, whether it be AM or FM, involves

RCA Victor photo

Photo above shows Leonard Bernstein as soloist and conductor of the N. Y. Philharmonic orchestra during a recording session.

As the orchestra plays in the recording studio, a tape recorder picks up the sound. The engineer, left, adjusts controls for proper loudness, fidelity and musical quality.

Columbia Records photo

the superimposition of an audio wave, called the *modulation,* upon a radio wave, called the *carrier.* This modulated wave is transmitted through the air to the antenna of a radio receiver. In the tuner section of the radio set the audio component of the signal is recovered by a process known as *detection,* or *demodulation.* At this point the audio is an electrical signal, no different from those from a microphone, phono cartridge or tape head.

The original modulation method employed by De Forest is still the most widely used today. It is usually called AM, an abbreviation for *amplitude modulation.* In this system the power output of the broadcast transmitter is alternately increased and decreased as the audio level varies. The power thus swings above and below its normal unmodulated value, the amount of these swings being determined by the intensity of the audio signal.

While it is theoretically quite possible for AM radio to meet hi-fi standards as well as any other medium, the practical fact of the matter is that in today's commercial broadcasting setup it does not do so. There are several reasons for this, some physical and some economic, but it was another shortcoming of AM that Major Armstrong had in mind when he advanced the idea of FM radio.

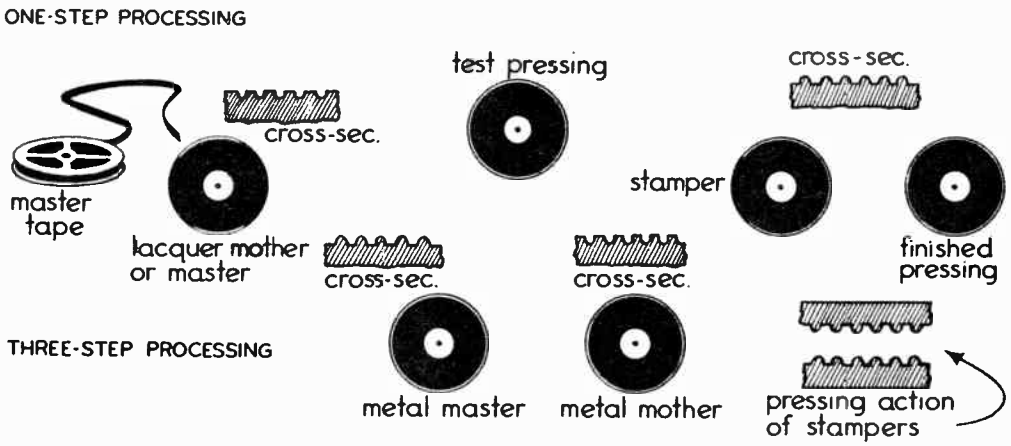
RCA Victor photo

For recording of a phonograph record, high-quality tape recorders are used. Usually two machines record the program material on tape.

RCA Victor photo

Above. From the tape the music is recorded onto a lacquer disc. Photo shows sound grooves being cut into the disc's surface with help of lathe.

FIG. 1, below, shows the steps involved in making a phono record from master tape.



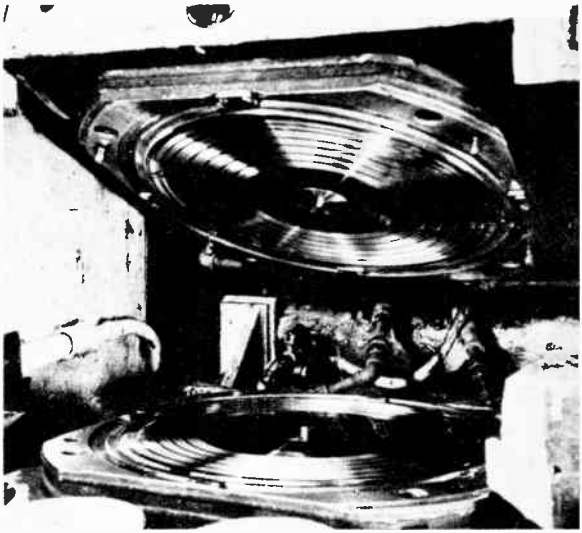
Earlier experimenters had felt that "static" noise was inseparable from radio signals because the two were identical in character. It was this noise that Armstrong wanted to eliminate, and he devoted many years to the problem. His first efforts were concerned with receiver circuits, and while many permanent contributions were made to the design of radio sets, the noise problem was still present.

Having decided that nothing further could be done at the receiving end, Arm-

The lacquer disc receives a chemical bath where thin separate layers of silver, nickel and copper are deposited on its surface. The metal portion is separated from the lacquer, giving us a "master."

RCA Victor photo

A metal mold disc is made of the master by applying coatings of nickel and copper. The mold disc is coated with nickel, making a final disc of hard nickel, a "stamper." This presses the records.



RCA Victor photo

strong then turned his attention to the method of transmission. If AM radio and static noise are so similar in character, he reasoned, then why not some other method of modulation, which is *not* like static? From this line of development came the system of FM radio broadcasting we know today.

Frequency modulation, as its name implies, involves varying the frequency, rather than the amplitude or power of the carrier wave. The power in fact remains perfectly constant regardless of the modulation. With a receiver which is absolutely insensitive to variations in amplitude—and this is essential—the FM system will provide substantially noise-free reception. It was wisely decided at the outset to apply a rigid set of specifications for audio quality in FM service, including a frequency range of 30 to 15,000 cps, and thus it happened that we had our first true hi-fi nearly twenty years ago.

The recording industry was hardly as enlightened, however, and it took another dozen years before they gave any thought to hi-fi at all. Then it took some tremendous efforts to catch up with a world which had passed them by, but there is no longer any doubt that they have succeeded.

Today all original recordings, regardless of the ultimate form they are to take, are first made on magnetic tape. At the session, performances are recorded not just once, but many times over. The best of these tapes may be picked as the master to be rerecorded to disc, but more often there are a couple of intermediate steps.

The first of these is editing of the tapes. In this case the best parts of each of the many recorded takes are physically cut out of the originals and spliced together to make a new composite master. Thus the performance on the final record is better than one would be likely to hear in a live show, being really a synthesis of the best of many performances.

The composite master can also, of course, serve as the original for the disc, but more and more often there is still another step, rerecording from tape to tape. The copy tape is not an exact duplicate, but rather a revised version of the original. The signal from the edited original is fed through special filters, equalizers and other control equipment. This permits changes in balance, timber, dynamics—even changes in pitch. When all of the settings have been established and thoroughly rehearsed, finally a second tape recorder is started to take down the sound after revision.

When a finished tape is approved for mastering, it is then rerecorded onto a blank disc. A record cutting machine, along with its associated amplifying equipment, receives the sound from a tape reproducing

RCA Victor photo

Records are made from vinyl plastics, rolled into sheets. The sheets are cut into squares, or "biscuits," each biscuit making one phono disc.

RCA Victor photo

The stamper discs are put into a press, one for each side of the record. A heated biscuit is inserted and the closing press stamps the grooves.

RCA Victor photo

Final step in record manufacture is trimming off the excess material around edge and cutting the hole in center. The discs are then ear-tested.

machine and converts it into mechanical motion in an engraving stylus.

The blank recording disk is a plate of thin aluminum covered with an exceedingly smooth coating of soft black lacquer. One of the main ingredients of this lacquer is cellulose nitrate. This is the type invariably used for professional recording, but since cellulose acetate is also used for less exacting applications, any instantaneous recording is generally referred to as an "acetate."

To record the maximum information in the smallest possible groove area, the frequency characteristic of the cutter is deliberately distorted by a process called *pre-equalization*. It consists basically of increasing out of proportion the high end of the audio spectrum, so that a better ratio of recorded sound to high-frequency surface noise will result. At the same time the powerful low-frequency sounds are reduced in level, so that they won't cause overcutting into adjacent grooves. The specifics of this practice, as well as the means by which the hi-fi equipment compensates for them, are discussed in a later chapter. After recording is completed, the lead-out grooves and eccentric circle are cut, and the record is ready for processing and mass duplication.

A disc which is intended for processing is known either as a lacquer master or mother, depending upon the processing method. In either case an exact reproduction of it will appear on the finished record.

When the lacquer disc arrives at the plant from the studio, it is first placed in a cleaning solution and then spray-rinsed under pressure. Then the recorded side is coated with a thin film of silver, by chemical deposition similar to the process of silvering glass for mirrors. The record is now electrically conductive and can be electroplated with a heavy layer of copper over the silver.

The metal plate is then stripped away from the lacquer, and the silver side can be seen to have an exact negative impression of the disc surface, with ridges corresponding to the grooves in the lacquer. With a thin coating of chromium over the silver for durability, this metal negative may be used to press out finished records. This would be the case in one-step processing, as shown in Fig. 1, and the first metal

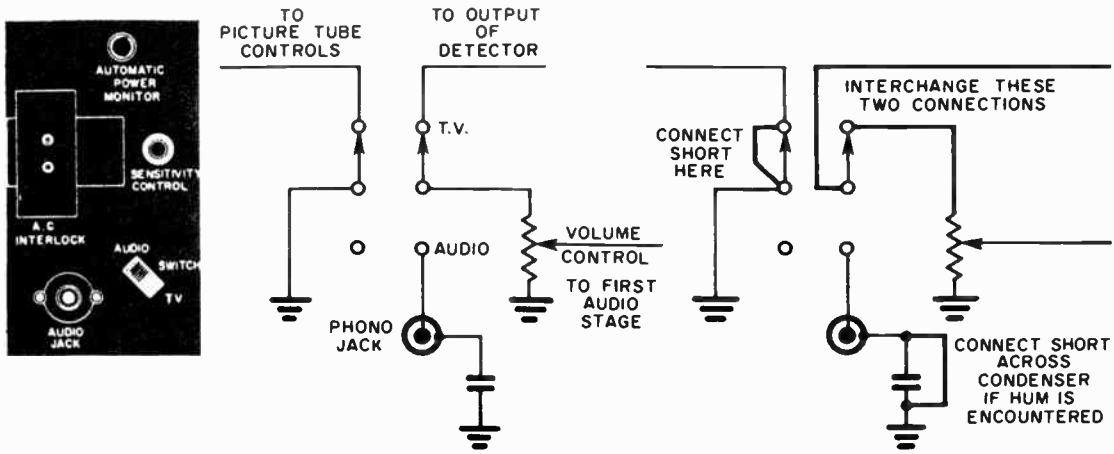
negative would be known as a stamper.

There may be two additional steps before pressing, however, in which case the first metal part becomes the master. In three-step processing the master is further electroplated to form a positive, known as the metal mother, and this in turn is electroplated again to provide another negative, which becomes the final stamper. The entire sequence is shown in Fig. 1.

With this system it is possible to make a large number of mothers and stampers from the single metal master, while in the one-step system it is necessary to cut a new lacquer mother whenever a stamper wears out. In the days of wax recording, when the original wax was destroyed as a result of processing, the three-step method was essential for mass production. Today one-step and three-step processes are used about equally, depending upon the length of the run and other economic factors.

The ridged surface of the stamper is chrome plated before it is inserted into the record press. This machine looks something like a huge waffle iron, except that it has steam and water lines running into its heating elements. Two stampers, representing opposite faces of the record, are fastened into the press to form the "grids"

FIG. 2. TV sets such as the Silvertone (diagram at left) which have jacks on the rear for feeding external signals into them, can be simply modified so audio can feed to your hi-fi amplifier or tape recorder.



For tape reproduction, original tape is loaded onto master machine of high speed duplicating line. Each master feeds six "slave" machines.

RCA Victor photo

Ray Heindorf's control room is equipped for up to four-channel playback and recording. It boasts six Ampex tape machines, twelve recording preamps.

ABC-TV photo

Pat Boone uses a hand microphone during his singing on the Chevy Showroom television show.

Howard Barlow, conductor of the Voice of Firestone TV show, is seen below. The sound problems involved on a show of this type are indicated by the photo at bottom, showing a typical set.

ABC-TV photo

of waffle iron. (See photograph on page 34.)

A label is placed facing either stamper at its center, and a preheated biscuit of vinyl plastic record material is placed on the lower plate. The stampers are then brought together under pressure against the biscuit, while steam is passed through the hollow dies of the press.

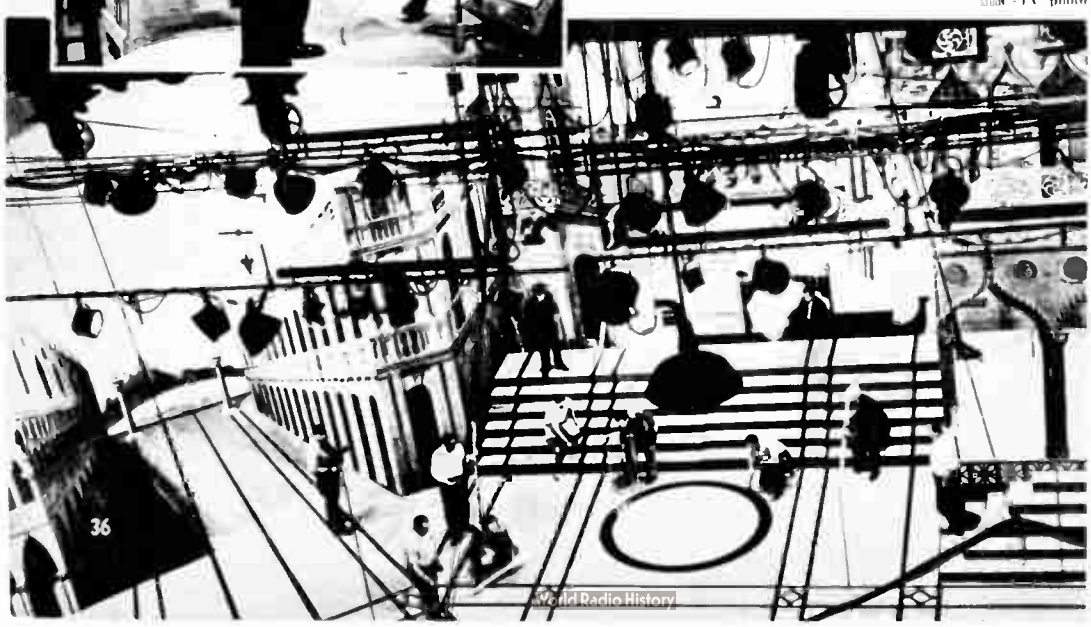
After a short period the steam is cut off and replaced by a stream of cold water. When the disc is cool and hard, the press is opened and the record pressing removed. The spilled-over material around the edge of the disc is trimmed away, and the finished record is then ready for packing and shipment.

The compression method of molding records has been in use since the beginning of the mass production of discs, and before that in the button industry from which it was borrowed. And as there have since been developments in button molding equipment and techniques, it is only natural that the record industry should follow suit.

The newer method of record making resulting from these developments is injection molding. The processing of metal parts is essentially the same as for pressing, but the material is a styrene rather than a vinyl. It is heated to a molasses-like consistency and then squirted into the cavity between two "stampers," sort of like filling a jelly doughnut. After cooling and hardening, the record is removed from the machine, and then labels are applied.

There has been heated argument within the industry concerning the relative merits of compression and injection, but they seem to be mostly at the level of the accountants and production men. As far as audiophiles are concerned, the best records made by

ABC-TV photo



either method seem to be about equally good.

Recorded tape provides another measure of enjoyment in the use of your hi-fi system. These are tapes which are electrically rerecorded directly from original tape masters. The entire recorded tape industry is no more than a half-dozen years old, and it wasn't until mid-1954 that the first major company, RCA Victor, got into the swim with the release of fifteen tapes. Another three years passed before all of the other major record companies got into the tape field, but today there is a wide selection of material available from all the major and many of the minor record companies, plus several dozen tape-only producers.

Tape recordings are still quite a bit more expensive than their disc counterparts, but the gap is being closed all the time. It is most unlikely that it will ever be possible to manufacture raw tape as cheaply as the few cents worth of plastic required for a disc, so the economies have to be in the more efficient utilization of the tape.

There are two ways of doing this. One is to use a slower tape speed, and the other is to get more separate tracks of music on the same width of tape. As we shall see in another chapter, the speed of tape has been dropping consistently from the original speed of 30 inches per second. While 7.5 ips is today's standard for home hi-fi use, successful recordings have been made at speeds as low as 15/16 ips, and it may well be that 3¾ ips will become the new hi-fi standard. And while it was once customary to use all of the tape width for a single recording, dual-track recording has been with us for several years, and now there are four-track tapes on the market.

But despite these economies, tape is still more expensive than disc and must justify itself on other grounds. In quality tape leads, if only by a narrow margin. It can play much longer than the longest LP disc. Most important of all, however, is its long life and resistance to damage. The number of plays available from a tape with no deterioration in quality are almost limitless, while a record will ultimately get noisy and wear out. Hence as a long-term investment tape will often be more economical than disc.

There are two basic methods of duplicating tapes, contact printing and multiple copying at high speed. The latter method is the only one currently used, but contact printing holds forth interesting promise for the future. Multiple copying involves electrical rerecording, and there are two different arrangements for doing this.

One of these is called the common-mandrel duplicator, which holds a master tape plus eight or ten reels of raw tape. All tapes are driven by the common shaft, and while the master tape plays the raw tapes are recorded. The other multiple copying method which is widely used has a separate recording machine for each raw tape. In addition there is a tape reproducer which receives the master, the signal from which is simultaneously fed into the entire bank of copying machines. Both the master and the slaves run at several times normal speed for rapid duplication.

Since the television producers have finally outgrown their preoccupation with their nice shiny new pictures, and have come to realize that audio is fairly important after all, this medium can no longer be entirely overlooked by hi-fi fans. The trouble is that

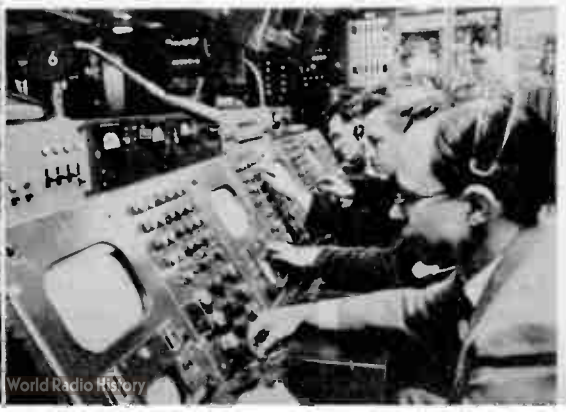
Production shot of a TV program shows the ever-present boom microphone, used whenever there is any action across stage. Camera, left, and director are also visible.

NBC photo

ABC-TV photo

1. NBC-TV production shot of the opera Rigoletto shows microphones on booms, hidden from the cameras. 2. Action shot of "Cheyenne" TV program with boom-suspended mike above actors' heads. 3. Mobile TV unit transmits sound and picture by microwave relay, shown at right of roof-mounted camera. 4. Tape Central at NBC Burbank, Calif., studio with TV tape machines in action. 5. Main control room of NBC in New York. 6. Main control board with TV monitor sets.

NBC photo



TV set manufacturers haven't awakened to this yet. While many hi-fi amplifiers now sport a TV jack, not very many television sets are equipped with hi-fi output jacks. This means that to work your TV set into your hi-fi or recording system, you'll almost certainly have to do a little screwdriver and soldering iron work.

The volume control is the logical place in the TV circuit for picking up a signal to be fed into the hi-fi system. In the chapter on tape recording, the reasons for this are discussed in detail. The method described there for feeding the output of a tape machine into the system can also be used for a TV set without any change.

There is an even easier way of accomplishing this on many sets, however, because of a special built-in sound switching circuit. By modifying it somewhat, we can adapt it to hi-fi use and avoid the inconvenience of reaching from the back to the front of the set, or actually pulling the chassis out of the cabinet to get at the volume control terminals.

Many TV sets have a slide switch and phono jack arrangement on the rear of the chassis, designed to permit playing a phonogaph or tape recorder through the "superb" audio system of the TV set. No self-respecting audiophile would ever think of using that jack for its intended purpose, so there it lies, unused and just made to order for hi-fi use. But there will have to be some changes made.

What we want to do with this circuit is just exactly the opposite of what its designer had in mind. As it is set up now, it permits feeding an external signal into the TV audio with the picture off. Now we want to take the sound portion of a TV broadcast out of the set before it reaches its own audio system, and instead feed it into our own hi-fi system and/or tape recorder. Since the volume control is the key point for either one of these switching operations, the switch and jack must already be at the right place in the circuit. All we need do is change their functions.

To understand more fully what must be done here, consider what the switch is doing at present. It is a 2-position switch, with one setting marked TV and the other designated AUDIO. In the TV position the receiver operates as an ordinary television set. In the AUDIO position, both the TV picture and sound are killed, and whatever external signal is plugged into the jack will be heard through the TV set speaker.

But while both the picture and sound go dead, the set is still entirely operative and receiving television signals. The switch merely disconnects the voltage on the picture tube, and connects the audio amplifier to the jack, so that the output of the audio detector is no longer heard.

The switch doing this job is known as a double pole-double throw type. This means that two circuits are controlled by the switch, and each of them will have a choice of two possible paths, depending upon the setting of the switch.

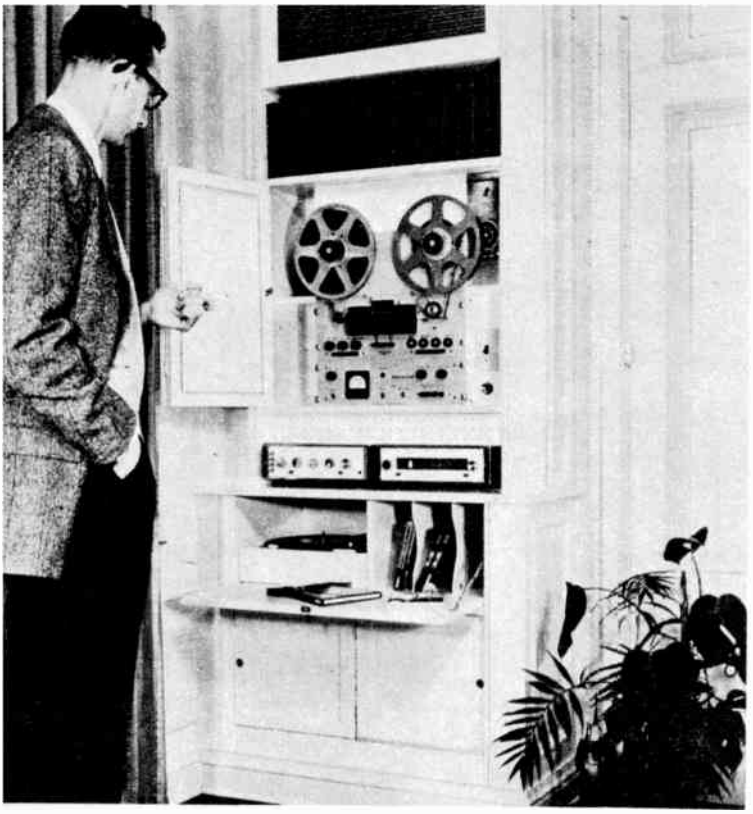
In this case the two circuits are (1) the picture-tube voltage, and (2) the audio amplifier input. The selection for the picture-tube circuit is either (a) high voltage, or (b) no voltage. The selection for the audio input is either (a) detector output, or (b) external circuit.

Now since we want to be able to see the TV show as well as hear its audio through the hi-fi system, the first thing to be done is to assure that the picture is on at all times. That is, the picture-tube circuit should have high voltage regardless of the switch position. This is accomplished by adding the simple short circuit shown in Fig. 2. If it is ever necessary to kill the picture, this can still be done by turning down the brightness control on the front of the set.

The audio part of the switch involves three factors: TV audio amplifier, TV detector output, and external circuit. But instead of letting the amplifier do the selecting, we now want the detector output to be the selector. That is, the detector output will be able to feed the internal audio system in the normal fashion, or the external system for hi-fi. And this is done very simply by interchanging the positions of the detector and amplifier wires on the switch terminals. A phono cable is then connected from the jack on the television set to the TV or TUNER jack on the hi-fi amplifier.

As Fig. 2 shows, the shell of the phono jack on the TV set is sometimes not connected directly to ground, but instead has a condenser in series. If hum is encountered after the changes are completed, this condenser is probably at fault. A direct short across the condenser to take it out of the circuit will usually clear the trouble. If a slight tingling is felt when the metal parts of either set are touched, there is a small potential difference which can be cleared by reversing the AC plug feeding the TV set or the hi-fi system, but not both.

All recordings, whether on tape or disk, must have a means of constant propulsion before any electrical signals can be developed. These means are discussed in the next chapter. •



Using a stop watch, left, to time tape and turntable rotation will often show up serious defects in the system. Variation in speed affects the musical pitch.

Audio Motion

Turntables and tape machines must have the proper motors for good hi-fi reproduction.

SINCE the making of both discs and tapes requires mechanical movement of the recording medium, it is implicit that there is a similar motion necessary when reproducing the records. In the case of discs the device employed is a turntable or record changer, and for tape it is the transport mechanism. The heart of either of these devices is its source of motive power.

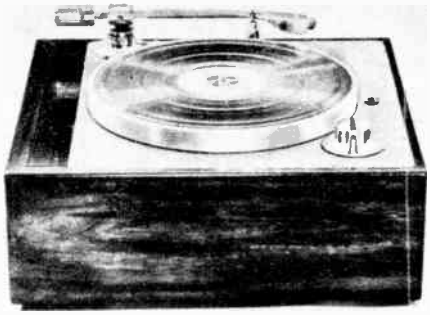
In the early days of disc recording, weight-driven motors were used for recording and spring-wound motors were used for reproduction. The electric motor is now used exclusively for these purposes, but it had to be modified considerably before it could be adapted to this purpose.

Normally when we think of an electric motor, we think first in terms of power. The important thing is that the whirligig has enough guts to turn the job. But for audio work the total power is not nearly so important as are the requirements of smoothness, silence and constant speed.

The simple induction type motor, so common in small power applications, is totally unsuitable for hi-fi use. Its speed of rotation is determined by the line voltage supplying it, which in some locations may vary by as much as 20 per cent or even more. The resultant pitch variation during musical reproduction would be intolerable.

But while the electric power companies cannot maintain a perfectly constant line voltage, they can and do hold the frequency of their alternating-current circuits to a point of hair-splitting accuracy. Thus a motor whose speed could be determined by the power line frequency would be most desirable for this application. Such a motor is said to be synchronous, and it is the first essential of a high fidelity turntable system.

The most elementary synchronous motor, and the one which is used in the least expensive equipment, has only two poles. This means that each armature coil passes a point of maximum torque development only twice in each 360° of rotation. The rotor is then almost coasting during a large part of each revolution, receiving an additional push only every half-turn. This

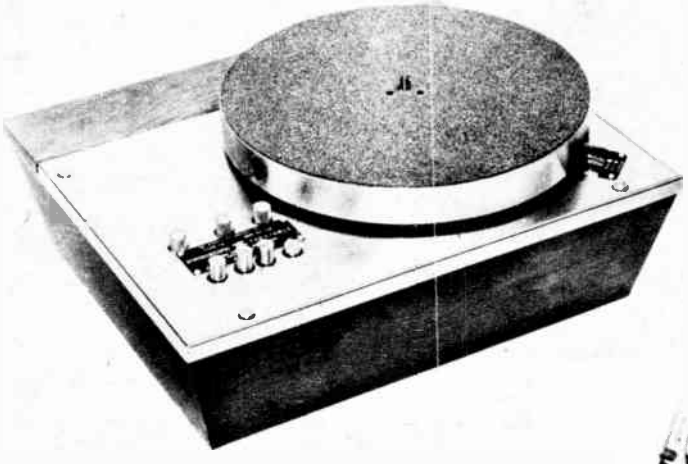


Rondine B-12H Rek-O-Kut 3-speed turntable comes with self-lubricating hysteresis motor, has permanently affixed strobe disc, 45 rpm center hub.

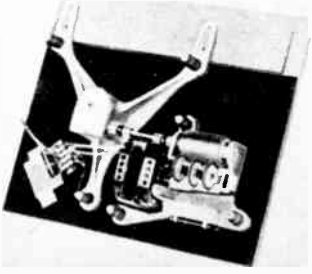
Pickering turntable has novel design, having the linkage between turntable and motor assembly suspended magnetically; costs $59.85, less base.

Garrard 301 transcription turntable has variable speed control, 4-pole motor, 12-inch turntable rotating on phosphor bronze bearing spindle.

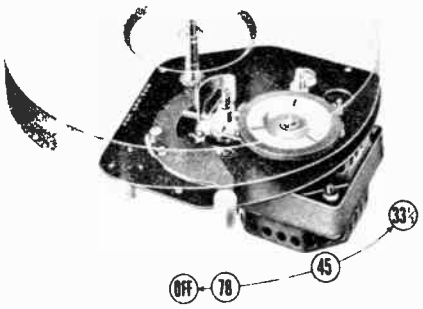
Lafayette 4-speed player sells for $37.50, has 4-pole motor, produces less than 0.2 per cent wow and flutter with 3 lbs. aluminum turntable.



H. H. Scott turntable has push-button 3-speed selection, built-in stroboscope; motor board is stainless steel-covered. Special slip clutch, at right, allows turntable to be cued, avoids drive shock.



Fairchild Model 412-4 uses synchronous motor, has variable speed with its "electronic drive" unit, which drives the motor at four speeds.



Top right, General Industries' four-pole motor turntable changes speeds by shifting idler wheel vertically to appropriate speed on motor shaft.

Components Corp. makes the Professional 4-speed turntable which weighs 12 lbs. It is driven by an endless belt, eliminating the idler pulleys.

makes for uneven rotation, with consequent pitch variation during reproduction. The two-pole motor also radiates a very strong magnetic field which is almost impossible to shield. Serious hum troubles are thus an ever-present problem with this type.

A considerable refinement of the synchronous motor is in the four-pole type, which cuts these troubles just about in half. The improvement is analogous to the greater smoothness of operation of a four-cylinder engine over a twin. The rotor receives twice as many propelling impulses in each revolution, and the delivery of power is considerably less uneven. At the same time the hum problem is reduced by a similar amount. This type of motor is standard equipment on all medium-priced high fidelity equipment, and no one with a wide-range system should settle for anything less.

But despite the near-perfection of the four-pole motor, it still leaves something to be desired. It generates some noise in the 30 to 60 cps range, which interferes markedly with the bass response in that bottom octave. The only way to avoid this is to cut off the system response below 50 or 60 cps—or to use a hysteresis synchronous motor. This motor represents the highest state of the art today, with smoothness of operation which is unapproachable by any other type. Its cost is about double that of a comparable system with a four-pole motor, but the results speak for themselves. For a hi-fi system with a bass response which is otherwise flawless, hardly any other choice is possible.

A good motor for hi-fi use often operates in the vicinity of 1800 rpm. This speed represents about the best compromise point for the requirements of efficiency, smoothness of operation and adequate cooling. It is obvious then that some sacrifices must be made in the design of a multispeed unit which achieves its speed changes by altering the motor rpm. Such a motor will almost certainly be subject to overheating, vibration or poor speed regulation. A much more satisfactory approach is a constant rpm for all turntable speeds, with the variation being taken care of in the power linkage between motor and table or capstan.

The most obvious means of transmitting the motor rotation to the turntable would be simply to attach the table to the motor shaft. But in that case the motor would itself have to rotate at turntable speed, and this we have already ruled out. Furthermore the amount of noise transmitted from the motor into the system would be ex-

A turntable for $49.50 by Components Corp., has 4-pole motor, belt drive, 12-inch turntable. It's made available in two or three speed variations.

Right, Presto two-speed and three-speed models feature 12-inch turntables, idler wheels with 4-pole motors. They range from $59.50 to $131.

cessive. This method of power linkage is the basis of a direct-drive system, which was once thought to be the best possible means of propelling a turntable. This is true, however, only with some important qualifications.

The direct-drive systems employed in commercial practice actually have a set of gears and some means of vibration filtering interposed between the motor and turntable. Such a system is very good, provided that its components are machined throughout to an exceedingly high degree of precision. And even then, it is better only because it can withstand the wear and tear of heavy-duty service, such as in broadcast stations or wire music services. But the average hi-fi fan will never be subjecting his equipment to such constant abuse, and many equipment manufacturers have learned to their sorrow that they cannot produce a popular-priced direct-drive system which will stand up even under ordinary home use.

Since a precision-machined set of gears is an exceedingly expensive proposition, the objective in the design of a reasonably-priced turntable assembly is some other means of stepping down the motor rpm to the desired record rpm, while at the same time meeting the requirements of

Stromberg-Carlson PR-499 model has continuously variable speeds from 14 to 80 rpm, stroboscopic window pilot light, belt drive. Price is $99.95.

Audiogersh makes the two models shown above and left. The Miraphon is the transcription player, Miracord is the changer. The push-button changer allows you to use the unit automatic or manual.

Heathkit record changer comes in kit form, takes G.E. cartridges. It includes 4-pole motor, friction drive, has four speeds and manual operation.

Voice of Music changer has aluminum cast die tone arm, plays twelve 10-inch, ten 12-inch or fourteen 7-inch records. It has rubber disc mat.

smoothness and quietness. One gearless system employs a smooth motor pulley bearing against a smooth idle-wheel, or idler, which in turn bears against the turntable rim. This rotation method is called friction drive.

When properly designed and built, this system will perform every bit as satisfactorily as the most expensive direct-drive assemblies. And it can be purchased at a much more reasonable price, simply because there are far fewer precision parts. The idler is made of rubber and therefore subject to deterioration, but it can be replaced quickly and inexpensively.

Although the idle wheel drive has been the hi-fi standard for some years, there is now some tendency toward belt drive. This has been occasioned by the perfecting of the stereo disc. Suddenly the problem of vertical rumble has taken on an importance it never had before.

Previously the phono cartridge was not required to respond to motion in the vertical direction. It was in fact purposely made insensitive to vertical movement, both in its compliance and in the placement of its motor element. And for the turntable designer, any vibration transferred in the vertical plane was of little consequence.

But the stereo cartridge must respond to both vertical and lateral movement, and it was soon discovered that many turntables which were quite satisfactory for lateral monophonic recordings, couldn't meet minimum rumble requirements for stereo. Hence the move to belt drive.

In this case an endless belt wraps around the motor shaft and the outer rim of the turntable, or a drum attached to the turntable. There is still a step down in speed from the motor to the turntable, as the motor shaft will have to make many more revolutions than the turntable or drum to traverse the same length of belt. This type of drive is also frequently used in tape recorders.

The table itself, when properly designed,

Garrard changer, shown above with motor drive removed, has three speeds, automatic and manual operation, interchangeable plug-in heads. Turntable is steel covered with rubber traction mat.

Bogen transcription player has plug-in heads for change of styli. The unit is shock-insulated, has 4-pole induction motor. Prices, from $27 to $44.

can do much to aid in the smooth rotational movement, for it will act as a flywheel and oppose any tendency toward speed fluctuation. A cheap turntable is simply a flat flanged disc stamped out of a piece of sheet metal. But a really good table is made of a heavy casting, precisely machined for perfect balance and smooth fit of its moving parts. Since most hi-fi phono pickups operate on magnetic principles, it is essential that the table be made of a non-magnetic metal, such as aluminum or brass. When in operation, the pickup lies in such close proximity to the turntable that any residual magnetic fields would seriously interfere with the reproduction and increase record wear.

The surfaces of cheaper turntables are usually covered with a spray coating of flock, consisting of tiny plastic fibers. This material does not wear very well, it has a great attraction for dust particles, and very often induces an electrostatic charge into plastic records so they, too, catch dust.

Wool or cotton felt has been used for years as a turntable covering, with a fair degree of success. But while static is no problem, this material also has a rather poor wear factor, and it does become imbedded with dust.

Many of the better tables today have rubber mats on which the record rests. This provides a fairly rugged surface, although rubber is subject to deterioration in time. The slightly tacky mat provides a positive non-slip grip, there is no static, and it is quite easy to clean. Some manufacturers mold a ridged surface into the mat, which reduces contact with the disc by 60 or 70 per cent. This, of course, greatly reduces the possibility of the transfer of dust from turntable to disc, but at the same time it reduces traction somewhat.

One of the best turntable surfaces available today is one of cork impregnated with neoprene rubber. This is considerably more rugged than rubber alone, has a longer life, has no static attraction, and is less susceptible to imbedded dust particles. Slippage is no problem, and the surface is smooth and flat.

Turntables for home use are available in sizes from as little as four inches and up to twelve inches in diameter. The smallest size has the advantage that it supports only the label area of the record, while the sound grooves on the underside never touch the surface of the table at all. The dust problem on the discs is thereby minimized, but, of course, the flywheel effect of such a small table is negligible, and slippage between the table and disc could be serious. Whenever a turntable supports a record larger than itself, the soft plastic record will sag slightly under the weight of the pickup. The stylus will therefore ride more heavily on the outer groove wall, resulting in uneven wear and distortion.

The chassis which supports all of the turntable elements must likewise be large and sturdy. A flimsily stamped chassis will be subject to vibration from a number of sources, not excluding its own sympathetic resonance. And since there must be a true and positive connection between the several elements in the power train from motor to turntable, the chassis must be strong enough to resist stresses and strains which might throw the linkage out of alignment. A heavy casting of non-magnetic metal seems to be the best means of eliminating these troubles at their source and providing a firm foundation.

The problem of the tape transport is somewhat more complex, because there are more functions which the mechanism must perform. Not only must the tape be moved

past the heads at a constant speed, but it must also bear against those heads accurately, it must pay out of the supply reel smoothly, and it must reel in on the takeup side. And when playing or recording is finished, the tape must be rewound from takeup reel to supply reel.

These functions are best performed by three separate motors, an arrangement still too seldom found in home hi-fi tape equipment. When one or two motors are required to do the job of three, the underside of the machine is a mechanical nightmare and the performance is less than the best.

The types of motors used are the same as those found in turntables, hysteresis synchronous being the best, and four-pole motors being used more often because they are cheaper. Both idle-wheel and belt drives are used, with belts probably in the majority.

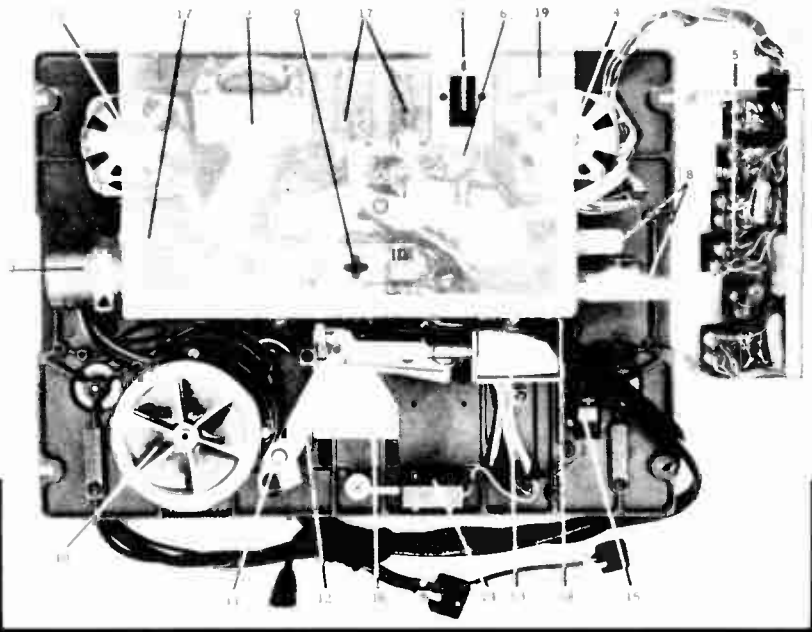
In a turntable the motion is imparted to the disc simply by friction. The disc and table move as one, while the cartridge moves across the face of the record in scanning the grooves. But in a tape machine the head does the scanning, and this remains stationary. Thus new tape has to be pulled constantly past the head.

The special tape pulling mechanism is known as capstan drive. The tape winds partly around the revolving capstan, while a pressure roller squeezes the tape against the capstan to ensure adequate traction. The capstan is usually a precisely machined metal shaft and the roller is a rubber puck looking very much like an idler wheel. Rubber has also been used for the capstan, but the wow and flutter are too great for hi-fi reproduction.

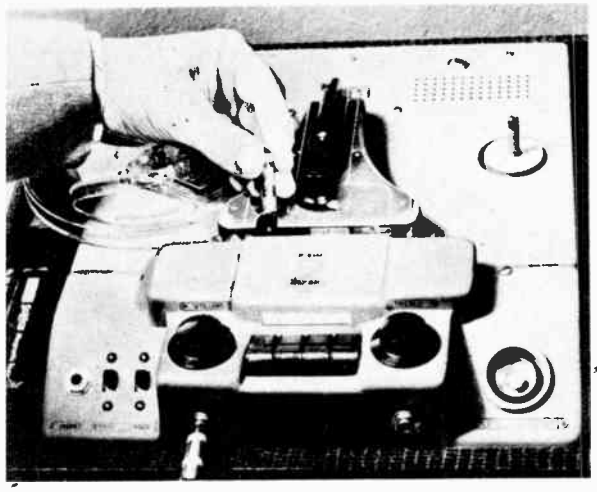
While the turntable itself acts as a flywheel to damp out speed irregularities, the tape capstan is so small that the addition of a flywheel is mandatory. This is made an integral part of the capstan shaft, but is out of view below the mechanism chassis.

At first glance the function of a changer is deceptively simple: when a record has

Berlant Concertone tape mechanism is shown below, with major parts called out.

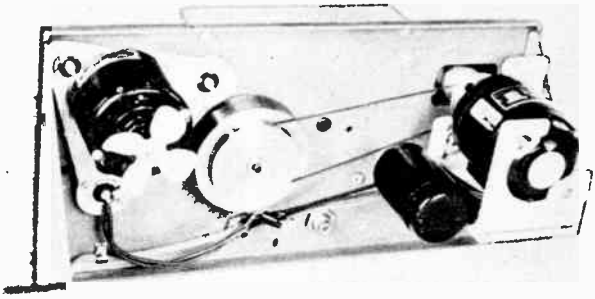


1. Take-up Motor
2. 24-Volt Transformer
3. Remote Control Cable Receptable
4. Supply Motor
5. Relay Box
6. Brake Solenoid
7. Motor Capacitors
8. Standee Resistors
9. Tape Drive Control Lever
10. Synchronous Drive
11. Pressure Roller Adjust Screw
12. Solenoid Lever Arm
13. Drive Solenoid
14. Record Microswitch
15. Cut-off Switch
16. Tape Lift Slide
17. Motor Disconnect Plugs
18. Fuse Posts
19. Junction Box Cover



3M Scotch Tape photo

The spindle or shaft—often the motor shaft itself—which rotates against the tape is called the capstan. Interchangeable capstan alters speed.



Do-it-yourself tape recorder by Patterson has two drive motors, five tape speeds to 15 ips. Either full-track or half-track record heads may be used.

finished playing, another record must be put on the turntable and the pickup placed in its lead-in groove. But let us consider the number of separate operations necessary to perform that simple task. When the end of the record is reached, the pickup must move, first vertically upward, and then laterally to a point outside the turntable periphery. There it must wait while the next record is put into place.

Then follows another two-step motion, usually consisting of lateral movement of the record away from the stack, followed by the vertical movement of dropping the record into place. Finally the pickup arm must move laterally and vertically to engage the lead-in groove at the proper diameter of the particular record being played. The complexity of cams, gears, levers, pulleys, belts, pawls, ratchets and drums necessary to perform this action are complex enough to send the average radio serviceman running to his benzedrine.

Almost all changers manufactured today for home use are of the drop mechanism type, in which a stack of records is supported several inches directly over the turntable, and each record is dropped in turn onto the table as it reaches the bottom of the stack. They also involve some variation of the pusher platform. In this system the stack is supported at two points, by a fixed platform at the edge and by an offset in the center spindle. When a new record is called for, a small arm in the outer platform simply pushes the edge of the bottom record until it falls off the platform and down the spindle, while the remainder of the stack drops into place on the platform.

Some changers provide such additional features as a muting switch which kills the audio during the changing cycle, and an automatic stop switch which turns off the changer power after the last record has finished playing. This is just about the height of luxury for the lazy man, but a price must be paid for it, because all record changers have at least some of the following disadvantages:

1. Abrasion between groove surfaces when records are stacked
2. Possible damage to center holes or edges, from the platforms
3. Wear on the center hole, as the spindle remains stationary while playing
4. Change of pickup angle with respect to record as height of stack changes
5. Possible sacrifice of motor smoothness in favor of more power to operate changer mechanism and move heavy stack of records on turntable
6. Slippage of disc as it is played on stack
7. Slowing down of turntable as weight of stack increases.
8. Uneven groove wear at inner section of record, as underneath extension of pickup arm begins to bear against pawl and ratchet mechanism
9. Exceedingly difficult maintenance and adjustment.

The changer has one big advantage on its side, however, and this can't be denied. It is certainly more convenient. A great many people feel that this advantage outweighs all the disadvantages. Whether they do for you will depend entirely upon your personal taste and requirements. •

In the First Place

Translating grooves into sound, the quality of stylus, cartridge and arm determines the overall performance of your hi-fi system.

HAVING the motive power for our recordings, we now must consider the means of translating the striations on the face of a disk or the magnetic pattern on the coating of tape into electrical voltages which will eventually emerge as hi-fi sound.

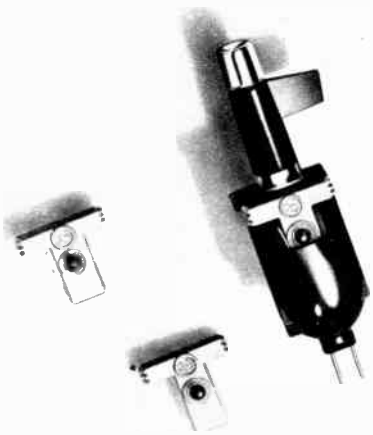
The element which traces the grooves in a disk, sometimes known as the "needle," is more properly called a *stylus*. Many different materials have been used for styli, including some very soft ones such as pressed fiber, thorn and cactus. Ordinary steel needles were used for years with 78-rpm shellac records, which actually contained an abrasive to grind the needle to shape.

The first styli in which some serious consideration was given to their shape during manufacture were the semi-permanent types, made of chromium plated steel, osmium or tungsten carbide. Later came the jeweled tips of sapphire, ruby or diamond, and these are the only ones worth considering for hi-fi use.

It is now known that stylus shape is a most important factor in fidelity and record wear, and the jeweled types are more desirable simply because they hold their shape longer. The record groove is cut in the shape of a V, with the two side walls forming approximately a right angle. The distance between opposite edges at the top of the groove is about 2.5 mils (0.0025 inch) for LP and 45, and about 7.5 mils for 78-rpm records.

The playback stylus has a rounded tip of such size that it rides about midway down the walls of the groove. If it rides near or on the bottom, reproduction will be excessively noisy. If it rides too close to the top, the loud passages may cause *groove skating*, or sliding of the pickup across the record. This causes excessive

Pickering 350 Fluxvalve magnetic pickup uses a tracking force of 2 to 6 grams. Output is 25 millivolts at 10 cm/sec. Sold with diamond stylus.



Electro-Sonic Concert series cartridge comes with .001" diamond stylus, has 0.8 mv output. Stylus force, 3 to 7 grams, output impedance, 1.5 ohms.

General Electric TM-2G stereo or monaural tone arm accommodates G.E. cartridges, sells for $29.95. Static balance provides constant tracking pressure, enables arm to hold its lateral equilibrium at all times.

wear, distortion and damage to the record.

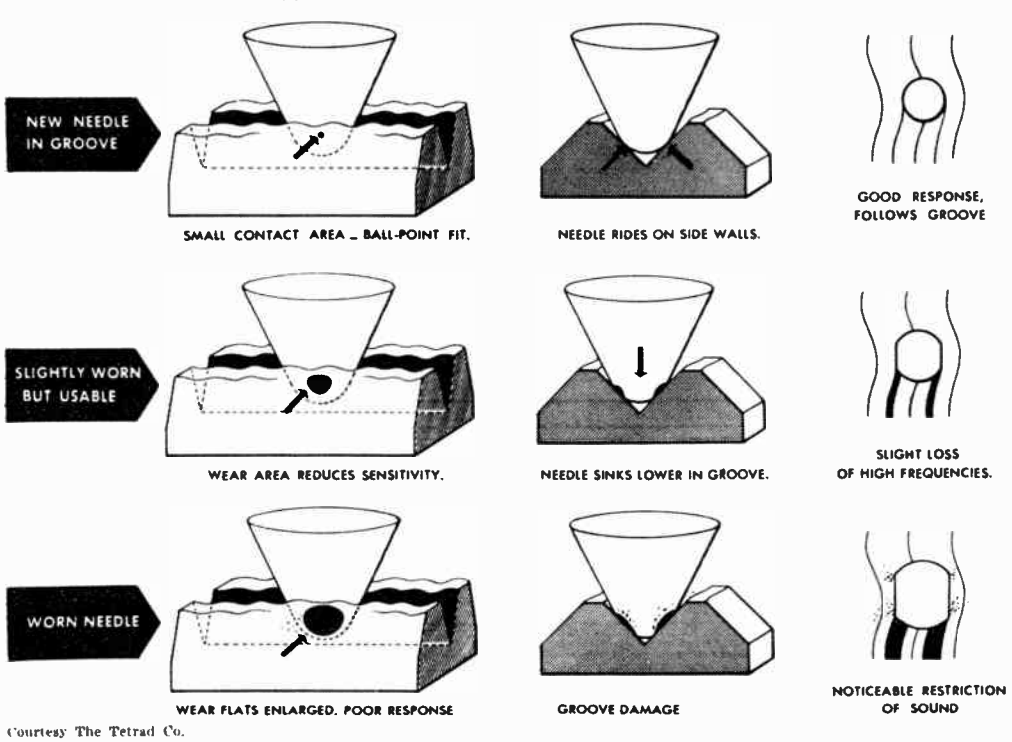
The stylus must therefore be the correct size to fit the groove it is expected to trace. Record manufacturers recommend a tip radius of 1 mil for microgroove disks and 3 mils for 78's. Lately there has been some tendency toward a tip radius of 0.7 mil, for which it is claimed there is better tracing of the higher frequencies.

The best reason for the great popularity of diamond styli among audiophiles can be gathered from these comparative figures:

	Durability	Breaking Strength	Bearing Friction
Diamond	90	5	0.7
Sapphire	1	1	1.4

This indicates that the sapphire will wear out ninety times faster, that it will chip five times more readily, that it will develop twice as much frictional heat as it traces the groove. Although the diamond is more expensive initially, it will give much longer and better service, and therefore is the wiser investment.

Any stylus must be inspected periodically for wear. This should be done on a regular schedule, for when a worn stylus becomes evident in the reproduction, permanent damage has already been done to the record. The only way to be certain of stylus condition is to examine it under a microscope of 50 or 100x power. As soon as the length of the worn flat exceeds the tip radius, the stylus is due for replacement or repolishing. All of the better audio retailers have microscopes available for customer use, and competent personnel to



Courtesy The Tetrad Co.

Chart above shows the damage that may be caused by worn stylus to your phonograph discs.

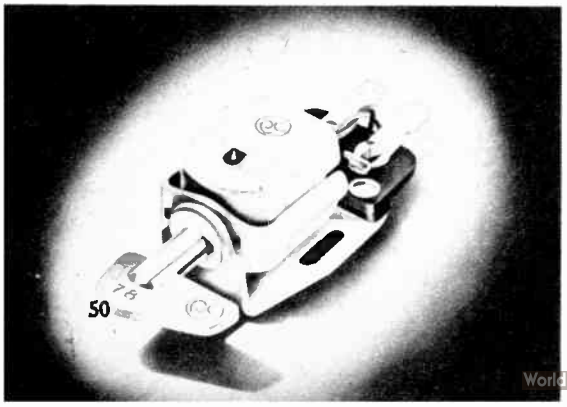
help if you're not sure of what you see.

With the stylus tracing the winding path of the groove, the next item in the chain is the reproducer, pickup or cartridge, which must translate this mechanical motion into an audio-frequency voltage. The first requirement of the pickup is that it do as little as possible to impede the motion of the stylus.

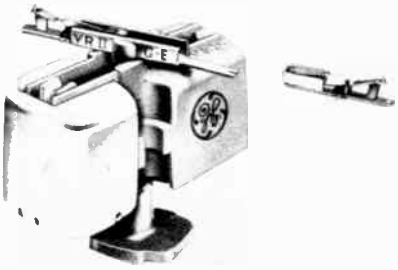
This means that the pickup must exhibit excellent compliance. This should be true not only in the lateral plane, where the modulation is, but also in the vertical direction as well, due to pinch effect. This is a narrowing of the groove due to the motion of the cutting stylus, as shown in Fig. 1. But while the pickup must permit this vertical motion, it must not generate a signal because of it, for all of the desired sound information is contained in the lateral movement of the groove.

Another problem peculiar to disk recording is illustrated in Fig. 2. This shows that the distance traveled by the stylus becomes progressively less as the groove nears the center of the record. As a result,

Pickering turnover pickup Model 260 is available with diamond/diamond or diamond/sapphire styli. Output is 30 mv, tracking pressure, 4 to 8 grams.



General Electric VRII variable reluctance cartridge has clip-in stylus for easy replacement. Output voltage is 22 mv, tracking force 4 to 8 grams.



the side-to-side movements of the groove must be squeezed into a smaller area. Difficulties begin to appear at the high frequencies when they are so compressed that the groove is loaded with very sharp hairpin turns which the stylus can't follow.

Two methods are used to alleviate this condition. One is simply to keep the recording areas as close to the outside of the disc as possible. This is the reason that the blank center of an LP is so much larger than a 78. The ultimate in this direction was seen in the original 45, when only a small area near the edge of the record was grooved. But the temptation of all that blank center area proved too great, and so the 45 became an EP and the advantage was lost.

The other means of improving high-frequency response in the center region is diameter compensation. This is simply a boost in the highs applied to the record cutter as it approaches the middle region. This, of course, increases the groove displacement, but it can't reduce the sharpness of the turns, and so its effectiveness is not very great. It is used frequently in LP recording, but one can still safely bet that the center region of any record will have less cleanness in the highs than will the outer grooves.

Phonograph pickups are classified either in terms of the physical principles on which their operation is based, or according to the characteristics of the signal which they generate. On the latter basis, pickups are described as either amplitude responsive or velocity responsive. These terms will be discussed in more detail in the next chapter, but for now it can be said that since the record modulation is a composite of velocity and amplitude characteristics, either type pickup will have to be compensated somewhat to obtain faithful reproduction.

Any pickup is known technically as a

FIG. 1. Cutting stylus during record manufacture doesn't twist to face grooves, causing steep cuts at high frequencies, forces stylus up and down.

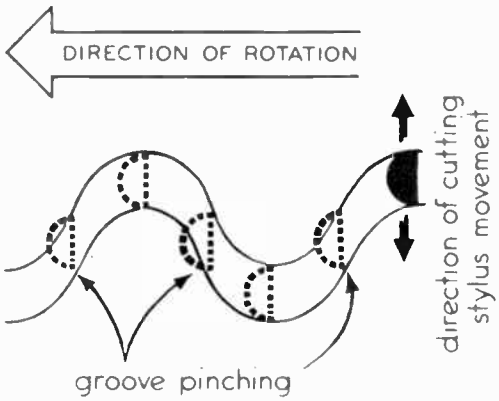
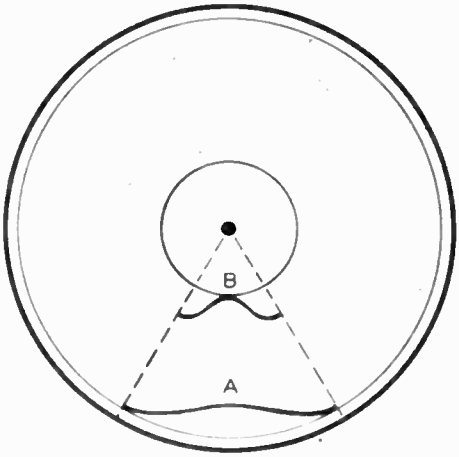


FIG. 2. Grooves A and B show exaggerated high frequency sound at outside and inside of record. Tracking will be more difficult at inside grooves.



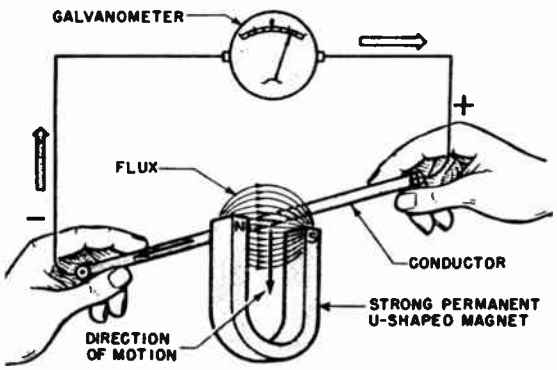
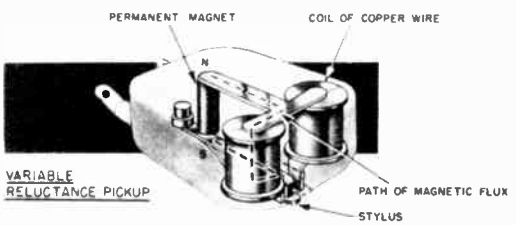
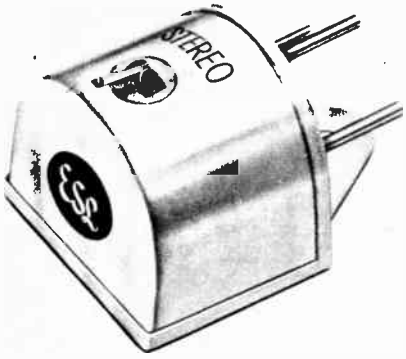
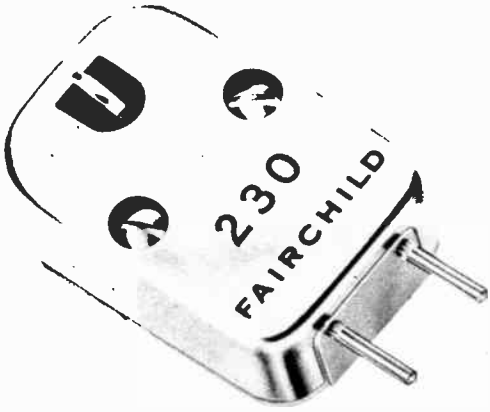


FIG. 3. Left, electromagnetic induction is caused by metal bar moving through magnetic force lines, registering on meter. Below, magnetic cartridge.





Electro-Sonic Gyro-Jewel cartridge for stereo records costs $85, has 2 mv output, .003 grams dynamic mass. Response is ± 3 db, 30-15,000 cps.



Fairchild monaural pickup sells for $49.50, has 5 mv output, 0.7 mil diamond stylus, air damping; fits all arms except viscous damped models.

transducer, because it converts mechanical motion into electrical signals. Transducers are widely used in electronic instrumentation, and just about every type of transducer known has at one time or another been tried for record reproduction. But of all of the principles employed, the types most widely used finally narrow down to two.

Nearly all of the pickups in general use today are either magnetic or piezoelectric. The magnetic types are in effect miniature electric generators, and they obey the same laws of physics as do the huge dynamos in electric power stations. The principle in each case is that of electromagnetic induction.

The drawing of Fig. 3 shows how it works. As the metal bar is moved through the magnetic lines of force, there will be a voltage induced in it as indicated on the meter. If the bar is twisted into a coil, more voltage will be generated because more lines of force will be cut. This is basically all there is to the magnetic phono pickup: a magnet, a coil, and a linkage which permits the stylus to move one or the other of them.

Since a moving coil and a stationary magnet will induce a voltage just as will a moving magnet and a stationary coil, it was inevitable that there should be two schools of thought on the subject. And so we have both moving iron and moving coil pickups. Since the mass of the magnet is too great to be moved readily by the tiny stylus, there is usually a third element in the form of an armature in the magnet gap. Then both the magnet and coil remain stationary, but the moving armature attached to the stylus varies the reluctance of the magnetic path and thereby induces a voltage in the coil. In the electrodynamic type, however, the coil itself actually does move within the field of the magnet. In either case a pair of wires attached to the ends of the coil carry off the signal to the amplifier.

The voltage output of magnetic cartridges is considerably less than that of the piezo types, and it varies rather widely. Some types put out as little as 0.01 volt, while others give as much as 0.2 volt. The output of the moving coil types is always considerably less than that of the moving iron variety, and therefore a step-up transformer is usually required between the pickup and the amplifier.

Since magnetic outputs now vary so widely, there has been an increasing tendency in amplifier design to provide two magnetic inputs, marked HI MAG and LO MAG, or a single input jack with a variable level control. Both of the magnetic types are inherently velocity responsive.

The other basic type of pickup depends upon one of several piezoelectric effects, which is the generation of a voltage when the material is mechanically strained. The magnitude of the voltage is directly proportional to the amount of the strain.

The material used is either a slab cut from a natural crystal of sodium potassium tartrate, commonly called Rochelle salt, or a synthetic ceramic material, usually barium titanate.

Recent developments in crystal pickups have enabled the development of units of reasonably high fidelity, although Rochelle salt crystals are still rather sensitive to

Sonotone ceramic cartridge is of the turnover type, plays records of all speeds. The high output of this model makes a preamp unnecessary.

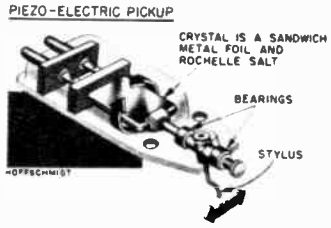
excessive heat and humidity, as well as mechanical shock. The ceramic cartridge, on the other hand, is rather impervious to these weaknesses.

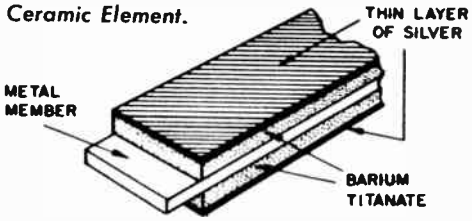
The best piezo cartridges, both crystal and ceramic, approach closely the average magnetic pickup in quality. Their output is from 0.5 to 1 volt, with most of the hi-fi types running around 0.75 volt. This is considerably higher than the typical magnetic output, and a preamplifier is thus unnecessary. The other advantages of piezo pickups are low cost and freedom from hum pickup. They are essentially amplitude responsive.

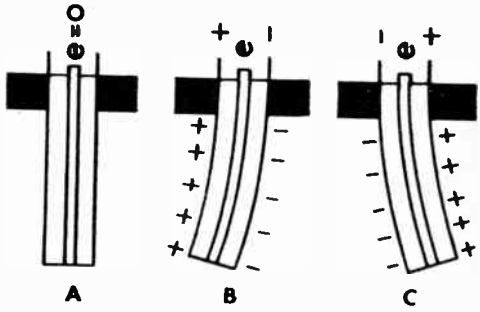
Since in all of these pickups the stylus assembly itself must do the work which results in the generation of a voltage, many experimenters have considered the possibility of having the pickup act as a sort of lever to modify an already existing voltage.

The idea would be to generate independently a very small radio-frequency voltage, which would be directly modulated by the stylus motion, making the whole unit in effect a tiny broadcasting station. This radio signal would then be detected by the usual means, and finally amplified as any other audio signal.

Hundreds of patents have been granted on systems embodying this radio pickup principle, but only one of them is used to any extent in hi-fi today. This is the capacitance pickup, in which part of the stylus assembly is one plate of a fixed capacitor. With the other plate fixed in position, the movement of the stylus causes a change in the air gap between them, resulting in a change in capacitance and a

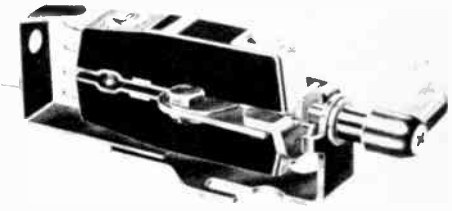






Distribution of Charge in Ceramic Element.

Drawings show how voltage is developed in piezo ceramic cartridge when distorted by stylus motion. A has zero voltage. Left bending (B) causes left side to become positive, developing a voltage.

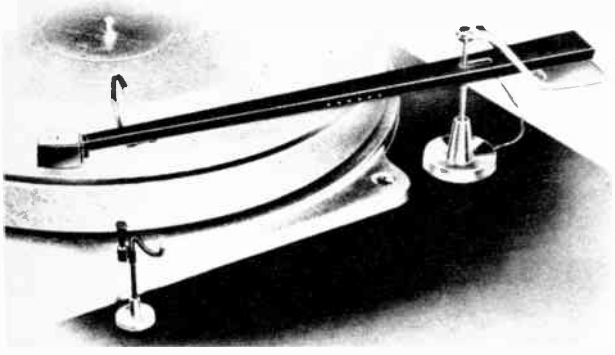


Electro-Voice Series 80 piezo-electric has two completely separate generating elements, fits all arms, has ± 2.5 db, 20-15,000 cps response.

Astatic ceramic cartridge for record changer arms is available in various single, double and turnover models; unit fits most changer arms.

Leak dynamic pickup arm and cartridge. Arm is $59, 78 rmp diamond pickup, $32.50. The arm includes matching transformer, has single pivot.

Fluxvalve-Unipoise arm by Pickering comes with a cartridge which is an integral part of arm. The stylus assembly is replaceable. Price, from $59.85 to $65.85.



Garrard TPA10 tone arm is $24.50, less cartridge. The arm is fully adjustable for length and tracking angle, will extend to 16 inches.

modulation of the frequency of the oscillator.

The audio modulation is detected right within the oscillator circuit, and is then fed to the power amplifier. Since the output of the system is about a volt, it requires no preamplifier, although it might be said that it has its own, self contained. Equalization is provided within the oscillator-detector, and the audio should therefore be introduced into the hi-fi amplifier at some point without equalization, such as an AUX jack.

The primary purpose of the tone arm is the transporting of the pickup, while maintaining the stylus in the proper relationship to the groove. It also carries the electrical wiring which connects the pickup to the amplifying system. Since the arm must do nothing to impede the motion of the stylus and pickup, it too must have little mass or stiffness, and a high order of both lateral and vertical compliance. Thus a good arm will always have finely-machined bearings at all pivot points.

The design and adjustment of the tone arm have much to do with the matter of stylus force, which is usually determined by a system of sliding counterweights or springs. With present-day stylus forces being on the order of only a few grams, a change of only a gram or two can be most important, and for this reason the force should be checked periodically and adjusted if necessary.

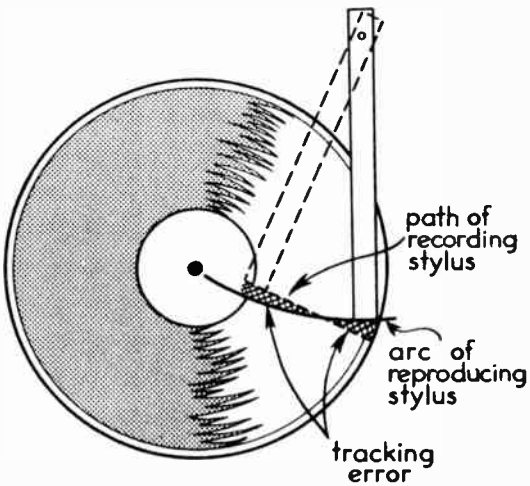
The cutting stylus on a commercial recording machine moves in a straight line across the record, while the reproducer stylus moves in an arc. The difference between these two motions is known as

Electro-Sonic arm uses ball bearings throughout, provides for tracking error within ± 1 degree. Arm will track with a force of only two grams.

Rek-O-Kut stereo-monaural arm is made of tubular aluminum, has micrometer weight adjustment, interchangeable cartridge shells; $27.95-$30.95.

Shure Model M-16 with overall length of 14¾ inches, comes with cartridge of 20-20,000 cps ± 2 db response. Output is 14 mv at 1,000 cycles.

FIG. 4. Tracking error caused by pickup arms



tracking error, and is illustrated in Fig. 4. This can cause distortion and record wear, and should therefore be held to a minimum.

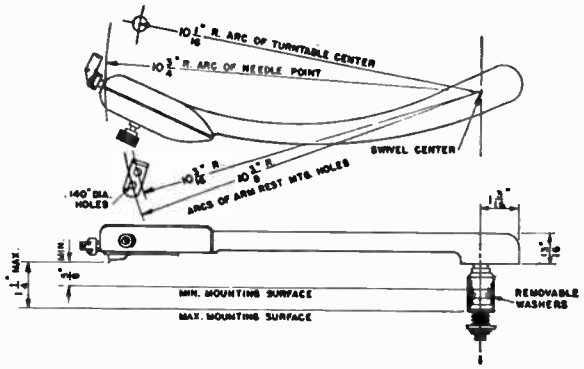
It is interesting to note, however, that the placement of the arm for the single of minimum tracking error doesn't necessarily afford minimum distortion. This is because tracking is most critical at the innermost grooves, as we've already seen.

Mathematical formulas have been developed for the dimensions of tone arms for minimum distortion. Any of the leading arms are designed for minimum distortion provided they are mounted properly. The method of mounting a straight arm, for example, is different from that for the curved or offset type.

The straight arm will exhibit minimum distortion when it is underhung, when the stylus point falls short of the center spindle by a small amount. For the offset arm, on the other hand, there will be minimum distortion when the arm is overhung, with the stylus point extending beyond the spindle by a small amount. There is an ideal length of overhang or underhang for any given arm, and it is therefore exceedingly important that the manufacturers' instructions be followed when mounting an arm.

When the stylus is properly mounted in the pickup, the pickup in the tone arm, and the arm on the motor board, the stylus at rest in the record groove should be perfectly vertical to prevent uneven wear on the groove walls. Since the stylus is rather well concealed when the record is playing, it is often difficult to determine its angle by visual examination.

This can be accomplished, though, by the



Studio Master by Astatic comes with crystal cartridge for records of all speeds. The drawing, above right, shows how the curve of the tone arm is designed to overcome and minimize tracking error.

General Electric stereo and monaural arm is fully compatible for both types of records. The arm head accommodates only G.E. phono cartridges.

H. H. Scott makes this stereo arm, developed by their engineers and London Record research staff. It includes monaural stereo cartridge; $89.95.

use of a small mirror, preferably about the thickness of a record. The mirror is placed on the turntable and the pickup placed gently on the mirror. The stylus and its reflection should then be perfectly in line when viewed from all angles. If there is any angular break between the two, the need for adjustment is indicated.

The reproducer head in a tape recorder operates on the same principles as the moving-iron phono pickup. A recorder tape is really a series of tiny magnets, which is drawn rapidly past a coil. Voltages are then induced in the coil in accordance with the magnetic pattern on the tape. In the tape head this coil has a metal core, but the principle is still that of a moving-iron pickup.

The purpose of the core is to conduct the magnetic flux away from the tape and into the coil, for greater signal strength, better frequency response and less distortion. The core is bent around in the shape of a ring, as shown in exaggerated form in Fig. 5. In practice the ends of the ring are closed so tightly that the gap is barely discernible.

The size and shape of this gap is most important in determining fidelity. As an example, suppose we have a tape machine operating at 7.5 inches per second, and we want to be able to reproduce up to 15,000 cycles per second. Then a steady tone of that frequency would place 15,000 complete magnetic reversals on that tape every 7½ inches.

To find the length of one wave, we would divide 15,000 into 7.5, to find that one

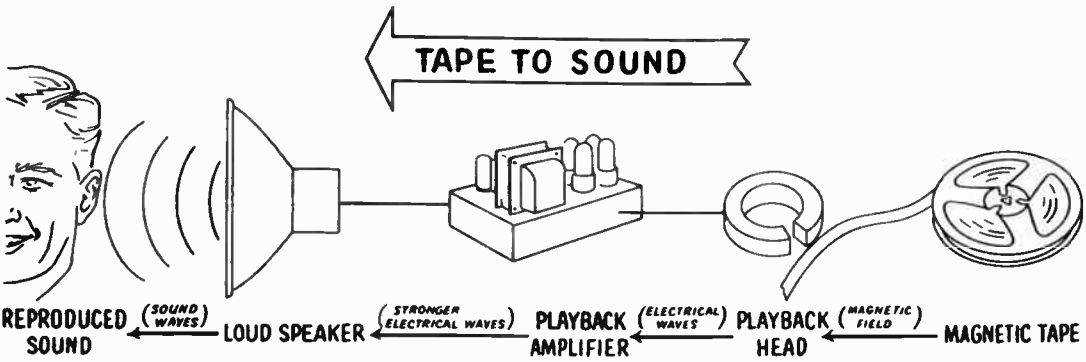


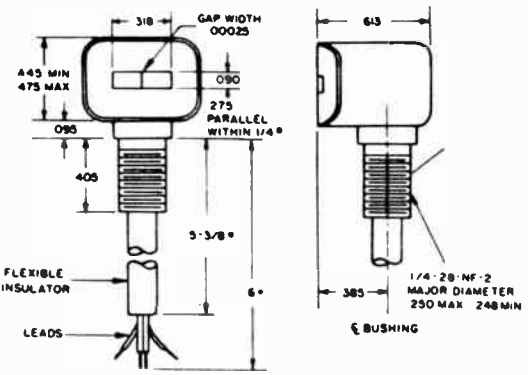
FIG. 5. Magnetic tape moves across the playback head of tape recorder, inducing voltages in the coil. The tape head's coil has metal core which conducts the magnetic flux away from the tape into coil.

wavelength is only 0.0005 inch, or a half mil long. Now experiment has shown that when the gap length is the same as the recorded wavelength, the output is almost zero. But when the gap length is half the wavelength, the induced signal is maximum. And so it is clear that to reproduce up to 15,000 cps on 7.5-ips tape, the head gap must be ¼ mil, which is half the wavelength. And by the same token, to handle 15,000 cps on 3.75-ips tape which could very well become the standard for home instruments, we need a tape head with a gap only 0.000125 inch, or ⅛ mil.

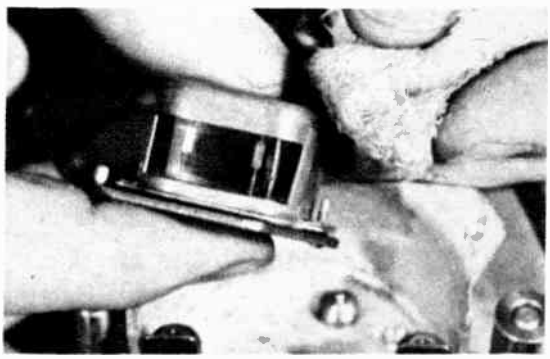
This is initially the problem of the manufacturer, and he has brought us far from the days when it was believed that the maximum possible response from 7½-inch tape was 7,500 cps. But it soon becomes the problem of the audiophile as well, for wear and tear can rather quickly impair the all-important dimensions of this gap.

Probably no other trouble is so consistently responsible for deterioration of sound in a tape recorder as are worn heads. Since the core material is somewhat softer than the magnetic oxide on the tape, some head wear is inevitable. It can be held to a minimum, however, by keeping the heads clean and well lubricated, using only liquids specifically designed for the purpose.

Both tape and disk recordings are purposely distorted in transmission, and compensation must be made in reproduction. This is one of the matters covered in the next chapter. •



Dimensional drawing of Shure magnetic tape head



This is photograph of a typical tape erase/playback head, removed from a home tape recorder.

John B. Gambling of WOR-Mutual, discusses the merits of a new record with Julie Rubin, a member of his orchestra. The compensator-preamplifier as well as the tuner at their left is by Altec-Lansing.

Compensation and the Preamp

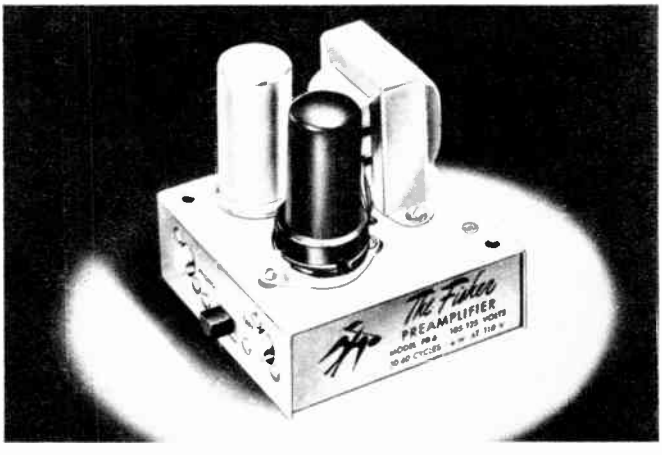
Correct preamplification is necessary for today's hi-fi systems.

IF you were to take the best record ever made, or the best recorded tape available today, and play it on a perfectly "flat" system, the results would be rather terrible. Both of them would sound thin and screechy, with almost no bass at all. Obviously the sound has been jimmied in order to squeeze it into the groove or onto the oxide. Our object now is to find what has been done, why and how it was done, and what we must do at the reproducing end to compensate for it.

Considering the disc recording first, the winding course pursued by groove as a record is cut is the result of three separate motions:

General Electric Model A1-901 incorporates three separate filters in one unit. They are high and low cutoff and six-position record compensator.

Preamplifier by Fisher is used for phono, mike or tape-head preamplification. Response is 30-20,000 cps, ± 2 db. Hum, noise level, 60 db below 1v.



G.E. variable reluctance cartridge preamplifier provides equalization and increased output for cartridge. Unit should be located within 4 ft. of turntable for best results.

1. The steady rotation of the turntable at a predetermined number of revolutions per minute.

2. The steady movement of the cutter toward the center of the record at a predetermined number of grooves to each inch.

3. The varying side-to-side motion of the cutting stylus, which is determined at every moment by the frequency and amplitude of the audio voltage.

Imagine now the cutting of a record with a perfect piezoelectric cutter. With a characteristic just opposite that of a crystal pickup, the cutter will tend to twist out of shape when a voltage is applied to it. If the voltage is audio, the crystal will twist back and forth as it follows the reversals in direction of the current.

Now if we attach a cutting stylus to this crystal, it will swing from side to side with the torsion of the crystal. With these elements we have a basic recording system, which can engrave a wavy groove on a soft disc: When an audio voltage is applied, the stylus will swing the groove from side to side around the center position.

The sidewise distance the groove is moved, called the groove displacement, is determined by the intensity of the audio voltage. The louder the signal, the wider the groove swings. This seems simple and straightforward enough that you may be wondering, so what?

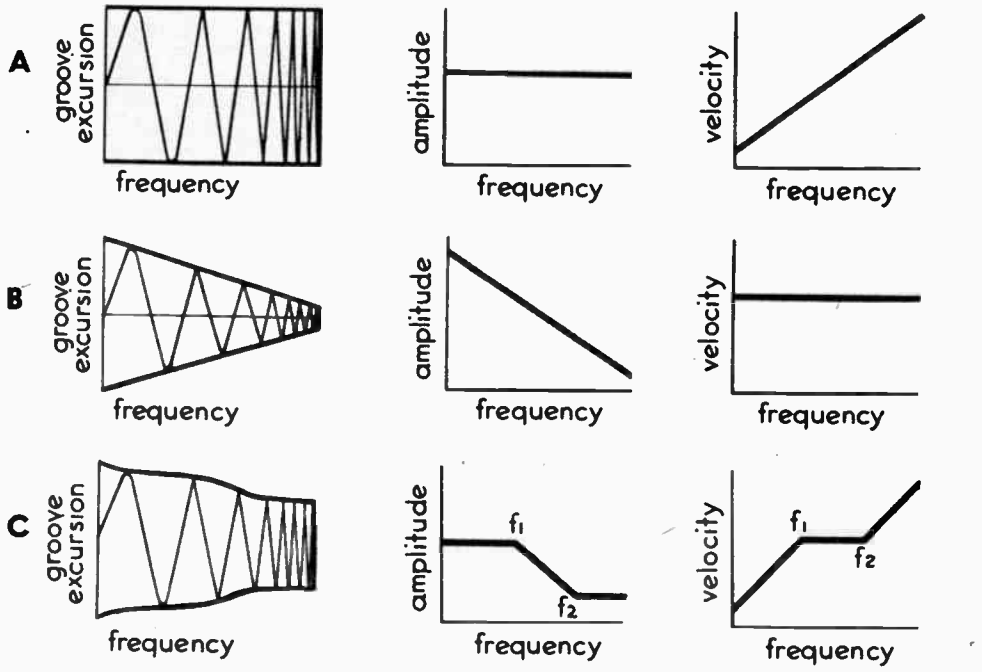


FIG. 1. In constant-amplitude recording (A), the groove excursion remains constant at all frequencies, while stylus velocity increases. In constant velocity recording (B), groove excursion and amplitude decrease with frequency increase. Composite recording (C) is constant-velocity at mid-range between f_1 and f_2; bass and treble are recorded at a constant amplitude. The reproducing curve is inverse of recording characteristic.

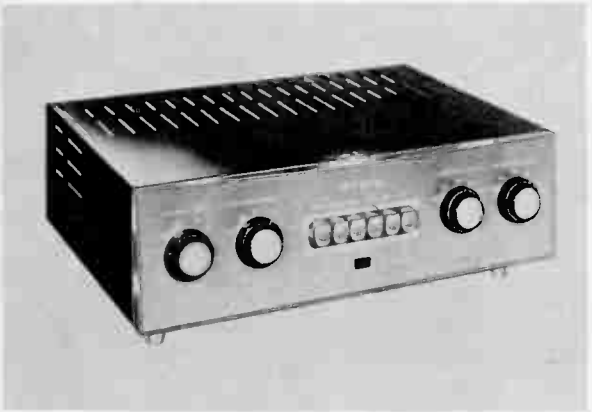
Brociner Mark 30c audio control center is of printed circuit construction, has 24 record compensation curves, rumble filter. Price is $88.50.

The point is that commercial record cutters do not operate in this ideal fashion. If they did, they would be known as *constant amplitude* devices. That would be a cutter whose groove displacement is directly proportional to the amplitude of the driving signal.

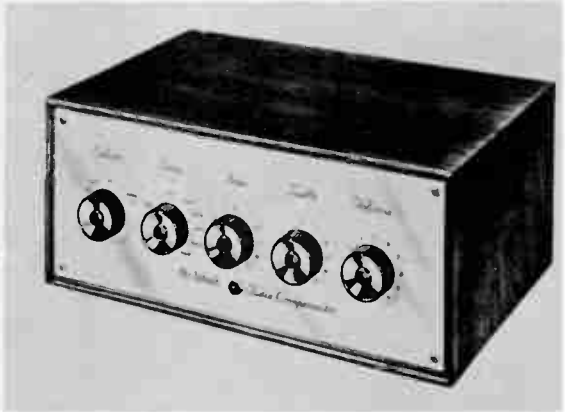
Now consider what happens in a magnetic cutter, which in fact all commercial cutters are. Just as we likened the magnetic pickup to an electric generator, the magnetic cutter is a specialized electric motor. So let's take an ordinary DC electric motor, with which everyone is familiar, and connect a battery to it.

When voltage is applied to the motor, it will rotate at a constant speed. If we swap the two wires around, the motor will reverse direction. If we insert a switch between the battery and motor to let us reverse the wiring very rapidly, the motor will rotate back and forth, changing direction just as rapidly as we throw the switch. Now reversing the wiring between the battery and the motor actually results in reversing the direction of current flow through the motor. Thus we conclude that the direction of rotation of the motor is determined by the direction, or polarity, of the current which feeds it.

Next, suppose we used a different battery in the circuit, one with just half as much voltage. Immediately the motor speed would drop to half. And if we used a battery

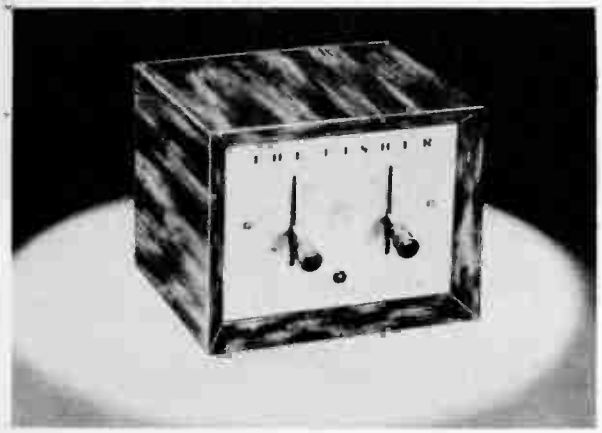


Bogen PR100A audio control unit and preamp sells for $109, has tape monitor push button, volume control for regulating sound of a second channel.

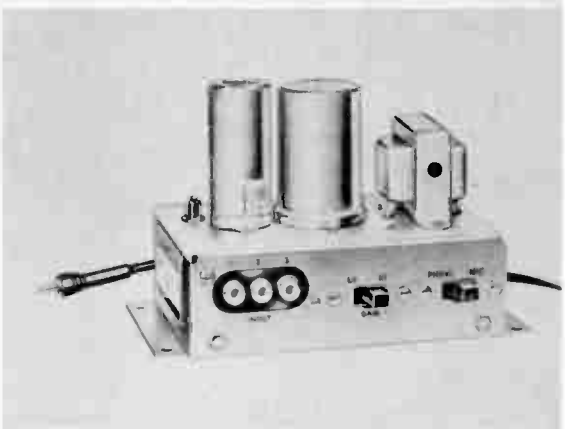


Equalizer-preamplifier Model C-4 by McIntosh is priced at $64.50, has five input channels, two of them equalized with magnetic cartridge pickups.

Fisher Hi-Lo Filter is used to surpress noise with minimum loss of tonal range, can be used with almost any system. Chassis is AC self-powered.



General Electric preamplifier uses one npn transistor and one double triode, has RIAA playback curve, is used for microphones and phonographs.



with double the voltage the speed would double. This gives us another fact concerning DC motors: their speed is directly proportional to the amplitude of the driving voltage.

These are the operating principles of the magnetic phonograph record cutter. The motor rotation and hence the stylus displacement, will continue right up to the point where the current reverses and sends it back in the other direction.

Now a bass tone has less current reversals in a given period than a treble tone, so in a magnetic cutter the stylus will have more time to travel further at the low-frequency end of the spectrum. Then when the motor speed is constant, the stylus displacement is very great at the lowest tones and quite slight at the high end. The stylus displacement is thus said to be inversely proportional to the driving frequency. And as we know, the motor speed and hence the stylus velocity is directly proportional to the driving voltage. Such a cutter is therefore said to be a *constant velocity* device.

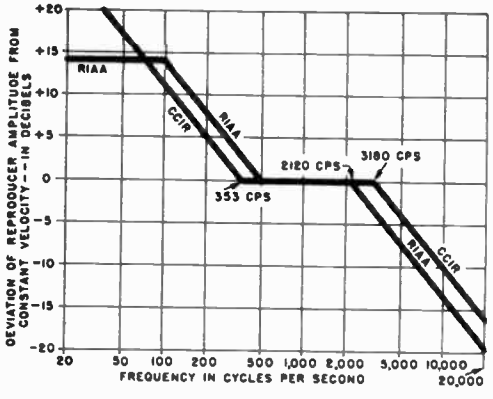
Now to review the basic operation of the two systems:

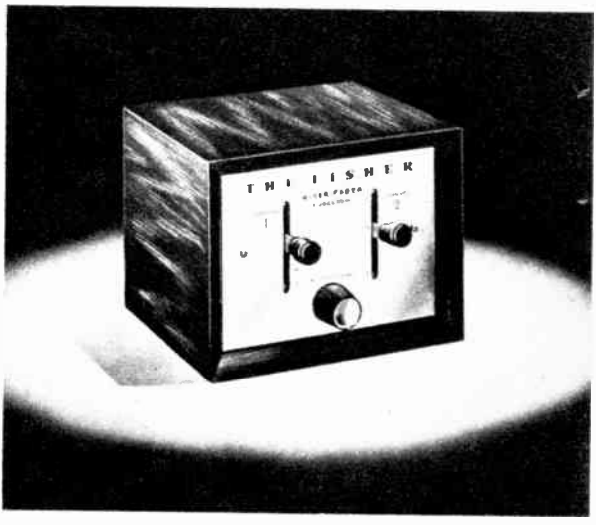
1. In a constant amplitude cutter the amount of stylus displacement is determined by the magnitude of the driving voltage.

Above, Tannoy preamp has rumble and treble filter, eight phono compensation positions, tape and tuner inputs, bass, treble and volume control.

Mixer-Fader by Fisher mixes two signal sources of equal or varying amplitude. Permits smooth fading from channel to channel; self-powered.

FIG. 2. U.S. and European tape equalization





2. In a constant velocity cutter the speed of stylus movement is determined by the magnitude of the driving voltage.

It would seem at first glance that either method should be equally acceptable for the cutting of a record, provided the reproducer is a device of the same type. But each of these systems has inherent advantages and disadvantages which vary with the part of the audio spectrum in which they are operating. The development of a recording characteristic then consists of an effort to use each system in that part of the audio range where it will be the most advantageous.

The early acoustic cutters had a characteristic which was, in its limited way, essentially that of constant velocity. Then the first electrical cutters were of the magnetic variety, and these were likewise of the basic constant velocity form. Since it has never been possible to design a good constant amplitude cutter, which would operate satisfactorily throughout the entire audio range, all disc recorders in commercial use today are still of the magnetic constant velocity type.

But in a constant velocity cutter, as we have seen, the stylus displacement is inversely proportional to the frequency with the result that the bass notes will force the stylus into exceedingly wide excursions. Thus the groove area traversed on low tones will be much greater than would otherwise be necessary. We can avoid this complication in two ways. The first method would be simply to keep the grooves widely separated so that they do not interfere with one another.

But this expedient would seriously shorten the playing time available on the record. The other method, and the one employed in commercial practice is to modify the constant velocity characteristic so that it becomes constant amplitude below a certain frequency. The point at which the characteristic changes is known as the turnover frequency.

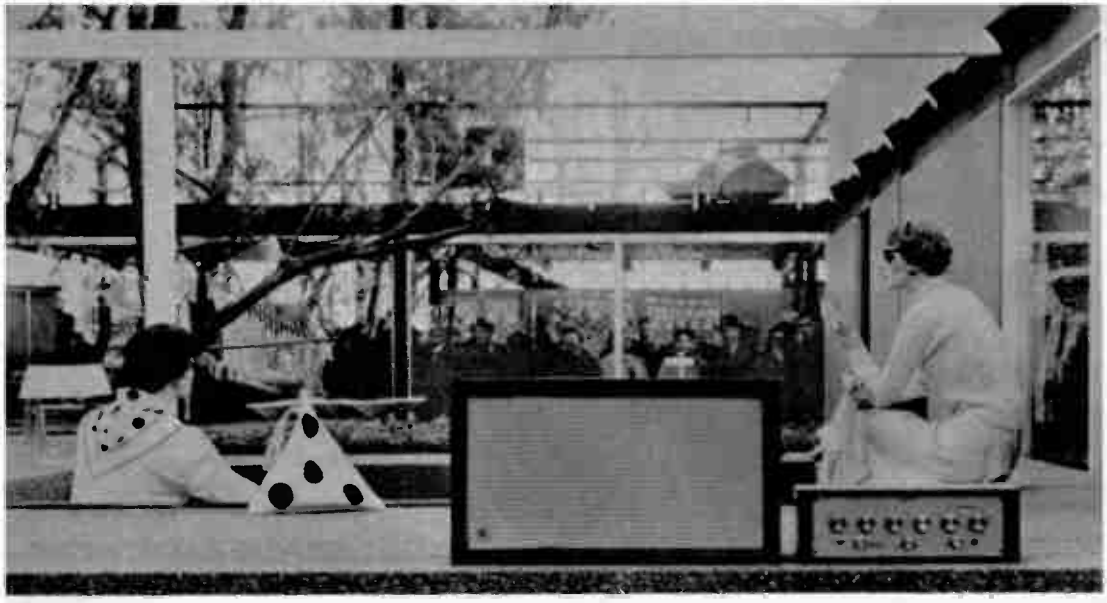
We now have a modified constant velocity curve which is constant amplitude in the bass region and constant velocity in the middle and upper regions. A characteristic such as this with a turnover frequency around 250 cps, was generally employed in Europe as the standard for 78-rpm records for some years.

Such a recording characteristic is still not ideal, however, for the amplitude of the constant velocity signal is pitifully weak at the high frequencies. We have here two seriously conflicting factors, for at the same time as the signal amplitude is decreasing with increasing frequency, the surface noise of the record is characteristically much greater in the high frequency region. Thus our signal-to-noise ratio is exceedingly poor under these conditions

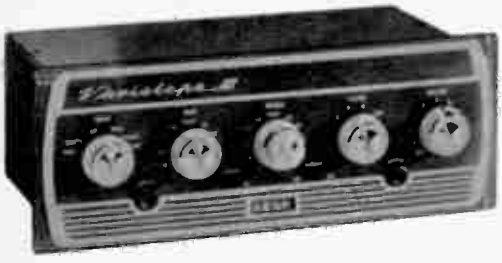
We therefore counteract this drooping high frequency characteristic of the constant velocity curve by inserting treble boost, or tip-up. This rising characteristic, which is in effect a change to constant amplitude once again, begins somewhere between 2,000 and 5,000 cps, and continues on to the upper limit of the system. Now we have a curve which is a sort of lazy *S* shape, flat in the middle, with a drooping low end and a tipped-up high end. Each of the bends in the curve really represents a

Lafayette control and preamp unit sells for $59.50, includes tape monitor switch, three outlets, seven inputs. Hum and noise is 80 db below 3v.

Heathkit monaural-stereo preamplifier, below, can be purchased as monaural unit and converted to stereo by "plugging in" the other channel. The control knobs plug through the larger monaural dials, allowing them to operate concentrically.



Photograph above shows some of the American high fidelity components selected for the Brussels World's Fair. The speaker is the Acoustic Research AR-1, the preamplifier to its right is made by Marantz.



Varislope III preamplifier is made by Leak, incorporates two magnetic inputs, rumble filter, infinite equalization position control. It sells for $79.

The 400 stereo audio control center by Fisher provides 16 input jacks, four outputs, has an electronic crossover. Hum is below 85 db at 2v.

turnover frequency, but in order to avoid differentiating between two of them, we usually describe the tip-up in terms of the number of decibles increase at 10,000 cps.

Still another bend is added to the curve of American records, to obtain a more favorable signal-to-noise ratio in the rumble region below 50 cps. All of this has now been adopted as standard in the RIAA (Record Industry Association of America) curve, which can be broken down into four parts, beginning at the bass end of the spectrum:

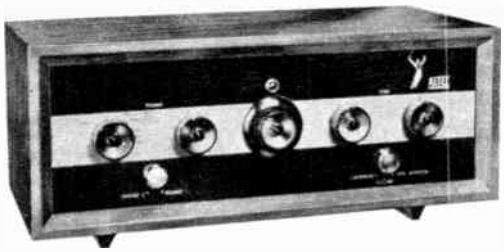
1. First there is a very low frequency constant velocity "shelf," extending up to 50 cps.

2. Then we have in the remaining bass region a constant amplitude curve extending up to 500 cps.

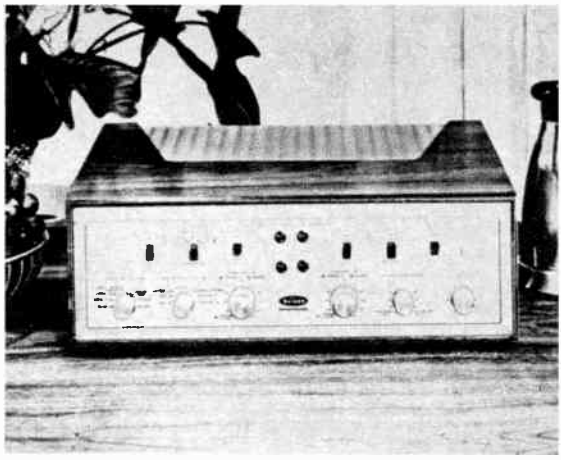
3. Next there is the basic constant velocity region in the midrange, extending up to about 2,000 cps.

4. Finally we have the constant amplitude treble tip-up, extending to the top of the range, and amounting to about 13 db at 10,000 cps.

There was a time not very many years ago when there were about as many different curves as there were companies making records. This has largely been disposed of with the RIAA curve but we still don't have international agreement with the result that the Europeans have gone their own way in the matter. The CCIR (Consultive Committee on International Radio) curve differs in having no bass shelf, and turnover frequencies of about 350 and



Altec-Lansing control preamp has five inputs, continuously variable loudness control, tape monitor; noise is 95 db below 1.5v; $147, less case.



Top right, Scott Model 130 stereo preamplifier comes with stereo tape monitor switch, is equipped for "trereo"—a 3-channel amplification; $169.95.

Music control center by Electro-Voice with a ± 1 db, 20-20,000 cps response, has six inputs, six-position phono equalizer, bass and high cut.

3200 cps, with a tip-up of 10 db at 10,000 cps.

Whether or not you will require the CCIR characteristic on your equipment will depend upon whether you buy European records, and if so, what route they have followed in getting to you. There are three procedures normally used:

1. Tapes are recorded in Europe and sent here for mastering and processing
2. Masters are cut in Europe and masters or mothers are sent here for processing
3. Discs are pressed in Europe and exported for sale here.

Only in the first instance are the records likely to have the RIAA characteristic. Under the latter two circumstances it is almost a certainty that the CCIR curve is used. The only way for the record buyer to be sure in such cases is to check the information on the record jacket, or communicate with the manufacturer responsible.

The problem in obtaining accurate reproduction from the recording is to have a system whose characteristics are the exact complement of the recording characteristic. That is, where the recording is boosted, the reproducer must roll it off, and vice versa. The two basic reproducing characteristics would be those shown in idealized form in Fig. 1.

The device which causes an essentially flat preamplifier to have such a characteristic is the reproducing equalizer or compensator. The simplest units, which are connected between the pickup and the amplifying equipment which follows, usually provide a choice of four or five of the most commonly needed curves. A system like this cannot begin to provide all of the possible combinations of characteristics, but at least some choice is available and a reasonably close match can be obtained. Operation of this unit simply involves rotating the selector switch to the characteristic which is nearest that of the record to be played.

A much more flexible system is one in which the bass boost and high roll-off are adjusted separately. Thus with four bass positions plus four high positions for example, sixteen different reproducing characteristics are possible, a number which will meet just about all normal requirements.

Equalization is necessary in tape recorders also, and for reasons similar to those for disc recording. There is the problem of hiss and other high frequency noise at the treble end, plus hum and rumble at the bass end. In addition to these factors there is the peculiar non-linearity of the tape recorder itself.

Without equalization, the output of a tape recorder will double each time the frequency is doubled. If the output were two volts at 1,000 cps, for example, it would be 4 volts at 2,000 cps, 8 volts at 4,000 cps, and so forth, up to a critical frequency, above which the output would begin to drop again. The unequalized playback is therefore described as having a normal rise of 6 decibels per octave.

The recording and reproducing characteristics for tape are a combination of the inherent peculiarities of the magnetic process, plus electronic equalization where needed. During recording the electronics system is flat up to the critical frequency, permitting the 6 db octave rise to go directly on to the tape. Then where the magnetic system begins to droop, electronic equalization continues with a tip-up of about 6 db per octave.

In playback the reverse holds true. A roll-off of 6 db per octave is inserted electronically up to the critical frequency, but the electronics becomes flat where the magnetic roll-off takes over. This is shown in idealized form in Fig. 2, where this country's standard curve, the NARTB (National Association of Radio and Television Broadcasters), rolls off to 3,000 cps and then flattens out. The European CCIR curve, however, flattens off an octave lower, at about 1,500 cps.

There is still another difference between the NARTB and the CCIR curves, as Fig. 2 shows. It has been found that the bass end of the spectrum, rumble tends to be accentuated if a 40 cps signal is equalized up to the point of maximum response. In the American system, therefore, the system is again flattened off, amounting to a bass roll-off, below 50 cps.

This equalization is normally taken care of automatically in the tape preamplifier, and no adjustment is necessary. In the case of the hi-fi tape system, the output of the reproducing preamp is fed directly into the hi-fi power amplifier. Many amplifiers now have a second tape jack, marked NARTB TAPE. The purpose of this is to permit connecting directly from the tape head into the hi-fi system, with proper equalization and adequate gain.

Phono pickups also will normally have a preamplifier between the compensator or equalizer and the main amplifier. This is often a source of confusion, for one wonders why all of the necessary amplification cannot be contained in one single unit. This is entirely possible as a matter of fact, and it is sometimes done. But there is logical argument for having the preamplifier separate, and this is worthy of some careful consideration.

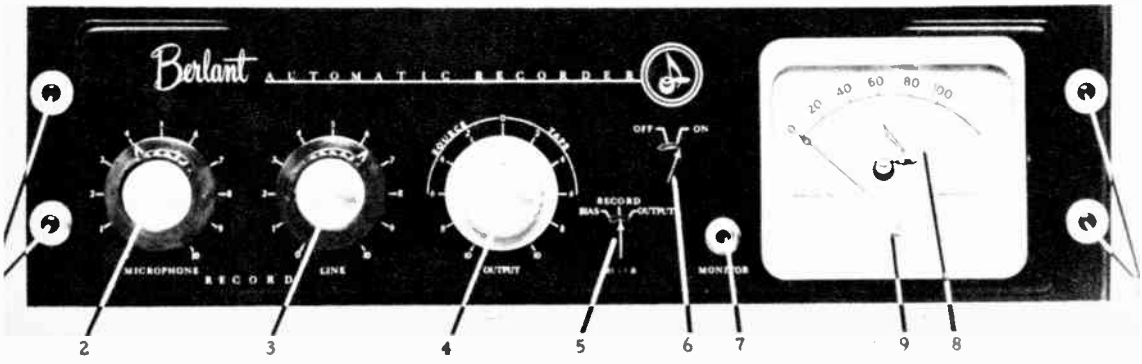
Let us begin by assuming a main audio amplifier which is able to accommodate

Grommes 209 Premier stereo preamp comes with 12 inputs, is self-powered, has a 10-20,000 cps frequency response at ± 0.25 db, four outputs.

Pentron tape preamplifier is self-powered for recording and playback, has 40-14,000 cps frequency response, safety recording button and VU meter.

1. Mounting Slots
2. Microphone Level Control
3. Line Level Control
4. Output Level Control
5. Meter Switch
6. Power Switch
7. Headphone Monitor Jack
8. Meter
9. Zero Adjust

Berlant-Concertone tape preamplifier has two channel mixer, A-B test fader, VU meter.



directly the output of a crystal pickup, radio tuner or crystal microphone. Such an amplifier cannot accommodate directly the output of a magnetic pickup, for this unit has a voltage which is only around one-hundredth that of these other devices. Additional amplification is therefore necessary to bring the level of the magnetic cartridge up to par.

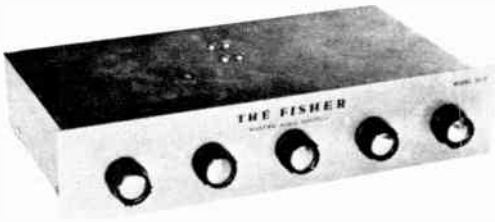
This extra gain is not needed otherwise, and would be wasted in a system which didn't use a low output pickup. The very small voltage developed by the magnetic pickup is even lower by the time it reaches the preamplifier, due to the insertion loss of the compensator. This device supplies no gain of itself, the apparent boost at the low end actually being due to losses inserted elsewhere.

The simplest preamplifier is essentially a fixed-gain device, without volume control or other adjustments. Its sole function is to increase the feeble output of the pickup-compensator combination to a value which is comparable to that of the other common signal sources. The requirements of the preamplifier are very exacting, for any noises which might get into the system at this point would become exceedingly serious after the tremendous amplification which follows.

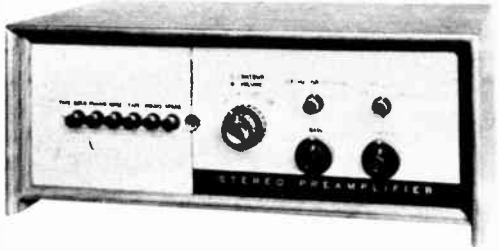
It is much easier from a design standpoint to keep the preamplifier completely isolated from the main amplifier, rather than take the additional precautions necessary to avoid noise induction from associated equipment. A separate preamplifier, then, is usually to be preferred over one which is included as part of the main amplifier.

Very often, however, the preamplifier and compensator are constructed as a single unit, and this is an entirely logical and useful combination. The unit may have a self-contained power supply, or it may obtain its necessary operating voltages from the same supply as the main amplifier. The self-contained unit is naturally more expensive, but it avoids possible troubles in obtaining satisfactory isolation between preamp and the main unit.

Most of the technical specifications for preamplifiers are the same as for power amplifiers. These and amplifier controls are discussed two chapters hence. Before that, we'll talk about another device for handling still another program source, the radio broadcast tuner. •

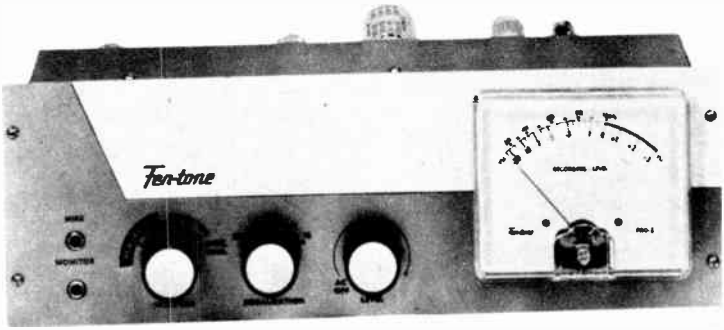


Fisher 30-C audio control sells for $49.50, is designed to be used for converting your existing monaural system to stereo; six inputs, two outputs.



Altec 445A stereo preamplifier gives 12 inputs, four outputs, rotary-ganged two-channel volume control, bass and treble dial for each channel.

Fen-Tone tape preamplifier Model PRO-2 conforms with NARTB standards, has signal to noise ratio of 60 db, VU meter, one volt output.



Altec AM-FM tuner 306A, 440C control preamplifier, 340A 40-watt amplifier and "Capistrano" speaker system. Total price of components: $912. Sensitivity of tuner is 1.1 microvolt.

Signals Through the Air

Whether AM or FM, consider all aspects of a tuner before you buy.

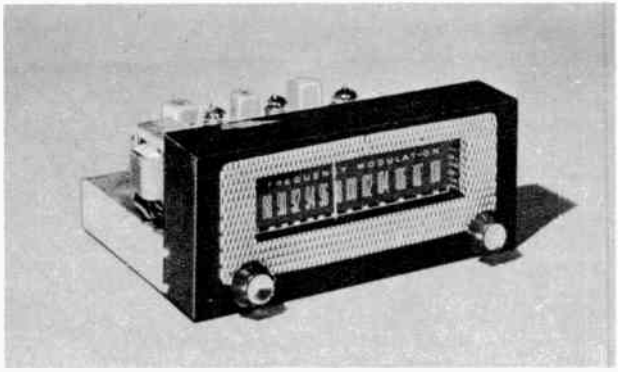
THE device used to receive radio signals is known as a tuner. There is no affectation in the use of the term, for the tuner is rather different from the ordinary radio set in several important respects. The first obvious difference is the fact that a tuner is only part of a receiver.

The usual home radio for broadcast reception comprises five basic elements. First is the antenna, which collects the radio signals. Next is the radio-frequency section, which selects the desired signal out of the many thousands striking the antenna, and builds it up to usable strength.

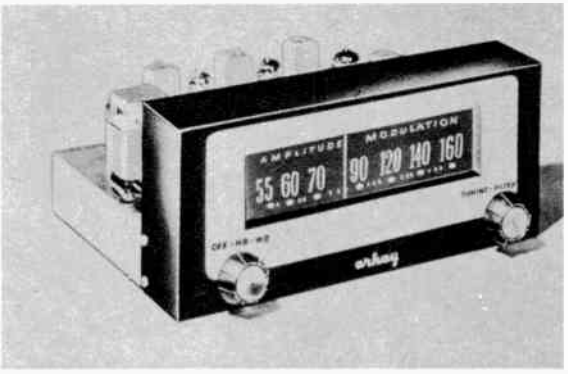
The third unit in the receiver is the detector, which picks up the sound of the radio carrier, discards the radio portion and

Bell AM-FM tuner Model 2520 includes logging scale, AFC; FM sensitivity is 2 uv for 20 db of quieting, image rejection, 31.5 db. Frequency response for FM, 20-20,000; for AM, 20-5,000 cps.

Below, Bogen RB140 FM-AM receiver includes a 40-watt amplifier and control preamp; $294.50. FM sensitivity is 2.5 uv for 30 db quieting on 75 ohm antenna input. The unit contains 19 tubes.



FM tuner kit by Arkay has 88 to 108 MC tuning range, 4 uv for 20 db quieting sensitivity. The image rejection is 30 db minimum. It uses 300-ohm antenna, has AFC and a —65 db hum level.



Arkay also makes this AM tuner kit with 540 to 1650 KC tuning range. Sensitivity: 2 uv for 20 db; hum level: 65 db below 1 volt. Includes whistle filter to eliminate whistle between stations.

sends along the remainder in the form of an electrical audio signal. The final two units in the receiver then are the audio amplifier and loudspeaker.

Since a high quality audio amplifier and speaker system is the very heart of any hi-fi setup, there is no need for these elements to be included as part of the radio system. In some cases the tuner is made an integral part of a hi-fi amplifying and control system, but it needn't be. The basic tuner is simply a radio set without the audio and speaker. It ends with the detector, which is usually connected directly into the hi-fi audio system.

This being the case, it might seem that the front end of any radio could be used for hi-fi, as long as the speaker is muted and the signal picked up off the detector. This might be true, but more likely not, for the differences between a radio and a tuner don't end there. To understand both the similarities and the differences, consider Fig. 1.

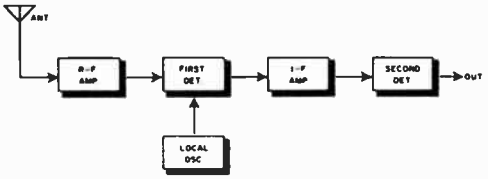


FIG. 1. Basic arrangement of broadcast receiver.

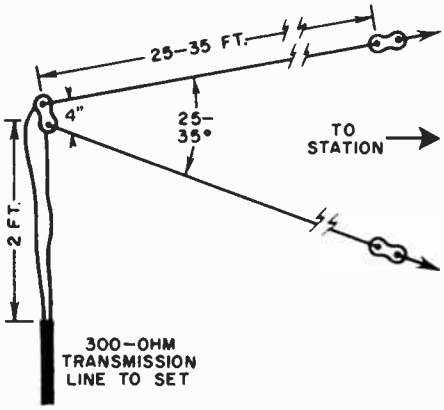


FIG. 2. Design for a 300-ohm outdoor antenna.

Pilot FM-AM tuner FA-540 has tuning "eye" for both bands. FM sensitivity is 3.5 uv for 20 db quieting at 300 ohms; it includes AFC, AM whistle filter, built-in AM antenna. Operates on AC only.

Here we see the basic arrangement of nearly all current broadcast receivers, both AM and FM, table model or hi-fi console. Beginning at the antenna, all of the signal voltages induced in it from surrounding radio waves are fed into the radio-frequency amplifier or preselector. This amplifier tunes and amplifies the desired signal, ignoring all others. Thus it must be both *sensitive* and *selective*.

It is easy enough to build both sensitivity and selectivity into a receiver, as long as fidelity isn't an important consideration. But to get all three requires considerably more skill, more and better components,

Fisher FM-AM tuner and audio control Model 90-T. FM sensitivity: 0.85 uv for 20 db quieting, 1.6 uv for 30 db. Audio control has eight-position channel selector, record and tape equalization.

and consequently more expense. Thus in the low-cost home radio, quality is degraded beginning right here, long before the signal gets to the audio stage.

The following elements are typical of the superheterodyne receiver, which is the type used almost exclusively today. Note that the first detector receives not only the r-f signal just discussed, but also a signal from a local oscillator within the set. The local signal is also a radio frequency, but without modulation.

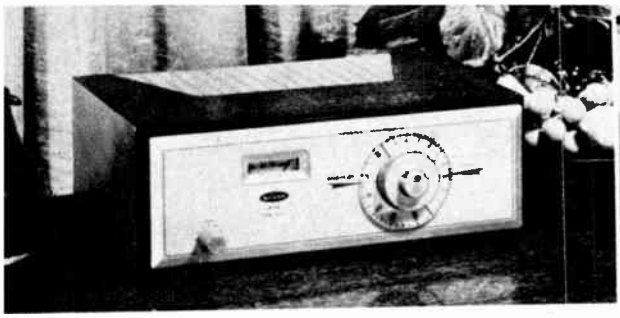
Now when these two signals combine in the first detector, the output is a new and lower carrier frequency, carrying the same modulation which arrived at the input. This is possible because the local oscillator frequency is varied at the same time the tuning of the r-f amplifier is adjusted by the knob and dial on the front of the set.

Thus there is a constant difference between the frequency of the local oscillator and that of the incoming signal. The result is that the two "beat" together and emerge as a modulated carrier of fixed frequency, called the intermediate frequency. In most AM broadcast tuners the i-f is 455 kilocycles, and 10.7 megacycles in FM sets.

The advantage of this arrangement is that the intermediate amplifier can be fixed, specifically designed to operate only at the intermediate frequency. This not only simplifies the design, but also enables greater selectivity. Here again, however, the selectivity can be overdone, and in cheaper sets it usually is. The components used in i-f circuits of hi-fi tuners are therefore quite different from ordinary types.

The detector in AM sets may be either a grid, plate or diode type, depending upon the tube and circuitry used. The first two are considerably more sensitive, and are therefore often used in cheaper sets, but they also exhibit considerable distortion. The diode detector is therefore almost always used for AM hi-fi tuners.

There are two basic types of FM detectors, one known as a phase discriminator or Armstrong circuit, the other called a



H. H. Scott 311-C FM tuner gives sensitivity of 2 uv for 20 db quieting at 300 ohms, 1 uv with 72-ohm antenna. Two stages of full limiting and 2-megacycle detector bandwidth are also featured.

Scott 330-C AM-FM tuner can be used for monaural or stereo operation. FM specifications are same as for tuner shown at left. The AM portion needs external antenna, at least 10 feet in length.

ratio detector. Both of these are in fact discriminators, and there is little practical difference between the two. The ratio detector was developed to get around the necessity for limiting amplifiers, but it was not wholly successful for that purpose.

Limiting is a process occurring in one or more i-f amplifiers immediately preceding the discriminator, wherein any AM noise is rejected. Without it, the full signal-to-noise capabilities of FM cannot be realized. But since FM sets were built without limiters, and with ratio detectors having insufficient limiting, the ratio detector was held to blame. There is nothing wrong with a ratio detector that a good limiter won't cure, but since it now has a bad name, you won't often find it in hi-fi FM tuners.

Hi-fi tuners are available in FM-only, AM-only, AM or FM, and AM *and* FM. The first two types are self-explantory, but the latter two designations may be somewhat confusing. The difference is that the either-or type can handle only one signal at a time, since many of the tubes and circuits in the set are shared by both the AM and FM functions. The AM and FM type, on the other hand, is really two complete tuners in one, and if desired it can feed two separate programs to two different hi-fi systems simultaneously. Since such tuners can also handle AM-FM stereocasts, this type unit is usually described as a stereo tuner.

There is very little problem in the antenna for AM. Local signals are so strong that almost any sort of antenna will suffice, and the broadcast spectrum is so crowded that distant reception is hardly worth the trouble. Tuners usually have some sort of small antenna built in, often a ferrite loopstick. If this isn't sufficient, just a length of wire of ten feet or so will usually do the job.

Some sort of antenna is usually necessary for FM, but it may often be the indoor type. An ordinary TV "rabbit-ears," for example, makes an excellent indoor antenna. The accompanying photos show how a folded dipole can be made very simply, using inexpensive ribbon-type transmission line, the same kind used for TV lead-ins. This type antenna is often included as standard equipment with FM tuners.

There are a number of good outdoor FM antennas available. They closely resemble television antennas, which is to be expected, since the FM band is right in the middle of the TV spectrum, between channels 6 and 7. Many outdoor TV antennas will work very well on FM, but some will not. There are some such antennas which are especially designed to have poor reception in this region, to avoid interference from FM to the adjacent TV channels.

A very hot outdoor FM antenna can be made according to the drawing in Fig. 2. Ordinary antenna wire and three insulators are all that are required. The antenna can be strung from garage to house, between trees, or with supporting posts or towers. To get a fair impedance match between the antenna V and the ribbon transmission line, the twin wire should be split for a length of two feet so the two wires can fan out to about four or five inches.

The ribbon-type line of 300 ohms impedance is the type most generally used along with a 300-ohm antenna, but there are some variations. In noisy areas it may be necessary to use shielded 300-ohm line. Some antennas have a characteristic impedance closer to 72 ohms, in which case 72-ohm line should be used. This is available in both ribbon and coaxial types. Many of the better tuners have antenna input terminals for both 72 and 300 ohms, to accommodate these varying conditions.

Tuning indicators are useful with AM tuners and essential in FM operation. They can be either of the electron-ray "magic eye" variety or an electric meter. In AM sets they usually indicate the condition of maximum signal, while in FM they normally indicate the correct tuning to the center of the channel.

Sensitivity specifications for tuners are

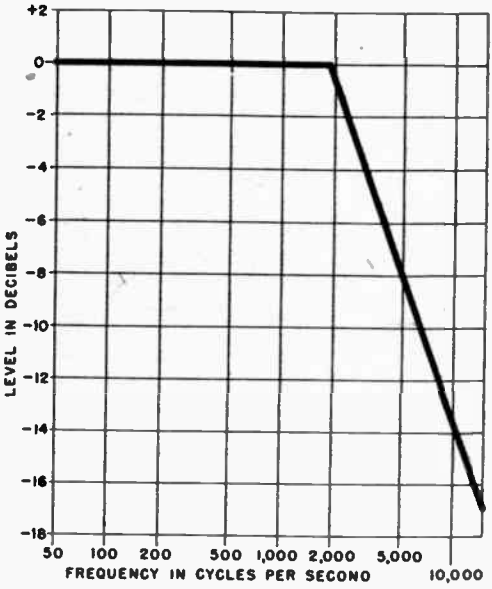


FIG. 3. Compensation characteristic of FM tuners.

New FM tuner by Sherwood has 0.95 uv for 20 db of quieting. Featured are AFC, cathode-follower output, output level control and FM multiplex. Intermodulation is below 1½ per cent; $99.50.

Fisher FM-40 tuner has center-of-channel tuning meter, 3 uv for 20 db quieting sensitivity, 300- or 72-ohm inputs, multiplex, is self-powered. It features logging scale, power/volume control.

Lafayette makes this low-cost FM-AM tuner for $49.50. It has AFC and less than 1 per cent distortion; hum level is 60 db below 100 per cent modulation. Unit comes complete with its case.

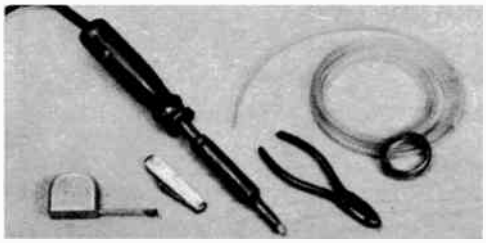
best given in terms of the amount of input required to give a certain signal-to-noise ratio. Although this method is quite generally used for FM, it has unfortunately not been used much in this country for AM, although that procedure has become increasingly popular in England.

Here the usual AM sensitivity specification gives the number of microvolts necessary to be fed into a standard antenna to obtain the rated output of the receiver. This is too nebulous to enable one to compare receivers of different manufacture, although it probably does enable valid comparisons of tuners in the same line. With these reservations, it should be understood that the fewer the microvolts required, the more sensitive is the receiver.

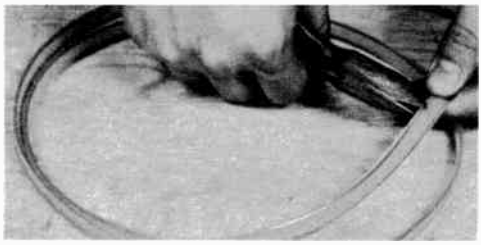
There are several types of sensitivity measurements which can be made on FM tuners, but the one usually mentioned in manufacturers' literature is the quieting-signal sensitivity. This in effect tells the minimum amount of radio signal required to produce a certain signal-to-noise ratio in the output. Good engineering practice calls for this quantity to be expressed in terms of 30 db (decibels) of quieting, but apparently some have found this a little too stringent.

Some have therefore arbitrarily decided that a figure based on only 20 db of quieting looks a lot prettier. This makes for confusion in the mind of the prospective purchaser, which possibly was the purpose. Just as you can't add oranges and apples, so you can't compare sensitivity figures based on two different reference levels.

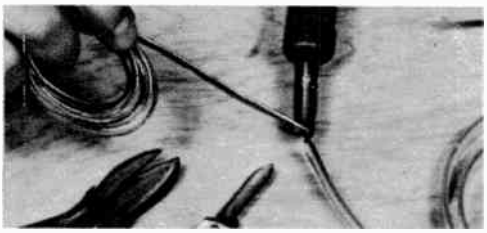
Remember that 30 db of quieting is more



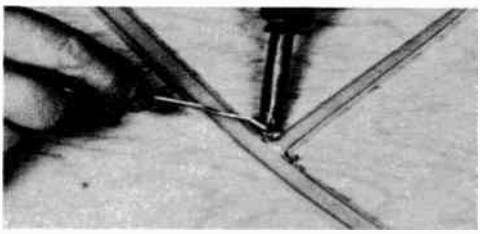
Folded dipole FM antenna is easily made with the tools and ribbon-type 300-ohm line shown above.



Cut 300-ohm line to exactly 60 inches, then make two cuts into one conductor at its midpoint.



Both ends of 60-inch line get trimmed and insulation cut back ½ inch. Twist ends and solder.



Lead-in from antenna to tuner is soldered to the midway point of 60-inch line, previously bared.

difficult to achieve than 20 db. Obviously then a receiver which 2 microvolts for 20 db of quieting is less sensitive than one requiring 2 microvolts for only 20 db of quieting. From this we can formulate two rules for comparing FM sensitivity figures:

1. If the microvolts are the same, the set with more decibels of quieting is more sensitive;
2. If the decibels are the same, the set requiring less microvolts of signal is the more sensitive.

Another circuit in tuners which is exclusive with FM is the de-emphasis network. In FM transmission the treble end of the spectrum is tipped up to allow an even better signal-to-noise ratio, by the amount of 13.7 db at 10,000 c.p.s. This is a broadcasting standard which is automatically compensated for in the tuner, as shown in Fig. 3. No further external compensation is required.

A feature of most of the better tuners, both AM and FM, is automatic volume control (avc). This is a device which automatically varies the gain of the tuner to compensate for changes in received signal level. This is seldom important when tuned to nearby stations, but it is useful when tuned to more remote signals which have a tendency to fade.

Another refinement is quiet avc, which automatically kills the noise ordinarily heard when tuning between stations. Such circuits are also sometimes referred to as muting, squelch or interstation noise suppression. This is just a convenient nicety which has no effect on the fidelity or performance otherwise.

Since broadcast transmissions are held to their assigned channels within very close tolerances, the tuner, too, should have some means of keeping itself zeroed in on the signal. But there is a tendency for tuners, especially on FM, to drift, and the means used to compensate for this is automatic frequency control (afc). It normally works on the local oscillator, to correct its frequency so that the required i-f is always produced. On FM an afc circuit is indispensable, and it's rather handy to have on AM, too.

Another factor sometimes mentioned in tuner descriptions is FCC radiation specifications. Since every superheterodyne circuit has a local radio-frequency oscillator, it is in effect a miniature broadcasting station. The Federal Communications Commission has laid down specifications concerning the amount of external radiation permissible from these circuits, so as to minimize interference with other receivers. All tuners must meet or exceed these specifications.

Sometimes the term *capture ratio* is encountered in the literature. It has to do with the ability of an FM tuner to accept the stronger of two signals on the same channel while rejecting the weaker. Since there is no standard procedure for measuring this factor, it will only be seen when preceded by some sort of laudatory adjective. What else?

After all of the signal sources have been shaped to your satisfaction, they finally go to the power amplifier which readies them for the loudspeaker. A few words on that subject begin on the next page. •

General Electric Model PA-20 control amplifier has 20-watt power output, costs $99.95. Harmonic distortion is below 1 per cent. Phono input hum level is 60 db at full output. Unit contains a rumble filter.

Amplified Power

The last step in the hi-fi chain is the amplifier. It determines the power that reaches your speaker.

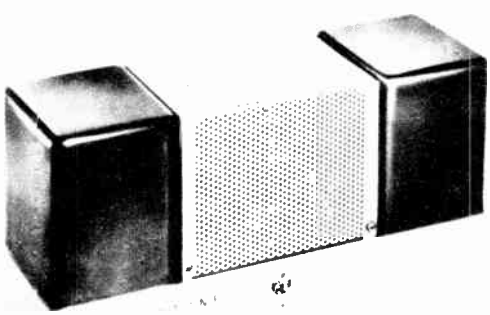
THE final electronic element in the hi-fi chain is the power amplifier, which builds up the feeble voltages of the program sources and releases them as powerful signals which drive the loudspeaker system. The power amplifier can be exceedingly simple or highly elaborate, depending upon the other functions it is to perform. In its simplest form the basic amplifier is essentially a fixed-gain device, which handles whatever signals are fed into it from a master control center. At the other extreme, the hi-fi amplifier may include preamplification, switching and other controls.

These controls seem to be one of the more confusing aspects of hi-fi operation to the uninitiated, so we'll attempt to clarify this subject which is fundamentally quite simple. To begin with, there has to be a switch controlling the electric power. It might be a rotary, a toggle or a slide, but it's still just a switch, which is turned either on or off. Sometimes this switch is ganged with the volume or tone control, and sometimes it is entirely separate.

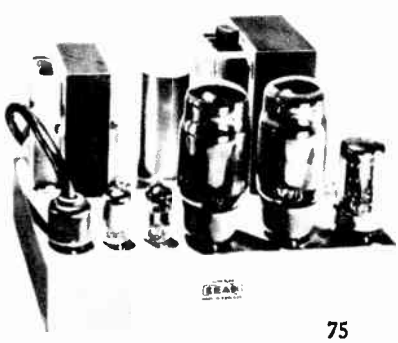
At the input to the amplifier is the selector switch. Since a number of devices from various program sources may be connected to the input circuit, a rotary switch or series of push buttons is necessary to select the one desired at any given time. In many cases this switch will also select the phono compensation.

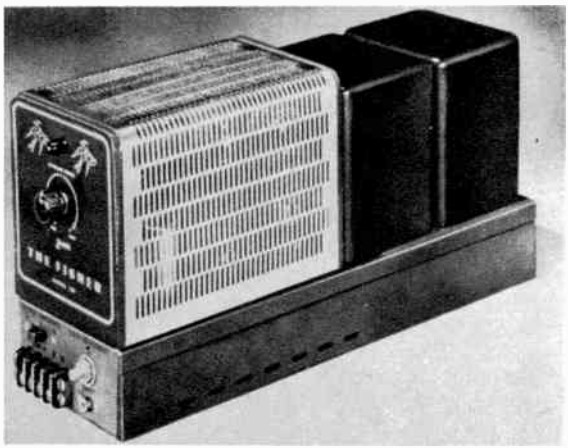
It should be remembered, however, that the design of most compensators is predicated on the use of a magnetic pickup. When using such an equalizer with ceramic or crystal cartridges, an adapter must be connected between the pickup and the magnetic input jack. The piezo type cartridge is reasonably well equalized internally to the RIAA curve, so it may be connected directly to any high-level flat input, such as TV, TUNER, TAPE or AUX. If there is an input jack specifically indicated for this type cartridge,

Pilot 20-watt power amplifier has frequency response of 20-20,000 ± 0.5 db at rated output. Harmonic distortion is less than 1 per cent at 20 watts. Hum level, 90 db below rated output.

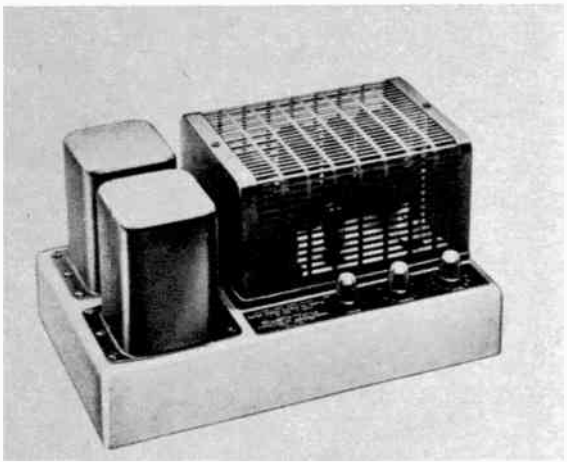


Power amplifier by Leak costs $109.50, is rated at 32 watts, has harmonic distortion of 0.1 per cent for 25-watt output; hum and noise is 86 db below 25 watts; for 3- to 20-ohm speakers.

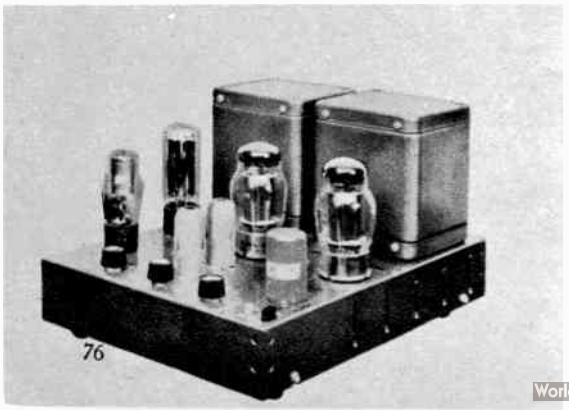




Fisher 30-watt amplifier has uniform frequency response within 0.5 db at 20-20,000 cps. Hum and noise level is 88 db below 30 watts. It can be used with speakers of 4, 8 and 16 ohm impedance.



Electro-Voice 30-watt power amplifier with less than 0.3 per cent harmonic distortion at rated output. Hum and noise level is 85 db below output. Frequency response, ± 0.5 db, 20-75,000 cps.



The Altec 350A 40-watt amplifier has frequency response of ± 1 db, 5-100,000 cps, 86 db below full output noise level. Output impedances are 8 and 16 ohms, continuously adjustable; $171.

it probably includes some additional fixed equalization. Otherwise there may be some touching up necessary with the tone controls.

There are usually two tone controls on the modern hi-fi amplifier, one for bass and one for treble. Unlike the treble rolloff control found on cheap radios, these controls permit independent selection of either boost or roll-off at both ends of the spectrum. These controls permit adjustment of sound quality to satisfy personal tastes, and to accommodate any acoustical peculiarities of the listening room.

The midrange is not usually controllable, but a few amplifiers feature a "presence" control. Since the human ear is most sensitive in the region between 3,000 and 5,000 cps, it has been found that boosting this range during amplification will help to make solo voices stand out and to improve articulation. The change in quality is striking, but since similar controls are now widely used in broadcasting and recording, it is seldom that they will be needed during reproduction.

Still another form of frequency response control is the fixed filter, which is simply switched in and out as needed. At the low end is the rumble filter, which is used to cut out low frequency noise from the turntable or in the program source. It is inevitable that some bass reproduction will be lost with such an arrangement, but every effort is made in the design of the filter to minimize these losses while still removing the offending noise.

At the other end of the spectrum are the scratch and hiss filters, which are intended to reduce these types of interfering noises to a comfortable volume. There may be several of these, each cutting off everything above a specified frequency. They may start as low as 3,000 or 5,000 cps and go up to as high as 10,000 or 12,000 cps. When using these filters, the highest cut-off frequency available should be tried first. If this doesn't remove the annoyance sufficiently, the next lowest should be tried, and so on until the best compromise is found between optimum sound quality and minimum noise.

There are two types of sound level control, and even one of these is a form of tone control as well. The ordinary volume control adjusts the level of all parts of the spectrum equally, but the more elaborate

loudness control does not. Thus the loudness control is seemingly a contradiction in the quest for maximum fidelity, but there is legitimate reason for its use.

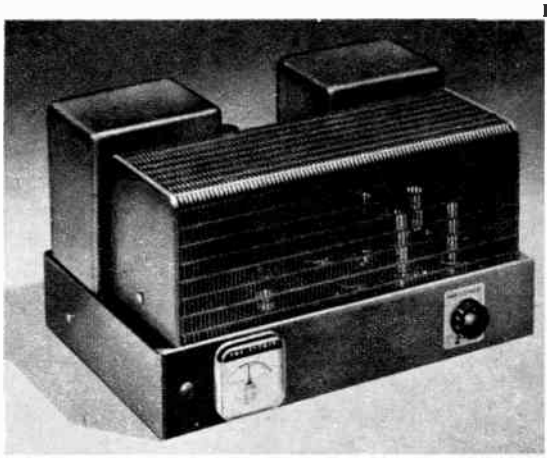
As we have observed, the response of the ear is not actually flat, but has considerably greater sensitivity in the near-octave of 3,000 to 5,000 cps. This is true at all volume levels, only more so at the lower intensities. Putting it another way, the ear is always less sensitive in the bass and treble regions than in the midrange, but as the volume is lowered the droop at each end becomes more pronounced, that is, the bass and treble drop even faster than does the middle.

Now most of the time we listen to a hi-fi system at a much lower level than that of the sound originally produced. This may not be true of a solo piano or string quartet, but it certainly does obtain in the case of a dance band or symphony orchestra. And listening at a lower level than we would hear these sounds in life, we lose perspective and musical balance.

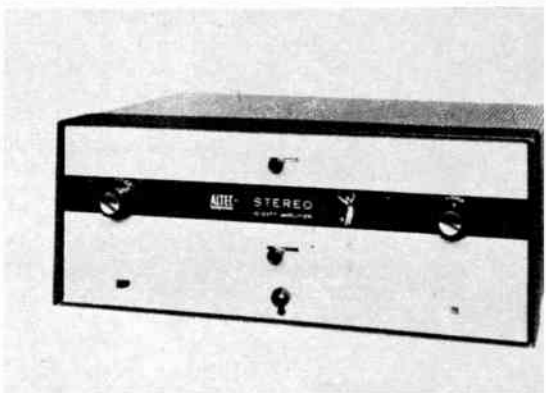
Tipping up both tone controls will enable us to restore the balance when listening at lower than normal levels, but this will only be guesswork. The loudness control corrects the balance by just the right amount, an amount determined by hearing tests on thousands of people, and presented graphically in a set of graphs known as the Fletcher-Munson curves.

Loudness controls are generally of two types. One of them operates just as the volume control, except that the balance varies continuously as the control is adjusted. The other is a filter or tone control which is set for the listening level, and which controls the tone in a manner just the inverse of the Fletcher-Munson curve for that level. Then the volume control is used with this in the conventional manner.

Some amplifiers also have an output selector switch. Sometimes this permits the selection of the correct amplifier output impedance to match the speaker being connected to it. In other cases it may select the speaker itself. Say you have a speaker in the living room and another in the den, for example, and want both connected to the same hi-fi system. With some amplifiers you could listen in either room you wished, or have both speakers playing at the same time if you preferred.

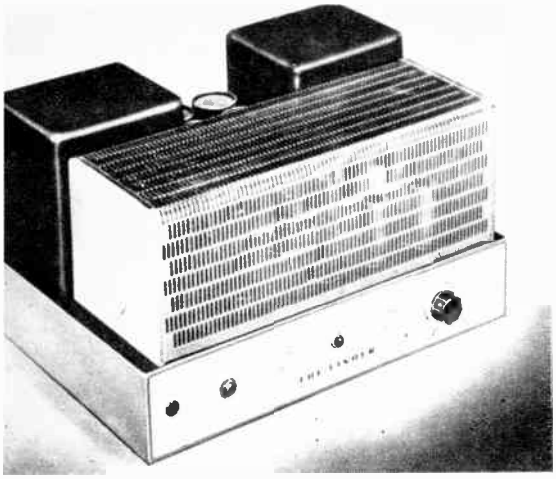


Fisher 55-watt all-triode amplifier has frequency response of 1 db, 5-100,000 cps; hum and noise level is 92 db below full output. Controls include input, level, bias, speaker impedance, Z-Matic.



Altec 345A stereo power amp is rated at 60 watts continuous stereo or monaural, 40 watts continuous each channel. Response is ± 1 db, 10-100,000 cps. It has a noise level of 85 db below full output.

McIntosh 60-watt amplifier with a frequency range of ± .1 db, 20-30,000 cps at 60 watts. Harmonic distortion is less than ⅓ per cent at rated output, hum and noise, 90 db below output.



Fisher 60-watt Model 200 amp has 160 watts of peak power, 20-20,000 cps response within 0.5 db. Intermodulation distortion, less than 0.5 per cent; hum and noise, below 90 db at rated output.

Fairchild Model 275 65-watt power amplifier has variable damping control, 0.5 db at 20-20,000 cps response. Hum and noise level is 90 db below rated power; 4, 8 and 16-ohm outputs; $213.

In addition to the primary function of driving the loudspeaker, many amplifiers now have a secondary output for feeding a tape recorder as well. Some amplifiers even have provision for tape monitoring. This is for use with tape recorders having separate record and playback heads, which permits hearing a tape played back only an instant after it is made. In this case the front end of the amplifier feeds into the tape recorder input, while the remainder of the amplifier connects to the tape output and reproduces in the speaker a playback of the recorded tape, just as it happens.

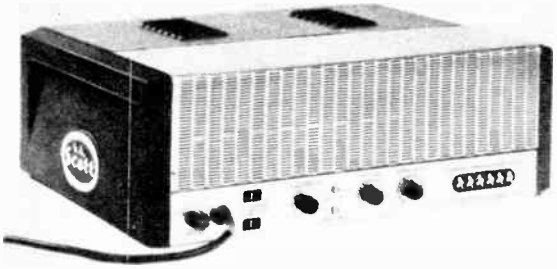
The most common amplifier rating is the number of watts output it produces, but a nebulous term at best. Since a watt is a watt the world around, it does seem strange that it is not very informative to compare amplifiers on the basis of watts power. The reason is that this rating doesn't refer to the maximum number of watts possible to get out of the amplifier when it is cooking away under forced draft. And even if it did, the rating would likely be even more meaningless.

The power rating of an amplifier is supposed to tell the maximum watts it develops in its output load with only a respectable amount of distortion. But what kind of distortion? And how much distortion? And how is it measured? And into what kind of load is the power developed? These are the kinds of questions which are seldom answered in manufacturers' literature. And even if they are detailed, the information isn't very useful. Since everyone has his own methods and standards, you are still left trying to compare apples and pears.

There are several instances of record in which a manufacturer has changed the power rating of an amplifier. These revisions have usually been upward, after seeing what the competition has been doing and deciding that one's own amplifier is too conservatively rated. Undoubtedly standards will be agreed upon in time, just as the Society of Automotive Engineers has established standard procedures for determining car horsepower, but right now the power rating of an amplifier is not a very good basis for comparison.

Since distortion is such an important factor in rating amplifier power, it naturally follows that distortion will be less when the system is operated well below its maximum rating. This is the basis of the argument for using amplifiers of upwards of fifty watts in home installations, when the program content most of the time is only a fraction of a watt. This argument has some validity, particularly when a low efficiency loudspeaker is used. But for most people most of the time, ten or twenty watts will more than satisfy normal requirements.

Frequency response used to be an important bench mark of amplifier quality in the days when we were straining to get something reasonably flat throughout the audible range of 30 to 15,000 cps. But now improved tubes and components, coupled with video amplifier design techniques,



H. H. Scott 80-watt power amplifier gets 160-watt peaks, less than 0.5 per cent harmonic distortion. Frequency response is flat from 12-80,000 cps; continuously adjustable speaker damping control.

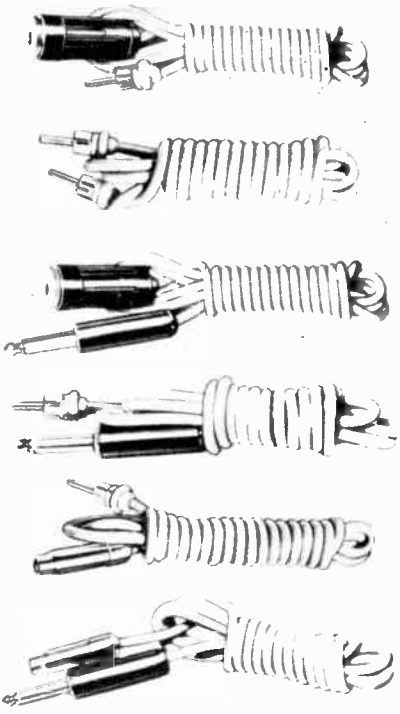
make possible amplifiers which are flat as a die throughout the audible range, and extend far into the supersonic and subsonic regions as well.

Just as there is a difference of opinion concerning the amount of power needed, there is also lack of agreement concerning these super wide range audio amplifiers. The question is, if you can't hear it, what good is it? One side of the argument says that there will be less distortion in such an amplifier. Sharp transients include components which extend way beyond the audible regions, and for the audible signal to be cleanly reproduced, the superaudible parts must be present, too.

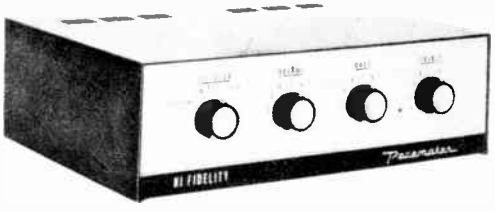
Not so, say the opponents. If you can't hear it and the speaker can't handle it, then it has no place in the amplifier. Such signals can cause trouble in the amplifier but setting up spurious responses and ringing in the areas beyond audibility. Although they cannot be heard themselves, they overload the amplifier, and cause intermodulation distortion of the audible signal.

Both arguments are entirely valid, and the audiophile will probably do best to compromise the two. Thus a good response beyond the audible range, but not too far beyond, may be the best answer. There are those who believe that a flat amplifier response from 20 to 20,000 cps, makes good sense.

At the same time that extensive efforts were being made to extend the frequency range, the one type of distortion which was fairly well understood was harmonic dis-

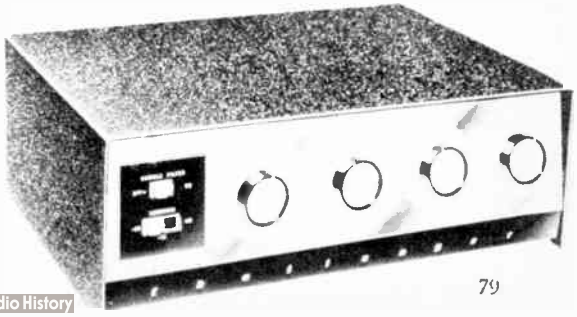


Lafayette Radio makes these hi-fi cables and connectors; from 45 to 85 cents. They include interconnection cables for tuners, amplifiers, preamps, speakers, tape recorders and changers.

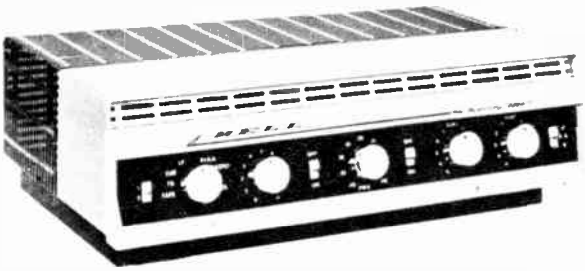


Bell sells the Pacemaker 10-watt single channel amplifier, priced at $55. It has inputs for magnetic and ceramic cartridges, tape head, tuner and auxiliary. Frequency response is 20-20,000 cps ± 1 db.

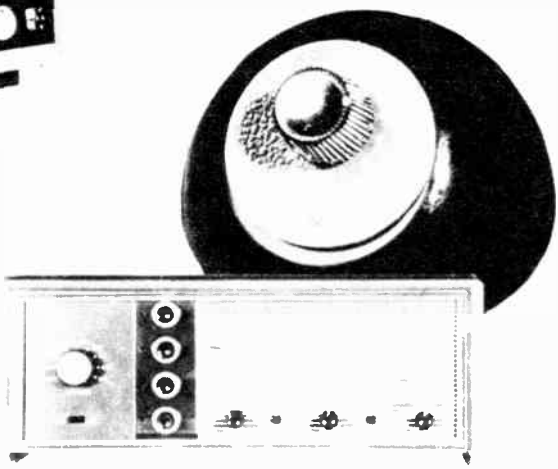
Bogen 10-watt control amplifier, 20-20,000 cps ± 1 db frequency response. It includes separate bass and treble controls, loudness contour selector, rumble filter, NARTB, RIAA equalization curves.



Pilot AA-903B 14-watt amplifier has preamp, individual tone controls, 5-position loudness contour switch, scratch and rumble filter, tape equalization and tape jack; 4, 8 and 16-ohm outputs.

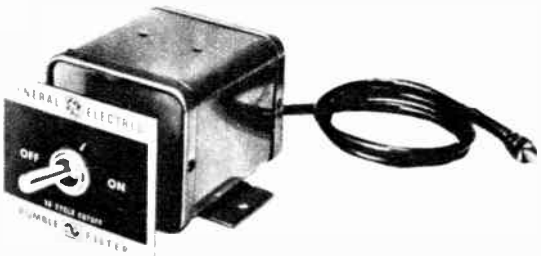


Bell 2360 50-watt control amplifier has ± .5 db, 20-20,000 cps response, 75 db below 50-watt hum level. It features seven inputs, 13 controls, seven outputs. Peak power is 100 watts.



Altec makes a stereo control which plugs into their regular amplifier, provides a master channel control when used with two amplifiers for stereophonic reproduction. Units cost $12.

Sherwood 20-watt amplifier sells for $99.50, features six inputs; two with the preamp, tape head and microphone equalization. Frequency response, ± ½ db, 20-20,000 cps at 20 watts.



Rumble filter by General Electric eliminates low frequency signals with G.E. cartridge. It has a single cut-off at 50 cps, reduces turntable rumble and signals below 50 cps.

tortion. This is the addition of spurious harmonics and subharmonics to the signal as it passes through the system. Harmonic distortion is no longer of any great consequence in a well-designed amplifier, unless it is being driven beyond its capacity.

The most serious forms of distortion are those which occur when more than a single pure tone is fed into the amplifier simultaneously. Since most hi-fi programs comprise music as the audio signal, and since most music is made up of chords of tones and their harmonics, the resultant waveform which must pass through the system is very complex indeed. A type of distortion which often occurs under these conditions is known as intermodulation. This occurs when two or more audio frequencies in the amplifier combine to form sum-and-difference tones in the output.

When this same thing occurs within the ear, the results are known as subjective tones and are accepted as part of normal hearing phenomena. But since the additional tones produced are not harmonically related to the music, their occurence within the amplifier is exceedingly undesirable. As a practical matter, the average ear will probably tolerate up to about 5 per cent intermodulation distortion, a specification which is met or surpassed by most of today's high fidelity equipment. Under these conditions, harmonic distortion is usually far under this figure, being perhaps 1 or 2 per cent, an amount which is perfectly acceptable to all but the most exacting.

When two or more signal frequencies enter an amplifier simultaneously, they may not receive equal treatment by the system, and one of them may be delayed in passage slightly more than another. When various frequencies are displaced in time with respect to one another, the resulting effect is known as phase distortion, and is expressed in terms of electrical degrees of rotation. As an example, if one tone were caused to lag another by a quarter-cycle, the amount of phase delay would be 90°. Similarly, a half-cycle delay would be 180° and a full cycle would be 360°.

There is considerable disagreement concerning the importance of phase distortion, many authorities claiming that the ear simply cannot detect it. At any rate, we can usually regard it as inconsequential when the other forms of distortion are held to tolerance, and under these conditions a phase shift of 15° or less is not uncommon.

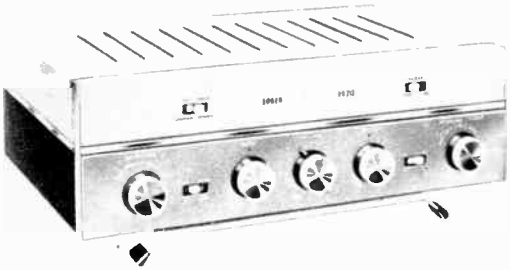
Another index of amplifier performance is the important matter of transient response. This is the reaction of the system to steep waveforms, that is, to attacks and releases. Whenever a musician tongues a mouthpiece, or depresses a key, or strikes a drum, there will be a brief instant between the initial impact and the point of maximum amplitude. Similarly, at the end of the tone there will be a decay period, which is usually less steep. The system which can react instantly to these sharp parts of the wave is said to have low transient distortion. This distortion is sometimes expressed in terms of the manner in which it alters the shape of a square wave passed through it, observed on an oscilloscope. But since transient response is an instantaneous phenomenon, the square wave test is at best an indirect measurement, and the only truly satisfactory indicator is your own ear.

When considering a given amplifier, then, listen carefully to its handling of program material containing many sharp attacks, staccato, pizzicato and sforzando passages. These should all be perfectly clean, without "hash" or "ringing." The loudspeaker is a far worse offender in this regard than the amplifier, for it is a mechanical device which has a very real moment of inertia. The amplifier can help alleviate this problem by the proper design of its output circuit, which will tend to act as a short circuit to transient distortions set up in the speaker.

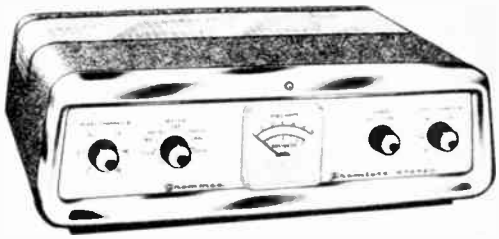
Any audio power amplifier is really a series of smaller amplifiers in cascade, and each of these sub-units is known as a stage of amplification. The number of stages in an amplifier simply indicates the number of amplifying processes the signal goes through between input and output. Each stage will most often comprise a single vacuum tube, although there may be two or more.

The means by which the signal is transferred from the output of one stage to the input of the next is known as the coupling. Audio amplifiers have been built which are transformer, impedance, resistance, and direct coupled, but only the latter two are in common use for amplifiers today. The transformer and impedance systems involve very large and expensive components for performance comparable to that of the other methods, and they are now generally regarded as obsolete.

Resistance coupling really involves a network of resistors and condensers between the plate circuit of the previous stage and the grid circuit of the following tube. The function of the coupling condenser is to pass the audio signal between stages while at the same time preventing the high DC plate voltage from getting to the grid of the next tube. But the reactance of the condenser to the audio signal is not



Bogen stereo control center and dual amplifier has 24 watts (two 12-watt channels). Price is $115, less cabinet. Controls include tape and phono equalization, two speaker phasing positions.



Grommes "Premiere" 40-watt stereo amplifier has 20 watts for each channel, 1 per cent harmonic distortion. The preamp part has 10 inputs, includes NARTB and RIAA selectors. Price is $159.50.

Fisher X-101 Stereo Master audio control and Duplex amplifier sells for $189.50. It has two separate 17-watt power amplifiers, twelve inputs. Each channel has 4, 8 and 16-ohm output terminals.

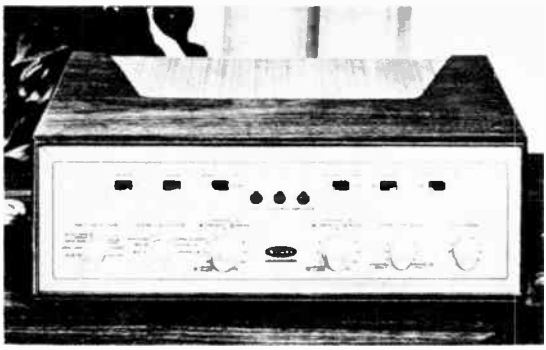
Lafayette stereo control center and amplifier has 14-watt power output on each channel, with a switch for stereo/monaural operation. It has dual tuner, cartridge and tape inputs; $72.50.

the same at all frequencies, and this unit may therefore be a source of frequency response and phase distortion.

The direct-coupled circuit is essentially resistance coupling without the condenser. In this system the high plate voltage on a given stage does apply to the grid of the next stage. The plate voltage of that following stage is then raised very much higher so that the proper relationship between grid and plate voltages within each stage is maintained. Obviously, a direct-coupled amplifier having very many stages will require an exceedingly high-voltage power supply. This amplifier is therefore more expensive to construct and difficult to adjust, but it does have inherently better frequency response, particularly at the low end, along with lower distortion.

A rather special type of coupling is the cathode follower, in which the output signal is taken from the tube at the cathode circuit rather than the plate. This unit is actually a loss device, that is, its output is less than its input. But it also has a very low internal impedance, which is very useful in some applications. It is sometimes used to couple the amplifier output to the loudspeaker, where it provides an exceptionally high damping factor.

When more than one tube is used in a single amplifier stage, the connection of the tubes is usually in push-pull. In this arrangement the signal is fed simultaneously into both tubes, in such a phase relationship that a positive peak at the output of one tube coincides with a negative peak at the output of the other. Thus the operation of this circuit is somewhat analogous to alternating fire in a two-cylinder gasoline engine. This system has inherently



Scott 299 stereo amplifier consists of dual 20-watt power amplifiers and dual preamps on one chassis. It has stereo balance control, phono and tape equalization switches. Price: $139.95.

Stromberg-Carlson AR-432 stereo control amp has 30-watt power output, speaker selector, low and high frequency equalization, rumble filter. Response is ± .9 db, 20-20,000 cps full output; $119.95.

less hum and harmonic distortion, and permits the use of smaller and less costly output transformers. All good amplifiers have a push-pull final stage, and many are push-pull throughout.

The proper phase relationships at the input of a push-pull stage may be established by a center-tapped transformer, but the more common device is the phase inverter stage. This is simply a means of using resistance coupling to connect the output of a single-ended amplifier tube to the input of a push-pull stage. Phase inversion has the advantages common to any resistance coupling, namely better frequency response and the elimination of expensive transformers.

Audio amplifiers have been designed which are allocated variously into classes as A, AB and B. The class of operation of an amplifying tube depends upon its operating voltages, which in turn determine the method of use of the tube's characteristic curve. Class A is the method in which tube plate current flows at all times and the tube operates only over the linear portion of the curve. The other systems offer greater efficiency, but the tube operates in a nonlinear fashion, that is, the output is not precisely proportional to the input. This means distortion, which would later have to be cancelled out by some form of trick circuitry. Thus a truly high fidelity amplifier always operates with a Class A system throughout.

In some audio amplifiers, a portion of the output of the system is returned to the input. The signal which is fed back is out of phase with the incoming signal and therefore reduces it. This action is known as degeneration, and the system is called negative, or inverse, feedback. It results in some loss of signal, of course, but it also causes a much greater reduction in noise and distortion. Thus inverse feedback is desirable in limited amounts, although excessive degeneration will result in instability on peaks and high distortion on overloads.

There are two basic types of vacuum tubes used as audio frequency amplifiers. One is the three-element tube known as a triode, and the other is a five-electrode device called the pentode. A third type, known as the beam power tube, operates on the same principle as the pentode, with a somewhat different form of construction.

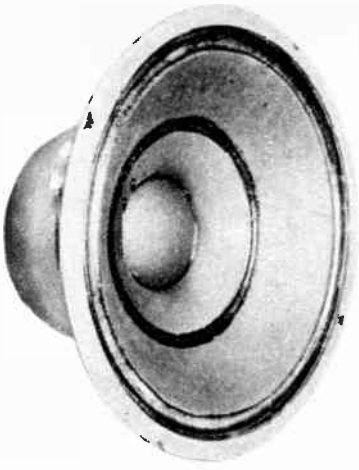
Much heated discussion has revolved around the relative merits of these two tube types for audio applications, and no agreement is yet in sight. Classic theory tells us that the triode has less innate distortion, although the pentode exhibits greater efficiency. But many engineers argue that proper circuit design will enable the pentode to equal the triode in quality, and they can prove it with any sort of distortion measurement. The triode school retorts that there must still be some forms of distortion which we have not yet indexed and catalogued, because a good triode amplifier sounds unmistakably cleaner to the ear than the best pentode rig.

You take it from there. A triode amplifier will cost more than a pentode unit of the same power output, because more stages will be necessary to achieve the same gain. If you can hear a difference, and if your budget can stand it, get an all-triode amplifier. If you can find a pentode circuit which sounds fine to you, then take it by all means. •

Stromberg-Carlson 15-inch coaxial transducer with induction tweeter, RF-484, $149.95. Range is 15-20,000 cps. Woofer part handles 100 watts, tweeter takes over 50 watts of program material.

The Loudspeaker System

James B. Lansing bass reflex enclosure is the Harlan. It includes four 12-inch speakers.



Altec-Lansing viscous-damped apex decoupler, Model 412B, has frequency range of 40-15,000 cps. It is a single voice-coil speaker, handles the above frequencies if placed in a proper baffle cabinet.

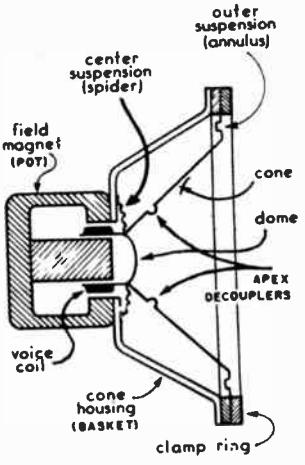


FIG. 1. Above drawing shows the cross-section of a simple direct radiator loudspeaker with the apex decouplers developed by Altec. The crossover function is mechanical, phasing is automatic.

THE loudspeaker is the final transducer in the hi-fi system. This is the place where the electric currents, generated by the input transducer and amplified and controlled by succeeding equipment, finally must be reconverted to sound. This is the end of the line. If the sound isn't good when it leaves the speaker, nothing can save it. The job is done.

The demands made upon the speaker are substantial. Here is a device, seldom more than sixteen inches across, which must be able to simulate with great accuracy, the great sounds of a symphony orchestra or an onrushing train, or the delicate sounds of a celeste or the song of a whippoorwill. It must be able to recreate the entire range of audible sound, and to fool our ears into telling our brains that they are hearing the real thing.

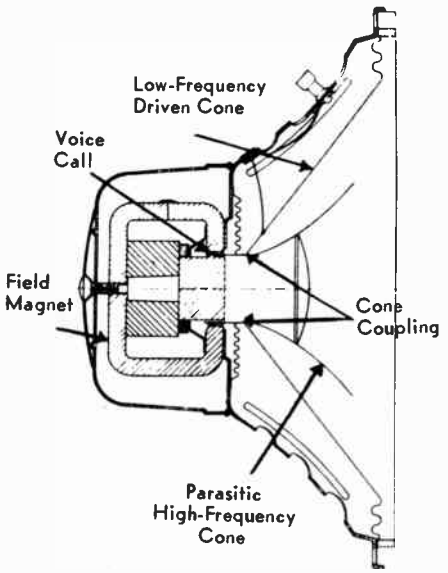
The fact of the matter is that *no* loudspeaker can meet such stringent demands. But a complete *system*, comprising a group of two or more speakers, an appropriate set of controls, and a well-designed enclosure, can do the job quite satisfactorily.

The speaker most prevalent in hi-fi is the moving-conductor or *dynamic* type. The basic speaker has two magnetic fields. One of these is of constant value and fixed in position. The other varies with the audio currents fed into it and is free to move within a limited area.

The fixed field is produced by a large mug-shaped magnet at the rear of the unit, as shown in Fig. 1. This may be an electromagnet, but since such an arrangement also requires a source of smooth direct current to energize it, the field magnet is usually of the permanent type, requiring no external excitation.

The size and weight of the magnet is some indication of the speaker quality, as more powerful fields help to damp out distortion, increase efficiency and extend frequency response. This is not the whole story, however, as the magnet material must also be considered. Most loudspeaker field magnets are made of *Alnico*, an alloy of aluminum, nickel and cobalt, but there are many grades of this material. The one generally used in quality speakers today is Alnico V or the Gold Dot type.

Within the gap of the field magnet is a small coil of wire or



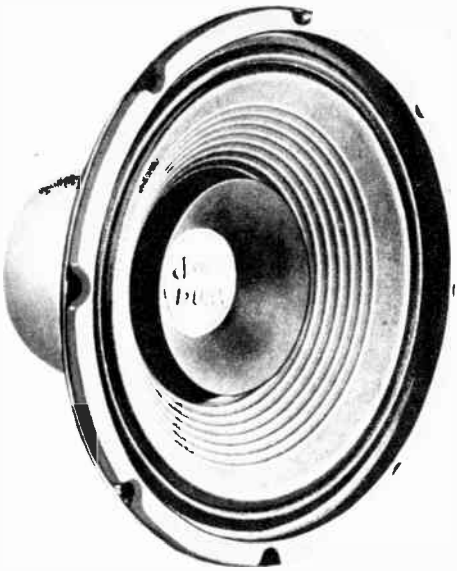


FIG. 2, above left, is cross-section of a 2-way single-element speaker. Above right, Jensen Duax 2-element loudspeaker, 12-inch, $25.50; power rating: 20 watts. Single voice coil drives two radiators.

metallic ribbon, called the voice coil. This little coil is the electrical terminus of all that has gone before in the hi-fi system. No other part of the speaker carries current. Everything else is mechanical.

When the powerful audio currents from the amplifier course through the coil, an alternating magnetic field is set up around it, which at one instant is attracted to the fixed field magnet and at another instant is repelled by it. Since the coil is free to move, it will oscillate back and forth in a manner dictated by the audio current flowing through it. The combination of the field magnet and the voice coil is called the loudspeaker *driving motor*.

The unit which is driven by this motor, and which actually generated the sound, is known as the *acoustic radiator*. In many speakers this is the *cone*, made of paper having both wood pulp and cloth fiber components. With a supporting framework and suspensions for the cone, this is the basic speaker to be found in ordinary radios, TV sets and home phonographs.

Even the simplest of the hi-fi speakers has several refinements, however, which are shown in Fig. 1. Because the high frequencies are produced only in the area near the apex of the cone, there is often a decoupling ridge molded into the cone to permit the apex to vibrate independently of the overall motion of the cone.

Often the actual consistency of the cone changes at this point, with the apex having a harder surface than the outer region. Finally a dome is placed over the center of the apex area, which serves to disperse the high frequencies over a broader area.

A speaker of this sort is the fundamental extended-range hi-fi unit, but experience has shown that such single speakers cannot adequately reproduce the entire audible range. Only two or more speakers, each one specifically designed to reproduce a part of the spectrum, can do the job well. The first 2-way systems were designed for motion-picture theaters, where the low-frequency speaker was called a "woofer" and the high-frequency element was named a "tweeter." These terms haven't as much meaning now, however, as 3- and 4-way systems have been introduced.

The speakers may be entirely independent of one another, or they may be constructed coaxially. Since there is a great deal of confusion among audiophiles concerning the seemingly endless variety and conflicting claims concerning coaxial speakers, these deserve careful attention.

Moving up one step from the basic extended-range unit of Fig 1, we encounter the 2-element speakers typified by the drawing of Fig. 2. Note that this unit has two cones, coaxially mounted, one for bass and one for treble. But note also that the speaker has only *one* motor to drive both cones. There is a direct mechanical coupling between the large cone and the smaller one inside it. The inner cone is in effect

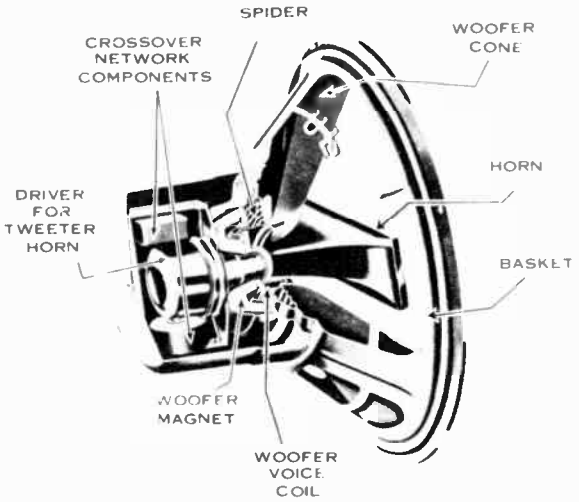
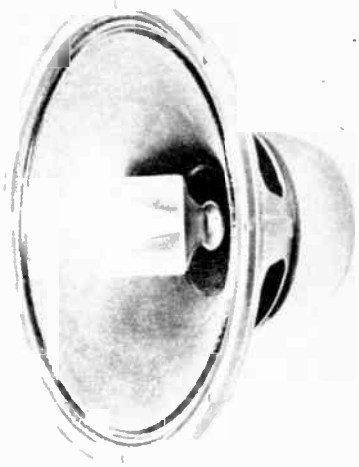


FIG. 3. Cut-away view of University dual range coaxial 12-inch speaker. Tweeter is coaxially mounted through woofer, uses a compression driver and wide angle horn with reciprocating flare.



Altec-Lansing 602B Duplex coaxial features a 3,000-cycle high-frequency driver coupled to an exponential sectoral horn. Range is 30-22,000 cps.

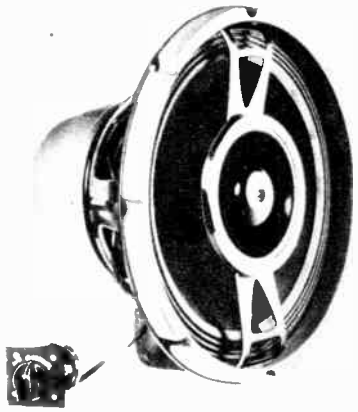
getting a free ride along with the motion of the outer one. This is *not* a true 2-way speaker, nor do conscientious manufacturers make any such claim.

A speaker of this type is sometimes said to have a "mechanical crossover." This means that while the voice coil vibrates at all frequencies, each cone will vibrate only in the range for which it was designed. This separation is determined solely by the physical size and shape of the two cones.

A true 2-way speaker system operates quite a bit differently, however. The splitting of the frequencies is done *electrically*, before the signals ever reach the voice coils. There is a separate driving motor for bass and treble, each of which receives only those signals which it is expected to convert to sound.

A good example of the true 2-way coaxial speaker is shown in Fig. 3. The woofer magnet and voice coil are completely independent of the tweeter driver, which is mounted to the rear. The coil and condenser which comprise the crossover network are mounted within the speaker structure in this case, although they could be located at any convenient point between the output transformer and speaker.

The next little step up in speaker quality is shown in Fig. 4. This speaker is essentially the same type as that of Fig. 2, with the addition of an independent high-frequency unit. This has a driven unit for the bass, a parasitic unit for the mid-range,



Above, Jensen H-223F coaxial 12-inch speaker with reflexed compression driver tweeter. Below, Vitavox duplex coaxial has 12-inch bass cone, 3-inch hf tweeter; 30-15,000 cps, 30 w, 15 ohm.

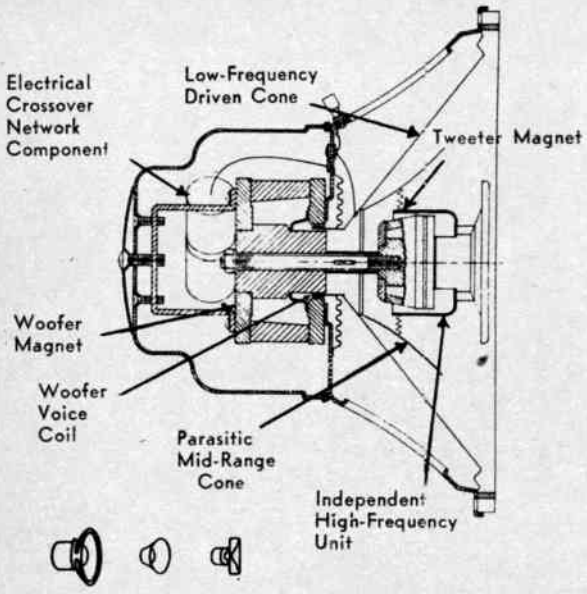


FIG. 4. Jensen 3-way coaxial, two driving units

Electro-Voice 12TRXB 12-inch triaxial speaker. $64. Response is 35-15,000 cps. 20-watt capacity. Sensitivity is 46 db.

and a separate driven unit for the highs. Thus it has three radiating elements, but only two motors, as shown in the inset of Fig. 4. It is therefore not properly known as a true 3-way system.

There is in fact only one manufacturer who makes a true 3-way coaxial loudspeaker. It is shown in cross-section in Fig. 5. This unit actually comprises three independent loudspeakers, each acoustically and electrically distinct from the others.

These are the five basic hi-fi loudspeaker types. When shopping for a speaker on the basis of performance and price, be sure you are comparing models within the same quality class. Frequent attempts are made to convince the unwary that a class 2 speaker is actually in class 3. Even greater attempts are made to have class 4 speakers pass for class 5. But you can easily establish the truth of the matter by keeping in mind these sectional drawings and photos. When you know what you're looking for, a visual inspection will quickly tell the story. When using separate speakers, of course, as in Fig. 6, then there can be no question.

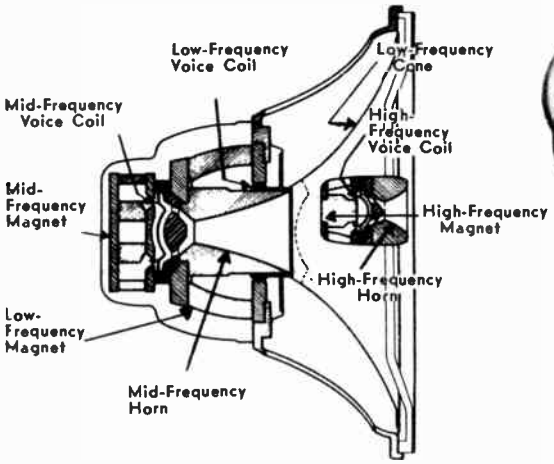
Closer inspection of these drawings indicates that the tweeter units don't quite fit the description given for the cone type speaker. This doesn't necessarily have to be so, as it is quite possible to construct a cone tweeter, and in fact this type high-frequency speaker in the 3-inch size is fairly common. Such a unit has a rather sharp beam, however, with the result that the reproduction at any distance off the center line of the speaker is rather deficient in highs.

This condition may be partially rectified by using two or more tweeters arrayed around in an arc, but it is often more desirable to use a *horn* at these frequencies. The differences between a horn and a cone loudspeaker will be evident from a comparison of Fig. 7 with Fig. 1.

The motor in the horn is the same, but the acoustic radiator is a small diaphragm instead of a cone. This in turn is surrounded by a chamber, with an opening for the throat of the horn. Broader high-frequency coverage and much greater efficiency are possible with the horn. But if this be so, why are horns not always used, to the exclusion of other types?

There is much to be said for that viewpoint, and some purists do actually use horns for all audible frequencies. It's not possible for most of us, unfortunately, due to lack of space. For a low-frequency horn must be huge.

The horn is effectively a low-pass filter. While it has practically limitless high-frequency response, it cuts off rather abruptly below a certain point determined by its geometry. For a horn to go down to 30 c.p.s., it would need a mouth diameter of over eleven feet, and would have to be even longer than that.



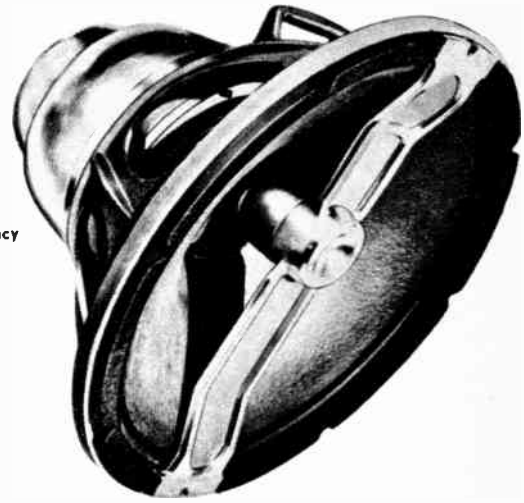


FIG. 5. Cut-away drawing of a Jensen 3-element coaxial loudspeaker shows separate hf magnet. Above is photo of the Jensen G-610 triaxial as shown in drawing, left. It needs dividing network.

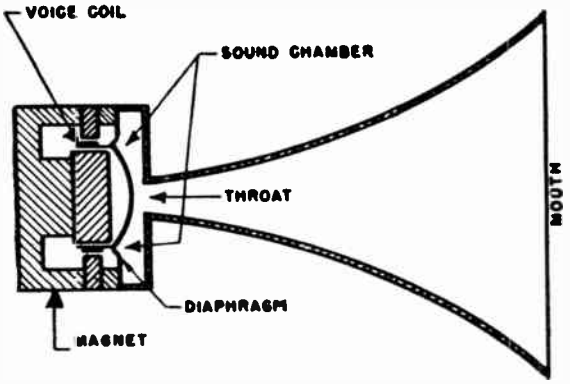


FIG. 7. Jensen basic horn and driver unit.

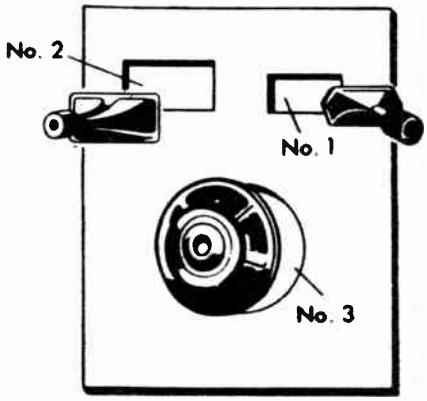


FIG. 6. University 3-way speaker system.

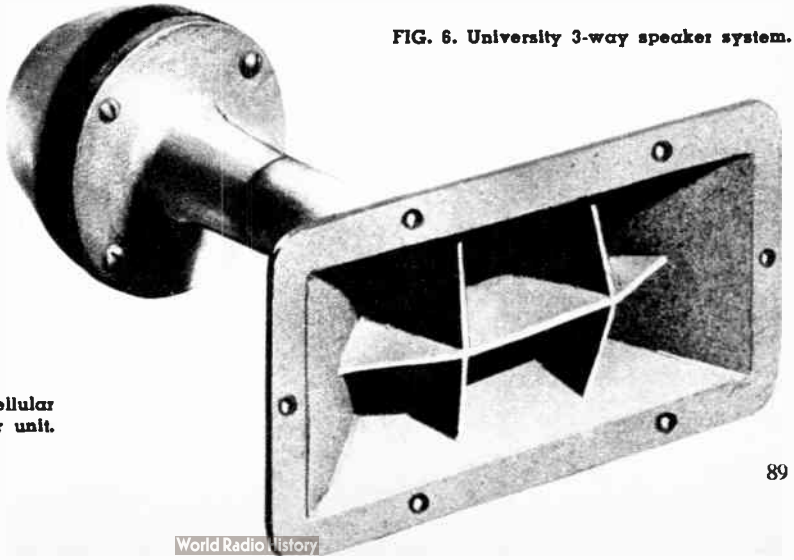


FIG. 8. Jensen multicellular high-frequency tweeter unit.

Stromberg-Carlson RT-477 induction tweeter has frequency range of 800-20,000 cps, 50-watt power capacity; $49.95.

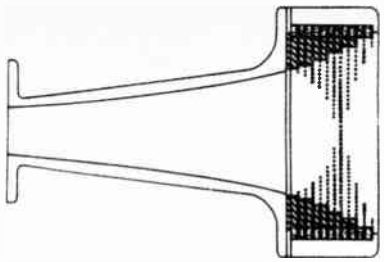
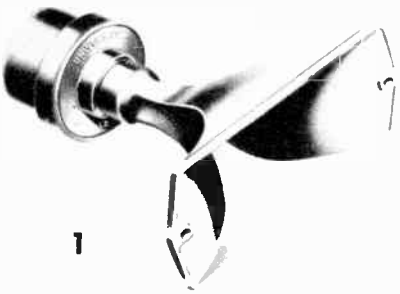


FIG. 9, above, shows cut-away drawing of the James B. Lansing acoustic lens assembly. At right, photo of same unit. It is a round exponential horn to be used with separate driver. Horn length is 12 inches; throat diameter, 2 inches; 70° dispersion. Price: $87.



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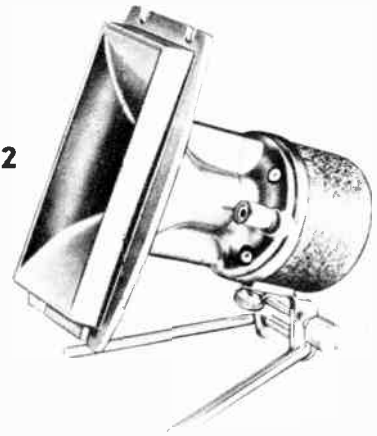

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1. University UL/HC hypersonic tweeter is used in conjunction with a woofer; unit is reciprocating flare horn. 2. Lafayette 20-watt tweeter has 1,500-16,000 cps response, sells for $8.95. 3. Stentorian super tweeter T-12, 15-watt power rating, 16,000 gauss; it has a 3,000-20,000 cps response.

In practical hi-fi systems the woofer is generally a cone type, the tweeter a horn, and the mid-range speaker(s) may be either one. There does seem to be a trend toward horns for all except the deepest bass, however, largely due to their better efficiency.

Although the round horn affords better high-frequency dispersion than does the cone, it nevertheless tends to beam sound energy over a relatively small listening angle. Additional steps are therefore usually taken to obtain less beaming of the highs.

One approach is the multicellular horn, shown in Fig. 8. This is essentially a cluster of square-mouthed horns, radiating separately but driven by a common motor. Since the horns are stacked in an array which is several times wider than it is high, there are more horns to throw sound into the horizontal direction than the vertical. This is the most useful dispersion for home hi-fi listening.

Another answer to high-frequency beaming is the acoustic lens, which can spread sound energy just as an optical lens spreads a light beam. The principle is illustrated in Fig. 9. The wave as it travels from the diaphragm through the horn is

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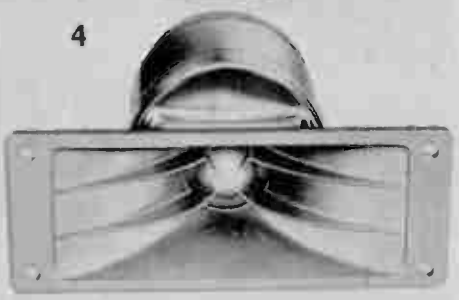

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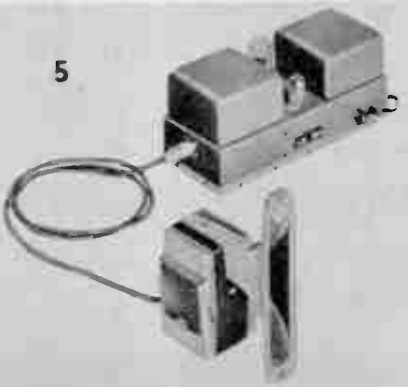


Above, University stereo-matched speaker system measures 25"x14"x14½", has 12-in. woofer and a tweeter. Right, 4, Electro-Voice tweeter with patented Avedon Sonophase throat design, said to eliminate hf sound breakup. 5, Electro-Voice Ionovac VHF driver unit wherein the action of the speaker diaphragm is replaced with a "cloud" of ionized air. It reaches the highest frequencies.

essentially a plane, or flat. But as it reaches the labyrinth of obstacles at the mouth of the horn, it is slowed down more around the edge of the horn, where the series of perforated screens is most dense. Conversely, the sound in the open area at the center travels. Thus the plane wavefront which enters the lens emerges in spherical form, with consequent scattering.

A very common high-frequency horn, because it is simple and cheap to build, is the diffraction type. An example of such a unit is shown in photo. In this case the mouth of the horn is regarded as a narrow slit, several times higher than it is wide.

Quite the opposite of the multicell horn, the diffraction horn radiates mostly outward from the long sides of the slit.

The reciprocating-flare horn shown in photo looks much the same, but it doesn't act that way. Note that around two-thirds distance out from the throat there seems to be a hump in the walls of the horn. Up to this point the shape looks very much like the beginning flare of a diffraction horn, with most of the expansion in the vertical direction. But beyond this point the directions change and most of the further expansion is in the horizontal direction. The result of this fancy curving is a dispersion which is exceedingly wide in the horizontal direction and quite narrow in the vertical direction.

When a loudspeaker cone or diaphragm vibrates in air, it sets up two sets of opposing sound waves simultaneously, one from its front surface and another from the rear. If these two waves combine, they can either add together and sound boomy, or try to cancel each other out, with the resulting sound being weak and thin. As a third alternative, they can combine additively to compensate for an inherent deficiency. One of the most important functions of the speaker enclosure is to determine whether these waves combine at all, and if they do, to control the conditions.

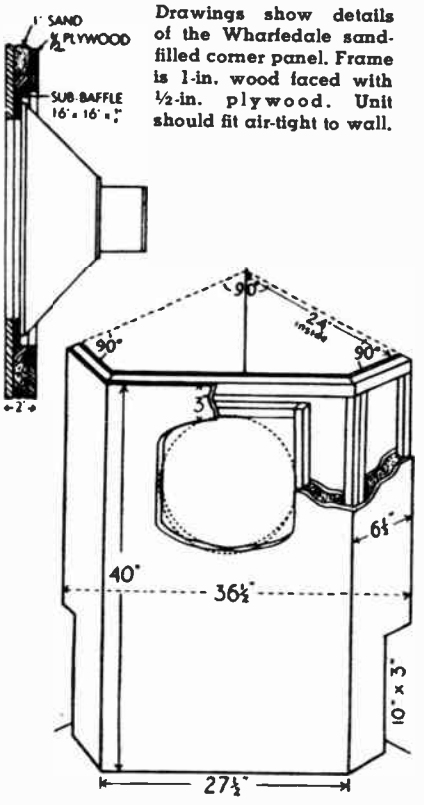
Of all the wide variety of enclosures designed to do this job, each will fall into one of these categories:

1. The *direct radiator,* in which the backwave is never permitted to join the forward wave

2. The *resonator,* in which the backwave joins the forward wave under controlled conditions

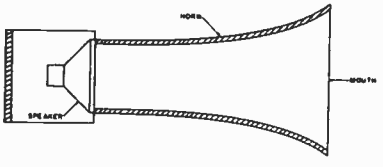
3. The *horn,* which is a direct radiator with the addition of a flared opening at the front, presenting a partially-enclosed volume of air for the cone or diaphragm to push against.

The direct radiator mounting is often called a baffle, and in its simplest form is just a plane surface with a hole in it, through which the speaker is mounted. The backwave cannot join the forward

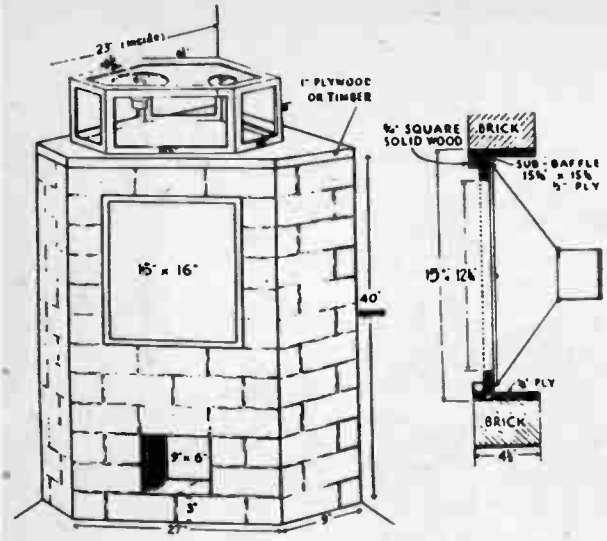


Drawings show details of the Wharfedale sand-filled corner panel. Frame is 1-in. wood faced with ½-in. plywood. Unit should fit air-tight to wall.

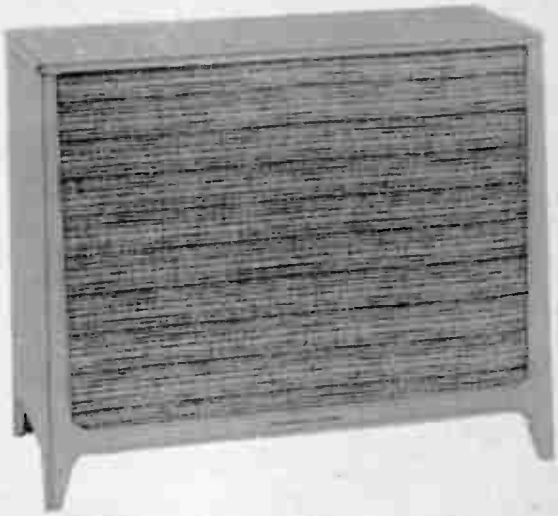
Jensen Dual Stereo Reproducer contains two separate 3-way systems with 12-inch Flexair woofers.



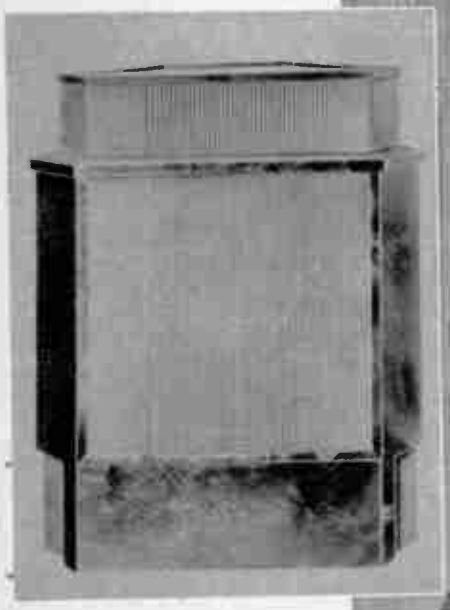
The directional baffle of the exponential horn is ingeniously folded in the Klipschorn cabinet.



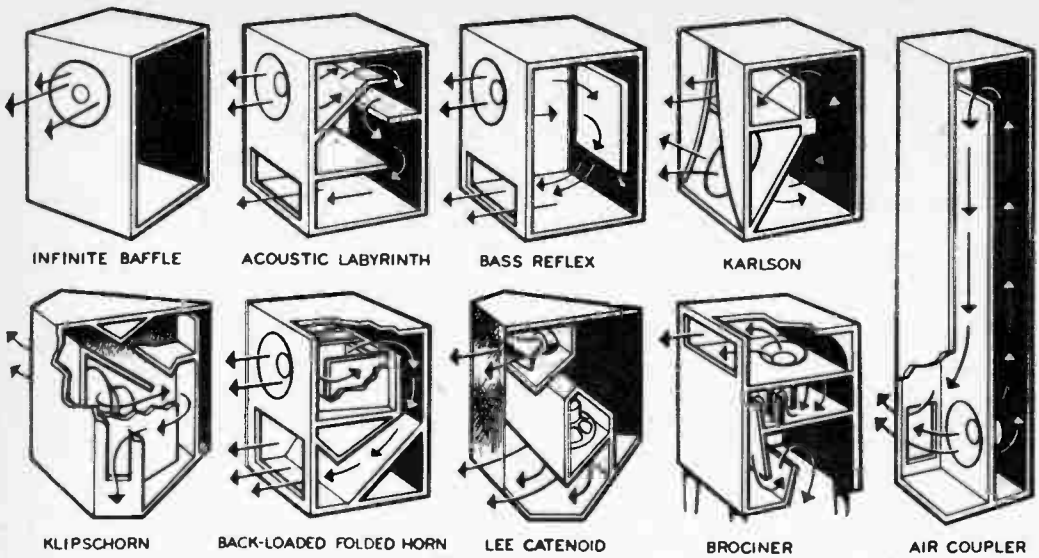
Wharfedale design for two-speaker system brick reflex enclosure has 9 cu. ft. reflex loading, is easily built when redecorating your house.



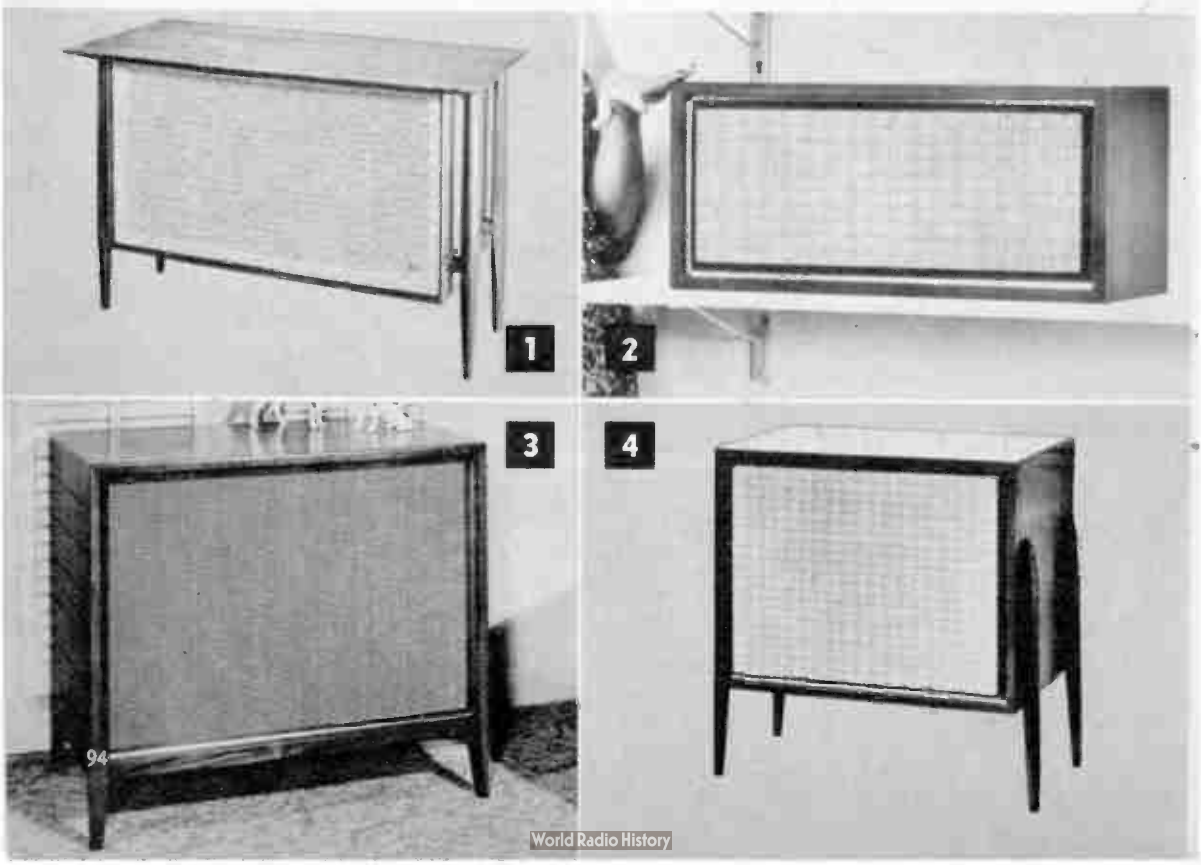
Stromberg-Carlson RH-416 cabinet with built-in "quarter wave length" can be used with 15-inch coaxial speaker or woofer, mid-range and tweeter.



Above, Briggs 3-way corner enclosure has Wharfedale 15-inch woofer, mid-range and tweeter units. Right, James B. Lansing horn-loaded cabinet can be adapted for 12- or 15-inch loudspeakers.



Drawings above show the sound paths of the most popular speaker systems. Below, 1, Altec-Lansing Capistrano system features 15-inch woofer, dividing network and driver with hf horn; range is 35-22,000 cps; price: $426. 2, Electro-Voice Wolverine enclosure for 8-inch speakers and separate 2-way speaker systems; enclosure only: $29-$34.50. 3, Jensen TP-250 Tri-Plex II 3-way speaker system sells for $294.50. It has a frequency response range from 16 cycles per second to inaudibility. 4. The Electro-Voice Lancaster enclosure is designed for 12-inch speakers and separate 2 and 3-speaker systems; it sells for $48.



wave until it travels out to the end of the baffle and thence into the speaker area. To prevent the backwave from ever catching up with the forward wave, the baffle would have to be infinitely large, hence an *infinite baffle*.

A reasonable approximation of an infinite baffle is the wall of a room, where the front of the speaker feeds sound into the listening room while the backwave escapes into the adjacent room. By this same reasoning, if the system were reduced in scope, the next room could become a closet, with the speaker installed in a wall or the door. Carrying the miniaturization even further, the infinite baffle becomes just a completely enclosed small box. But when it gets down to these dimensions, the system tends to have a strong peak in its bass response, with a quite sharp cutoff below that peak.

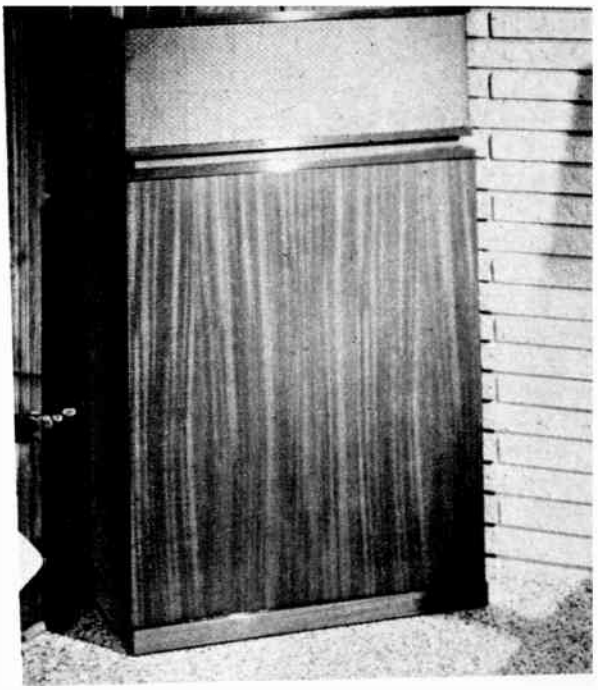
The basic principle of all of the resonator types is phase inversion, which means that the backwave is shifted in such a manner that when it joins the forward wave, it adds to it and reinforces it. Since adequate bass is always the greatest problem in speaker systems, the treble end of the spectrum is normally absorbed by padding within the enclosure, so that the part of the backwave emerging from the front is in effect a bass boost.

An example of the resonant phase inverter is the *acoustic labyrinth*, which has a "mystic maze" pathway for the backwave to follow before it reaches the front. Performance of this enclosure is excellent, but its complex construction and higher cost have limited its popularity.

The most popular enclosure by far continues to be the bass reflex. This is just a padded box with two holes in it, one for the speaker and another for a vent or port, to allow emission of the backwave.

Whether buying or building a bass reflex enclosure, however, it is important that the cabinet be specifically designed for the speaker to be used with it. The size and shape of the box, the size and location of the port, and the resonant frequency of the loudspeaker, must all be properly integrated for optimum performance. This fact doesn't pose any serious problem, of course. But it does mean that you should accept the speaker manufacturer's recommendations when considering a specific enclosure. He will gladly advise you what to buy or how to build a bass reflex designed to get the most out of your speaker.

As we've noted, the true horn loudspeaker employs a small diaphragm driver which sets air into motion in the narrow neck of a straight flaring trumpet. And we have also seen that the size of such an instrument for good bass response makes it almost prohibitive for home use.



Klipschorn enclosure pictured above uses three speakers with its exponential horn principle.

A cone-type driver may also be used with a horn, as shown in photo, in which case the enclosure is really a directional baffle. For best performance the flare of the horn should follow a mathematical formula, but this again brings us face to face with the space problem. Because of it, the horn enclosure usually found in home hi-fi systems is a compromise design known as a *folded horn*.

To increase the effective mouth area to something approaching theoretical requirements, the folded horn is usually designed for installation in a corner of a room. The walls thus act as extensions of the sides of the horn, and the listener is in effect seated *inside* the horn. Since most of the highs would be lost in traversing the intricate bends in the enclosure, folded horns are normally bass radiators only.

An exception to this may be the back-loaded folded horn, wherein the cone radiates a forward wave directly, while the backwave escapes through the folded horn. Operation of this instrument is thus more nearly akin to that of the resonator.

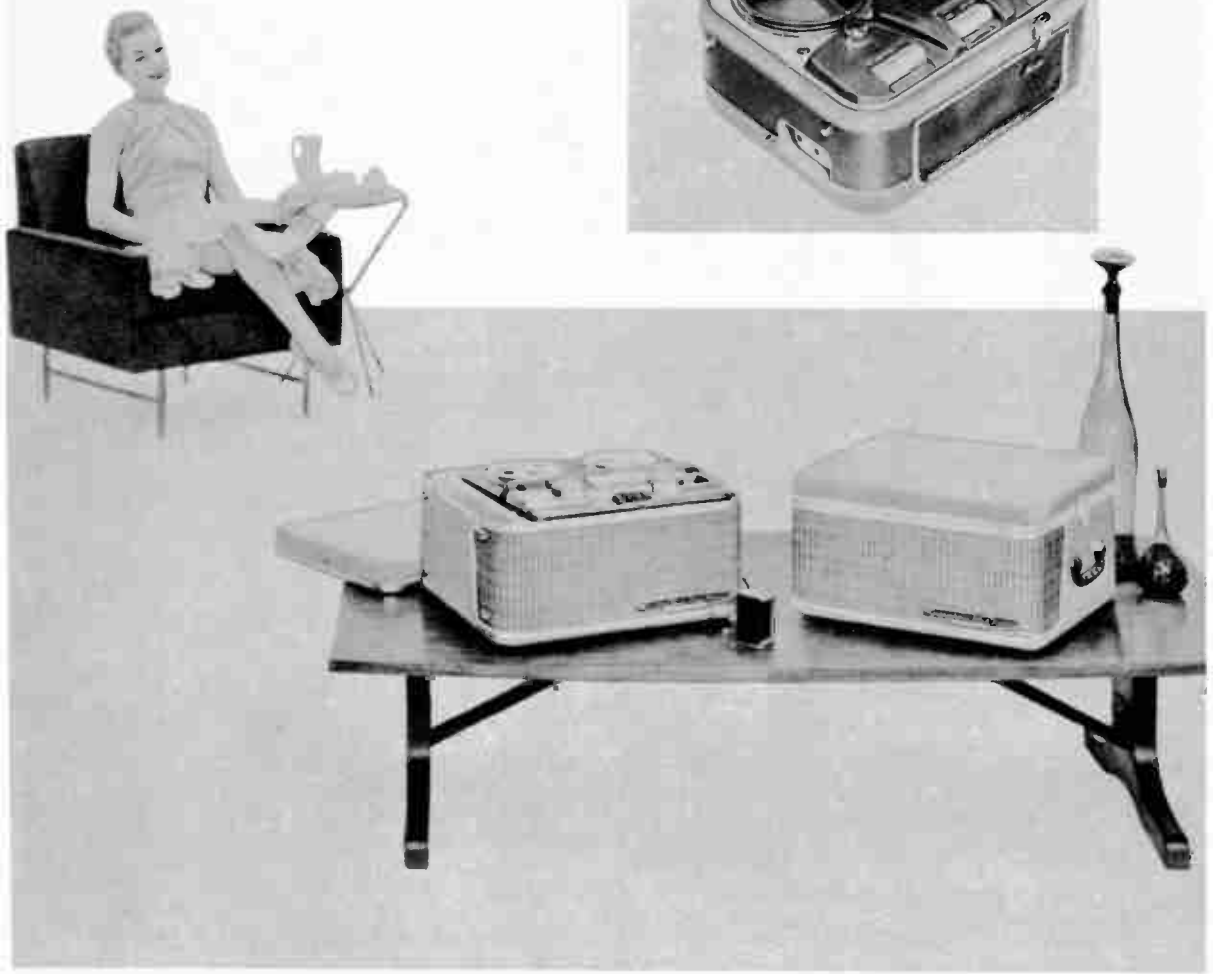
These then are the basic types of speakers and enclosures. Your own ears still must make the final decision on the system for you, but now you can be more certain just what is producing the sound you're hearing. •

Tape Recording

To fully realize the pleasures of your hi-fi system plan on installing a good quality tape recorder.

Norelco stereo tape recorder has 7½, 3¾ and 1⅞ ips tape speed, 40-16,000 cps response at 7½ ips, incorporates 5-inch speaker. Price of recorder, $299.50. Extra amp and speaker, $95.

RCA Victor Stereotape player transport and right channel speaker system are shown below. Each unit has three separate speakers. Tape speed: 7½ and 3¾ ips. Playback heads are arranged in-line.



SINCE tape recording and high fidelity are both comparatively young arts, there hasn't yet been time to integrate the two types of equipment completely. With a few simple materials and a few new connections, however, any audiophile can do it himself. Many tape decks are now designed primarily as hi-fi components. These are fairly easy to install, as we shall see, but a more difficult problem is that of working into an existing hi-fi system a tape recorder of the common everyday type. But such integration is essential, if the tape recorder is to deliver the maximum performance of which it is capable.

The ordinary unitized recorder is a quite simple device, designed to record sound using a small crystal (or ceramic) microphone, and to reproduce tapes made by this or other means. It includes a transport mechanism, all the electronic devices necessary for recording and reproduction, plus a loudspeaker. This arrangement is less than the best for hi-fi, for several reasons.

It doesn't provide for recording from other sources, such as radio, TV, records or other tape. Neither does it permit playing the tape through a good hi-fi amplifier and speaker system. The greatest weakness of such a recorder, in fact, is its puny audio amplifier and tiny speaker. Furthermore, a hi-fi speaker should never be in the same case as the amplifier, as we've already shown.

But this same tape recorder, on the other hand, has all of the elements necessary for hi-fi recording and playback. It has the transport mechanism, the heads, the recording amplifier, the bias oscillator and playback preamplifier. And it will be quite a simple task for you to utilize only those elements in your hi-fi system, while eliminating the others.

There are two problems to be solved: getting signals from the hi-fi system into the recorder at a suitable level to be handled by the recording amplifier, and getting signals from the recorder playback into the hi-fi system at a suitable level to be handled by the power amplifier. To understand this better, let's take a closer look at the electronic elements of a typical recorder.

The block diagram of Fig. 1 shows the basic functions performed by these elements. Very often some of these blocks do double duty. Both recording and playback are often performed by a single head and preamp-control-amplifier chain, for example, and the bias and

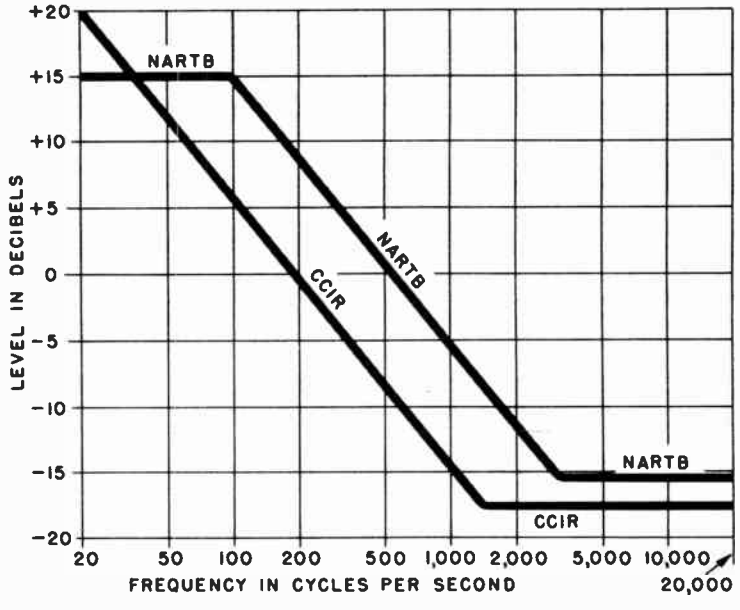
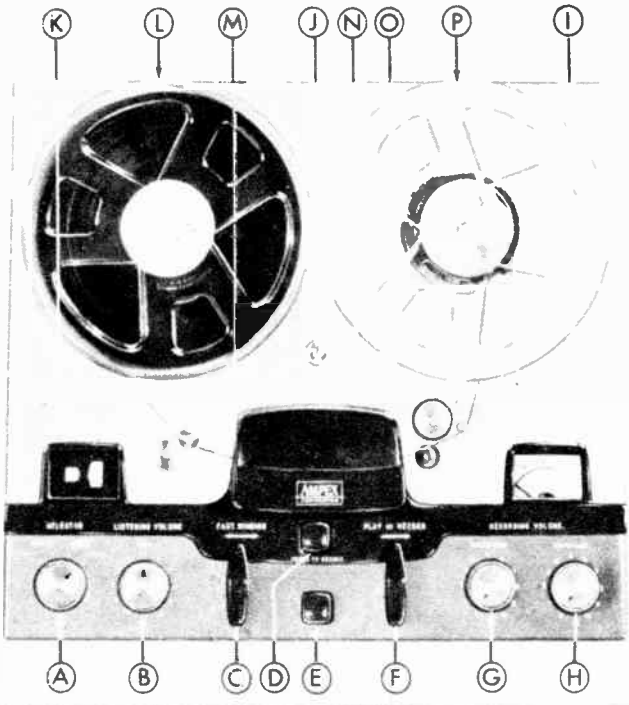
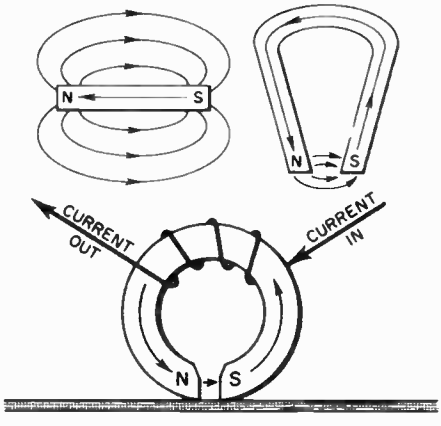
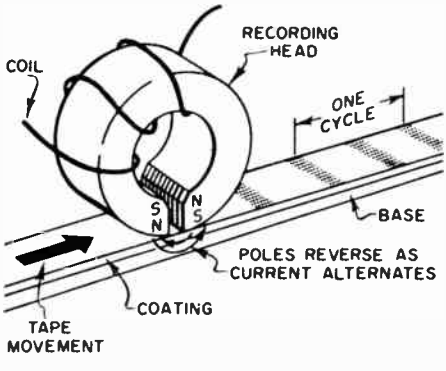


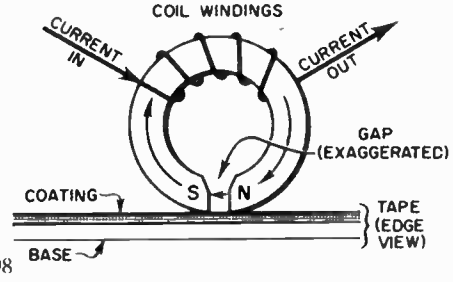
Chart at right shows the differences in equalization used in the American (NARTB) and British (CCIR) recordings.



Ampex home recorder, portable model, is shown in the photo above. The unit's main controls, which differ to some degree, are called out. (K) is a tape position indicator that allows you to make quick return to any point on a recorded tape; (G) a volume level control is for recording from radio, disc, another tape recorder, or television sound; (J) tape speed selector.







Magnetic polarity is determined by direction of current through exciting coils. Audio current changes polarity of recording head as flow reverses. Varying force-field induces magnetism on tape's coating—a cycle per peak of like polarity.

erase oscillators are often one and the same. But it doesn't matter what specific arrangement is used on your recorder. The discussion which follows will apply in nearly all cases.

We can see from Fig. 1 that, whether the amplifier chains are separate or double-duty, they have certain things in common. In each case there is a low-level amplifier (preamp) and a high-level amplifier (power amp), with a volume control between them. The volume control is thus a sort of gate or valve which determines how much of the signal from the preamplifier is fed to the power amplifier.

Now the signal level at the volume control is a "comfortable" one, perhaps on the order of a volt or so. This level could be carried over some distance by cable if necessary, without danger of the signal being so high as to cause cross-talk, or so low as to be susceptible to induced noise. Obviously then, the volume control would be a useful point to connect signals both to and from the hi-fi system.

For hi-fi recording, we want to introduce a signal into the recording amplifier from the hi-fi system instead of the microphone preamplifier. And for reproduction we want to send a signal from the playback preamp into the hi-fi power amplifier instead of to the tape amplifier and speaker.

This means that in addition to connection at the proper point, we also need a means of selective switching, unless the recorder is to be permanently connected into the hi-fi system. For maximum flexibility, the recording amplifier should be able to receive signals either from the hi-fi system or its own preamp. And the playback preamp should be able to feed either the hi-fi power amp and speaker, or its own internal audio system.

Tape recorders which are designed for integration into a hi-fi system will accomplish the connections through a conventional phono jack and patch cord arrangement, while the selection is handled through a function switch. The method we'll describe here does both the connecting and selection through the jack itself. It eliminates the complex wiring of a selector switch, and is nearly as convenient in operation.

To make the installation, it will first be necessary to remove the electronic elements of the recorder from the case. In some cases the electronic chassis is attached directly to the mechanical chassis. In others, the two chassis are separate, and plug-in cables connect the electronic elements to the heads.

If it is necessary to remove the transport mechanism, be sure to have blocks ready to support the four corners of the chassis, so that its weight need not rest on the motors, spindles or other fitted parts. Make sure that all mountings have been freed. Be especially careful of wires or cables which have been stapled to the wooden case. When all mounting fixtures are free, the unit should remove easily. Don't attempt to use force.

With the electronic unit removed and in a well-lighted place, the next step is to locate the volume control and identify its terminals. You will note three terminals fanning out in an arc around the edge of the control. One of these terminals will be seen to be connected to the metal chassis. It may go first to a terminal strip or to a tube-socket terminal used as a tie point, but in any case it will be possible to trace a wire connection from one volume control terminal to chassis ground. We'll call this terminal 3, and it should be so marked with pencil on the back of the control.

The center terminal will be connected directly to a tube socket. This we'll identify as point 2. The remaining terminal will connect to a condenser, which in turn goes to another tube socket terminal. This we'll call terminal 1.

If there is a second pair of terminals behind the three, these are for the on-off switch. On tape recorders this switch is very often coupled with the tone control instead. In any case it is of no concern to us, nor is volume control terminal 2. Our work will have to do only with the two outer terminals, Nos. 1 and 3.

For each function (record or playback), the following materials will be required:

1—Single-closed-circuit (SCC) 2-conductor phone jack

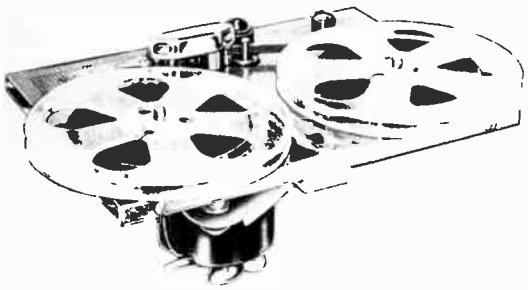
1—Two conductor phone plug to fit jack

1—Length insulated hookup wire

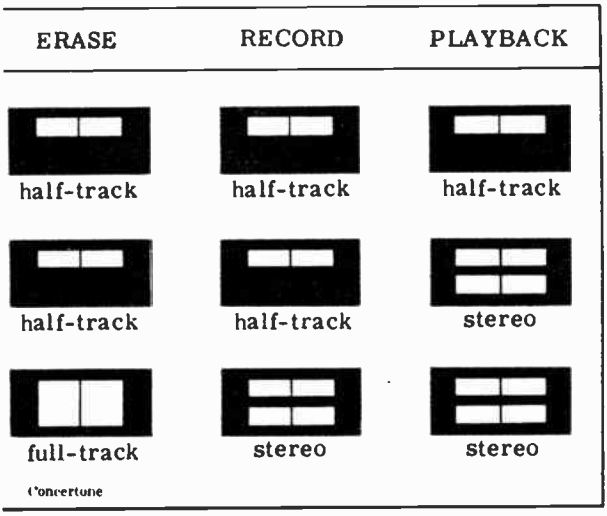
1—Length insulated phono cable, sufficient to reach from recorder to hi-fi amplifier.

The jack is mounted at any convenient point on the case, chassis or escutcheon plate, where it will be accessible from the outside. The most convenient place, as far as wiring is concerned, is right next to the volume control. It is essential, however, that it not interfere with any of the existing wiring on the rear of the plate, nor with the operation of any of the controls on the front. Check this carefully before you start drilling.

First let's consider the case of recording only from the hi-fi system. This is illustrated schematically in Fig. 2(A). If the recorder has separate recording and play-



A tape deck such as this Viking may be installed in your present hi-fi system; it eliminates duplication of electronics.



Some of the head arrangements possible in tape recorders. For optimum quality there must be separate heads for erase, record and reproduce.

back level controls, it will be the *recording* volume control to which the connections will be made. If the recorder uses the double-duty system, then the one single volume control common to both functions will be used.

Now as a last step before making the new connections, let's identify the three terminals on the jack, referring again to Fig. 2(A). One of the terminals will be seen to connect directly to the outer frame. This will be known as terminal 3. The other two terminals connect to a pair of contacts, which are closed when no plug is inserted, but which open up when the plug enters. The moving arm, which swings down to make contact internally when the plug is removed, and which swings up to make contact with the plug tip when that is inserted, will be called terminal 1. The remaining contact, which connects to terminal 1 when the plug is out and is open when the plug is in, should be labeled as terminal 2.

Now with the jack mounted and both volume control and jack terminals properly identified, the steps for interconnection are simple:

1. Unsolder the wire from terminal 1 of the volume control and solder it to terminal 2 of the jack
2. Connect a short piece of hookup wire from terminal 1 of the jack to terminal 1 of the volume control. Solder the wire at each terminal
3. Connect a short piece of hookup wire from terminal 3 of the jack to any convenient chassis ground point, such as terminal 3 of the volume control. Solder the wire at each end.

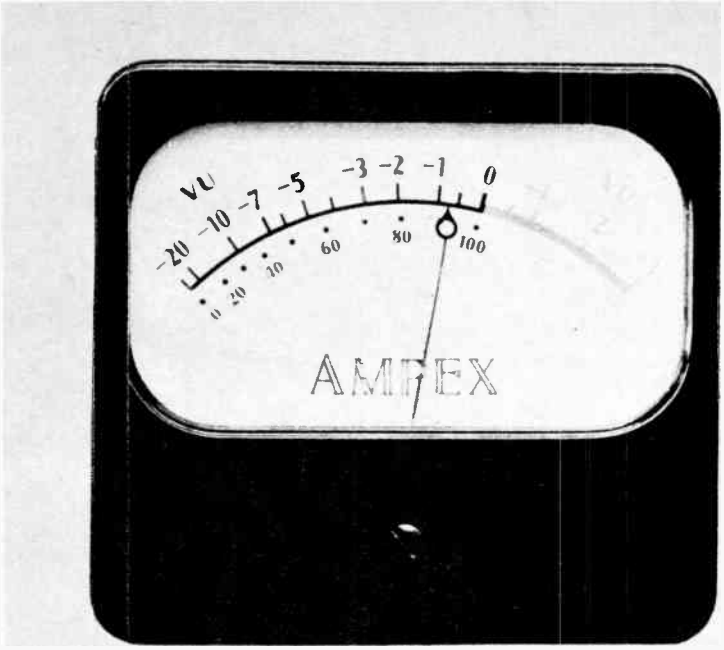
That's all there is to it. Three easy steps. Now the recording amplifier will receive audio signals from its own preamp when there is no plug in the jack, and from any external source when it is plugged in. The recording volume control will continue to determine level as before.

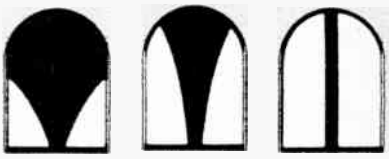
For reproduction only from the tape recorder, playing through the hi-fi system, the jack connection will be made at the playback volume control, or at the common volume control in the double-duty system, as shown in Fig. 2(B):

1. Unsolder the wire from terminal 1 of the volume control and solder it to terminal 1 of the jack
2. Connect a short piece of hookup wire from terminal 2 of the jack to terminal 1 of the volume control. Solder the wire at each terminal
3. Connect a short piece of hookup wire from terminal 3 of the jack to any convenient chassis ground point. Solder the wire at each end.

You will note that the procedure for reproduction is the same as for recording, except that the connections to terminals 1 and 2 of the jack are reversed. But the result in this case is that the playback preamp will now feed the internal playback amplifier and speaker when the plug is removed, and will play through the hi-fi sound system when the plug is inserted. The setting of the recorder volume control will have no effect on the hi-fi system level.

These procedures will work for both playback and recording only if the machine has separate playback and recording preamps, and separate level controls for each. For the double-duty system, where one





Volume level indicators are seen here. Input would be diminishing with the greater angle of shadow of the magic-eye type. VU meter is superior, providing a more accurate indication. It is used exclusively in broadcasting, recording, film studios.

amplifier chain performs both functions, two jacks are used, and both are inserted between the preamp and volume control. One jack, which will feed the preamp output to the hi-fi system for playback, will be known as *hi-fi out*. The other jack, which will accept the output from the hi-fi system and feed it into the tape recording amplifier, will be designated *hi-fi in*.

The wiring procedure is nearly as simple as with the single jack, and is shown schematically in Fig. 2(C):

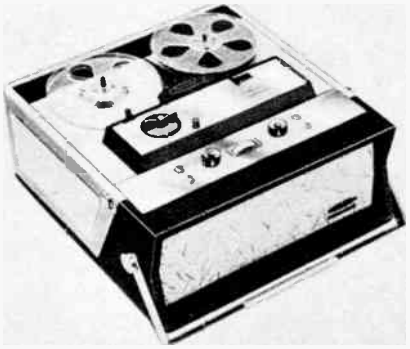
1. Unsolder the wire from terminal 1 of the volume control and solder it to terminal 2 of the *hi-fi in* jack
2. Connect a short piece of hookup wire from terminal 2 of the *hi-fi out* jack to terminal 1 of the volume control. Solder the wire at each terminal
3. Connect a short piece of hookup wire from terminal 1 of the *hi-fi in* jack to terminal 1 of the *hi-fi out* jack. Solder the wire at each terminal
4. Connect a short piece of bare hookup wire from terminal 3 of the *hi-fi in* jack to terminal 3 of the *hi-fi out* jack and then to any convenient chassis ground point, such as terminal 3 of the volume control. Solder the wire at all three terminals.

Since in this system the jacks do the switching as well as the connecting, the signal path being determined by the position of the plug, it is important that the plug be inserted only when its particular function is desired. For example, if plugs are inserted into both the *hi-fi in* and *hi-fi out* jacks simultaneously, a recording signal would bypass the recorder completely, going in one jack and out the other.

Each phone plug has two terminals, for

Playback and recording through a high-fidelity system are possible without modification of this Ampro home type tape recorder which features amplifier by-pass.

This recorder by Pentron has input jack for connecting to hi-fi preamp; second output for external speaker only. Low-level output entails very simple modification.



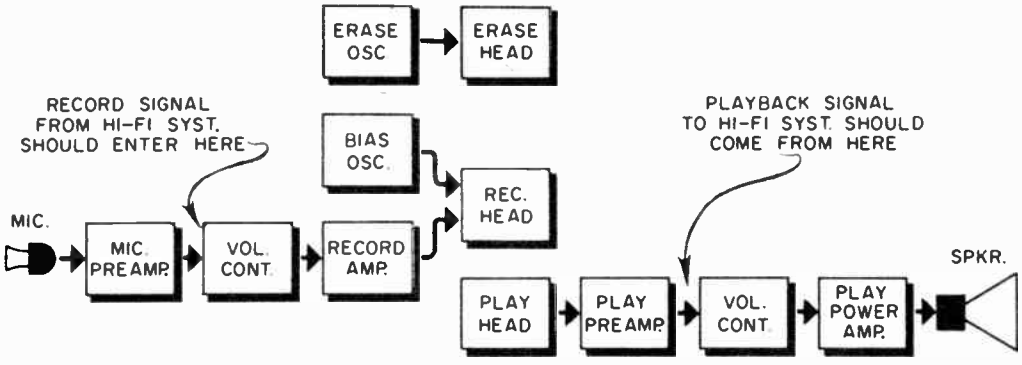


FIG. 1. The block diagram of a tape recorder's electronic elements. Many machines have one head for playback and erase, one amplifier chain with switching arrangement for both record and playback.

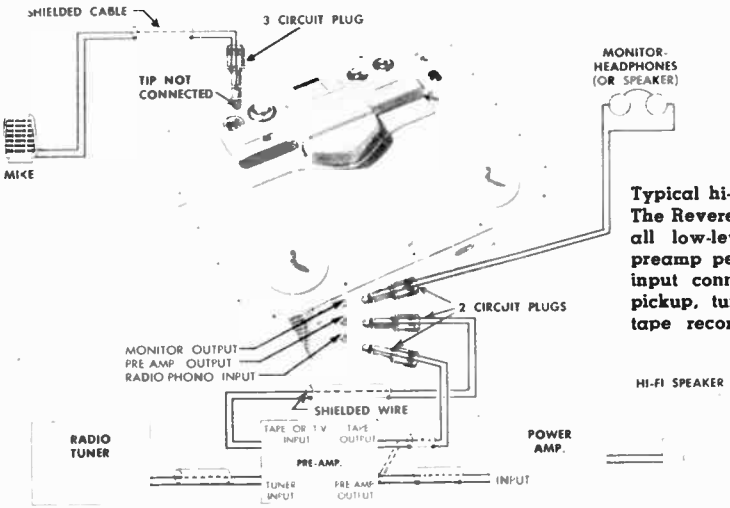
This Ekotape model is correctly matched for recording from hi-fi, but for direct playback connection to setup, slight modification is needed.

connection to each of the two conductors of the phono cable. After the insulation is stripped from the wires and the ends dressed, the braided outer conductor is connected to the terminal which goes to the body and shank of the plug. The center conductor of the cable is connected to the terminal which goes to the plug tip.

Now we still have the problem of connection at the hi-fi amplifier end of the system. If there are tape jacks on your preamp, control amp or power amplifier, the answer is simple. Just attach phono plugs to the free ends of the recorder cables, and plug from the *tape out* jack to the *hi-fi in* jack on the recorder. Similarly, connect from the *tape in* jack to the *hi-fi out* jack on the recorder.

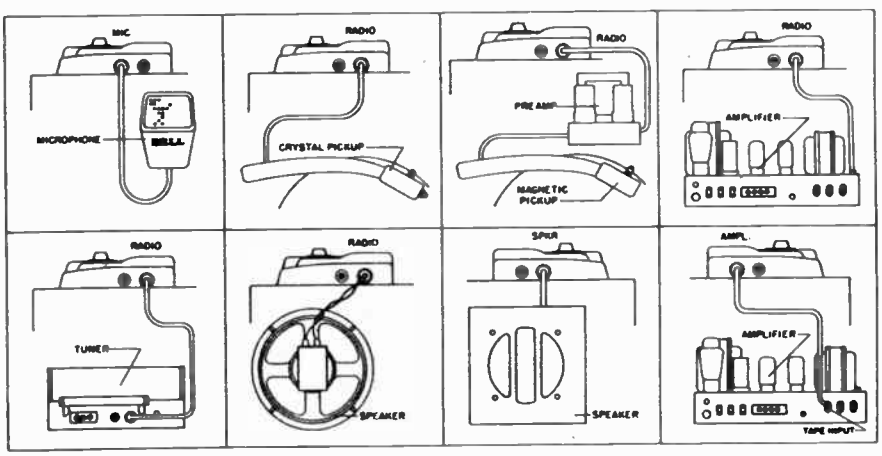
If your amplifier doesn't have tape jacks, then you'll have to do another installation job. For both recording and reproduction, the circuit and procedure will be exactly the same as that just described and illustrated in Fig. 2(C) for the dual-function recorder. The only difference will be in the labeling and the functions. The jack shown on the drawing for the recorder as *hi-fi in* will become *tape in*, and that shown as *hi-fi out* will become *tape out*.

In making these modifications, our purpose in effect was to eliminate certain elements of the complete tape recorder, and replace them by better components already in the hi-fi system. These elements are the



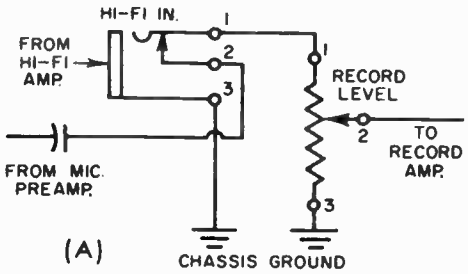
Typical hi-fi hook-up of a tape deck. The Revere T-11 deck shown includes all low-level electronics. Its input preamp permits recording via direct input connection from mike, phono pickup, tuner, TV receiver, another tape recorder, or a hi-fi amplifier.

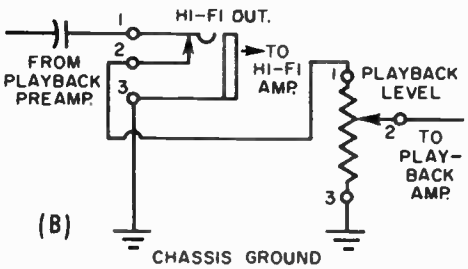
The mechanism of the Bell RT-204, a complete three-motor tape recorder adaptable to stereo, is also available as a separate tape deck. All types of operation shown below are possible with this recorder, using only two input and two output jacks in any instance.

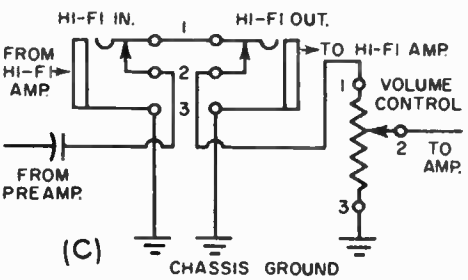


Recording and playback through a high-fidelity system with this Wollensak tape recorder is possible without further modification. Built-in speakers are silenced by merely plugging the cord into the extension speaker closed-circuit jack.

FIG. 2. Schematic of hook-ups for recording from hi-fi amplifier (A), playing back through hi-fi amp (B), and for recording or playing back through hi-fi system when amplifier-volume control chain is common to both functions (C).







microphone preamplifier, the playback power amplifier and the loudspeaker.

If you don't already have a tape recorder, but comtemplate adding one, perhaps you should consider getting a tape system which has eliminated these superfluous components in the initial design. Such a system is known as a *tape deck.*

This term sometimes refers to the tape transport mechanism and heads alone, while in other cases it is meant to include the erase, bias, record and playback preamp circuits. In any event, it never includes the elements which are superfluous in a complete hi-fi system, nor any sort of carrying case or cabinet.

A little different philosophy is seen in products of some other manufacturers, such as Pentron, Bell and Viking. These makes provide a transport mechanism alone, plus a variety of electronic units. This arrangement provides maximum flexibility in the selection of equipment for any desired functions.

The number of possible combinations becomes quite large when one considers that in recording there can be full-track monaural, half-track monaural, staggered or stacked half-track stereo, and now two versions of quarter-track stereo. These latter types are discussed in more detail in the next chapter.

There are also an equal number of reproduce systems, plus several speed possibilities. Now when we start mixing up recording only, playback only, recording systems, playback systems, and speeds, a considerable number of combinations is possible. For this reason it would seem that the mechanism-plus electronics offers the

Did Someone Say "Switch?"

When the art of recording was just taking shape

And it seemed to the experts that tape was just tape,

It made sense to try switching from this brand to that—

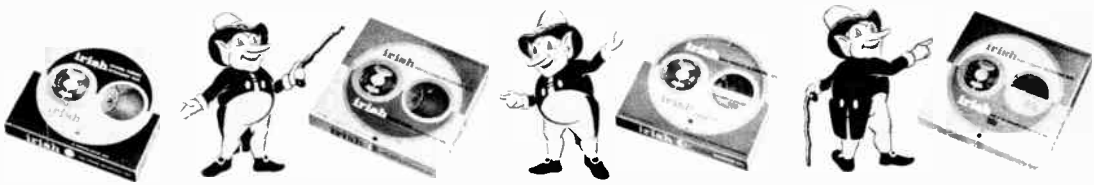
Until **irish** pulled **FERRO-SHEEN** out of the hat!

Now the **FERRO-SHEEN** process, the experts agree,

Has made **irish** tape different in *kind,* not degree,

So there's no earthly reason for switching your brand,

Save from Long Play to Double, or Brown to Green Band!



...if you are using
irish BROWN BAND

(an inexpensive general-purpose tape of excellent characteristics)

. . . and want all the advantages of FERRO-SHEEN . . .

...switch to
irish
FERRO-SHEEN GREEN BAND

(it costs no more than old-fashioned coated tape)

. . . if you then want 50% more playing time on the same size reel . . .

...switch to
irish
FERRO-SHEEN LONG PLAY

(on 1-mil Mylar or acetate base)

. . . if you then want twice the normal playing time on the same size reel . . .

...switch to
irish
FERRO-SHEEN DOUBLE PLA

(made on ½-mil Mylar base an available on 5" and 7" reels)

There's an **irish** tape for every recording purpose!

Available wherever quality tape is sold.

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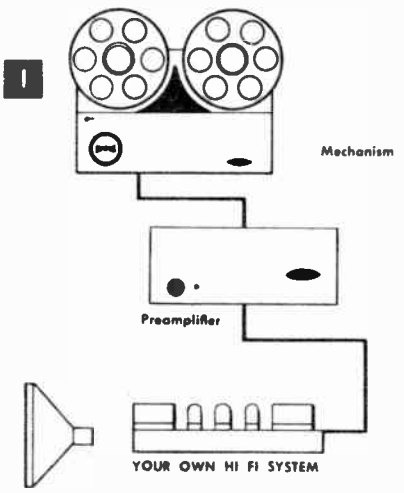
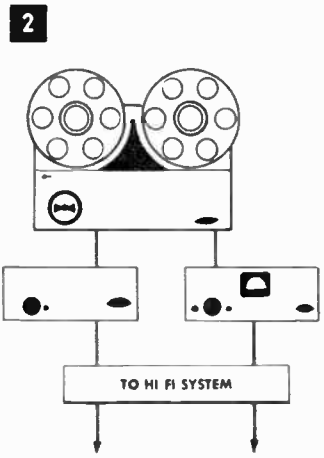
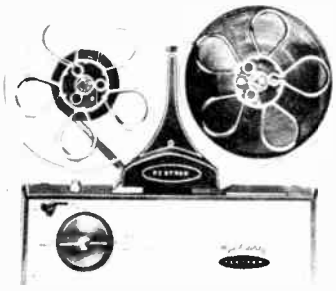
Export: Morhan Exporting Corp., 458 Broadway, New York 13, N. Y.
Canada: Atlas Radio Corp., Ltd., 50 Wingold Avenue, Toronto 19, Ont.

These drawings show the Pentron components needed to add tape facilities indicated to an existing hi-fi system. 1. Monaural playback: tape mechanism and playback preamp. 2. Stereophonic playback and monaural record and play: mechanism, playback preamp and combined playback preamp-record amplifier. 3. Monaural record/play: tape mechanism and one preamplifier.



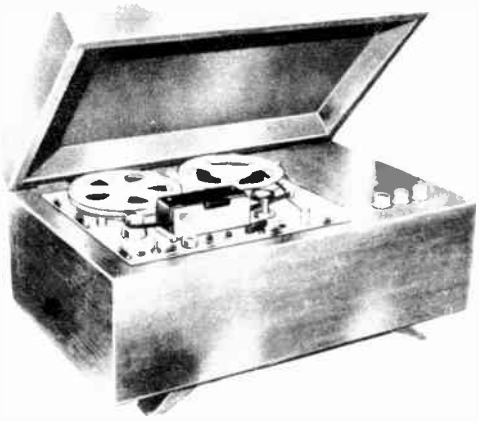


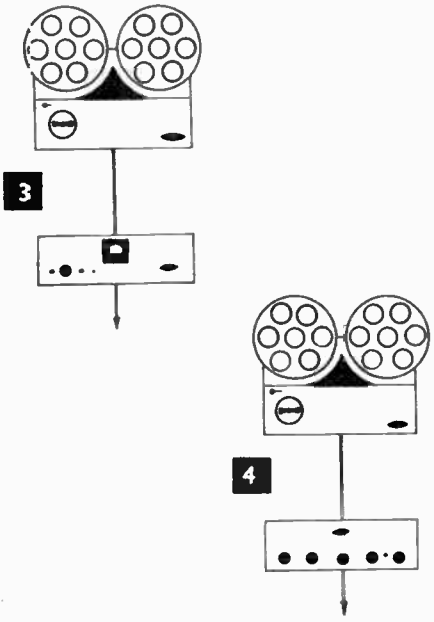
Tape mechanisms, or decks, such as this Pentron model, are for use with separate electronic units, provide for greater flexibility of home installation.

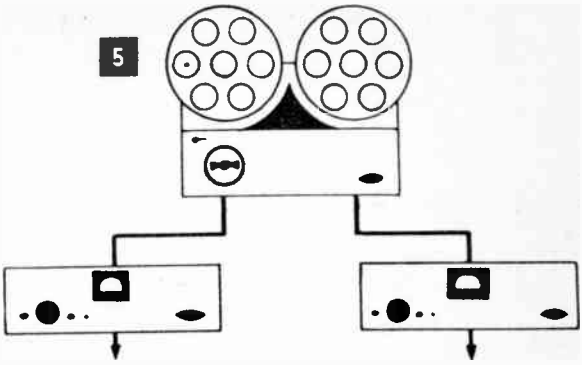


Roberts recorder-reproducer, bottom right, could be the focal point of hi-fi system. It features volume meter and hysteresis synchronous motor.

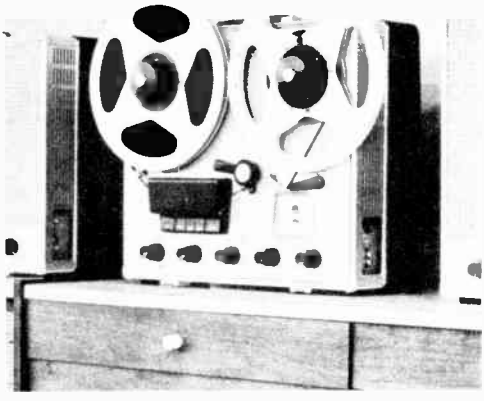
Tancordex, below, a Lafayette Radio import for monaural or stereo recording, has three motors and three heads. Blond or mahogany cabinet houses the system's two-channel tape preamplifier.



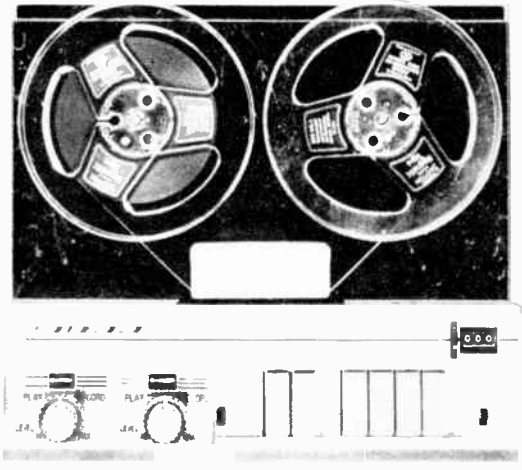




4. Stereo playback only: tape mechanism and preamplifier. 5. Stereo play/record and monaural play/record: mechanism, two playback preamp record amplifier combinations. The Pentron line includes mechanisms, or decks, for staggered stereo as well as in-line and staggered stereo.



American Concertone "Globematic" 60 recorder has mechanism and preamp, separate speaker.



Bell deck has provisions for stereo in-line or staggered play, as well as half-track monaural.

widest flexibility, along with the opportunity of expanding as your budget permits.

Still another approach to the integration of tape and hi-fi—especially good if your requirements are modest or your budget limited—is to buy a complete recorder of good quality, let it be the center of your hi-fi system, and build up the other components around it. Certain models of the Ampex, or the Tapesonic or Roberts serve admirably for this purpose.

Each of these has a complete electronic system, including a fairly husky audio amplifier and an extended-range speaker. It also has input facilities for phono, tuner, TV, or other tape. Thus it could serve as the focal point of a fine little hi-fi system.

The Roberts, for example, is a complete sound reproduction unit, with amplifier, preamplifier and 5″ x 7″ extended-range speaker. Overall response is reasonable flat from 40 to 15,000 cps.

So whether we bring tape to hi-fi, or hi-fi to tape, the two belong together. And the proper wedding of the two will permit getting the optimum performance. •

Special Section

Stereophonic Sound

The JBL-Ranger Paragon by James B. Lansing, a result of ten years of research, is designed to reproduce stereo sound independent of the listener's position. Each channel has 60-watt input; unit weighs 850 lbs.

IT is perhaps inevitable that any development as exciting as stereo sound should be surrounded by a wide area of confusion as to its purpose, its methods, indeed to its very identity. We'll try to clear the air a little on the subject as we know it today.

If you infer from that a hint that we are far from knowing all the answers, you are quite right. Everyone is still feeling his way, from the original producer of stereo program material to the manufacturer of hi-fi reproducing equipment.

Don't misunderstand: *Stereo is good.* It is right in concept, and often right in execution. But a thing like this attracts bunco artists as a big bowl of strawberries attracts fruit flies. As usual, the opportunistic phonies are in the minority. You can avoid them if you know the straight story. That's what we'll try to give you here.

To begin with, contemporary stereo is not quite as revolutionary as the invention of the wheel. Sound recording wasn't very far out of the tinfoil stage when crude efforts were already being made toward using it for stereo. The outstanding example of this occurred at the Paris Exposition in 1881.

There were many investigators seriously interested in stereo as early as the 1930's. Among them were the Bell Telephone Laboratories, National Broadcasting Company, and several Hollywood film studios. These several efforts were independent and, therefore, quite divergent in theory and application. Even then the term "stereophonic sound" had several different shades of meaning.

We need a stereophonic system simply because we hear with two ears. Conventional methods of hi-fi recording and reproduction are monaural or monophonic. In simple terms, they are "one-eared."

Hardly anyone interested in hi-fi has by now escaped being indoctrinated with the stereo photography simile. Stereoscopic pictures are made in pairs, exposed by lenses which are separated by the distance between the eyes. We need two pictures, hence we need two audio channels. What could be simpler? The trouble is, the analogy is too simple. When you look at something with just one eye, the effect isn't much different from when you use two. The scene may lose some depth and roundness, and you may experience a little more difficulty in judging distances or speeds of moving objects. But the differences are quite subtle, because the shading, tonal quality, contrast or color of what you see are not visibly affected. So if the difference between stereo and mono were no more

Completely portable stereo system by Bell uses two matched speaker-amplifiers. The tape transport in foreground will play back and record stereo.

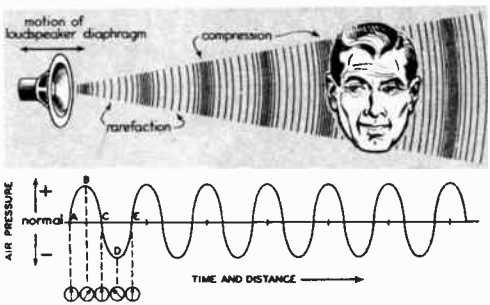


FIG. 1. Sound is caused by alterations of air pressure. If the listener is placed in the position shown, one ear will be in compression region, one in rarefaction area, as indicated above.

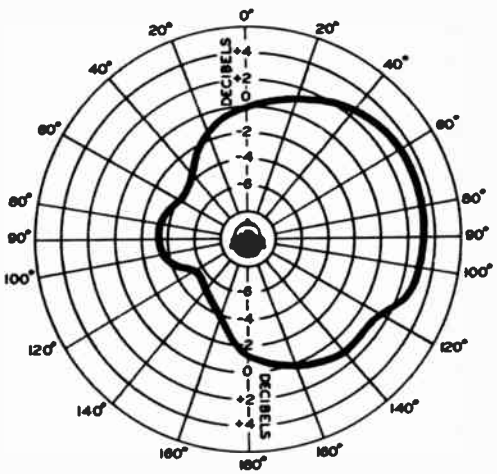


FIG. 2. Graph shows how each ear responds if sound of constant intensity is moved from front to back around the right side of listener's head, center.

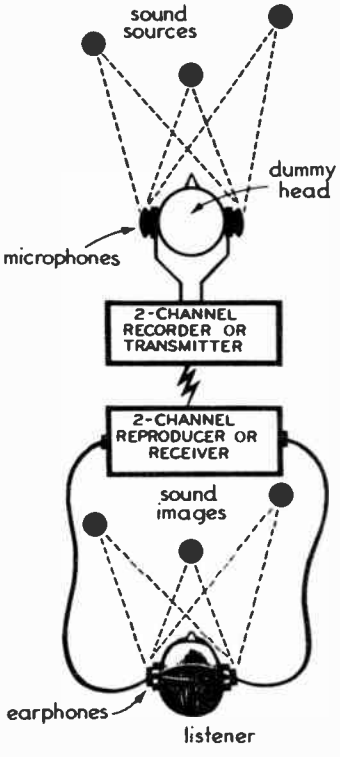
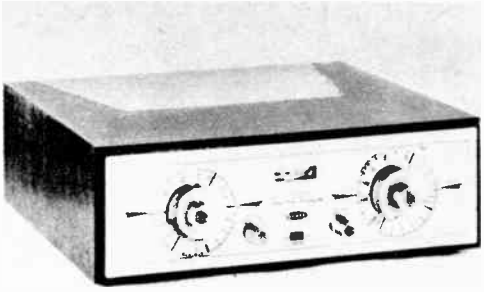


FIG. 3



H. H. Scott 330-C AM-FM stereophonic tuner has separate AM and FM sections and level controls, output jacks for binaural operation and tape.

FIG. 3, left, gives idea of ideal, "true" binaural two-channel system, with microphones on dummy's head placed in same position as earphones on listener's head. This is rarely the case (see text).

than between one-eyed and two-eyed vision, it would hardly have created the excitement it now has.

But try the same experiment with the ears. First cover one, then the other, then neither. In each case you note that there is a distinct difference in the sound. True, some of the effect may be due to differences in hearing ability between the two ears themselves. This doesn't account for nearly all of it, though, and it's that extra difference which explains the importance of stereo and its superiority over conventional systems.

To understand this more fully, we have to go back to first principles and consider just what a sound wave is and how it affects the ears. We'll use a loudspeaker as the sound generator, although the same principles will apply regardless of the source.

Up to the point where sound is perceived by the brain—and maybe beyond that—it can be defined by one word: *vibration*. In the beginning sound is created by a vibrating object. This could be a bowed or plucked string, the human vocal cords or maybe a windowpane with a rock crashing through it. Whatever the source, the initial vibrations immediately set up secondary vibrations in the surrounding air. When sound is reproduced by a loudspeaker, for example, the moving cone is actually causing variations in the pressure of the air around it. When the cone moves out the air particles are compressed, thereby increasing the pressure above normal. When the cone moves in, on the other hand, the particles are stretched out or rarefied and the pressure goes below normal. If we measure the pressure at many points along a line moving out from the speaker, we'd find that the sound is actually moving in waves, as shown in Fig. 1.

Now let's see what happens to you when you're within earshot of that speaker. The varying air pressures will push and pull against each of your eardrums. These vibrations in turn set in motion the complicated process of hearing which ends with your brain receiving the sensation of sound. Since your eardrums are separated by the width of your head, the sound must travel different paths between the source and each ear.

In the diagram you see that your right ear is closer to the speaker. Thus the sound will get to it before it reaches the left ear. This is so because your head is turned at an angle relative to the speaker.

Now remembering that distance traveled equals rate x time, let's see how that applies to the sound from the single speaker striking your two ears. The rate—

in this case the velocity of sound—will be constant. The distances will be different. Therefore the *times* will not be the same. In fact, we can generalize and say that, except for those circumstances when the sound is directly in front of or directly behind you, the arrival times of the sounds at each ear will *not* be the same.

This time differential is in turn responsible for a difference in *phase* of the sounds reaching each ear. Notice in the drawing that while your right ear is in a high pressure area, your left ear is in a low pressure trough. Since sound is a wave motion moving constantly outward from the source, in another instant the compression part of that wave will have moved on to your left ear, while the right ear will be in a rarefied area.

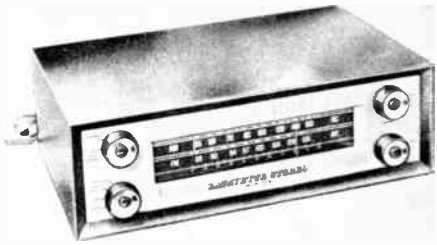
In Fig. 1 the wavelength of the sound is such that the distance between compression peaks is perhaps a foot or more. Now suppose the waves were much longer, so that both ears were in a compression or rarefaction area simultaneously. The wavelength varies with frequency, and a 300-cps tone will have a wavelength of about 2½ feet. This particular figure will have an important bearing on our stereo enjoyment, as we shall see.

These differences in time and phase between sounds striking each ear will give your ears the clues they need to enable them to estimate both the distance and direction of the sound source. You can get some idea of the ability of your ears to sense direction by referring to Fig. 2. This shows how each of your ears would respond if a sound of constant intensity were moved from front to back around the *right* side of your head.

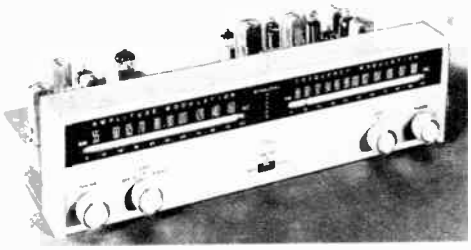
The ear on the same side as the source—in this case the right—of course, hears more. But the loudness of the sound does seem to vary as the sound moves around. The response of the near ear is almost heart-shaped, with greatest sensitivity to sounds arriving from a little ahead of a beam, or about 75 degrees.

The opposite ear, naturally, hears most when the sound is closest to it, which would be directly forward or behind. But there is also a secondary lobe of sensitivity to sounds arriving from directly opposite, between 80 and 90 degrees.

Between these three peaks there are a couple of valleys, showing that the opposite ear is less sensitive to sounds arriving from the areas of 2 and 4 o'clock, or 50 and 130 degrees. If the sound were to arrive from the left side, the ears would simply exchange functions, and the curve of Fig. 2



Lafayette stereo AM-FM tuner has 3 uv sensitivity for 20 db quieting on FM, 20-20,000 cps response, outputs for tape, multiplex, monaural.



Arkay AM-FM stereo tuner can also be used for monaural reception. FM range is 88 to 108 MC, 4 uv sensitivity for 20 db quieting; it has AFC.

Stromberg-Carlson amplifier/control center for stereo has separate controls for each channel, includes output signal button for proper balance.

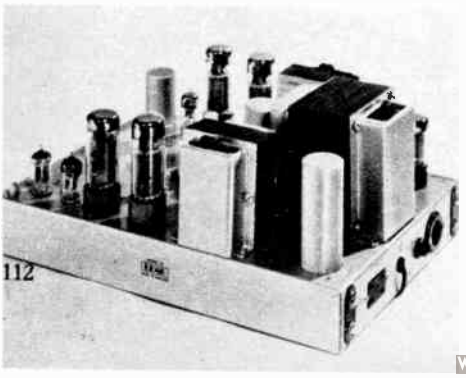
Electro-Voice AM-FM tuner and preamp unit has completely independent AM and FM sections which permit reception of stereophonic broadcasts.

Model 101-R Fisher FM-AM gives stereo or monaural operation. Sensitivity for FM is 1.6 uv for 20 db of quieting; 20-20,000 cps within 1 db.

"Point One Stereo" preamplifier by Leak makes provisions for separate channel operation or stereo. It is used with a stereo power amplifier.

This Scott unit, Model 135 Stereomaster Control Center, combines with a regular preamplifier to give you stereo control for the added channel.

Power amplifier, minus controls, by Leak is rated at 50 watts. This dual-channel unit must be used with stereo preamp, or two regular preamps.



would be simply flopped around the center axis. Then the big lobe would be on the left and the smaller undulating one on the right.

These differences in directional responses of the ears are evidently due to the physical construction of the external parts of the ear and of the head. When combined with the differences in time and phase of sounds arriving at each ear, there is sufficient information for the brain to discern distance and direction.

This is strictly true, however, only at the higher frequencies. As we have already noted, the differences in time and phase become scarcely noticeable at the longer wavelengths around 300 cps and lower. Just what this fact means in terms of a hi-fi stereo system is still a matter of some controversy. One school of thought argues that two wide-range channels are not necessary, that the bass can all come from one loudspeaker since it is basically non-directional in character. Others say that it's a nice theory which doesn't prove out in practice.

This is one of the areas where it is all too easy for the beginner to be flummoxed by a lot of fancy engineering jargon, when his own intuition and good sense should tell him better. In this case, as in all other hi-fi matters, never mind the hard sell but let your own two ears be the final judge.

As for the frequencies above 300 cps or so, there can be little doubt. The ear is very definitely quite sensitive to changes in direction of the source. Referring again to Fig. 2, the sound intensity as perceived by the near ear varies as much as 4 decibels. This is an audio power ratio of 2½ to 1. The response of the far ear will vary with direction by as much as 6 db, which is a power ratio of 4 to 1.

But in the conventional audio system the sound comes from only a single speaker system, practically a point source. At first glance it would seem that this could be corrected simply by adding more speakers around the listening room. This is the principle of "spread sound," but it isn't stereo. It doesn't tell us whether the first violin section is to left or right, but instead gives the effect of placing it both left *and* right.

Since directionality and depth are what we're seeking in this quest for higher fi, let's consider a different approach. Starting from the original sound source, suppose we had a separate microphone for every single performer, a separate channel for each mike, and a separate speaker for each channel at the reproducing end. If the loud-

speakers were arranged in the same physical setup as were the performers, this should effect true stereo.

This is the principle of the "electronic orchestra," and it has worked very well in experimental multi-channel tape recordings with small groups of performers. But for a symphony or an opera, the idea is just a dream and nothing more. Aside from the elaborateness of the system, the listener would have to have a position chart for each of the performers on each record, plus some means of pushing around 50 or 100 speakers to match the original arrangement.

But pursuing this line of thought a little further, it should be possible to scale it down to usable size. If we used only a channel for each section or voice of an orchestra, for example, we might reduce their number to maybe a dozen or so. Paring even further, we soon get down to the seven channels of Cinerama, five of Cinemascope, or three of Fantasound.

Even as few as three channels, however, will stretch a little beyond the capabilities of present hi-fi systems. Two channels, on the other hand, can be worked in quite handily with existing equipment. Since a 2-channel system would offer maximum "compatibility" with current hi-fi, its possibilities should be investigated.

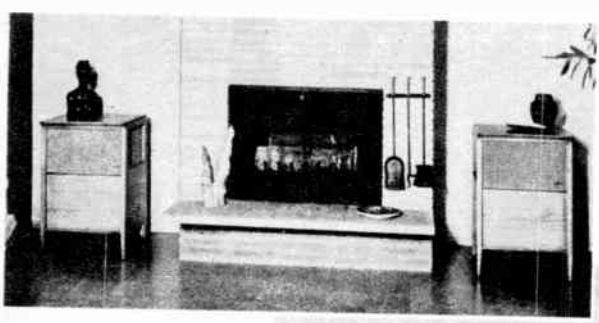
We can see in Fig. 3 an entirely different approach to the problem, which uses only two channels. Thirty years ago the then Acoustical Research Director of the Bell Telephone Laboratories, Dr. Harvey Fletcher, said of this arrangement: *"Any variation from this ideal transmission system will produce results which are different from those ordinarily produced by direct listening."*

This ideal transmission system, known as *true binaural,* requires two microphones, placed in something which is acoustically identical to the human head. The size, shape and features must all be the same, and the microphones are actually placed within the ears. Two channels are used. They are kept separate throughout and are terminated in split headphones. Under these conditions the listener has the same impression as if he were actually listening with both ears at the location of the dummy microphone head.

The system is, as Dr. Fletcher said, ideal from a psycho-acoustic point of view, but it has several practical drawbacks:

1. Continuous use of the earphones is fatiguing.
2. Group listening is difficult if not impossible.
3. If the listener turns his head, the performers will seem to swing around in a wide arc, sort of like a game of "crack the whip."

Two-channel stereo is thus a practical approach—a compromise if you will—be-



Two cabinets by Jensen are the SS-100 Stereo-Director Reproducers; they are matched units.

First complete stereo system in kit form is offered by Heathkit. All cabinetry, stereo tape, disc player, tuners, amplifiers and speakers to match, are made available to the buyer in a kit package.

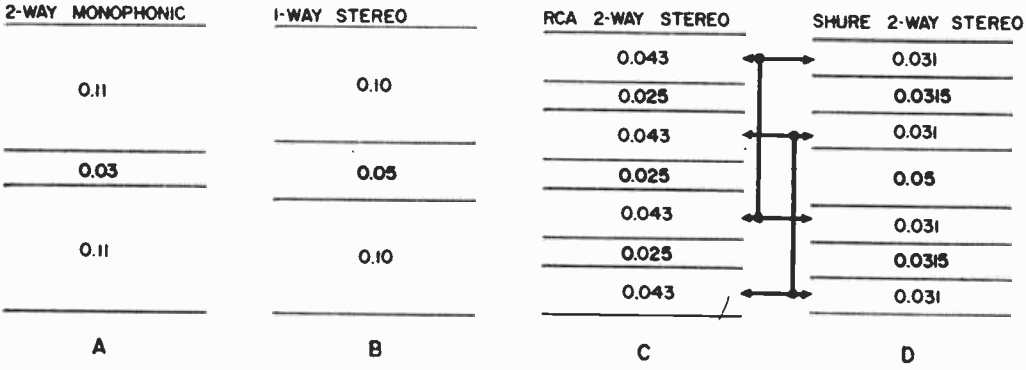


FIG. 4, above, shows one piece of standard tape and what happens to it when exposed to the various head configurations of different systems.

Conversion kits for tape recorders are available for most makes, include head and cables to convert monaural recorder to stereophonic unit.

tween multi-channel stereo and true binaural. At its best it is overwhelmingly superior to monophonic, and in fact often closely approaches the more ideal systems.

All of the usual hi-fi program sources, namely tape, disc, and radio broadcasts, are available in stereo to some degree. Broadcasting is certainly in the least settled state of the three, so we'll get that out of the way first.

The simplest way of accomplishing 2-channel transmission for stereo is simply to use two separate stations. If both stations were of the same type, there would be the possible combinations of AM-AM, FM-FM or TV-TV. In each case there must be at the receiving end two tuners of the same type. This is the first objection, but there is another which almost rules these methods out for everyday use.

The United States government (FCC) will not permit any single owner to have more than one station of each type in a given area. That means that stereo methods such as these, using two transmitters of the same type, require the participation of two separate owners. Such programs have been carried on experimentally for some years, and in many places this is still being done. But when commercial sponsorship is involved, the whole thing becomes impractical and we are not likely to see much of it.

Since an operator may have one AM, one FM and one TV station in the same area, however, he is perfectly at liberty to use any combination of these for 2-channel stereo. Thus we might have AM-FM, AM-TV or FM-TV stereocasts. All of these types have been used for stereo, but the AM-FM type is the only one which is used with any regularity.

To receive these programs and reproduce them in stereo, you will require separate AM and FM tuners, or an AM-FM stereo tuner. Note that not all AM-FM tuners can be used for stereo. Many of them have shared circuits, enabling them to receive only one or the other type signal at a given time.

In addition to the tuners you will require *two* hi-fi power amplifiers and *two* speaker systems. All of the monophonic hi-fi gear you now have can be incorporated into a stereocast system. You will have to add to it, but none of it is obsoleted.

The newest method of stereocasting, and one which shows great promise, uses only one FM station in a system known as *multiplex*. In this arrangement a conventional modulator superimposes an audio signal on the FM carrier in the usual way. At the same time a supersonic frequency is im-

posed on the FM carrier and audio superimposed on that as well. Thus the supersonic signal acts as a sub-carrier for the second audio signal, which really makes the system FM within FM.

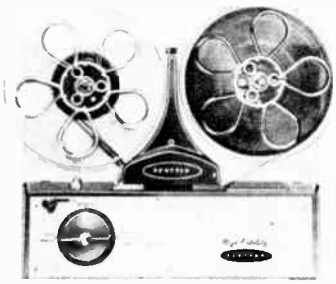
Ordinarily an FM tuner will detect only the main carrier, or one channel of a stereocast. Some of the better hi-fi FM tuners have the multiplex detection circuit included. Multiplex adapters are also available for use with any existing tuner. The thing which has held back FM multiplex stereo is lack of a decision from the FCC concerning the frequency of the sub-carrier. At least two are now used, 41 and 67 kc, and until this question is standardized, this type of stereocast will unfortunately remain in the experimental stage.

The commonest source of stereo program material, which has been in use for several years, is, of course, magnetic tape. When it was discovered that the full quarter-inch width of tape is not really essential for high fidelity and low noise, the door was immediately opened for stereo.

In the preceding chapter we noted how economies are effected by using only half the tape width for recording. The approximate dimensions for such recordings are shown in Fig. 4(A). When a very similar arrangement is used for stereo, as in Fig. 4(B), the economy is no longer there, as the full width of the tape is once again used for a single program.

An existing monophonic tape recorder with a good transport mechanism can often be converted to stereo, with just a few simple replacements and additions. Referring again to the preceding chapter, remember that there are four magnetic and electronic functions performed in the recorder:

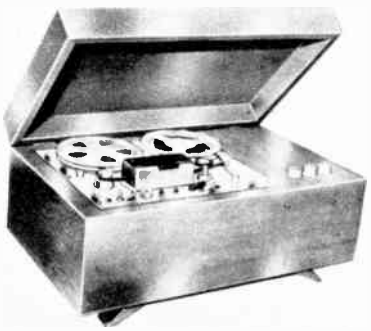
1. Erase (oscillator and head)
2. Record (amplifier and head)



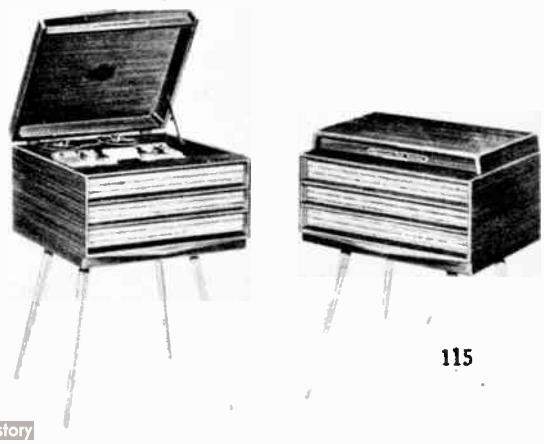
Pentron makes this tape deck for stereo recording and playback plus monaural recording and playback. Heads are staggered, half-track; price: $95.

This is the preamplifier for the model shown at left. Two of these Pentron units are required for complete stereophonic recording and playback.

Lafayette Tancordex stereo tape recorder has three motors. It plays back stereo, needs two recording amplifiers if you want to record stereo.



RCA unit shown here has all the monophonic elements in one unit, the extension speaker/amplifier is in the other (right) for stereophonic reproduction.



Above, this Patterson tape transport is available in kit form or assembled, in either monophonic record/stereo playback or in full stereo/stereo.

3. Bias (oscillator only, usually same as erase; head is same as for record)
4. Playback (amplifier and head, either or both of which may be shared with record circuits).

Most of this can be salvaged when we go to stereo. The transport mechanism will, of course, remain intact. The erase system need not be disturbed if it already wipes the full width of the tape at a single pass. This is the case in full-track recorders, but not in dual-track systems, where only half the tape width is erased at a time. In the latter instance the half-track erase head must be replaced by a full-track head, but no other changes are usually necessary.

Since the record and bias are combined both in the amplifier and head, we'll consider them together. First, the head must be replaced, whether it is half- or full-

Bell tape transport T-203 for custom hi-fi installation. Model shown has two record/playback preamps (RP-120), will play and record stereo tapes.

American Concertone "Globematic" 60 has stereo, half-track, full-track, hysteresis motor drive, push button operation and 10½-inch tape reel capacity.

track. Now you require a double-track head, which will record separate signals on each half of the tape simultaneously. The record-bias electronics can be retained intact for one of the tracks, while a second is added for the opposite track.

If the original recorder is of the two-head type, with recording and playback performed by the same components, no further changes are necessary except for a more elaborate switching arrangement. If the record and playback systems are separate, then a double-track playback head must be used as a replacement, and a second playback amplifier must be added.

The most popular speed for stereo tapes today is 7½ ips, although more and more of them are becoming available at 3¾ ips as well. Both RCA and Ampex are known to have been very active in the development of improved 3¾-inch tape reproduction.

Both RCA and Shure have developed 4-track tape recording systems, not for 4-channel stereo, but to give to 2-channel stereo the economy of half-track monophonic. The approximate dimensions of the tapes for both types are shown in Fig. 4(C) and (D).

In each case alternate channels are used simultaneously. One stereo program will be recorded on channels 1 and 3, while the other is recorded in the reverse direction on channels 2 and 4. The Shure operation would be the same as dual-track tape, in that after the tape plays through in one direction, it is simply moved from the take-up to the supply reel, and threaded up to play the alternate program. Thus no rewinding is necessary.

The RCA system uses a cartridge which just slips into the machine, without threading or rewinding. Each of the systems has certain advantages over the other. The RCA system makes more efficient use of the tape, with more of the available magnetic material actually being used for recording. The greater separation between tracks in the Shure system will on the other hand afford greater isolation from crosstalk.

The RCA system is in no way compatible. The magazine cannot be played on conventional machines, nor can ordinary reels be played on the magazine machine. The tape is to be "B" (oxide-out) wound, and the head dimensions will further preclude the use of conventional 2-track stereo tapes. Comparing Fig. 4(B) and (D), however, it can be seen that Shure 4-track heads will satisfactorily reproduce 1-way stereo.

The latest thing in stereo, and the method which is due for the widest public popular-

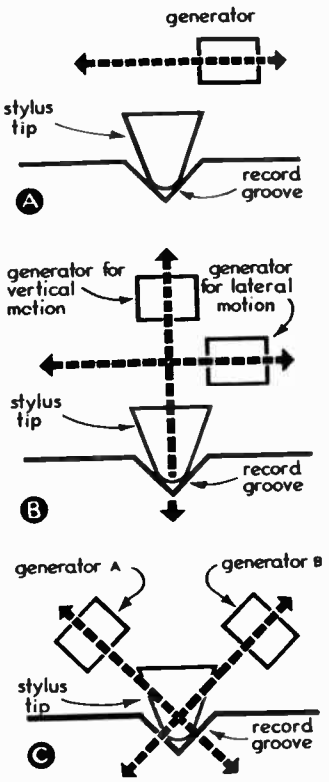


FIG. 5, above and below, shows function of standard and stereo cartridges for phono discs.

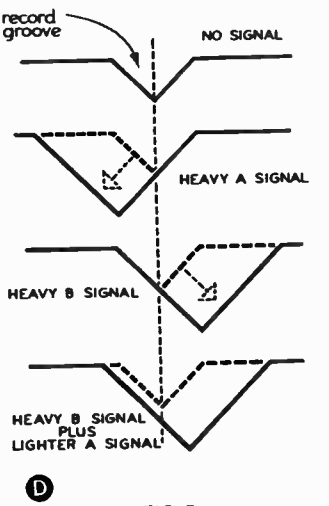
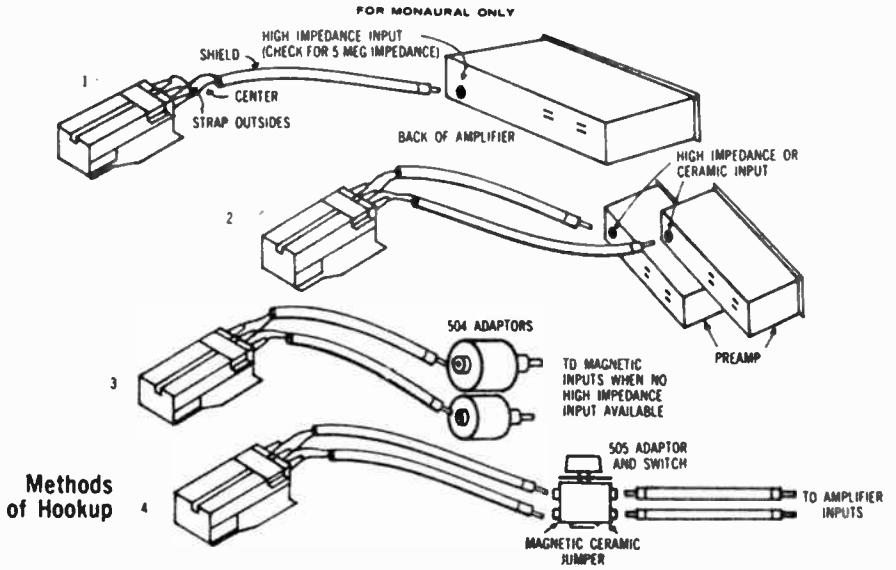


FIG. 5

In 45-45 stereo records each side of the groove has its own signal: each side is one channel.



Electro-Voice drawings show method of hook-up for monaural and stereophonic phonograph cartridges.

ity is the stereo disc. As we have noted, experiments with this method of recording have been tried ever since the medium was invented. There have been many approaches to the problem, but the one which appears to be the winner was developed from scratch, and had its public unveiling within about eight months of its inception.

To review briefly, there have been two basic methods of inscribing modulation in a phonograph record groove. The one most commonly used today is lateral, shown schematically in Fig. 5(A). It is also possible for the engraving stylus to have an up-and-down motion, to make a record known as vertical or hill-and-dale.

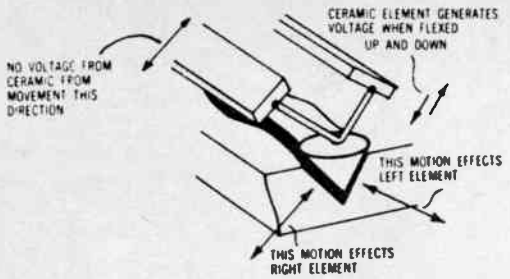
It naturally followed that the first serious attempts at creating a stereo disc should use a combination of the vertical and lateral methods. The reproducer then had two driven elements or voltage generators, one responsive to the vertical motion representing one channel, the other responsive to the lateral channel.

The elements of this system are shown in Fig. 5(B). Records of this type have been known for two decades or more, and in fact are now being produced commercially in England and elsewhere. A somewhat different approach has been introduced in this country, however, and it has already been accepted here as the industry standard.

This is known as the 45-45 stereo system and is shown schematically in Fig. 5(C). It can be regarded somewhat as the vertical-lateral system tipped at a 45-degree angle. Two generators are still used, one for each channel, but the groove configuration is rather different.

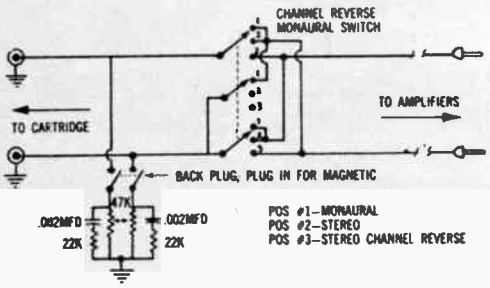
One set of stylus motions, affecting generator *A* is along a line of 45 degrees to the record surface, and moving between northeast and southwest. The effect of one half-cycle of a heavy *A* signal is shown in Fig. 5(D). A second set of motions, between northwest and southeast, similarly affects generator *B*.

It can be seen from Fig. 5(D) that the groove deepens under modulation, but only the left wall moves with an *A* signal, and only the right wall moves with a *B* signal. Thus in effect each wall of the groove is modulated separately, and each wall repre-



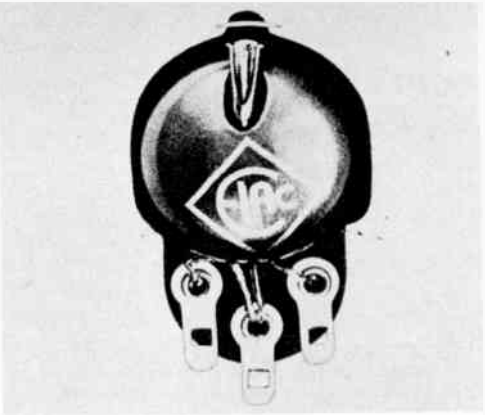
STYLUS ACTION

Simplified sketch shows stereo stylus action.



SCHEMATIC OF MODEL 505

Electro-Voice stereo cartridge hookup schematic.

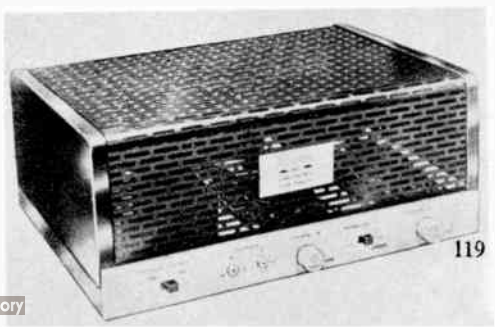


Audiogersh Corp., sells the "Stereotwin" 200 stereo cartridge for $59.50, with .7 mil diamond stylus. It is of the variable reluctance type.

The Miracord XS-200 tone arm can be used with the cartridge shown at top of page. This changer is monaural/stereo, has push-button operation.

Pilot stereo preamp and control amplifier features two power amplifiers rated at 14 watts each. It has inputs for AM-FM, tape, discs, microphone.

Lafayette Kt-310 stereo amplifier kit has two 18-watt stereo channels, 4, 8, 16 and 32-ohm output impedances. Price of the kit is $44.50.



sents one channel of the 2-channel stereo system.

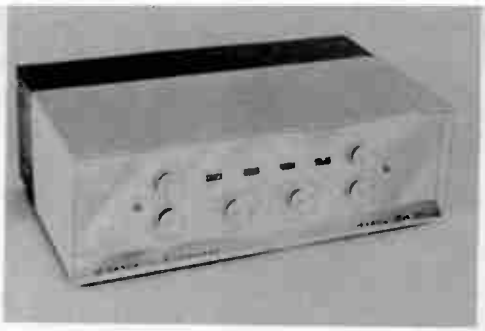
In a true stereo signal, however, both channels will be active. In this case both groove walls will have a tendency to move, and there will be a resultant motion in two directions. The effect of a heavy *B* signal plus a lighter *A* signal is shown in Fig. 5(D).

The best stereo reproducers will behave under these conditions in such a way that generator *A* will respond only to the *A* component of the complex groove motion, and generator *B* will respond only to the *B* component. The more accurately they do this, the greater will be the isolation between channels, and the more realistic the stereo effect will be.

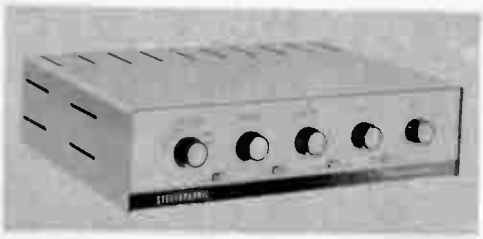
The only piece of equipment which is obsoleted by the stereo disc is the reproducer cartridge itself. The stereo cartridge will reproduce monophonic records, however, sending the same signal through both channels for a spread-sound effect.

Beyond the source equipment—tuners, tape and phono gear—conversion to stereo essentially requires the duplication of all

Stereo-monaural amplifier by Knight delivers 30 watts monaurally or 15 watts each for stereo. Outputs are 4, 8, 16 and 32 ohms; it costs $69.95.



Stereo-binaural dual preamp/amplifier is sold in kit form by Arkay. Each channel has separate preamp. One 25-watt amplifier is included in unit.

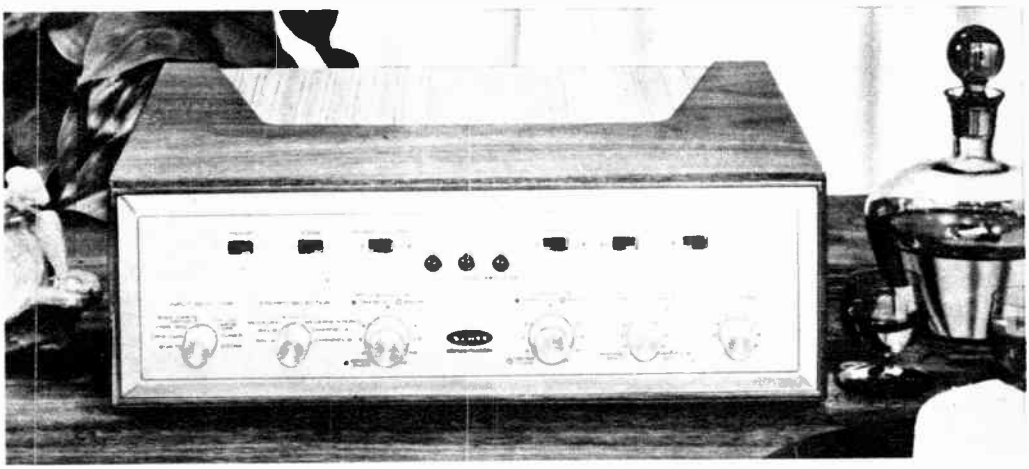


Pacemaker Model 2221 by Bell contains two 10-watt power amplifiers, has one set of controls for both channels. Response is 20-20,000 cps, ± 1 db.

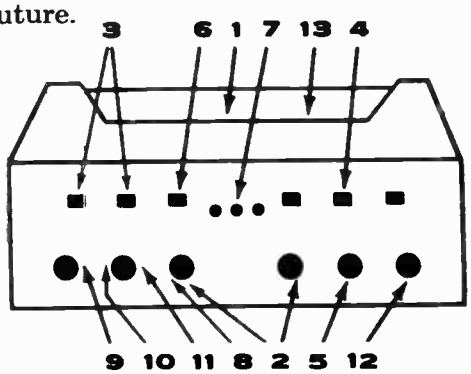
Bell components in custom installation for stereo reproduction include FM-AM tuner, Model 3030 stereo amplifier, tape transport, Bozak speakers.

Electro-Voice "Stereon" system (left) produces sound above 300 cps, based on the principle that the human ear does not distinguish a stereo effect when listening to sounds below 300 cps.

The Stereo Amplifier that sets the Standards for the Next Decade!



The H. H. Scott engineering laboratories proudly introduce the new Model 299 40-watt stereophonic amplifier control center. It contains many advance features that not only meet the needs of today's stereophonic program sources, but anticipate the requirements of the future.



1 40-watt power stage consisting of dual 20-watt power amplifiers. You need this much power to meet the requirements of today's speaker systems. 2 Completely separate Bass and Treble controls on each channel so that different speakers may be matched. 3 Provision for connecting both a stereo phono cartridge and stereo tape heads. 4 Phase reverse switch to compensate for improperly phased tape recordings or loudspeakers. 5 Special balancing circuit for quick and accurate volume balancing of both channels. 6 Separate record scratch and rumble filters. 7 Unique visual signal light control panel. Instantly indicates mode of operation. 8 Can be used as an electronic crossover (bi-amplifier). 9 Special compensation for direct connection of tape playback heads without external preamp. 10 Special switching lets you use your stereo pickup on monaural records. 11 You can play a monaural source such as an FM tuner through both channels simultaneously, effectively doubling power. 12 Loudness compensation. 13 Stereo tape recorder output.

Size in accessory walnut case: 15½w x 5h x 12½d. Price $199.95. (*West of Rockies $204.95*)

Write for complete technical specifications and new catalog G-58

h. h. Scott

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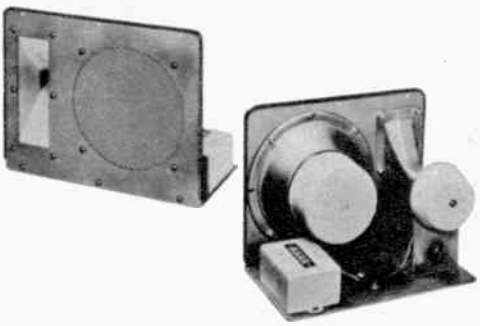
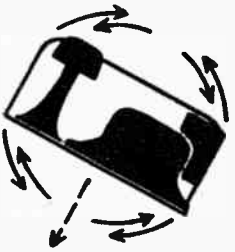


Jensen "Stereo Director" system contains the Flex-air woofer for bass response below 20 cps. The directive elements in the unit, top right, enable you to rotate the sound in the direction you want.

Directive elements are assembled on a rotatable chassis on top of the woofer enclosure. By rotating Stereo Director to point toward the listening area, you get the best stereo plus flexibility in speaker placement.



of the amplifying and reproducing equipment you now have. You will need two phono compensators, two preamplifiers, two sets of controls, two power amplifiers and two loudspeaker systems.

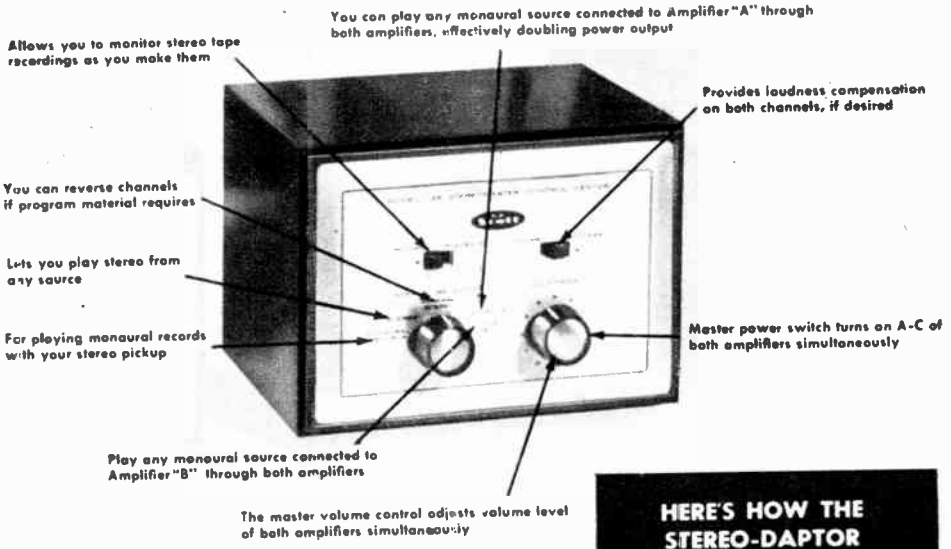
It is possible to cut corners by skimping on your second loudspeaker or power amplifier. There are many who would advise you to do just exactly that, in hopes of getting you into the stereo swim a little sooner. It is the view of this writer that such admonitions are misleading if not dishonest.

If you now have a good monophonic hi-fi system which pleases you, by all means duplicate it right down the line when you go stereo. Your investment will still be considerably less than double, while your listening enjoyment will be increased many times over. •

Bel-Aire speakers, designed for full-range stereo coverage, are acoustically matched when two are used.

h.h. Scott

HERE IS HOW YOU CAN CONVERT TO STEREO



NEW H. H. SCOTT STEREO-DAPTOR

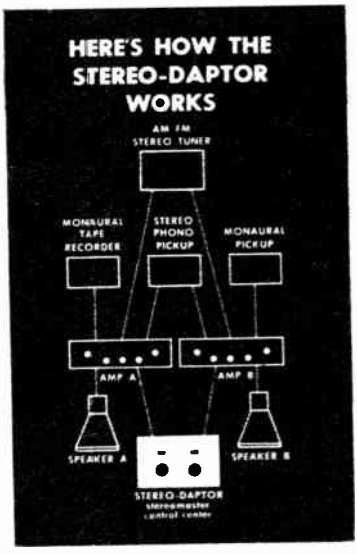
- Updates your *present* H. H. Scott Systems for Stereo records and tape.
- Lets you buy a monaural H. H. Scott System *now;* convert later.

Just add the Stereo-Daptor and a new H. H. Scott amplifier to your present H. H. Scott system and you can play the new stereo records; stereo tape; stereo AM-FM or stereo from any source.

The Stereo-Daptor permits control of two separate amplifiers from a central point. A Master Volume Control adjusts the volume levels of both channels simultaneously. Special switching lets you play Stereo, Reverse Stereo, use your Stereo Pickup on Monaural Records, or play monaural program material through both amplifiers at the same time. This gives you the full power of both amplifiers. No internal changes are required when used with H. H. Scott amplifiers.

only $24.95*

*slightly higher West of the Rockies

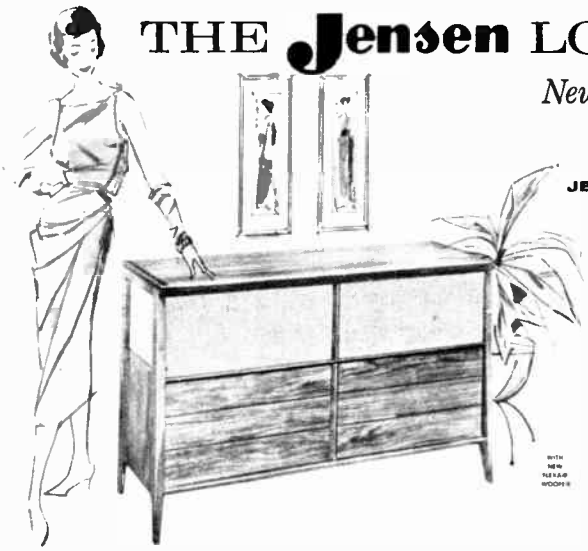


IMPORTANT!

Stereo-Daptor works with *All* current H. H. Scott amplifiers and most older models . . . with any system having separate preamplifier and power amplifier . . . and with complete amplifiers having tape monitor input and output provisions.

THE Jensen LOOK OF FASHION

New standard for hi-fi performance...



JENSEN DS-100 DUAL 3-WAY SYSTEM

WITH THE NEW Jensen STEREO DIRECTOR*

The DS-100 dual stereo unit, in the popular low-boy, is the answer to the buyer's demand for a complete stereo reproducer in one cabinet. This handsomely styled loudspeaker system provides two completely independent 3-way speaker systems with 12" Flexair woofers (total of 6 speakers) which can be used together for superior spread source monophonic sound, as well as stereo. The two Stereo Directors, each having an 8 inch mid-channel and compression driver h-f unit, allow flexibility in cabinet placement with maximum effectiveness in aiming the sound to the favored listening area. Crossover frequencies 600 and 4000 cycles. 32" H., 52" W., 18¼" D. Available in Walnut, Tawny Ash and Mahogany.

Net Price.....369.50

NEW TP-250 TRI-PLEX II 3-WAY SYSTEM

This latest version of the Jensen Tri-Plex reproducer incorporates the extreme bass capability of the 15" Flexair woofer, in combination with advances in midchannel and supertweeter design. This beautiful unit outperforms any speaker system of comparable size or cost. Excellent for superb monophonic reproduction or as one side of a stereo system. Response range, 16 cycles to beyond audibility. Crossover frequencies, 400 and 4000 cycles. Components available also in kit form (see KT-34). 30½" H., 34½" W., 18¾" D.

Net Price.....294.50

BF-200 CABINET FOR 15" SYSTEMS

Bass-Superflex cabinet only as used for TP-250 Reproducer. Ideal for any 15" speakers or systems. 30½" H., 34½" W., 18¾" D. Available in Walnut, Tawny Ash and Mahogany.

Net Price.....129.75

JENSEN SS-100 3-WAY SYSTEM

WITH THE NEW Jensen STEREO DIRECTOR*

Space speakers, suit decor ... always perfect stereo.

Perfect stereo wherever you listen, even with adjacent wall layout.

Equivalent in performance to one section of the DS-100 Dual Stereo system, this elegant model includes Stereo Director Chassis and 12" Flexair woofer in the Jensen Bass-Superflex enclosure for smooth coverage of the range from 20 to 15,000 cycles. Adequately driven to normal room levels with a 10 watt amplifier. Two SS-100's are ideal for stereo in the difficult-to-arrange living room, assuring perfect sound in the favored listening area. 32" H., 21" W., 18¼" D. Available in Walnut, Tawny Ash and Mahogany.

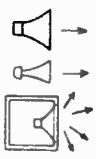
Net Price.....179.95

ABOUT JENSEN'S NEW FLEXAIR WOOFER

The new Jensen Flexair Woofers are designed to extend bass response down to very low frequencies. They have highly-damped superlow resonance at the very bottom of the audio range—16 to 20 cycles. They have an exceptional degree of linearity and are capable of a total movement of 1". In even a relatively small Bass-Superflex enclosure, they deliver their extreme low-frequency performance with a new low in distortion.

HOW THE NEW JENSEN STEREO DIRECTOR WORKS ...

Jensen acoustic research in a great many living rooms proves you need the highest possible ratio of direct sound to generally reflected sound from each speaker system for best stereo effect in the favored listening area. In other words, the speakers should beam the sound as much as possible directly toward you. Ordinarily this would mean twisting the cabinet at an ugly angle.

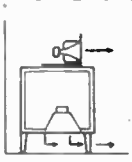


Jensen STEREO DIRECTOR solved the problem this way:

A. The speaker system is divided into two sections . . .

1. The directional elements which can be independent of the enclosure.

2. The nondirectional element (woofer) which needs the acoustic enclosure.



B. We assemble all the directive elements on a STEREO DIRECTOR chassis, arranged to be rotatable.

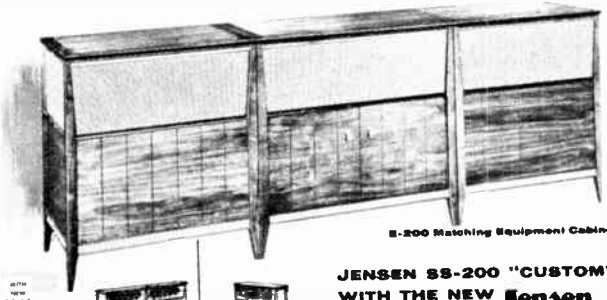
C. We put the STEREO DIRECTOR on top of the acoustic enclosure so it can point to you independently of the enclosure placement.

Trade Mark.
*Patents applied for.

TAKES THE LEAD IN SOUND...

Challenging comparison with speakers of any size...at any price!

FOR MONOPHONIC...FOR STEREOPHONIC SOUND



The New JENSEN "FLAIR LINE" FURNITURE

With the aid of nationally known furniture designers and interior decorators, Jensen conducted a comprehensive research on buyer preferences and trends in furniture styles, woods and finishes. The result is the high-fashion, living-wise "Flair Line", a sculptured transitional style with warmth, grace and interesting details, and a high degree of compatibility with existing pieces. Illustrated here in Walnut with Rattan, all new Flair Line pieces are also available in Tawny Ash and Mahogany with complementary grille fabrics.

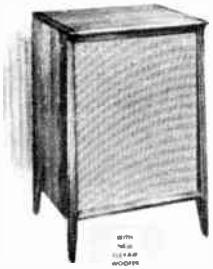
SS-200 Matching Equipment Cabinet—Net Price.....298.50

Director principle even allows adjacent wall placement for stereo, impossible with conventional systems.

JENSEN SS-200 "CUSTOM" 4-WAY SYSTEM WITH THE NEW Jensen STEREO DIRECTOR

Stereo Director sends the sound straight to you regardless of cabinet location. A lift top permits easy access to the Stereo Director for instant directional adjustment. This 4-way system consists of a unique 15-inch Flexair high compliance superlow resonance woofer in a Bass-Superflex enclosure for response down to 16 cycles, plus (on Stereo Director chassis) special 8-inch upper bass unit, compression-driver horn-loaded mid-channel, and a new phase correcting supertweeter unit for response beyond audibility. Crossover frequencies 200, 400 and 4000 cycles. 36½" H., 32¼" W., 23" D. Available in Walnut, Tawny Ash, and Mahogany.

Net Price.....439.50



NEW JENSEN CN-100 3-WAY SYSTEM

A new 12" 3-way system, the CN-100 reproducer gives a new small-scaled fine furniture look to the hi-fi speaker, ideally suited to small living spaces. The 12" Flexair superlow resonance woofer in Bass-Superflex enclosure gives full bass response to a low 20 cycles. Special 8-inch mid-channel and RP-103 h-f unit assure smooth clean response to 15,000 cycles. Crossover frequencies 600 and 4000 cycles. 32" H., 21" W., 18¼" D. Available in Walnut, Tawny Ash, and Mahogany. **Net Price.....149.50**

BF-100 ENCLOSURE FOR 12" SYSTEMS

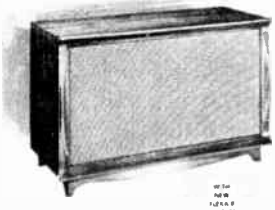
In up-to-the-minute "Flair Line" styling, the BF-100 cabinet is ideal for all 12" speakers, and system kits including those with Flexair 12" woofers. Incorporates new acoustical design with tube-loaded port for unusual extension of the l-f range. Available in Walnut, Tawny Ash and Mahogany. **Net Price.....69.50**

Used with ST-944 stand, Tri-ette makes handsome little lowboy

Stands on end to meet space requirements (fully finished all four sides!)

JENSEN'S AMAZING TR-10 TRI-ETTE • Big Speaker Bass in Smallest Space

Sophisticate's Choice in 3-Way Components
Conversation-Piece Flair Styling To Grace The Living Space

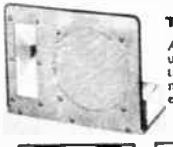


Heart of the Tri-ette is the new Flexair 12" woofer with its superlow free-air resonance of 20 cycles and high damping. In conjunction with the new Bass-Superflex enclosure, useful response down to 25 cycles is attained with the lowest distortion ever measured on such a small reproducer. Cabinet is extra rigid with Fiberglass lining. Special 8-inch midchannel handles the range from 600 to 4,000 cycles, through L-C crossover network. RP-103 Tweeter carries the response from 4,000 to 15,000 cycles. 13⅞" H., 25" W., 11⅜" D. Choice of Walnut, Tawny Ash and Mahogany. **Net Price....114.50**

ST-944 Stand*. For floor use. Places top of cabinet 28" above floor. **Net Price.....12.95**

ST-945 Base*. For table or shelf. **Net Price..... 5.45**

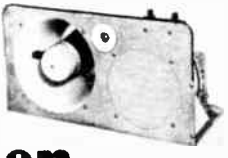
*(Specify Walnut, Tawny Ash or Mahogany finish.)

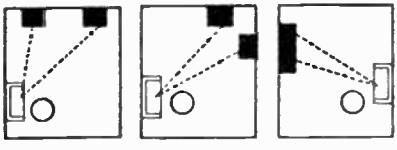


THE TWO STEREO DIRECTORS • FOR 3-WAY, FOR 4-WAY SYSTEMS

A pair of these rotatable Director assemblies are used in the DS-100 Dual 3-way System (illustrated above), a single assembly in the SS-100, mounted on the shelf above the Flexair woofer enclosure.

Used in the SS-200 Custom 4-way System. Cabinet lid lifts for directional adjustments. 8" upper base unit, new midchannel and phase corrected supertweeter for the frequency range above 200 cycles.





Jensen STEREO DIRECTOR lets you place the speakers wherever decor dictates, square to the wall for best appearance. You send the sound to you, instantly adjust for best stereo listening without moving cabinet.

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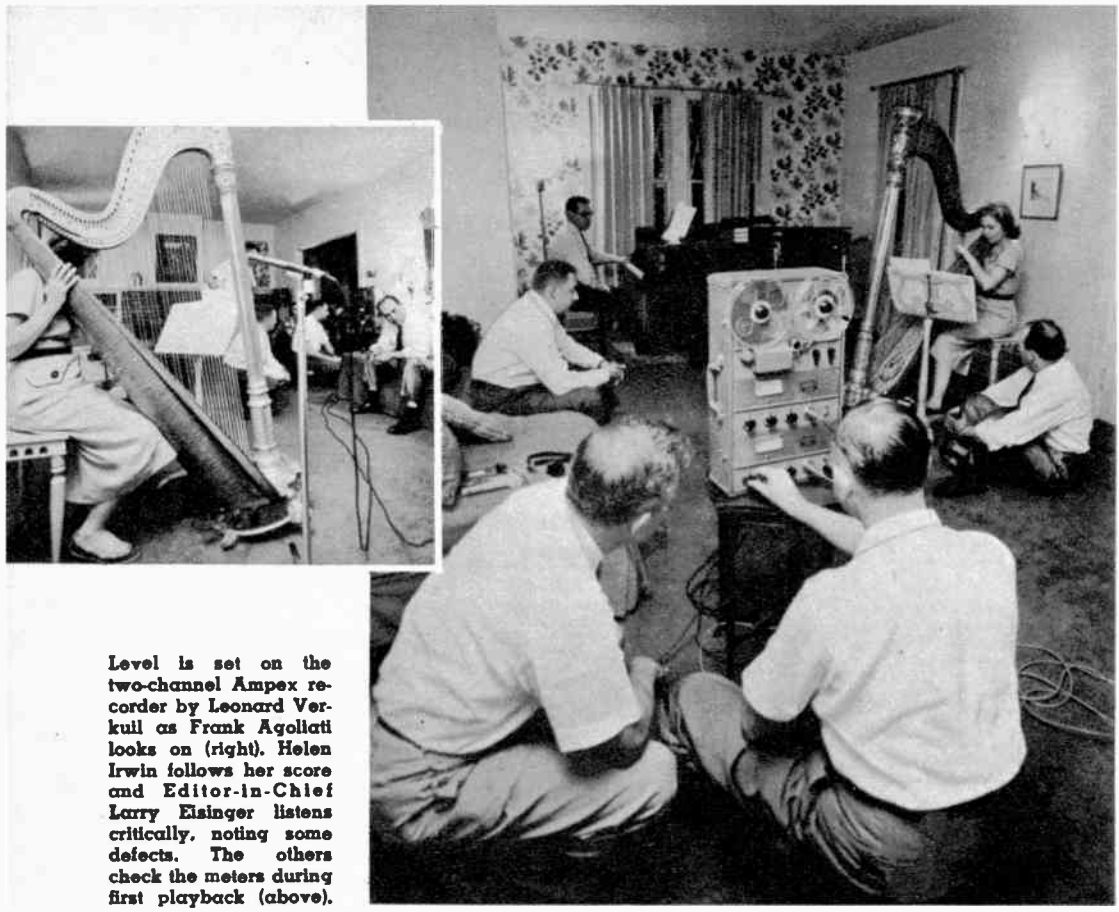
Send for your copy of Bulletin JH-1 which describes the Jensen STEREO DIRECTOR and other new Jensen firsts in speakers.



Level is set on the two-channel Ampex recorder by Leonard Verkuil as Frank Agoliati looks on (right). Helen Irwin follows her score and Editor-in-Chief Larry Eisinger listens critically, noting some defects. The others check the meters during first playback (above).

Making a Hi-Fi Record

Two professional musicians and two hi-fi amateurs make the first Fawcett "Fabulous Fidelity" Record.

"LET'S bring out a new kind of hi-fi record to go with your new hi-fi book." The speaker was Larry Eisinger, the energetic Editor-in-Chief of Fawcett Books.

The man is full of ideas, most of them good, but this one I didn't like. So I hedged. "Just what do you mean by *new?*" I asked, trying to appear casual.

The gambit didn't work. "I mean a record with unusual sounds. A record made by top artists. A record which entertains. A record which instructs. A record like anyone could make in his own home."

And that was the next-to-impossible assignment for the first in a new series of Fawcett Records. The problems we had to solve were considerable, but we think we've accomplished what we set out to do. The new Fawcett Record is different in several respects from any other, and this is its story.

The problems of unusual sound and top artists were solved simultaneously when we engaged the piano-harp duo of Will Irwin and his charming wife, Helen Thomas Irwin. These people are both very well known in the Broadway musical theater, and Will's arrangements for the two

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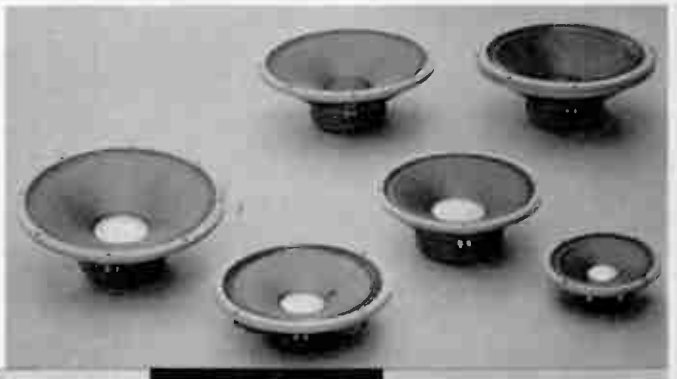
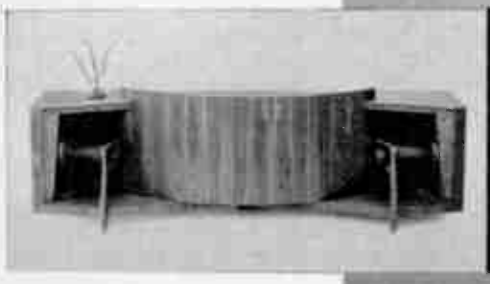
JBL Signature loudspeakers embody feats of audio craftsmanship never duplicated. JBL extended range speakers are made with large voice coils of edge-wound aluminum ribbon for brilliant highs, crisp lows, rich mid-range, highest efficiency. Frames are rigid castings, dural center dome is attached directly to voice coil for clean sound, free of spurious resonances.

Left to right are the virtuoso 15" Model D130 with 4" voice coil; the versatile 12" D123, 3" voice coil; the singular 12" D131, 4" voice coil; precision miniaturized 8" D208, 2" voice coil.

Then, above, there are the famed JBL low frequency drivers, the 130 series with curvilinear cone, 4" voice coil, for 1200 cps crossover; and the fabulous 150-4 series with 4" voice coil and straight-sided cone for 500 cycle crossover.





JBL acoustical enclosures are engineered for JBL transducers. Pleasingly proportioned, precision built, impeccably finished, there is one for every taste.

At top, the sensational Ranger-Paragon integrated stereophonic speaker system. Next, the mighty Hartsfield, universally acclaimed the finest of monaural speaker systems, and the extremely popular C40 Harkness back-loaded folded horn.

Below, the JBL C37—criterion for reflex enclosures, and the C39 Harlan corner reflex enclosure of provocative design and extraordinary versatility. Detailed prints for constructing the C37, C39, and C40 are available at $3.00 a set from the factory.

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The JBL 175DLH assembly combines precision driver and complex phasing plug with machined aluminum exponential horn and the exclusive JBL acoustical lens which distributes highs evenly over a 90° solid angle.

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Listening indicates the mike setup isn't right, and Verkuil makes first of many changes. Irwin is anxious to resume, Helen wants more rehearsal.

Recording again, Helen plays a "dolce" passage. Felt picks on table are for loud "glissandos."

Eisinger, who produced the record, and the author observe the operation of the tape recorder set up by Verkuil and Agoliati. Will Irwin plays on.

instruments are quite unique. A search of the musical literature turns up plenty of material for harp with piano accompaniment, but a true blending of the two instruments in duet form is extremely rare. Will Irwin, however, has done just that.

He has also played, conducted or composed for many Broadway shows, just a few of which include "Of Thee I Sing," "Three's A Crowd," "Very Warm For May," "Oklahoma!", "The King And I" and "South Pacific." He studied at The Louisville Conservatory of Music, and is now a graduate teacher at Juilliard in New York. His own piano teachers included Percy Grainger and James Friskin.

Helen Thomas Irwin has done much radio work, including the orchestras of Mark Warnow and Richard Himber. Her Broadway shows include "Foolish Notion," "Ziegfeld Follies," "Follow The Girls," "Are You With It?", "If The Shoe Fits" and "Oklahoma!". She was a scholarship student of The New York Philharmonic Society, and studied under Mme. Djina Ostrowska, and Edward Vito of the NBC Symphony. She was a member of Mme. Ostrowska's Pro Arpa Quartette, and later had her own harp quartet, which accompanied ballerina Irina Baranova and was also featured in the show, "Artists and Models."

With the matters of artists and repertoire neatly settled, the next question had to do with the actual mechanics of making the recording itself. Since the program might be called pop chamber music, it was decided to record "on location" in a living room, rather than in a studio or concert hall. The Irwins' own living room was ideally suited, since they lived on a quiet street in Staten Island, and they would be working in familiar surroundings.

The equipment to be used posed no particular problems. As this writer has stated repeatedly over the past few years, the greatest difference between professional and amateur recording equipment today is in ruggedness rather than quality. There was no reason then why we couldn't use light-duty, but high-grade, machines such as the Ampex 600 series.

Finally came the question of technical personnel. My own experience of twenty years in broadcasting and recording would hardly jibe with our argument that this would be the kind of record anyone could make. And so we invited a couple of typical audiophile amateurs to do the actual recording.

We wanted people who were true hi-fi enthusiasts, who knew good sound when

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Weathers products are not copies, adaptations, or mere improvements over other Hi Fi components or systems. Unfettered by precedent, Weathers equipment is designed on bold new principles which add astonishing quality and brilliance to Hi Fi reproduction.

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FM Monaural • FM Stereo • Ceramic Stereo • All Weathers pickups play both monaural and stereophonic records without damage. All are available with diamond or sapphire styli. **FM Monaural** and **FM Stereo** cartridges are designed only for the Weathers Tonearm in which an oscillator develops the signal. They track at 1 gram . . . cannot damage records. They have exceptionally wide frequency range, low intermodulation, low cross modulation, and low harmonic distortion. **The Weathers Ceramic Stereo Cartridge** fits all other tonearms and is superior to any magnetic pickup. Tracks at 2 grams. Complete absence of hum. 25 db separation between channels.

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Tonearm is designed exclusively for the Weathers FM Pickups. It is light and so perfectly balanced that accurate levelling of turntable is unnecessary. Shock mounting isolates it from outside vibrations. Viscous damping prevents tonearm resonance down to 15 cps.

The Weathers Oscillator-Modulator

Transforms the impulse from the pickup and produces the FM signal. Signal-to-noise ratio is considerably higher than that of the best magnetic pre-amps.

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Another take is made and Helen applies her critical ear as Verkuil plays back the tape. With her approval, recording can begin in earnest.

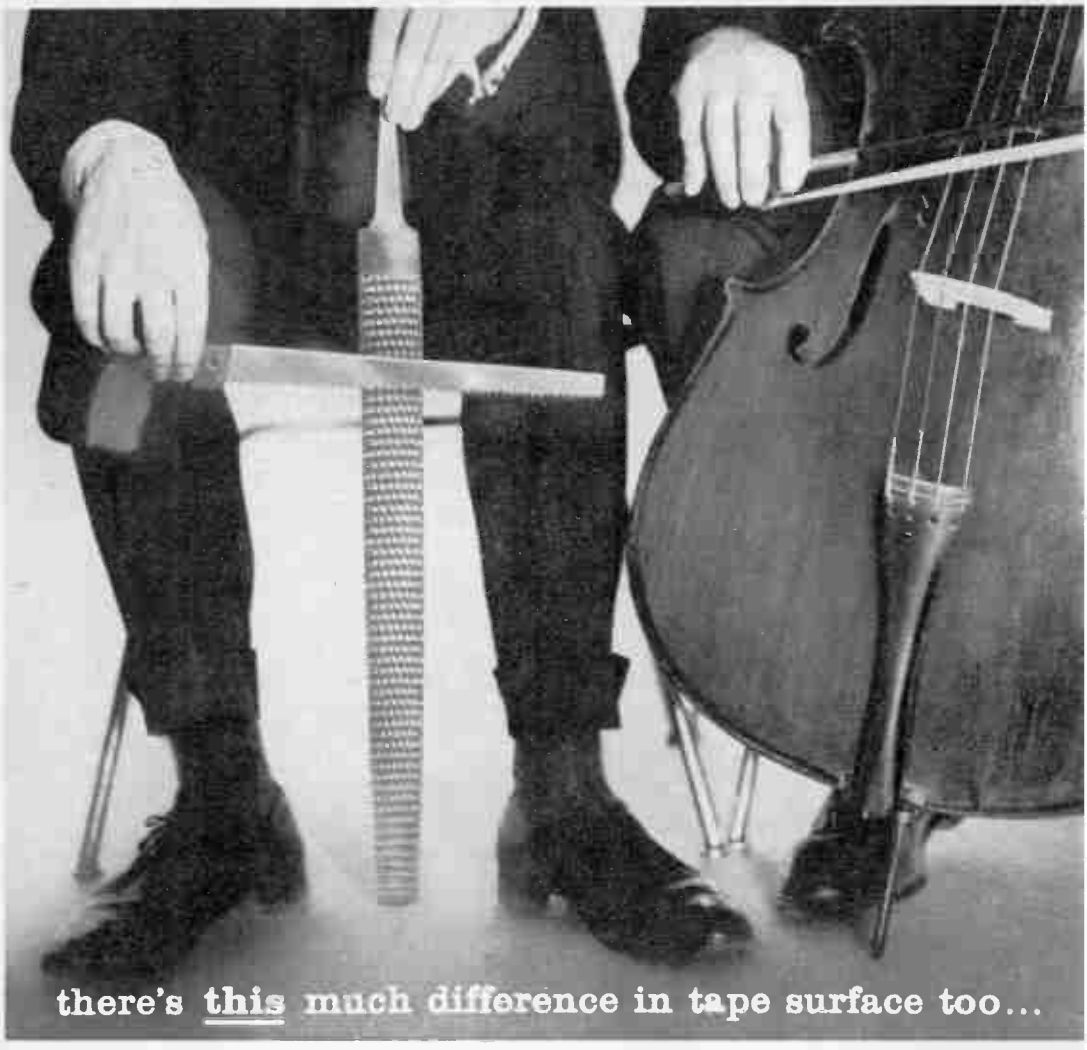
they heard it, but whose day-to-day activities were in no way connected with audio. The men chosen were Messrs. Frank Agoliati and Leonard Verkuil, both of Staten Island, New York. Frank is a tool design engineer, and Leonard is an optician, both occupations rather far removed from hi-fi.

The only preparation they had, other than an intense interest in the audio hobby, was the assignment to read *All About Hi-Fi Tape Recording*, another Fawcett Book, with particular emphasis on the chapter concering microphone techniques, "Living Sound." This done, we all went to the Irwin home, and Frank and Leonard were told to go to it.

Their efforts were strictly cut-and-try for a while, as they are even under the most professional auspices. A little more level here, a little less there, move this mike, shift that instrument, raise the mike, lower the mike—on and on the trial and error went.

Then quite suddenly the sound began to take shape. Will's arrangements began to sing, and Helen's harp never sounded richer. From the taping that night emerged the first Fawcett *Fabulous Fidelity* Record. ●

HI-FI HARP, Fawcett's "Fabulous Fidelity" Record, is now on sale to our readers. To get your copy and hear this record for yourself send $4.98 to Fawcett Records, Fawcett Building, Greenwich, Connecticut.



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Do-It-Yourself With Kits

New techniques make kit assembly more fool-proof

but certain precautions must still be observed.

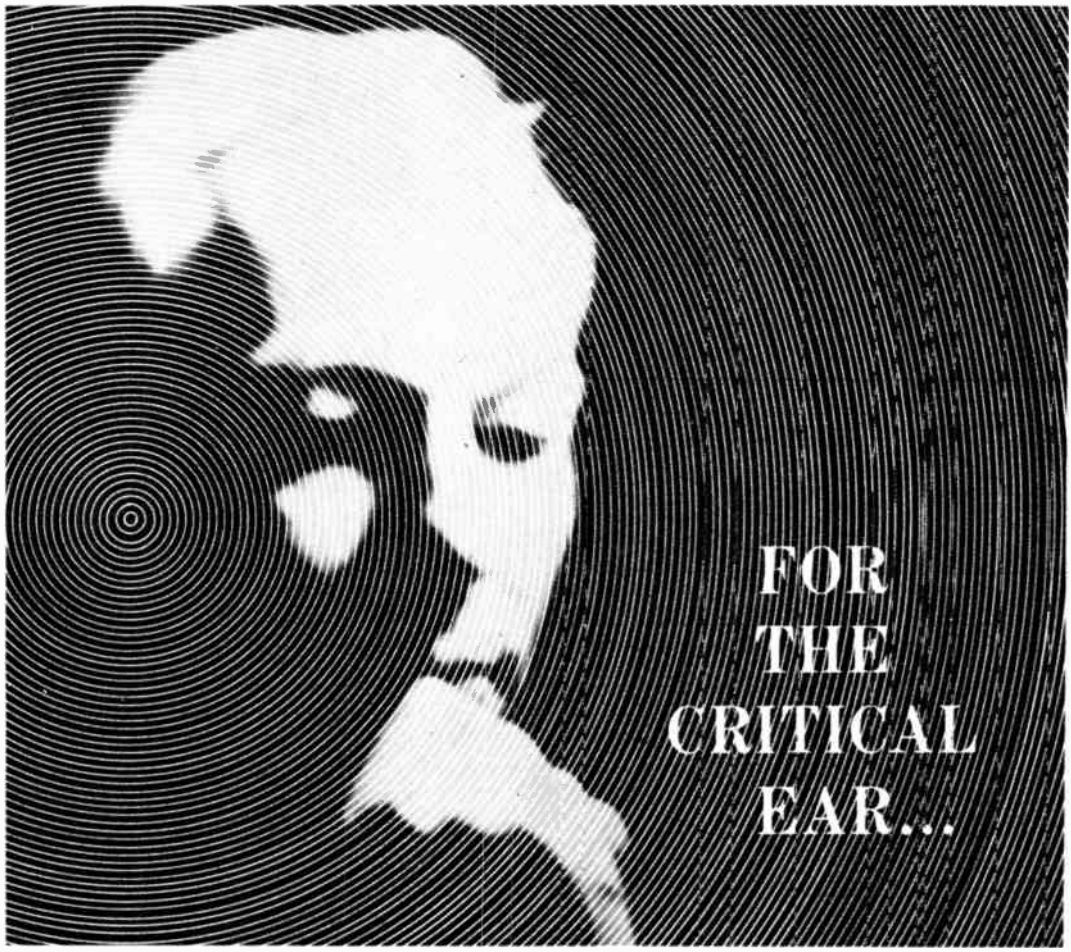
FOR many people, hi-fi is a purely passive activity, requiring just listening and more listening. Making your own live recordings is one means of active participation, and building your own system is another. For one who wants to get more out of this hi-fi hobby than just listening, kit building is made to order.

There are other reasons why one might want to construct his own hi-fi system rather than buy a package or a group of components. The student or experimenter wants to increase his skill or knowledge. The music lover on a budget has to get the very most out of his hi-fi dollar. But many more would be taking this road to hi-fi enjoyment if they realized how well paved it is.

The only qualifications you need for assembling a well-designed kit are the ability to read and follow instructions, the knack of soldering an electrical joint, and the ability to use a few simple hand tools.

We'll begin our tips on soldering technique with the obvious truism that first you'll need a soldering iron and some solder, and that after you have these items ready, you practice with a few odd lengths of wire and a tube socket for a half hour or so. It isn't at all difficult, but if it isn't done right you can run into all kinds of grief later. (*Turn page*)

All components and tools necessary for assembly are spread out here before the author holding instruction manual. Small and delicate parts are enclosed in plastic packages or cardboard boxes.



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*For those who prefer a monaural cartridge with monaural records: Shure Professional Dynetic Cartridge or Studio Dynetic Tone Arm. Studio Dynetic tracks at one gram. (If conversion to stereo is desirable later, Shure "Plan-of-Protection" guarantees 75% trade-in allowance until Dec. 31, 1959.)

Literature available: Dept. M-2

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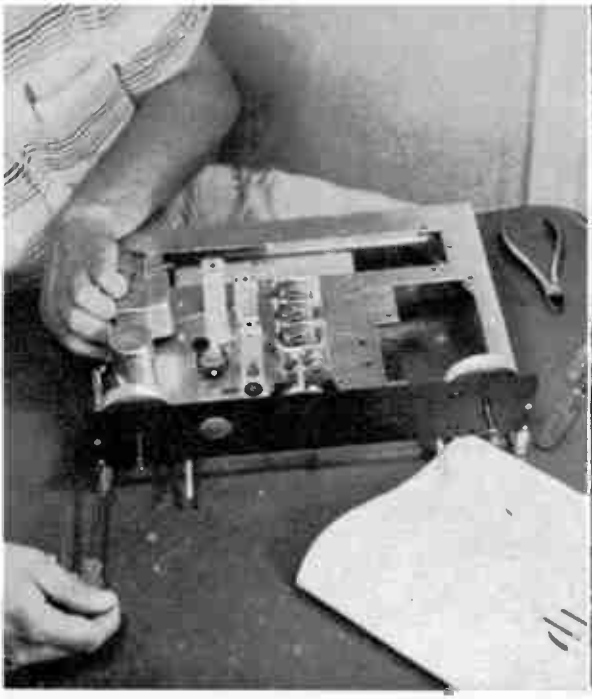
a note to the technically inclined:

Shure Stereo Dynetic Cartridges are individually tested and must meet or exceed the following specifications before being placed on the market:

Frequency response: 20 to 15,000 cps
Compliance: 4.0 x 10^{-6} centimeters per dyne
Channel separation: More than 20 db throughout the critical stereo frequency range.

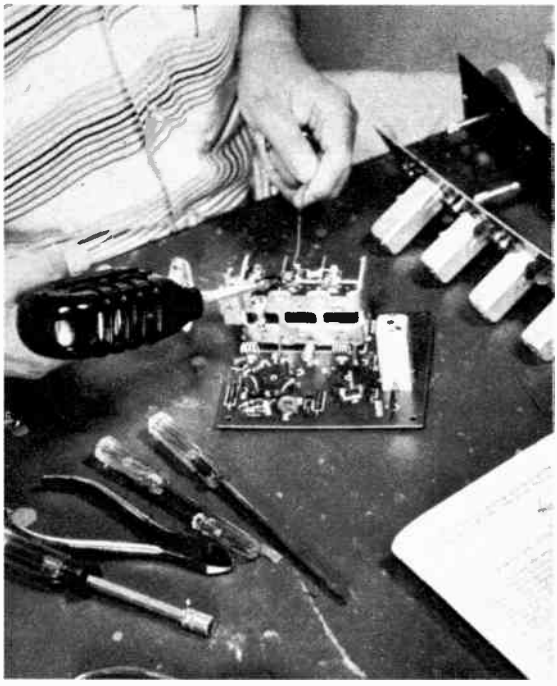
Recommended Tracking Force: 3 to 6 grams.
The M3D fits all 4-lead and 3-lead stereo changers and arms. 10 second stylus replacement.

SHURE ALSO MANUFACTURES HIGH-QUALITY PICKUP ARMS, MICROPHONES, AND MAGNETIC RECORDING HEADS



First step is assembly on main chassis. Transformers, filter condensers and AM tuning condenser are mounted. Note the tuning flywheels.

Installation of components on i-f etched circuit board of FM tuner comes next. Using soldering gun, apply solder sparingly to all proper points.



Etched r-f circuit board for FM is assembled here. Installation includes larger components such as the tuning condenser and tube sockets.

Soldering is a process of uniting two or more metals by first heating their junction, *and then* applying to the joint a fusible alloy called solder. Thus the whole problem can be broken down into three simple elements:

1. How to join the metals
2. How to heat them
3. What solder to use and how to apply it

Now let's discuss each one in order.

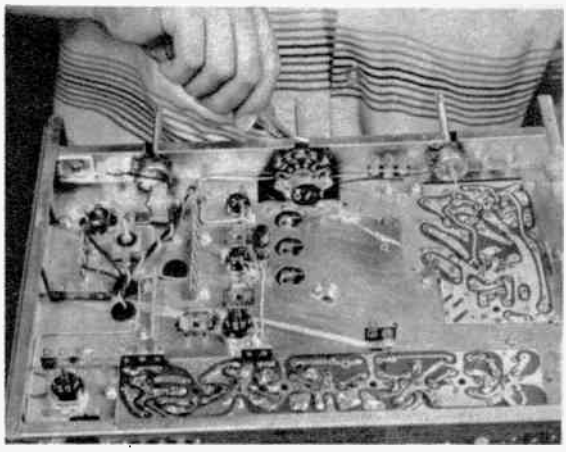
Nearly all of your soldering will involve attaching a piece of hookup wire, or a wire built into a component, to some fixed point such as a tube socket, control, tie point or terminal strip. In any case the wire is first cut to length, stripped and cleaned, and then attached to the terminal so that it is mechanically secure.

The physical strength of the joint should not depend upon the solder. The wire is therefore doubled back on itself for about ⅛ inch at the end and crimped with long-nose pliers so that it is clamped to the terminal. Before soldering, of course, make certain that the wire is going to the correct point and only to that point. When working on miniaturized components in confined quarters it is quite easy to have the bare end of the wire brushing against some point where it doesn't belong.

Now that the metals are properly joined.

Circuit boards are installed on main chassis with machine screws, lock washers and bolts at several location points. Author used socket wrench.

Function switch is largely prewired prior to its installation. Wired switch is then mounted with lockwasher and control nut, using end wrench.



the next question is how to heat them preparatory to soldering. The heat is usually applied by contact with a piece of hot copper, which itself is usually heated by electricity. The chunk of copper is the tip end of a tool misnamed a soldering *iron*.

The electric soldering iron may take several forms. The older and better-known type has a tip which is indirectly heated by a resistance element. For most work such an iron in a 70- to 125-watt size is quite adequate, with a ⅜-inch tip. Many audiophiles feel that an iron this size is not necessary, and they prefer a pencil type, having a power rating of about 30 watts with a tip around ¼ inch. This type is especially useful when working with etched or printed circuits, or small selector switches.

If you do use a pencil type, you'll probably require a larger size occasionally. For while the little baby will handle about 95 per cent of your requirements, you will probably find times when there just isn't enough heat on larger elements to flow solder correctly.

The other approach to electric soldering is the *gun*, which is really a step-down transformer with a switch, forcing a high current at low voltage through a copper-wire tip. The tip is therefore directly heated by the current passing through it. It heats instantaneously, and therefore the trigger is pulled to apply heat only as it is needed. One advantage of the soldering gun is that the tips are usually pretinned, while the user of the iron must go through this process before he is ready to solder.

Before attempting to solder with an iron, the part of the bit which comes into contact with the joint must be covered with a coating of solder, or *tinned*. In the case of a new iron you will begin by plugging in the power and rubbing solder against the tip every few moments. The iron, of course, won't be hot enough to melt the solder at first, but continue the operation so that solder begins to flow the instant the temperature becomes high enough. The reason for this is to have the tinning accomplished before the copper tip gets a chance to oxidize.

With molten solder flowing freely over both faces of the tip of the iron, wipe off the excess with a rag rolled up into a ball, thus exposing a thin, shiny layer of metal covering the tip. After some hours of use the tinning will become dull and flaked, and the tip may even become pitted. When this occurs, simply dress down the tip faces to the bare copper, using an old file, and then repeat the procedure.

Finally we come to the question of what solder to use and how to use it. The solder

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employed in radio and audio work is an alloy of two metals, lead and tin, and usually has a flux built into its hollow core. The purpose of the flux is to prevent rapid oxidation of the metals as they are heated.

Some types of fluxes are highly corrosive, which is not a great handicap in some types of work, but can't be tolerated on any electrical installation. There is always the possibility of small amounts of the corrosive flux remaining in the joint and in time eating through the connection and opening the circuit. Furthermore, the use of a corrosive acid flux on any kit you build will automatically void your guarantee. The kit packagers are most co-operative in helping you out if you strike a snag in construction, or if the unit fails to operate after you're done. But if you have used acid-core solder in your work all bets are off.

The flux commonly used for audio work is rosin, and if it is included within the solder, the material will probably be known as *rosin core radio solder*. Flux is also available in paste, liquid and powdered form, but the flux-core solder is so convenient it is now used almost universally.

Solder used in audio work is known as soft solder, as opposed to silver and aluminum solders which have much higher melting points. The best flowing solder, and therefore the easiest for the beginner to handle, consists of 60 percent tin and 40 percent lead. The 50-50 alloy is a little better for electrical work, but it has a higher melting point and is a little harder to work. You might therefore try a small kit using the 60-40 type, and when you feel that you have the soldering technique well in hand, switch to 50-50.

Having the joint securely crimped and mechanically solid, hold the heated iron in such a way that the iron heats the joint and the joint melts the solder. Unless the joint gets hot enough to fuse the solder itself, a cold solder joint will result, which may in time result in an open circuit.

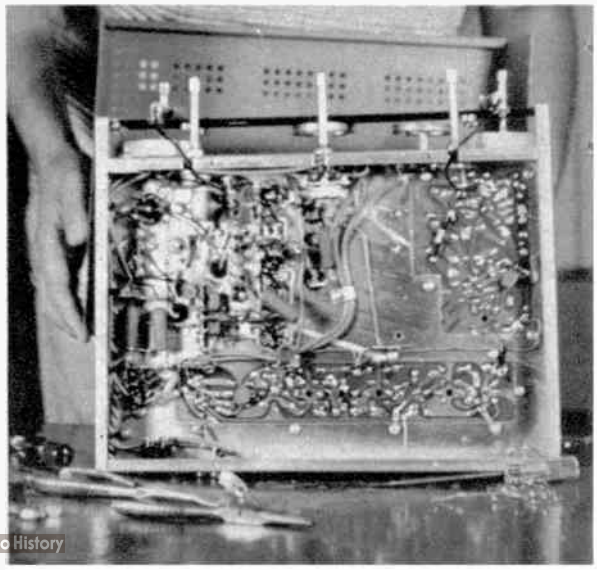
Although the joint must be heated sufficiently to melt the solder for a smooth flow, you must be careful not to apply heat too long. Excessive heat from the iron may damage components or the insulation on the wire being soldered. When soldering small, fragile components, they may be protected from excessive heat with a pair of long-nose pliers, used to grasp the lead between the joint and the component as the iron is applied. The pliers then act as a "heat sink," conducting much of the heat away from the component and maintaining it at a safe temperature.

There are several reasons for using as little solder as possible. Since its electrical conductivity is only one seventh that of copper, there should be a minimum of solder separating the conductors. Furthermore, molten solder is slippery stuff and has a way of getting itself right where it's not wanted.

Excess solder may form "bridges" or shorts between adjacent terminals or nearby wiring, especially on tube sockets and switch terminals. When working with such small, closely spaced terminals, be sure to preheat the work for several seconds

All major components in place, wiring of underside of chassis progresses to completion. Resistors, condensers and cables are fixed in place.

Sub-chassis wiring completed, top cover plate—previously installed temporarily — is removed. Cover prevents damage to delicate parts above.



before applying the solder, and then use the solder most sparingly. As soon as a good clean joint is made, remove the heat before the solder has a chance to flow further down into the contact clips and make the switch inoperative.

Another source of potential trouble is the etched circuit board. This is a fiber sheet on one side of which is overlaid a maze of conducting paths. One function of the board is to act as insulation between the components mounted on one side of it, and many of the conductors on the reverse side. But if solder flows through the holes in the board, it will short out the thickness of the board and may cause serious trouble.

The next common tool you'll require for your kit building is a screwdriver or two. The ordinary flat-bladed screwdriver is usually designated in terms of its blade length. Thus a 4-inch screwdriver has a blade four inches long. It is fairly important that the size screwdriver you use be one intended for the screws involved. Obviously an oversize tool is useless, but one which is very undersize is difficult to work with and may damage the screw slots. For most electronic kit construction you'll probably never require anything larger than a 4-inch model, although wood cabinets may well call for something bigger.

Screws are of three basic types. Wood screws are intended for fastening wood or some other material to wood. They cut their own threads into the wood after an undersize starter hole has been drilled. Thus the assembly is simple and obvious.

Another prevalent type is the machine screw. This is used for fastening in or to metal. It does not cut a thread in the material into which it is screwed, If the screw is to go into a heavy piece of metal, that material must first have a thread cut with a tap in the sides of a drilled hole. This type of assembly is not very usual in audio work, however.

Normally the screw passes completely through holes in the material which are just large enough to allow clearance, and a washer and nut are turned on at the other end. With a screwdriver in the screw slot and a wrench on the nut, one or both of them is turned clockwise until snug. The only precautions to observe are to be sure to use the screw size and washer type specified in the kit instructions, and not to turn the screws so tightly as to strip the threads.

Another type of fastener is the self-tapping screw, often called a sheet-metal screw. It is used to make fastenings not

only to sheet metal, but also to thick aluminum and plastics. It forms its own thread as it is turned into a drilled, punched or molded hole. In hi-fi work it is often used in final assembly, for attaching escutcheons, cover plates and bumper feet.

Wrenches are of several types, including end wrenches, socket wrenches and "finger" wrenches. A very small adjustable end wrench will usually suffice for most kit construction. A set of socket wrenches, of the type with a shaft and screwdriver handle, is easier to use but considerably more expensive. The little

Next step: the bane of radio service men—installation of the dial cord. Here, AM cord is in place. FM installation is being completed.

Tuning indicator front panel and control dials are mounted. The AC cord with strain relief clamp is installed through the opening in rear apron.

finger wrenches look something like thimbles with small openings protruding at one end. They are particularly useful for getting into inaccessible areas. In a pinch, however, you can probably forego the wrenches entirely and get along with just an ordinary pair of pliers.

But while the ordinary combination pliers are a useful multipurpose tool, you should invest in a pair of long-nose pliers as well. These are handy for working in confined areas and for the finer detail in shaping wires to fit.

Another equally indispensable tool is the wire cutter, usually in the form of a pair of diagonal cutting pliers. Most components, particularly resistors, condensers and audio transformers, are supplied with long wire leads, often referred to as "pigtails." Since a standard rule in electronic construction is to keep the leads as short as possible, it is necessary after installing a part in place to snip off the excess wire. This is done quickly and simply with a pair of diagonals, and no other tool will do nearly as well.

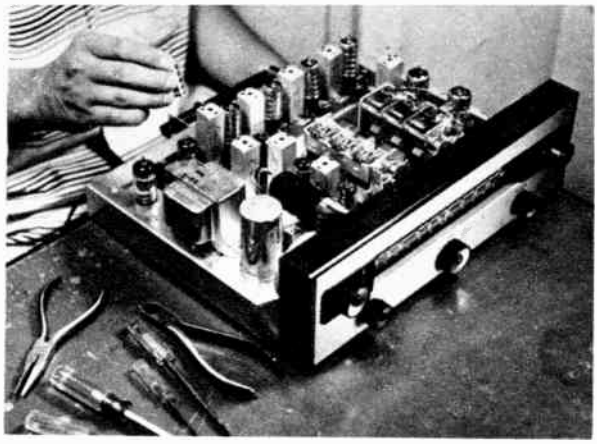
Finally we come to another tool of many uses, the ordinary pocketknife. The most important application in audio work is in the preparation of wire ends for soldering. If the wire is insulated, it may be necessary to trim back the end of it for a quarter-inch or so to expose the metal. Some wires may have additionally a baked enamel coating. In the case of components, many of them are dipped in wax, including the pigtails. All of this stuff must be cleaned off the part of the wire to be soldered, until clean, bare metal is exposed. One of the easiest ways of doing this is by scraping with a knife. Another is with a bit of sandpaper.

With these few simple tools and a good kit, you need only take the time and care to follow simple step-by-step instructions until you have built yourself a complete system of top-notch hi-fi components.

One such component might be the Lafayette tuner whose assembly is shown in the accompanying illustrations.

This is an AM-FM tuner of the stereo type, which means that the AM and FM functions are completely independent and may be operated simultaneously. Thus they can feed two different broadcast programs to separate systems, or both channels of a stereocast to a stereo hi-fi system. There is also provision for FM multiplex.

The FM section has a stage of preselection ahead of the converter, two stages of i-f and two limiters. Discriminator type detection is used, with a cathode follower stage used to couple the output into the



Final step before enclosing tuner is insertion of tubes and shields. At this point all previous wiring steps should be reviewed and the set checked for possible unsoldered or loose joints.

hi-fi amplifier. The tuning circuit also has automatic frequency control.

The AM set is less elaborate, but still quite adequate. There is a stage of preselection, a single i-f stage and diode detection. There is also a cathode follower for the AM output as well. Tuning indication for both tuners is by a 6U5 magic-eye tube.

Construction of the set begins in the conventional manner, by mounting of parts. The precise location of components is even more important with radio equipment than with audio, to prevent spurious responses caused by stray r-f fields.

Orientation of parts is simple, but instructions must be followed carefully. Tube sockets, coils, rectifiers, and adjustable condensers are usually asymmetrical and therefore positioned simply by matching their terminal or lead locations to a drawing or photograph.

Switches and controls have a locating tab which fits through a hole in the front of the chassis. This not only makes locating foolproof, but also prevents the body of the control from rotating when the knob and shaft are turned.

Symmetrical items such as i-f transformers and electrolytic condensers normally have code markings to aid in correct positioning. The condensers have distinctive markings adjacent to each terminal, while the transformers have an off-center colored dot or slot opening as a clue to the internal constructions.

Both the r-f and i-f sections of the FM tuner are built around etched circuit boards. These afford very close control over stray capacitance and inductance effects, and thus virtually guarantee that all the critical circuits will be practically identical

Tuning components of set are previously aligned at factory, but front end touch-up may be done at home. Tuning eye can be used as alignment indicator; when the alignment is completed, tuner is ready.

to those in the original factory prototype.

Construction with these boards requires a little more delicate care, but the appearance and performance are worth the effort. A small soldering iron is mandatory, and the rosin flux should be cleaned off with alcohol after all points are soldered. All tube sockets should be loosened up by having tubes inserted and removed several times, before they are installed on the board.

Critical tuned components are prealigned at the factory, so that no elaborate equipment is required even if minor touching up is necessary. Normally this can be done using only broadcast signals as the primary source, with the tuning eye as an alignment indicator. •

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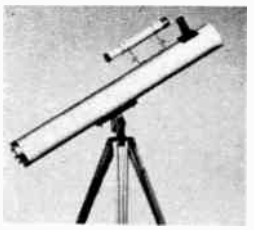

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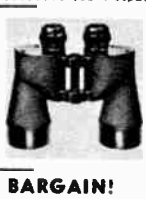

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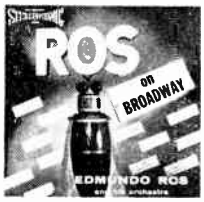

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